

OCTOBER 2000 VOL. 43, NO. 10



COMMUNICATIONS AND PCNs

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Spectrum —
Avoiding the FCC

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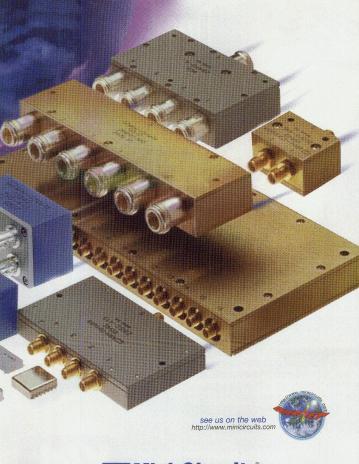
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ADE-4 ADE-14 ADE-901 ADE-5 ADE-13 ADE-20 ADE-18	2022020	200-1000 800-1000 800-1000 5-1500 60-1600 1500-2000 1700-2500	+7 +7 +7 +7 +7 +7 +7	6.8 7.4 5.9 6.6 8.1 5.4 4.9	53** 32 32 40 40 31 27	15 17 13 15 11 14 10	4.25 3.25 2.95 3.45 3.10 4.95 3.45
ADE-3GL ADE-3G ADE-30 ADE-30 ADE-35 ADE-18W	20000000	2100-2600 2300-2700 1500-2800 200-3000 2500-3200 1600-3500 1760-3500	+7 +7 +7 +7 +7 +7 +7	6.0 5.6 5.1 4.5 5.4 6.3 6.4	34 35 30 35 29 25 33	17 13 8 14 15	4.95 3.45 5.95 6.95 6.95 4.95 3.95
DE-30W DE-1LH DE-1LHW DE-1MH DE-1MHW DE-12MH DE-25MH	3433433	300-4000 0.5-500 2-750 2-500 0.5-600 10-1200 5-2500	+7 +10 +10 +13 +13 +13 +13	6.8 5.0 5.3 5.2 5.2 6.3 6.9	35 55 52 50 53 45 34	12 15 15 17 17 17 22 18	8.95 2.99 4.95 5.95 6.45 6.45 6.95
NDE-35MH NDE-12MH NDE-10H NDE-12H NDE-17H NDE-20H	3343333	5-3500 8-4200 0.5-500 400-1000 500-1200 100-1700 1500-2000	+13 +13 +17 +17 +17 +17 +17	6.9 7.5 5.3 7.0 6.7 7.2 5.2	33 29 52 39 34 36 29 ard is 0.32i	18 17 23 30 26 25 24	9,95 14,95 4,95 7,95 8,95 8,95 8,95







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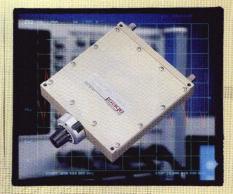
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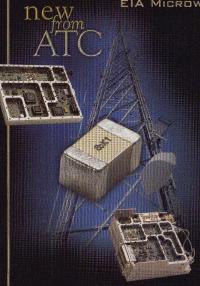
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Effective Capacitance vs Frequency

It is generally assumed that the capacitance value selected from a vendor's catalog is constant over frequency. This is essentially true for applications with applied frequencies that are well below the capacitors self-resonant frequency. However as the operating frequency approaches the capacitors selfresonant frequency, the capacitance value will appear to increase resulting in an effective capacitance (C_i) that is larger than the nominal canacitance. This article will address the details of effective capacitance as a function of the application operating frequency. In order to illustrate this phenomenon, a simplified lumped element model of a capacitor connected to a frequency source operating in a network will be considered, as depicted in Figure 1.

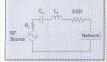


Figure 1 Lumped Element Equivalent Model

This model has been selected because the effective capacitance is largely a function of the net reactance developed between the capacitor and its parasitic series inductance (Ls). The equivalent series resistance 'ESR' shown in this illustration does not have a significant effect on the effective capacitance.

Effective Capacitance:

The nominal capacitance value (Co) is established by a measurement performed at 1MHz. In typical RF applications the applied frequency is generally much higher than the 1MHz measurement frequency, hence at these frequencies the inductive reactance (X_i) associated with the parasitic series inductance (Ls) becomes significantly large as compared to the capacitive reactance (Xd). Figure 2 illustrates that there is a disproportionale increase in X₁ as compared to X₂ with increasing frequencies. This results in an effective capacitance that is greater than the nominal capacitance. Finally at the capacitors series resonant frequency the two reactance's are equal and opposite yielding a net reactance of zero. The expression for Cr becomes undefined at this frequency.

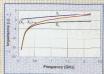


Figure 2 Net Impedance vs. Frequency

As illustrated in Figure 1, the physical capacitor can be represented as Co in series with Ls. The impedance of the series combination of Co and Ls can then be set equal to Cr, which may be referred to as an "ideal equivalent" capacitor. This will yield the following equation:

This will yield the following equation: $j(\omega L - 1/\omega C) = -j 1/\omega C$ $\omega^2 L - 1/C = -1/C$

The relationship between the operating frequenstated as

 $C_{1} = C_{1}/(1 - \omega^{2} L_{1} C_{2})$ $C_{r} = C_{r}/1 - (2\pi F)^{2} L C_{r}$ Where

C, = Effective Capacitance

- at the application frequency, (F.) C, = Nominal Capacitance at 1 MHz
- L. = Parasitic Inductance, (Ω) F. = Operating Frequency, (Hz)
- C_c vs Frequency ATC100A, 100pF (PP)

Frequency (GHz)

Figure 3 Effective capacitance (C_E) vs. frequency vs Fo

From this relationship it can be seen that as the applied frequency increases the denominator becomes smaller thereby yielding a larger effective capacitance. At the capacitors series resonant frequency the denominator goes to zero and the expression becomes undefined. The relationship of CE vs frequency is a hyperbolic function as illustrated in Figure 3.

Example:

Consider an ATC 100A series 100pF capacitor. Calculate the effective canacitance (C.) at 10MHz. 100MHz, 500MHz, 900MHz, 950MHz.

Solution: Calculate by using the relationship $C_1 = C_0/1 - (2\pi F_0)^2 L_1 C_0$. Refer to Table 1.

Operating Frequency (MHz)	Effective Capacitance (Cs), pF	Impedance, (Ω)
10	100.01	0.013 - j 159.13
100	101.01	0.023 - j 15.76
500	133.34	0.051 - j 2.38
900	526.29	0.069 - 10.337
950	1025.53	0.070 - J 0.168

Table 1

Relationship between F. C, and Z

Application Considerations:

Impedance matching and minimum drift applications such as filters and oscillators require special attention regarding C. For applications below the capacitors self-resonant frequency the net impedance will be capacitive (-i) whereas for applied frequencies above resonance the net impedance will be inductive (+j). Operating above series resonance will correspondingly place the impedance of the capacitor on the inductive side of the Smith chart (+j). When designing for these applications both Co and the sign of the net impedance at the operating frequency must be carefully considered. In contrast, the majority of coupling, bypass and DC blocking applications are usually not sensitive. to the sign of the impedance and can be capacitive or inductive, as long as the magnitude of the impedance is low at the applied frequency. The effective capacitance will be very large and the net impedance will be very low when operating close to resonance. At resonance the net impedance will be equal the magnitude of ESR and the capacitance will be undefined.

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relief is on the wax. It is coming in the form of
digital audio broadcasting (DAB), popularly
called CD radio, which, in its two incarnations
— terrestrial and satellite — will not only pro-

vide some 100 channels of high quality fadeand static-free audio, but data as well. (Figure I shows the satellite version of CD radio; its terrestrial counterparts will use established commercial broadcasting facilities.)

There are several major players in the CD ratio area. Some, like Lucent and Delphi Delco, are well known; others, like XM, Strius and DRE, are not, but will be. The parts needed to begin nationwide service are either in place or quickly coming together, and the point of entry will not be the home but the automobile.

According to Ben Benjamin, senior vice president of product management at Lucent Digital Radio (LDR), Warren, NJ, ever since the merger of LDR and USA Digital Radio (USADR) into iBiquity Digital, everything has been going very well. "The merger is good for us and the consumer, who we envision will benefit from this type of radio," he said, adding that the technology can now be brought to market faster and more cost-effectively: "Faster, because now a standard will be adopted in the US much earlier than it would have if we were competing. Cost-effectively, because we'll get to higher run rates and bring economies of scale to bear faster than if we were competing."

XM Satellite Radio, Washington, DC, is building a prototype digital satellite radio receiver. According to Richard Wormington, senior vice president of engineering and opera-



[Continued on page 24]

ERNEST REJMAN Contributing Editor

Fig. 1 The satellite version

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tion for XM, "We'll provide all this technology license-free to our partners to build AM/FM/XM radios so that when you want to listen to us in your car you just punch the XM button, and if you want to listen to an FM radio station you punch the FM button."

Ken Erickson, product director of North America Audio Business for Delphi Delco, Kokomo, IN, is confident receiver development and broadcast schedules will converge as expected. "Sirius already has one of its satellites up, and XM will get at least one up this fourth quarter, and the rest of their laumch schedule is set up," he said. "We're at the point of getting first physical hardware on the receiver side in two months. Everything's reasonably on schedule, close to the timing stated by both XM and Sirius."

DISPLAYS AND RECEIVERS

Delphi Delco is working with General Motors and "others" it is not yet prepared to name on a remote box that will feed the audio signals into the radio head. "From the user interface viewpoint it's transparent just another band on the dial," explained Erickson, Although this new technology's first application will be focused on music, there are a number of data applications. "Newer radios today typically have larger displays with more text capability, so messages will be shown there. If you had a station panel such as '80s Oldies, that could be on the first line, the song or artist on the second." In fact, depending on the service provider, there is a string of messages that could be shown on the display, including where to buy the CD that is playing. Over the last few years the trend

has been to increase display content, particularly in the case of cellular phones. In the navigation world, some displays are comparable to cathode ray tubes in their capabilities. This improvement has spilled into personal digital assistants (PDA) and, now, to radios. Ten years ago, a typical display had a 3.5-figure capability, showing time and frequency, and perhaps four icons at best. "Now

you're seeing 8, 12, 2 × 12 with icons, dot matrix displays to enable increasingly more graphics and text capabili-

ty," said Erickson.

This graphic capability is not cheap, "You pay a price," admitted Erickson, "The new base radios have more graphics than the old ones, and high end radios have significantly more graphics capabilities still, with sometimes a color LCD display, depending on the OEM." Although the new radios will be rolled into the base price of the car, disguising the cost, the fact remains that, depending on the content display capability, the cost of the radios can have as much as a 20-to-1 price spread.

Bringing 2.5 GHz into the automotive environment is a new field. Indications are that both Sirius and XM have done a fine job working out compression techniques and fitting considerable data into the bandwidth the FCC has regulated for them. The hardware is being built and tested as you read this. Obviously, beyond the the computer simulation, design re-

[Continued on page 28]





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VSWR (Input/Output)	1.5:1/2:1	1.5:1/2:1	1.5:1/2:1	
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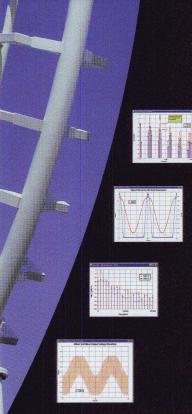






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views, peers reviews and progress made, the proof of the pudding should come out during the next quarter, when real-life testing begins. As Erickson put it, "Then the satellites get turned on and we start driving cars to see whether we have a saleable product, then do further development." There is still a list of minor action items being followed, such as getting the right type of decoding through software adjustment. However, as Erickson views it, "The proof is when I turn that switch and hear the music and get the data."

THE STANDARDS QUESTION

There were three proponents for in-band on-channel (IBOC): Digital Radio Express (DRE), Milpitas, CA; USADR (a consortium of broadcasters); and Lucent Digital Radio. The Lucent/USADR merger into iBiquity Digital has as investors 15 of the nation's top 20 radio broadcasters, including Infinity Broadcasting Corp. of Viacom Inc. and Clear Channel Communications Inc.

iBiquity will develop and commercialize digital broadcasting technology solutions, including Lucent's perceptual audio coder (PAC) audio compression technology, to enable radio broadcasters to send audio and data content via digital signals. These signals will allow existing radio stations to transmit CD-quality audio with crystal-clear reception plus wireless data for a variety of consumer applications, such as station and program content, stock and news information, local traffic and weather, and much more, over existing radio frequencies without degrading the transmission of current analog programming.

For a time, it appeared there would be a drawn-out systems battle. It was recognized that if IBOC was to become a reality in a reasonable timeframe, there had to be some form of a grand alliance.

According to Norm Miller, DRE's president, no one knows what the launch date is for IBOC. "This is the \$64 question," he said, "when a system will be finalized, deployed and be production-ready. Particularly with the merging of Lucent and US-ADR, it means that there must be a melding of both technologies to a certain extent. With a consortium

they can move forward quickly; at least there will be no opposition from the marketplace - it'll be just like digital TV, which only became reality when a heavyweight consortium was formed. The USADR alliance with Lucent brings in the 600-pound gorilla that creates the de facto standard which then everyone follows."

Automobiles will be first in fielding the technology, at least at the receiver end. IBOC proponents do not propose subscription fees as part of their model, and conventional broadcasting will keep its current business model, which is commercial revenues driven. Once digital radio is established and there is a low cost receiver, the expectation is that the public will slip into digital radio almost without noticing it. The newer cars will have it, as will new stereos and portables.

IBOC allows digital to co-exist with analog. The listener still receives the standard analog AM/FM signal, so if he buys a new receiver and installs it in his car, there will be no difference as far as the analog stations are concerned - he will get them as he always has. When he switches to the digital station format, audio quality will be improved but, more importantly, he will acquire the capability to receive a powerful data channel that can provide all sorts of customized information - from realtime traffic to stock quotes and news. As it is defined now, the business model shows that the standard audio and news and conventional broadcasting will continue being free. Not so with the valuable, nationwide data channel that provides a wireless data link into your car as well as to handheld devices.

TWO-WAY DATA

Although the downlink is one way. it would be easy to couple it with an uplink using cellular technology. From a business model perspective this works well because users download data in a 10:1 ratio compared with what they upload; therefore, using the more expensive cellular infrastructure as an uplink would not be prohibitive. The view is that downloading more data than needed is expensive. For instance, the service supplier would pump out a flood of stock or traffic information, and the [Continued on page 30]





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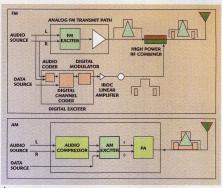
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▲ Fig. 2 LDR's approach to hybrid IBOC transmitter implementation.

user would program his receiver, whether radio or PDA, to pick up the stocks of interest or the traffic zones he wants. Such a low cost, real-time data download like this is ideal and, if something more specific is required, the user can always reach for his cellular phone. The radio link for low cost downloading could be networked to work side-by-side with a cellular link for uplinking.

SATELLITE REPEATERS AND IBOC

Satellite digital radio has two proponents: XM and Sirius. The FCC has granted them licenses to use the 2.5 GHz frequency. However, satellites still need to be orbited and earth stations set up for the system to work. On the other hand, IBOC uses the

current broadcast infrastructure approximately 14,000 radio stations in the US divided 50/50 between AM and FM. These stations already have towers and transmitters and are broadcasting signals. Converting over to IBOC is not an expensive proposition and, practically overnight, it enables these broadcasters to acquire a digital terrestrial network across the country. (Lucent Technology's approach to CD radio, shown in Figure 2, lies in adding an IBOC module to existing AM or FM transmitters in operating commercial radio broadcast facilities, providing them with digital

capabilities for audio as well as a data channel)

It is interesting to review the development of digital radio. At first. broadcasters fought satellite radio, fearing that it would ruin them. When the FCC finally ruled that it would grant licenses to XM and Sirius, things began looking less bleak, especially when it was realized that a shortcoming of satellite digital radio is its line-of-sight problem. In a metropolitan area, there is what is known as the "canyon effect." If you park under a shelter or drive through a skyscraper-lined street, you may not receive digital satellite radio.

A year after receiving their initial license, XM and Sirius realized that to enable themselves to offer a viable service, they needed terrestrial repeaters for the major cities and applied to the FCC for an additional license. Again, broadcasters did not like this, claiming that with repeaters they were no longer a satellite broadcaster but a terrestrial one. The FCC. however, granted XM and Sirius a license to operate low power terrestrial repeaters in metropolitan areas.

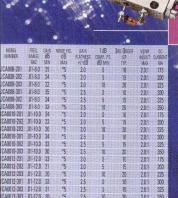
Thus, for satellite radio to work in metropolitan areas, the signal must be put through a repeater, providing the listener with a terrestrial signal. However, it should keep subscribers [Continued on page 35]

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SPECIAL REPORT

paying \$9.95 a month for CD-quality music from being annoyed by a signal that keeps fading in and out while they are driving, as is sometimes the case with some FM stations. This addition increases cost but makes the system viable, assuming you are within range of a repeater. It also brings up the issue of how many repeatars are needed for cities like Los Angeles, New York, San Francisco, Detroit or Chicago.

IBOCs overwhelming advantage is its low implementation cost, and that makes possible a digital data network covering the US, capable of providing valuable wireless data links into PDAs and car radios. Here is the real advantage of true terrestrial digital radio.

For AM stations especially, the IBOC conversion cost is relatively low in the \$10,000 range — because most broadcasters have relatively modern transmitters. It just requires an IBOC generator that is plugged into the transmitter. The digital signal is fed through the box into the main transmitter as with subcarriers, where a subcarrier box is put into the transmitter, which already has a subcarrier feed. FM's case is somewhat more complicated because IBOC requires a linear amplifier, and many of the older FM amplifiers are extremely nonlinear

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IBOC's overwhelming advantage is its low implementation cost, and that makes possible a digital data network covering the US, capable of providing valuable wireless data links into PDAs and car radios. Here is the real advantage of true terrestrial digital radio. Approximately 40 million other radios are consumed in the US, rateheting this number up to a 50 to 60 million yearly consumption. Clearly, some are cheap, givenway radios, but with a market like car radios, boomboxes and stereo tuners, a US 40-million-radios-per-year market is reasonable. Obviously there is no question of volume— it exists.

In addition, there will be low cost receiver chip sets implemented for PDAs, laptops and others as add-on modules. Those numbers are also significant. Consider the case of the PalmPilot, for instance, already a fairly powerful computational device with memory and processing power. Getting a small plug-in unit with an FM decoder that - whether it is used for audio or not is immaterial provides a low cost data link capable of feeding information into it becomes very attractive. It would be possible to go a step further and add a Global Positioning System (GPS) chip to the module to prove location information as well, permitting the incoming datastream to be customized for the user's location, enabling him, for example, to find out when the next bus will arrive at the street corner where he is standing.

DRE has an alliance with Cue Networks, Los Angeles, CA, and this fall will bring in a digital carrier system based on its IBOC technology using the subcarrier spectrum, which can be taken to market now without any further FCC approvals. The focus will be on digital subcarriers, and DRE is designing with them a plugin for the Handspring PDA, which is expected to be available before Christmas. The basic Handspring unit costs about \$150 and the user can buy plug-in modules from independent suppliers that convert it into a GPS unit or a cellular phone. Some seven modules are available for it already. The module that Cue will deliver is a small FM radio with an IBOC-based digital subcarrier unit, and Cue will provide a host of datastreams for the unit.

Digital radio — whether satellite or terrestrial — will bring a robust wireless datalink to the mobile envi-

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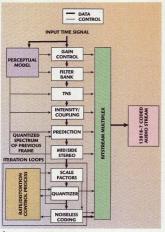


Fig. 3 Audio stream block diagram for DAB, data tracking and control modes.

ronment, as shown in Figure 3. Many of the problems with wireless are related to the mobile environment-particularly in the case of a vehicle traveling at 60 or 70 mph. Present systems work well if the user is stationary or moves slowly, but that is not a true mobile environment, and few wireless datalinks are capable of feeding reasonable amounts of information into it. With digital radio using the broadcast infrastructure across the US, the technology with which to provide a robust datalink in the mobile environment will be available.

The wireless data link will also drastically reduce repetition. A problem with harsh environments is that if the bit error rate (BER) is too high, this must be met with redundancy, consuming bandwidth. If a data system has 128 kb available but redundancy becomes necessary, this is reduced to 64 kb — half the bandwidth capability is lost.

LOOKING FOR COMMITMENT

The LDR/USADR merger came up with a unified design — a system developed at Bell Labs that uses a high quality audio coder (2ndC) recording to Lucent's Benjamin, PAC will be used because it allows efficient bandwidth use, always a challenge when attempting to communicate through digital means. PAC allows transparent CD quality at 120 kb. The channel consists of both the analog and digital signal in the sideband, which Lucent refers to as a hybrid IBOC implementation because it contains both the analog and digital means.

signals. In that configuration, the digital signal is 25 dB down from the analog signal at the center of the channel. This provides an interesting challenge to receive the signal in the same coverage area as the analog signal requiring a modicum of processing, which must be accomplished while maintaining CD quality.

Although everyone involved in digital broadcasting is quick to point at partnerships with radio receiver manufacturers, the fact is that beyond those involved in supplying car radios, there does not appear to be much gearing up. All major manufacturers are looking at designing receivers for this technology, but not much seems to be happening. Sony is often mentioned: however, a call to the company revealed that although it is "closely following developments," it has no plans to go into production.

It appears no one is willing to commit or allocate resources until there is a standard in place and some sort of service has begun - production lines are expensive things to keep idle. Receiver manufacturers will not get involved until after having identified the production time and the number of units that will be manufactured. All of this action will be triggered by the FCC implementing a standard. "Our expectation was that the standard would be adopted by year's end," said Benjamin. This may not happen due to purely political and bureaucratic reasons. One way or another, there is going to be a change of administration in Washington and, as an industry insider confided, "We're seeing a number of people from the FCC commission already beginning to look for, and finding, other jobs." A realistic appraisal indicates it would be surprising if a standard is in place before well into the first quarter of 2001.

Once the FCC adopts a standard, three major requirements must be fulfilled before service can begin on a commercial scale. Obviously, the first one is getting a number of digital stations up. Because of the relatively small costs involved, it is likely they will appear in sufficient numbers, at least in major markets, with large, readily available listening audiences. According to Lucent, this change should take place around the third of fourth quarter of 200 place around the third of fourth quarter of 200.

"We expect to have the major building blocks for receiver manufacturers to begin delivering product to the marketplace around the first quarter of 2002," said Benjamin. "A major element that must be provided is the IC that will allow them to build their radios in the compact form necessary for integration into a car's dashboard." This would meet the second requirement. The third most important requirement is exciting the prospective consumer about the technology through demonstrations at a number of shows and in markets in conjunction with broadcasts. Everyone involved has fresh in his mind what happened to stereo AM and there is no desire to repeat that debacle.

Lucent is working with "three of the major consumer IC manufactures," which it declined to identify until that arrangement can be disclosed. "They will determine costs, said Benjamin. "Our assessment of the incremental cost for such a system is that it will fit within the construct of a \$100 increment at the retail price level." (This means that, whatever its price is now, you will have to pay an additional C-note for the boombox or tuner of your choice.)

It is expected that eventually satellite and terrestrial broadcasting will merge. Because dashboard real estate is

[Continued on page 38]

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unlikely to increase, there will not be a second radio receiver there. Lucent is already providing some of the subsystems for the satellite broadcasters, who are using PAC in both the Sirius and XM satellites.

OFFSHORE DIGITAL

There are some countries, notably Great Britain and Germany, where digital broadcasting is already taking place. The European standard, Eureka 147, has been operational for three years. However, digital radio has not exactly set Europe on fire. One of the principal reasons is that receivers run about \$1000.

Future service providers in the US are betting on IBOC for a different outcome. "First, US receivers will cost \$100 or less in terms of incremental cost," said Benjamin. "Second, we know that broadcasters have speut considerable money and effort.

developing a brand following associated with their call signs. People know their favorite stations call signs and with IBOC that won't change. They'll find the signal where it's always been. With Eureka 147, the European listener must migrate to an entirely different band and familiarize himself all over again with where to find the stations he wants.

While volume will certainly bring costs down in IBOC's case, the European receiver's design elements are different because it operates in S band. As one climbs up in frequency, equipment tends to be more expensive. "This is an advantage that has made the proposed US system's incremental cost smaller — we're operating in the same frequency band," pointed out Benjamin.

It now appears that the European and American systems will be incompatible, but Lucent expects that once its system begins service in the US, there will be offshore applications. Lucent is presently dealing with European authorities, who, according to the company, are actively considering IBOC's adoption.

THE DATASTREAM

As mentioned previously, if a broadcaster has upgraded its equipment over the years, or the equipment is five years old or less, only a small modification is required. For an FM station, the upgrade cost would mostly be a high power combiner. The signal leaves the power amplifier and is delivered into the antenna to transmit; with today's analog power amplifier, the combiner is used to essentially sum the analog and digital paths, the latter being the second path that would be coming into the combiner. For an AM station, there are relatively inexpensive digitalready exciter boxes for the transmitter. Because of linearity requirements, modern AM equipment is already designed to accept a digital

Crucial data applications are linked to the more efficient use of time," said Benjamin. There are situations related to traffic and down-loadable maps. We see the system working as an adjunct to what is out there already, in terms of GPS-type guidance systems. We see in GPS (Continued on page 40)



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SPECIAL REPORT



▲ Fig. 4 An example state-of-the-art CD radio facility.

that people need maps of very wide areas and often local municipalities need to redirect traffic due to construction or other factors such as traffic flow situations where a twoway road becomes a one-way road." This information would be automatically updated in the system as the driver enters the vicinity.

Today, as commuters crawl to work, traffic reports come in maybe every 15 minutes and emphasize heavily traveled roads that may not be of interest. A driver who might want to know about traffic that is beyond his or her area could program the receiver to profile his or her interests, and it would only pick up information specific to the route of interest, avoiding having to listen to all the other broadcasts. These functions would not necessarily be available as part of a subscription service, but rather be made available free by present broadcast service providers. However, other data such as sports scores and stock quotes that people want instantaneously wherever they may be, might be provided on a subscription basis.

These data could reach the user in audio or visual format. However, there are concerns linked to providing too much visual input. Work is under way with the Consumer Electronics Association to set boundaries on what to put on a dashboard without dangerously distracting the driver. A usage etiquette is being developed around how data can be displayed without encumbering the driver.

SATELLITE RADIO GEARS UP

XM's development plan is typical of digital satellite broadcasting. "First you have to get a signal source programming center," said Wormington. "That is already under construction at our new facility in Washington, DC. Eighty-two studios, all modular, all digital, all tied together by fiber optics - everything will be operational by year's end." (Figure 4 shows an example of a state-of-theart facility under construction by XM.

Next comes satellite transmission capability. In XM's case, this means 15 kW Hughes 702 satellites, the biggest, most powerful commercial communications satellites ever made. The first was orbited in the first quarter of this year, and the next one launches the first quarter of next year.

Then come the repeaters to cover urban canvons, "We have 1500, and their test deployment has begun," said Wormington. "There's a network set up in Pittsburgh that we're running tests on, and full deployment will begin by the first quarter of 2001. These will go in 70 cities to cover the top 70 Arbitron markets. The number of repeaters ranges from 200 in New York, down to four or five for a place like Albuquerque. It is directly dependent upon the urbanization level, and the amount of acreage that we need to cover."

All of this preparation is useless without fielded radio receivers. "We don't produce radios," said Wormington, "but have a number of partners — people like Pioneer, Sony, Alpine, Delco, Sharp, Mitsubishi and others. We have a group in Florida whose sole purpose is building the hardware reference platform: antenna, tuner, an ASIC for channel decode and a DSP housing the software for the service layer decode, decompression and encryption.

XM is doing the engineering for a prototype radio capable of tuning into its system. The company has a working lab radio: satellite and repeater signals in, music out. It is now in what it describes as the "chip fabrication mode," leading to converting the lab radio prototype into chips. According to XM, these should be commercially available during the second quarter of 2001, with transmission beginning commensurate with receiver availability.

SYSTEM SPECS

The signal is divided into an A and B side. The output is 4 Mb, which can be thought of as 2 Mb per side, plus padding and error-correction bits; thus, it is not a 4 Mb signal when it is sent, but the data content is 2 Mb. The A and B sides go to the satellites via an X-band uplink, returning as an S-band downlink. Both links are time division multiplex quadrature phase-shift keying (TDMOP-SK)-modulated, going directly to the car. If the signal goes through a repeater, the repeater does an in-band receive and transmit with an amplification and change in the modulation scheme, from TDMQPSK to coded orthogonal frequency division multiplex (COFDM). The repeaters act as a single network, and the signal then is repeated out to the car.

The same information content comes over each of the two satellites and through the repeater. The radio can receive all three signals and is indifferent to which one it receives. The receiver is smart enough to select the best signal on a BER basis. This process is transparent to the user, who is unaware of which signal is being processed. In fact, the radio may switch back and forth rapidly, depending on signal quality.

The repeaters are mostly 2 kW, with approximately 10 percent of them slightly higher in power. In general, about 70 percent of the repeaters will be on a tower, monopole or building. Range is heavily dependent on environment. Placed on Mount Wilson in Los Angeles, a repeater might cover 20 miles. The same unit in New York City might reach five blocks. XM has already signed leases for 500 of the 1500 locations it needs, and the company indicates the remaining leases are coming in at a rate of 200 to 300 per month.

The 4-Mb datastream is divided into 8-kb primary channels, with every application working in some multiple

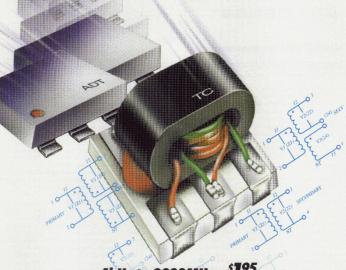
[Continued on page 42]

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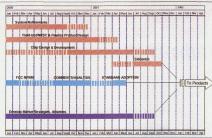
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▲ Fig. 5 LDR's IBOC realization program time line.

of a primary channel. There is an overhead allocation of 2 kb for each channel, providing a way to do things like sending information on stocks in parallel with, and transparent to, listening to music. This capability is used as what is called 'program-associated data' so that, for instance, the artist and song title of the piece being played appear on the display. Whatever can be digitized can be displayed.

A digital system has many capabilities, but just because they are available, it does not follow that they will be used. As Wormington puts it. "We're a broadcast system - what we send, we send to everybody. We could use the system for point-topoint applications, but it's an inefficient way of using it, because it is like taking a message and broadcasting it over every radio station. Digitally it can do a lot of things; but from a business point of view there are only a few things we will concentrate on. Right now, we're putting out 4 Mb of data, and the bit doesn't care what it translates to. In this case, we're having it translate to music and talk. We can do a lot with it; the question is what we can make money on, and right now music and talk are it that is our business plan.

As for GPS or any other ancillary data source, XM is not considering it.
"CM and Honda are very interested in telematics, but our system is designed to be a 4-Mb pipe to the car and that's it." Wormington added that a car radio manufacturer like Delphi Deleo might choose to implement

other data sources such as GPS or cellular, and integrate the systems. "We'll be a part of it, but aren't planning on doing the whole package. We don't make the radios, just facilitate their manufacture."

Like others, while admiring it, Wormington believes the value lies not in the technology, but in the improvement in programming. "People are going to hear radio like they think radio ought to be. Because we are nationwide, we don't have to appeal to a broad audience in a narrow geographic area and can focus on very narrow listener niches and provide the music that they love. Before, you could never have focused so exclusively on specific demographic sectors. People can make a business out of providing for narrowly focused musical tastes for \$9.95 a month."

Of course, the big question is what the timeline is for an actual launch of services, and there does not yet appear to be a definitive timeframe. Experts like DRE's Miller believe that by the time systems are finally rationalized, field-tested, fine-tuned and taken to the receiver manufacturer (who then, and only then, will gear up for production), it may take as long as two years. Figure 5 shows a mulestone chart for LDR's IBOC realization program.

BUT WILL THEY COME?

The movie 2001: A Space Odyssey has one of the most inspired scenes in film history. In it, man's distant ape ancestor tosses into the air in triumph the bone tool that has given him su-

premacy over his environment and, as it spins skyward, it transmutes into a space vehicle in Earth orbit — an elegant encapsulation of humanity's million-year arduous climb toward civilization.

The concept of digital radio brings to mind the culmination of that difficult evolution. While there is nothing technologically revolutionary about it, the ingenuity and application of existing technologies — the marriage of satellites, high frequency, terrestrial repeating networks, large-scale integration on the IC side, decoding and encryption techniques — to offer a capability that did not exist before is mind-boggling.

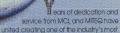
Some in the business wax poetical about it, like Delphi Delco's Erickson. "I frequently drive to the foothills in Tennessee and Kentucky, and go through several hours during which it's impossible to get a single radio station. Now, for the first time, people everywhere will be able to listen to the muste and talk they want. They'll have more choices and reliability, as well as nationwide information services. The technology's promise is its message."

As Hamlet muttered, albeit in a somewhat different context, "Tis a consummation devoutly to be wished." My satellite TV service boasts 220 channels. When channel-surfing, I am often awed by the incredible progress mankind has made given that they grow a present with the channel surface.

surfing. I am often awed by the incredible progress mankind has made since that long-gone ape creature tossed that bone on its way to the stars. We have acquired the ability to casually speed a radio signal off on a 46-thousand-mile journey, enabling me to receive anywhere on the planet and in the comfort of my own home. two channels that regale me with I Love Lucy in glorious black and white, as well as Roseanne and The Love Boat. It gives me three channels that try to sell me things I do not want or need, 20 that show me movies that were old before I was born, five that urge me to redecorate my budoir and prepare a gourmet meal, 16 that carry sports (often the same event) and so on, ad nauseam.

CD radio promises enormous potential, as did television and the Internet. However, if past performance of the use given to these resources is any indication, the promise should be taken with an extra hefty pinch of salt.

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S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
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and related engineering support.

The THAAD radar is an X-band, phased-array, solidstate system. Using high power transmit/receive modules and advanced signal processing and data processors, the radar provides surveillance, detection, target tracking and kill assessment of threats. The three radars awarded under this contract are a follow-on to the successful two THAAD User Operational Evaluation System radars provided to the US Army in 1996.

The THAAD program is an integrated system consisting of launchers, missiles, battle management and control, and radars, and is the upper tier of the Army's two-tier theater missile defense concept. The higher altitude and wide area protection furnished by the THAAD system interface with the lower tier Patriot Air and Missile Defense system to provide a complete missile defense of critical and high value assets.

Alternative to MR TRIGAT Anti-tank **Guided Weapon**

UK to Seek

The UK Defence Secre-tary has notified the UK's European partners in the Medium Range Antitank Guided Weapon system (MR TRIGAT) collaboration that the UK has decided not to proceed with the Industrialization and Production phase of the program. The lack of

progress on the program since the UK indicated a willingness to proceed last summer is cited as evidence that there will be further and unacceptable delay and uncertainty in the program whose service date is already 10 years later than originally planned. The Defence Department has decided that the UK's operational requirements for a modern anti-tank weapon will be best met by an alternative national program and is investigating such a

MR TRIGAT is a crew-portable Medium Range Antitank Guided Weapon system planned to replace MILAN in the armed forces of the UK, France, Germany, the Netherlands and Belgium. UK collaboration on the TRIGAT programs began in the mid-1970s, and the Full Development phase started in 1988 with an in-service date (ISD) of 1995. The most recent ISD is 2005.

The Industrialisation and Production memorandum of understanding (MoU) had been agreed to in 1998. The UK, Germany and France signed the MoU in 1999, but the Netherlands and Belgium have vet to do so. Aerospatiale Matra Missiles was the prime contractor for the Industrialization and Production phase; Matra Bae Dynamics was the major UK subcontractor. To date, expenditures on MR TRIGAT have been approximately £100 M. It is estimated that procuring an alternative system to MR TRIGAT will save more than that amount over 10 years.

Multiyear Javelin Anti-tank Weapon System Contract Awarded

The US Army has award-ed the Raytheon-Lockheed Martin Javelin Joint Venture a \$1.2 B multivear contract for the production of Javelin anti-tank weapon systems. The contract extends over four years beginning in 2000, and includes the delivery of 11,805 missiles, 2968 com-

mand launch units (CLU), 1990 student and field tactical trainers, and other associated equipment. Javelin is currently in full-rate production under a multiyear contract awarded in 1997, and is in service with US Army and US Marine Corps units.

The Javelin medium-range, anti-tank missile system is a one-man transportable and employable fire-and-forget missile system that permits a single infantryman to engage any armored vehicle at ranges up to 2.5 kilometers. It replaces the wire-guided Dragon missile in Ranger and Special Operations units, infantry and engineer battalions, and armored scout platoons.

Raytheon, the leader of the joint venture, will provide system engineering and support for the joint venture and produce the CLU, missile guidance electronic unit and system software. Its Missile Systems business unit in Tucson, AZ will be the primary Javelin work site. Lockheed Martin will provide missile engineering and production support in its Orlando, FL facility; produce missile seekers in Ocala, FL; and perform missile all-up-round assembly in Troy, AL.

FCC Decision Extends Approval of AirCell Airborne **Cellular Service**

n a recent decision, the Federal Communications Commission (FCC) sided with AirCell Inc. and its 21 cellular carrier partners and ended a contentious proceeding between the Air-Cell group and seven of the US' largest cellular services carriers. The FCC's deci-

sion reaffirmed AirCell's public safety benefits and the viability of its communication technology. In addition, the Commission extended AirCell's operating authority by an additional two years.



NEWS FROM WASHINGTON

The dispute between AirCell and the group of cellular carriers began in 1997 when the FCC's Office of Experimental Technology (OET) interrupted AirCell's experimental operations after appeals from several of the carriers. Subsequent extensive FCC-supervised tests in July 1997 verified the non-interfering nature of AirCell's technology, and the FCC OET lifted its restriction and permitted AirCell to resume operations.

In late 1998, the FCC's Wireless Technology Bureau granted AirCell and its partners a two-year exemption of the FCC's prohibition on the use of cellular phones in airborne aircraft. Under that exemption, AirCell was able to provide airborne cellular service to mobile terminals in-stalled on general aviation aircraft using 800 MHz cellular frequencies in cooperation with licensed carriers. In its recent decision, the FCC found that there was no available evidence to support the claim that AirCell service is likely to cause harmful interference with ground-based cellular systems and ruled that the public safety benefits associated with the AirCell system were substantial. The ruling effectively extends the life of AirCell's authority to provide air-to-ground cellular service.

AirCell presently operates 84 cellular sites nationwide and has partnerships with 21 cellular service providers. The company plans to expand its network to approximately 150 sites and 25 service partners so that it can offer full nationwide service. Global Hawk
Advanced Concept
Technology

Demonstration Reviewed Areport from the General Accounting Office (GAO), "Progress of the Global Hawk Advanced Concept Technology Demonstration" (GAO/NSIAD-00-78), reviews the results of the High Altitude Unmanned Aerial Vehicle Advance Concept Demonstration with respect to the period with respect to the period of the Proposition of the P

formance and cost objectives of the program. To assess the military utility of the Global Hawk, the US Air Force has been demonstrating prototype aircraft since June 1999. To date, the aircraft has demonstrated basic flying capabilities but has not had sufficient testing to determine whether it can successfully conduct reconnaissance missions on a regular basis. In October 1999, the Air Force reported prototype flights at altitudes over 66,000 feet for more than 27 hours. At the end of January, however, only 260 of 1200 planned flight test hours had been completed. While it appears possible that the aircraft may meet its performance goals, its escalating cost is a real concern. Neither the Department of Defense nor the Global Hawk contractor expects to achieve the \$10 M flyaway price goal for the second group of 10 production vehicles. A July 1999 projection places that cost at \$15.3 M, \$500 K higher than the July 1998 estimate.

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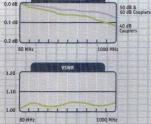
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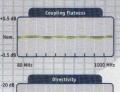
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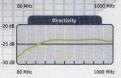
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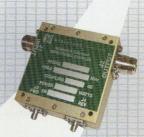
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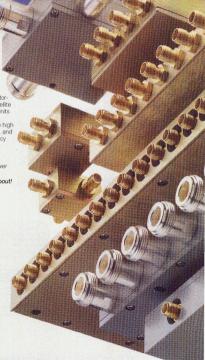
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10WAY 12WAY	11 9	0.75-2.40 0.50-4.20
14WAY 16WAY	1 28	0.90-0.99
VAMOR		0.95-1.75

For detailed model numbers, specifications, and prices, consult our web site, RF/IF Designer's Guide, or call Mini-Circuits.







EADS Wins US Radar Contract The European Aeronautic, Defence and Space (EADS) Co.'s Ulm. Germany-based Airborne Systems unit has been awarded a US\$11.9 M contract by the US Navy (USN) that covers the supply of components for its AN/APG-65 radar programme, EADS'

connection with APG-65 is based on the former DaimlerChrysler Aerospace's licence production of the radar for use in the Luftwaffe's (German Air Force) F-4 Phantom upgrade programme that began during 1987. Work on the USN contract is expected to be completed during 2002.

> **R&S Signs** with Honeywell

GRohde & Schwarz (R&S) has entered into a joint marketing agreement on Joint Radio with US contractor Honeywell that covers the promo-Marketing Venture tion of its M3AR (series 6000) military radio in the North American market. R&S describes the Multi-

erman

contractor

band, Multimode, Multirole Airborne Radio (M3AR) as a software-driven device that operates in the 30 to 40 MHz frequency range and can transmit digitised voice and data at high data rates. The equipment is further described as lightweight and available in cockpit or separately controlled configurations. Equipment control is by means of an MIL-STD bus.

> South African Contractor Re-brands

Starting 1 September, South African defence electronics contractor GST was expected to trade as Grintek EWATION following Grintek's agreement with the former Daimler-Chrysler Aerospace with regard to the merging of their respective groundbased signals intelligence

(SIGINT) and communications jamming business lines. Now a part of EADS. DaimlerChrysler is understood to have hived off its ground-based electronic warfare (EW) line into the new Ewation GmbH EADS subsidiary. As currently structured, Ewation GmbH has a staff of 500, and the combined Ewation/Grintek EWATION product line (which includes power amplifiers and HF/VHF communications jammers as well as SIG-INT equipment) will be internationally trademarked as MRCMR (Monitoring, Reconnaissance, Countermeasures) products.

INTERNATIONAL REPOR

Martin Streetly, International Correspondent

Australia Buys SIRFC

A s part of the US-Australian government-togovernment Advanced Integrated Aircraft Survivability Technology (AIAST) programme, Australia has procured an example of ÎTT's AN/ALO-211 Suite of Integrated Radio Frequency Countermeasures (SIRFC) with which to

conduct ongoing systems-related, co-operative research, development and engineering with the US Army. ALO-211 was selected for AIAST because it represents a nextgeneration modular, open architecture, integrated EW system. As part of the effort, a digital model of SIRFC has already been integrated into a UH-60 Blackhawk helicopter simulator by the Australian Defense Science and Technology Organisation. The integrated model allows pilots and engineers to work with SIRFC technology in the areas of sensor fusion, threat warning, situational awareness and electronic countermeasures. Launched during 1998, AIAST is expected to run until 2004.

> **UK Looks** for New Fast let IMPC

The UK's Ministry of Defence has issued a requirement for a new fast jet defensive aids suite (DAS) package (the Integrated Multi-Platform Countermeasures (IMPC) system) based on the Royal Air Force's (RAF) recent operational experience in the Balkans and the Persian

Gulf. Analysts have suggested that a key driver in the IMPC programme is the service's switch from predominantly low level operations to those at medium altitude. Expressions of interest in the programme were due by 29 September, with the tight time scale reflecting the urgency being placed on the effort and the likelihood of any IMPC solution selected being based on off-the-shelf equipment. The new DAS will include on- and off-board countermeasures (possibly includ-

ing towed active decoys) and a missile approach warner.
As its name suggests, IMPC will be applicable to a number of airframes (effectively, the RAF's Tornado, Harrier and, possibly, Jaguar strike aircraft) and is, therefore, required to be modular to facilitate mission-specific fits and maximum utilisation of common system elements. Likely bidders include BAE Systems, Northrop Grumman and Thomson Racal Defence. The RAF's strike Tornados are currently fitted with the Skyshadow radar jamming pod, a BAE Systems radar homing and warning receiver. and a BOZ 100 series countermeasures dispensing system (CMDS) pod; its Harriers are fitted with a BAE Systems Zeus integrated radar jamming and warning system together with a CMDS. The Jaguar light strike aircraft carries the Phimat CMDS pod and an updated variant of the former Westinghouse ALQ-101(V) radar jammer.



W1 Communications
Satellite Set

for September Launch The European Telecommunications Satellite (EUTELSAT) Organisation's WI fixed and broadcast communications satellite was scheduled to be launched aboard an Ariane rocket on 6 September. Developed by Europe's multinational Astrium space conglomerate. WI

has a launch mass of 3250 kg and is equipped with a payload comprising 28 transponders that operate in the 10.95 to 11.2 GHz and 11.45 to 11.7 GHz frequency bands. Transponder applications include business communications, Internet-based services and television transmission services, and the devices can be switched between fixed (up to 20 transponders) and steerable (up to 12) coverage. The fixed-coverage (termed fixed widebeam) footprint takes in Europe, North Africa and the Middle East from a 10° East orbital location. Available channel bandwidths are 40 MHz (four transponders), 54 MHz (eight), 62 MHz (four) and 72 MHz (12), and the vehicle utilises a 32 m solar array that will still offer DC spacecraft power of 7 kW at the end of the satellite's 12-year design life. The WI bus is based on a variant of Astrium's EUROSTAR design, 31 examples of which have been procured to date.

INTERNATIONAL REPORT

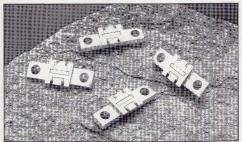
HAI Encouraged to Develop EW Capability Greek aerospace contractor Hellenie Aerospace Industries (HAI) is being encouraged to develop an EW capability following the Greek Ministry of Defence's decision to procure a DAS for its F-16 Block 50 Plus aircraft from national sources rather than from the international

defence industry. Prior to this decision, Thomson-CSF, Elisra and Raytheon were known to have been bidding for the \$200 M programme. Alongside this effort, HAI is also involved in the upgrading of 10 existing Greek Mirage 2000 combat aircraft to the Mirage 2000-5 Mk 2 standard. Here, the national contractor will undertake the necessary work, which involves modifications to both the aircraft's radar and DAS. Sources suggest that the EW equipment to be installed may incorporate elements from the equipment package Thomson-CSF, Matra BAe Dynamics France and Italian contractor Elettronica have developed for the Mirage 2000-9 aircraft being supplied to the United Arab Emirates. Existing Greek Mirage 2000s are fitted with a variant of the Thomson-CSF/Matra BAe Dynamics Integrated Countermeasures Suite.

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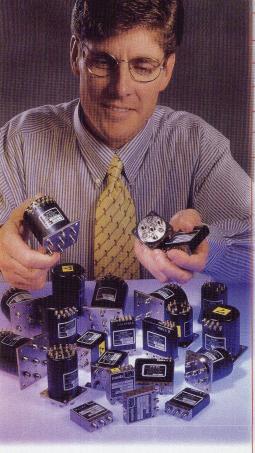
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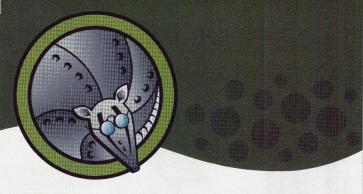
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THE COMMERCIAL MARKET

New Consortium

Aims to Make TV

More Personal

and Interactive

Microsoft Corp., DI-RECTV Inc. and THOMSON multimedia have announced an alliance to bring a new advanced RCA* DIRECTV* system with the new Microsoft* Ultimate TV* service to market. The RCA DS4290-RE system with Ultimate TV and DIRECTV service

is the first direct broadcast satellite (DBS) television platform that integrates DIRECTV programming, digital video recording, interactive television and Internet access in one package. The package will permit viewers to watch two shows on DIRECTV at the same time (picture-in-picture), watch one show while recording a second and record more than 30 hours of digital-quality programming for later viewing in their own personal lineup. Viewers will be able to choose from more than 500 hours per week of interactive television, respond to promotions with a remote control, and send and receive e-mail.

The D\$4290RE receiver incorporates two DIRECTV satellite tuners and a hard disk drive for digital video recording. In addition, it provides a digital audio output, a standard V.90-capable modem for Internet communications and two USB ports that are planned to support printers as well as keyboards and broadband network interfaces such as DSL modems. The receiver package includes a digital satellite receiver, an 18-inch dish antenna with dual-output LNB and a universal remote control. The receiver with the two television services was expected to be available for retail purchase by the last quarter of this year.

New Venture to Provide Vehicle Telematics

Provide
lematics
Services
Services

Order of Motor Co. and QUALCOMM Inc. have announced the creation of Wingcast, a new company to develop and deliver wireless mobility and information services that will equip cars and trucks with voice, entertainment and safety services.

vices and Internet access. Ford cars and trucks will be the initial recipients of these newly developed products and services. Ford expects that more than one million of its vehicles will be so equipped by the end of 2002, more than three million by 2003 and virtually all of its cars and trucks by the end of 2004.

Wingcast expects to combine QUALCOMM's CDMA wireless technology with Ford's telematics and consumer experience to provide consumers with seamless access to applications and services in their vehicles such as communications, information, asyigation, entertainment, safety and security. The company's first offerings are scheduled for introduction in late 2001. Nissan is also working with Ford and QUALCOMM to bring Wingcast services into

some of its luxury vehicles and may extend their application to a broader selection of Nissan and Infiniti vehicles in the future.

Ford and QUALCOMM each own equity in Wingcast under undisclosed terms. Cartell, a Michigan-based supplier of telematics equipment to automakers, is a minority stakeholder in the company, Initial Wingcast services will be available in North America over cloud non-One-M digital wireless networks. Advanced offerings requiring high speed wireless data will become available as third-generation cdma2000 and wideband CDMA networks are implemented.

First In-flight
Bluetooth
Wireless Technology

Test is Successful

AirCell Inc. and Monounced the successful completion of the world's first in-flight test of Bluetooth wireless technology. Current Federal Communications Commission (FCC) rules prohibit the use of personal cellular

phones while airborne due

to potential interference with terrestrial wireless networks, but AirCell has developed an FCC-approved inflight cellular link that avoids interference with terrestrial cell sites. The systems rely on hard-wired handsets within the aircraft that are widely deployed in commercial fleets. The test combined Bluctooth technology links between personal communications devices like wireless phones and laptops with the fixed AirCell air-to-ground link within the aircraft. The system is expected to drastically reduce the cost of phone calls made while airborne and, at the same time, provide a variety of advanced services such as fax. e-mail and Internet access.

Globalstar
Introduces Satellite
Telephone Service
in Russia

dobalstar has introduced its satellite telephone service in Russia, bringing wireless telecommunications service to virtually the entire country and introducing it into nearly 40,000 communities that presently have little or no access to wireless or wireline telephone service.

GlobalTel, the exclusive provider of Globalstar service in Russia, will use its gateway in Moscow to offer basic telephone services including voice and short messaging service (SMS) and, in early 2001, will offer far and data service. Later this year, gateways in Novosibirsk and Khabarovsk will be on line to provide service to central and eastern Russia, respectively, expanding Globalstar's coverage to virtually the entire country from the Baltic Sea to the Pacific Ocean. In addition to covering nearly all of Russia's land areas, Globalstar will provide service up to 200 miles off of the country's coastlines to commercial and



THE COMMERCIAL MARKET

private maritime vessels as they travel outside the coverage area of traditional cellular and radio services.

GlobalTel will market Globalstar products and services through its regional providers and distribution network as well as through its sales office in Moscow. Phone units are being offered at prices starting at US\$999, and call rates within Russia range from US\$1.19 to \$1.99 per minute.

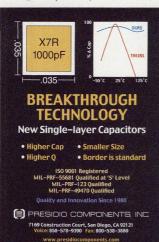
CDMA-800 and PCS-1900 **Expected to Lead Base Station Growth**

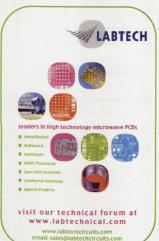
▲ report from the Cahners In-Stat Group, "Towers, Towers, Everywhere: 2000 Worldwide Base Station Forecast," estimates that the global count of 800 and 900 MHz cellular and 1800 and 1900 MHz PCS, PDC base stations will grow at a compound annual growth rate

(CAGR) of 30.4 percent through 2004. During that period, the report predicts that CDMA-800 and PCS-1900 installations will grow at rates of 48.9 and 35.3 percent, respectively, to lead the market. TDMA-1900 is expected to be very close to the leaders in third place.

The report forecasts that the number of US base stations will grow 17.5 percent this year and, at that level, account for the majority of new installations in the Americas. Canada's base station count is also expected to grow this year but, since its high population centers already have good coverage, no significant additional growth is forecast. During the next four years, South America's share of the Americas market is expected to increase from its current 21.8 percent to 50.2 percent. In Europe, the current dominance of GSM/DCS-1800 is expected to limit growth. Europe's market share at the end of 2004 is forecast to decrease by 10 percent. The report notes further that the significant year-to-year decline of analog in Europe is likely to take it to the point of non-existence by the end of 2001 and that DCS-1800 will be growing at a faster rate than GSM-900.

In other areas, the study finds that Japan, with 8.6 percent of total worldwide base stations in 2000, is likely to see that share drop to 3.7 percent in 2004. Russia is identified as one of the few geographic areas to enjoy significant analog growth, which is expected to peak in 2004 and begin a moderate decline as digital technology begins to replace it. The anticipated surge in new subscribers in third-world nations is also expected to contribute to the dynamic growth in base stations through 2004 and beyond. China, in particular, is expected to contribute heavily to this growth. For additional information, contact Kirsten Skedd, Cahners In-Stat (480) 609-4534 or e-mail: kskedd@instat.com...







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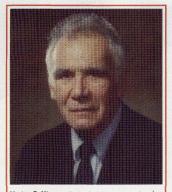
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AROUND THE CIRCUIT



Marion E. Hines, a pioneer in microwave semiconductors and one of the "Grand Old Men" of the industry, died on August 25. He was 82 years old.

Marion was born in Bellingham, WA and received his BS and MS degrees in electrical engineering from the California Institute of Technology. After serving in the US Army Air Force during World War II, he was employed on the technical staff at Bell Laboratories until 1960, when he joined Microwave Associates Inc. (now M/A-COM). He was still employed as a consultant to M/A-COM when he passed away.

Marion was a prolific contributor. He published more than 50 technical papers and was awarded more than 40 patents. He published landmark papers on semiconductor theory and circuits, ferrite devices, time domain theory and manylys as the seminary and the seminary practical circuit designs and devices. He was a Life Fellow of the IEEE and winner of the IEEE Lamme Medal, as well as the Electron Devices Society J.J. Ebers Medal, the IEEE Centennial Medal and the Microwave Theory and Techniques Society Microwave Career Award. He won the MTT-S Microwave Prize for best paper of the year in 1972 and again in 1978. He is the only person to win it twice.

I am fortunate to have worked with Marion for 23 years. Over that time, he continually amazed me with his intellectual curiosity, inventiveness and creativity. He was responsible for many of the developments and products that made the company successful, from sophisticated semiconductors to practical, low cost designs for police radar detectors. During all of this, he was a patient mentor to many of us. Above all, he was a wonderful gentleman. He is already missed.

Harlan Howe, Jr.

INDUSTRY NEWS

- Anaren Microwave Inc., Syracuse, NY, has acquired substantially all of the assets of Ocean Microwave Corp., a privately held New Jersey-based manufacturer of ferrite isolators and circulators. Anaren will operate the Ocean Microwave business through its newly formed subsidiary, Anaren Power Products Inc. The acquisition will be accounted for as a purchase acquisiting the products of the Corp. The Acquisition will be accounted for as a purchase acquisiting.
- VoiceStream Wireless Corp. has entered into a definitive agreement to acquire Powertel Inc. The transaction will substantially expand VoiceStream's all-digital GSM wireless coverage in the southeastern US.
- The Laird Group Plc (parent of APM Inc.) has announced plans to acquire Instrument Specialties Co. Inc. for \$937 M plus debt. The acquisition was conditional on Laird Group shareholders' approval at a meeting scheduled for August 25.
- Frequency Electronics Inc. (FEI), Mitchel Field, NY, has signed a definitive agreement to purchase Gilliam 5.A., a privately held Belgian company that develops and manufactures wireline telecom synchronization, network monitoring and power supply products. FEI will pay approximately 88.5 M in cash and 200,000 shares of FEI stock for the stock of Gilliam. The transaction was expected to close by the end of September.
- Illinois Superconductor Corp. (ISC) has consummated its acquisition of Spectral Solutions Inc., pursuant to a merger agreement executed and amounced in May. Richard Herring, CEO of Spectral Solutions before the merger, has been added to ISC's board of directors.
- Spirent Communications, Eatontown, NJ, has acquired InfoSOFT Technologies Inc., Ft Worth, TX. With the acquisition, Spirent now offers a full range of wireless test and deployment solutions that enable CDMA handset manufacturers and network operators to quickly develop and roll-out next-generation products and services.
- Alamosa PCS Holdings Inc. has signed definitive agreements to merge Sprint PCS affiliates Roberts Wireless Communications LLC and Washington Oregon Wireless LLC into its operations. The combined transactions will result in a new entity named Alamosa Holdings Inc. and are expected to close by December 31.
- SandCraft Inc. has changed the company's business model to manufacture, market and distribute products for the high performance needs demanded by the communications, consumer and office automation markets. The company's ultra-high performance MIPS-compatible central processing units will be manufactured and marketed under the SandCraft brand name. Previously, SandCraft licensed intellectual property and designs.

[Continued on page 58]

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AROUND THE CIRCUIT

- TEMIC Semiconductors has changed its name to Atmel Wireless & Microcontrollers to emphasize the name of its European shareholder. Along with the new name, the company has introduced a new logo.
- Stratos Lightwave Inc. has acquired additional mamifacturing space adjacent to its Chicago headquarters. The 60,000-square-foot building will be used to increase the space dedicated to manufacturing gigabit-speed optical transceivers and fiber-optic products.
- RF and microwave filter designer and manufacturer K§1. Microwave Inc., a division of Dover Corp., has expanded its manufacturing facilities to include a new building that will make available 64,000 square feet of additional space.
- Superconducting RF product supplier Illinois Superconductor Corp. will open a new office in Japan. The office will be headed by Derek Schneideman, former president and representative director of Gateway Japan KK.
- Space Electronics Inc. (SEi) has completed its acquisition of Shason Microwave Corp.'s Instruments Group. The addition provides SEi with the ability to offer RF/microwave components and modules for satellite applications. The acquisition also includes a unique product line of automated test equipment.

- Unitek Miyachi Corp. has formed Unitek Miyachi International Ltd. (UMI), a corporate holding company that will oversee and coordinate strategy and business planning, global product and marketing integration, next-generation technology and product development, corporate finance and administration, and future acquisitions for all of its business units. In related news, Unitek Miyachi has formed a new multinational accounts group, which was necessitated by the company's rapidly expanding international sales growth and the need for dedicated focus on the management of key global accounts.
- Advanced RF technology developer Silicon Wave Inc., San Diego, CA, has formed an advisory board of wireless communications experts to consult with the company's executive management team on such matters as business strategy, technical trends and regulatory developments.
- Bartley RF Systems Inc., Amesbury, MA, has created a new corporate logo to reflect its growth and current position in the wireless network equipment marketplace. The new identity coincides with the company's move to a 78,000-square-foot facility, which houses more than 250 employees, up from its original nine in 1995.
- Motorola Inc. has moved its largest volume assembly and test manufacturing facility for high power RF products from Seremban, Malaysia to Kuala Lumpur, Malaysia. The move provides growth opportunities for

[Continued on page 60]

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AROUND THE CIRCUIT

manufacturing RF power devices that are required to continue to meet the needs of customers and the wireless market.

- IFR Systems Inc. has signed major distribution agreements with LeCroy Corp., Geneva, Switzerland, for distribution of test products in Europe. Under the partnership, IFR will be the exclusive distributor for LeCroy's test and measurement products in Spain and Portugal, while LeCroy will become a key distributor for IFR's test and measurement products in Italy.
- Richardson Electronics Ltd. has signed a worldwide distribution agreement with ANADIGICS inc. Under the terms of the agreement, Richardson will become ANADIGICS' first distribution channel to market and sell the company's wireless, fiber, and cable and broadcast RFIC product lines.
- E*TRADE Group Inc. has formed an alliance with Sprint PCS to provide clear, mobile access to E*TRADE's wireless trading capabilities and applications via Internet-ready Sprint PCS phones and the Sprint PCS Wireless Web.
- RF Micro Devices Inc., Greensboro, NC, has collaborated with Atmel Corp., San Jose, CA, to produce reference designs based on the IEEES02.11b 11 Mbps wireless local area network standard. Together, the companies are providing complete reference designs to qualified customers, including schematics, lavout files and bills of materials.
- Rogers Corp. has captured more than 90 percent of the market in Taiwan for high frequency circuit materials used in the manufacture of Ku-band low noise block downconverters (LNB) in direct satellite TV systems. Taiwan has eight major LNB manufacturers who supply a significant portion of the LNBs needed worldwide.
- SSB Technologies Inc.'s Stealth Microwave division has received ISO 9001:1994 certification for the design, development and manufacture of microwave amplifiers for the wireless communications industry.
- Universal Voltronics Corp., Mt. Kisco, NY, has achieved full ISO 9001 certification.
- According to the recently published "Broadband-to-the Home Services, Equipment and Components Market Forecast," residential broadband services revenue will reach \$175 B in 2009. The revenue obtained from providing all types of residential broadband services to North America will grow from \$481. B to \$174.8 B during the same period. This increase is in addition to narrowband residential communications services revenue, which is expected to advance from \$52.4 B to \$130 B during the forecast period.
- **ANADIGICS Inc.**, Warren, NJ, has shipped more than 100 million broadband RFICs for cable systems and fiber-optic networks. The increased development of fiber-optic

infrastructure to support rising demand for Internet bandwidth as well as emerging two-way digital cable services have resulted in a strong demand for broadband solutions.

■ First Source Inc., San Jose, CA, a national distributor of RF, microwave, wireless, cellular and millimeter-wave components, celebrated its fifteenth year in business at the company's annual sales meeting.

FINANCIAL NEWS

- Molex Inc. reports record sales of \$614.6 M for the fourth quarter, ended June 30, compared to \$445.9 M for the same period last year. Net income was \$65 M (363c/share), compared to \$50 M (26c/share) for the fourth quarter of 1999.
- Andrew Corp. reports record sales of \$259.2 M for the third quarter, ended June 30, compared to \$186.1 M for the same period last year. Net income was \$20.9 M (26c/dhluted share), compared to \$14.7 M (18c/dhluted share) for the third quarter of 1999.
- REMEC Inc. reports sales of \$63 M for the second quarter, ended July 28, compared to \$47.3 M for the same period last year. Net income was \$3.2 M (7c/diluted share), compared to a net loss of \$2.8 M (7 c/diluted share) for the second quarter of 1999.
- ANADIGICS Inc. reports record sales of \$47.5 M for the second quarter, ended July 2, compared to \$30.5 M for the same period last year. Net income was \$6.6 M (21c/diluted share), compared to \$2 M (8c/diluted share) for the second quarter of 1999.
- Cree Inc. reports record sales of \$33.4 M for the fourth quarter, ended June 25, compared to \$18.3 M for the same period last year. Net income was \$11.4 M (30c/diluted share), compared to \$4 M (12c/diluted share) for the fourth quarter of 1999.
- Norsat International Inc. reports sales of \$27.5 M for the second quarter, ended June 30, compared to \$13.5 M for the same period last year. Net loss was \$5.3 M (20/c share), compared to a net loss of \$493 K (2c/share) for the second quarter of 1999.
- Robinson Nugent Inc. reports sales of \$25.1 M for the fourth quarter, ended June 30, compared to \$18.9 M for the same period last year. Net income was \$1.7 M (32c/share), compared to \$1.2 M (24c/share) for the fourth quarter of 1999.
- Alamosa PCS Holdings Inc. reports sales of \$17.2 M for the second quarter, ended June 30. compared to \$35.1 K for the same period last year. Net loss was \$12.9 M (2Le/share), compared to a net loss of \$4 M (8e/share) for the second quarter of 1999.
- SEMX Corp. reports sales of \$12.67 M for the second quarter, ended June 30, compared to \$11.5 M for the same period last year. Net income was \$60.9 K (8c/diluted share), compared to \$991 K (16c/diluted share) for the second quarter of 1999.

[Continued on page 62]

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HMC307QS16G	5 Bit ,1 to 31 dB Neg. Bias	DC - 4	1, 2, 4, 8, 16	2	± 0.5	+ 44	29.4
HMC306MS10	5 Bit, 0.5 to 15.5 dB Pos. Bias	0.7 - 3.7	0.5, 1, 2, 4, 8	1.8	± 0.25	+ 52	14.8
HMC230MS8	3 Bit, 2 to 28 dB Pos. Bias	0.75 - 2	4, 8, 16	1.8	± 0.5	+ 46	14.8
HMC288MS8	3 Bit, 2 to 28 dB Pos. Bias	0.7 -3.7	2, 4, 8	1.5	± 0.3	+ 51	14.8
HMC291	2 Bit, 4 to 12 dB Pos. Bias	0.7 - 4	4, 8	0.9	± 0.2	+ 54	9
HMC290	2 Bit, 2 to 6 dB Pos. Bias	0.7 - 4	2, 4	0.6	± 0.2	+ 52	9

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AROUND THE CIRCUIT

- Ansoft Corp. reports sales of \$8.7 M for the first quarter, ended July 31, compared \$6.9 M for the same period last year. Net income was \$202 K (2c/diluted share), compared to a net loss of \$311 K (3c/diluted share) for the second quarter of 1999.
- Merrimac Industries Inc. reports sales of 85 M for the second quarter, ended July 31, compared 85.1 M for the same period last year. Net income was \$40 K (2c/diluted share), compared \$82 K (5c/diluted share) for the second quarter of 1999.
- RF Micro Devices Inc. intended to offer, subject to market and other conditions, \$250 M of convertible subordinated notes due 2005 (plus an additional amount of up to \$50 M at the option of the purchasers) in a private placement. The notes will be convertible into the company's common stock at the option of the holder, at a price to be determined. The offering was expected to close in August.
- Silicon Wave Inc. has completed its fourth round of financing with nearly \$52 M infused into the company. The round includes new investments from 3Com Ventures, Access Technology, Alps Electric Co. Ltd., CTG Ventures, Intersil Corp., JMG Triton, Nexus Capital Partners, Sands Brothers Venture Capital, Senvest International and \$1DUS, and allows Silicon Wave to continue its

innovations, including highly integrated chips, systems and software for Bluetooth wireless technology.

■ MediaQ Inc. has completed its third round of venture capital financing, securing \$23.4 M. New investors include Weston Presidio Capital, El Dorado Ventures, Infineon Technologies, Summit Accelerator Fund and ViVentures. MediaQ intends to use the capital to fund the development of ICs for Web terminals/pads, hand-held personal digital assistants, communicators and smart phones.

CONTRACTS

- Raytheon Co., Lexington, MA, has been awarded a contract valued in excess of \$1.4 B by Lockheed Martin Co. to design, develop and manufacture three engineering and manufacture manufacture three engineering and manufacturing development radars for the Theater High Altitude Defense System. The contract also includes the hardware design, development and manufacture of six battle management/command control, communications and information tactical/shelters groups and related engineering support.
- Cree Inc., Durham, NC, has received contracts from several Asian and European customers totaling \$70 M for shipments through September 2001. Included in these contracts is a one-year purchase agreement with Osram Opto Semiconductors GmbH and Co. for standard brightness, high brightness and small chip silicon carbide light-emitting diodes and wafer products. The Osram agree-





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AROUND THE CIRCUIT

ment is the largest product contract signed in the history of the company

Andrew Corp., Orland Park, IL, has received an initial \$3 M order as part of a \$23 M letter of agreement for the development and supply of single-channel PCS-TDMA linear power amplifiers to Lucent Technologies Inc. Andrew was expected to deliver the first consignment of prototype amplifiers to Lucent in September and will move into full production at the beginning of 2001.

PERSONNEL

- Applied Epi Inc. has named Brett D. Heffes chief financial officer. Most recently, Heffes was VP of corporate development and treasurer for Department 56 Inc.
- Silicon Wave Inc. has elected Bruce Edwards and Dave Rickey to its board of directors. Edwards currently serves as president and CEO and is a member of the board of directors at Powerwave Technologies, Irvine, CA. Rickey is currently president and CEO of Applied Micro Circuits Corp., San Diego, CA.
- Yahya Rahmat-Samii and Anand Gopinath have joined Altra Broadband Inc.'s board of technical directors. Rahmat-Samii is the chairman of UCLA's electrical engineering department; Gopinath is a professor of electrical engineering at the University of Minnesota.
- Alamosa PCS Holdings Inc. has appointed Tony Sabatino senior VP of engineering and network operations, and Lovd Rinehart senior VP of corporate finance. Previously, Sabatino was the national RF engineering director at Sprint PCS: Rinehart was chief financial officer at Affordable Residential Communications
- Lars Jehrlander has been appointed head of business area Allgon Systems, Previously, Jehrlander was VP of the mobile communication business at Ercisson in Brazil.
- GIL Technologies has promoted lerry Moran to the newly created position of VP, global sales and marketing. Previously, Moran was the regional sales manager for the company.



named VP and general manager of VertexRSI's Santa Clara, CA facility. Cahlander will be responsible for the overall direction of the facility's systems business.

GHz Technology Inc. has appointed Charles Leader VP, operations. Previously, Leader held senior positions in manufacturing and engineering at Agilent Technologies and Avantec Inc.

In preparation for its initial public offering, American

Microsystems Inc. has appointed Michael C. Reilly to

the newly created position of treasurer. Reilly joins the company from Anacomp Inc. and has more than 12 years of experience in treasury management.

Lindgren RF Enclosures Inc. has named Bob Piemonte sales manager for industrial products. Piemonte, a former Lindgren employee, brings 15 years of sales and marketing experience to the company.



Stellex Communications has appointed Bill Nicklin international sales manager. Nicklin assumes responsibility for the sales of Stellex RF and microwave components through a network of representatives and distributors in Europe, the Middle East, India and Africa

Marconi Applied Technologies has

appointed Hal Spooner director, Satcom Operations, Previously, Spooner was the acting director of sales and marketing, regional sales manager and product marketing manager at Litton Electron Devices.

Stanford Microdevices has appointed Norm Hilgendorf director of marketing for standard products. Prior to joining the company, Hilgendorf was VP and general manager of Richardson Electronics' solid-state division and business unit manager for wireless products.



- ITT Industries, Cannon has named Lisa G. Blais general manager of its C&K Components switch products business. Most recently, Blais was C&K's VP, sales and marketing.
- NEC Electronics Inc. has promoted Omid Milani to assistant general manager of the Displays and Energy Devices Strategic Business Unit. Previously, Milani was senior manager of

the Flat Panel Displays Group at the company.



- Quad Systems Corp. has named Brent A. Fischthal APS product manager. Previously, Fischthal served as product marketing specialist for Universal Instruments Corp.
- Wyle Electronics has named Dave Hartman and Chuck Kunai division managers for the company's Minneapolis and Houston divisions, respectively. Hartman joined the compa-
- ny as division manager in Houston in 1999; Kunai most recently served as the company's south central region strategic business manager.
- Micro Networks Corp. has appointed John N. Gau, Jr. principal SAW design engineer. Gau joins the company from TOKO America Inc.'s SAW Filter Design Center.

[Continued on page 66]

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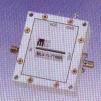
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Gain Flatness (dB)	-1.0 dB	±1.0 dB
Noise Figure(typ)	0.9 dB	1.2 dB
In/Output VSWR(max)	1.5:1	1.5:1
1dB Compression Point	21 dBm	21 dBm
IMD3 (typ)	55dBc (@+5dBm)	55dBc(@+5dBm
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AROUND THE CIRCUIT

- Aeroflex Laboratories has added James R. Guinaw to the marketing and sales staff for Instrument Products. Guinaw has held senior positions with Hassir Corp., Grumman Corp. and Telephonics Corp.
- BTC Electronic Components has named Kerry Hathaway account executive in its Apopka, FL sales office. Previously, Hathaway was with PCD as an inside sales manager.

NEW MARKET ENTRY

Universal Microwave Corp. (UMC) is a new company formed to design and manufacture high performance VCOs, ceramic resonator oscillators and synthesizers for the wireless market. UMC is located at 2339 Destiny Way, Odessa, FL 33556 (877) 375–3932, fax (797) 376-7271.

REP APPOINTMENTS

- Sprague-Goodman Electronics Inc., Westbury, NY, has appointed Soquelec Telecommunications, Montreal, Quebec, Canada, to represent its products in Quebec, Ontario and the Maritime Provinces. In addition, the company added Diamond Advanced Components, Norcross, GA, and Integra Electronics, Orange, CA, to its franchised distributor network.
- Universal Microwave Corp. has named three firms to represent its VCOs and synthesizers in the USs. dBm Technical Sales will cover New England, Youngewirth & Olenick will cover Arizona and New Mexico, and Trionic Associates will cover Long Island, New York City and New Jersey.
- mmWave Technologies Inc., Ottawa, Ontario, Canada, has signed a vendor contract with Karl Suss America, adding to its communication test and measurement line card.
- Coleman Microwave Co., Edinburg, VA, has made several new rpe appointments, including Applied Technical Sales and Marketing, San Juan Capistrano, CA, to cover Southern California; E. Reid Miller Corp., Saratoga, CA, to cover Northern California; and Lear Associates, Richardson, TX, to cover Texas and Oklahoma.

WEB SITE

■ Murata Electronics North America has made available a free EMI filter selection simulator on its Web site at www.murata.com. The noise suppression-measuring service aids design engineers in the process of selecting EMI filters by replicating the conditions of their circuit to evaluate the performance of various filters.

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irect frequency multipliers are commonly used in applications where the
added phase noise or circuit complexity of a phase-locked loop is undesirable. At
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directly, but generally require RF drive power
levels that are incompatible with the low curents and voltages in modern portable products. An injection-locked oscillator (ILO) can
supply the desired harmonic efficiently, but it
will continue to deliver output power at the
wrong frequency if the tuning is incorrect due
to aging, or if the input level becomes insufficient to lock the oscillator at the desired miltiple. There is no comparable threshold prob-

lem if an overdriven amplifier is used as a harmonic generator; however, both the output power and DC-to-RF efficiency are likely to become impractically small for large values of multiplication N.

The circuit shown in Figure I, along with its conceptual model, avoids these problems. Since no DC bias is provided for Q, there is no measurable RF output power when the fundamental frequency input signal is removed. The output is a damped sinusoid; hence, the output power can be concentrated in a few spectral lines clustered around the desired harmonic, rather than in the wideband comb spectrum characteristic of an impulse generator or overdriven amplifier.

BACKGROUN

It is assumed that the input to a broadband (impulse) frequency multiplier is a CW input signal $A_{\rm COS}(2R^*_{\rm R}t+\varphi_0)$ and that the output is observed only after the DC bias terms at all internal nodes have reached their steady-state values. When the multiplier output is sampled at a rate $F_{\rm SAMP} > 2F_{\rm R}$, its output frequency components will be aliased down to the frequency band from DC to $F_{\rm R}$. The sampler output will

[Continued on page 70]

D.R. LANG Comtech/EFData Tempe, AZ

Fig. 1 The direct frequency multiplier's schematic.

C2 L2 1000 pF 68 nH	$ \begin{array}{c} 3.9 \text{ pF} \\ \hline C4 & R_L = 50 \Omega \end{array} $
R2 \$150 \(\Omega\$ \frac{1}{150} \) \(\Omega\$ \Omega\$ \frac{1}{150} \) \(\Omega\$ \frac{1}{150} \) \(\Omega\$ \frac{1}{150} \) \(\Omega\$ \frac{1}{150} \) \(\Omega\$ \Omega\$ \frac{1}{150} \) \(\Omega\$ \frac{1}{150} \) \(\Omega\$ \(\Omega\$ \O	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
VOLTAGE SOURCE fo = 72 MHz SQUARE WAVE 5 V p-p R _{INT} = 0	

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be limited to Γ_R provided the multiplier output consists of only integral multiplies of the input frequency and is free of spurious (nonharmonically related) components. Stated another way, the phase offset values ϕ_n in the multiplier output spectrum $\Lambda_n\cos(N2\pi\Gamma_R^2 + \phi_n)$ must be stationary between successive evcles of the input reference signal.

An ILO consists of a (generally) narrowband oscillator, which has an intrinsic or unlocked frequency F_0 . The ILO is provided with an additional input port for insertion of a reference signal $F_R = F_0/M$. When M = 1, the structure is termed an injection-locked amplifier (ILA). When an ILO is used as a multiplier, the reference frequency is injected into the oscillator feedback loop with sufficient amplitude to reset the ϕ_n terms between input cycles, and the ILO output effectively consists only of $F_0 = MF_R$. Numerous papers describe the design and adjustment of ILOs.¹

The multiplier input signal at F₁ is nominally a square wave from a CMOS or equivalent logic buffer used as a low impedance voltage source. Since the duty cycle of most system reference clocks is close to 50 percent, this value is used in the analysis. The DC component of the clock signal is blocked, and R₂ allows forward bias of Q₁ only during the negative-going half of the reference cycle. No general significance is claimed for the choice of the collector for the grounded terminal of Q₁. At the operating frequency used in the original design, this configuration required a smaller load admittance transformation ratio than alternate topologies evaluated.

The initial design procedure parallels that of any one-port oscillator. The circuit elements are adjusted to meet the minimum requirements for oscillation at F_Ω as

$$mag[\Gamma_D] = \frac{1}{mag[\Gamma_L]}$$
 (1)

$$ang[\Gamma_D] = -ang[\Gamma_L]$$
 (2)

where Γ_D and Γ_L represent the reflection coefficients of the oscillator and load, respectively.

Next, the effects of the active and passive component variations within the oscillator and load are examined to verify that no reasonable combination of Γ_D and Γ_L near F_O violates the Kurokava criteria for steady-state oscillator stability. 45 These criteria are sufficient but not necessary for steady-state stability at a specific frequency and power level. When Γ_D can be accurately represented as impedance $R_D \pm j X_D$ (series resonant oscillator), the first criterion is

$$\left\lceil \frac{\delta X_{L}(\omega)}{\delta \omega} \bullet \frac{\delta R_{D}(A)}{\delta A} - \frac{\delta R_{L}(\omega)}{\delta \omega} \bullet \frac{\delta X_{D}(A)}{\delta A} \right\rceil > 0 \quad (3)$$

Two empirically based simplifying assumptions generally apply:

$$\frac{\delta X_D(A)}{dA} \cong 0$$
 (4)



$$\frac{\delta R_D(A)}{\delta A} > 0$$
 (active device gain compression) (5)

Therefore,

$$\frac{\delta X_L(\omega)}{\delta \omega} \bullet \frac{\delta R_D(A)}{\delta A} > 0$$
 (6)

and

$$\frac{\delta X_L(\omega)}{\delta \omega} > 0$$
 for stable oscillation (7)

When Γ_D can be represented as an admittance $G_D \pm$ iBD, the shunt resonant counterpart of Equation 3 applies such that

$$\left[\frac{\delta G_L(\omega)}{\delta \omega} \bullet \frac{\delta B_D(A)}{\delta A} - \frac{\delta B_L(\omega)}{\delta \omega} \bullet \frac{\delta G_D(A)}{\delta A}\right] < 0$$

The dual versions of the simplifying assumptions in Equations 4 and 5 are

$$\frac{\delta B_D(A)}{\delta A} \cong 0$$

$$\frac{\delta G_D(A)}{\delta A} > 0$$
 (9)

and the admittance form of the result of Equation 7 is

$$\frac{\delta B_L(\omega)}{\delta \omega} > 0$$
 for stable oscillation. (10)

The criterion of Equation 3 is, for example, sufficient to ensure that when an initial operating point [Po(Z1), $F_O(Z_L)$] migrates to a new point $[P_O(Z_{L2}), F_O(Z_{L2})]$ due to a change in load impedance $Z_{1,2}=Z_1+\delta Z$, the oscillator will return to $[P_O(Z_1),F_O(Z_1)]$ when $\delta Z=0$. (For example, the oscillator tuning will not exhibit hysteresis or moding.)

The idealized categorization of an oscillator as essentially series or shunt resonant may affect the choice of load topology. Consider a series resonant oscillator terminated with a shunt resonant load, where

$$\begin{split} Z_D &= R_D + j X_L - j X_C \\ Q_A &= \frac{X_L}{-R_D} \\ &= \frac{X_C}{-R_D} \text{ at } F_O \\ Y_L &= G_L - j B_L + j B_C \end{split}$$

$$Q_{B} = \frac{B_{L}}{-G_{D}}$$

$$= \frac{B_{C}}{-G_{D}} \text{ at } F_{O}$$



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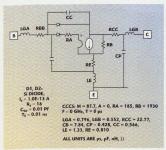


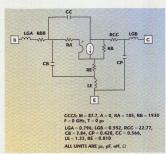
Fig. 2 The BJT nonlinear me	A	A Fig. 3 The BJT		
	TABL	.E I		
MOD	EL'S SMALL-SIGN	IAL S PARAMET	TERS	
mag[Skk] RMS error	0.0505	0.0141	0.1280	0.0731
ang[Skk] RMS error (°)	7.36	2.83	20.20	13.30
Frequency range for S-param			1 GHz steps	

mag[S14] error = ((model mag[S14] - measured mag[S14])/measured mag[S14])2

Now Y_U is defined as the admittance of the previously described network, measured at the shunt end, with only Gr removed. It is easy to verify that for arbitrarily closely spaced frequencies F_1 and F_2 , Q_A and Q_B ($Q_A > Q_B$) can be determined such that $Y_{UF1} = Y_{UF2}$; that is, oscillation is possible on both frequencies. When QA < QB, the slope of $\delta B_U(\omega)/\delta \omega$ is dominated by the shunt elements and no frequency ambiguity exists. If the above exercise is repeated with a shunt resonant oscillator terminated with a series resonant load, where Z_U is the impedance looking into the load end with R_L removed and Q_A and Q_B are as previously defined, then frequency ambiguity exists for QB > QA, and conversely. An example of a series topology oscillator incorrectly terminated with a shunt resonant load (and its resulting undesirable tuning behavior) is provided by Hamilton.6

 $ang[S_{kk}]$ error = (model ang[S_{kk}] - measured ang[S_{kk}]

The following design procedure is for a multiplier currently used in volume production for equipment qualified over the -40° to +65°C environment. For this design, F_R = 72 MHz, N = 20 and $P_O \ge -15$ dBm at $F_O = 1440$ MHz, and the nominal current demand is 6 mA at +5 V. In the end application, an inexpensive surface acoustic wave (SAW) bandpass filter was used to suppress the N ≤ 19 and $N \ge 21$ harmonics. The SAW filter port impedance Z_L is poorly defined outside of a narrow bandwidth centered on the desired N = 20 harmonic.



linear model.

Since the Spice parameters of the MMBR901 bipolar junction transistor (BIT) were not readily available, a modified hybrid-pi bipolar model,3 shown in Figure 2, was created. In this model, both D1 and D2 are ideal Si diodes with negligible junction capacitance. With both the base resistance and the dynamic resistance of D1 replaced by RA, element optimization is used to force the model's small-signal S parameters to match the published device S parameters to an accuracy sufficient for the

time domain simulation. Figure 3 shows the BIT's linear model. The model's small-signal S parameters are listed in Table I

With C_4 omitted, Γ_D is quite accurately represented by a shunt topology. A one-port Touchstone linear analysis of the multiplier circuit verified that Re[YD] > 0 from 100 MHz to 10 GHz (excluding the operating band) and $Re[Y_D] + Re[Y_L] < 0$ within the operating band (1440 ± 100 MHz) after optimization of TLIN, C5, C4 and C3. As with any active circuit, failure to verify that potentially unstable regions are confined to the desired frequency band creates a risk of spurious signal generation. Although the decision to insert C₄ at this port appears to be a violation of the criterion in Equation 10, the specific broadband input impedance of the SAW filter transformed through C4 was sufficiently close to the required shunt topology Γ that stability was ensured.

Next, the multiplier is modeled using a time domain simulator (such as PSpice) to verify output level, biasing and drive margin. The negative-going transition of Vs at the start of the on period defines the initial amplitude and phase offset terms A_n and ϕ_n for the sinusoidal burst. During the off period, Q1 is inactive and undesired contributions to the stationary values of ϕ_n are minimized to the extent that the harmonic amplitudes An decay to negligible levels between reference cycles. The net series impedance of C2, R2 and L2 is made large enough that the

[Continued on page 75] MICROWAVE TOURNAL # OCTORER 2000

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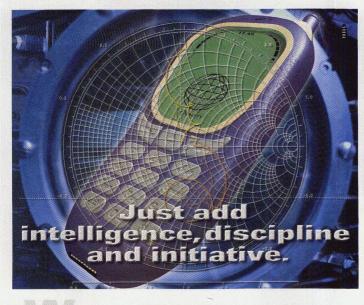


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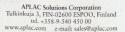
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effect on Z_0 is negligible, C_2 and B_3 are adjusted so that the average current through Q_1 does not exceed the desired supply limit and the combination of C_2 and L_2 determines the RF pulse width. Small changes (20 percent or less) in the duty cycle have very little effect on output power. For the fractional pulse width ratio T_{pw} used (0.27), the multiplier output spectrum is wide enough that no tuning or selection of TLIN or C_3 is required. Some suggested limiting values of remaining components are listed in Table 2 cell Table 2 c

Figure 4 shows the output of a PSpice simulation for the 1440 MHz multiplier using the nonlinear BJT model. For practical cases, modeling the output burst envelope as a damped exponential function is consistent with both time domain simulations and physical measurements. Equations 11 to 21 and Figure 5 define the parameters used in the Fourier representations of both the baseband and RF

	ABLE II
MILITIDITED	COMPONENT VALUES

R_2	$V_{dd}/(4I_{PEAK})$
R ₃	$V_{dd}\beta T_{PEAK}$
L_3	$L_3 \ge 5R_2/(2\pi F_R)$
C_2	$C_2 \ge 4T_{PW}I_{PEAK}/V_{dd}$
L ₂	$L_2 \leq R_2/(2\pi F_R)$
L ₃	$L_3 \ge 5Z_D/(2\pi F_R)$
C ₅ , TLIN	$F_{\alpha} \cong 1/2\pi \sqrt{C_5 Z_0 \tan \theta/2\pi F_c}$

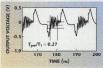


Fig. 4 PSpice simulation of the 1440 MHz multipler using the nonlinear model.

Fig. 5 Parameters used in the exponential envelope function.

$$V_{max} \stackrel{|\leftarrow T_1|}{=} 1/(repetition \ rate)$$

$$V_{max/2} \stackrel{|\leftarrow T_1|}{=} t \stackrel{\rightarrow}{\to} t$$

$$t \stackrel{\rightarrow}{\to} |\leftarrow T_d|$$

burst exponential function. If the availtime domain simulator has discrete Fourier transform capability, the spectral output amplitudes can be evalated directly. If not, the amplitude and width of the RF output pulse envelope can be visually estimated and Equations 11 to 21 applied to obtain the harmonic amplitudes.

$T_{pw}/T_1 = \beta \cdot 2.4464 =$	
pulse width ratio at Vmax/2	(11)

 $\beta = \text{Tpw/}(T_1 \bullet 2.4464)$ (12) Baseband pulse: Vmax = $1/(2 \bullet \beta \bullet \exp(1))$

Burst pulse:

 $X_{m} = m \cdot 2 \cdot \pi \cdot \beta \qquad (14)$ $Mag_{m} = 1/(1 + (X_{m})^{2}) \qquad (15)$

 $Ang_m = 2 \bullet ATAN2(1,X_m)$ (16)

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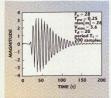
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A Fig. 6 An example of the burst

$$BQ_m = Mag_m \bullet sin(Ang_m)$$

 $m = 1, 2, ..., P, Fo > P$

where Fo is in units of cycles per T1 period
and
$$t \le T_1$$
.

Exponential burst waveform amplitude =

 $\sum BI_m \bullet \cos((t - T_d) \bullet (Fo + m) \bullet 2\pi/T_1)$

$$+ \sum \! \mathrm{BI}_{\mathrm{m}} \bullet \cos((t-T_{\mathrm{d}}) \bullet (\mathrm{Fo}-\mathrm{m}) \bullet 2\pi/T_{\mathrm{1}})$$

$$-\Sigma BQ_m \bullet \sin((t - T_d) \bullet (Fo - m) \bullet 2\pi/T_1)$$

$$+\Sigma BQ_m \bullet \sin((t-T_d) \bullet (Fo+m) \bullet 2\pi/T_1)$$

$$+1.0 \cdot \cos((t-T_d) \cdot \text{Fo} \cdot 2\pi/T_1)$$

$$0.5 + \Sigma BI_m \bullet \cos((t - T_d) \bullet m \bullet 2\pi/T_1)$$

$$+\Sigma BQ_m \bullet \sin((t - Td) \bullet m \bullet 2\pi/T_1)$$
 (20)

The scaling constant 2.4464 in the fractional pulse width expression is the difference between the two t parameter values for which the pulse amplitude is half the maximum value such that

$$\begin{array}{l} 0.500 \!=\! [\exp(1)t_1 \bullet \exp(-t_1)] \\ =\! [\exp(1)t_2 \bullet \exp(-t_2)] \end{array}$$

where

$$t_2 = 2.67834...$$

 $t_1 = 0.23196...$

and

$$t_2 - t_1 = 2.4464..$$

Assuming $R_I = 50 \Omega$, the power levels of the $\pm m^{th}$ sidebands are then computed directly as

$$P(dBm) = 10log_{10}(1000^{\circ}(Vpeak/Vmax)^{2} \bullet (BI_{m}^{2} + BQ_{m}^{2})/(50^{\circ}2))$$
 (21)

where Vpeak = 0.5 • (the measured or simulated peak-topeak RF output magnitude) and Vmax is defined by Equation 13

Note that Equations 11 to 21 are listed in a format that is directly insertable into a spreadsheet such as Excel. An example of the burst waveform is shown in Figure 6.

Fig. 7 Measured vs. simulated output spectrum.

(18)

(19)



Both the calculated spectrum of the time domain simulation and the measured spectrum are plotted in Figure 7. The measured spectrum includes both the active multiplier contribution and the harmonics due to the square wave reference waveform coupled directly through C2, C4, Lo and Ro.

The phase noise of the above multiplier was evaluated by comparing its performance with that of a 1440 MHz brute force multiplier utilizing limiting diodes and gain stages. Both multipliers were driven by the same 72 MHz phase-locked crystal oscillator reference source; no significant difference between the output phase noise spectra of the two multipliers was observed. The sideband levels measured for both multipliers are listed in Table 3.

A direct frequency multiplier has been described that is suitable for high order, low power multiplier applications. A modified model using PSpice was used to optimize the required circuit component values and analyze the multiplier's performance. The resulting multiplier's phase noise performance compared favorably with a brute force multiplier at 1440 MHz.

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SOLR CALIBRATION FOR GROUNDED COPLANAR WAVEGUIDE LINES

This article examines short-open-line-reciprocal (SOLR) calibration of grounded coplanar waveguide (GCPW) lines. The calibration is made possible by using the WinCalTM software. The standards used for the calibration, including a knee type of discontinuity, were measured and the results are described. The measured standards are shown after the calibration process, and a measured 90° bend is compared with predictions made by the SonnetTM EM simulator. The results confirm that SOLR is a valid calibration procedure.

¬ he first step in any vector network analyzer (VNA) probe measurement is the L calibration process. There are several well-known methods to calibrate the instrument to the tip of the probes or to some reference plane away from the probes. Calibration types such as thru, reflect, line (TRL); short, open, load, thru (SOLT); and line, reflect, match (LRM) have proved to be accurate and relatively easy to perform, but with one common restriction: The probes must be in line. The SOLR calibration makes no assumptions about the transmission standard used other than that it must be reciprocal $(S_{12} = S_{21})$. A significant advantage of this permutation of the SOLT calibration is that it is applicable to orthogonal probing systems where the thru standard is difficult to implement. In an orthogonal probing environment, a transmission line with a 90° bend suffices for the reciprocal standard. The SOLR technique was suggested by Ferrero¹ and has been implemented in Cascade Microtech's WinCal software.² Basu and Hayden³ provide a good overview of the basics of this technique.

This article presents an effort to achieve an acceptable SOLR calibration on GCPW lines using the WinCal software. Some basic theory is given for those individuals interested in the concepts behind the SOLR method, and the definitive process of standard definitions is described. After each calibration process, the standards were measured and examined to explore calibration accuracy.

[Continued on page 80]

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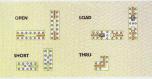
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Model	(GHz)	(V)	(mA)		(dBm)		Resistance ("CW)
NGA-186	0.1-6.0		50.0	12.6	14.6	32.9	120
NGA-286	0.1-6.0	4.0	50.0	15.5	15.2	32.0	120
NGA-388	0.1-5.0	1240	35.0	20.8	14.5	25.8	22212124
NGA-486	0.1-6.0	5.0	80.0	14.8	18.3	39.5	118
NGA-586	20.1-6.0	5.0	80.0	19.9	18.9	39.6	11111251111
NGA-686	0.1-6.0	5.9	80.0	11.8	19.5	37.5	121

Data at 1 GHz and is typical of device performance.



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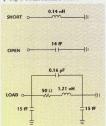


▲ Fig. 1 GCPW SOLR calibration standards.

Fig. 2 The GCPW line's (a) characteristic impedance and (b) effective dielectric constant.



W Fig. 3 SOLR standard models.



CALIBRATION STANDARDS STRUCTURES

The calibration standards structures used in this research (and shown in Figure 1) are the same as those previously presented by the authors. ⁴ The four standards are GCPW

lines fabricated on an FR-4 substrate with an effective dielectric constant of 2.57 and a characteristic impedance of 92 Ω. The actual characteristic impedance of the lines was measured using MultiCal™ and Cap™ software by NIST and is shown in Figure 2.5 Those results showed a good comparison to predictions made using Lineadc™ software.⁶

One of the important issues of SOLR calibration using the WinCal software is to know exactly the capacitance introduced by the open standard, the inductance introduced by the short standard and the inductance introduced by the load standard. The models utilized for the three standards are shown in Figure 3. The model element values were found through optimization to data measured using a reliable TRL calibration. The optimization process was accomplished using ESS Series IV⁶ and the results are shown in Figures 4, 5 and 6.

RESULTS

The calibration parameters were computed and downloaded to a Wiltron 360 VNA using WinCal, and the various standards were re-measured, this time with SOLR calibration. The calibration process was repeated a number of times until the results were consistent. No two calibrations can ever be identical due to repeatability errors, noise and drift in the system, but the results appeared to be consistent and reliable.

The best way to examine the validity of a calibration is to measure the same device under test using an additional calibration method and compare the results. Since special structures that are required for any additional calibration methods were not available, an alternative way to check the validity of the SOLR calibration is simply to observe the results and examine them with regard to the ex-



Fig. 4 Phase comparisons for the open standard.

Fig. 5 Phase comparisons for the short standard.

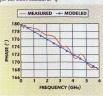
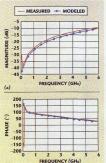
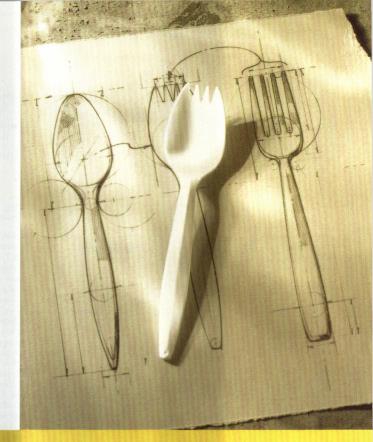


Fig. 6 Magnitude and phase comparisons for the load standard.



pected/calculated values. This way it can be determined if the calibration is fairly accurate, but not how accurate it is compared to any other method.

[Continued on page 82]





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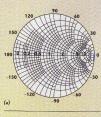
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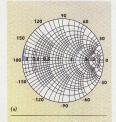


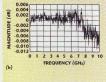
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▲ Fig. 7 The open standard's S₁₁ measurement.





▲ Fig. 8 The short standard's S₁₁ measurement.



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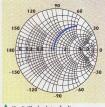
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▲ Fig. 9 The load standard's S₁₁ measurement.

First, by looking at the measured open standard data, as shown in Figure 7, it can be seen that the reflected signal is less than 20,005 dB with a phase of less than 5°; compared to an ideal case of 0 dB/0°. The same trend is observed when the short standard is examined. Figure 8 shows that the reflected signal is less than 20,011 dB with a phase of 12°. The results are not as good as in the case of the open; the phase seems to be somewhat higher than expected, but is still in an acceptable range.

Next, the load standard is examined. Looking at the Smith chart representing S₁₁ of the load, as shown in Figure 9, it is clear that the load resembles a 50 Ω resistor with a parasitic series inductance. By selecting a single set of measured data from the load, with a known frequency and the normalized imaginary value, it is possible to calculate the value of the parasitic inductance such that

f = frequency at sampled data point = 10 GHz

Load impedance at sampled data point:

Resistor = $50 (1.00756 + j1.52283) \Omega$ = $50.378 + j76.141 \Omega$ (unnormalized)

 $jX = j\omega L (\omega = 2\pi f)$

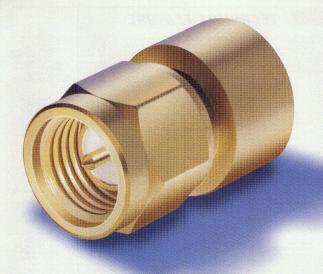
where

X = Im(resistor)

 $L = \frac{X}{\Omega}$ \Rightarrow L = 1.212 nH

Note that the measured resistance of the load is $50.378~\Omega$ compared to $50.4~\Omega$, which was measured directly on the resistor using an ohmmeter.

[Continued on page 84]



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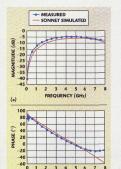


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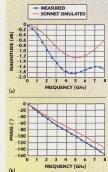
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▲ Fig. 10 S₁₁ of a knee structure.





Furthermore, the measured reactance is 1.212 nH compared to 1.210 nH, the value of the series inductance used in the load's model. The model for the load was based on a TRL measurement and an optimization process; the fact that both reactances agree increases the confidence in the SOLR calibration.

Perhaps the most interesting results are those shown in Figures 10 and 11.

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Using the Sonnet Suite EM simulator,7 the knee type of the previously shown structure was simulated. The same knee was measured with the SOLR calibration and compared to the simulated results. The S₁₁ results are in a good agreement through 6 GHz, with some noticeable phase deviation above that. The S21 results show tracking in shape through the same frequency; however, there is more loss in the measured data. It is surmised that the loss is due to radiation and conductor losses that were not accounted for in the EM simulation.

CONCLUSION

The measurement results show that a good SOLR calibration using GCPW lines is feasible. Orthogonal on-wafer measurements were successfully completed with an SOLR right-angle calibration. The use of a bend in the orthogonal calibration does not appear to cause significant error. In the case where WinCal is used for the SOLR computation, an important step is to make sure that accurate models for the standards are in hand; otherwise, the calibration will not succeed. It is crucial to make sure that the optimized standard models rely on an accurate reference calibration to guide the process.

ACKNOWLEDGMENT

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EFFECTS OF A DRIVER'S ACLR ON TOTAL ACLR

The effects of a driver's adjacent-channel leakage ratio (ACLR) on the total ACLR have been tested to investigate the relationship between the ACLR of a driver and a device under test (DUT). The ACLR test results show that the degradation in ACLR is 4.1 to 4.5 dB when both ACLR values are the same. If the difference in ACLR calues between a source and a DUT is 12 to 12.5 dB, then there is no degradation in total ACLR.

The capacity of a CDMA system is determined in part by system noise and interference. The system performances are linked to adjacent-channel interference ratio (ACIR) values. ACIR is defined as the ratio of the total power transmitted from a source to the total interference power affecting a victim receiver, resulting from both transmitter and receiver imperfections. The imperfections of the receiver and transmitter are adjacentchannel selectivity (ACS) and ACLR, respectively. ACS is a measure of a receiver's ability to receive a signal at its assigned channel frequency in the presence of a modulated signal in the adjacent channel. Therefore, ACS is the ratio of the receiver filter attenuation on the assigned channel frequency to the receiver filter attenuation on the adjacent-channel frequency. ACLR determines how much the transmitted power is allowed to leak into the first and second neighboring carriers. If the ACLR is low, the efficiency of the spectrum and the capacity of the system are decreased.

All transmitters contain nonlinear components, such as amplifiers and mixers. The output signals of a transmitter consist of amplified input signals and distortion signals caused by the nonlinear characteristics of components in the transmitter. Distortion signals generated in nonlinear components are called intermodulation distortion (IMD). ACLR didintermodulation distortion (IMD). rectly relates to the linearity of a transmitter. Even though the linearity of a transmitter is high, if the purity of the input signal of the transmitter is low, the purity of the output signal of the transmitter becomes low. In this article, the effects of an input signal & ALCR on the ACLR of the output signal of a transmitter are presented. ACLR test results show how the ACLR of the output signals of an amplifier can be determined by the ACLR of the input signal and amplifier.

The linearity of an amplifier for analog transmitting systems is sufficiently representated as IMD and measured with a two-tone IMD test. However, the real signal in a digital mobile system has a different cumulative distribution function from that of tone signals. Therefore, the linearity of an amplifier for a digital mobile system should be tested using an actual signal generated from the signal source for the digital mobile system or the

[Continued on page 89]

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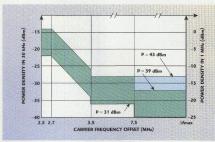
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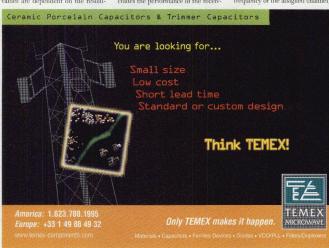
▲ Fig. 1 Base station output power spectrum mask.

transmitter of the digital mobile system in order to exactly measure the linearity.

Recently, the adjacent-channel power ratio (ACPR) of a transmitter has been used for describing the linearity of the transmitter in a digital mobile system. The measured ACPR values are dependent on the resolution bandwidth. Therefore, ACPR is a meaningful value only with regard to resolution bandwidth (RBW). ACPR does not represent the real power leaked into adjacent channels because it does not include the performance of the receiving filter of a victim receiver. However, ACLR includes the performance of the receiving filter of a victim receiver. Therefore, ACLR is used for describing the linearity of a transmitter in the Thirdgeneration Partnership Project (3GPP) specifications.

Figure 1 shows the spectrum mask of a transmitter, described in the 3GPP specification, according to the output power of the transmitter. The simulation results that compare the ACLR measurement using a raised-root cosine (RRC) filter with a 0.22 rolloff factor (with the ACPR measurement using a 30 kHz RBW) show that the difference between each measurement is 5.6 dB for a 5 MHz offset and 1.52 dB for a 10 MHz offset. Therefore, the ACLR measurement is performed with a proper instrument equipped with an RRC filter with a 0.22 rolloff factor.

The ACLR requirements of a base station described in the 3GPP specifications are 45 dB for ACLR1 (measured at ±5 MHz offset from the center frequency of the assigned channel) and 50 dB for ACLR2 (measured at ±10 MHz offset from the center frequency of the assigned channel).



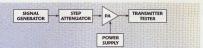


Fig. 2 Block diagram for ACLR testing.

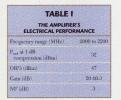
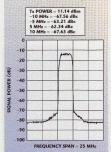


Fig. 3 The W-CDMA signal used for testing the amplifier's ACLR.



The ACLR requirements are derived from the ACIR, causing a one percent capacity loss in the system.³ However, ACLR2 has less of an effect on system performance than ACLR1; therefore, this work focuses on the relationship between the driver's and the DUT's ACLR1.

The high power amplifier mainly determines the linearity of a transmitter. The ACLR specifications described in 3CPP require a linear power amplifier. Even though a linear power amplifier has high ACLR, the ACLR of the input signal of the linear power amplifier is low, thus the ACLR of the output signal of the linear power amplifier is low, thus the

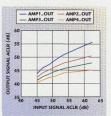
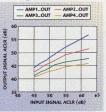


Fig. 4 ACLR1 at the amplifier's output port at +5 MHz offset.

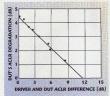
Fig. 5 ACLR1 at the amplifier's output port at −5 MHz offset. ▼



ear amplifier also becomes low. Therefore, the effect of the transmitter's input signal ALCR on the output signals ACLR must be considered to implement the transmitter. In addition, it must be determined that the required ACLR of a signal generator does not affect the ACLR of the amplifier in testing the ACLR of a power amplifier.

TEST RESULTS

Figure 2 shows the block diagram for the ACLR test. The signal generator and transmitter tester meet the requirements of 3GPP specifications. The electrical performance of the amplifier used in the ACLR test is listed in Table 1.



▲ Fig. 6 ACLR degradation as a function of the difference between an input signal and an amplifier's ACLR (input ACLR > amplifier ACLR).

Figure 3 shows the spectrum of the wideband CDMA (W-CDMA) signal used for the amplifier's ACLR test. ACLR1 of the signal is 62.34 dB for +5 MHz offset and 63.21 dB for -5 MHz offset. Figures 4 and 5 show ACLR1 values at the output port of the amplifier with respect to the ACLR value of the input signal and amplifier at ±5 MHz offset, respectively. In general, the nonlinear characteristics of components are not symmetric to the center frequency of output signals in the spectrum domain. Therefore, measurements of the nonlinear characteristics are performed at low and high frequency offsets from the center frequency of output signals. The amplifier's ACLR1 is controlled by adjusting the bias voltage of the amplifier. The controlled ACLR1 value of the amplifier for 5 MHz offset is 55.67, 50.55, 47.95 and 45.10 dB, respectively. In the case where the amplifier's ACLR1 is 55.67 dB, the ACLR1 of the input signal must be 47 dB above to meet the 45 dB ACLR1 requirement. If the amplifier's ACLR1 is 47.95 dB, then the ACLR1 of the input signal must be 51 dB above to keep the ACLR1 requirement in 3GPP. The controlled ACLR1 amplifier values for -5 MHz offset are 56.55, 51.50, 48.45 and 45.72 dB, respectively.

The degradation in ACLR1 according to the difference between the ACLR1 of the input signal and the amplifier is presented. The data are obtained using the ACLR1 values given in the previous two plots. Figure 6 shows the degradation in the amplifier's ACLR1 when the ACCLR1 of the

[Continued on page 92]

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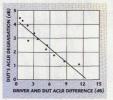
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A Fig. 7 ACLR degradation as a function of the difference between an input signal and an amplifier's ACLR (amplifier ACLR > input ACLR).

input signal is better than the ACLR1 of the amplifier; Figure 7 shows the case where the input signal is less than the ACLR1 of the amplifier. In general, the ACLR of the input signal is better than that of the amplifier. The degradation from the amplifier's ACLRI is = 4.5 dB when both ACLR1 values are the same. If the ACLR1 of the input signal is 12 dB above or better than the ACLR1 of the amplifier, then there is no degradation in the amplifier's ACLR. Therefore, the ACLR1 requirement of a signal generator used to measure the ACLRI of an amplifier is approximately 12 dB greater than the ACLR1 of the amplifier. The data show the degradation in the input signal's ACLR1 when the ACLR1 of the amplifier is better than that of the input signal. In this case, the degradation in the signal's ACLR is approximately 4.1 dB when the ACLR1 of the input signal is the same as that of the amplifier. If the ACLR1 of the amplifier is 12.5 dB greater than that of the input signal, then there is no degradation from the ACLR1 of the input signal. Thus, how much the ACLR degradation occurs in transmitters or amplifiers can be predicted.

CONCLUSION

The effects of the ACLR characteristics of a driver and amplifier on total ACLR have been tested. The ACLR test results show that the degradation in ACLR1 is 4.1 to 4.5 dB when the ACLR of the input signal is the same as that of an amplifier. If the ACLR1 of the input signal is 12 to 12.5 dB greater than that of an amplifier, then the total ACLR1 is the same as that of the amplifier. Therefore, to measure the ACLR1 of an amplifier, a signal source that has an ACLR 12 to 12.5 dB higher than that of the amplifier must be used. Test results presented in this article are useful for determining the required ACLR specification of base station transmitters that compose a baseband modulator, frequency upconverter and power amplifier to meet 3GPP ACLR requirements. These ACLR test results also can be useful for user equipment.

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department at the Chungnam National University in Korea. His research interests are in the area of high frequency circuit design for mobile communication

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ASYMPTOTIC BEHAVIOR OF COSINE WINDOWS

The asymptotic behavior of the even-cosine series windows presented here reveals that the series has an asymptotic decay 6 dB/octave higher than the odd-cosine series. The coefficients of the series are determined for the condition of maximum asymptotic decay, and the frequency response plots of the series are given.

t is well known that an ideal rectangular bandpass filter requires an impulse response of infinite duration, which is unrealizable in practice. Truncating this infinite impulse response after a certain time duration results in undesirable ripples (known as Gibb's ripples) in the passband and stopband. Windows (finite even time functions), when multiplied with the infinite impulse response of the ideal rectangular filter, tend to smooth the Gibb's ripples in the frequency response; however, this improvement is at the cost of widening the transition width. A window is characterized in the frequency domain in terms of its mainlobe width, peak sidelobe response and asymptotic decay. The widely used window functions are the Dolph-Chebyshev window, kaiser window. Gaussian window and cosine windows. An exhaustive discussion on windows has been provided by Harris1 and Nuttall.2

The cosine windows comprise a wide range of window functions, including the Hanning, Hamming and Blackman windows, the cosine temporal weightings, and the odd- and evencosine series. Nuttall discusses the criteria for maximizing asymptotic decay and minimizing the sidelobe peaks, along with the trade-off in achieving one characteristic at the expense of the other. The odd-cosine series functions presented by Malocha and Bishop³ are the same as the cosine temporal weightings, with the coefficients of the series determined by minimizing the sidelobe peaks. The

coefficients of the even- and odd-cosine series functions are further refined in Kulkarni and Lahiri⁴ to obtain improved sidelobes. The even- and odd-cosine series have an even and odd number of kernels in their respective frequency responses as described by Malocha and Bishop.³

This article presents the asymptotic behavior of the even-cosine series and compares in with that of the odd-cosine series. The findings reveal that the even-cosine series has a 6 dB/octave higher asymptotic decay of the side-lobes than the odd-cosine series.

ASYMPTOTIC BEHAVIOR WHEN DECAY IS MAXIMIZED

The asymptotic behavior of the odd-cosine series (or the cosine temporal weightings) has been explained in past literature.² The asymptotic behavior of the even-cosine series has not been discussed previously and is presented here. For this purpose, the even-cosine series is expressed in the time and frequency domains as ⁴

$$h_{N2}\!\left(t\right)\!=\!\sum_{n=0}^{N-1}\!b_n\,\cos\!\left[\frac{\left(2n+1\right)\!\pi t}{T}\right]\!,\,\left|t\right|\!\leq\!\frac{T}{2}\quad\left(1\right)$$

[Continued on page 98]

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$$H_{N2}(f) = \frac{T}{2} \sum_{n=0}^{N-1} b_n \left[\frac{\sin \left(\pi f T - \frac{\left(2n+1 \right) \pi}{2} \right)}{\left(\pi f T - \frac{\left(2n+1 \right) \pi}{2} \right)} + \frac{\sin \left(\pi f T + \frac{\left(2n+1 \right) \pi}{2} \right)}{\left(\pi f T + \frac{\left(2n+1 \right) \pi}{2} \right)} \right] \tag{2}$$

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PHONE: 888-FONEJSM FAX: 407-831-0087 where the time domain function, h_{N2} , exists only in the interval from -T/2 to T/2. The coefficients b_n are real and positive and are determined by the criteria applied on the sidelobes of the frequency function H_{N2} .

The function H_{N2} is rearranged in a convenient form for this discussion as

$$H_{N2}(f) = \left[\frac{\cos(\pi f T)}{2\pi T f^2}\right]$$

•
$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1)$$

$$\bullet \left[1 + \frac{\left(2n+1\right)^2}{4T^2f^2} + \frac{\left(2n+1\right)^4}{16T^4f^4} + \dots\right] (3)$$

after recognizing that the term $[1-((2n+1)^2/4T^2f^2]]^{-1}$ has been expressed in a power series. Note from Equation 3 that when the first term in the series is not equal to zero such that

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) \neq 0$$

the function decays as 1/f², resulting in a 12 dB/octave decay. Note that the minimum asymptotic decay that can be obtained with the even-cosine series is 12 dB/octave; for cosine temporal weightings² it is 6 dB/octave. However, if

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) = 0$$
 (4)

and if the second term (numerator part) is non-zero such that

$$\sum_{n=0}^{N-1} \left(-1\right)^{n+1} b_n \left(2n+1\right)^3 \neq 0$$

the function will decay as $1/f^2$, giving a 24 dB/octave decay. In the same way, if the first two terms in the power series vanish such that

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) = 0$$

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1)^3 = 0 \quad (5)$$

and the third term is not equal to

[Continued on page 102]

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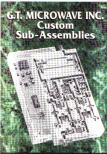
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TECHNICAL NOTE

TABLE I

AND DESCRIPTION OF THE PARTY OF	Note to Beauty Beauty Bloom	DD- AIRD L	TEN-COSHIEL.	LINES
Function	Mainlobe Width	Peak Sidelobe (dB)	Asymptotic Decay (dB/Octave)	Coefficients
Odd Serie:				
Н11	±1/T	-13.0	-6	ì
H ₂₁	±2/T	-31.5	-18	1,1
H ₃₁	±3/T	-46.7	-30	1, 4/3, 1/3
H41	±4/T	-60.9	-42	1, 3/2, 3/5, 1/10
Even Serie				
H ₁₂	±1.5/T	-23.0	-12	1
H ₂₂	±2.5/T	-39.3	-24	1, 1/3
H ₃₂	±3.5/T	-53.1	-36	1, 1/2, 1/10
H ₄₂	±4.5/T	-67.8	-48	1, 3/5, 1/5, 1/35

PARAMETERS RESULTING FROM MAXIMIZING ASYMPTOTIC DECAY OF ODD- AND EVEN-COSINE SERIES

zero, as in

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1)^5 \neq 0$$

then the function will decay as 1/f6. resulting in a 36 dB/octave decay.

From the discussion on unique coefficients,4 note that bo = 1 and only b, can be determined, leading to a two-term even-cosine series. From Equation 5, only b1 and b2 can be determined, and a three-term cosine series results. The coefficients of the

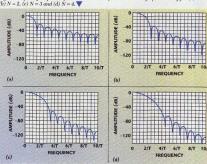
even-cosine series up to four terms are determined and listed in Table 1 along with mainlobe width, peak sidelobe level and asymptotic decay. The frequency domain plots of H₁₂ to H₄₂ are shown in Figure 1. Comparing the asymptotic decays of the evenand odd-cosine series from the table. note that for a given N, the even-cosine series has a 6 dB/octave higher decay of sidelobes than the

odd-cosine series With the condition of maximizing asymptotic decay, the odd- and evencosine series together can be represented by a single expression as

$$h_k(t) = \cos^k\left(\frac{\pi t}{T}\right)$$
 (6)

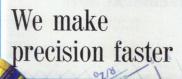
where k assumes integer values. When k is odd, the even-cosine series is obtained; when k is even, the oddcosine series results. The window function given in Equation 6 is called the cosine powered window, or Hanning window.1

Fig. 1 Frequency response of even-cosine series for maximum asymptotic delay for (a) N = 1, (b) N = 2, (c) N = 3 and (d) N = 4.



[Continued on page 104]

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TECHNICAL NOTE

ASYMPTOTIC BEHAVIOR OF SIDELORES WHEN THE SIDELOBE PEAKS **ARE MINIMIZED**

When the condition of minimizing sidelobe peaks is used for determination of coefficients of the even-cosine series, then Equation 4 is not satisfied and the inequality expression governing the coefficients

$$\sum_{n=0}^{N-1} (-1)^{n+1} b_n (2n+1) \neq 0$$

prevails. The coefficients bn are given in the literature.4 With these coefficients the asymptot-

> ic decay achievable is 12 dB/octave. However, for the criteria of minimizing sidelobe peaks, the odd-cosine series presents a 6 dB/octave decay of the sidelobes.2 Thus. the even-cosine series has a 6 dB/octave higher decay of the sidelobes when compared with the odd-cosine series. Table 2 lists various parameters along with the asymptotic decay of the sidelobes for an even

and odd-cosine series for the condition of minimizing sidelobe peaks. The values of peak sidelobes are obtained using the results in the literature.4

CONCLUSION

The asymptotic behavior of an even-cosine series has been presented and compared with the odd-cosine series. It was found that the even-cosine series has a 6 dB/octave higher asymptotic decay than the odd-cosine series. The coefficients of the series were determined for the condition of maximum asymptotic decay. The frequency responses of the series up to the fourth order were also shown.

ACKNOWLEDGMENT

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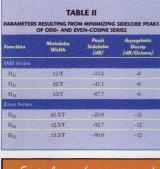
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Institute of Technology

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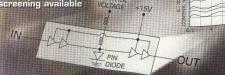
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AVG5-0	4000800-12	4-8	30	±1.00	1.2	2.0:1	+10	150
AVG5-0	0101800-35	.1-18	24	±2.50	3.5*	2.5:1	+10	175
AVG6 0	0102000 45	1-20	24	±2.50	4.5	2.5:1	+10	250
AVG4-0	6001200-19	6-12	24	±1.50	1.9	2.0:1	+10	175
AVG4-0	6001800-25	6-18	22	±2.00	2.5	2.3:1	+10	185
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TECHNICAL NOTE



DISTORTIONS IN CASCADED MMIC POWER AMPLIFIERS

This article presents an experimental investigation of the influence of a second harmonic phase delay between two cascaded GaAs MESFET MMIC power amplifiers (PA) on the total distortion characteristic. Two-tone intermodulation distortion (IMD) products may vary by several decibels through the saturation region, depending on the value of the series feedback source inductance used in both stages. In addition, an improvement of several decibels in ACPR values at moderate output power levels for digitally modulated standards may be reached with the proper choice of a phase delay.

any methods exist for the linearization of RF/microwave PAs.¹⁻⁴ In most cases, these methods are applicable to high power amplifiers taking into account their cost, size, weight and power consumption. For low- and mid-power portable PAs, these issues can play a decisive role in the choice of the required circuit. Thus, PA circuit-level linearization techniques may be more attractive to achieve low distortion characteristics. ³⁵⁻⁷ It is known that the main source of IMD in a PA is typically the cubic term of the PA transfer characteristic. These distortions may be compensated for by utilizing a second harmonic adjustment.^{3,48}

This goal may be quite easily achieved with discrete components. However, purchased MMIC utilization complicates the task. This article describes a simple way to adjust distortions in a set of cascaded MMIC PAS.

PHASE-DELAYED INTERSTAGE ADJUSTMENT

Figure 1 shows the interstage circuit between cascaded MMIC FET PAs. The only transmission line length in the circuit may be adjusted. It is known⁴ that the PA output signal spectral purity may be improved by careful adjustment of the gain and phase shift of the second harmonic path. For maximum improvement, the power required for the second harmonic should be high enough (7 dB below that of the fundamental in the example⁴). It is also known that the series source inductance can decrease IMD in the PA and simultane-onsy facilitate a low noise amplifier (LNA) in

[Continued on page 108]

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Fig. 1 The analyzed circuit. ▼





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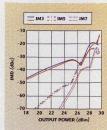


Fig. 2 IMD products for the low inductance circuit.

Fig. 3 The high inductance circuit's (a) gain and (b) IMD products.



put and noise matching condition⁸ with increased in-band stability. Taking these issues into account, it can be concluded that a drive MMIC PA with bad linearity must be utilized and the line length adjusted to achieve the best total distortion characteristics of the complete MMIC set. The power produced by the final stage of the drive PA and the gain of the first stage of the second PA should have sufficient values to achieve this performance.

OUTPUT POWER (dBm)

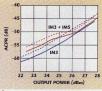


Fig. 4 ACPR for the high inductance circuit.

MEASUREMENT RESULTS

Measurements have been performed for a set of 3.5 GHz GaAs MESFET MMIC PAs to evaluate how much improvement of distortion characteristics may be achieved. The series feedback source inductance in both stages may be varied due to the non-via chip structures used.

First, the minimum possible inductance values were chosen. Figure 2 shows the two-tone extreme intermodulation characteristics resulting from adjustment of the line length over a wide margin. The difference in the line length between extreme values corresponds to a quarter-wavelength at the second harmonic. Accordingly, the amplifier's small-signal, single-tone gain is 42 dB at P1dB = 28.5 dBm and 40.7 dB at P1dB = 29.5 dB. The drain bias voltage is 7 V DC.

Next, both series inductances were increased by two to three times. Both drive and power MMIC PA stages were tuned for the highest linearity by operating as separate stages and tested using wideband 50 Ω input and output transmission lines. These two stages are combined through the variable-length transmission line, and the extreme values of the two-tone gain and IMD for the complete set are shown in Figure 3. Again, the line length corresponds to a quarterwavelength at the second harmonic. The single-tone PldB values are equal to 30.7 dBm for both cases. The input return loss values are better than 14 dB for both stages.

A great difference in characteristics is observed in the two data plots. In the first case, the variation of IMD products is quite small through the entire range of output power. Only a small difference can be observed for high power levels. However, it can be explained by an improvement of matching conditions for the input port of the power stage elevating PIdB. (As a reference, the input return loss value is 5 to 6 dB.) In the second case, the variation of IMD products is perceptibly high at midpower levels with clearly observed sweet spots, 6,7 At power levels close to P1dB and at the saturation region, the variation noted is very small. At some power levels, the IMD product difference reaches 5 to 7 dB. It should be noted that the circuits have different bias conditions. For both cases, the gate voltages were adjusted to achieve a maximum P1dB value.

Mid-power levels are important for operating within digitally modulated communication standards. Figure 4 shows the calculated results of ACPR10 for the 4,096 Mchips wideband CDMA standard. Calculations have been carried out taking into account only the IM3 (solid line) and IM3 + IM5 (dashed line) influence. The statistical drive signal has a logarithmic-normal distribution with a 2 dBm RMS power value (a close approximation of a one-user channel). A 2.5 dB improvement in ACPR value is observed through a wide range of output powers. This value corresponds completely to the gain difference between the extreme cases. For case I, the analysis does not show any difference in ACPR value with the same output power back off. Comparing case 1 and case 2, a larger difference between adjacent IMD products for case 2 and more perceptible sweet spots due to the frequency-dependent negative feedback circuit (out-of-band harmonic termination adjustment^{6,11}) are observed.

The drive stage for the set in case 2 was substituted for the low inductance stage for the set in case 1 (with less linearity). Improvements of 2 to 3 dB for IM3 and 5 to 7 dB for IM5 and IM7 were achieved at wide enough power levels close to saturation. Thus, the proposed MMIC set has perceptibly improved the distortion characteristics and spectral purity for CDMA signals without any additional filtering and amplifying stages for the second harmonic.⁴ Note that no attempt was made to reach the highest linearity by adjust-

[Continued on page 110]

(b)

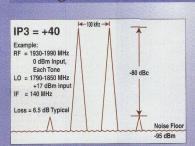
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ing the input and output matching networks. The operation of the complete set is similar to using predistortion.1 By using this approach, it was determined that the first stage of a power MMIC should have fairly low gain to achieve better results. This fact is in contrast to commonly used design rules when the first stage of a multistage PA is usually tuned for high gain.

CONCLUSION

The method of adjustment of the second harmonic phase delay between two cascaded MMIC PA stages has been investigated. It was shown that the choice of a drive stage with bad linearity and a simple inductive feedback circuit at the input of the power stage allows the complete amplifier set to have an ACPR improved by 2 to 3 dB through a wide range of the output power for digitally modulated signals. This approach can be used for portable low cost circuits in different wireless communication systems.

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A DUAL POLARIZATION, PHASE-COMPENSATED WAVEGUIDE BEND SYSTEM

his article describes a waveguide bend system that preserves amplitude and phase for all polarizations over a very wide frequency range. Although the idea for this system appears to be very simple, the author has not seen a description of it published in the microwave literature.

BEND SYSTEM APPLICATIONS

This bend system finds applications in dualor circular-polarized microwave systems where it is important to preserve the relative phase of all field components through the bend system. For example, in a reflector antenna, the bend system can enable the orthomode transducer or polarizer to be located away from the feedhorn. This configuration is an advantage in certain antenna systems. Utilizing this bend system, circular polarization can be propagated with good axial ratio through the system, dual linear polarizations can be propagated with good cross-polarization isolation and complex waveguide runs can be accommodated.

DESIGN DESCRIPTION

A waveguide with a square, circular or quad-ridged cross section is used as the transmission line. A carefully made waveguide of this type can propagate orthogonal linear polarizations with good polarization isolation. Each individual bend is made using this type of transmission line.

The waveguide bend system consists of two identical bends in cascade. The second bend is joined to the first with a straight section of this transmission line and rotated 90° with respect to the plane of the first bend. The individual bend angle can have any value. Figure 1

[Continued on page 114]

(a) (b) (c)

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Fig. 1 Three configurations

of the waveguide bend

sustem.

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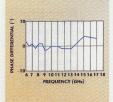


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▲ Fig. 2 Differential phase of orthogonally polarized fields.

shows examples of three waveguide bend configurations.

Each bend creates a differential phase shift between the orthogonal polarized fields. This differential phase shift can reach very large values in practice. The amount of differential phase shift depends strongly on the effective radius of curvature of the swept bend, waveguide dimensions and frequency. This effect can seriously degrade the cross polarization of the microwave system. Therefore, a single bend in which orthogonal polarizations propagate is not used.

The second bend fully compensates for this differential phase shift. This result is due to the 90° rotation of the second bend. (For example, a vertical field undergoes an E-bend and then an H-bend, a horizontal field undergoes an H-bend and then an E-bend.) Therefore, the total differential phase shift for both field components is identical as long as the two bends are identical and this symmetry is preserved.

Moment method analysis of a pair of spine 90° mitered square waveguides demonstrates excellent differential phase shift and amplitude over more than an octave bandwidth, even though the impedance match of each bend is not optimum. Figure 2 shows the phase differential of orthogonally polarized fields vs. frequency for the bend configuration depicted in Figure 1a.

IMPEDANCE MATCHING AND MODING

Although the symmetrical arrangement of the bend pair preserves the differential phase shift, each bend also must be designed to have a good impedance match and to control higher order mode generation. This capability requires swept or mitered benchs using good design practices. If the individual bends are poorly matched or generate higher order modes, amplitude and phase degradation can occur.

POSSIBLE CONFIGURATIONS

This system can enable the waveguider run to change direction in many ways. Possible structures include the use of foru 90° bends with the input on the +2-axis and the output on a translated +2-axis (or -2-axis) (Figure 1b), the use of four bends of any angle for a general rotation of the input on the +2-axis to any other compound output angle and the use of only two bends of any angle with the input on the +2-axis and the output at any compound angle above the x-y plane (Figure 1c).

In the general case of two bends, the planes of linear polarizations will be rotated by the bend angle. A fourbend system can compensate for this polarization rotation. Circular polarization axial ratio, sense and isolation will not be changed by the bend pairs. This effect can be utilized to form a rotational joint.

CONCLUSION

A little-known, but interesting, microwave geometry has been presented, which can be used in dual-polarized or circular-polarized waveguide runs. The waveguide bend system can preserve amplitude and phase for all polarizations over a wide frequency bandwidth.

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Seavey Engineering Associates Inc. in Pembroke, MA. This firm is engaged in commercial antenna development and manufacturing. Seavey holds

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ISM VS. SPREAD SPECTRUM — AVOIDING THE FCC

he Federal Communications Commission (FCC) recognizes two types of devices that intentionally emit RF energy: communications equipment and everything else. The first category includes AM/FM, TV, point-to-point, satellite, cell phones, taxi radios, CB, garage door openers and anything else that uses radio waves to convey intelligence, broadly construed. The everything-else category is properly called industrial, scientific and medical (ISM) equipment. It includes devices used for heating, ionization of gases, mechanical vibration, particle acceleration, hair removal and any other noncommunications application of radio waves. Household examples include microwave ovens, jewelry cleaners and ultrasonic humidifiers. Industrial applications cover a wide range of cooking, heating and ionization devices.

CONTENDING FOR SPECTRUM

Both ISM and radio communications require spectrum, and both obtain if from the FCC. For decades after the FCC opened in 1935, enough bandwidth was available to give exclusive allocations to all who wanted them. Isolating ISM into bands of its own made particular sense, because some ISM equipment generates high power radio noise that otherwise threatens sensitive communications equipment. As communications technologies evolved toward higher frequencies, so too did ISM. Today, 11 distinct ISM bands range from 7 MHz to 245 GHz. ISM equipment can legally operate at any power level in these bands. Indeed, ISM is the only FCC-regulated service having no in-band limits whatsoever (other than RF safety limits). ISM equipment is also permitted to operate outside the designated bands; however, there its RF emissions are limited to relatively low levels.

The demand for spectrum has accelerated, and now far exceeds the supply. During the 1980s, the FCC allocated the last available frequencies below 1 GHz, and since then has filled the gaps up to approximately 40 GHz. Many applications prefer the 0.5 to 5 GHz ange, where antenna size, propagation and cost factors are favorable for communications. When demand continued to mount after all of those frequencies were assigned, the FCC had little choice but to require that services share their spectrum allocations.

One form of sharing has been commonplace for decades. The FCC's Part 15 rules

[Continued on page 118]

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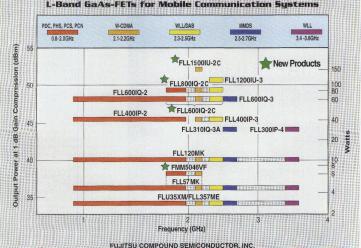
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have long allowed unlicensed communications transmitters to operate at low power throughout the spectrum, except for certain restricted bands. Early examples included garage door openers and remote-comtrol toys and, later, cordless telephones. Traditional Part 15 devices operate at a few microwatts, with a useful range of only a few meters.

The main benefit of Part 15 operation is flexibility. Where licensed users must usually file with the FCC to move or install a transmitter, a Part 15 user simply powers up the equipment. But the flexibility comes at a price. A Part 15 device must accept incoming interference, no matter how severe, from any other service. Moreover, a Part 15 device must shut down if it causes harmful interference to almost any other service. These rules discouraged applications that require any significant reliability

from using Part 15. Licensing was slow and inconvenient, but it bought protection from interference.

SPREAD SPECTRUM ARRIVES

In 1985, the FCC approved spread spectrum modulation under Part 15. A spread spectrum transmitter distributes its signal over more spectrum than it otherwise would need to carry the data payload. Because the spread-out signal puts low average energy onto any one frequency, it causes little interference to other users. In addition, because the receiver is active over a wide bandwidth, it is relatively immune to interference from a conventional narrowband transmitter.

The FCC authorized spread spectrum at the unprecedented (for Part 15) output power of 1 W and put it in the 915, 2450 and 5800 MHz ISM bands. These three bands, sometimes called the "junk bands," would be crowded even without spread spectrum. They are heavily used by ISM, including tens of millions of microwave ovens and industrial devices. All three bands are allocated for amateur use and for conventional Part 15 operations at milliwatt levels. A vehicle location service operates throughout the 915 MHz band. Various parts of the 2450 MHz band are used for local positioning, private land mobile radio and downlinks in the Mobile Satellite Service. The US government has significant radar and military operations in all three bands.

crations in all three bands.

Spread spectrum radio was slow to catch on. The FCC revised the rules in 1990 and again in 1997, each time opening new options for manufacturers. Prices gradually came down, while data rates went up to 2 Mbps. The mid-1990s saw a developing market in niche applications. The picture changed suddenly in 1998, when an FCC rule interpretation pushed data speeds to 11 Mbps. Overnight, spread spectrum became competitive with wire-in-the-wall office local area networks.

Today, approximately \$1.5 B worth of spread spectrum wireless equipment operates in every sector of the economy, including retail, transportation, utilities, manufacturing, health care and finance. Half the transac-

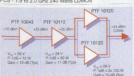




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tions on the New York Stock Exchange are mediated by spread spectrum wireless terminals. Spread spectrum Internet access offers broadband speeds across 40 km distances. In consumer markets, spread spectrum cordless phones are commonplace, and in-home video and audio distribution systems will soon follow. The Bluetooth spread spectrum protocol will be incorporated into most wireless phones, laptops, commost wireless phones, laptops, computer peripherals, personal digital assistants and other consumer devices beginning later this year.

SPREAD SPECTRUM VS. ISM

Although relegated to last priority in the band, spread spectrum designers achieve respectable levels of reliability. Some of the applications listed above demand it. Hospitals, stock exchanges and wireless phone companies (among others) are sophisticated

users who do not knowingly risk service interruptions.

On the other hand, no one can harden a communications receiver against unlimited interference. Equipment designers necessarily make assumptions about the RF environment in which their products will operate. Not unreasonably, Part 15 designers assume an environment populated with devices that comply with the FCC rules. Spread spectrum receivers today are reasonably well insulated against interference from other communications equipment and from existing categories of ISM devices, such as microwave ovens. But they remain potentially vulnerable to interference from new and different kinds of ISM equipment, such as RF lights.

In principle, ISM's priority in the band protects it absolutely against Part 15. However, in practice, the ISM industry has expressed two fears about the growth of Part 15 spread spectrum. First, some are concerned that spread spectrum may acquire enough economic and political power to impose limitations on ISM. Second, some ISM vendors worry that customers may reject ISM products that interfere with spread spectrum operation.

Both concerns are largely hypothetical so far. The only ISM product to date that raises any serious concern among Part 15 interests is RF lighting. Spread spectrum interests fear these lights will operate continuously from positions overhead and emit high levels of RF. Therefore, some manufacturers have asked the FCC to limit emissions from RF lamps. Moreover, one lighting manufacturer has told the FCC that potential customers are avoiding the product because they fear interference into their spread spectrum equipment. Other new ISM applications may raise some of the same issues.



Both ISM and Part 15 will benefit if they can resolve the technical incompatibilities and competitive issues between them. However, they should do it in private, away from the FCC. Part 15 has little to gain at the FCC, whose rules make it unambiguously subordi-

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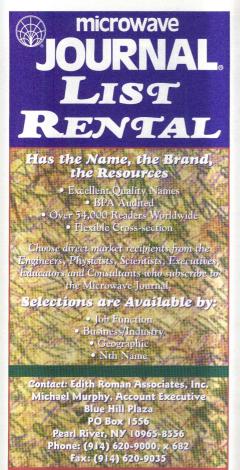
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nate to ISM. No one expects the FCC to regulate any ISM product out of existence, not even RF lights. In addition, the FCC will not listen to Part 15 complaints about interference from existing ISM products that comply with the rules. At most, the FCC might limit new ISM products that pose exceptional interference threats but, even then, it will try to ensure that the products remain commercially viable.

The FCC also will not address ISM's concerns. If customers come to believe they cannot use both ISM and spread spectrum, the FCC will not stop them from choosing spread spectrum. Although Part 15 devices must accept ISM interference, Part 15 customers do not. They are free to eliminate the interference by rejecting ISM products if they think it necessary to protect their communications.

Instead of contending at the FCC, both industries will achieve better results by negotiating directly with each other. Together they can seek standards that permit ISM products to operate properly, as well as provide an RF environment hospitable to spread spectrum operations. If communications engineers can help to set the characteristics of ISM equipment in the vicinity, they can design systems that tolerate the interference well. That in turn will enable ISM vendors to assure customers that their products will not degrade spread spectrum performance. The spread spectrum industry can assist those ISM marketing efforts by certifying suitable ISM devices for compatibility with spread spectrum communications devices.

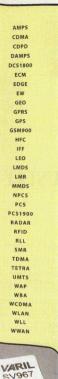
In short, customers should not be forced to choose between the two types of products. Both industries come out ahead if customers can buy and use both successfully.



Mitchell Lazarus received his BSEE and MSEE from McGill University and MIT. respectively, and his PhD in experimental psychology from MIT. He also holds a law degree from Georgetown University Law Center. Currently,

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his list represents most of the acronyms and abbreviations used in Microwave Journal technical articles and editorial features during the last five years. The evergrowing list has proven enormously useful to our staff and should prove equally helpful to our readers, who are continually bombarded with new and confusing abbreviations for the plethora of technical terms associated with the RF/microwave industry. Although it has always been our policy to define all but the most commonly used abbreviations within each article, a central reference list can be quite helpful to everyone. The original acronym and abbreviation list was first published in the February/March 1997 issues of Microwave Journal, and our staff has received many positive comments and continued requests for updates.

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ACW ADC adaptive cruise control adjacent-channel interference ratio

ratio adjacent-channel leakage ratio aperture-coupled microstrip patch antenna

adjacent-channel power adjacent-channel power rejection adjacent-channel protection ratio asymmetrical coplanar

waveguide autonomous collision warning (system) analog-to-digital converter ADEOS ADPCM

ADS ADSL

> AFP AGC AICC

AM AME AMF AML AMPS AMR ANA

AO APC API

APL AR advanced Earth observation satellite

adaptive differential pulse-code modulation automatic debiting system (auto toll collecting) asymmetric digital subscriber

loop airborne early warning ground integration system automatic frequency planning automatic gain control autonomous intelligent cruise

control
amplitude modulation
average model error
automated module fabrication
amplitude modulated link
Advanced Mobile Phone Service
adaptive multirate codes
automatic network analyzer
American National Standards

acoustic-optical American Personal Communications system application programming interface

Institute

airport pseudolites axial ratio

[Continued on page 126]

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CIRCLE 176 ON READER SERVICE CARD

APRE adaptive radial basis function ARM antiradiation missile ARMA autoregressive moving average ARDIS Advanced Radio Information Service ARFCN absolute radio frequency channel number ARO active resonator oscillator ASAP Airborne Shared Aperture Program American National Standard Code for ASCII

Information Interchange ASIC application-specific integrated circuit ASH amplifier-sequenced hybrid ASK amplitude-shift keying **ASTM** American Society for Testing and Materials ASV advanced safety vehicle (system) ATC air traffic control ATDE adaptive time domain equalizer

ATE automatic test equipment ATM air traffic management ATM asynchronous transfer mode ATPC automatic transmit power control AUC authentication center AVI automatic vehicle identification

automatic vehicle location automatic vehicle location and navigation

arbitrary waveform generator AWG AWG American Wire Gauge (standard) AWGN additive white Gaussian noise AWNV all weather and night vision system BAW bulk acoustic wave

binary-coded decimal broadcast channel BCH BCM block-coded modulation bit error rate BER BERT

bit error rate tester REM boundary element method BFL buffered field-effect transistor logic

BFN beam-forming network BICMOS bipolar complementary metal-oxide

semiconductor BIFODEL binary fiber-optic delay line BJT bipolar junction transistor BLOS beyond line-of-sight

BOM bill of materials BOR body of revolution

BPSK biphase-shift keying or binary phase-shift keying

BSC base station controller BSS base station system RCC broadcast satellite service BT bandwidth-time product

BTS base transceiver station BZ Brillouin zone CIA clear and acquisition code (GPS)

C-AFM calibrated atomic force microscope CAE computer-aided engineering CALLUM combined analog locked-loop universal

modulator community antenna television

[Continued on page 128]



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circuit card assembly CCD charge-coupled device CCDF complementary cumulative distribution function CCK complementary code keying CCMT computer-controlled microwave tuner

conductor-backed coplanar stripline

CBCPS

CCA

CCPR co-channel power ratio CDF cumulative distribution function CDMA code division multiple access

CDPD cellular digital packet data CE Conformite Europeene (European EMC standard)

CEPT Conference on European Posts and Telecommunications administrations CFC chloroflourocarbon CFR Code of Federal Regulations

CI carrier-to-interference ratio CI carrier-to-intermodulation ratio CIC controller in charge CIM computer integrated manufacturing CMOS complementary metal-oxide semiconductor CMRF combined mode resonator filter

CMS combined symbol matching C/N carrier-to-noise ratio CNC computerized numerical control

CNR carrier-to-noise ratio CNS/ATM Communication and Surveillance/Air Traffic

Management COFDM

coded orthogonal frequency division multiplex

соно coherent oscillator COM Component Object Model COMINT communications intelligence CONUS continental United States COPS complex operations per second COTS commercial off-the-shelf CPCI compact protocol control information **CPFSK** continuous phase frequency-shift keying CPM continuous phase modulation CPS coplanar stripline CPU central processing unit CPW coplanar waveguide COFP ceramic quad flat pack CRC cyclic redundancy check CREAM cosmic radiation effects and activation CRTSSDA cascaded reactively terminated single-stage distributed amplifier CSL coupled-slot antenna CSM combined symbol matching CSMA/CD carrier sense multiple access/collision detection

composite second order

chip scale package

cordless telephone

cordless telephone-second generation composite triple beat coefficient of thermal expansion conformal transformation method [Continued on page 130]





CSO

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CT

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CTR common technical regulations CVD chemical vapor deposition continuously variable delay line CVDL CW continuous wave constant width slot antenna CWSA DAR digital audio broadcast DAC digital-to-analog converter DAMA demand-assigned multiple access D-AMPS DAG data acquisition DAWS

Digital Advanced Mobile Phone Service Digital Advanced Wireless Service

DBF digital beamforming DBS direct broadcast service direct broadcast satellite DBS DCFL

DCOM

DC\$1800

DCR

DCXO

DDS

DEBS

DECT

DECT

DESC

DF

DFB DFD

D-FFT DFT

DGPS

DHRT

DIMM

DIRU

DLVA

DMO

DMOS

DMSP

DIN

direct-coupled field-effect transistor logic Distributed Component Object Model downconverting receiver digital communication system at 1800 MHz

digitally compensated crystal oscillator direct digital synthesis dynamic electronic bias system

Digital European Cordless Telecommunications (1880 to 1900 MHz) Digital Enhanced Cordless Telephony

(new name) Defense Electronic Supply Center direction finding

distributed feedback digital frequency discriminator depletion-mode field-effect transistor

discrete Fourier transform Differential Global Positioning System double-heterojunction bipolar transistor dual in-line memory module Deutsche Industrial Norms

(German standards agency) decov launch/recovery unit detector log video amplifier

direct-mode operation diffused metal-oxide semiconductor

Defense Meteorological Satellite Program

dual-mode resonators DMUX demultiplexer

DPLL

DPSK

DRFM

DRO

DDDC

EDA

EEA

DNL dynamic nonlinearity DOPSK differential quadrature phase-shift keying **DPHEMT** double heterojunction pseudomorphic high

electron mobility transistor digital phase-locked loop differential phase-shift keving digital radio frequency memory dielectric resonator oscillator digital radio relay system direct sequence

DS DSC differential scanning calorimetry DSO digital storage oscilloscope

digital signal processing DSP DSSS direct sequence spread spectrum DTF distance-to-fault

DTMF dual-tone multiple frequency DTO digital test oscilloscope DTO digitally tuned oscillator DTX discontinuous transmission

DUIT device under test digital video broadcasting DVB DWC digital wireless communications FBI electron beam lithography

FRSD electron backscatter diffraction EC **European Community** ECB enhanced cellular base station ECC error correction code FCC

embedded communication channel ECL emitter-coupled logic **ECM** electronic countermeasures ECSD enhanced circuit switched data ED electrodeposited E/D enhancement/depletion (mode)

electronic design automation **FDFA** erbium-doped fiber amplifier Enhanced Data Rate for GSM Evolution EDGE FDM electronic discharge machining

EU and EFTA merge unit Continued on page 1321

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EEC European Economic Community **FDTD** finite difference time domain **EEPROM** electrically erasable programmable read-only FEC forward error correction FEM finite element method E-FET enhancement-mode field-effect transistor FEP fluoroethylene propylene EFIE FFR electric field integral equation frame error rate FFTA European Free Trade Area FET field effect transistor (Austria, Finland, Liechtenstein, Norway, FFO fixed-frequency oscillator Sweden and Switzerland) fast Fourier transform EGI embedded global positioning satellite inertial FH frequency hopping frequency hop multiple access **FHMA** navigation system **EGPRS** FHSS Enhanced General Packet Radio System frequency-hopping spread spectrum EGSM FIR European Digital Extended Group Special finite-duration impulse response (filter) FIT failures in time EHF FLC extremely high frequency (30 to 300 GHz) ferroelectric liquid crystals FLOP **EHTPS** extra high tension power supply floating octal points EIA/TIA Electronics Industry Association/ FLR forward looking radar FM frequency modulation Telecommunications Industry Association EIN equivalent input noise FMC fixed mobile convergence (service) EIR **FMCW** frequency-modulated continuous wave equipment identity register EIRP effective isotropic radiated power (radar) FLINT FO fiber optic electronic intelligence systems EM **FOBP** fractional out-of-band power electromagnetic EMC **FPLMTS** electromagnetic compatibility Future Public Land Mobile EMF electromotive force Telecommunication Systems EMI electromagnetic interference **FPGA** field-programmable gate array **EMR** electromagnetic radiation FRA fixed radio access EN European Norm (EMI regulations) FS free space ENG FSCS frequency-selective conducting surface electronic news gathering **FSK** ENR excess noise ratio frequency-shift keying equivalent power-flux density FSS fixed satellite service erasable programmable read-only memory FSS **EPROM** frequency-selective surface ERMES GAM Global Positioning System-aided munitions European radio message system GBAS ERP effective radiated power ground-based augmentation systems ESD electrostatic discharge GBR ground-based radar GCPW grounded coplanar waveguide ESL equivalent series inductance ESM electronic support measure GEO geostationary earth orbit ESMR extended specialized mobile radio **GFSK** Gaussian frequency-shift keying ESR GLONASS Global Navigation Satellite System (Russian) electron spin resonance **GMDSS** ESR equivalent series resistance Global Maritime Distress Signal System **GMSK** ETACS Extended Total Access Communications Gaussian minimum shift keying System (British cellular) GNSS Global Navigation Satellite System (US) electronic toll collecting general-purpose interface bus ETC **GPIB** GPR ETL embedded transmission line ground-penetrating radar GPRS ETRE electronically tuned RF (filter) General Packet Radio Service ETS European Telecommunications Standard GPS Global Positioning System/Satellite ETSI European Telecommunications Standard GSM Global System for Mobile Communications GSM-900 Group Speciale Mobile (European GSM) Institute GSO **ETTM** electronic toll and traffic management geostationary orbit EU G/T receive antenna gain divided by noise European Union EUT equipment under test temperature European Telecommunications Satellite GUI **EUTELSAT** graphical user interface high speed anti-radiation missile EUV extreme-ultraviolet HARM HBT heterojunction bipolar transistor **EVM** error vector magnitude HDSL high bit-rate digital subscriber line EW electronic warfare FANS future air navigation system HDTV high definition television HEMT high electron mobility transistor FAR false alarm rate FBW fractional bandwidth HEO high elliptical orbit (satellite) FCA HFC hybrid fiber/coax flip-chip assembly HFET heterostructure field-effect transistor FCC Federal Communications Commission frequency-division duplexing HFSS FDD high frequency structure simulator fiber-distributed data interface HGA **FDDI** high gain antenna

HIPERLAN

HJFET

HLR

[Continued on page 135]
MICROWAVE JOURNAL # OCTOBER 2000

high performance local area network

heterojunction field-effect transistor

home location register

FDFD

FDM

finite difference frequency domain

frequency division multiple access

frequency domain reflectometry

frequency division multiplex



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HMIC hybrid microwave integrated circuit HPA high power amplifier HDRW/ half power beam width HSCSD high speed circuit switched data HTS high temperature superconductor interface bus interactive control IRIC in-band on-channel IROC IBW instantaneous bandwidth IC integrated circuit IDECM integrated defense electronic countermeasures IDET IDT interdigital transducer IEC

IFM

IIR

ILA

ILO

IM

IMD

IMDN

IMFET IMP

IMEL

IGBT

IGEET

countermeasures
inverse discrete Fourier transform
interdigital transducer
international Electrotechnical Commission
ideal electric plane
internediate frequency
indirect feedback
indirect feedback
iffer internediate frequency
internediate frequency
internediate frequency

identification friend or foe instantaneous frequency measurement insulated gate bipolar transistor insulated gate field effect transistor infinite impulse response (filter) injection-locked amplifier injection-locked oscillator

intermodulation
intermodulation distortion
Intelligent Mobile Data Network
international mobile equipment identity
internally matched field-effect transistor
intermodulation products

IMPATT impact avalanche and transit time intermodulation rejection

IMSI international mobile subscriber identity
INMARSAT International Maritime Satellite consortium,

INS incrtial navigation system
INTELSAT International Telecommunication Satellite

consortium, Washington
Internet Protocol
IPBO input power backoff

input power backoff
Institute for Interconnecting and Packaging

Electronic Circuits
integrated power systems
in-phase/quadrature

IR infrared impulse radiating antennas

IRM image reject mixer
IS-95 North American cellular standard
ISAR inverse synthetic-aperture radar
integrated services digital network

intersymbol interference industrial, scientific and medical

(frequency bands)

International Standards Organization
intelligent transportation systems

ITM-2000 International Mobile Telecommunication 2000

ITU International Telecommunication Union
ITU-R ITU Radio Communications Sector

[Continued on page 137]



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IVHS Intelligent Vehicle Highway System IDC Japanese Digital Cellular system IEDEC Joint Electron Device Engineering Council IFET junction field effect transistor **JPEG** Joint Picture Expert Group (compression standard) KGD known good die LAN local area network LAAS local area augmentation systems LAO LaAlO2 (substrate) LBC linked boundary condition LC inductor/capacitor LCC leadless chip carrier LCD liquid-crystal display LD laser diode LDMOS laterally diffused metal oxide semiconductor LEC liquid encapsulated Czochralski (semi-insulating substrates) LEO low earth orbit (satellite) LEP lumped element prototype LHCP left-hand circular polarization LIDAR light direction and ranging LINC linear amplification with nonlinear components LMCS local multipoint communications system IMDS local multipoint distribution system LMS location and monitoring services

LNA low noise amplifier LNB low noise block LNBF low noise block feed LO local oscillator

LOS line of sight LPE lowpass equivalent LPF lowpass filter IPI low probability of intercept LRL line-reflect-line (calibration) LRRM line-reflect-reflect-match (calibration)

LSB least significant bit LSG large-signal gain LSI large-scale integration LTCC

low temperature co-fired ceramic

LTCC-M

MAFET

low temperature co-fired ceramic on metal core ITI linear time invariant LTSA linear taper slot antenna

LTP long-term predictor LUT look-up table LVDS low voltage differential signal MAC medium access control

Technology project MBA multi-beam antenna MBE molecular beam epitaxy MBPA multi-beam phased array MCE manufacturing cycle efficiency MCF message communication function MCL microstrip constrained lens

Microwave and Analog Front End

MCM multichip module MCM-C multichip module with co-fired substrate MCPA multicarrier power amplifier MCPW microstrip coplanar waveguide

MCT metal-oxide semiconductor-controlled MDS multipoint distribution system MEADS medium extended air defense system MEMS microelectromechanical system MESFET metal-semiconductor field effect transistor

MEO medium earth orbit (satellite) MIC microwave integrated circuit MIC monolithic integrated circuit MIDAS multiple integration and defense

communications satellite network MIM metal-insulator-metal (capacitor) MIMIC Millimeter-wave and Microwave Integrated Circuit (R&D program) MIPS

million instructions per second MIR microwave impulse radar MLA microwave link analyzer multilayer board MLB MLC main lobe clutter MICM multilevel coded modulation

[Continued on page 139]



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matched-line directional divider MLDD MMC metal-matrix composite MMCA microwave multichip assembly MMDS multichannel multipoint distribution system MMI man-machine interface multimedia interface MMI MMIC microwave monolithic integrated circuit MMW millimeter wave MOCVD metal-organic chemical vapor deposition MOCT multi-order cancellation technique MODEM modulator/demodulator MoM method of moments MOS metal-oxide semiconductor MPEG Motion Picture Experts Group MPIE mixed potential integral equation MPM microwave power module MQW multi-quantum well

MQW-FP multi-quantum well Fabry-Perot optical transmitter MS mobile station MSB most significant bit MSBVW magneto-static backward volume waves MSC mobile switching center MSFVW magneto-static forward volume waves MSI medium scale integration MSK minimum-shift keying MSMT micro surface-mount technology MSOP mini(micro) small outline package MSS mobile satellite system (service) MSSW magneto-static surface waves MSW magnetostatic wave microwave transition analyzer MTA MTBF mean time between failures MTD moving target detection moving target indicator MTI MTTF mean time to failure mean time to repair MTTR MU minimum stability factor MUNDI multiplexed network for distributed

and interactive services (UK)

multiplexer

MUX

multipoint video distribution system NADC North American Dual-Mode (or Digital)

NA numerical aperture N-AMPS Narrowband Advanced Mobile Phone

NAVSTAR

Navigational Satellite Timing and Ranging system NEC numerical electromagnetic code NEMA National Electrical Manufacturers

Association NFA noiseless feedback amplifier NGA noise gain analyzer

NGSO nongeostationary orbit NIC network interface card (WLAN)

NIST National Institute of Standards and Technology

NMC network management center NMOS n-channel metal-oxide semiconductor NMR nuclear magnetic resonance NMSE normalized mean square error NMT Nordic Mobile Telephone system

NODS near obstacle detection system NPR noise power ratio NPRM notice of proposed rule making

NOR nuclear quadruple resonance NRZ nonreturn to zero NSA normalized site attenuation NSOM near-field scanning optical microscopy

NSSN National Standards System Network NTSC National Television Systems Committee OAD

optical admittance diagram OATS open area test site

OBU onboard unit orthogonal code division multiple access **OCDMA OCPAR** optically controlled phased-array radar ocxo oven-controlled crystal oscillator OEIC optoelectronic integrated circuit

> original equipment manufacturer orthogonal frequency division multiplex [Continued on page 141]

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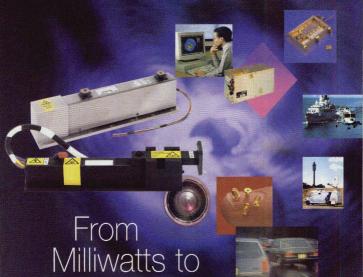
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OFHC oxygen-free high conductivity (copper) OFS operational fixed service OHI one-horn interferometer OMC operations and maintenance center OMT orthogonal-mode transducer OOK on-off keying OPBO output power backoff OPIP output power intercept point OPLL optical phase-locked loop **OQPSK** offset quadrature phase-shift keving OSI open systems interconnection OTDR optical time domain reflectometer OTH over the horizon PA power amplifier PAA phased-array antenna PABX private automatic branch exchange PAC perceptual audio coder PACS personal access communications system (US version of PHS) PACT personal air communications technology PAE nower-added efficiency PAL programmable array logic PAL phase-alternation line (video) PAM pulse amplitude modulation PAMR Public Access Mobile Radio PAN public access network PRG photonic bandgap PBX private branch exchange PCI peripheral component interconnect (bus) PCIA Personal Communication Industry Association PCM pulse code modulation PCM process control monitor PCMCIA Personal Computer Memory Card International Association PCN personal communications network PCS personal communication service PCU power conditioning unit

PDC PDF PDH PDIP PDO PEBB PEC PECL PECVD PEEC PEP PEP PFD PHEMT PHP PHS PHY PIC PIM PIN PLCC PLD PLD PLF PLL PLMN PM PM PMC PMD PML PMOS PMR PN

(portable computing) personal digital cellular probability distribution function plesiochronous-digital hierarchy plastic dual-in-line package packet data optimized power electronic building blocks perfect electrical conducting positive/pseudo emitter-coupled logic plasma-enhanced chemical vapor deposition partial element equivalent circuit primary entry point peak envelope power phase/frequency discriminator pseudomorphic high electron mobility personal handyphone, JPHP (Japan, 1895.15 to 1905.15 MHz) personal handyphone system (Japan) physical layer (WLAN) photonic integrated circuit passive intermodulation positive-intrinsic-negative (diode junction) plastic leaded chip carrier (molded plastic) programmable logic device pulsed laser deposition polarization loss factor phase-locked loop private land mobile network

Private Mobile Radio PNF PON POCSAG

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perfect magnetic conducting

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POF plastic optical fiber POFS private operational fixed service POS Post Office Protocol POTS plain old telephone service PPM periodic permanent magnet (focused) PPM pulse position modulation PPS precise positioning service (GPS) POFP plastic quad flat pack PR pseudorange PRBS pseudorandom binary or bit sequence PRF pulse repetition frequency PRN pseudorandom noise PROM programmable read-only memory PRT planar resistor technolog PSA polysilicon self-aligned (bipolar transistor) PSD power spectral density PSK phase-shift keying PSMM pilot strength measurement message PSTN public switched telephone network PTFE polytetrafluoroethylene PTH plated-through hole

public telecommunications operator

post, telephone and telegraph (Europe)

P1dB power 1 dB compression point QAM quadrature (quaternary) amplitude modulation **QIFM** quadrature intermediate frequency mixer **OPSK** quadrature phase-shift keying ORNS quadratic residue number system

pulse width modulation

OSOP quality small outline package OWIP quantum well infrared photodetector OWR quarter-wave rule RACH random access channel RADAR radio detection and ranging RAIM receiver autonomous integrity monitoring

RAM radar-absorbing material RAM random access memory RAP radar-absorbing paint RAS radio astronomy synthesis RBC radiation boundary conditions RBER residual bit error ratio

RRW resolution bandwidth RCS radar cross section RDS radio data system RELP residually excited linear predictive coder

RF radio frequency RFID radio frequency identification RFMU radio frequency monitoring unit RES radio frequency simulator RHCP right-hand circular polarization

RIE reactive ion etch RIN relative intensity noise RISC reduced instruction set computing RL

rotating linear (antenna pattern) RLL radio local loop RMS root mean square RNSS radio navigation satellite service

[Continued on page 144]



Plan to attend the IEEE-APS Conference on Antennas and Propagation for Wireless Communications (APWC2000) for a firsthand look at the latest technological developments in the wireless antenna industry. The purpose of this conto-date view of problems and solutions in antennas and propagation that are relevant to the rapidly expanding wireless communications industry.

TOPICS:

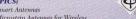
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- · Microstrip Antennas for Wireless
- Mobile Antennas and Vehicle Modeling
- · Human Interactions with Antennas

· Smart Antennas



· Antennas for PCS, WLL, WLAN, RFID, LMDS, GPS

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Base Station Antennas

The Conference will feature twenty-minute presentations. invited papers and an exhibition. The exhibition will include manufacturers of antennas and related components for wireless systems and applications.

The following Short Courses will be offered:

- Sunday, November 5: 1 PM to 5 PM Microstrip Antennas Dr. Rod Waterhouse
- Practical Considerations in the Design of Antennas for Wireless Communications Dr. Naftali Herscovici
- · Tutorial on IE3D and Fidelity by Zeland Software Dr. Jian Zheng

Monday, November 6: 8 AM to 12 PM

 Modern Topics in Personal Communications **Antennas: Design and Analysis Techniques Including Human Interaction** Prof. Yahya Rahmat-Samii

Smart Antennas

Prof. Christos Christodoulou

 UHF Propagation for Modern Wireless Systems Prof. Henry Bertoni

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SINAD

ROTHR relocatable over-the-horizon radar RP range processor RRC raised-root cosine RRE radar range equation RSSI received signal strength indicator RSU roadside unit (auto toll collecting) RTD resistance-temperature detector (probe) RTD roundtrip delay RwoH reliability without hermeticity RWR radar warning receiver RX receiver/receive RZ return to zero SA selective availability (GPS error introduction/correction) SAR synthetic-aperture radar SAR search and rescue SAR specific absorption rate SAT supervisory audio tone SATCOM satellite communications (Satellite Communications Agency, Department of Defense) SAW surface acoustic wave SBAS satellite-based augmentation system SBN single-sideband phase noise SCFL source-coupled field effect transistor logic SCPI Standard Commands for Programmable Instruments SCR semiconductor-controlled rectifier SCSI small computer standard/system interface SDD symbolically defined device SDH synchronous digital hierarchy (European telecommunication) SDLA successive detection log amplifier SDMA spatial division multiple access SDR software-defined radio SDRAM synchronous dynamic random access SFAD suppression of enemy air defenses SEM scanning electron microscope SES severely errored seconds

space ground link system super high frequency semi-insulating selectively implanted collector Special Interest Group signal intelligence subscriber identity module signal-to-noise and distortion (ratio) single inline package stepped impedance resonator signal in space satellite link emulator spatial light modulator sample matrix inversion subminiature push-on (connector) surface-mount package specialized mobile radio short message service surface-mount technology scalar network analyzer signal-to-signal plus interference ratio signal-to-noise ratio silicon on insulator small outline integrated circuit short-open-line-reciprocal (calibration) short-open-load-thru (calibration) synchronous optical network (US telecommunications) small outline transistor third-order suppression statistical process control serial peripheral interface satellife position reporting equipment standard positioning service (GPS) single-phased unidirectional transducer static random access memory spread spectrum single sideband surface-skimming bulk wave simultaneous signal detection small-signal gain

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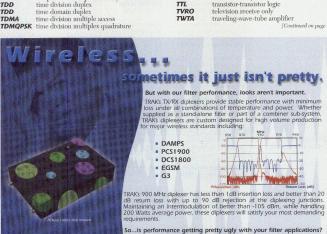


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phase-shift keving SSI small-scale integration TOWR terminal Doppler weather radar SSOP shrink small outline package transverse electric SSOT shrink small outline transistor TE SSPA solid-state power amplifier TEC. thermal electric cooler SSPE single solid-phase epitaxy TEM transverse electromagnetic trans-European trunked radio (old name) TETRA SSR surface search rada STALO stable local oscillator **TETRA** terrestrial trunked radio (new name) STM synchronous transport module thin-film transistor/technology (1 STM = 155 Mbps) TFTS terrestrial flight telephone system TIM transmission line matrix STOVL short takeoff, vertical landing (aircraft) TM STW surface transverse wave transverse magnetic SWAP shared wireless access protocol TMA thermomechanical analysis SWR standing wave ratio TMN telecommunication management network TOI third-order intercept (point) TAB tape-augmented bonding TACAN T/R transmit/receive tactical air navigation system TACS Total Access Communications System TRAC Technical Regulations Application TAG technical advisory group Committee (of ETSI) TRAM transimpedance amplifier TARD towed active radar device TBCCO thallium barium calcium copper oxide TRP Technology Reinvestment Program (NIST) TRL thru-reflect-line (calibration) TCAS Traffic Alert and Collision Avoidance System TRX temperature coefficient of capacitance transceiver TS timeslot TCE thermal coefficient of expansion TCH traffic channel TSA tapered-slot antenna TSOP thin small outline package TCM trellis-coded modulation TCR temperature coefficient of resistance TSS tangential signal sensitivity TTD true time delay TCXO temperature-compensated crystal oscillator

[Continued on page 147]



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SPECIAL REPORT

VSB VMEbus subsystem bus transmit/transmitter UAV unmanned aerial vehicles VSWR voltage standing wave ratio UFMOP VVA voltage-variable attenuator unintentional frequency modulation on pulse VXIbus VMEbus extension for instrumentation UIM uniform impedance resonator WAAS wide area augmentation system UM unintentional modulation (GPS ground based) UMTS Universal Mobile Telecommunications WADSP wideband acquisition/digital signal System (Europe) processing U-NII Unlicensed National Information WAN wide area network Infrastructure WAP Wireless Application Protocol LIPT universal personal telecommunications WBMCS wireless broadband multimedia URE user range error communications systems W-CDMA USAT ultra-small aperture terminals wideband code division multiple access UTC Universal Time, Coordinated WDM wavelength division multiplexing UWB ultrawidehand WDDM wavelength division demultiplexing WEP VANA vector automatic network analyzer wired equivalent privacy WLAN VBW video bandwidth wireless local area network VCO voltage-controlled oscillator WLL wireless local loop XFCB VDU video display unit extra-fast complementary bipolar VHDL very high speed IC description language XPD cross-polarization discrimination VISA XPIC cross-polar interference canceller virtual instrument software architecture XPOL VLR visitor location register cross-polarization level very large scale integration YAG VLSI vttrium aluminum garnet **VMEbus** versa module Eurocard computer bus YRCO yttrium barium copper oxide VNA vector network analyzer YIG yttrium iron garnet VPN YTO YIG-tuned oscillator virtual private networks



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COVER FEATURE



A BROADBAND BIAS TEE FOR OPTICAL NETWORKING APPLICATIONS

The explosive growth of the Internet has created an insatiable demand for communications bandwidth by everyone. from the Web-browsing individual in the home office, to the multibillion-dollar corporation that is at a severe competitive disadvantage without it. Although several broadband access methods are now available, fiber optics is still the primary vehicle for broadband connectivity, particularly for communications traffic over long distances. Even with the large number of fiber-optic links already in place, over 90 percent of the commercial buildings in the US are still not served. This market represents an enormous opportunity for optical networking system, module and component manufacturers, and is the reason for the unprecedented growth rates that are expected in this market segment, some of which have already started to take shape.

Fiber-optic technology has made tremendous progress in recent years with respect to bandwidth and data capacity to support this demand. Optical carrier (OC) systems have quickly evolved from 2.5 Gbps (OC-48) to 5 Gbps (OC-96), and now 10 Gbps (OC-192) systems have reached mass production levels, which, not too long ago, were thought to be impossible. However, the demand continues to explode. Internet traffic is growing at a rate of 200 percent per year and now exceeds the amount of voice traffic. In order to support the necessary data applications, 40 Gbps (OC-768) systems are already being developed and prototyped for use in several long-haul and transoceanic communications links.

However, 40 Gbps systems present entirely new challenges because the overall speed and performance of the components used in these systems must be effectively increased four times over existing 10 Gbps systems. In addition to the challenges associated with the optical components (such as laser diodes and photodetectors), unique challenges also exist with the RF/microwave components that are required to support these functions. Due to the non-return-to-zero (NRZ) modulation methods used in these systems and the high frequency performance needed to support the desired data rates, RF/microwave components must operate over an extremely broad frequency range. Examples of passive components that face this challenge are DC blocks and bias tees that utilize frequency-dependent components, such as capacitors and inductors.

The model 8810EF bias tee has been introduced in response to the increasing market

[Continued on page 150]

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COVER FEATURE



Fig. 1 Insertion loss and return loss vs. frequency on a standard log scale. ▼



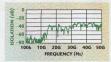
▲ Fig. 2 Expanded high frequency detail.

demand for broadband RF/microwave components used in higher data rate optical networking applications. The S810EF bias tee utilizes 2.4 mm connectors and is targeted to operate over the 100 kHz to 50 GHz frequency band. Since a low cost design approach was the focus from the beginning of product development,

TABLE I **BIAS TEE SPECIFICATIONS** Frequency 100 kHz to 50 GHz Impedance (Ω) 50 Insertion loss (dB) 100 kHz 50 CHz SWR f < 12 GHz 1.3 (max) f > 12 GHz 1.8 (max) DC voltage (V) 16 (max) DC current (mA) 250 (max) Isolation (dB) f≤14 CHz > 40 f > 14 GHz > 30 RF power (W) 5 (max) RF connectors 2.4 mm Dimensions (*) $0.63 \times 1.20 \times 0.50$

the 8810EF is priced very competitively and can consequently be used in the production of optical systems and modules, as well as for test and measurement applications.





▲ Fig. 3 DC-to-RF isolation performance.

Typical insertion loss and return loss performance of the 8810EF bias tee is shown in Figure 1, where the frequency is plotted on a log scale so that the low frequency performance is easier to distinguish. The graph shows that the insertion loss at 100 kHz is still less than 0.5 dB and the return loss is approximately 18 dB, equating to an SWR of 1.3. Figure 2 shows the insertion loss and return loss vs. a linear frequency range from 10 to 50 GHz. The 8810EF was designed to handle 250 mA of DC current so that it can be used to bias higher current components (such as transimpedance amplifiers) in addition to lower current components (such as optical modulators). A summary of the product's specifications is listed in Table 1.

Figure 3 shows the typical isolation performance of the bias tee between the DC and RF ports. The device typically exhibits better than 40 dB of isolation at the lower frequency range and equals or exceeds 30 dB over the entire 100 kHz to 50 GHz bandwidth.

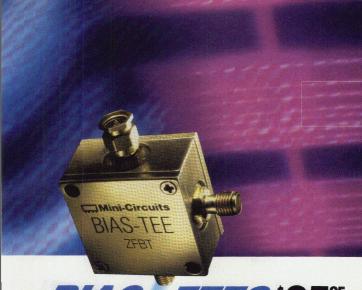
Although the 8810EF bias tee consists of two female 2.4 mm connectors, other sex configurations are available (for example, male/female combinations). There are also plans to offer this bias tee with 2.9 mm connectors for 40 GHz applications, as well as with a variety of connectors used for injecting the DC bias. The model 8810EF uses an SMA connector for the DC bias: however, an SMC connector can also be provided in addition to the option of two terminals for voltage and ground. Additional information on broadband bias tees and other broadband components such as DC blocks, DC blocking terminations and attenuators can be obtained via email from clindberg@inmeteorp.com.

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▲ZFBT-6G-FT ▲ZFBT-4R2GW-FT ▲ZFBT-6GW-FT ★ZNBT-80-1W	10-8000 0.1-4200 0.1-8000 2.5-8000	0.15 0.15 0.15 0.15	0.6 0.6 0.6	1.0 0.6 1.0 1.6	N/A N/A N/A 75	N/A N/A N/A N/A 45	NVA NVA NVA 36	1.13.1 1.13.1 1.13.1 1.35.1	79.9 79.9 89.9 82.9
■PBTC-1G ■PBTC-3G ■PBTC-1GW ■PBTC-3GW	10-1000 10-3000 0.1-1000 0.1-3000	0.15 0.15 0.15 0.15	0.3 0.3 0.3	0.8 1.0 0.8 1.0	27 27 25 25 25	33 30 33 30	30 35 30 35	1.10:1 1.60:1 1.10:1 1.60:1	25.95 35.95 35.95 46.95
*JEBT-4R2G *JEBT-6G *JEBT-4R2GW *JEBT-6GW	10-4200 10-6000 0.1-4200 0.1-6000	0.15 0.15 0.15 0.15	0.6 0.7 0.6 0.7	0.6 1.3	32 32 25 25	40 40 40	40 40 40 30		39.96 59.96 59.96 69.96

NOTE: Isolation dB applies to DC to (RF) and DC to (RF+DC) pons.

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▲ Antenna Catalog

This 114-page catalog describes several antennas, including omnidirectional, sector, dual polarization, patch, parabola, Yagi, inverted, cellular phone, ceramic, retractable, dual-band. CT2 base station, half-wavelength sleeve dipole, dual-band magnetic and GPS. Product photographs, characteristics, and electrical and mechanical specifications are included. An environment test engineering report, glossary and company profile are also provided. ACE Technology, Chatsworth, CA (818) 718-1534.

Circle No. 310



▲ Electronics Manufacturing **Functional Test Products** and Services Catalog

This 68-page catalog contains detailed information on the company's test system components, accessories and support services, which can help test engineers reduce the cost of building test systems. Product descriptions, specifications and photographs are included.

Agilent Technologies Inc.,

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Circle No. 311



▲ RF/Microwave/Millimeter-wave Selection Guide

This brochure includes all of the company's products from DC to 40 GHz, including thousands of high performance, low cost RF, microwave and millimeter-wave products designed for telecommunications applications. The guide is designed so the customer can quickly find the right product for any requirement. Alpha Industries.

Woburn, MA (781) 935-5150.

Circle No. 312



▲ Product Catalog

This 752-page catalog is a complete reference source for the company's products and services. Detailed product descriptions, specifications, planning guides, technical data and system planning software information are provided. New sections cover broadband antenna products. PerforMax™ base station antennas. ValuLine® antennas and ISM, MMDS and UNII band passive products. Andrew Corn.

Orland Park, IL (800) 255-1479. Circle No. 313



▲ Component Catalog

This 40-page catalog provides complete features, specifications and applications for the company's full line of adapters, attenuators, terminations and connectors. Components, including instrumentation-grade adapters, precision attenuators, high return loss connectors from DC to 65 GHz and precision terminations, as well as microwave defectors, power dividers, RF limiters and bias tees, are highlighted. Anritsu Co.,

Microwave Measurements Division. Morgan Hill, CA (800) 267-4878. Circle No. 314 ▲ Test and Measurement Solution **Product Guide**

This full-length product guide details power meters, peak power meters, RF voltmeters, VXI products and power sensors that can be used in many commercial and military applications. Included are descriptions and specifications of the company's family of peak power meters/analyzers, including the model 4400A, model 4500A and 4530 series Boonton Electronics Corp

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▲ Wireless and Microwave Filter Product Brochure

This eight-page brochure features transmit filters, receive filters, duplexers, 2.4/5,8 GHz radio products, delay filters, integrated assemblies, combline cavity filters, interdigital cavity filters and waveguide filter products. An overview of the company, product descriptions and photos, and ordering and shipping information are included.

ClearComm Technologies Inc., Salisburu, MD (410) 860-0500.

Circle No. 316



▲ Microwave Switch Catalog

This 16-page catalog features the company's various SMA, N and TNC connectorized switches. Specifications, available options, schematics, outline drawings and product photos are given for each component. General specifications, instructions on constructing a part number, definitions and notes are also provided DR Products Inc.

Pasadena, CA (626) 449-3790.

Circle No. 317



▲ Miniature Voltage-controlled Oscillator Catalog

This 32-page catalog describes various ELCO and EVCO series VCOs. Information on care soldering techniques and assembly is included, as well as features, outline drawings and notes. Specifications, common questions, instructions on creating a model number, and quote and order information are also provided. Emhiser Micro-Tech (EMT),

Verdi, NV (775) 345-0461.

Circle No. 318



▲ Frequency Control Product Catalog

This 96-page catalog features detailed information on the company's recently expanded line of products. A complete listing of distributor stocking standards is provided, with a policy that none of the standards is noncancellable and nonreturnable (NCNR) to distributors or **OEMs** Fox Electronics,

Fort Myers, FL (888) 438-2369.

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▲ Filter and Subsystem Catalog

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FSY Microwave Inc. Columbia, MD (410) 381-5700.

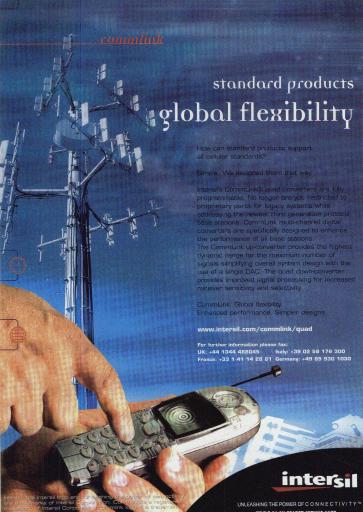
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▲ Custom Microwave Cable Assembly Catalog

This eight-page catalog features SMA-M, TNC-F bulkhead and SMA-M 90° cable assemblies. In-depth product descriptions, drawings, specifications, qualifications, performance characteristics, applications and "insertion loss vs. frequency" graphs are included. A company overview is also provided. Kaman Aerospace Corp., Colorado Springs, CO (719) 635-6954.

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▲ Isolator and Circulator Catalog

This 38-page cutalog details a variety of isolators and circulators available in coaxial, vaveguide, drop-in and surface-mount configurations covering the 300 MHz to 40 GHz frequency range. General information, electrical specifications, mechanical specifications and schematics are provided. A mall-back "request for quote" form is included. M2 Global Technology Ltd.,

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Circle No. 323



▲ RF, Microwave and Millimeter-wave Product Brochure

This brochure features information on DML Microwave Ltd., Inmet, KDI/Triangle, Metelies and Weinschel. Product offerings and photos are included for each company. A corporate profile and description are also featured, as well as a worldwide design and manufacturing map. MCE Companies Inc.,

Ann Arbor, MI (734) 426-1230.

Circle No. 324



▲ SiO₂ Cable System Brochure

This six-page brochure features RF coasial and multiconductor transmission lines and SiO₂ cable and connector systems for nuclear applications and SiZ400 fireproof cables. Product photos and graphs are provided, as well as features, specifications, applications and full descriptions. Installation and customer support information is also provided. Meggitt Softly Systems Inc.,

Simi Valley, CA (805) 584-4100. Circle No. 325

Circle No. 325



▲ Waveguide Subsystem and Component Catalog

This 45-page catalog features various waveguide subsystems and components, including flexible waveguide; E-plane bends; flange adapters; tapered transitions; builkhead flanges; low, medium and high power terminations; Eand H-plane tees; hybrid tees; coaxial adapters; standard guin horns; shorting plates; pressure windows; waveguide flanges; and alloys.

Mesa Microwave Inc., San Diego, CA (800) 739-9173.

Circle No. 326

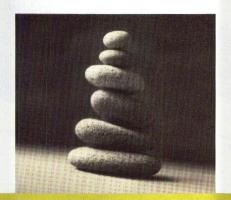


▲ Hand-formable Microwave Cable Brochure

This stepage brochure features the UTFORM family of tin-dipped, hand-formable microwave cables, economical alternatives to semirigid and flestible cables. All mechanical and electrical characteristics of the cables are provided in easy-to-read charts. Graphs are also included to tilustrate the cables' insertion loss, shielding effectiveness and power handling. MIGRO-GOM.

Collegeville, PA (800) 223-2629. Circle No. 327

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▲ Voltage-controlled Oscillator Short-form Catalog

This five-page catalog features a full voltagecontrolled oscillator selection guide, which lists each product's full specifications by model number. Information on product applications, design and performance, assembly and testing is provided, as well as package outline drawings. Modeo Inc., Sparks, NV (800) 672-4552.

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Compounds, texterois, and texterois,

▲ Component, Network and Instrument Catalog

This 648-page catalog offers the latest in high performance components, networks and instruments. The company's complete product line appears in the catalog, and is presented in six primary categories: wireless products, electromechanical RF switches, passive components, active components, active components, active components, active Components, active Components, active Norda-an_L-3 Communications company.

Narda-an L-3 Communications company Hauppauge, NY (631) 231-1700.

Circle No. 329



▲ Buried Single-layer Capacitor Catalog

This six-page catalog features Buried Single LayerTM capacitors and provides general size information, capacitance ranges, available test methods and characteristic graphs. Product specifications, features, applications and a "how to order" chart are also provided.

Presidio Components Inc., San Diego, CA (858) 578-9390.

Circle No. 330



A Radar and RF Product Catalog

This 28-page catalog contains information on radar systems and RF products, including the AN/MPS-19 S-band mobile tracking system designed for precision instrumentation tracking and drone control. Also featured are many radar systems. RF packages and microwave tubes. Test and engineering capabilities are described. Product photos and specifications are considered.

Radio Research Co. Inc., Waterbury, CT (203) 753-5840.

Circle No. 331



▲ Microelectronic Packaging Solution Catalog

This catalog describes the company's Plated Copper on Thick Film (PCTF)³⁴ proprietary manufacturing process, which combines patterned copper-plated images with air-fireable thick films on ceramics for the nanufacture of metallized substrates, chip carriers and packages. Special Features, compatible assembly methods and hypical packaging solution examples are also described.

Remtec Inc., Norwood, MA (781) 762-9191.

Circle No. 332



▲ Coaxial Connector Catalog

This 120-page catalog features a full range of standard and RF enstom coaxial connectors, including 400 new items. More than 2000 coaxial products, including cable assemblies, connector kits, Unidapt* universal adapter products, cellular products and hand tools, are described. Product specifications and photographs are included.

RF Connectors, San Diego, CA (800) 233-1728 or(858) 549-6340.

6) 549-6340. Circle No. 333

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RF/Microwave



▲ Antenna Design and Development Catalog

This catalog presents hundreds of new antennas along with standard products that are availnable from stock or for near-term delivery. Sections feature antennas, antenna feeds, specialized microwave components, microwave subsystems and testing services. Seateue Engineering Associates,

Pembroke, MA (781) 829-4740.

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▲ Specialty Materials Catalog

This 16 page catalog details the company's line of specialty materials such as urefune frames, electroluminescent lamps and inverters, indinex laminates, PORON silicone materials, R/lies flexible circuit materials, R/liem flexible circuit materials, R/liem flexible circuit materials, R/liem flexible circuit materials, OR4000 and R/03000 high frequency circuit materials, elastomer components and compare the materials, polications, markets, material details and key properties are listed for each product.

Rogers Corp., Rogers, CT (800) 774-9605. Circle No. 335



▲ Product Catalog

This catalog features solid-state amplifiers, frequency converters, power dividers and instrumentation systems. Specifications, electrical characteristics, product outlines, descriptions, photographs, applications and features are inciuded. Corporate information and descriptions of the company facilities are also provided.

Shason Microsceve Corp.,
Webster, TX (281) 536-6336.

Circle No. 336



▲ RF/Microwave Component Catalog

This 90-page catalog features the company's complete line of RF/microwave components, including bandpass filters, diplexers, coaxial resonators and dielectric resonators. Product specifications, application notes and technical drawings are included.

Adamstown, MD (301) 695-9400.

Circle No.

Circle No. 337



▲ Coaxial Connector Catalog

This catalog details a wide range of RF coaxial connectors and a line of adapters and custom-consectors and a line of adapters and custom-designed cable assemblies. It features quick-disconnect connectors that correspond to LC, C, SC, BNC and TNC types, super-quick designs for sputiering under processing and high power applications, and quick-change types for use with waturbers and other high power testing and monitoring equipment.

Tru-Connector Corp., Peabody, MA (800) 262-9878 or (978) 532-0775.

Circle No. 338



▲ Thin-film Circuit Device Catalog

This 12-page catalog features thin-film circuit devices. Included in the catalog are substrate materials used for the devices, paled the schemes, there resistor designs, paled thru holes/slots, filled via products, layout and design guidelines, and a checklist. Product specifications, applications and outline drawings are included. A "request for quotation" form is also provided. UttraSource Inc.

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UltraSource Inc., Hollis, NH (603) 881-7799.

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This 16-page catalog features voltage-controlled oscillators, ceramic resonator oscillators, phaselocked loops, fixed-frequency oscillators and synthesizers. An engineer's notebook, applications notes, definitions, and tape-and-reel information are included. Complete product descriptions, specifications, applications, features and photographs are provided.

Universal Microwave Corp., Odessa, FL (877) 375-9332.

Circle No. 340



▲ Commercial Special Assembly Catalog

This 13-page catalog features special frequency conversion and frequency generation modules. Product photographs, diagrams, schematics, performance specifications, performance graphs, programming ealculations and outline drawings are included. Packaging and installation information is also provided.

Vari-L. Denver, CO (303) 371-1560. Circle No. 341



▲ 2000 Product Catalog

This 525-page catalog covers telecom and enterprise networks, multimedia and wireless. It describes test solutions for development, manufacture, installation, maintenance and repair of systems and networks for transmitting speech, data and images. A company overview as well as product photographs, specifications, applications and full descriptions are included. Wavetek Wandel Goltermann.

Eningen, Germany +49 7121 86 1616.

Circle No. 342



▲ Microwave and RF Component and Subsystem Catalog

This 224-page catalog features microwave and RF components and subsystems, including coaxial fixed attenuators, terminations and loads, phase shifters, programmable attenuators, SmartStep components and subsystems, power splitters/dividers, directional couplers and coaxial adapters. Product descriptions, specifications and photographs are included.

Weinschel Corp., Frederick, MD (800) 638-2048 or (301) 846-9222.

Circle No. 343



▲ Microwave Product Catalog

This 12-page catalog features a company introduction, business focus description, technology overview and product descriptions, including comb generators, crystal stabilized sources, multi-channel sources, frequency multipliers, frequency synthesizers and converters, receivers and microwave subsystems. Product photographs, specifications and key features are also provided.

Zeta, San Jose, CA (408) 434-3600.

Circle No. 344



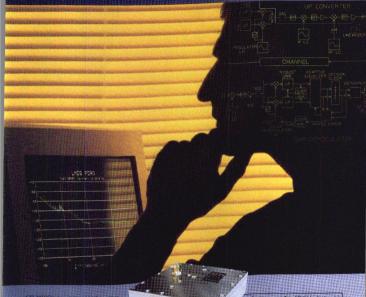
▲ Engineer's Survival Kit

This survival kit is intended for use with interference control and includes a variety of product samples such as foam absorbers, MA-GRAM and new EMI materials, as well as a new capabilities brochure. These samples can be used in prototyping the user's next design. ARC Technologies,

Amesbury, MA (978) 388-2993.

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▲ High Frequency Electronic Design Automation Brochure

This 10-page brochure features Microwave Office 2000 design automation software, which combines an advanced IC layout editor with state-of-the-art simulation technology. Screen shots, features, capabilities, characteristics and ordering information are included.

Applied Wave Research Inc., El Segundo, CA (310) 726-3000.

Circle No. 346



▲ High Performance Synthesizer

Datapack

This datapack contains information on several

frequency synthesizers. The data sheets include performance specifications, and mechanical and block diagrains. Products covered include the STEL-2375 DDCS chirp synthesizer hybridthe STEL-9563A DDS synthesizer with internal clock and the MS-2000 LMDS synthesizer. ITI Industries.

Lowell, MA (978) 441-0200.

Circle No. 347



▲ High Performance Mini-OCXO Catalog

This 23-page catalog contains several immovative OCXO designs, including the 205-series, which is the most compact OCXO in the industry. The hermetic package measures 0.815 × 0.515 × 0.394. The 220 series performs to STRATUM III, IIIe standards and is ideal for applications requiring low power consumption. MTI-MIIIIes.

Newburyport, MA (978) 465-6064

Circle No. 348





RF DIGITAL ATTENUATORS IN PLASTIC MLP PACKAGES

Proadband digital attenuators have been used to set power levels in RF and microwave circuits for many years. The concept is to electronically switch resistive T and II networks to attenuate and control signals. In doing so, attenuators must have low insertion loss, generate accurate (flat with frequency) attenuation levels, maintain low input and output SWR for all attenuation levels, produce low spurious signals, consume low DC power and switch very quickly. Although the basic "switched pad" circuits are well

known and very useful, recent developments in GaAs MMICs and plastic packaging technologies have expanded operating frequencies while reducing physical size and costs.

Using this GaAs MMIC base, a family of digital attenuators producing five- and six-bit formats with least significant bit (LSB) weights of 0.5 and 1 dB have been developed in various package platforms. Initially, the product line consisted of multichip GaAs MMICs and silicon-based CMOS applicationspecific IC (ASIC) drivers packaged in ceramic flatpacks. For example, the model AT-263 attenuator utilizes a five-bit, 1 dB LSB MMIC in the RF path and two quad drivers to perform the interface for the TTL control signals. Its sister component, the model AT-283, has the same structure except the MMIC has a 0.5 dB LSB. The six-bit attenuators (models AT-106 and AT-107) employ five-bit MMICs with an additional dual-bit 16 dB MMIC connected in series to create the sixth bit. The 16 dB MMIC can be wirebond configured to produce a most significant bit (MSB) of 16 or 32 dB as the application requires. Figure 1 shows the interior views of five- and six-bit ceramic attenuators. For reference, the AT-106 attenuator with its four semiconductor chips occupies a total package area (body and leads) of 0.450" × 0.650" (11.4 × 16.5 mm).

[Continued on page 168]

M/A-COM Lowell, MA





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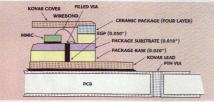




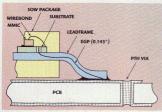




PRODUCT FEATURE



▲ Fig. 2 Cross section of a ceramic package on a PCB.



▲ Fig. 3 Cross section of an SOW package on a PCB.

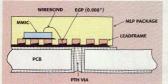
Two important aspects for high frequency performance are maintaining the impedance match for series (I/O) ports and minimizing the shunt (GND) inductance. Unless the MMIC designer specifically knows the final package in which the MMIC will be placed, MMICs are designed a stand-alone components. That is, the I/O ports are designed to look into 50 m cetworks while the dies base and the sub-



▲ Fig. 4 Sizes of the ceramic, SOW and MLP packages.

strate it sits on should be a low inductance to ground. For example, Figure 2 shows the cross-sectional view of the effective ground path (EGP) for the MMIC in a

▼ Fig. 5 Cross section of an MLP package on a PCB.



ceramic package, This path effectively begins at the end wirebond and ends at the PCB ground. Ceramic packages, with their electrically grounded base and short EGP lengths, produce excellent RF performance up to 2.5 GHz. However, these packages have higher costs compared with plastic small outline integrated circuit (SOIC) devices, and that has resulted in limited demand in high volume, low cost applications.

To pursue the low cost attenuator market, the family of attenuators was expanded to include SOW-16 and 24-lead plastic packages. The AT65 series atten-

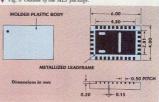
uators have reduced costs compared to the ceramic attenuators. However, the downside of transitioning to plastic packages was an increase in insertion loss and SWR. The additional lead inductance reduced the upper frequency limit to 2 GHz. The 0.300°-wide SOW package has an EGP that is approximately three times that of the ceramic (0.143° vs. 0.500°), as shown in Figure 3. While the SOIC plastic packages are perfectly acceptable for today's CSM and PGS telecommunication systems, they cannot support tomorrow's higher frequency applications or denser packaging objectives.

PACKAGE SELECTION

To realize a low cost plastic attenuator for frequencies beyond 2 CHz, the miniature leadless package (MLP) offered by various package vendors was investigated. This package platform offers low inductance I/O pads on a 0.5mn pitch. In addition, an exposed conductive center die paddle provides improved RF grounding, which permits operation at higher frequencies. Aside from the size recluction, the packages main feature is that its cost is only slightly higher than that of the plastic SOIC packages. Figure 4 shows the ceramic, plastic SOW and MLP packages of the digital attenuator family.

The MLP package, with its ability to have the leadframe and paddle soldered directly to the PCB, can produce an EGP that is 82 percent shorter than that found in the referenced ceramic package. As shown in Figure 5, the EGP is limited to the thickness of the 0.005° copper leadframe. The outline for the 6.0×4.0 mm MLP package is shown in Figure 6.

Fig. 6 Outline of the MLP package



[Continued on page 170]

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PRODUCT FEATURE

DIE DEVELOPMENT

Once the package format was selected, developing ASICs and MMICs to accommodate the MLP platform became the next step. With typical package footprints at 10 to 30 percent of the SOIC packages, a total die shrink for all internal components was in order. The two drivers had to be combined into a single hex driver, and the single six-bit MMICs had to be developed to replace the two MMICs in the six-bit attenuators. Because new MMICs were required, it was determined that they should be designed to support much higher frequencies than the previous devices. For this effort, the upper frequency goal was increased to 4 GHz. This range would produce a respectable margin to ensure that the MLP attenuators would operate to a minimum of 3 GHz.

ASIC DRIVER

The MLP design effort began with the development of the hex channel ASIC driver, which meant increasing the number of channels while reducing the die size. Adding two driver channels was not an issue: however, reducing the size of the die to the required area meant minimizing output drive capability. Specifications were reduced from ±25 mA to ±1 mA with the ability to drive 4 pF loads vs. the original specification of 25 pF. By using smaller output FET junctions, the hex driver was realized at a respectable die size of 2.33 × 1.22 mm.

RF MMIC DEVELOPMENT

Four new MMICs were designed using patented compensation techniques.1 Two five-bit, 1 dB LSB attenuators were designed - one used the standard 10-mil GaAs process, while a second device was designed with the advanced 4-mil GaAs via process. Two six-bit MMICs (0.5 and 1 dB) were also designed with the 10mil process.

The main difference between the two GaAs processes is the method used to connect the MMIC with circuit ground. In the 4-mil via process, the ground returns are platedthrough vias. This configuration allows the designer to use vias at specific ground points in the layout. In the standard 10-mil process ground points must be routed to I/O pads at the edge of the die and wirebonded to ground. The upside of the 4-mil process is the extension of the upper frequency limit. However, downsides include lower yields associated with thinner wafers and higher processing costs due to the vias and backside metallization process steps.

All of the GaAs MMICs were designed with the aide of HP EEsof Series IV software and the company's GaAs MMIC design manual. Extensive modeling was performed on all designs to minimize insertion loss and optimize the attenuation flatness of the individual bits and their summation. During this process it was determined that the physical order of the bits is very important to bit accuracy. and must be optimized to minimize sensitivity to external loading and bit errors. For example, the optimum

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[Continued on page 172]

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SPECIFICATIONS

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MODEL

MODEL	OLO OLINEO				
Frequency	1–15 GHz				
Frequency step size	200 kHz to 10 MHz				
Tuning range	Up to half octave				
Switching speed	500 μs*				
Output power	10 dBm min.				
Output power variation	±2 dB min.				
In band spurs	70 dBc min.				
Harmonics	20 dBc				
Phase noise	See graph				
Reference	Internal or external				
External reference Frequency Input power	5/10 MHz 3 dBm ±3 dB				
Frequency control	BCD or binary				
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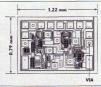


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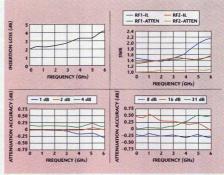
PRODUCT FEATURE



A Fig. 7 The five-bit, 1 dB, 4-mil, GaAs MMIC layout.

physical order for the bits in the 4mil. five-bit attenuator is 16, 1, 2, 4 and 8 dB.

Another technique that lessened the interaction of the bits was to add 0.25 pF decoupling capacitors to the control lines on the larger bits. This addition minimizes coupling between the RF signals and control lines, which improves the accuracy of the bits. In addition, using the single standard series FET cell for the insertion loss path in the 16 dB bit limited the frequency performance. The isolation of the single FET is too



▲ Fig. 8 Performance of the 31 dB five-bit, 4-mil, GaAs MMIC

close to the desired attenuation at high frequencies. While a very small FET could be used, its on resistance would significantly increase the insertion loss of the bit. To overcome this dilemma, a series/shunt/series configuration was implemented. This structure allows the insertion loss to remain low while, at the same time, increasing the isolation across the series-switching FET elements. The result is an extremely flat 16 dB bit.

In an effort to keep the die size as small as possible, the impedance of the internal transmission lines was increased to 70 Q. This change allowed the width of RF lines to be reduced from 73 to 30 µm while the SWR remained less than 2 over most of the band. The resultant die size was essentially limited by the number and position of the I/O bond pads, and not the internal circuitry. Figure 7 shows the die layout; Figure 8 shows the measured results.

ASSEMBLY

Both the driver and MMIC dice are attached to the grounded paddle with epoxy. Unlike the ceramic and SOW plastic devices that contain internal circuitry, interconnections between ASIC and MMIC dies utilize direct die-to-die wirebonds. Extensive testing has shown that this method is an effective and reliable assembly technique for interconnecting die in small packages.

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PRODUCT FEATURE

TABLE I

P/N	Max. Frequency (GHz)	Bits	Bit Size (dB)	Dynamic Range (dB)	Power Supplies (V)
AT90-0001	6	5	1.0	31.0	+5, -5
AT90-0106	3	6	1.0	50.0	+5, -5
AT90-0107	4	6	0.5	31.5	+5, -5
AT90-0263	4	5	1.0	31.0	+5, -5
AT90-0283	3	5	0.5	15.0	+5, -5
AT90-1106	3	6	1.0	50.0	+5
AT90-1107	4	6	0.5	31.5	+5
AT90-1263	4	5	1.0	31,0	+5
AT90-1283	3	5	0.5	15.0	+5

PRODUCT DESCRIPTION

Table 1 lists the characteristics of the AT90-XXXX attenuator family. The initial product operates with +5 and -5 V supplies at +6 and -1 mA (max), respectively. Logic inputs are TTL compatible. A logic 0 sets the bits to reference loss while a logic 1 selects the attenuation levels. Typical switching speed is 35 ns with rise and fall times of 5 ns

The AT90-0001 attenuator containing the 4-mil via process die exceeded expectations and is specified to operate to 6 GHz. While DC blocks are not needed on the RF ports, 0.01 µF decoupling capacitors are required on each power supply line to ensure switching speed performance. The plastic MLP package measures 6.0 × 4.0×0.9 mm. Thirty-two 0.25×0.40 mm I/O pads are set at 10 per long side, six per short side on a 0.5 mm pitch. The 2.8 × 4.8 mm center die pad must be soldered to the PCB to ensure good RF performance.

To accommodate single power supply systems, four single-supply (+5 V at 10 mA) attenuators are presently in development. These devices will use an internal GaAs DC-DC converter to produce the required negative voltage. The two previously referenced decoupling capaci-

[Continued on page 176]



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PRODUCT FEATURE

TABLE II

AT90-0001 PRELIMINARY SPECIFICATIONS

Parameter	Test Conditions	Frequency	Min.	Typ.	Max.
Insertion loss (dB)	All logic inputs at logic 0	DC to 1.0 GHz DC to 2.0 GHz DC to 4.0 GHz DC to 6.0 GHz		2.4 2.5 3.3 5.0	2.9 3.1 3.8 5.8
Attenuation accuracy (dB)	1 to 31 dB bits 1 to 25 dB bits 25 to 31 dB bits	DC to 3.0 GHz DC to 6.0 GHz DC to 6.0 GHz	- - -	- - -	$\pm (0.3 + 3\%)$ of attenuation in d $\pm (0.3 + 3\%)$ of attenuation in d $\pm (0.3 + 5\%)$ of attenuation in d
SWR	full range	DC to 2.0 GHz DC to 6.0 GHz	10	1.4 1.7	1.7 2.4
1 dB compression (dBm)	Ē.	50 MHz 0.5 to 6.0 GHz	-	22 28	<u> </u>
Input IP2 (dBm)	two tone inputs to +5 dBm	50 MHz 0.5 to 6.0 GHz	_	43 60	-
Input IP3 (dBm)	two tone inputs to +5 dBm	50 MHz 0.5 to 6.0 GHz	Ē	37 48	5
Vcc (V) Vee (V)	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-	4.75 -8.00	5.0 -5.0	5.25 -5,00
Switching speed (ns)	50% control to 90% RF 50% control to 10% RF 10% to 90% RF 90% to 10% RF	T_{on} T_{off} T_{risc} T_{fall}	2	27 16 13 3	
Logic 0 (V) Logic 1 (V)	control currents are 1 µA (max)	=	0.0 2.0	-	0.8 5.0
Ice (mA) Ice (mA)	Vcc, Vee min to max 0 V • logic 0 • 0.8 V Vcc - 2.1 V • logic 1 • Vcc		=	3 0.01	6 1

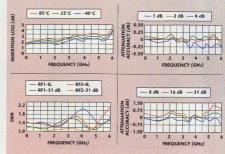
Fig. 9 A test board for the AT90-0001 attenuator.



tors must be increased to 0.1 μ F, and a third 0.01 μ F coupling capacitor is required between pins 23 and 21.

Sample attenuators (AT80-XXXX) and/or test boards (AT90-XXXX-TB) are available upon request. Table 2 lists the AT90-0001 31 dB, five-bit attenuator's preliminary specifications. A test board for the device is shown in Figure 9. Figure 10 shows measured results. Full data sheets containing suggested PCB layouts are available on the company's Web site at www.macom.com.

▼ Fig. 10 The AT90-0001 attenuator's measured performance on a test board.



References

 Shmuel Ravid, Alan R. Olsen and Gary E. St. Onge, "Electronic Attenuator," US Patent 5,281,928. M/A-COM, Lowell, MA (800) 366-2266.

Circle No. 305



Chip Coupling Capacitors at 12c each (50 min.)

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.002, .047, .068, .1 µf



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PRODUCT FEATURE



HIGH EFFICIENCY L- AND S-BAND TRANSMITTERS

A new line of miniature airborne telemetry transmitters has been introduced that uses a proprietary approach to amplifier design and features previously unattainable DC-to-RF efficiencies. The breakthrough design utilizes GaAs FETs in a configuration that eliminates the usual transmitter design trade-off of a linear regulator (very poor efficiency) vs. a switching regulator (electromagnetic/RF interference problems).

In many telemetry applications, the transmitter represents the major portion of the current draw and becomes the determining factor in flight time, range, battery size/weight, heat dissipation and other flight parameters. By dramatically lowering the current draw requirement, the new transmitter completely resets this trade-off equation.

Another common situation requiring design compromises is an esisting system's increased data rate specification. For example, a requirement to double the data rate of an existing system requires the pre-detect handwidth of the receiver to double. A 3 dB gain in received power is needed for the link to maintain the original range and bit error rate.

Since lowering the low noise amplifier (LNA) noise figure by 3 dB is probably impossible, the system designer is usually left with the choices of increasing the gain of the transmit and/or receive antenna(s) or increasing

the transmitter power. Assuming the existing telemetry pack system represented an optimal design prior to the introduction of this series of transmitters, the designer's choices are narrowed even further to increasing the transmit antenna gain (difficult due to flight constraints) or increasing the receive antenna gain (usuall very expensive).

The new line of ultra-high efficiency (UHE) transmitters effectively solves this system design dilemma. For example, doubling the transmit power from 5 W (conventional design) to 10 W (UHE) actually lowers the current draw requirement and heat dissipation. Other link elements, including the transmit antenna, receive antenna and LNA, as well as system elements, such as battery size and heat radiators, remain unchanged.

Yet another situation posing a design dilemma is one where higher RF power is not needed, but more current is required for additional processing circuitry and, of course, no additional supply current is available. In this case, changing from a conventional 5 W transmitter to a new UHE model frees up nearly 1 A of supply current.

[Continued on page 180]

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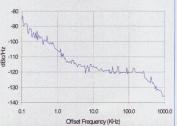
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 100 KHz
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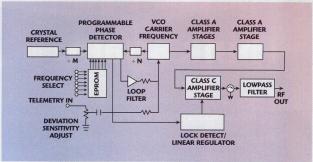
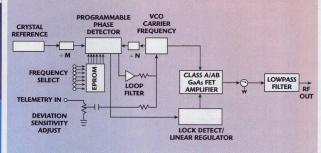


Fig. 1 Block diagram of a conventional L-/S-band transmitter.

▼ Fig. 2 Block diagram of the UHE L-/S-band transmitter.



PERFORMANCE COMPARISON

Most conventional telemetry transmitters are configured similar to the block diagram shown in *Figure I*. A phase-locked exciter generates the RF carrier and determines the modulation characteristics. This exciter drives several cascaded linear (class A) amplifier stages, which, in turn, drive the power stage(s) operating in class C. The power stage(s) is typically a silicon bipolar transistor.

In contrast to high power bipolar transistors, high power GaAs FETs are optimized for class A or AB rather than class C operation. While a class C stage is more efficient than a class A or AB stage in terms of DC-to-RF power conversion, the situation reverses when taking into account the much higher gain S21 of GaAs FETs.1 Typical L- and S-band GaAs FET gains are 16 to 18 dB, as opposed to approximately 8 dB for silicon bipolar transistors. Therefore, the poweradded efficiency (PAE) of GaAs FETs far exceeds the efficiency of a class C silicon bipolar device.

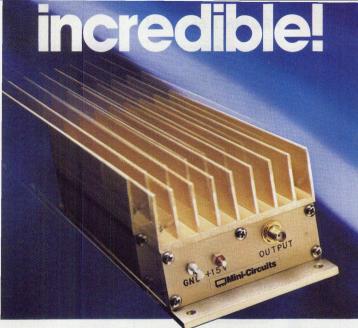
A block diagram of the new UHE transmitter is shown in Figure 2. The multiple class A bipolar driver stages (two stages minimally, three typically) and class C power stage are entirely replaced by the new GaAs FET amplifier. The high gain of the GaAs FETs permits the removal of several amplifier stages and their attendant DC power losses.

The elimination of amplifier stages, the increased GaAs FET RF power out/DC power in efficiency (up to 70 percent) over silicon bipolar transistors and the GaAs FET amplifier configuration significantly reduce the total current draw. In addition, the overall transmitter efficiency increases as the RF power output of the transmitter increases since the overhead current of the exciter represents a smaller percentage of the total current draw.

Performance comparisons between the UHE line of telemetry transmitters and conventional designs dramatically demonstrate the advantages of the new

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[Continued on page 182]



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Gain Flatness, dB, Max.	±1.0	±1.5	±1.5	±1.5
Power Out @1dBCP, dBm	min. +28	+28	+28*	+28*
VSWR n/out, max.	2.5:1	2.5:1	2.5:1	2.5:1
Noise Figure, dB, typ.	10.0	8.0	8.0**	8.0**
Power Supply, V/mA	+15/880	+15/900	+15/880	+15/900
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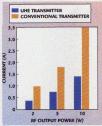


Fig. 3 Transmitter current comparison.

transmitters. Figures 3 and 4 show the decreased current draw and power dissipation, respectively, while Figure 5 shows the increased transmitter efficiency. Using these figures, the following examples evaluate the replacement of conventional telemetry transmitters with the company's new UHE line.

A change from a 10 W conventional transmitter to a 10 W UHE series transmitter with the same data rate re-

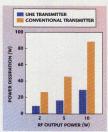


Fig. 4 Transmitter power dissipation comparison.

sults in no reduction in range, a 60 percent reduction in current and 67 percent less power dissipation. Changing from a 5 W conventional transmitter to a 10 W UHE series transmitter with the same data rate provides 41 percent additional range with a 22 percent reduction in current draw and a 35 percent reduction in power dissipation. A similar change from a 5 W convention-

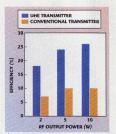


Fig. 5 Transmitter efficiency comparison.

al transmitter to a 10 W UHE series transmitter with double the data rate produces no range change but a 22 percent reduction in current draw and 35 percent less power dissipation. A final example is a change from a 2 W conventional transmitter to a 5 W UHE series transmitter with the same data rate. This replacement results in a 58 percent increase in range, a 25 percent reduction in current draw and a 38 percent reduction in power dissipation.

With standard input voltage levels of +28 V ±4 V, the frequency-agile UHE 2 W design draws 400 mA (max), the 5 W draws 750 mA (max) and the 10 W draws 1.4 A (max). Conventional frequency-agile telemetry transmitters draw 1.0, 1.8 and 3.5 A for 2, 5 and 10 W, respectively.

CONCLUSION

A new line of UHE telemetry transmitters offers designers new choices for system optimization. The transmitters are available in 2, 5 or 10 W RF power levels in the standard nine- or 11-cubicinch packages (2.5" \times 3.5" \times 1" or 2.5" \times 3.5" × 1.3"), and in 2 and 5 W RF power levels in the five- or six-cubic-inch packages $(2" \times 3" \times 0.8" \text{ or } 2" \times 3" \times 1")$.

Reference

1. Tim Bambridge, "High Efficiency 5 W S-band Telemetry Transmitter Using Gallium Arsenide Field Effect Transistors." Proceedings of the 1995 International Telemetering Conference, Volume XXXI, Las Vegas, Nevada, 30 Oct. 1995 to 02 Nov. 1995.

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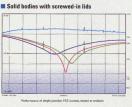
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PRODUCT FEATURE



A 6 GHz Dual Fractional-N Frequency Synthesizer

oday's high performance radio systems require low power and fine step sizes as well as the usual low phase noise, fast switching and small size that have become prevalent in modern portable communications equipment. The model CX72302 direct digital modulation fractional-N frequency synthesizer has been designed to provide all of these characteristics while featuring ultra-fine frequency resolution and an on-chip crystal oscillator. The new frequency synthesizer IC features a 6 GHz (max) operating frequency, -80 dBc/Hz phase noise floor and 400 Hz or less step size, making it ideal for very narrowband wireless applications. This performance is a direct result of the on-chip low noise dividers and low divide ratios provided by the IC's high fractionality.

The IC's ultra-fine step size is capable of compensating for crystal oscillator drift or IF filter drift using the proper temperature sensing. As a result, a simple crystal oscillator may be used as a reference as opposed to the bulkier and more costly temperature-compensated or oven-controlled crystal oscillators, thus reducing parts count, size and associated component costs. The IC's fine step size can also be used for Doppler shift corrections.

The crystal frequency is divided down by one to 32 independent programmable dividers for the main and auxiliary synthesizers. As a result,

reference crystals or oscillators up to 50 MHz may be used with the CX72302 synthesizer.

The phase detectors operate at a maximum speed of 25 MHz, thus permitting better phase noise due to the lower division value. In addition, with the high reference frequency, the loop bandwidth also is increased, resulting in improved settling time and reduced in-band phase noise. The lower in-band phase noise permits the use of lower cost VCOs in the system.

The CX72302 synthesizer features a patent-pending Frequency Power Steering Twicircuit that assists the loop filter in steering the VCO when the frequency is too fast or too slow. In this configuration, acquisition times up to five times faster than conventional phase/frequency detectors can be achieved. Typical switching times of less than 100 μ s are possible with a 10 MHz reference.

A combination of wide bandwidth, fine frequency resolution and a three-wire, high speed serial interface permits direct phase and frequency modulation of the VCO. This capability supports any constant envelope or continuous phase modulation, meaning any analog FM or digital FM, and can eliminate the

[Continued on page 186]

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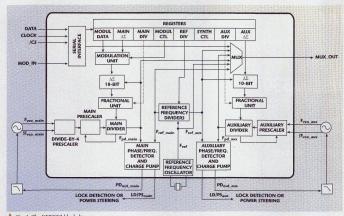
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▲ Fig. 1 The CX72302 block diagram.

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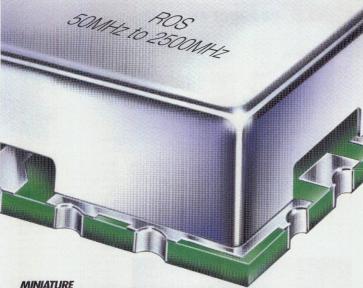
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need for in-phase and quadrature digital-to-analog converters, quadrature upconverters and IF filters from the transmitter portion of the system. Figure 1 shows the CX72302 IC's block diagram.

PERFORMANCE SPECIFICATIONS

The CX72302 synthesizer is designed to operate over a -40° to +85°C temperature range from a 3 V DC supply and consumes 51 mW (typ). Under power down operation the device draws typically 10 µA of current. The main VCO output frequency range is from 800 MHz to 6 GHz, while the auxiliary VCO output has a range of 400 to 1100 MHz. The reference oscillator's frequency can be up to 50 MHz. The main fractional-N tuning step size is Frefmain/216 or F_{ref main}/28 (Hz), while the auxiliary step size is Fref aux/210 (Hz). Both the main and auxiliary phase detectors have a maximum operating frequency of 25 MHz. The charge pump output source current is in the range of 125 to 1000 µA, and the sink current is -125 to -1000 μA. The synthesizer's phase noise within the loop bandwidth is $-128 + 20\log(N)$

[Continued on page 188]



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ROS-1000PV ROS-1435PV ROS-1600PV ROS-1605PV ROS-100 ROS-150	900-1000 1375-1435 1520-1600 1500-1605 50-100 75-150	5 5 5 5 5 17 18	-104 -101 -100 -98 -105 -103	-33 -26 -26 -17 -30 -23	5 5 3.3 12 12	22 20 25 16 20 20	19.95 19.95 18.95 19.95 12.95 12.95
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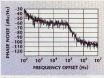
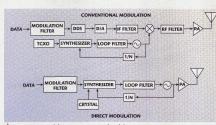


Fig. 2 The synthesizer's typical phase noise characteristics.

Fig. 3 The synthesizer's spectral purity at 5.185 GHz. ₩



(dBc/Hz), while the total spurious power is –70 dBc. *Figures* 2 and 3 show the device's typical phase noise and close-in spectral purity, respectively. The CX72302 synthesizer is



A Fig. 4 Direct modulation vs. conventional modulation.

supplied in a 28-pin EP-TSSOP plastic package that measures $9.7 \times 6.4 \times 1.1$ mm high and is designed for surface mounting to a PCB.

APPLICATIONS

The CX72302 dual fractional-N frequency synthesizer is part of a family of similar devices that includes the CX72300 (2.1 GHz) and CX72301 (1.1 GHz) synthesizers. The CX72302 device is targeted for wireless local loop

(WLL) and wireless local area network applications, as well as local multipoint distribution system, multichannel multipoint distribution system and microwave radio applications. Its features are particularly useful in providing direct digital modulation that significantly simplifies a communications transmitter by eliminating D/A converters, RF and IF filters, mixers, buffer amplifiers and costly temperature-controlled crystal oscillators. Figure 4 shows an example of a simplified transmitter block diagram utilizing the CX72300series synthesizer as a direct digital modulator. The other two models in the family are targeted toward two-way radios and pagers (CX72301) and multimode cellular phone satellite handsets, tuners, receivers and 3G/cellular/PCS base station applications (CX72300).

CONCLUSION

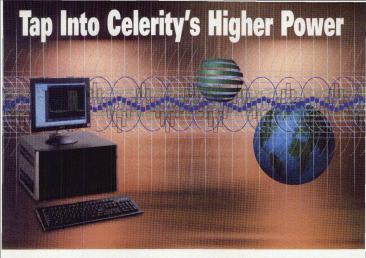
A 6 GHz dual fractional-N frequency synthesizer IC is now available that features ultra-fine step sizes, a high reference frequency, low phase noise, and fast switching and settling times. The new device can greatly simplify a digitally modulated transmitter by implementing direct digital modulation, and its use of an on-chip crystal oscillator significantly reduces component cost and system complexity. Additional information on this device and others in the synthesizer family may be obtained from the company's Web site at www.conexant.com.

Conexant Systems Inc., Nepean, Ontario, Canada (613) 274-0922.

922. Circle No. 303



0.....



For More Intelligent 3G Wireless Amplifier and Digital Radio Testing

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CS2010 Vector Signal Generator/Analyzer All the

capability of the CS2010 VSA and the CS2010 VSG in one package. By simply adding hardware and software modules, the VSA or VSG can be upgraded to provide multi-path fading, smart antenna testing, bit error rate testing and protocol testing.

Utilizing a unique architecture, the CS2010W offers a completely open test environment with selection of functions (spectrum analysis, oscilloscope, digital pattern generation/analysis), along with a series of digital and RF multi-carrier waveform generation capabilities.

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PRODUCT FEATURE



MULTISTAGE DEPRESSED COLLECTOR KLYSTRONS

inding ways to operate satellite communications (SATCOM) high power klystrons more efficiently has a double-edged benefit. The SATCOM transmitter uses less prime power, saving uninterruptible power supply capacity, and the klystron runs cooler, significantly improving its reliability. The multistage depressed collector (MSDC) high power klystron has been specifically designed for SATCOM uplink applications and features a collector efficiency of 80 percent or greater. This improved efficiency permits a prime power savings of two to three kilowatts when

operating at full power. For low operating powers under clear-sky conditions, the prime power savings could amount to five to six

Figure 1 shows the prime power savings vs. RF output power of the MSDC klystron compared to a standard klystron design.

Since most blystrons operate at low RF operating powers for intermodulation consideration, the MSDC has the capability to provide maximum savings at the most likely set of operating conditions. Thus, the MSDC tubruns cooler with the potential of a longer lifetime than its standard blystron cousins.

time than its standard klystron cousins.

MSDC klystrons have been developed for both C- and Ku-band commercial satellite service and feature a small, compact design and a four-stage depressed collector configuration use. Utilizing collector depression the collector heat dissipation is much reduced, thus lowering the required air flow for cooling. This reduced air flow permits the use of small-er AC power systems, especially in hot, humid environments. Lower collector temperatures are key to enhancing the klystron's lictime.

[Continued on page 192]

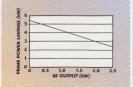
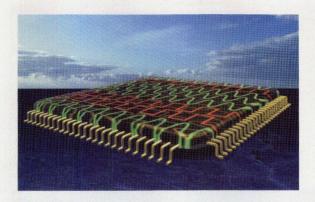


Fig. 1 MSDC prime power

savings.

COMMUNICATIONS & POWER INDUSTRIES CANADA INC. (CPI CANADA) Georgetown, Ontario, Canada

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PRODUCT FEATURE

TABLE I

MSDC KLYSTRON TYPICAL CHARACTERISTICS

Model				
Frequency range (GHz)	5.850 to 6.425	5.725 to 6.725	13.75 to 14.50	12.75 to 13.25
Instantaneous bandwidth (MHz)	45	45	85	85
Output power (W)	3350	3350	2500	2500
Gain (dB)	41	41	49	49
Beam voltage (kV)	8.7	8.7	8.6	8.6
Beam current (A)	1.09	1.09	1.06	1.06
Body current (mA)	5	5	7	7
Heater current (A)	6.1	6.1	4.2	4.2
Heater voltage (V)	6.0	6.0	6.5	6.5

Table 1 lists the various MSDC klystron models and their typical operating characteristics. Both the C- and Ku-band klystrons are mounted with the collector up and use permanent magnet focusing. The C-band klystrons' RF input connector mates

with a type-N plug, YG-21 D/U or equivalent, and the RF output connector is a CPR 137 waveguide flange. The Ku-band units' RF input and output ports mate with UG-419/U waveguide flanges. All models require external air flow cooling. Communications & Power Industries Canada Inc. (CPI Canada), Georgetown, Ontario, Canada (905) 877-0161.

Circle No. 301

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A HIGH POWER LDMOS TRANSISTOR FOR BROADCAST TRANSMITTER APPLICATIONS

paying the way for major new markets, such as high speed Internet access and mobile multimedia in-car entertainment, as well as high definition TV and a huge expansion in program choice. With standards now in place, as well as an increasing number of commercial services and rapidly maturing technology, broadcasters and service providers are keen to push forward the move to digital transmission. A unique ultra-high frequency (UHF) power lateral double-diffused metal-oxide semiconductor (LDMOS) transistor has been developed that cuts the cost of upgrading terrestrial transmitters for digital operation.

Digital technology enables terrestrial broadcasters to simultaneously increase revenues and reduce costs; however, transmitter equipment first must be adapted. The key requirement is sufficient BF power — a need addressed directly by the model BLF861 power LDMOS transistor. Designed specifically for terrestrial transmitters, this new device offers greatly improved output power and gain over existing bipolar technology, dramatically reducing the number of amplifiers required and significantly reducing the coutput power for transmitter manufacturers.

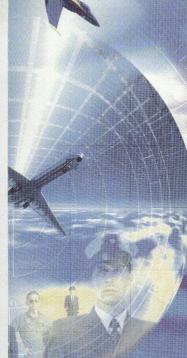
The BLF861 transistor also provides excellent ruggedness and linearity. In addition, unlike competing devices the unit covers the entire spectrum of bands IVV, which are used for TV transmission worldwide (470 to 860 MHz). This unique leature allows transmitter manufacturers to offer maximum flexibility for service providers, with transmission capability for all broadcast channels. Overall, the BLF861 transistor's many advantages meet all transmitter manufacturers' needs for reliable, cost-effective solutions. Currently, the BLF861 is in volume production and is being used by major broadcast transmitter manufacturers.

PRODUCT PERFORMANCE

The BLF861 device uses the company's LDMOST technology, which utilizes gold metallization for reliable performance. Due to the nature of LDMOST, no insulator is required; therefore, toxic materials (such as BeO) are not used.

[Continued on page 201]

PHILIPS SEMICONDUCTORS Eindhoven, The Netherlands



LDMOS Prodi	uct Range for A	Avionics	Applications		Mode of	Efficience
Type Number	Frequency (MHz)	Vds (V)	Mode of Operation	Pload (W)	Operation (dB)	(typical) (%)
BLA1011-05	1030-1090	26	Class-A	0.5	16	-
BLA1011-2	1030-1090	36	Class-AB	2.0	16	- 48
BLA1011-10	1030-1090	36	Class-AB	10	16	48
BLA1011-200	1030-1090	36	Class-AB	200	14	48



Golden Innovations in LDMOS Transistors for Avionics

Philips Semiconductors, one of the world's leading manufacturers of LDMOS transistors, offers the world's first complete line up of LDMOS parts designed and tested for **Avionics** applications.

The use of Philips Semiconductors LDMOS transistors in **Avionics** amplifiers improves design architecture by reducing the number of transistors and surrounding circuitry.

which leads to overall cost savings.

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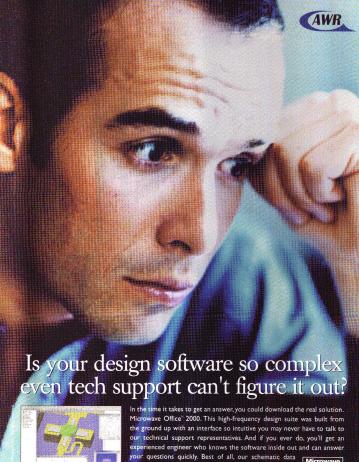
Philips LDMOS transistors show an excellent thermal behavior, and an all-gold metallization system ensures superb reliability. LDMOS transistors from Philips Semiconductors also ensure device consistency in large volume production by using automated die attach and wire bonding equipment.

Plus, with a dedicated RF/microwave business group, local market resources, and the largest RF inventory in the world, Avnet Electronics Marketing is uniquely positioned to be your source for LDMOS transistors.

Call Avnet Electronics Marketing to learn more about using Philips Semiconductors LDMOS transistors in pulsed Avionics applications, 1-800-332-8638. Or visit the Avnet Electronics Marketing gateway page at www.em.avnet.com/rfm/avionics.html.



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translators can even import existing Agilent EEsof Series IV or ADS designs, so you won't lose all the valuable data that you worked so hard to create. For more information, visit www.mwoffice.com or call us at 310-726-3000.



PRODUCT FEATURE

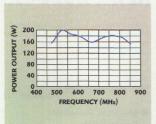
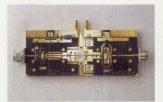
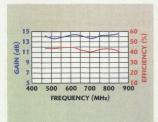


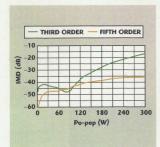
Fig. 1 Output power over the UHF



A Fig. 2 The broadband test circuit.



▲ Fig. 3 Gain and efficiency over the UHF band.



▲ Fig. 4 IMD performance at 860 MHz.

The BLF861 transistor was designed specifically for band IV/V UHF transmitter applications, thus placing severe pressure on the transistor design to achieve real broadband performance. By applying inter-

nal input and output matching, the broadband performance is realized. Furthermore, the target was to achieve an output power of at least 150 W in CW operation. Figure 1 shows the unit's output power over the entire UHF band. Figure 2 shows the broadband circuit used with the BLF861 device to achieve the described performance. Apart from output power, other important requirements for an RF power transistor for TV transmitters are efficiency, gain (shown in Figure 3) and intermodulation distortion (IMD) (shown in Figure 4).

THE NEXT STEP

The BLF861 transistor demonstrates exceptional performance for UHF transmitters. However, another RF power LDMOS transistor, the model BLF861A, is being introduced for two compelling reasons. First, LDMOST technology development is an ongoing process that leads to significant improvements. One of these major improvements is the I_{dq} drift reduction — a well-known phenomenon related to LDMOST devices. New process improvements have significantly reduced this I_{dq} drift. Second, the device's ruggedness was able to be further improved. The existing BLF861 is able to withstand mismatch conditions of an SWR of 10. However, there may be failure situations in a transmitter where abrupt source/load mismatch conditions occur (for example, a disconnected antenna). The new BLF861A device can withstand these source/load failures under full power conditions for a short period of time with no thermal damage. This feature has been implemented using an extra process change.

From an applications point of view, the differences between the BLF861 and BLF861A are minimal. This means that the BLF861A transistor can be substituted in a BLF861 application with only minor changes. The company is now in the process of industrializing the BLF861A device and plans to start volume production in December.

Philips Semiconductors, Eindhoven, The Netherlands (800) 234-7381 (US) or +31 40 27 82785.

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CIRCLE 87



COMPONENTS

SPDT RF Relay



The model RF 2X1 SPDT RF relay is designed for remote switching of VHF signals. The unit provides high isolation and low loss in the frequency range from DC to 900 MHz, and isolation is approximately 60 dB with an insertion loss of approximately 0.5 dB. The switch is ideal for broadband or IF control switching in cable and wireless systems. Three F connector ports are mounted on one side for ease of connection and placement. Eight-foot leads are provided for control voltage, and the power requirement is 30 mA at 12 V DC (approximately 300 mW). Alaun Electronics.

La Canda, CA (888) 810-0333.

Circle No. 216

SP6T Radial Solid-state Switch

The model SWN-1140-6DB-DEC-SP reflective SP6T radial solid-state switch works from 0.5 to 18.0 GHz



with an insertion loss of < 1.0 dB (typ) at 0.5 GHz and < 2.45 dB at 18.0 GHz. Video transient is < 320 mV at 300 MHz bandwidth and

< 100 mV at 20 MHz bandwidth. SWR is better than 2, and isolation is ≥ 90 dB at 0.5 GHz and ≥ 40 dB at 18 GHz. Switching speed is < 60 ns delay ON and < 40 ns delay OFF. Supply voltages for the switch are +5 V at 31.3 mA and -12 V at 44 mA. Weight: 2.0 oz. (typ). Size: 1.25" × 1.25" × 0.4".

American Microwave Corp. (AMC), Frederick, MD (301) 662-4700. Circle No. 217

SMA Phase-adjustable **Adapters and Connectors**

The Coaxicom 3993 phase adjusters offer a precise and simple means of phase adjustment over frequency ranges up to 18 GHz. A phase ad-

justment nut that is locked into place after setting provides the user with incremental changes in elec-

trical length at 10°/GHz. The series is offered as an in-line adapter or as a direct solder SMA plug for semirigid cable. All models can also be specified for 4.0, 8.0 or 12.4 GHz operation. The units eliminate cable trimming and allow phase matching to be done at the final production stages. The 3993-1 adapter operates to 18 GHz, with an adjustment range of 180° (min) and a maximum SWR and insertion loss of 1.30 and 0.42 dB, respectively. The 3993A adapter operates at 4 GHz with an SWR of 1.10 (max) and an insertion loss of 0.2 dB. The 3993-2 and 3993-3 phase-adjustable connectors have SMA plugs for 0.141" and 0.086" semirigid cables, respectively. Their performance is essentially the same as the adapters. Coaxial Components Corp

Islandia, NY (800) 583-9954 or (631) 234-4447.

Circle No. 220 High Power Termination



The model 150-WT-FN high power termination was designed utilizing thermal imaging photography to ensure even heat distribution. It offers a power rating of 150 W (avg) at 25°C and an impedance of 50 Ω (nom). The frequency range and SWR are DC to 1 GHz at 1.10 (max) and 1 GHz to 2.4 GHz at 1.25. N female connectors are included, and the operating position is horizontal or vertical. Size: 4.850" × 5.400" × 4.30". Weight: 2.5 lb. BCP (Bird Component Products), Largo, FL (727) 547-8826.

Circle No. 219

Mini Coax Connector System



The har-pak® mini coax connector system is a high contact density modular connection system using cutting-edge back plane wiring techniques. Excellent crosstalk characteristics make the connectors ideal for many applications in the wireless telecom market. Noted for its rugged, compact board-to-board interconnections, the system is flexible and can accommodate a wide variety of cable assemblies, such as SMA, SMB and N-type. The modules are available in various sizes, offering two to 10 coax lines per module. Both the straight and

NEW PRODUCTS

angled connectors feature blind mating boardto-backplane RF connection and are press-fitted with flat rock tooling. The system also features board-to-cable RF interconnection and float plate solutions for blind mating of heavy subassemblies. Price: \$28 (100). Harting Inc. of North America, Elgin, IL (877) 741-1500.

Circle No. 223

Miniature Monolithic Crystal Filter



The model ATFN6024A monolithic crystal filnot compromise the performance of the three-pole crystal filter housed within. It is specifically designed for use in multimode phone, digital TDMA, two-way

radio and telecommunications infrastructure applications. In addition, the filter offers increased functionality and operates in the 73 to 135 MHz frequency range. It can be customized to operate at higher frequencies. Size: 3.8 × 3.8 mm

CTS Corp., Elkhart, IN (800) 757-6686. Circle No. 221

14-position Coaxial Switch The model 5E1]-5808 14-position coaxial

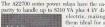


switch developed specifically for the automated test equipment market is best used as a building block to provide various switching solutions. Its most typical applications are switch matrices

switchable filter banks. The SP14T switch is normally open and has an operating voltage of 24 V DC over the DC to 13 GHz (upgradable to 18 GHz) frequency range. SWR is 1.6, insertion loss is 1.6 and isolation is 50 dB (min). Dow-Key Microwave Corp.

Ventura, CA (805) 650-0260. Circle No. 222

30 A Power Relays



electric, making them ideal for a wide variety of applications from HVAC to UPS systems to microwave ovens. Mounting options

include PCB, E bracket, screw and panel mount. Connections are PCB or 0.250° quickconnect. Price: \$3.79 (1000). American Zettler Inc. Aliso Viejo, CA (949) 831-5000.

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Circle No. 218 [Continued on page 204]

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Solid-state Matrix Switch



The model 12321 32 × 32 output solid-state matrix switch features a DC to 24 MHz frequency bandpass, crosspoint verfication, and RS 232C and IEEE-488 interfaces. Typical applications of the non-blocking full fanout switch include routing NTSC video, HF antenna switching and automatic testing. Size: 5.25" × 19.00" × 25.00".

Matrix Systems Corp., Calabasas, CA (818) 222-2301. Circle No. 226

Low Cost Coaxial Power Interconnect

The PowerDirectTM low cost coaxial power interconnect delivers high currents as close to

the integrated circuit as possible. The new power distribution architecture provides an extremely low. inductance and resistance path from the power

source to its destination. The current carrying capacity is 50 A, providing transients (slew rates) as high as 400 A/us with a minimal required board area of only 0.11 square inches. PowerDirect technology combines a high performance coaxial interconnect with an optimal PCB layout pattern to provide a cost-effective solution for power delivery directly to high performance semiconductor devices. Benefits include low PCB surface and interplane area and improved PCB routability. There are several interconnect methods for the PowerDirect including platethrough-hole screw and surface-mount technology

INCEP Technologies Inc. San Diego, CA (858) 547-9925.

Circle No. 224

■ 50 and 75 Ω **Rotary Step Attenuators**



step size and dynamic range. Dual concentric attenuators are also available. where the outer control knob steps in either 0.1 or 1.0 dB steps. depending on the

model. All units are available for panel mounting, or two or more units can be supplied cascaded for bench-top operation. Connector op-tions include SMA, N, BNC, TNC and F (75 Ω units only MIDISCO.

Islandia, NY (800) 637-4353

Circle No. 228

■ Japanese Band CDMA Duplexer



The model WSD-00179 high performance Japanese band CDMA duplexer offers low insertion loss and excellent selectivity in a small size. It is configured with a transmit passband of 832 to 870 MHz and a receive passband of 887 to 925 MHz, and features 1.5 dB (max) insertion loss and 15 dB (min) return loss within each passband. The unit offers channel-tochannel isolation of 70 dB (min), with transmit-to-antenna rejection of 20 dB (min) from

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[Continued on page 206]

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DC to 810 MHz, 70 dB (min) from 887 to 925 MHz and 50 dB (min) from 925 to 2775 MHz Antenna-to-receive rejection is 70 dB (min) from DC to 870 MHz and 50 dB (min) from 1000 to 2775 MHz. Applications include filtering for pico, micro and macrocell base station installations, and general-purpose handset or equipment test systems. Size: 4.65" × 4.20" × 2.75", excluding type N-F connectors K&L Microwave Inc.,

Salisbury, MD (410) 749-2424.

Circle No. 225

International C-band **Bandpass Filter**



The model 11383 international C-band waveguide bandpass filter is installed between a television receive-only feedhorn and the low noise amplifier or low noise block to suppress strong out-of-band interference caused by marine or airport radar systems. The filter has an insertion loss of 0.5 dB (typ) at the center frequency and 1.25 dB (max) (1.0 dB typ) at 3.6 and 4.2 GHz. Suppression is 25 dB (min) at 3.55 and 4.25 GHz. The flanges are rectangular CPR229G (grooved) and CPR-229F (flat). The unit measures 5.375 inches long (flange to flange) and is also available in lightweight aluminum construction (model 11383AL) Microwave Filter Co. (MFC), East Suracuse, NY (800) 448-1666

Circle No. 227

■ Ultra-thin Frequency Mixers The model ADE-1MH ultra-thin 0.108° fre-



or (315) 438-4700.

quency band. At midband, the mixers have low 5.2 dB conversion loss (typ) and good 50 dB L-R. 45 dB L-I isola-

tion (typ). The mixers are patent-pending and level 13 (LO). Price: \$5.95 each (10-49). Mini-Circuits,

Brooklyn, NY (718) 934-4500. Circle No. 229

Low Intermodulation Isolator

The model INA-0808 isolator operates over the 869 to 894 MHz frequency range with an



insertion loss of 0.2 dB (max), isolation of 25 dB (min) and SWR of 1.2 (max). Intermodulation is < -110 dBc and the

operating temperature range is -40° to +60°C. SMA female connectors are provided. Size: 1.50" × 1.50" × 0.75". Narda-an L-3 Communications company,

Circle No. 231

Folsom, CA (916) 351-4550. Miniature Transformers

This new family of miniature RF transformers is available in a variety of impedance ratios and perates over wide frequency band-



widths from 500 kHz to 1.5 GHz while maintaining a flat frequency re-

are used to match impedances, step-up/stepdown voltages and create DC isolation, as well as convert the circuit from balanced to single ended. The miniature package makes these transformers ideal for space-constrained RF applications, including cable modems, set-top boxes, wireless and cable network infrastructure equipment, and other high frequency communication systems and Internet devices. The transformers are available with and without centertaps in both DC-isolating and non-DC-isolating configurations, Size: 0.15" × 0.15" (3.81 × 3.81 mm). Price: 99c (10,000)

Pulse, San Diego, CA (858) 674-8100. Circle No. 232

[Continued on page 208]



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MACOM

NEW PRODUCTS

IMD-free Diplexer

The model W1840D diplexer was designed free of intermodulation distortion (IMD). Standard dual +43 dBm input signals produce less than -140 dBc of IMD. The unit covers full PCS hands with < 1.2 dB insertion loss Band centers RX/TX isolation is > 90 dB. Return loss on the W1840D is > -16 dB and power capability is > 50 W. SMA or type-N connectors are available. Size: 2.0" × 2.0" × 9.0". Wireless Technologies Corp.,

Springdale, AR (501) 750-1046.

Circle No. 239

Single Junction Isolators

These isolators are designed for high performance, AMP, GSM, DCS 1800 and PCS 1900 frequency bands.



and provide better than 25 dB isolation < 0.25 dB insertion loss and 25 dB (min) the -10° to +85°C temperature range. The units are ideal for use

in base station combiners, amplifiers and other filter subsystems, and can handle up to 70 W reverse power. They are designed using strip line technology and have a solid body with a screwed-in lid. Designs are free of NdFeB magnets. Large quantities are available on short notice and at competitive prices. SDP Components Inc.,

Pointe-Claire, Quebec, Canada (514) 428-8749.

Circle No. 233

Bulk Cable Products

The Vital Links™ series flexible cables offer a wide range of options specifically designed to



provide extra performance margins for applications with demanding specifications. The DB and SI series are an economical performance upgrade over standard and BC142 cables. The SW series is a cost-effec-

tive, microporous PTFE cable group offering much better flexibility and performance than solid TPFE cables. The KW series is a flexible, high power and ultra-low loss cable group. KW800 has a loss factor of only 2.2 dB/100 feet at 1 GHz and can be formed by hand into a four-inch-diameter loop without using special mandrels or bending apparatus. The HP series offers excellent SWR performance and low loss for applications up to 50 GHz. Semflex Inc., Mesa, AZ (800) 778-4401.

Circle No. 235

Multilayer Chip Inductors

The HK series high Q-value multilayer chip in-



improve overall efficiency in cell phones, pagers, notebook PCs and other products employing high frequency circuits. The inductors also fea-

ture 100 percent silver internal conductors, advanced dielectric ceramics and unique fabrication techniques to achieve superior price/performance characteristics in small case sizes. They offer extremely low DC resistance values, from 0.04 to 1.10 Ω (typ). The series is surface mountable and available on tape and reel for high speed manufacturing. Price: 3¢ to 8¢ per piccc (depending on part) in OEM quantities. Taiyo Yuden (USA) Inc.

Schaumburg, IL (847) 925-0888.

Circle No. 238

RF Coaxial Connectors



This line of C-series coaxial connectors handles p to 3000 V peak and is designed for high voltage semiconductor, wafer processing, sputtering and research applications. The connectors feature overlapping Teflon dielectrics to provide a longer electrical leakage path.



[Continued on page 210]

THE HEIGHT SET

Ka-BAND FILTERS



UP TO 40 GHz

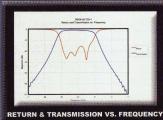
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PRODUCTS

which allows them to handle up to 3000 V peak. Male and female designs for both semirigid and flexible cables are available in straight, right-angle and bulkhead configurations. Manufactured in accordance with MIL-STD-348 and MIL-C-39012 specifications, the connectors can be made with TruLustre, silveror nickel-plated brass or aluminum shells, and silver- or gold-plated brass, phosphor bronze or beryllium-copper center conductors. Price: \$19.95 each, depending upon configuration and quantity.

Tru-Connector Corp., Peabody, MA (800) 262-9878 or (978) 532-0775.

Circle No. 237

High Power Stripline **Mountable Circulators**

These high power, low loss tab-mount circulators and isolators designed to protect solid-



state circuits are available over a 10 percent minimum bandwidth in the 1 to 3 GHz frequency range. Various models cover IFF, PCS

and radar bands. The units are rated at 300 W CW and 3 kW peak power, and typically provide greater than 20 dB isolation, 0.2 dB loss and 1.25 SWR. SMA connectors are an option. Size: $1.25" \times 1.33" \times 0.75"$.

UTE Microwave Inc., Asbury Park, NI (732) 922-1009.

Circle No. 266

High Frequency Coaxial **EMI Filters**

The dual-polar series solder-in style high frequency coaxial EMI filters are available in C-



and L-sections and offer EMI suppression from MHz to 10 GHz. They are ideal for the satellite construction market, for

high volume usage in test and measurement equipment and for microwave repeater applications. The dual C- and L-section filters replace two individual filters, decreasing the size and weight of the systems in which they are used, thereby reducing overall costs. The series meets MIL-PRF-28861 standards and is offered with a working voltage of either 50, 100 or 200 V DC and a minimum capacitance of 10,000; 2700 and 5000; or 100, 500 and 1000 pF, respectively. Price: \$3 to \$5 (1000). Sierra-KD Components,

Carson City, NV (775) 887-5700. Circle No. 236

AMPLIFIERS

S-band, Solid-state **RF Amplifier**

The model SSPA 2227-80 high power, S-band, solid-state RF amplifier (SSPA) covers in



excess of 500 MHz of bandwidth from 2.2 to 2.7 GHz. This class AB SSPA offers greater than 30 dB of gain and a minimum of 70

W across the band. Typical output power from 2.3 to 2.7 GHz is greater than 100 W. The amplifier offers 35 percent efficiency (typ) across the band with a noise figure of < 5.0 dB. Input/output SWR is better than 2.0, and the unit operates from+12 V DC over a -40° to +85°C temperature range. Size: $4.00" \times 8.25" \times 2.50"$

Aethercomm Inc., San Marcos, CA (760) 598-4340.

Circle No. 240

3 V GaAs PA Driver Amplifier

The model RF2367 low noise CDMA/ TDMA/GSM PA driver amplifier has a frequency range of 150 to 2500 MHz and is optimized for operation in the DCS and PCS bands for applications where low transmit noise power is of concern. In addition to its use as a DCS/PCS driver amplifier, the new IC can also be used for a variety of applications including WLAN or other wireless systems in the

MICROWAVE JOURNAL - OCTOBER 2000

[Continued on page 212]

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"Solid State of the Art" Satellite Microwave Technology





SSPA MICROWAVE CORPORATION is a recognized leader in the microwave solid state power amplifier industry.

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- Ku-band SSPAs: Output power up to 125W
- ✓ Single or redundant systems.

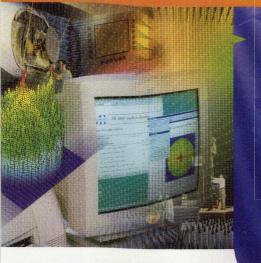
- ✓ SSPAs available as modules, indoor rack-mount assemblies, or outdoor hubmount assemblies.
- Standard product line or customized units for your particular specifications and needs
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Typical Specifications

Input Frequency Band: 19.7 to 20.2 GHz L.O. Frequency: 18.75 GHz Output Frequency Range: 950-1450 MHz Noise Figure: 1.5 dB at +25°C Input Return Loss: 18 dB Conversion Gain: 58-62 dB Gain Flatness: <1 dB Output VSWR: <2.0: 1 into a 75 Ohm

Power Requirements: +10-20V DC, 200mA

Operating Range: -40°C to +55°C



Feature

- Superior low noise figure
- Waterproof guaranteed · Low gain flatness
- · Superior input return loss
- · Environmentally protected
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NEW PRODUCTS

2.4 GHz ISM band. Operating from a single 3 V power supply, the RF2367 features adjustable bias current, a high intercept point and power down control. The device's performance at 1880 MHz includes 21.5 dB gain, +24 dBm ouput IP3 and 2.2 dB noise figure.

RF Micro Devices, Greensboro, NC (336) 664-1233.

Circle No. 241

ANTENNAS

■ Indoor/Outdoor Antenna

The model DB794CM5N-KU indoor/outdoor ceiling-mount, singlemonopole, corner reflector antenna features high directional gain with reliable coverage of up to three bands, including GSO1800, PCS1900 and UMTS frequencies in the 1710 to 2200 MHz range. The antenna was specifically designed for high capacity pedestrian venues that require reliable mass voice and/or data communications. Typical applications include walkways, concert halls and convention centers. Its light weight and compact size allow the DB794CM5N-KU to be inconspicuously situated indoors with minimal disruption to its surroundings. Weight: 0.5 lb. Size: 5.0" × 5.0" × 5.0".

Decibel Products, Dallas, TX (214) 631-0310.

Circle No. 242

High Gain Directional Panel Antenna

The model PCW24-01518-BFL 18 dBi panel antenna covers the 2.4 to 2.5 GHz frequencies and provides 15° of horizontal and vertical beamwidth. Size: $15.75^\circ\times15.75^\circ\times4.00^\circ$ HD Communications Corp.,

Systems Group, Ronkonkoma, NY (631) 588-9661.

Circle No 265

Microwave Heater Horn

The model 0023-800 high power horn for use in industrial microwave process heating operates at 2450 MHz and features a special throat



geometry that creates waveguide modes for very uniform near-field power density. In use, materials to be heated or dried are placed a short distance from the horn aperture and heating occurs much more uniformly than with a standard horn, eliminating hot spots and optimizing process control. The 0023-800 is designed for sample dimensions up to 12" square, though other sample dimensions can be accommodated on order, SWR is 1.08 (max).

Seavey Engineering Associates Inc., Pembroke, MA (781) 829-4740.

Circle No. 234

DEVICES

Miniature Ultra-flat Schottky Detectors

These miniature ultra-flat detectors utilize a zero-bias Schottky design. The microwave power is coupled directly to the extremely small components, reducing pack-



age parasities and transition mismatches. The design results in a very low SWR and a flat, smooth output over a wide bandwidth. Options available include negative or positive output, choice of three output connectors and operation to 26.5 GHz. The detectors operate

over a 0.01 to 18.5 GHz frequency range with 100 mW input power

(max). The operating temperature range is -55° to $+100^{\circ}$ C with video resistance of 5000 Ω (nominal).

RLC Electronics Inc., Mt. Kisco, NY (914) 241-1334.

Circle No. 244

Low Capacitance, High Voltage Schottky Diode

The model SMS3925-079 40 V, 0.6 pF RF Schottky diode is designed for use as a level detector in wire-

0 40 V, 0.6 pF RF I for use as a level detector in wireless handsets and for general-purpose switching applications. It is packaged in the surface-mount

miniature SC-79 package, and is designated for low cost, high volume applications. Price: 17¢ (100,000).

Alpha Industries,

Woburn, MA (781) 935-5150.

Circle No. 243

■ Detector



The model STZ500 detector for telecommunications and wireless applications operates over the 0.01 to 18.0 GHz frequency range. It has a positive output polarity and a video load of ≥ 1 MΩ. In addition, the STZ500 handles an input range of 0 to 20 dBm over a temperature range of −55° to +125°C.

Signal Technology California Operation, Sunnyvale, CA (408) 773-3744.

Circle No. 245

HARDWARE

Crimp Tools

The models CT-400/300 and CT-240/200/100
crimp tools are designed to work with LMR*
cables size 400
and smaller. The
works with all
LMR_4/00 and



patible with all JMR-240, EMR-240 and LMR-100 cables and crimp-style connectors. Crimp dies are integral with both tools. LMR cables are flexible, non-kinking low loss RF transmission line cables that utilize easy-toinstall connectors and are suitable for use as antenna feeders, system jumpers and interconnects.

Times Microwave Systems, Wallingford, CT (203) 949-8424.

Circle No. 246

INTEGRATED CIRCUIT

Common Mode Logic IC



The model \$Y5581 AnyGate³⁴ Common Mode Lagie (CML) IC can be configured as any of the mine most common two-input logic functions, providing unparalleled fleedbilty for designers of uttra-lugh speed systems. It is capable of being configured as either AND, NAND, OR, NOR, NOR, XNOR, DELAY, EEGATION or 2 MUX. Operating from a wide voltage range of 23 to 5.75 V, the outputs are guaranteed to logic bet at least 2.5 GPL. The part uses CML logic levels for all IOS and is compatible with legacy PECL and IDDS interfaces. Price. \$10.50 (1000+). Delivery, stock to eight weeks (ARO).

Micrel Inc., San Jose, CA (408) 944-0800. Circle No. 247

PROCESSING EQUIPMENT

■ Integrated Assembly and Manufacturing System



The model 7323 integrated assembly system provides a comprehensive all-in-one solution for the precision manufacturing of microdisplays and liquid-crystal displays (LCD). With LCD dimensions as large as 2" square, it is well suited to the manufacturing of personal and projection microdisplays and LCDs for personal electronics displays, wearable computers, head-mounted displays and mobile phones. By performing parallel operations, the system produces throughputs as high as 250 units per hour (material presentation and process dependent). The 7323 tightly integrates tacking, alignment, bonding and unloading operations. Designed for use as either a complete standalone production cell or as part of an overall automated production environment, the system uses a flexible Windows NT*-based programming and control environment MicroJoin, Poway, CA (858) 877-2100.

Circle No. 249 [Continued on page 214]



NEW PRODUCTS

Solder Stencil Capability for PCB Production

A solder stened capability has been added to the company's environmentally friendly systems for the production of prototype circuit boards. Streakie smure the application of precisely defined amounts of solder paste to PC boards for optimum SMD connections, replacing compressed air techniques that often result in bubbles and bridges. A typical stened can be produced in less than 10 minutes, which allows it to be used for short ran prototyping work in design labs. Stenells accommodate pads as small as 10 mls in diameter with a minimum pitch of 20 mls between pad centers. Steneil hischness can be selected in the range from 3 to 5 mll. To complete the assembly, 2 aEFFex stretching frame is included to mount the stenel for precise positioning. A low cost pick-andplace system is also available to automate component assembly.

LPKF Laser & Electronics, Wilsonville, OR (800) 345-5753.

Circle No. 248

Automated Installation System

The CRESCENDOTM installation system is designed for automatic, rapid and accurate in-



stallation of CORE-SHIELD® EMI gaskets. It is intended for high volume application of EMI shielding gaskets, protective acoustic covers and thermal interface products used

portable devices. The system is the fastest technique available for EMI gasket application, with installation ratts of up to 12 cycles per minute. With a compact design, it can be integrated with automated assembly lines to minimize or eliminate labor content.

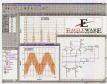
W.L. Gore Associates.

Newark, DE (302) 738-7880.

Circle No. 258

SOFTWARE

Harmonic Balance Simulator



The HARBEC harmonic balance nonlinear simulator allows the designer to specify any number of fundamental tones for analysis and to co-simulate EM, linear and nonlinear circuits. The engine also uses artificial intelligence techniques to find and incorporate the best convergence strategy. In the GENESYS design environment, EM, linear and nonlinear circuit co-simulation is nearly transparent. Behind the scenes, GENESYS automatically recognizes the lumped components, removes them, adds internal ports and runs the EM simulation. The multiport data are transparently included in a circuit theory simulation. Once the initial design is complete, the lumped components can be interactively tuned or automatically optimized at high speed. This capability brings the accuracy of EM simulation to the design of nonlinear circuits, Price: \$4990. Eagleware, Norcross, GA (678) 291-0995.

Circle No. 250

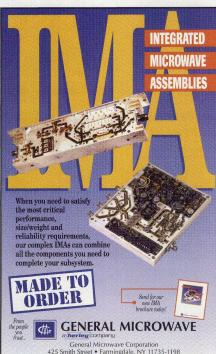
Guided Scalar

Measurement Software
This guided scalar measurement software allows the 6800 series scalar and system microwave analyzers to



be configured so that unskilled operators can simply and precisely perform complex or repetitive measurements. It al-

lows the instruments to be customized for short-run production measurements on composed to the composition of the composition of the and waveguide installation measurements in aircraft and ships and for radio link feeder test-



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ing. The software also allows for sensitive measurement parameters, such as frequency, to be suppressed. Once set up, the software uses a series of screens to guide the operator in: selecting the pre-defined measurement or test such as insertion loss, return loss or fault location; setting the relevant measurement options for accessories; calibrating the instrument; conneeting the device under test; and carrying out the desired measurement. Price: \$990.

IFR Systems Inc. Wichita, KS (800) 835-2352 or (316) 522-4981.

Circle No. 251

RF Analysis Software

SpurFinder 2.02 helps a designer to evaluate various frequency conversion schemes and provides a quick idea of the pre-selection and post-selection filter rejection requirements for the conversion scheme. It also draws a mixer spur chart showing the output frequencies of all mixer spurious products for a given range of frequencies. The latest version includes many improvements, such as the new Slider Bar, which lets the user slide a cursor across the input frequency range, and a table displays the output mixer spurious products and their frequencies in real time. The designer can also use this program to pick the conversion scheme with the best spurious performance. Price: \$129 or \$29 for an upgrade to Version 2. R.A. Wood Associates,

Utica, NY (315) 735-4217.

Circle No. 252

SOURCES

Miniature OCXOs

The 270 double oven controlled crystal oscillator (OCXO) series rivals rubidium clock per-



formance and drops into a standard European CO-08 footprint. Available with an output frequency

between 4.8 and 90 MHz and utilizing a full-size TO-8 quartz resonator, the oscillator performs to the stability required for Stratum II and IIe, GPS and TDMA PCS applications. The device operates over a -30° to +70°C temperature range with steady-state power consumption of 5.5 W (typ). Typical RF output is +9 dBm ±2 dB sinewave (into a 50 Ω load) with < -30 dBc harmonics and -80 dBc spurious levels. The 270 series is also ideal for phase noise related issues, delivering -100 dBc/Hz at a 1 Hz offset and -155 dBc/Hz at a 10 kHz offset for a 5 MHz unit. Size: 1.423" × 1.071" × 0.765".

MTI-Milliren Technologies Inc Newburyport, MA (978) 465-6064. Circle No. 253

Surface-mount DTCXO

The QED 110-AH/BH digital compensation temperature-controlled crystal oscilla-



tor (DTCXO) achieves a stability of ±0.4 PPM over the operating temperature range of -40° to +85°C. Designed for use in test

radios, the unit operates with a supply voltage of 3.3 V DC (5 V upon request). It is available in a frequency range from 1.25 to 110 MHz, and current compensation is as low as 4 mA for the 3.3 V models, depending on frequency. The phase noise floor is -150 dBc/Hz and the overall phase noise performance is matched to the frequency stability achieved. The OED 110-AH/BH has a low aging rate, which in the first year is < ±1 PPM (typ) and ±4 PPM (typ) total aging in 10 years. Size: 0.79" × 0.51" × 0.39"

TEMEX Components. Phoenix, AZ (623) 780-1995.

Circle No. 254

SUBSYSTEMS

I-Q Vector Modulator



The model 7328H I-O vector modulator oper ates over a frequency range of 6 to 18 GHz and includes an enhanced modulation rate of > 50 MHz via 12-bit ECL control inputs for both I and Q channels. In addition, its high performance characteristics include an attenuation range exceeding 60 dB, with variation of amplitude vs. temperature of 0.04 dB/°C (max). Operating over a temperature range of -40° to +70°C, the unit provides a full 360° of phase shift, absolute insertion phase accuracy vs. frequency of ±15° and a variation of phase vs temperature ±2°C (max). Size: 6.00" × 3.12"

General Microwave Corp., Farmingdale, NY (631) 630-2000. Circle No. 255

Low Cost, High Performance Synthesizers



The CFS HP series synthesizers feature phase noise of -100 dBc/Hz at 10 kHz offset at C band, as well as a tunable C band or Ku band and a fixed L band. The units are built with a low profile construction and can be fitted with a parallel or serial interface. Applications include use in dual-conversion up- and downconverters. Miteg Inc.,

Hauppauge, NY (631) 436-7400. Circle No. 256

[Continued on page 216]

Introducing TrueTri>ngle

Celeritek's NEW **HBT** amplifier modules.

HIGHLY INTEGRATED SOLUTION LINEAR EFFICIENT POWER

- ► 50 OHM MATCH
- SINGLE, POSITIVE SUPPLY
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NEW **PRODUCTS**

Digital Microwave Radio

SYSTEM

The 3000 series SONET/SDH digital microwave radio features the XPIC (cross-polarization interference cancellor) technology that allows transmission on both the horizontal and vertical polarity of any given frequency pair, making it possible to transmit up to 16 155 MB OC-3s in the 6 GHz band. This makes the radio one of the highest capacity long-haul microwave products on the market and offers network operators a complete solution by accommodating OC-3 needs with the flexibility to transport up to 48 DS3s or 1344 DS1s. The radio also features a modular design, various systems applications, excellent threshold/interference ratio and standard automatic transmitter control, synchronization flexibility, advanced operation, administration, maintenance and provisioning, as well as low power consumption and convection cooling. NEC America Inc.

Irving, TX (888) 632-9283.

Circle No. 257



RF Vector Network Analyzers

The PNA series BF vector network analyzers combines fast measurement speed, low noise, dynamic range and comprehensive automation and connectivity. It is an entirely new family of instruments designed to exploit state-of-the-art technologies and incorporate the Windows® 2000 Professional operating system, which links the measurement environment with the PC environment. The instruments combine fast sweep speeds, wide dynamic range, low trace noise, four measurement receivers with direct access and 9 GHz frequency coverage. The Windows operating system provides the full power of network connectivity and allows designers to use a variety of tools for automated test, such as COM/DCOM and programming languages, as well as Microsoft* applications for the post-processing of measurement

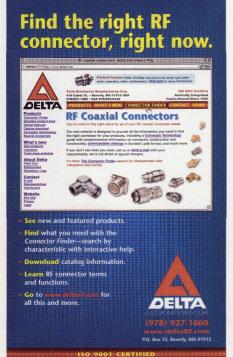
Agilent Technologies, Palo Alto, CA (800) 452-4822, ext. 7127. Circle No. 259

Direct Receiver Access Models

The models MS4622C and MS4623C direct receiver access (DRA) models are members of the company's Scorpion® family of vector network measurement systems (VNMS). Both allow increased flexibility in testing amplifiers not conveniently handled by other models and can use



MICROWAVE TOURNAL - OCTORER 2000



NEW PRODUCTS

RF/IF MICROWAVE COMPONENTS



"DO-IT-YOURSELF" 10dB COUPLER LOWERS COSTS

Mini-Circuits TCD-10-1W-75 needs only a commercially available external chip resistor, and a complete 10 to 750MHz 75 ohm directional coupler is realized. Designed for automated manufacturing to lower costs, this rugged "60-1-yourself" SM coupler provides 10.5dB ±0.5dB nominal coupling (±0.7dB max. litatness) with 1.4dB mainline loss and 18dB directivity typical micband. The 50/75 ohm TCD lamily contains 9 units with 9 to 2005 pour litatness.



ULTRA-THIN 0.07" MIXER PERFORMS 1600 TO 3200MHz

The MBA-18L level 4 (LO) frequency mixer, part of Mini-Circuits patiented family of Blue Cell" mixers, operates over 1600MHz to 3200MHz with 24dB L-R, 16dB L-1 isolation and low 6.5dB midband conversion loss (all typ). The Blue Cell" mixer series delivers a unique combination of performance repeatability, low conversion loss, superformance tractions of the conversion loss, superformance to the conversion loss, and performance of the conversion loss, superformance to the conversion loss, superformance of the conversion lo



5W TYPE-N ATTENUATORS FOR DC TO 18GHz

Mini-Circuits family of broadband DC to ISGNE procision fixed attenuation scantain 15 models with nominal attenuation values from 1 to 1046 plus 12, 15, 20, 30, and 404B. Built tough to handle 5W average with 125W peak power, these small 1.90" units exhibit high temperature stability, outstanding phase inearity, and excellent VSWR. Equipped with stainless steel Type-N Male/Female connectors. Model number is BW-NXWS substituting X with desired value.

CELLULAR BAND AMPLIFIER IS LOW NOISE SOLUTION

Mini-Circuits announces a new 25dBm (typ, output at 1dB comp.) medium high power 50 ohm amplifer ideal for cellular applications in the 800 to 900MHz band. The 2QL-900MLNW typically displays ultra-low 1.2dB noise figure and high +41dBm IP3 to suppress intermodulation products. Gain is 27dB (=1.8dB flatness) and VSWR is 1.3:1 in/1.4:1 out (all typ). This tough built coaxial ampliffer is equipped with SMM-Female connectors and operates within -40°C to +70°C (max).





612 TO 1200MHz VCO HAS LINEAR TUNING

Mini-Grautis ROS-1200W voltage controlled coscillator performs in the 612 to 1200MHz band targeting cellular and test equipment applications with low -1304BCHz SSB phase noise typical at 1MHz offset, wide 3dB modulation bandwidth typical at 20MHz, and 26-68MHz/V (typ) tuning sensitivity. Housed in a miniature 0.5*X0.5*X0.18* industry standard surface mount package, typical power output is 10dBm. Harmonics is -280BG typical (specified to the fourth).



BROADBAND 2WAY SPLITTER SPANS 20 TO 3000MHz

Designed to spirt a signal Zways 0°, the 1 watt (max. input as spirtter) ZAPD-30 power splitter from Mini-Circuits covers the broad 20 to 3000MRJ frequency band. This SMA-Female coaxial unit displays 0.168 amplitude and 1 degree phase unbalance (typ), plus low 1.1dB insertion loss (above 3.06B) and 16dB isolation typical at midband. Housed in a rugged metal case, applications include UHF TV/DTV, aircraft radio navigation, and PCS/Cellular/CSM. Value priced.



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an external test set selected by the user. In addition, they have the ability to measure nonlinear effects in mixers, enhanced antenna measurements over the GPIB and high power amplifiers, making them both complete high performance measurement solutions. The MS4622C provides measurement capabilities from 10 MHz to 3 GHz and the MS4623C provides the same measurement capabilities from 10 MHz to 6 GHz. Both can include a second synthesizer for ease in intermodulation distortion and multiple test port measurements. Price: \$28,500 for

the MS4622C and \$33,500 for the MS423C. Delivery: six to eight weeks (ARO). Anritsu Co.,

Microwave Measurement Division, Richardson, TX (800) 267-4878.

Circle No. 260

Handheld Microwave Oven Leakage Meter

The model HI-1801 microwave oven survey meter provides an easy and inexpensive way for public health agencies and services technicians to check for microwave leakage. Durable, compact and portable, the instrument is not susceptible to damage caused by excessive fields. The HI-1801 provides 2450 MHz frequency response with 0 to 10 mW/cm² and ±1 dB accuracy. Response time is 2 to 3 seconds and maximum power density 2 W/cmg continuous. Size: 2.87" × 4.2" × 2.2" Holaday Industries Inc.,

Eden Prairie, MN (877) 465-2329. Circle No. 271

Photodiode Meter



The model 2500 photodiode meter is designed for testing of laser diode modules (LDM), and has the capability for very fast low level current measurement, optical power measurement and extended voltage output. It also provides more targeted functionality for testing and controlling LDM than any comparable instrument. The model 2500 has a space-saving footprint and has been fine-tuned to provide the essential features, high speed and repeatable performance needed for efficient production testing in the rapidly growing LDM industry. The built-in picoammeter can resolve currents as low as 10 femtoamps, which supports more precise dark current measurement. The architecture of the model also supports greater measurement flexibility and includes a built-in ±10 V/±100 V voltage source that offers the extended range needed to power a variety of user-selected photodetectors, including largearea and avalanche types. Software drivers for LabVIEW™ and LabWindows™CVI are available with the model 2500 for easier development of test programs and test software packes. Price: \$7995. Delivery: four to six weeks. Keithley Instruments Inc., Cleveland, OH (888) 534-8453.

Circle No. 261

Power Meter

The model 9000B low cost, high performance CW power meter uses a diode-based power

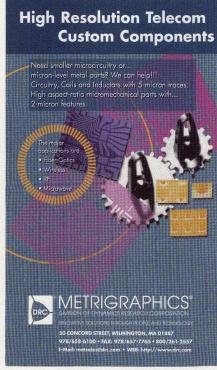


sensor and can measure power levels from -39 to +20 dBm and cover frequencies from 100 kHz to 40 GHz. The power meter is completely port-

able and can be used for swept measurement. It is designed to offer excellent measurement speed at all power levels, auto zero and dB relative mode, and operation on internal rechargeable batteries that offer greater than 12 hours of operation, and includes an internal fast battery charger. The 9000B has a built-in 50 MHz, 0 dBm reference oscillator and V/dB output port for swept scalar measurement system and auxiliary display and bus reading when used with a DVM.

Sunnyvale, CA (408) 734-5999.

Circle No. 262 [Continued on page 222]



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Step-Rotary Attenuators

Product Code No.	KAT2DO4SA000	KAT1DO4SA002		
Operating Type	Make-Be	fore-Break		
Frequency Range	DC ~ 3GHz	DC ~ 3GHz		
Insertion Loss (Max.)	0.2dB	0.2dB		
VSWR (Max.)	1.15:1	1.15:1		
Incremental Attenuation Range (dB)	0 ~ 1	0 ~ 10		
Attenuation Step (dB)	0.2	1		
Nominal Impedance	50	ohm		
I/O Port Connector	SMA(F) / Right Angle SMA(F)			
verage Power Handling	1W @ 2GHz			
Temperature Range	-30°C - +80°C			
Dimension (inch)	1.925*1.	567*2.224		





Continuously Variable Attenuators

Product Code No.		A type: KAT13O4CA00 B type: KAT13O4CA00		
Frequency Range	DC - 1GHz	1 – 2GHz	2 ~ 3GHz	
Insertion Loss (Max.)	0.15dB	0.3dB	0.35dB	
VSWR (Max.)	1.25:1	1.25:1	1.25:1	
Attenuation Range (Min.)	13dB @ 2GHz			
Nominal Impedance	50 ohm			
I/O Port Connector	SMA(F) / SMA(F)			
Average Power Handling	2W @ 2GHz / 25°C, without Heat-Sink			
Temperature Range	-55°C ~ +85°C			
Dimension (inch)	A type: 1.496*1.102*0.457 B type: 1.224*1.102*0.457			

Fixed Coaxial Attenuators are available

N-type, SMA-type Connectors











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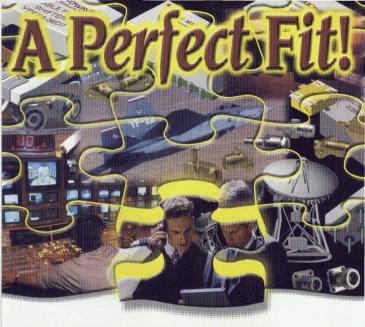
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ment, RF, optical, and or digital design experience. Technical knowledge of CATV or Broadtend HFC Systems BSEE or MSEE, MBA a plus.

RF Power Amp Design: Design and develop high-efficiency low-voltage SiGe power devices and amplitiers for cellular/PCS applications. Requirements include MS or PhD and experience in MMIC or RRIC design and test ng with 5+ years experience in bipolar and GaAs power amp design

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Key Account Manager: This position will work closely with vey customers to implement standard product do ins and custom IC development projects. Individual will manage all phases of project development sched ules, forecasts, resources and fechnical goals. Requires engineering degree and experience with project manage ment methods and tools. Account management or sales management experience is also a plus.

Filter Design Engineer: MS. Minimum 3 years experience in the design and development of Broad Band ne, strip line, interdigital, low pass and high pass filters, multiplexers, diode switches (phase shifters) atmustors and microwave subsystems desirable Sr. MMIC Besign: Design highly integrated GaAs MMICs for advanced cellular products. Circuits to be designed

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Birector of Manufacturing Operations: The director will be a key driver of the company's growth plan by planning resources needed to meet company goals with regard to production, sales, quality, time to market and de very to customer. By working in close cooperation with the Business Development Group, this individual will as certain current and future capacity needs and be responsible for formulating and executing manutacturing plans to fulfill the company's commitments to its customers. This individual will coordinate with the Engineering, Product Development, Quality, Materials and Facilities groups to assure that these operational disciplines provide the nec essary resources to accomplish the manufacturing plans

Active Components Engineer: Design discreet RF active components for RF systems. BSEE with at least 2 years experience in designing LMAs required. Experience with high power amplifier design is a plus.

Design Engineer: Designs and develops passive RF and microwave components and systems including filters couples and related components, for release into manufacturing. A BSEE and min mum 2 years extended in RF/microwave circuit design and development required.

Global Account Manager: Must be able to devise and implement sales strategies for increasing sales and prof its through the Global account. Forecast sales based on Identified targets of opportunity. Must maintain continual awareness of new business opportunities within and ensure customer satisfaction through promoting positive cus-former relationships. Implement and morefor the service commitments media to customers and resolve custome problems and complaints as they arise. Prepare proposals, coordinate and conduct presentations and reportate suitable contract terms. Travel required.



Sr. Synthesizer Engineer: The ideal candidate will have a BS in Electrical Engineering and tive years experience in the design of RF and microwave synthesizer products. In particu-lar, he or she should have hands-on design experience with VCOs, frequency/bhase detectors, dividers, phase lock ampli fiers, mixers, quadrature search circuitry, combline filters and multipliers. Familiarity with design techniques that permit low microphonics and minimum phase hits are a must, in addition experience in the use of commercial and/or custom PLL chips and microcontrollers would be an advantage.

Manager RF Power Amos: RF Power Amolities desi and development for CDMA and TDMA Base Station prod uct development. The individual will also be part of a managament team focused on RF Hardware Development. Minimum 10 years experience in RF Hardware development engineering or besearch. Must have storing exchinical shills in RF Power Ampitier Design, Thermal Management, Physical Design, Ribusci Design and Component Strategy, Must have proven leadership ability, with strong written and verbal communication shills and good project man-

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Sensor Scientific Inc., Fairfield, NI (973) 227-7790.

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XEMOD, INC. Xemod, Inc is a dynamic, closely-held, pre-IPO designer/manufacturer of semiconduc tors for the wireless industry, with needs in Tempe, AZ and in Sunnyvale, CA. They seek Engineers with this experience:

SR. RF/RF DESIGN ENGINEERS

To design/develop amplifier circuitry to 3.5GHz. Senior Engineers need a BSEE and 8+ years, including extensive RF/Microwave circuit design experience, and should be familiar with various modulation formats used in commercial wireless applications. RF Engineers need a BSEE and 2+ years related experience, with LDMOS a plus. Both levels require knowledge of RF CAD tools, good analytical skills and solid bench experience.

SR. RFIC DESIGN ENGINEER

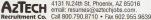
To take a hands-on role leading the development of a new line of RFIC products for the wireless infrastructure market, covering baseband processing to RF power amplifiers. BSEE, or equivalent, and 5+ years related experience is required, which must include knowledge of RFIC CAD tools; experience with LDMOS is a plus.

SR. DEVICE ENGINEER

Experienced with process/device simulation software (Suprem, Pisces, etc), and who can perform device layout utilizing layout software (L-Edit preferred). You should be able to work with foundries to provide support with parameter extraction of the devices, and be able to write technical documentation of newly developed test chips. BS in Engineering or Physics (MS preferred), with 3+ years related experience and good communication skills required.

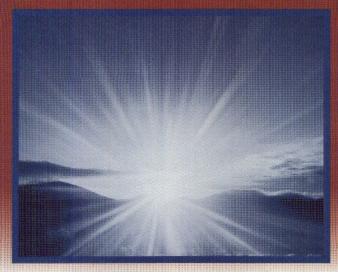
SR. PACKAGING ENGINEER To lead the effort to develop new, cost-effective, high performance packaging for high volume commercial manufacturing. This will involve: defining new materials, mechanical design, analysis, and testing of the packages. BSME, or equivalent, and 8+ years related experience, including RFIC/hybrid packaging design, and familiarity with common analysis tools and CAD packages

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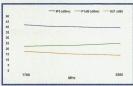
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For more information on the SXT-289 or any of our other products, visit our website today and experience RF Innovation from Stanford Microdevices.



Typical device performance. Bias =5V

⊕ 110mA typ.



In "The Design of Intermediate Linear Phase Bandpass Crystal Filters in Semilattice Form," a technical feature by Mark Mell that appeared in the August issue of Microwave Journal, Tables 2 and 3 contained several errors. The corrected tables appear below. In addition, in Appendix C a j term was missing in the first Ya(s) equation. It should read

$$Ya(s) = \frac{1.730769s^2 + 0.4267183 - j0.8875740s}{s^3 + 1.331361s - j0.5769231s^2 - j0.4267183}$$

In the same issue in the article "A Simplified Approach to Determining AM/PM Conversion Coefficient in Mi-

TABLE III

CALCULATIONS TO DETERMINE Ya(s) CRYSTAL FREQUENCIES AND MOTIONAL INDUCTANCE

crowave Low Noise Amplifiers and Systems" by Maurice

Toolin, the definitions for S1 and S2 on page 82 should

Also, PooutΔ(P1out - Poout) is recorded as 30.5 dB. On page 90 in Appendix A, the final equation should read

 $K_p(\circ/dB) = 13.2 \log^{-1} \left(\frac{P_1 \text{in} + G - P_1 \text{int}}{10} \right)$

 $S_1 = \text{voltage amplitude of } P_2 \text{out} \Delta \text{ normalized to } P\Delta$

 S_2 = voltage amplitude of P_3 im Δ normalized to $P\Delta$

 $f_0 = 21.4 \text{ MHz}$

BW = 100 kHz

 $R = 2000 \Omega$

Then:

Low-pass Values from Table 2 Xa = -j2.242706 La = 1.680141

Lb = 1.326637 Xb = j1.4057114 Lc = 2.619207Xc = -60.7902054

RLa $fa = f_0 - \frac{BW}{2} \frac{Xa}{iLa}$ πBW

(2000) • (1.680141) fa=21.4•10⁶ 100•10³ • -j2.242706 2 jl.680141 π100•10³

Lta = 0.010696 fa = 21.46674 • 106 Substituting Lh/Le for La and Xb/Xe for Xa yields

Ltb = 0.0084456 fb = 21.34702 • 106 Ltc = 0.016674 fe = 21 41585 • 106

Finally, Cta, Ctb and Ctc are determined as

4 Lta(fa2n2)

Cta = 5.139 • 10-15 Ctb = 6.582 • 10-15 Ctc = 3.312 • 10-15

TABLE II

IMPLEMENTATION OF THE PARTIAL SYNTHESIS PROCEDURE

Pole Locations	Selected Pole Locations
-0.335733689 + j0.90131941	-0.335733689 + i0.90131941
-0.335733689 - j0.90131941	-0.646039867 - j0.49841682
-0.646039867 + j0.49841682	-0.748995671 + j0.174020484
-0.646039867 - j0.49841682	
-0.748995671 + (0.174020484	
-0.748995671 - j0.174020484	

U(s) = (s + 0.335733689 - j0.90131941) (s + 0.646039967 + j0.49841682)(s+0.748995671-j0.174020484)

 $U(s) = s^3 + (1.730769 - j0.57692311) s^2 + (1.331361 - j0.88757401) s^2$ + 0.4267183 - j0.42671831

> M+jN N+iM

where N denotes all odd real terms, jN all odd imaginary terms M all even real terms and jM all even imaginary terms

 $M = 1.730769s^2 + 0.426718$ jN = -j0.8875740s $N = s^3 + 1.331361s$ $(M = -j0.57692311s^2 - j0.4267182)$

 $Ya(s) = \frac{1.730769s^2 + 0.4267183 - j0.8875740s}{s^3 + 1.331361s - j0.5769231s^2 - j0.4267183}$ $Ya\{s\} = \frac{0.59518825}{\left[s-j1.33483227\right)} + \frac{0.75378601}{\left(s+j1.05960567\right)} + \frac{0.38179497}{\left(s-j0.30169648\right)}$

 $La = \frac{1}{0.5951882}$ $Lc = \frac{1}{0.3817949}$

 $X_{C} = -j0.30169648$ 0.38179497

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0.5 (0.020)	3.20 (0.125)	EDR-05-020-0125-SC	C020-0125-SC-50
	6.35 (0.250)	EDR-05-020-0250-SC	C020-0250-SC-50
	9.50 (0.375)	EDR-05-020-0375-SC	C020-0375-SC-50
	12.70 (0.500)	EDR-05-020-0500-SC	C020-0500-SC-50
1.0 (0.040)	3.20 (0.125)	EDR-05-040-0125-SC	C040-0125-SC-50
	6.35 (0.250)	EDR-05-040-0250-SC	C040-0250-SC-50
	9.50 (0.375)	EDR-05-040-0375-SC	C040-0375-SC-50
15125	12.70 (0.500)	EDR-05-040-0500-SC	C040-0500-SC-50
1.5 (0.060)	3.20 (0.125)	EDR-05-060-0125-SC	C060-0125-SC-50
	6.35 (0.250)	EDR-05-060-0250-SC	C060-0250-SC-50
	9.50 (0.375)	EDR-05-060-0375-SC	C060-0375-SC-50
	12.70 (0.500)	EDR-05-060-0500-SC	C060-0500-SC-50
2.0 (0.080)	3.20 (0.125)	EDR-05-080-0125-SC	C080-0125-SC-50
2.5 (0.100)	6.35 (0.250)	EDR-05-125-0250-SC	C125-0250-SC-50



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This six-page brochure features EMI shielding products, such as EMI gaskets, conductive silicones, conductive yarn over elastomer gaskets, wire mesh gaskets, elastomer gaskets, combination gaskets, EMI shielding tape, shielded windows, air vent panels and metallized fabries. Product photographs, descriptions and contact information are included

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or (314) 344-9300. Circle No. 200

MICROMACHINED INTEGRATION **TECHNOLOGY BROCHURE**

This brochure on µmIntegrationTM (micromachined integration) technology shows the benefits and applications of the latest technology and products being released. It includes information on the µmIsolation™ (micromachined isolation) IC-based approach to digital isolation, as well as the µmRelay™ (micromachined relay) technology Analog Devices Inc.,

Wilmington, MA (800) 262-5643. Circle No. 201

RF DESIGN MODULE BROCHURE

This four-page brochure describes the compa ny's RF design module, which extends modeling capabilities to high frequency analysis. Screen shots, characteristics, features and a list of supported operating systems are included. APLAC Solutions Corp., Helsinki, Finland +358 9 5404 5000.

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ELECTRONIC COMPONENT SUPPLIER BROCHURE

This brochure features the company's new logo and contains a list of its product line, suppliers, MIL specs and clients. A company profile, catalog request form, contact information and a distributor update are also included. BTC Electronic Components, Raleigh, NC (800) 526-2828.

Circle No. 203

■ COMPANY BROCHURE

This four-page brochure provides an overview of the newly formed company and its products. Focused on providing various semiconductor system solutions for communications electronics, the company offers wireless communications solutions, network access solutions, digital infotainment solutions, personal imaging solutions and personal computing solutions. Con-tact information is included. Conexant Systems Inc.,

Newport Beach, CA (800) 854-8099. Circle No. 204

PRODUCT DATA SHEET

This two-page data sheet describes a variety of procurement products for distribution, purchasing, outsourcing, supply management and kitting. Product photographs and overviews and a listing of the company's product line are included. Delaire USA.

Manasquan, NI (732) 528-4520. Circle No. 205

NEW LITERATURE CRYSTAL OSCILLATOR DATA SHEET

This two-page data sheet features the model FE-101A OCXO subminiature oven-controlled commercial quartz crystal oscillator. The unit warms up to stabilized frequency in less than two minutes with temperature stability of 5 × 10-8 at 50°C. Full specifications, technical

highlights, available options and an outline Frequency Electronics Inc., Mitchel Field, NY (516) 794-4500.

Circle No. 206 SEMICONDUCTOR DATA SHEET

This data sheet provides information on the company's S- and L-band radar products as well as its avionics and MOSFET products. Part number, frequency band, ouput power, voltage and pulse width/duty factor are listed. The sheet also includes the company's mission statement and quality policy. Integra Technologies Inc.

El Segundo, CA (310) 606-0855. Circle No. 207

REFERENCE GUIDE

drawing are included.

This 12-page reference guide (Connecting Multiple Converters, PowerPage™ 44) describes how to connect multiple DC-to-DC converters to make complete power supply systems. The guide also details some cautionary areas such as switching frequency synchronization and controlling multiple power systems with a single switch. Powercube

Chatsworth, CA (800) 866-3590. Circle No. 208

PRODUCT BROCHURE

This four-page brochure features dielectric resonators, ferrite materials and dielectric substrates. Product photographs, descriptions, and a company and facilities overview are included. Product applications and contact information are also listed TRAK Ceramics Inc. (TCI),

Hagerstown, MD (301) 766-0560.

Circle No. 209 RF CONNECTOR CATALOG

This 12-page catalog features the company's full line of QDS series quick-disconnect RF connectors for use with telecommunications, semiconductor and test equipment. The product line combines the performance of type-N connectors with a fast on/off capability that mates securely without bayonets or threaded nuts. Technical drawings, product descriptions and specifications are included. Tru-Connector Corp.

Peabody, MA (800) 262-9878 or (978) 532-0775.

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PRODUCT BROCHURE

This six-page brochure features devices, building blocks, jammer amplifiers, command transmit systems, communications products, replacement amplifiers and special applications. Product photographs, descriptions and specifications are included, as well as a company overview. Zeta, a division of Sierra Networks Inc., San Jose, CA (408) 434-3600.

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THE BOOK END Handbook of CDMA System Design,

Kyoung II Kim Prentice Hall PTR 252 pages plus CD ROM; \$80 ISBN: 0-13-017572-2

Engineering and Optimization

ode division multiple access (CDMA) has become a preferred choice of the wireless telecommunications industry. This book is the result of recent efforts by many members of the technical staff of Bell Labs at Lucent Technologies Inc. to study CDMA technology as it applies

"The book provides practical guidelines for individuals interested or engaged in the engineering and optimization of CDMA networks."

to cellular or PCS. The text summarizes the work that has been developed and applied to the design and deployment of IS-95 CDMA systems, and provides an indepth discussion of various engineering guidelines for a multitude of real-world issues involved in the design, deployment and optimization of IS-95 CDMA systems and networks. The goal is to aid the reader in understanding the types of issues involved in engineering suc-

cessful CDMA mobile communication systems and the guidelines required to deal with those issues.

To make the book more useful for those readers interested in cell planning, a demonstration version of Cellular Engineering 4 (CE4), a CDMA coverage prediction software tool developed at Bell Labs, has been included. Using this software, readers can obtain hands-on experience in CDMA cellular engineering techniques as well as in the design and analysis of CDMA networks. The North American PCS CDMA system operating at 1800 MHz is the example used for the discussions. However, almost all of the discussions are equally applicable to both 1.8 GHz. and 850 MHz systems if appropriate modifications for frequency-related values are made.

The book begins with a CDMA overview and a summary of CDMA concepts and operations, then covers spectrum coordination, pilot assignment, mobile station access and paging, and handoff issues. It continues with discussions of link budgets, capacity, coverage, traffic engineering and antennas. The appendices provide a sample RF design process, an outline of RF optimization procedures and RF coverage predictions using CE4.

The book is easily understood, with clear, helpful graphics and minimal complex math. It provides practical guidelines for individuals interested or engaged in the engineering and optimization of CDMA networks.

To order this book, contact: Prentice Hall, PO Box 11073, Des Moines, IA 50336 (800) 947-7700.

Advanced Techniques for Digital Receivers

Phillip E. Pace Artech House Inc. 430 pages plus software; \$119, £82 ISBN: 1-58053-053-2

This book presents new electronic, electro-optic and superconductor digitization methods and emphasizes high resolution, symmetrical number system (SNS) techniques that can be applied to a variety of receiver components, architectures and receiver subsystems. The book is appropriate for senior undergraduate and first-year graduate students, and contains a disk with MATLAB/ SIMULINK programs that may be used for problem exercises that appear at the end of each chapter.

Chapter 1 presents the concepts of time domain and frequency domain signals and systems. Linear time-invariant systems are discussed and filtering concepts are introduced. Chapter 2 presents a brief overview of analog receiver architectures. New digital receiver techniques are investigated, and radar, infrared, satellite ground station, Global Positioning System and electronic warfare receivers are described. Chapter 3 explains the signal conversion process. Both elec-

tronic and optical circuits are emphasized, as well as the concept of coherent sampling. Chapter 4 describes the parameters used to measure the dynamic performance of the signal conversion process. Transfer functions of the digital-to-analog and analog-todigital converters (ADC) are presented.

Chapter 5 provides a detailed overview of high performance signal conversion

"This book presents new electronic electro-optic and superconductor digitization methods..."

architectures, including full-flash, two-step and folding ADCs, electro-optical digital antennas, time interleaved digitizers and pipelined ADC architectures. Chapter 6 discusses oversampling theory and sigma-delta modulation, and describes first- and second-order modulators. Chapter 7 presents the theory of digital RF memories; Chapter 8 covers the application of superconductor technology to amplitude-analyzing and sigma-delta ADCs.

Chapter 9 offers a complete discussion of SNS theory, and Chapter 10 discusses SNS undersampling discrete Fourier transform receivers and their advantages. The final chapter presents phase-sample, direction-finding antenna theory. A two-channel example is shown and experimental results are demonstrated.

To order this book, contact: Artech House Inc., 685 Canton St., Norwood, MA 02062 (781) 769-9750. ext. 4002; or 46 Gillingham St., London SW1V 1HH, UK +44 (0) 20 7596-8750.

Frank Bashore

Frank Bashore is a member of the Microwave Journal staff

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CONVERSION LOSS/SPURIOUS





TYPICAL OPERATING BANDS

RF		-5 dBm
6-8	10	
8-10	12	IF IF
10-12	14	2104
12-14	10	(1 to 5)
14-16	12	A
16-18	14	. 47 dDm
	LO	+17 dBm
12-14 14-16	10 12 14	2 to 4 (1 to 5) +17 dBm

SPECIFICATIONS - Model TBR0618HA1/TBR0618HA1-S

		а.
RF/LO Input Frequency Range	6 to 18 GHz	
IF Output Frequency Range	0.05 to 5 GHz	1
Conversion Loss	6 dB Typical	
Spurious	-55 dBc	
Third Order Intercept Point	+23 dBm Typical	7111
1 dB Compression Point	+13 dBm Typical	1
		100

For further information, please contact Mary Becker at (631) 439-9423 or e-mail mbecker@mitec.com

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