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April 2013

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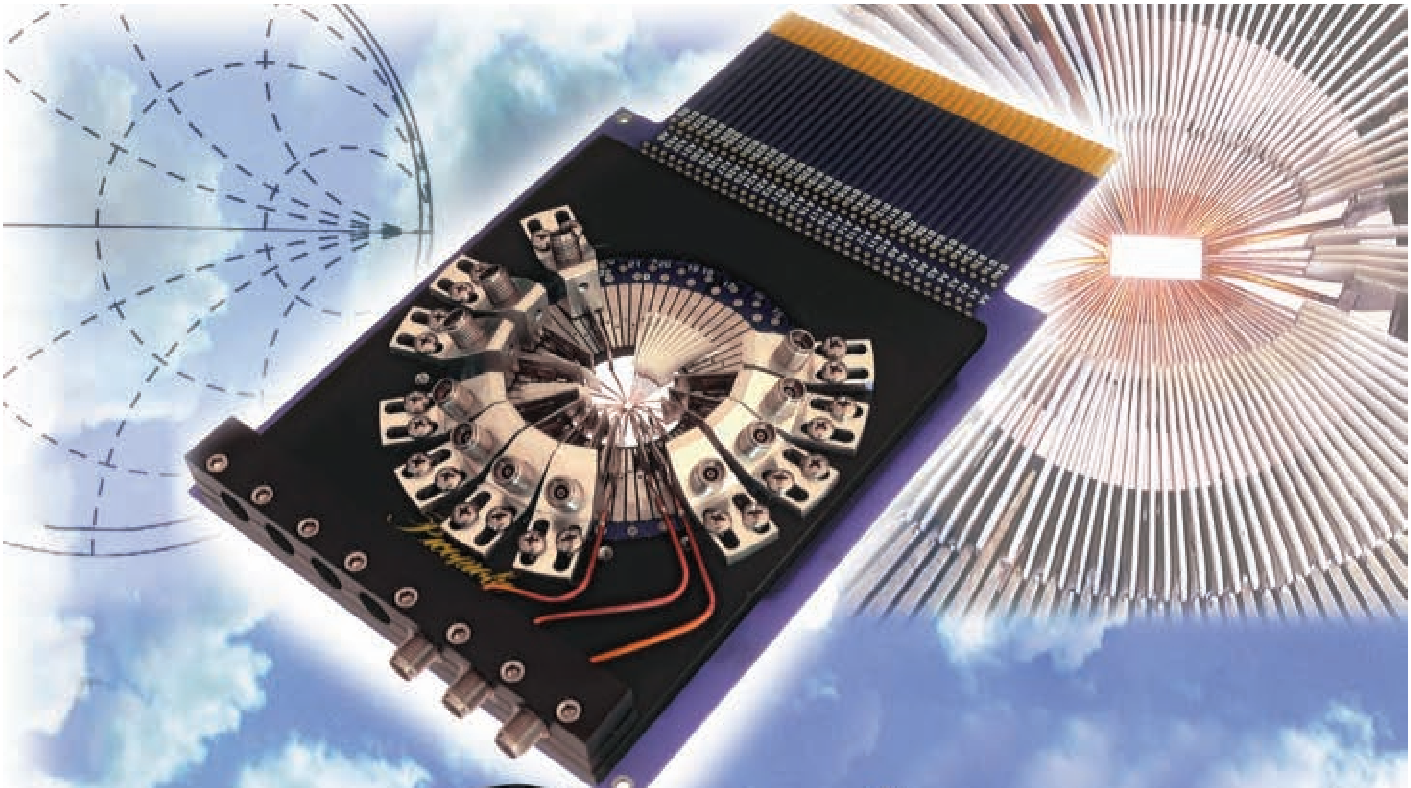

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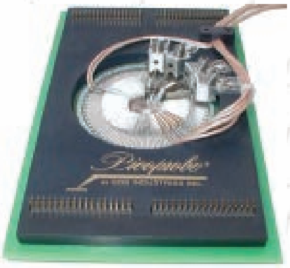

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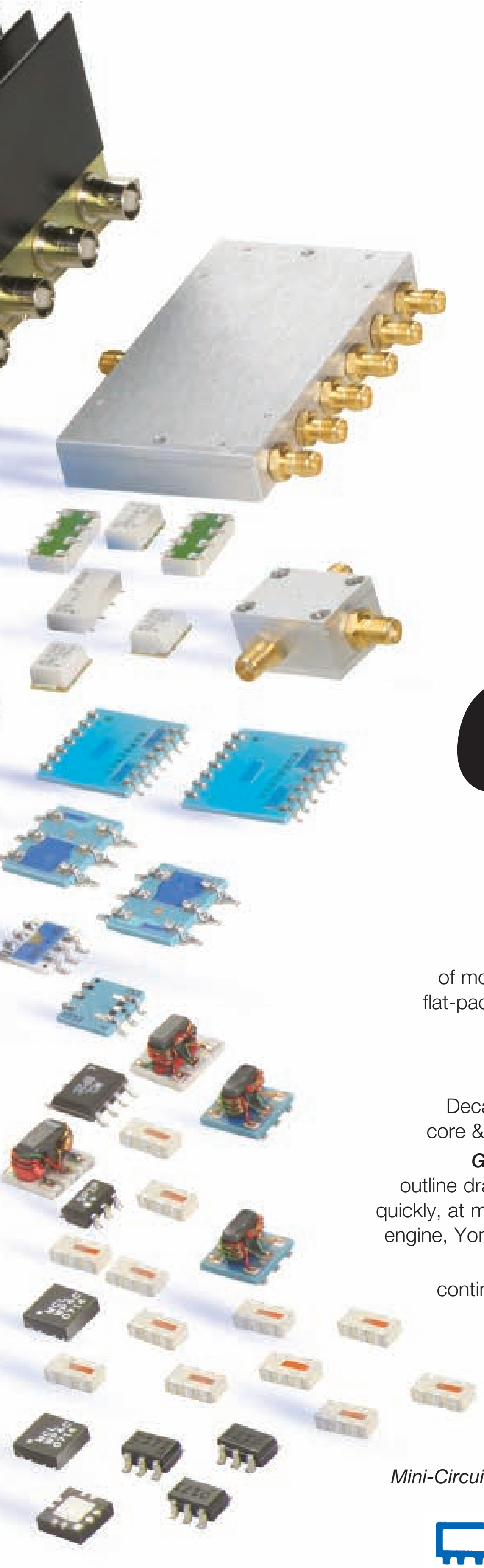

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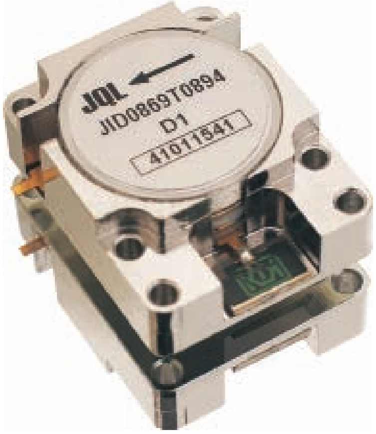

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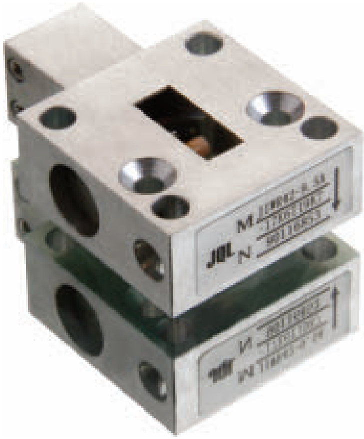

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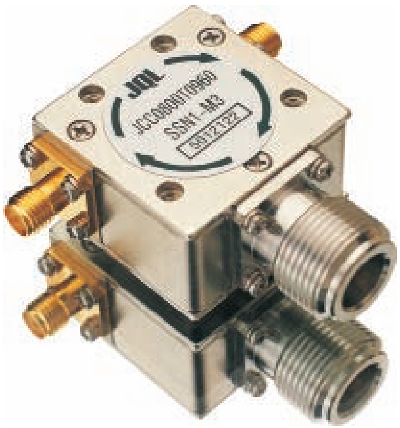

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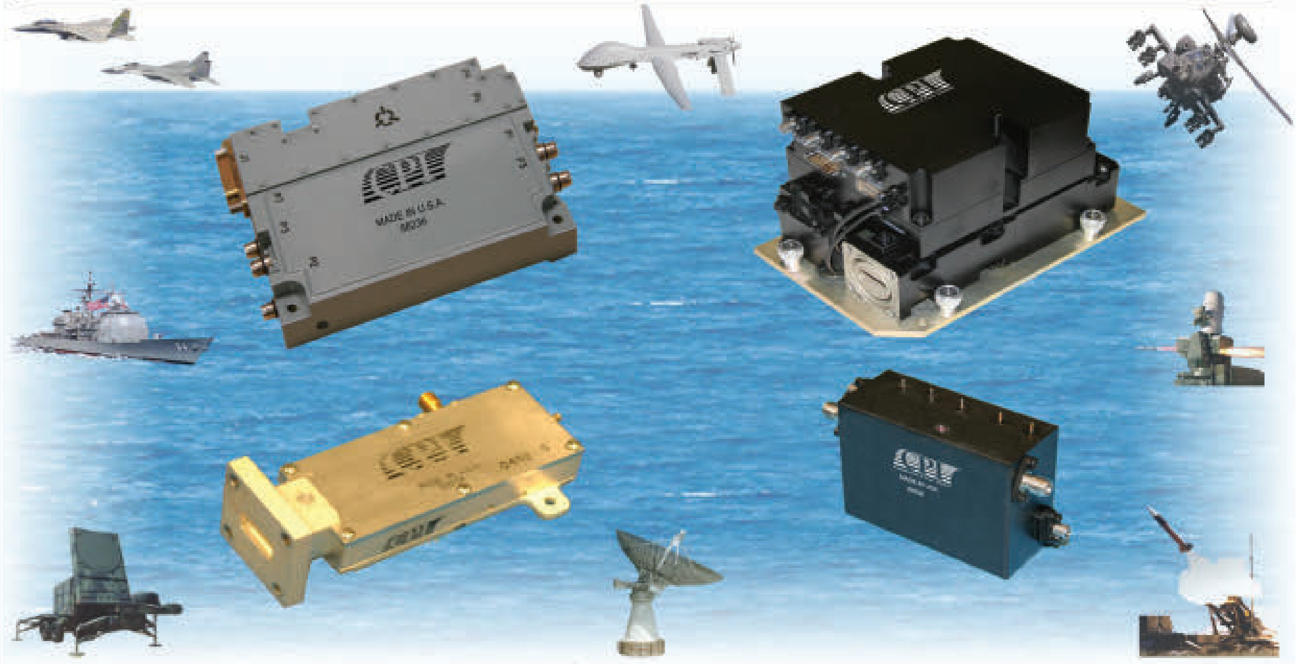

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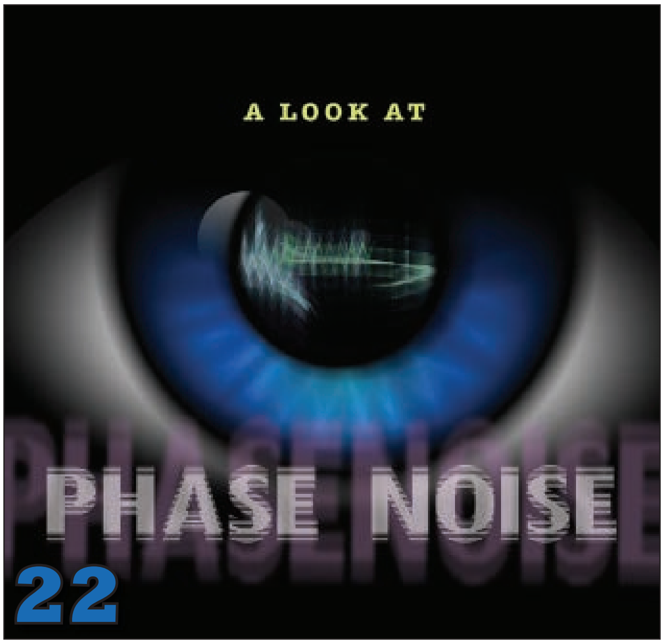

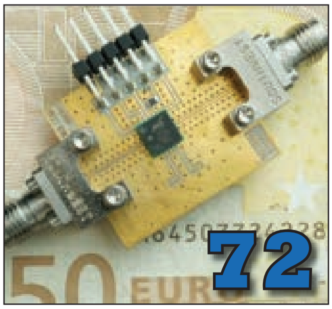

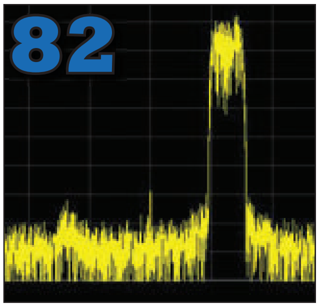

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- Device Characterization Methods for Advanced RF/Microwave Design
- Techniques to Minimize Phase Noise of Crystal Oscillator Circuits

Microwave Journal (USPS 396-250) (ISSN 0192-6225) is published monthly by Horizon House Publications Inc., 685 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

POSTMASTER: Send address corrections to *Microwave Journal*, PO Box 3256, Northbrook, IL 60065-3256 or e-mail mwj@omeda.com. Subscription information: (847) 291-5216. This journal is issued without charge upon written request to qualified persons working in the RF & microwave industry. Other subscriptions are: domestic, $120.00 per year, two-year subscriptions, $185.00; foreign, $200.00 per year, two-year subscriptions, $370.00; back issues (if available) and single copies, $10.00 domestic and $20.00 foreign. Claims for missing issues must be filed within 90 days of date of issue for complimentary replacement.

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February Survey
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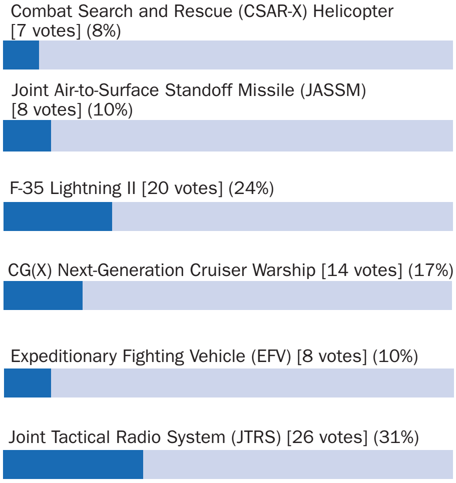

Executive Interview

Erkan Ickam, director of marketing for **EMSCAN** talks about his company's very-near-field measurement tools and how they offer PCB designers real-time results for antenna design and EMC/EMI studies.

White Papers

Solutions for Design and Test of Downlink 8x8 LTE MIMO
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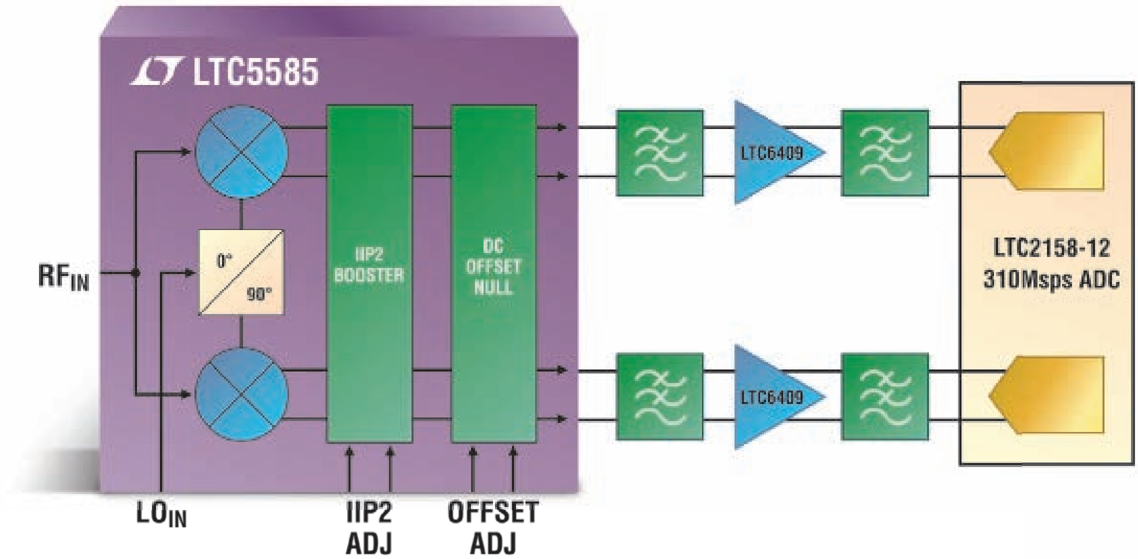

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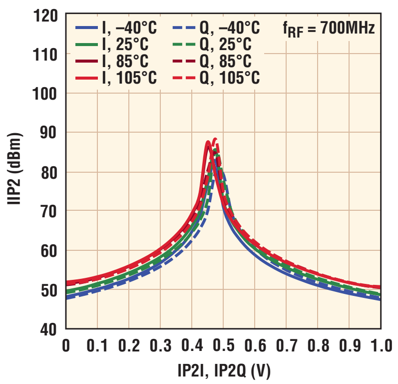
Adjustable IIP2	>80dBm	>80dBm
DC Offset Cancellation	Yes	Yes

IIP2 Optimization vs Trim Voltage



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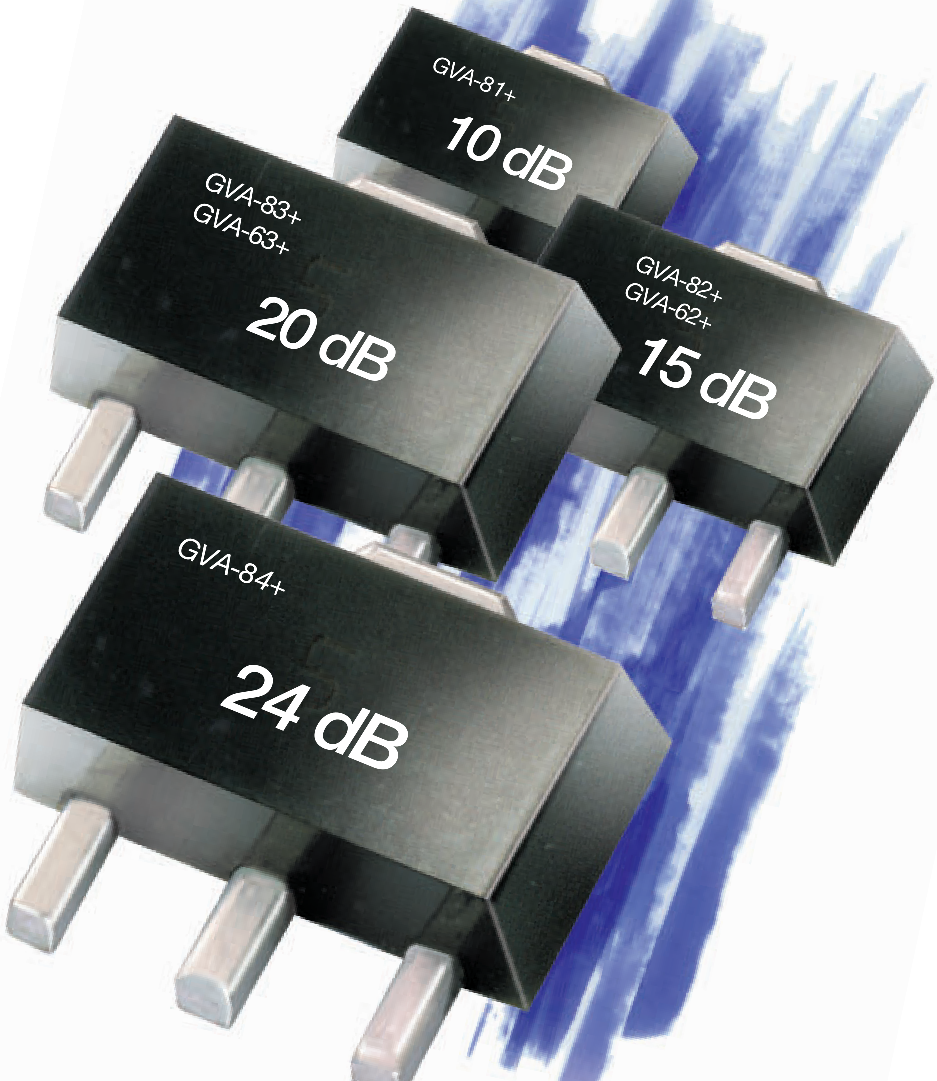

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U.S. Patents 7739260, 7761442

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28	29	30	1	2	3	4
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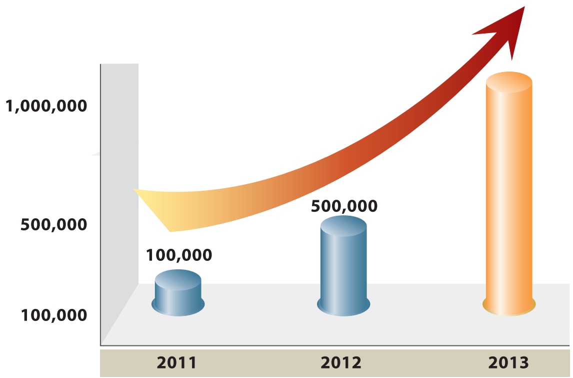
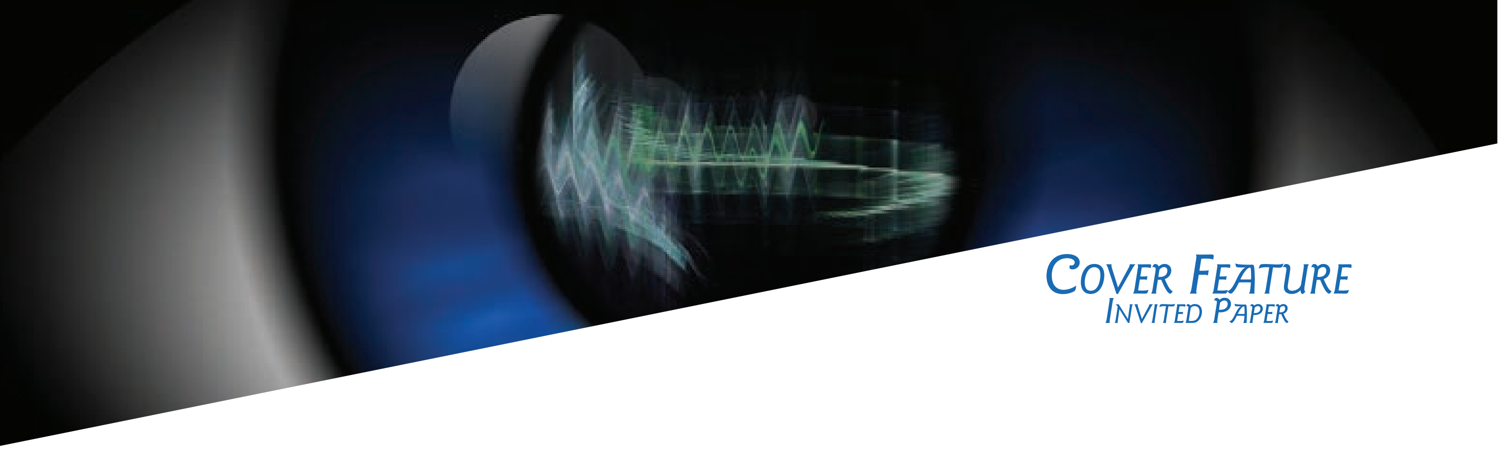


RFHIC's GaN solutions are so affordable that RRHs based on RFHIC's GaN pay for themselves in just a few years.

While LDMOS is the mainstay of the Telecom industry, recent price drops of GaN based amplifiers have placed it on par with LDMOS based Remote Radio Head (RRH) systems' price. GaN's technological advantage remains in its wider bandwidth coverage, allowing future application upgrades, and most importantly, its efficiency. With more than 35 million watts of GaN powered RRHs rolled out to LTE providers in the U.S. and Asia already, GaN technology is starting to take hold of the wireless market. Thanks to these efficient GaN power amplifiers, these carriers will not only save billions of dollars of operating costs over the lifespan of the RRH systems but also be greener by reducing significant amounts of carbon dioxide. Again, analyst estimates that wireless carriers in U.S. alone can save over $2 billion per year on operating costs, primarily from energy savings on their wireless infrastructures by simply switching to GaN power amplifiers from LDMOS.

Moreover, GaN's efficiency enables RRH designers to make systems smaller by reducing the heat sink size and power supply requirement. This directly translates to lower installation and RRH space rental expenses for carriers. Additionally, overall reliability also affects the carriers' bottom lines by producing more reliable LTE services to end users, and also by reducing expected maintenance expenses. Furthermore, carriers can save on future upgrades as GaN based RRHs can support multi-band, multi-mode, and multi-carrier technology.

RFHIC is the leading manufacturer of GaN power amplification solutions worldwide, having produced solutions for Sprint, LG Telecom, SK Telecom, and a major Japanese carrier for their RRH solutions. RFHIC will deliver around 500,000 GaN power amplifiers for LTE roll-outs in 2012 - consider updating this to what we rolled out or what we will roll out in 2013. For more information, contact us at sales@rfhicusa.com



COVER FEATURE
INVITED PAPER

Phase Noise Measurements and System Comparisons

One of the most important parameters for oscillators is phase noise as it is critical to most applications.[1-21] There are several methods for measuring phase noise which will be covered here including the pros and cons of each technique. Example measurements on various types of systems will also be compared including their accuracy and speed.

The pioneer in phase noise measurement was Hewlett Packard.[1,2] Modern phase noise systems use the correlation principle but this method has some drawbacks. The most direct and sensitive method to measure the spectral density of phase noise, $S_{\Delta\theta}(f_m)$, requires two sources – one or both of them may be the device(s) under test – and a double balanced mixer used as a phase detector (see ***Figure 1***). The RF and LO input to the mixer should be in phase quadrature, indicated by 0 V DC at the IF port. Good quadrature assures maximum phase sensitivity K_θ and minimum AM sensitivity. With a linear mixer, K_θ equals the peak voltage of the sinusoidal beat signal produced when both sources are frequency offset.

When both signals are set in quadrature, the voltage ΔV at the IF port is proportional to the fluctuating phase difference between the two signals.

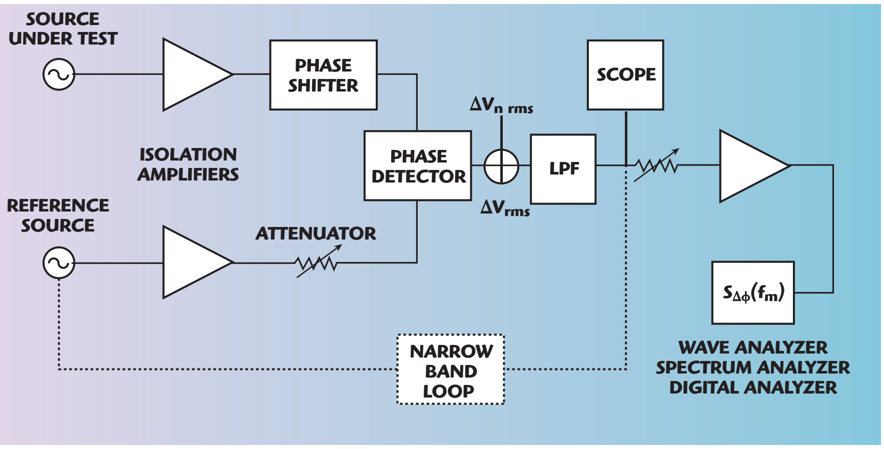
$$\Delta\theta_{rms} = \frac{1}{K_\theta V_{rms}} \qquad (1)$$

$$S_{\Delta\theta}(f_m) = \frac{(\Delta V_{rms})^2 (1Hz)}{V_{B\,peak}^2} \frac{1}{2} \frac{(\Delta V_{rms})^2 (1Hz)}{V_{B\,rms}^2} \qquad (2)$$

$$L(f_m) = \frac{1}{2} S_{\Delta\theta}(f_m) = \frac{1}{4} \frac{(\Delta V_{rms})^2 (1Hz)}{V_{B\,rms}^2} \qquad (3)$$

where K_θ = phase detector constant,
= $V_{B\,peak}$ for a sinusoidal beat signal.

ULRICH L. ROHDE, AJAY K. PODDAR AND ANISHA M. APTE
Synergy Microwave Corp., Paterson, NJ



▲ *Fig. 1 Phase noise system with two sources maintaining phase quadrature.*

The calibration of the wave analyzer or spectrum analyzer can be read from the equations. For a plot of $L(f_m)$, the 0 dB reference level is to be set 6 dB above the level of the beat signal. The –6 dB offset has to be corrected by +1.0 dB for a wave analyzer and by +2.5 dB for a spectrum analyzer with log amplifier and average detector. In addition, noise bandwidth corrections may have to be applied.

Since the phase noise of both sources is measured in this system, the phase noise performance of one of them needs to be known in order to measure the other source. Frequently, it is sufficient to know that the actual phase noise of the dominant source cannot deviate from the measured data by more than 3 dB. If three unknown sources are available, three measurements with three different source combinations yield sufficient data to accurately calculate each individual oscillator's performance.

Figure 1 indicates a narrowband phase-locked loop that maintains phase quadrature for sources that are not sufficiently phase stable over the period of the measurement. The two isolation amplifiers should prevent injection locking of the sources. Residual phase noise measurements test one or two devices, such as amplifiers, dividers or synthesizers, driven by one common source. Since this source is not free of phase noise, it is important to know the degree of cancellation as a function of Fourier frequency.

The noise floor of the system is established by the equivalent noise voltage, ΔV_n, at the mixer output. It represents mixer noise as well as the equivalent noise voltage of the following amplifier:

$$L_{system}(f_m) = \frac{1}{4} \frac{\left(\Delta V_{n\ rms}\right)^2 (1Hz)}{V_{B\ rms}^2} \quad (4)$$

Noise floors close to –180 dBc can be achieved with a high-level mixer and a low-noise port amplifier. The noise floor increases with f_m^{-1} due to the flicker characteristic of ΔV_n. System noise floors of –166 dBc at 1 kHz have been realized. This is the limitation of this approach.

In measuring low-phase-noise sources, a number of potential problems have to be understood to avoid erroneous data:

- If two sources are phase locked to maintain phase quadrature, it has to be ensured that the lock bandwidth is significantly lower than the lowest Fourier frequency of interest.
- Even with no apparent phase feedback, two sources can be phase locking (injection locked), resulting in suppressed close-in phase noise.
- AM noise of the RF signal can come through if the quadrature setting is not maintained sufficiently.
- Deviation from the quadrature setting will also lower the effective phase detector constant.
- Nonlinear operation of the mixer results in a calibration error and will add noise.
- A non-sinusoidal RF signal causes K_θ to deviate from $V_{B\ peak}$.
- The amplifier or spectrum analyzer input can be saturated during calibration or by high spurious signals such as line frequency multiples.
- Closely spaced spurious signals such as multiples of 60 Hz may give the appearance of continuous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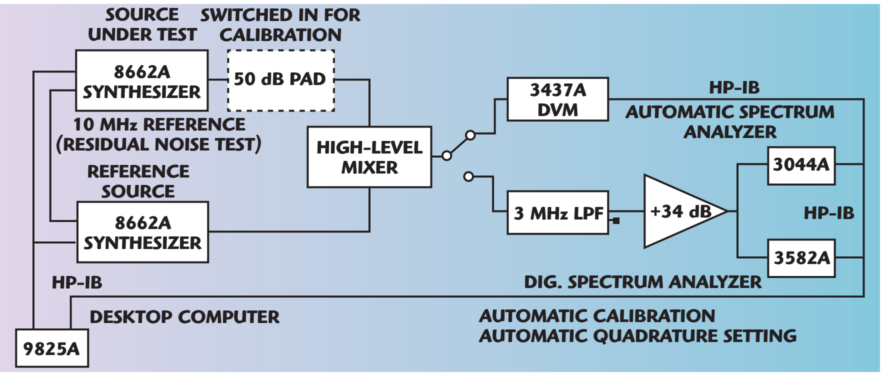
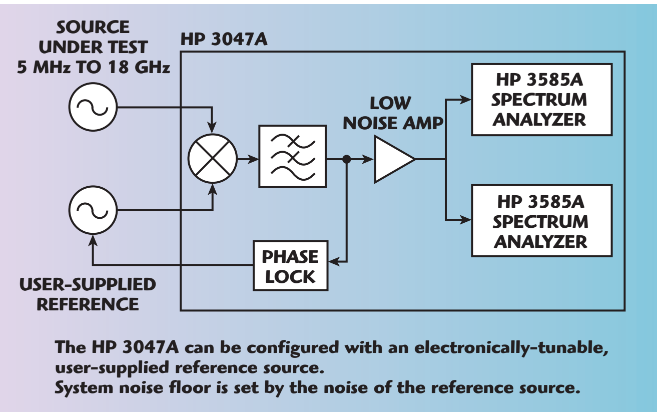


▲ *Fig. 2 Automatic system to measure residual phase noise of two 8662A synthesizers (courtesy of Hewlett-Packard Co.).*

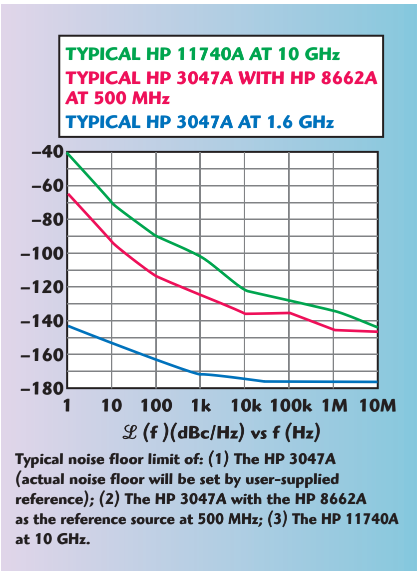
phase noise when insufficient resolution and averaging are used on the spectrum analyzer.

- Impedance interfaces should remain unchanged when going from calibration to measurement.
- In residual measurement system phase, the noise of the common source might be insufficiently canceled due to improperly high delay-time differences between the two branches.
- Noise from power supplies for devices under test or the narrowband phase-locked loop can be a dominant contributor of phase noise.
- Peripheral instrumentation such as the oscilloscope, analyzer, counter or DVM can inject noise.
- Microphonic noise might excite significant phase noise in devices.



▲ *Fig. 3 Block diagram of HP 3047A.*

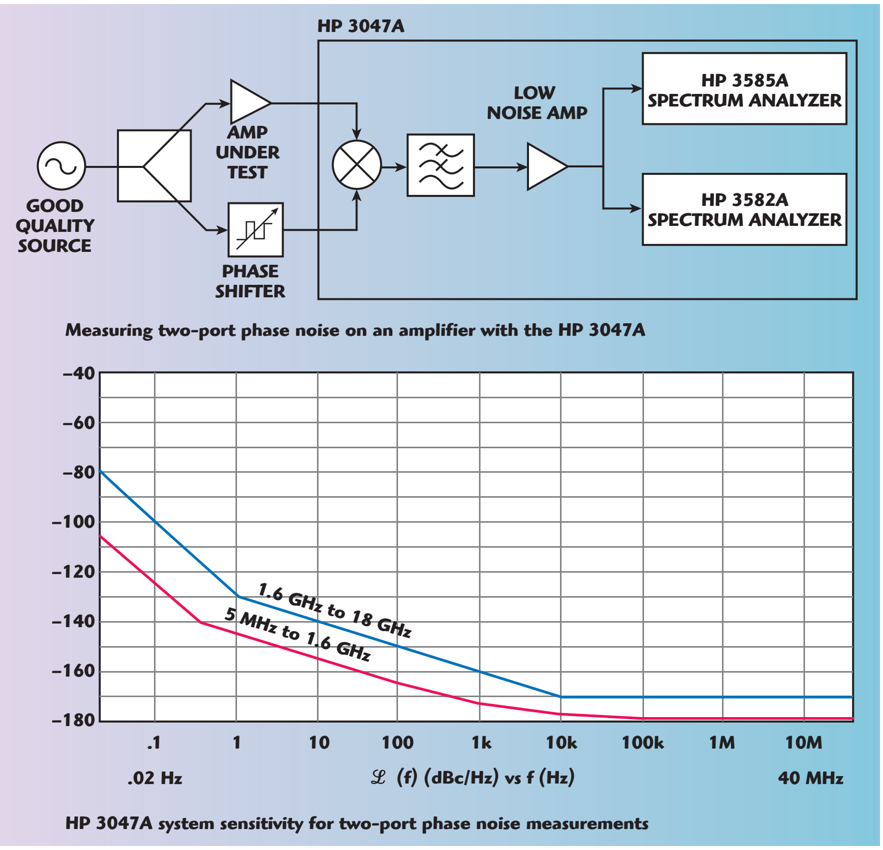
Despite all these hazards, automatic test systems have been developed and operated successfully for years.[4] ***Figure 2*** shows a system that automatically measures the residual phase noise of the 8662A synthesizer. It is a residual test, since both instruments use one common 100 MHz referenced oscillator. Quadrature setting is conveniently controlled by probing the beat signal with a digital voltmeter and stopping the phase advance of one synthesizer when the beat signal voltage is sufficiently close to zero.



▲ *Fig. 4 Typical noise floor limit.*

DOING MEASUREMENTS

As shown in ***Figure 3***, the Hewlett Packard test equipment HP3047A was built around a double-balanced mixer which can handle +23 dBm of power. While this HP equipment is no longer manufactured and has been



▲ *Fig. 5 The HP 3047A residual phase noise measurement, not oscillator phase noise.*

replaced by the Agilent E5052A and E5052B, this system shows some interesting features.

1. The noise floor is about −177 dBc/Hz and the resolution, shown in ***Figure 4*** is approximately −180 dBc/Hz.
2. The limit of the dynamic range is (P_{out} (dBm) + kT – NF), (where NF = NF_{osc} + NF_{amp}) which in the case of a 0 dBm oscillator would be −174 dBc or relative to one sideband −177 dBc - NF. Assuming a signal to be +20 dBm, then the dynamic range is approximately 200 dBc - NF.
3. The term NF_{osc} refers to the large signal noise figure of the oscillator, which can vary from 2 dB at 10 MHz to 6 dB at 100 MHz or even higher at 1000 MHz. As an example, the far out SSB noise at 1000 MHz is typically −172 dBc/Hz at 5 dBm of output power.
4. The mixer and the post amplifier can easily go into compression which raises the noise floor. In the previous publications for this system, this effect was not considered. It was found that some of the measurements done with this system at low frequencies were off, the crystal oscillators in question were actually better.

From a system's point-of-view, the numbers are not that optimistic, as seen from ***Figure 5***. The reason for this is that the transistor used in the oscillator has its own noise contribution. This system is used to measure residual noise in amplifiers or switches. This is an important diagram for system planning.

The HP 3047A has a built-in crystal oscillator and its measured phase-noise is shown in ***Figure 6***. These measurements are actually a little better than what was specified by HP but these are not as good as modern measurement systems.

Synergy kept the old HP system hardware for these references. The system is software based and used an FFT analyzer; for its time this was the best system around, but the measurements took a long time to make. Modern test equipment using the cross-correlation methods are at least 20 times faster.

NOISE IN CIRCUITS AND SEMICONDUCTORS

Microwave applications generally use bipolar transistors and following are their noise contributions.[3,5,6,9,21]

Johnson Noise

- The Johnson noise (thermal noise) is due to the movement of molecules in solid devices called Brown's molecular movements.
  It is expressed as

$$v_n^2 = 4kT_0RB(emf)\left(\text{volt}^2/\text{Hz}\right) \qquad (5)$$

The power can be written as:

$$\text{Noise Power} = \frac{v_n^2}{R} = 4kT_0B\left(W/\text{Hz}\right)$$

for $B = 1\text{Hz}$, Noise Power $= 4kT_0$

$T = 290K$ and

k – Boltzmann's const. $=$

1.38×10^{-23}

by Thevenin, Noise Power $=$

$1.38 \times 10^{-23} \times 290 = 4 \times 10^{-21}\ W$

$$L(\omega) = 10.\log\left(\frac{v_n^2/R}{1\text{dBm}}\right) =$$

-173.97 dBm or about -174 dBm (6)

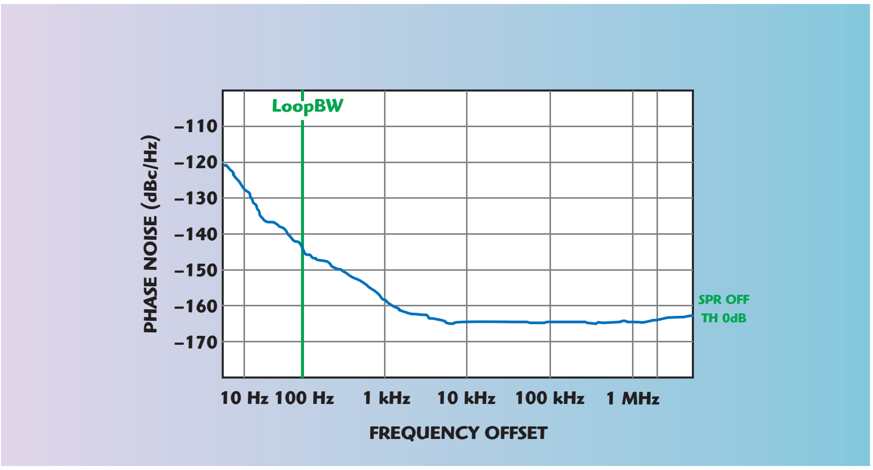


Fig. 6 HP10811B measurement of 10 MHz signal on R&S FSUP.

- In order to reduce this noise, the only option is to lower the temperature, since noise power is directly proportional to temperature.
  The Johnson noise sets the theoretical noise floor.

Planck's Radiation Noise

- The available noise power does not depend on the value of resistor but it is a function of temperature T.
  The noise temperature can thus be used as a quantity to describe the noise behavior of a general lossy one-port network.
- For high frequencies and/or low temperature, a quantum mechanical correction factor has to be incorporated for the validation of equation. This correction term results from Planck's radiation law, which applies to blackbody radiation.

$$P_{av} = kT\Delta f$$

$$P_{av} = kT\Delta f \bullet p(f,T);$$

$$\text{with } p(f,T) = \left[\frac{hf}{kT}\Big/\left(e^{\frac{hf}{kT}} - 1\right)\right]$$

where $h = 6.626 \cdot 10^{-34}$ J/s,

Planck's constant (7)

Schottky/Shot Noise

- The Schottky noise occurs in conducting PN junctions (semiconductor devices) where electrons are freely moving. The root mean square (RMS) noise current is given by

$$\overline{i_n^2} = 2qI_{dc}; P = i_n^2Z \qquad (8)$$

where q is the charge of the electron, P is the noise power, and I_{dc} is the DC bias current.
Z is the termination load (can be complex).

- Since the origin of this noise generated is totally different, they are independent of each other.

Flicker Noise

- The electrical properties of surfaces or boundary layers are in-

fluenced energetically by states, which are subject to statistical fluctuations and therefore, lead to the flicker noise or 1/f noise for the current flow.

- 1/f noise is observable at low frequencies and generally decreases with increasing frequency f according to the 1/f-law until it will be covered by frequency independent mechanism, like thermal noise or shot noise.

Example: The noise for a conducting diode is bias dependent and is expressed in terms of AF and KF.

$$\left\langle i_{Dn}^2 \right\rangle_{AC} = 2qI_{DC}B + KF\frac{I_{DC}^{AF}}{f}B \qquad (9)$$

- The AF is generally in range of 1 to 3 (dimensionless quantity) and is a bias dependent curve fitting term, typically 2.
- The KF value is ranging from $1E^{-12}$ to $1E^{-6}$ and defines the flicker corner frequency.

Transit Time and Recombination Noise

- When the transit time of the carriers crossing the potential barrier is comparable to the periodic signal, some carriers diffuse back and this causes noise. This is really seen in the collector area of NPN transistor.
- The electron and hole movements are responsible for this noise. The physics for this noise has not been fully established.

Avalanche Noise

- When a reverse bias is applied to semiconductor junction, the normally small depletion region expands rapidly.
- The free holes and electrons then collide with the atoms in depletion region, thus ionizing them, and produce a spiked current called the avalanche current.
- The spectral density of avalanche noise is mostly flat. At higher frequencies, the junction capacitor with lead inductance acts as a low-pass filter.
- Zener diodes are used as voltage reference sources and the avalanche noise needs to be reduced by big bypass capacitors.

Prediction of Phase Noise

- In designing an oscillator, one needs to have a concept of how to do this and can hopefully validate the same.

The basic equation (Rohde's Modified Leeson Equation) needed to calculate the phase noise is found in *The Design of Modern Microwave Oscillators for Wireless Applications: Theory and Optimization*.[1,13,14,15,16] It is:

$$\pounds(f_m) = 10\log\cdot\left\{\left[1+\frac{f_0^2}{\left[2f_mQ_0m(1-m)\right]^2}\right]\cdot\left(1+\frac{f_c}{f_m}\right)\frac{FkT}{2P_0}+\frac{2kTRK_0^2}{f_m^2}\right\} \qquad (10)$$

where $\pounds(f_m)$, f_m, f_0, f_c, Q_L, Q_0, F, k, T, P_0, R, K_0 and m are the ratio of the sideband power in a 1 Hz bandwidth at f_m to total power in dB, offset frequency, flicker corner frequency, loaded Q, unloaded Q, noise factor, Boltzmann's constant, temperature in degree Kelvin, average output power, equivalent noise resistance of tuning diode, voltage gain and ratio of the loaded and unloaded Q, respectively.

In the past this was done with the Leeson formula, which contains several estimates, those being output power, flicker corner frequency and the operating (or loaded) Q. Now, one can assume that the actual phase noise is never better than the large signal noise figure (F) given by the following equation:[13,14]

$$F = 1+\frac{Y_{21}^{+}C_2C_c}{(C_1C_2)C_1}\cdot\left[r_b+\frac{1}{2r_e}\left(r_b+\frac{(C_1+C_2)C_1}{Y_{21}^{+}C_2C_c}\right)^2\cdot\left(\frac{1}{\beta^{+}}+\frac{f^2}{f_T^2}\right)+\frac{r_e}{2}\right] \qquad (11)$$

APPLYING CROSS-CORRELATION

The old systems have an FFT analyzer for close-in calculations and are slower in speed. Modern equipment use the noise-correlation method. The reason why the cross-correlation method became popular is that most oscillators have an output between zero and 10 dBm and what is even more important is that only one source is required. The method with a delay

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Compact Opto-Electronic Oscillator

Micro-Opto-Electronic Oscillator

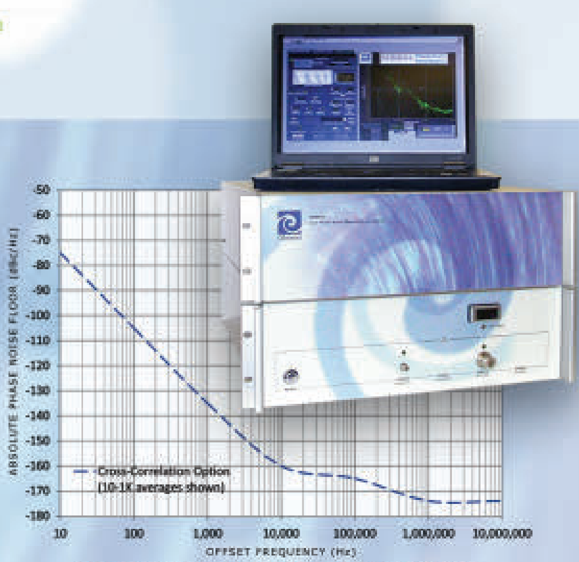
	Advanced OEO	Compact OEO	Micro OEO
Output Frequency	10 GHz	10 GHz	35 GHz
Offset Frequency	SSB Phase Noise (dBc/Hz) – Free Running		
10Hz	-75	-60	-30
100Hz	-115	-90	-55
1kHz	-145	-120	-85
10kHz	-163	-140	-108
100kHz	-165	-150	-120
1MHz	-170	-160	-130
10MHz	-170	-170	-135
Size	19" Rack Mount	25in³	0.06in³

FEATURES

- EMI tolerant
- High stability
- Low vibration/acceleration sensitivity
- Low spurious content

Microwave and Millimeter Wave Phase Noise Test Measurement System

- Complete automated connect & click microwave phase noise/jitter measurement system
- -174 dBc/Hz absolute phase noise measurement capability
- **No** reference source required
- **No** microwave down-converter required



Absolute Phase Noise Floor at 10 GHz

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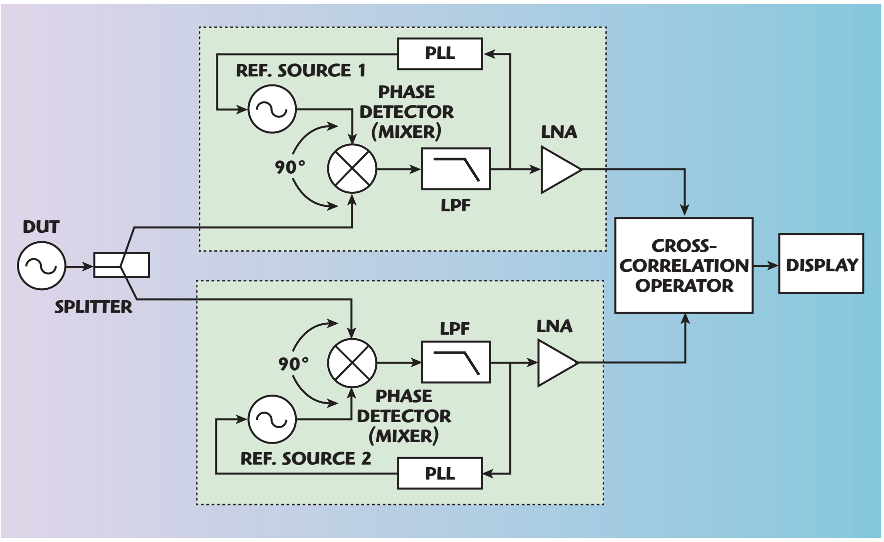


▲ *Fig. 7 Block diagram showing the noise-correlation method.*

line, in reality required a variable delay line to provide correct phase noise numbers as a function of offset (this is shown in reference 1, pp. 148-153, Fig. 7.25 and 7.26).

This technique combines two single-channel reference source/PLL systems and performs cross-correlation operations between the outputs of each channel, as shown in ***Figure 7***.[7,8] The DUT noise through each channel is coherent and is not affected by the cross-correlation, whereas the internal noise generated by each channel is incoherent and is diminished by the cross-correlation operation at the rate of M (M being the number of correlations). This can be expressed as:

$$N_{meas} = N_{DUT} + \left(N_1 + N_2\right) / M^{1/2} \quad (12)$$

where N_{meas} is the total measured noise at the display; N_{DUT} the DUT noise; N_1 and N_2 the internal noise from channels 1 and 2, respectively; and M the number of correlations. The two-channel cross-correlation technique achieves superior measurement sensitivity without requiring exceptional performance of the hardware components. However, the measurement speed suffers when increasing the number of correlations.[5] The built-in synthesizer limits the dynamic range and that is the reason why at lower frequencies crystal-oscillators are used.

The assumption is that the internal reference sources 1 and 2 are at least equal in noise contribution as the DUT and assuming a correlation of 20 dB (limited by leakage and other large signal phenomena) divider noise, those references can be 20 dB worse. Both Rohde & Schwarz and Agilent use a synthesized approach. This limits the dynamic range close-in to the carrier and far-out to the carrier. When using the correlation to get 10 dB more dynamic range, 100 correlations are necessary or the measurement is one hundred times slower. The R&S FSUP is a combination of a spectrum analyzer and the phase noise test setup while the Agilent E5052B is a dedicated system, about 4-6 times faster.

ADVANTAGES OF THE NOISE CORRELATION TECHNIQUE[11-19]

1. Increased speed
2. Requires less input power
3. Single source set-up
4. Can be extended from low frequencies like 1 MHz to 100 GHz

All of which depends upon the internal synthesizer.

DISADVANTAGES OF THE NOISE CORRELATION TECHNIQUE

1. Different manufacturers have different isolation, so the available dynamic range is difficult to predict.
2. These systems have a "sweet-spot," both Rohde & Schwarz and Agilent start with an attenuator, not to overload the two channels; 1 dB difference in the input level can result in significantly different measured numbers. These "sweet-spots" are different for each system. The RF attenuation that is needed to find the "sweet-spot" reduces the overall dynamic range of the correlation by this amount.

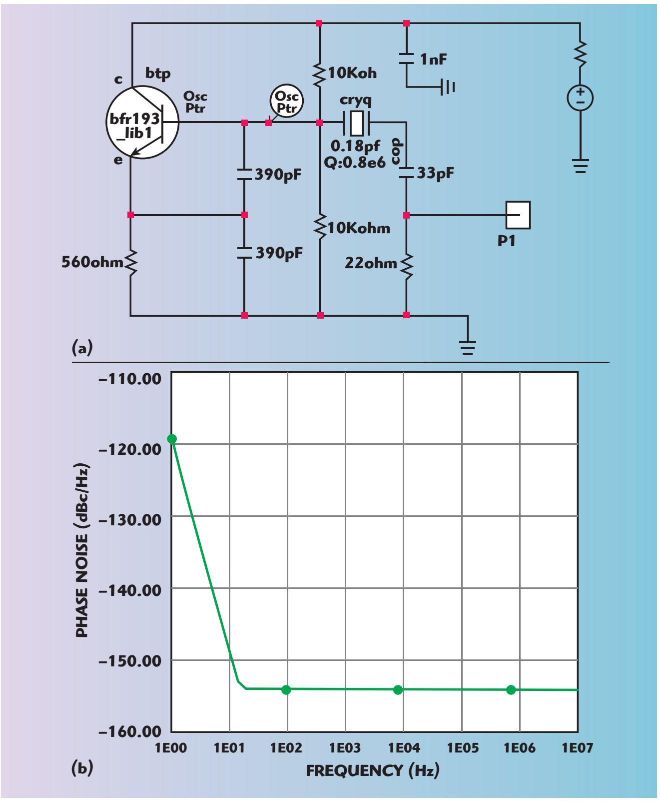


Fig. 8 4 MHz low noise crystal-oscillator (U.L. Rohde, 1975) (a) and simulated phase noise (b).

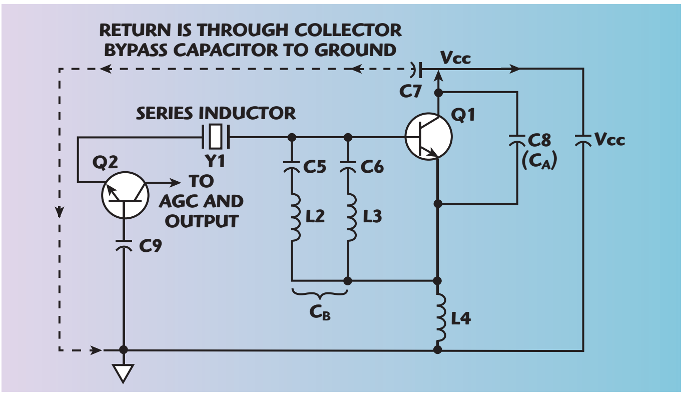


Fig. 9 Rohde design later implemented by HP.

3. The harmonic content of the oscillator can cause erroneous measurement so a switchable lowpass filter (such as the R&S Switchable VHF-UHF Lowpass Filter Type PTU-BN49130 or its equivalent) should be used.[6]

4. For frequencies below 200 MHz, systems such as AnaPico or Holzworth using two crystal oscillators instead of a synthesizer must be used (there is no synthesizer good enough for this measurement). Example: Synergy LNXO100 crystal oscillator measures about –142 dBc/Hz (100 Hz offset), limited by the synthesizer of the FSUP and –147 dBc/Hz with the Holzworth system. Agilent results are similar to the R&S FSUP, just faster.

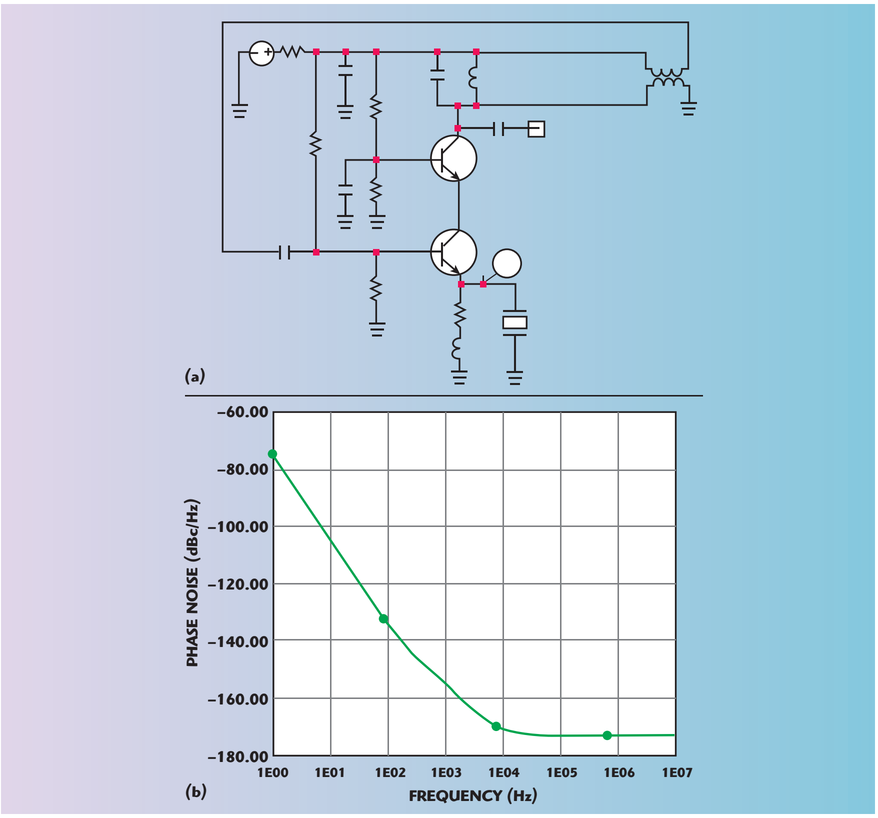
5. At frequencies like 1 MHz off the carrier, these systems gave different results. The R&S FSUP, taking advantage of the "sweet-spot," measures –183 dBc, Agilent indicates –175 dBc/Hz and Holzworth measures –179 dBc/Hz.

We have not researched the "sweet-spots" for Agilent and Holzworth, but we have seen publications for both Agilent and Holzworth showing –190 dBc/Hz far off the carrier. These were selected crystal oscillators from either Wenzel or Pascall.

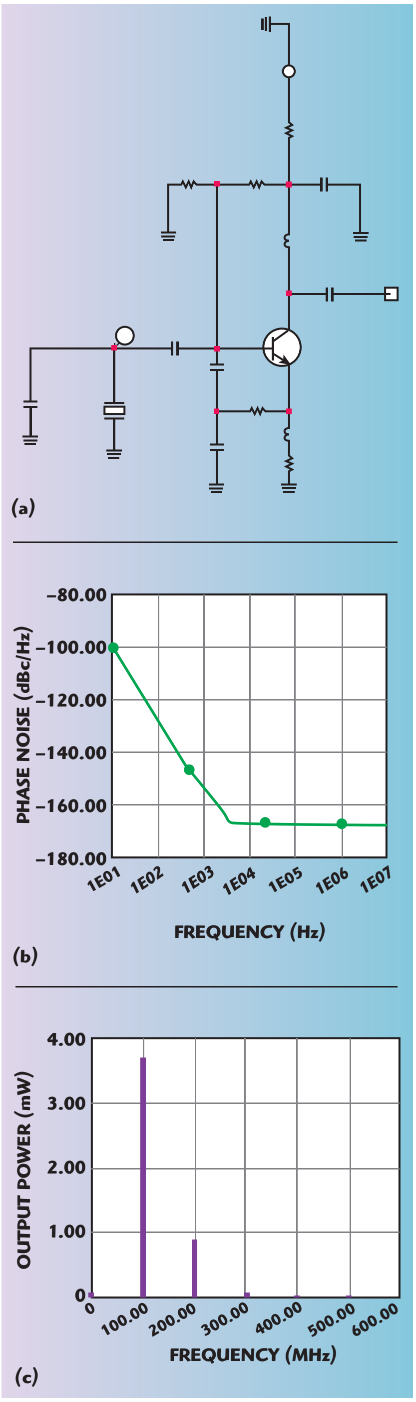
Another problem is the physical length of the crystal oscillator connection cable to the measurement system. If the length provides something like "quarter-wave-resonance," incorrect measurements are possible. The list of disadvantages is quite long and there is a certain ambiguity concerning whether or not to trust these measurements or if they are repeatable.

CRYSTAL OSCILLATORS

Here are some important examples of crystal oscillators. The first one is by Rohde (1975) and is shown is ***Figure 8a*** with simulated phase noise shown in ***8b***.[4,9] This represents the phase-noise of the oscillator without the buffer-amplifier shown in Figure



▲ *Fig. 10 Driscoll oscillator (a) and simulated phase noise (b).*



▲ *Fig. 11 100 MHz crystal oscillator without buffer stage (a), simulated phase noise (b) and output power (c).*

8a. Most modern equipment uses the crystal oscillator using Rohde's design technique (see ***Figure 9***). The actual measured numbers are shown in Figure 6. Another important oscillator is by Michael Driscoll. This circuit is shown in ***Figure 10a*** and its simulated phase noise in ***Figure 10b***. The crystal is used as a filter to ground. We have seen applications of this de-

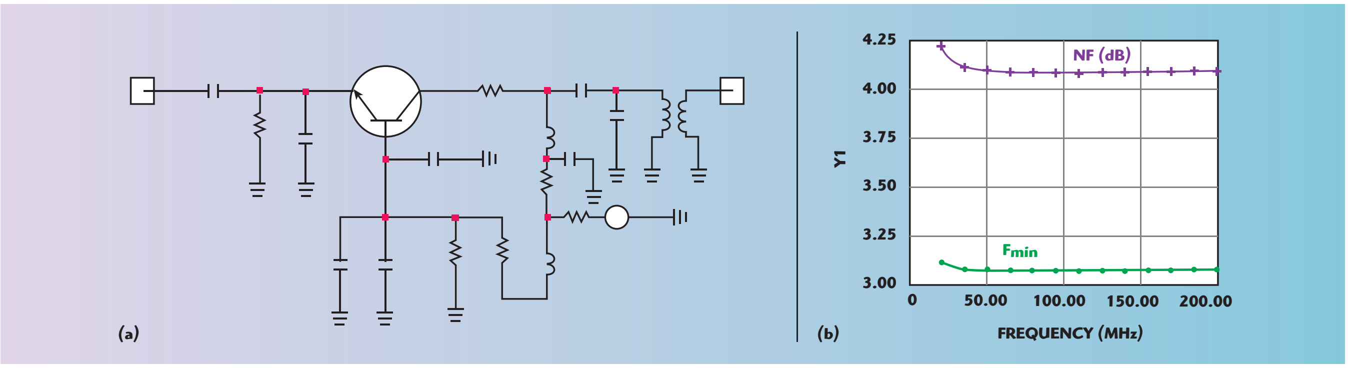
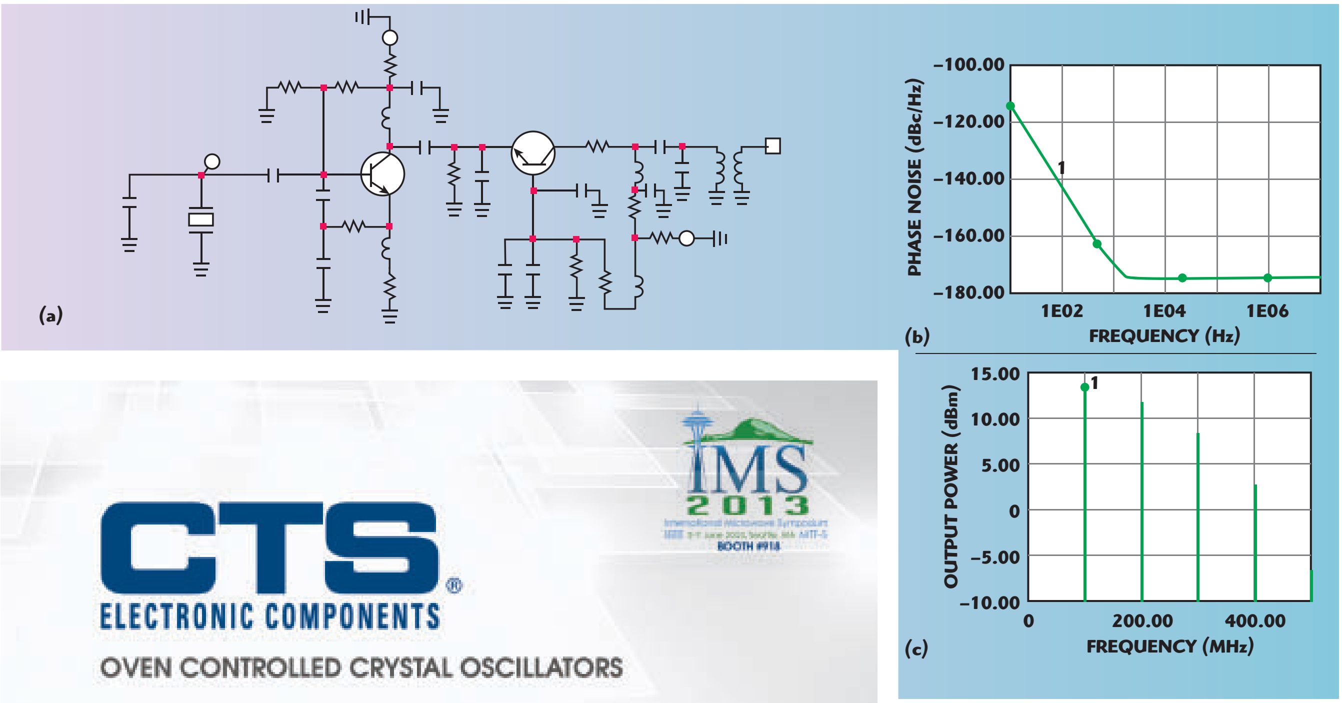


Fig. 12 Buffer amplifier block diagram (a) and simulated noise figure and F_{min} (b).

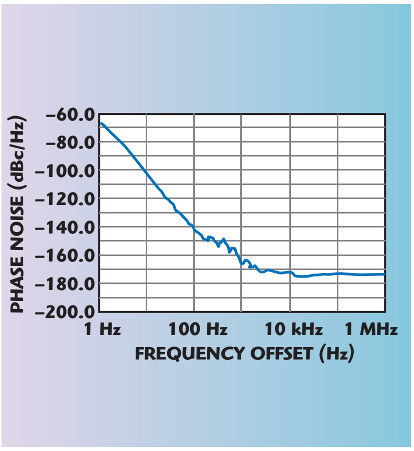
sign from 10 to 100 MHz. Sometimes there is a stability problem with upper transistor of the cascode. Another important contribution is the introduction of the stress-compensated or doubly-rotated crystal, in short SC cut. This took over after the AT cut. Its drawbacks are possible spurious resonance and higher cost, but the actual phase-noise is 6 to 10 dB. So far there is no clear explanation of why this is the case.[10,11]

The 100 MHz crystal oscillator measurements are most demanding and these oscillators are the backbone of many test and communication equipment. ***Figure 11*** shows a typical simple 100 MHz crystal oscillator and its simulated phase noise. Its output power is shown in ***Figure 11c***. This oscillator is missing a buffer stage. ***Figure 12a*** shows the buffer amplifier and ***Figure 12b*** shows its simulated noise figure and F_{min}. An increase in the noise figure, seen below 50 MHz, is due to coupling capacitor. Finally, a 100 MHz crystal oscillator with a grounded base amplifier is shown in ***Figure 13a*** with simulated phase noise and power output plot in ***Figure 13b*** and ***Figure 13c***, respectively.

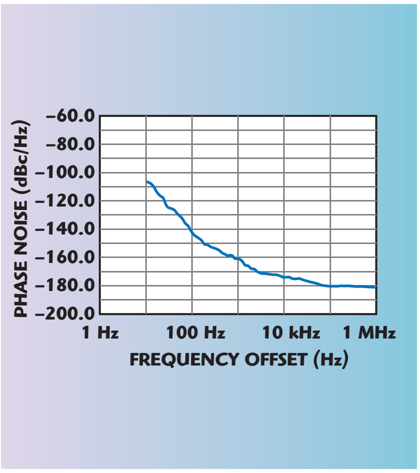
Figures 14 through ***17*** show measured results from the 100 MHz crystal oscillator performed on systems from Agilent, Rohde & Schwarz, Holzworth and AnaPico, respectively. ***Appendix 1*** (see online at www.mwjournal.com/synergyappendix) shows the phase noise calculation for this oscillator. The calculated 100 Hz offset phase noise is –146 dBc/Hz and the far out phase noise is – 183.3 dBc/Hz (see ***Figure 18***). These numbers agree well with the R&S FSUP measurements. The Agilent results are close, but the system is not optimized as the "sweet-spot" has not been characterized. This may be frequency and power level dependent. The Holz-



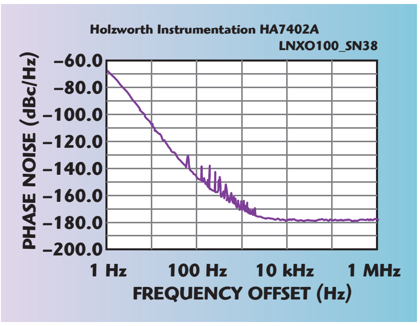
▲ *Fig. 13 100 MHz crystal oscillator with the grounded-base amplifier (a), simulated noise figure (b) and power output plot (c).*



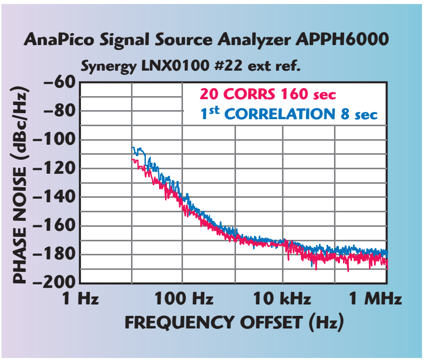
▲ *Fig. 14 100 MHz crystal oscillator measured on Agilent E5052B (Corr_4000).*



▲ *Fig. 15 100 MHz crystal oscillator measured on R&S FSUP.*



▲ *Fig. 16 100 MHz crystal oscillator measured on Holzworth phase noise engine.*



▲ *Fig. 17 100 MHz crystal oscillator measured on AnaPico.*

worth equipment shows the best close-in correct phase noise level, but we have not found the proper correlation figures. The AnaPico test equipment seems to have a hump, but generally agrees well with the calculations. The Holzworth equipment performs the measurement in approximately 3 to 4 minutes (5 correlations), and about 1 minute with no correlations and 3 dB worse phase noise.

What does the law of physics tell us? As pointed out, here is the calculation for the Synergy LNXO100, SSB phase noise = P_{out} (dBm) + 177 (dB) – NF (large signal noise figure of the buffer amplifier). In our case, we get 14 + 177 – 7.7 =183.3. This means the SSB phase noise far out is –183.3 dBc/Hz.

CONCLUSION

In this article, we have looked at typical oscillator circuits and some of their design rules. Calculations for phase noise were reviewed. Various systems were reviewed measuring a 100 MHz crystal oscillator. The phase noise equations give the best possible phase noise. If the equipment in use, after many correlations, gives a better number, it violates the laws of physics as we understand them and if it gives a worse number, then either the correlation settings need to be corrected or the dynamic range of the equipment is insufficient. We realize that this treatment is exhaustive, but we think that it was necessary to explain how things fall into place. At 20 dBm output, the output amplifier certainly has a higher noise figure, as it is driven with more power and there is no improvement possible. There is an optimum condition and some of the measurements showing –190 dBc/Hz do not seem to match the theoretical calculations. The correlation allows us to look below KT, but the noise contribution below KT is as useful as finding one gold atom in your body's blood. This gold atom has no contribution to your system. ■

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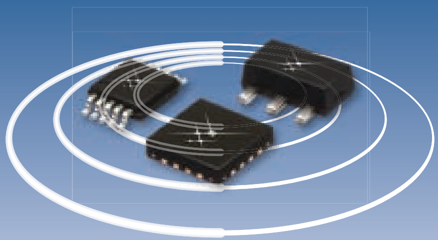

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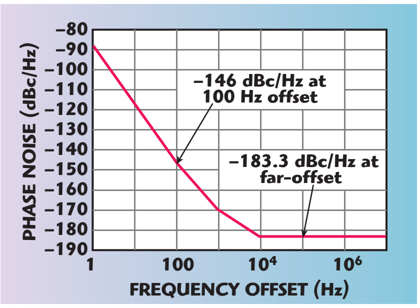

▲ *Fig. 18 Calculated phase noise plot for 100 MHz crystal oscillator.*

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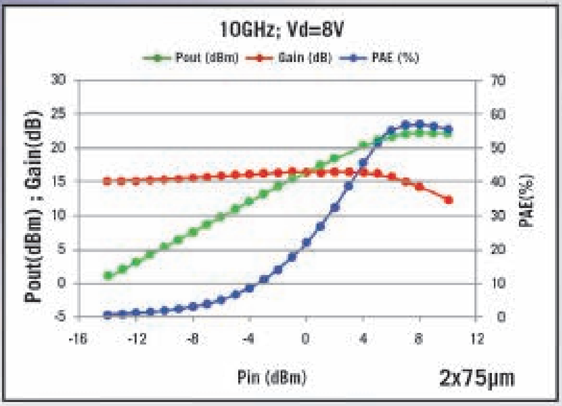
Leading Global Communications

PP25/-21 0.25μm Power pHEMT

- 0.25μm PHEMT process on 100μm substrates
- Power performance at 8V and 10GHz: >1W/mm, PAE 56%, 14dB Gain

PP25-21 (Class-AB) Tuned for Pout



Gain (dB)	P1dB (dBm)	P1dB (mW/mm)	Psat (dBm)	Psat (mW/mm)	PAE Max(%)
15.0	22.1	1086	22.2	1114	56.8

2x75μm device @8V, 10GHz, 150 mA/mm

Summary of WIN mmWave pHEMT portfolio

	PP25-21	PP15-50/51	PL15-12	PP10-10/11
Gate length	0.25 μm	0.15 μm	0.15 μm	0.1 μm
Max Drain Bias	8 V	6 V	4 V	4 V
Idmax (Vg=0.5V)	490 mA/mm	620 mA/mm	525 mA/mm	760 mA/mm
Peak Gm	410 mS/mm	460 mS/mm	580 mS/mm	725 mS/mm
Vto	-1.15 V	-1.3 V	-0.7 V	-0.95 V
BVGD	20V(18V min)	16V(14V min)	9V(8V min)	10V(8V min)
f_T	65 GHz	90 GHz	100 GHz	130 GHz
f_{max}	190 GHz	185 GHz	150 GHz	180 GHz
Power Density (2x75μm)	1100 mW/mm @ 8V, 10GHz	870 mW/mm @ 6V, 29GHz	580 mW/mm @ 4V, 29GHz	860 mW/mm @ 4V, 29GHz (2x50μm)

WIN SEMICONDUCTORS CORP. Tel:+886-3-397-5999 Fax:+886-3-397-5069 http://www.winfoundry.com

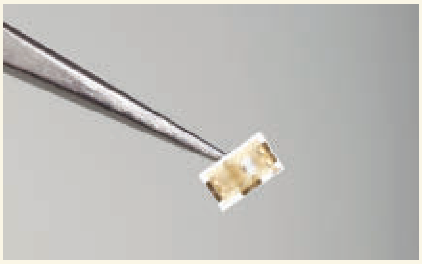
Microlithic Mixers: A Paradigm Shift in Mixer Technology

Marki Microwave Inc.
Morgan Hill, CA

Microlithic™ mixers are a new technology from Marki Microwave that improves previous levels of performance and packaging. Based on a patent pending technique, Microlithic technology reduces the size of state-of-the-art mixers by 14 times while still maintaining the high performance associated with Marki mixers (see ***Figure 1***). The technology achieves this combination of small size and high performance through a design methodology that combines multi-layer 3D circuitry with high-performance Schottky diode ICs in a miniaturized, integrated package. Perhaps more importantly, Microlithic mixers are optimized completely in 3D EM simulation prior to fabrication, giving Marki engineers full control over the design process, and giving customers the promise of performing full mixer simulations before they complete their bill of materials.

THE MIXER PARADOX: HYBRID VS. MMIC

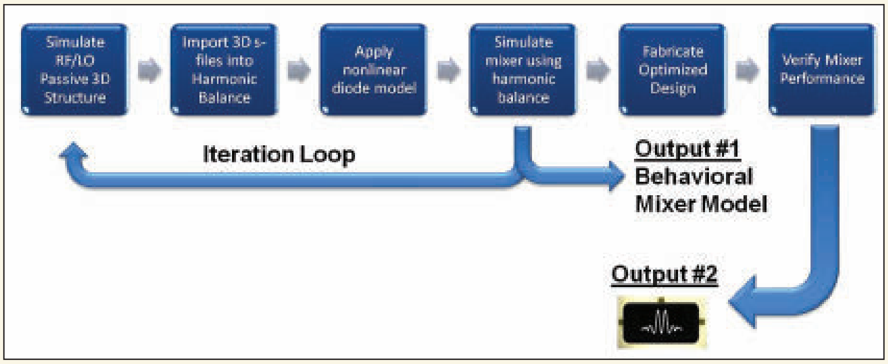
The pervasive trend in electronic systems design is to improve size, weight and power (SWaP). In military applications such as satellite communications and unmanned aerial vehicles (UAV), for example, future technologies are needed that provide a reduction in SWaP while still maintaining the performance associated with existing solutions. Many companies and designers have chosen monolithic microwave integrated circuit (MMIC) technology to build RF building blocks to reduce SWaP. Indeed, components such as MMIC amplifiers and switches can achieve high performance at a fraction of the form factor of their hybrid counterparts.



▲ *Fig. 1 Microlithic mixer.*

However, not all components are ideally suited for MMIC fabrication. Hybrid mixers continue to exceed MMIC electrical performance. The hybrid/MMIC performance chasm has insulated high performance mixer vendors from the disruptive impact of MMIC technology because many applications exist that simply cannot be satisfied by existing MMIC solutions. Nevertheless, hybrid mixer vendors have had a difficult time developing smaller form factor products, and customers are often left with a paradoxical dilemma: select a hybrid mixer that is too large but offers superior performance, or select the smaller MMIC mixer that does not satisfy system requirements.

Traditional hybrid mixers are mixers that are manufactured using several different types of materials and manufacturing processes that are combined into a single package. Hybrid mixers are commonly assembled by attaching discrete semiconductor integrated circuits (IC) to pre-etched low dielectric substrates. The use of discrete ICs and low dielectric materials is both an advantage and a disadvantage when designing traditional hybrid mixers. On one hand, the de-



▲ *Fig. 2 Microlithic mixer design flow.*

signer can select the highest quality ICs from any number of potential vendors, and the low dielectric material will have low losses and minimal transmission line dispersion. On the other hand, attaching discrete ICs to the 3D mixer structure requires great skill and the low dielectric constant precludes circuit miniaturization. Nevertheless, traditional hybrid mixers cannot be replaced in many applications owing to their superior performance and their ability to be customized without added cost or lead time.

MMIC mixers, especially those based on GaAs processes, have demonstrated several-octave bandwidth at a fraction of the size of comparable hybrid mixers. The primary advantage of MMIC mixers is that the entire circuit (i.e., the IC devices and the passive circuitry) are integrated onto a single semiconductor wafer, thereby obviating the need for hand assembly. Monolithic mixers are well suited for high volume applications where size and cost are key drivers. Despite the obvious benefits of fully automated assembly, MMIC fabrication has certain drawbacks. Specifically, MMIC designs are inherently restricted by the finite device options and geometry design rules imposed by the foundry. Among other technical issues, GaAs foundries generally fabricate 0.004" thick wafers. This relatively thin substrate is not conducive to achieving a high even mode to odd mode impedance ratio in the mixer baluns, and therefore restricts the achievable bandwidth of the mixer. Hybrid mixers, by comparison, are often built using suspended substrates to create significantly higher even/odd mode ratios. Moreover, GaAs has a relatively high dielectric constant, which results in significant amounts of dispersion, and hence inferior mixer balance and bandwidth. Finally, the price per area in MMIC fabrication is significantly higher than in hybrid mixers, so the designer will often be forced to trade performance for chip size in order to reduce cost.

RESOLVING THE MIXER PARADOX

Microlithic mixers from Marki Microwave offer a combination of advantages that have not been achieved by either traditional hybrid mixers or MMIC mixers. The performance of hybrid mixers has been combined with the size and manufacturing advantages of MMICs to produce a mixer that can achieve decade bandwidth, low conversion loss and small form factor. This performance is achieved through a combination of 3D multilayer fabrication and IC integration that is amenable to both low volume prototyping and customization and high volume manufacturing. ***Table 1*** highlights the key attributes of the Microlithic mixers compared to traditional hybrids and MMICs.

MICROLITHIC PERFORMANCE

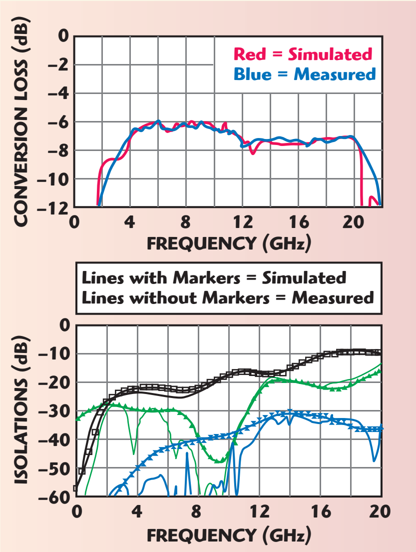
Microlithic mixers are designed using CAD tools, giving engineers full control over the optimization and customization of the designs. While traditional Marki mixers have been designed using decades of experience and painstaking trial and error, Microlithic mixers are designed completely in the virtual space and sent to fabrication only after countless optimization routines are performed to hone the design and study the inherent tradeoffs (see ***Figure 2***). Owing to the precision of the fabrication process, and the accuracy of harmonic balance modeling of the diodes, Marki engineers have demonstrated very good agreement between the mixer simulations and the bench top measurements. As shown in ***Figure 3***, simulations exhibit good agreement with measurement data.

In terms of overall bandwidth coverage, Microlithic designs have already been demonstrated through 40 GHz. These designs are all based on double balanced topologies — such as those available in Marki Microwave's M1 and M9 mixer lines — and compare either favorably and/or better than their legacy counterparts. For example, typical conversion loss for Microlithic mixers ranges from 6 to 8 dB with L-R isolation on the order of 40 dB. Furthermore, Microlithic designs are not specific to any particular semiconductor device meaning that ICs can be selected to optimize for any particular application. For example, by selecting silicon Schottky diode quads, mixers can be driven with LO drive as low as +7 dBm. This represents significant power savings compared to GaAs MMIC mixers, which require at least +13 dBm

TABLE I

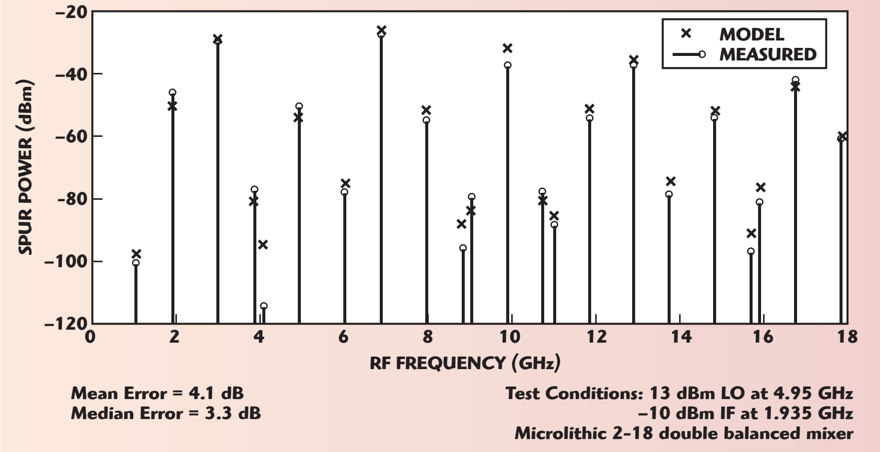
KEY ATTRIBUTES OF THE MICROLITHIC MIXERS COMPARED TO TRADITIONAL HYBRIDS AND MMICs

	Traditional Hybrid Mixer	Monolithic Mixer	Microlithic Mixer
Package Area	0.600" × 0.320"	0.120" × 0.120"	0.152" × 0.090"
Minimum LO Drive	+7 dBm	>+13 dBm	+7 dBm
Typical Bandwidth	Multi-decade	Multi-octave	Decade
Development Lead Time	Days to weeks	Months to years	Weeks to months
Target Volume	Low to medium	Medium to high	Low to high
Circuit Complexity	High	Low	High
Repeatability	Good	Excellent	Excellent
Customizability	High	Low	High
Nonlinear Devices	Any vendor, many choices	Limited by foundry process	Any vendor, many choices
RoHS Compliance	Sometimes	Yes	Yes
Simulation Support	Spur tables, s-files	Spur tables, s-files	Harmonic balance behavioral model



▲ *Fig. 3 Microlithic mixer simulated and measured performance.*

or more. Microlithic mixers have also been subjected to key environmental stress tests such as acceleration, shock, vibration and temperature shock with 100 percent passing yield. The performance, size and reliability of these mixers make them ideal for both military and commercial applications.



▲ *Fig. 4 Measured spur level vs. microlithic model (MWO).*

THE FUTURE OF MIXER MODELING

A significant and useful byproduct of the Microlithic design flow is the creation of an accurate and usable mixer model. These behavioral mixer models are dynamic within the context of the harmonic balance engine. In other words, no assumptions are made about the boundary conditions of the mixer ports (I/O frequencies, power levels, etc). In the Microlithic models, the nonlinear performance is predicted by the interaction of the 3D simulated passive structures, the Schottky diodes and the loading conditions of the ports — as opposed to ad hoc programming using a spur look up table and s-files. The Microlithic user will therefore have more flexibility in studying the mixer's behavior within a system and be able to optimize the design more quickly and accurately, thus saving time, money, and enhancing the scientific understanding of the mixer interaction. The plot in ***Figure 4*** demonstrates the accuracy of the Microlithic models for predicting spurious performance. Marki plans to initially develop downloadable Microlithic models for its customers who use AWR Microwave Office and eventually expand the simulation support to programs such as ADS.

THE FUTURE OF MICROLITHIC TECHNOLOGY

Microlithic mixers covering up to 20 GHz are currently available as demo units and will be available for volume purchase as both RoHS compliant wire-bondable chips and surface mount units by late Q2 2013. High frequency units are expected to demo in early Q3, with special function mixers (IQ, IR, SSB) later this year.

Ultimately, the Microlithic technology platform promises to offer smaller size, higher performance, lower power and faster time to market for a wide variety of applications. This technology represents a giant step forward in our quest to enable our customers to design faster, simplify production, eliminate complexity and shatter performance barriers.

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Raytheon Helps MDA Counter Ballistic Missile Threat with AN/TPY-2 Radar

Raytheon Co. delivered its eighth AN/TPY-2 radar to the Missile Defense Agency (MDA) in support of the U.S. combatant commands. An integral capability of the Ballistic Missile Defense System (BMDS), AN/TPY-2 is a mobile, X-Band phased-array radar that helps protect the U.S., deployed forces, and America's allies by searching, acquiring and tracking threat ballistic missiles and discriminating between threats and non-threats.

"Delivering the vital AN/TPY-2 helps meet the growing demand for radars that can help defend the U.S. and its allies from the more than 5,500 ballistic missiles MDA estimates are not controlled by the U.S., NATO, Russia or China," said Dave Gulla, vice president of Global Integrated Sensors in Raytheon's Integrated Defense Systems business. "The AN/TPY-2 has proven itself an indispensable component of our nation's ballistic missile defense and has performed flawlessly in every test to date against every category of ballistic missile and in raid scenarios."

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The AN/TPY-2 radar Raytheon delivered will serve in terminal mode as the fire control radar for the U.S. Army's Terminal High Altitude Area Defense missile defense system. Other forward-based AN/TPY-2's that are deployed around the globe cue the BMDS by detecting, tracking and discriminating enemy ballistic missiles in the ascent phase of flight.

Source: Raytheon Co.

Lockheed Martin to Continue Providing Life Sciences Support to NASA

As part of the Wyle-led team, Lockheed Martin has been selected by NASA's Johnson Space Center to provide biomedical, medical and health services in support of all human spaceflight programs. These services under the Human Health and Performance Contract (HHPC) monitor astronaut health and enable bioastronautics research that benefits life on Earth.

The potential contract value to Lockheed Martin is about $250 million over the expected 10-year life of the contract. Lockheed Martin is responsible for flight hardware development, facilitation of life sciences research conducted on the International Space Station (ISS), human factors engineering to optimize tools and experiments for astronauts in zero gravity, radiation analysis, space food development, flight/ground crew training, and life sciences data archival.

"Lockheed Martin has provided life sciences support at Johnson Space Center for more than 30 years and has supported America's human spaceflight program for more than 50 years," said Rick Hieb, vice president of exploration and mission support for Lockheed Martin's Information Systems & Global Solutions. "Together with Wyle, we apply that experience to ensure the high quality of science on human space missions and leverage the knowledge gained in space to enhance life here on Earth."

Cobham Wins £16M Order for IED Detection Systems

Cobham has been awarded a £16 million order to supply NATO forces with leading-edge vehicle mounted improvised explosive device (IED) detection equipment.

These systems will be delivered in 2013 by Cobham Antenna Systems in the UK. Fred Cahill, VP Cobham Antenna Systems, explained, "Cobham will deliver enhanced Counter-IED detection capabilities, which can be safely deployed from within the protection of mine-resistant ambush-protected (MRAP) vehicles. These advanced systems are designed for the most demanding military requirements and complements existing technology which Cobham provides to protect lives and livelihoods."

"Cobham will deliver enhanced Counter-IED detection capabilities, which can be safely deployed from within the protection of mine-resistant ambush-protected (MRAP) vehicles."

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U.S. Army Increases Harris IDIQ Tactical Communications Contract Ceiling by $500M

Harris Corp. has received a $500 million increase in the ceiling value of its 2011 Indefinite Delivery, Indefinite Quantity (IDIQ) contract with the U.S. Army Communications Electronics Command.

The increased ceiling provides the U.S. government with greater flexibility in acquiring Harris radios, accessories, systems and services to assist international partners with their mission-critical communication needs.

Under the contract, Harris provides military and land mobile radio systems to international partners of the U.S. State Department and U.S. Department of Defense. The contract is part of the U.S. government's Foreign Military Sales program, which supports coalition building and interoperability through sales of defense equipment, training and services.

The contract enables these organizations to acquire equipment from the entire Harris Falcon radio portfolio, including advanced wideband solutions — such as the RF-7800H high-frequency, RF-7800M multiband networking and RF-7800S secure personal radios — as well as Harris Unity and other land mobile radios for public safety and first responder communications.

"The increased ceiling expands our ability to support international customers with advanced tactical radios and integrated communications system solutions," said Dana Mehnert, group president, Harris RF Communications. "Backed by 50 years of expertise and world-class customer support, our radios have been proven extensively in missions all around the world. We provide users with mission-critical network communications for applications in command and control, border security, counter-terrorism and other missions."

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€50 Million EU Research Grants Aim to Develop 5G Technology

European Commission vice president Neelie Kroes announced €50 million for research to deliver 5G mobile technology by 2020, with the aim to put Europe back in the lead of the global mobile industry. "I want 5G to be pioneered by European industry, based on European research and creating jobs in Europe – and we will put our money where our mouth is," Kroes said.

By 2020, worldwide mobile traffic alone will have increased by 33 times compared to 2010 figures. In this time, Internet access will become dominated by wireless devices such as smartphones, tablets, machines and sensors, requiring more efficient and ubiquitous technology to carry the data traffic.

"I want 5G to be pioneered by European industry, based on European research and creating jobs in Europe – and we will put our money where our mouth is."

METIS, 5GNOW, iJOIN, TROPIC, Mobile Cloud Networking, COMBO, MOTO and PHYLAWS are some of the new EU research projects that address the architecture and functionality needs for 5G/beyond 4G networks. Under this new initiative, the METIS project, in particular, gains a €16 million fresh EU investment.

EU industrial players joining forces with academia and research institutes involved in these projects span from worldwide leading telecom operators (British Telecom, Deutsche Telekom, France Telecom/Orange, Telecom Italia, Telefonica, Portugal Telecom), to the world's major telecom manufacturers (Alcatel-Lucent, Ericsson, Nokia Siemens Networks, Thales Communications), the world's leading provider of business software (SAP) and world-renowned automotive manufacturers (BMW).

EDA Chooses Thales to Conduct Study on Military Communications

The European Defence Agency (EDA) has commissioned Thales to conduct a study of the main terrestrial and satellite communication network programmes in European Union countries: FUCOM (for future communications).

The FUCOM project will compile, in the area of military communications, an inventory of the main member states' existing and future assets, including military satellite communication systems, terrestrial tactical communications (software-defined radio), professional mobile radio (PMR) and LTE capabilities. On the basis of this inventory, the FUCOM project will then propose ways of combining available resources to provide European Union forces with the systems they would need to conduct various types of missions.

To ensure interoperability in a context where few frequency bands are available, wireless communications need to be harmonised. EU member states have tended to address this issue in a piecemeal approach, through a varying array of developments and standards that are not always compatible with each other. This has resulted in a loss of overall efficiency and has made it increasingly difficult for forces to cooperate on multinational operations. It also increases the risk of reliance on third-party nations, particularly the United States, for certain interoperable assets or resources.

To ensure interoperability in a context where few frequency bands are available, wireless communications need to be harmonised.

The FUCOM project will issue a set of recommendations based on the existing and future systems of EU member states and will specify the technical and operational resources and technological solutions needed to ensure a cohesive capability.

The FUCOM project will comprise four phases: Identification of operational scenarios and capability requirements, including an inventory of the main existing space-based communication systems (Syracuse in France, Skynet 5 in the UK, Sicral in Italy, etc.) and terrestrial systems (software-defined radio projects such as Contact in France, etc.); technical characterisation of the communication systems needed to support these operational scenarios; identification of possible future capability gaps; and analysis of the radio frequency spectrum to determine which frequency bands are available.

NGMN Alliance Launches Next Generation Networks Projects

The Next Generation Mobile Networks (NGMN) Alliance has launched four new project activities highlighting the Alliance's commitment to further enhance next generation networks and to guide the industry with its recommendations. The four new projects will determine the focus of the NGMN Alliance for the next 12 months.

The objective of the Next Generation Converged Operations Requirements (NGCOR) project is to reduce complexity and integration costs in the area of network management by achieving standardised interfaces between the Telco infrastructure and the operations support systems (OSS). The RAN Evolution project will evaluate options and give recommendations for a future radio access net-

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work architecture providing optimised operations, higher efficiency and enhanced performance.

The Mobile Content Delivery Optimisation project will evaluate mobile network enhancements for the optimised delivery of content, while the objective of the Small Cells project is to define scenarios, use cases, system architecture and functional requirements for the fast and efficient introduction and operations of Small Cells.

The main tasks for the global NGMN Partner project teams will be the definition of Operator driven requirements, the development of use cases and the assessment of technology options in the four areas. The outcome of these projects will give essential guidance for the successful deployment, operations and further development of next generation mobile networks.

EIB Supports EADS Innovation Programmes

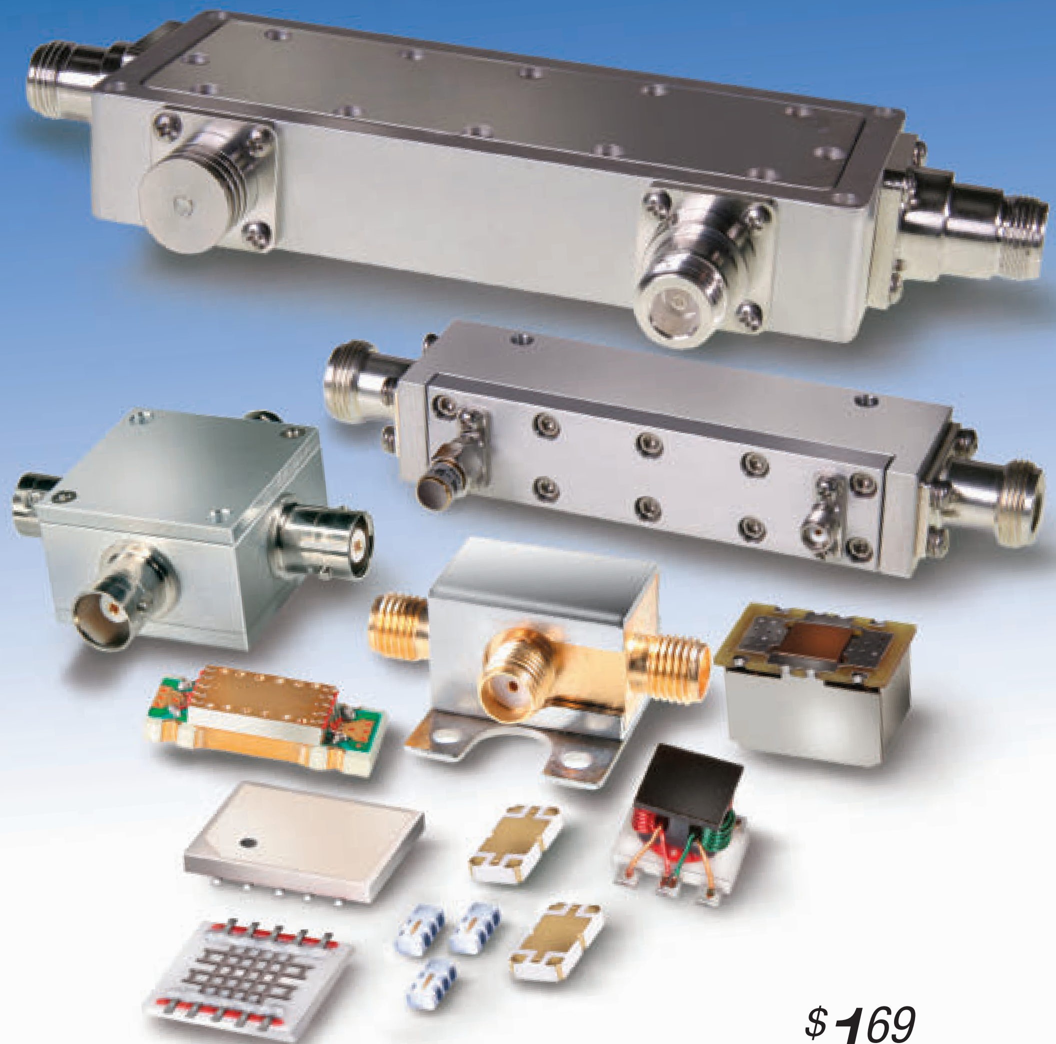
The European Investment Bank (EIB) and EADS have announced the signature of a €300 million finance contract in support of EADS Group's innovation and R&D programmes. This loan reflects the long-standing quality partnership that has formed between the EIB and EADS over the past ten years. It represents the second tranche of a first agreement signed in August 2011, whereby the EIB already made available €500 million to EADS. This new finance contract brings the total volume of the EIB support under this agreement to €800 million.

"Innovation and research are at the heart of EADS' mission and essential to guarantee the long-term success of the group."

This is a flagship financing operation for the EIB, one of the first major loans to finance innovation in Europe since the Member States unanimously decided to give the bank of the European Union the means to stimulate the economy by increasing its capital by €10 billion. This commitment so early in 2013 enables the bank to step up its support for innovation and projects fostering growth and employment in Europe.

EIB vice president Philippe de Fontaine Vive welcomed the signature: "This first major loan following the EIB's capital increase demonstrates our priority commitment to innovation and R&D in Europe. The bank aims to help develop a successful and competitive economy by focusing on leading-edge technologies, which hold the key to the future in terms of sustainable economic development. This sector is also a source of employment for young people."

Harald Wilhelm, chief financial officer of EADS & Airbus commented, "Innovation and research are at the heart of EADS' mission and essential to guarantee the long-term success of the group. The EIB is one of our privileged finance partners, which has been supporting EADS for several years in developing ever innovative technologies."



Dan Massé, Associate Technical Editor

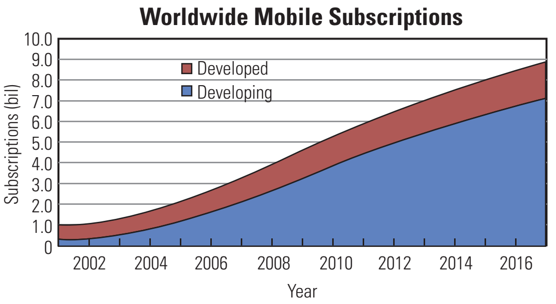
80% of Mobile Subscribers Will be in Developing Countries by 2017

Over the next five years, the worldwide base of mobile subscriptions will rise to 8.9 billion, and four out of five of these will be in developing countries. According to Worldwide Cellular User Forecasts, 2012-2017, the most recent forecast from Strategy Analytics' Wireless Operator Strategies (WOS) service, subscriptions in developing countries will grow at a compound annual rate of 7.5 percent, substantially faster than the 2.8 percent growth that will be seen in developed countries.

With worldwide mobile service revenue growth slowing to about 2 percent per year through 2017, developing countries like Nigeria, where revenue is growing at twice that rate, can be very attractive markets to international players. Phil Kendall, director of WOS, notes that "the Middle East and Africa will generate an impressive 28 percent revenue growth between 2012 and 2017, confirming its significance to investors from outside the region such as Airtel, Orange and Vodafone."

By the beginning of 2014 there will be more mobile connections than people in the world.

The developing countries are changing dramatically as markets for communications devices and services. For example, the African Development Bank estimates that in 2010, more than a third of Africa's population – some 350 million people – could be counted as middle class, up from 220 million in 2000. Although the levels of disposable income do not match those of developed countries, the emergence of a sizable group of economically stable consumers creates an opportunity for communications suppliers, according to Tom Elliott, director of Emerging Markets Consulting. "Of course there is still a lot of demand for basic products and services, but the growing middle class is starting to demand more extensive data services on a widening range of smartphones, high end feature phones and tablets."



Source: Strategy Analytics, Wireless Operator Strategies

The emerging markets have been the major source of mobile subscription growth over the past decade, and will continue to outpace the developed countries over the next five years. China and India will account for the bulk of emerging market subscriptions, but rapid growth is also expected in the Middle East and Africa. By the beginning of 2014 there will be more mobile connections than people in the world.

Asia-Pacific LTE Subscriptions Expected to Double to 72.1M by the End of 2013

In 4Q-2012, the LTE subscription in Asia-Pacific has increased by 60.92 percent quarter-on-quarter (QoQ), reaching 34.6 million. ABI Research expects that the LTE subscription market will continue to grow rapidly in 2013 to reach 72.1 million.

"The operators in South Korea have aggressively promoted LTE since launch. For example, SK Telecom, the largest operator in terms of subscriptions, had gained 7 million LTE subscribers by the end of 2012, and aims to secure 13 million by the end of 2013, a feat that will mean 50 percent of its subscribers will be on LTE," said Marina Lu, research associate at ABI Research.

"The strong growth trend of mobile subscription is expected to keep up until 2015, where it will surpass 100 percent."

The Asia-Pacific 4G cellular market still has considerable potential. In 4Q-2012, Asia-Pacific had notched up 3.45 billion subscriptions, up 8.7 percent year-on-year (YoY), resulting in a cellular penetration of 87.5 percent. "The strong growth trend of mobile subscription is expected to keep up until 2015, where it will surpass 100 percent," stated Jake Saunders, VP and practice director of core forecasting.

In terms of significant movers and shakers, China Unicom, the second largest mobile subscription operator in Asia-Pacific, has grown its mobile subscribers 22 percent YoY compared to Q4-2011 to attain 239 million, making it the fastest growing operator in Asia. The next fastest growing operator was China Telecom, which increased its subscriber base by 16.89 percent YoY, reaching 160 million, fueled by 3G tariffs and smartphones. Smartphone penetration stood at 19.4 percent at the end of 2012, and is expected to approach 26.5 percent by year-end 2013. The third fastest growing (15.44 percent) operator was Indonesia's Telkomsel with 125 million.

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Commercial Market

World Government Expenditures for Space Facing Short-Term Decline

According to Euroconsult's newly released research report, Government Space Markets: World Prospects to 2022, government spending on space reached a peak in 2012 of $72.9 billion, a non-negligible increase compared to 2011 which followed two consecutive years of minimal growth. This upswing is attributed to increased activity of countries such as Russia, China, India and new world or regional leaders who compensated for budget uncertainties affecting North America and Europe. Euroconsult expects global government expenditures on space to decrease due to fiscal policies exerting continuous pressure on public finances; improvement is not expected before 2015.

"As forecasted in the previous editions of this research report, global government spending in space has entered a deceleration phase," said Steve Bochinger, COO at Euroconsult. "2013 should mark for the first time in 12 years a global decrease in government funding for space programs."

According to the research report, government space programs should be affected in the short term by an overall flat spending environment and decrease in global funding. The situation is expected to recover in the second part of the decade, driven by a cleaner public finance environment, a new procurement cycle and R&D in historical leading space nations, and sustained spending from new world/regional leaders and nascent programs. By 2022, global government funding for space activities are anticipated to pass the $77 billion mark.

"2013 should mark for the first time in 12 years a global decrease in government funding for space programs."

The landscape for civil space activities has experienced profound structural changes in the last decade. In 2003, the top three civil space programs (U.S., Europe, Japan) accounted for 90 percent of world's civil expenditures. In 2012, their share accounted for only 64 percent illustrating the "decentralization" of space investment worldwide.

Significant Launch Rate to Continue

Following a peak launch of 65 satellites in 2011, governments worldwide sustained a dynamic launch rate in 2012 with 58 satellites for civil and defense applications, marking the second highest launch rate over the last decade. Between 2003 and 2012, governments launched 514 satellites. A total of 744 satellites are planned to launch over the next decade.

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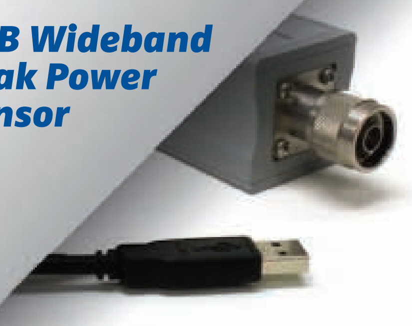

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Around the Circuit
Laura Glazer, Staff Editor

COLLABORATIONS

Defense and security company **Saab** has partnered with **Tawazun**, a strategic investment company focusing on defense and strategic manufacturing, to create a new UAE-based radar company. The new company is **Abu Dhabi Advanced Radar Systems** (ADARS), which is a joint venture where 51 percent is owned by Tawazun and 49 percent by Saab. This will be the Middle East region's first company for the development, manufacture, assembly and integration of next generation radar systems. As part of the agreement, 15 UAE nationals will participate in a Master's program in microwave and radar technology engineering in Sweden.

Thales Alenia Space and **ISS Reshetnev** have established a jointly-owned company that will initially focus on the production of equipment meeting the most demanding international standards for use on Russian telecommunications satellites. It will then work on the development of new products for satellites, enabling it to more completely address the requirements of both Russian and international markets in the future, where ISS, in collaboration with Thales Alenia Space, has already won several business opportunities. The new company, incorporated under Russian law and with ISS holding a majority stake, will be based in Krasnoyarsk, Russia.

Raytheon Co. and **General Atomics Aeronautical Systems Inc.** (GA-ASI) are working together to develop a highly autonomous, unmanned electronic warfare capability based on equipping GA-ASI's Predator®B/MQ-9 Reaper Remotely Piloted Aircraft (RPA) with Raytheon's Miniature Air Launched Decoy (MALD®). With the Ground Verification Test phase completed November 2012 at GA-ASI's Gray Butte Flight Operations Facility in Palmdale, CA, integration of MALD on the aircraft is estimated to conclude in 2013. When employed, MALD confuses the target integrated air defense system and then kinetic weaponry is selectively employed to permanently disable IADS nodes.

Texas Instruments Inc. (TI) and **Sub10 Systems** announced their collaboration on a differentiated and future-proof backhaul solution for small cell base stations. By using TI's KeyStone-based TMS320C6678 multicore digital signal processors (DSP) in its new Liberator V100, Sub10 Systems is able to more effectively and rapidly meet the operators' challenges of improving resilience in hostile radio conditions.

Peregrine Semiconductor Corp. is collaborating with **Intel** on the latest generation of its popular DuNE™ tuning technology offering for Intel's LTE platform reference design. The tuning solution utilizes Peregrine's third generation tuning products, which feature multidimensional tuning capabilities, for full coverage of the 41 available LTE bands.

Anaren Inc.'s Integrated Radio (AIR) module team is partnering with Austin, TX-based middleware developer **Emmoco** to create the AIR Support for BLE solution. The solution is scheduled for release in the spring/summer of 2013. As is the case with all AIR modules, this latest model in the AIR product family is based on Texas Instruments technology, in this case TI's C2541 SoC.

NEW STARTS

Agilent Technologies Inc. announced that all new Agilent electronic test instruments sold will be covered by a "bumper-to-bumper" three-year repair warranty. The increase from one year to three years is the result of ongoing quality initiatives that, from 2002 to 2012, yielded unprecedented improvements in product reliability and earned top marks in an independent customer survey rating RF and microwave product quality.

Hesse Mechatronics Inc. (formerly Hesse & Knipps), the Americas subsidiary of **Hesse GmbH**, announced the company's recent name change from Hesse & Knipps Inc. to Hesse Mechatronics Inc. The name change is a move back to the company's roots, named Hesse GmbH when first launched in 1986. In addition, the new name signifies more accurately what the company does: develop and manufacture thin wire wedge bonders and heavy wire bonders utilizing mechatronics, a multidisciplinary engineering approach that combines mechanical, electrical, control and computer engineering.

ACHIEVEMENTS

Lockheed Martin completed a successful demonstration at Camp Grayling, MI in which its Squad Mission Support System (SMSS™) was being controlled via satellite from more than 200 miles away. The SMSS vehicle conducted several battlefield surveillance operations while being controlled beyond line-of-sight via satellite from the U.S. Army's Tank Automotive Research, Development and Engineering Center in Warren, MI.

Skyworks Solutions Inc.'s industry-leading silicon-on-insulator (SOI) switching technology is now being utilized by European, Japanese, Korean and North American car manufacturers for advanced infotainment systems. Specifically, Skyworks' solid-state technology is enabling seamless low noise and broadband switching between audio, Blu-ray/DVD, navigation, cell phone and vehicle security display inputs as well as a variety of other high bandwidth media sources in automobiles.

Rosenberger has started operations in the company's new EMC laboratory in Fridolfing, Germany. Centerpiece of the new EMC lab is an anechoic chamber for EMI emission measurements at the component level according to

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Around the Circuit

EN 55025 (CISPR 25) as well as EMI immunity measurements according to ISO 11452. A range of tests accompanying development can be performed in the new EMC lab. Examples include signal integrity measurements on high-speed data connections, coupling mechanisms within high-voltage systems or measurements of the far-field radiation characteristics of active and passive RF components.

CONTRACTS

Boeing will continue modernizing the GPS satellite constellation for up to five more years, extending the company's role in the vital military and civilian navigation network. The U.S. Air Force, which operates the GPS network, recently awarded Boeing a $51 million, one-year contract with four one-year options. The contract covers GPS IIF satellite shipment to the launch site in Florida, pre-launch preparation, post-launch checkout, handover and on-orbit support. The company is on contract for 12 GPS IIF satellites, three of which have been launched into service.

ITT Exelis has been awarded a direct commercial contract valued at $11.6 million to provide a wide range of communications equipment to an undisclosed international customer. This sale includes SpearNet UHF radios in both vehicular-mounted and soldier-wearable configurations as well as ancillaries and spare parts for the SpearNet radio systems.

Beam Communications Pty Ltd. has entered into an agreement with **Beijing Marine Communications & Navigation Co.** (MCN) for the supply of an initial $1 million of Beam Inmarsat marine satellite terminals. This initial order follows the successful trial and now acceptance of the Beam terminals after MCN committed in July 2012 to undertake a trial deploying 200 Beam Oceana 400 and Oceana 800 marine communications terminals on fishing vessels in China, using the Inmarsat FleetPhone Service.

Ericsson has been contracted to deliver mobile backhaul to **Polska Telefonia Cyfrowa S.A.** (PTC), the operator arm of the T-Mobile brand in Poland. Ericsson will supply T-Mobile with its MINI-LINK SP packet aggregation nodes, Ericsson SPO 1400 Packet Optical Transport and IP Transport network management system products. The company is also providing deployment, support and spare parts management services as part of the solution.

Thales Communications Inc. announced a new low rate initial production (LRIP) contract for secure radios to support the U.S. Army's Nett Warrior Program. The Nett Warrior Radio is capable of providing soldiers with access to the government's classified networks at the Secret or Sensitive But Unclassified level. The radio is a lightweight, body worn unit that transmits voice and data simultaneously utilizing the Soldier Radio Waveform (SRW). It allows self-forming, ad hoc, voice and data networks and enables any leader at the tactical level to track individual soldier position location information.

PEOPLE

LadyBug Technologies announced the appointment of **Orwill Hawkins** as the company's vice president of

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Around the Circuit

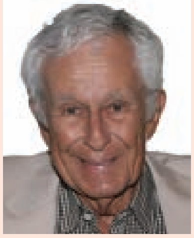
▲ Orwill Hawkins

marketing. In his new position, Hawkins will hold responsibility for all of LadyBug's marketing and business development strategies worldwide. Hawkins brings over three decades of management, marketing, engineering and manufacturing experience to his new position.

Radio Frequency Systems (RFS) announced the addition of **Sal Betro** as area vice president (AVP) of sales for North America. Betro, who most recently served as executive director of sales at Alcatel-Lucent, brings more than 30 years of experience in the network wireless space with particular expertise in the development and execution of sales strategies, new business development, and pipeline and sales cycle management. In his new role at RFS, Betro will provide critical support to the company's valued customers during ongoing 4G data network build outs.

▲ Les Besser

Les Besser, founder of **Compact Software** and **Besser Associates**, is among the latest contributors to a website dedicated to former **Hewlett Packard** employee memoirs. The two chapter installment covers Besser's technical training and the birth of commercial microwave CAD and can be found at www.hpmemory.org/timeline/company/memories_home.htm.



▲ Charles Alan Borck

RLC Electronics Inc. mourns the loss of its esteemed founder, **Charles Alan Borck**. Borck passed away suddenly on March 1, 2013 at the age of 87. He graduated from RPI in 1946 with a degree in electrical engineering and has maintained a long relationship with the school ever since. His passion, entrepreneurial drive, technical expertise and humor will be deeply missed by the entire staff at RLC as well as all who knew him.

REP APPOINTMENTS

Custom MMIC announced the appointments of **Castle Microwave** and **SM Electronic Technologies** as its technical sales representatives. Castle Microwave will represent Custom MMIC in the United Kingdom and SM Electronic will represent the company in India.

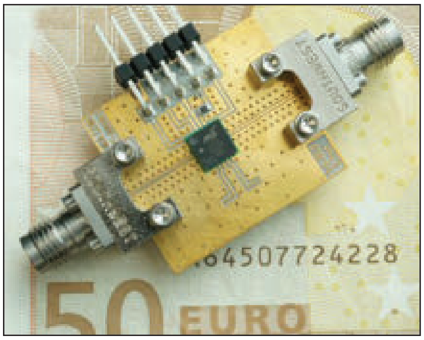
Richardson RFPD Inc. announced it has completed an agreement to distribute products from **Lime Microsystems**, an England-based manufacturer that specializes in field programmable RF transceivers. Under the agreement, Richardson RFPD will distribute Lime's LMS6002D multi-band, multi-standard transceiver worldwide, with the exceptions of Korea and Taiwan.

Vaunix Technology Corp. has announced the hiring of a new sales representative, **Amska Amerikanska Teleprodukter**, to handle customer relationships in Sweden, Denmark, Norway and Finland.

A Compact, Low Cost 10 MHz to 40 GHz Amplifier Module

Applications, from instrumentation to electronic warfare to radio astronomy, require simple, low cost, broadband amplification. A commercially available bare chip distributed amplifier is hard to apply and purchasing a complete solution can be expensive. This article demonstrates a state-of-the-art monolithic integrated circuit (MIC) overmold on a laminate module that is easy to use and low cost. It covers a 12 octave continuous bandwidth, 10 MHz to 40 GHz, with 13 dB gain, 50 Ω I/O match and +20 dBm power output. The MIC module integrates the DC blocks and bias network. Additional pins allow access to a temperature compensated power detector and 20 dB of gain control. With the optional 2.4 mm connector application board, a user has an amplifier that covers that full band with only +5 V, 190 mA and –5 V applied.

Most commercial applications for RF and microwave have predetermined narrow frequency bands. However, in many military, industrial and scientific applications, the frequency of interest varies over a wide bandwidth. This includes such environments as characterization, modeling, radio astronomy, radar detection, instrumentation and reliability testing. Some applications require extreme bandwidths, since users not only look at a fundamental frequency, but also harmonics.

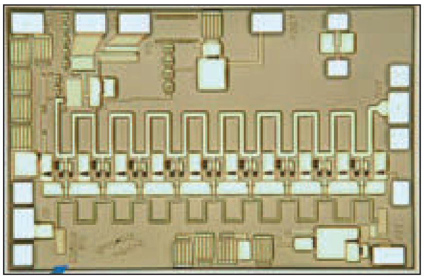


▲ *Fig. 1 10 MHz to 40 GHz MIC module mounted on an application board.*

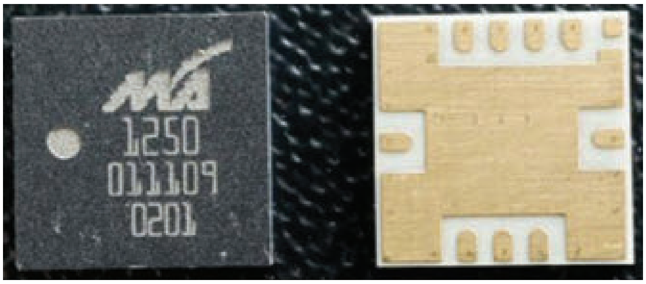
Numerous vendors provide narrow band ASICs for consumer and commercial applications. However, obtaining a simple broadband amplifier is challenging. If an off-the-shelf distributed MMIC amplifier is bought, the design of the bias, control and assembly can be difficult. If a complete solution is used, it can be very expensive. Presented in this article is an alternative approach with a MIC module solution that is easy to use, low cost and covers 10 MHz to 40 GHz amplification.

The MIC module is housed in a 5 × 5 mm plastic on laminate construction that is compatible with modern reflow and wash reliable. Typical usage is on a 28 mm application board with 2.4 mm connectors and DC pins, as shown in ***Figure 1***. A typical gain of 13 dB was measured on this module, while still maintaining a 50 Ω I/O impedance from 10 MHz to 40 GHz. The dynamic range was large, with the lowest noise figure at 2.8 dB and highest output power greater than +20 dBm. DC requirements are +5 V,

Henrik Morkner and Alfred Riddle
M/A-COM Technology Solutions, Lowell, MA



▲ *Fig. 2 A GaAs distributed amplifier MMIC is the heart of the module.*



▲ *Fig. 3 MIC module top and bottom.*

–5 V and 190 mA. The MIC module also integrates gain trim control and power detector.

MMIC DESIGN

At the core of the MIC module is the same basic 0.15 micron gate PHEMT distributed amplifier found in many optical and catalog products as shown in ***Figure 2***. A nine section construction has constant impedance inter-sections transmission lines and cascode stacked FETs. It has integrated simple bias networks and ESD protection. Unique to the MMIC is a temperature compensated power detector. It is integrated into the "termination" load on the distributed amplifier, in order to not disrupt the inherent bandwidth of the traveling wave. The amplifier also utilizes a cascode stage element that allows an RF isolated DC control pin for effective gain control. The I/O match is largely not affected over gain control range, due to the excellent isolation available in a cascode. The resulting MMIC is very process and temperature tolerant, making an excellent base for a complete module.

MODULE DESIGN

In order to increase performance and lower cost, the design approach for the MIC module was holistic in nature. Ultra-low cost plastic QFN was not an option, since series elements, such as DC blocks, bias choke and resistors are hard to incorporate into a lead frame. Brazed leads on ceramic or LTCC substrates are too expensive. Driven by cell phone technology, it was discovered that recent advances in laminate low loss dielectric materials allow the construction on a high performance substrate perfect for this application. The final result was a Rogers RO4003 two-layer 0.2 mm laminate based PCB, with 0.2 mm copper filled via grounds.

Mounted on the laminate substrate are SMD capacitors, resistors and inductors. These SMD elements are used primarily for DC block, DC chokes and DC supply bypass. They are not integrated into the MMIC, since that is a very inefficient use of expensive real estate. Instead, many vendors' SMD products were characterized and de-embedded to 50 GHz, often beyond the vendors' own specifications. With an accurate library, a full module could be simulated and eventually built. This technique was critical for the design of a wide band bias tee. It was decided not to use the traditional conical inductor due to its cost, size and reliability. Instead, an SMD 0402 replacement was used that was not only lower in cost, but had better performance. Switching to an SMD also allows plastic over mold of the laminate, further reducing cost and improving manufacturability.

The net result is the efficient module shown in ***Figure 3***. The correct cost/performance balance between SMD components and integration is achieved. The laminate allows the top metal to be patterned for optimal performance. The standard SMD sizes and construction allow assembly, using high volume techniques. In the final step, the entire module is over molded with a low loss mold compound and technique that ensures wide bandwidth without compromise of reliability or quality.

OPERATION

The MIC module is configured with RF I/O signals on two sides and DC I/O on the other two sides. A top view configuration is shown in ***Figure 4***.

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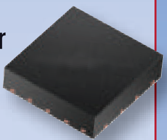

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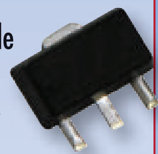

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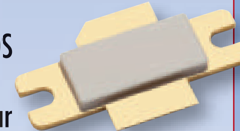

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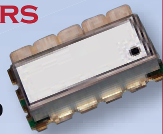

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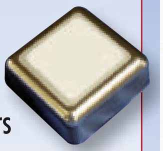

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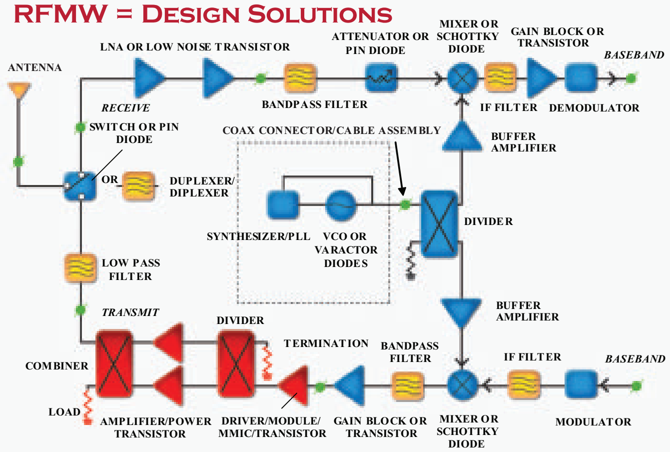

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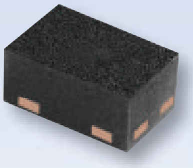

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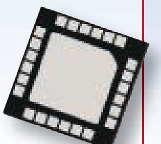

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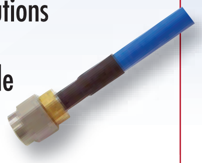

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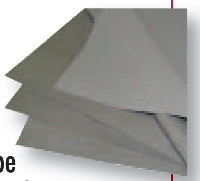

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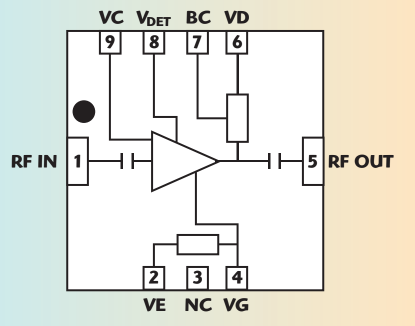

▲ *Fig. 4 MIC module pin designations.*

The pins are designated as:

1. RF IN = input (internally DC blocked) 50 V
2. VE = negative supply (–5 V). Typically draws less 1 mA and should be left open if using the VG gate override pin
3. NC not used (should be grounded)
4. VG = optional gate override pin for active current control, typical value is about –0.5 V and should be left open if using VE (–5 V)
5. RF OUT = output (internally DC blocked) 50 V
6. VD = positive supply (+5 V, 250 mA maximum). Can also be adjusted to as low as +3 V to tune bandwidth and power
7. BC = optional bias tuning. Typically left open, but can be used to smooth gain through the bias tee
8. V_{DET} = optional power detector output. Produces a DC voltage that corresponds to RF output power. Ranges from +2.7 (–5 dBm) to +3.8 V (+20 dBm)
9. VC = optional gain control. This is normally left open for maximum gain, can be varied from 0 to –1 V, 10 mA

For proper operation, a DC voltage is applied at the VE (–5 V) and VD (+5 V) pins in that order. The optional VG pin was used to override the automatic VE bias network to hard set the gate. Adjusting VG from –0.2 to –0.6 V changes the quiescent current. When VG is used, the VE was left unconnected.

The VC pin was left unconnected, unless gain control or output power limiting was desired. When used, the gain reduction was almost linear, with VC between 0.1 to –0.8 V. The VC pin was driven below –1 V or above 1.2 V, due to internal ESD protection that kicks in. The nominal open circuit voltage at the VC pin was 0.8 V. Reducing VC below 0.8 V also reduced Id, gain, P1dB and Psat.

The VD pin was bypassed with at least 0.1 µF for stability. For operation below 100 MHz, a ferrite bead (Murata BLM18BB471) was inserted between the VD pin and the bypass capacitor. The VG and VC pins were also bypassed with a 0.1 µF capacitor, if operating below 100 MHz.

The V_{DET} pin is typically left unconnected, unless a voltage reference was desired that is correlated to the output power. The detector is internally connected so that it responds predominately to the power generated by the amplifier. The detector had a low pass characteristic, which rolls off gradually above 2 GHz. The detector is temperature compensated so no reference is needed. Finally, even with zero output power, the detector had a DC output voltage proportional to VD (nominally 2.8 V for VD = 5 V).

The BC pin is typically left unconnected, unless gain bandwidth and shape change are desired. This article will not go into these details, due to space limitation. The input and output pins are internally DC blocked. It was found that not more than ±12 V should ever be present on these RF only pins. The backside paddle of the MIC module was connected to ground with as many vias as possible to maximize high frequency performance, thermal dissipation and stability. Typical applications would use the MIC module as a broadband amplifier. In that case, the 5 × 5 mm MIC module would be placed between 50 Ω lines and only the VD (+5 V) and VE (–5 V) need be applied.

MEASURED RESULTS

An application board was used for measurements. This board was also found to be very useful for customer evaluation or even laboratory or industrial applications. For measurement, the MIC module was soldered onto a 4-layer, 28 × 25 mm laminate application board. Also included on the board are DC supply bypass capacitors and a DC pin. A ferrite bead was placed in the VD supply line and this allows operation down to 10 MHz.

Typical measurements were made by directly probing the board with 400 µ GSG probes. Alternatively, Southwest 2.4 mm (DC to 50 GHz) cable adapters were attached to the board. ***Figure 5*** demonstrates a 13 dB typical gain over 40 GHz of 3 dB

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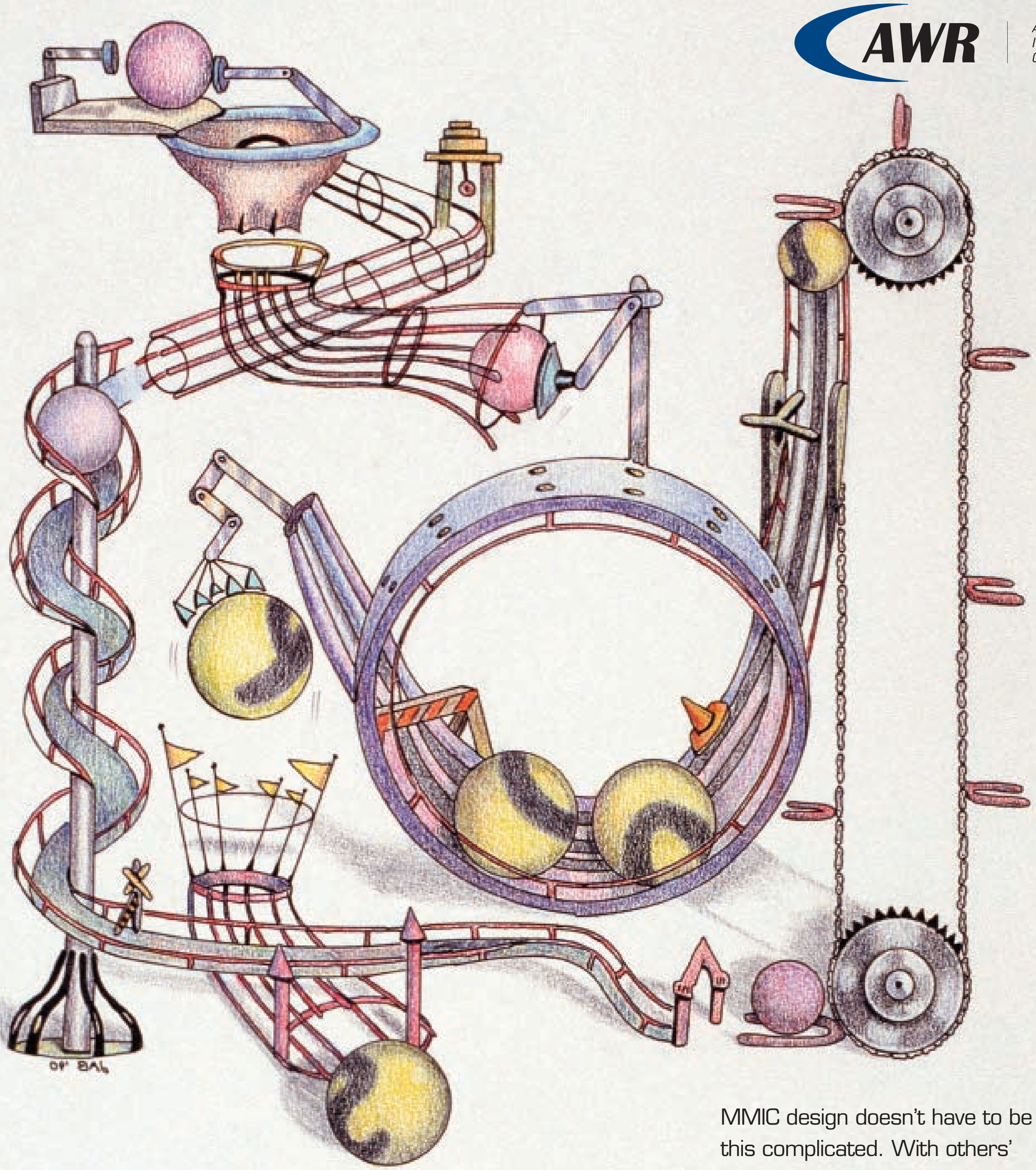

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bandwidth. ***Figure 6*** shows nearly 20 dBm saturated power over most of the band and ***Figure 7*** shows a typical noise figure less than 6 dB across band.

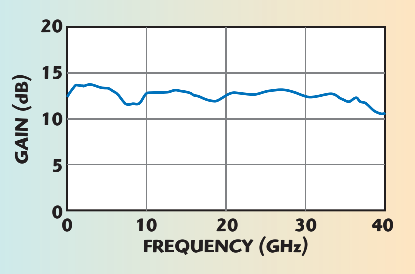


Fig. 5 MIC module typical gain.

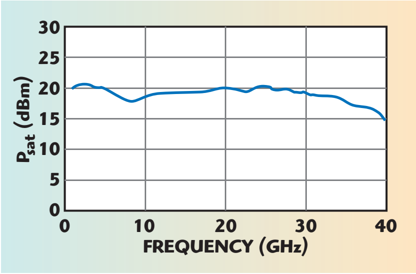


Fig. 6 MIC module typical output power.

Figure 8 shows the application board performance with 2.4 mm connector and demonstrates over 12 dB gain, –12 dB return loss and over 25 dB isolation (K is >1). ***Figure 9*** shows the gain control available with the optional VC pin and ***Figure 10*** shows the typical power detector output over –40° to +85°C at 2 GHz. ***Figure 11*** shows the low frequency performance, using the application board and ferrite bead. ***Figure 12*** demonstrates little gain change over temperature, –40° to +85°C.

CONCLUSION

Many applications require extremely broad bandwidth amplifiers. While

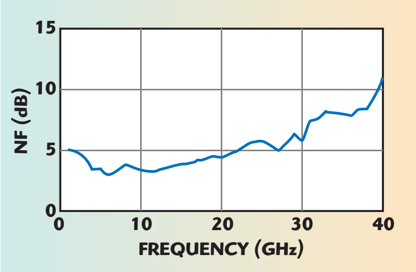


Fig. 7 MIC module typical noise figure.

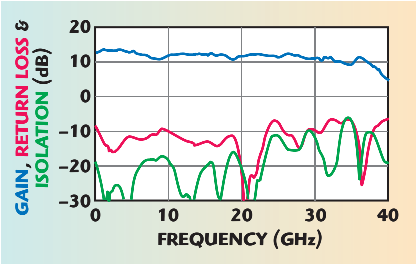


Fig. 8 MIC module gain, return loss and isolation.

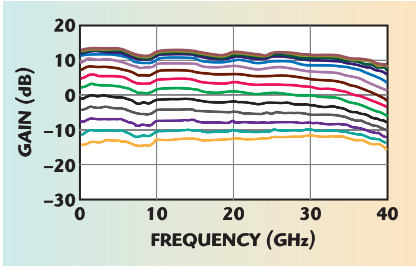


Fig. 9 MIC module gain control.

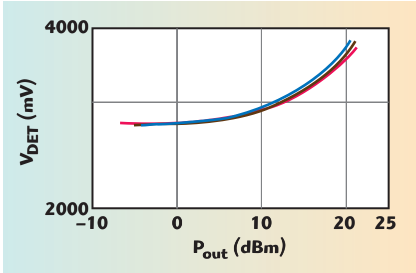
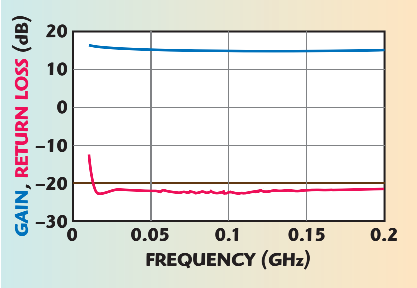
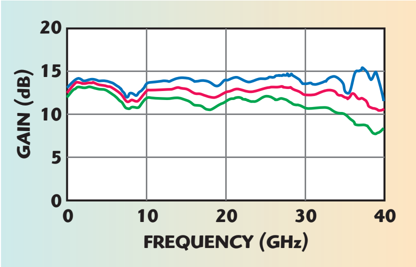


Fig. 10 MIC module V_{DET} output over temperature at 2 GHz.



▲ *Fig. 11 Low frequency gain and return loss.*



▲ *Fig. 12 MIC module gain over temperature.*

several vendors sell chip distributed amplifiers, assembly and bias for these in an application can be difficult. Complete solutions can be very expensive. This article has demonstrated a monolithic integrated circuit on laminate and overmold construction. It is low cost and easy to use for applications requiring 10 MHz to 40 GHz bandwidth or less. Measured performance shows 13 dB typical gain and +20 dBm of output power. Matching is 50 Ω with typical return loss better than 15 dB. It requires dual DC supplies: 5 V (190 mA typical) and –5 V (< 1 mA).

The MIC module pushes SMD technology by using an integrated, ultra-broadband, bias choke, DC blocking and bypass capacitors. Some other features include: a gate bias adjust pin to change current setting for power or temperature; a gain trim control pin that allows 15 dB of gain control and a temperature compensated detector pin that provides a DC voltage in relation to output power.

The MIC module in this article has demonstrated enough gain, power and low enough noise figure to be used in instrumentation front ends and buffer applications. It also has very flat response with low group delay distortion so it can be used in pulse applications. For higher gains, multiple amplifiers may be cascaded. It also makes a very good low cost optical driver capable of delivering to 8 V p-p into 50 Ω.

ACKNOWLEDGMENT

The authors wish to acknowledge M/A-COM management for the continued support in research of ultra-wideband MMICs and modules.

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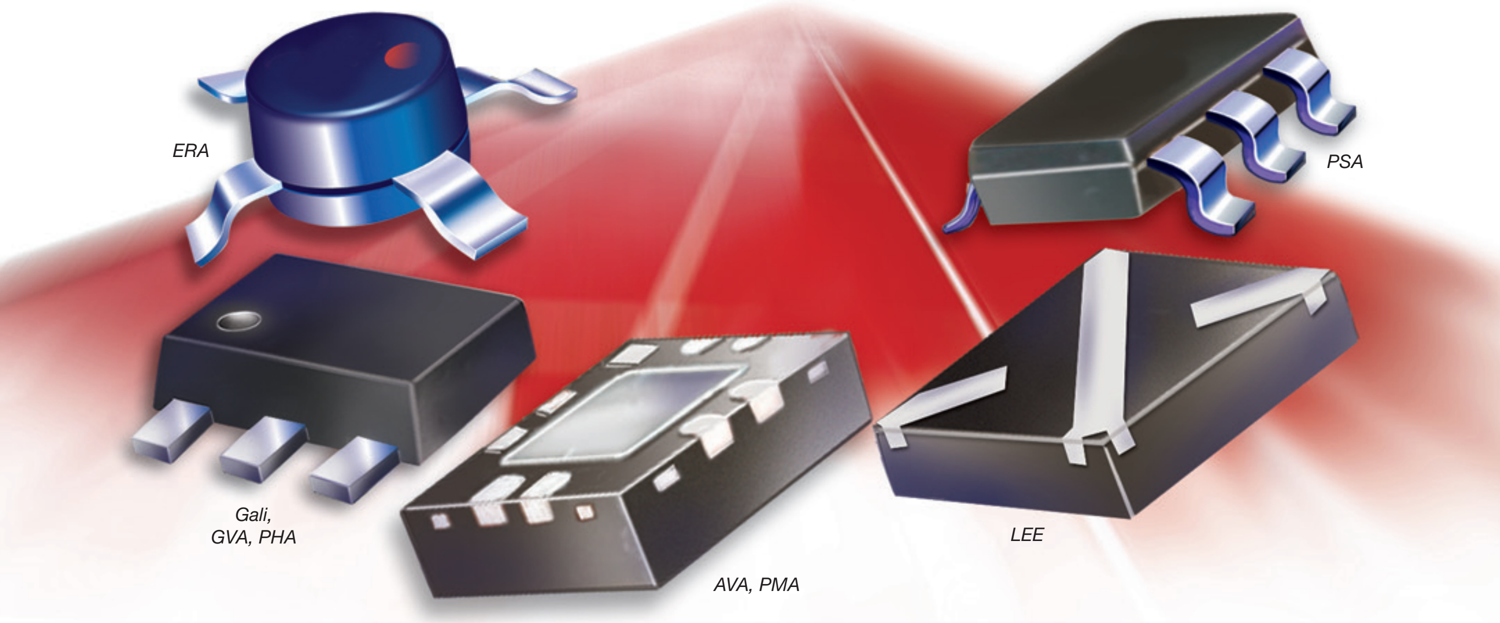

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IF/RF MICROWAVE COMPONENTS

Digital Baseband Tuning Technique Speeds Up Testing

With the increasing demand for smartphones and tablets in the world and the growing need for high data rates, wireless semiconductor manufacturers are exposed to the convergence of multiple market and technology forces, pressing them to look for new architectures and technology innovations in their RF components test environments.

- The fragmentation of frequency ranges, combined with the increasing number of modulation schemes and RF paths, creates an exponential growth of test scenarios. Up to 1 million tests may be required during the characterization phase of latest generation RF components.
- Component test time needs to be reduced to minimize supply response time, match market windows and keep competitive price points.
- Wider bandwidths, such as 160 MHz for the new WLAN 802.11ac standard, are driven by the need for higher data rates. These new standards are expanding the test stations requirements and challenging calibration techniques.

One of the key instruments in a wireless test station is the Vector Signal Generator (VSG). This equipment will generate either ideal or complex real world signals to test the performance of RF components under a large number of test scenarios. To increase the test speed, the VSG must quickly change stimulus parameters, such as signal frequency, power and waveforms. VSG architectures have been improved over the years, but the traditional analog frequency and amplitude tuning speeds are optimized to a point where any speed in-

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Agilent Technologies, Santa Clara, CA

crease may be achieved at the expense of signal quality.

An innovative tuning technique, enabled by digital baseband processing technology, helps break the speed barrier without compromise on the signal quality within latest generation VSGs. This article discusses the typical limitations of RF tuning, the theory behind digital baseband tuning, its advantages and how it can be used to accelerate RF component test.

DEVICE TYPES AND TEST SPEED REQUIREMENTS

Production and pre-production testing are the most demanding environments for high speed testing. When thinking about mobile devices, there are three major testing periods in the production food chain: assembled mobile device, RF boards and RF components.

During production testing of the assembled mobile device, the speed of the test process is often limited by the mobile device itself. Test response time for a mobile device is typically measured in milliseconds.

At the board level, testing is performed at all frequencies and power levels. Due to the huge number of tests, the key components are set into a special test mode which sequences through the entire test with a 5 ms step (typical) between data collection points. For the VSG, it must be able to stay in step with this sequence rate. Latest generation VSGs, when used in list mode, have analog RF tuning speed around 220 µs and can stay synchronized with the DUT's test sequence.

The ultimate speed challenge occurs at the component level of the wireless food chain. There are several key RF components that require performance testing of each device: power amplifiers, transceivers, front-end modules (FEM), and often a system on chip (SoC) for WLAN/Bluetooth/RF tuner. Testing these components will require the test instrumentation and VSG to work at the highest possible speed.

One example of a time consuming test sequence is the power loop test scenario. Performance measurements of a power amplifier or front-end module are normally made at a specific output level of the DUT. Since all devices have variations in gain, it is necessary to run multiple iterations of the input power level to reach the desired output level. Getting the loop to quickly converge requires very high switching speed and excellent linearity and repeatability of the VSG. Only after the DUT output level is set at the correct value can the specified parameters be tested. Reducing the number of iterations while accelerating the switching time between each iteration has a significant impact on the test speed.

MAXIMIZING ANALOG RF TUNING SPEEDS

Latest generation PXI VSGs offer analog RF tuning at speeds as fast as 220 µs in list mode for both amplitude and frequency changes. There are two important mechanisms that limit speed within a VSG: the frequency synthesizer and the amplitude leveling control (see ***Figure 1***).


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The frequency synthesizer has an output frequency whose accuracy is directly related to the 10 MHz reference. The phase-lock-loop that compares these two signals and optimizes the phase noise typically has a settling time of a millisecond. Over the years, a number of proprietary techniques have been established to minimize the PLL settling time for frequency changes and reach hundreds of microseconds frequency switching time.

A VSG includes many active components that are temperature sensitive. The amplitude leveling control (ALC) is a real-time loop that monitors the output level and maintains a constant output level. There are a number of techniques to optimize the ALC settling time after changing amplitude or frequency. In addition, a full featured VSG will typically offer multiple modes including ALC On, ALC Off and ALC hold modes so the ALC can be turned off to achieve the fastest speeds. A typical optimized source can settle within 0.2 dB in about 500 μs.

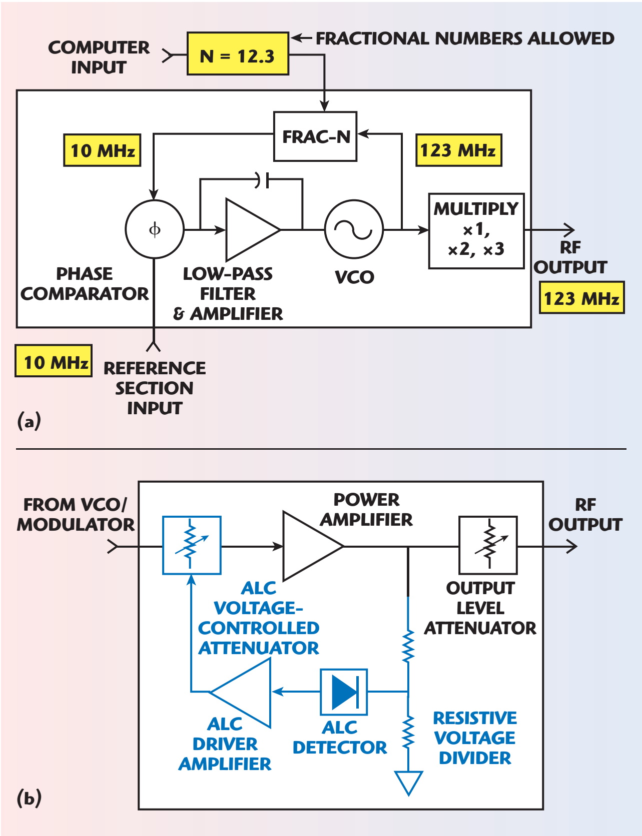

Fig. 1 Traditional VSG architectures utilize two important loops to ensure accurate frequency (a) and amplitude (b) levels.

Optimizing tuning speeds and signal quality is where test equipment vendors have invested a lot of IP over the years. An architectural advancement was needed to dramatically improve the VSG's measurement speed without compromising the signal quality required by today's wireless standards.

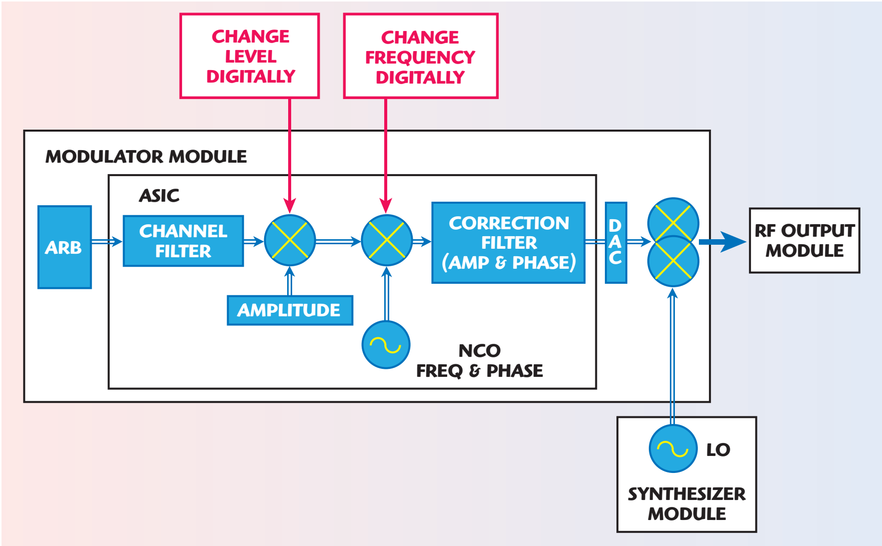

Fig. 2 Digital baseband tuning changes the frequency and amplitude level digitally within the specified bandwidth of the VSG.

INTRODUCING DIGITAL BASEBAND TUNING

Digital baseband tuning techniques offer the ability to digitally shift both the frequency and amplitude levels of the signal within the VSG's available modulation bandwidth without the need to retune the synthesizer (see ***Figure 2***). As new generation VSGs offer larger modulation Bandwidths, the digital baseband allows wider frequency shifts.

The maximum frequency shift is dependent on the modulation bandwidth of the VSG. For example, within a 160 MHz bandwidth, this technique enables frequency shifts to be achieved in 10 μs, an order of magnitude faster than analog tuning techniques. The same speed also applies to any level change within typically a 20 dB range. Of course the actual signal bandwidth has to be considered within this tuning range. For example, a 5 MHz WCDMA signal can have a 155 MHz of frequency offset range. An 80 MHz 802.11ac signal can only be offset ±40 MHz. To take advantage of the 10 μs switching speeds, test plans should perform all tests within the VSG's bandwidth range first, prior to taking larger frequency or amplitude steps. These larger steps outside of the VSG's bandwidth require 220 μs. Then a new VSG bandwidth tuning window is available with 10 μs switching (see ***Figure 3***).

These extremely fast performance improvements are enabled by proprietary ASICs. The ASIC includes several important processing functions inside the VSG's modulator module including:

- Real-time numerical controller oscillator for frequency offset
- Real-time multiplier for amplitude offset
- Real-time signal correction, based on fully characterized RF and IF path

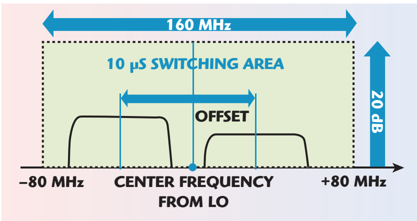

Fig. 3 Within a 160 MHz bandwidth range, simultaneous frequency shifts and amplitude level changes can be made in 10 μs over a 20 dB range.

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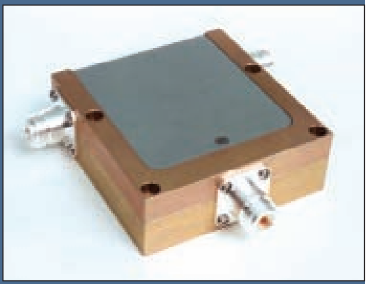

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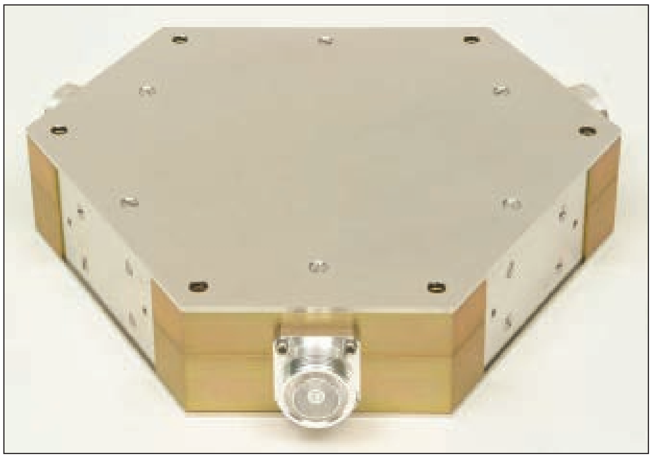

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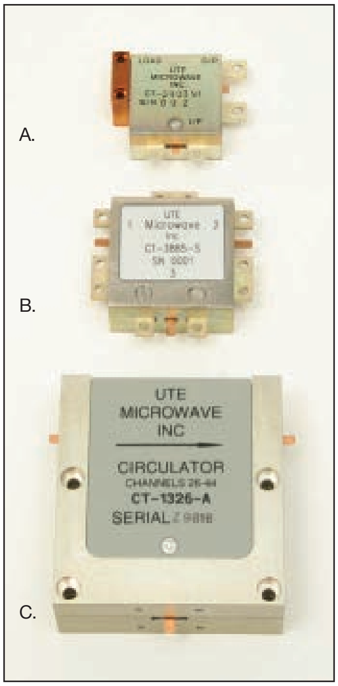

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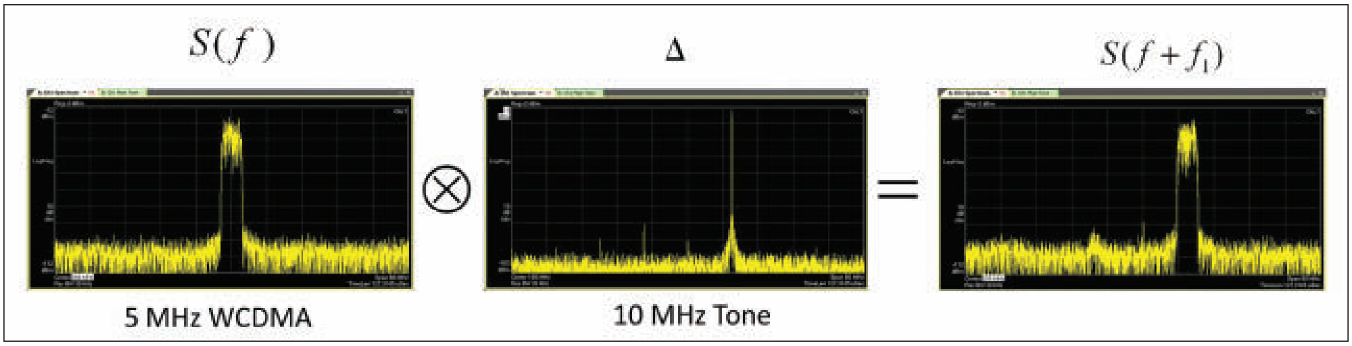


▲ *Fig. 4 The input waveform S(f) is convoluted with the digitally created shift frequency, S(f_1), to produce very fast, accurate frequency and level changes, S(f + f_1).*

HOW THE FREQUENCY AND AMPLITUDE LEVEL ARE CHANGED DIGITALLY

For frequency changes that occur within the baseband tuning bandwidth, let's examine what is occurring inside the processing chain that enables the digital frequency shift. Assume that a sampled complex waveform, s(nT), is stored in memory on the VSG. It will be processed, sent to the DACs, and then upconverted to the desired center frequency by the IQ modulator.

In the time domain, the sampled waveform is multiplied by the numerically controlled oscillator's (NCO) complex sinusoid:

$$A \bullet s(nT) \bullet \left[\cos(2\pi f_1 nT) + j\sin(2\pi f_1 nT)\right] \quad (1)$$

The scaling factor, A, allows the amplitude level to be adjusted.

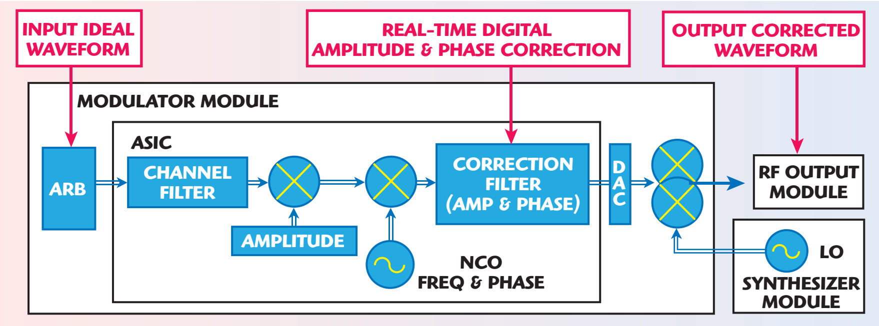
Multiplication by a complex sinusoid in time domain is equivalent to convolution in the frequency domain with the impulse function δ(f):

$$S(f) \otimes \delta(f_1) \quad (2)$$

This results in a frequency shift of the original signal's spectrum:

$$S(f + f_1) \quad (3)$$

Figure 4 shows an example of this process using a 5 MHz wide WCDMA waveform which is shifted up in frequency by 10 MHz. When this process is done in the analog world, special filtering is required to eliminate unwanted sum and difference terms that are generated in the process. When frequencies are shifted in the digital world, there are no negative frequencies or other error terms generated. Therefore, the mathematical ideal

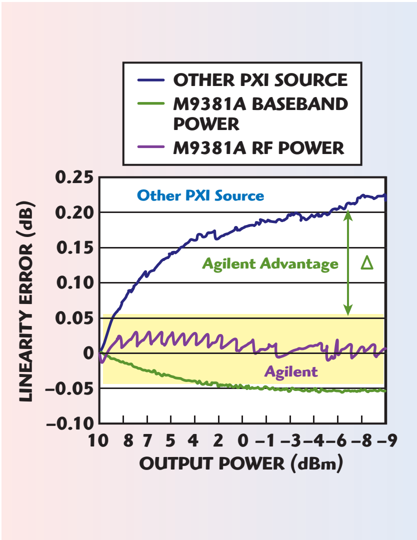
▲ *Fig. 5 Test engineers input their desired waveforms and the VSG's real-time correction capability ensures both amplitude and phase linearity.*

frequency shift does not require any filtering. To digitally shift frequencies, all that is needed is a sine lookup table, a cosine lookup table, and a complex multiplication algorithm. This process occurs in real-time in the ASIC across the 160 MHz baseband tuning range. In Figure 4, a few low level spurs in the resulting signal may be seen. These are residual errors from the analog IQ modulator that include signal images and carrier feed through.

REAL-TIME CORRECTIONS

Narrow bandwidth VSGs (< 40 MHz) have been able to use single values for correcting quadrature and gain imbalance across the tuning bandwidth. When the tuning ranges extend to 160 MHz, a more thorough real-time correction process is required to meet the linearity needs of today's higher data rates.

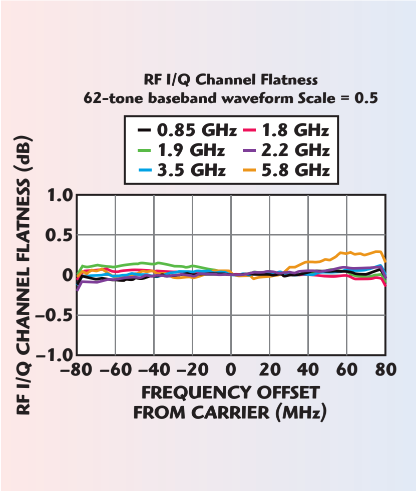
The optimal way to maintain highest signal quality is to include a correction filter using 2×2 matrix taps that offers full magnitude and phase correction across the entire 160 MHz tuning band (see ***Figure 5***). The entire IF and RF path of each VSG must be completely characterized during manufacturing calibration, and the resulting complex data are stored in the modulator and RF output module's flash memory. This data is used during runtime to construct and load a new 160 MHz wide complex correction filter whenever the RF center frequency



▲ *Fig. 6 Digital baseband tuning enables accurate linearity across a 20 dB leveling range. The speed improvement of 10 μs vs. 250 μs for RF power leveling offer only a very small degradation in linearity.*

or RF attenuator state changes. This provides exceptional magnitude and phase corrections up to the RF output (see ***Figures 6*** and ***7***).

To take advantage of digital baseband tuning for power amplifier testing, engineers can set the RF frequency to the center of the band being tested and the RF power level to the maximum required for all tests. From there, baseband frequency adjustments are made to test at multiple frequencies across the band and the baseband power level is adjusted servoing the DUT output level to the correct value. Better linearity, repeatability and resolution further reduce the test time by enabling the servo loop to converge in fewer steps. Figure 6 shows the measured linearity of the M9381A over a 20 dB range from +10 to –10 dBm, using both the baseband and RF level adjustments.



▲ *Fig. 7 Wider tuning bandwidths require full matrix real-time corrections to achieve accurate linearity.*

CONCLUSION

With billions of components going into mobile wireless devices, reducing test times can have a major cost benefit. As device data rates continue to increase, reducing test times while maintaining signal quality adds new test station challenges.

Digital baseband tuning introduces a new VSG architecture that is dramatically faster than traditional RF tuning techniques. Signal quality is maintained due to new real-time matrix correction techniques that are applied across the entire 160 MHz tuning bandwidth. This results in excellent amplitude and phase linearity to assure the signal quality required by increasingly demanding wireless standards. ■

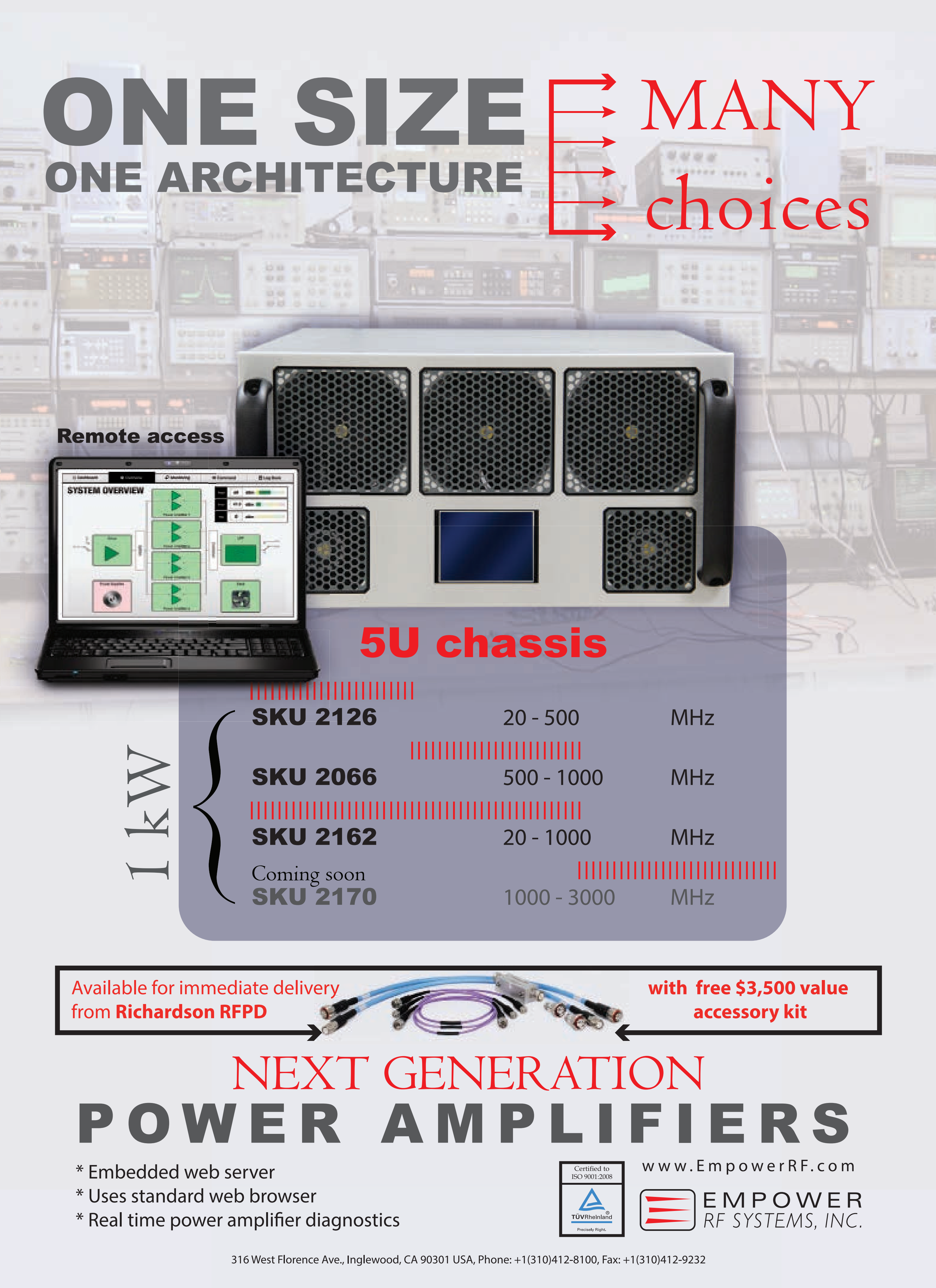
Verifying Very-Near-Field Antenna Measurements: Algorithm Evaluation

Ruska Patton and Ning Yang
EMSCAN Corp., Calgary, Canada

In this article, it is demonstrated that accurate antenna far-field predictions can be made from very-near-field measurements. The results obtained from near-to-far field algorithms, which are based on the plane wave spectrum approach, accurately correlate with full-wave simulated and anechoic chamber measured far-field results. By comparing the results between measurements obtained at a distance of 25 mm with those obtained at 80 mm, the advantages of measurements taken at extremely close distances are demonstrated. The far-field results predicted from the very-near-field measurements taken using a scanning instrument are compared with the results obtained from a conventional anechoic chamber. This research establishes that antenna measurements taken at very-near-field provide valid far-field results. Compared with traditional planar near-field methods, the very-near-field measurement technique has a wider angle of coverage and makes a small-area scanning plane possible, which reduces the size and cost of the instrument and also makes the measurement much faster.

The far-field radiation pattern is conventionally characterized by measuring the received amplitude and phase in a far-field region (where a perfect plane wave field is expected) by mechanically rotating the antenna under test (AUT) about the relevant coordinate. Usually, it is done in an anechoic chamber that is large and expensive and can take a long time due to mechanical constraints. An alternative to the far-field measurement is to measure the antenna in the near-field region. A near-field measurement system was first built in 1950 by Barrett and Barnes of the Air Force Cambridge Research Center.[1] Most of the current near-field measurement instruments are based on the near-field measured in the radiating near-field region. This requirement means the size of the scanning surface and hence the overall systems can still be quite large, even though they are smaller than far-field systems. In this article, a description is made of a very-near field measurement technique that allows the scanning system to be compact and portable and allows measurements to be made in seconds without any mechanical movement of sensors.

Measuring antenna performance in the very-near-field had previously been avoided,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due to the fact that the sensors can influence the performance of the AUT.[2] Although not formally defined, the very-near-field is described here as being much closer to the sensors than traditional near-field measurements. Most of the measurements presented in this article were taken at a distance of 25 mm from the AUT. Depending on the frequency, this distance can even range into the reactive region which is mathematically defined as $d < \lambda/2\pi$ for small radiators.[3] Although it is normally assumed that measurements cannot be done in the reactive region, there is nothing in the near field transformation that limits the distance to the measurement plane.[3-7]

The very-near-field measurements, described here, are taken so close that coupling between the AUT and the measurement probes cannot be avoided. An important part of the measurement process is minimizing this coupling effect and making it predictable. The approach chosen for this implementation was to have a static array of probes. The advantage of this approach is that for all measurement probe locations, the coupling is exactly the same. A secondary advantage of the array of probes used for these measurements is that there is no mechanical movement and therefore measurement of the very-near-field data can be done incredibly quickly. Even with this approach, there is no single solution to the coupling problem, since it is dependent on the AUT and the measurement probes, but a reasonable approximation of the effect can be made for unknown antennas.

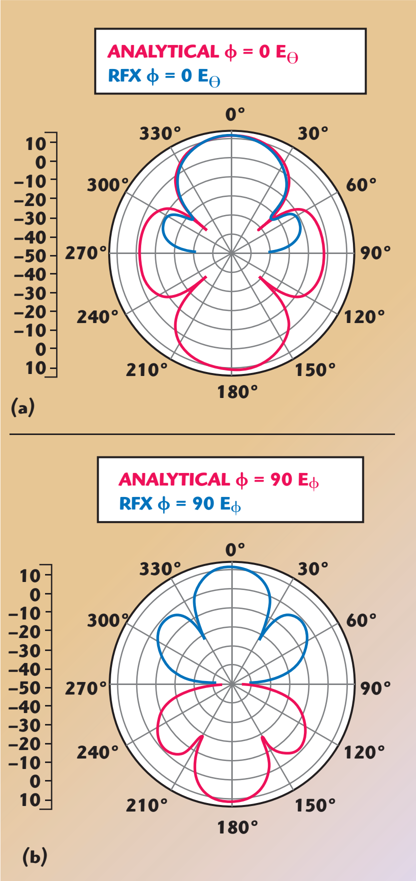
The implementation of this approach is to measure the magnetic field (H-field) with the probe coupling effects and project this data to the far-field using the planar aperture distribution to angular spectrum transformation or plane wave spectrum (PWS) transformation.[4,5] A second custom algorithm then adjusts the far-field projection to eliminate the predictable coupling effects of the measurement array. This leaves some small but unpredictable error that is dependent on the form of the AUT.

VALIDATING THE VERY-NEAR TO FAR-FIELD ALGORITHM

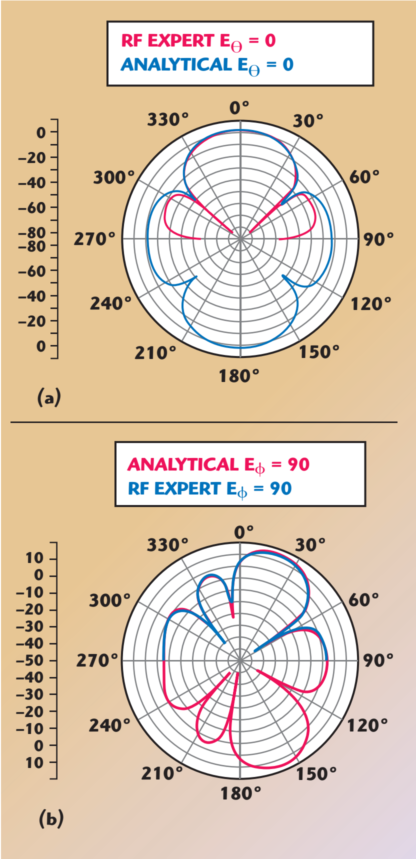
The first step is to verify that the implemented PWS transformation is accurate. This was done by generating ideal field values, which could be those generated in the very-near-field of an antenna, applying the PWS transformation to the ideal field values to get projected far-field results and comparing these far-field pattern shapes to theoretical results from the same ideal distributions.

Y-Polarization with a Uniform Very-Near-Field

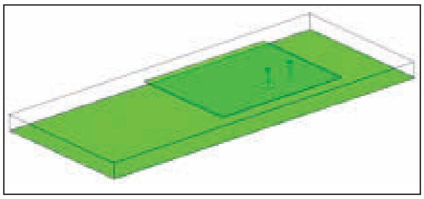
A uniform H-field distribution is used in this test. Field values are generated over an aperture of 16 × 24 cm with samples every 1 cm, creating a measurement array totaling 16 × 24. These values were chosen to match the implemented very-near-field measurement system that will be discussed later. Amplitudes for these measurements were set to 1 A/m uniformly and all phases are set to zero degrees for simulating the broadside radiating aperture. The polarization



▲ *Fig. 1 Comparison of theoretical and implemented very-near-field scanned radiation patterns evaluated at 2.5 GHz: (a) ϕ = 0° plane and (b) ϕ = 90° plane.*



▲ *Fig. 2 Comparison of theoretical and implemented very-near-field projected radiation pattern at 2.5 GHz: (a) ϕ = 0° plane, and (b) ϕ = 90° plane.*



▲ *Fig. 3 Diagram of the 1.8 GHz radiating patch antenna.*

is in the Y-axis or along Phi = 90°. The near-field measurements were implanted into the code of the very-near-field measurement system and the predicted far-field radiation patterns at the two main planes (Phi = 0° and Phi = 90°) are compared with the theoretical results shown in ***Figure 1***. For the pattern where Phi = 0° plane, the size of the scanner limits the accuracy to approximately ± 60° from 0°, while for the pattern where Phi = 90° shows an almost perfect match at all angles.

Y-Polarized Beam-Steered Very-Near-Field

The data is again a 2D array of 16 × 24, with the same size aperture described previously. The amplitudes are set to 1 A/m uniformly and phases are set to have a 10.8° progressive phase shift (in the Y direction) to obtain the 21° maximum radiation. The radiation patterns obtained from theoretical analysis and the implemented very-near-field instrument are compared in ***Figure 2***.

Again there is very good correlation between the theoretical and projected far field results. The same variation where Phi = 0° plane can be seen, where the size of the scanner limits the accuracy to approximately ±60° from 0°, while the results for Phi = 90° show a perfect match.

COMPARISON OF 25 AND 80 MM MEASUREMENTS PROJECTED TO THE FAR-FIELD

In this section, the PWS transformation is applied to ideal very-near-field values that are generated from a simulated radiating structure. The chosen structure is a patch antenna at 1.8 GHz, radiating in free space. This antenna is shown in ***Figure 3***. The

radiating patch on the top is 44 × 36 mm and the maximum dimension of the ground plane backing the patch is 110 mm.

After a full-wave simulation, the H-field is sampled at a distance of 80 and 25 mm. In both cases, the sampling area is the same 16 × 24 array described earlier. The values generated at 25 mm are within the reactive region and those at 80 mm should be outside the reactive region. The simulated data is imported into the very-near-field measurement system's software to predict the far-field radiation patterns and compared with the results from the full-wave simulation (see ***Figure 4***).

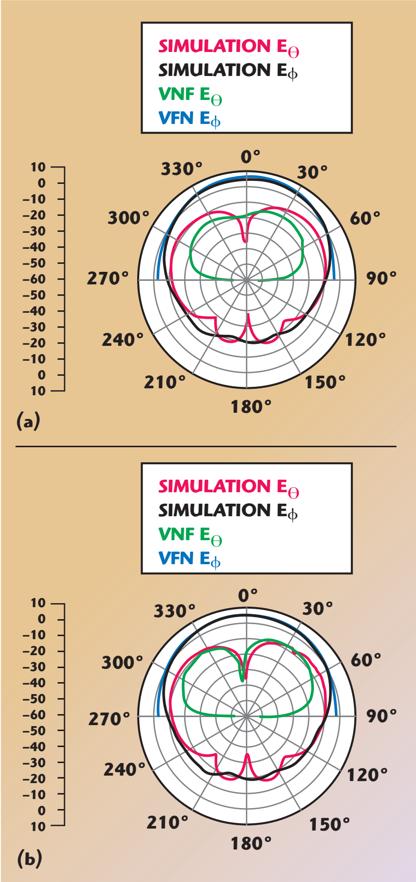
Not only do the far-field results projected from the 25 mm very-near-field scan correlate well with simulated results, they are much closer to the simulated results than the 80 mm scan. This result is due to the fact that the 25 mm scan has a wider angle of coverage than the same size scan area at 80 mm. As a result, the 25 mm scan can produce excellent pattern accuracy, with a very small scan area. The directivity projected from the 25 mm very-near-field scan is 6.0 dBi, which compares very closely to the simulated directivity of 5.7 dBi. The 80 mm scan projected a directivity of 7.8 dBi.

COMPARISON OF PATCH ANTENNA MEASUREMENTS: SIMULATED, VERY-NEAR-FIELD AND CHAMBER RESULTS

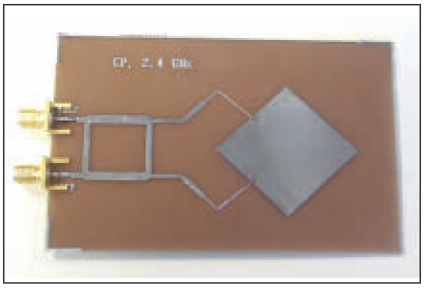
The patterns shown in the previous two sections were produced with ideal very-near-field data generated through full-wave simulations. In this section, the results are produced from a fully implemented very-near-field measurement system. The array of probes is present for the measurement of the field values. The probes are linearly polarized loops that are arranged in two polarizations on the planar surface.

The antenna chosen for testing in this section is a circularly polarized patch shown in ***Figure 5***. The patch antenna was set up to be right hand polarized for the tests. The results show that linearly polarized very-near-field measurements can be used to measure the performance of a circularly polarized antenna. The very-near-field measurement system is able to indicate rotation direction (right-handed or left-handed), plot both right-handed and left-handed circular polarization patterns and provide the axial ratio at all angles.

The results, shown in ***Figure 6***, show good correlation both for the right hand pattern and for the left hand pattern. The patterns generated by the implemented very-near-field system are labeled RFxpert. For the low level left hand patterns, two mea-



▲ *Fig. 4 Far-field patterns projected from very-near-field scans (a) ϕ = 0° plane, very near-field measured at 80 mm, (b) ϕ = 0° plane, very-near-field measured at 25 mm.*



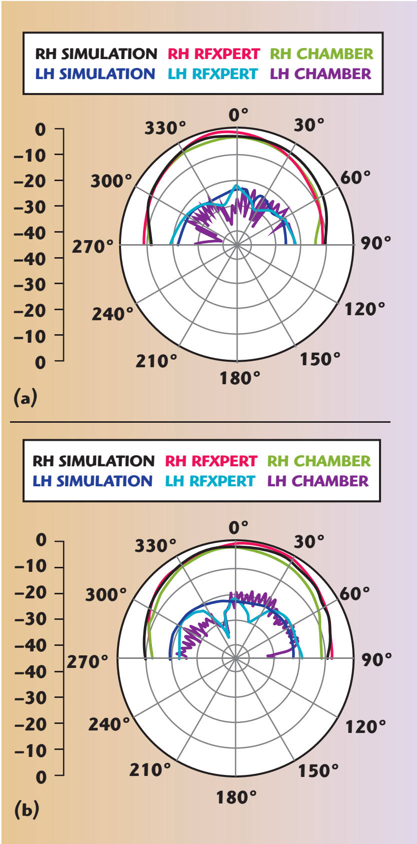
▲ *Fig. 5 The circularly-polarized patch antenna.*

sured results detect a small null that appears around 340°, while the simulation results miss this.

COMMERCIAL RESULTS COMPARING VERY-NEAR-FIELD SCANS WITH CHAMBER MEASUREMENTS

The results presented thus far have all related to far-field patterns. In addition to patterns, very-near-field measurements can also generate absolute values for other parameters such as total radiated power (TRP). This is demonstrated in ***Figures 7*** and ***8***.

The results shown are a collection of data from a very-near-field measurement system in a commercial environment. This system was used to measure a batch of same model mobile devices. The two sets of results shown here are with the generic compensation for coupling effects. This is the one that has no knowledge of



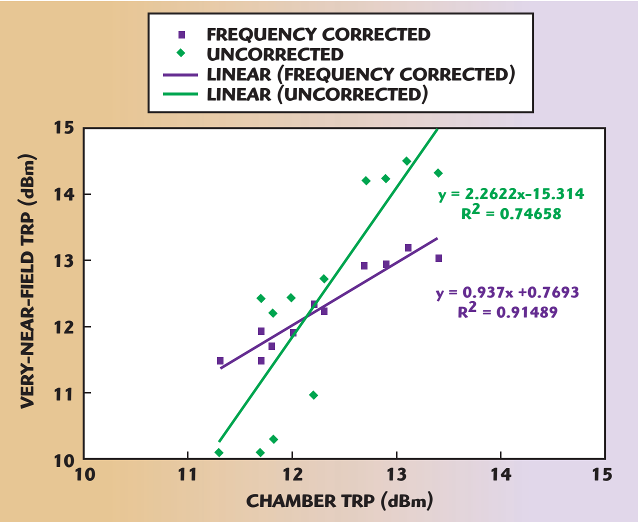
▲ *Fig. 6 Simulated and measured radiation patterns for the circularly polarized patch antenna (a) $\phi = 0°$ plane and (b) $\phi = 90°$ plane.*

the AUT and is labeled 'Uncorrected' here. The second set of results has been corrected for variations that are device-specific and can only be determined after some measurements have been collected.

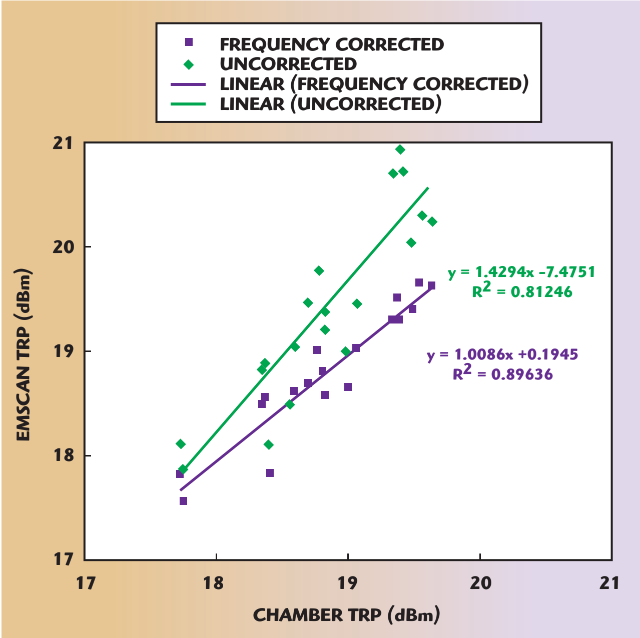
These results confirm that measurements, made in the very-near-field, can be used to predict TRP when corrected for predictable coupling effects. Over this large data set, the difference is less than ±1.5 dB. The results also show that improvements to the generic coupling compensation can be made with knowledge of a device-specific coupling factor. With this added compensation, a very strong positive correlation can be seen.

CONCLUSION

Measurements, obtained by scanning antennas in the very-near-field and using this data to generate far-field projections, demonstrate close correlations with patterns and direct measurement parameters obtained in anechoic chambers. It was confirmed that the implementation of the algorithm is accurate and then that very-near-field



▲ *Fig. 7 Comparison of chamber results (green) with very-near-field results from a very-near-field scanning system at 2.4 GHz.*



▲ *Fig. 8 Comparison of chamber results (green) with very-near-field results from a very-near-field scanning system at WCDMA bands 5 and 6 frequencies.*

scans at 25 mm can give accurate far field projections, even if the measurement points lie in the reactive region. A second advantage of the very-near-field measurement system was demonstrated to be good pattern accuracy with a very small scan area. Far-field radiation patterns predicted from actual very-near-field measurements were compared with results measured in an anechoic chamber and results generated by full-wave simulations for a circularly polarized (RH) patch antenna. The comparison confirmed the close correlation between chamber results and those obtained from the implemented very-near-field scanning system. In this case, compensation was only made for the predictable coupling effects, which demonstrate that accurate patterns can be measured with no knowledge of the AUT. It was also demonstrated that very-near-field measurements could also accurately obtain direct measurement results for other antenna parameters, such as total radiated power and radiation efficiency. ■

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Automated Additive Phase Noise Measurements

Phase noise measurements fall under two categories: absolute and additive (residual). Absolute phase noise measurements are typical of oscillator or LO system level noise. Additive phase noise measurements are more specific, measuring the additive noise of an individual component or subsystem. Additive noise measurements are typically at a lower level and a more difficult measurement than absolute, requiring careful measurement setup and calibration. While the setup involves traditional microwave plumbing, the calibration can be tedious and prone to significant error. Holzworth Instrumentation's HA7000B Series of phase noise analyzers addresses this problem by completely automating the calibration as well as an option for automating the setup.

Holzworth Instrumentation's HA7000 Series phase noise analyzers were designed to optimize measurement speed and low noise floors, while being highly intuitive to set up and operate. The high level of automation was driven by the customers' requirements to transition phase noise testing from R&D to the manufacturing environment while maintaining the low noise expected in R&D.

In response to customer requests to measure both absolute and additive phase noise with Z540 traceability, Holzworth has released revision B of the HA7000 Series. The revisited design for the HA7062B and HA7402B include: a more advanced front end, an external power supply for cleaner spurs (also allowing for powering the analyzer via a 12 V battery), and a Z540 traceable calibration. Most significantly, it has introduced fully automated additive phase noise measurements.

Using external HX series components designed specifically for the HA7062B and HA7402B, the calibration process has become completely automated. By using calibrated and traceable external components, the Z540 traceability is extended from absolute measurements to additive phase noise measurements. Using the advanced capability of the instrument, the measurement is both automated and accurate.

HA7000 CROSS CORRELATION PERFORMANCE ADVANTAGE

Additive phase noise measurements share some common issues with absolute phase noise measurements. Problems such as port to port isolation and match in traditional instruments can lead to false readings by allowing the independent branches in the cross correlation system to not be independent enough for cross correlation theory to hold true. Depending on the setup, this can lead to either false measurements being high or low. To be confident in the data, the port match and port to port isolation need to be as close to as ideal as possible — not unlike a spectrum analyzer or network analyzer. The HA7000 Series typically has better

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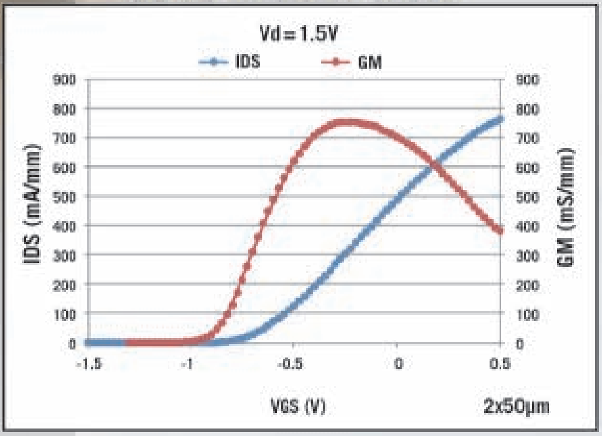
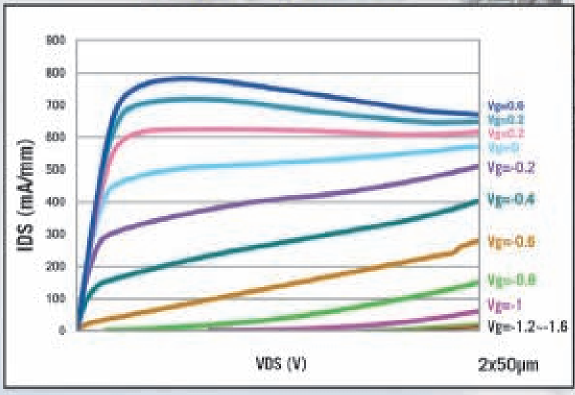
PP10-10/-11 0.1µm Power pHEMT

- 0.1µm high performance power / low noise process
- 50µm and 100µm thickness are standard
- Useable gain to 110GHz
- 4V operation - Psat > 800mW/mm, > 50% PAE, and 13dB Gain at 29GHz

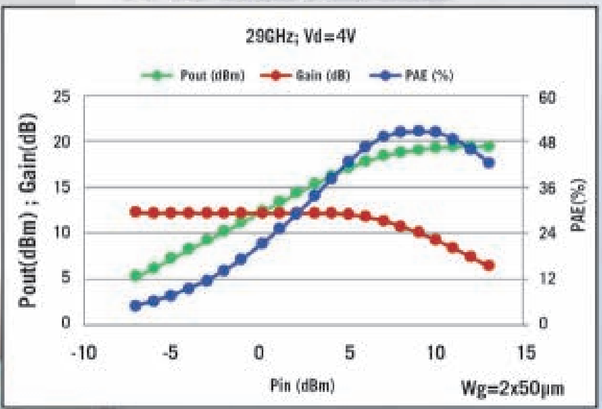
PP10 Transfer Curve



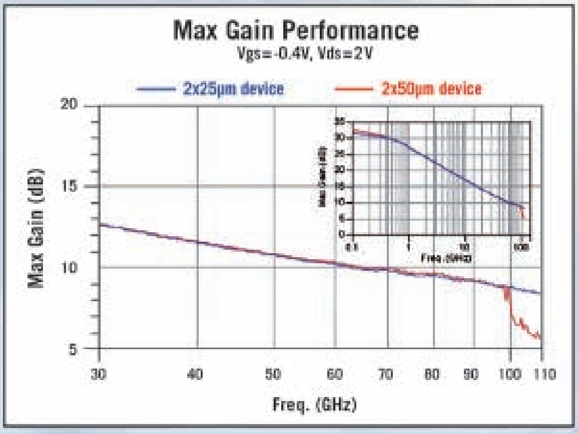
PP10 I-V Curves



PP10 Load Pull Data



PP10 Max Gain



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than –20 dB return loss and isolation greater than 80 dB. Internal to the instrument, attention to detail involving ground loops, spurious and shielding provides confidence that the raw data reflects the true performance of the DUT. Without tedious attention to these performance parameters, the cross correlation function may be ineffective at accurately isolating the noise due to the DUT only.

ADDITIVE PHASE NOISE TEST SETUPS

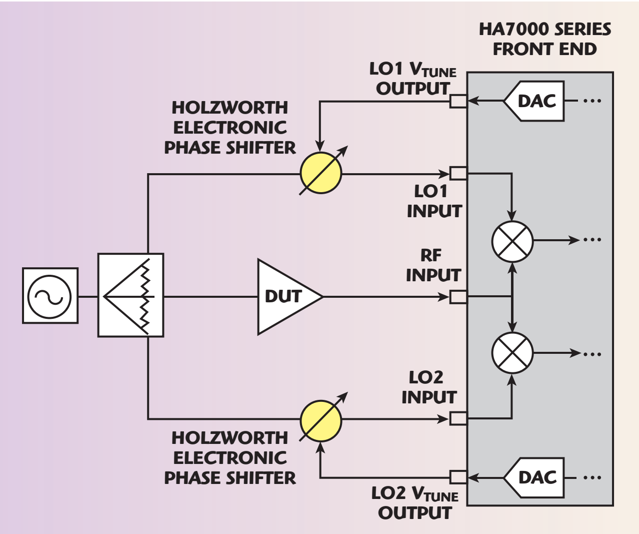
Additive phase noise of components and subcomponents give designers and manufacturers valuable insights to the performance of their systems. While absolute phase noise (oscillator or LO noise) can provide the user with the overall performance of a source or total system, additive phase noise focuses the noise contributions of individual two-port elements. The results can help to troubleshoot or predict overall system performance, similar to cascading S-parameters or calculating noise figure. Oscillator designers can even isolate the effect of different amplifiers on the overall noise.

Proper calibration of the additive phase noise system has traditionally been a manual process that is not extremely difficult, but even a small error can lead to erroneous results. The greatest challenge in the calibration is calculating the phase detector constant in relation to a known phase shift. The HA7000 Series phase noise analyzers feature a series of checks involving the internal frequency counters and power meters in conjunction with the new external calibration standards. To aid measurement setup, the software includes an active quadrature monitor for visual feedback.

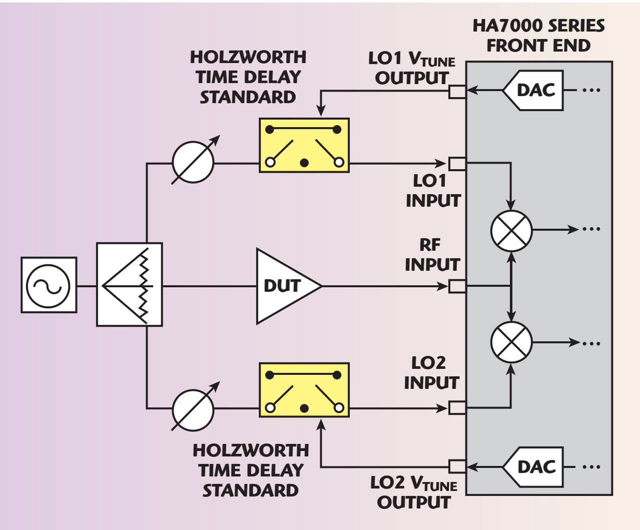
Two different external calibration standards are available. The first is a narrowband electronic phase shift calibration standard that adjusts the instrument into quadrature (where phase detection occurs) and performs full calibration. The second is a broadband time delay calibration standard where the user uses the software quadrature monitor to achieve quadrature and the time delay calibration standard is used to calibrate the instrument.

NARROWBAND, INTEGRATED PHASE SHIFT AND CALIBRATION

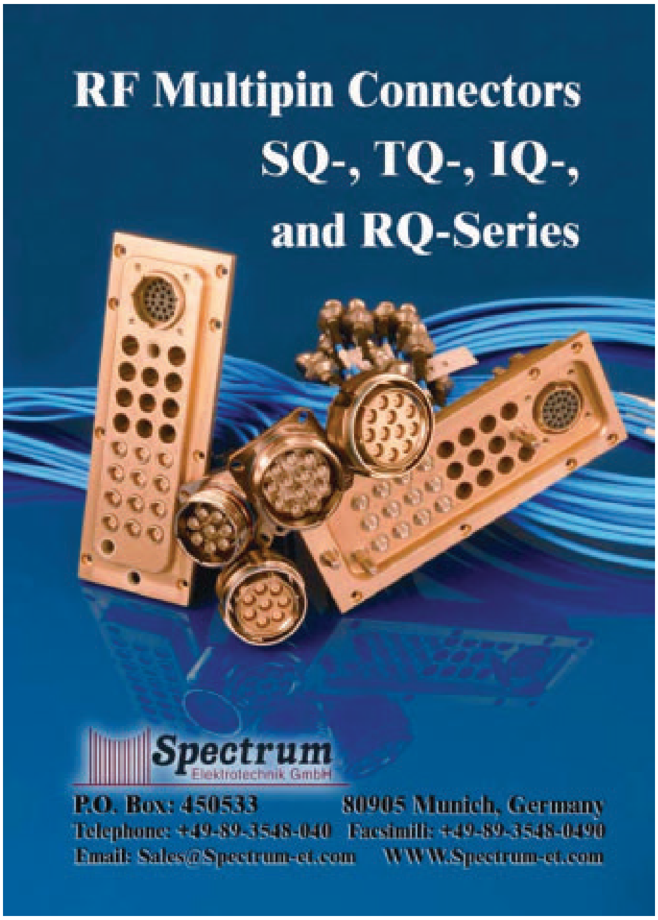
The first calibration standard setup incorporates a pair of Holzworth electronically (system) tuned phase shifters.



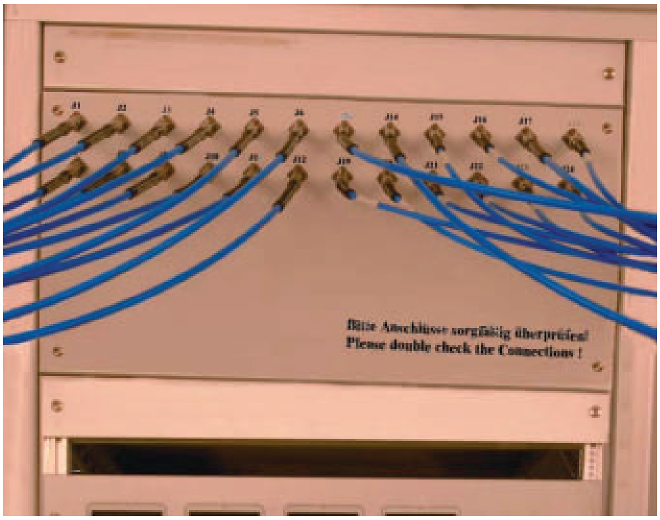
▲ *Fig. 1 Fully automated, narrowband test setup.*



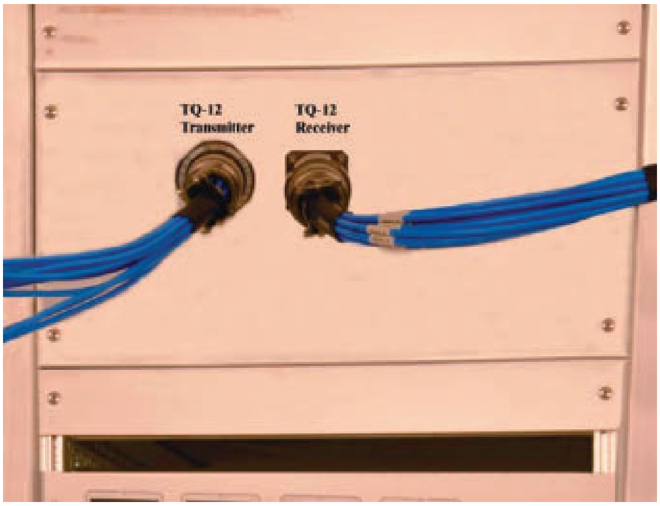
▲ *Fig. 2 Automated, broadband test setup.*



Catalogue RF Multipin Connectors 52 pages showing in detail 4 coaxial Multipin Connector Series, demonstrating how to connect and disconnect up to 23 coaxial lines in seconds and saving space.



The Problem: In various applications many coaxial microwave links have to be connected and disconnected. This means threadening and unthreadening, torquing and untorquing. Very dense packaging is not possible, as there is still room needed for manual threadening and for the use of a torque wrench. In helicopters and aircrafts all connectors usually have to be safely secured, wiring the coupling nuts of the connectors, using wire holes, a time-consuming process.



The Solution: Spectrum's Multipin Connectors are available with four (4), seven (7), eight (8), twelve (12) and twenty three (23) coaxial inserts (terminating the coaxial cable assemblies) at the Multipin end, and connecting all the coaxial cable assemblies at once and in seconds with no need of a torque wrench, no need for safety wires and using minimum space.

Spectrum Elektrotechnik GmbH
P.O.Box 450533 80905 Munich Tel. +49-89-3548-040
Email: Sales@Spectrum-et.com www.Spectrum-et.com

In this scenario, both quadrature adjustment and calibration is fully automatic. As shown in ***Figure 1***, the test system setup includes a frequency source, a three-way power divider and two Holzworth Electronic Phase Shifter Calibration Standards. The user introduces a DUT with an appropriate power level set and simply selects "acquire" on the analyzer's GUI. The software takes over and monitors input frequency and power, then automatically adjusts each phase shifter to optimize conditions for phase lock and calibration. If any out of spec conditions occur, a warning message will appear.

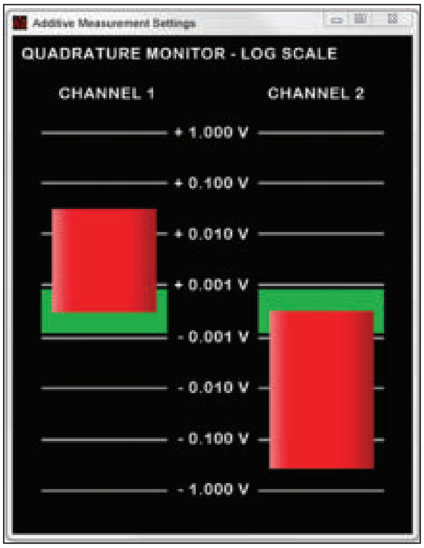
The Electronic Phase Shifter Calibration Standards are sold in matched pairs and are for narrowband applications, optimized for frequency measurement offsets of 10 Hz to 1 MHz, but will operate down to a 1 Hz offset. Each calibrated pair is narrowband and may be ordered at any frequency. A range of standard models are available from Holzworth to cover common frequencies.

BROADBAND, USER SUPPLIED PHASE SHIFTER, AUTOMATED CALIBRATION

The second additive phase noise test setup automatically calibrates the system over a broad range of frequencies. It is up to the user to provide the necessary phase shift for quadrature. As mentioned previously, the software includes a log scale quadrature monitor to assist the user with setting exact quadrature. As shown in ***Figure 2***, the test system configuration again includes a frequency source and a three-way power divider. The phase shift is performed manually, typically with a mechanical phase shifter. Calibration is automatic using a Holzworth time delay calibration standard.

Once the user has the DUT in place, the log scale Holzworth Quadrature Monitor (see ***Figure 3***) is used to monitor the quadrature variation of each LO channel, while making small adjustments to each phase shifter. Once the quadrature of each channel is set to inside the target range, the user simply selects "Acquire" and the system automatically calibrates and begins taking data.

The broadband Time Delay Calibration standards are also Z540 traceable standards that are available as a calibrated set. They are optimum for either broadband work where mechanical phase shifters are available or when the very lowest noise at close to the carrier is required. Mechanical phase shifters offer a performance advantage over electronic phase shifters close to the carrier when the lowest noise floors



▲ *Fig. 3 Holzworth quadrature monitor interface.*

are required. The reduced noise floor is a trade-off for complete automation.

ADDITIVE TEST SETUP EXAMPLE

The block diagram for a typical phase noise measurement setup is shown in Figure 1. In a traditional system, the phase shifters are mechanical and the calibration is manual, relying on the operator's experience with the system. In this scenario, a pair of Holzworth Electronic Phase Shifter Calibration Standards move the system into quadrature and automatically calibrate the test setup prior to each measurement. A photograph of the system setup configured to demonstrate the noise floor of the additive test system is shown in ***Figure 4***.

Additive phase noise measurements allow the measurement setup and system noise floor to be accurately measured under a given condition. ***Figure 5*** shows the measurement noise floor of the Holzworth HA7402A system for this setup. This evaluation is performed at fc=100 MHz and the power is +15 dBm. In this scenario, 1000 correlations are used to reduce the noise floor, approaching the limit of the system. At 10 correlations, the noise floor is approximately –180 dBc/Hz (10 kHz offset). At 100 correlations, the noise floor had reached –185 dBc/Hz (10 kHz offset). At 1000 correlations, the noise floor had reached a floor of approximately –190 dBc/Hz (10 kHz offset). If mechanical phase shifters are used with the Time Delay Calibration Standards, a much lower noise close to the carrier can be expected.

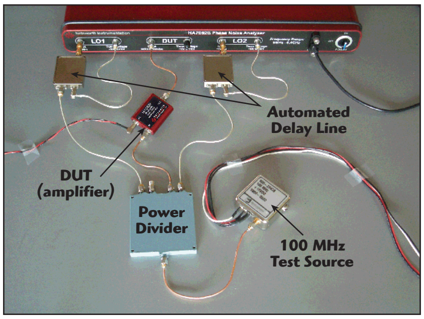


Fig. 4 Holzworth additive phase noise setup.

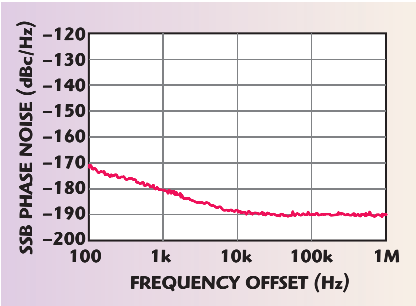


Fig. 5 Test system noise floor at 100 MHz.

The HA7000 Series has fully automated a difficult and sensitive measurement in an easy to use system. Like the absolute phase noise of high performance sources, additive phase noise is becoming an important evaluation parameter for two-port devices as they influence the overall phase noise of a system. The Holzworth HA7000 Series phase noise analyzers now include valuable additive phase noise features that automate the residual phase noise measurement by way of an intuitive interface. The revised designs couple versatility and ease of use with NIST traceable accuracy.

VENDORVIEW

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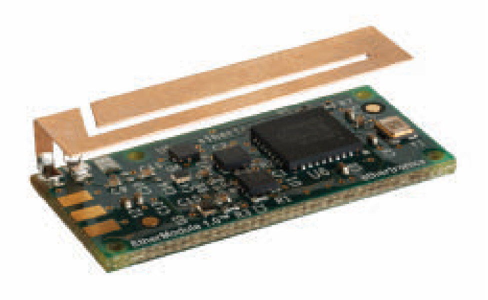


Plug-and-Play Solution Module Maximizes M2M Performance

The machine-to-machine (M2M) market is continuing to grow exponentially. By 2021, annual global M2M revenue will hit $50.9 billion according to Analysys Mason. That's also when M2M connections will have grown twentyfold to 2.1 billion worldwide, up from more than 100 million today. The growth will come from a wide range of products – from water meters and vending machines to point-of-sale (PoS) terminals, medical devices and many more. Vendors are excited about the growing revenue opportunities but these deployments do not come without challenges. In addition to a challenging RF environment, designers must figure out how to accommodate the wide range of frequencies used for M2M, given the limited amount of space within the device for the antenna and RF system componentry necessary for high performance and reliable connectivity. Additionally, vendors may not have RF expertise and test equipment in house to meet these challenges.

Ethertronics' new EtherModule 1.0™, a turnkey, plug-and-play, active antenna system module combining Ethertronics' advanced antenna architecture and EtherChip 1.0™ tunable capacitor using proprietary Air InteRFace Digital Conditioning™ technology on a printed circuit board, provides easy integration by wireless product designers. EtherModule 1.0 is a result of the collaboration of Ethertronics' three divisions: antennas, systems and chips to provide the highest performance and connectivity under the most challenging RF conditions. Below are the reasons why EtherModule 1.0 is an excellent fit for M2M applications:

Active antenna system approach adapts to RF and environmental conditions. EtherModule 1.0 combines advanced antenna architecture, active components and proprietary algorithms to provide tuning capability. This design enables the antenna's characteristics to be seamlessly adjusted to its dynamic requirements, such as hand, head and environmental effects, more bandwidth and frequency shift.

By dynamically sensing and optimizing the antenna system, EtherModule 1.0 gives M2M

ETHERTRONICS
San Diego, CA

devices the unique ability to maintain optimal performance and connectivity even when the device is installed on a metal surface, such as a water meter housing, that would wreak havoc with a traditional passive antenna. The combination of an active design and closed-loop impedance matching also enables M2M vendors to create a single platform that can be quickly and cost-effectively integrated to meet the unique requirements of each new application. By comparison, passive designs typically require extensive and expensive customization.

Closed-loop impedance matching – this architecture enables the module to dynamically sense and optimize the antenna system, all without external control signals from the device. As a result, EtherModule can seamlessly adjust the antenna's characteristics to meet its dynamic requirements, including frequency shift, hand, head and environmental effects or more bandwidth.

This technique automatically corrects frequency shifts that are a fact of life for nearly all M2M devices. For example, EtherModule 1.0 automatically corrects the detuning that occurs due to the user's hand, such as in the case of a point-of-sale terminal, or to wet leaves and snow, such as in the case of a water meter in an underground vault.

EtherModule 1.0 also uses this technique to maximize bandwidth by automatically matching the antenna whenever the transceiver moves to a new frequency. This technique gets its name from the ability to conduct matching without any external information, such as which frequency is being used and/or the power level.

A highly compact footprint covers a wide frequency range. Another trend compounds the challenges for M2M devices: the growing number of bands that many applications require, such as two or more for LTE, another couple for 3G/2.5G fallback and possibly one for GPS. If the application requires a low frequency, such as 400 or 900 MHz, larger antennas are required. As a result, designers are further challenged to accommodate a wide range of frequencies, in a less than optimum amount of space, without undermining performance and reliability in the process.

EtherModule 1.0 enables developers to overcome both challenges. At just 35 × 15 × 10 mm, EtherModule 1.0 avoids the time and expense of a custom antenna solution. It covers a wide frequency range from 100 MHz to 3 GHz, so designers can create M2M devices that span 2G, 3G and 4G cellular, Bluetooth®, ISM, WiFi and ZigBee, depending on their needs. Additionally, a typical dynamic range of 20 dB ensures maximum performance across a wide range of frequencies and use cases.

Years of experience designing and integrating high performance antenna solutions. EtherModule 1.0 leverages Ethertronics' 12-plus years of providing high-performance antenna solutions used by handset vendors to successfully pass operator certification. This experience benefits M2M vendors whose applications use cellular frequencies by significantly increasing the likelihood that an EtherModule 1.0 based M2M device will pass certification the first time, reducing development time and avoiding the expense of re-engineering.

EtherModule 1.0 benefits M2M vendors without the large RF engineering staffs that smartphone and tablet vendors have to re-design products that don't pass operator certification the first time. And as a turnkey, plug-and-play solution, EtherModule 1.0 can be quickly and cost-effectively integrated into products. Lower development costs help vendors balance profitability with M2M's price sensitivity, while rapid integration reduces both time-to-market and time-to-revenue.

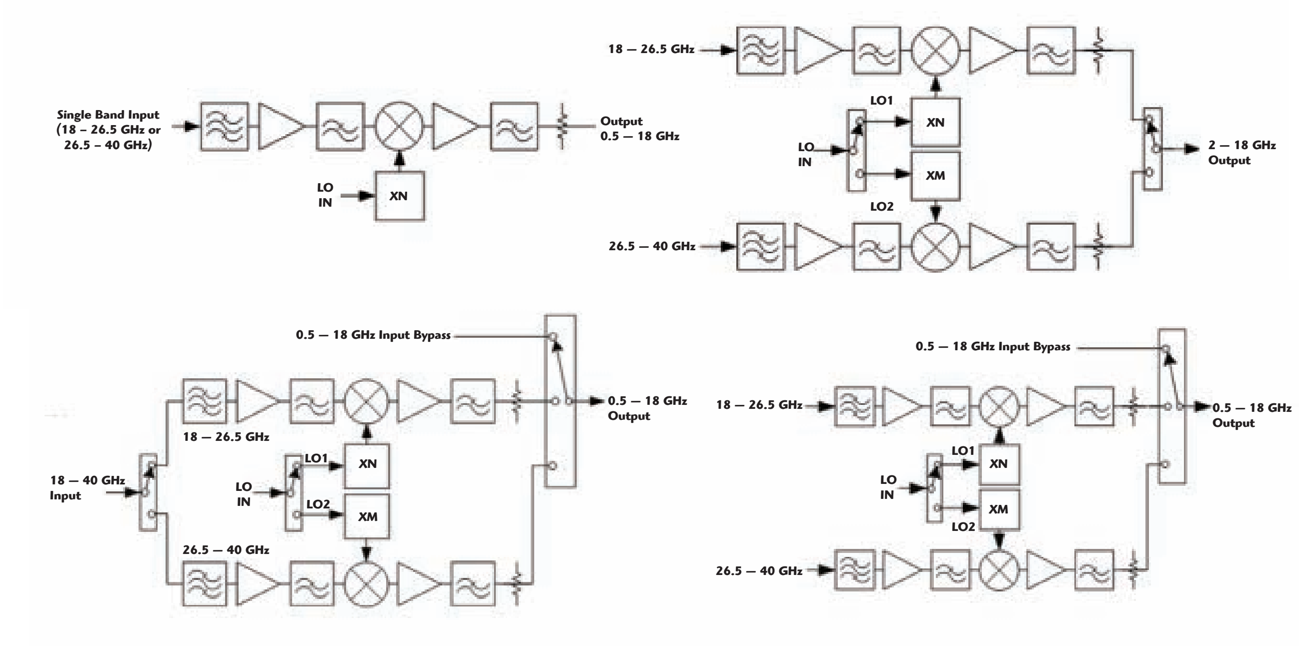
The M2M opportunity is growing quickly, but it's also getting more challenging. EtherModule 1.0 gives M2M device vendors an opportunity to overcome those challenges while quickly and cost-effectively creating products with market-differentiating features. It's also the ideal foundation for applications that require high performance and mission-critical reliability.

Ethertronics,
San Diego, CA (858) 550-3820,
usasales@ethertronics.com,
www.ethertronics.com.

18 to 40 GHz Downconverter Family

Norden Millimeter has developed a variety of 18 to 40 GHz downconverters for use in electronic intelligence (ELINT), intelligence, surveillance, and reconnaissance (ISR) and electronic warfare (EW) applications. These converters have been designed to cover any variation of frequency bands between 18 and 40 GHz. Some of the converters include an integrated 0.5 to 18 GHz bypass path for combing the 18 to 26.5 GHz and 26.5 to 40 GHz band into a single 0.5 to 18 GHz output. If required, a local oscillator can be added to the converter.

Norden Millimeter Inc., Placerville, CA (530) 642-9123, sales@nordengroup.com, www.nordengroup.com.



Attenuator Family Goes Green

SPINNER has developed the Green Line series of symmetrical attenuators in the medium output range of 25 to 200 W. At the heart of this new development is an aluminium nitride (AlN) ceramic material that is used as the medium substrate. Compared to other ceramics with similar properties, this ceramic is environmentally friendly to manufacture, process and with regards to waste disposal.

Another 'saving' feature of this new development is the use of identical parts across the series, which guarantees quick availability over all power ratings and attenuation classes. The ceramics coated with the different attenuation values are installed into just one base body. The appropriate heat sinks are applied depending on power rating, although the 25 W models do not require a heat sink. The available standard connectors are N male/female and 7-16 male/female.

The attenuators are available in 25, 50, 100 and 200 W power ratings and are supplied with the attenuation values 3, 6, 10, 20, 30 and 40 dB. The whole mobile communication range has been covered thanks to the broadband development of DC to 4 GHz, optionally to 6 GHz. This means the attenuators can be used universally in many high frequency systems.

From a manufacturing standpoint, a Kanban system is used for assembly, which enables the quick and constant ability to supply even with fluctuating throughput. Also, the slim and compact structure of the attenuators enables them to be installed into the tightest of spaces, while the modular design approach means that a large variety of types can be offered, in conjunction with fast delivery capabilities.

SPINNER GmbH,
Munich, Germany
Tel (Europe): +49 89 12601-0,
Tel (USA): +1(770) 263-6326,
Email: info@spinner-group.com,
www.spinner-group.com.

High Performance Ceramic Filters

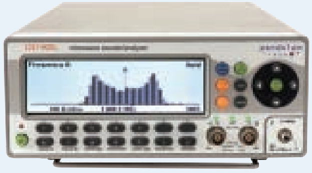
Ceramic filter technology now offers advantages over other filter technologies, and can even replace some cavity filter designs. Integrated Microwave Corp.'s (IMC) ceramic filters offer improved frequency coverage, higher Q, higher power handling capabilities, more poles, more package options and lower cost than many alternative filter technologies. IMC ceramic filters have higher Q values, greater than 1600 at some frequencies, with frequency coverage from 200 MHz to 10 GHz and bandwidths of 0.3 to 100 percent. Powers levels of >100 W CW and >2 KW peak are possible in some frequency ranges and configurations. IMC ceramics exhibit less AM/FM microphonics than lumped-element filters in every axis, at every vibration frequency and amplitude.

IMC ceramic filter technology produces up to 11 pole filters at full production rates and 13 pole filters are possible. NRE is now typically $500 or less for an eight-pole bandpass filter design due to better simulation software combined with expert databases.

IMC manufactures RF and microwave filters for many Space programs and applications (orbital, deep space and planetary missions). IMC is proud to have ceramic diplexers on the surface of Mars (in all three rovers and the Phoenix Lander), onboard the Mars Orbiter and supporting the International Space Station. They offer ceramic filters, diplexers and triplexers that are multipaction-resistant and ready for deployment in high-reliability applications.

Integrated Microwave Corp.,
San Diego, CA
(858) 259-2600,
sales@imcsd.com,
www.imcsd.com.

Tech Brief



High-Speed Pulsed Measurements for Radar

Modern radars are multi-functional and multi-mode; using active antennas allowing "instantaneous" beam pointing and interlacing different modes, like the track-while-scan mode of airborne radars. Such radars use fast switching of different pulse patterns. Classical techniques for distance ambiguity solving use staggered PRF techniques. Frequency diversity increases the range. Pulse compression, which employs an intra-pulse frequency modulation (chirp), is another known technique to increase the distance resolution.

Independent of design and complexity, all radar systems rely on processing raw data from the basic radar pulse. Testing the basic "analog" radar pulse performance involves the following pulse parameter measurements:

- Timing: Pulse repetition interval or pulse repetition frequency, pulse width
- Frequency: Frequency in pulse, frequency modulation in pulse
- Power: Power in pulse

Full testing of these waveform parameters at the development/qualification stage generally required sophisticated and expensive test instruments, like real-time spectrum analyzers and high-bandwidth oscilloscopes. Now, the cost-effective Pendulum CNT-90XL Microwave Counter/Analyzer can do the job, due to ultrafast measurements (250,000 samples/s). It measures fast changes in PRI/PRF and pulse-width in radar pulses down to 30 ns width. It further measures frequency in pulses down to 100 ns and power in pulse down to 20 us. The CNT-90XL can also provide the intra-pulse frequency profile. It is possible to measure frequency in each 20 ns slice of the pulse.

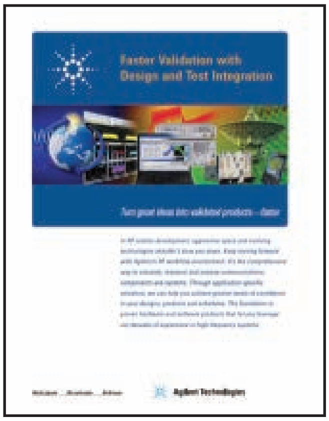
The CNT-90XL is available in four frequency input ranges (27/40/46/60 GHz). A battery option allows mains free operation for field applications. The software TimeView™ provides enhanced Modulation Domain Analysis. Another key feature is the graphic display of measured parameters. With the introduction of Pendulum CNT-90XL Pulsed RF, Spectracom brings an affordable instrument (<$10,000) to the radar community, allowing high speed pulse measurement of all time/frequency parameters, supporting modern radars where pulse patterns change rapidly.

Spectracom,
Rochester, NY (585) 321-5800,
www.spectracomcorp.com.

Catalog Update

Design and Test Integration Brochure

VENDORVIEW



Agilent's new design and test brochure describes how you can turn great ideas into validated products – faster. Agilent's RF workflow environment is the comprehensive way to simulate, measure and analyze communications components and systems. The brochure shows how enabling fast and effective RF/microwave communication systems and component development demands a workflow with better integration between design and test to help teams reduce development cycle time, achieve higher performance and attain earlier system validation.

Agilent Technologies Inc.,
www.agilent.com.

RF and Microwave Instruments Catalog

VENDORVIEW

Anritsu offers an RF and microwave instruments catalog which provides an overview of its RF and microwave testing solutions for spectrum analysis, vector network analysis, base station analysis, cable and antenna analysis, power measurements, signal analyzers and signal generators. The catalog is available for free download at www.anritsu.com.

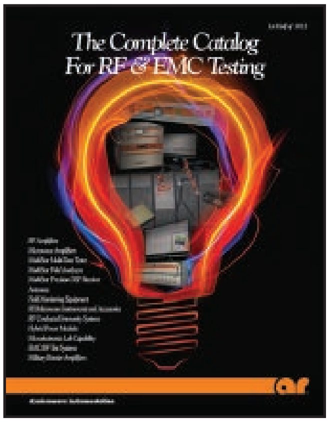
Anritsu,
www.anritsu.com.

EMC & RF Testing Catalog

VENDORVIEW

AR's new product catalog is now available from the company's local AR sales associate. The catalog is easy to use, with "find-it-fast" charts and color coding to help get right to whatever you need for RF and EMC testing. It is available for free download, either in full or by section on AR's website.

AR RF/Microwave Instrumentation,
www.arworld.us.



Components Catalog

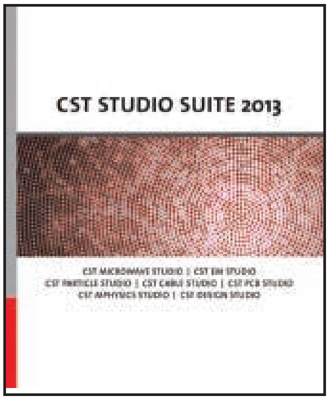
VENDORVIEW

AtlanTecRF has published its new components catalog, accessible from its website and in paper format. Packed with over 600 product lines, many available from stock, it is the biggest edition to date. The online version has a search facility to make it easy to navigate through the comprehensive portfolio of oscillators, active, passive and control components. It is also possible to search by keyword or phrase and zoom in to view drawings, specifications or model tables in greater detail.

AtlanTecRF,
www.atlantecrf.com.

CST STUDIO SUITE 2013 Brochure

VENDORVIEW



The newest version of CST's 3D EM simulation software, CST STUDIO SUITE® 2013, has been released. The latest brochure accompanies the release and describes the new design environment and latest usability and performance improvements. The software's wide applicability is shown through illustrated examples, and for each product, its simulation performance and its contribution to workflow integration, the integrated design environment, and the complete technology interface are described. The brochure is accessible online now: www.cst.com/Content/Products/Brochures.aspx.

Computer Simulation Technology AG,
www.cst.com.

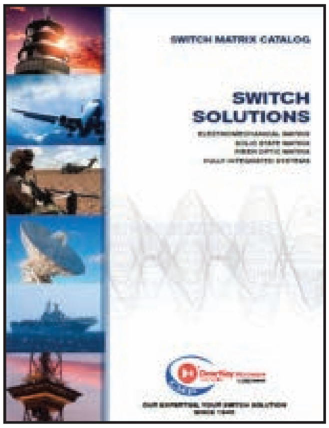
SSPA Brochure

CTT announces a new family of compact, GaN-based solid-state power amplifiers (SSPA) operating in the 6.4 to 11 GHz frequency range for a wide variety of RF and microwave applications including commercial, industrial and military radar applications. CTT's latest SSPA designs offer as much as 160 W of output power in a compact package. They include 15 models for narrowband applications operating from 7.8 to 10.7 GHz in continuous wave (CW) mode.

CTT Inc.,
www.cttinc.com.

Switch Matrix Product Catalog

VENDORVIEW



Dow-Key Microwave's matrix catalog features the next generation platform with brand new electromechanical switch designs, along with updated solid state and fiber optic matrices. Dow-Key has vast experience in designing and manufacturing matrix solutions with excellent performance and reliability. Dow-Key is an expert in custom designs – from small 1RU design to fully integrated 19" rack solutions – and offers a broad range of commercial off-the-shelf (COTS) matrices to meet all types of switching requirements.

Dow-Key Microwave,
www.dowkey.com.

"At a Glance" Brochures

VENDORVIEW

Empower RF Systems has improved on the traditional, published catalog concept and is pleased to offer instead a series of continuously updated and downloadable "At a Glance" brochures which detail (in separate editions) an overview of the company, recommended products for each of its four key markets and new product introductions as they occur. Organized and consistent in presentation of key information, the "At a Glance" materials are especially useful for engineers, buyers and sales reps.

Empower RF Systems,
www.empowerrf.com.

Product Selector Guide

Freescale is the global leader in RF transistors for power amplifiers, a trusted source of RF solutions for more than 30 years. Freescale offers RF solutions for most communication and industrial applications serving wireless infrastructure, broadcast, aerospace, land mobile communication and industrial, scientific and medical (ISM) markets. With products ranging from less than 100 mW to 1.25 kW using GaAs and LDMOS technologies, Freescale offers the broadest portfolio of RF power transistors. Download the Freescale RF Product Selector Guide at www.freescale.com/RFSelectorGuide.

Freescale Semiconductor,
www.freescale.com.

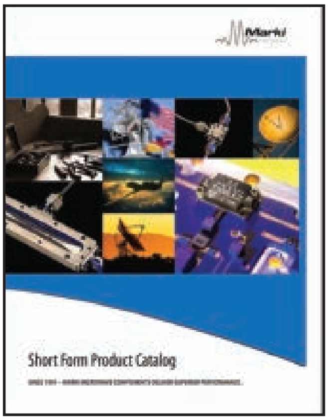
Wireless & RF Solutions

VENDORVIEW

Linear offers high performance RF and signal chain solutions for wireless and cellular infrastructure, supporting LTE, LTE-Advanced, GSM, W-CDMA, TD-SCDMA, CDMA, CDMA2000 and WiMAX. Applications include broadband microwave data links, secure communications, satellite receivers, broadband wireless access, wireless broadcast systems, cable infrastructure and wireless sensor networks. Linear's products include high linearity active mixers, direct conversion I/Q demodulators, low distortion IF amplifiers/ADC drivers, variable gain amplifiers, integrated RF-to-digital receivers, high speed ADCs, RF detectors, active filters and wireless sensor network products.

Linear Technology,
www.linear.com.

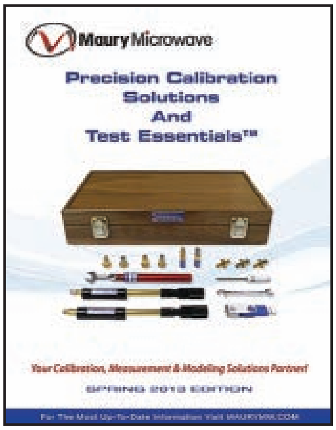
Short Form Product Catalog



Marki Microwave's goal is to invent technologies to empower the RF and microwave industry to design faster, simplify production, eliminate complexity and shatter performance barriers. Its product portfolio of high performance components includes broadband, low conversion loss and highly linear mixers, high directivity, low return loss couplers and directional bridges, well balanced power dividers and hybrid couplers and many other quality products. The company offers short lead times, extensive design support, and superior custom components when required.

Marki Microwave,
www.markimicrowave.com.

Precision Calibration Solutions Catalog

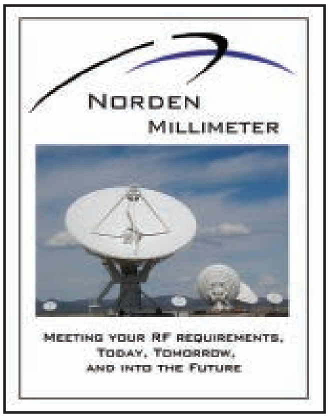


The spring 2013 edition of Maury Microwave's Calibration Solutions Catalog is now available. The catalog covers precision VNA calibration kits, cal standards and components, connector gages & kits, metrology-grade adapters, TestEssentials™ lab adapters, ColorConnect™ precision adapters, Stability™ RF/microwave cable assemblies, thermal and cryogenic noise calibration systems and components, and more.

Maury Microwave,
www.maurymw.com.

Catalog Update

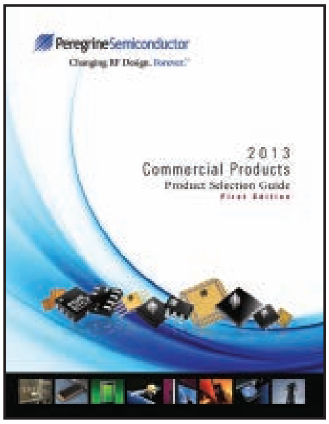
Company Catalog



Norden Millimeter designs and manufactures microwave and millimeter wave active components operating from 500 MHz to 110 GHz. Norden specializes in producing components to customer's exact specifications. The company produces amplifiers, frequency multipliers, frequency converters, VCOs, DROs, RF switches, switched filters, transceivers and integrated assemblies. Its products are developed for use in commercial, military and scientific systems for applications such as test equipment, ELINT and EW systems, radar and radio astronomy just to name a few.

Norden Millimeter,
www.nordengroup.com.

Commercial Product Selection Guide



Peregrine's product selection guide includes information and key specifications on its high-performance RFICs, including switches, digital attenuators, mixers/upconverters, prescalers, frequency synthesizers and DTCs. These solutions leverage Peregrine's proprietary UltraCMOS® technology, which enables the design, manufacture and integration of multiple RF, mixed-signal and digital functions on a single chip and target a broad range of applications in the broadband, industrial, mobile wireless device, test and measurement equipment, and wireless infrastructure markets. Download the catalog at www.psemi.com/pdf/sell_sheet-psg/PSG2013_73-0009-17web.pdf.

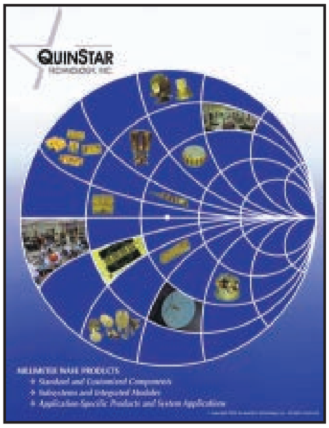
Peregrine Semiconductor,
www.psemi.com.

Microwave Capabilities Brochure

Phase Matrix's new 16-page microwave capabilities brochure highlights the company's technical pedigree and its well-established design and production expertise in custom RF and microwave components and integrated microwave assemblies. The brochure showcases oscillator, converter, and transceiver assemblies with high-resolution images of complex, multi-function circuits. Copies of the brochure are available from Phase Matrix sales representatives or on the company's website.

Phase Matrix,
www.phasematrix.com.

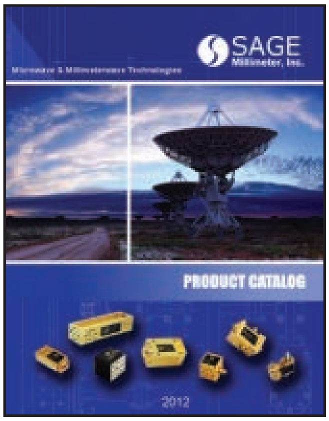
Product Catalog



QuinStar Technology's product catalog features a wide range of millimeter-wave product solutions for digital and analog sensors, communications and test applications. The catalog provides a comprehensive overview of the products characteristics, description, specifications and ordering information. QuinStar Technology is dedicated to providing the best service in the industry. The catalog is available in full for free download online or from your local QuinStar representative.

QuinStar Technology Inc.,
www.quinstar.com.

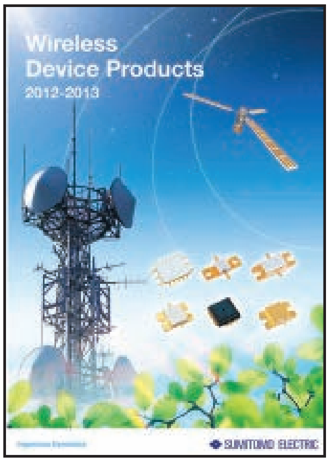
Solutions Catalog



SAGE Millimeter's 110-page catalog features complete microwave and millimeter-wave solutions that include antennas, amplifiers, frequency converters, control devices, ferrite devices, oscillators, waveguides and sub-assemblies in the frequency range of 18 to 140 GHz. The products offered are organized into 10 product families based on their functionalities. Many application notes are included in the catalog for reference. The catalog is offered both electronically or in print. Physical copies can be requested from the company via email at info@sagemillimeter.com free of charge.

SAGE Millimeter,
www.sagemillimeter.com.

Wireless Device Products



GaAs and GaN products from Sumitomo Electric Device Innovations (SEDI) provide total RF solutions with complete line-ups for cellular basestation, WiMAX, SATCOM, digital radio, VSAT, DBS, FWA and mobile terminals. GaAs products include low noise HEMTs, power FETs, LNA MMICs and power MMICs. GaN HEMTs include L-Band, S-Band, C-Band and X-Band GaN. GaN features high impedance for easy matching, high breakdown voltage, and compatibility with wideband DPD systems. Both GaAs and GaN devices have been qualified for space vehicle applications.

Sumitomo Electric Device Innovations,
www.sei-device.com.

New Waves: Amplifiers and Oscillators

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE

FEATURING VENDORVIEW STOREFRONTS

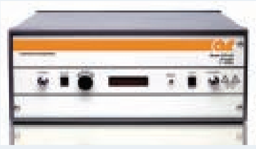
TWT Amplifier

The state-of-the-art model 277 TWT amplifier is dual mode, grid pulsed and CW and provides 150 W at pulse widths from 0.05 µseconds to CW. The model 277K frequency range is 18 to 26.5 GHz. The Model 277Ka frequency range is 26.5 to 40 GHz. The RF output pulse width tracks the input 5 V video pulse. All power supplies are regulated, phase shifted resonant mode DC to DC converter designs operating at 50 KHz. The TWT power supplies feature full load efficiency greater than 90 percent.

Applied System Engineering Inc.,
www.applsys.com.

Single Band Amplifiers

VENDORVIEW



Models 15S1G6 and 50S1G6 are single band amplifiers that cover the 1 to 6 GHz frequency band. Solid-state, 1 to 6 GHz amplifiers are not unusual, but they all require dual bands (two separate amplifiers) to provide high output power and good gain flatness to provide one with a useable instrument. That is, until AR RF/Microwave Instrumentation created these single band models. They provide 15 and 50 W of linear output power with excellent gain flatness.

AR RF/Microwave Instrumentation,
www.arworld.us.

DOCXO

RFMW provides design and sales support for a new double oven crystal controlled oscillator from Bliley Technologies. The N6B series stability is rated at ±0.4 ppb over an operating temperature range of -20° to +70°C. Two variations of the N6B series, the N6B-ABA-D1A-10M and N6B-ABA-D1B-10M, provide a sine wave output of +5 dBm (typical) into 50 Ω. Bliley's N6B series DOCXOs operate from a +5 V DC supply with or without electronic frequency control and offer aging performance per year of less than ±0.1 ppm.

Bliley Technologies Inc.,
Distributed by RFMW Ltd.,
www.bliley.com.

Solid-State RF Amplifier

COMTECH PST introduces its latest rack mounted wideband high power solid-state RF amplifier. Comtech has integrated its proven RF GaN PA module designs into a single 19" rack. The company consistently evaluates its amplifier performance at rated power over the

temperature range into a 2:1 VSWR load. Its latest standard model features an internal AC power supply, full Ethernet interface/GUI control, front panel digital display for forward and reverse power, temperature, current, and separate fault LEDs.

COMTECH PST,
www.comtechpst.com.

CRO

Crystek's new CVCO55CXT-5580-5685 CRO is a coaxial-based VCO with an internal proprietary frequency doubler. It operates from 5580 to 5685 MHz with a tuning voltage range of 0.3 to 4.7 V DC. This coaxial VCO features a typical phase noise of -102 dBc/Hz at 10 KHz offset and has good linearity. The CVCO55CXT-5580-5685 CRO exhibits an output power of 0.0 dBm typ. into a 50 Ω load with a supply of +5 V DC and a current consumption of 30 mA (maximum).

Crystek Corp.,
www.crystek.com.

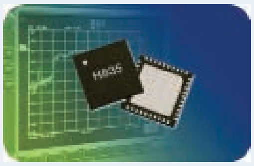
OCXO

CTS announced development of its model 148 oven controlled crystal oscillator, which uses the unique SC cut crystal technology to significantly reduce power consumption (0.23 W at +25°C) and allows for additional board space with its miniature-sized package. The ideal applications for this oscillator include airborne and ground mobile, wireless communications, broadband access, test and measurement, WLAN/WiMAX/WiFi and portable equipment and applications. Its strong mechanical construction enables durability of up to 500G of mechanical shock.

CTS Electronic Components Inc.,
www.ctscorp.com.

PLL with VCO

VENDORVIEW



Hittite has launched the HMC835LP6GE, a wideband fractional-N PLL with integrated VCO that generates continuous fractional frequencies between 33 and 4100 MHz. Targeted at the cellular infrastructure market, the HMC835LP6GE features industry leading PLL and VCO phase noise performance with a PLL figure of merit of -230 dBc/Hz in integer mode and -227 dBc/Hz in fractional mode, and typical VCO phase noise of -134 dBc/Hz at 4 GHz output frequency and 1 MHz offset.

Hittite Microwave Corp.,
www.hittite.com.

Wideband Amplifier

VENDORVIEW

GVA-60+ (RoHS compliant) is a wideband amplifier fabricated using HBT technology and offers ultra flat gain over a broad frequency range and with high IP3. In addition, the GVA-60+ has good input and output return loss over a broad frequency range without the need for external matching components and has demonstrated excellent reliability. Its lead finish is SnAgNi. It has repeatable performance from lot to lot and is enclosed in a SOT-89 package for very good thermal performance.

Mini-Circuits,
www.minicircuits.com.

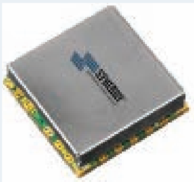
DRO

VENDORVIEW

PMI model PIA-12D8G-CD-1 is a phase locked, dielectric resonator oscillator with internal reference having an output frequency of 12.8 GHz. This model provides a minimum output of +13 dBm with all spurs held to -80 dBc and harmonics held to -25 dBc. The frequency stability is ±3 ppm with an internal reference of 100 MHz. The phase noise is as follows: -34 dBc/Hz at 1 Hz, -65 dBc/Hz at 10 Hz, -85 dBc at 100 Hz, -108 dBc/Hz at 1 kHz, -115 dBc/Hz at 10 kHz, -120 dBc/Hz at 100 kHz, and -140 dBc/Hz at 1 MHz offsets.

Planar Monolithics Industries,
www.pmi-rf.com.

Miniature Footprint Synthesizer



This miniature intelligent interactive synthesizer operates over an octave bandwidth of 1000 to 2000 MHz with a 500 kHz step size in a 0.6" × 0.6" × 0.175" RoHS size surface mount package. The features include an onboard microcontroller for simplified communication, +3 dBm minimum output power and excellent phase noise performance (-90 and -106 dBc/Hz typical at 10 kHz and 100 kHz offsets) with an external 10 MHz reference applied over an operating temperature range of -40° to +85°C.

Synergy Microwave Corp.,
www.synergymwave.com.

New Products

Components

Hybrid Coupler

VENDORVIEW

Richardson RFPD Inc. announces immediate availability and full design support capabilities of a new Xinger® III 3 dB hybrid coupler from Anaren. The X3C17A1-03WS-CT is ideally-suited for broadband transmit and receive systems where wide bandwidth, low insertion loss and high isolation is required, including wireless applications like LTE, GSM, CDMA, DCS, PCS, UMTS, WiMAX and WiFi. The device may be used in applications with up to 50 W of average power. It is in stock and available for immediate delivery.

Anaren,
Distributed by Richardson RFPD Inc.,
www.anaren.com.

Ka-Band Isolator

DiTom Microwave has released D3I2731-2, a new Ka-Band isolator 27 to 31 GHz. This isolator covers both the military and commercial Ka-Band applications and is available with 2.92mm female or male connector configurations. The company can improve these electrical specs for high reliability use and narrow the band if necessary. This isolator can be manufactured for thermal vacuum or ambient environments with optional finishes available for humidity, corrosion, EMI/RF leakage and magnetic shielding.

DiTom Microwave,
www.ditom.com.

Directional Couplers

KRYTAR Inc. announced the continued expansion of its line of directional couplers with the addition of two new models offering high performance over the ultra-broadband frequency range of 2 to 40 GHz, each in a single, compact and lightweight package. KRYTAR's model 102040020 and model 102040020K are multipurpose, stripline designs that exhibit excellent coupling over the 2 to 40 GHz frequency band. The compact size (1.75" × 0.40" × 0.65") makes these directional couplers ideal solutions in many space-restricted applications.

KRYTAR Inc.,
www.krytar.com.

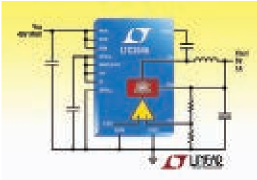
Ultra-Thin Filters

Lark offers a full line of ultra-thin filters for commercial and military markets. Lark's new ultra-thin package offers superior performance in less than 0.09" high package with low insertion loss and ultimate rejection levels of 60 dB while maintaining better than 1.5:1 VSWR. Units are lightweight and ruggedized for today's air, sea and land applications.

Lark Engineering Co.,
www.larkengineering.com.

Buck Converter

VENDORVIEW

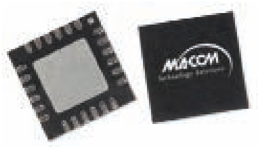


Linear Technology announced the LTC3646, a 40 V input capable synchronous buck converter that can deliver up to 1A of continuous output current from a 3 × 4 mm DFN-14 (or thermally enhanced MSOP16) package. It operates from an input voltage range of 4 to 40 V. It utilizes a unique controlled on-time architecture that can step inputs as high as 36 down to 3.3 V with switching frequencies in excess of 2 MHz, keeping switching noise out of critical frequency bands.

Linear Technology Corp.,
www.linear.com.

Phase Shifter

M/A-COM Tech introduced a new digital phase shifter for C-Band radar applications that facilitates easy implementation in communication antennas, phased array radars and weather radars. The MAPS-011008 is housed in a 4 mm 24-lead PQFN package. It provides 360° phase shift range with a step size of 5.6°. It is controlled with a single +5 V serial or parallel control line. Its insertion loss is 4 dB, with a low ±0.5 dB attenuation variation, and ±3° phase accuracy over the 5 to 6 GHz frequency range.



M/A-COM Technology Solutions Inc.,
www.macomtech.com.

Baluns

Responding to a flood of customer demand, Marki is proud to offer surface mount baluns from 500 kHz to 6 GHz in a package that is just 0.320" square. The design of the BAL-0003SM and BAL-0006SM are significantly different from their connectorized versions. Nonetheless excellent phase match of ±3° and amplitude balance of ±0.4 dB is typical. These baluns are an excellent choice for use with differential chips such as ADCs, DACs, amplifiers and many other applications.

Marki Microwave Inc.,
www.markimicrowave.com.

Low PIM Terminations

VENDORVIEW

MECA Electronics is pleased to announce its Low PIM Loads/Terminations with industry leading -170 dBc (typical) passive intermodulation from 698 to 2700 MHz. Ideal for IDAS, ODAS and in-building, base station applications. Available in 20, 50, and 100 W versions. All models feature 7/16 DIN male and female

New Products

or Type N male and female connectors. VSWR 1.10:1 (typical). Made in USA – 36 month warranty.
Microwave Electronics Corp. of America,
www.e-meca.com.

Microstrip Isolator on Carrier

VENDORVIEW

Renaissance has designed a Ka-Band microstrip isolator that can handle 2 W forward and reverse for SATCOM applications. It has a compact 5 × 6 mm case. It provides low insertion loss in the forward direction and high isolation in the reverse.
Renaissance Electronics/HXI,
www.rec-usa.com.

1P12T Relay

RelComm Technologies Inc. offers a low cost high performance 1P12T relay configured with SMA type connectors, providing exceptional RF performance to 18 GHz. The relay measures 2.25" square and is less than 2" tall. It is fitted with standard DA15P header for ease of installation. The relay is available in both latching and failsafe configurations with 12 and 24 V DC operation. Options include TTL control input.

RelComm Technologies Inc.,
www.relcommtech.com.

Broadband DC Block

Response Microwave announced its new broadband DC Block for use in automated test and production applications. The new RMDC.26500SMA27mf covers the 5 to 26.5 GHz band offering typical electrical performance of 0.8 dB insertion loss and 1.25:1 VSWR. Working voltage is 50 V and the unit is operational over the -55° to +85°C range. Mechanical package is 1.18" × 0.354" in diameter. Unit is made from SUS303F passivated stainless steel and connectors are super SMA male to female.
Response Microwave Inc.,
www.responsemicrowave.com.

WiFi Module

VENDORVIEW

RFMD introduced the highly-integrated RFFM4501E front end module (FEM) for 802.11ac notebook and mobile equipment applications. RFMD's newest WiFi FEM meets or exceeds the system requirements for 802.11ac connectivity in the 5.15 to 5.85 GHz frequency band. The RFFM4501E integrates a +17.5 dBm (80 MHz MCS9) PA at 3.3 V, a low insertion loss/high isolation single pole two throw (SP2T) switch, harmonic filtering, and a low noise amplifier with bypass mode for equipment manufacturers seeking to adjust receive sensitivity.
RF Micro Devices Inc.,
www.rfmd.com.

Switched Bit Attenuator

S2D Microwave Inc.'s S3-AS6055R520 is a broadband, high performance RF/microwave switched bit attenuator. This high performance compact unit offers low insertion loss, fast switching speed, low harmonic distortion, and three-bit attenuation control that has TTL driver.

S2D Microwave Inc.,
www.s2dmicrowave.com.

Sensor Module

SAGE Millimeter's model SSP-24303-42-D1 is a low cost, production ready K-Band FMCW ranging and directional sensor module. The center frequency of the module is set at 24.125 GHz with ±150 MHz frequency modulation bandwidth and +3 dBm nominal output power. The sensor operates from a single +5 V DC power supplier and typically draws 250 mA current and requires 0 to +15 V voltage swing for electrical tuning. The sensor incorporates an I/Q mixer to provide target moving direction information.
SAGE Millimeter Inc.,
www.sagemillimeter.com.

Backlight LED Drivers

VENDORVIEW

Skyworks Solutions Inc. introduced several new backlight LED drivers supporting next-generation smartphones and tablets. Skyworks' family of highly efficient, integrated, multi-channel products are tailored to support display panels ranging in size from 4 to 12 inches, significantly enhancing image quality and resolution while maximizing battery life. The multi-channel architecture and highly efficient, DC/DC boost-technology enable LED backlight driver efficiencies exceeding 90 percent and facilitate superior dimming performance.

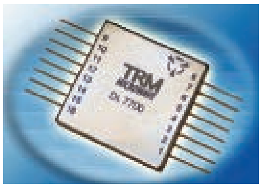
Skyworks Solutions Inc.,
www.skyworksinc.com.

COTS RF Adapters

Trilithic Inc. has released a new series of COTS RF adapters, available in a wide selection of connector types and configurations. In-series and between series adapters are available in DC to 18 GHz frequency range with passivated stainless steel body material and gold plated beryllium copper contacts. Most connector types can be accommodated to

fulfill your specific requirements. All adapters are RoHS compliant.
Trilithic Inc., http://rfmicrowave.trilithic.com.

Power Divider



The DL7700 is a space qualified, low-profile seven-way power divider that spans a 25 percent bandwidth of 620 to 820 MHz. It uses a combination of ferrite and microstrip technologies in a hermetically sealed flatpack. The maximum amplitude balance is ±0.5 dB while the phase balance between output ports is ±5°; with a total insertion loss of 2.3 dB. The maximum input and output VSWR is 1.5:1. The output isolation is 16 dB minimum. The DL7700 measures 1" × 1" × 0.170".
TRM Microwave, www.trmmicrowave.com.

Test Equipment

Directional Antenna

Narda Safety Test Solutions introduced a new loop antenna for the interference and direction analyzer IDA-3106 that covers a frequency range from 9 kHz up to 30 MHz. Its typical antenna factor of 47.5 dB (1/m) at 1 MHz gives it unusually high sensitivity. This makes it particularly suitable for such tasks as tracing defective or poorly screened switched mode power supplies or electrical controls that generate interference fields or identifying interference due to data transmissions made using the power line carrier technique.

Narda Safety Test Solutions GmbH, www.narda-ida.com.

Mixed-Signal Oscilloscope

VENDORVIEW

Agilent announced the expansion of its Infiniium 90000 X-Series oscilloscope family to include the world's highest performance MSO. The expansion adds six new MSO models, as well as 13 GHz DSO and DSA models, to the X-Series. The tightly integrated digital channels of the new MSO models can function at 20 GSa/s in an eight-channel configuration, 60 percent faster than other high-performance MSOs, or at 10 GSa/s in a 16-channel configuration. Agilent now offers MSOs ranging from 70 MHz to 33 GHz of analog bandwidth.
Agilent Technologies Inc., www.agilent.com.

Signal Generators

Berkeley Nucleonics released a full line of RF/microwave signal generators. It is capable of producing in excess of 20 GHz, with very low phase noise, fast switching speeds and extensive modulation capabilities in a variety of packaging options, including benchtop, portable battery operation, 1U 19" rackmount, and card-level for OEM integration. These instruments offer the widest array of options to meet almost any application requirement.
Berkeley Nucleonics Corp., www.berkeleynucleonics.com.

Oscilloscopes

VENDORVIEW

The R&S RTO and R&S RTM oscilloscopes analyze power supply units. The front ends of both instruments have features offering clear advantages over other solutions. Their high dynamic range allows for precise characterization of the power on operations of an embedded system. Rohde & Schwarz offers high end voltage and current probes and now also the new R&S RT-ZF20 deskew fixture for power measurements. The deskew fixture makes it easy to measure delay differences, which can then be corrected in the oscilloscope.
Rohde & Schwarz, www.rohde-schwarz.com.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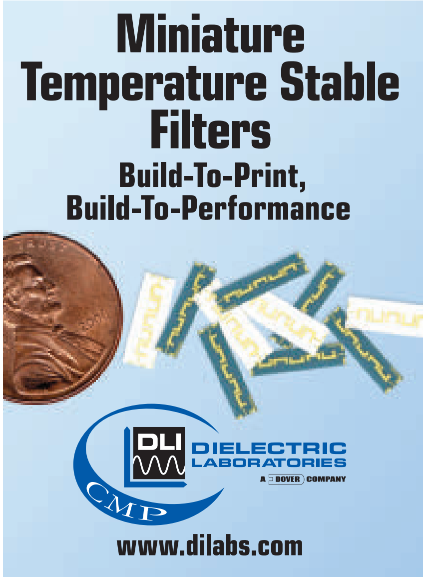
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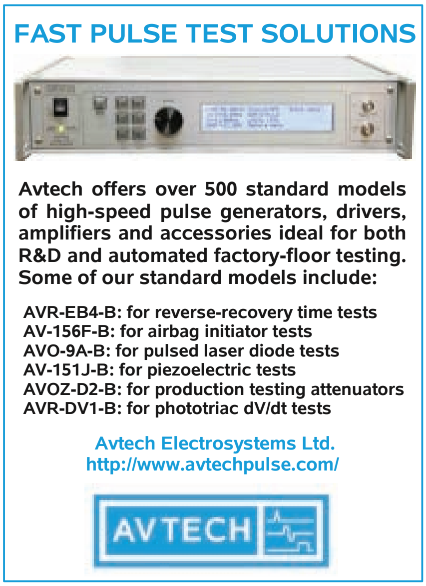
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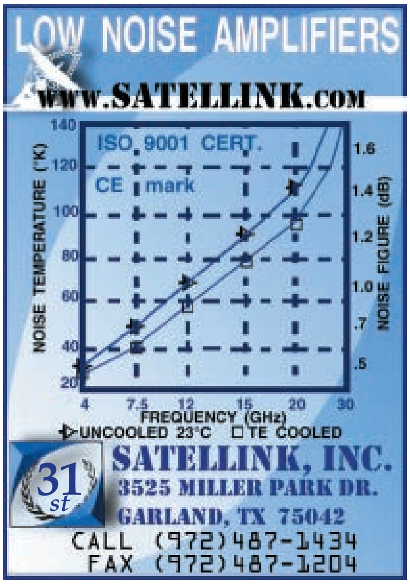
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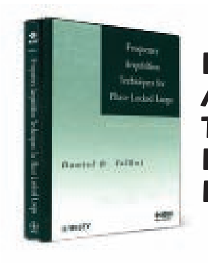

Frequency Acquisition Techniques for Phase Locked Loops

Daniel B. Talbot

A phase locked loop (PLL) by itself cannot become useful until it has acquired the applied signal's frequency. Often, a PLL will never reach frequency acquisition (capture) without explicit assistive circuits. However, few books on PLLs treat the topic of frequency acquisition in any depth or detail. *Frequency Acquisition Techniques for Phase Locked Loops* addresses this information gap with an easy to understand approach.

The author introduces readers to the basics and delivers useful information with minimal mathematics. With most of the approaches having been developed through years of experience, this guide explores methods for achieving the locked state in a variety of conditions as it examines:

- Performance limitations of phase/frequency detector-based phase locked loops
- The quadricorrelator method for both continuous and sampled modes
- Sawtooth ramp-and-sample phase detector and how its waveform contains frequency error information that can be extracted
- The benefits of a self-sweeping, self-extinguishing topology
- Sweep methods using quadrature mixer-based lock detection
- The use of digital implementations versus analog

Frequency Acquisition Techniques for Phase Locked Loops is a good resource for RF/microwave engineers – in particular, circuit designers; practicing electronics engineers involved in frequency synthesis, phase locked loops, carrier or clock recovery loops, radio-frequency integrated circuit design, and aerospace electronics; and managers wanting to understand the technology of phase locked loops and frequency acquisition assistance techniques or jitter attenuating loops.

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The conference will take place on October 21-23, 2013 in Tel Aviv, Israel.
The David Intercontinental Hotel on the Mediterranean Sea offers an excellent venue for networking and the candid exchange of ideas.

Papers are solicited in a wide range of topics including:

- Aeronautical and space applications and challenges
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- RF power amplifiers and devices
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Regular oral presentations will be 20 min. in length; there will also be Poster sessions.
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See author instructions at www.comcas.org

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• ZHL-50W-52	50-500	50	40	63	1395	1320
• ZHL-100W-52	50-500	50	63	79	1995	1920
LZY-1+	20-512	43	37	50	1995	1895
• ZHL-20W-13+	20-1000	50	13	20	1395	1320
• ZHL-20W-13SW+	20-1000	50	13	20	1445	1370
LZY-2+	500-1000	46	32	38	1995	1895
NEW ZHL-100W-13+	800-1000	50	79	100	2195	2095
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ZHL-10W-2G	800-2000	43	10	13	1295	1220
ZHL-30W-252+	700-2500	50	25	40	2995	2920
ZHL-30W-262+	2300-2550	50	20	32	1995	1920
ZHL-16W-43+	1800-4000	45	13	16	1595	1545
ZVE-3W-83+	2000-8000	36	2	3	1295	1220
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Listed performance data typical, see minicircuits.com for more details.

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