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Microwave Journal



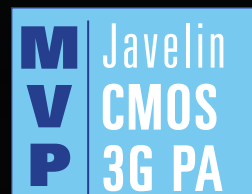
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			10	100	1K	10K	100K	1M		
XTO-05	5-130 MHz	Ovenized Crystal	-95	-120	-140	-155	-160	-	100 MHz	11
PLD	30-130 MHz	P.L. Crystal	-95	-115	-140	-155	-155	-	100 MHz	13
PLD-1C	130-1000 MHz	P.L. Mult. Crystal	-80	-100	-120	-130	-135	-	560 MHz	13
BCO	100-16.5 GHz	P.L. Single Loop	-65	-75	-80	-90	-115	-	16.35 GHz	13
VFS	1-14 GHz	Multiple Freq. Dual Loop	-60	-75	-110	-115	-115	-	12.5 GHz	13
DLCRO	8-26 GHz	P.L. CRO Dual Loop	-60	-85	-110	-115	-115	-138	10 GHz	13
PLDRO	2-40 GHz	P.L. DRO Single/Dual	-60	-80	-110	-115	-120	-145	10 GHz	13
CP	8-3.2 GHz	P.L. CRO Single Loop	-80	-110	-120	-130	-130	-140	2 GHz	13
CPM	4-15 GHz	P.L. Mult. Single Loop	-60	-90	-105	-110	-115	-130	12 GHz	13
ETCO	1-24 GHz	Voltage Tuned CRO	-	-	-70	-100	-120	-130	2-4 GHz*	13

* Octave band.

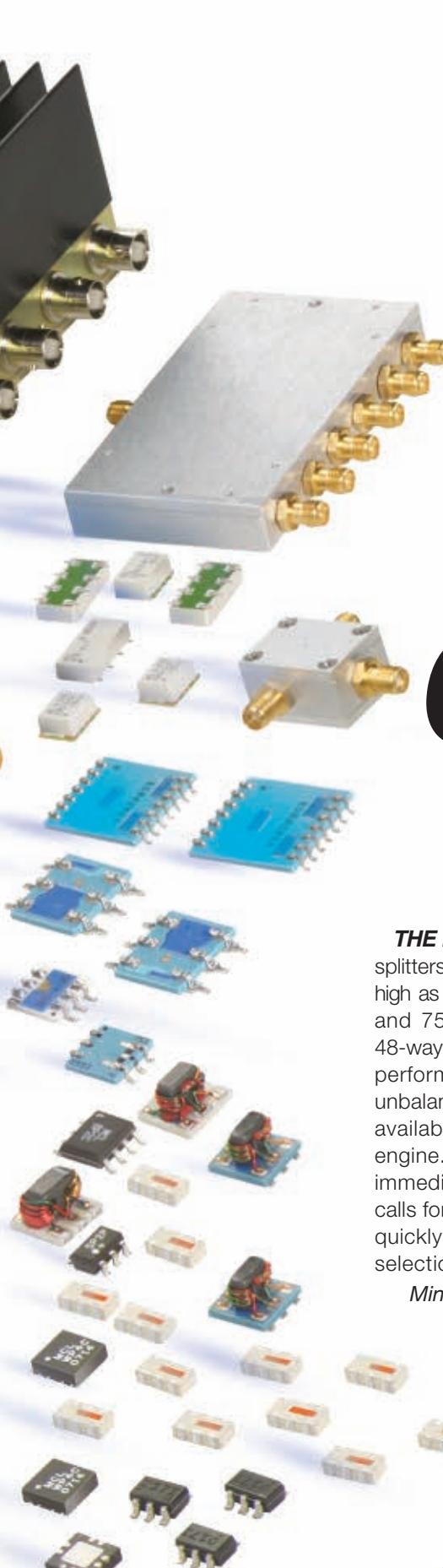
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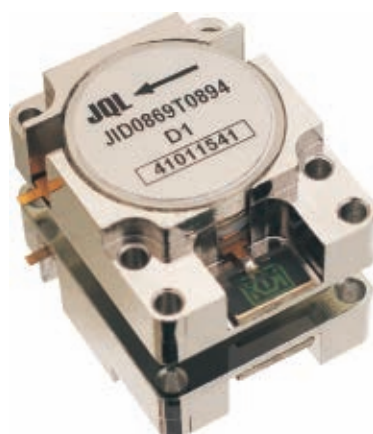
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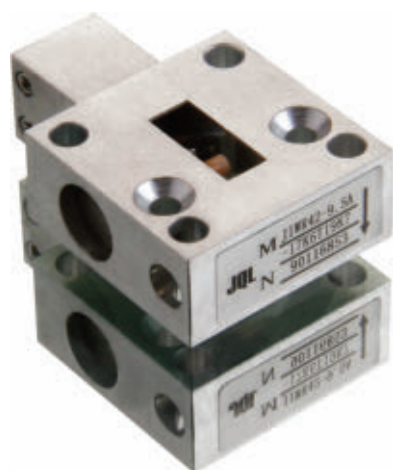
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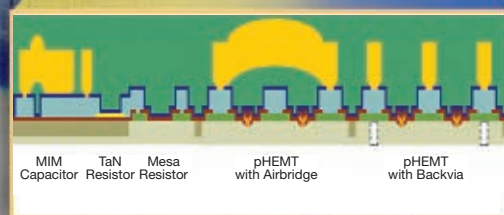


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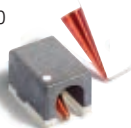
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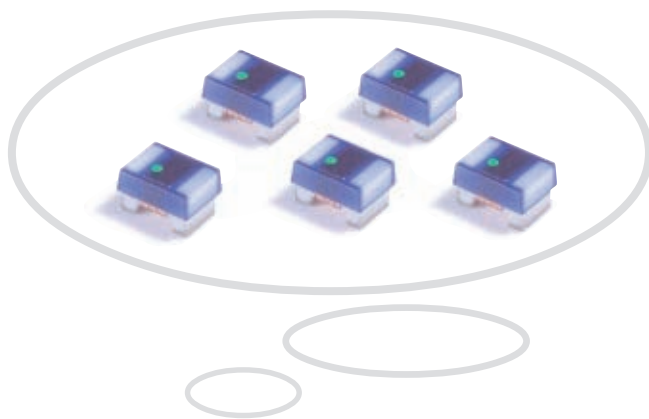


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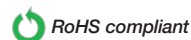
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EMERGING TECHNOLOGY AND MARKET TRENDS FOR FREQUENCY CONTROLLED CIRCUITS AND TIMING DEVICES

This article reports the current trends in timing solutions (timing devices and frequency control circuits) for modern electronic and communication systems, including the transition from discrete frequency sources to integrated circuits. Solutions that are gaining more popularity such as MEMS and tunable active inductor oscillators (TAIO) are described for completeness. The aim is to explore trends in market demands, competing technologies and the considerations of cost, size and performance (i.e. power-consumption, thermal drifts, phase noise, jitter, short-term stability, startup time, long-term stability and aging).

Current versions of handsets do not seem to be getting smaller as they are already quite small. In fact, some handsets are becoming bigger to accommodate more functions desired by consumers, such as DSC, DVC, MP3, GPS, Internet access, Bluetooth, DTV, etc. Opposite to the earlier thought that fewer piezoelectric frequency control components would be needed as time progressed, handsets nowadays have many more of them, including quartz tuning forks, quartz crystals, crystal oscillators (XO), voltage-controlled crystal oscillators (VCXO), temperature-compensated crystal oscillators (TCXO) and RF SAW/FBAR filter/duplexers.

However, downtrends in the economy have forced the entire electronic industry, including manufacturers of frequency generating devices to be more competitive. As conventional frequency controlled circuits and timing devices based on high Q resonators such as quartz, ceramic and SAW fail to follow economies of scale, the industry has begun looking toward alternative technologies. Growth in consumer products operating at high-frequencies is also driving the strong demand for “sili-

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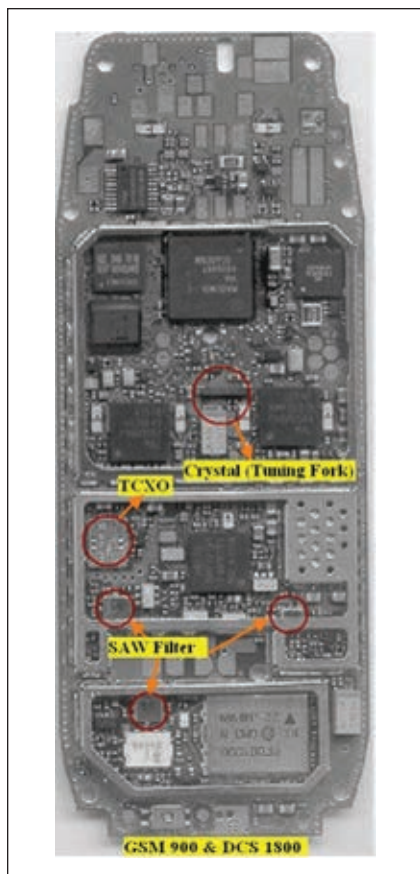
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▲ Fig. 1 Piezoelectric components in a typical dual-band GSM handset (GSM900 and DCS1800).¹

con resonator"-based oscillators and VCOs.

CMOS resonators are a breakthrough technology that could replace ceramic and SAW resonator-based frequency controlled circuits operating at 500 MHz and above because they offer significant advantages in total manufacturing capacity and lower cost. CMOS resonators are just beginning the learning curve, and are expected to follow Moore's Law on future size and cost reductions. CMOS resonators also offer a path towards IC integration, which is not possible with non-CMOS products.

Silicon MEMS resonator oscillators are another potential big player in an integrated solution. Although still in its infancy, MEMS technology offers low cost and higher integration over a non-silicon quartz resonator operating at less than 200 MHz. They target applications where the size and degree of integration are key, leading to the ultimate usage of MEMS oscillators in almost all portable systems such as PDAs, camcorders and MP3 players. The potential for smaller footprint

components and resistance to electromagnetic interference also supports new cell phone designs. Moreover, MEMS oscillators can meet price points set by crystal oscillators by leveraging established high-volume silicon manufacturing processes.

A noticeable marketing push for all-silicon MEMS resonators and oscillators has re-ignited the interest in displacing quartz crystal technology in order to support the prospect of clock source integration. MEMS oscillators appear well suited to high-vibration environments, non-critically-timed applications and applications where the signal-to-noise ratios are not critical. MEMS devices, unlike ICs, contain moving fragile parts that must be properly packaged and meet the requirements such as protection against handling, shielding against electromagnetic fields, near hermetic cavity seal, low temperature process, good heat-exchange, minimal thermal stress, and RF electrical feed through before becoming commercially viable alternatives. As the handset market continues to grow, developing MEMS-based RF components such as switches, filters, resonators, oscillators, VCOs, etc. in the RF section of handsets seems to be the logical route toward integration.

DYNAMICS OF TIME AND TIMING DEVICES

The accuracy of frequency generating devices for timing solutions depends on phase noise, thermal drift, harmonics, tuning sensitivity, stability, aging, etc. Crystals, SAW, ceramic resonator oscillators, RC oscillators and silicon resonator oscillators are the four main types of clock sources for use with a microcontroller. From simple RC oscillators, accurate to about 30,000 ppm, to atomic clocks, with accuracies of greater than 0.001 ppb, there are clocking options to meet the needs of every application.

For years, bulk acoustic wave (BAW) crystal oscillators satisfied the majority of requirements, providing accuracies in the 10 ppm range. Less accurate options, such as surface acoustic wave (SAW) oscillators, ceramic resonator oscillators and IC oscillators, each have advantages to meet specific needs. While many characteristics define the performance of the frequency generating device, phase

noise is the most important parameter for any timing solution. Quartz-based devices have long been a standard by which most other timing devices are compared. The history of quartz as a stable, controllable, high-quality material for frequency selective and clocking devices is universally recognized, and frequency vs. temperature response, aging, and jitter and phase noise characteristics are well chronicled.

HIGH Q-FACTOR RESONATORS

Discrete Resonators

The majority of frequency control and timing products in the market are based on resonators, such as quartz crystal and ceramics. In earlier days, a typical GSM handset had four different sets of piezoelectric frequency control components, namely the RF SAW filter (~900 MHz to 2 GHz using piezoelectric lithium tantalate or lithium niobate) for transmission and receiver filtering between the antenna and the transceiver chipset; IF SAW filter (~50 to 400 MHz using mainly quartz) if super heterodyne down conversion was used; TCXO (13/26 MHz using quartz crystal) as a clock reference in the transceiver synthesizer for channelization; and a tuning fork (32.768 KHz using quartz crystal) for standby clocking in the baseband section ($2^{15} = 32768$). Later on, the successful development of direct conversion technology made the IF SAW filter obsolete in many GSM handsets (see **Figure 1**), and GSM transceiver chipsets with an on-chip digitally-compensated crystal oscillator (DCXO) circuit began to appear.¹ The TCXO was no longer needed to pair with these transceiver chipsets. However, an off-chip quartz crystal was still needed (see **Figure 2**). **Table 1** describes the typical crystal and SAW-based products for frequency control circuits and timing devices.

Designers and manufacturers have been able to pursue new applications, thanks to some recent developments in oscillator technology. These include configurable oscillator technology, which makes the delivery of oscillators and VCXOs more timely and affordable than ever before. This type of oscillator remains extremely competitive with its MEMS and SAW oscillator counterparts in terms of cost, performance and delivery times. What



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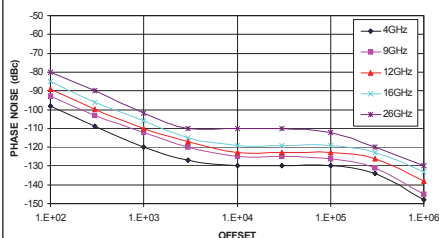
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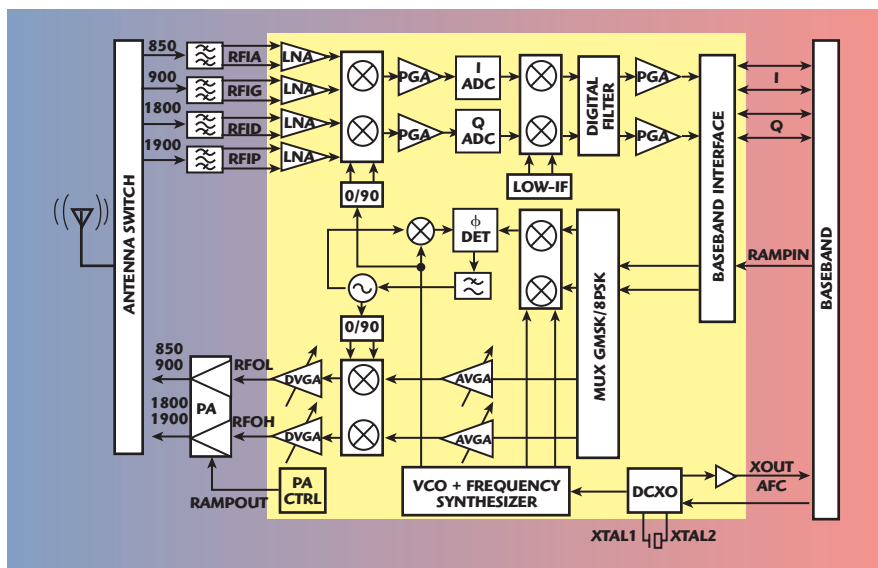
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▲ Fig. 2 GSM transceiver chipset with on-chip DCXO.²

sets configurable crystal oscillator technology apart is its ability to deliver its technical and business advantages across a frequency range of 750 kHz to 1.35 GHz with low jitter (less than 1 ps) and phase noise characteristics comparable to conventional crystal oscillators and SAW oscillators, as well as jitter and phase noise characteristics better than MEMS oscillators. Designers of subscriber applications such as wireless WiMAX or WiBRO data networks find this combination particularly attractive.

This customizable technology also enables new crystal oscillators to find homes as diverse as the clock source in 10G Ethernet, optical networks, storage-area networks (SAN), FPGAs, ADSL and many other applications. The demand for quartz crystals and crystal oscillators had been increasing steadily between 4 to 10 percent annually since the beginning of the decade, but was restricted to frequencies below 200 MHz. Recent downtrends in the telecom market caused a 50 to 80 percent drop in revenues as the business strategies of many crystal oscillator manufacturers were tied to mostly servicing telecom giants with their mid- to high-end quartz crystals and crystal oscillators (HFF inverted mesa crystal, XO, VCXO/VCSO, TCXO, OCXO and timing module). Now that the telecom quartz crystal and crystal oscillator market is showing signs of recovery, many more crystal oscillator suppliers are investing in developing mid- to high-end crystals and crystal oscillators to prepare for the telecom

TABLE I

CRYSTAL- AND SAW-BASED PRODUCTS¹

Crystal-based (<MHz~200 MHz)	Saw-based (<50 MHz~2. GHz)
Passives	
Tuning Fork and AT-Cut Crystal	SAWR
MCF	SAWF
Oscillators	
CXO	CSO
PCXO	PCSO
VCXO	VCSO
TCXO	TCSO
OCXO	OCSO
Timing Modules	
Clock Data Recovery	
Clock Smoother	
Frequency Translator	
Synchronous Timing Module	

market return. Suppliers who suffered during the downturn will be glad to see the market rebound, but they will find more competitors out there and telecom customers demanding lower prices.

Despite quartz being the material of choice for high performance TCXOs, there are several drawbacks and limitations. The first difficulty is related to the attachment of miniaturized quartz plates to the ceramic package with solder balls. Precise control during assembly is crucial to preventing spurious modes and packaging related stresses that can impact the tem-



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MODEL	FREQ. RANGE (GHz)	NOMINAL LEAKAGE LEVEL (dBm)	TYPICAL LEAKAGE LEVEL (dBm)	TYPICAL THRESHOLD LEVEL (dBm)
LL0110-1	0.01 - 1.0	-10	-	-11
LL0110-2		-5	-	-6
LL0110-3		0	-	-1
LL0110-4		+5	-	+4
LL0120-1	0.1 - 2.0	-10	-	-11
LL0120-2		-5	-	-6
LL0120-3		0	-	-1
LL0120-4		+5	-	+4
LL2018-1	2 - 18	-	-10 TO -5	-10
LL2018-2		-	-5 TO 0	-5
LL2018-3		-	0 TO +5	0

Notes:

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2. Typical and nominal leakage levels for input up to 1W CW.
3. Threshold level is the input power level when output power is 1dB compressed.

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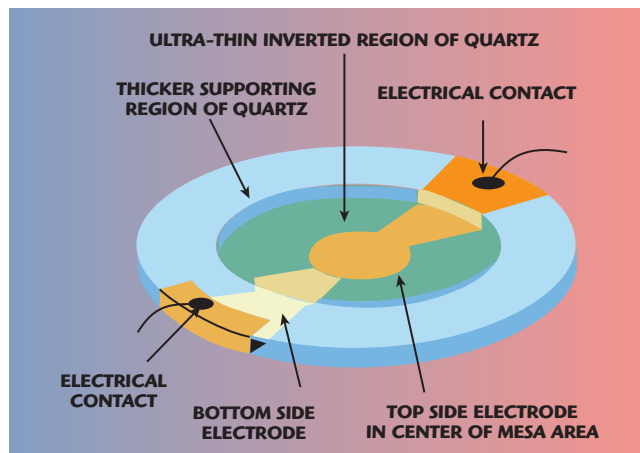
perature stability of the quartz resonator. Secondly, the quartz is a fragile material. Handset manufacturers have moved towards smaller packages, leading to the use of smaller quartz plates and making the absolute manufacturing tolerances more challenging.

It has long been a research activity to produce a low cost high frequency fundamental crystal resonator in the GHz range. One possible solution has been the development of the inverted mesa-type crystal resonator.³ As shown in **Figure 3**, the center portion of the mesa quartz resonator is comparatively thinner than the outer ring, so that the center ring vibrates at higher frequency without breaking. The outer thicker ring forms a strong frame structure around the thin and fragile, etched

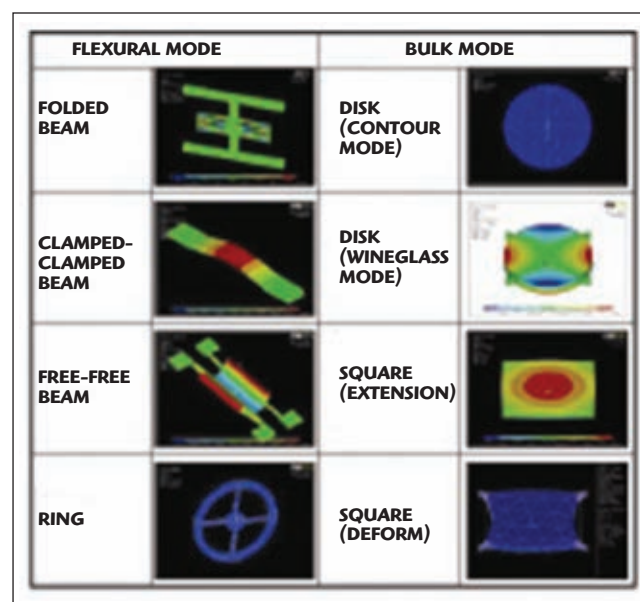
central resonating structure, which is etched to the thickness corresponding to the operating frequency. The strong outer ring enables easier handling. This technique allows the manufacture of very thin quartz crystals resonators, but needs lot of effort and is therefore not an economically viable solution at the moment.

Integrated Resonators

As ICs continue to shrink, resonators based on non-silicon technology unfortunately do not follow Moore's Law for miniaturization. Ultimately, this restricts further reductions in the footprint of IC/quartz, ceramic, or SAW hybrid timing solutions. Additionally, quartz crystal, ceramic and SAW devices are produced through fairly labor intensive processes,



▲ Fig. 3 A typical inverted high frequency mesa.



▲ Fig. 4 A typical matrix of MEMS resonators and their mode shapes.

wherein each device has to be finely tuned to achieve the desired resonant frequency characteristics, further adding to their overall cost and making the replacement of these devices with an monolithic IC solution all the more attractive. RF system designers also stress the need for higher levels of integration in RF function blocks, an approach that is amenable to RF and digital interfaces, and therefore speeds the time to market while simplifying system-level integration.

As mentioned, integrated resonators are typically fabricated using silicon and CMOS MEMS technology. **Figure 4** shows the typical matrix of MEMS resonators and their mode shapes,²² including folded beam, clamped-clamped beam, free-free beam and ring resonators. Typically, flexural mode

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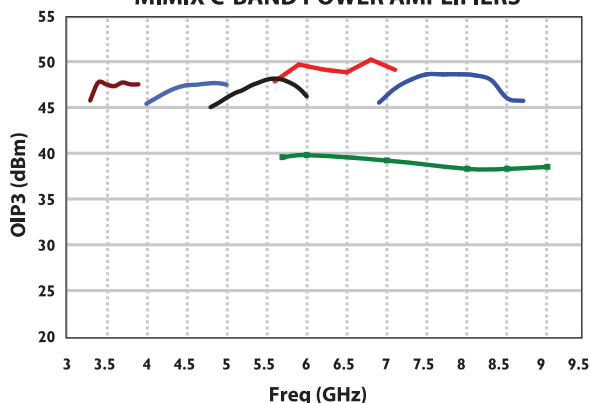
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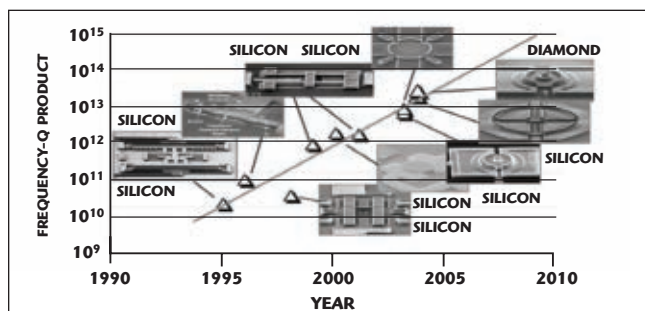
	Device	Frequency (GHz)	Gain (dB)	P1 dB (dBm)	OIP3 (dBm)	Current (mA)	Voltage (V)	Package (mm)
Power Amplifiers	XPI044-QL	3.5-6.0	18.5**	34.0	46.0	900	8.0	7x7
	XPI039-QJ	5.6-7.1	16.6	35.5	49.0	1400	8.0	6x6
	XPI050-QJ	7.0-9.0	15.0	34.5	48.0	1400	8.0	6x6
	XPI035-QH	5.9-9.5	26.0	29.0	39.0	500	6.0	4x4
FETs	XF1000-DB*	DC-4.9	10.0***	34.0	47.0	550	8.0	3x6
	XF1001-SC	DC-6.0	10.0**	30.0	46.5	350	8.0	SOT-89

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▲ Fig. 5 A typical plot showing exponential growth in the frequency-Q product of micromechanical resonators over time.²³

resonators cover frequencies less than 100 MHz due to the limit of the resonator's mechanical stiffness. **Figure 5** shows a graph showing the frequency-Q product, which have increased exponentially over recent years.²³

With the advent of MEMS technology, there has been an ongoing debate whether MEMS resonators could offer a competitive alternative to quartz crystal resonators. In particular, as the integration difficulties of the quartz crystal with the oscillator IC scale inversely with the size of the package, the use of MEMS resonators would promote a monolithic solution of MEMS and IC. Commercially available MEMS oscillators targeting low-end timing solutions still struggle for general acceptance as a replacement of TCXO because current MEMS oscillators fail to achieve the combination of temperature stability, low phase noise and frequency accuracy.

The high levels of miniaturization achieved by MEMS will allow these cost-effective, high-Q resonators, which can operate at different frequencies, to be fabricated simultaneously within the same device "footprint." Selection of the desired frequency is subsequently achieved with software. This is a big advantage compared to a quartz crystal, which is only capable of resonating at a single frequency throughout its lifetime. Changing the function of the quartz clock from a cell phone application to a high-definition television, for example, requires fabricating an entirely different batch of crystals, operating at different frequencies. **Figure 6** shows the typical 67.5 MHz quartz crystal and MEMS oscillator for comparative analysis,²² showing the MEMS com-

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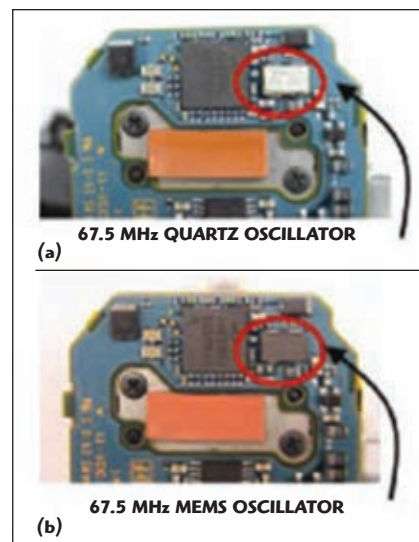
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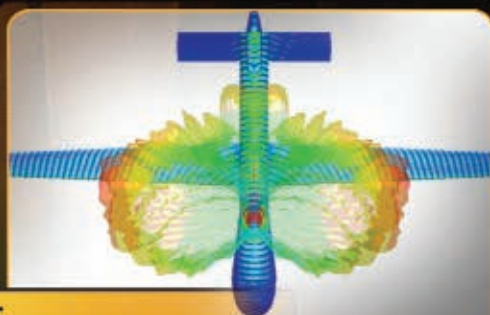
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▲ Fig. 6 Typical quartz and MEMS oscillator.



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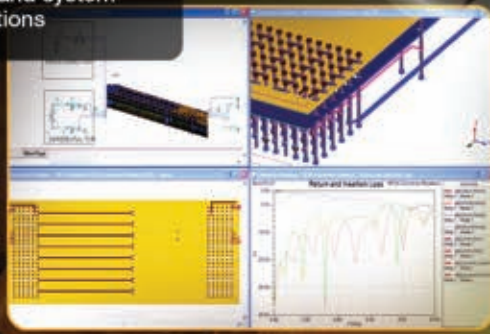
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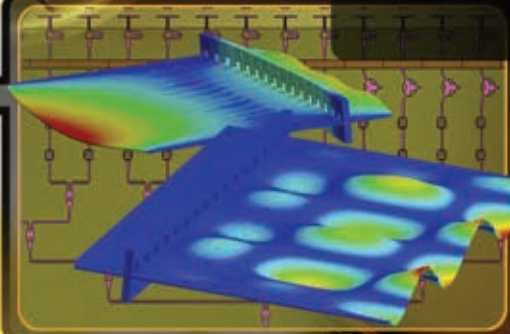
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ponent as a drop-in replacement for the quartz crystal. The downside to MEMS is its capital-intensive development and up-front manufacturing cost, hampering suppliers from taking advantage of its ultra low phase noise performance. It will take at least 10 years before MEMS oscillators could ease out their longtime competitive quartz crystal resonator oscillator counterparts.¹⁻²¹

EXAMPLES: FREQUENCY GENERATION CIRCUITS

Crystal Oscillators

In order to adapt to the highly competitive IC market, chip suppliers are racing to reduce the total chip count by integrating functionality onto a single IC. However, one of the few elements that escaped this integration and remains to be off-chip is the timing source. In both wireless and wired

systems, the reference source requires varying degrees of accuracy and stability over time and temperature. More often these accuracy requirements can only be met by using externally compensated reference sources such as TCXOs or VCXOs, which occupy a large fraction of the board space. Hence, a large emphasis is placed on eliminating these components by either integrating their functionality on-chip or replacing them with a much smaller footprint solution.

The quartz crystal oscillator XO has been the de facto frequency source in electronic platforms for nearly 100 years. Through precise manufacturing and economic scale, XOs have proven to be stable and low-cost frequency sources. However, XOs are referenced to macroscopic crystals (XTAL), which are not able to be integrated, thus often limiting device form-factor. Furthermore, fundamental-mode XTALs scale only to modest frequencies.

The following section looks at crystal oscillator technologies. There are three groups of solutions with different performances.

The first group consists of the pairing of either a high frequency fundamental (HFF) quartz crystal, a 3rd overtone (OT) quartz crystal, or a fundamental SAW resonator with a traditional feedback loop oscillator IC. The second group pairs a low frequency quartz crystal (20 to 35 MHz) with a simple divider PLL IC. The third group consists of the pairing of a 3rd OT quartz crystal with a higher level PLL IC, e.g. a 3rd OT quartz crystal with an analog frequency multiplierTM (AFM, e.g. $\times 2$) IC, a 3rd OT quartz crystal with a fully programmable DSPLL oscillator IC.²⁻⁴ The above solutions offer less than 1 ps rms phase jitter (12 kHz to 20 MHz). Except for the SAW solution, the above solutions offer typical AT-cut quartz crystal's cubic frequency-temperature property and ± 100 , 50 and 25 ppm options are available.

Crystal oscillators using additional temperature compensation, also referred to as a temperature compensated crystal oscillator (TCXO), are able to achieve typical frequency stabilities of ± 2.5 ppm/year at room temperature, typical phase noise of -138 dBc/Hz at 1 kHz offset and power consumption as low as 1.5 mA. The smallest commercial TCXOs are currently



VCO Performance and Dependability

85 MHz to 18 GHz

Model	Freq. Range (MHz)	Tuning Voltage Range (Volts)	Output Power/Variation (dBm/ $\pm$ dB)	Typical Phase Noise Offset at 10kHz/100kHz (dBc/Hz)	Nominal Modulation Sensitivity Min.-Max. (MHz/V)	Typical Harmonic Suppression (dBc)	D.C. Bias	
							Voltage (Volts)	Current (mA)
Oscillator with internal MMIC amplifier available in SMT0-8 or CougarPakTM								
OAS5100	4300-5100	0-15	13.0/2.0	-84/-108	50-85	-22	5.0	94
OAS7700	5700-7700	0-15	10.0/2.0	-75/-100	70-250	-30	5.0	95
OAS8900	6900-8900	0-15	10.0/2.0	-70/-95	100-270	-30	5.0	95
Oscillator available in SMT0-8 or CougarPakTM								
OS6700	5400-6700	0-15	0/2.0	-75/-100	80-180	-17	5.0	25
OS7700	5700-7700	0-15	2.0/2.0	-75/-100	70-250	-17	5.0	25
OS8900	6900-8900	0-15	1.0/2.0	-70/-95	100-270	-25	5.0	24
Oscillator available in TO-8, SMT0-8 or CougarPakTM								
OC1000	500-1000	0-20	10.0/2.0	-90/-105	15-55	-10	15.0	35
OC3400	2700-3400	0-15	10.0/2.0	-80/-105	75-115	-12	15.0	60
OC4500	3500-4500	0-15	8.0/2.0	-75/-100	50-150	-10	15.0	60
Oscillator, Amp, Filter and Voltage Regulator in 2- and 3-Stage CougarPakTM								
OA2CP2001	1000-2000	0-(-15)	15.0/2.0	-70/-100	50-150	-15	15.0	250
OA2CP12500	9000-12500	0-(-12)	15.0/2.0	-65/-95	150-450	-25	15.0	250
OA3CP18001	12000-18000	0-(-12)	15.0/2.0	-55/-85	150-750	-15	15.0	350

Typical and guaranteed specifications vary versus frequency; see detailed data sheets for specification variations.

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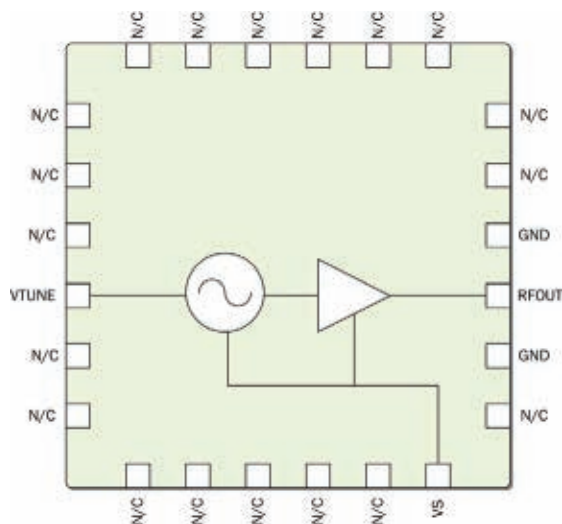
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SPECIFICATIONS

Part Number	F Low (MHz)	F High (mHz)	Output Power (dBm)	10 kHz Phase Noise (dBc/Hz)	100 kHz Phase Noise (dBc/Hz)	Pushing (MHz/V)	Pulling (MHz p-p at 2:1 VSWR)	Power Supply
RFVC-1800	8000	12000	4.0	66.0	93.0	75	7	5 V at 55 mA
RFVC-1801	5000	10000	3.0	72.0	96.0	18	6	5 V at 55 mA
RFVC-1802	4000	8000	3.5	74.0	99.0	16	4	5 V at 55 mA
RFVC-1803	6000	9000	3.5	73.0	97.0	22	—	5 V at 52 mA



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available with dimensions of $2.0 \times 1.6 \times 0.8$ mm.⁵ **Figure 7** shows the phase noise plot of a differential coupled 100 MHz crystal oscillator (XO). As shown in the figure, the mode-feedback technique minimizes the phase noise by 10 to 15 dB, resulting in a cost-effective solution. The typical measured phase noise is -139 dBc/Hz at 100 Hz offset from the carrier; this is a reasonably low phase noise for this class of inexpensive crystal resonator oscillators.

Ceramic Resonator Oscillator

Ceramic coaxial resonator oscillators (CRO) are widely used in wireless applications, since the technology features low phase noise and high quality factor (Q), at fixed frequencies through about 4000 MHz. Typically, a ceramic resonator is comprised of a dielectric material formed into a rectangle prism with a coaxial hole running lengthwise through the prism and an electrical connector at one end.

The outer and inner surfaces of the prism, with the exception of the end connected to the electrical connector and possibly the opposite end, are coated with a metal such as copper or silver. A device formed in this manner forms a resonant RF circuit, including capacitance, inductance and loss resistance that oscillates in the transverse electromagnetic (TEM) mode, if loss resistance is compensated.

Unfortunately, CROs have several disadvantages, including a limited temperature range, limited tuning range and sensitivity to phase hits (due to the different rates of expansion/contraction by the outer metallic body of the coaxial ceramic resonator and other components of the oscillator circuit over temperature). A designer can consider using a digitally implemented CRO to overcome the above problems; however, due diligence must be done upfront in order to avoid the large phase hits that can unlock a communication link if not adequately absorbed.

Figure 8 shows the layout and phase noise plots of a 1 GHz CRO; the typical phase noise at 10 kHz offset is -125 dBc/Hz. CROs are generally used for less accurate applications.⁶ Initial accuracy (calibration) of these devices ranges from ± 0.05 percent to ± 1.0 percent. Temperature stability is approximately 15 ppm/ $^{\circ}$ C for ceramic resonators. Aging is in the range of ± 0.5 percent/10 years. These devices have a much lower Q than quartz crystals and also seem to be more prone to spurious modes of operation.

Saw Oscillator

The bulk of the quartz is the area of excitation for the previously mentioned crystals (BAW). SAW devices

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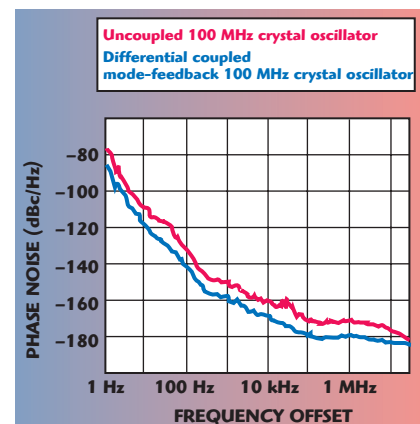
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▲ Fig. 7 Measured phase noise plots of XOs.

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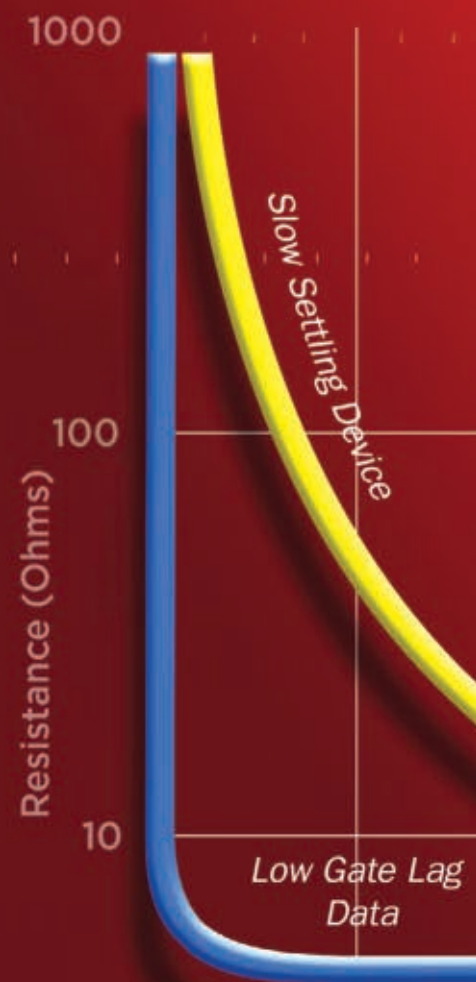
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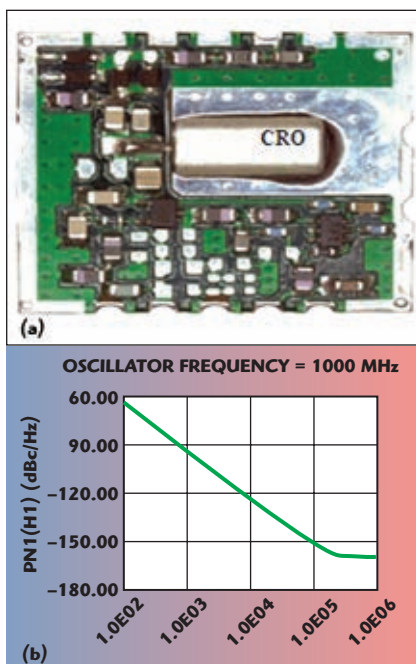
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▲ Fig. 8 Layout of 1 GHz CRO⁶ (a); simulated phase noise plot of 1 GHz CRO (b).

are generally used in frequency ranges above those targeted with BAW crystals. The SAW involves only the surface of the substrate. The frequency is set by the distance between the electrode "fingers". Quartz, LiTaO₃ and LiNbO₃ are common substrates for such devices. Initial accuracy is dependent on the accuracy of the printing of the "fingers", ranging in the ± 50 to 200 ppm range. The approximate temperature constant of quartz is 0.03 ppm/°C and -20 ppm/°C for LiTaO₃.² Upper frequencies of 3.5 GHz are currently obtainable. The lower end is limited primarily by size, since the AT becomes more practical. Currently, SAW resonator oscillators are used for high frequency signal sources where frequency stability is especially important.

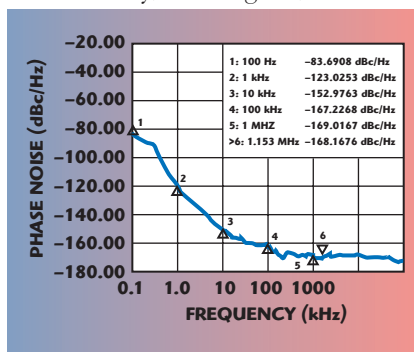
The shift to multi-band, multimode phone models has increased the number of SAW filters per handset. As more phones operate over multiple bands, manufacturers are expected to require more SAW filters, thereby increasing the overall SAW filter market size, specifically SAW filters, resonators and oscillators. SAW oscillators are widely used in wireless applications, since the technology features very low phase noise at fixed frequencies up to about 3 GHz. SAW resonator oscillators are also known for their low micro-phononic noise (tolerance to vibration), high Q and low jitter. Un-

fortunately, SAW oscillators have several disadvantages, including a limited operating temperature range and tuning range (which limits the amount of correction that can be made to compensate for the tolerances of other components in the oscillator circuitry). In addition, since the design of a new SAW oscillator is much like that of an integrated circuit (IC), development of an oscillator with a nonstandard frequency requires NRE costs on the order of \$10,000, in addition to the costs of the oscillators.

Synergy Microwave has developed a low-cost ultra low phase noise SAW VCO that offers improved thermal-drift and phase noise performance compared to other commercially available SAW oscillators at comparable frequencies. **Figure 9** shows the phase noise plot of the 1 GHz SAW oscillators; the typical phase noise at 10 kHz offset is -152 dBc/Hz. These SAW devices are available in standard frequencies, such as 622.08, 800, 915.5 and 1000.01 MHz, as well as in customer-specified frequencies from 300 MHz to 4 GHz. Ultra-low phase noise VCSOs offer significant promise in terms of performance, price and product delivery.

MEMS Oscillators

Until now, MEMS oscillators had taken only limited advantage of MEMS integration. The market for such devices is obvious when one looks at existing timing solutions, currently consisting of a large socket on which a PLL ASIC is placed to a discrete, bulky quartz sensor. MEMS oscillators offer the same functionality as a one-chip solution and now compete directly with products that have temperature stability of about 50 ppm. Regarding the 10 ppm temperature stability, this is good, as MEMS



▲ Fig. 9 Measured phase noise plot of 1 GHz VCSO.

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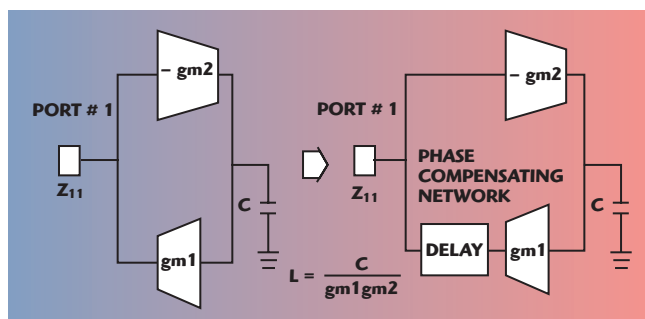
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MASWSS0192	DC-3	0.25	28.5	20
MASW-008955	DC-3.5	0.55	35	22
MASW-007587	DC-4	0.8	39.5	30
MASW-007107	DC-8	0.5	30	30
MASW-008543	DC-4	0.7	25	65*
MASW-007588	DC-6	0.8	40	28
MASW-007921	DC-7	0.65	39	26
MASW-009590	DC-8	0.6	32	23
MASW-008322	DC-20	1.9**	30	40**

* at 2.1 GHz ** at 20 GHz



▲ Fig. 10 A typical equivalent representation of gyrator-based active inductor.

oscillators had offered 25 to 50 ppm so far. It is not clear, however, if there is a market for this specific temperature stability range. Most consumer and IT applications can work with 30 to 100 ppm, on the higher side, and TCXO for mo-

bile phones and GPS require 0.5 to 2 ppm. A recent publication reports a temperature compensated MEMS oscillator (TCMO™) with 5 ppm over the temperature range from -40° to +85°C and phase noise performance of -136 dBc/Hz at 1 kHz offset from the 13 MHz carrier.⁵ Although the technology offers a cost-effective solution, the phase and frequency discontinuity deteriorates the jitter, resulting in sudden jumps in phase that plague commercially available fractional N-PLL-based designs. The small size and rugged reliability that MEMS oscillators can offer are an important part of the future of the frequency control market. The MEMS-based oscillator addresses a strong need for high-shock resistant timing components in the Precision Guided Munitions (PGM) markets.

The relatively recent introduction of MEMS-based oscillators has been accompanied by claims that this technology would finally replace quartz by providing lower costs, shorter design and production cycle times, excellent shock and vibration performance, and superior signal quality. Despite these claims, few studies have been available to help understand the performance characteristics of MEMS oscillators. Due to their material characteristics, silicon-based MEMS oscillators have to use a temperature compensated circuit to tune the resonant frequency back to an acceptable scale. The vibration mechanism of the silicon MEMS resonator is still not very stable in the short term and that makes the MEMS oscillator unable to achieve wide market acceptance at this time.

Tunable Active Inductor Oscillators

Another new technology that is a suitable alternative for cost-effective integration is the tunable active inductor oscillator (TAIO). TAIO technology, by virtue of its small size, is extremely rugged and well-suited to low-jitter applications such as in military and aerospace equipment, where resistance to shock and vibration is at a premium. Exciting new devices exist for active tunable inductors in areas such as tunable oscillators, filters and resonators.

The typical active inductor is based on a gyrator (see **Figure 10**), which can be realized by connecting an inverting amplifier to a non-inverting

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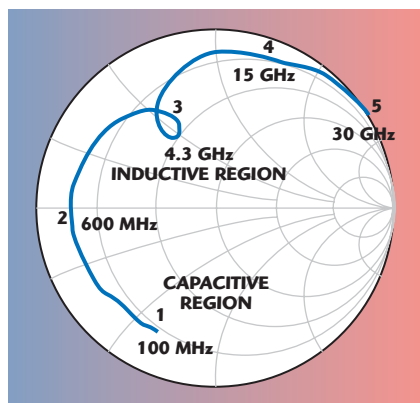
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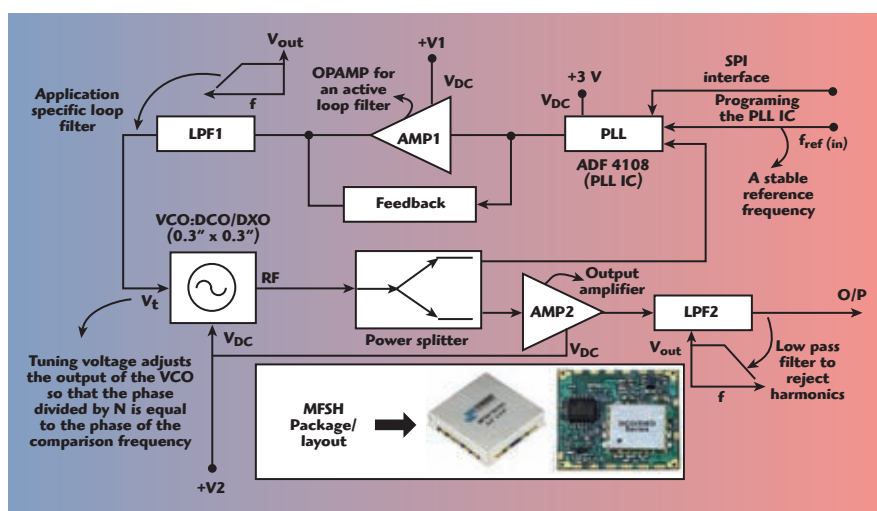
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▲ Fig. 11 Impedance plot.

one in parallel and back-to-back. Care must be taken to avoid encircling and crossing the impedance at 4.3 GHz (see **Figure 11**, point #3), which limits certain applications.²⁰ Several approaches to overcome these problems have been considered, including the minimization of the noise introduced by the active devices that make up the ATI circuits. However, these techniques can be power hungry and result in limited band characteristics.

Technologies for creating frequency synthesizers are diverse, from traditional analog methods using PLLs to



▲ Fig. 12 Block diagram of a configurable synthesizer using configurable TAI Os.

direct digital synthesizers (DDS) that rely on high-speed digital-to-analog converters (DAC). Frequency synthesizers can be categorized into mainly three groups: analogue, digital or mixed signal (hybrid). The frequency synthesizer described in **Figure 12** falls into the hybrid category. A typical unit tunes from 500 to 1000/1000 to 2000/2000 to 4000/4000 to 8000 MHz in 1 MHz steps with settling time of

less than 4 ms and typical phase noise of -108 dBc/Hz at 100 kHz offset from the carrier.

Market Dynamics

Developing RF circuits and sub-systems require a series of engineering trade-offs that are limited by the technology currently in use.²¹ This is "easy" to deal with for single-mode systems like an old-fashioned cell



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phone, or modern Bluetooth circuit, but gets harder to do as frequencies get higher, data bandwidth gets larger, and most of all, when multiple broadband signals have to be managed in the same device. This is a defining trend in the wireless industry, and one that is taxing the limits of conventional technologies and “old-school” radio architectures. Wireless engineers in the broadband, multi-standard world need a better way of doing things,

and better technologies that can easily handle these widely varying signals.

Essentially, RF MEMS devices offer “best of breed” in a host of performance and usage parameters out of all possible technologies considered to be an alternative for a very wide variety of RF applications. The most widely recognized advantages are low loss, high isolation, near-perfect linearity, and unbelievable large instantaneous bandwidth that conventional

mechanical and semiconductor technology simply cannot compete with. On top of this are a host of usage parameters like cost, size, speed, ruggedness, reliability, repeatability and lifetime, that each range from fantastic to poor depending specifically on what they are being compared to and depending on whether or not a customer values that particular specification.

RF MEMS came into their own as a nascent industry in the early '90s, which is when most of the classic devices were invented by researchers working for major defense-oriented companies. These device-level development efforts were largely funded by DARPA and the Air Force, with a system-level view of how these devices could actually improve radar and communication systems. Soon after, other Federal services and agencies recognized their own needs for improved RF systems, and followed suit with programs directed towards broadband, highly multi-band, and/or millimeter-wave applications such as tactical radio programs (JTRS, WIN-T etc.), satellite communications, and terrain-penetrating imaging radar (FOPEN, URPEN, etc.). RF MEMS enable switching and tuning of front-end circuits for applications of mode switching, antenna tuning and antenna beam steering with phase shifters.

There are still significant obstacles for RF MEMS to enter conservative application areas with long histories of well-established technologies and very strict screening requirements. There are a number of challenges that face anyone who wishes to take an RF MEMS device or circuit prototype into component production. The most significant challenges are those associated with packaging. These packaging aspects are designed to enable the high RF performance of the MEMS devices inside to shine, yet still provide customer-demanded levels of four critical operational characteristics: lifetime, repeatability, reliability and ruggedness.

While integrated silicon solutions are cost-effective and compact in size, they leave much to be desired in comparison to the performance of non-silicon resonator-based oscillators. The recent strong marketing push of the MEMS silicon resonator-based

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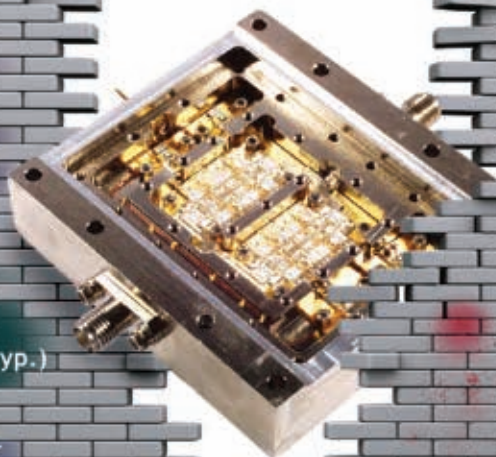
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Gain: 45 dB min

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oscillators seems to have re-ignited the interest in displacing quartz crystal technology and once again open up the prospect of clock source integration. However, the risk factors are alarming for the application of ultra stable and ultra low phase noise frequency generating circuits and timing devices, since optimization (stability, jitter, thermal drift, reliability) and changes during the IC design phase can be expensive and time consuming.

Bubble or Hit?

There is a dynamic market for frequency control devices, including quartz crystals and oscillators, SAW devices, ceramic resonators, and the evolving market for MEMS and TAI oscillators. With today's new business model, a company no longer focuses on individual technology such as MEMS and LC oscillators, but instead sells IP that supports the design and manufacture of integrated MEMS

devices (probably focused on SiGe). Technology breaks in R&D include resonators, temperature sensors, pressure sensors and inertial sensors. Indeed, there are only a few companies with advanced development of MEMS oscillators as well as a larger group in the quartz and timing industry that are interested in adding this technology to their portfolio. Competition from silicon MEMS, SAW and other oscillators has made crystal oscillators better than ever.

Future Trends

How will market trends for frequency controlled circuits and timing devices shape up? While silicon-based timing devices are still not as capable of sophisticated tasks as crystal oscillators, they are getting better, and will eventually replace crystals in many contexts. That will produce further synergies for the industry as mass production becomes cheaper and easier. These days, designers require higher frequencies and low jitter in oscillators, while buyers demand low cost and quick delivery. Timely oscillator options that can deliver the highest desired performance, while minimally compensating design steps are key to cost-effective solutions.

Fortunately, in the ongoing battle to push the limits of technology and lower component costs, oscillator manufacturers continue to close the gap between high-level performance and cost-effective purchasing, with conventional crystal technology paired with configurable oscillator technology. Like every exciting new technology targeting mass markets and driven by start-ups, confusion or exaggeration are present, but all in all, it is believed that MEMS oscillators will follow the successful bulk acoustic wave devices as the second RF MEMS mass product. If SiTime Corp., an analog semiconductor company focused on MEMS-based timing solutions, keeps to schedule and ships its first million devices by year's end, a major step will have been taken towards a bright future. As Senior Analyst for ABI Research, Doug McEuen stated, "The current steady, moderate growth in timing solutions revenue is being driven by the expansion of strong consumer electronics and computer applications sectors, and because silicon timing solutions are improving. Sili-

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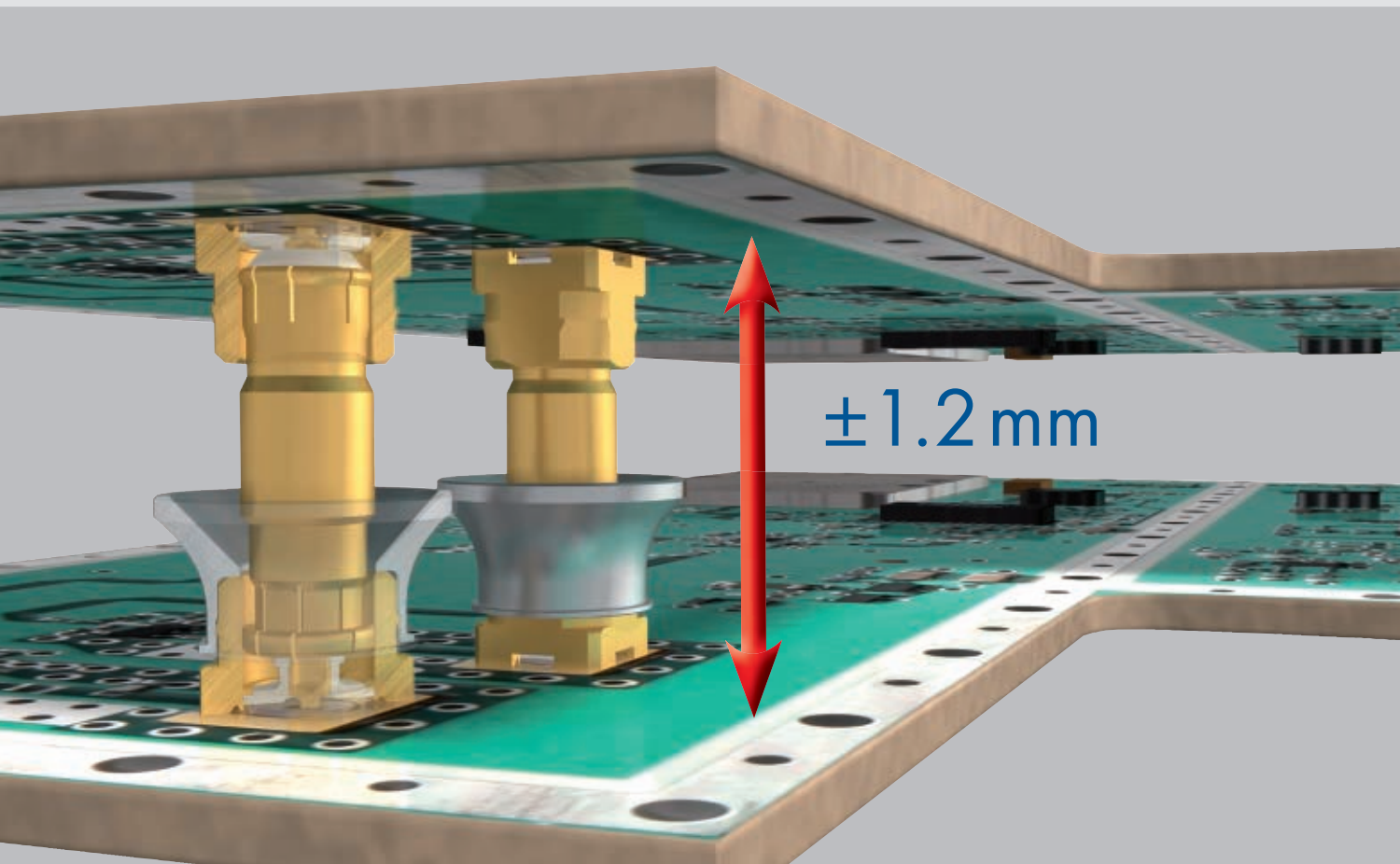
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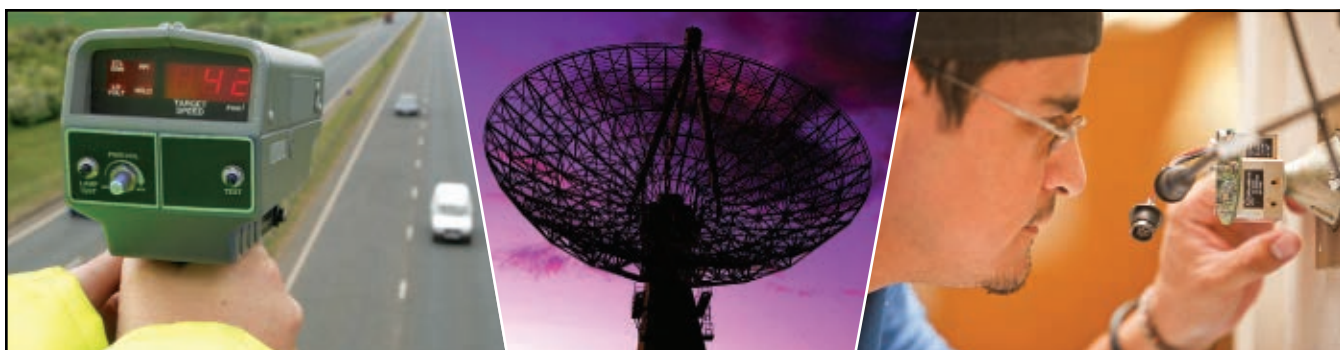
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con is increasingly able to handle some of the timing tasks traditionally given to crystals. However, continued under-investment by telecom infrastructure vendors could have a negative effect in the medium term." Overall, it is expected that the market for both non-silicon and silicon resonator oscillators will share 50 percent of the timing solution market down the road. ■

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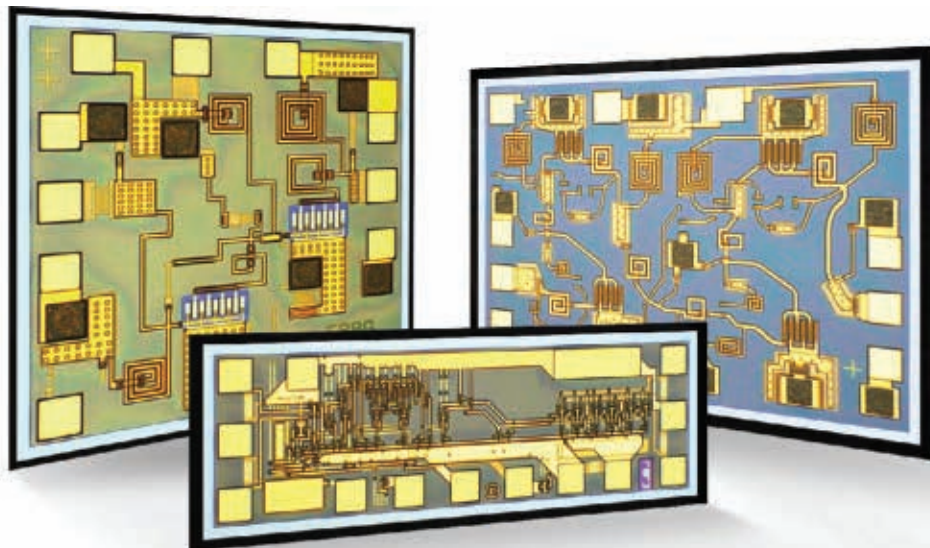
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3G POWER AMPLIFIER PROMISES TO INITIATE INDUSTRY SHIFT TO CMOS



Brad Fluke,

President and CEO of Javelin Semiconductor.

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CMOS power amplifiers (PA) are prevalent in today's WiFi and Bluetooth markets, yet extensive industry-wide development efforts for CMOS PAs for 2G and 3G mobile handsets have so far failed to yield a product that met the performance of incumbent GaAs PAs. However, a new CMOS PA from Javelin Semiconductor, the JAV5001, promises to out-

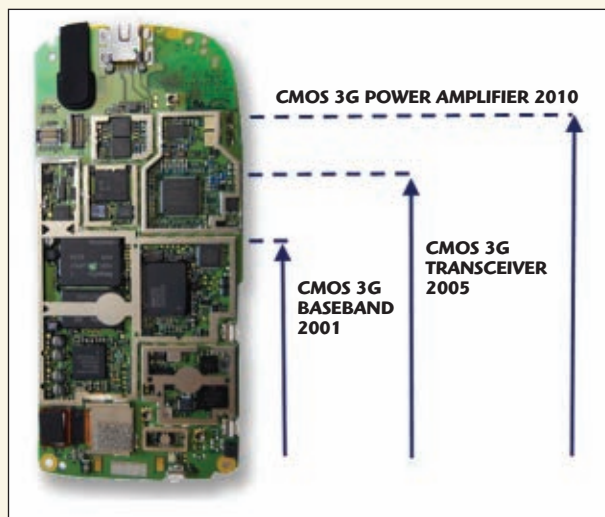
perform existing solutions with a patented power combiner that delivers the lowest average current under real world 3G operating conditions. The JAV5001 also features a "bandpass" PA architecture,

which produces over 10 dB lower noise and includes attenuation outside the band of interest that can enable the Tx SAW filter to be removed on some mobile handset platforms. By outperforming conventional GaAs PAs and providing virtually unlimited manufacturing capacity, the JAV5001 represents a breakthrough in the industry that could initiate the long-anticipated shift in handset PA technology from GaAs to CMOS.

GROWTH OF CMOS IN 3G HANDSETS

Approximately ten years ago, the world's first 3G mobile handsets appeared on the market. Though the digital baseband processor was implemented in a standard CMOS process, the analog functions, including the various radio transceivers and amplifiers, were implemented in custom processes such as SiGe or GaAs. Since that time, CMOS has been steadily growing toward the antenna, as shown in **Figure 1**. Today, CMOS is the dominant process of choice for Bluetooth, WLAN and other peripheral radios in the handset.

There are multiple reasons for the growth



▲ Fig. 1 Growth of CMOS in 3G mobile handsets.

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of CMOS. Baseband platform vendors improve economies of scale by driving as many chips as possible in the same foundry. Furthermore, GaAs PAs run on more expensive and smaller volume foundry lines. Standard CMOS foundries ensure high quality and reliable supply, which is particularly important to a market that is often subject to allocation during peak demand cycles. Additionally, CMOS enables architectural innovations and key product features not possible with custom processes that have limited digital circuitry.

CMOS PA CHALLENGES

While the PA has long been a major opportunity for CMOS, the technical challenges have been notoriously difficult to overcome. The first concern is the belief that CMOS transistors were not fast enough to support high frequency, low noise operation. In 2005, after the ramp of the Aero transceiver from Silicon Labs into a \$250 M business quieted those concerns, the attention turned to breakdown voltage limitations of CMOS. In 2007, Axiom's GSM/GPRS PA showed that those voltages could be effectively managed using a clever architecture implemented in CMOS, but the product fell short on efficiency performance. The Silicon Labs GSM/GPRS PA marked a similar achievement in the laboratory, but also fell short on efficiency.

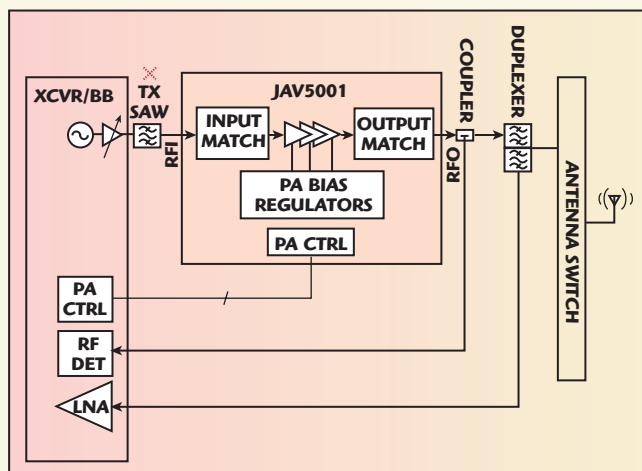
The structure of the 3G network presents an excellent opportunity for CMOS PAs. Unlike the 2G GSM/EDGE network, the 3G network requires the mobile handset transmit power to be very accurately controlled over a wide range from -50 to +24 dBm. The PA is expected to maintain efficiency over the entire range of output power, not just at maximum power. Furthermore, the power must be highly accurate over temperature, voltage, frequency and output load impedance. These system requirements force new types of PA circuit architectures and designs to be considered for a 3G CMOS PA to achieve best-in-class performance, as well a focus on device modeling and simulation.

W-CDMA MOBILE HANDSET EXAMPLE BLOCK DIAGRAM

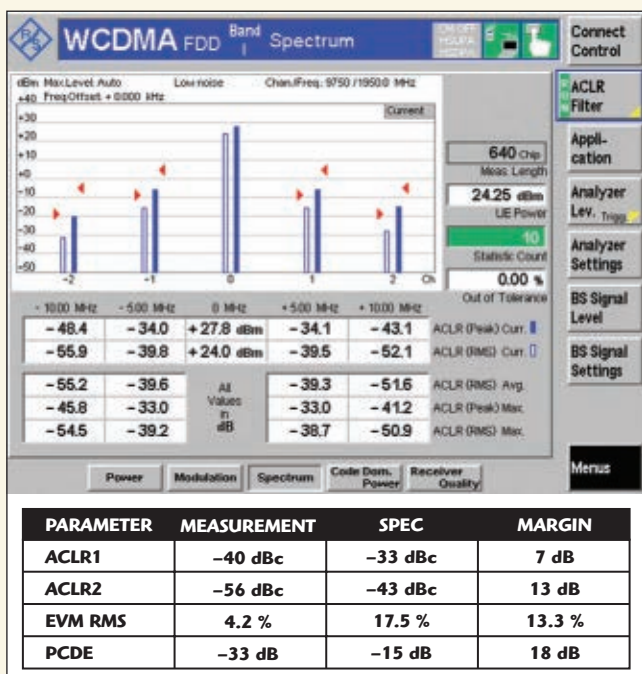
Figure 2 shows a block diagram of a single W-CDMA band of a mobile handset including the JAV5001 PA. The signal is transmitted and received by the transceiver and baseband (XCVR/BB). To minimize noise in the system, the transmitted signal is filtered by the Tx SAW before it is amplified by the PA. The coupler passes a weak version of the transmitted signal that is detected and used by the baseband for transmitter power control. The duplexer provides additional filtering in both the transmit and receive paths of the signal before it is connected to the antenna switch. The JAV5001 PA integrates complete circuitry for power regulation, PA bias, input and output matching, and power control.

ACLR, EVM AND PCDE MEASUREMENTS

While amplifying the signal, the PA must maintain strict linearity requirements. Signal distortion for W-CDMA is measured by adjacent channel leakage ratio (ACLR), error vector magnitude (EVM) and peak code domain error (PCDE). Typical ACLRs reach better than -40 dBc (ACLR1) or -55 dBc (ACLR2) at +24 dBm of handset output power. The EVM is typically around 4 percent and the PCDE is -33 dB, providing significant margin to the 3GPP specifications (see **Figure 3**).



▲ Fig. 2 Mobile handset block diagram including JAV5001 PA.



▲ Fig. 3 ACLR, EVM and PCDE measurements in a commercially available smartphone.

PA CURRENT CONSUMPTION

While maintaining linearity, the PA consumes significant current that has a direct impact on the talk time, standby time and battery life of the mobile handset. The actual average current consumed by the PA depends on where and how the handset is used. Today's 3G handsets and data cards operate occasionally at maximum power, but spend most of the time at medium and low output power levels. The PA average current is calculated by multiplying currents over all output power levels by a usage profile and summing the results. Each mobile handset operator develops its own usage profile based on histograms of output power measurements from handsets or data cards in the field. The standard profile used to benchmark W-CDMA PAs is published in the GSM Association official document DG.09 entitled "Battery Life Measurement Technique." Over this usage profile, typical PA average currents range



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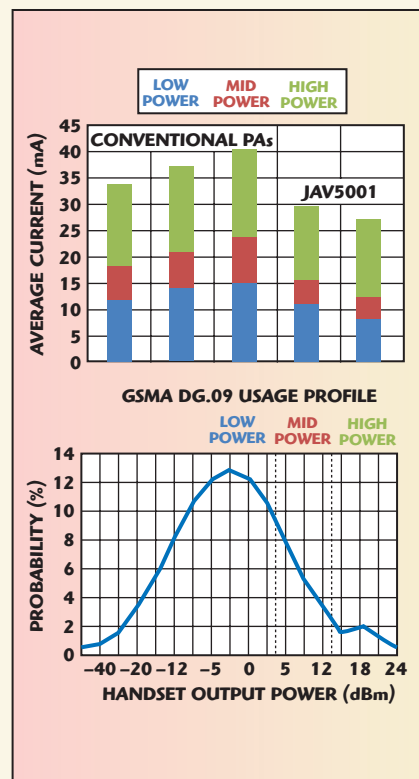


from 30 to 40 mA, as shown in **Figure 4**. The JAV5001 features a unique integrated power combiner that delivers a low average current of less than 27 mA.

BANDPASS PA ARCHITECTURE

PA noise is an often-overlooked but critically-important parameter that impacts receiver sensitivity for W-CDMA and also for other systems in the hand-

set such as Bluetooth or GPS. Unlike the GSM/EDGE 2G system, which is time division duplex, W-CDMA is a full duplex system, which means the mobile handset receives signal while its transmitter is turned on. To get a feel for the numbers, the W-CDMA receiver is typically specified to receive signals as low as -110 dBm at the antenna while the W-CDMA transmitter operates at 24 dBm. In practice the PA may operate as



▲ Fig. 4 Average PA current calculated from the GSM4 DG.09 usage model.

high as 28 dBm to overcome the front-end losses, which means that large isolation of around 138 dB between the PA output power and the receiver signal must be achieved. Furthermore, receivers for GPS and Bluetooth can be active during W-CDMA transmit, which places additional limitations on the W-CDMA transmitter power.

The strategy employed in the handset is to filter out the unwanted W-CDMA power that leaks from the transmitter into the receiver frequency bands. Typically, the Tx SAW provides about 35 dB of filtering, but also reduces the signal by about 2 dB due to insertion loss. However, the Tx SAW filtering is counteracted by the PA gain. For conventional PAs, the counteraction is significant. For example, at the GPS frequency of 1575 MHz, conventional PAs provide 25 dB of gain. An alternative architecture, employed by the JAV5001 CMOS 3G PA, is to create a "bandpass" PA response, which provides significant attenuation outside the band of interest. At 1575 MHz, the JAV5001 attenuates the signal by 8 dB, corresponding to 33 dB of rejection compared to a conventional PA. This response essentially mimics the rejection of the Tx SAW filter and can en-

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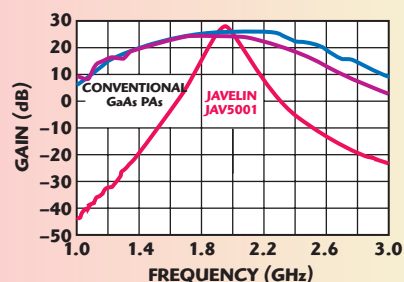
able it to be removed. Removing the Tx SAW not only saves the system bill of materials, but it also saves Tx current by allowing the transceiver and PA to operate at lower output powers. **Figure 5** shows the gain measurements.

INDUSTRY-STANDARD FOOTPRINT

Today's PAs are converging to a 3 x 3 mm package for single band designs. The JAV5001 is already implemented

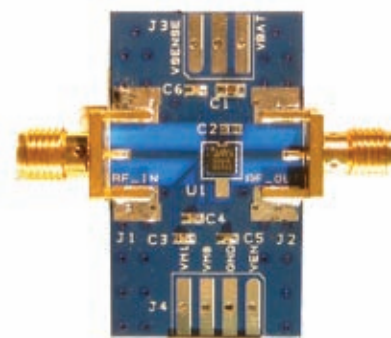
in a standard 3 x 3 mm footprint. The PA uses an industry standard digital power control using two mode pins.

The wireless industry has long enjoyed the benefits of CMOS solutions in Bluetooth and WLAN products, as well as in the baseband and transceiver portions of 2G/3G cellular handsets. After years of research and failed attempts, a power amplifier has finally been developed in CMOS that meets



Parameter	Frequency (MHz)	Conventional PA (dBm/Hz)	JAV5001 (dBm/Hz)	Javelin Margin (dB)
GSM RX	810-960	-143	-156	13
GPS RX	1570-1580	-142	-152*	10
BAND 1 RX Image	1730-1790	-131	-149	18
DCS RX	1805-1880	-135	-144	9
BAND 1 RX	2110-2170	-135	-150	15
Bluetooth	2400-2480	-137	-158	21

▲ Fig. 5 Javelin's bandpass PA architecture includes the function of the TX SAW filter.



▲ Fig. 6 The JAV5001 is implemented in a standard 3 x 3 mm package and requires only two external components.

the stringent performance requirements, and outperforms the GaAs incumbents. Javelin Semiconductor's JAV5001 is the first product in a family of high performance 3G CMOS PAs to address the fast growing 3G mobile handset market. As RF complexity continues to increase in the mobile handset, including multiple frequencies, band sharing and multimode requirements, the JAV5001 represents a core technology that can initiate the long-anticipated industry shift from GaAs to CMOS.

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- High Output Power Option Available



Standard Frequency Options		Output Frequency	Typical Output Level	Typical Phase Noise (dBc/Hz) (Free-Running)				Harmonics	Sub-Harmonics	Spurious
Part Number	Package Size			100 Hz	1 kHz	10 kHz	100 kHz			
MXO-200-31	2.25 x 4 x 1"	200 MHz	+13 ±2 dBm	-123	-149	-167	-168	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc
MXO-500-31	2.25 x 4 x 1"	500 MHz	+13 ±2 dBm	-115	-142	-160	-161	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc
MXO-1000-31	2.25 x 4 x 1"	1 GHz	+13 ±2 dBm	-109	-133	-151	-152	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc
MXO-1280-32	3.205 x 4 x 1"	1.28 GHz	+13 ±2 dBm	-107	-129	-147	-148	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc
MXO-2560-33	4.16 x 4 x 1"	2.56 GHz	+13 ±2 dBm	-101	-122	-140	-141	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc
MXO-5120-33	4.16 x 4 x 1"	5.12 GHz	+13 ±2 dBm	-95	-115	-133	-134	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc
MXO-10000-33	4.16 x 4 x 1"	10 GHz	+13 ±2 dBm	-89	-111	-129	-130	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc
MXO-12000-33	4.16 x 4 x 1"	12 GHz	+13 ±2 dBm	-87	-108	-126	-127	≤ -25 dBc	≤ -60 dBc	≤ -80 dBc

NOTES:

Contact factory to discuss external reference frequencies and loop bandwidth options.

Contact factory to discuss custom frequency options to 12 GHz and beyond.

Output Levels to +21 dBm available on some models.

+12 VDC Supply Voltage option available on some models.



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- High output power, e.g. typ. $+25$ dBm at 20 GHz
- Flexible pulse generation for radar applications
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OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Harris Corp. Receives Order for US Navy Satellite Terminals

Harris Corp. has received a follow-on \$10.7 M order from the US Navy for 23 shipboard terminals that will provide personnel onboard frigates, access to the Internet, video and other high-speed, broadband services. These capabilities will help sailors stay better connected to their families and allow them to easily handle routine activities online.

The terminals are part of the potential \$77 M Commercial Broadband Satellite Program (CBSP) Unit Level Variant (ULV) contract awarded to Harris in 2008. Awards-to-date under the five-year Indefinite Delivery/Indefinite

***Awards-to-date
under the five-year
Indefinite Delivery/
Indefinite Quantity
contract total
\$28.2 M.***

Quantity contract total \$28.2 M. Through this follow-on order, Harris is supplying the Navy with 1.3-meter satellite communications terminals that offer both X- and Ku-band capabilities and support 10 times the bandwidth now accessible onboard Navy ships.

The new terminals will enable the Navy to augment military satellite communications by supporting essential mission requirements and providing high-speed Internet access and video communications on Unit Level class ships.

Successful operational assessment of the shipboard satellite terminal in November 2009 moved the CBSP ULV program into this production phase. The CBSP program began as a Rapid Deployment Capability acquisition designed to reduce the time required to deliver critical/emerging warfighting capabilities.

"These SATCOM terminals will significantly enhance the Navy's ability to provide the latest advances in broadband communications services to shipboard personnel, and will play a key role in maintaining their high morale and well-being," said Allen Lindsay, Vice President of Harris Defense Programs. "Provision of high-data-rate satellite communications equipment is a core competency of Harris. We are pleased to support the Navy with this innovative technology."

Net-centric Communication Trends to Boost MilSatCom

Satellite-based communications, with their broad coverage areas, allow geographically dispersed users to exchange information quickly and efficiently. Higher bandwidth availability and networking requirements in Military Satellite Communications (MilSatCom) create new opportunities for advanced electronic components. The Strategy Analytics Advanced Defense Systems (ADS)

service report, "MilSatcom Electronic Market Trends through 2020," predicts that the annual market for electronics will grow at a compound annual average growth rate (CAAGR) of 12 percent through 2020.

MilSatCom represents the largest category of defense satellites. MilSatCom platforms include the Wideband Gapfiller System (WGS) program, based on Boeing 702 platforms and designed for the US military, and the SICRAL satellites built by Thales Alenia Space, supporting both Italian and NATO military communications. Both growth in satellite launches and increasingly sophisticated capabilities will translate into an annual electronics market of nearly \$2.58 B in 2020.

"As satellite capabilities become more sophisticated, the total electronics content for all the functions will also increase," noted Asif Anwar, Director of the Advanced Defense Systems (ADS) service at Strategy Analytics. "Strategy Analytics estimates that the proportion of satellite system costs attributable to transponders, communications, computer, sensor and other related systems will continue to increase through 2020. Transponder electronics, as one example, will increasingly use multiple phased arrays to create multiple beams from a single array face, while communications systems will utilize more optical modules and fiber links. The overall shift toward net-centric communications philosophies will also increase the need for computer processing power."

Northrop Grumman Begins Installing First EHF Satcom Hardware on B-2

Northrop Grumman Corp. technicians have begun installing the first set of hardware for a B-2 stealth bomber upgrade that will eventually allow the jet to send and receive battlefield information up to 100 times faster than its current satellite communications system. The work is being done as part of Increment 1 of the US Air Force's B-2 extremely high frequency (EHF) satellite communications program. Northrop Grumman is the Air Force's prime contractor for the B-2 Spirit, the flagship of the nation's long range strike arsenal, and one of the world's most survivable aircraft systems. The B-2 is the only combat-proven stealth platform in the current US inventory.

"EHF Increment 1 puts in place the high speed data handling infrastructure that the B-2 will need to perform its most advanced communications and weapons delivery missions in the future," said Col. Kevin Harms, USAF, Commander, 702nd Aeronautical Systems Group. "The begin-

***...the annual market
for electronics will
grow at a CAAGR of
12 percent through
2020.***

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ning of hardware installation means that we are making solid progress getting this new capability out of the lab and into the hands of the warfighter."

"The installation of EHF Increment 1 hardware also means that we're nearly done with a significant task of software development, integration and testing for the program," added Dave Mazur, Northrop Grumman's Vice President of Long Range Strike and B-2 Program Manager. According to Mazur, the new software was developed, integrated and tested by Northrop Grumman employees working at the Air Force's Weapon Systems Support Center, Tinker AFB, OK. Ground testing of the EHF Increment 1 hardware is planned early in 2010.

The first "kit" of EHF Increment 1 hardware includes:

- A new integrated processing unit (IPU) developed by Lockheed Martin Systems Integration, Owego, NY, that will replace up to a dozen current stand-alone avionics computers on the B-2;
- A new disk drive unit developed by Honeywell Defense and Space Electronic Systems, Plymouth, MN, that will enable transfer of EHF data onto and off of the B-2; and
- A network of fiber optic cable that will support the high speed data transfers within the aircraft.

The three-increment EHF Satcom program is part of an on-going effort by the Air Force and Northrop Grumman to modernize the B-2 to keep it fully mission capable against evolving enemy threats.

Increment 2 involves installation of a new communications terminal and new antennas that will allow the B-2 to transmit and receive information securely via satellite. Increment 3 will integrate the B-2 into the US Department of Defense's Global Information Grid, a worldwide network of information systems, processes and personnel involved in collecting, storing, managing and disseminating information on demand to warfighters, policy makers and military support personnel.

The B-2 is the only

US aircraft that combines stealth, long range, large payload and precision weapons in a single platform. In concert with the Air Force's air superiority fleet, which provides airspace control, and the Air Force's tanker fleet, which enables global mobility, the B-2 helps ensure an effective US response to threats anywhere in the world. It can fly more than 6,000 nautical miles unrefueled and more than 10,000 nautical miles with just one aerial refueling, giving it the ability to reach any point on the globe within hours. The 20-aircraft fleet of B-2s is operated by the 509th Bomb Wing from its headquarters at Whiteman AFB, MO.

"EHF Increment 1 puts in place the high speed data handling infrastructure that the B-2 will need to perform..."

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20 - 75 MHz, minimum	≥ 40 dB @ 90 MHz & ≥ 50 dB @ 135 - 600 MHz
20 - 115 MHz, minimum	≥ 40 dB @ 150 MHz & ≥ 50 dB @ 250 - 600 MHz
20 - 150 MHz, minimum	≥ 40 dB @ 200 MHz & ≥ 50 dB @ 300 - 600 MHz
20 - 220 MHz, minimum	≥ 40 dB @ 300 MHz & ≥ 50 dB @ 450 - 900 MHz
20 - 335 MHz, minimum	≥ 40 dB @ 440 MHz & ≥ 50 dB @ 660 - 1400 MHz
20 - 500 MHz, minimum	≥ 35 dB @ 670 MHz & ≥ 50 dB @ 1005 - 2000 MHz
20 - 700 MHz, minimum	≥ 40 dB @ 980 MHz & ≥ 50 dB @ 1470 - 2000 MHz
20 - 1010 MHz, minimum	≥ 35 dB @ 1400 MHz & ≥ 50 dB @ 2100 - 3000 MHz
20 - 1400 MHz, minimum	≥ 40 dB @ 2000 MHz & ≥ 50 dB @ 3000 - 4200 MHz
20 - 2000 MHz, minimum	≥ 40 dB @ 2800 MHz & ≥ 50 dB @ 4200 - 5000 MHz
20 - 3000 MHz, minimum	≥ 40 dB @ 3940 MHz & ≥ 50 dB @ 5910 - 6000 MHz

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ZigBee Alliance Expands Participation in European Standards

The ZigBee® Alliance, a global ecosystem of companies creating wireless solutions supporting energy management in residential, commercial and consumer electronics applications, has announced its intention to expand its participation in the European Union's various standardization efforts. The Alliance will focus on the European Union's Smart Grid programs and on meeting the needs of the EU implementation of ZigBee Smart Energy in the Home Area Network (HAN). To accomplish these

"...expanding our efforts there will allow us to be more available to European standards organizations as they plan for the future."

objectives, and support a thriving membership base, the Alliance will establish a European headquarters (HQ).

The European HQ will be tasked with ensuring that ZigBee standards meet the needs of the European standards organizations. It will also enable these participat-

ing organizations to more effectively understand, and respond to, the changing needs of the EU market.

The ZigBee Alliance has agreements with the European Smart Metering Industry Group (ESMIG) and Device Language Message Specification (DLMS) User Association focused on this effort. The Alliance's European HQ will also support European standards organizations in their work to develop plans to create market-ready solutions and the evolving EU M441 mandate.

"ZigBee has enjoyed widespread European support since its inception and expanding our efforts there will allow us to be more available to European standards organizations as they plan for the future," said Bob Heile, Chairman of the ZigBee Alliance. "We believe that deeper and broader collaboration will allow ZigBee Smart Energy to emerge as the best wireless HAN choice for European Smart Grid standardization."

Government Commits to UK Technology and Innovation Centres

The UK Business Secretary, Lord Mandelson, has asked the Technology Strategy Board to guide the development of a network of technology and innovation centres that will help deliver the industries and jobs of the future. The Board has been tasked to work with industry, stakeholders, and wider government including the Research Councils, Regional Development Agencies and Devolved Administrations on the implementation of the recommendations in the Hauser review, a report by technology entrepreneur Hermann Hauser. The report looks at

leading technology and innovation centres in other countries and recommends that the UK builds its own network.

Welcoming the report, Lord Mandelson said it recognised the UK was strong in many technology areas and the centres to be developed would help exploit that commercially. They would take new discoveries from the point where university researchers recognise the potential for commercialisation and help develop the concepts to a stage where the private sector would be able to commercialise it.

"Too often in this country we have been brilliant at research and let others walk away with the commercial benefits of development. If we

are to develop new industrial capabilities in Britain, we have to get more D out of our R&D," said Lord Mandelson. "Centres can play a vital role in bridging the gap between research and the market, strengthening our national capabilities in innovation."

"I am now determined that the UK builds a capability for the long term, through a more strategic and sustained approach to investing in these centres. Hauser is right that these centres need long term, predictable funding and I am committed to making that happen. I want to understand the UK's strengths, weaknesses and where there are gaps we need to invest in."

"Too often... we have been brilliant at research and let others walk away with the commercial benefits of development."

STMicroelectronics and Mentor Graphics Enter New DeCADE

Mentor Graphics Corp. and STMicroelectronics have entered into a broad-scoped collaboration to develop advanced design solutions at the 32-nm technology node and down to 20-nm node. The three-year joint-development project, named DeCADE, seeks to build on advanced design solutions for System On Chip (SoC) development for digital and analogue design, including system-level approaches, design methodologies, place and route strategies, optical correction for advanced manufacturing, modelling, electrical characterization and parasitic extraction.

DeCADE will provide design solutions for core CMOS technologies as well as for value-added and application-specific derivative technologies that are developed from the core CMOS process. These projects can make a fundamental difference in chip capability and performance, as well as in system-solution cost; among the value-added derivative technologies being considered by the DeCADE projects include RF and wireless technologies, as well as 3D packaging and chip stacking technologies.



“This joint development effort will provide ST with tools to develop state-of-the-art Systems-on-Chips at 32-nm and below...”

Philippe Magarshack, STMicroelectronics General Manager of Central CAD and Design Solutions.

“This joint development effort will provide ST with tools to develop state-of-the-art Systems-on-Chips at 32-nm and below for ST’s customers, taking full advantage of the strong silicon process, device modelling and design know-how present on the Crolles [France] Site,” said

STC Selects Alcatel-Lucent for LTE Trial in Saudi Arabia

The Saudi Telecom Co. (STC), the main telecommunications carrier in Saudi Arabia, has tasked Alcatel-Lucent to conduct an end-to-end Long Term Evolution (LTE) trial, to begin in the second half of 2010. This trial will enable STC to test the performance of LTE-based services and assess the related business models.

Alcatel-Lucent will be leveraging its industry-leading LTE expertise to provide an end-to-end integrated solution including LTE base stations (eNodeBs), the Evolved Packet Core (EPC), IP service routing network elements as well as operation, administration and maintenance (OAM) systems. The company will also provide a range of professional services including project management, planning, installation, integration and commissioning, and testing.

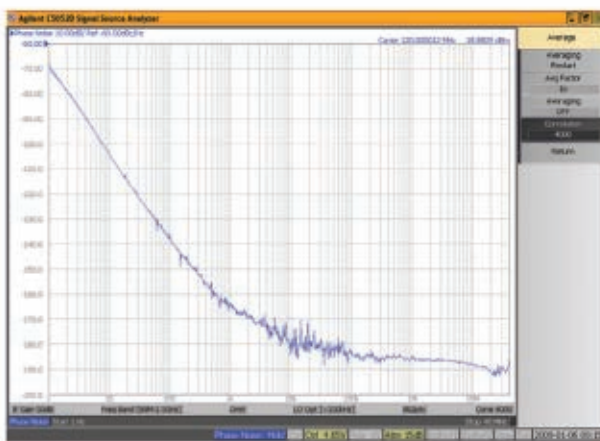
“As a major operator, STC is committed to providing its customers superior service. It is clear to us that LTE has evolved to being more than just a promising technology,” said Zeyad Al-Otaibi, STC’s Vice President Networks. “As STC and Alcatel-Lucent are both

on the edge of innovation, we are confident that this trial will help us fulfil our customers’ needs for innovative mobile broadband services.”

Amr El Leithy, head of Alcatel-Lucent’s activities in Africa and the Middle East, commented, “This trial is a major step in the adoption of LTE technology in the Middle East. STC can count on our technical leadership and transformation expertise to unleash LTE’s full business potential.”

“This trial is a major step in the adoption of LTE technology in the Middle East.”

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level 1	-100	-135	-162	-176	-182	dBc/Hz
level E	-102	-137	-164	-178	-182	dBc/Hz

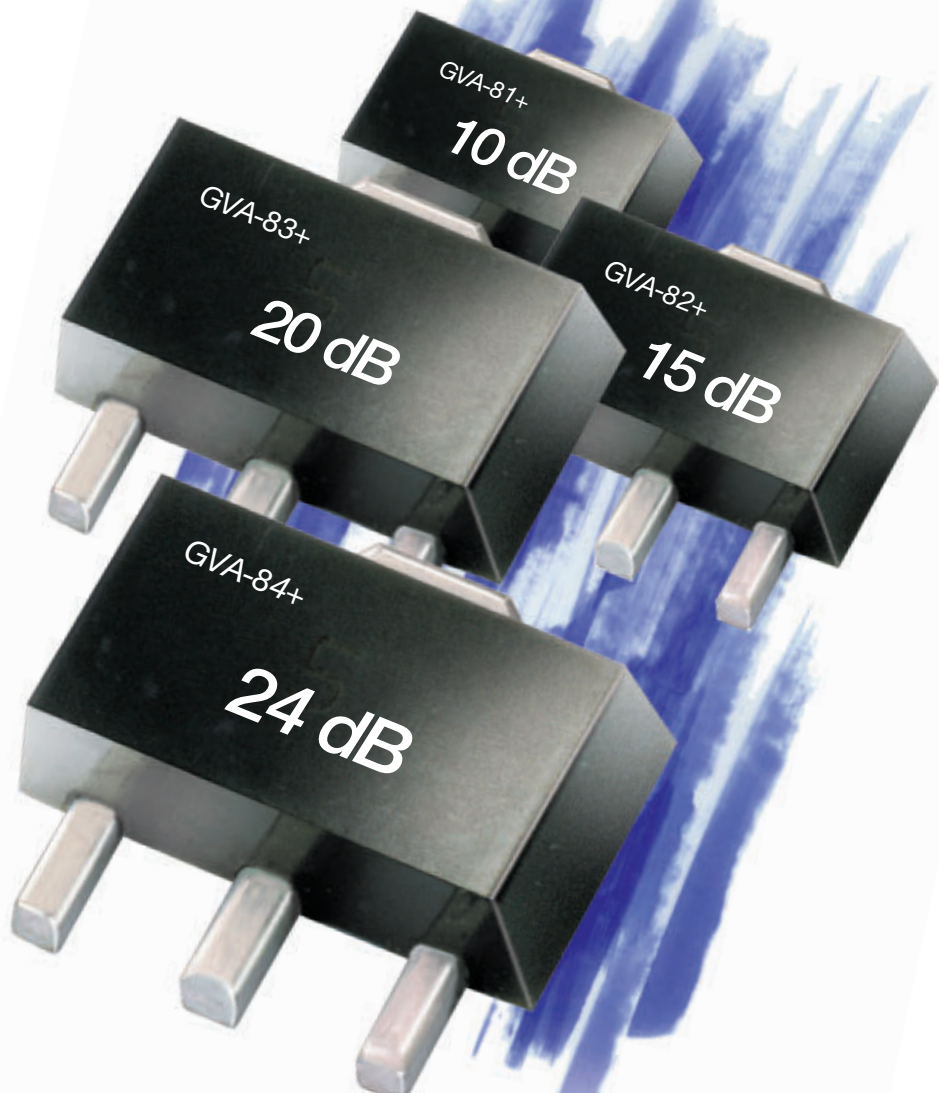
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US patent 6,943,629 *Low frequency determined by coupling cap.

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MODEL	FREQ. (GHz)	GAIN (dB)	POUT (dBm) @ 1 dB Comp.	NOISE FIG. (dB)	PRICE (1-9)
 ZVA-183X+	0.7-18	26	+24	3.0	845.00
ZVA-213X+	0.8-21	26	+24	3.0	945.00

Note: Alternative heat-sink must be provided to limit maximum base plate temperature.



ZVA-183+	0.7-18	26	+24	3.0	895.00
ZVA-213+	0.8-21	26	+24	3.0	995.00

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COMMERCIAL MARKET

Dan Massé, Associate Technical Editor

Peregrine and IBM Partner on SOS Roadmap

Peregrine Semiconductor and IBM have teamed up to develop and manufacture future generations of Peregrine's patented UltraCMOS™ silicon-on-sapphire (SOS) process technology. When fully qualified, the next-generation UltraCMOS RF ICs will be manufactured by IBM for Peregrine in the jointly-developed 180-nanometer RF CMOS process at IBM's 200 mm semiconductor manufacturing facility in Burlington, VT. This development marks the first commercial use of 200 mm (8-inch) wafer processing for silicon-on-sapphire process, a patented variation of silicon-on-insulator (SOI) technology that incorporates an ultra-thin layer of silicon on a highly insulating sapphire substrate.

The joint development agreement represents an inflection point in Peregrine's business says Rodd Novak, Chief Marketing Officer, allowing Peregrine to deliver "products with unmatched levels of RF performance and monolithic integration, ideal for high-growth applications such as the RF front-end of mobile phones and multi-mode, multi-band mobile wireless devices; broadband communications including 4G LTE equipment and base stations; mobile DTV/CATV RF signal conditioning; and space satellite systems." In addition, the migration to 200 mm wafers will facilitate the evolution of the process to advanced 180 nm, 130 nm and 90 nm nodes.

GaN Power Management Chip Market Set for Boom

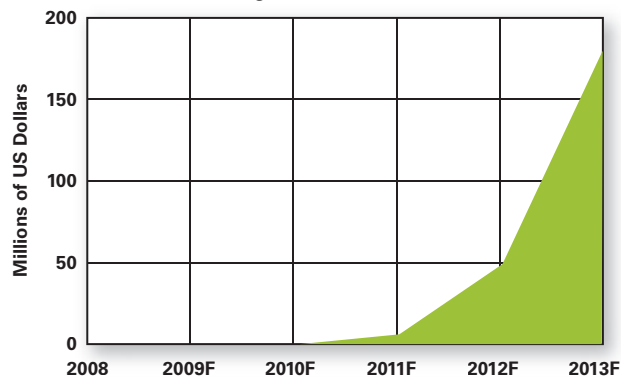
Thanks to rapid growth in the high-end server, notebook, mobile handset and wired communication segments, the GaN power management semiconductor market is expected to reach \$183.6 M in revenue by 2013, up from virtually nil in 2010, according to iSuppli Corp.

GaN is an emerging process technology for power management chips that recently moved beyond the universally-based testing phase and into the commercialization stage. The technology represents an attractive market opportunity for suppliers by providing their customers with capabilities that may be out of the reach of present semiconductor process materials.

iSuppli believes that during the past two years, several events have occurred that have made GaN an up-and-coming star in the power management semiconductor world.

First, the use of silicon has reached its practical limits in power management semiconductors. Furthermore, there have been major breakthroughs in growing GaN layers on silicon. Power designers also want to develop more efficient systems and to update their high-voltage products to waste less electricity. Component suppliers have begun offering GaN parts. International Rectifier Corp., for instance, released its first GaN technology-based Point-of-Load (POL) solutions in February, while Efficient Power Conversions Corp. (EPCC) is placing all its bets on GaN technology, recently releasing 10 power MOSFET devices.

Global Gallium Nitride (GaN)
Power Management Semiconductor Revenue



The adoption of GaN devices will be driven by the improved efficiency and small form factors enabled by the material. Such benefits are in particularly high demand for portable electronic products, including mobile PCs and smart phones. They also provide advantages for power-hungry electronic equipment, such as enterprise servers and wired communications infrastructure gear.

However, adoption of GaN technology for these applications in 2010 and 2011 will be slow due to the high cost of parts using the material. As the technology advances and the cost of manufacturing GaN technology drops in 2012 and 2013, the technology will begin to steal market share away from conventional MOSFETs, driver ICs and voltage regulator ICs.

The first adoption of GaN devices most likely will be among servers, which always demand high-performance devices and often are one of the first product areas to accept new technologies that improve performance. Over the next three years, the bulk of device volume likely will be driven by notebooks, as the power savings and smaller form factor delivered by GaN will be in high demand.

The Road to 4G is Not a One-way Street

According to In-Stat, the cellular industry has been a battle ground between different communication technology standards driven by regional and industry politics, and Super 3G/4G appears no different. However, the industry appears to be narrowing down to just three standards: LTE, WiMAX and XGP. Despite the differences in the technologies, all three are based on OFDM technology and represent the transition to IP-based networks for communications. Unlike previous generations, however, those similarities are making it easier for the silicon vendors to support more than one technology in a single chip.

Software defined radios (SDR) have been a reality in silicon for several generations due to the need to support multiple frequency bands and/or 2G/3G standards. With the next generation solutions, however, using similar technologies is easier through a programmable modem architecture combined with dedicated or configurable

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IP to handle the network interface and security. As a result, many baseband chipset suppliers are considering support for multiple technologies through an SDR architecture. Thus far, the newer market entrants that viewed the transition to 4G technologies as a disruptive opportunity appear to be taking the lead. Companies like Comsys, which recently announced a WiMAX + GSM baseband chipset, and Wavesat, which is the first vendor to support all three next generation standards, LTE, WiMAX and XGP, on a single chip appear to be the leading innovators. Even Intel, which already offers WiMAX chipsets and has a 3G license through a partnership with Nokia, has hinted at the possibility of supporting LTE in the future. And, there is sure to be 3G + LTE solutions from the industry leader Qualcomm, even if supporting WiMAX is out of the question.

The clear trend is that the next generation of baseband solutions will have to support multiple communication standards to be competitive. In addition, as silicon space becomes more readily available with the 28 nm and 22 nm semiconductor process generations, we are also likely to see more baseband solutions integrated into processors, similar to what Qualcomm has accomplished with its Snapdragon product line that is rapidly gaining momentum in the mobile market. Just as the baseband market appeared to be a commodity with little differentiation, 4G and Moore's Law are once again turning the technology into a competitive race. For more information on the outlook

for baseband technology and chipsets, please refer to the upcoming In-Stat report, "New Baseband Solutions Fuel Mobile Broadband Devices."

Assessing a Company's Worth

A recent Price Waterhouse Cooper report claims most merger and acquisitions (M&A) will come from the middle market and smaller firms. Late 2009 already saw some notable M&A activity in the microwave industry. In November, Channel Microwave was acquired by Smiths Group plc (now operating as an independent division of Lorch Microwave Inc.). Last December, Spectrum Microwave Inc. acquired Micro Networks Corp., a subsidiary of Integrated Device Technology Inc. (IDTI), for a total purchase price of approximately \$13 M. That same month, Crane Co. signed a definitive agreement for the acquisition of Merrimac Industries Inc. for \$16.00 cash per share of common stock and associated common stock purchase rights (transaction valued at approximately \$52 M).

So how does a potential seller determine the worth of his/her company when an interested buyer makes an offer? In this month's MarketWatch, Kenneth F. Stern, President and Founder of Synxronos, discusses some of the fundamental issues that need to be considered when assigning value to a company. Good to know information, whether you plan to sell or hold.

Read online at www.mwjjournal.com/marketwatch/stern.

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PA020180-3025	2.0 - 18	30	P1dB > 30	40	9	+12 / 2000
PA002005-21	0.2 - 0.5	20	P1dB > 21	35	1.1	+5 / 100
PA001002-22	0.1 - 0.2	19	P1dB > 23	37	1.5	+5 / 100
PA001040-27	0.1 - 4.0	25	P1dB > 27	40	5	+10 / 290
PA001060-4440	0.1 - 6.0	40	Psat > 44	50	-	+50 / 1000

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AROUND THE CIRCUIT

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS

Wireless Telecom Group Inc. announced the execution of a definitive agreement to sell substantially all of the operating assets of its wholly owned subsidiary **Willtek Communications GmbH** and affiliates to **Aeroflex Inc.**, a Delaware corporation, in exchange for \$2,750,000 in cash and the assumption of certain liabilities. The closing of the sale is subject to certain customary closing conditions. The cash purchase price is subject to a post-closing adjustment if the adjusted net assets sold at the date of closing are less than the adjusted net assets target set forth in the purchase agreement. As part of the sale, all current employees of Willtek Communications GmbH and its affiliates will be assumed by Aeroflex.

SemiGen Inc., a modern outsource for die packaging, hybrid assembly, and automated PCB manufacturing and test, announced the acquisition of **Alternative Microwave Resources (AMR)** of Amherst, NH. AMR is a privately held contract manufacturer specializing in hybrid assembly, engineering, and testing of RF and microwave modules up to 20 GHz. The company also troubleshoots and repairs various units such as amplifiers, VCOs, limiters, and other military subsystems and modules that need repair down to the component level.

PPC® announced that it has agreed in principle to acquire **Evolution Broadband**, a supplier of home distribution and subscriber drop systems for the North American cable and telecommunications market. PPC will leverage the sales and new product development strengths of both companies to deliver innovative solutions from both product lines and to continue providing responsive sales and service across its newly expanded customer base.

Capella Intelligent Subsystems Inc. and **Innovative Micro Technology Inc.** announced the formation of a strategic foundry relationship. The collaboration combines Capella's vision and expertise in next-generation high performance Wavelength Selective Switches (WSS) with IMT's ability to develop and manufacture sophisticated optical micro-electrical mechanical systems (MEMS) devices to enable the products.

EB (Elektrobit), a developer of embedded technology solutions for wireless and automotive industries, and **ETS-Lindgren**, a provider of electromagnetic measurement solutions, announced their partnership on MIMO Over-the-Air (OTA) testing. EB and ETS-Lindgren now provide customers with a simple, unified solution for complex MIMO OTA testing. The new solution combines the EB Propsim F8 MIMO OTA emulator with ETS-Lindgren's AMS-8700 MIMO OTA test system that enables systematic and repeatable performance measurement of MIMO devices from 700 MHz to 6 GHz. Following extensive test-

ing of the prototype system at ETS-Lindgren's CTIA authorized wireless test lab in Cedar Park, TX, the solution is now available for immediate delivery.

TECOM Industries Inc., a Smiths Interconnect business, announced the opening of a new manufacturing facility dedicated to commercial SATCOM antenna systems. The new facility is located at 951 Lawrence Drive, Newbury Park, CA 91320, six miles from the company's main facility in Thousand Oaks, CA.

Peregrine Semiconductor Corp., a supplier of high performance RF CMOS and mixed-signal communications integrated circuits (IC), announced the expansion of its European design and manufacturing operations and the opening of a new facility located in Aix-en-Provence, France. Peregrine Semiconductor Europe (PSE) operations include RF integrated circuit (RFIC) design and engineering at its design center in Aix-en-Provence, France; IC wafer manufacturing from wafer foundry Sapphicon in Australia and UMC in Taiwan; assembly and packaging from Hybritech Composants Microelectroniques (HCM) in France; and back-end testing at partner Rood Microtec in Germany.

AR/RF Microwave Instrumentation has the distinction of having the only commercially available pulsed E-field probe that is approved by name in the new FORD-EMC-CS-2009 specification. The new specification, which addresses the pulse E-field probe method calibration for ALSE method bands 6 & 7, singles out AR Model PL7004 (800 MHz to 3.6 GHz/80 to 800 V/m) as the only commercial pulsed E-field probe capable of accurately measuring the high-field strengths needed to conduct the tests.

TowerJazz, a specialty foundry leader, announced it has joined the IPL Alliance, an organization chartered with establishing an interoperable custom design ecosystem. The IPL Alliance, comprised of major EDA and foundry companies, has devised the first open standard for interoperable Process Design Kits (iPDK) for analog/mixed-signal designs. The iPDK is based on the OpenAccess database and uses standard languages and unified architecture that ensure interoperability among all EDA vendor tools.

The ZigBee® Alliance and the **Wi-Fi Alliance®** announced an agreement to collaborate on wireless home area networks (HAN) for Smart Grid applications. The initial focus of the collaboration will be ZigBee Smart Energy 2.0, which is the next-generation energy management protocol for Smart Grid-enabled homes based on today's successful ZigBee Smart Energy Profile. The ZigBee Smart Energy 2.0 is expected to operate over Wi-Fi technology as a result of the collaboration. The two organizations will identify opportunities to use ZigBee Smart Energy 2.0, capitalizing on the unique strengths and capabilities of

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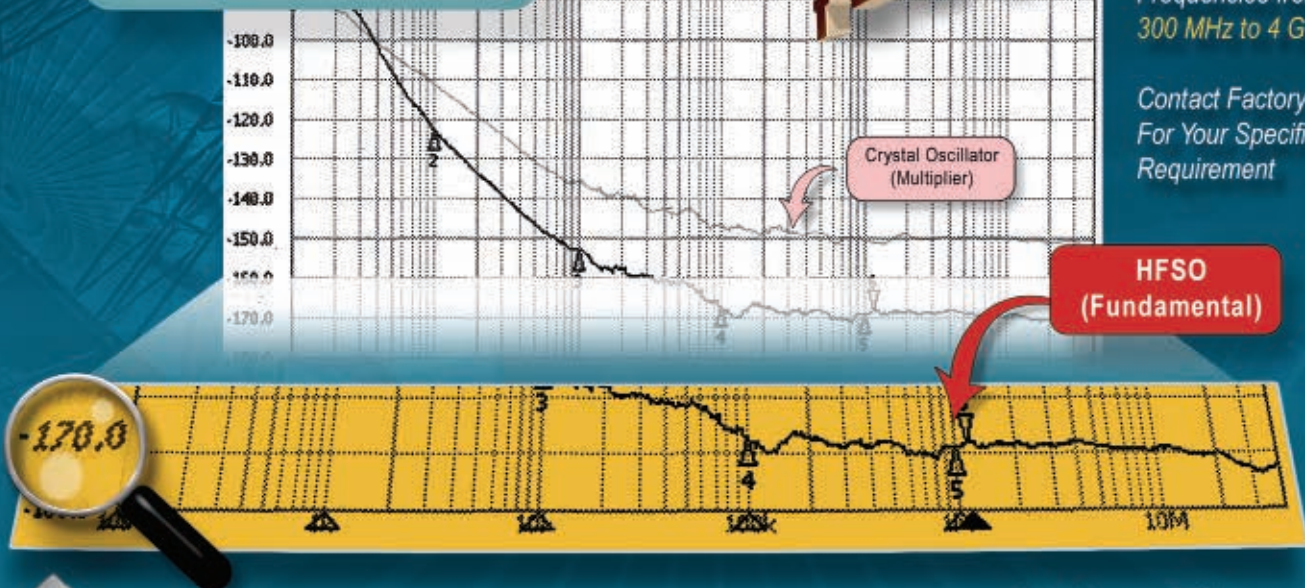
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their respective technologies. This will expand the utility of the HAN in the management of energy consuming or producing devices, a crucial part of Smart Grid efforts now underway. ZigBee Smart Energy 2.0 was selected last year by the US Department of Energy and the National Institute of Standards and Technology (NIST) as an initial interoperable standard for HAN devices.

TriQuint Semiconductor Inc., an RF front-end product manufacturer and foundry services provider, announced it has received **ZTE Corp.**'s "Supplier of the Year" award. A leading Chinese manufacturer of wireless communication system equipment, ZTE annually recognizes top suppliers with superior cost, quality, delivery and service performance. TriQuint has achieved top supplier recognition for the third consecutive year, while experiencing a compound annual growth rate of 70 percent with ZTE.

RF Micro Devices Inc. (RFMD), a leader in the design and manufacture of high-performance radio frequency components and compound semiconductor technologies, announced that RFMD has surpassed 100 million units in cumulative shipments of its RF71xx family of 2G dual-band and quad-band transmit modules. RFMD achieved the 100 million milestone in less than one year of production shipments, positioning the RF71xx product family among RFMD's all-time most successful product launches.

Rogers Corp. and its Advanced Circuit Materials (ACM) Division earned a distinguished DesignCon Paper Award at the recent DesignCon 2010 Conference and Exhibition in Santa Clara, CA. The paper, *Effect of Conductor Profile on the Insertion Loss, Phase Constant, and Dispersion in Thin High-Frequency Transmission Lines*, was co-authored by Allen F. Horn III, John Reynolds and Patricia LaFrance of Rogers Corp., and James Rautio, President of Syracuse, NY-based Sonnet Software. It offers insights and solutions on issues that have long plagued designers of thin printed-circuit boards (PCB), issues specifically related to the effects of conductor surface roughness on PCB performance.

Teledyne Ltd. announced that it has been granted AS9100 status effective from 31st March 2010. AS9100 is the Quality Management System recognised by the aerospace industry, fully incorporating ISO9000, adding additional quality and safety requirements particular to the aerospace market. Teledyne Reynolds' position as a major supplier of cable assemblies to Tier One and Tier Two customers in both the aerospace and military markets was the driver in the decision to achieve compliance with AS9100.

CONTRACTS

Miami-Dade County, FL, has selected **Harris Corp.**, an international communications and information technology company, to upgrade the county's public safety and public service communications system as part of an overall communications project for the county. The project will provide the county with a new Harris P25^{IP} (Project 25 to

the power of Internet Protocol) 800 MHz radio communications system, and also includes radio terminals for the county to comply with the Federal Communications Commission (FCC)'s rebanding mandate (FCC 04-168). The new standards-based system will bring the county greater functionality on a flexible system platform.

KOR Electronics announced that it has received a prime contract from the government for \$44.4 M to supply advanced Digital RF Memory (DRFM) jammers for the US Navy and Air Force. The contract is a firm-fixed-price, indefinite-delivery/indefinite-quantity time-and-material award from the United States Navy.

Comtech Telecommunications Corp. announced that **Comtech Systems Inc.**, its Florida-based subsidiary, received a \$35.4 M contract from a domestic prime contractor to provide system design and telecommunications transmission equipment for use in a North African government's communications network.

Herley Industries Inc. announced that its **Herley-CTI** subsidiary located in Whippany, NJ, has received an award valued at approximately \$5 M from a major US prime contractor to manufacture an integrated microwave assembly (IMA) for a US Navy electronic attack aircraft.

Auriga Microwave announced it received its fourth Small Business Innovative Research (SBIR) award. The company starts a two-year contract with the Navy's Naval Space Warfare Command (SPAWAR) to build a shipboard LNA assembly under SBIR N07-194. The award, part of the SBIR program, is one of four Phase II awards granted to Auriga since early 2009. Auriga anticipates moving forward an additional Phase II contract in the next few months.

PERSONNEL



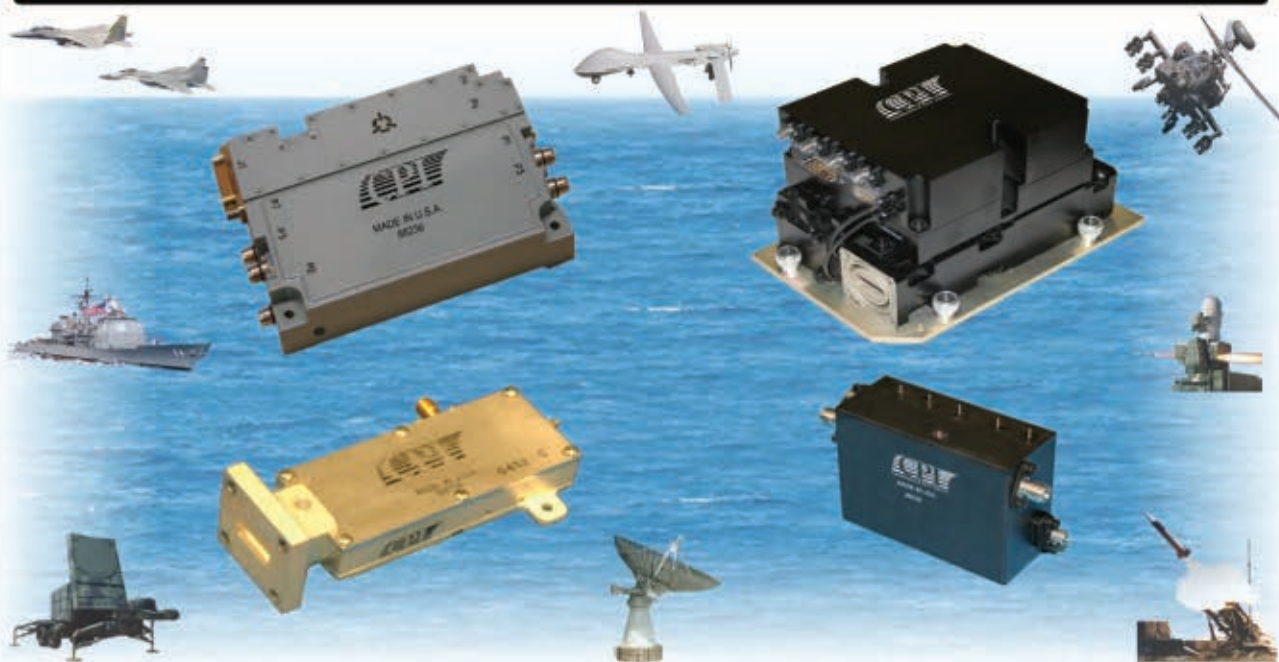
▲ Scott Pianalto

Sabritec, a Smiths Interconnect business and a highly integrated engineering and manufacturing company providing special interconnect solutions for military, aerospace, telecom, space, test and measurement, and commercial applications, announced the appointment of **Scott Pianalto** as President. Pianalto brings over 20 years experience in the connector industry and most recently served as the Director of Marketing and Operations for a major connector manufacturer within the military aerospace market. In this new role, Pianalto will focus on implementing an accelerated growth strategy for Sabritec to strengthen and expand its position in the market place.

Compex Corp. announced the hiring of a new Vice President of Sales and Marketing, **Wendell Hautaniemi**. Hautaniemi will fulfill the role of Vice President of Sales and Marketing by expanding the Compex field representative network and managing the marketing efforts. He has 28 years of experience in the RF/microwave market selling and marketing high frequency single layer capacitors and thin film circuits.

Exalt Communications announced that it has named **Perry**

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Constantine Executive Vice President of Business Development. Constantine will immediately focus on building the company's markets in the Asia-Pacific region as well as other international markets. Constantine has over 30 years of experience as a successful entrepreneur in a variety of high tech Silicon Valley based companies.

RFMW Ltd. announced the promotion of **Russ Dahl** to the newly created position Director of North American Sales. Dahl has been with RFMW since April 2006 and in that time has earned the respect of customers, suppliers and the RFMW team. He has over 20 years of diversified experience in technology and management roles within RF sales, marketing and specialty distribution.

Nitronex announced the addition of a key sales director and strategic partnerships with three premier sales representative firms. These recent sales additions are part of Nitronex's overall strategy to expand sales and customer support in North America. Nitronex has recruited **Diane DuVall** as Director of North American Sales. Recently, DuVall set up sales, marketing and operations across the US and Canada at Navman Wireless. Nitronex has also partnered with TAI Corp., Tri-Tech Electronics and Thom Luke Sales, three major sales representative organizations in North America, to assist DuVall in accelerating sales and customer support activities.

Laser Services Inc., an ISO and AS-9100 registered precision laser cutting, drilling, scribing, etching and welding job shop, has announced the promotions of two internal employees, **Melida Aizupura** and **Paul Iria** in January of 2010. Aizupura began working with the company in 1992 as a Production Manager, and has moved to sales after 18 years on the shop floor. Her new tasks will include developing and overseeing new customers while maintaining the long-term relationships currently held with existing customers. Iria will ensure on-time delivery and quality products to Laser Services customers, maintain that the production process continues to run efficiently at every level, and implement "lean" production techniques and quality control programs.

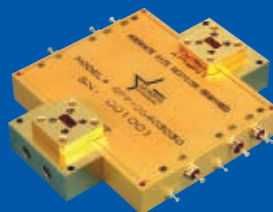
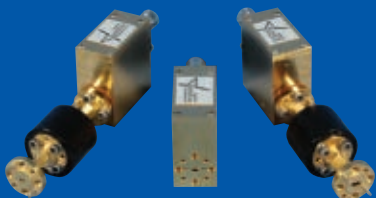
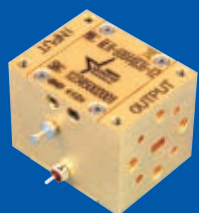
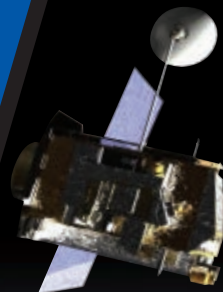
REP APPOINTMENTS

Technical Communities Inc. announced an exclusive government services partnership agreement with **AEA Technology Inc.**, a manufacturer of RF and cable test equipments. The agreement authorizes Technical Communities to distribute AEA Technology products, including hand held network analyzers, SWR meters, time domain reflectometers (TDR), spectrum analyzers, frequency domain reflectometers (FDR) and pre-amplifiers.

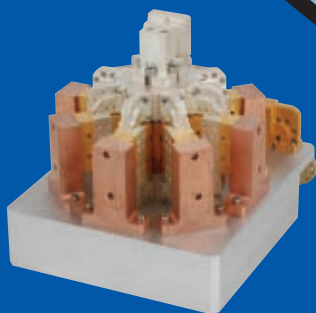
MITEQ Inc. announced the appointment of **Spartech-South** as the company's exclusive sales representative in Florida, Georgia, Alabama, Mississippi, North and South Carolina, and Tennessee. Spartech-South will represent MITEQ's Component division of products that includes amplifiers, mixers, frequency multipliers, passive power components, switches, attenuators, limiters, phase shifters,

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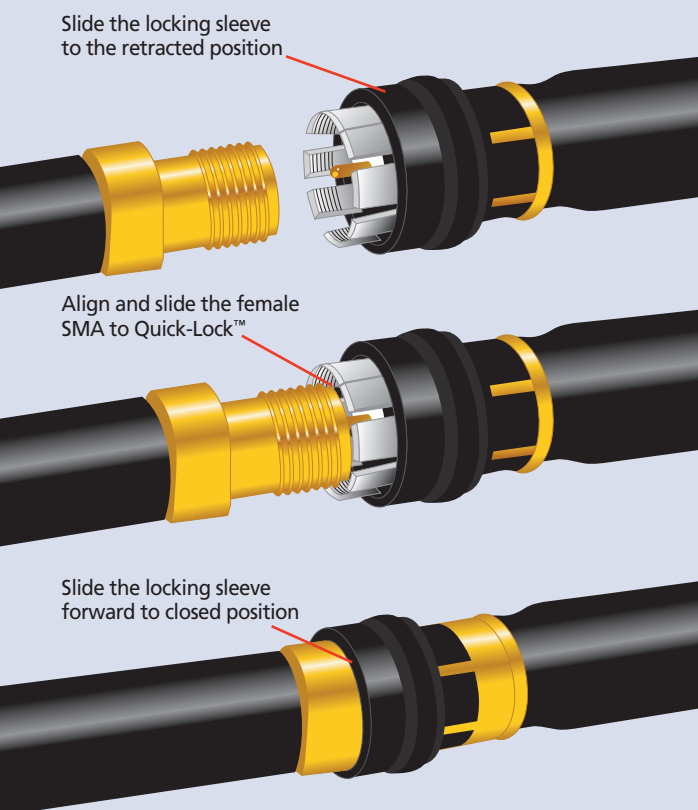
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PMI and **Amplitech** announced that **Lorill Electronic Sales** has entered into an exclusive sales representation agreement for Southern California. In related news, PMI and Amplitech announced that **TeraComm** has entered into an exclusive sales representation agreement for Maryland, Washington, DC and Virginia. Also, **Camponil Electronics** is a worldwide distributor of electronic components and will be its exclusive worldwide distributor of both companies' products to bring to market a complete array of RF components since it is their ability to stock and distribute within a short period of time.

Eclipse Microwave Inc., a manufacturer of RF and microwave mixers, detectors, limiters, and amplitude equalizers for the commercial and military industry, announced the appointment of **ASPEN Electronics Ltd.** to distribute and to expand its customer base in the United Kingdom. Based in Ruislip, Middlesex, United Kingdom, ASPEN Electronics is also a supplier of state-of-the-art test equipment and an extensive range of amplifiers, filters, oscillators and sources, frequency control products and waveguide products.

Linx Technologies Inc. announced the appointment of **Embedded Works Corp.** as a worldwide stocking distributor for its full product line, including RF modules, OEM products, antennas, connectors, ICs, interface modules and development systems. Linx products simplify challenging areas of electronics, such as RF, by providing solutions that can be quickly and easily applied by engineers of all skill levels. Embedded Works' strength in RF application engineering, marketing and customer-centered focus will provide Linx the opportunity to better serve customers globally.

WiSpry Inc., a leader in tunable radio frequency (RF) semiconductor products for the wireless industry, announced the addition of **Takachiho Koheki Co. Ltd.** (TK) as its technical distributor for Japan. TK is one of Japan's leading distributors of electronics components to consumer electronics manufacturers and mobile phone makers. With over 50 years of experience in bringing Western technology to the Japanese market, TK gives companies the vital support necessary to make their products a success.

Duplex CSA Ltd., a supplier of industry standard and custom-made RF connector solutions, shielding products and cable assemblies for the telecommunications, cable/satellite and related industries, announced the appointment of **RF Connections LLC** as the company's authorized sales representative for the southeastern US region, including Florida, the Dixie states and the Carolinas. Duplex CSA has also entered into agreement with RF Connections LLC to be its authorized distributor in the Americas for Duplex products. RF Connections is a woman owned small business (WOSB) focused on supplying high quality microwave components, cable assemblies and connectors.



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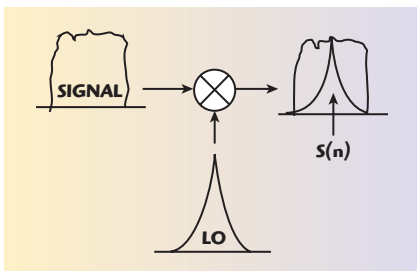
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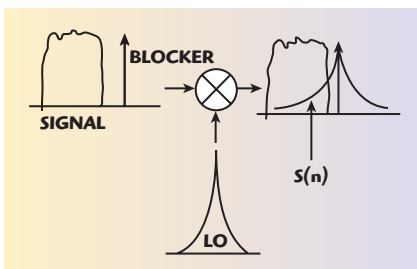
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PHASE LOCKED LOOP SYSTEMS DESIGN FOR WIRELESS INFRASTRUCTURE APPLICATIONS

Base stations use phase locked loop (PLL) systems to generate either RF or IF local signals to up-convert base-band signals to RF signals or vice versa. There are different ways of integrating PLL system blocks, including voltage-controlled oscillators (VCO), based on system requirements, performance and material cost. Why PLL performance is critical in wireless system design will be determined first, followed by a comparison of high level integrations. Detailed analytical approaches will be used to predict the baseline performance for synthesizer systems, using linear models of phase noise analysis in a closed loop, as well as overall system performance optimization, including loop filter designs.



▲ Fig. 1 Close-in phase noise impact to the incoming signal.



▲ Fig. 2 Phase noise impact to the incoming signal with a blocker present.

HOW PLL PERFORMANCES AFFECT WIRELESS SYSTEMS

Phase noise is one of the most critical impairments of radio systems, as it corrupts the information carried in the phase of the carrier due to its non-ideality. There are two different types of corruptions that

phase noise can make in the systems. One is from in-band (modulated signal band) phase noise, which directly affects down converted or up converted signals, as shown in **Figure 1**. The amount of in-band phase noise, other than the one that is very close to the carrier, which is slow varying enough for the data to be affected, can be represented as a phase error or error vector magnitude (EVM). Another key aspect of phase noise impact can be explained with an interferer, which is often called a blocker, as shown in **Figure 2**. When a blocker gets up or down converted, the LO's phase noise will override its phase noise onto the blocker and parts of the phase noise will stay on top of the signal band. These types of non-ideal phase noise can impact any type of radio system such as wideband code division multiple access (W-CDMA) and global system for mobile communications (GSM). Therefore, a certain level of phase noise performance will be expected in wireless infrastructure systems.

What about long term evolution (LTE) systems? What is needed to know about LTE systems in terms of phase noise, as it becomes the next generation mobile standard? LTE uses a multi-carrier modulation technique that transmits data over a number of orthogonal sub-car-

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Frequency (GHz)	Gain Typ. (dB)	NF (dB)	OIP3 Typ. (dBm)	OP _{1dB}	V _{DC} (V)	Quiescent Current Typ. (mA)	Part Number SOT-89 (-70LF) 4.5 x 2.4 mm, SC-88 (-92LF) 2.1 x 2.0 mm
LF-12	12.5	5.5	29	12.5	3.5	40	SKY65013
LF-9	16.0	4.8	36	18.0	4.7	70	SKY65014
LF-6	18.0	4.2	35	18.0	4.7	70	SKY65015
LF-3	20.0	4.8	27	14.0	3.5	40	SKY65016
LF-6	20.0	4.5	35	20.0	5.0	100	SKY65017

Ultra Linear Power Amplifier Drivers

Frequency (GHz)	Gain Typ. (dB)	NF (dB)	OIP3 Typ. (dBm)	OP _{1dB}	V _{DC} (V)	Quiescent Current Typ. (mA)	Package (mm)	Part Number
0.25–2.5	12.0	4.3	42.0	27.0	3.3 or 5	100	4-pin SOT-89 4.5 x 2.4	SKY65009-70LF
0.25–2.7	16.0	5.5	42.0	25.0	3.3 or 5	125	4-pin SOT-89 4.5 x 2.4	SKY65028-70LF
0.25–6	15.0	2.0	40.0	21.5	3 to 5	140	4-pin SOT-89 4.5 x 2.4	SKY65038-70LF
0.39–1.5	14.0	1.8	37.5	25.0	5	46	4-pin SOT-89 4.5 x 2.4	SKY65045-70LF
1.5–2.5	14.0	2.1	38.0	21.0	5	47	4-pin SOT-89 4.5 x 2.4	SKY65080-70LF
2.0–3.0	14.3	2.0	43.9	22.3	5	55	4-pin SOT-89 4.5 x 2.4	SKY65081-70LF
0.4–2.3	18.0	–	39.0	27.0	5	260	SOIC-8 Exp. Pad. 5.99 x 4.93	SKY65112-84LF
0.4–2.3	20.0	–	40.0	30.0	5	450	SOIC-8 Exp. Pad. 5.99 x 4.93	SKY65113-84LF
0.9–2.1	20.0	3.6	42.5	28.0	5	139	4-pin SOT-89 4.5 x 2.4	SKY65161-70LF
0.4–2.7	20.0	3.8	47.0	28.8	5	180	4-pin SOT-89 4.5 x 2.4	SKY65162-70LF

Ultra Low Noise Amplifiers

Frequency (GHz)	Test Range (GHz)	Gain Frequency (GHz)	OIP3 Typ. (dBm)	OP _{1dB} (dBm)	V _{CC} (V)	NF (dB)	Current Typ. (mA)	Package (mm)	Part Number
1.7–2.0	1.75	17.6	34.3	18.9	4	0.55	55	4-pin QFN 2 x 2	SKY67100-396LF
0.7–1.0	0.90	17.9	34.1	19.1	4	0.49	56	4-pin QFN 2 x 2	SKY67101-396LF
2.3–2.7	2.50	16.5	35.5	18.0	5	0.70	75	4-pin QFN 2 x 2	SKY65066-360LF

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riers, which consist of data and pilot within various formats of frame structures. Since orthogonal frequency division modulation (OFDM) signals transmit multi-carriers in the frequency domain, multi-carriers with the same phase noise on each carrier can be analyzed as one single-carrier with the same phase noise. However, the far-out phase noise can cause inter symbol interference (ISI), which means there is going to be a system requirement on phase noise for this system as well.

COMPARISON OF HIGH LEVEL INTEGRATION FOR PLL SYSTEMS

Both system and component designers know why good phase noise is important in wireless systems. In this section, an approach to designing the best fitting PLL systems will be considered by demonstrating the pros and cons for each approach in designs. **Table 1** shows three different integration types of PLL systems. Type 1 has one die that covers the VCO as well as PLL. This approach can be suitable for low to mid performance systems, as VCO phase noise performance will be greatly limited by low tank Q. In general, the tank Q will be limited by the Q of the inductor. Also, if a CMOS VCO is used, the 30 dB/decade slope of phase noise can be extended above 100 kHz offset, assum-

ing the device requires high operating current and voltage swings to meet far-out phase noise performance. This will limit the usage of this type of device in low RMS phase error required systems such as higher modulation systems. It will also require off-chip loop filter components that could require great tunings to maximize the performance. Even with these performance disadvantages, the benefit comes with lower cost and smaller package size.

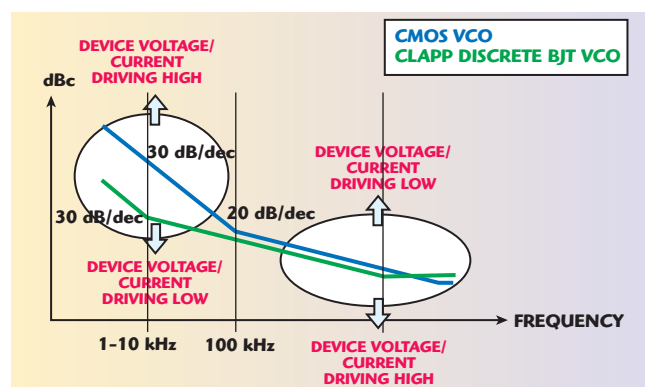
Type 2 is based on multi chip module (MCM). This type has a few dies as well as discrete components on a substrate. The die include VCO, PLL and varactors, while discrete parts include R, L, C and more. The benefit of this approach is that the VCO can have its own tank with either a low loss printed inductor using the substrate or a high Q wire wound inductor. The Q of these inductors varies from 40 to 150 depending on the size and different ways of making it. The loop filter can be either integrated or tunable outside the device. As can be expected from the high Q of the VCO tank, the phase noise performance can be quite good. If the system only requires good phase noise at high offsets—100 kHz and above—a CMOS VCO operated in high current and voltage swings could be a solution. However, if the system requires a low RMS phase error, a discrete bipolar VCO could be a better solution. **Figure 3** shows a typical phase noise difference between a CMOS VCO and a bipolar VCO in Type 2 cases. In Figure 3, one can tell the difference in phase noise slope that can affect system performance.

LOOP FILTER DESIGN AND OPTIMIZATION

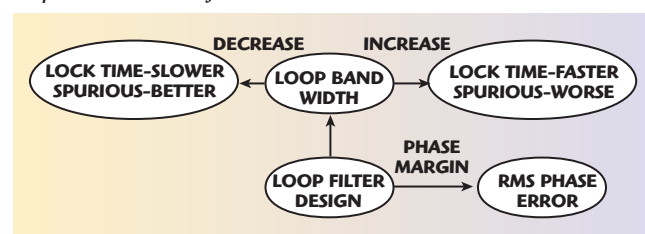
A good loop filter design is critical for the success of a complete PLL system design, since it affects the performance of closed loop composite phase noise, spurious as well as lock time. Designers can design a specific loop bandwidth to optimize performances required for their systems. The phase margin should be above 45°, probably better than 50° to minimize the RMS phase error in the systems. **Figure 4** shows the general rule of how the loop filter design can affect performance of a PLL system. This article will not discuss how the loop bandwidth or phase margin can be calculated, as this information is available in many other articles. Rather, how the Z(s) transfer function of a loop filter can be obtained, for either passive or active cases, so that designers can optimize the performance in a closed loop will be analyzed.

Figure 5 shows typical passive and active loop filter circuits. Finding Z(s) should not be a big issue, if only up to 2nd order filters including R1, C1, C2 can be used in a passive filter; however, if one has to go for a higher order filter such as 3rd or even 4th or 5th order for better rejections on spurious, it will cause a headache for a designer to calculate the transfer function Z(s). Here, an ABCD matrix [F] will be used to effectively and easily find Z(s). The definition of an ABCD matrix [F] and the relationship with the Z matrix are shown in **Figure 6**. As one can see from the Figure, the interest is to find out 1/C, which is Z₂₁ since it equals V₂/I₁, the definition of Z(s) of a loop filter. The main reason an ABCD matrix is used is that the cascaded two-port networks can simply be multiplied to calculate the combined matrix. Series and parallel components can be translated in an ABCD matrix, as shown in **Figure 7**, for the calculations.

TABLE 1			
PLL SYSTEM INTEGRATION			
	Type 1 (One die)	Type 2 (MCM)	Type 3 (Discrete)
Performance	Poor	Good	Very good
Cost	Low	Medium	High
Size	Small	Medium	Big
Usability	Average	Easy	Difficult
Manufacturers	SWK, SST, TI, ADI	SWKS	Many

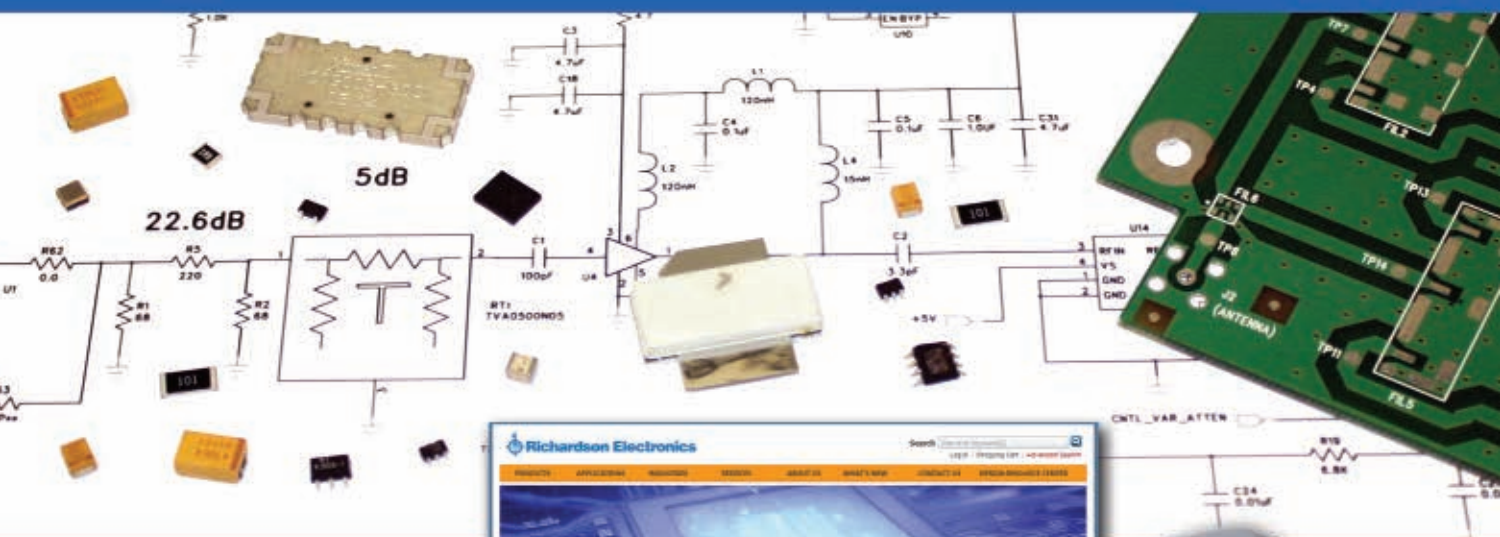


▲ Fig. 3 Phase noise characteristics 1.5 to 2.4 GHz CMOS cross-coupled vs. discrete BJT.



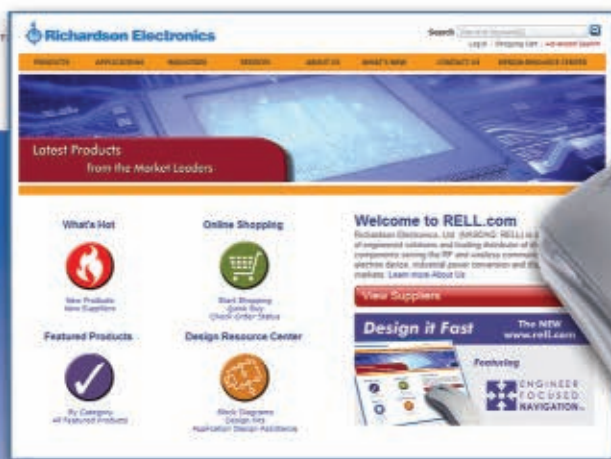
▲ Fig. 4 Loop filter design vs. performance parameters.

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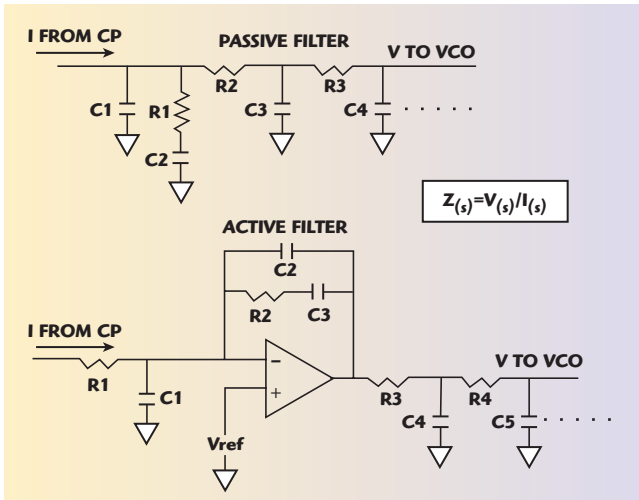
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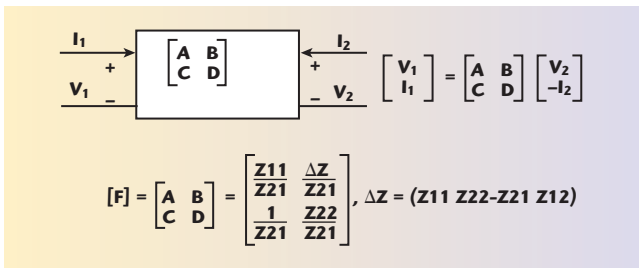


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▲ Fig. 5 Typical passive and active loop filters.



▲ Fig. 6 Definition of the ABCD matrix and the relationship with the Z matrix.

Figure 8 shows the breakdowns of each series and parallel components from the original passive and active loop filters to calculate the ABCD matrix.

If $[F]$ is found, it will be $[F] = [F1][F2][F3][F4][F5][F6]$ for the passive filter, and $[F] = [F1][F2][F3][F4][F5][F6][F7]$ for the active filter.

The complete matrix for the passive and active cases is shown here:

- Passive filter case

$$[F] = \begin{bmatrix} 1 & 0 \\ SC1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \left(\frac{SC2}{1+SR1C2} \right) & 1 \end{bmatrix} \begin{bmatrix} 1 & R2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & R3 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC4 & 1 \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} 1 & 0 \\ SC3 & 1 \end{bmatrix} \begin{bmatrix} 1 & R3 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC4 & 1 \end{bmatrix}$$

- Active filter case

$$[F] = \begin{bmatrix} 1 & R2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC1 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 \\ \left(\frac{S(C3+C2(1+SR2C3))}{1+SR2C3} \right) & 0 \end{bmatrix} \begin{bmatrix} 1 & R3 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & R4 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC5 & 1 \end{bmatrix} \quad (2)$$

The rest of the calculation to extract $1/C$ can be easily done by using any kind of engineering software such as Matlab or Mathcad. By using an ABCD matrix, finding a loop filter transfer function can be much easier as it can

separate the series and parallel components as an independent unit.

CLOSED LOOP PHASE NOISE ANALYSIS USING A LINEAR MODEL

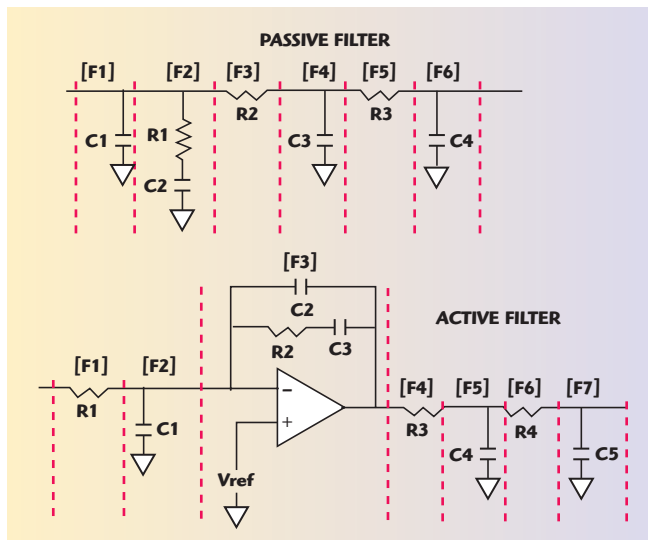
One of the big issues in designing a PLL system

is to estimate the performance by knowing how the loop will perform in terms of phase noise. The process of phase noise estimation will give a baseline performance that can be expected before the actual device is available for testing. In **Figure 9**, one can see each block as a noise source and how the noise contribution can be displayed as a different form of source.

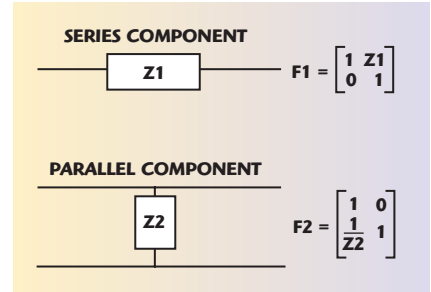
For example, the reference clock, reference divider, phase frequency detector (PFD), voltage-controlled oscillator (VCO) and main divider contribute phase noise as a form of phase error. The charge pump (CP) and loop filter (LF) generate a noise source as a form of noise current and voltage. All of these noise sources can be simulated from each block of circuit and be extracted from noise simulation. As the noise source of each block is identified and quantified, finding the transfer function (TF) for each noise source will be needed to come up with a number for the phase noise at the VCO output, so that the total composite contributions from all different sources will be known.

The transfer functions can be calculated based on control system theory. Below is the TF for each block, referenced to the VCO output.

- **Reference clk, Reference buffer** – [dBc]
 $1/R^*N^*open_loop/(1+open_loop)$
- **CP (charge pump)** – RMS noise current [A]
 $2\pi/Kd^*N^*open_loop/(1+open_loop)-20\log_{10}(\sqrt{2})$
- **LPF (low pass filter)** – RMS noise voltage [V]
 $(2\pi K_{vco}/s)/(1+open_loop)-20\log_{10}(\sqrt{2})$

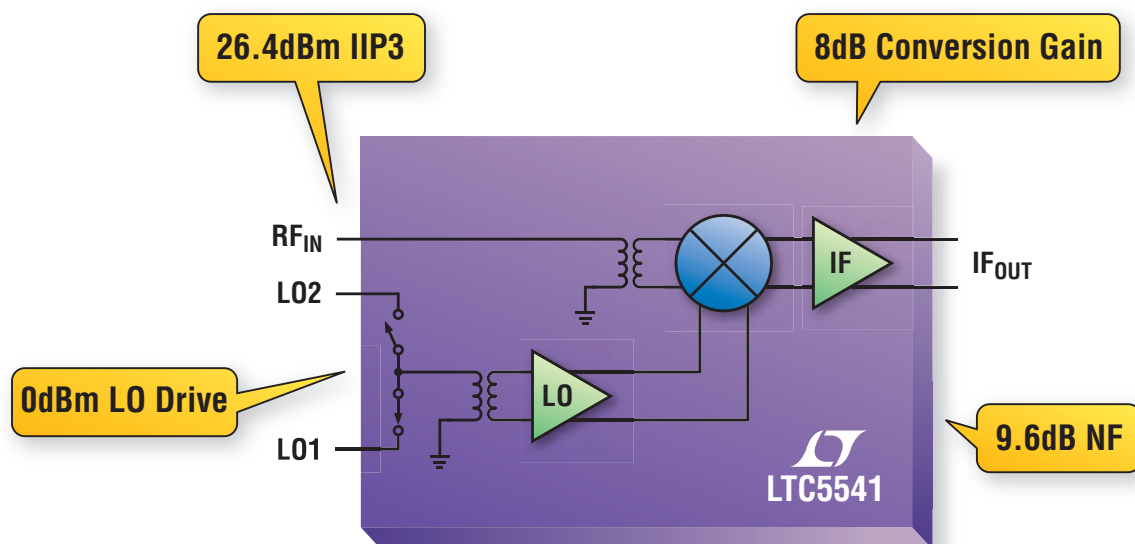


▲ Fig. 8 Breakdown of each series and parallel components.



▲ Fig. 7 Series and parallel components in an ABCD matrix.

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Conversion Gain	8dB	8dB	8dB	8dB
Noise Figure (NF)	9.9dB	9.6dB	9.9dB	10.2dB
NF @ 5dB Blocking	16.2dB	16.0dB	17.3dB	17.5dB
Power Consumption	0.66W	0.63W	0.65W	0.66W

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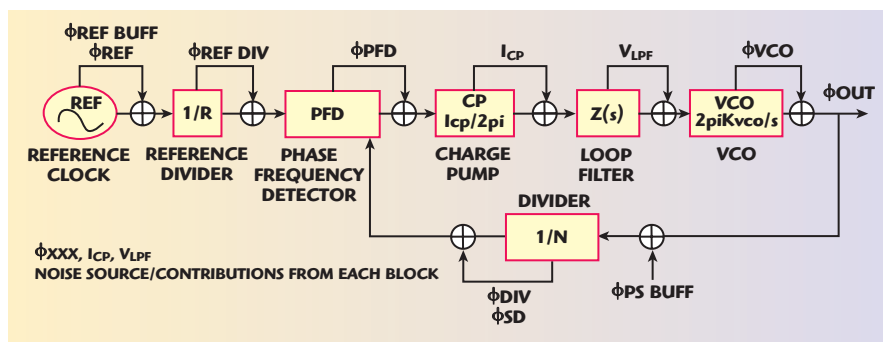
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▲ Fig. 9 Linear time invariant (LTI) phase domain model of a synthesizer system.

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Low-Noise Amplifiers

RF Freq (GHz)	N. F. (dB)	Gain (dB) (min/typ)	P-1dB (dBm) (min/typ)	VSWR in/out (typ)	Bias mA/VDC	Model
2 - 20	2.5 max	28/30	+10/+12	3:1/1.5:1	175 mA/+8 to 12	SL1118-30-2
18 - 30	2.5 typ/ 3.4 max	30/32	+12	2.2:1/2:1	145 mA/+8 to 12	SL2412-30-3
26.5 - 40	2.4 typ/ 3 max	30/37	-10	2:1	175mA/+8 to 12	SLKa-30-3
33 - 50	3.5 typ/ 4 max	15/18-20	-3	2.5:1	50 mA/+8 to 12	SLQ-15-4W
50 - 75	4 typ/ 5 max	15/18	-5	3:1	50 mA/+8 to 11	SLV-20-4
75 - 110	4.5 typ/ 5.5 max	15/18	-10	2.5:1	50 mA/+8 to 11	SLW-15-5

Power Amplifiers

RF Freq (GHz)	P-1dB (dBm) (typ)	Gain (dB) (min)	VSWR in/out (typ)	Bias mA/VDC	Model
13 - 18	+37/36 min	35/37 typ	2:1 max	2850 mA/+10	SP155-35-37
20.2 - 21.2	+32	43	2:1	1520 mA/+9 to 12	SP211-43-33W
25 - 30	+34/33 min	20/23 typ	3:1/2:1	2400 mA/+9 to 10	SP285-20-33
26.5 - 40	+29	30/32 typ	2:1 max	2400 mA/+8 to 12	SPKa-32-29
39 - 44	+31/29 min	26/33 typ	2:1	2200 mA/+9 to 12	SP435-33-31
50 - 66	+17	40/45 typ	2:1	500 mA/+8 to 12	SP5816-28-20W
77 - 82	+14	15/18 typ	3:1	150 mA/+10	SP805-15-10
92 - 96	+19/18 min	28/30 typ	3:1/2.5:1	750 mA/+8 to 11	SP944-30-23
75 - 110	+14 Psat	15 typ	3:1	250 mA/+8 to 12	SPW-15-14

Active Multipliers

RF Freq Input (GHz)	Input Pwr (dBm)	RF Freq Output (GHz)	Output Pwr min/typ (dBm)	Spur/Har (dBc) max	Bias mA/VDC	Model
13.5 - 20	+17	26.5 - 40	+23/+25	-15	1050 mA/+8 to 12	AKa-2XW-23
8.25 - 12.5	+12 - 18	33 - 50	+15/+18	-15	550 mA/+7 to 15	AQ-4X-18
10 - 15	+17	40 - 60	+4/+8	-15	400 mA/+8 to 12	AU-4XW
10 - 15	+15	60 - 90	+3/+5	-15	300 mA/+8 to 12	AE-6XW
7.66 - 8	+12 - 15	92 - 96	+13	-15	450 mA/+8 to 12	A944-12XW-10

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• R, N divider, PFD (phase frequency detector), SD (sigma delta modulator) – [dBc]

$$N^{\text{open_loop}}/(1+\text{open_loop})$$

$$\text{Open_loop} = G(s) \cdot H(s)$$

$$G(s) = (Kd/2\pi) \cdot Z(s) \cdot (2\pi Kvco/s)$$

$$H(s) = 1/N$$

By multiplying the noise source to the noise TF, a composite noise level has been estimated, as well as each block's noise contribution, as shown in **Figure 10**. One can tell that the measured data matches the simulated composite phase noise very well. Surprisingly in this particular case, one can also tell that the major noise contributor is the low pass filter (LPF). Therefore, one can go back and check what resistor values are being used and how big the Kvco is. This analysis not only gives the estimated composite phase noise, but also gives a possible clue for the circuit block of noise source that could be a dominant noise contributor in a PLL system. The composite phase noise simulation can be compared to the measured data, when the complete PLL system is available, to increase the reliability of the simulation data compared to the measured data, even though measuring each noise block may not be easy.

TIPS ON ESTIMATING AND TUNING MAJOR PLL SYSTEM SPECIFICATIONS

Phase Noise

First, one needs to know the target phase noise specification. For example, if the system requires -82 dBc at 1 kHz, -95 dBc at 10 kHz and -115 dBc at 100 kHz, then one should be able to plan what phase noise will be needed for each of the VCO, LPF and what noise floor will be needed on the synthesizer, so that it can be estimated if the current VCO, LPF and synthesizer have adequate phase noise margin by changing the loop BW (bandwidth) in the calculation. In general, one can set the loop BW close to where the free running VCO phase noise crosses the PLL noise floor to minimize RMS phase error. Also, one must make sure that the reference signal, either from a crystal or signal generator, is not affecting the composite phase noise.

Loop Filter Design

In general, a passive loop filter is preferred as it generates less noise compared to an active filter, since an

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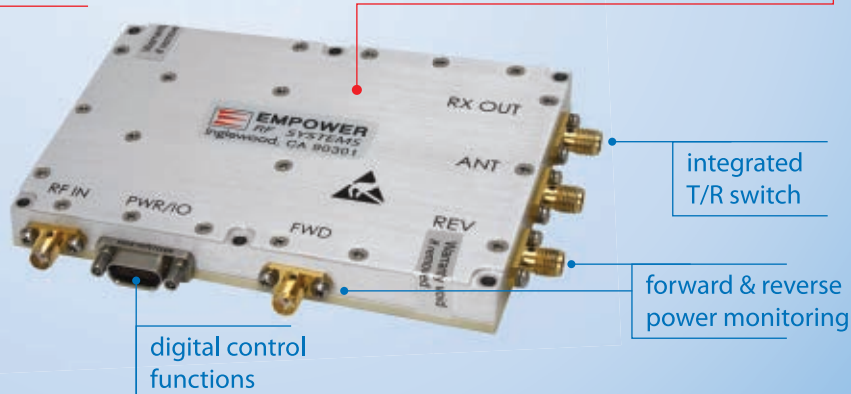
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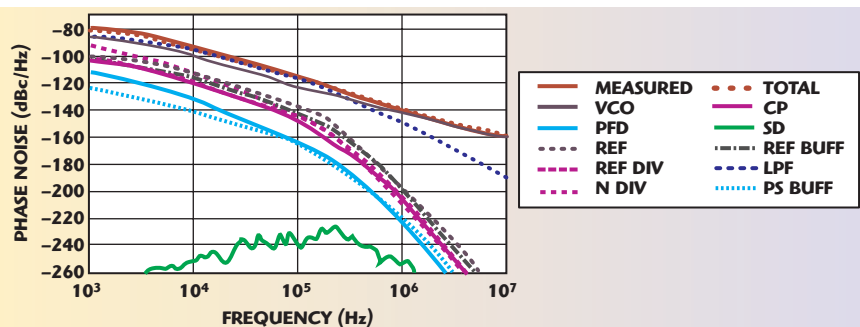
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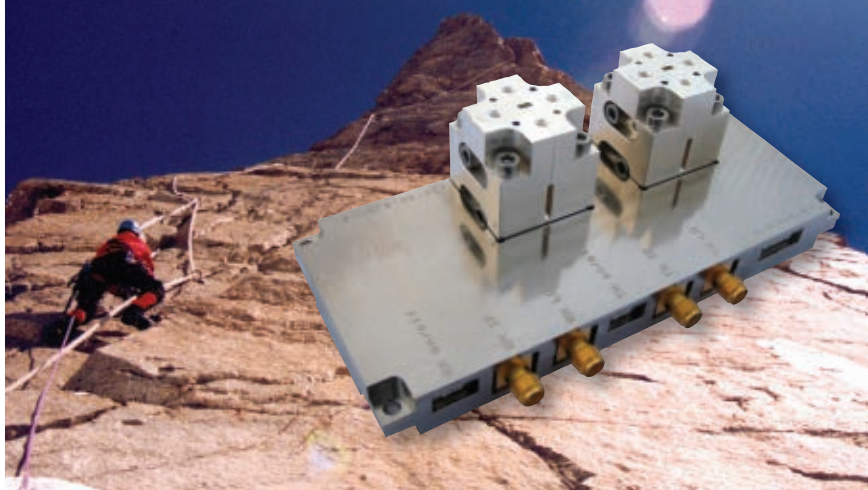
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▲ Fig. 10 An example of simulated block noise source contribution to composite phase noise of a 2.1 GHz PLL system.

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active filter requires many active devices. However, resistors, even in a passive loop filter design, need to be carefully chosen if the VCO has a very high K_{vco} , since the K_{vco} term is in the numerator of the noise transfer function.

The loop filter components' grounding can affect the performance of the loop filter in terms of spurious and other. If one thinks the rejection of the loop filter is not enough, the layout of the loop filter components should be checked.

Spurious

If high spurious levels are seen, one must figure out whether the spurious is coming through the CP or directly coupling to the VCO output. If the spurious is coming through the CP, one should be able to reject it with the loop filter design. However, if it is from direct coupling to the VCO output, the coupling path will have to be determined to remove or lower the spur level. By increasing the loop BW, one may be able to tell if the spurious coupling is directly related to the VCO output, since the VCO noise transfer function works as a high pass filter. In general, the comparison frequency spur is the highest spurious in an Int N system and boundary and fractional spurs are the concerns in Frac N system. The performance of synthesizers regarding boundary spurs can be checked by making boundary spurs at locations close to carriers within the loop bandwidth and compare the levels. One can also check if the loop filter is rejecting spurious properly by comparing with a spurious that is outside of the loop bandwidth as well.

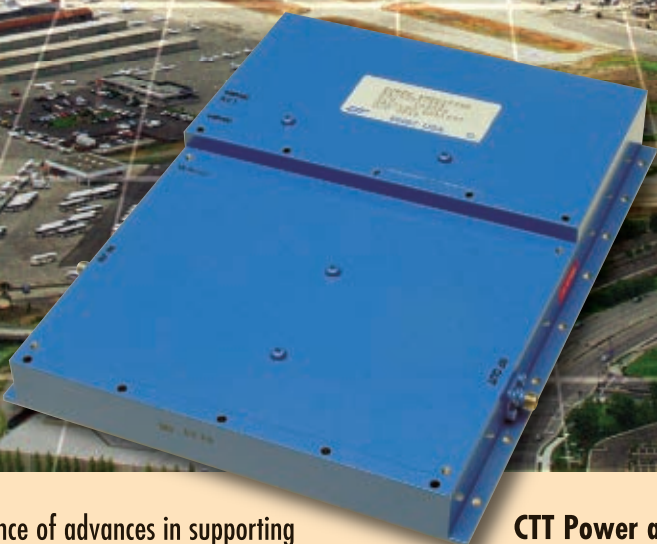
Frequency Pulling

Frequency pulling is a frequency change defined for a certain load condition in a VCO. In general, the load condition can be defined as a VSWR. To minimize the pulling effect, the design needs sufficient isolation between the VCO core tank and the output. One can add high reverse isolation buffer stages for this purpose.

Frequency Pushing

Frequency pushing is a rate change in free running VCO frequency, when the power supply level changes. The unit may be MHz/V. Since the injecting signal would generate side band

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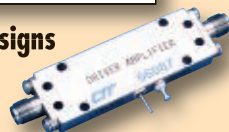
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FM modulated components, it could also be measured as the difference between the side tone to carrier power as well. Pushing could be greatly reduced by using linear drop output (LDO), as it specifies power supply rejection ratio (PSRR) as one of the main performance factors. One may check if the design SPEC needs LDO to meet the pushing specification. The down side of using LDO is that it generates a sig-

nificant amount of low frequency noise that could affect the performance of the VCO up to a 100 kHz offset. Therefore, more filtering will be needed to reduce LDO noise in high performance PLL applications such as a base station.

Here is an example of how the expected side band level as well as LDO noise impact on phase noise can be calculated:

Side band dBc at VCO output

$$\cong 20\text{Log}10\left(\frac{K_p * N_{rms}}{\sqrt{2} * \text{Freq_offset}}\right) \quad (3)$$

where:

K_p = pushing factor (Hz/V)

N_{rms} = Injected LDO RMS noise level

Freq_offset = Injected noise frequency

This equation works well as long as the peak deviation, which is the numerator in the above equation, is small enough. If an exact level of side band is wanted, one needs to use the Bessel function to find the number. Since pushing in a VCO open loop condition has been described, look at what will be different in a closed loop. The level of side band could be highest around the loop BW in a closed loop, since the VCO has a noise transfer function of high pass shape and even small gains around loop BW. With this equation, one can input any of the variables, such as side band dBc, K_p , N_{rms} or Freq_offset to extract any output needed.

CONCLUSION

Consideration has been given to how a synthesizer system can affect the overall performance of wireless systems and how a designer can choose different configurations in terms of PLL system integration. On the design side, how a loop filter transfer function can be designed by an ABCD matrix and optimized in the system was demonstrated. Also, closed loop phase noise analysis was shown to present the estimation of PLL phase noise performance by calculating noise source of each block of circuits with transfer function in a closed loop. ■

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2. K. Kundert, "Predicting the Phase Noise and Jitter of PLL-based Frequency Synthesizers," available at www.designer-guide.org.

Jun Lee has worked on Skyworks' CDMA2000, EVDO, WiMAX RF systems and applications and designed CDMA and EVDO single package radio (SPR) solutions. He is currently working on W-CDMA, GSM and LTE VCO circuits and phase lock loop circuits and system developments for base station applications. His current research interests include RF systems, circuits, communication theory and simulations.

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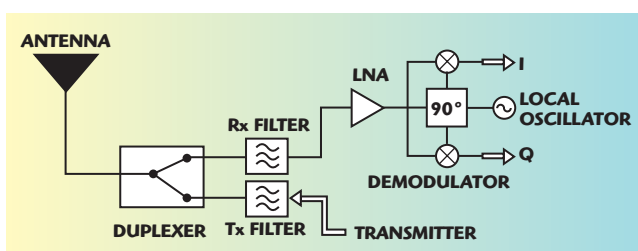
In full-duplex communication systems such as W-CDMA, a receiver's tolerance to unwanted transmit signals, including a co-located transmitter, is significantly important since transmission and reception occur simultaneously. Since transmit signals can be as little as 30 MHz away in frequency from the receive signal, surface acoustic wave (SAW) filters are typically employed to reject such close-in interferers. The receiver's low noise amplifier (LNA) must accommodate all signal levels delivered at the SAW filter output. In this article, a highly signal-tolerant LNA is designed, with a worst-case 1 dB compression point (P1dB) of -11 dBm, a gain (S_{21}) of over 17 dB and a noise figure (NF) close to 2.6 dB, for implementation in 0.35 μm , 4-metal CMOS technology.

A conventional direct conversion receiver is described in **Figure 1**, in which a common antenna is used for both transmission and recep-

tion of the radio signal. The common path to the antenna is established by the duplex filter and further filtering is provided by individual transmit and receive filters as required. In a full-duplex W-CDMA system, the maximum power amplifier (PA) output power is 29 dBm, which will find its way to the receiver via the duplexer, as shown in the Figure.

From W-CDMA 3GPP specifications,^{1,2} the maximum signal at the input to the receiver is -25 dBm at the low gain setting and -43 dBm at the high gain setting. An LNA filter therefore has to attenuate the transmitter signal by at least $43 + 29 = 72$ dB, when operating the LNA at the prescribed -43 dBm, in order to prevent the LNA from being compressed by the transmitter signal.

A filter that produces 72 dB of attenuation of the transmission signal will inevitably require a considerable amount of poles, which in turn would imply that the wanted frequency band itself will be subjected to losses due to this filtering process. By improving the linearity of the receiver path and in particular the LNA, it is possible to implement a low-loss



▲ Fig. 1 System diagram of a direct conversion receiver.

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TABLE I**MAXIMUM TRANSMITTER SIGNAL AT THE LNA INPUT**

	Minimum	Typical	Maximum
PA Output Power ¹ (dBm)	24	27	29
Duplexer Filtering ³ (dB)		-50	
Crest Factor ¹ (dB)		8.6	
Total (dBm)		-14.4	

TABLE II**BIASING OF THE CASCODE AMPLIFIER AND ITS GAIN CALCULATION**

Cascode Amplifier		
Load Impedance (R_L)	300	Equivalent impedance of L2 & C1 in parallel at resonance
V_t	0.550	Threshold voltage ⁶
V_{gs}	0.590	DC bias voltage
K	0.049	$K = \frac{1}{2} \mu_n C_{ox} \frac{W}{L}$
I_d (mA)	0.971	Drain current
G_m	0.010	Transconductance
A_v	2.914	Voltage gain
A_v (dB)	9.290	Voltage gain in dB

filter with fewer poles. Fewer poles in the receive path inevitably means a filter with reduced signal loss at the wanted receiver frequency, thereby resulting in an increase in sensitivity of the receiver. By considering a highly linear LNA, with an input P_{1dB} of -14 dBm or better, the SAW filter in the receive path can be removed, thereby substantially reducing receiver path losses and reducing component count and cost of the receiver (see **Table 1**).

stage cascode amplifier, biased to a point just above the threshold voltage, followed by a second-stage PMOS amplifier. As illustrated in **Figure 2**, the LNA consists of an input cascode section and a second-stage drain follower. The cascode section consists of two NMOS devices M1 and M2 and an LC parallel resonant circuit consisting of L2 and C1.

The transistor M1 is a common-source amplifier that is biased just

THE METHOD OF ACHIEVING THE INCREASED COMPRESSION POINT

In the power amplifier world, highly linear amplifiers are designed such that the transistor is biased either at the class B or class AB bias points. In this work, the same technique is employed to achieve a highly linear LNA, by biasing the transistor at the class AB bias point. This technique, however, lowers the transconductance (g_m) value, reducing the gain of the transistor and improving its dynamic range. The design is structured in two stages: A first-

above its threshold voltage. The function of M1 is essentially to convert the input signal voltage into an equivalent drain current I_{D1} . The transistor M2 is a common-gate amplifier that provides isolation between the input to the amplifier and the output to capacitor C2 and thus reduces the Miller capacitive effect.⁴ The inductor L2 and capacitor C1 are chosen such that they have a parallel resonance at the chosen frequency of operation, thus providing maximum voltage gain at the receiver frequency, while rejecting frequencies outside this band, including the amplified co-located transmitter signal.

The amplifier second-stage consists of a PMOS device M3 and an LC resonant circuit. Here again L3 and C3 are chosen such that they resonate at the frequency of operation and reject frequencies outside of this band, including the amplified co-located transmitter signal. In addition, the second stage of the LNA provides:

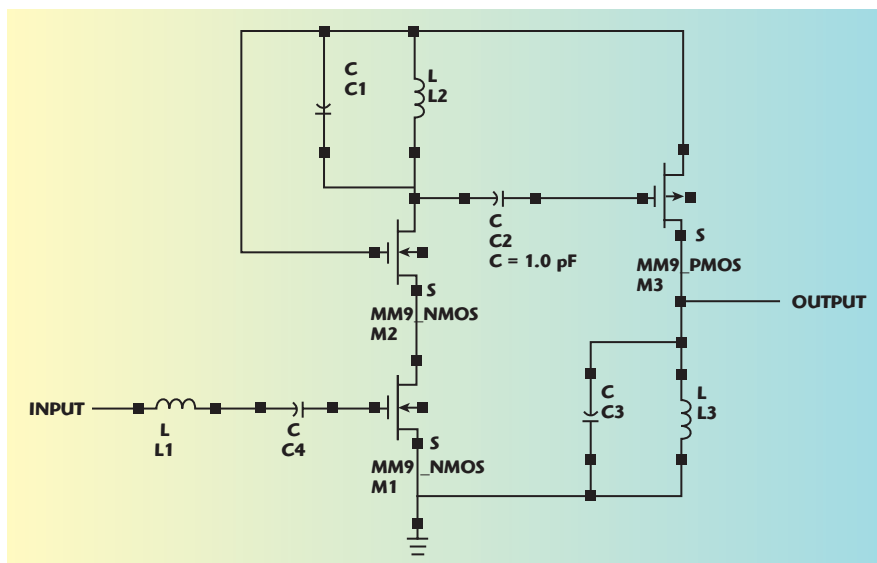
- Isolation between the first-stage load and the down-conversion mixer input impedance, thereby maximizing the first-stage cascode amplifier's load impedance.
- The PMOS device hole mobility is typically one-quarter of the electron mobility of the NMOS device, improving tolerance to larger signals.

A PMOS device has an increased thermal noise contribution when compared to an equivalent NMOS device. The noise effect of the PMOS device is reduced, however, by the gain of the previous NMOS cascode stage, with a net total LNA noise figure defined by the Friis formulae.⁵

DESIGN OF THE LNA

Due to the duplexer filter impedance-matching requirements at the input of the LNA, the input impedance is set to 50 Ω . Given that the output of the LNA is to be connected to a down-conversion mixer of approximately 200 Ω input impedance, the output of the LNA is matched to this value. The biasing and gain calculations of the input first-stage cascode amplifier are based on the linearity requirements due to the presence of the unwanted transmitter signal. **Table 2** is derived from the values obtained from the process manual.⁶

A calculated gain of approximately 9.3 dB is obtained with a drain current



▲ Fig. 2 LNA circuit diagram.

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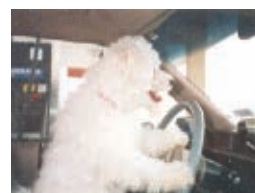
					
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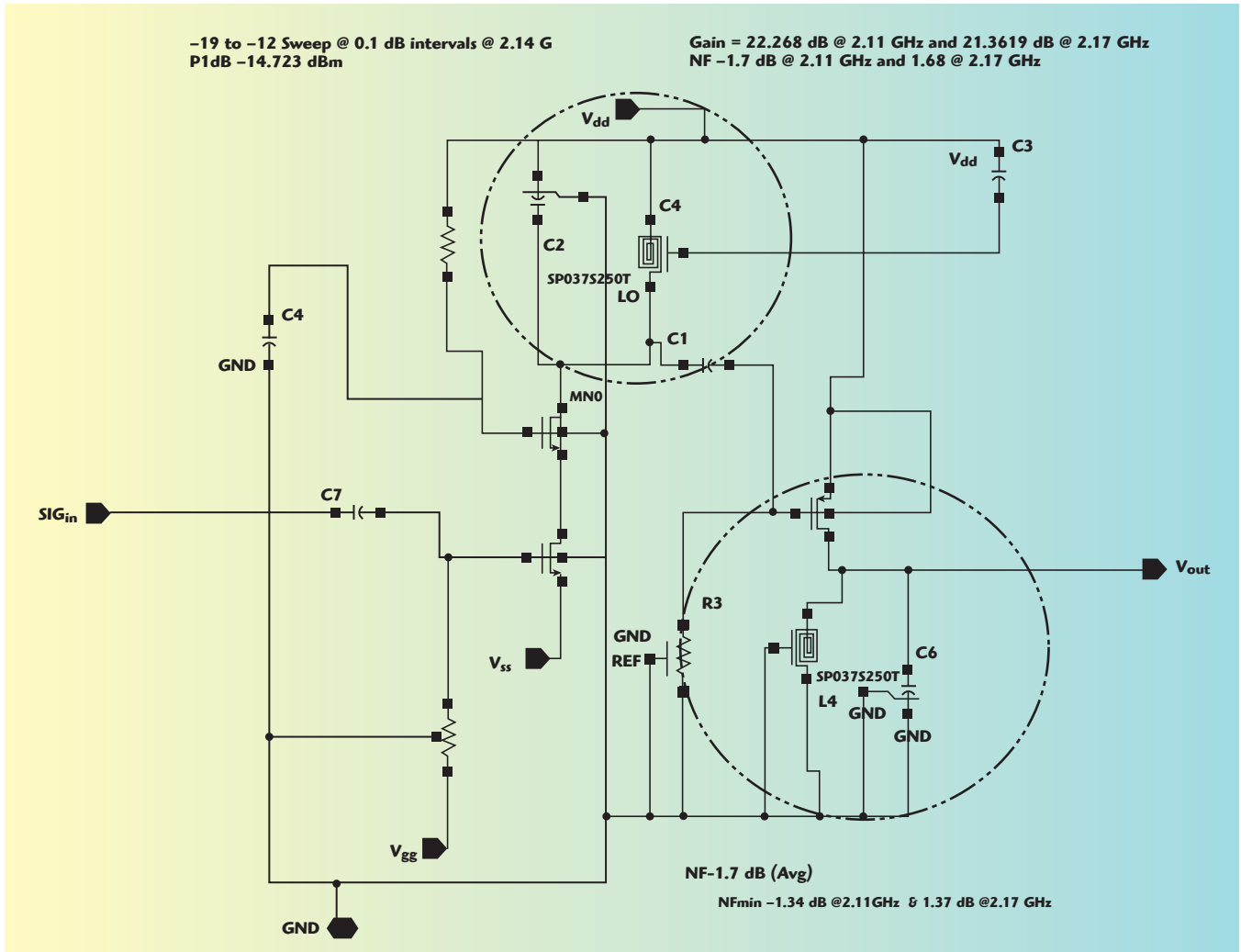
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▲ Fig. 3 Schematic diagram of the simulated LNA.

of just less than 1 mA, in the absence of an input signal. With the RF signal present, the bias and gain vary; the current variation with applied signal is presented later in the article.

The second-stage PMOS drain follower amplifier is also biased in the class AB mode, but the final bias is set according to the amount of transmitter signal attenuated by the parallel resonance circuit L2 and C1 of the input cascode amplifier. The design is then implemented in the simulator in schematic form, as indicated in **Figure 3**.

The circled sections indicate the parallel resonance circuits. The input inductor, L1, is implemented as a bondwire inductor and therefore external to the schematic entry. The initial bond-wire inductance, L_{BW} , was chosen as 5 nH, based on the rule of thumb of 1 nH per mm, and then calculated using the Greenhouse formulae.⁷ An on-chip inductor is not

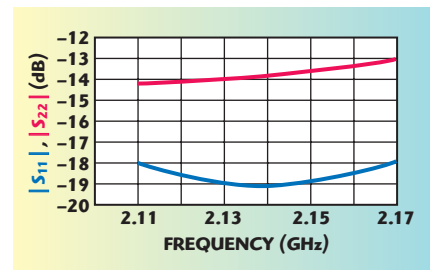
implemented in this design as they are generally of lower Q and hence high NF contribution, due to the increased ESR value.

SIMULATED INPUT AND OUTPUT RETURN LOSS

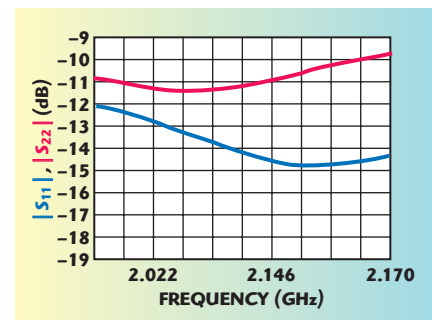
Figure 4 shows the log magnitude plot of the input and output return losses. The input return loss (S_{11}) is better than -17.5 dB and the output return loss (S_{22}) is better than -13 dB over the receive frequency range of 2.11 to 2.17 GHz. Both simulations include the effects of substrate coupling and other parasitic effect from the extracted layout.

MEASURED INPUT AND OUTPUT RETURN LOSSES

Figure 5 shows the measured input and output return losses of the LNA, measured with a network analyzer. The S_{11} is better than -12 dB and the S_{22} is better than -9.8 dB over

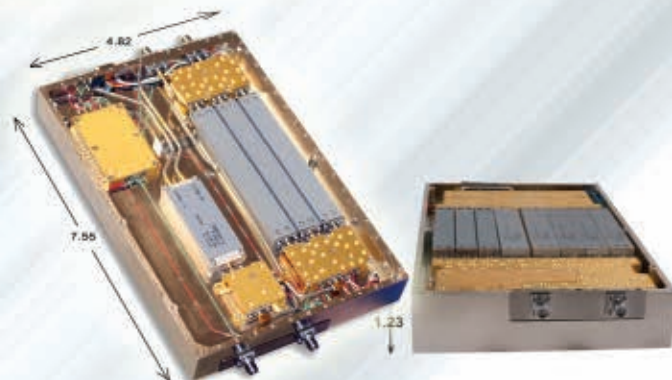


▲ Fig. 4 Simulated input and output return losses.



▲ Fig. 5 Measured input and output return losses.

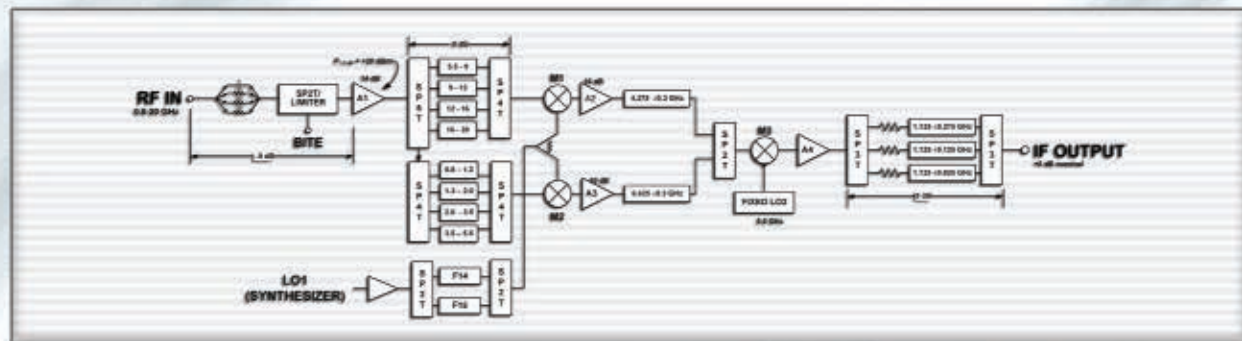
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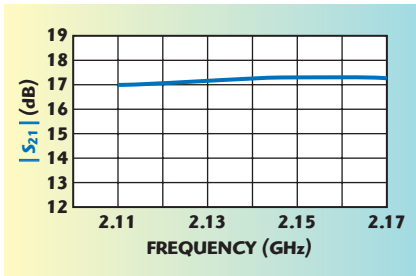
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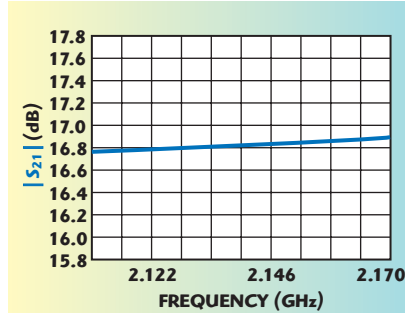
▲ Fig. 6 Simulated voltage gain of the LNA.

the receive frequency range of 2.11 to 2.17 GHz. The measured results marginally differ from the simulated results as they display a slight shift in center frequency resonance.

SIMULATED AND MEASURED LNA GAIN

The forward gain plot shown in **Figure 6** indicates a consistently flat gain between 17 and 17.25 dB over the frequency band of interest, with the gain peaking at approximately 2.15 GHz, which is the center of the receive frequency band.

The plot shown in **Figure 7** indicates a forward gain between 16.75 and 16.9 dB over the frequency of



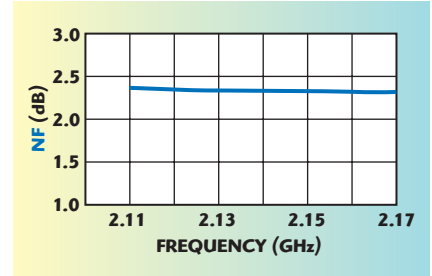
▲ Fig. 7 Measured voltage gain of the LNA.

interest. The gain is slightly higher at 2.17 GHz and slightly lower at 2.11 GHz and is primarily due to the better input return loss at that frequency.

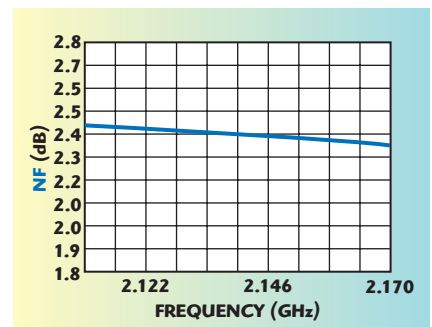
SIMULATED AND MEASURED LNA NOISE FIGURE

The simulated LNA noise figure in **Figure 8** shows that the NF is just under 2.4 dB across the frequency band of interest and is uniformly flat. This is desirable as it is a further indication of a uniform sensitivity of the receiver over the entire receive frequency band.

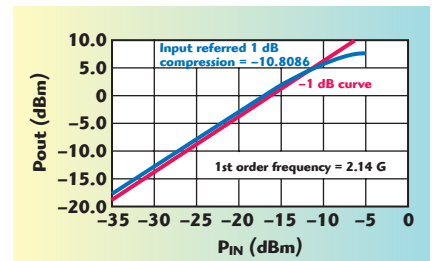
The measured LNA noise figure



▲ Fig. 8 Simulated noise figure of the LNA.



▲ Fig. 9 Measured noise figure of the LNA.



▲ Fig. 10 Simulated P1dB compression point of the LNA.

shown in **Figure 9** shows that the NF is less than 2.45 dB for the frequency band of interest and falls by less than 0.1 dB at the higher frequency of 2.17 GHz.

SIMULATED AND MEASURED LNA P_{1dB}

Figure 10 shows the simulated input referred 1 dB compression point of the LNA. The simulation was performed at the center frequency of 2.14 GHz, which is the mid-channel frequency for the receiver channel.

Figure 11 shows the input referred 1 dB compression point of the LNA. The measurement was performed at the center frequency 2.14 GHz, and was found to be -11.6 dBm. It is comfortably larger than the calculated requirement of -14.4 dBm (see Table 1), but slightly worse than the simulated value of -10.8 dBm. The compression point curve also shows a slight gain expan-

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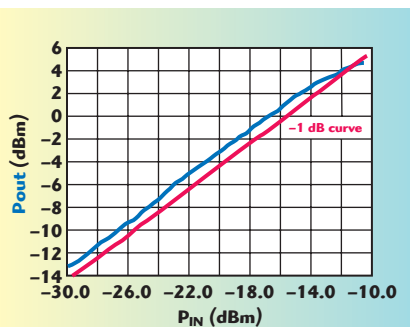
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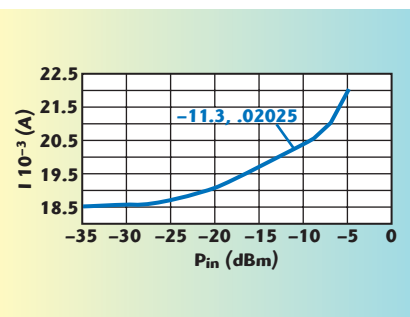
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▲ Fig. 11 Measured P1dB compression point of the LNA.



▲ Fig. 12 LNA current consumption vs. input power.

TABLE III						
SENSITIVITY CALCULATIONS						
	Typical			This work		
Circuit Block	Gain	NF	Tx loss	Gain	NF	Tx loss
Duplexer A260 ³	-2.0	2.0	50	-2.0	2.0	50
RX Filter LE19 ³	-1.8	-	48	-	-	-
LNA	15.4 ⁸	1.57 ⁸	-	16.75	2.45	-
Cascaded effect	11.60	5.37	98	14.75	4.45	50

sion prior to compression and is a characteristic commonly seen in class AB power amplifiers.

LNA CURRENT CONSUMPTION ANALYSIS

Figure 12 shows the current consumption of the LNA. Since the bias is an AB type, the signal input level has an effect on the bias point. The current is dependent on the input signal level for levels higher than -25 dBm. For width selection and sizing purposes due to problems with electromigration, the maximum current consumption at 2.7 V supply is 20.25 mA.

CONCLUSION

A suitable method has been developed to design a highly linear receiver LNA that can down-convert high power signals in conformance to modern wireless standards. The increased linearity of the LNA and the subsequent filtering provided by the tuned load impedances allows an increasing sequential rejection of interference signals through the LNA sections. The slight increase in NF, due to the biasing technique implemented, allows for a lower system NF for the entire receiver due to the reduced receiver filtering requirements. As demonstrated in Table 3, a cascaded NF of 4.45 dB and a gain of 14.75 dB is achievable. ■

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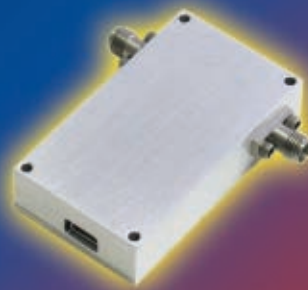
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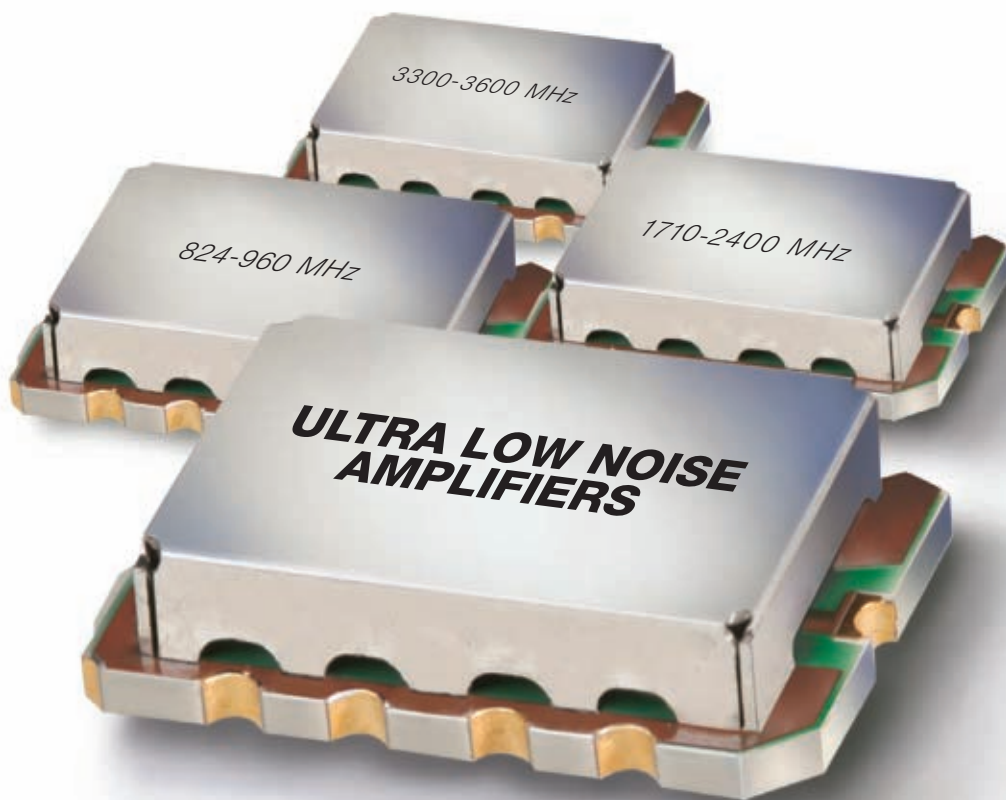
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MULTIPOINT POWER AMPLIFIERS FOR FLEXIBLE SATELLITE ANTENNAS AND PAYLOADS

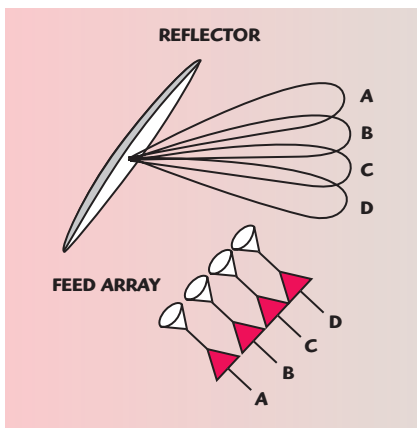
In the last few years, the architectural design of satellite communications payloads has benefited from the view point of flexibility, from the adoption of Multipoint Power Amplifiers (MPA). Multipoint power amplifiers offer a means to combine discrete amplifiers in a way that is reconfigurable and will degrade gracefully in the event of any failures. The first reference to the basic element of a multipoint power amplifier dates back to 1960,¹ although the application of MPAs to satellite transponders was first envisioned at Comsat Laboratories in 1974.²

The first practical application of the MPA concept to satellite communications came many years later, when it was adopted by Nippon Telephone and Telegraph Co. (NTT) for the S-band mobile communications payload on board the experimental Japanese satellite ETS VI.³ After intense R&D activity on MPAs applied to antenna architectures performed at the European Space Agency (ESA),⁴ multipoint power amplifier configurations were then adopted for the Inmarsat III satellites⁵ and for the Artemis L-band payload.⁶ Nowadays,

MPAs are being used on board several mobile communications satellites including the Inmarsat IV fleet.⁷ At present, an MPA configuration is implemented in the payload at Ka-band of the recently launched Japanese Kizuna satellite (WINDS, Wideband InterNetworking engineering test and Demonstration Satellite).⁸

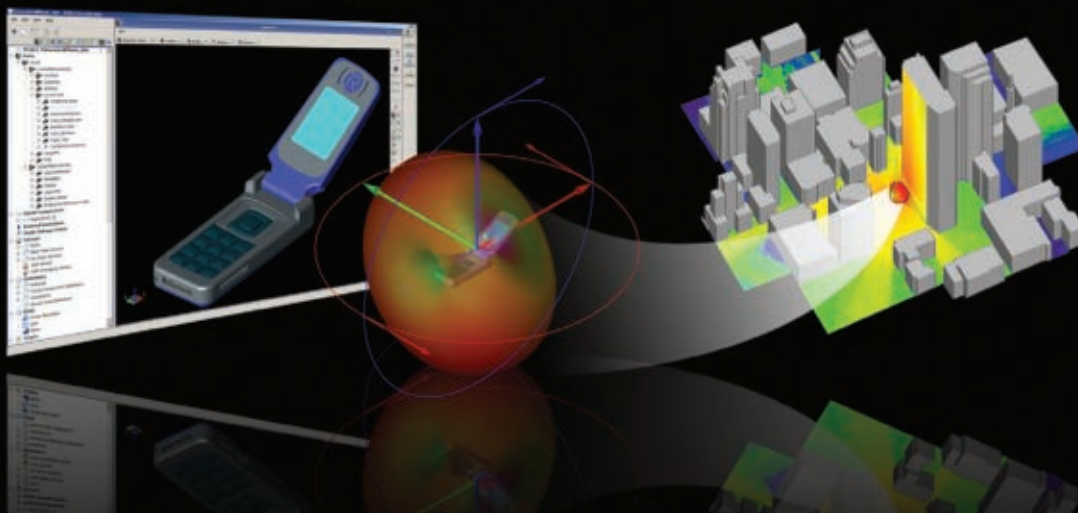
The suitability of MPAs to satellite payloads is closely related to multiple beam antenna configurations. Multiple beam coverages are adopted to provide higher edge of coverage (EOC) antenna gains and/or to implement frequency reuse schemes among the beams (that is, a more efficient use of the available bandwidth). While obtaining higher gain and reducing interference from and to other systems, they also limit the freedom to assign bandwidth and RF power resources. The application of MPAs in multibeam adaptive antenna (MAA) configurations allows efficient and flexible sharing of the total power from the power amplifiers among the beams, thus meeting varying traffic conditions⁹ or variable link conditions.¹⁰

The conventional transmit front-end of a multiple beam satellite transponder is depicted in **Figure 1**. The main drawbacks of such



▲ Fig. 1 Conventional multibeam antenna.

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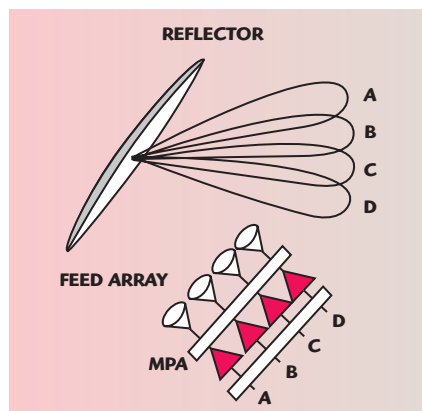
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▲ Fig. 2 MPA-based transmit front-end.

configurations are related to failure mechanisms and traffic allocation. First, the failure of one high-power amplifier (HPA) might lead to the total loss of one beam, unless appropriate redundancy schemes are adopted. The share of the total traffic capability that can be handled at an individual beam level is limited by the size of the HPA assigned to that same beam. Moreover, there is no way to take advantage from the statistical distribution of the traffic among the beams in order to divert RF power (that is, traffic capability) where the traffic demand is higher.

In transparent satellite transponders, the proportionality between traffic capability (in terms of the number of users handled at the same time) and EIRP is evident, whether frequency division multiplexing (FDM), code division multiplexing (CDM) or single carrier per channel (SCPC) down-links are considered. A front-end configuration based on a multiport power amplifier can solve, to a great extent, all the mentioned problems.

The schematic block diagram of an MPA-based transponder topology is shown in **Figure 2**. Before entering in more detail into the theory of a multiport power amplifier, the following main features of MPAs need to be highlighted:

- At each instant in time, the RF power assigned to one beam is a percentage of the total available RF power, all amplifiers now contributing to each individual beam.
- The failure of one HPA no longer causes the total loss of one beam, although a non-negligible reduction in RF output power has to be accounted for.
- It is possible to apportion in a

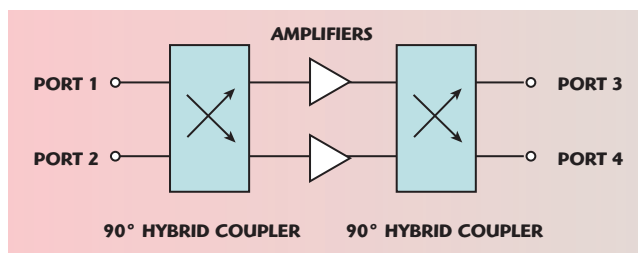
completely flexible manner the total available RF power among the antenna beams, just by a proper adjustment of low level input signals.

Possible drawbacks deriving from the adoption of MPAs are the presence of post-HPA losses in the output hybrid matrix and the need for the power amplifiers to work in multicarrier operation,¹¹ which makes MPAs less attractive in single-carrier-per-beam applications (such as in time-division multiplexed down-links).

MULTIPOINT POWER AMPLIFIER BASICS

In its simplest implementation, the MPA takes the form of a well known circuitual configuration: The balanced amplifier network (see **Figure 3**). A balanced amplifier consists of two power amplifiers sandwiched between two quadrature (90°) hybrid couplers. When the voltage transmission coefficients (S_{21}) of the two amplifiers are identical, the output power is twice that of a single amplifier and no power is lost into the isolated output port. It can also be demonstrated that, if the input voltage reflection coefficients (S_{11}) of the two amplifiers are identical, all reflected voltages will sum to the termination at the isolated input port; the result will be a balanced amplifier perfectly matched at its input.

The balanced amplifier network is usually used to combine the power of two identical amplifiers and, in this application, the input signal is fed only to one of the two input ports. Consider now what happens when two non-coherent signals are present at the two input ports. With the aid of the superposition principle, it can be demonstrated that the signal V_1 , applied at input port 1, will appear at output port 4, while the signal V_2 , fed into input port 2, will exit from the output port 3. It is also worth noting that, regardless of the amplitude ratio between the two input signals, the two amplifiers will see at their input the same average envelope RF power; hence, they will work at the same operating point. By varying the amplitude ratio between V_1 and V_2 , it will be possible to move continuously



▲ Fig. 3 Balanced amplifier configuration.

from one of the two opposite extreme cases, where the total RF output power comes out from either of the two output ports to the other, achieving all possible power splitting ratios between output ports 3 and 4.

THE N-PORT MPA CONFIGURATION

In its most general topological configuration, an MPA is composed of an array of HPAs, an input multiport network (INET) and an output multiport network (ONET). The input and output networks generally consist of two identical Butler matrices.² A Butler matrix¹ is a beam forming network¹² consisting of interconnected fixed phase shift sections and 3 dB hybrid couplers. The matrix produces N orthogonal sets of amplitude and phase output coefficients, each corresponding to one of the N input ports. A Butler matrix performs a discrete Fourier transform; it is, in fact, a hardware analogue of the FFT radix-2 algorithm. **Figure 4** shows 4×4 and 8×8 Butler matrices. In the 8×8 matrix, the circles are 90° hybrids and the numbers are phase shifts in units of $\pi/8$.

If the number of input ports and output ports of the MPA is N , N being an integer power of 2 ($N = 2^n$), then the number of hybrid couplers composing input and output matrices will be $n \times 2^{n-1}$.

The fact that the order N of the hybrid matrices is an integer power of 2 does not constitute a serious limitation. Actually, when the number of beams is less than N the unused output ports of the power combining $N \times N$ hybrid matrix can be terminated by matched loads. Each 3 dB hybrid coupler can be represented by a 2×2 transfer matrix T relating the signal phasors at the two input ports, V_1 and V_2 , with the phasors of the outgoing waves at ports 3 and 4, V_3 and V_4 :

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$$\begin{bmatrix} V_3 \\ V_4 \end{bmatrix} = [T] \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}; [T] = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & j \\ j & 1 \end{bmatrix} \quad (1)$$

Moving from the transfer matrix of the 3 dB hybrid coupler, transfer matrices of higher order hybrid networks can be easily derived.

The possibility to eliminate the intermediate phase shifters was proposed by S. Egami and M. Kawai⁹ and is currently widely adopted. It is interesting to note that in their configuration, the input network divides the signal at one input port into N equal amplitude signals with phase multiples of 90° . Depending on the input port, the N equal signals fed to the HPAs will assume different phases. Such phases will, however, result from permutations of the same phase distribution, typical of the order N of the hybrid matrix.

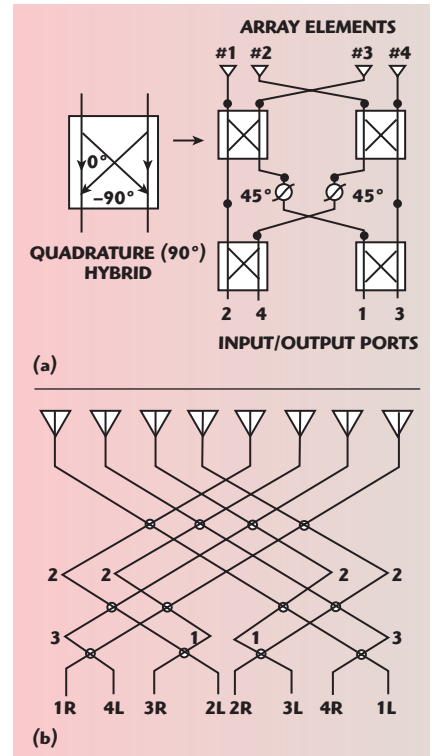
EFFECTS OF AMPLITUDE/PHASE ERRORS AND OF HPA FAILURES

In an ideal MPA, the signal at one input port, after being power split in the input network (INET), amplified by the HPAs and recombined in the output network (ONET), will appear at one single output port, with no leakage of power to the other outputs. A "real-world" MPA will in fact be affected by amplitude and phase imbalance in the hybrid matrices by the finite matching between cascaded elements and by the amplifiers' gain and phase shift non-uniformities. This last contribution is usually dominant and will therefore be addressed in more detail.

Amplitude and phase errors in HPAs (whether they are travelling wave tube amplifiers (TWTAs) or solid-state power amplifiers (SSPA) does not make any qualitative difference) can be classified in two main categories: systematic errors and random errors.

Systematic errors are composed of gain and absolute phase length discrepancies between the HPAs, as deriving from the intrinsic spread of their characteristics. Systematic errors can be easily calibrated out in the assembly process of the MPA by inserting suitable amplitude and phase trimmers at the HPA inputs.

Random errors derive from discrepancies in relative amplitude and



▲ Fig. 4 4×4 (a) and 8×8 (b) Butler matrices.

phase, which cannot as easily be removed. These could come from a variety of sources, such as:

- Variations in relative amplitude/phase with frequency
- Variations in amplitude/phase with temperature
- Variations in amplitude/phase of the drive level
- Variations in amplitude/phase due to aging

All these characteristics can be summarized with the general term of amplitude and phase tracking, respectively, over frequency, temperature, drive level and aging.

Several authors have derived isolation and output power loss in an MPA configuration as a function of the rms amplitude and phase errors of the amplifiers.

Naming Δ and δ the standard deviations of amplitude and phase non-uniformities of the amplifiers, respectively, the following expressions can be applied:

$$\frac{P_{\text{out}}}{P_{\text{tot}}} = 1 - \left(\frac{N-1}{N} \right) (\Delta^2 + \delta^2);$$

$$\frac{P_{\text{iso}}}{P_{\text{tot}}} = \frac{\Delta^2 + \delta^2}{N} \quad (2)$$



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where:
 P_{out} = output power of a single port;
 P_{tot} = total RF power of all amplifiers;
 P_{iso} = power leakage to nominally isolated output ports;
 Δ = standard deviation of amplifier gain errors (ratio);
 δ = standard deviation of amplifier phase errors (in radians).

It has to be taken into account that the formula listed above can only provide an average value for the MPA performance degradation. If the number of amplifiers is small, as it is in the case of a 4-port or 8-port MPA, the worst case degradations can be substantially worse (up to two or three times) than the average ones. A conservative rule-of-thumb would then suggest the consideration of a more practical worst case isolation degradation some 3 to 5 dB worse than the theoretical value.

Drastic modification of the MPA performance may then be expected when some amplifiers fail. The degradation of the MPA in terms of output power and isolation, in the case of one amplifier failure, is expressed by the following formulae:

$$\frac{P_{\text{out}}}{P_{\text{tot}}} = \left(\frac{N-1}{N} \right)^2 ; \quad \frac{P_{\text{iso}}}{P_{\text{tot}}} = \left(\frac{1}{N} \right)^2 \quad (3)$$

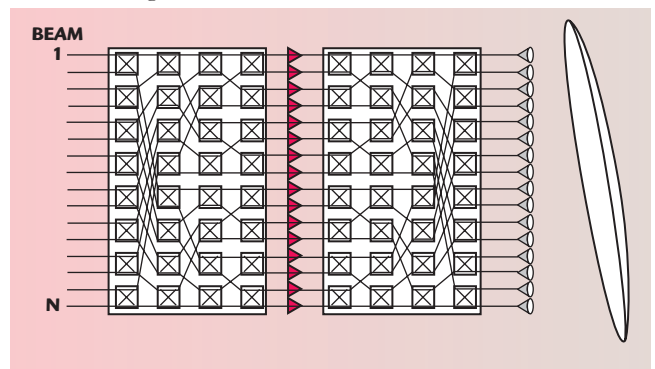
For example, if an 8-port MPA is considered, the failure of one amplifier would result in an output power loss of 1.2 dB and an isolation degradation to 18.1 dB. The higher the order of the MPA, the less significantly it will be affected by the failure of any single power amplifier. Similar to the features usually associated with active phased-array antennas, it is here possible to speak of a “graceful degradation” feature of multiport power amplifier systems.

MPA SATELLITE TRANSPONDERS

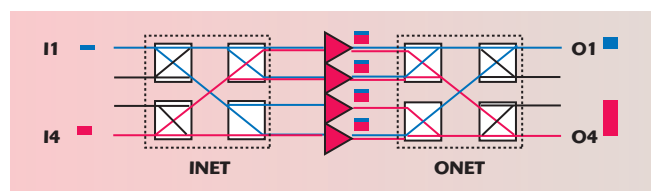
An ideal reconfigurable payload

should allow redistributing the available RF power based on the real-time needs. Achieving this objective is strictly dependent on the architecture of the high-power section. The leading idea is to have a common power pool from which a channel can adaptively draw the power it requires. In the transmit section of an MPA satellite transponder, a plurality of input signals is transformed by the input microwave network (INET), presented to the stack of amplifiers and recombined by the output microwave network (ONET), as shown in **Figure 5**. The power sharing flexibility is achieved through the parallel amplification of all signals by a stack of power amplifiers (see **Figure 6**).

Intermodulation products are generated due to the nonlinear nature of the amplifier devices and recombined by the ONET and distributed among the output ports. This intermodulation products scattering can be exploited to increase multi-carrier efficiency. The cascade of the INET-ONET scattering matrices should correspond to an ideal permutation matrix. In this case, the architecture guarantees that amplified replicas of the input signals appear at the permuted output ports. The INET/ONET matrices resemble a multi-stage butterfly structure common to both FFTs and Butler matrices topologies. Assuming a constant loss per hybrid stage (α), the total ohmic output loss (in dB) of an ideal M-ports butterfly network is roughly given by



▲ Fig. 5 Single feed-per-beam with full sized multiport amplifier.



▲ Fig. 6 Basic principle of power sharing in multiport amplifier.



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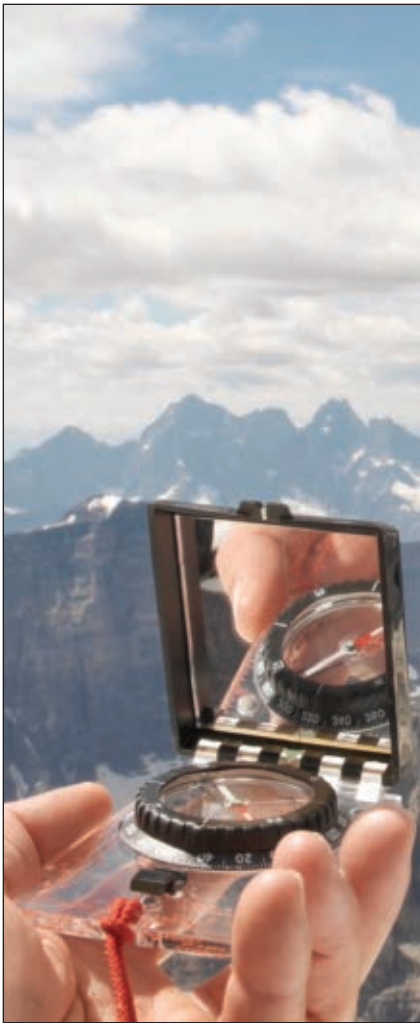
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$$\alpha[\text{dB}] \cdot \log_2 M \quad (4)$$

The high-power ONET realization typically involves TEM transmission line technologies at L- and S-band frequencies and waveguide technologies at Ku- and Ka-bands. Any unbalance between matrix ports results in some power lost at the desired output port and appearing elsewhere. Although the Butler matrix is the most efficient network topology to achieve orthogonal vector distributions, the choice of a different network can be suggested by the adoption of specific transmission line technology. It is worth noting that the input network operates at low power levels, hence ohmic losses can often be neglected (affecting gain but not the overall output power). To achieve the full sharing of all the RF power, the order of the multiport-amplifier should correspond to the overall number of high power amplifiers (M_{HPA}). Unfortunately, the ONET insertion loss, mass, and layout/manufacturing complexity grow together with the number of ports (M) to the point that ONET matrices of order higher than about 16 readily become difficult to realize.

The architecture can be simplified if the M_{HPA} -ports amplifier can be replaced with a plurality (M_P) of smaller, identical M -port amplifiers, with $M_P \cdot M = M_{\text{HPA}}$. These smaller M -port amplifiers require fewer hybrid stages and thus will have a lower total mass as well as lower insertion loss. The drawback of this partitioning (shown in **Figure 7**) stands in the reduced degree of sharing of the power.

In a M -port amplifier, neglecting in a first instance the detrimental effects of the HPA's non-linear behaviors, INET/HPAs/ONET tracking unbalances and ONET ohmic insertion losses, the maximum allocable power to a single channel P_{MAX} is

$M \cdot P_{\text{HPA}}$, where P_{HPA} is the saturated RF power of each TWTA (that is, in the degenerate case of a single channel, the multiport-amplifier acts as a power combining network).

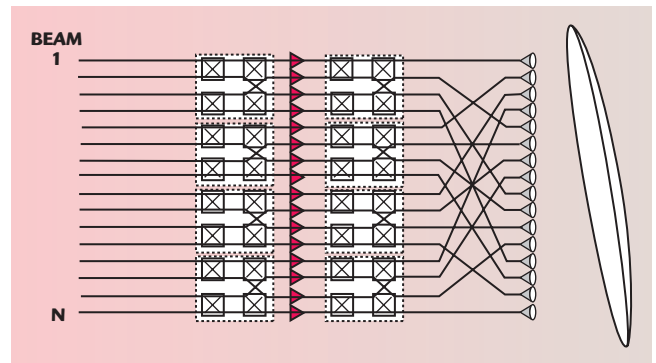
Generally speaking, indicating with P_i the power of the i -th channel and assuming statistical independence of the channel signals amplified by the k -th multiport-amplifier (MP_k), one has:

$$\sum_{i \in \text{MP}_k} P_i \leq M \cdot P_{\text{HPA}} \quad (5)$$

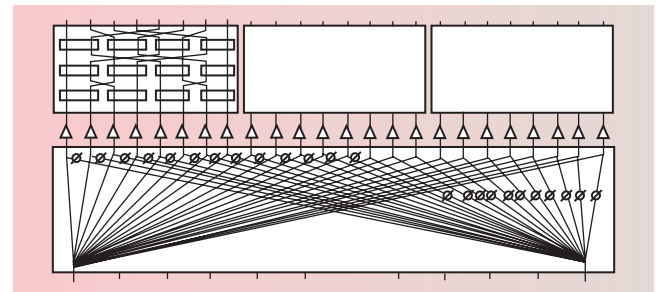
The number of amplifier contributing to a single beam can be increased, retaining the partitioning in smaller matrices, if the beam is generated by several feed elements. In such a case, the amplitude and phase distribution at the output ports of the input network (INET) can be synthesized by a more conventional corporate power divider/combiner beamforming network⁴ (see **Figure 8**).

MPA APPLICATIONS IN COMMUNICATIONS SATELLITE PAYLOADS

The first satellite flying a multiport amplifier was the Japanese Engineering Test Satellite ETS-VI, launched in 1994, which suffered problems at launch and failed to reach a geostationary orbit. ETS-VI included an MPA in its Multibeam Mobile Com-



▲ Fig. 7 Single feed-per-beam with partitioned multiport amplifier.



▲ Fig. 8 Typical multimatrix configuration for semi-active antennas.

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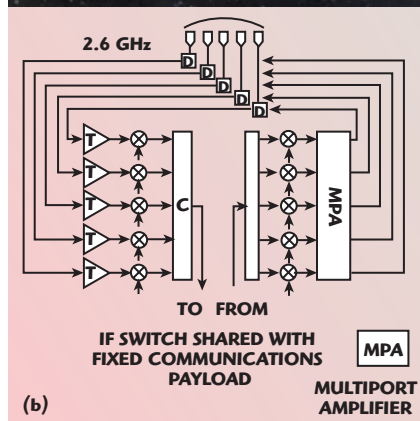
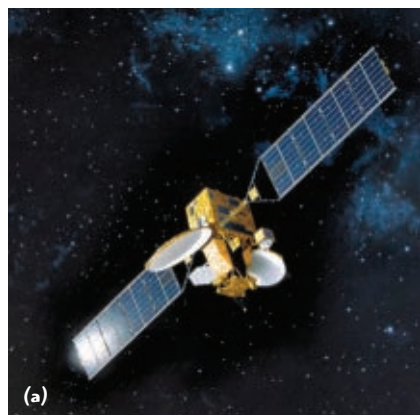
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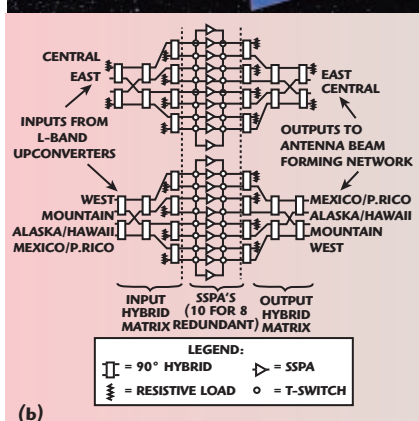
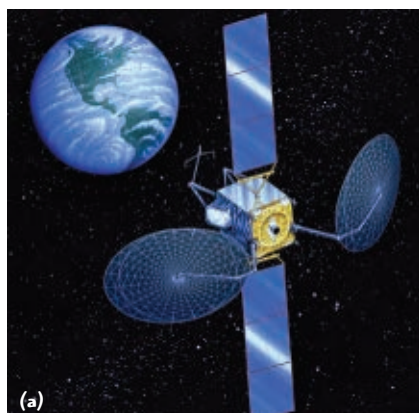
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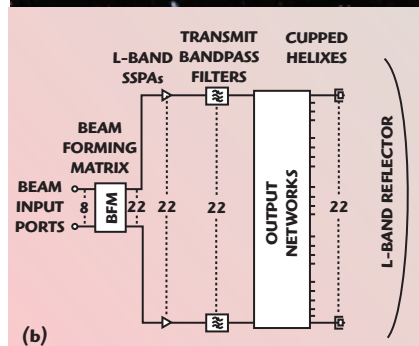
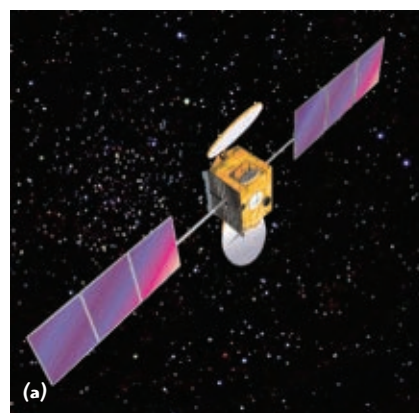
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▲ Fig. 9 ETS-6 satellite (a) and payload block diagram (b).



▲ Fig. 10 MSAT (AMSC) satellite (a) and payload block diagram (b).



▲ Fig. 11 Immarsat-3 satellite (a) and payload block diagram (b).

munications Transponder, operating at S-band (see **Figure 9**).

In 1995 the AMSC-1 (also called MSAT-2) satellite was launched, followed in 1996 by MSAT-1. Both satellites, built by Hughes (now Boeing), included L-band hybrid matrix amplifiers to provide traffic reconfigurability in their mobile communications transponders (see **Figure 10**).¹³ In 1996, the first of the Immarsat 3 satellites was launched. In this global mobile communications satellite, seven spot beams and a global beam are generated using a 22-element cup helix feed array and 22 SSPAs. The amplifiers are combined in four 4×4 matrices and one 6×6 matrix (see **Figure 11**). This configuration allows the power of each individual amplifier to be routed to any one spot beam, or any combination of spot and global beams.

In 2001, Artemis, telecommunications satellite of the European Space Agency, was launched, but, because of a launcher failure, could not reach its final geostationary orbit. After a long recovery procedure, it finally succeeded in reaching the intended geostationary orbit in 2003. Artemis, which is still operational, includes an L-band Land Mobile (LLM) payload, integrating an MPA-based transmit configuration, allowing traffic recon-

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• ZHL-50W-52	50-500	50	+46 +48	6.0	+55	24 9.3	1395 1320
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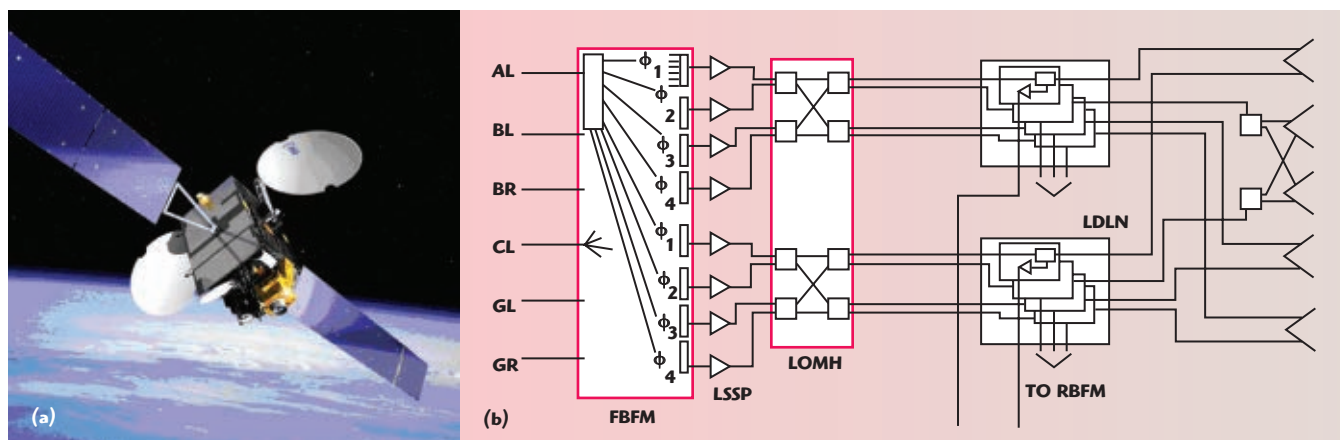


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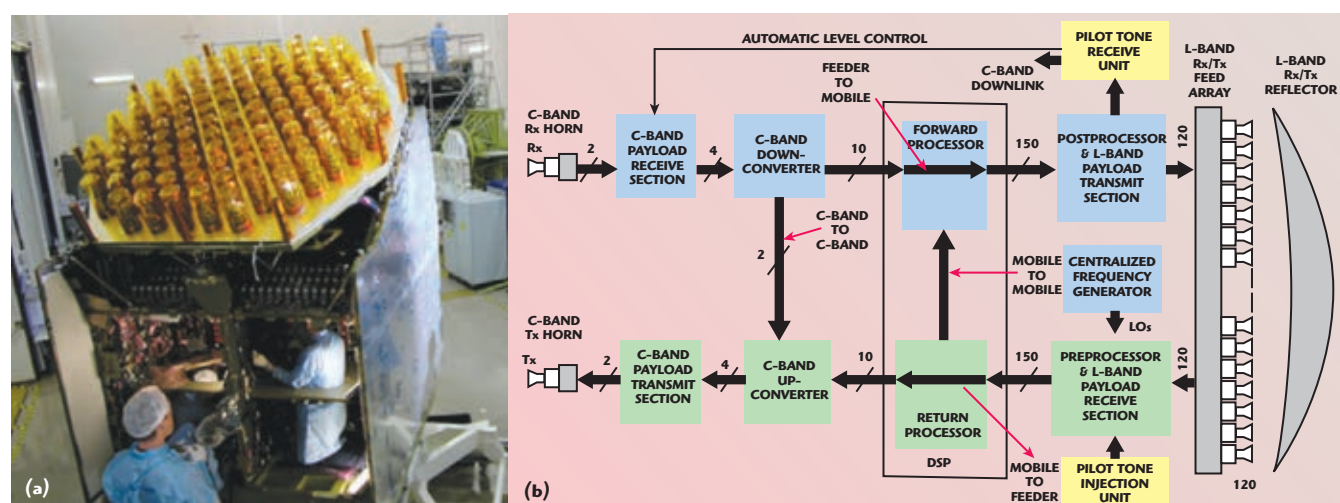


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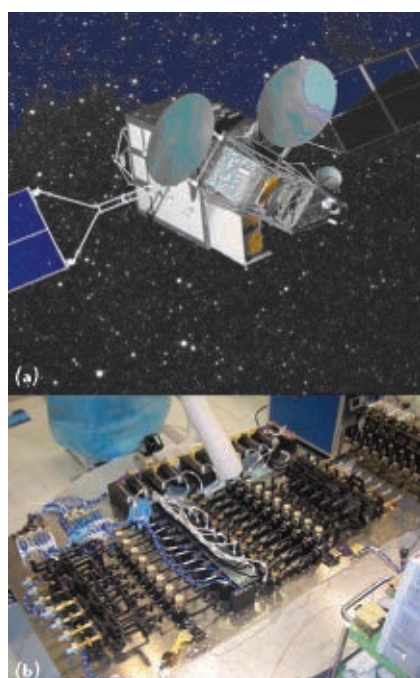
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▲ Fig. 12 Artemis satellite (a) and LLM payload block diagram (b).



▲ Fig. 13 Immarsat-4 antenna array (a) and Ka-band MPA (b).



▲ Fig. 14 Kizuna (WINDS) satellite (a) and Ka-band MPA (b).

figurability between a European coverage beam and three spot beams (see **Figure 12**).

The first satellite of the fourth generation of Inmarsat platforms, Inmarsat-4, was launched in 2005. Inmarsat-4, developed and manufactured by EADS Astrium, includes a very complex payload, including a nine meter unfurlable reflector and a sophisticated digital signal processor, to support the innovative Broadband Global Area Network (BGAN) service. The 150 SSPAs (120 are active), constituting the transmit section of the active antenna, are grouped in 15 8×8 multi-port power amplifiers (see **Figure 13**).⁷

One of the most limiting factors to be taken into account for satellite communications systems operating at Ka-band frequencies is rain attenuation. The application of MPAs in a Multibeam Adaptive Antenna (MAA) configuration was proposed to counteract rain attenuation at Ka-band as

early as 1989.^{10,14} An advanced example of the use of MPA at Ka-band for traffic flexibility and for counteracting rain attenuation is offered by the recently launched Japanese Kizuna satellite (Wideband Inter-Networking engineering test and Demonstration Satellite, WINDS). The high power MPA, based on efficient TWTAs, can flexibly allocate more power to beams over rainy regions (see **Figure 14**).⁸

CONCLUSION

Multiport power amplifiers have found widespread use in microwave systems, especially for satellite communications. The use in satellite transponders has allowed exploitation of multiple beam antenna systems and hence the achievement of higher EOC gains and more efficient use of the frequency spectrum. The MPA technology is still very promising and worth further R&D efforts, especially in view of future applications at Ka-band. ■

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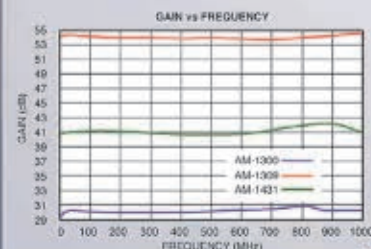
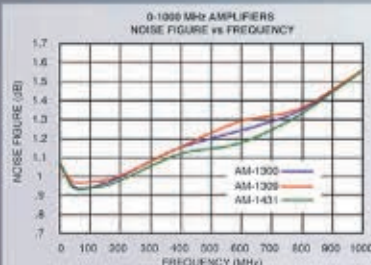


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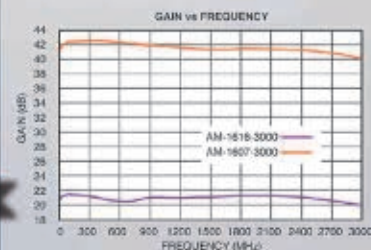
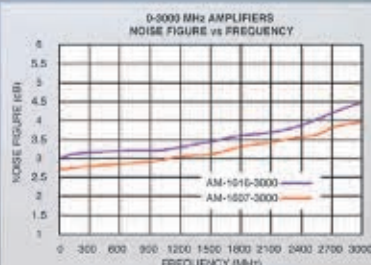
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AM-1309	0.001-1000	50	54	1.00	1.2	1.4	1.7	10	10	9	2.0:1	90
AM-1616-3000	0.01-3000	20	21	2.00	3.2	3.5	4.3	14	11	7	2.0:1	60
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design of telecommunication and navigation satellite systems and payloads.

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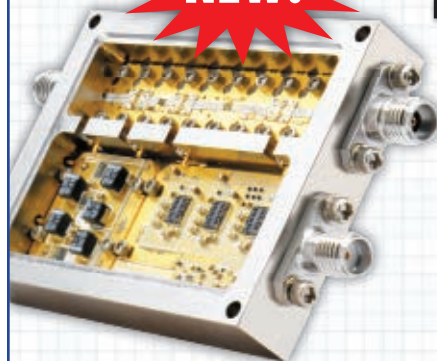
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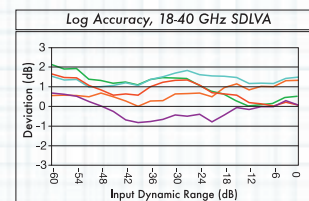
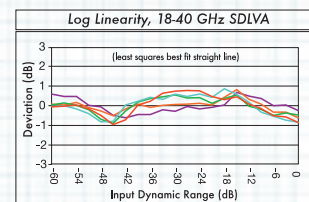
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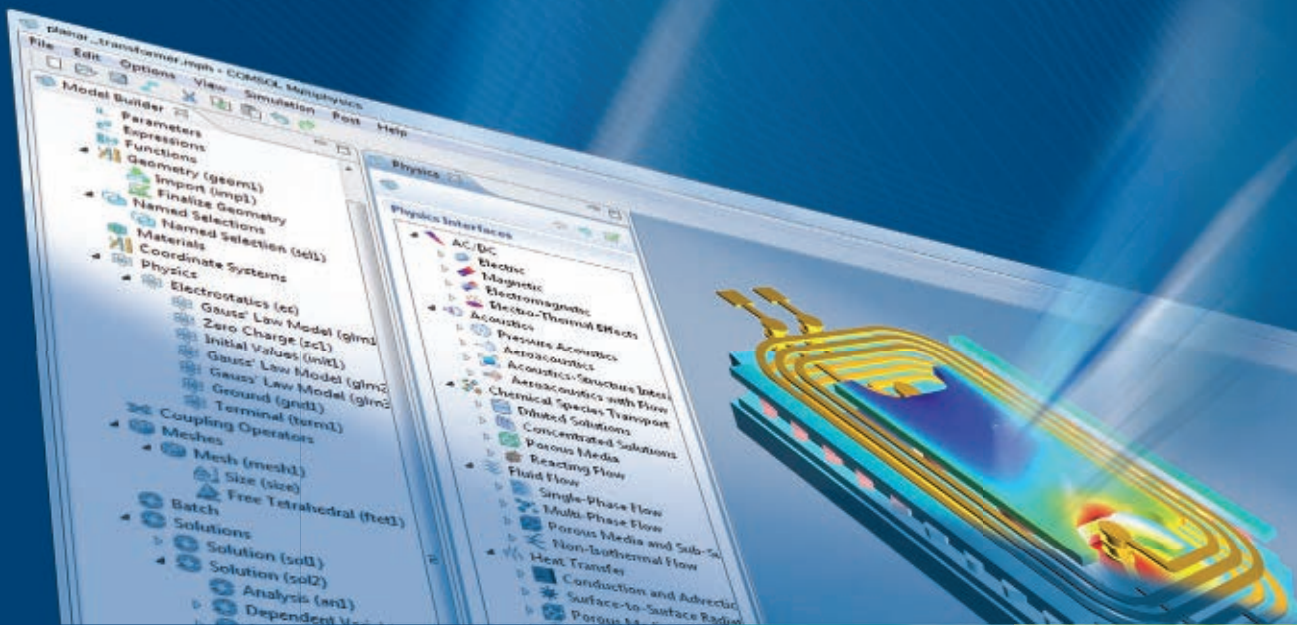
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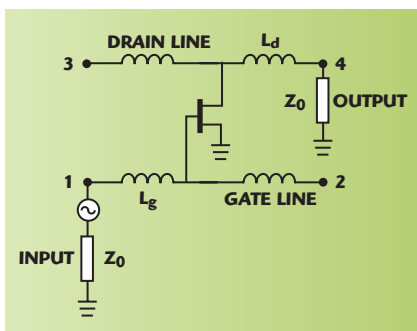
A novel design of a single-stage microwave distributed amplifier is presented in this article. The design is based on the use of a Chebyshev polynomial to express the transducer power gain of the distributed amplifier. The obtained amplifier provides a considerable increase in the bandwidth as compared to both the conventional single-stage distributed amplifier and multi-stage distributed amplifier.

Conventional MESFET distributed amplifiers (CDA) are formed by two artificial transmission lines, called gate and drain lines, actively coupled by a number of MESFET transistors.¹ The gate and drain lines are made out of series inductances L_g and L_d and capacities C_g and C_d , respectively, of the MESFET transistors. In this circuit configuration, the idle ports of the gate and drain lines are terminated by the particular impedance Z_0 , commonly equal to $50\ \Omega$.

The conventional single-stage distributed amplifier (CSSDA) consists of one section²⁻⁴ in which the gate and the drain line idle ports are open-circuits terminated, as shown in **Figure 1**. The structure is obtained from the dual-fed distributed amplifier⁵ in which the transducer power gain of this configuration can be improved up to 12 dB. This improvement is due to the fact that the volt-

age is doubled along the gate line and the recovered power will be absorbed by the loads at ports 2 and 3 within a conventional distributed amplifier structure. In this circuit, the gate line is not matched since it is open-circuited; this engenders a variable signal with frequency at the input of the transistor. The signal at the level of the load undergoes the same problem as the input signal. Unlike the CDA, the transducer power gain will oscillate within the bandwidth.

For the CSSDA amplifier, the $50\ \Omega$ matching condition of the gate and drain lines do not have meaning since both lines are open-circuited at one of their extremities. Thus, the matching constraint is raised, leading to more freedom on the choice or the determination of the gate and drain lines' characteristic impedances, according to the wanted objectives. These characteristic impedances highly influence the circuit bandwidth. The goal that has been fixed is to look for the values of these characteristic impedances that lead to the enhancement of the bandwidth as compared to the bandwidth



▲ Fig. 1 Single-stage distributed amplifier.

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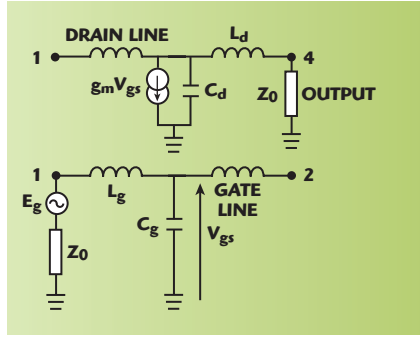
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of the usual cases (CDA and CSSDA amplifiers) where $50\ \Omega$ is attributed to these impedances. Consequently, these characteristic impedances will serve the role of design parameters. The objective of the present work is to obtain a bandwidth at least twice

as large as that obtained by CSSDA and greater than the bandwidth of the conventional distributed amplifier CDA. The amplifier with these performances has the abbreviated name of SSDA. To accomplish this, the frequency response (transducer gain) of the SSDA amplifier is approximated by a Chebyshev polynomial.⁵



▲ Fig. 2 Equivalent circuit of the distributed amplifier.

PROBLEM FORMULATION

To express the transducer power gain of the distributed amplifier, a simple unilateral MESFET model is considered, as shown in **Figure 2**. In this figure, C_g and C_d are the capacitor of the gate and the drain of the field effect transistor in common source configuration, respectively, and g_m is its transconductance. For this structure, the transducer power gain G_T is given by

$$G_T = \frac{\frac{1}{2} \operatorname{Re}(v_2 i_2^*)}{\frac{|E_g|^2}{8Z_0}} \quad (1)$$

where v_2 and i_2 are respectively the voltage and the current at the output while E_g is the internal voltage of the generator and * represents the complex conjugate. After some mathematical development the expression of the transducer power gain becomes:

$$G_T = \frac{4Z_0^2 g_m^2}{\left[(1 - 4x^2)^2 + \alpha_1^2 x^2 \right] \left[(1 - 4a^2 x^2)^2 + \alpha_2^2 a^2 x^2 \right]} \quad (2)$$

where $x = \frac{\omega}{\omega_{C1}}$ is the normalized frequency with respect to the cut-off frequency of the gate line $\omega_{C1} = \frac{2}{\sqrt{L_g C_g}}$ while the parameters $\alpha_1 = 2 \frac{Z_0}{Z_{C1}}$, $\alpha_2 = 2 \frac{Z_0}{Z_{C2}}$ and $a = \frac{\omega_{C1}}{\omega_{C2}}$.

With $z_{C1} = \sqrt{\frac{L_g}{C_g}}$, $z_{C2} = \sqrt{\frac{L_d}{C_d}}$, respectively, the characteristic impedances at relatively low frequencies, of the constant-k circuits constituting the gate and the drain lines, and $\omega_{C2} = \frac{2}{\sqrt{L_d C_d}}$.

At DC signals, $x = 0$, the transducer power gain of the SSDA given by Equation 1 is $G_T = 4Z_0^2 g_m^2$ and the power gain of a conventional distributed amplifier of N transistors (model without gate to source and drain to source resis-

tances) at zero frequency is given as: $G_p = 0.25Z_0^2 g_m^2 N^2$.¹ The gain G_p of the conventional distributed amplifier is equal to its transducer power gain since its input is matched. The comparison between G_T and G_p is valid and it shows that the SSDA amplifier has a gain equal to that of the CDA amplifier with 4 transistors (4CDA).

To approximate the transducer power gain using a Chebyshev polynomial, choose the smallest cut-off frequency among the two cut-off frequencies ω_{C1} and ω_{C2} as normalizing frequency (the frequency at which the gain starts decreasing). The choice of ω_{C1} as the normalizing frequency is justified by the fact that the capacitor C_g is always higher than C_d . If otherwise considered, that is ω_{C2} being the normalizing frequency, the gate line will start to decrease the gain at a frequency much less than ω_{C2} , whereas the polynomial approximation results in a constant gain until that frequency. In this case, the approximation is not possible.

Dividing the gain G_T by the quantity, $4Z_0^2 g_m^2$ the normalized gain is written by the following expression:

$$g_T = \frac{G_T}{4Z_0^2 g_m^2} = \frac{1}{\left[(1 - 4x^2)^2 + \alpha_1^2 x^2 \right] \left[(1 - 4a^2 x^2)^2 + \alpha_2^2 a^2 x^2 \right]} \quad (3)$$

Equation 3 contains dimensionless quantities, so it can be applied to any transistor and to any line; this in fact constitutes an important advantage. Expanding the denominator, the normalized gain of Equation 3 can be rewritten as:

$$g_T = \frac{1}{1 + A_2 x^2 + A_4 x^4 + A_6 x^6 + A_8 x^8} \quad (4)$$

where

$$\begin{aligned} A_2 &= a^2 (\alpha_2^2 - 8) + (\alpha_1^2 - 8) \\ A_4 &= 16a^4 + a^2 (\alpha_2^2 - 8)(\alpha_1^2 - 8) + 16 \\ A_6 &= 16a^4 (\alpha_2^2 - 8) + 16a^2 (\alpha_1^2 - 8) \\ A_8 &= 16a^2 a^4 \end{aligned} \quad (5)$$

The denominator of Equation 3 is written like $D = 1 + Q_n(x^2)$, an approximation by a polynomial of degree 8, which is the most appropriate.

To achieve the Chebyshev polynomial approximation, first the denominator of g_T is written under the form of

$$D = (1 - \epsilon_1^2) \left[1 + \epsilon^2 \left(1 + \frac{Q_n(x^2)}{\epsilon_1^2} \right) \right] \quad (6)$$

where $\epsilon = \sqrt{\frac{\epsilon_1^2}{1 - \epsilon_1^2}}$

represents the ripple ratio, and then the approximation is

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carried out by using the Chebyshev polynomial $T_n(x)$ of the terms between the brackets of the denominator D in the following manner:

$$1 + \epsilon^2 \left(1 + \frac{Q_n(x^2)}{\epsilon_1^2} \right) = 1 + \epsilon^2 T_n^2(x) \quad (7)$$

The adopted form of Equation 7 results from the fact that the frequency response (the transducer gain) of the SSDA amplifier is a low pass type. Consequently

$$T_n^2(x) = 1 + \frac{Q_n(x^2)}{\epsilon_1^2} \quad (8)$$

Equations 6 and 7 indicate that g_T can be greater than unity for certain frequencies within the bandwidth of the circuit. In fact, the normalized gain g_T may also be written under the form of:

$$g_T = \frac{1 + \epsilon^2}{1 + \epsilon^2 T_n^2(x)} \quad (9)$$

The variation of the transducer gain versus frequency, within the frequency bandwidth, is given as

$$\Delta G_T = 4Z_0^2 g_m^2 \epsilon^2 \quad (10)$$

and in decibel $(\Delta G_T)_{dB} = 10 \log(1 + \epsilon^2) = 1.3 \text{ dB}$, so constant regardless the values of Z_0 and g_m . Since $Q_n(x^2)$ is of degree 8, $T_n(x)$ must be of degree 4 and $T_n^2(x)$ of degree 8:⁶

$$T_n^2(x) = 64x^8 - 128x^6 + 80x^4 - 16x^2 + 1 \quad (11)$$

After identification, Equations 4 and 9 imply the following nonlinear system:

$$\begin{cases} A_8 = 64\epsilon_1^2 \\ A_6 = -128\epsilon_1^2 \\ A_4 = 80\epsilon_1^2 \\ A_2 = -16\epsilon_1^2 \end{cases} \quad (12)$$

where $A_i (i=2,4,6,8)$ are the coefficients given by Equation 5.

To design an SSDA amplifier, the system of Equation 12 should be first solved where the roots are α_1 , α_2 , α and ϵ_1 (or ϵ). The values taken by these roots are the same, regardless of the characteristics of the field effect transistor.

RESULTS AND DISCUSSION

The solution of system of Equation 12 gives the following:

$$\begin{aligned} \alpha_1 &= 2.38; \alpha_2 = 0.556; \\ a &= 0.509; \epsilon^2 = 0.37 \end{aligned} \quad (13)$$

These values are only valid for the SSDA amplifier; the following are found for the CSSDA amplifier

$$\alpha_1 = \alpha_2 = 2 \text{ and } a = 1 \quad (14)$$

With the values of Equation 13 and by taking $Z_0 = 50 \Omega$, the design parameters as a function of the gate capacitance C_g may be deduced as:

$$\begin{aligned} C_d &= 0.119 C_g; L_g = 1746 C_g; \\ L_d &= 3846 C_g \end{aligned} \quad (15)$$

The results given by Equations 13 and 15 are general and thus can be applied to any field effect transistor. It is sufficient only to know the value of C_g , the used transistor parameter, to proceed with the design of the amplifier.

The following remarks can be deduced from the obtained results:

- The field-effect transistors with a ratio $\frac{C_d}{C_g}$ less than 0.119 require the addition of a shunt capacitor to the drain. The added capacitor form, in combination with C_d , a new capacitor C'_d such that $\frac{C'_d}{C_g} = 0.119$. The shunt capacitor at the gate should be avoided since it leads to a reduction of the bandwidth.

The value of $Z_{C1} = \sqrt{\frac{L_g}{C_g}} = 42 \Omega$ is

always less than the gate and the drain lines' characteristic impedance ($Z_0 = 50 \Omega$) of the CDA amplifier. This implies an increase of the cut-off frequency of the SSDA amplifier by 19 percent as compared to that of the CDA amplifier. In fact, knowing that

$$\omega_{C1} = \frac{2}{Z_{C1} C_g} \text{ and } \omega_{C0} = \frac{2}{Z_0 C_g}, \quad \omega_{C0}$$

being the cut-off frequency of CDA, thus $\frac{\omega_{C1}}{\omega_{C0}} = \frac{Z_0}{Z_{C1}} = 1.19$. Moreover, this

deviation of 19 percent is calculated by comparing the cut-off frequencies which are not defined for the same value of the gains of the SSDA and CDA amplifiers. Indeed, ω_{C1} of

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	50 Hz - 3.0	Log Detector / Controller	74 ±3	19	-66	+3.3V @ 29mA	LP4	EAR99	HMC612LP4E
	0.001 - 8.0	Log Detector / Controller	70 ±3	-25	-61	+5V @ 113mA	LP4	EAR99	HMC602LP4E
	0.001 - 10.0	Log Detector / Controller	73 ±3	-25	-65	+5V @ 103mA	Chip	EAR99	HMC611
	0.001 - 10.0	Log Detector / Controller	70 ±3	-25	-65	+5V @ 106mA	LP4	EAR99	HMC611LP4E
	0.01 - 4.0	Log Detector / Controller	70 ±3	19	-68	+3.3V @ 30mA	LP4	EAR99	HMC601LP4E
	0.05 - 4.0	Log Detector / Controller	70 ±3	19	-69	+3.3V @ 29mA	LP4	EAR99	HMC600LP4E
	0.05 - 8.0	Log Detector / Controller	54 ±1	17.5	-55	+5V @ 17mA	LP3	EAR99	HMC713LP3E
	0.1 - 2.7	Log Detector / Controller	54 ±1	17.5	-52	+5V @ 17mA	MS8	EAR99	HMC713MS8E
	8 - 30	Log Detector	54 ±3	13.3	-55	+3.3V @ 88mA	LP3	EAR99	HMC662LP3E
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	0.6 - 20	SDLVA	59	14	-54	+3.3V @ 80mA	LC4B	EAR99	HMC913LC4B
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RWP05040-10	20~1000	45
RWP06040-10	450~880	45
RWP15020-10	1000~2000	43
RUP15020-11	500~2500	40
RUP15030-10	500~2500	44
RUP15050-10	500~2500	46
RWP15020-G1	1000~2000	43
RWP25020-G1	2000~3000	43
RWM03125-10	20~520	50.8
RWS05020-10	20~1000	43
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the SSDA amplifier is the frequency at which the power transducer gain starts to decrease, while that of the CDA amplifier is the value where no wave propagation exists. If the bandwidth is defined starting from DC until the frequency at which signal propagation turns off, the SSDA amplifier will yield a bandwidth larger than 19 percent with respect to that of the CDA amplifier.

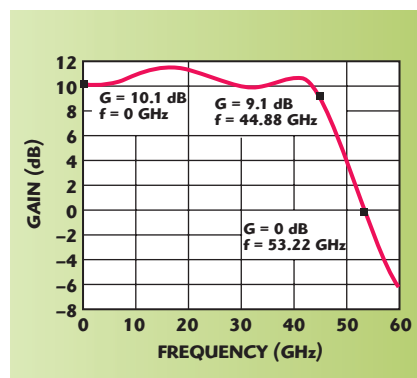
DESIGN AND SIMULATION

The results obtained by the current approach are compared to those obtained using Microwave Office software. To accomplish this, the three amplifiers SSDA, CSSDA and 4CDA are first designed using a MESFET transistor with $C_g = 0.17$ pF, $C_d = 0.006$ pF and $g_m = 32$ mS. The calculations suggest a shunt capacitor of $C = 0.014$ pF to be added to the transistor drain and yield the inductances $L_g = 300$ pH and $L_d = 653$ pH for the SSDA and $C = 0.164$ pF and $L_g = L_d = 425$ pH for the CSSDA.

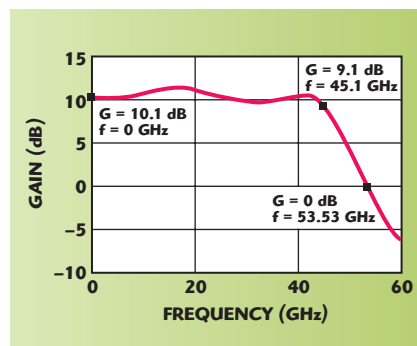
Figure 3 shows the simulated gain G_T obtained using the proposed approach and **Figure 4** shows the simulated gain using Microwave Office software of the SSDA amplifier. The curves are practically the same. These figures point out the accuracy of the proposed approach. The maximum variation in dB of G_T , picked up from the curves, is the same and is equal to approximately 1.3 dB, which proves the theoretical results obtained previously.

Replacing the parameters in Equation 3 by their values given by the Equations 13 and 14 and using the expression of the power gain of the CDA amplifier,¹ the normalized power gain is calculated as a function of the normalized frequency for the three amplifiers SSDA, CSSDA and 4CDA. The obtained calculated gains are shown in **Figure 5**. The principal characteristic is that these curves are universal. It should be remarked that the SSDA amplifier, whose gain is approximated by a Chebyshev polynomial, offers a bandwidth twice as large as the CSSDA amplifier and at the same time larger than the 4CDA amplifier. Here, the bandwidth is defined as a band of frequencies in which the gain is constant or with small variations. The

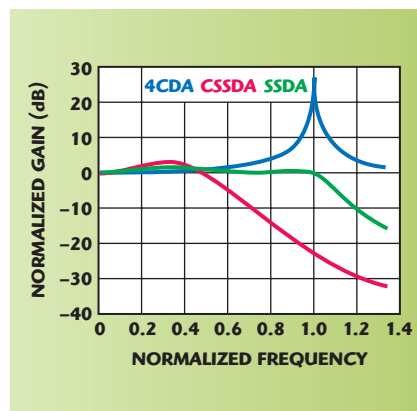
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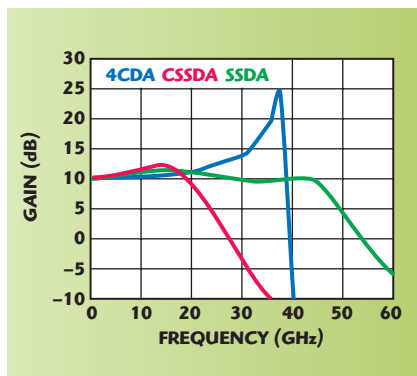
▲ Fig. 3 SSDA amplifier gain approximated by a Chebyshev polynomial.



▲ Fig. 4 SSDA amplifier gain simulated by Microwave Office software.



▲ Fig. 5 Normalized power gains of the 4CDA, CSSDA and SSDA amplifiers.



▲ Fig. 6 Power gains of the 4CDA, CSSDA and SSDA amplifiers simulated with Microwave Office software.

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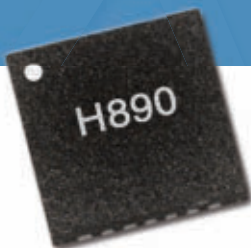
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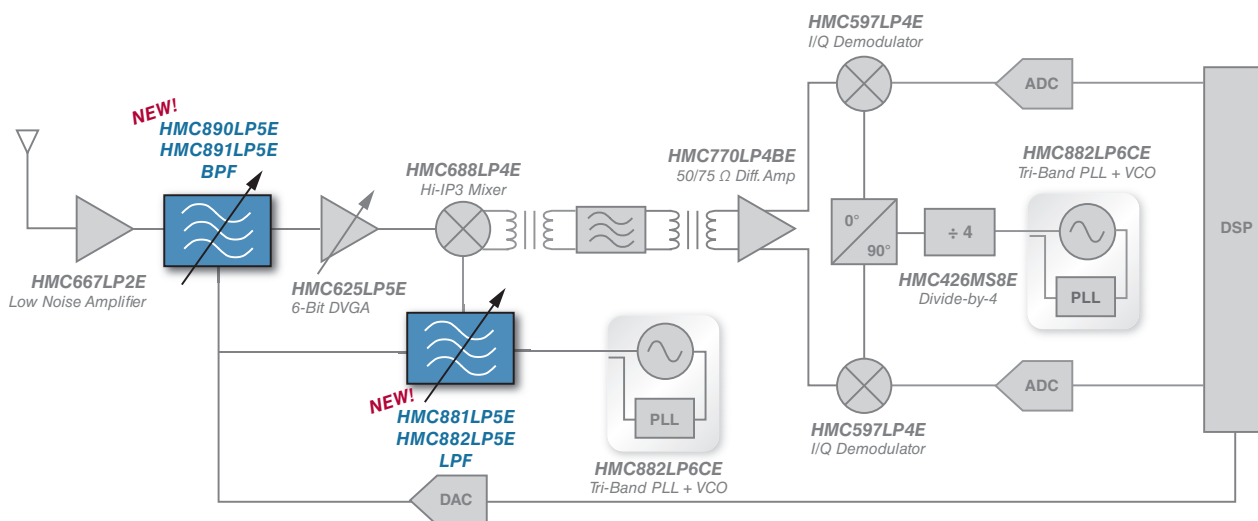
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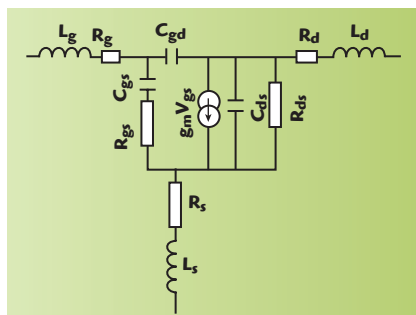
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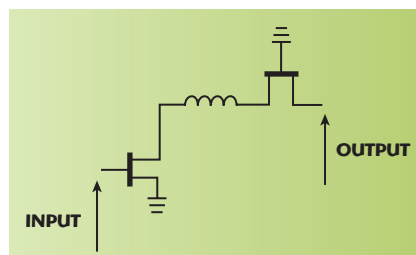
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shape of the normalized gain curve of the 4CDA amplifier is the same as the one obtained by Moazzam and Aitchison.^{2,3}

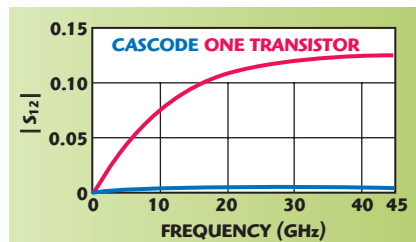
The curves of the power gains of the three amplifiers (SSDA, CSSDA



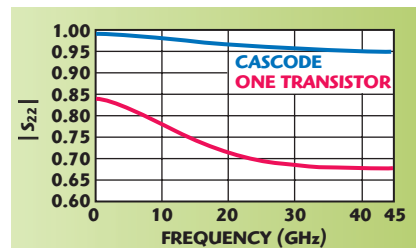
▲ Fig. 7 Real model of the transistor.



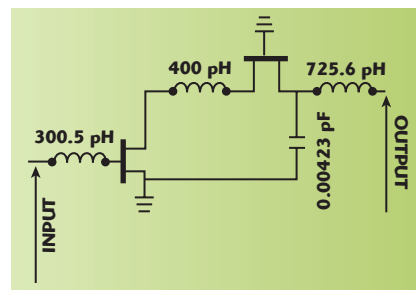
▲ Fig. 8 Cascode circuit.



▲ Fig. 9 Comparison of S_{12} for one transistor and a cascode circuit.



▲ Fig. 10 Comparison of S_{22} for one transistor and a cascode circuit.



▲ Fig. 11 Diagram of the SSDA using a cascode circuit.

TECHNICAL FEATURE

and 4CDA) shown in **Figure 6** are obtained by simulation using Microwave Office software. It is clear from this figure that if the bandwidth is defined from DC until the frequency for which the amplification ceases (gain = 0 dB), the bandwidth of the SSDA:

- Is larger than that of the 4CDA by 14.69 GHz (53.53 to 38.84 GHz). This corresponds to an increase of 39 percent, larger by 19 percent as already stated in the previous conclusion;
- Is larger than that of the CSSDA by 26.63 GHz (53.53 to 26.9 GHz). This corresponds to an increase of 98.9 percent;

The three amplifiers have the same gain in the bandwidth, which is 10.1 dB.

MEASUREMENT RESULTS

The study was done on a transistor assumed, in the bandwidth considered, unilateral and with almost an infinite capacitive output impedance value. While a real transistor does not correspond to this (see **Figure 7**), the circuit, which best answers the model chosen by the transistor in this study, is the cascode, in which an inductance is added between both transistors to reduce, at high frequencies, the effects of the input and the output capacity of the first and the second transistors (see **Figure 8**). Indeed, the curves of **Figures 9** and **10** show that, contrary to the circuit with a single transistor, the cascode is practically a unilateral circuit presenting almost an infinite output impedance. The diagram of the SSDA using a cascode circuit is shown in **Figure 11**. **Figure 12** shows the respective simulated gains of the SSDA, 4CDA and the SSDA using the cascode circuit, a real improvement of the bandwidth of the cascode compared to the other circuits.

A comparison between the results obtained by simulation and measurements of the cascode circuit is summarized in **Figure 13**. The circuit was biased at 5 V drain-to-source voltage and a total drain current of 95 mA. A gain of 10.1 ± 1 dB has been achieved over the 1 to 32 GHz frequency range. A photograph of the fabricated amplifier is shown in **Figure 14**.

CONCLUSION

The proposed approach can be applicable to any MESFET transistor. The design parameters can be

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NEW! 0.01 - 20	Portable Signal Generator	0.01	+27 @ 2 GHz +25 @ 10 GHz	-113 @ 1 GHz -93 @ 10 GHz	-80	300	Portable / Benchtop	HMC-T2100B
0.7 - 8.0	Signal Generator	1	+17 @ 2 GHz +15 @ 4 GHz	-78 @ 1 GHz -87 @ 4 GHz	-57	<200	Benchtop / Rack Mountable	HMC-T2000

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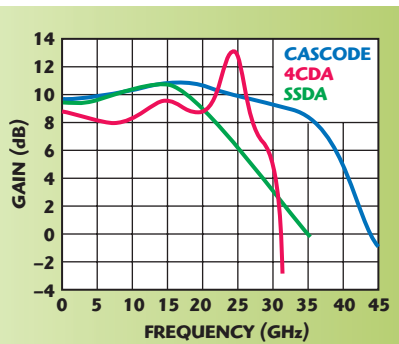
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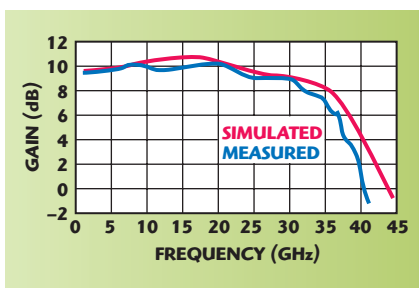
Model	Frequency	@P1dB (min)
A080M102-5252R	80-1000MHz	150W
A080M102-5757R	80-1000MHz	500W
A080M102-6060R	80-1000MHz	1kW
DBA080M102-5252R	80-1000MHz	150W
DBA080M102-5757R	80-1000MHz	500W
DBA080M102-6060R	80-1000MHz	1kW
GA801M302-4444R	800-3000MHz	20W
GA801M302-4747R	800-3000MHz	40W
GA801M302-4949R	800-3000MHz	60W
GA801M302-5151R	800-3000MHz	100W
GA801M302-5353R	800-3000MHz	150W
GA801M302-5656R	800-3000MHz	300W
GA801M302-5858R	800-3000MHz	500W
GA252M602-4040R	2500-6000MHz	10W
GA252M602-4343R	2500-6000MHz	20W
GA252M602-4747R	2500-6000MHz	40W
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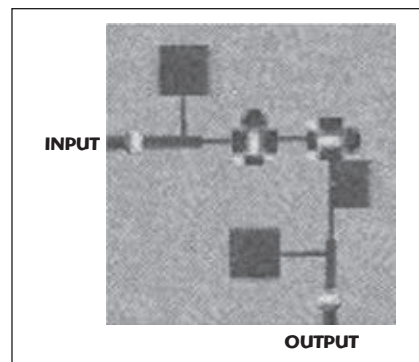
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▲ Fig. 12 Simulated gains of the 4CDA, SSDA and the SSDA using a cascode circuit.



▲ Fig. 13 Comparison of the simulated and measured gains of the cascode circuit.



▲ Fig. 14 Photograph of the fabricated amplifier.

determined in a very simple manner since it is only sufficient to know the gate capacitance of the transistor. This approach allows significant improvement of the bandwidth of the SSDA amplifier as compared to the bandwidth of the 4CDA and CSSDA amplifiers, without any deterioration of the gain, which very often happens in the case of the conventional amplifiers. ■

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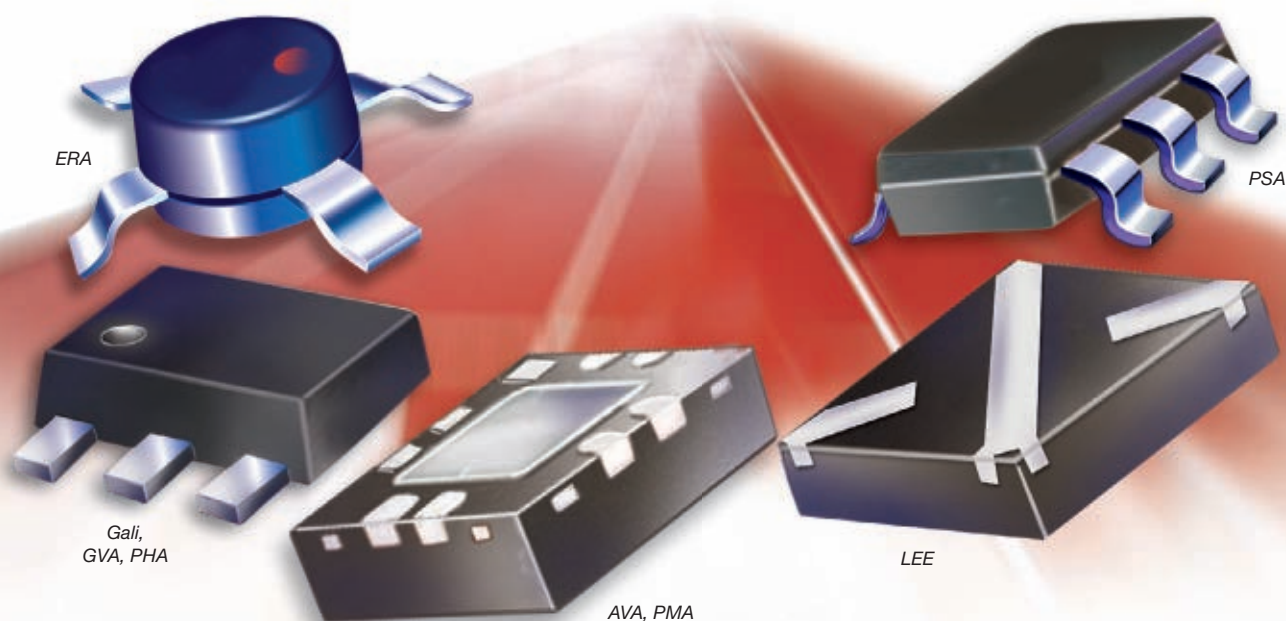
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A DUAL-BAND CPW-FED MONOPOLE ANTENNA FOR IMT-2000/WLAN

A novel and simple dual-band design of a coplanar waveguide (CPW)-fed monopole antenna is proposed. By adding lateral patches to the sides of a pentagonal monopole, multi-resonant modes with two separate broad operating bands can be generated for wireless applications. The electromagnetic performance of the proposed antenna has been examined. The measured results show good dual-band operation with 10 dB impedance bandwidths of 14 and 45 percent at bands centered at 2.1 and 6.7 GHz, respectively, which cover the international mobile telecommunication (IMT)-2000 and 5.2/5.8 GHz wireless local-area networking (WLAN) operating bands. The results also show good monopole-like radiation patterns and antenna gains over the operating bands.

Over the past decade, extensive research on broad dual- or multi-band antennas, with low-profile, lightweight, flush mounted and single-feed to fit the limited equipment space of portable wireless devices, has contributed to the development of modern communication technology. In the past, a whole host of dual- or multi-band planar antennas fed by either a microstrip line or a probe have been developed for various communication-related applications. These antenna designs include planar inverted-F antennas (PIFA),^{1,2} a microstrip-fed antenna³ and planar monopole antennas.^{4,5} However, a new coplanar waveguide structure, used to design a dual- or multi-band planar antenna, has recently received much attention due to its potential in providing various required radiation features, good impedance matching, dual- or multi-band operation, easy integration with system circuits, omnidirectional radiation pattern, etc.⁶⁻⁸

In this article, a dual-band monopole antenna, with both a simple structure and simultaneous wide operating bands, is proposed and

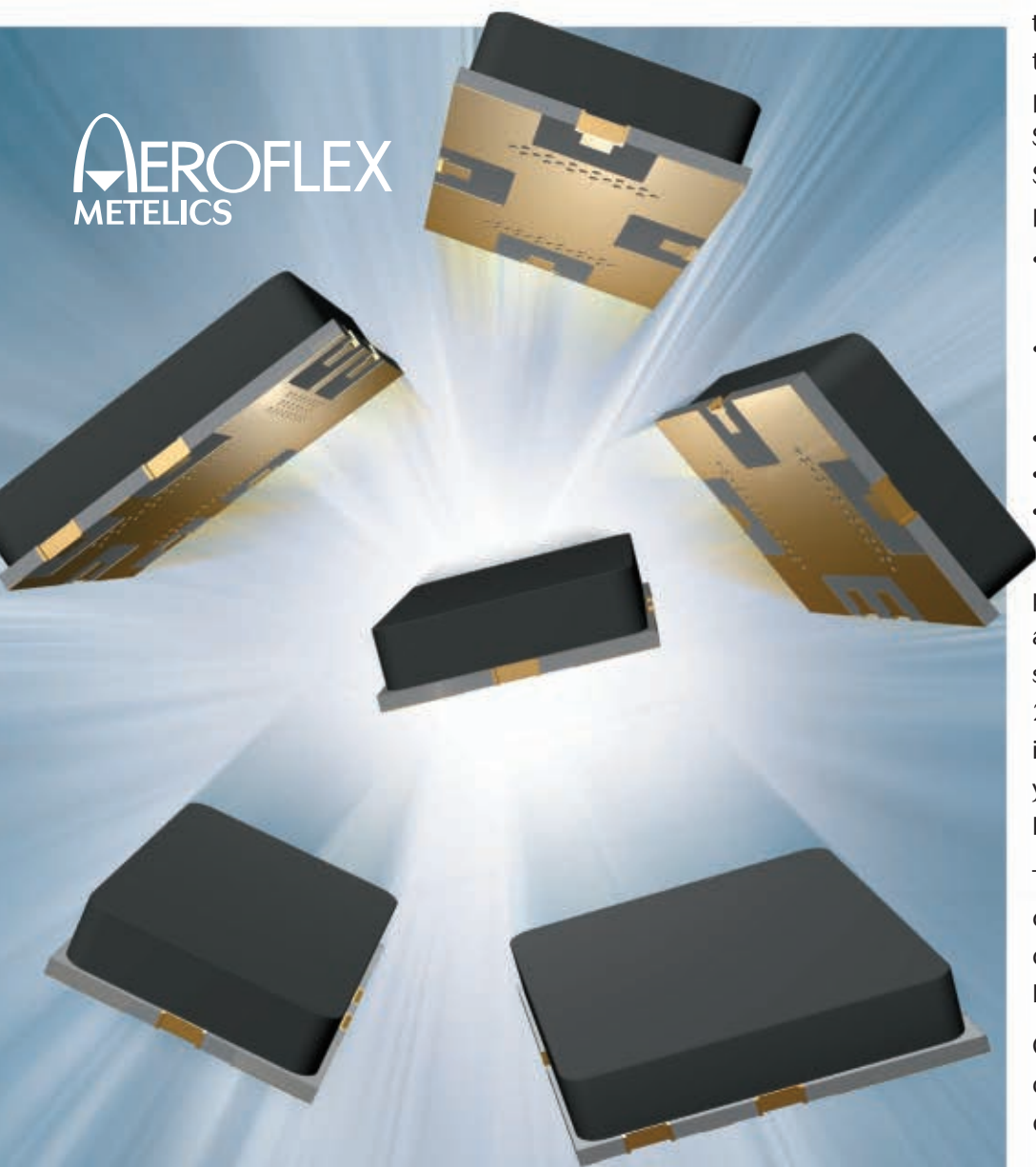
investigated, which is suitable for the international mobile telecommunication (IMT)-2000 and wireless local-area networking (WLAN) communication systems. The proposed antenna is fed by a CPW structure and has a simple uni-planar geometry. The dual-band characteristic is achieved by adding lateral patches to the pentagonal radiating monopole. In addition to the details of the antenna design, the dual-band impedance matching, the radiation patterns and gains are also presented and discussed.

ANTENNA CONFIGURATION AND DESIGN

The geometrical configuration of the proposed lateral pentagonal CPW-fed monopole antenna for dual-band operation is depicted in **Figure 1**, with dimensions in millimeters. The

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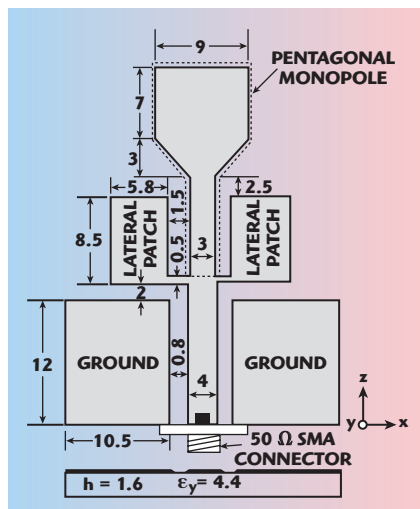
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MSW2051-205	SP2T T-R Switch	400-4000	0.25	1.3:1	40	+ 52
MSW2030-203	Symmetrical SP2T	50-1000	0.3	1.2:1	50	+ 51
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MSW3000-310	Symmetrical SP3T	50-1000	0.4	1.2:1	50	+ 51
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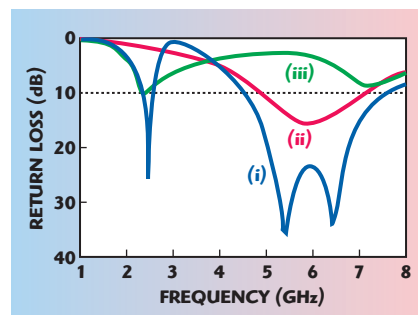
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▲ Fig. 1 The proposed lateral pentagonal CPW-fed monopole antenna.

antenna, including the ground plane, is printed symmetrically with respect to the longitudinal direction (z-axis) on only one side of an FR4 dielectric substrate (thickness = 1.6 mm and relative permittivity = 4.4); the other side is without any metallization. The basis of the antenna structure is a pen-

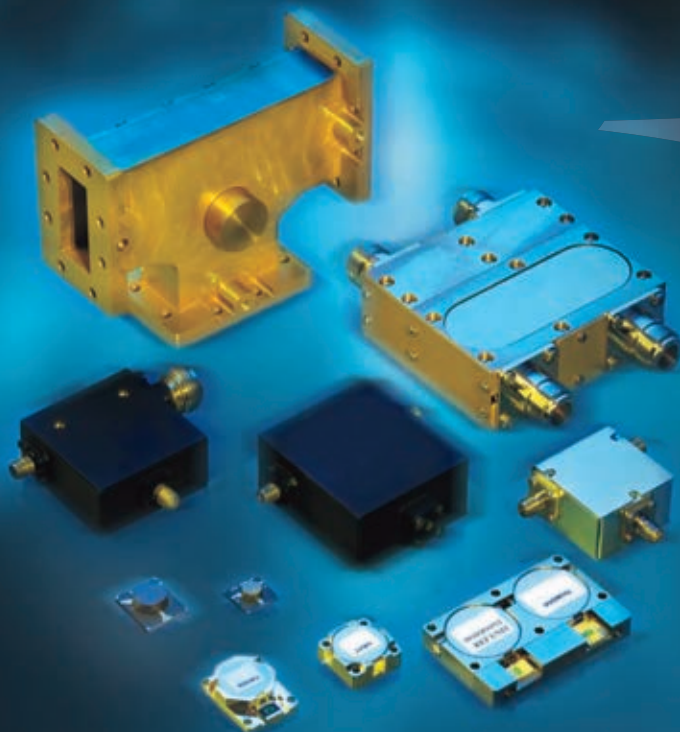
tagonal radiating patch, which has the selected dimensions of 9×10 mm and is cut with a triangle notch of 3×3 mm at each of its two lower corners. The feed is a CPW structure with two sections for the central feeding strip. The top end of the upper section with length = 10.5 mm and width = 3 mm is connected to the pentagonal patch, while each side of the lower section with dimensions of 14.5×4 mm has a spacing of 0.8 mm away from a rectangular ground of height = 12 mm and width = 10.5 mm. In this design, to obtain good dual-band operation, a rectangular patch of length = 8.5 mm and width = 5.8 mm is added on each side of the top end of the feed strip as a lateral element. The spacing between the lateral patch and the central feed strip is chosen to be 1.5 mm; the width of the thin strip used to connect this patch and the feed strip is 0.5 mm. These antenna dimensions were obtained from theoretical analysis using the IE3D™ simulation software to achieve dual-band operation in the 2.45 and 5 GHz WLAN bands.



▲ Fig. 2 Simulated return loss of the proposed antenna.

Figure 2 shows the simulated frequency responses of the return loss for the proposed antenna (denoted as curve (i)), of the proposed antenna without the central pentagonal monopole (denoted as curve (ii)) or without the two lateral patches (curve (iii)). Obviously, for the proposed antenna, three resonant modes are excited at 2.45, 5.4 and 6.4 GHz. The two higher modes are close and thus form a broad operating band. The two wide separate operating bands have been obtained, with 10 dB impedance bandwidths of 250 MHz (2.32 to

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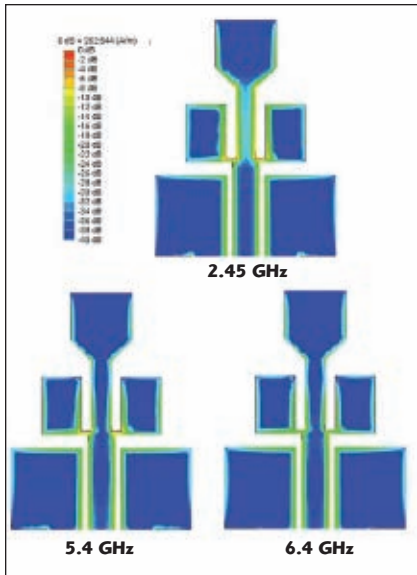
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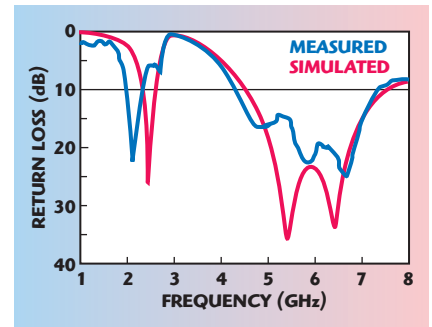


▲ Fig. 3 Simulated surface current distribution for the proposed antenna.

2.57 GHz) and 3.04 GHz (4.52 to 7.56 GHz) at 2.45 and 5.4 GHz, respectively. However, for the case without the central pentagonal monopole, the lower resonant mode band vanishes; only the higher resonant mode at ap-

proximately 5 GHz exists. As for the case without the two lateral patches, though it seems that there exists two resonant modes at the lower (2.3 GHz) and upper (7 GHz) bands, the impedance matching is very poor. These results clearly show that the pentagonal monopole principally controls the lower resonant mode, while the added two lateral patches significantly affect the higher frequency modes as well as improve the impedance matching condition to thus enhance the bandwidths.

Further, the excited surface current distributions on the radiating patch, obtained from the IE3D simulator for the proposed antenna at the resonant frequencies of 2.45, 5.4 and 6.4 GHz, respectively, are also studied and presented in **Figure 3**. It can be seen that when operating at the lower frequency (2.45 GHz), a large current density is observed along the monopole path, whereas for the upper excitations at 5.4 and 6.4 GHz, the current distributions, as expected, become both more concentrated on the lateral patches. These phenomena are con-

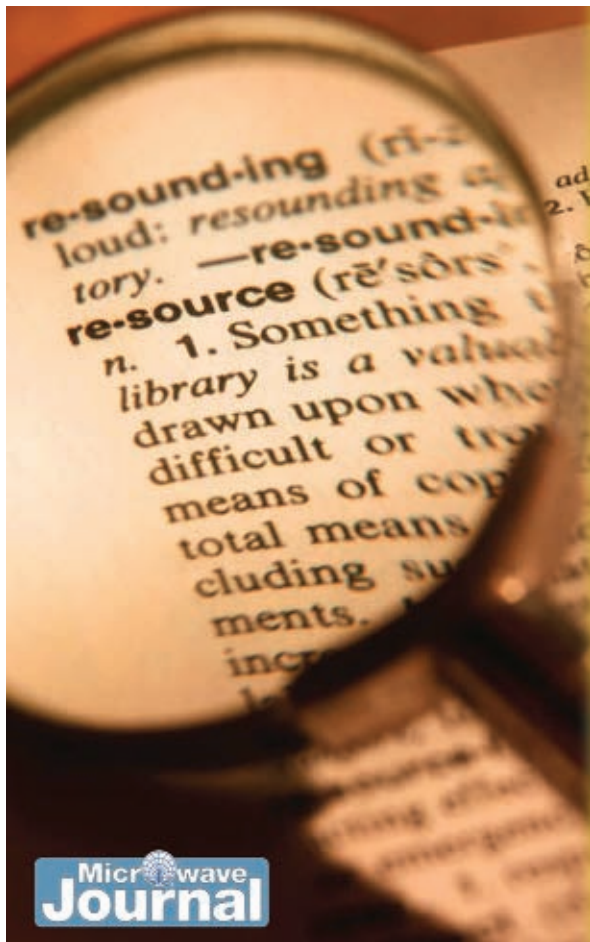


▲ Fig. 4 Measured and simulated return loss vs. frequency of the proposed antenna.

sistent with the predictions obtained from the analysis of the return loss.

EXPERIMENTAL RESULTS AND DISCUSSION

Based on the design parameters illustrated, a prototype of the proposed antenna, suitable for dual-band operation, was fabricated and its impedance matching and radiation characteristics were measured. **Figure 4** shows the return loss of the proposed antenna. As can be seen from the figure, three dominant resonant modes were excited at frequencies of 2.1, 5.8 and 6.7



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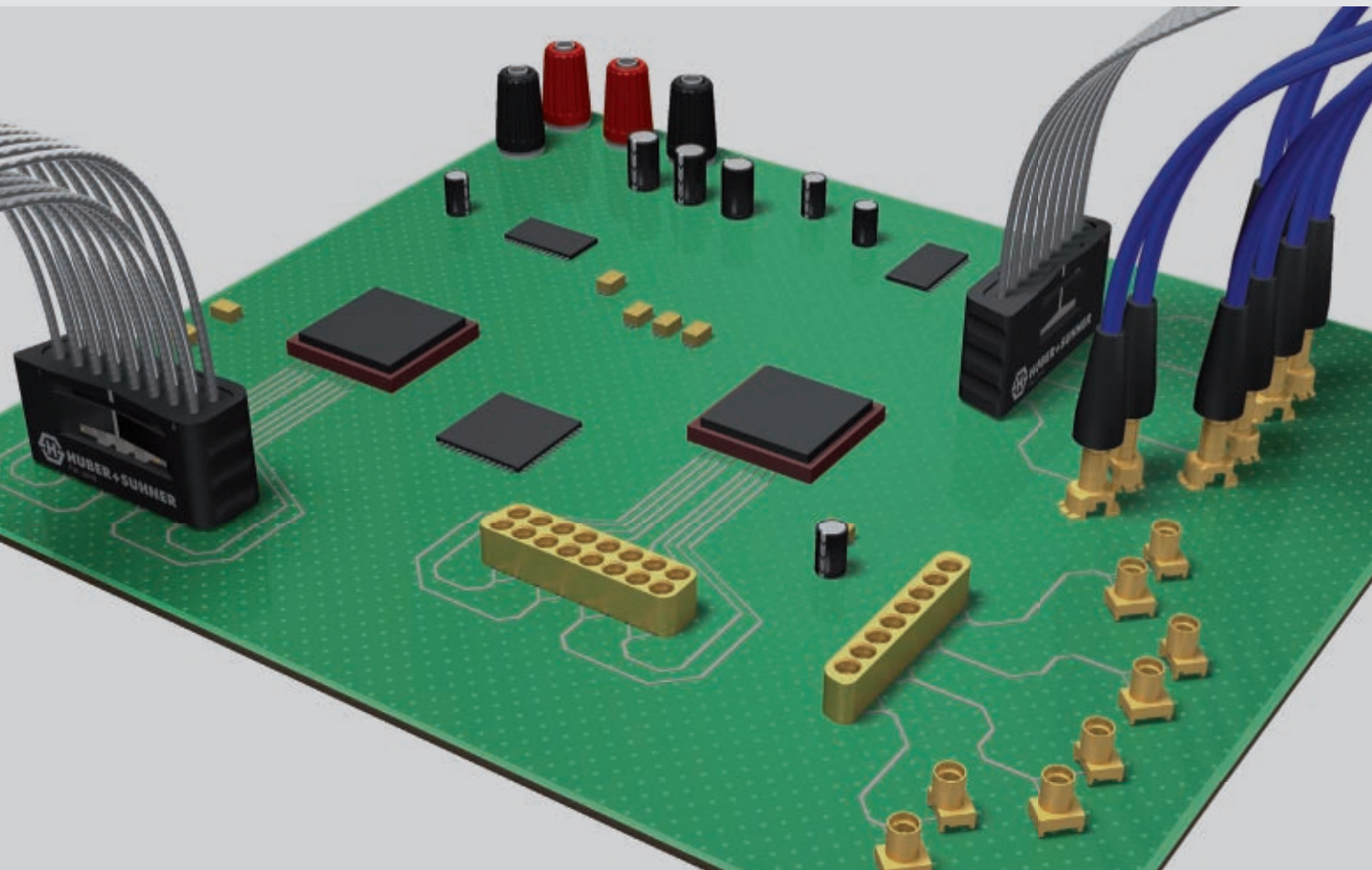
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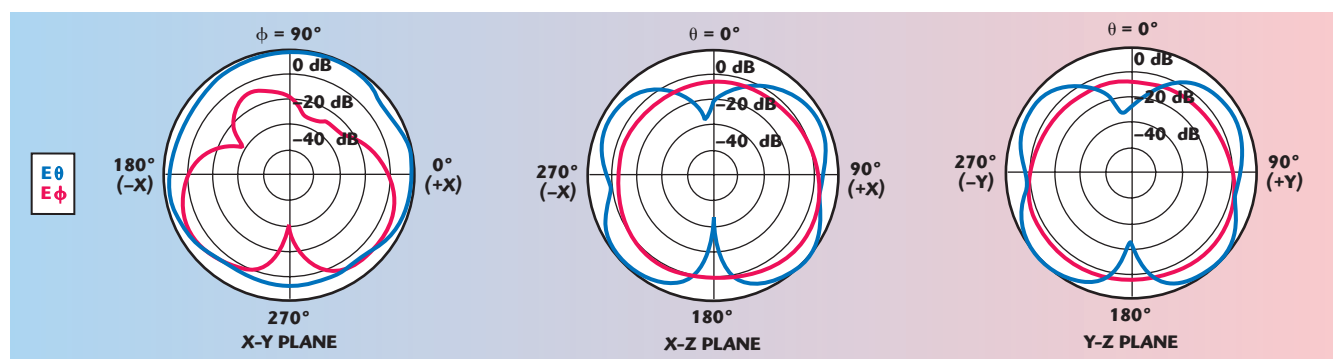
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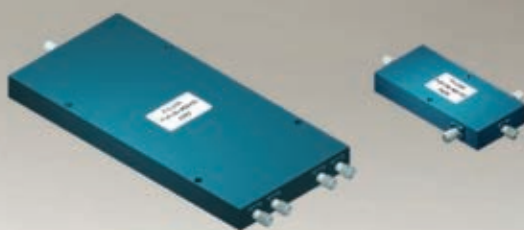


▲ Fig. 5 Measured far-field radiation patterns at 2.1 GHz.

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3	2.0-20.0	1.8	16	0.5 dB	PS3-51
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4	0.5-18.0	4.0	16	0.5 dB	PS4-17
4	2.0-18.0	1.8	17	0.5 dB	PS4-19
4	15.0-40.0	2.0	12	0.8 dB	PS4-52
8	0.5-8.0	1.5	20	0.4 dB	PS8-12
8	0.5-18.0	6.5	16	1.2 dB	PS8-16
8	2.0-18.0	2.2	15	0.6 dB	PS8-13
8	3.0-15.0	1.3	15	0.5 dB	PS8-15

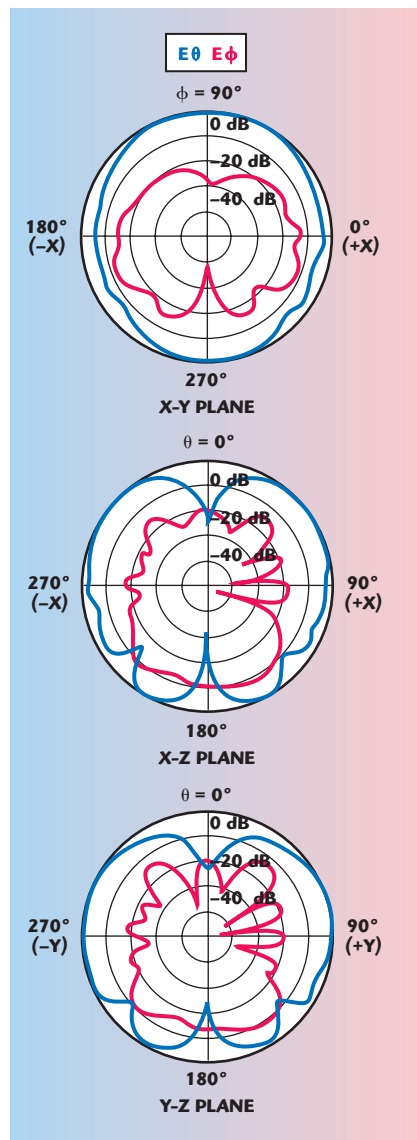
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▲ Fig. 6 Measured far-field radiation patterns at 5.8 GHz.

GHz, with good impedance matching.

Similar to what was shown in simulation, the latter two resonances are very close to produce a continuous wide impedance bandwidth. The impedance bandwidths obtained, defined by a 10 dB return loss, are 290

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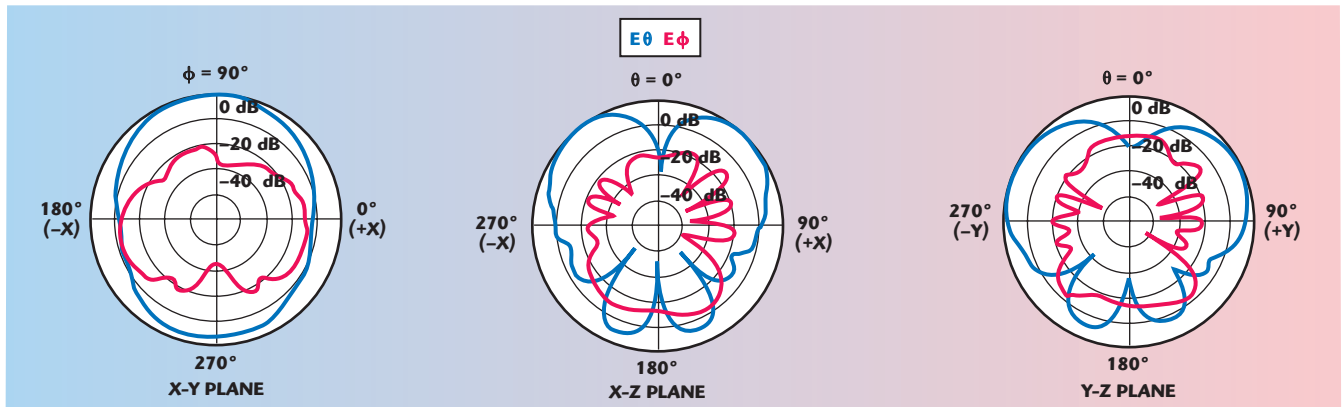
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▲ Fig. 7 Measured far-field radiation pattern at 6.7 GHz.

MHz (1.95 to 2.24 GHz) and 3.02 GHz (4.32 to 7.34 GHz), corresponding to an impedance bandwidth of 14 percent and 45 percent with respect to the appropriate resonant frequencies of 2.1 and 6.7 GHz. Obviously, the two bandwidths achieved provide sufficient bandwidths for the IMT-2000 (2.11 to 2.2 GHz) and the WLAN standard in the 5.2 GHz (5.15 to 5.35 GHz) and 5.8 GHz (5.725 to 5.825 GHz) bands. Also note that the measured results generally agree with those obtained from simulation, allowing for some frequency discrepancies at the resonant frequencies. The largest error occurs in the location of the lowest resonant frequency. This difference is probably caused by fabrication tolerances, because of the uncertainty in the thickness and/or the dielectric constant of the substrate.

The typical radiation characteristics, including the radiation pattern and the antenna gain of the proposed antenna, have also been investigated. **Figures 5 to 7** show the measured radiation patterns of the co-polarized field (E_θ) and cross-polarized field (E_ϕ) in the azimuth (x-y) plane and the elevation (x-z and y-z) planes, for the antenna operating at the three main resonant frequencies of 2.1, 5.8 and 6.7 GHz, respectively. The patterns are very similar for all these frequencies. In the azimuth plane, the patterns are nearly all omnidirectional, and those in the elevation plane, as expected, are all very similar to a monopole. Finally, the measured peak antenna gains for operating frequencies across the dual bands are shown in **Figure 8**. The measured average gains are 2.1 dBi (1.1 to 2.6 dBi) and



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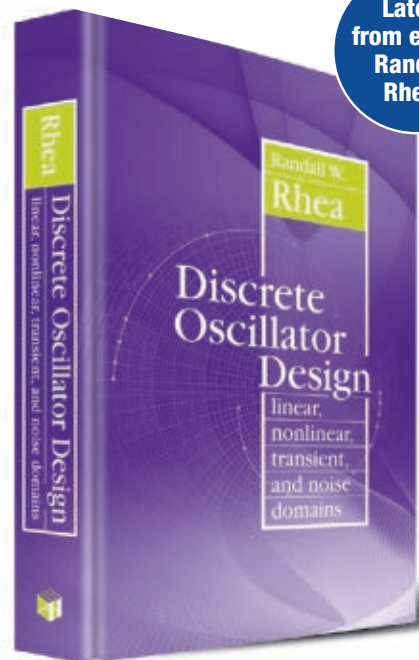
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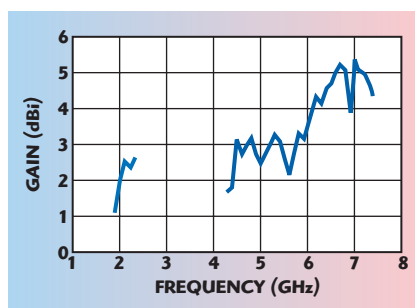
TECHNICAL FEATURE

3.5 dBi (1.7 to 5.2 dBi), respectively, within the bandwidths of the lower and upper operating bands.

CONCLUSION

A dual-band CPW-fed planar pentagonal monopole antenna with lateral patches has been designed,

built and measured. The proposed antenna effectively produces a dual broad bandwidth, a stable monopole-like radiation pattern, and a sufficiently high gain, to make itself robust and suitable for application in a dual-band wireless communication system. ■



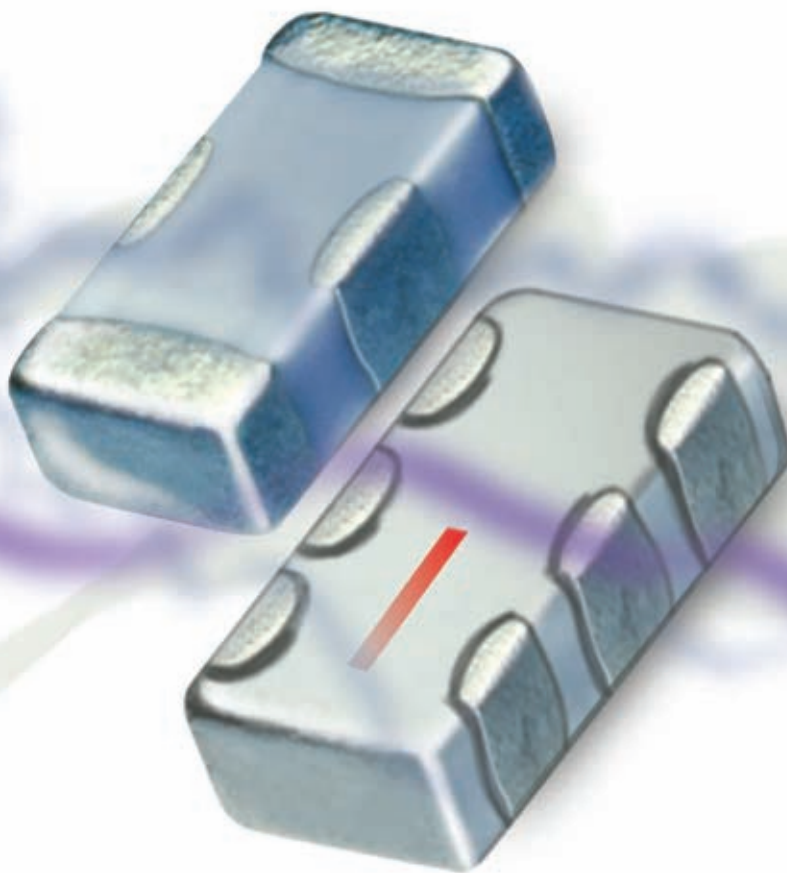
▲ Fig. 8 Measured antenna gain of the proposed antenna.

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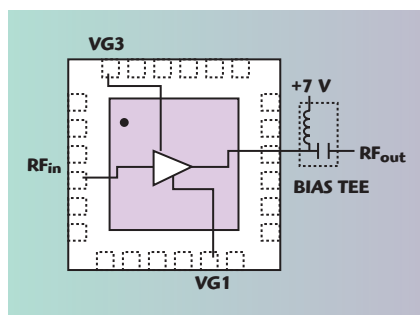
NEW ULTRA BROADBAND QFN PACKAGED AMPLIFIER

Mimix Broadband's XD1008-QH is a packaged broadband PHEMT distributed amplifier designed for medium power output over the 500 MHz to 32 GHz frequency range. It features gain slope adjustment, wide dynamic range gain control, $50\ \Omega$ match on the input and output ports, and robust protection against ESD damage. The product is packaged in an industry standard 4×4 mm QFN, allowing the use of standard SMD production lines for installation.

Distributed amplifier products historically address two principal markets: microwave instrumentation and defense, although communication systems have recently taken an interest in broader band performance of driver and power amplifiers. This is mainly due to the need to cover multiple octaves with broadband linear performance. The XD1008-QH has the benefit of being able to source a single device usable over the entire operating bandwidth of a com-

munication system that must accommodate multiple services. Military systems, including C4I, surveillance, EW and ECM commonly cover frequencies from HF to millimeter wavelengths. Microwave test equipment is typically designed to make measurements contiguously from near-DC through millimeter wavelengths. The XD1008-QH provides this broadband performance in a single QFN plastic package with high output power and linearity.

The internal design of the XD1008-QH consists of nine stages of cascade connected PHEMT devices that ensure flat gain and return losses. The RF I/O ports are DC coupled. The external bias-T is a key component of the application of this packaged device (see **Figure 1**). External input and output coupling caps must present a low, resonant-free impedance across the desired RF bandwidth. At the lowest frequency, X_C should be small compared to $50\ \Omega$. At the high end of the application band, these large external capacitors and their in-



▲ Fig. 1 XD1008-QH connection diagram.

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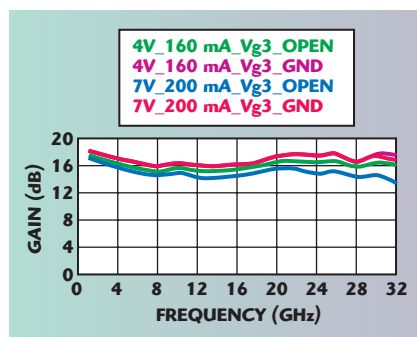


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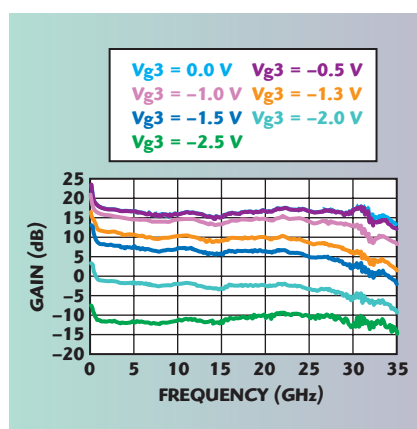


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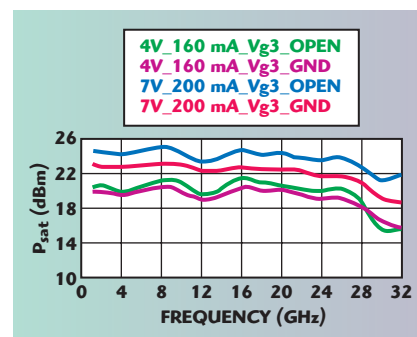
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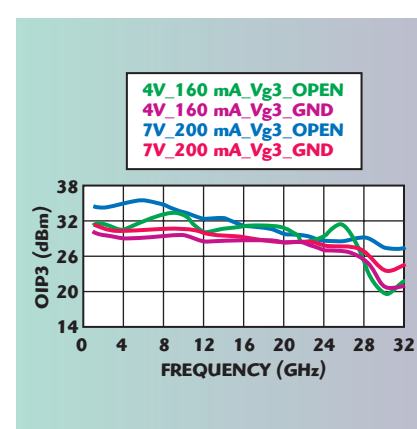
▲ Fig. 2 XD1008-QH gain vs. frequency.



▲ Fig. 3 XD1008-QH gain control.



▲ Fig. 4 XD1008-QH typical Psat performance.



▲ Fig. 5 XD1008-QH typical OIP3 performance.

herent parasitics may produce series and parallel resonances. Specialized broadband caps are necessary and are available from multiple vendors. The design of the choking inductor depends greatly on the use of SMT vs. printed components, and careful selection and design is needed to maximize performance.

Figure 2 shows the gain of this device through 32 GHz at four bias settings. A typical gain of 16 to 17 dB is achieved from 500 MHz to beyond 32 GHz. The bias can be tailored to best suit the application and its average gain, gain flatness and gain slope requirements.

The XD1008-QH not only has a gain slope control feature, it also has an adjustable gain control feature that allows over 25 dB of dynamic range. The gain control feature enhances the versatility of applications where variable gain over a wide bandwidth is necessary. **Figure 3** demonstrates this feature by charting the gain for a range of gate voltages from 0 to 2.5 V.

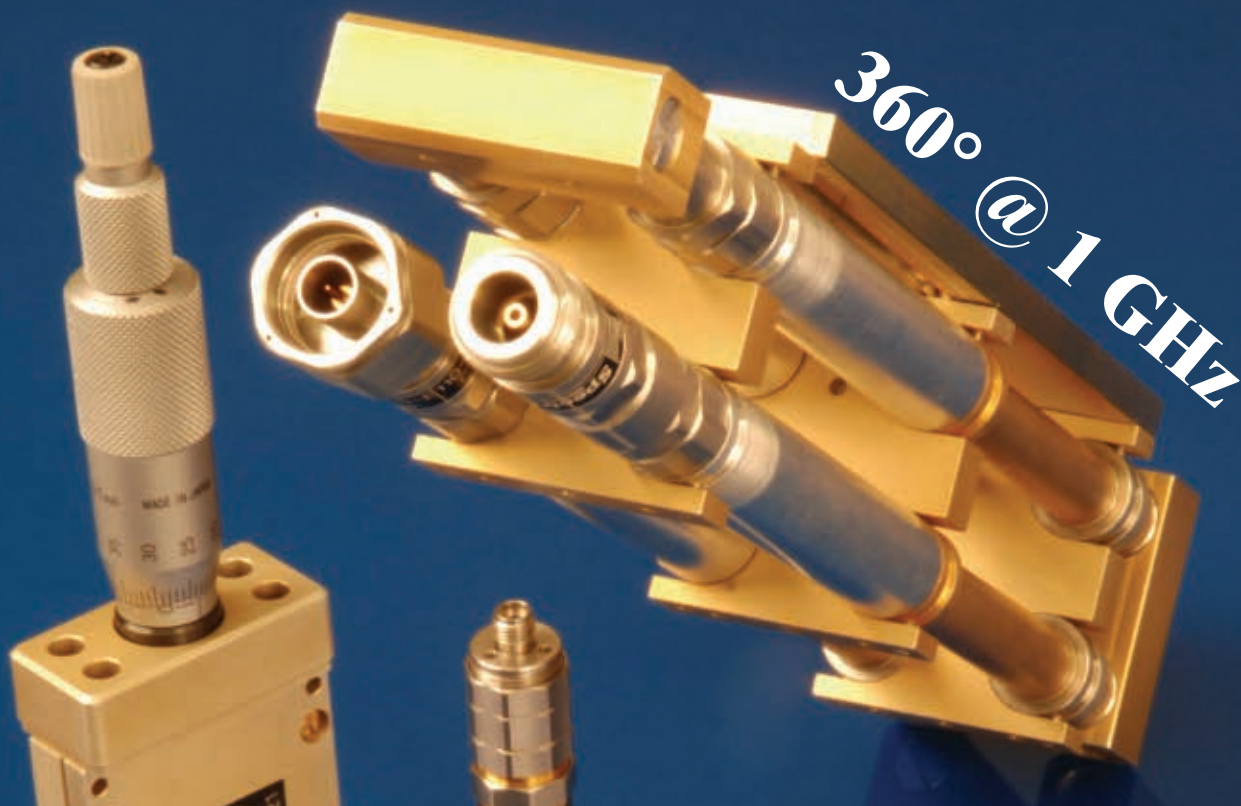
Delivering efficient saturated and linear power is also a requirement in

many instrumentation and military applications. The XD1008-QH offers competitive power performance, with a typical saturated power of 24 dBm over a bandwidth extending as low as 500 MHz through 26.5 GHz. Over this same range, if linear performance is required, the XD1008-QH can be biased to achieve a minimum of 29 dBm OIP3. **Figures 4** and **5** show typical Psat and OIP3 performance up to 32 GHz, respectively.

In conclusion, to address today's microwave instrumentation and defense requirements, in addition to general wideband communications needs for broadband amplifiers in a convenient package, the XD1008-QH is a solution that allows for standard surface-mount assembly and meets the needs of many of these applications.

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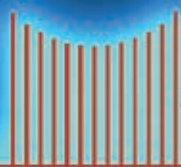
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NEW HIGH FREQUENCY PCB MATERIALS FOR THE POWER AMPLIFIER INDUSTRY



It is obvious that the selection of the transistor for a power amplifier circuit is critical. However, it is often less obvious how the properties of the printed circuit board (PCB) can impact overall performance. The materials used to make the PCB can have an influence on a power amplifier's stability, gain and possible maximum output power.

With the trend to more compact designs, a PCB material with a higher Dk (dielectric constant, relative permittivity, ϵ_r) can help to enable this technology. Some of these materials have been on the market for several years now, all of which have trade-offs between electrical performance and other issues. Rogers Corp. recently released a laminate with the proven performance of the RO4000® product family, which is formulated specifically for the demands of new power amplifier applications. The product is the RO4360™ laminate.

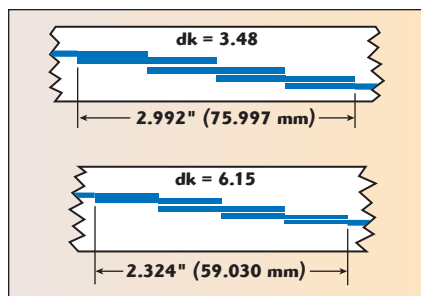
The RO4360 substrate has a Dk of 6.15 and a Df (dissipation factor, loss tangent, $\tan \delta$) of 0.003 when tested at 2.5 GHz. Other substrates

RO4000 products have been proven to be easy for circuit fabrication and have demonstrated high plated thru-hole reliability.

The higher Dk offers the circuit designer the ability to reduce the size of the circuit. An example of how much a microstrip bandpass filter segment of a PCB can be reduced is shown in **Figure 1**. In order to maintain a 50 Ω transmission line, the conductor width needs to be reduced. With a reduced conductor width, some concern may be related to thermal management. However, this is offset by the thermal conductivity of the RO4360 material, which is 25 percent higher than the proven legacy RO4350B™ laminate. Considering that PCB power handling capability is usually a function of the conductor width, ground plane spacing and the Df of the material, the low Df of the RO4360 laminate is also advantageous. The low loss also ensures maximum gain from the amplifier design. An insertion loss graph is shown in **Figure 2** for a 20 mil thick laminate and tested as a microstrip transmission line.

Another material property associated with temperature change is the coefficient of thermal expansion (CTE). The RO4360 laminate has a CTE that is very closely matched to copper in the x-y plane, which is about 16 ppm/°C. This is very important for several reasons. During the assembly stage of the process, having the PCB substrate expand the same amount as the copper will develop much

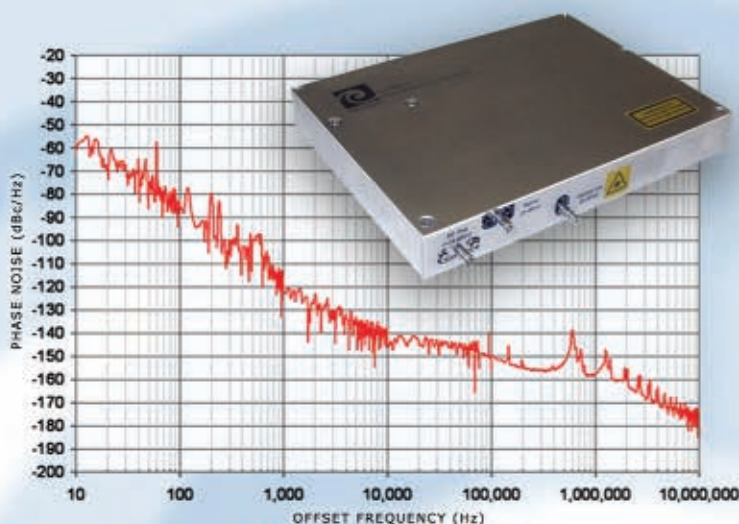
on the market with this higher Dk prior to the release of this product were primarily polytetrafluoroethylene (PTFE)-based. PTFE materials offer good electrical performance; however, there can be issues with PCB fabrication and plated thru-hole reliability. In addition, the overall cost of PTFE circuit fabrication is typically higher than a thermoset substrate. The



▲ Fig. 1 2.4 GHz microstrip edge coupled bandpass filter size reduction of 29%.

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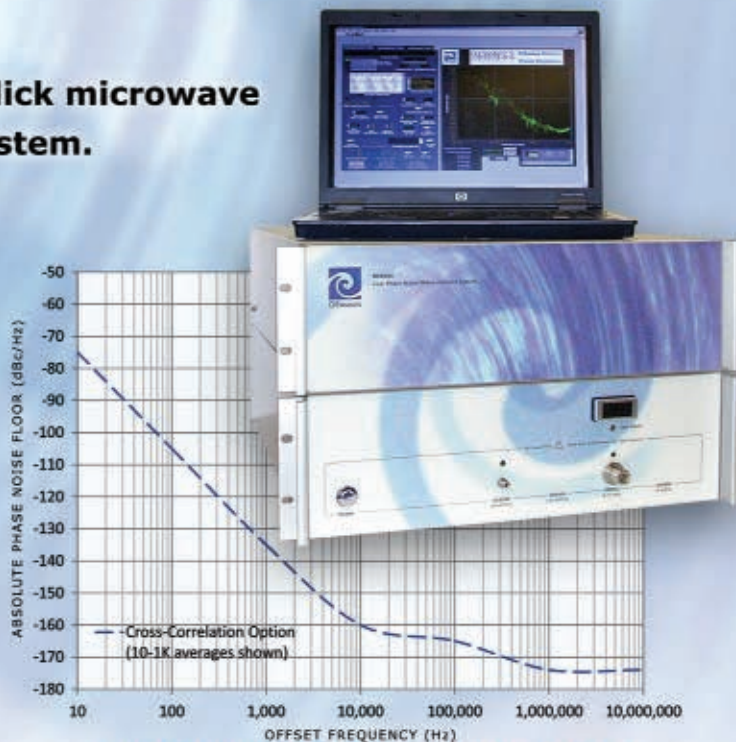
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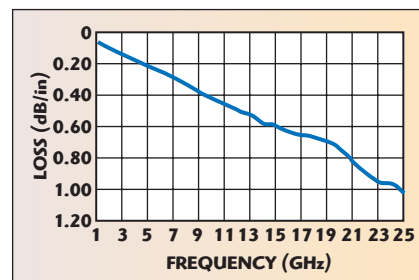


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less stress and yield a more reliable circuit assembly. When the x-y plane CTE is significantly higher than the copper, the substrate will expand at a different rate than the copper during soldering; this can shear the copper pads off of the circuit. If this extreme situation does not occur, there will be a “locked-in” stress in the solder joints. This induced stress can cause a field issue as the circuit cycles through temperatures during its normal use.

The matched CTE in the x-y plane of the RO4360 laminate eliminates this potential issue. One more concern associated with CTE is the plated through hole (pth) reliability. It is very common for PCB laminates to have a CTE much higher in the z-axis (laminate thickness axis) than the x-y plane. Since this will be higher than the CTE of the copper that is plated in the through hole, this too can cause reliability issues. It is typically understood that a CTE that is less than 70 ppm/°C in the z-axis will yield



▲ Fig. 2 Microstrip insertion loss for 20 mil thick RO4360 laminate.

a circuit of good reliability. The CTE of the RO4360 substrate in the z-axis is 30 ppm/°C, making it a very reliable material for pth issues.

Lastly, the T_g (glass transition) of the material can also be important for a reliable circuit assembly. The T_g is the temperature where the material has a transition in the CTE or modulus vs. temperature slope. Most PCB laminates have a T_g that is below the soldering temperature experienced in assembly. This has been known to cause assembly reliability issues and is typically accepted as the “nature of the beast”. What could exaggerate this issue are the newer designs using lead free soldering, which is done at a higher temperature. Typically, lead-free soldering reflow temperatures are around 260°C; most PCB laminates are well beyond their T_g at that temperature. The T_g of the RO4360 laminate is greater than 280°C, well above the maximum exposure temperature during lead-free soldering.

Moisture absorption is another material property that needs to be well controlled for a good power amplifier circuit. It is not uncommon for some PCB laminates to have a moisture absorption value as high as 2 percent. This absorbed water usually comes in the way of absorption from the environment by way of humidity. Since water has a Dk of about 73, the humidity can change the Dk value of the substrate, which can cause the circuit to perform poorly. Besides the change in impedance due to the absorbed moisture and the reflections caused by this change, the Df value of the PCB can also increase as well. A power amplifier design could have much worse performance than expected in a humid environment when using a PCB material that absorbs significant moisture. The RO4360 laminate has a very low moisture absorption property of 0.13 percent even when it is tested for 48 hours in warm water submersion.

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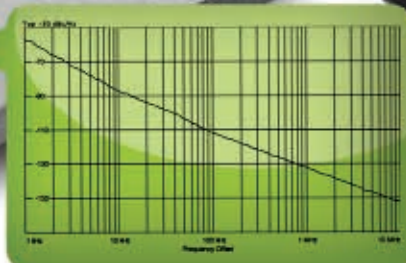


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DCO490517-3	4900 - 5175	0.5 - 5	+3 @ 22 mA	-86	0.3 x 0.3 x 0.1
DCO495550-5	4950 - 5500	0.5 - 12	+5 @ 22 mA	-87	0.3 x 0.3 x 0.1
DCO495550-3	4950 - 5500	0.5 - 12	+3 @ 22 mA	-85	0.3 x 0.3 x 0.1
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DCO608634-5	6080 - 6340	0.5 - 5	+5 @ 22 mA	-86	0.3 x 0.3 x 0.1
DCO608634-3	6080 - 6340	0.5 - 5	+3 @ 22 mA	-84	0.3 x 0.3 x 0.1
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DXO900965-5	9.0 - 9.85	0.5 - 12	+5 @ 22 mA	-80	0.3 x 0.3 x 0.1
DXO900965-3	9.0 - 9.85	0.5 - 12	+3 @ 22 mA	-78	0.3 x 0.3 x 0.1
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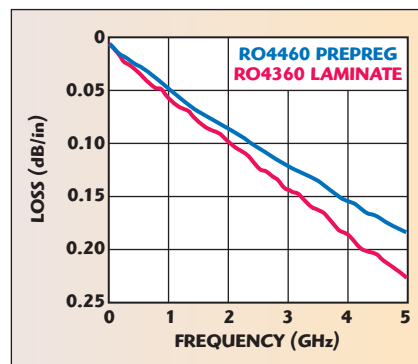
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As power amplifier designs evolve, the need for more complex PCBs increases. It is common to have a high frequency material, such as the Rogers RO4000 family of products, combined with other materials to build a hybrid PCB. This is typically done by using a low cost FR-4 material in the circuit design layers where the high performance capabilities of the RO4000 materials are not needed. However, when stripline structures are needed, which are becoming more prevalent

in new power amplifier designs, then a high performance prepreg (bonding layer) is necessary. Until now the prepreg layer would be a lower Dk material and a non-homogeneous stripline would be necessary. The Dk difference between the laminate and prepreg layers will influence the effective Dk value and some dispersion issues could result. Having a prepreg of the same Dk for the stripline structure is extremely advantageous. Rogers will soon release a prepreg to join the



▲ Fig. 3 Microstrip insertion loss for 20 mil thick RO4460 prepreg and RO4360 laminate.

RO4400™ family of products that will closely match the Dk of the RO4360 laminate. The prepreg will also match the other critical properties of the laminate as well. This is the first thermoset prepreg that has a higher Dk, making it very friendly to the PCB fabrication process. It also has excellent high frequency capabilities.

Of the several different properties previously discussed about the RO4360 laminate, in general, similar values for these properties apply to the laminated RO4460™ prepreg. As an added benefit to the PCB fabrication process, the resin flow properties have been improved over the capabilities of the other Rogers RO4400 prepreps.

The RO4460 prepreg has a Dk and Df closely matched to the RO4360 laminate. Insertion loss testing was done on microstrip circuits made with this prepreg and compared to the laminate. This comparison is shown in **Figure 3**. As an added interest to power amplifier designers, the RO4360 laminate and RO4460 prepreg utilize RoHS-compliant, flame-retardant technology for applications requiring UL 94V-0 certification.

There can be many interactions between any substrate and the circuit fabrication, assembly processes and end-user application. Such interactions are difficult to predict. Rogers therefore strongly recommends that the customer evaluates each material and design combination to determine fitness for use over the entire life of the end product.

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A COMPACT, HIGH POWER 2.45 GHz MICROWAVE GENERATOR

The requirement for low cost, light weight, compact and portable laboratory equipment is becoming more commonplace in industry. In the field of microwave test and measurement, customers are increasingly demanding complete, fully functional and certified systems that meet industrial standards. To provide customers with this complete solution, Emblation Microwave has developed the ISYS245 microwave generator.

This new model uses state-of-the-art technology to produce a highly efficient 2.45 GHz microwave system capable of generating variable power in excess of 110 W at 2.45 GHz with superior reflection measurement capability and temperature stability. The ISYS245 has been designed with an easy to use interface with the capability of being operated as a standalone system or externally controlled via PC and/or microwave signal generator.

APPLICATIONS

The use of microwave technology in communication, industrial and laboratory applications is constantly advancing with high power capability becoming a necessity. Also, curing and drying applications as well as microwave chemistry are reliant on systems being developed specifically for their applications, based on modified, readily

available microwave amplifier modules at a significant development cost to the end user. The additional cost to have the systems safety tested and certified for use and sale adds to both the financial and time to market burden.

However, the ISYS245 allows the user to take advantage of a compact off the shelf system and incorporate it into their existing laboratory/process setup/product design. With simple interfacing and ease of control, the ISYS245 is readily adaptable for a number of uses in industrial, scientific, medical, instrumentation and food science.

Potential applications include:

- Microwave measurement – material analysis (moisture), test & measurement, university research (hyperthermia/ablation, antenna measurements and wireless communication research)
- Microwave chemistry – organic chemistry, liquid phase reactions, intercalation reactions, organo-metallic chemistry, polymer chemistry and solid-state chemistry
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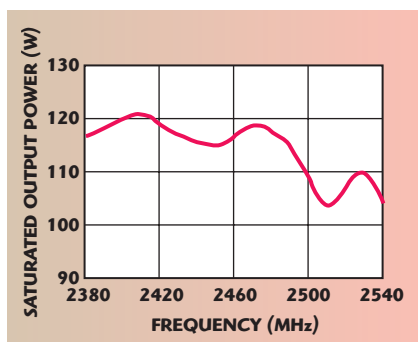


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▲ Fig. 1 Saturated output power of ISYS245.

- Food science – meat tempering and curing and material analysis (moisture, salinity, density)

OPERATION

The microwave amplifier uses GaN on SiC solid-state technology, operating in Class AB mode to generate microwave power in excess of 100 W CW, when used in the internally regulated standalone mode (as shown in **Figure 1**). In this mode and the swept mode, the output power can be varied in 5 W increments from 0 to 110 W using pulse width modulation (PWM) techniques with power stability maintained within 5 percent of the set value.

The ISYS245 can also be used as a standard amplifier when used in external source mode, where a small-signal gain of 55 to 58 dB is typical. Using this mode of operation, the amplifier operates without any internal power regulation, allowing the user to

TABLE I	
ISYS245 SUMMARY	
Performance Summary	
Small-signal gain	55 to 58 dB typical
Saturated o/p gain	52 to 54 dBm typical
Saturated o/p power	50 to 51 dBm typical
Noise figure	<10 dB
OIP3	56 to 58 dBm
Input/output impedance	50 Ω nominal
Amplifier efficiency	>62%
Switching time	10 μ s
Operating voltage	38 Vdc
Quiescent current	<2 A
Protection Interlocks	
Amplifier temp.	Max 65°C
RF input	15 dBm (max) BW $\pm$ 75 MHz
VSWR	∞
Power Supply	
Voltage supply	100 to 240 Vac 50 to 60 Hz
Dimensions	
W $\times$ H $\times$ D	300 $\times$ 85 $\times$ 275 mm 11.8 $\times$ 3.3 $\times$ 10.8 in
Approvals	
UK, US & Canada	CE Mark & 61010 approved

have full control of the output power levels. A performance summary of the ISYS245 is shown in **Table 1**.

ADVANCED REFLECTION MEASUREMENT

The ISYS245 has, as standard, an innovative reflected power measurement mode of operation. When used in the swept mode, the system has the capability to reduce the reflection measurement error significantly when the input match of the device under test is non-optimal. As an example, for a device with an input match of -12 dB connected to the system at a distance in excess of 1 m, an improvement of approximately 75 percent in measurement error is easily achievable, thereby reducing the overall uncertainty in the measurement. This mode of operation is particularly useful for applications that are dependent upon the accuracy of a reflected signal to identify material properties or relaying test progress and safety.

IMPROVED COOLING

The use of higher operating voltages on the GaN on SiC semiconductors in the ISYS245 system design helps reduce the drain current and the resultant Joule effect losses. The system has an amplifier efficiency of ~62 percent, resulting in a low channel temperature rise and also significantly reduced thermal loss, requiring reduced thermal management (see **Figure 2**).

The ISYS245's efficient design has facilitated the implementation of a novel, thermal cooler solution to dissipate heat losses and maintain the amplifier temperature when operating at

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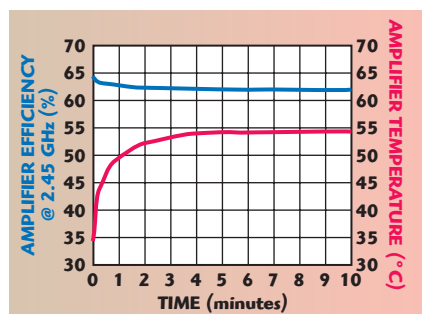
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▲ Fig. 2 ISYS245 amplifier efficiency and temperature stability.

full power at below 55°C. The cooling system employed is very compact with superior thermal capacity per unit volume, enabling the overall system to be significantly smaller and lighter, with an optimised air-flow management system.

SIMPLE USER INTERFACE

The microwave generator's user interface has been ergonomically designed for ease of use, with an intuitive interface having all controls in full view of the user. The system has three main controls for basic operation: the Output Power setting has increments and decrements in 5 W steps; as for the Reflection Power Trip setting, if a process requires the microwave power to be disabled when a certain reflected power level is detected, this function will allow that trip value to be set. This function increments and decrements in 1 W steps; with the Timer setting the system has the option of being used in continuous or timer mode.

When used in timer mode, the time can be set up to 99 minutes. When the microwave power is enabled, the timer function will decrement in 1 second steps and disable the microwave power when the timer reaches zero. All information is displayed on a high contrast white LED display.

The system also has six function buttons: the RF On button enables and disables microwave power; the Swept button, when used in standalone mode, allows an improved accuracy measurement of real-time reflected power to be made and displayed; the Timer button is for when the user requires to have power automatically disabled after a predetermined test duration; the External Source button is for use with the users' own signal generators via an SMA female connector on the rear panel; the External Control is for when data logging or specialised control is required via the parallel interface on the rear panel. This function disables the front panel controls. This mode allows the user to fully control the system including the output power through a time or reflection dependent power profile to get a unique power characteristic response. Lastly, the Reset button resets the system back to the power-on values.

With RF On enabled, the system displays the real-time measurement of both the output and reflected power, and warning LEDs and audible alarms are included in the ISYS245 as standard. The output power is delivered to an N-type (female) on the front panel,

with all external control on the rear panel via an SMA (female) RF input and parallel data control interface.

FUTURE DEVELOPMENTS

The external communication is currently carried out using a simple parallel data communication interface. However, a USB module is in the final stages of development, which connects to the ISYS245, thus enabling full control and data logging capability via a USB interface to a PC. All communication software will be provided with the USB module. The external software adds to the system flexibility and can be customized for the user for their specific development purposes. Other systems under development include higher frequency applications and OEM/ODM systems designed specifically for highly regulated sectors.

CONCLUSION

With the introduction of the ISYS245, Emblation Microwave is providing an affordable, light weight and compact, fully packaged solution with all the functionality and performance that is expected in today's high power marketplace.

**Emblation Microwave,
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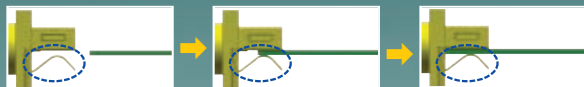
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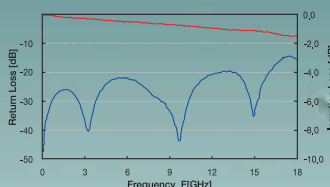
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CATALOG UPDATE



Test and Measurement Product Catalog CD

Keithley Instruments Inc. has published its 2010 Test & Measurement Product Catalog in CD form. The CD offers details and technical specifications on Keithley's general-purpose and sensitive sourcing and measurement products, DC switching, RF/microwave switching, data acquisition solutions, and semiconductor test systems. Useful selector guides and tutorials simplify choosing the right solutions for specific applications. To request a free copy of the CD, visit: www.ggcomm.com/Keithley/Dec09NR_2010ProductCatalogCD.html. The CD is arranged by product type and application area with sections containing Keithley's newest offering in test and measurement.

Keithley Instruments Inc.,
Cleveland, OH (440) 248-0400, www.keithley.com.

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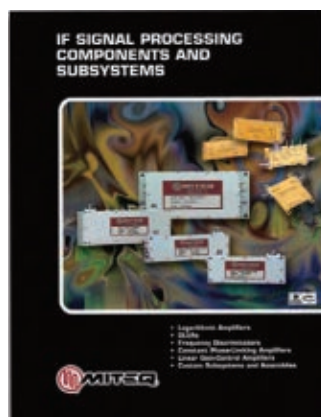
IF/RF Microwave Signal Processing Components Guide

VENDORVIEW

Mini-Circuits' new 164-page catalog includes over 750 new products and is the industry's most comprehensive listing of RF/IF and microwave components and subsystems with more than 4100 products and over 25 product lines, including state-of-the-art amplifiers, mixers, VCOs, synthesizers, filters, test accessories and USB Power Sensors. Mini-Circuits' website provides additional data, application notes, design tools and its powerful YONI search engine.

Mini-Circuits,
Brooklyn, NY (718) 934-4500, www.minicircuits.com.

RS No. 315



Components and Subsystems Catalog

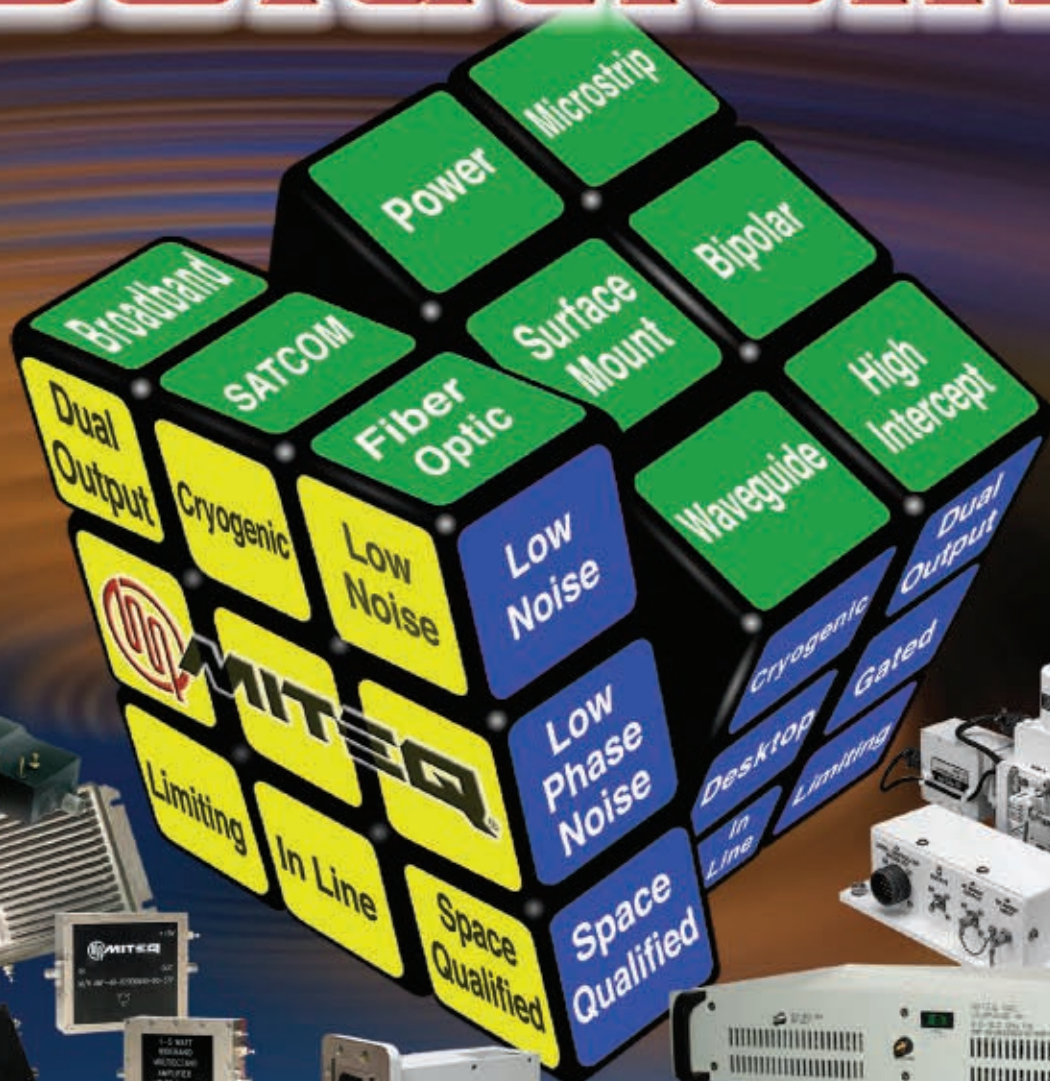
VENDORVIEW

MITEQ's new 72-page IF Signal Processing Components and Subsystems catalog (C-17C) provides detailed information on its logarithmic amplifiers, DLVAs, frequency discriminators, constant phase-limiting amplifiers, linear gain-control amplifiers, and custom subsystems and assemblies. Included as well are full electrical specifications, outline drawings, block diagrams as well as test data.

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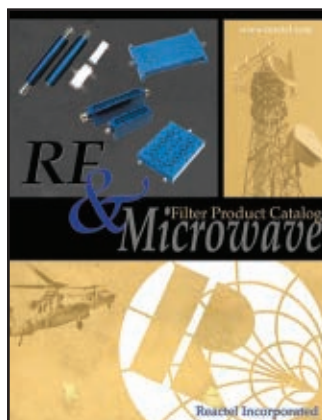
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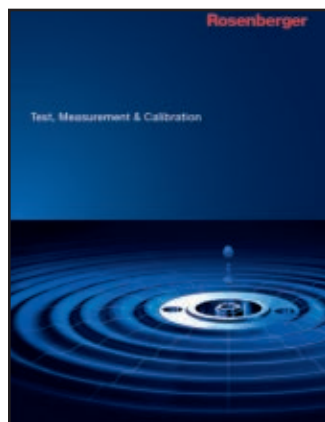


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Test, Measurement & Calibration

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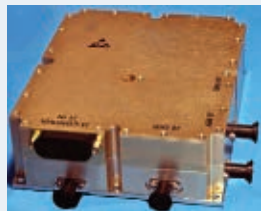
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AML Communications Inc.,
Camarillo, CA (805) 388-1345,
www.amlj.com.

RS No. 216

RF Power Amplifier

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BC Systems Inc.,
Setauket, NY (631) 751-9370,
www.bcpowersys.com.

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Voltage-controlled Oscillators

Crystek's CVCO55CC-3345-3955 voltage-controlled oscillator (VCO) operates from 3345 to 3955 MHz with a control voltage range of 2.5 to 23.5 V. This VCO features a typical phase noise of -100 dBc/Hz at 10 kHz offset and offers excellent linearity. Output power is typically +3.5 dBm.

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consumption of 50 mA. Pulling and pushing are minimized to 5 and 3 MHz/V, respectively. Second harmonic suppression is -15 dBc typical.

Crystek Corp.,
Fort Myers, FL (239) 561-3311,
www.crystek.com.

RS No. 218

MMIC Power Amplifier

VENDORVIEW

The HMC755LP4E is a high gain, high linearity GaAs InGaP HBT MMIC power amplifier that is rated from 2.3 to 2.8 GHz and provides up to 31 dB of gain. This high efficiency amplifier



operates from a single +5 V supply, and achieves 28 percent power added efficiency (PAE) at +33 dBm of saturated output power. Three power control pins can be used to reduce the RF output power of the PA, or for full power down of the amplifier to conserve DC power. The integrated output power detector pin (VDET) is internally coupled and provides excellent measurement accuracy while requiring only a single external decoupling capacitor. With an OFDM output power of +25 dBm (64 QAM, 54 Mbps), the HMC755LP4E achieves an error vector magnitude (EVM) of only 2.5 percent, making it ideal for WiMAX and LTE/4G applications. This high performance amplifier is packaged in a compact 4 x 4 mm QFN SMT package, requires a minimum of external matching components, and is rated for operation from -40° to +85°C.

Hittite Microwave Corp.,
Chelmsford, MA
(978) 250-3343,
www.hittite.com.

RS No. 220

Compact X-band Power Amplifiers

VENDORVIEW



MITEQ has introduced a new line of low profile, lightweight and small volume high power X-band amplifiers. The new PA

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MITEQ Inc.,
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MOSFET Power Modules



These new linear MOSFET power modules (part numbers: APT-MLxxx...) are used to provide a

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Richardson Electronics,
LaFox, IL (800) 737-6937,
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RS No. 247

4 W 340 to 470 MHz SSPA

Stealth Microwave introduces the SM034047-34MQ2, a MOSFET amplifier designed for military and commercial applications to include



COFDM video and C2 links in UAVs and in portable battery powered transmitters. The unit

operates from 340 to 470 MHz with a P1dB of +4 W. Small-signal gain is 11 dB with a flatness of 0.8 dB across the band. Standard features include high speed on/off for TDD switching and a lightweight housing designed to meet most MIL-STD-810G testing methods. In module form, the unit measures 3.375" x 1.9" x 0.49".

Stealth Microwave,
a division of Micronetics Inc.,
Ewing, NJ (609) 538-8586,
www.stealthmicrowave.com.

RS No. 223

GaN Product



TriQuint Semiconductor has expanded its revolutionary wideband, high power RF transistor family with the new T1G6003028-SP, a 25 W (P1dB) GaN device operating from 20 MHz to 6 GHz. This PowerBand™ discrete GaN on SiC HEMT product delivers high-efficiency, high-power performance across an exceptionally wide bandwidth. The T1G6003028-SP is ideal for commercial applications such as WiMAX and professional radio systems, as well as wideband defense communications systems.

TriQuint Semiconductor,
Hillsboro, OR (503) 615-9000,
www.triquint.com.

RS No. 239

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Photos: Courtesy of U.S. Navy and NASA

Mini-Circuits is an industry leader in synthesizer designs with over 250 standard catalog models and many more custom units designed into major programs supporting a wide range of applications.

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Visit <http://mwj.hotims.com/28489-85> or use RS# 85 at www.mwjjournal.com/info

477 Rev. Orig.

Components

40 and 50 GHz SMPM Terminations



Just announced are two high frequency SMPM push-on terminations from Aeroflex/Inmet.

The TMP-400F (DC to 40 GHz) and the TMP-500F (DC to 50 GHz) are designed to mate with GPPO and SMPM male connectors. These terminations complement Aeroflex/Inmet's existing blind mate 8541-MPF SMPM DC blocking terminations. The new terminations are ideal for use in 40 Gbs optical transmission systems as well as in test and measurement applications.

Aeroflex/Inmet,
Ann Arbor, MI (734) 426-5553,
www.aeroflex.com/inmet.

RS No. 224

Bandpass Filter

VENDORVIEW



AKON's model number A65-MH131 bandpass filter covers the 3.1 to 3.5 GHz frequency range with only

0.4 dB (maximum) insertion loss, 1.35:1 maximum VSWR, passband rejection > 20 dBc from DC to 2.9 GHz, +43 dBm CW power handling, all packaged within 2.98" x 1.22" x 0.82". AKON is a manufacturer of RF/microwave components and subsystems for military, space and commercial applications. AKON's compact filters are available in all topologies for low pass, high pass, bandpass and band reject requirements. Customer specified filters are available per individual customer requirements.

AKON Inc.,
San Jose, CA (408) 432-8039,
www.akoninc.com.

RS No. 225

Microwave Horn Antennas

VENDORVIEW



AR RF/Microwave Instrumentation has a family of broadband RF and microwave horn antennas offering coverage up to 50 GHz. These antennas

are specifically designed to compensate for the losses that typically occur in test systems as frequency increases and can be used in shielded rooms or in free space.

AR RF/Microwave Instrumentation,
Souderton, PA
(215) 723-8181,
www.ar-worldwide.com.

RS No. 254

EMI Filters

Models FMCE-0328, FMCE-0528, FMCE-0828 and FMCE-1528 are FMCE filters designed to work with Crane's Interpoint brand 28 V input, 1.5 to 120 W DC/DC converters and are backward compatible and fully interoperable with Interpoint brand FMH, FMC, FMD and FME filters. They have been designed to provide exceptional attenuation performance with a minimal loss of power in the filter as well as to make sure that heat generated in the filter is efficiently dissipated by the device to minimize stress on components, ensuring optimal product life.

Crane Aerospace & Electronics,
Electronics Group, Redmond, WA,
www.craneae.com.

RS No. 226

High Frequency Coaxial Attenuator

VENDORVIEW



This product expands EMC's current offering of SMA coaxial products out to 18 GHz. In EMC tradition, this product is offered in commercial or high reliability versions for all applications. EMC can offer a standard test plan or up-screen product for custom requirements. EMC coaxial attenuators are manufactured with a stainless steel body and standard SMA male/female interface. This product is offered in values from 0 to 10 dB in one dB increments and up to a maximum frequency range of 18 GHz. The rugged construction of this device

ensures reliability and continuous performance in the most demanding environments.

EMC Technology/Florida RF Labs,
Stuart, FL
(772) 600-1360,
www.emct.com.

RS No. 227

Wideband Attenuator

VENDORVIEW

The new 50P-1857 is a programmable attenuator that offers solid-state reliability and superior



broadband performance. With an operating frequency range of 200 to 6000 MHz, it is ideal for today's wideband variable

attenuator requirements including VHF/UHF, LTE and WiMAX testing applications. This 50 ohm device has a dynamic range of 0 to 95 dB in 1 dB steps and is guaranteed monotonic across its entire bandwidth. SMA female connectors are standard on the input and output.

JFW Industries,
Indianapolis, IN (317) 887-1340,
www.jfwindustries.com.

RS No. 228

Diplexer

The 10DPS-6082/8400-S is a diplexer that is designed with a low band of 6082 to 6482 MHz and a high band of 7900 to 8400 MHz. The



diplexer features a 1.2 dB maximum insertion loss with a 1.5:1 VSWR.

The isolation is specified as 50 dB from the band edges. The physical size is 3.7" x 1.15" x 0.750" excluding SMA-female connectors. The unit also contains flange mounting.

Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 229

Medium Power Attenuators



Microlab announced the addition of a new range of medium power attenuators with guaranteed low PIM of less than

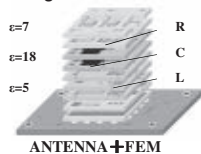
-150 dBm when measured with two 20 W test tones. These products are available in attenuation values from 4.8 to 30 dB to meet the exacting needs of the wireless market across the whole 698 to 2700 MHz band. The AY series is designed for powers from 30 to 45 W depending on the attenuation value, and is available with either N or 7-16 mm DIN, male to female connectors. Units have been designed using mechanically stable connections and achieve an input VSWR better than 1.20:1 across the whole frequency band for all values except the 4.8 dB, which is less than 1.30:1.

Microlab,
Parsippany, NJ (973) 386-9696,
www.microlab.fxr.com.

RS No. 230

"Reasonable device-LTCC"

HIRAI's featured LTCC process, in-house plating, forming and mm-wave technologies enable you to design SiP with high Q and lower cost.

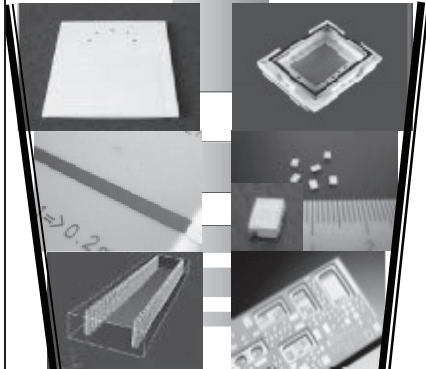


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Honorable Zachary J. Lemnios

2010 IEEE International Microwave Symposium is proud to announce this year's keynote speaker, The Honorable Zachary J. Lemnios. Mr. Lemnios currently serves as the Chief Technology Officer (CTO) for the Department of Defense. Prior to acceptance of his current role, Mr. Lemnios has held many key and influential positions which have helped advance technology. His remarkable career includes positions, within MIT Lincoln Laboratory, eventually serving as CTO. His responsibilities in this role called for strategically coordinating technology and growth to support current and future laboratory missions. Mr. Lemnios was also the Director of the Defense Advanced Research Projects Agency (DARPA) Microsystems Technology Office (MTO) as well as the Deputy Director of Information Processing Technology Office (IPTO).

Mr. Lemnios has served on numerous DoD, industry and academic committees. Mr. Lemnios has authored over 40 papers, holds 4 patents in advanced GaAs device and MMIC technology and is a Senior Member of the IEEE.

We encourage your participation in joining us during this exciting Plenary Session to be held May 25th, 2010. Due to Mr. Lemnios' busy work schedule, this is a rare opportunity you will not want to miss! To learn more about Mr. Lemnios and his upcoming discussion, please visit our website at www.ims2010.org.

We look forward to your visit. To see what is new at IMS2010, visit www.ims2010.org.



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NEW PRODUCTS

Limiter Protection Circuits



Mini-Circuits' new VLM-73+ extends a popular line of SMA connectorized high power limiter protection circuits to 7

GHz. Ideally suited for protecting low noise receivers from exposure to unwanted high level signals, the VLM-73+ has only 0.3 dB typical insertion loss in the linear region, yet reacts almost instantaneously (2 nSec typical response time and 10 nSec recovery time) to signals up to 1 W input power by limiting the output power to less than +15 dbm across the frequency band. Housed in Mini-Circuits' patented uni-body construction, the VLM series is a tough unit for the most rugged receiver applications.

Mini-Circuits,
Brooklyn, NY (718) 934-4500,
www.minicircuits.com.

RS No. 231

Coaxial Attenuator



The model 766-20 is a 20 dB bi-directional coaxial attenuator that operates from DC to 4 GHz and can handle full RF

input power at either connector without damage. Attenuation deviation of the Model 766-20 is ± 0.25 dB to 3 GHz and ± 0.5 dB to 4 GHz. It handles 20 W average and 1 kW peak input power, and maintains a VSWR of less than 1.15:1. The compact unit is heavily heat-sinked, uses Type-N connectors, measures 3.07" long and $\times 1.52$ " diameter, and weighs 5.6 oz. The model 766-20 coaxial attenuator is available

from Narda for immediate delivery.
Narda Microwave-East,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com/east.

RS No. 222

SP4T RF Switch



The PE42440 SP4T (single pole four throw) RF switch is designed on Peregrine's green UltraCMOS™ silicon-on-sapphire (SOS) process technology and features excellent broadband RF performance from 50 MHz up to 3 GHz. The HaRP™-enhanced switch has best-in-class linearity, making it ideal for general purpose TRx switching in cellular and 2.4 GHz industrial, scientific and medical (ISM) radio bands; antenna tuning; and filter bank tuning/switching in a wide range of applications, including cellular radios and radio modules; antenna tuning of UHF bands through 3 GHz; RFID antenna tuning; 2.4 GHz ISM; Femtocells and other industrial applications.

Peregrine Semiconductor Corp.,
San Diego, CA (858) 731-9400,
www.psemi.com.

RS No. 232

Directional Coupler



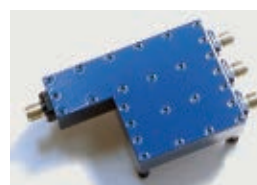
Pulsar model CS20-51-435/1 is a new 20 dB coupler covering the frequency range of 6 to 40 GHz with 1.2 dB insertion

loss. Directivity is greater than 10 dB and flatness is ± 0.4 dB from 8 to 20 GHz and ± 1.0 dB 6 to 40 GHz. The VSWR is 1.70:1 maximum and the unit can handle 20 W into a 1.20:1 load. Connectors are 2.92 mm female.

Pulsar Microwave Corp.,
Clifton, NJ (973) 779-6262,
www.pulsarmicrowave.com.

RS No. 233

VHF LC Triplexer



Reactel part number 3TP-86/198-11 is a VHF LC triplexer. This unit exhibits low loss and high isolation as it splits

the VHF band into 30 to 88, 100 to 172 and 225 to 400 MHz channels. This unit has a high power option and can be outfitted with most any RF connector you desire. Please contact the factory for this or any other filter requirement that you have.

Reactel Inc.,
Gaithersburg, MD (301) 519-3660,
www.reactel.com.

RS No. 234

Coaxial to Waveguide Adapters



RLC Electronics now offers coaxial to waveguide adapters in a variety of configurations for specific applications. Option A are broadband adapters whose excellent electrical specs are maintained over the entire adapter bandwidth, while option B offers enhanced performance over a specific band of the adapters' bandwidth. Computer design and the latest in RF techniques coupled with precision assembly ensure optimal electrical performance in the recommended frequency ranges.

RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

RS No. 235

Base Station Duplexer

Trilithic Inc. has released a new base station duplexer for the LTE Band 13. Utilizing high "Q" cavities and a pseudo elliptic response, this duplexer provides low insertion loss and high isolation in a compact size. The maximum

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NEW PRODUCTS



insertion loss in the passband is 1.25 dB while providing a minimum of 100 dB of isolation between the TX to RX ports. It also

provides 80 dB minimum isolation out to 2800 MHz. This unit can handle up to 100 W CW across a temperature range of 0 to +70°C. Standard delivery: five to six weeks.

Trilithic Inc.,
Indianapolis, IN (317) 895-3600,
www.trilithic.com.

RS No. 237

100 MHz Power Circulator

A new high power circulator suitable for FM broadcast, scientific and medical applications is now available.



The unit provides 10 MHz bandwidth in the 85 to 110 MHz spectrum. Specifications are 20 dB mini-

mum isolation, 0.3 dB maximum loss and 1.25 maximum VSWR. Operating power is 1 kW average and 25 kW peak. The 8-1/2" hex x 2" thick unit operates over a 15° to 50°C temperature range. DIN 7/16 are standard. Other units are available at higher frequencies.

UTE Microwave,
Ashbury Park, NJ (732) 922-1009,
www.utemicrowave.com.

RS No. 238

Semiconductors/ICs

Single-chip ISM Band Transceivers



RFMD announced the introduction of the ML2730, a single-chip fully integrated Frequency Shift Keyed (FSK) transceiver with integrated power amplifier (PA) and low noise amplifier (LNA). The ML2730 expands RFMD's portfolio of ISM band single-chip transceivers, covering 900 MHz, 2.4 and 5.8 GHz. The ML2730 is optimized for a variety of wireless media applications (audio, video and data) operating in the 2.400 to 2.485 GHz unlicensed ISM band. The high data rate capability of the ML2730 supports streaming applications like wireless audio and wireless video. The ML2730 is also suitable for a variety of radio controlled applications. By integrating the PA and LNA on a single chip, the ML2730 enables customers to develop robust wireless links with improved sensitivity and output power while reducing both costs and board size.

RF Micro Devices Inc.,
Greensboro, NC (336) 664-1233,
www.rfmd.com.

RS No. 250

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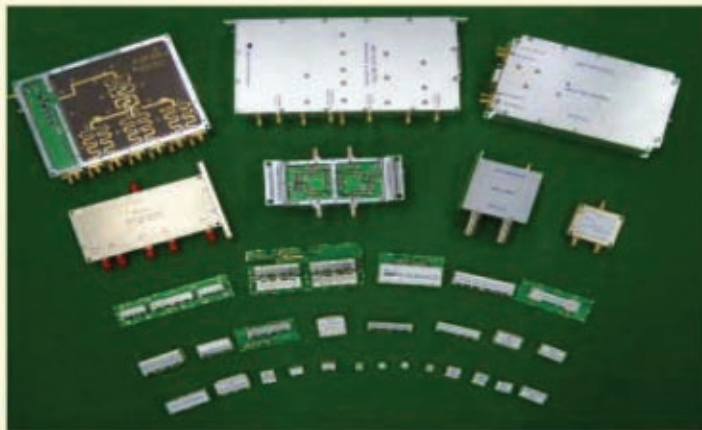
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Wideband Amplifier Modules

Part Number	Operating Frequency	Output Power(Watts)
RCA00205HoxA	20~500MHz	25W/50W/100W
RCA05~25HoxA	500~2500MHz	25W/50W/100W
RCA10~30HoxA	1000~3000MHz	25W/50W/100W
RCA30~60H43A	2000~6000MHz	20W



Wideband Amplifier Systems

Part Number	Operating Frequency	Output Power(Watts)
RCA00201Uox	20~100MHz	300W/500W
RCA0105Uox	100~500MHz	300W/500W
RCA0510Uox	500~1000MHz	100W/400W
RCA0820U53	800~2000MHz	200W



Wideband & High Power Switches

Part Number	Operating Frequency	Output Power(Watts)
RSW0020SH50A	20~500MHz	100W
RSW025H47A	500~2500MHz	50W

- Commercial
- EW / Jamming
- Broadcasting
- Military communication
- Wireless communication
- Medical

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e-mail sales@rfcore.com

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SemiGen Inc.,
Londonderry, NH
(603) 425-1144,
www.semigen.net

RS No. 240

Software

Design and Simulation Software

ACS has recently released a new version of the LINC2 Pro RF and microwave design and simulation software suite. LINC2 V2.72 release 1 includes many new enhancements and upgrades.



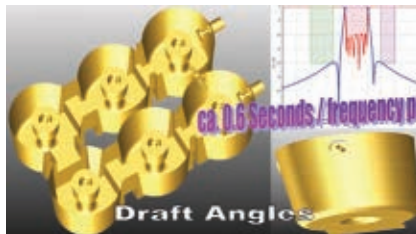
The latest version of LINC2 Pro ships with new RF tools software that includes nonlinear amplifier analysis. The

software provides schematic capture for entering schematics manually or schematics can be created automatically by a number of circuit synthesis modules. The LINC2 Pro RF and microwave circuit design and analysis software suite combines circuit synthesis, simulation, optimization and statistical yield analysis into a single integrated design environment at an affordable cost.

Applied Computational Sciences (ACS),
Escondido, CA
(760) 612-6988,
www.appliedmicrowave.com

RS No. 241

Combining CAD Speed with 3D Flexibility



WASP-NET® combines unparalleled efficiency now with unlimited flexibility; WASP-NET version 8.0 features convenient 3D data file import and 3D structure editors, by which users can create arbitrary, user-defined geometries. WASP-NET's unique hybrid MM/FE/MoM/FD CAD engine yields EM CAD precision in seconds for general 3D microwave components and antennas, including arbitrarily shaped waveguide and coaxial components, combine/interdigital and dielectric resonator filters, feed systems, corrugated horn antennas, shaped re-

flector antennas, large slot arrays, dielectric loaded antennas, lenses, radomes, etc.

Microwave Innovation Group (MiG)
GmbH & Co. KG,
Bremen, Germany +49 421 223 7966 0,
www.mig-germany.com

RS No. 242

Sources

Surface-mount Synthesizer



The UPN-7500 is a surface-mount synthesizer that operates in a frequency range from 5500 to 7500 MHz.

The unit is designed to withstand up to 9.26 Grms random vibration and 30 G's peak pulse of shock, tested in accordance with MIL-STD-202G. The UPN-7500 features 5 MHz step size, < 200 µSec settling time (any frequency step), 125 MHz external reference, +3 dBm output power and low phase noise (< -90 dBc/Hz at 100 KHz). The units feature low power consumption (115 mA, typical), extended operating temperature range (-45° to +85°C), small, SMT package (0.9" x 0.9" x 0.21"), and manufactured to IPC-A-610 standards.

EM Research Inc.,
Reno, NV (775) 345-2411,
www.emresearch.com

RS No. 243

Microwave Frequency Synthesizers



The QuickSyn® series of microwave synthesizers, designed

and manufactured by Phase Matrix's Frequency Synthesis group, delivers instrument-grade performance, increased functionality, and efficient power consumption at a reduced size and low cost. The synthesizers employ a revolutionary phase-refining technology that provides a unique combination of fast-switching speed and low phase noise characteristics.

Phase Matrix Inc.,
San Jose, CA (408) 428-1000,
www.phasematrix.com

RS No. 244

Integrated Synthesizers

VENDORVIEW



The SKY73134 is a wideband integer-N frequency synthesizer with an ap-

proximate 6 GHz locking range. This extremely small 5 x 5 mm device includes four differential VCOs which, by applying internal VCO frequency division, continuously cover the output frequency from 0.375 to 5.6 GHz. The integrated phase noise from 100 Hz to 100 kHz measures less than 0.6 degree RMS at 960 MHz frequency. In addition, the phase noises at 100 kHz, 1 MHz and 3 MHz frequency offsets are -115 dBc/Hz, -143 dBc/Hz and 150 dBc/Hz, respectively, making the SKY73134 an ideal solution for GSM/EDGE, CDMA/WCDMA and LTE base station transceivers. The SKY73134 is controlled by a bi-directional read/write serial to parallel interface

Network with the RF/Microwave Industry

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Join the leading suppliers of high frequency electronics solutions in The RF/Microwave Zone at CTIA. MWJ organizes a complementary array of RF and microwave companies in this technology pavilion to provide one-stop-shopping for potential buyers at this global event.

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Leading suppliers of cables, connectors and related components love this supplement for its targeted content and bonus distribution at CTIA and IMS. Your ad reaches engineers looking for the latest developments in transmission-line technology.

Newsletters

MWJ delivers the weekly Microwave FLASH and Microwave ADVISOR and the monthly MicroView to targeted audiences of opt-in subscribers. Your sponsorship of these popular newsletters provides exposure to more than 40,000 readers and is a proven lead generating tool.

Military Microwaves Supplement

If your company sells into the defense sector, you won't want to miss this annual publication. Always our most popular print supplement with advertisers, this piece features the latest developments in component and sub-system architecture and delivers bonus distribution to the EuMW and MILCOM events.

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Mobile Communications Supplement

This annual publication focuses on the rapidly evolving wireless communications market with cutting-edge content from industry experts. Bonus distribution at the Mobile World Congress provides exposure to this enormous audience of potential buyers.

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Your ad in *Microwave Journal* reaches 50,000 qualified design engineers and engineering managers in the publication that RF and microwave professionals rate as the number one magazine in its field. More companies advertise in MWJ than in any competing publication because they know that MWJ delivers.

The Website

Reach more than 60,000 registered users with your message on the "Home Page of the RF/Microwave Industry". The website combines the editorial content from the magazine with unique engineering tools and resources and provides an array of lead generating advertising/sponsorship opportunities.

European Microwave Week

Exhibit at the largest RF/Microwave trade show in Europe and showcase your company's products to this global audience. The Symposium boasts four conferences and various workshops and courses by leading experts to attract highly qualified delegates.

Expert Advice

Industry experts share their insights and knowledge in this regular feature to the MWJ website. Interaction with members of the community creates a blog environment providing perspectives on different market segments.

Webinars

Are you interested in receiving over 1,000 quality leads from a single webinar sponsorship? Our webinar series with partners Besser Associates and Strategy Analytics do just that, while also presenting your company's message to this global audience.

Executive Interviews

MWJ editors speak with industry executives to gain insight to their company's current activities and long-term objectives. This monthly feature is archived in the Resources section of the MWJ website.

Show Coverage

Online Show Dailies and Newsletters provide in-depth coverage of the EuMW and IMS events and excellent opportunities for exhibitors to deliver their message to attendees of the industry's two biggest industry trade shows.

Vendor View Storefronts

These featured storefronts in the Buyer's Guide section of the MWJ website provide a portal for your company's news, products, MWJ articles, white papers and downloads. Vendor View companies get their products featured in the Microwave ADVISOR and the RFIQ tool generates instant leads to your marketing group.

China Website

MWJ is pleased to announce the debut of our China website, designed to meet the needs of the rapidly growing Asian RF and microwave market. This website provides the opportunity for your company to target this important market through banner ads and sponsorships.



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RS 120

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RS 90

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Plug or Socket
acc. to MIL-STD-348A



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MIL-C-39029/102 or 103

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sales.usa@cpeitalia-group.com

RS 24

NEW PRODUCTS

that allows flexible device configurations that may be locked with an external VCO or external PLL, or be used as a divider chain only.

Skyworks Solutions Inc.,
Woburn, MA (781) 376-3000,
www.skyworksinc.com.

RS No. 245

Fixed Frequency Synthesizer

Model SFS1770A-LF is an RoHS compliant fixed frequency synthesizer in L-band. The SFS1770A-LF is a single frequency synthesizer that operates at 1770 MHz. This synthesizer features a typical phase noise of -95 dBc/Hz at 10 kHz offset and typical sideband



spurs of -70 dBc. The SFS1770A-LF is designed to deliver a typical output power of 6 dBm with a VCO voltage supply of 5 VDC while drawing 35 mA (typical) and a phase-locked loop voltage of 3 VDC while drawing 9 mA (typical) over the temperature range of -40° to 85°C. This fixed frequency synthesizer features typical second harmonic suppression of -15 dBc and comes in Z-Comm's industry standard PLL-V12N package measuring 0.60" x 0.60" x 0.13".

Z-Communications Inc.,
San Diego, CA (858) 621-2700,
www.zcomm.com.

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Subsystems or Systems

Amplifier Systems LCD Controller



The LCD touch screen display and microprocessor is a powerful tool that can be added to any Empower system. The LCD controller allows

easy, intuitive access to all the monitoring and control functions of the amplifier, both locally on the screen and remotely via RS422, RS232 or Ethernet. The controller extends the capability of the amplifier to control; T/R switches, sub-octave filters, system interlocks and other miscellaneous internal and external features.

Empower RF Systems Inc.,
Inglewood, CA (310) 412-8100,
www.empowerrf.com.

RS No. 248

OFDM Compatible Transceiver

The MiniTrans 2401 is a 2.45 GHz radio modem, based on the patented dual mode radio architecture, for data rates up to 25 MBit/s and higher and for a point to point data transfer with digital input and digital output. A spread spectrum transmission is standard with the integrated noise generator (~ 10 MHz) or an external signal source, leading to a secure, rugged and tap-proof link. Except for the lower price-range, the module is readily comparable with OFDM systems.

Applications for UWB are possible.
Heuermann HF-Technik GmbH,
Stolberg, Germany
+49 2402/9749764, www.hhft.de.

RS No. 249

Ground Data Terminal Antenna System



The GDT-2100 is a military-grade, lightweight portable tracking antenna system for ground-based Ku-band data link transmit and receive communication. This standard COTS system is used by mobile ground forces to exchange imagery and data from UAV's utilizing CDL or other Ku-band

data links. The GDT-2100 also supports data link relay, and UAV command and control missions. This ruggedized, portable system offers reliable field-proven performance, at a low cost.
TECOM Industries Inc.,
Thousand Oaks, CA (805) 267-0100,
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Test Equipment

Portable Positional Simulator

Aeroflex introduced the GPSG-1000, the first truly portable GPS and Galileo positional simulator. The GPSG-1000 is lightweight, easy to use, configurable and inexpensive. It fills a gap in the market by providing a low-cost 12-channel test set that creates three-dimensional simulations for under \$20,000. With the advent of GPS signal modernization, many GPS simulators on the market today are now obsolete. The GPSG-1000 supports civil and military avionics field and bench maintenance technicians, production test technicians, and system integrators with a modern simulator for L1, C/A code and L1C, L2C, L5 GPS modernization signals, as well as new Galileo E1, E5, E6 services. It can be configured with single channel, 6-channel, or 12-channel simulation. Typical tests include acquisition sensitivity, tracking sensitivity, time-to-first-fix for cold/warm/hot starts, time-to-second-fix, positional accuracy, RAIM failure tolerance, and subsystem stimulation for 3D flight execution.

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Noise Source

Micronetics SMN7108 noise source is ideal for dithering for high speed A/D conversion for



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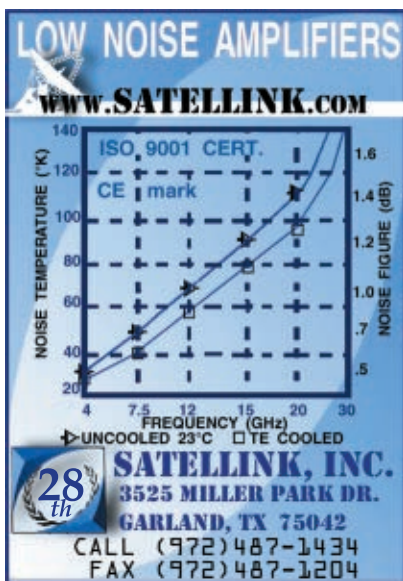


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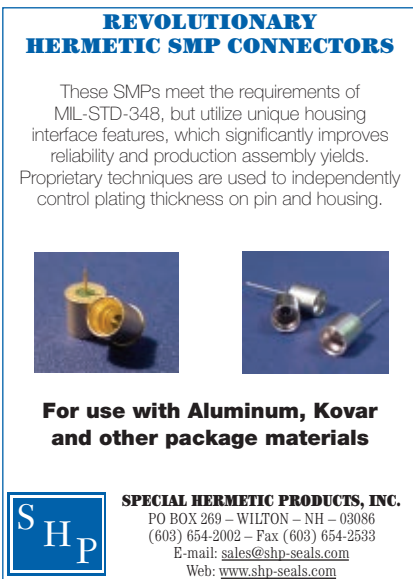
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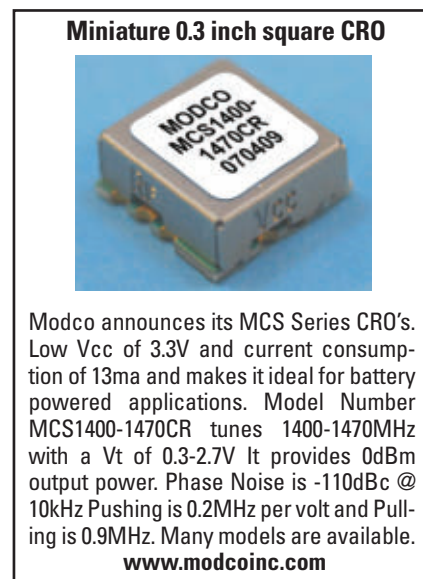
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RS 91



Discrete Oscillator Design: Linear, Nonlinear, Transient, and Noise Domains

Randall W. Rhea

This is Randy Rhea's third book on oscillator design and is motivated by a decade of advancement in the state-of-the-art, his additional design experience and questions/feedback from his students. *Discrete Oscillator Design: Linear, Nonlinear, Transient, and Noise Domains* covers the practical design of high-frequency oscillators with lumped, distributed, dielectric and piezoelectric resonators. Linear, nonlinear harmonic balance, nonlinear transient and nonlinear noise analysis techniques are described in detail with many examples. All of these domains are integrated into a unified theory of oscillator design for easier understanding.

This book assumes a basic understanding of RF terminology and measurement techniques, but is not a complete mathematical treatment of oscillator theory. It covers the subject well and focuses on teaching a practical understanding of the subject (for a more rigorous book, the author recommends *RF and Microwave Oscillator Design* edited by Michal Odyniec). Rhea's book covers more in-depth the areas of nonlinear and transient behavior than his previous books and includes over 40 example oscillators, many with measured data to confirm the theories presented.

The first four chapters introduce linear, nonlinear, transient and noise theory. The remaining chapters apply those techniques to examples of general purpose R-C and L-C, distributed, wide-tuning and piezoelectric oscillators. Appendix A has models for lumped elements; Appendix B covers biasing of active devices. *Discrete Oscillator Design: Linear, Nonlinear,*

THE BOOK END

Transient, and Noise Domains does rely heavily on the use of computer simulation to analyze circuit behavior and presents the results graphically (HENESYS software suite developed by the Eagleware group of Agilent Technologies Inc.).

Rhea always offers practical approaches to understanding and practicing the theory for real world applications. His informal style is typically much more enjoyable to read than more formal publications found in technical books and articles.

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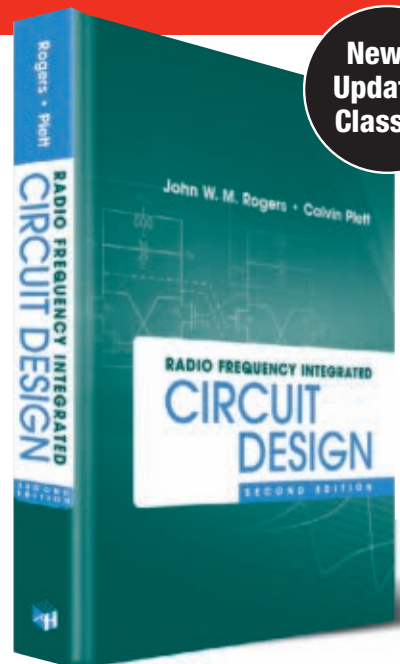
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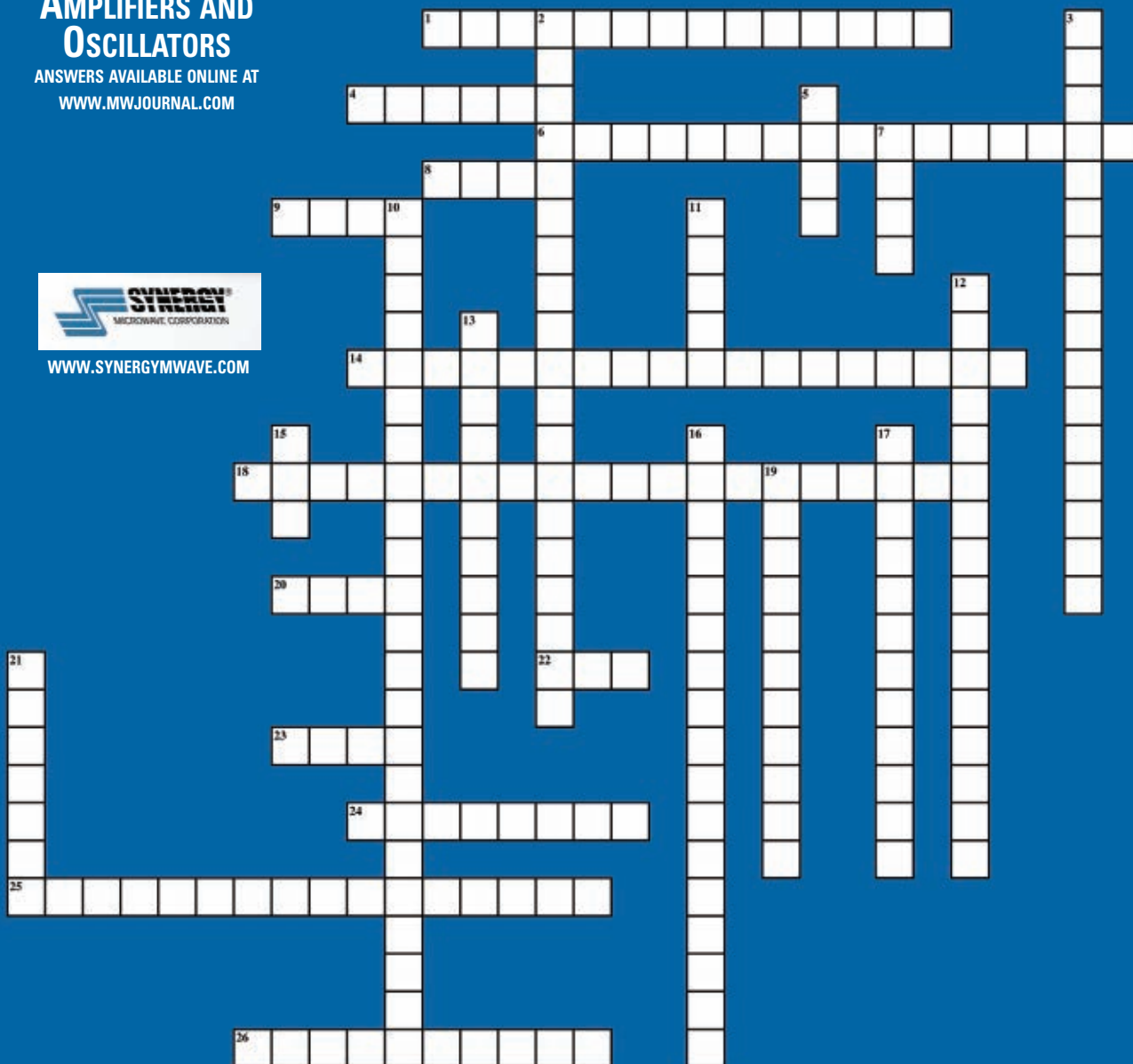


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- 22 Voltage Controlled Oscillator
- 23 Traveling Wave Tube Amplifier
- 24 Undesired signals present at the output of a device

under test that are neither harmonics nor intermodulation products

- 25 BAW (3 words)
- 26 $-20 \log_{10} |I|$ (2 words)

Down

- 2 SAW (3 words)
- 3 Q_m
- 5 Voltage Controlled Crystal Oscillator
- 7 The reduction in gain of an amplifier by 1 dB that results from saturation as a consequence of increased input signal magnitude
- 10 MPA (3 words)
- 11 Wideband Code Division Multiple Access
- 12 A frequency change defined for a certain load condition in a VCO (2 words)

- 13 Short term random frequency fluctuations of a signal (2 words)

- 15 Coaxial Resonator Oscillator

- 16 Two amplifiers of equal gain that are arranged in quadrature (2 words)

- 17 A beam forming network that uses a combination of 90° hybrids and phase shifters (2 words)

- 19 Measure of degradation of the signal-to-noise ratio (2 words)

- 21 Mode of operation when two amplifiers conduct more than half of the time as a means to reduce the cross-over distortions of Class B (2 words)

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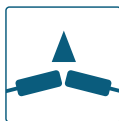
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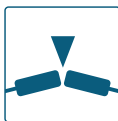
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QUADRATURES



COMBINERS



DIVIDERS



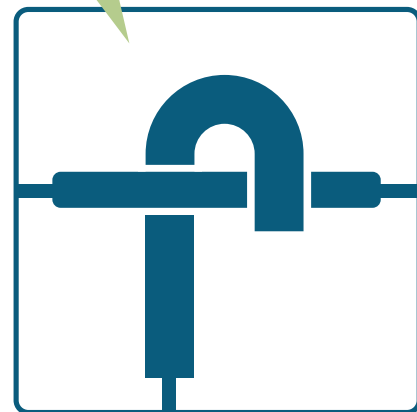
HYBRIDS



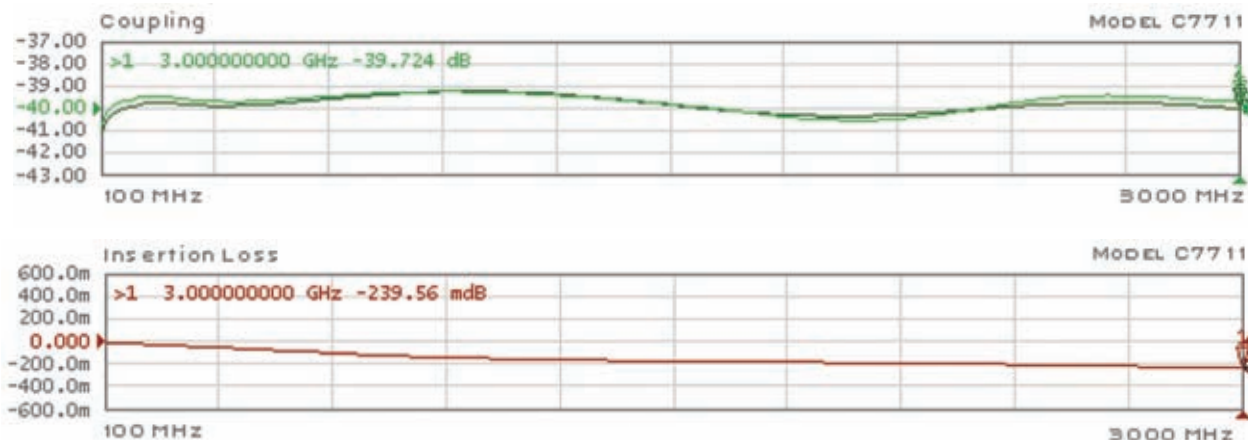
Breaking
all the
Rules

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COUPLERS



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Model	Coupler Type	Frequency (MHz)	Power CW (Watts)	Coupling (dB)	Flatness (±dB)	Insertion Loss (dB)	VSWR (Mainline)	Directivity (dB)	Size (Inches)
C7734	Dual Directional	30-2500	100	43	±1.5	0.35	1.25:1	18	3.5 x 2.6 x 0.7
C7148	Bi Directional	60-600	200	10	±1.0	0.35	1.20:1	20	6.0 x 4.0 x 0.75
C7711	Dual Directional	100-3000	100	40	±1.0	0.35	1.25:1	18	3.0 x 2.2 x 0.7
C7783	Bi Directional	200-1000	200	20	±0.75	0.2	1.20:1	20	3.0 x 1.5 x 0.53
C6600	Bi Directional	200-2000	200	20	±1.2	0.25	1.25:1	18	4.0 x 2.0 x 0.72
C7152	Bi Directional	300-3000	100	20	±1.0	0.35	1.20:1	15	3.7 x 2.0 x 0.75
C7811	Dual Directional	500-2500	100	40	±0.5	0.2	1.25:1	20	3.0 x 2.0 x 0.6
C7753	Bi Directional	700-4200	100	20	±1.0	0.35	1.25:1	18	1.8 x 1.0 x 0.6

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May 2010

Product Selection Guide



Amplifiers

Control Products

Filters

Integrated Products

Optical Components

Connecting the Digital World
to the Global Network®

TriQuint 
SEMICONDUCTOR

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This guide contains a subset of the total selection of products available from TriQuint. If you are unable to locate the product you need, please contact your local sales representative or the factory for more information.

About TriQuint Semiconductor

TriQuint Semiconductor 'Connects the Digital World to the Global Network®' by designing, developing and manufacturing advanced, high-performance RF solutions with Gallium Arsenide (GaAs), Gallium Nitride (GaN), Surface Acoustic Wave (SAW) and Bulk Acoustic Wave (BAW) technologies. TriQuint is an innovation and market diversity leader, serving customers in mobile device, 3G / 4G wireless base station, optical, CATV / FTTH, WLAN, GPS / PND, defense and aerospace markets.



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TriQuint solutions, designed and crafted with the industry's largest in-house technology portfolio, enable quicker design turns while lowering overall system costs. We are an award-winning provider of innovative RF products serving start-up firms as well as the world's largest, most well-established companies. We also support the need for custom solutions through the industry's widest selection of foundry processes based on GaAs and GaN technologies.

In 2009 TriQuint expanded its CATV portfolio with the TriAccess™ line of cable TV and FTTH solutions. CATV products now include 'green' Edge QAM amplifiers (40%+ PAE), low-loss FTTH amplifiers, SAW filters and integrated devices for cable headend, infrastructure and home applications. In 2008, TriQuint acquired WJ Communications in Silicon Valley, California to expand its Networks product line, with an emphasis on standard solutions for 3G / 4G base stations.

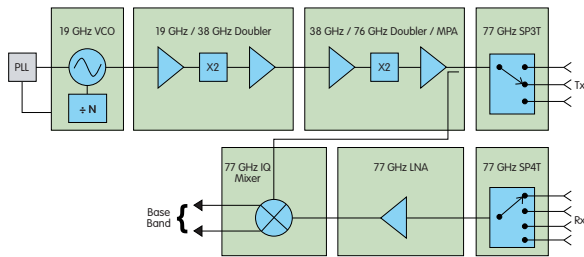
TriQuint's wide-ranging technology portfolio enables us to make highly reliable, high-performance products. Our design and manufacturing processes can reduce design time, enhance performance and reduce BOMs.

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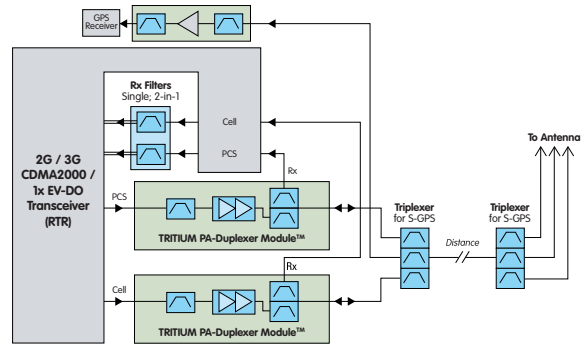
Key advantages of GaAs, GaN, SAW and BAW technologies:

- GaAs can operate efficiently at higher breakdown voltages compared to silicon-based semiconductor technologies while generating less noise in frequencies in excess of 250 MHz. GaAs offers high efficiency, linearity and good wide-band performance.
- GaN offers greater power handling and density than GaAs beginning at 20 MHz; this enables performance at a given power level using fewer or smaller devices. GaN offers strong linearity and efficiency, plus greater wideband capability.
- SAW filter technology offers excellent performance and economy through 2.5 GHz.
- BAW filters offer superior loss levels, stronger ESD performance and greater resistance to temperature effects from 2.5 to 6 GHz.





Example of a 77 GHz Radar Front-End



Cellular & GPS Transceiver for Auto Telematics

Amplifiers & Low Noise Amplifiers

Description	Frequency Range (GHz)	Psat (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
77 GHz LNA	72 - 80	5	20	5	3.5 / 54	Die	TGA4705-FC
77 GHz MPA	76 - 80	14	12	—	3.5 / 75	Die	TGA4706-FC

Switches

Description	Frequency Range (GHz)	Insertion Loss	Isolation (dB)	PI dB (dBm)	Control Voltage (V)	Package Style	Part Number
SP3T	60 - 90	2.3	20	>-13	-5 / 1.35	Die	TGS4305-FC
SP4T	70 - 90	3	20	>-8	-5 / 1.35	Die	TGS4306-FC
SP5T VPIN 77 GHz	71 - 90	2.5	25 / 40	>-8	-5 / 1.35	Die	TGS4307

Frequency Converters & Mixers

Description	Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 / Psat (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
19 GHz VCO w/8:1 Prescaler	18.5 - 19.5	—	-105**	— / 7.0	5 / 158	Die	TGV2204-FC
19 / 38 GHz Converter / MPA	36 - 40	9	—	— / 14.5	3.5 / 65	Die	TGC4703-FC
Down Converting I/Q Mixer	75 - 80	-13.5	22	—	1.1 / 7	Die	TGC4702-FC
38 / 77 GHz Converter / MPA	76 - 78	6	—	— / 15.0	4 / 230	Die	TGC4704-FC

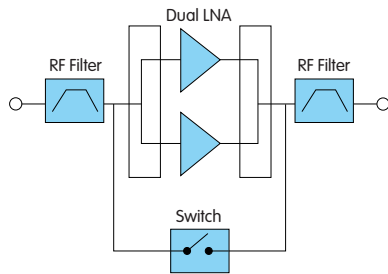
NOTES: ** = Phase Noise (dBc / Hz @ 1 MHz Offset)

Integrated Products

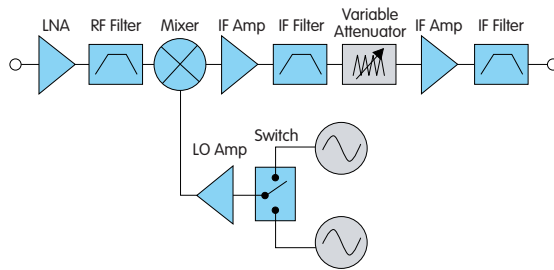
Description	Frequency Bands	Package Size (mm)	Part Number
QB GSM / GPRS Tx Module; PA / LPF / SP6T Switch	GSM850 / 900, DCS / PCS	6.0x6.0x1.1	TQM6M4003
QB GSM / GPRS / EDGE-Polar PA Module	GSM850 / 900, DCS / PCS	5.0x5.0x1.0	TQM7M5012

Filters

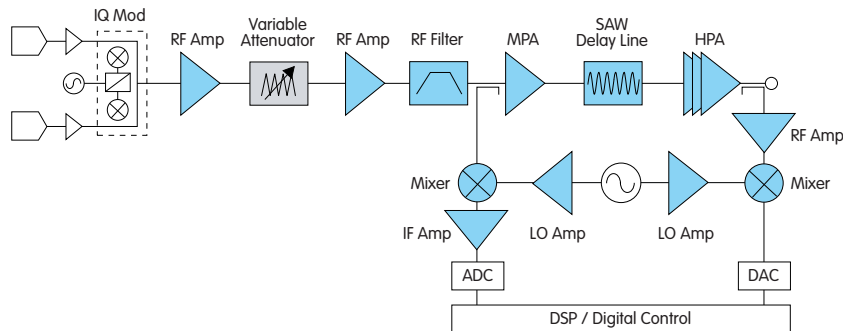
Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Duplexer, Cell Band	836.5 / 881.5	25 / 25	1.9 / 1.9	SE / SE	—	3.8x3.8	856356
GSM850 Rx Filter	881.5	25	1.6	SE / BAL	40 @ 836.5	1.4x1.2	856522
CDMA 2-in-1 Rx Filter	881.5 / 1960	25 / 60	1.6 / 2.2	SE / BAL	—	2.0x1.5	856565
GPS RF Filter	1575.42	2	1.25	SE / SE	30 @ 1624.00	2.0x1.5	856584
GPS RF Filter	1575.42	2	0.75	SE / SE	35 @ 1635.00	1.4x1.2	856561
GPS RF Filter	1575.42	2	1.1	SE / BAL	20 @ 1635.00	1.4x1.2	856576
GPS RF Filter, Auto	1575.42	2	1.8	SE / SE	45 @ 1637.00	3.0x3.0	856039
GPS RF Filter, Auto	1575.42	2	1.3	SE / SE	45 @ 1640.00	3.0x3.0	856139
GSM1900 Rx Filter	1960	60	1.5	SE / BAL	17 @ 1880.00	1.4x1.2	856577
SDARS Filter	2332.5	45	1.7	SE / BAL	35 @ 2100.00	1.4x1.2	856604



Tower Mounted LNA



Base Station Receiver (Single Branch Shown)



Base Station Transmitter & PA

General Purpose Amplifiers

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
General Purpose Gain Block	DC - 3000	18.5 / 33	16.5	3.8	6 / 75	SOT89	AG603
General Purpose Gain Block	DC - 3500	18.5 / 33	13.6	4.4	6 / 75	SOT89	AG602
General Purpose Gain Block	DC - 3500	20.5 / 33.5	17.2	3.5	7 / 96	SOT89	EC1078
General Purpose Gain Block	DC - 4000	19.5 / 31	18.5	2.9	6 / 70	SOT89	EC1019
General Purpose Gain Block	DC - 4000	17.5 / 32	21.5	3.4	6 / 65	SOT89	ECG005
General Purpose Gain Block	DC - 4000	23.5 / 37	14.3	4.6	9 / 120	SOT89	ECG008
General Purpose Gain Block	DC - 4000	18 / 34.5	15.3	5.5	6 / 70	SOT89	ECG040
General Purpose Gain Block	DC - 5500	15 / 30	14.2	3.7	5 / 45	SOT86 / SOT363 / SOT89	ECG006
General Purpose Gain Block	DC - 6000	5.8 / 18.5	11	4.4	5 / 20	SOT86 / SOT363	AG201
General Purpose Gain Block	DC - 6000	7.5 / 19.5	17.7	3.1	5 / 20	SOT86 / SOT363	AG203
General Purpose Gain Block	DC - 6000	12 / 25	14.3	3.2	5 / 35	SOT86 / SOT363	AG302
General Purpose Gain Block	DC - 6000	12.5 / 25	18.4	3	5 / 35	SOT86 / SOT363	AG303
General Purpose Gain Block	DC - 6000	16 / 28.5	14.5	3.7	6 / 60	SOT86 / SOT89	AG402
General Purpose Gain Block	DC - 6000	16 / 28	18.9	3	6 / 60	SOT86 / SOT89	AG403
General Purpose Gain Block	DC - 6000	14.5 / 27.5	19.1	2.9	6 / 45	SOT86 / SOT89	AG503
General Purpose Gain Block	DC - 6000	19 / 33	18.2	3.5	6 / 75	SOT86 / SOT89	AG604
General Purpose Gain Block	DC - 6000	12.5 / 26	21.4	3.4	5 / 30	SOT363 / SOT89	ECG001
General Purpose Gain Block	DC - 6000	15 / 29	19.5	3.7	5 / 45	SOT86 / SOT363 / SOT89	ECG002
General Purpose Gain Block	DC - 6000	23 / 36	19	3.5	9 / 110	SOT89	ECG003
General Purpose Gain Block	DC - 6000	13 / 27	15.5	3.2	5 / 35	SOT89	ECG004
General Purpose Gain Block	DC - 6000	18 / 32	20.1	3.4	6 / 65	SOT86 / SOT89	ECG055
MESFET IF Gain Block	50 - 870	20 / 41	13	3	5 / 150	SOT89	AH3
MESFET IF Amplifier	50 - 1000	22 / 42	19	2.2	5 / 150	SOT89	AH31
+5V Active Bias IF Gain Block	50 - 1000	20.5 / 44	19.5	5	5 / 95	SOT89	WJA1500
+5V Active Bias IF Gain Block	50 - 1000	19.5 / 36.5	19.3	4.7	5 / 65	SOT89	WJA1505
+5V Active Bias IF Gain Block	50 - 1000	20 / 47	14.4	5.4	5 / 95	SOT89	WJA1510
VGA, 20 dB Range, 5V Control	50 - 2200	22 / 42	15.5	4.5	5 / 150	4x4 QFN16	VG025

General Purpose Amplifiers (cont.)

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
+5V Active Bias Gain Block	50 - 2300	19 / 36.5	15	5.2	5 / 85	SOT89	WJA1010
+5V Active Bias Gain Block	50 - 3000	20 / 44	19	5.4	5 / 100	SOT89	WJA1001
+5V Active Bias Gain Block	50 - 4000	20 / 40	18.5	5.6	5 / 90	SOT89	WJA1021
+5V Active Bias Gain Block	50 - 4000	19.5 / 37	14.5	5.5	5 / 80	SOT89	WJA1030
E-pHEMT LNA Gain Block	50 - 4000	21 / 36	20	1.3	5 / 85	SOT89	TQP3M9008*
E-pHEMT LNA Gain Block	50 - 4000	22 / 40	21.5	1.3	5 / 125	SOT89	TQP3M9009*
MESFET Gain Block	60 - 3000	15 / 32	14	2.4	4.5 / 50	SOT89	AG101
MESFET Gain Block	60 - 3000	18 / 36	14	2.4	4.5 / 70	SOT89	AG102
MESFET Gain Block	60 - 3000	18 / 39	14	2.4	4.5 / 78	SOT89	AM1
MESFET Dual Amplifier	150 - 3000	24 / 46	12	4.1	5 / 300	SOIC-8	AH11
MESFET Amplifier	250 - 4000	21.5 / 42	14	3.2	5 / 150	SOT89	AH1
MESFET Amplifier	250 - 4000	21.5 / 42	14	3.2	5 / 150	SOT89	AH1-1

NOTES: * = New

High Linearity Driver Amplifiers

Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
24 dBm HBT Amplifier	10 - 2500	24 / 40	15.5	5.1	5 / 160	SOT89	EC1089
26.5 dBm MESFET Amplifier	50 - 1500	26.5 / 47	13.5	3.5	9 / 200	SOT89	AH101
30 dBm MESFET Amplifier	50 - 2200	30 / 47	17	2.5	11 / 330	6x6 QFN28	AH202
24 dBm HBT Amplifier	60 - 2500	24 / 40	19	5	5 / 150	SOT89	AH114
27 dBm MESFET Amplifier	60 - 2700	27 / 46	29	2.5	4.5; 9 / 275	SOIC-8	AH103A
24 dBm HBT Amplifier	60 - 3500	24 / 40	19.5	4	5 / 160	SOT89	AH118
25 dBm HBT Amplifier	60 - 3500	25 / 40	19.5	4.6	5 / 115	SOT89	AH128
27 dBm MESFET Amplifier	350 - 3000	27 / 46	14.5	3.1	9 / 200	SOT89	AH102A
31 dBm HBT Amplifier	400 - 2300	31 / 46	18	7	5 / 450	4x4 QFN16	ECP100
31 dBm HBT Amplifier	400 - 2300	31 / 46	18	7	5 / 450	SOIC-8	AH215
33 dBm HBT Amplifier	400 - 2300	33 / 49	18	8	5 / 800	4x4 QFN16	ECP200
33 dBm HBT Amplifier	400 - 2300	33 / 49	18	8	5 / 800	SOIC-8	AH312
28.5 dBm HBT Amplifier	400 - 2700	28.5 / 45	20	4.5	5 / 150	SOT89	AH125
31 dBm HBT Amplifier	400 - 2700	31 / 47	20	5.9	5 / 300	SOIC-8	AH225
33 dBm HBT Amplifier	400 - 2700	33 / 49	19.5	4.6	5 / 500	SOIC-8	AH322
35.5 dBm HBT Amplifier	400 - 2700	35.5 / 50	16	7	5 / 800	4x5 DFN12	AH420
VGA, 29 dB Range, 5V Control	700 - 1000	22 / 40	16	3.5	5 / 150	6x6 QFN28	VG101
33 dBm HBT Amplifier	700 - 2700	33 / 50	27.5	7	5 / 680	5x5 QFN20	AH323*
39 dBm HBT Amplifier	700 - 2900	39 / -	16.5	8	12 / 300	5x6 DFN14	AP561
28 dBm HBT Amplifier	700 - 3800	28 / 42	28.5	2.9	5 / 225	4x4 QFN24	TQP8M9013*
28.7 dBm HBT Amplifier	800 - 1000	28.7 / 43	17.5	7	5 / 250	SOIC-8	AH116
28.7 dBm HBT Amplifier	800 - 1000	28.7 / 43	17.5	7	5 / 250	4x4 QFN16	ECP052
VGA, 28 dB Range, 5V Control	1800 - 2200	30 / 46	23	8	5 / 415	6x6 QFN28	VG112
28.5 dBm HBT Amplifier	1800 - 2300	28.5 / 44	14.5	6	5 / 250	SOIC-8	AH115
30 dBm HBT Amplifier	1800 - 2700	30 / 46	24.6	5.5	5 / 400	SOIC-8 / 4x5 DFN12	AH212
VGA, 27 dB Range, 5V Control	1800 - 2700	22 / 39.5	13.5	4.5	5 / 150	6x6 QFN28	VG111
39 dBm HBT Amplifier	3300 - 3800	39 / -	11.5	8	12 / 400	5x6 DFN14	AP562
33 dBm HBT Amplifier	3300 - 3800	33 / -	25	7.3	5 / 600	5x5 QFN20	AH315

NOTES: * = New

Low Noise Amplifiers

Description	Frequency Range (GHz)	P1dB / IIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
LNA, Discrete	DC - 4000	- / 13	17	0.5	3 / 30	SOT343	CFH800
LNA, Balanced FET Low Band	700 - 915	- / 13.5	17	0.4	2.5 / 100	4x4 QFN16	TQP3M6004
LNA, Discrete Low Band High Linearity	700 - 915	26 / 23.5	16	0.8	5 / 150	SOT89	TGF2021-04-SD
LNA, Balanced FET	800 - 3000	21 / 11	22	0.4	4 / 100	SM-O2-6	TGA2602-SM

28V Transistors

Description	Frequency Range (MHz)	P1dB / IMD3 (dBm) / (dBc)	Gain (dB)	Efficiency (%)	Voltage / Current (V / mA)	Package Style	Part Number
InGaP HBT PA, 1.8W, Ultra High Linearity	800 - 2350	32.5 / -60	15.8	55	28 / 40	5x6 DFN14	AP601
InGaP HBT PA, 3.7W, Ultra High Linearity	800 - 2350	35.7 / -62	15.5	55	28 / 80	5x6 DFN14	AP602
InGaP HBT PA, 7W Ultra High Linearity	800 - 2350	38.5 / -51	17	53	28 / 160	5x6 DFN14	AP603

Control Products

Description	Frequency (MHz)	Insertion Loss (dB)	Isolation / Atten Range (dB)	P1dB (dBm)	Control Voltage (V)	Package Style	Part Number
SP3T High Power CDMA	DC - 2000	0.45	28	>36.5	2.6 / 0	MLP12	TQP4M3018
SP3T High Power CDMA	DC - 2000	0.6	22	>34.5	2.6 / 0	STSLP12	TQP4M3019
SP2T General Purpose	DC - 2500	0.3	24	30	3 / 0	SOT363	CSH210R
6-Bit, Digital Attenuator, Parallel Ctrl	DC - 4000	1.3	31.5	30	5 / 0	4x4 QFN24	TQP4M9071*
6-Bit, Digital Attenuator, Serial Ctrl	DC - 4000	1.3	31.5	30	5 / 0	4x4 QFN24	TQP4M9072*
SP2T 802.11 a, b, g	DC - 6000	0.6	28	31.5	3 / 0	SLIM7	TQS5200
Diversity Switch 802.11 a, b, g	DC - 6000	0.8	33	33	3 / 0	MLP12	TQS5202

NOTES: * = New

Frequency Converters & Mixers

Description	RF Frequency Range (MHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage Current (V / mA)	Package Style	Part Number
WB Mixer, LO	500 - 2500	-5.7	8	24	3 - 6 / 6	MW6	CMY210
WB Mixer, LO, IF	500 - 2500	10	8	9	3 - 6 / 12	SCT598	CMY212
WB Mixer, LO, IF, Low Current	500 - 2500	9.5	10	10	3 - 6 / 8	SCT598	CMY213
WB Mixer, LO	500 - 2500	4	-	9	3 - 6 / 6.2	SOT23-6	TQ5M31
Mixer, LO	700 - 1000	-9	17	36	5 / 50	MSOP-8	ML483*
Single Branch Converter, RF, LO, IF	800 - 915	22	60	15	5 / 360	6x6 QFN28	CV110-1A
Dual Branch Converter, LO, IF	800 - 915	10	20	20	5 / 385	6x6 QFN28	CV210-1A
Mixer	800 - 960	-7.3	30	34	N/A	SOIC-8	MH203A
Mixer	800 - 960	-7	37	35	N/A	SOIC-8	MH205A
Single Branch Converter, RF, LO, IF	800 - 960	22	60	15	5 / 360	6x6 QFN28	CV110-3A
Dual Branch Converter, LO, IF	800 - 960	10.5	14	18.5	5 / 390	6x6 QFN28	CV210-3A
Mixer, LO	1600 - 3200	-8.5	2	35	5 / 40	MSOP-8	ML485
Mixer	1700 - 2000	-8.3	30	35	N/A	SOIC-8	MH1A
Single Branch Converter, RF, LO, IF	1700 - 2000	21	45	17	5 / 360	6x6 QFN28	CV111-1A
Dual Branch Converter, LO, IF	1700 - 2000	10	8	19.5	5 / 380	6x6 QFN28	CV211-1A
Mixer, LO	1700 - 2200	-8.2	9	30	5 / 105	SOIC-8	ML401
Single Branch Converter, RF, LO, IF	1900 - 2200	21	40	17	5 / 360	6x6 QFN28	CV111-3A
Dual Branch Converter, LO, IF	1900 - 2700	10	12	20	5 / 380	6x6 QFN28	CV211-2A
Mixer, LO	1900 - 2700	-8.1	9	30	5 / 110	SOIC-8	ML501
Mixer	1900 - 2700	-8.2	28	34	N/A	SOIC-8	MH103A

NOTES: * = New, RF = RF Amplifier, LO = LO Amplifier, IF = IF Amplifier

Discrete Transistors

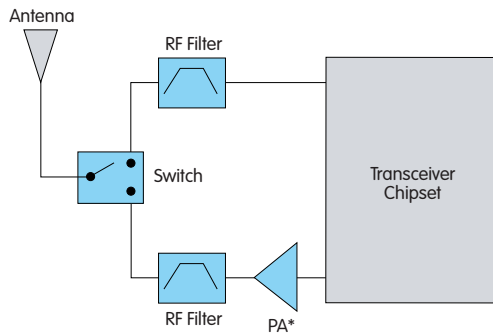
Description	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
MESFET	DC - 2500	26.5 / -	11	1.72 / 55	2 - 6 / 350	SOT223	CLY5
MESFET	DC - 3000	23.5 / -	15.5	1.48 / 55	2 - 6 / 180	MW6	CLY2
0.5W HFET	DC - 6000	28 / 40	18	3.2 / -	8 / 100	SOT89	TGF2960-SD
1W HFET	DC - 6000	31 / 43	16	4 / -	8 / 200	SOT89	TGF2961-SD
MESFET	50 - 4000	21 / 42	19	2 / -	5 / 140	SOT89	FH1
MESFET	50 - 4000	18 / 36	19	2 / -	5 / 140	SOT89	FH101
0.5W HFET	50 - 4000	27 / 40	19	2.7 / -	8 / 125	SOT89	FP1189
1W HFET	50 - 4000	30 / 44	18	4.5 / -	8 / 250	SOT89	FP2189
2.5W HFET	50 - 4000	34 / 46	18	3.5 / -	9 / 450	6x6 QFN28	FP31QF

RF Filters

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
FRS RF or GPS IF Filter	465	6	1.4	SE / SE	40 @ 445.00	3.0x3.0	856288
RF Filter, 700 MHz Band	707	18	1.5	SE / SE	9 @ 728.00	3.0x3.0	856884*
RF Filter, 700 MHz Band	737	18	1.8	SE / SE	37 @ 708.00	3.0x3.0	856883*
RF Filter, 700 MHz Band	751.5	11	1.5	SE / SE	40 @ 776.00	3.0x3.0	856794
RF Filter, 700 MHz Band	781.5	11	1.5	SE / SE	38 @ 757.00	3.0x3.0	856764
RF Filter, 700 MHz Band	782	10	1.52	SE / SE	15 @ 765.00	3.0x3.0	856844*
RF Filter, Cell Band	836.5	25	2.7	SE / SE	28 @ 869.00	3.0x3.0	855729
RF Filter, Cell Band	836.5	25	1.8	SE / SE	30 @ 869.00	3.0x3.0	855779
RF Filter, Cell Band	836.5	25	1.9	SE / SE	35 @ 869.00	3.0x3.0	855821
RF Filter, Cell Band	836.5	25	2.0	SE / SE	10 @ 869.00	3.0x3.0	856704
RF Filter, Cell Band	881.5	25	2.7	SE / SE	40 @ 849.00	3.0x3.0	855728
RF Filter, Cell Band	881.5	25	1.8	SE / SE	35 @ 849.00	3.0x3.0	855782
Cell Band Delay Filter, 450 ns	881.5	25	25	SE / BAL	N/A	7.0x5.5	856716
RF Filter, EGSM	897.5	35	1.9	SE / SE	14 @ 930.00	3.0x3.0	856671
RF Filter, EGSM	897.5	35	1.5	SE / SE	15 @ 930.00	3.0x3.0	856657
RF Filter, EGSM	897.5	35	1.4	SE / SE	10 @ 984.00	3.0x3.0	856824*
RF Filter, EGSM	942.5	35	2	SE / SE	5 @ 915.00	3.0x3.0	855820
RF Filter, EGSM	942.5	35	3.2	SE / SE	12 @ 915.00	3.0x3.0	855810
RF Filter, EGSM	942.5	35	2.5	SE / SE	25 @ 915.00	3.0x3.0	856528
GSM Band Delay Filter, 450 ns	942.5	35	25.5	SE / SE	N/A	7.0x5.5	856766
RF Filter, DCS	1747.5	75	2	SE / SE	22 @ 1676.00	3.0x3.0	856654
RF Filter, DCS	1747.5	75	2.6	SE / SE	10 @ 1681.00	3.0x3.0	856846*
RF Filter, DCS	1842.5	75	1.9	SE / SE	10 @ 1785.00	3.0x3.0	855860
RF Filter, PCS	1880	60	2.4	SE / SE	7 @ 1930.00	3.0x3.0	855849
RF Filter, PCS	1880	60	2.8	SE / SE	30 @ 1930.00	3.0x3.0	856530
RF Filter, PCS	1880	60	2.2	SE / SE	15 @ 1806.00	3.0x3.0	856705
RF Filter, PCS	1880	60	2.3	SE / SE	10 @ 1790.00	3.0x3.0	856880*
RF Filter, UMTS	1950	60	2.2	SE / SE	40 @ 2110.00	3.0x3.0	856532
RF Filter, UMTS	1950	60	1.8	SE / SE	20 @ 2100.00	3.0x3.0	856678
RF Filter, PCS	1960	60	2.1	SE / SE	10.3 @ 1910.00	3.0x3.0	855817
RF Filter, PCS	1960	60	2.3	SE / SE	8 @ 1910.00	3.0x3.0	855850
RF Filter, PCS	1960	60	2.25	SE / SE	14 @ 1910.00	3.0x3.0	856531
Delay Filter, PCS 450 ns	1960	60	25	SE / BAL	N/A	7.0x5.5	856717
Delay Filter, UMTS 450 ns	2140	60	25	SE / BAL	N/A	7.0x5.5	856649
RF Filter, UMTS	2140	60	2.3	SE / SE	25 @ 1980.00	3.0x3.0	856738

NOTES: * = New

TriQuint Semiconductor offers a wide variety of **base station IF filters**. To view a selection of the most common filters, please go to the SAW filter section on pages 31-36.



Broadband Transceiver

** Note: For MIMO implementations, multiple PAs may be required*

Amplifiers

Description	Frequency Range (GHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
39 dBm HBT Amplifier	0.7 - 2.9	39 / –	16.5	8	12 / 300	5x5 QFN20	AP561
WiMAX Driver Amp / PA, SB	2.3 - 2.8	29 / 40	28	–	6 / 710	SM-O5-28	TGA2702-SM
10W HPA, HFET	2.6	40 / 51	12	–	8 / 1200	SG-A4-2	TGA2924-SG
33 dBm HBT Amplifier	3.3 - 3.8	33 / –	25	–	5 / 600	5x5 QFN20	AH315
39 dBm HBT Amplifier	3.3 - 3.8	39 / –	11.5	–	12 / 400	5x6 DFN14	AP562
10W HPA, HFET	3.3 - 3.8	40 / 51	9	–	7 - 9 / 1200	SG-A3-2	TGA2923-SG
WiMAX Driver Amp / PA, SB	3.4 - 3.8	30 / 42	24	–	6 / 770	SM-O5-28	TGA2703-SM
5W HPA, HFET	3.5	37.5 / 49	11	–	8 / 750	SG-A4-2	TGA2925-SG

NOTES: SB = Self Biased

Discrete Transistors

Description	Frequency Range (GHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
MESFET	DC - 3000	23.5 / –	15.5	1.48 / 55	2 - 6 / 180	MW6	CLY2
0.5W HFET	DC - 6000	28 / 40	18	3.2 / –	8 / 100	SOT89	TGF2960-SD
1W HFET	DC - 6000	31 / 43	16	4 / –	8 / 200	SOT89	TGF2961-SD
MESFET	50 - 4000	21 / 42	19	2 / –	5 / 140	SOT89	FH1
MESFET	50 - 4000	18 / 36	19	2 / –	5 / 140	SOT89	FH101
0.5W HFET	50 - 4000	27 / 40	19	2.7 / –	8 / 125	SOT89	FP1189
1W HFET	50 - 4000	30 / 44	18	4.5 / –	8 / 250	SOT89	FP2189
2.5W HFET	50 - 4000	34 / 46	18	3.5 / –	9 / 450	6x6 QFN28	FP31QF

Switches

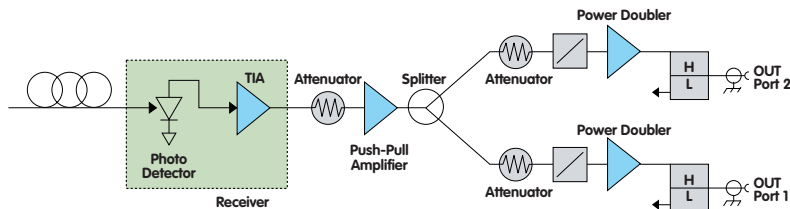
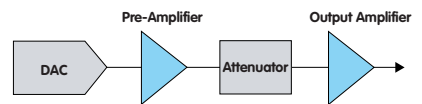
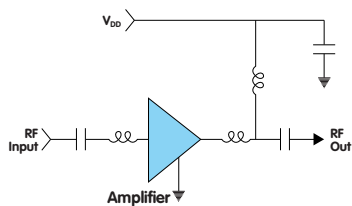
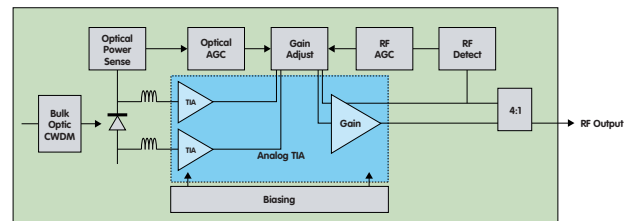
Description	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	P1dB (dBm)	Control Voltage (V)	Package Style	Part Number
SP2T General Purpose	DC - 2.5	0.3	24	30	3 / 0	SOT363	CSH210R
SP2T 802.11 a, b, g	DC - 6	0.6	28	31.5	3 / 0	SLIM7	TQS5200

Filters

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
ISM Passband Filter	2436	72	2	SE / SE	20 @ 2495.00	1.70x1.30	885007
ISM Notch RF Filter	2440	72	1.5 (Out of Band IL)	SE / SE	25 @ 2440.00	1.70x1.30	885008
ISM Notch RF Filter	2440	85	2 (Out of Band IL)	SE / SE	18 @ 2440 (Notch Rej)	1.70x1.30	885010

IF Filters

TriQuint Semiconductor offers a wide variety of BWA / WiMAX IF filters. To view a selection of the most common filters, please go to the SAW filter section on pages 31-36.


CATV Infrastructure

Edge QAM DOCSIS® 3.0

Subscriber Home Amplifiers

FTTH / RfOg

Amplifiers

Description	Application	Frequency Range (MHz)	P1dB / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
Dual HBT Amplifier	General Purpose	DC - 2700	19 / 33	18	3.5	>6 / 75	SOT86 / SOT89	AG604
CATV Ultra Linear PA	Infrastructure GP	40 - 1000	31.5 / 55	12	2.75	12 / 510	SG-01-16	TGA2801D-SG
On-Chip Linearized Amplifier	DOCSIS® 3.0 Output	40 - 1000	- / 43	17	4.7	5 / 380	SOIC-8	TAT7467H*
CATV Gain Block	DOCSIS® 3.0 Output	40 - 1000	27 / 46	20	1.5	8 / 350	SM-08-20	TGA2803-SM
CATV Gain Block	DOCSIS® 3.0 Output	40 - 1000	27 / 46	20	1.5	8 / 350	SM-08-02	TGA2806-SM
CATV Gain Block	DOCSIS® 3.0 Output	40 - 1000	28 / -	18.5	2.5	6 / 318	5x5 QFN	TGA2807-SM*
Dual pHEMT Amplifier, High Gain	Infrastructure GP	50 - 1000	- / 38	17.5	3.2	5 / 235	SOIC-8	TAT7469*
Dual pHEMT Amplifier	Infrastructure GP	50 - 1000	- / 41	13	4.0	6 / 190	SOIC-8	TAT7466*
Dual MESFET Amplifier	Infrastructure GP	50 - 1000	25.5 / 43	11.1	4.5	5 / 320	SOIC-8	AH22S
CATV Gain Block, High Gain	Home Amplifier, MOCA Multi	50 - 1000	- / 41	22.5	2.0	8 / 190	SOT89	TAT7430B*
CATV Gain Block, High Gain	Home Amplifier, MOCA	50 - 1000	- / 39	18	2.0	6 / 145	SOT89	TAT7427*
CATV Gain Block	Home Amplifier	50 - 1000	- / 39	16	2.7	6 / 130	SOT89	TAT7461*
MESFET Amplifier	General Purpose	50 - 1000	20 / 40	14.8	3.5	5 / 150	SOT89	AH2
Single Ended Darlington	Return Path Amplifier	50 - 1000	20 / 37	13.5	4.5	>7 / 165	SOIC-8	AG606
Fiber to the Home TIA + Output Amp	Fiber to the Home, RfOg	50 - 1000	-62 dBc CTB / CSO	32	3.9 pA / rHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254D*
Fiber to the Home TIA + Output Amp	Fiber to the Home, High Output	50 - 1000	-63 dBc CTB / CSO	33	3.9 pA / rHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254C*
MESFET Amplifier	General Purpose	50 - 1500	30 / 50	10.4	5.3	9 / 400	SOT89	AH101
Dual pHEMT Amplifier, Wideband	CATV+SAT Wideband Amp / VONU	50 - 2600	-77 dBc CTB / -83 dBc CSO	13	4.4	5 / 160	SOIC-8	TAT7464*
CATV Gain Block, Wideband	CATV+SAT Wideband Amp / VONU	50 - 2600	- / 36	16.5	2.5	5 / 100	SOT89	TAT7460*
HFET Gain Block	General Purpose	50 - 4000	27 / 39	12.4	2.7	8 / 200	SOT89	FP1189
MMIC Gain Block	General Purpose	60 - 3000	15 / 32	14	2.4	4 - 5 / 50	SOT89	AG101
MESFET Gain Block	General Purpose	60 - 3000	21 / 39	10	2.4	4.5 / 150	SOT89	AM1

NOTES: * = New

Filters

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Cable IF Filter	36.15	8	19.7	SE / SE	38 @ 10.23	DIP	855748
Cable IF Filter	44	6	20.4	SE / SE	38 @ 7.60	DIP	855079
Cable IF Filter	44	6	20.8	SE / SE	38 @ 7.40	24.6x9.0	856129
Cable IF Filter	202.75	1.2	6.6	SE / SE	40 @ 10.00	13.3x6.5	855068
Cable IF Filter	499.25	1	7	SE / SE	35 @ 6.00	9.0x7.0	855104
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046.00	3.0x3.0	855964
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046.00	3.0x3.0	856330
Tuner IF Filter	1090	10	5	BAL / BAL	50 @ 1050.00	3.8x3.8	856096
Tuner IF Filter	1216	8	3.75	BAL / BAL	12 @ 24.00	3.0x3.0	856365
Tuner IF Filter	1220	10	4.5	BAL / BAL	30 @ 60.00	3.0x3.0	856298
Tuner IF Filter	1220	50	3.9	BAL / BAL	33 @ 96.00	3.8x3.8	856598
Tuner IF Filter	1250	96	6	BAL / BAL	44 @ 1152.00	3.0x3.0	856653
Tuner IF Filter	1892	8	4.2	BAL / BAL	23 @ 1932.00	2.5x2.0	856236

Protectors

Description	Application	Leakage Current (nanoAmps)	Trigger Voltage (V)	Series Capacitance (pF)	Package Area (mm ²)	Package Style	Part Number
CATV Protector	ESD & Secondary Protection	20 @ 1V, 500 @ 15V	18, 25, 41	0.29, 0.29, 0.22	1.8	T / SLP-3	TQP200002

GUIDE BY MARKET | Defense & Aerospace

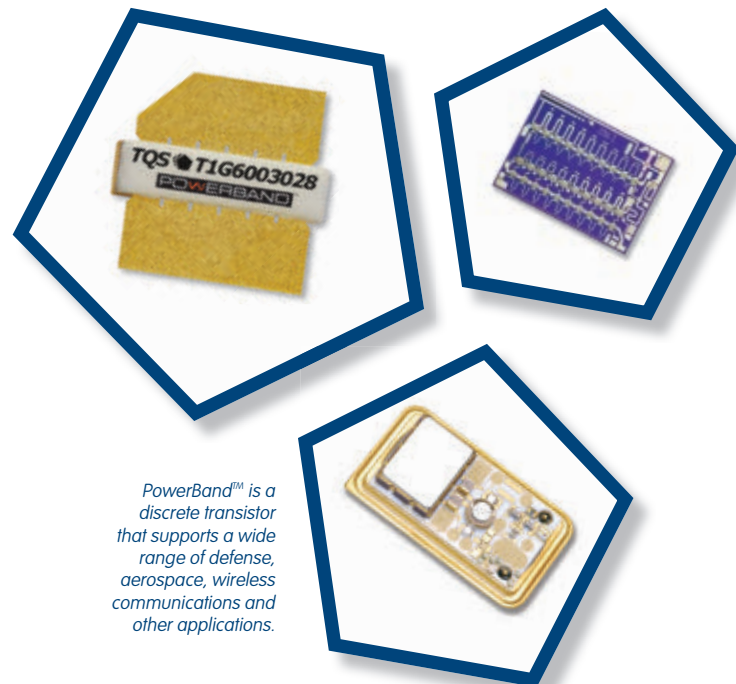
TriQuint Semiconductor is a major supplier of high-performance, high-reliability products for defense, aerospace and similar demanding applications. TriQuint has used its substantial expertise in packaging die-level devices for commercial markets and extended this experience to meet defense contractor requirements. We continue to demonstrate how packaging flexibility, multi-chip modules and high-level integration can benefit defense and commercial customers alike. We are a technology and customer service leader in these applications:

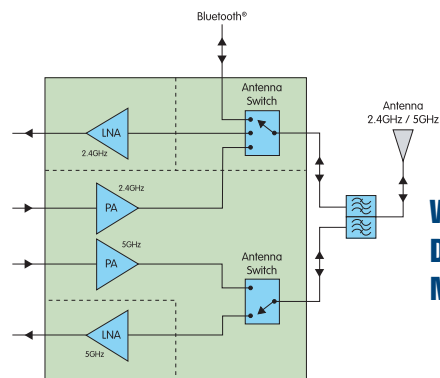
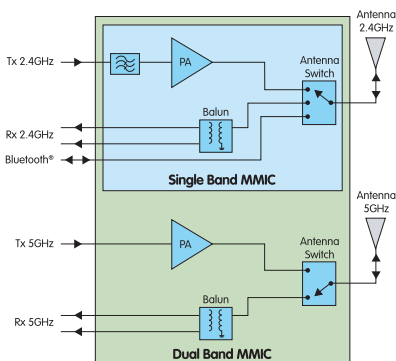
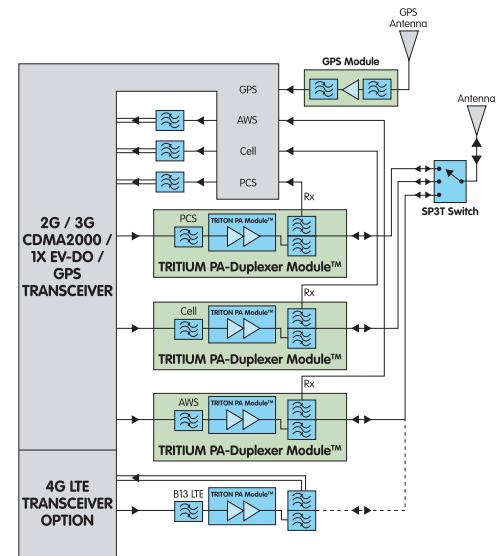
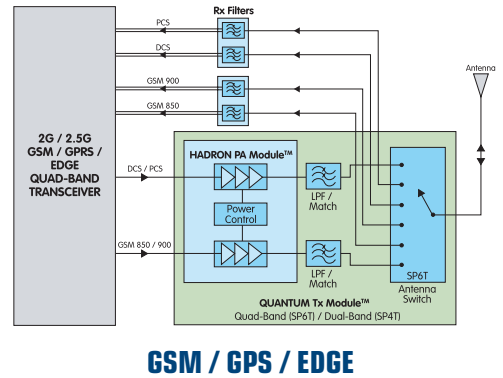
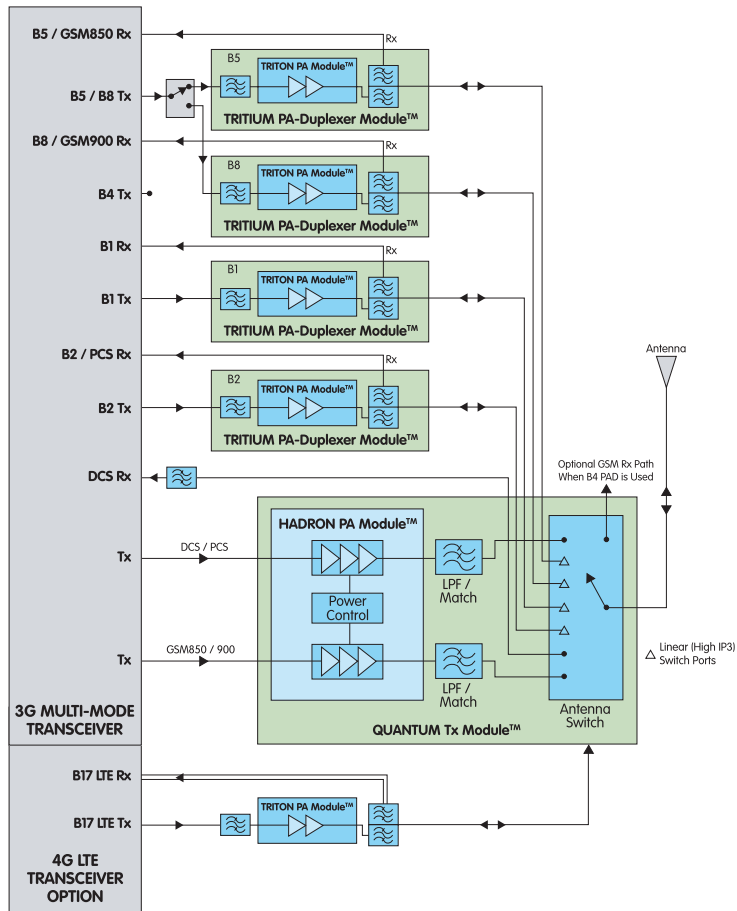
- **Phased Array Radar**
- **Communications**
- **GPS Navigation Systems**
- **Missile Systems**
- **EW**

Many TriQuint products listed elsewhere in this brochure see widespread defense and space usage in support of budget-critical, fast-turnaround COTS applications. Practically any product now in development for non-defense usage (GaAs / GaN amplifiers, switches, filters and integrated devices) can be modified to fit a contractor's particular needs through processes including Class B screening for extra quality assurance. Typical MMIC products in GaN or GaAs HFET, pHEMT, mHEMT or VPIN include:

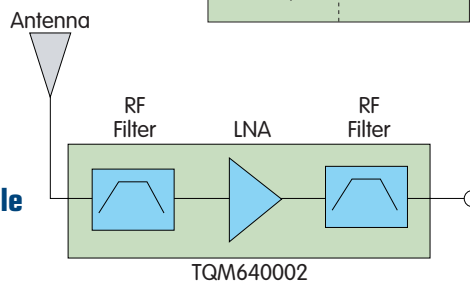
- **Amplifiers**
- **Phase Shifters**
- **Switches**
- **Couplers**

SAW and BAW technology products for defense applications include filters and oscillators. Filter solutions (center frequencies: 30 MHz to 20 GHz) are available in package sizes potentially as small as 1.5x0.8 mm. TriQuint oscillators, with superior phase noise (as low as -180 dBc / Hz; with exceptional g-sensitivity), can provide best-in-class performance.





GPS Integrated Module



GSM / GPRS PA Module

Description	Bands	Features	Package Size (mm)	Part Number
Quad-Band GSM / GPRS PA Module	GSM850 / 900, DCS / PCS	Low Band I _{batt} < 1.1A @ P _{cal} 2 / PAE 55%	5.0x5.0x1.0	TQM7M4007

QUANTUM Tx Module™ Family (GSM / GPRS / EDGE)

Description	Bands	Features	Package Size (mm)	Part Number
Dual-Band GSM / GPRS Tx Module; PA / LPF / SP4T Switch; Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	6.0x6.0x1.1	TQM6M4048
Quad-Band GSM / GPRS Tx Module; PA / LPF / SP6T Switch	GSM850 / 900, DCS / PCS	High Efficiency Broadband Tx, 4 Rx Ports	6.0x6.0x1.1	TQM6M4049
Quad-Band GSM / GPRS / EDGE-Linear TRP Tx Module; PA / LPF / SP6T Switch	GSM850 / 900, DCS / PCS	High GMSK Efficiency & Best TRP	6.0x8.0x1.0	TQM6M5014

HADRON PA Module™ Family (EDGE, 7x7mm Footprint)

Description	Bands	Features	Package Size (mm)	Part Number
Quad-Band GSM / GPRS / EDGE-Polar PA Module	GSM850 / 900, DCS / PCS	-87 dBm Typ Rx Noise, +3 to +8 dBm Pin Nominal	7.0x7.0x1.1	TQM7M5008

HADRON II PA Module™ Family (EDGE, 5x5mm Footprint)

Description	Bands	Features	Package Size (mm)	Part Number
Quad-Band GSM / GPRS / EDGE-Linear PA Module	GSM850 / 900, DCS / PCS	Low Band I _{batt} < 1.5A @ P _{cal} w/PAE 55%	5.0x5.0x1.0	TQM7M5005H
Quad-Band GSM / GPRS / EDGE-Polar PA Module	GSM850 / 900, DCS / PCS	-90 dBm Typ Rx Noise, +3 to +8 dBm Pin Nominal	5.0x5.0x1.0	TQM7M5012H
Quad-Band GSM / GPRS / EDGE-Linear PA Module	GSM850 / 900, DCS / PCS	Input Power Controlled for GMSK & 8PSK	5.0x5.0x1.0	TQM7M5013
Quad-Band GSM / GPRS / EDGE-Polar PA Module	GSM850 / 900, DCS / PCS	+3 to +8 dBm Pin Nominal, Current Limiter	5.0x5.0x1.0	TQM7M5022

CDMA Duplexers & Tx Filters

Description	Bands	Features	Package Size (mm)	Part Number
CDMA Duplexer, SE / SE	Cellular 881.5 / 836.5 MHz	1.9 / 2.4 dB Insertion Loss	3.8x3.8x1.47	856450
CDMA450 Duplexer Block C, SE / BAL	Block C, 452.4 / 462.4 MHz	2.7 / 3.0 dB Insertion Loss	5.0x5.0x1.2	856820
CDMA450 Tx Filter Block C, SE / SE	Block C, 452.4 MHz	1.5 dB Insertion Loss	3.8x3.8x1.27	856867
CDMA450 Duplexer Block A / B, SE / BAL	Block A / B, 455 / 465 MHz	2.6 / 3.0 dB Insertion Loss	5.0x5.0x1.2	856799
CDMA450 Tx Filter Block A / B, SE / SE	Block A / B, 455 MHz	1.5 dB Insertion Loss	3.8x3.8x1.27	856847

CDMA Switches

Description	Bands	Features	Package Size (mm)	Part Number
CDMA SP3T Switch	Cellular / PCS / AWS	Antenna Routing	3.0x3.0x0.9	TQP4M3018
CDMA SP3T Switch	Cellular / PCS / AWS	Antenna Routing	2.0x2.0x0.57	TQP4M3019

TRITON PA Module™ Family (CDMA, WCDMA / HSPA, LTE)

Description	Bands	Features	Package Size (mm)	Part Number
WCDMA / HSPA PA Module, w/Coupler	Band 1	2-Bit (Hi / Med / Lo Power Modes)	4.0x4.0x0.9	TQM776003
WCDMA / HSPA PA Module, w/Coupler	Band 1	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM776011

TRITON PA Module™ Family (CDMA, WCDMA / HSPA, LTE) (cont.)

Description	Bands	Features	Package Size (mm)	Part Number
CDMA & WCDMA / HSPA PA Module, w/Coupler	PCS / Band 2	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM766012
CDMA & WCDMA / HSPA PA Module, w/Coupler	AWS / Band 4	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM756014
CDMA & WCDMA / HSPA PA Module, w/Coupler	Cellular / Band 5	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM716015
WCDMA / HSPA PA Module, w/Coupler	Band 8	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM726018
WCDMA / HSPA PA Module, w/Coupler	Band 1	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM776061
CDMA & WCDMA / HSPA PA Module, w/Coupler	PCS / Band 2	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM766062
CDMA & WCDMA / HSPA PA Module, w/Coupler	Cellular / Band 5	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM716065
WCDMA / HSPA PA Module, w/Coupler	Band 8	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM726068

TRITIUM II PA-Duplexer Module™ Family (CDMA, 7x4mm Footprint)

Description	Bands	Features	Package Size (mm)	Part Number
CDMA PA-Duplexer Module; BAL Input w/Coupler	Cellular	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM613027
CDMA PA-Duplexer Module; SE Input w/Coupler	Cellular	2-Bit (Hi / Med / Lo Power Modes)	7.0x4.0x1.1	TQM613029
CDMA PA-Duplexer Module; SE Input w/Coupler	Cellular	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM613030
CDMA PA-Duplexer Module; SE Input w/Coupler	PCS	2-Bit (Hi / Med / Lo Power Modes)	7.0x4.0x1.1	TQM663029A
CDMA PA-Duplexer Module; SE Input w/Coupler	AWS	2-Bit (Hi / Med / Lo Power Modes)	7.0x4.0x1.1	TQM653029

TRITIUM III PA-Duplexer Module™ Family (WCDMA / HSPA, 7x4mm Footprint)

Description	Bands	Features	Package Size (mm)	Part Number
WCDMA / HSPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 1	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM676021
WCDMA / HSPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 2	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM666022
WCDMA / HSPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 4	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM656024*
WCDMA / HSPA PA-Duplexer Module; SE Input w/Coupler, Detector	Bands 5 & 6	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM616025
WCDMA / HSPA PA-Duplexer Module; SE Input w/Coupler, Detector	Bands 5 & 6	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM616020**
WCDMA / HSPA PA-Duplexer Module; SE Input w/Coupler, Detector	Band 8	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM626028L

NOTES: * = **New**, ** For a specific HSDPA transceiver variant, contact Customer Service.

QUANTUM II Tx Module™ Family (WGPRS & WEDGE)

Description	Bands	Features	Package Size (mm)	Part Number
Quad-Band GSM / GPRS / EDGE-Linear TRP Tx Module: PA / LPF / SP8T WEDGE Switch w/ Quad-Band WCDMA Antenna Pass-Through	GSM850 / 900, DCS / PCS & WCDMA B1, B2, B5 / 6, B8	Integrated QB GSM / GPRS / EDGE PA & Antenna Switch Supporting WCDMA	7.0x7.5x1.1	TQM6M9014

4G LTE Duplexers & Tx Filters

Description	Bands	Features	Package Size (mm)	Part Number
LTE SE / BAL SAW Duplexer	Band 13, 751 MHz Rx / 782 MHz Tx	2.3 dB (Rx) / 1.8 dB (Tx) Insertion Loss	2.5x2.0x0.5	856879
LTE SE / SE Tx SAW Filter	Band 13, 782 MHz	1.9 dB Insertion Loss	1.4x1.2x0.46	856894
LTE SE / BAL SAW Duplexer	Band 17, 710 MHz Tx / 740 MHz Rx	1.2 dB (Tx) / 1.8 dB (Rx) Insertion Loss	2.5x2.0x0.56	856931
LTE SE / SE Tx SAW Filter	Band 17, 710 MHz	1.8 dB Insertion Loss	1.4x1.2x0.46	856911

WLAN PA

Description	Bands	Features	Package Size (mm)	Part Number
5 GHz WLAN PA MMIC	802.11 a	ETSLP-16 Package	3.0x3.0x0.45	TQP787011*
2.4 GHz WLAN PA MMIC	802.11 b, g	VQFN-16 Package	3.0x3.0x0.90	TQP777002

NOTES: * = New

WLAN LNA

Description	Bands	Features	Package Size (mm)	Part Number
5 GHz WLAN LNA MMIC	802.11 a	SLIM-7 Package	1.3x2.0x0.4	TQL5000

WLAN Switch

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz & 5 GHz SPDT Switch MIMC	802.11 a, b, g	ETSLP-6 Package	1.3x2.0x0.45	TQS5200E

WLAN LNA / Antenna Switch

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz WLAN LNA + SP3T Switch MMIC WLAN Tx & Bluetooth® Paths	802.11 b, g	LNA Bypass, ETSLP-12 Package	1.5x1.5x0.55	TQP879007

WLAN PA / Antenna Switch

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz WLAN PA + Switch MMIC w/WLAN Rx Balun & Bluetooth® Path	802.11 a	ETSLP-16 Package	3.0x3.0x0.45	TQM679002A
2.4 GHz & 5 GHz WLAN PA + Switch MMIC w/WLAN Rx Baluns & Bluetooth® Path	802.11 a, b, g, n	ETSLP-24 Package, Coupler / Detector	4.0x4.0x0.45	TQP6M9002

Bluetooth® PA

Description	Bands	Features	Package Size (mm)	Part Number
Bluetooth® EDR v2.0 Class 1 PA MMIC	2.4 to 2.5 GHz ISM Band	STSLP-12 Package	2.0x2.0x0.57	TQP770001
Bluetooth® Class 1 PA MMIC	2.4 to 2.5 GHz ISM Band	SLIM-7 Package	1.3x2.0x0.4	CGB241

GPS LNA

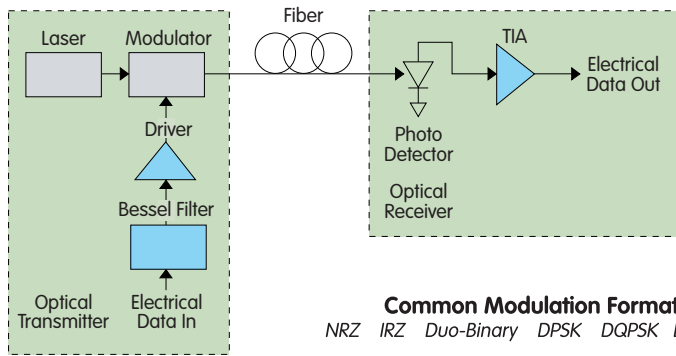
Description	Bands	Features	Package Size (mm)	Part Number
GPS LNA MMIC	1575 MHz, GPS L1	Ultra Compact Package, Shut-off Function	1.3x2.0x0.4	TQP340003

GPS LNA / Filter Module

Description	Bands	Features	Package Size (mm)	Part Number
GPS Filter-LNA-Filter Module	1575 MHz, GPS L1	Low Noise (1.56 dB) and High Gain (16 dB)	3.0x3.0x1.0	TQM640002

GPS Filters

Description	Bands	Features	Package Size (mm)	Part Number
GPS SAW Filter, SE / SE	1.25 dB Insertion Loss (Hermetic CSP)	2.0x1.5x0.76	1575 MHz, GPS L1	856584
GPS SAW Filter, SE / SE	1.0 dB Insertion Loss (Hermetic CSP)	1.5x1.5x0.76	1575 MHz, GPS L1	856463
GPS SAW Filter, SE / SE	Ultra-low Insertion Loss of 0.5 dB (Hermetic CSP)	1.4x1.2x0.46	1575 MHz, GPS L1	856756
GPS SAW Filter, SE / SE	0.75 dB Insertion Loss (Hermetic CSP)	1.4x1.2x0.46	1575 MHz, GPS L1	856561
GPS SAW Filter, SE / BAL	1.1 dB Insertion Loss (Hermetic CSP)	1.4x1.2x0.46	1575 MHz, GPS L1	856576



Optical Systems (10, 40 & 100 Gb/s)

Common Modulation Formats

NRZ IRZ Duo-Binary DPSK DQPSK DP-QPSK

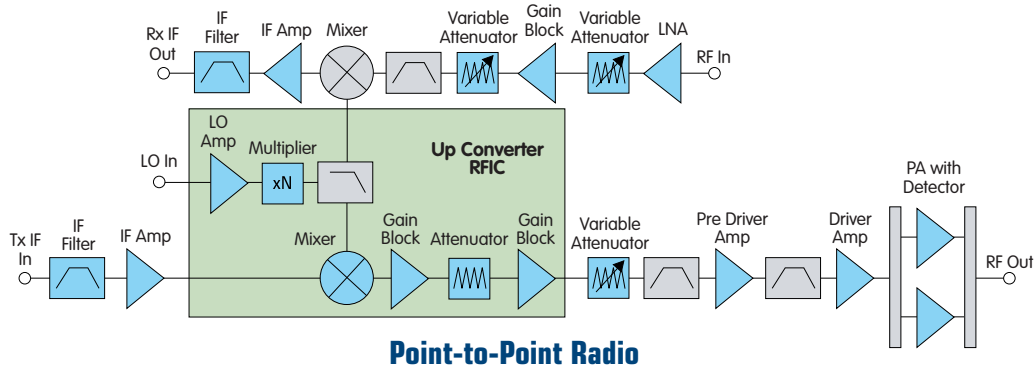
Drivers

Description	Frequency (GHz)	Power (Vpp or dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
9.9 - 12.5 Gb/s 3V - 7V Driver	DC - 13	3 - 7 Vpp	32	–	3.3 - 5 / 115	SM-A8-28	TGA4956-SM
9.9 - 12.5 Gb/s Mod. Driver	DC - 16	3V - 10V	35	2.5	5.5 - 8 / 210	SL-A2-18	TGA4953-SL
9.9 - 12.5 Gb/s Mod. Driver	DC - 16	3V - 9V	35	2.5	5.5 - 8 / 210	SL-A4-18	TGA4954-SL
12.5 Gb/s NRZ Driver	DC - 18	11V	16	–	8 / 285	Die	TGA4807
12.5 Gb/s NRZ Driver	DC - 18	24 dBm	16	3.5	5 - 8 / 70 - 175	Die	TGA1328-SCC
12.5 Gb/s NRZ Driver	DC - 18	8V	16	3.5	8 / 175	SL-A1-12	TGA8652-SL
15 Gb/s 10V Mod. Driver	DC - 20	3 - 10 Vpp	22	–	7 / 280	6x6 QFN	TGA4826-SM*
40 & 100 Gb/s 8 Vpp SE Driver	DC - 30	3 - 9 Vpp	32	–	6 - 7 / 270	SL-A7-21	TGA4943-SL
45 Gb/s 8V pp SE Driver	DC - 35	5 - 9 Vpp	30	–	6 - 7 / 300	SL-A7-21	TGA4942-SL**
45 Gb/s 10 Vpp Diff In / Out Driver	DC - 35	6 - 10 Vpp Diff	27 Diff	–	5 - 6 / 500	–	TGA4958-SL**
Wideband Driver (40 Gb/s)	DC - 35	4V	12	–	5 / 135	Die	TGA4832
40 Gb/s TIA, SE	DC - 40	–	250 dB W	15pA √Hz	5 / 30	Die	TGA4812
LNA / Gain Block	DC - 40	11.5 dBm	13	3.2	5 / 50	Die	TGA4830
LNA / Gain Block	DC - 60	13 dBm	15	3	6 / 50	Die	TGA4811
43 Gb/s Driver	DC - 78	3V	8	5	6 / 82	Die	TGA4803
10.7 - 12.5 Gb/s Linear Mod. Driver	0.03 - 8	25 dBm	20	–	8 / 310	SM-A8-28	TGA4823-2-SM
CATV TIA / Gain Block, SB	0.04 - 1	27 dBm	20	1.5	8 / 350	SM-O8-20	TGA2803-SM

NOTES: * = New, ** = Coming Soon, SB = Self Biased, SE = Single-Ended

Control Products

Description	Frequency (GHz)	Insertion Loss (dB)	Control Range (dB)	P1dB (dBm)	Supply Voltage (V)	Package Style	Part Number
Analog Attenuator	DC - 30	2	17	–	0 to -2	SM-O12-16	TGL4203-SM
Analog Attenuator	DC - >50	2	17	–	0 to -2	Die	TGL4203
Discrete Thru (0 dB Attenuator)	DC - 65	0	0	–	N/A	Die	TGL4201-00
Discrete Attenuators	DC - 65	–	2, 3, 6, 10	–	N/A	SM-O12-16	TGL4201-02, 03, 06, 10
Bessel Filter	–	6, 7, 8, 9, 10 & 11 Cut-Off Freq	–	–	N/A	Die	TGB2010-00, -09 etc.
Bessel Filter	–	5, 6, 6.5, 7.5, 8 & 9 Cut-Off Freq	–	–	N/A	SM-O2-6	TGB2010-00, -09-SM etc.



Amplifiers

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
2W HPA	5.5 - 8.5	32 (34) / 41	30	7 / -	6 / 1260	SM-O13-24	TGA2706-SM
2.5W HPA	5.9 - 8.5	34 / 42	18	7.5 / 37	6 / 1000	SM-O14-28	TGA2701-SM*
HPA	6 - 18	(34.5) / -	24	- / 20	8 / 1200	Die	TGA9092-SCC
Gain Block	6 - 18	12.5 / -	13	5 / -	5 / 80	Die	TGA8035-SCC
2.8W HPA	6 - 18	(34.5) / -	24	- / 20	7 - 9 / 800 - 1200	Die	TGA2501
HPA	7 - 8.5	(38) / -	21	- / 42	7 / 2000	Die	TGA2701
Driver Amp	7 - 13	(30) / 37	25	- / 30	9 / 450	Die	TGA2700
Wideband Driver Amp	8 - 18	13 / -	17	5 / -	4.5 / 50	Die	TGA8399C
HPA	9 - 10.5	(38) / -	20	- / >38	4 - 9 / 2000	Die	TGA2704
HPA	10.5 - 12	(38) / -	19	- / >39	4 - 9 / 2000	Die	TGA2710
Driver Amp, SB	11 - 17	17 / -	23	6 / -	6 / 75	SM-O6-12	TGA2507-SM
Driver Amp, SB	12 - 18	14 / -	17	-	6 / 40	Die	TGA2506
Driver Amp, SB	12 - 18	20 / -	28	6 / -	6 / 80	Die	TGA2507
1W HPA	12 - 19	30 / -	30	-	5 - 7 / 435	Die	TGA2508
HPA	12 - 19	29 / -	25	-	5 - 7 / 435	SM-O6-12	TGA2508-SM
2W HPA	12.3 - 15.7	(31) / -	33	7.0 / -	6 / 850	Die	TGA2520
2W HPA	12.5 - 16	(32) / 37	32	-	6 - 7 / 680	SM-O1-24	TGA2503-SM
2W HPA	12.5 - 17	(34) / -	26	- / 25	7.5 / 650	Die	TGA2510
2W HPA	12.5 - 17	(33.5) / -	25	- / 25	7.5 / 650	SG-A1-6	TGA2510-SG
2W HPA	13 - 17	(34) / 40	32	-	6 - 7 / 680	Die	TGA2503
2W HPA	13 - 17	(34) / -	25	-	6 - 7 / 640	Die	TGA2505
2W HPA	13 - 17	(34) / -	33	-	5 - 8 / 680	FL-A1-10	TGA2904-FL
2W HPA, PD	13 - 17	(34) / 38.5	26	- / 30	7.5 / 650	SG-A1-6	TGA2902-1-SCC-SG
2W HPA	13 - 17	(34) / 40	33	-	5 - 8 / 680	SG-A1-6	TGA8658-SG
4W HPA, Balanced	13 - 17	(36) / 44	25	- / 30	6 - 7 / 1300	Die	TGA2502
2W HPA, PD	13.75 - 14.5	(34) / 38.5	26	- / 30	7.5 / 650	SG-A1-6	TGA2902-2-SCC-SG
1W HPA, PD	17 - 20	30 (32) / 42	20	-	5 - 7 / 825	Die	TGA4530
HPA	17 - 20	31 / 41	22	6.5 / -	6 / 820	SM-O10-20	TGA4532-SM*
HPA	17 - 20	30.5 / 41	23	-	6 / 900	Die	TGA4532*
1W HPA, PD	17 - 21	29 (31) / 41	21	-	6 / 825	SM-A4-20	TGA4530-SM
Driver Amp	17 - 24	22 / -	19	4 / -	5 / 270	SM-O9-16	TGA2521-SM
HPA	17 - 24	31 (32) / 40	23	6 / -	7 / 720	Die	TGA4531
HPA, AGC, PD	17 - 24	(29) / 38	22	-	5 / 712	SM-O10-20	TGA2522-SM
HPA	17 - 27	29 (31) / 37	22	-	7 / 760	Die	TGA4502-SCC
Gain Block & 2x / 3x Multiplier	17 - 37	18 (22) / 26	20	7 / -	5 / 140	SM-O3-16	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	18 (22) / 24	22	7 / -	5 / 140	SM-A3-16	TGA4031-SM
Gain Block, Multiplier	17 - 43	22 / -	25	-	5 / 225	Die	TGA4040
2W HPA	18 - 23	32 (33) / 39	26	-	7 / 840	Die	TGA4022

Amplifiers (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
HPA	18 - 27	29 / 37	14	–	6 / 480	Die	TGA1135-SCC
MPA	19 - 27	25 / 32	22	–	5 - 7 / 220	Die	TGA1073G-SCC
Gain Block	19 - 38	(22) / 30	20	–	5 / 160	Die	TGA4036
MPA	25 - 35	25 / –	18	–	6 / 220	SM-A4-20	TGA4902-SM
MPA	26 - 35	25 (32) / –	19	–	5 - 7 / 220	Die	TGA1073A-SCC
1W HPA	27 - 31	30 / –	22	– / 25	4 - 6 / 420	Die	TGA4509
2W HPA	27 - 31	32.5 (33) / 36.5	20	25 / –	6 / 840	Die	TGA4513
HPA	27 - 32	28.5 / –	25	–	6 - 8 / 420	Die	TGA1073B-SCC
1W HPA	28 - 31	30 / –	19	– / 25	6 / 420	SM-A4-20	TGA4509-SM
Driver Amp	29 - 31	16 (17) / 22	15	–	6 / 60	SM-A4-20	TGA4510-SM
Driver Amp	29 - 37	16 / –	16	–	6 / 60	Die	TGA4510
2W HPA	30 - 40	31.5 (33) / –	20	–	6 / 1050	Die	TGA4516
MPA	32 - 45	24 (25) / 33	16	–	6 / 175	Die	TGA4521
MPA	33 - 47	27 (27.5) / 36	18	–	6 / 400	Die	TGA4522
HPA	37 - 40	28 / 38	24	–	5 / 600	Die	TGA4538*
HPA	36 - 40	26 / –	15	–	5 - 7 / 240	Die	TGA1073C-SCC
HPA	36 - 40	30 / –	14	–	6 - 7 / 500	Die	TGA1171-SCC

NOTES: * = New, SB = Self Biased, AGC = Automatic Gain Control, PD = Power Detector

Low Noise Amplifiers

Description	Frequency Range (GHz)	P1dB / IIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
LNA, AGC	2 - 18	18 / 29	17	2.0	5 / 75	Die	TGA2525
LNA, AGC	2 - 20	19 / –	17.5	2.5	5 / 100	Die	TGA2526
LNA, AGC	2 - 20	17.5 / –	9	3.5	5 - 8 / 60	Die	TGA1342-SCC
LNA, AGC	2 - 20	16 / –	17	2.5	5 / 75	SM-O7-12	TGA2513-SM
LNA, AGC	2 - 23	17 / 26	17	2	5 / 75	Die	TGA2513
LNA, SB, AGC	4 - 14	6 / 16	22	2.3	5 / 90	SM-O4-12	TGA2512-1-SM
LNA, AGC, GB	4 - 14	13 / 24	25	2.3	5 / 160	SM-O4-12	TGA2512-2-SM
LNA, SB, AGC	5 - 15	6 / 13	27	1.4	5 / 90	Die	TGA2512
LNA	6 - 12	2 / –	31	0.7	2.5 / 17	Die	TGA2600
LNA, SB	6 - 13	11 / –	26	1.5	5 / 65	Die	TGA8399B-SCC
LNA, SB, AGC	6 - 14	6 / 12	20	1.3	5 / 90	Die	TGA2511
LNA	20 - 27	12 / –	21	2.2	3.5 / 60	Die	TGA4506
LNA	21 - 27	10 / –	21	2.5	3.5 / 60	SM-A4-20	TGA4506-SM
LNA	28 - 36	12 / 21	22	2.3	3 / 60	Die	TGA4507
LNA	30 - 42	14 / –	21	2.8	3 / 40	Die	TGA4508
LNA	57 - 69	–	13	4	3 / 41	Die	TGA4600

NOTES: SB = Self Biased, AGC = Automatic Gain Control, GB = Gate Bias

Discrete Transistors

Description	Frequency Range (GHz)	P1dB (Psat) (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
24mm HFET	DC - 4	40	13	– / 51	8 / 2170	Die	TGF4124
18mm HFET	DC - 6	38.5	13.5	– / 53	8 / 1690	Die	TGF4118
12mm HFET	DC - 8	37	14	– / 55	8 / 750	Die	TGF4112
4.8mm HFET	DC - 10.5	34	8.5	– / 53	8 / 200	Die	TGF4250-SCC
9.6mm HFET	DC - 10.5	37	9.5	– / 52	8.5 / 520	Die	TGF4260-SCC

Discrete Transistors (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
1.2mm HFET	DC - 12	28.5	10	- / 55	8 / 50	Die	TGF4230-SCC
2.4mm HFET	DC - 12	31.5	10	- / 56	8 / 100	Die	TGF4240-SCC
1mm Pwr pHEMT	DC - 12	(31.5)	11	- / 55	12 / 900	Die	TGF2021-01
2mm Pwr pHEMT	DC - 12	(34.5)	11	- / 55	12 / 150	Die	TGF2021-02
4mm Pwr pHEMT	DC - 12	(37.5)	11	- / 55	12 / 300	Die	TGF2021-04
8mm Pwr pHEMT	DC - 12	(40.2)	11	- / 55	12 / 600	Die	TGF2021-08
12mm Pwr pHEMT	DC - 12	(42)	11	- / 52	12 / 900	Die	TGF2021-12
0.3mm MESFET	DC - 18	13	11	1.5 / -	3 / 15	Die	TGF1350-SCC
0.6mm Pwr pHEMT	DC - 20	(29)	13	- / 56	12 / 45	Die	TGF2022-06
1.2mm Pwr pHEMT	DC - 20	(32)	13	- / 56	12 / 90	Die	TGF2022-12
2.4mm Pwr pHEMT	DC - 20	(35)	13	- / 58	12 / 180	Die	TGF2022-24
4.8mm Pwr pHEMT	DC - 20	(38)	13	- / 58	12 / 360	Die	TGF2022-48
6.0mm Pwr pHEMT	DC - 20	(39)	12.5	- / 53	12 / 448	Die	TGF2022-60
0.3mm pHEMT	DC - 22	16	13	0.8 / -	3 / 15	Die	TGF4350

Switches

Description	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	P1dB (dBm)	Control Voltage (V)	Package Style	Part Number
SP2T 802.11 a, b, g	DC - 6	0.6	28	31.5	3 / 0	SLIM7	TQS5200
SPDT FET	DC - 18	1.5	36	27	-5	Die	TGS2306
SPDT FET	DC - 18	2	39	21	-7 / 0	Die	TGS8250-SCC
SP4T FET	DC - 18	2.5	37	19	0 / -5	Die	TGS8422-SCC
SP3T VPIN	1 - 20	0.5	35	23	10 mA	Die	TGS2303-EEU
SP4T VPIN	1 - 20	0.6	38	23	10 mA	Die	TGS2304-SCC
SP3T VPIN	4 - 18	1	35	20	+/- 2.7	Die	TGS2313
SPDT VPIN	4 - 20	0.9	35	>20	+/- 2.7	Die	TGS2302
SPDT VPIN	24 - 43	<2	36	27	+/- 5	Die	TGS4301
SPDT VPIN	27 - 46	0.9	30	>34	+/- 5 / 15	Die	TGS4302
SPDT VPIN Absorptive	32 - 40	1	36	>33	+/- 5 / 18	Die	TGS4304

Frequency Converters & Mixers

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
Doubler w/Amplifier	16 - 30	18	30	-	5 / 150	Die	TGC4403
Doubler w/Amplifier	16 - 30	18	30	-	5 / 150	SM-O11-16	TGC4403-SM
Upconverting Mixer	17 - 26	-9	40	-	-0.9 / 0	SM-O11-16	TGC4402-SM
Upconverting Mixer	17 - 27	-9	35	18	-0.9 / 0	Die	TGC4402
Upconverter	17 - 27	13	30	-	5 / 425	Die	TGC4405
Upconverter	17 - 27	13	30	-	5 / 425	SM-O11-16	TGC4405-SM
Gain Block & 2x / 3x Multiplier	17 - 37	9	N/A	6	5 / 140	SM-O3-16	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	9	N/A	2	5 / 140	SM-A3-16	TGA4031-SM
Doubler (Input 10 - 20 GHz)	20 - 40	-12	25	18	-	Die	TGC1430F
Tripler (Input 8.5 - 13.5 GHz)	20 - 40	-15	15	18	-	Die	TGC1430G

Control Products

Description	Frequency (GHz)	Insertion Loss (dB)	Control Range (dB)	P1dB (dBm)	Supply Voltage (V)	Package Style	Part Number
Discrete Thru (0 dB Attenuator)	DC - 65	0	0	-	N/A	Die	TGL4201-00
Analog Attenuator	DC - >50	2	17	-	0 to -2	Die	TGL4203
Analog Attenuator	DC - 30	2	17	-	0 to -2	SM-O12-16	TGL4203-SM

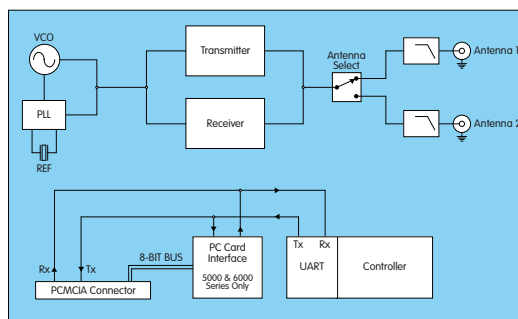
Control Products (cont.)

Description	Frequency (GHz)	Insertion Loss (dB)	Control Range (dB)	P1dB (dBm)	Supply Voltage (V)	Package Style	Part Number
Discrete Attenuators	DC - 65	–	2,3,6,10	–	N/A	SM-012-16	TGL4201-02, 03, 06, 10
Digital Attenuator	0.5 - 18	4	15.5	20	0 / -5	Die	TGL6425-SCC
Analog Attenuator	2 - 20	2	15	23	2.5	Die	TGL8784-SCC
Passive Wideband Limiter	3 - 25	<0.5	N/A	18	N/A	Die	TGL2201
Range Coupler	12 - 21	<0.25	–	–	N/A	Die	TGB2001
Range Coupler	18 - 32	<0.25	–	–	N/A	Die	TGB4001
Range Coupler	27 - 45	<0.25	–	–	N/A	Die	TGB4002

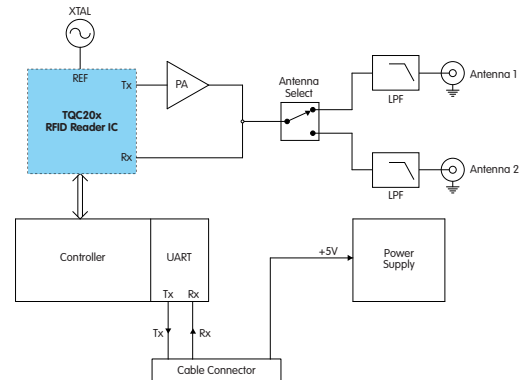
Filters

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
High Selectivity IF Filter	140	1.5	12.1	SE and BAL	48 @ 143.00	9.1x4.8	856691
High Selectivity IF Filter	140	3	13.6	SE and BAL	46 @ 144.00	9.1x4.8	856692
High Selectivity IF Filter	140	6	11	BAL / BAL	39 @ 147.00	9.1x4.8	856693
High Selectivity IF Filter	140	7	13.6	SE and BAL	43 @ 147.00	9.1x4.8	856694
High Selectivity IF Filter	140	10	10	BAL / BAL	41 @ 152.50	9.1x4.8	856695
High Selectivity IF Filter	140	14	8.5	SE and BAL	43 @ 155.00	9.1x4.8	856696
High Selectivity IF Filter	140	20	9.8	BAL / BAL	40 @ 158.50	9.1x4.8	856697
High Selectivity IF Filter	140	28	18	SE and BAL	42 @ 168.00	9.1x4.8	856698

GUIDE BY MARKET | RFID



WJR Series Functional Block Diagram



WJM Series Application Block Diagram

UHF RFID Modules

Description	Frequency (MHz)	Channels / Spacing (kHz)	Max Output Power (W)	Protocol Support	Region of Operation	Interface	Part Number
Reader PCMCIA Form Factor Module (ETSI 302.208)	865.7 - 867.5	4 / 600	1	ISO18000-6B & -6C	Europe	Serial TTL	WJR7081
Reader PCMCIA Form Factor Module (FCC Pt 15)	902.75 - 927.25	50 / 500	1	ISO18000-6C	N. America	Serial TTL	WJR7000
PCMCIA Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	0.5	ISO18000-6B & -6C	N. America	PCMCIA	MPR6000
PCMCIA Reader Module (FCC Pt 15) w/Int. Antenna	902.75 - 927.25	50 / 500	0.5	ISO18000-6B & -6C	N. America	PCMCIA	MPR5000
Embedded Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	1	ISO18000-6B & -6C	N. America	Serial TTL	WJM3000
Embedded Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	0.25	ISO18000-6B & -6C	N. America	Serial TTL	WJM1000
PCMCIA Form Factor Module	910.6 - 913.4	15 / 200	1	ISO18000-6B & -6C	Korea	Serial TTL	WJR7090

Qualified Amplifiers

TriQuint has a proud space / aerospace history, supplying highly-reliable active / passive devices for satellite and planetary missions. Space-level qualification includes high-level visual inspection, 100% element electrical results and wafer lot qualification testing. See tables for standard products already space qualified; most foundry and standard products throughout this brochure may be space qualified.

Qualified Amplifiers							
Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
12.5 Gb/s NRZ Driver	DC - 18	24 / -	16	3.5 / -	5 - 8 / 70 - 175	Die	TGA1328-SCC
Wideband Driver (40 Gb/s)	DC - 35	18 / -	12	-	5 / 135	Die	TGA4832
Gain Block, SB	2 - 10	17 / -	17	6	5 / 90	Die	TGA8810-SCC
Gain Block, AGC	2 - 18	22 / -	23	6	7 / 340	Die	TGA6345-EEU
Gain Block	2 - 18	20 / -	7.5	5.5	6 / 100	Die	TGA8300-SCC
Wideband Gain Block, AGC	2 - 20	20 / -	7.5	7	6 / 150	Die	TGA8622-SCC
Wideband PA, AGC	2 - 20	26 / -	8	-	8 / 440	Die	TGA8334-SCC
0.5W PA	6 - 18	27 / -	11	8 / -	8 / 400	Die	TGA8014-SCC
HPA	6.5 - 11.5	37 (39) / -	19	35	7 - 9 / 1200	Die	TGA9083-SCC
Wideband Driver Amp	8 - 18	13 / -	17	5 / -	4.5 / 50	Die	TGA8399C
HPA	9 - 10.5	(38) / -	20	>38	4 - 9 / 2000	Die	TGA2704
Driver Amp, SB	11 - 17	17 / -	23	6	6 / 75	SM-O6-12	TGA2507-SM
Driver Amp, SB	12 - 18	20 / -	28	6	6 / 80	Die	TGA2507
4W HPA, Balanced	13 - 17	(36) / 44	25	30	6 - 7 / 1300	Die	TGA2502
Gain Block	19 - 38	(22) / 30	20	-	5 / 160	Die	TGA4036
HPA	24 - 31	35.5 (36) / -	23	-	6 / 2100	Die	TGA4505
3.5W HPA	31 - 37	(35.5) / -	20	-	6 / 2000	Die	TGA4517
MPA	32 - 45	24 (25) / 33	16	-	6 / 175	Die	TGA4521

NOTES: SB = Self Biased, AGC = Automatic Gain Control

Qualified Low Noise Amplifiers							
Description	Frequency Range (GHz)	P1dB (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
LNA, AGC	DC - 14	16	11	3.1	8 / 80	Die	TGA8349-SCC
LNA, AGC	2 - 18	16	19	4	5 / 120	Die	TGA8344-SCC
LNA, AGC	2 - 20	17.5	9	3.5	5 - 8 / 60	Die	TGA1342-SCC
LNA, AGC	2 - 20	17.5	9	3.5	5 - 8 / 60	Die	TGA8310-SCC
LNA, SB	6 - 13	11	26	1.5	5 / 65	Die	TGA8399B-SCC
LNA	20 - 27	12	21	2.2	3.5 / 60	Die	TGA4506
LNA	21 - 27	10	21	2.5	3.5 / 60	SM-A4-20	TGA4506-SM
LNA	30 - 42	14	21	2.8	3 / 40	Die	TGA4508

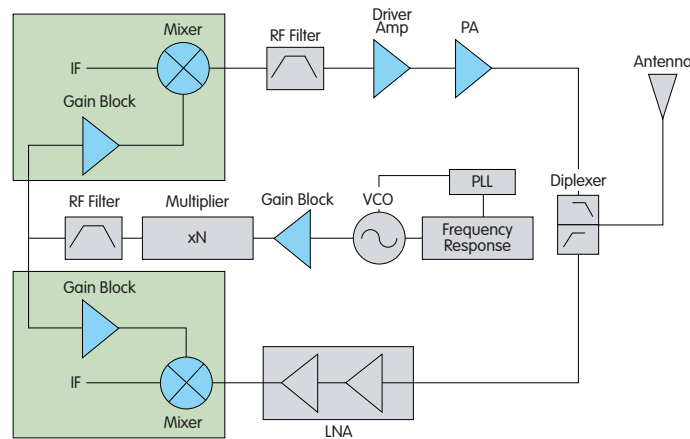
NOTES: SB = Self Biased, AGC = Automatic Gain Control

Qualified Frequency Converters & Mixers							
Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
Tripler (Input 8.5 - 13.5 GHz)	20 - 40	-15	15	18	-	Die	TGC1430G

Qualified Optical Drivers							
Description	Frequency (GHz)	Power (Vpp or dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
12.5 Gb/s NRZ Driver	DC - 18	24 dBm	16	3.5	5 - 8 / 70 - 175	Die	TGA1328-SCC
Wideband Driver (40 Gb/s)	DC - 35	4V	12	-	5 / 135	Die	TGA4832

Qualified Control Products

Description	Frequency (GHz)	Insertion Loss (dB)	Control Range (dB)	P1dB (dBm)	Supply Voltage (V)	Package Style	Part Number
Analog Attenuator	DC - >50	2	17	–	0 to -2	Die	TGL4203
Digital Attenuator	0.5 - 18	4	15.5	20	0 / -5	Die	TGL6425-SCC
Analog Attenuator	2 / 20	2	15	23	2.5	Die	TGL8784-SCC



VSAT RF Subsystem

Amplifiers

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
Driver Amp, SB	11 - 17	17 / –	23	6 / –	6 / 75	SM-O6-12	TGA2507-SM
Driver Amp, SB	12 - 18	14 / –	17	–	6 / 40	Die	TGA2506
Driver Amp, SB	12 - 18	20 / –	28	6 / –	6 / 80	Die	TGA2507
1W HPA	12 - 19	30 / –	30	–	5 - 7 / 435	Die	TGA2508
HPA	12 - 19	29 / –	25	–	5 - 7 / 435	SM-O6-12	TGA2508-SM
2W HPA	12.3 - 15.7	(31) / –	33	7 / –	6 / 850	Die	TGA2520
2W HPA	12.5 - 16	(32) / 37	32	–	6 - 7 / 680	SM-O1-24	TGA2503-SM
2W HPA	12.5 - 17	(34) / –	26	– / 25	7.5 / 650	Die	TGA2510
2W HPA	12.5 - 17	(33.5) / –	25	– / 25	7.5 / 650	SG-A1-6	TGA2510-SG
4W HPA	13 - 15	(36) / 41	25	–	7 / 1300	FL-A1-10	TGA8659-FL
6.5W HPA	13 - 16	(38) / –	24	–	8 / 2600	FL-A2-10	TGA2514-FL
2W HPA	13 - 17	(34) / 40	32	–	6 - 7 / 680	Die	TGA2503
2W HPA	13 - 17	(34) / –	25	–	6 - 7 / 640	Die	TGA2505
2W HPA	13 - 17	(34) / –	33	–	5 - 8 / 680	FL-A1-10	TGA2904-FL
2W HPA	13 - 17	(34) / 40	33	–	5 - 8 / 680	SG-A1-6	TGA8658-SG
2W HPA, PD	13 - 17	(34) / 38.5	26	– / 30	7.5 / 650	SG-A1-6	TGA2902-1-SG
4W HPA, Balanced	13 - 17	(36) / 44	25	– / 30	6 - 7 / 1300	Die	TGA2502
6.5W HPA	13 - 18	(38) / 44	24	–	8 / 3600	Die	TGA2514
2W HPA, PD	13.75 - 14.5	(34) / 38.5	26	– / 30	7.5 / 650	SG-A1-6	TGA2902-2-SG
4W HPA	24 - 31	35.5 (36) / –	23	–	6 / 2100	Die	TGA4505
4W HPA	25 - 31	35.5 (36) / –	22	–	6 / 2100	CP-A1-8	TGA4905-CP

Amplifiers (cont.)

Description	Frequency Range (GHz)	PI dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
MPA	25 - 35	25 / –	18	–	6 / 220	SM-A4-20	TGA4902-SM
7W HPA	26 - 31	(38.5) / –	22	–	6 / 4200	CP-A3-8	TGA4915-CP
1W HPA	27 - 31	30 / –	22	– / 25	4 - 6 / 420	Die	TGA4509
2W HPA	27 - 31	32.5 (33) / 36.5	20	– / 25	6 / 840	Die	TGA4513
MPA	27 - 32	24 / –	15	–	5 / 170	4x4 QFN	TGA4903-SM*
1W HPA	28 - 31	30 / –	19	– / 25	6 / 420	SM-A4-20	TGA4509-SM
4W HPA	28 - 31	36 (36.5) / –	22	– / 22	6 / 1600	Die	TGA4906
4W HPA	28 - 31	36 (36.5) / –	22	– / 22	6 / 1600	SM-A5-24	TGA4906-SM
7W HPA	28 - 31	(38.5) / –	22	– / 20	6 / 3200	Die	TGA4916
Driver Amp	28 - 32	17 / 24	14.5	–	6 / 60	3x3 QFN	TGA4512-SM*
Driver Amp	29 - 31	16 (17) / 22	15	–	6 / 60	SM-A4-20	TGA4510-SM
Driver Amp	29 - 37	16 / –	16	–	6 / 60	Die	TGA4510

NOTES: * = New, SB = Self Biased, PD = Power Detector

Frequency Converters & Mixers

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
Doubler w/Amplifier	16 - 30	18	30	–	5 / 150	Die	TGC4403
Doubler w/Amplifier	16 - 30	15	25	–	5 / 150	SM-O11-16	TGC4406-SM

Up to 1W

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage Current (V / mA)	Package Style	Part Number
Bluetooth® PA	DC - 2.5	22.5 / –	26	– / 50	0 - 5.5 / 200	SLIM-7	CGB241
12.5 Gb/s NRZ Driver	DC - 18	24 / –	16	3.5 / –	5 - 8 / 70 - 175	Die	TGA1328-SCC
12.5 Gb/s NRZ Driver	DC - 18	8 Vpp	16	3.5 / –	8 / 175	SL-A1-12	TGA8652-SL
Wideband Driver (40 Gb/s)	DC - 35	18 / –	12	–	5 / 135	Die	TGA4832
24dBm HBT Amplifier	0.01 - 2.5	24 / 40	15.5	5.1 / –	5 / 160	SOT89	EC1089
CATV TIA / Gain Block, SB	0.04 - 1	27 / 46	20	1.5 / –	8 / 350	SM-O8-02	TGA2806-SM
CATV Gain Block	0.04 - 1	28 / –	18.5	2.5	6 / 318	5x5 QFN	TGA2807-SM*
On-Chip Linearized Amplifier DOCSIS® 3.0 Out	0.04 - 1	– / 43	17	4.7	5 / 380	SOIC-8	TAT7467H*
MESFET IF Gain Block	0.05 - 0.87	20 / 41	13	3 / –	5 / 150	SOT89	AH3
MESFET Amplifier	0.05 - 1	20 / 40	14.8	3.5 / –	5 / 150	SOT89	AH2
Dual HBT Amplifier	0.05 - 1	20 / 37	13.5	4.5 / –	>7 / 165	SOIC-8	AG606
Dual MESFET Amplifier	0.05 - 1	25.5 / 43	11.1	4.5 / –	5 / 320	SOIC-8	AH22S
MESFET IF Amplifier	0.05 - 1	22 / 42	19	2.2 / –	5 / 150	SOT89	AH31
Fiber to the Home TIA + Output Amp (RfOg)	0.05 - 1	-62 dBc CTB/CSO	32	3.9 pA/rfHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254D*
Fiber to the Home TIA + Output Amp (Hi Out)	0.05 - 1	-63 dBc CTB/CSO	33	3.9 pA/rfHz EIN	5, 12 / 200, 130	4x4 QFN	TAT6254C*
Dual pHEMT Amplifier, High Gain	0.05 - 1	– / 38	17.5	3.2	5 / 235	SOIC-8	TAT7469*
CATV Gain Block, High Gain, MOCA Multi	0.05 - 1	– / 41	22.5	2.0	8 / 190	SOT89	TAT7430B*
CATV Gain Block, High Gain, MOCA	0.05 - 1	– / 39	18	2.0	6 / 145	SOT89	TAT7427*
CATV Gain Block	0.05 - 1	– / 39	16	2.7	6 / 130	SOT89	TAT7461*
MESFET Amplifier	0.05 - 1.5	26.5 / 47	13.5	3.5 / –	9 / 200	SOT89	AH101
Dual pHEMT Amplifier	0.05 - 2	– / 41	13	4.0	6 / 190	SOIC-8	TAT7466*
VGA, 20 dB Range, 5V Control	0.05 - 2.2	22 / 42	15.5	4.5 / –	5 / 150	4x4 QFN16	VG025
30 dBm MESFET Amplifier	0.05 - 2.2	30 / 47	17	2.5	11 / 330	6x6 QFN28	AH202
Dual pHEMT Amplifier, Wideband	0.05 - 2.6	-77 dBc CTB / -83 dBc CSO	13	4.4	5 / 160	SOIC-8	TAT7464*
CATV Gain Block, Wideband	0.05 - 2.6	– / 36	16.5	2.5	5 / 100	SOT89	TAT7460*
28.5 dBm HBT Amplifier	0.05 - 2.7	28.5 / 45	20	4.5 / –	5 / 150	SOT89	AH125
E-pHEMT LNA Gain Block	0.05 - 4	21 / 36	20	1.3 / –	5 / 85	SOT89	TQP3M9008*
E-pHEMT LNA Gain Block	0.05 - 5	22 / 40	21.5	1.3 / –	5 / 125	SOT89	TQP3M9009*
24 dBm HBT Amplifier	0.06 - 2.5	24 / 40	19	5 / –	5 / 150	SOT89	AH114
MESFET Amplifier, 2-Stage	0.06 - 2.7	27 / 46	29	2.5 / –	4.5; 9 / 275	SOIC-8	AH103A
MESFET Gain Block	0.06 - 3	15 / 32	14	2.4 / –	4.5 / 50	SOT89	AG101
MESFET Gain Block	0.06 - 3	18 / 36	14	2.4 / –	4.5 / 70	SOT89	AG102
MESFET Gain Block	0.06 - 3	18 / 39	14	2.4 / –	4.5 / 78	SOT89	AM1
24 dBm HBT Amplifier	0.06 - 3.5	24 / 40	19.5	4 / –	5 / 160	SOT89	AH118
24.6 dBm HBT Amplifier	0.06 - 3.5	25 / 40	19.5	4.6 / –	5 / 115	SOT89	AH128
MESFET Dual Amplifier	0.15 - 3	24 / 46	12	4.1 / –	5 / 300	SOIC-8	AH11
MESFET Amplifier	0.25 - 4	21.5 / 42	14	3.2 / –	5 / 150	SOT89	AH1
MESFET Amplifier	0.25 - 4	21.5 / 42	14	3.2 / –	5 / 150	SOT89	AH1-1
MESFET Amplifier	0.35 - 3	27 / 46	14.5	3.1 / –	9 / 200	SOT89	AH102A
VGA, 29 dB Range, 5V Control	0.70 - 1	22 / 40	16	3.5 / –	5 / 150	6x6 QFN28	VG101
28 dBm HBT Amplifier	0.7 - 3.8	28 / 42	28.5	2.9 / –	5 / 225	4x4 QFN24	TQP8M9013*
28.7 dBm HBT Amplifier	0.8 - 1	28.7 / 43	17.5	7 / –	5 / 250	SOIC-8	AH116
28.7 dBm HBT Amplifier	0.8 - 1	28.7 / 43	17.5	7 / –	5 / 250	4x4 QFN16	ECP052
VGA, 28 dB range, 5V Control	1.8 - 2.2	30 / 46	23	8 / –	5 / 415	6x6 QFN28	VG112
28.5 dBm HBT Amplifier	1.8 - 2.3	28.5 / 44	14.5	6 / –	5 / 250	SOIC-8	AH115
VGA, 27 dB Range, 5V Control	1.8 - 2.7	22 / 39.5	13.5	4.5 / –	5 / 150	6x6 QFN28	VG111
Wideband PA, AGC	2 - 20	26 / –	8	–	8 / 440	Die	TGA8334-SCC
Wideband PA, AGC	2 - 22	28.5 (30) / 36	17	–	12 / 1100	Die	TGA2509
WiMAX Driver Amp / PA, SB	2.3 - 2.8	29 / 40	28	–	6 / 710	SM-O5-28	TGA2702-SM

Up to 1W (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
Bluetooth® Class 1 PA	2.4 - 2.5	21.5 / –	27	– / 50	0 - 3.3 / 160	STSLP-12	TQP770001
ISM Band Matched PA, PD	2.4 - 2.5	25 / –	30	–	3.3 / 200	VQFN-16	TQP777002
WiMAX Driver Amp / PA, SB	3.4 - 3.8	30 / 42	24	–	6 / 770	SM-O5-28	TGA2703-SM
0.5W PA	6 - 18	27 / –	11	8 / –	8 / 400	Die	TGA8014-SCC
Driver Amp	7 - 13	(30) / 37	25	– / 30	9 / 450	Die	TGA2700
Wideband Driver Amp	8 - 18	13 / –	17	5 / –	4.5 / 50	Die	TGA8399C
1W HPA	12 - 19	30 / –	30	–	5 - 7 / 435	Die	TGA2508
HPA	12 - 19	29 / –	25	–	5 - 7 / 435	SM-O6-12	TGA2508-SM
1W HPA, PD	17 - 20	30 (32) / 42	20	–	5 - 7 / 825	Die	TGA4530
1W HPA, PD	17 - 21	29 (31) / 41	21	–	6 / 825	SM-A4-20	TGA4530-SM
Driver Amp	17 - 24	22 / –	19	4 / –	5 / 270	SM-O9-16	TGA2521-SM
HPA, AGC, PD	17 - 24	(29) / 38	22	–	5 / 712	SM-O10-20	TGA2522-SM
HPA	17 - 27	29 (31) / 37	22	–	7 / 760	Die	TGA4502-SCC
HPA	18 - 27	29 / 37	14	–	6 / 480	Die	TGA1135-SCC
MPA	19 - 27	25 / 32	22	–	5 - 7 / 220	Die	TGA1073G-SCC
MPA	25 - 35	25 / –	18	–	6 / 220	SM-A4-20	TGA4902-SM
MPA	26 - 35	25 (32) / –	19	–	5 - 7 / 220	Die	TGA1073A-SCC
1W HPA	27 - 31	30 / –	22	– / 25	4 - 6 / 420	Die	TGA4509
MPA	27 - 32	24 / –	15	–	5 / 170	4x4 QFN	TGA4903-SM*
HPA	27 - 32	28.5 / –	25	–	6 - 8 / 420	Die	TGA1073B-SCC
1W HPA	28 - 31	30 / –	19	– / 25	6 / 420	SM-A4-20	TGA4509-SM
Driver Amp	28 - 32	17 / 24	14.5	–	6 / 60	3x3 QFN	TGA4512-SM*
Driver Amp	29 - 31	16 (17) / 22	15	–	6 / 60	SM-A4-20	TGA4510-SM
Driver Amp	29 - 37	16 / –	16	–	6 / 60	Die	TGA4510
MPA	32 - 45	24 (25) / 33	16	–	6 / 175	Die	TGA4521
HPA	36 - 40	26 / –	15	–	5 - 7 / 240	Die	TGA1073C-SCC
HPA	36 - 40	30 / –	14	–	6 - 7 / 500	Die	TGA1171-SCC
MPA	33 - 47	27 (27.5) / 36	18	–	6 / 400	Die	TGA4522
HPA	37 - 40	28 / 38	24	–	5 / 600	Die	TGA4538*
0.5W HPA	40 - 45	28 / –	9	–	7 / 500	Die	TGA4043
Driver Amp	41 - 45	18 / –	14	–	6 / 168	Die	TGA4042

NOTES: * = New, SB = Self Biased, AGC = Automatic Gain Control, PD = Power Detector

1W to 4W

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
CATV Ultra Linear HPA	0.04 - 1	31.5 / 55	12	2.75 / –	12 / 510	SG-O1-16	TGA2801D-SG
31 dBm HBT Amplifier	0.4 - 2.3	31 / 46	18	7 / –	5 / 450	4x4 QFN16	ECP100
33 dBm HBT Amplifier	0.4 - 2.3	33 / 49	18	8 / –	5 / 800	4x4 QFN16	ECP200
31 dBm HBT Amplifier	0.4 - 2.3	31 / 46	18	7 / –	5 / 450	SOIC-8	AH215
33 dBm HBT Amplifier	0.4 - 2.3	33 / 49	18	8 / –	5 / 800	SOIC-8	AH312
31.5 dBm HBT Amplifier	0.4 - 2.7	31 / 47	20	5.9 / –	5 / 300	SOIC-8	AH225
33.5 dBm HBT Amplifier	0.4 - 2.7	33.5 / 50	19	4.6 / –	5 / 500	SOIC-8	AH322
35.5 dBm HBT Amplifier	0.4 - 2.7	35.5 / 50	16	7 / –	5 / 800	4x5 DFN12	AH420
33 dBm HBT Amplifier	0.7 - 2.7	33 / 50	27.5	7	5 / 680	5x5 QFN20	AH323*
InGaP HBT PA, 1.8W, Ultra High Linearity	0.8 - 2.35	32.5 / 49	15.8	– / 55	28 / 40	5x6 DFN14	AP601
InGaP HBT PA, 3.7W, Ultra High Linearity	0.8 - 2.35	35.7 / 52	15.5	– / 55	28 / 80	5x6 DFN14	AP602
30 dBm HBT Amplifier	1.8 - 2.7	30.5 / 46.5	27	5.5 / –	5 / 400	SOIC-8 / 4x5 DFN12	AH212
33 dBm HBT Amplifier	3.3 - 3.8	33 / –	25	–	5 / 600	5x5 QFN20	AH315
2W HPA	5.5 - 8.5	32 (34) / 41	30	7 / –	6 / 1260	SM-O13-24	TGA2706-SM
2.5W HPA	5.9 - 8.5	34 / 42	18	7.5 / 37	6 / 1000	SM-O14-28	TGA2701-SM*

1 W to 4 W (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
2.8W HPA	6 - 18	(34.5) / –	24	– / 20	7 - 9 / 800 - 1200	Die	TGA2501
HPA	6 - 18	(34.5) / –	24	– / 20	8 / 1200	Die	TGA9092-SCC
2W HPA	12.3 - 15.7	(31) / –	33	7 / –	6 / 850	Die	TGA2520
2W HPA	12.5 - 16	(32) / 37	32	–	6 - 7 / 680	SM-O1-24	TGA2503-SM
2W HPA	12.5 - 17	(34) / –	26	– / 25	7.5 / 650	Die	TGA2510
2W HPA	12.5 - 17	(33.5) / –	25	– / 25	7.5 / 650	SG-A1-6	TGA2510-SG
4W HPA	13 - 15	(36) / 41	25	–	7 / 1300	FL-A1-10	TGA8659-FL
2W HPA	13 - 17	(34) / 40	32	–	6 - 7 / 680	Die	TGA2503
2W HPA	13 - 17	(34) / –	25	–	6 - 7 / 640	Die	TGA2505
2W HPA, PD	13 - 17	(34) / 38.5	26	– / 30	7.5 / 650	SG-A1-6	TGA2902-1-SG
2W HPA	13 - 17	(34) / –	33	–	5 - 8 / 680	FL-A1-10	TGA2904-FL
2W HPA	13 - 17	(34) / 40	33	–	5 - 8 / 680	SG-A1-6	TGA8658-SG
2W HPA, PD	13.75 - 14.5	(34) / 38.5	26	– / 30	7.5 / 650	SG-A1-6	TGA2902-2-SG
HPA	17 - 20	30.5 / 41	23	– / –	6 / 900	Die	TGA4532*
HPA	17 - 20	31 / 41	22	6.5 / –	6 / 820	SM-O10-20	TGA4532-SM*
HPA	17 - 24	31 (32) / 40	23	6 / –	7 / 720	Die	TGA4531
2W HPA	18 - 23	32 (33) / 39	26	–	7 / 840	Die	TGA4022
4W HPA	24 - 31	35.5 (36) / –	23	–	6 / 2100	Die	TGA4505
4W HPA	25 - 31	35.5 (36) / –	22	–	6 / 2100	CP-A1-8	TGA4905-CP
2W HPA	27 - 31	32.5 (33) / 36.5	20	– / 25	6 / 840	Die	TGA4513
2W HPA	30 - 40	31.5 (33) / –	20	–	6 / 1050	Die	TGA4516
2W HPA	31 - 35	31.5 (33.5) / –	19	–	6 - 7 / 1150	Die	TGA4514
3.5W HPA	31 - 37	(35.5) / –	20	–	6 / 2000	Die	TGA4517
2W HPA	41 - 47	(33) / –	16	–	6 / 2000	Die	TGA4046
77 GHz MPA	76 - 80	14 / –	12	–	3.5 / 75	Die	TGA4706-FC

NOTES: * = New, PD = Power Detector

More Than 4W

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	PAE (%)	Voltage / Current (V / mA)	Package Style	Part Number
10W HPA	0.03 - 3	39.5 / 43	19.5	40	35 / 360	Flange	TGA2540-FL*
39 dBm HBT Amplifier	0.7 - 2.9	39 / –	16.5	8	12 / 300	5x6 DFN14	AP561
InGaP HBT PA, 7W Ultra High Linearity	0.8 - 2.35	38.5 / 55.5	17	53	28 / 160	5x6 DFN14	AP603
14W HPA	2 - 18	41.5 / –	10	23	35 / 1200	Die	TGA2573*
10W HPA, HFET	2.6	40 / 51	12	–	8 / 1200	SG-A4-2	TGA2924-SG
39 dBm HBT Amplifier	3.3 - 3.8	39 / –	11.5	–	12 / 400	5x6 DFN14	AP562
10W HPA, HFET	3.3 - 3.8	40 / 51	9	–	7 - 9 / 1200	SG-A3-2	TGA2923-SG
5W HPA, HFET	3.5	37.5 / 49	11	–	8 / 750	SG-A4-2	TGA2925-SG
HPA	6.5 - 11.5	37 (39) / –	19	35	7 - 9 / 1200	Die	TGA9083-SCC
16W HPA	6.5 - 12.5	42 / –	27	35	12 / 3000	Die	TGA2517
HPA	7 - 8.5	(38) / –	21	42	7 / 2000	Die	TGA2701
HPA	9 - 10.5	(38) / –	20	>38	4 - 9 / 2000	Die	TGA2704
HPA	10.5 - 12	(38) / –	19	>39	4 - 9 / 2000	Die	TGA2710
6.5W HPA	13 - 16	(38) / –	24	–	8 / 2600	FL-A2-10	TGA2514-FL
4W HPA, Balanced	13 - 17	(36) / 44	25	30	6 - 7 / 1300	Die	TGA2502
6.5W HPA	13 - 18	(38) / 44	24	–	8 / 3600	Die	TGA2514
7W HPA	26 - 31	(38.5) / –	22	–	6 / 4200	CP-A3-8	TGA4915-CP
4W HPA	28 - 31	36 (36.5) / –	22	22	6 / 1600	Die	TGA4906
4W HPA	28 - 31	36 (36.5) / –	22	– / 22	6 / 1600	SM-A5-24	TGA4906-SM
7W HPA	28 - 31	(38.5) / –	22	20	6 / 3200	Die	TGA4916

NOTES: * = New, PD = Power Detector

Gain Block

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
General Purpose Gain Block	DC - 3	18.5 / 33	16.5	3.8	6 / 75	SOT89	AG603
General Purpose Gain Block	DC - 3.5	18.5 / 33	13.6	4.4	6 / 75	SOT89	AG602
General Purpose Gain Block	DC - 3.5	20.5 / 33.5	17.2	3.5	7 / 96	SOT89	EC1078
General Purpose Gain Block	DC - 4	19.5 / 31	18.5	2.9	6 / 70	SOT89	EC1019
General Purpose Gain Block	DC - 4	17.5 / 32	21.5	3.4	6 / 65	SOT89	ECG005
General Purpose Gain Block	DC - 4	23.5 / 37	14.3	4.6	9 / 120	SOT89	ECG008
General Purpose Gain Block	DC - 4	18 / 34.5	15.3	5.5	6 / 70	SOT89	ECG040
General Purpose Gain Block	DC - 5.5	15 / 30	14.2	3.7	5 / 45	SOT86 / SOT363 / SOT89	ECG006
General Purpose Gain Block	DC - 6	5.8 / 18.5	11	4.4	5 / 20	SOT86 / SOT363	AG201
General Purpose Gain Block	DC - 6	7.5 / 19.5	17.7	3.1	5 / 20	SOT86 / SOT363	AG203
General Purpose Gain Block	DC - 6	12 / 25	14.3	3.2	5 / 35	SOT86 / SOT363	AG302
General Purpose Gain Block	DC - 6	12.5 / 25	18.4	3	5 / 35	SOT86 / SOT363	AG303
General Purpose Gain Block	DC - 6	16 / 28.5	14.5	3.7	6 / 60	SOT86 / SOT89	AG402
General Purpose Gain Block	DC - 6	16 / 28	18.9	3	6 / 60	SOT86 / SOT89	AG403
General Purpose Gain Block	DC - 6	14.5 / 27.5	19.1	2.9	6 / 45	SOT86 / SOT89	AG503
General Purpose Gain Block	DC - 6	19 / 33	18.2	3.5	6 / 75	SOT86 / SOT89	AG604
General Purpose Gain Block	DC - 6	12.5 / 26	21.4	3.4	5 / 30	SOT363 / SOT89	ECG001
General Purpose Gain Block	DC - 6	15 / 29	19.5	3.7	5 / 45	SOT86 / SOT363 / SOT89	ECG002
General Purpose Gain Block	DC - 6	23 / 36	19	3.5	9 / 110	SOT89	ECG003
General Purpose Gain Block	DC - 6	13 / 27	15.5	3.2	5 / 35	SOT89	ECG004
General Purpose Gain Block	DC - 6	18.2 / 32	20.1	3.4	6 / 65	SOT86 / SOT89	ECG055
LNA / Gain Block	DC - 40	11.5 / 20	13	3.2	5 / 50	Die	TGA4830
LNA / Gain Block	DC - 60	13 / 21	15	3	6 / 50	Die	TGA4811
CATV TIA / Gain Block, SB	0.04 - 1	27 / 46	20	1.5	8 / 350	SM-O8-20	TGA2803-SM
+5V Active Bias IF Gain Block	0.05 - 1	20.5 / 33	17.5	5	5 / 95	SOT89	WJA1500
+5V Active Bias IF Gain Block	0.05 - 1	19 / 33.5	17.5	4.7	5 / 65	SOT89	WJA1505
+5V Active Bias IF Gain Block	0.05 - 1	20 / 36	14	5.4	5 / 95	SOT89	WJA1510
+5V Active Bias Gain Block	0.05 - 2.3	19 / 28.5	14	5.2	5 / 85	SOT89	WJA1010
+5V Active Bias Gain Block	0.05 - 3	20 / 34	16.7	5.4	5 / 100	SOT89	WJA1001
+5V Active Bias Gain Block	0.05 - 4	20 / 37.5	16.7	5.6	5 / 90	SOT89	WJA1021
+5V Active Bias Gain Block	0.05 - 4	19.3 / 36.5	14.5	5.5	5 / 80	SOT89	WJA1030
Gain Block	2 - 6	17 / -	13.5	5.5	15 / 68	Die	TGA8226-SCC
Gain Block, SB	2 - 10	17 / -	17	6	5 / 90	Die	TGA8810-SCC
Gain Block, AGC	2 - 18	22 / -	23	6	7 / 340	Die	TGA6345
Gain Block	2 - 18	20 / -	7.5	5.5	6 / 100	Die	TGA8300-SCC
Wideband Gain Block, AGC	2 - 20	20 / -	7.5	7	6 / 150	Die	TGA8622-SCC
Gain Block	6 - 18	12.5 / -	13	5	5 / 80	Die	TGA8035-SCC
Driver Amp, SB	11 - 17	17 / -	23	6	6 / 75	SM-O6-12	TGA2507-SM
Driver Amp, SB	12 - 18	14 / -	17	-	6 / 40	Die	TGA2506
Driver Amp, SB	12 - 18	20 / -	28	6	6 / 80	Die	TGA2507
Gain Block & 2x / 3x Multiplier	17 - 37	18 (22) / 26	20	7	5 / 140	SM-O3-16	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	18 (22) / 24	22	7	5 / 140	SM-A3-16	TGA4031-SM
Gain Block, Multiplier	17 - 43	22 / -	25	-	5 / 225	Die	TGA4040
Gain Block	19 - 38	(22) / 30	20	-	5 / 160	Die	TGA4036

NOTES: SB = Self Biased, AGC = Automatic Gain Control

Low Noise

Description	Frequency Range (GHz)	P1dB / IIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
LNA, Discrete	DC - 4	- / 13	17	0.5	3 / 30	SOT343	CFH800
LNA, AGC	DC - 14	16 / -	11	3.1	8 / 80	Die	TGA8349-SCC

Low Noise (cont.)

Description	Frequency Range (GHz)	P1dB / IIP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
LNA / Gain Block	DC - 40	11.5 / 20	13	3.2	5 / 50	Die	TGA4830
LNA / Gain Block	DC - 60	13 / 21	15	3	6 / 50	Die	TGA4811
LNA, SB	0.1 - 3.5	15 / -	18	2.4	12 / 112	Die	TGA8061-SCC
LNA, Balanced FET Low Band	0.7 - 0.92	- / 13.5	17	0.7	2.5 / 100	4x4 QFN16	TQP3M6004
LNA, Discrete Low Band	0.7 - 0.92	26 / 23.5	16	0.8	5 / 150	SOT89	TGF2021-04-SD
LNA, Balanced FET	0.8 - 3	21 / 11	22	0.7	4 / 100	SM-O2-6	TGA2602-SM
LNA, AGC	2 - 18	18 / 29	17	2.0	5 / 75	Die	TGA2525
LNA, AGC	2 - 18	16 / -	19	4	5 / 120	Die	TGA8344-SCC
LNA, AGC	2 - 20	17.5 / -	9	3.5	5 - 8 / 60	Die	TGA1342-SCC
LNA, AGC	2 - 20	19 / -	17.5	2.5	5 / 100	Die	TGA2526*
LNA, AGC	2 - 20	17.5 / -	9	3.5	5 - 8 / 60	Die	TGA8310-SCC
LNA, AGC	2 - 20	16 / -	17	2.5	5 / 75	SM-O7-12	TGA2513-SM
LNA, AGC	2 - 23	17 / 26	17	2	5 / 75	Die	TGA2513
LNA, SB, AGC	4 - 14	6 / 16	22	2.3	5 / 90	SM-O4-12	TGA2512-1-SM
LNA, AGC, GB	4 - 14	13 / 24	25	2.3	5 / 160	SM-O4-12	TGA2512-2-SM
LNA	4.9 - 6	5 / -3	18	1.3	3 / 8	SLIM-7	TQL5000
LNA, SB, AGC	5 - 15	6 / 13	27	1.4	5 / 90	Die	TGA2512
LNA	6 - 12	2 / -	31	0.7	2.5 / 17	Die	TGA2600
LNA, SB	6 - 13	11 / -	26	1.5	5 / 65	Die	TGA8399B-SCC
LNA, SB, AGC	6 - 14	6 / 12	20	1.3	5 / 90	Die	TGA2511
LNA	20 - 27	12 / -	21	2.2	3.5 / 60	Die	TGA4506
LNA	21 - 27	10 / -	21	2.5	3.5 / 60	SM-A4-20	TGA4506-SM
LNA	28 - 36	12 / 21	22	2.3	3 / 60	Die	TGA4507
LNA	30 - 42	14 / -	21	2.8	3 / 40	Die	TGA4508
LNA	57 - 69	-	13	4	3 / 41	Die	TGA4600
77 GHz LNA	72 - 80	-	20	5	3.5 / 54	Die	TGA4705-FC

NOTES: * = New, SB = Self Biased, AGC = Automatic Gain Control, GB = Gate Bias

Discrete Transistors

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
MESFET	DC - 2.5	26.5 / -	11	1.72 / 55	2 - 6 / 350	SOT223	CLY5
MESFET	DC - 3	23.5 / -	15.5	1.48 / 55	2 - 6 / 180	MW6	CLY2
24mm HFET	DC - 4	40 / -	13	- / 51	8 / 2170	Die	TGF4124
18mm HFET	DC - 6	38.5 / -	13.5	- / 53	8 / 1690	Die	TGF4118
0.5W HFET	DC - 6	28 / 40	18	3.2 / -	8 / 100	SOT89	TGF2960-SD
1W HFET	DC - 6	31 / 43	16	4 / -	8 / 200	SOT89	TGF2961-SD
12mm HFET	DC - 8	37 / -	14	- / 55	8 / 750	Die	TGF4112
4.8mm HFET	DC - 10.5	34 / -	8.5	- / 53	8 / 200	Die	TGF4250-SCC
9.6mm HFET	DC - 10.5	37 / -	9.5	- / 52	8.5 / 520	Die	TGF4260-SCC
1.2mm HFET	DC - 12	28.5 / -	10	- / 55	8 / 50	Die	TGF4230-SCC
2.4mm HFET	DC - 12	31.5 / -	10	- / 56	8 / 100	Die	TGF4240-SCC
1mm Pwr pHEMT	DC - 12	(31.5) / -	11	- / 55	12 / 900	Die	TGF2021-01
2mm Pwr pHEMT	DC - 12	(34.5) / -	11	- / 55	12 / 150	Die	TGF2021-02
4mm Pwr pHEMT	DC - 12	(37.5) / -	11	- / 55	12 / 300	Die	TGF2021-04
8mm Pwr pHEMT	DC - 12	(40.2) / -	11	- / 55	12 / 600	Die	TGF2021-08
12mm Pwr pHEMT	DC - 12	(42) / -	11	- / 52	12 / 900	Die	TGF2021-12
0.3mm MESFET	DC - 18	13 / -	11	1.5 / -	3 / 15	Die	TGF1350-SCC
1.25mm GaN HEMT	DC - 18	38	15	- / 55	28 / 125	Die	TGF2023-01*
2.5mm GaN HEMT	DC - 18	41	15	- / 55	28 / 250	Die	TGF2023-02*
5.0 GaN HEMT	DC - 18	44	15	- / 55	28 / 500	Die	TGF2023-05*

Discrete Transistors (cont.)

Description	Frequency Range (GHz)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
10mm GaN HEMT	DC - 18	47	15	- / 55	28 / 1000	Die	TGF2023-10*
20mm GaN HEMT	DC - 18	50	15	- / 55	28 / 2000	Die	TGF2023-20*
0.6mm Pwr pHEMT	DC - 20	(29) / -	13	- / 56	12 / 45	Die	TGF2022-06
1.2mm Pwr pHEMT	DC - 20	(32) / -	13	- / 56	12 / 90	Die	TGF2022-12
2.4mm Pwr pHEMT	DC - 20	(35) / -	13	- / 58	12 / 180	Die	TGF2022-24
4.8mm Pwr pHEMT	DC - 20	(38) / -	13	- / 58	12 / 360	Die	TGF2022-48
6.0mm Pwr pHEMT	DC - 20	(39) / -	12.5	- / 53	12 / 448	Die	TGF2022-60
0.3mm pHEMT	DC - 22	16 / -	13	0.8 / -	3 / 15	Die	TGF4350
4W pHEMT	0.02 - 4	36 / -	10	- / 45	12 / 100	Ceramic Gullwing	TGF2021-04-SG
7W pHEMT	0.02 - 4	38 / -	10	- / 40	12 / 200	Ceramic Gullwing	TGF2021-08-SG
50W HVHBT	0.02 - 2	47 / -	10	- / 50	28 / 200	PowerBand™	TIH2005028-SP
7W GaN HEMT	0.02 - 6	38 / -	9.5	- / 50	28 / 50	Ceramic Flat Lead	TIG6000528-Q3
25W GaN HEMT	0.02 - 6	44 / -	11.5	- / 50	28 / 100	PowerBand™	TIG6003028-SP
MESFET	0.05 - 4	21 / 42	19	2 / -	5 / 140	SOT89	FH1
MESFET	0.05 - 4	18 / 36	19	2 / -	5 / 140	SOT89	FH101
0.5W HFET	0.05 - 4	27 / 40	19	2.7 / -	8 / 125	SOT89	FP1189
1W HFET	0.05 - 4	30 / 44	18	4.5 / -	8 / 250	SOT89	FP2189
2.5W HFET	0.05 - 4	34 / 46	18	3.5 / -	9 / 450	6x6 QFN28	FP31QF
30W LDMOS	0.5 - 2	45 / -	10	- / 45	28 / 200	PowerBand™	TIL2003028-SP
10W pHEMT	0.5 - 3	40 / -	10	- / 45	12 / 200	PowerBand™	TIP2701012-SP

NOTES: * = New

Frequency Converters & Mixers

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
WB Mixer, LO	0.5 - 2.5	-5.7	8	24	3 - 6 / 6	MW6	CMY210
WB Mixer, LO, IF	0.5 - 2.5	10	8	9	3 - 6 / 12	SCT598	CMY212
WB Mixer, LO, IF, Low Current	0.5 - 2.5	9.5	10	10	3 - 6 / 8	SCT598	CMY213
WB Mixer, LO	0.5 - 2.5	4	-	9	3 - 6 / 6.2	SOT23-6	TQ5M31
Mixer, LO	0.7 - 1	-9	17	36	5 / 50	MSOP-8	ML483*
Single Branch Bonverter, RF, LO, IF	0.8 - 0.92	22	60	15	5 / 360	6x6 QFN28	CV110-1A
Dual Branch Converter, LO, IF	0.8 - 0.92	10	20	20	5 / 385	6x6 QFN28	CV210-1A
Mixer	0.8 - 0.96	-7.3	30	34	N/A	SOIC-8	MH203A
Mixer	0.8 - 0.96	-7	37	35	N/A	SOIC-8	MH205A
Single Branch Converter, RF, LO, IF	0.8 - 0.96	22	60	15	5 / 360	6x6 QFN28	CV110-3A
Dual Branch Converter, LO, IF	0.8 - 0.96	10.5	14	18.5	5 / 390	6x6 QFN28	CV210-3A
Mixer, LO	1.6 - 3.2	-8.5	2	35	5 / 40	MSOP-8	ML485
Mixer	1.7 - 2.0	-8.3	30	35	N/A	SOIC-8	MH1A
Single Branch Converter, RF, LO, IF	1.7 - 2.0	21	45	17	5 / 360	6x6 QFN28	CV111-1A
Dual Branch Converter, LO, IF	1.7 - 2.0	10	8	19.5	5 / 380	6x6 QFN28	CV211-1A
Mixer, LO	1.7 - 2.2	-8.2	9	30	5 / 105	SOIC-8	ML401
Single Branch Converter, RF, LO, IF	1.9 - 2.2	21	40	17	5 / 360	6x6 QFN28	CV111-3A
Dual Branch Converter, LO, IF	1.9 - 2.7	10	12	20	5 / 380	6x6 QFN28	CV211-2A
Mixer, LO	1.9 - 2.7	-8.1	9	30	5 / 110	SOIC-8	ML501
Mixer	1.9 - 2.7	-8.2	28	34	N/A	SOIC-8	MH103A
Doubler w/Amplifier	16 - 30	18	30	22	5 / 150	Die	TGC4403
Doubler w/Amplifier	16 - 30	18	30	19	5 / 150	SM-O11-16	TGC4403-SM
Upconverting Mixer	17 - 26	-9	40	-	-0.9 / 0	SM-O11-16	TGC4402-SM

Frequency Converters & Mixers (cont.)

Description	RF Frequency Range (GHz)	Conversion Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
Upconverting Mixer	17 - 27	-9	35	18	-0.9 / 0	Die	TGC4402
Upconverter	17 - 27	13	30	-	5 / 425	Die	TGC4405
Upconverter	17 - 27	13	30	-	5 / 425	SM-O11-16	TGC4405-SM
Gain Block & 2x / 3x Multiplier	17 - 37	9	N/A	6	5 / 140	SM-O3-16	TGA4030-SM
Gain Block & 2x / 3x Multiplier	17 - 40	9	N/A	2	5 / 140	SM-A3-16	TGA4031-SM
19 GHz VCO w/8:1 Prescaler	18.5 - 19.5	-	-105**	- / 7.0	5 / 158	Die	TGV2204-FC
Doubler (Input 10 - 20 GHz)	20 - 40	-12	25	18	-	Die	TGC1430F
Tripler (Input 8.5 - 13.5 GHz)	20 - 40	-15	15	18	-	Die	TGC1430G
19 / 38 GHz Converter / MPA	36 - 40	9.0	-	- / 14.5	3.5 / 65	Die	TGC4703-FC
Down Converting I/Q Mixer	75 - 80	-13.5	22	-	1.1 / 7	Die	TGC4702-FC
38 / 77 GHz Converter / MPA	76 - 78	6.0	-	- / 15.0	4 / 230	Die	TGC4704-FC

NOTES: * = New, ** = Phase Noise (dBc / Hz @ 1 MHz Offset), LO = LO Amplifier, IF = IF Amplifier

Signal Conditioning

Description	Frequency (GHz)	Insertion Loss (dB)	Control Range dB or (Deg.)	P1dB (dBm)	Supply Voltage (V)	Package Style	Part Number
6-Bit, Digital Attenuator, Parallel Ctrl	DC - 4	1.3	31.5	30	5 / 0	4x4 QFN24	TQP4M9071*
6-Bit, Digital Attenuator, Serial Ctrl	DC - 4	1.3	31.5	30	5 / 0	4x4 QFN24	TQP4M9072*
Analog Attenuator	DC - 30	2	17	-	0 to -2	SM-O12-16	TGL4203-SM
Analog Attenuator	DC - >50	2	17	-	0 to -2	Die	TGL4203
Discrete Thru (0 dB Attenuator)	DC - 65	0	0	-	N/A	Die	TGL4201-00
Discrete Attenuators	DC - 65	-	2,3,6,10	-	N/A	SM-O12-16	TGL4201-02, 03, 06, 10
Digital Attenuator	0.5 - 18	4	15.5	20	0 / -5	Die	TGL6425-SCC
Analog Attenuator	2 - 20	2	15	23	2.5	Die	TGL8784-SCC
Passive Wideband Limiter	3 - 25	<0.5	N/A	18	N/A	Die	TGL2201
5-Bit Phase Shifter	6 - 18	9	(348)	-	6	Die	TGP6336
Bessel Filter	-	6,7,8,9,10 & 11 Cut-Off Freq	N/A	-	N/A	Die	TGB2010-00,-09 etc.
Bessel Filter	-	5,6,6.5,7.5,8 & 9 Cut-Off Freq	N/A	-	N/A	SM-O2-6	TGB2010-00,-09-SM etc.
6-Bit Phase Shifter	8.5 - 11	5	(354)	-	0 / -5	Die	TGP2103
Lange Coupler	12 - 21	<0.25	-	-	N/A	Die	TGB2001
5-Bit Phase Shifter	18 - 20	5	(180)	-	-2.5	Die	TGP1439
Lange Coupler	18 - 32	<0.25	-	-	N/A	Die	TGB4001
Lange Coupler	27 - 45	<0.25	-	-	N/A	Die	TGB4002
5-Bit Phase Shifter	28 - 32	6	(348)	-	5	Die	TGP2100
5-Bit Phase Shifter	33 - 37	6	(348)	-	-5	Die	TGP2102
1-Bit Phase Shifter	34 - 36	4	180	-	0 / 5	Die	TGP2104

NOTES: * = New

Switches

Description	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	P1dB (dBm)	Control Voltage (V)	Package Style	Part Number
SP3T High Power CDMA	DC - 2	0.45	28	>36.5	2.6 / 0	MLP12	TQP4M3018
SP3T High Power CDMA	DC - 2	0.6	22	34.5	2.6 / 0	STSLP12	TQP4M3019
SP2T General Purpose	DC - 2.5	0.3	24	30	3 / 0	SOT363	CSH210R
SP2T 802.11 a, b, g	DC - 6	0.6	28	31.5	3 / 0	SLIM7	TQS5200
Diversity Switch 802.11 a, b, g	DC - 6	0.8	33	33	3 / 0	MLP12	TQS5202
SPDT FET	DC - 18	1.5	36	27	-5	Die	TGS2306
SPDT FET	DC - 18	2.0	39	21	-7 / 0	Die	TGS8250-SCC

Switches (cont.)

Description	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	PIdB (dBm)	Control Voltage (V)	Package Style	Part Number
SP4T FET	DC - 18	2.5	37	19	0 / -5	Die	TGS8422-SCC
SP3T VPIN	1 - 20	0.5	35	23	10 mA	Die	TGS2303
SP4T VPIN	1 - 20	0.6	38	23	10 mA	Die	TGS2304-SCC
SP3T VPIN	4 - 18	1.0	35	20	+/- 2.7	Die	TGS2313
SPDT VPIN	4 - 20	0.9	35	>20	+/- 2.7	Die	TGS2302
SPDT VPIN	24 - 43	<2	36	27	+/- 5	Die	TGS4301
SPDT VPIN	27 - 46	0.9	30	>34	+/- 5 / 15	Die	TGS4302
SPDT VPIN Absorptive	32 - 40	1.0	36	>33	+/- 5 / 18	Die	TGS4304
SP3T	60 - 90	2.3	20	>-13	-5 / 1.35	Die	TGS4305-FC
SP4T	70 - 90	3.0	20	>-8	-5 / 1.35	Die	TGS4306-FC
SP5T VPIN 77 GHz	71 - 90	2.5	25 / 40	>-8	-5 / 1.35	Die	TGS4307

Protectors

Description	Application	Leakage Current (nanoAmps)	Trigger Voltage (V)	Series Capacitance (pF)	Package Area (mm ²)	Package Style	Part Number
CATV Protector	ESD & Secondary Protection	20 @ 1V, 500 @ 15V	18, 25, 41	0.29, 0.29, 0.22	1.8	T / SLP-3	TQP200002

SAW

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Cable IF Filter	36.15	8	19.7	SE / SE	38 @ 10.23	DIP	855748
Cable IF Filter	44	6	20.4	SE / SE	38 @ 7.60	DIP	855079
Cable IF Filter	44	6	20.8	SE / SE	38 @ 7.40	24.6x9.0	856129
CDMA IF Filter	69.99	1.26	17.1	SE / SE	25 @ 1.68	24.6x9.0	856199
BWA / WiMAX IF Filter	70	8	12.95	SE / SE	35 @ 3.20	13.3x6.5	855677
Low Loss IF Filter	70	0.5	7.6	SE / SE	35 @ 1.28	19.0x6.5	854651
Low Loss IF Filter	70	1	7.3	SE / SE	40 @ 2.80	19.0x6.5	854652
Low Loss IF Filter	70	1.5	7.5	SE / SE	40 @ 3.20	19.0x6.5	854653
Low Loss IF Filter	70	2	7.85	SE / SE	40 @ 4.25	19.0x6.5	854654
Low Loss IF Filter	70	2.5	8.75	SE / SE	40 @ 4.60	19.0x6.5	854655
Low Loss IF Filter	70	3	6.95	SE / SE	35 @ 6.90	13.3x6.5	854656
Low Loss IF Filter	70	3.5	7.25	SE / SE	35 @ 7.20	13.3x6.5	854657
Low Loss IF Filter	70	4	6.8	SE / SE	40 @ 8.25	13.3x6.5	854658
Low Loss IF Filter	70	4.5	6.8	SE / SE	35 @ 8.50	13.3x6.5	854659
Low Loss IF Filter	70	5	7.25	SE / SE	40 @ 9.35	13.3x6.5	854660
Low Loss IF Filter	70	6	7.5	SE / SE	40 @ 10.20	13.3x6.5	854661
Low Loss IF Filter	70	7	8.5	SE / SE	40 @ 11.55	13.3x6.5	854662
Low Loss IF Filter	70	8	9	SE / SE	40 @ 13.25	13.3x6.5	854663
Low Loss IF Filter	70	9	9.75	SE / SE	40 @ 13.90	13.3x6.5	854664
Low Loss IF Filter	70	10	10	SE / SE	40 @ 15.00	13.3x6.5	854665
Low Loss IF Filter	70	12	11.5	SE / SE	40 @ 17.35	13.3x6.5	854666
Low Loss IF Filter	70	14	12.5	SE / SE	40 @ 19.50	13.3x6.5	854667
Low Loss IF Filter	70	16	12.5	SE / SE	40 @ 21.40	13.3x6.5	854668
Low Loss IF Filter	70	18	13.5	SE / SE	40 @ 23.40	13.3x6.5	854669
Low Loss IF Filter	70	20	14.5	SE / SE	40 @ 25.40	13.3x6.5	854670
Low Loss IF Filter	70	22	15	SE / SE	40 @ 27.25	13.3x6.5	854671
Low Loss IF Filter	70	24	16.25	SE / SE	40 @ 29.65	13.3x6.5	854672

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Low Loss IF Filter	70	26	17	SE / SE	40 @ 32.00	13.3x6.5	854673
Low Loss IF Filter	70	28	17.6	SE / SE	40 @ 33.75	13.3x6.5	854674
Low Loss IF Filter	70	30	17.5	SE / SE	40 @ 37.00	13.3x6.5	854675
Low Loss IF Filter	70	36	20.2	SE / SE	40 @ 43.30	13.3x6.5	854678
Low Loss IF Filter	70	40	21.5	SE / SE	40 @ 47.25	13.3x6.5	854680
High Selectivity IF Filter	70	0.3	16.36	SE / SE	40 @ 0.90	24.6x9.0	855735
High Selectivity IF Filter	70	0.5	21.3	SE / SE	40 @ 1.63	24.6x9.0	855736
High Selectivity IF Filter	70	1	22.2	SE / SE	40 @ 2.11	24.6x9.0	855737
High Selectivity IF Filter	70	1.5	21.6	SE / SE	40 @ 2.52	24.6x9.0	855738
High Selectivity IF Filter	70	2	23	SE / SE	40 @ 3.40	24.6x9.0	855739
High Selectivity IF Filter	70	2.5	20.25	SE / SE	40 @ 4.30	24.6x9.0	855740
High Selectivity IF Filter	70	3	23	SE / SE	40 @ 4.46	24.6x9.0	855741
High Selectivity IF Filter	70	3.5	19	SE / SE	40 @ 6.00	15.3x6.5	855742
High Selectivity IF Filter	70	4	23	SE / SE	40 @ 6.00	19.0x6.5	855743
High Selectivity IF Filter	70	4.5	23.7	SE / SE	40 @ 6.64	19.0x6.5	855744
High Selectivity IF Filter	70	5.5	22.2	SE / SE	40 @ 7.84	19.0x6.5	855745
CDMA IF Filter	73.59	1.2	11.9	SE / SE	45 @ 79.58	19.0x6.5	856111
BWA / WiMAX IF Filter	80	8	11.7	SE / SE	35 @ 14.25	13.3x6.5	855679
GSM IF Filter	86.6	0.4	5.3	SE / BAL	28 @ 1.58	19.0x6.5	854823
GSM IF Filter	87	0.4	4.4	BAL / BAL	28 @ 1.59	19.0x6.5	855500
CDMA IF Filter	118.58	3.69	17.4	SE / SE	43 @ 123.48	13.3x6.5	855958
GSM IF Filter	125	0.4	5.9	SE / SE	20 @ 2.40	9.1x4.8	856444
Low Loss IF Filter	140	4	10.85	SE / SE	40 @ 9.10	13.3x6.5	854909
Low Loss IF Filter	140	7	5.5	SE / SE	40 @ 11.10	13.3x6.5	854913
Low Loss IF Filter	140	10	8.3	SE / SE	35 @ 15.00	13.3x6.5	854916
Low Loss IF Filter	140	10	11	SE / SE	35 @ 15.00	13.3x6.5	856656
Low Loss IF Filter	140	12	8.87	SE / SE	35 @ 21.30	13.3x6.5	854917
Low Loss IF Filter	140	15	11	SE / SE	35 @ 22.00	13.3x6.5	856684
Low Loss IF Filter	140	16	8.4	SE / SE	35 @ 22.00	13.3x6.5	854919
Low Loss IF Filter	140	18	9.1	SE / SE	40 @ 48.00	13.3x6.5	854920
Low Loss IF Filter	140	20	11	SE / SE	35 @ 24.00	13.3x6.5	856592
Low Loss IF Filter	140	24	11.3	SE / SE	35 @ 33.50	13.3x6.5	854923
Low Loss IF Filter	140	32	11.5	SE / SE	35 @ 44.00	13.3x6.5	854927
High Selectivity IF Filter	140	0.8	20.8	SE / SE	40 @ 1.93	19.0x6.5	856062
High Selectivity IF Filter	140	1.5	21.9	SE / SE	40 @ 2.71	19.0x6.5	856063
High Selectivity IF Filter	140	2	21.5	SE / SE	40 @ 3.45	19.0x6.5	856064
High Selectivity IF Filter	140	3	22.4	SE / SE	40 @ 4.86	19.0x6.5	856065
High Selectivity IF Filter	140	6	23	SE / SE	40 @ 8.34	13.3x6.5	856066
High Selectivity IF Filter	140	7	24.5	SE / SE	40 @ 9.15	13.3x6.5	856067
High Selectivity IF Filter	140	8	23.4	SE / SE	40 @ 11.28	13.3x6.5	856068
High Selectivity IF Filter	140	10	20.87	SE / SE	40 @ 13.17	13.3x6.5	856069
High Selectivity IF Filter	140	14	23.3	SE / SE	40 @ 18.26	13.3x6.5	856070
High Selectivity IF Filter	140	16	21.7	SE / SE	40 @ 20.69	13.3x6.5	856071
High Selectivity IF Filter	140	28	20	SE / SE	40 @ 37.00	9.0x7.0	856019
High Selectivity IF Filter	140	28.56	27.7	SE / SE	40 @ 44.00	13.3x6.5	856817
High Selectivity IF Filter	140	32	21.7	SE / SE	40 @ 40.70	9.0x7.0	856072
High Selectivity IF Filter	140	44	21.75	SE / SE	40 @ 54.10	9.0x7.0	856073
High Selectivity IF Filter	140	56	18.65	SE / SE	40 @ 75.60	9.0x7.0	856074
High Selectivity IF Filter	140	64	17.8	SE / SE	40 @ 84.00	9.0x7.0	856020
High Selectivity IF Filter	140	72	21	SE / SE	40 @ 102.00	9.0x7.0	856314
High Selectivity IF Filter	140	1.5	12.1	SE and BAL	48 @ 143.00	9.1x4.8	856691

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
High Selectivity IF Filter	140	3	13.6	SE and BAL	46 @ 144.00	9.1x4.8	856692
High Selectivity IF Filter	140	6	11	BAL / BAL	39 @ 147.00	9.1x4.8	856693
High Selectivity IF Filter	140	7	13.6	SE and BAL	43 @ 147.00	9.1x4.8	856694
High Selectivity IF Filter	140	10	10	BAL / BAL	41 @ 152.50	9.1x4.8	856695
High Selectivity IF Filter	140	14	8.5	SE and BAL	43 @ 155.00	9.1x4.8	856696
High Selectivity IF Filter	140	20	9.8	BAL / BAL	40 @ 158.50	9.1x4.8	856697
High Selectivity IF Filter	140	28	18	SE and BAL	42 @ 168.00	9.1x4.8	856698
CDMA IF Filter	141	1.18	11.7	SE / SE	42.5 @ 2.50	19.0x6.5	855395
High Selectivity IF Filter	144	75	21.2	SE / SE	40 @ 91.81	9.0x7.0	856727*
CDMA IF Filter	150	1.18	18.6	SE / BAL	30 @ 4.50	19.0x6.5	854833-1
CDMA IF Filter	150	8	12.1	SE / SE	35 @ 14.25	13.3x6.5	855678
CDMA IF Filter	153.6	3.75	12.04	SE / SE	45 @ 9.80	13.3x6.5	856048
TDSCDMA / WCDMA IF Filter	153.6	15	10	SE / SE	40 @ 25.00	13.3x6.5	856748
CDMA IF Filter	160	1.18	19.5	SE / BAL	30 @ 4.50	19.0x6.5	855049
GSM IF Filter	160	0.2	3.3	BAL / BAL	30 @ 12.00	7.0x5.5	855626
WCDMA IF Filter	167	5	8	SE / SE	20 @ 11.80	9.1x4.8	856683
CDMA IF Filter	167.1	1.18	10.9	SE / SE	15 @ 2.00	19.0x6.5	855394
CDMA IF Filter	167.1	11	13.1	SE / SE	40 @ 16.00	13.3x6.5	855753
WCDMA IF Filter	168.5	20	8	SE / BAL	33 @ 190.00	5.0x5.0	856512
WCDMA IF Filter	168.96	3.84	11.5	SE / SE	30 @ 16.00	9.1x4.8	856320
GSM IF Filter	170.6	0.18	5	BAL / BAL	40 @ 1.60	9.1x4.8	856706
WCDMA IF Filter	172.8	8.84	12.5	SE / BAL	32 @ 16.00	7.0x5.5	856620
WCDMA IF Filter	172.8	20	8	SE / BAL	30 @ 194.30	5.0x5.0	856802
WCDMA IF Filter	172.8	21	8.2	BAL / BAL	50 @ 200.00	7.0x5.5	856893*
WCDMA IF Filter	190	5.5	9.8	SE / BAL	30 @ 7.60	13.3x6.5	855529
WCDMA IF Filter	190	5	8	SE / SE	25 @ 9.00	5.0x5.0	855770
GSM IF Filter	190	0.2	4.2	BAL / BAL	30 @ 12.00	7.0x5.5	855625
GSM IF Filter	199	0.2	5.4	SE / SE	20 @ 1.20	9.0x7.0	856730
GSM IF Filter	199	0.2	6	SE / SE	45 @ 1.60	19.0x6.5	855131
GSM IF Filter	199	0.5	6.8	SE / SE	30 @ 47.00	13.3x6.5	855780
GSM IF Filter	201	0.22	6.1	BAL / BAL	27 @ 0.80	13.3x6.5	856541
Cable IF Filter	202.75	1.2	6.6	SE / SE	40 @ 10.00	13.3x6.5	855068
GSM IF Filter	208	0.4	5.9	SE / SE	20 @ 2.40	9.1x4.8	856445
WCDMA IF Filter	208	3.84	11.5	BAL / BAL	17 @ 5.03	9.1x4.8	856496
GSM IF Filter	211	0.2	5.2	SE / SE	25 @ 0.80	13.3x6.5	856378
WCDMA IF Filter	219	20	9.6	BAL / BAL	35 @ 36.00	9.0x7.0	856795
WCDMA IF Filter	230	4	16.2	SE / SE	40 @ 10.00	13.3x6.5	855832
CDMA IF Filter	240	3.6	14.3	SE / SE	12 @ 5.00	13.3x6.5	855992
CDMA IF Filter	240	1.1	13	SE / SE	10 @ 1.80	19.0x6.5	856151
BWA / WiMAX IF Filter	240	2	9.8	SE / BAL	45 @ 10.50	7.0x5.5	855091
BWA / WiMAX IF Filter	240	10	11	SE / BAL	40 @ 35.00	7.0x5.5	855092
CDMA IF Filter	249.6	3.84	16.11	SE / SE	40 @ 11.00	7.0x5.5	855915
BWA / WiMAX IF Filter	280	34	8.2	BAL / BAL	45 @ 15.00	7.0x5.5	855393
BWA / WiMAX IF Filter	280	17	8.95	SE / BAL	38 @ 60.00	5.0x5.0	855975
GPS IF Filter	298.75	2.4	8.35	BAL / BAL	50 @ 20.00	7.0x5.5	856305
BWA / WiMAX IF Filter	325	10	9.6	BAL / BAL	40 @ 35.00	7.0x5.5	855094
CDMA IF Filter	326.4	15	12.61	SE / SE	40 @ 25.00	7.0x5.5	855914
BWA / WiMAX IF Filter	330	5.45	18.26	SE / SE	50 @ 13.60	15.3x6.5	855730
BWA / WiMAX IF Filter	350	2.4	13.1	SE / BAL	35 @ 12.00	7.0x5.5	855398
BWA / WiMAX IF Filter	350	1.7	13.7	SE / BAL	45 @ 6.00	13.3x6.5	855399

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
BWA / WiMAX IF Filter	350	1	8.2	SE / BAL	45 @ 15.00	7.0x5.5	855377
WCDMA IF Filter	358.4	19.2	10.1	BAL / BAL	40 @ 61.40	7.0x5.5	856771
WLAN IF Filter	374	17	8.5	SE / BAL	10 @ 33.00	7.0x5.5	855653
WLAN IF Filter	374	17	8.5	SE / BAL	35 @ 33.00	5.0x5.0	855898
WLAN IF Filter	374	17	9	SE / BAL	30 @ 33.00	3.8x3.8	856278
BWA / WiMAX IF Filter	374	10	9	BAL / BAL	10 @ 25.00	3.8x3.8	856466
Low Loss IF Filter	374	17	9	SE / BAL	36 @ 357.00	3.8x3.8	856438
WCDMA IF Filter	380	5.4	15.4	SE / BAL	30 @ 8.30	13.3x6.5	855530
BWA / WiMAX IF Filter	380	13.75	9.4	SE / SE	40 @ 367.00	7.0x5.5	856272
General Purpose IF Filter	380	3.75	10	SE / SE	35 @ 8.00	7.0x5.5	856279
BWA / WiMAX IF Filter	380	3.75	11	BAL / BAL	30 @ 8.30	7.0x5.5	856464
BWA/WiMAX IF Filter	380	7	10	BAL / BAL	40 @ 20.00	7.0x5.5	856490
BWA / WiMAX IF Filter	380	10	8.7	BAL / BAL	40 @ 36.00	7.0x5.5	856631
WCDMA IF Filter	398	4.3	9.9	SE / SE	50 @ 36.00	9.1x4.8	855561
WCDMA / WiMAX IF Filter	398	15	7.5	SE / SE	30 @ 60.00	9.1x4.8	855559
WCDMA IF Filter	398	35	12	SE / SE	50 @ 368.00	9.1x4.8	856097
BWA / WiMAX IF Filter	398	10	11.2	BAL / BAL	35 @ 388.50	5.0x5.0	856652
BWA / WiMAX IF Filter	426	5.16	18.02	SE / SE	50 @ 14.00	13.3x6.5	855731
Duplexer, 450 Block C	452.4 / 462.4	4.8 / 4.8	2.7 / 3.0	SE / BAL	–	5.0x5.0	856820
Uplink Filter, 450 Block C	452.4	4.8	1.5	SE / SE	30 @ 460.00	3.8x3.8	856867
Duplexer, 450 Block A	455 / 465	5 / 5	2.6 / 3.0	SE / BAL	–	5.0x5.0	856799
Uplink Filter, 450 Block A	455	5	1.5	SE / SE	30 @ 462.5	3.8x3.8	856847
BWA / WiMAX IF Filter	456	7	12	BAL / BAL	33 @ 449.30	7.0x5.5	856498
WiBRO IF Filter	456	8.75	7.9	BAL / BAL	36 @ 443.25	5.0x5.0	856549
BWA / WiMAX IF Filter	456	10	8.3	BAL / BAL	37 @ 440.00	7.0x5.5	856672
BWA / WiMAX IF Filter	456	10	8.3	BAL / BAL	37 @ 440.00	5.0x5.0	856638
WCDMA IF Filter	456	19	10	BAL / BAL	40 @ 61.40	7.0x5.5	856687
General Purpose IF Filter	460	3.75	11.1	SE / SE	35 @ 8.00	7.0x5.5	856282
BWA / WiMAX IF Filter	464	3.5	10.6	BAL / BAL	53 @ 417.00	7.0x5.5	856623
WLAN IF Filter	465	17	11.9	SE / BAL	40 @ 50.00	5.0x5.0	855991
FRS RF or GPS IF Filter	465	6	1.43	SE / SE	40 @ 445.00	3.0x3.0	856288
BWA / WiMAX IF Filter	467	7	3	SE / SE	65 @ 438.00	3.8x3.8	856660
BWA / WiMAX IF Filter	468	7	13	SE / SE	70 @ 305.00	7.0x5.5	856624
BWA / WiMAX IF Filter	479.75	9	19.5	SE / SE	35 @ 22.00	7.0x5.5	855271
BWA / WiMAX IF Filter	479.75	23	9.8	BAL / BAL	35 @ 36.00	7.0x5.5	855272
Cable IF Filter	499.25	1	7	SE / SE	35 @ 6.00	9.0x7.0	855104
BWA / WiMAX IF Filter	580	10	10.7	BAL / BAL	40 @ 36.00	5.0x5.0	856665
RF Filter, 700 MHz Band	707	18	1.5	SE / SE	9 @ 728.00	3.0x3.0	856884*
Duplexer, Band 17	710 / 740	12 / 12	1.2 / 1.8	SE / BAL	–	2.5x2.0	856931
Uplink Filter, Band 17	710	12	1.8	SE / SE	40 @ 734.00	1.4x1.2	856911
RF Filter, 700 MHz Band	737	18	1.8	SE / SE	37 @ 708.00	3.0x3.0	856883*
Duplexer, Band 13	751 / 782	9 / 9	2.3 / 1.8	SE / BAL	–	2.5x2.0	856879
Uplink Filter, Band 13	782	9	1.9	SE / SE	20 @ 768.00	1.4x1.2	856894
WLAN IF Filter	770	17	3	BAL / BAL	32.5 @ 750.00	5.0x5.0	855942
RF Filter, 700 MHz Band	781.5	11	1.5	SE / SE	38 @ 757.00	3.0x3.0	856764
RF Filter, 700 MHz Band	782	10	1.52	SE / SE	15 @ 765.00	3.0x3.0	856844*
BWA / WiMAX IF Filter	810	10	3.5	SE / SE	10 @ 31.00	3.0x3.0	856526
RF Filter, Cell Band	836.5	25	2.7	SE / SE	28 @ 869.00	3.0x3.0	855729
RF Filter, Cell Band	836.5	25	2.0	SE / SE	10 @ 869.00	3.0x3.0	856704
RF Filter, Cell Band	836.5	25	1.8	SE / SE	30 @ 869.00	3.0x3.0	855779
RF Filter, Cell Band	836.5	25	1.9	SE / SE	35 @ 869.00	3.0x3.0	855821

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Duplexer, Cell Band	836.5 / 881.5	25 / 25	1.9 / 1.9	SE / SE	–	3.8x3.8	856356
Duplexer, Cell Band	836.5 / 881.5	25 / 25	1.9 / 2.4	SE / SE	–	3.8x3.8	856450
GSM850 Rx Filter - Auto Qualified	881.5	25	1.6	SE / BAL	40 @ 836.50	1.4x1.2	856522
RF Filter, Cell Band	881.5	25	2.7	SE / SE	40 @ 849.00	3.0x3.0	855728
RF Filter, Cell Band	881.5	25	1.8	SE / SE	35 @ 849.00	3.0x3.0	855782
Single Rx Filter	881.5	25	1.6	SE / BAL	–	1.4x1.2	856522
CDMA 2-in-1 Rx Filter	881.5 / 1960	25 / 60	1.6 / 2.2	SE / BAL	–	2.0x1.5	856565
Cell Band Delay Filter, 450 ns	881.5	25	25	SE / BAL	N/A	7.0x5.5	856716
RF Filter, EGSM	897.5	35	1.4	SE / SE	10 @ 984.00	3.0x3.0	856824*
RF Filter, EGSM	897.5	35	1.5	SE / SE	15 @ 930.00	3.0x3.0	856657
RF Filter, EGSM	897.5	35	1.9	SE / SE	14 @ 930.00	3.0x3.0	856671
ISM 915 Band RF Filter	915	26	2.3	SE / SE	35 @ 882.50	2.0x1.5	856327
ISM 915 Band RF Filter	915	4.4	2.4	SE / SE	55 @ 849.00	3.0x3.0	856686
RF Filter, EGSM	942.5	35	2	SE / SE	5 @ 915.00	3.0x3.0	855820
RF Filter, EGSM	942.5	35	3.2	SE / SE	12 @ 915.00	3.0x3.0	855810
RF Filter, EGSM	942.5	35	2.5	SE / SE	25 @ 915.00	3.0x3.0	856528
GSM Band Delay Filter, 450 ns	942.5	35	25.5	SE / SE	N/A	7.0x5.5	856766
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046.00	3.0x3.0	855964
Tuner IF Filter	1086	10	4	BAL / BAL	40 @ 1046.00	3.0x3.0	856330
Tuner IF Filter	1090	10	5	BAL / BAL	50 @ 1050.00	3.8x3.8	856096
WLAN IF Filter	1150	16	4.4	BAL / BAL	20 @ 1170.00	3.0x3.0	856256
GPS L5 RF Filter	1176	20	2.4	SE / SE	20 @ 1226.00	2.0x1.5	856440
Tuner IF Filter	1216	8	3.75	BAL / BAL	12 @ 24.00	3.0x3.0	856365
Tuner IF Filter	1220	10	4.5	BAL / BAL	30 @ 60.00	3.0x3.0	856298
Tuner IF Filter	1220	50	3.9	BAL / BAL	33 @ 96.00	3.8x3.8	856598
GPS L2 RF Filter	1227.6	20	1.1	SE / SE	27 @ 1152.00	2.0x1.5	856700
Tuner IF Filter	1250	96	6	BAL / BAL	44 @ 1152.00	3.0x3.0	856653
GPS RF Filter	1575.42	2	1.3	SE / SE	30 @ 1625.00	3.0x3.0	855969
GPS RF Filter	1575.42	2	1.25	SE / SE	30 @ 1624.00	2.0x1.5	856584
GPS RF Filter	1575.42	2	1.1	SE / SE	20 @ 1628.00	2.5x2.0	856042
GPS RF Filter	1575.42	2	2.5	SE / SE	30 @ 1625.00	2.5x2.0	856049
GPS RF Filter	1575.42	2	0.75	SE / SE	35 @ 1635.00	1.4x1.2	856561
GPS RF Filter	1575.42	2	1.1	SE / BAL	20 @ 1635.00	1.4x1.2	856576
GPS RF Filter	1575.42	2	0.53	SE / SE	16.5 @ 1700.00	2.0x1.5	856326
GPS RF Filter	1575.42	2	1	SE / SE	27 @ 800.00	1.5x1.5	856463
GPS RF Filter	1575.42	2	0.5	SE / SE	20 @ Cell Bands	1.4x1.2	856756
GPS RF Filter	1575.42	2	0.7	SE / SE	27 @ 1700.00	1.5x1.5	856398
GPS RF Filter	1575.42	2	0.6	SE / SE	21 @ Cell Bands	1.4x1.2	856793
GPS RF Filter, Auto	1575.42	2	1.8	SE / SE	45 @ 1637.00	3.0x3.0	856039
GPS RF Filter, Auto	1575.42	2	1.3	SE / SE	45 @ 1640.00	3.0x3.0	856139
RF Filter, DCS	1747.5	75	2	SE / SE	22 @ 1676.00	3.0x3.0	856654
RF Filter, DCS	1747.5	75	2.6	SE / SE	10 @ 1681.00	3.0x3.0	856846*
RF Filter, DCS	1842.5	75	1.9	SE / SE	10 @ 1785.00	3.0x3.0	855860
RF Filter, PCS (Split Band)	1880	30	2.0	SE / SE	35 @ 1930.00	3.0x3.0	855833
RF Filter, PCS	1880	60	2.2	SE / SE	15 @ 1806.00	3.0x3.0	856705
RF Filter, PCS	1880	60	2.3	SE / SE	10 @ 1790.00	3.0x3.0	856880*
RF Filter, PCS	1880	60	2.4	SE / SE	7 @ 1930.00	3.0x3.0	855849
RF Filter, PCS	1880	60	2.8	SE / SE	30 @ 1930.00	3.0x3.0	856530

SAW (cont.)

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
Tuner IF Filter	1892	8	4.2	BAL / BAL	23 @ 1932.00	2.5x2.0	856236
RF Filter, UMTS	1950	60	1.8	SE / SE	20 @ 2100.00	3.0x3.0	856678
RF Filter, UMTS	1950	60	2.2	SE / SE	40 @ 2110.00	3.0x3.0	856532
GSM1900 Rx Filter - Auto Qualified	1960	60	1.5	SE / BAL	17 @ 1880.00	1.4x1.2	856577
RF Filter, PCS	1960	60	2.1	SE / SE	10.3 @ 1910.00	3.0x3.0	855817
RF Filter, PCS	1960	60	2.3	SE / SE	8 @ 1910.00	3.0x3.0	855850
RF Filter, PCS	1960	60	2.9	SE / SE	15 @ 1910.00	3.0x3.0	855859
RF Filter, PCS	1960	60	2.25	SE / SE	14 @ 1910.00	3.0x3.0	856531
Delay Filter, PCS 450 ns	1960	60	25	SE / BAL	N/A	7.0x5.5	856717
Delay Filter, UMTS 450 ns	2140	60	25	SE / BAL	N/A	7.0x5.5	856649
RF Filter, UMTS	2140	60	2.3	SE / SE	25 @ 1980.00	3.0x3.0	856738
Bluetooth® RF Filter	2441	83.5	2.8	SE / SE	26 @ 2200.00	3.0x3.0	855916
Bluetooth® RF Filter	2441	83.5	2.5	SE / SE	20 @ 2300.00	1.5x1.5	856486
Bluetooth® RF Filter	2441	83.5	2.7	SE / BAL	35 @ 2250.00	1.5x1.5	856435
Bluetooth® RF Filter	2441	83.5	2	SE / SE	28 @ 2300.00	1.4x1.2	856539
Bluetooth® RF Filter	2441	83.5	2.7	SE / BAL	39 @ 2250.00	1.4x1.2	856548
Bluetooth® & GPS Filter	2441 / 1575.42	83.5 / 2	2 / 1.2	SE / SE	-	2.0x1.5	856646

Notes: * = New

BAW

Description	Frequency (MHz)	Bandwidth (MHz)	Typical IL (dB)	I / O Configuration	Rejection {dB @ BW or Freq (MHz)}	Package Size (mm)	Part Number
RF Filter	710	20	2	SE / SE	50 @ 140.00	3.81x2.54	880370
RF Filter, ISM	915	15	3.5	SE / SE	40 @ 35.00	6.35x4.57	880371
RF Filter	1030	15	2.5	SE / SE	40 @ 45.00	3.81x2.54	880367
RF Filter	1090	15	2.5	SE / SE	40 @ 45.00	3.81x2.54	880374
GPS RF Filter, L5	1176	28	2.75	SE / SE	40 @ 140.00	3.26x1.60	880364
GPS RF Filter, L2	1227	30	2.75	SE / SE	40 @ 140.00	3.26x1.60	880272
GPS RF Filter, L2	1227	15	1.5	SE / SE	40 @ 250.00	3.26x1.60	880366
GPS RF Filter, L2	1227	15	3	SE / SE	40 @ 45.00	3.81x2.54	880372
RF Filter	1280	20	3	SE / SE	40 @ 105.00	3.81x2.54	880368
GPS RF Filter, L3 / L4	1380	30	3	SE / SE	40 @ 160.00	3.26x1.60	880365
GPS RF Filter, L1	1575	30	3	SE / SE	40 @ 160.00	3.26x1.60	880273
GPS RF Filter, L1	1575	18	1.5	SE / SE	40 @ 350.00	3.26x1.60	880085
GPS RF Filter, L1	1575	25	3	SE / SE	40 @ 60.00	3.81x2.54	880373
RF Filter	2324	38	3	SE / SE	40 @ 150.00	3.81x2.54	880148
WCS Passband RF Filter	2332.5	55	3	SE / SE	10 @ 2300.00 & 2370.00	1.70x1.30	885002
SDARS	2332.5	45	1.7	SE / BAL	35 @ 2100.00	1.4x1.2	856604
SDARS Notch RF Filter	2332.5	55	1.5 (Out of Band IL)	SE / SE	17 @ 2332.50 (Notch Rej)	1.70x1.30	885003
ISM Passband Filter	2436	72	2	SE / SE	20 @ 2495.00	1.70x1.30	885007
ISM Notch RF Filter	2440	72	1.5 (Out of Band IL)	SE / SE	25 @ 2440.00	1.70x1.30	885008
ISM Notch RF Filter	2440	85	2 (Out of Band IL)	SE / SE	18 @ 2440 (Notch Rej)	1.70x1.30	885010
RF Filter, MMDS	2560	30	3	SE / SE	40 @ 150.00	3.81x2.54	880157
RF Filter, ISM	5775	100	4.5	SE / SE	20 @ 350.00	3.26x1.60	880369

Automotive

Description	Frequency Bands	Package Size (mm)	Part Number
QB GSM / GPRS Tx Module; PA / LPF / SP6T Switch	GSM850 / 900, DCS / PCS	6.0x6.0x1.1	TQM6M4003*
QB GSM / GPRS / EDGE-Polar PA Module	GSM850 / 900, DCS / PCS	5.0x5.0x1.0	TQM7M5012*

NOTES: * = New

GPS

Description	Frequency Bands	Features	Package Size	Part Number
GPS LNA MMIC	1575 MHz, GPS L1	Ultra Compact Package, Shut-off Function	1.3x2.0x0.4	TQP340003
GPS Filter-LNA-Filter Module	1575 MHz, GPS L1	Low Noise (1.56 dB) and High Gain (16 dB)	3.0x3.0x1.0	TQM640002

GSM / GPRS / EDGE

Description	Frequency Bands	Features	Package Size (mm)	Part Number
QB GSM / GPRS PA Module	GSM850 / 900, DCS / PCS	Low Band Ibatt < 1.5A @ Pcal w/PAE 55%	5.0x5.0x1.1	TQM7M4007
QB GSM / GPRS / EDGE-Linear HADRON II PA Module™	GSM850 / 900, DCS / PCS	Low Band Ibatt < 1.5A @ Pcal w/PAE 55%	5.0x5.0x1.0	TQM7M5005H
DB GSM / GPRS QUANTUM Tx Module™; PA / LPF / SP4T, Quad-Band Tx & Dual-Band Rx	GSM900 / DCS or GSM850 / PCS	High Efficiency Broadband Tx, 2 Rx Ports	6.0x6.0x1.1	TQM6M4048
QB GSM / GPRS QUANTUM Tx Module™; PA / LPF / SP6T	GSM850 / 900, DCS / PCS	High Efficiency & Smaller Application Size	6.0x6.0x1.1	TQM6M4049
QB GSM / GPRS / EDGE-Linear TRP QUANTUM Tx Module™; PA / LPF / SP6T	GSM850 / 900, DCS / PCS	High GMSK Efficiency & Best TRP	6.0x8.0x1.0	TQM6M5014

3G - CDMA / EV-DO, 4G - LTE

Description	Bands	Features	Package Size (mm)	Part Number
CDMA TRITIUM II PA-Duplexer Module™; BAL Input w/Coupler	Cellular	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM613027
CDMA TRITIUM II PA-Duplexer Module™; SE Input w/Coupler	Cellular	2-Bit (Hi / Med / Lo Power Modes)	7.0x4.0x1.1	TQM613029
CDMA TRITIUM II PA-Duplexer Module™; SE Input w/Coupler	Cellular	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM613030
CDMA TRITIUM II PA-Duplexer Module™; SE Input w/Coupler	PCS	2-Bit (Hi / Med / Lo Power Modes)	7.0x4.0x1.1	TQM663029A
CDMA TRITIUM II PA-Duplexer Module™; SE Input w/Coupler	AWS	2-Bit (Hi / Med / Lo Power Modes)	7.0x4.0x1.1	TQM6653029
CDMA SP3T Switch	Cellular / PCS / AWS	Antenna Routing	3.0x3.0x0.9	TQP4M3018
CDMA SP3T Switch	Cellular / PCS / AWS	Antenna Routing	2.0x2.0x0.57	TQP4M3019
LTE TRITON PA Module™, w/Coupler	Band 13	LTE, 2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM700013
CDMA TRITON PA Module™, w/Coupler	PCS	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM766012
CDMA TRITON PA Module™, w/Coupler	AWS	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM756014
CDMA TRITON PA Module™, w/Coupler	Cellular	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM716015
CDMA TRITON PA Module™, w/Coupler	PCS	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM766062
CDMA TRITON PA Module™, w/Coupler	Cellular	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM716065

3G - WCDMA / WGPRES / WEDGE, 4G - LTE

Description	Bands	Features	Package Size (mm)	Part Number
QB GSM / GPRS / EDGE-Polar HADRON PA Module™	GSM850 / 900, DCS / PCS	-87 dBm Typ Rx Noise, +3 to +8 dBm Pin Nom	7.0x7.0x1.1	TQM7M5008
QB GSM / GPRS / EDGE-Polar HADRON II PA Module™	GSM850 / 900, DCS / PCS	-90 dBm Typ Rx Noise, +3 to +8 dBm Pin Nom	5.0x5.0x1.0	TQM7M5012H
QB GSM / GPRS / EDGE-Linear HADRON II PA Module™	GSM850 / 900, DCS / PCS	Input Power Controlled for GMSK & 8PSK	5.0x5.0x1.0	TQM7M5013
QB GSM / GPRS / EDGE-Polar HADRON II PA Module™	GSM850 / 900, DCS / PCS	+3 to +8 dBm Pin Nominal, Current Limiter	5.0x5.0x1.0	TQM7M5022

3G - WCDMA / WGPRES / WEDGE, 4G - LTE (cont.)

Description	Bands	Features	Package Size (mm)	Part Number
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 1	2-Bit (Hi / Med / Lo Power Modes)	4.0x4.0x0.9	TQM776003
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 1	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM776011
WCDMA / HSUPA TRITON PA Module™, w/Coupler	PCS / Band 2	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM766012
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 4	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM756014
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 5	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM716015
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 8	2-Bit (Hi / Med / Lo Power Modes)	3.0x3.0x0.9	TQM726018
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 1	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM776061
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 2	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM766062
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 5	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM716065
WCDMA / HSUPA TRITON PA Module™, w/Coupler	Band 8	1-Bit (Hi / Lo Power Modes)	3.0x3.0x0.9	TQM726068
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™ ; SE Input w/Coupler, Detector	Band 1	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM676021
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™ ; SE Input w/Coupler, Detector	Band 2	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM666022
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™ ; SE Input w/Coupler, Detector	Band 4	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM656024*
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™ ; SE Input w/Coupler, Detector	Bands 5 and 6	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM616025
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™ ; SE Input w/Coupler, Detector	Bands 5 and 6	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM616020**
WCDMA / HSUPA TRITIUM III PA-Duplexer Module™ ; SE Input w/Coupler, Detector	Band 8	1-Bit (Hi / Lo Power Modes)	7.0x4.0x1.1	TQM626028L
QB GSM / GPRS / EDGE-Linear TRP QUANTUM II Tx Module™ : PA / LPF / SP8T WEDGE Switch w/Quad-Band WCDMA Antenna Pass-Through	GSM850 / 900, DCS / PCS & WCDMA B1, B2, B5 / 6, B8	Integrated QB GSM / GPRS / EDGE PA & Antenna Switch Supporting WCDMA	7.0x7.5x1.1	TQM6M9014

NOTES: * = **New**, ** For a specific HSDPA transceiver variant, contact Customer Service.

WLAN & Bluetooth® for Handsets

Description	Bands	Features	Package Size (mm)	Part Number
5 GHz WLAN PA MMIC	802.11 a	ETSLP-16 Package	3.0x3.0x0.45	TQP787011*
2.4 GHz WLAN LNA + SP3T Switch MMIC w/WLAN Tx & Bluetooth® Paths	802.11 b, g	LNA Bypass, ETSLP-12 Package	1.5x1.5x0.55	TQP879007
2.4 GHz WLAN PA + Switch MMIC w/WLAN Rx Balun & Bluetooth® Path	802.11 b, g, n	ETSLP-16 Package, Coupler / Detector	3.0x3.0x0.45	TQM679002A
2.4 GHz and 5 GHz WLAN PA + Switch MMIC w/WLAN Rx Baluns & Bluetooth® Path	802.11 a, b, g, n	ETSLP-24 Package, Coupler / Detector	4.0x4.0x0.45	TQP6M9002

NOTES: * = **New**

WLAN & Bluetooth® for Wireless Data & Personal Media Devices

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz WLAN PA MMIC	802.11 b, g	VQFN-16 Package	3.0x3.0x0.90	TQP777002
5 GHz WLAN PA MMIC	802.11 a	ETSLP-16 Package	3.0x3.0x0.45	TQP787011*
5 GHz WLAN LNA MMIC	802.11 a	SLIM-7 Package	1.3x2.0x0.4	TQL5000
2.4 GHz & 5 GHz SPDT Switch MIMC	802.11 a, b, g	ETSLP-6 Package	1.3x2.0x0.45	TQS5200E

WLAN & Bluetooth® for Wireless Data & Personal Media Devices (cont.)

Description	Bands	Features	Package Size (mm)	Part Number
2.4 GHz WLAN LNA + SP3T Switch MMIC w/WLAN Tx & Bluetooth® Paths	802.11 b, g	LNA Bypass, ETSLP-12 Package	1.5x1.5x0.55	TQP879007
2.4 GHz WLAN PA + Switch MMIC w/WLAN Rx Balun & Bluetooth® Path	802.11 b, g, n	ETSLP-16 Package, Coupler / Detector	3.0x3.0x0.45	TQM679002A
2.4 GHz & 5GHz WLAN PA + Switch MMIC w/WLAN Rx Baluns & Bluetooth® Path	802.11 a, b, g, n	ETSLP-24 Package, Coupler / Detector	4.0x4.0x0.45	TQP6M9002
Bluetooth® EDR v2.0 Class 1 PA MMIC	2.4 to 2.5 GHz ISM Band	STSLP-12 Package	2.0x2.0x0.57	TQP770001
Bluetooth® Class 1 PA MMIC	2.4 to 2.5 GHz ISM Band	SLIM-7 Package	1.3x2.0x0.4	CGB241

NOTES: * = New

UHF RFID

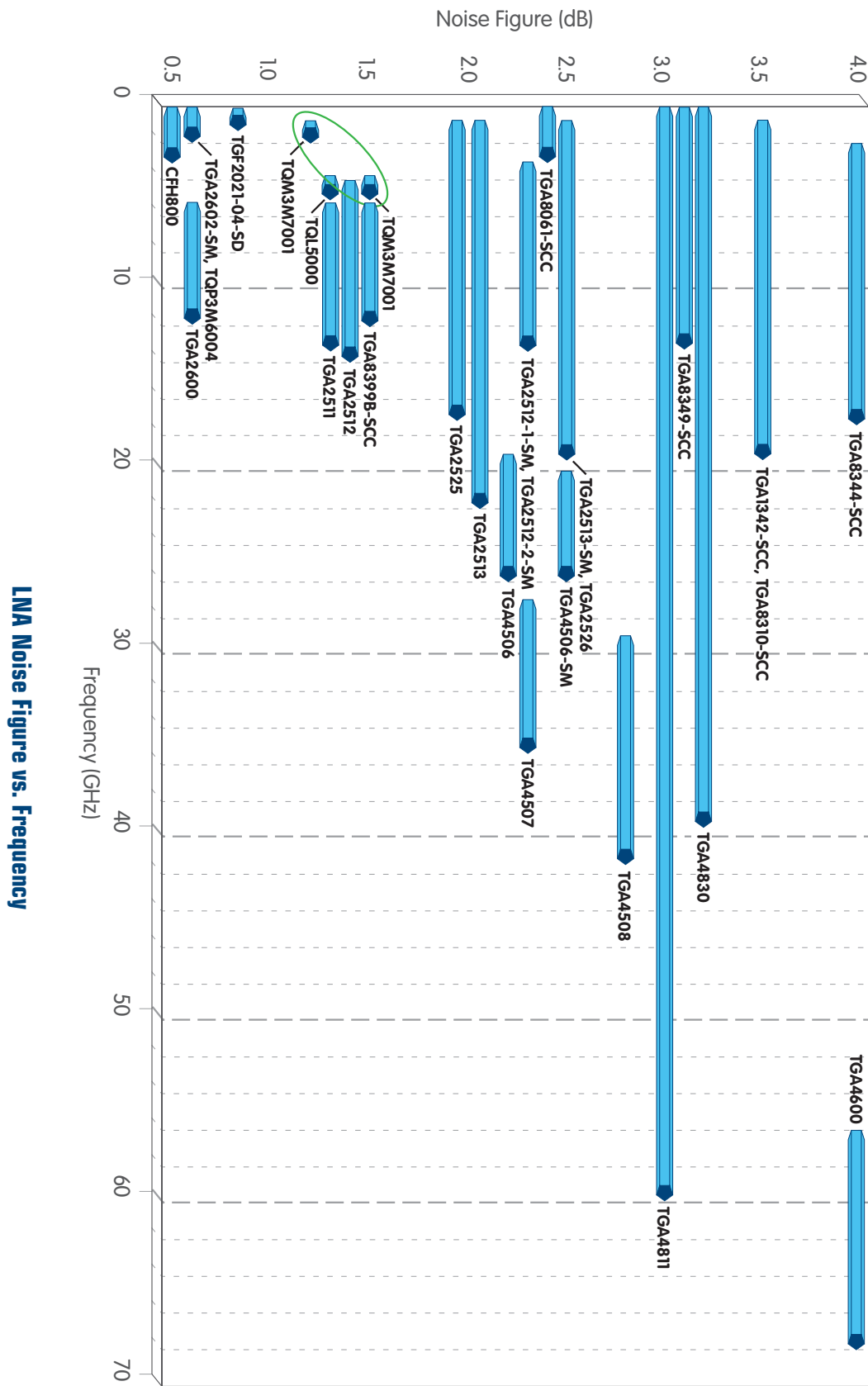
Description	Frequency (MHz)	Channels / Spacing (kHz)	Max Output Power (W)	Protocol Support	Region of Operation	Interface	Part Number
Reader PCMCIA Form Factor Module (ETSI 302.208)	865.7 - 867.5	4 / 600	1W	ISO18000-6B & -6C	Europe	Serial TTL	WJR7081*
Reader PCMCIA Form Factor Module (FCC Pt 15)	902.75 - 927.25	50 / 500	1W	ISO18000-6C	N. America	Serial TTL	WJR7000
PCMCIA Reader Module (FCC Pt 15)	902.75 - 927.25	50 / 500	0.5W	ISO18000-6B & -6C	N. America	PCMCIA	MPR6000
PCMCIA Reader Module (FCC Pt 15) w/Int. Antenna	902.75 - 927.25	50 / 500	0.5W	ISO18000-6B & -6C	N. America	PCMCIA	MPR5000
Embedded Reader Mod (FCC Pt 15)	902.75 - 927.25	50 / 500	1W	ISO18000-6B & -6C	N. America	Serial TTL	WJM3000
Embedded Reader Mod (FCC Pt 15)	902.75 - 927.25	50 / 500	0.25W	ISO18000-6B & -6C	N. America	Serial TTL	WJM1000
PCMCIA Form Factor Module	910.6 - 913.4	15 / 200	1W	ISO18000-6B & -6C	Korea	Serial TTL	WJR7090

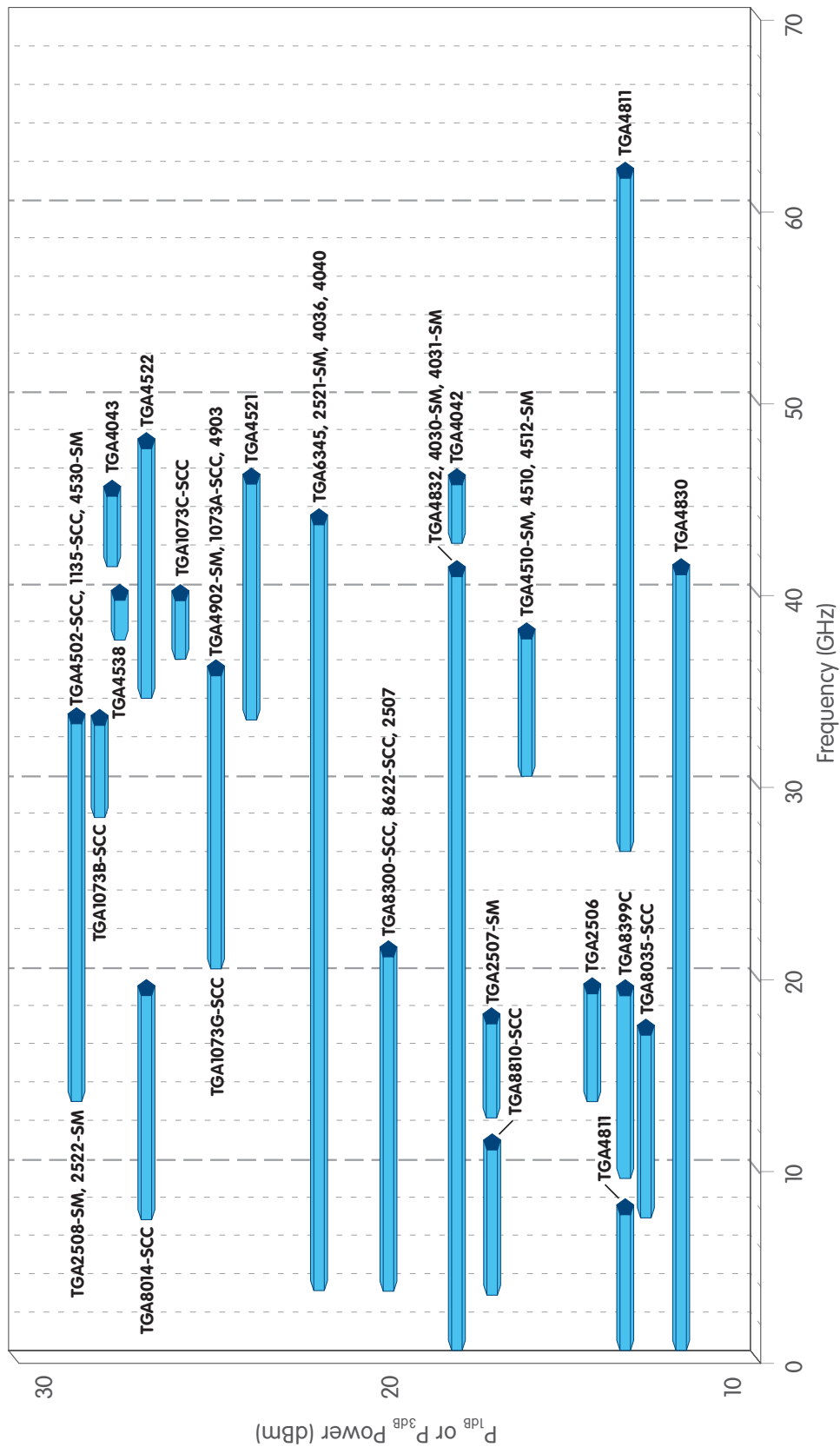
NOTES: * = New

Amplifiers

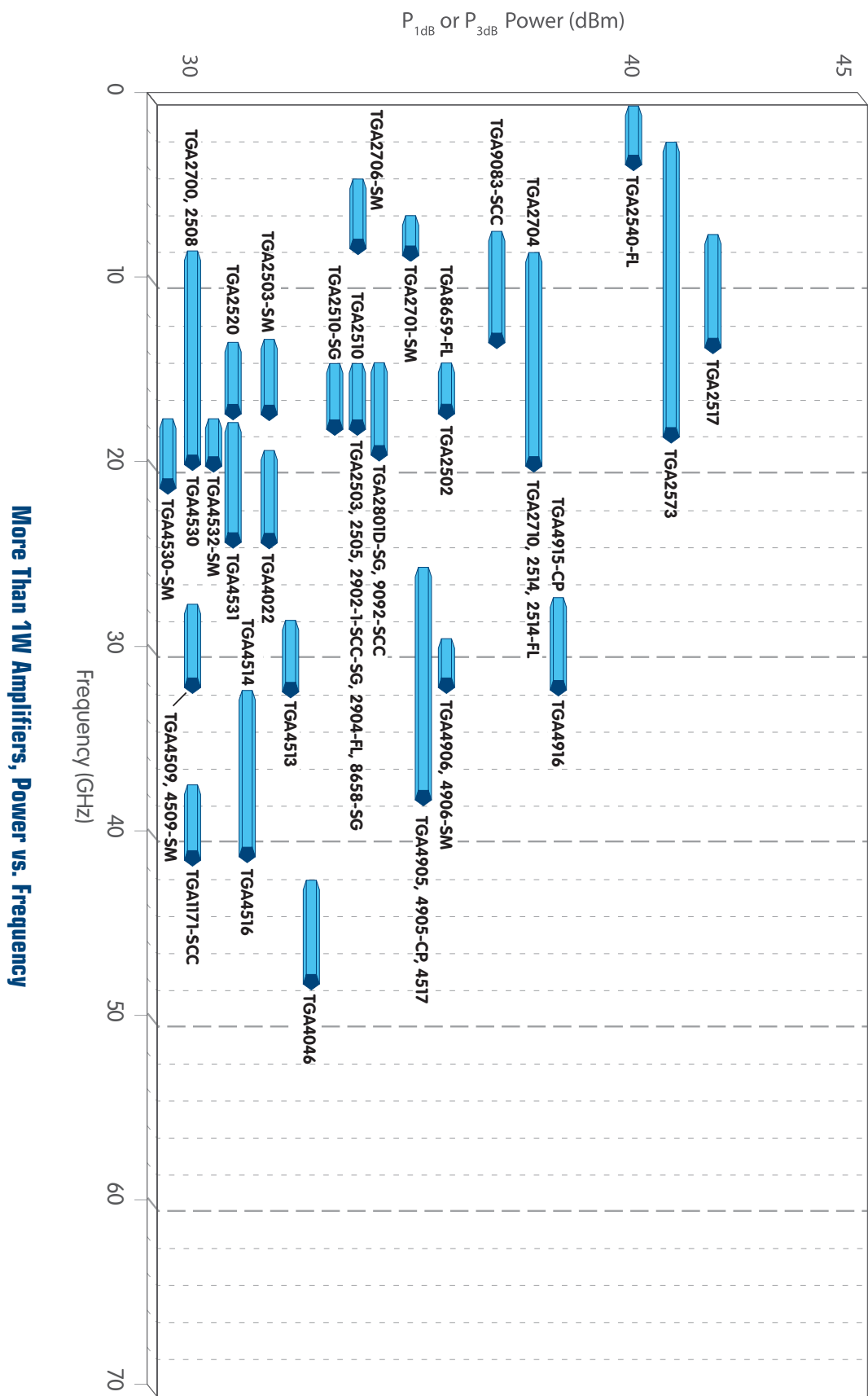
Description	Frequency (GHz)	Power (Vpp or dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
9.9 - 12.5Gb/s 3V - 7V Driver	DC - 13	3 - 7 Vpp	32	—	3.3 - 5 / 115	SM-A8-28	TGA4956-SM
9.9 - 12.5 Gb/s Modulator Driver	DC - 16	3V - 10V	35	2.5	5.5 - 8 / 210	SL-A2-18	TGA4953-SL
9.9 - 12.5 Gb/s Modulator Driver	DC - 16	3V - 9V	35	2.5	5.5 - 8 / 210	SL-A4-18	TGA4954-SL
12.5 Gb/s NRZ Driver	DC - 18	11V	16	—	8 / 285	Die	TGA4807
12.5 Gb/s NRZ Driver	DC - 18	24 dBm	16	3.5	5 - 8 / 70 - 175	Die	TGA1328-SCC
12.5 Gb/s NRZ Driver	DC - 18	8V	16	3.5	8 / 175	SL-A1-12	TGA8652-SL
15 Gb/s 10V Modulator Driver	DC - 20	3 - 10 Vpp	22	—	7 / 280	6x6 QFN	TGA4826-SM*
40 & 100 Gb/s 8Vpp SE Driver	DC - 30	3 - 9 Vpp	32	—	6 - 7 / 270	SL-A7-21	TGA4943-SL
Wideband Driver (40 Gb/s)	DC - 35	4V	12	—	5 / 135	Die	TGA4832
45 Gb/s 8Vpp SE Driver	DC - 35	5 - 9 Vpp	30	—	6 - 7 / 300	SL-A7-21	TGA4942-SL**
45 Gb/s 10Vpp Diff In / Out Driver	DC - 35	6 - 10 Vpp Diff	27 Diff	—	5 - 6 / 500	—	TGA4958-SL**
40 Gb/s TIA, SE	DC - 40	—	250 dB W	15pA/Hz	5 / 30	Die	TGA4812
43 Gb/s Driver	DC - 78	3V	8	5	6 / 82	Die	TGA4803
10.7 - 12.5 Gb/s Linear Modulator Driver	30 kHz - 8	25 dBm	20	—	8 / 310	SM-A8-28	TGA4823-2-SM

NOTES: * = New, ** = Coming Soon, SE = Single-Ended





Less Than 1W Amplifiers, Power vs. Frequency



PACKAGING

For detailed information on TriQuint product packaging, please visit our website at www.triquint.com/prodserv

ORDERING

TriQuint products can be purchased through:

- **Distributors / Resellers:**
TriQuint products can be purchased from any one of the distributors or resellers listed on our website at www.triquint.com/sales
- **Local Sales Representatives:**
Local sales representatives are skilled at examining application needs from a variety of angles to aid the design process. Their insight and specialized experience, paired with your goals, can find the combination of products that best meet overall objectives. Since these representatives work with a variety of customers in many different design environments, their experience can be valuable in determining the right 'fit' for a particular application. To locate a sales representative, please visit our website at www.triquint.com/sales
- **TriQuint Field Sales Offices:**
We have regional sales offices across the globe to work closely with you on your next TriQuint product purchase. To identify the closest regional sales office, please go to our website at www.triquint.com/sales

TERMS & CONDITIONS

For a complete listing of TriQuint terms and conditions of sale, please visit our website at www.triquint.com/sales

EXPORT COMPLIANCE

Virtually all products TriQuint offers for sale as detailed in the Product Selection Guide are available for export in compliance with US government regulations. Please contact your TriQuint salesperson for details.

PRODUCT SUPPORT

- **Product Data Sheets and Literature:**
Detailed information on our products including datasheets and other literature can be found on the TriQuint website at www.triquint.com/prodserv
- **Applications Support:**
Detailed product support information can be found on the TriQuint website at www.triquint.com/prodserv

RELIABILITY PROGRAMS

Our programs are in line with JEDEC and other industry standards.

ENVIRONMENTAL POLICY

TriQuint Semiconductor is committed to managing environmental matters as an integral part of our business, complying with all applicable laws, regulations and other requirements, preventing pollution and continually improving.

ENVIRONMENTAL SYSTEMS

- ISO-14001:2004 (Select Sites)

QUALITY POLICY

The people of TriQuint Semiconductor are committed to continuous improvement, quality, reliability and customer satisfaction in everything we do.

QUALITY SYSTEMS

- ISO-9001:2008 Certified (Select Sites)
- ISO / TS 16949:2009 Certified (Select Sites)
- ISO / AS9100 Certified (Select Sites)

QUALITY TOOLS UTILIZED

- Design Failure Mode & Effects Analysis (DFMEA)
- Process Failure Mode & Effects Analysis (PFMEA)
- Process Control Plan (PCP)
- Production Part Approval Process (PPAP)
- Eight Discipline Problem Solving (8-D)
- Real Time Statistical Process Control (SPC)
- Measurement System Analysis (MSA)
- Advanced Product Quality Planning (APQP)

For further details on TriQuint quality information, please visit our website at www.triquint.com/company/quality

PRODUCT COMPLIANCE POLICIES

TriQuint is committed to meeting all global product environmental regulations that affect its products. These regulations include:

- Directive 2002 / 95 / EC (RoHS Directive)
- Management Methods for Control of Pollution Caused by Electronic Information Products (China RoHS)
- Directive 94 / 62 / EC (Packaging Directive)
- Directive 2006 / 122 / EC (PFOS Directive)
- Regulation (EC) No 1907 / 2006 (REACH Regulation)
- Commission Decision 2009 / 251 / EC (Dimethylfumarate (DMF) Ban)

All active TriQuint commercial standard products are compliant with these Directives. Contact TriQuint for the RoHS Compliance status of custom products, military products and products manufactured prior to June 2006. All new product designs are halogen-free since late 2008. TriQuint does not use any REACH Substances of Very High Concern (SVHCs) in its products or packaging materials.

Contact TriQuint at rohs_info@tqs.com for any product compliance information requests.

In addition to being compliant with RoHS, TriQuint participates in the following customer programs:

- Sony Green Partner
- Samsung Eco-Partner

For further details on TriQuint Environmental, Health & Safety information, please visit our website at www.triquint.com/company/ehs

NOTICE

The data provided in this selection guide is subject to change without notice. TriQuint reserves the right to make changes to specifications and other information at any time.

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