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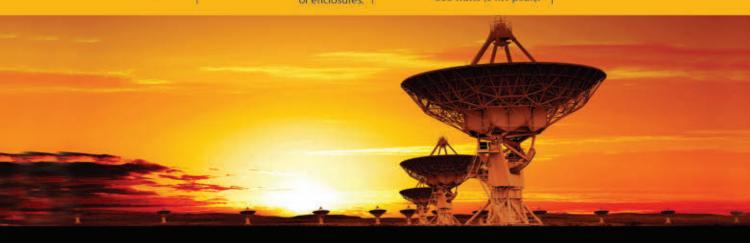
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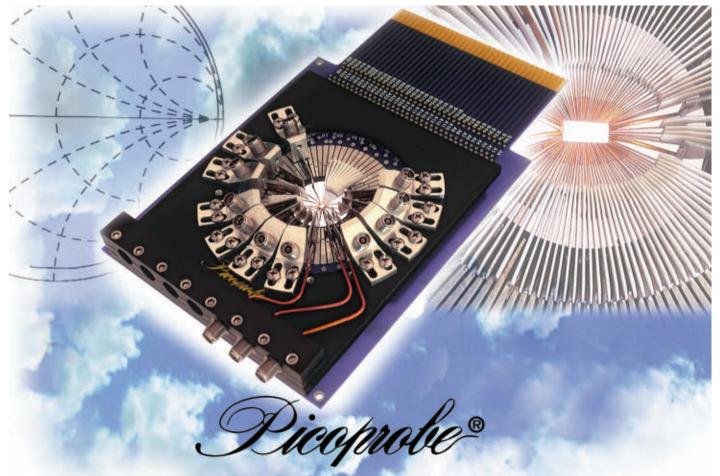
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PA Module Design Methodology

8/2/12 at 1:00 PM ET

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8/9/12 at 1:00 PM ET

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8/16/12 at 1:00 PM ET

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June Survey
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GaAs pHEMT [69 votes] (7%)

GaAs HBT [9 votes] (1%)

GaN [46 votes] (5%)

LDMOS [18 votes] (2%)

RF CMOS [803 votes] (85%)



Executive Interview

Chris Mosher, President of Semiconductor Enclosure talks about starting up an electronics packaging company in the U.S. during a recession, the company's innovative technology and opportunities for niche players in the billion dollar packaging market.

White Papers

Multicarrier TD-SCMA Feasibility Brad Brannon, Bill Schofield, and Yang Ming, Analog Devices Presented by Richardson RFPD

Application Guide to RF Coaxial Connectors and Cables

Michael J. Hannon and Pat Malloy, AR RF/Microwave Instrumentation

Small-Signal Intermodulation Distortion in OFDM Transmission Systems

Application Note, RFMD

Making Successful, Confident Noise Figure Measurements on Amplifiers Application Note, Anritsu

Bringing Rapid Prototyping In-House White Paper, LPKF

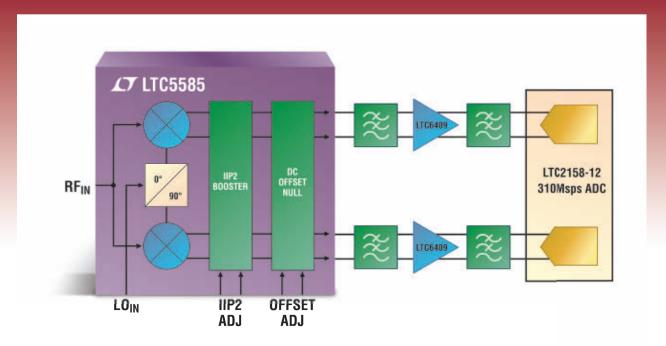
IEEE EMC Wrap-up

Microwave Journal covers the IEEE International Symposium on EMC in Pittsburgh, PA. Go online for our exhibition report, videos and photo gallery.





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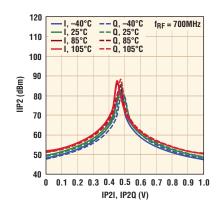
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Adjustable IIP2	>80dBm	>80dBm	
DC Offset Cancellation	Yes	Yes	

IIP2 Optimization vs Trim Voltage





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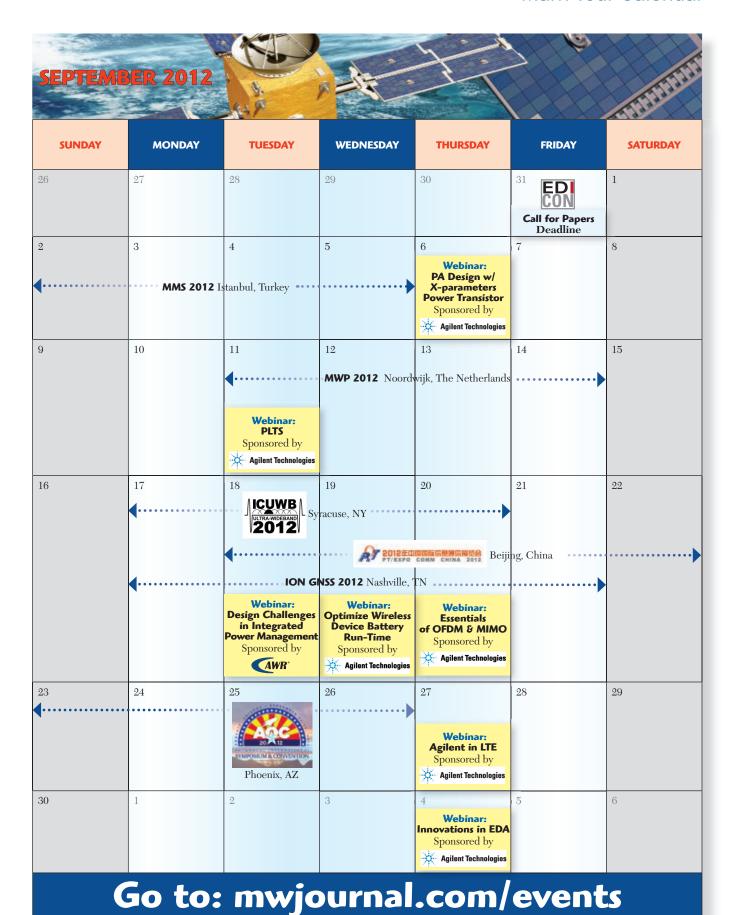
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80th ARFTG Conference Deadline: September 10, 2012

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MWP 2012

IEEE INTERNATIONAL TOPICAL MEETING ON MICROWAVE PHOTONICS

September 11–14, 2012 Noordwijk, The Netherlands www.congrexprojects.com/12A11

ICUWB 2012

IEEE INTERNATIONAL CONFERENCE ON ULTRA-WIDEBAND

September 17–20, 2012 • Syracuse, NY www.icuwb2012.org

ION GNSS 2012

September 17-21, 2012 • Nashville, TN www.ion.org/meetings/?conf=gnss

PT/Expo Comm China 2012

September 18-22, 2012 • Beijing, China www.expocommcn.com

AOC 2012

49TH ANNUAL AOC INTERNATIONAL SYMPOSIUM AND CONVENTION

September 23-26, 2012 • Phoenix, AZ www.crows.org/conventions/conventions.html

MILITARY ANTENNAS SUMMIT

September 24-27, 2012 • Washington, D.C. www.militaryantennasevent.com





OCTOBER

COMSOL CONFERENCE 2012 8TH ANNUAL MULTIPHYSICS CONFERENCE

October 3-5, 2012 • Boston, MA www.comsol.com/conference2012/usa

MUD 2012

MICROWAVE UPDATE

October 18–21, 2012 • Santa Clara, CA www.microwaveupdate.org

AMTA 2012

34TH ANNUAL SYMPOSIUM OF THE ANTENNA **MEASUREMENT TECHNIQUES ASSOCIATION**

October 21-26, 2012 • Bellevue, WA www.amta.org

RADAR 2012

INTERNATIONAL CONFERENCE ON RADAR

October 22-25, 2012 • Glasgow, UK www.radar2012.org

EuMW 2012

EUROPEAN MICROWAVE WEEK

October 28-November 2, 2012 Amsterdam, The Netherlands www.eumweek.com

MILCOM 2012

MILITARY COMMUNICATIONS CONFERENCE

October 29-November 1, 2012 • Orlando, FL www.milcom.org

4G WORLD 2012

October 29-November 1, 2012 • Chicago, IL www.4gworld.com

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November 5–7, 2012 • Shanghai, China www.imwexpo.com

ELECTRONICA 2012

November 13-16, 2012 • Munich, Germany www.electronica.de

80TH ARFTG MICROWAVE MEASUREMENT CONFERENCE

November 27-30, 2012 • San Diego, CA www.arftg.org

DECEMBER

APMC 2012

ASIA PACIFIC MICROWAVE CONFERENCE

December 4-7, 2012 • Kaohsiung, Taiwan www.apmc2012.com

JANUARY

IEEE RWS 2013

RADIO AND WIRELESS SYMPOSIUM

January 20-23, 2013 • Austin, TX www.radiowirelessweek.org

IEEE MEMS 2013

26TH IEEE INTERNATIONAL CONFERENCE ON MICRO ELECTRO MECHANICAL SYSTEMS

January 20-24, 2013 • Taipei, Taiwan www.mems2013.org

FEBRUARY

ISSCC 2013

IEEE INTERNATIONAL SOLID-STATE CIRCUITS CONFERENCE

February 17-21, 2013 • San Francisco, CA http://issec.org

NATE 2013

18TH ANNUAL CONFERENCE & EXPOSITION FOR THE NATIONAL ASSOCIATION OF TOWER ERECTORS

February 18-21, 2013 • Fort Worth, TX http://natehome.com/annual-conference

MWC 2013

MOBILE WORLD CONGRESS

February 27-March 1, 2013 Barcelona, Spain www.mobileworldcongress.com

MARCH

EDI Electronic Design Innovation Conference 电子设计创新会议 2013

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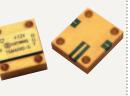


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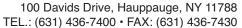


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Wireless Sensor Network Challenges and Solutions

The buildings that we work in have sensors monitoring temperature, occupancy, smoke and fire, and security. Our cars contain dozens if not hundreds of sensors, monitoring engine performance, braking, and passenger safety equipment, to name a few. Manufacturing environments need sensors because you cannot control what you cannot measure. Making products, while meeting safety, quality and efficiency targets, requires a lot of sensors.

Sensors have become much smaller, less expensive and lower power in the last few decades, driven in part by both Moore's law and the MEMS revolution. Unfortunately, the cost of installing sensors has not kept pace. The cost of running wires to carry power and data typically dwarfs the cost of the sensor itself. Take for example the closest light switch: the wiring for a \$1 switch can cost \$50, mostly labor, even in new construction. If you want to move that switch to the adjacent wall, the price of retrofit is much higher. In industrial process automation, the accepted rule of thumb is \$10,000 to install a sensor – even a simple switch. In this cost environment, many sensors only report data to a local controller – there can be little or no "big picture" when hundreds or thousands

of sensors are installed. What is needed is an inexpensive, reliable way to network sensors.

Almost since the time of Marconi, people have used wireless methods to communicate data from sensors, with mixed results. Traditionally these links have been line-powered and point-to-point, often with time-varying reliability due to environmental conditions. This is fine for some applications, but too restrictive for most.

MARKETS

Markets for wireless sensor networks (WSN) include building automation, industrial control, home automation, smart grid and automated metering infrastructure (AMI), industrial process automation, environmental monitoring, parking and transit infrastructure, energy monitoring, and inventory control. In most cases, these are bi-directional asymmetric data collection applications – large numbers of sense points forward data to a central host that may respond with a process set point or other configuration changes.

LANCE DOHERTY, JONATHAN SIMON AND THOMAS WATTEYNE Dust Networks Product Group, Linear Technology Corp., Milpitas, CA

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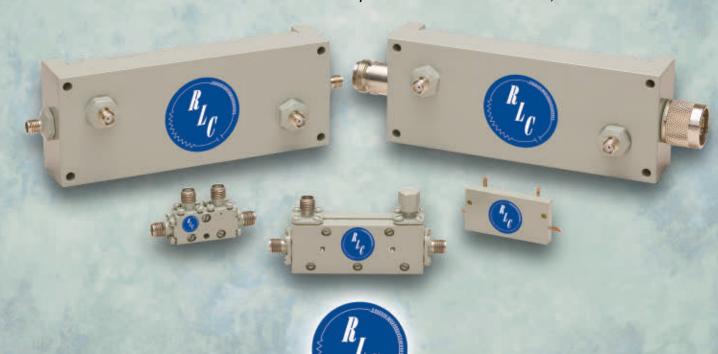
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TECHNOLOGY CHOICES

Customers ideally want a technology that is low cost, allows unrestricted sensor placement, receives periodic data reliably with low latency and runs for the device lifetime with no battery changes. Recent technological advances have enabled delivery of those features in many markets.

There are several technologies competing to fill this role, including satellite, cellular, WiFi, and a host of solutions based on IEEE 802.15.4 radios. These technologies allow users to form WSNs for collecting sensor data.

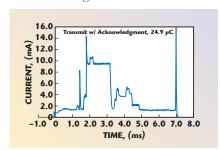
Satellite and cellular work well for many applications, but have the highest energy cost per packet. Data plan charges can also be prohibitive, although this is likely to change as carriers develop billing models appropriate for relatively sparse data flows. Coverage can also be an issue. Clearly it can be difficult for a satellite or cell phone signal to make its way out of a heavily obstructed structure, and the sensors generally do not have the capability of moving from side to side and asking "can you hear me now?" For an application sending at a very low data rate (e.g., one data packet per day) with good connectivity, however, satellite or cellular can make a lot of sense.

WiFi (IEEE 802.11b, g) sensors are now widely available. The energy cost for a WiFi packet is much lower than cellular, and there are no recurring fees for data. Connectivity and coverage remain important concerns, as the density of access points necessary for reliable communication with a fixed sensor is typically higher than that necessary for mobile humans with gadgets.

With reference to the OSI layer model, the 802.15.4 standard defines a physical layer (PHY) and medium access control (MAC) layer for shortrange, low-power operation that is well suited for wireless sensor networks. The radio is relatively low data rate (up to 250 kbps); the packets are short (< 128 bytes) and low energy. For example, sending a few bytes of sensor data, with routing, cryptography, and other headers, takes under 1 ms. This process uses under 30 μC of charge, including receiving a secure link-layer acknowledgment (see Figure 1). Sensors can forward radio packets from peers, extending the range of the network far beyond the range of a single radio, and providing the network with immunity to any single radio link failure.

PERFORMANCE METRICS

Evaluation of various WSN solutions is based on two questions, "Can I get all the data fast enough?" and "How much is it going to cost?" WSNs must be designed to work in environ-

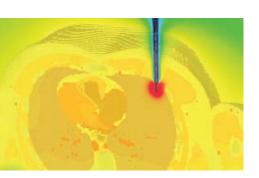


▲ Fig. 1 Energy to transmit a short 802.15.4 packet and receive an acknowledgment.





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CHANGING THE STANDARDS

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ments with link-layer packet delivery ratios (PDR) down to about 50 percent.

When developing a wireless datacollection system, there are a few performance targets that must be met. First, the system must meet a minimum reliability goal. For industrial applications, the target is typically to receive at least 99.9 percent of the generated data, as missing data can trigger expensive alarm conditions. Second, the system must support a certain throughput, a number of sensor data packets per second. Third, these data packets are only useful if received within a maximum latency period. Many processes rely on fresh data updates — for control, stale data may have no utility. Fourth, many systems must operate in challenging environments that include wide temperature ranges and intrinsic safety restrictions. Only solutions that meet

all four of these requirements are considered suitable for further evaluation.

When considering various solutions that meet the requirements, the key selection criteria become cost of ownership and flexibility. The cost of ownership encompasses several areas: product development, installation, hardware and providing power over the lifetime of the installation. Wireless technologies have reduced installation costs dramatically compared to wired solutions, but battery-powered wireless devices may require battery changes over the lifetime of the network. There is also a trade-off between building a network with a small number of high-power devices to reduce the hardware cost versus using a larger number of low-power devices. For devices powered by energy harvesting cells (e.g., solar, thermoelectric), capacitor size may determine a significant portion of the cost. Solutions with deterministic scheduling, such as Time-Division Multiple Access (TDMA), can help separate highcurrent events as much as possible to reduce the capacitor size require-

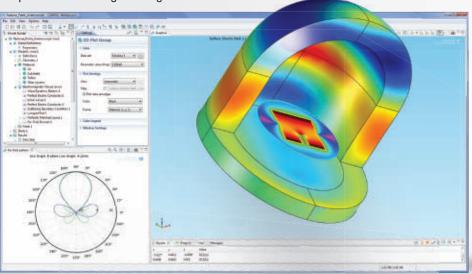
Because final deployment conditions are unpredictable, networks must be designed for flexibility. Networks must scale from small to large numbers of sensors and from low to high density. To be robust across diverse wireless environments, resource provisioning should ensure that devices reliably communicate with moderate interference and that the networks survive the loss of individual devices. Additional resources, including more wireless links, more neighbors for each device, or more signal amplification, improve reliability and latency. All these additions come at increased power costs that can be minimized with dynamic allocation. Solutions based on standards provide immunity to the supply chain vagaries of a single vendor component and the assurance that the community has agreed on the governing principles of operation, e.g., security architecture.



The wireless channel is unreliable in nature, and a number of phenomena can prevent a transmitted packet from reaching a receiver. One such phenomenon is interference. If two independent transmitters transmit on



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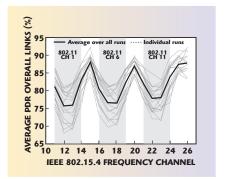
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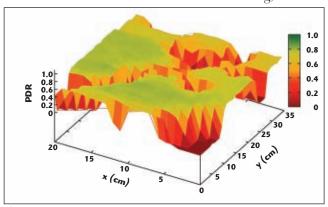
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the same channel such that their signals overlap, they may corrupt each other's signal at a receiver's radio. This requires the transmitter to re-transmit, at the cost of additional time and energy.

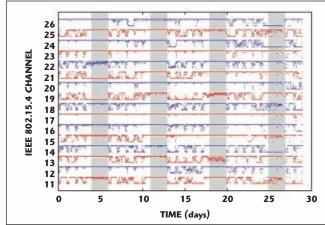
Interference can come from the same network if the underlying medium access technology does not schedule contention-free communications. This is particularly problematic if the two transmitters can hear the receiver, but not hear each other – this is



▲ Fig. 2 Interference between Wi-Fi and 802.15.4 in the 2.400 to 2.485 GHz frequency band.



▲ Fig. 3 Multipath fading causes the quality of a link to vary dramatically, even when moving the receiver by only a couple of centimeters.



▲ Fig. 4 The packet delivery ratio of a wireless link evolves over time.

known as the "hidden terminal problem," and it requires backoff and acknowledgment mechanisms to resolve collisions.

Interference can also come from another network operating in the same radio space, or from a different radio technology using the same frequency band. The latter, known as "external" interference, is especially present in unlicensed bands such as the 2.400 to 2.485 GHz Instrumentation, Scientific and Medical (ISM) band, crowded with WiFi, Bluetooth and 802.15.4.

Figure 2 was obtained by deploying forty-five 802.15.4 nodes in an office environment, and having them exchange 12 million packets, equally distributed over sixteen 802.15.4 channels. It plots the average packet delivery ratio of those packets as a function of the channel they are transmitted on; on channels overlapping WiFi channels, this delivery ratio is lower.

A second phenomenon, multipath fading, shown in *Figure* 3, can pre-

vent a transmitted packet from reaching a receiver and is both more destructive and harder to quantify. Often described as "selfinterference," this occurs when recipient receives both the signal traveling over the lineof-sight path from the transmitter as well as "echoes" of the same signal that have bounced off objects in the environment (floors, ceilings, doors, people, etc.). Since those copies travel different distances, they reach the receiver at different times, potentially interfering destructively. Fades of 20 to 30 dB are not uncommon.

Figure 3 was obtained by having a transmitter transmit 1000 packets to a receiver 5 m away, and

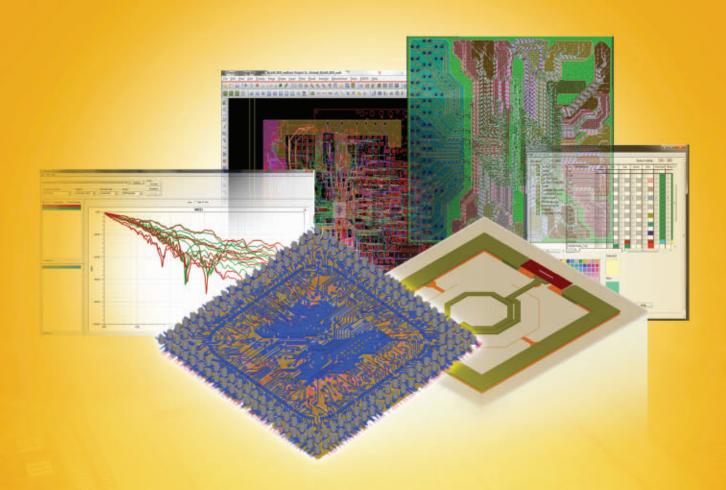
repeating this with the receiver positioned at each point in a 35 by 20 cm grid. The z-axis represents the packet delivery ratio over that link. While the link is good at most positions, at some positions no packets are received successfully because of multipath fading.

Multipath fading depends on the position and nature of every object in the environment and is unpredictable in any practical setup. One good property is that the "topography" depicted in Figure 3 changes with the frequency. That is, if a packet is not received because of the multipath fading, retransmitting on a different frequency has a high probability of succeeding.

Because objects in the environment are not static, e.g., cars drive by and doors are opened and closed, the effect of multipath changes over time. **Figure 4** shows the packet delivery ratio on a single wireless path between two industrial sensors over the course of 26 days, and for each of the sixteen channels used by the system. There are weekly cycles where workdays and weekends are clearly visible. At any given time, some channels are good (high delivery), others bad, and still others vary highly. Channel 17, while generally good, has at least one period of zero delivery. Each path in the network shows qualitatively similar behavior, but with different channel performance and there is never any one channel that is good everywhere in the network. Because of interference and multipath fading, the key to building a reliable wireless system is to exploit channel and path diversity.

SOLUTIONS

As stated previously, one technology well suited for solving the WSN problem is IEEE 802.15.4. Such 802.15.4 radios offer low-power, lowdata rate PHYs in several unlicensed frequency bands, including the 915 MHz band, available in North America, and the 2.4 GHz ISM band, available worldwide. The 2.4 GHz band spread spectrum PHYs provide immunity to noise – a particularly important feature for a low-energy device designed to operate in a potentially crowded, unlicensed band. The standard also defines a reliable, acknowledged, packet (or frame) based MAC layer with optional encryption and authentication. This flexible solution forms the basis of several proprietary



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and standards-based protocols including the ZigBee protocol, which uses it to form unsynchronized single-channel networks, and the WirelessHART protocol,² which uses it to form time-synchronized multichannel networks.

The WirelessHART protocol has an 802.15.4 2.4 GHz PHY and an 802.15.4-based link layer, which adds synchronization, channel hopping, priority and time-based authentication to the standard 802.15.4 MAC.

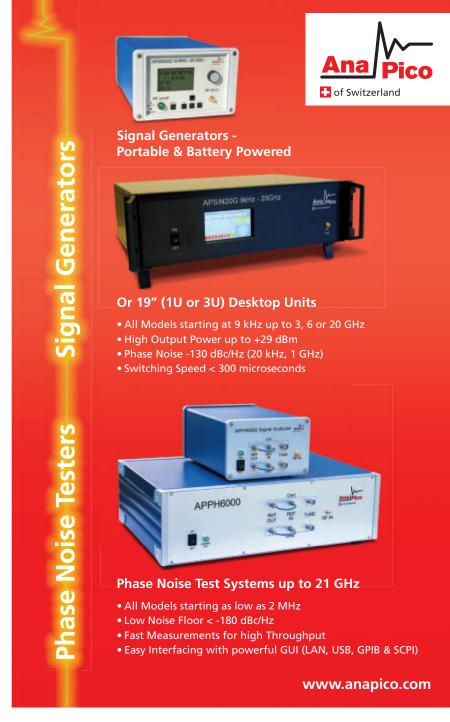
It has a network layer that provides routing and end-to-end security, and a thin unreliable/reliable mesh transport layer. The WirelessHART standard specifies timeslot timing, how devices maintain synchronization, and how devices schedule time/channel communications opportunities by dividing time into slotted communications opportunities (timeslots) on repeating superframes. The protocol was designed to allow seamless inte-

gration of wireless devices to existing wired HART installations, widely used in industrial process monitoring and control applications. WirelessHART extends the HART application layer command set, adding commands for managing wireless resources and monitoring network health. WirelessHART networks are highly reliable meshes - even with devices that do not have line-of-sight and at tens to hundreds of meters spacing, each device has multiple neighbors to which it can send data - providing the path diversity needed for reliability. WirelessHART networks are centrally managed, with most network "intelligence" residing in a Manager. Field devices (wireless sensors) report status information that the Manager uses to groom and optimize the network, and sensor data is reported to an application proxy called a Gateway.

Earlier this year, a new 802.15.4e amendment was released, which, among other things, formalized timeslotted channel-hopping features like those found in WirelessHART at the 802.15.4 MAC layer. The standard defines the mechanisms for advertising synchronization information to allow devices to synchronize to a network, provides for time-based security, and defines slotted communications and hop sequences. It makes extensive use of data encapsulation in "information elements" - this allows for custom extensions of the MAC without having to wait for the standard to be updated. It is intended to ease development of a multilayer protocol, and was specifically designed to couple to a 6LoW-PAN-compressed IPv6 network layer as defined in IETF RFCs 4944 and $6282.^{3}$

APPLICATIONS

Dust Networks Linear's SmartMesh[™] product line is an example solution that contains both WirelessHART and 6LoWPAN-compliant IPv6 product offerings that leverage 802.15.4 to provide reliable, low power WSN solutions. Dust Eterna™ motes are single chip devices that couple a Cortex-M3TM microprocessor, memory and peripherals to the lowest power 802.15.4 radio currently available (see *Figure 5*). Designers embed a mote in their sensor package and can rely on the network to



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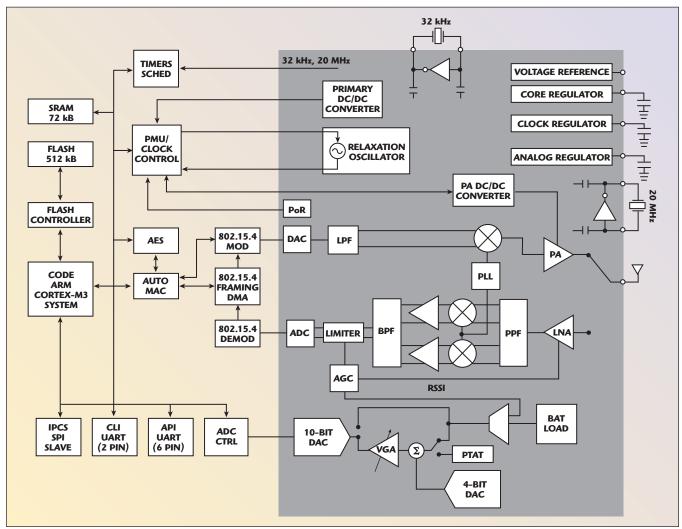
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▲ Fig. 5 Block diagram of the LTC5800 Dust Eterna motes.

form, optimize, and carry their sensor data to their application. Managers allow for graceful scaling from tens to thousands of devices, providing data and configuration interfaces for the network. They are suitable for solving a wide array of WSN problems. Some examples of applications using motes and managers include:

Parking: Streetline⁴ is a smart parking provider that monitors the real-time availability of urban parking spaces. Vehicle detectors are installed underneath parking spaces, inside the pavement and flush with the roadway. This brings challenges, as the antenna for the sensor device is located underground, and then covered by a metal vehicle when the space is occupied. Wireless path diversity is essential as different vehicle positions change the path quality between device pairs. Streetline installs elevated repeater devices on nearby street lamps to

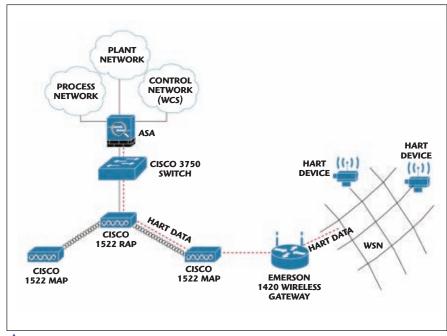


Fig. 6 Network architecture for refinery process control.

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obtain line-of-sight to the stall sensors. These repeaters form a multi-hop mesh to collect all the occupancy data to the local network manager, where it gets aggregated into a city-wide database available to customers and enforcement agencies. Wireless technology is critical for this application because it is intractable to wire sensors to each space, and low-power wireless decreases the frequency of battery changes.

Refinery Process Control: Chevron uses wireless networks to monitor oil extraction and refining facilities. These networks are often deployed in harsh environments (due to hazardous temperatures, chemicals or risk of explosion) where it is impossible to run conduit for wired sensors. Additionally, wireless enables monitoring of rotating structures and mobile operators. For one deployment (see *Figure 6*), wireless

networks were installed in various locations around a large refining facility. To gather the data to a centralized control center, a Cisco IEEE 802.11a wireless mesh was used as the backhaul connection for each IEEE 802.15.4 network manager. This allowed the low-power sensor devices to report to their local manager where data was aggregated and reliably shuttled along. This deployment represents a powerful fusion between the two standards.

Energy Monitoring: Vigilent⁵ provides intelligent energy management systems for indoor environments such as data centers where environmental control is critical. As increased temperature at any location in the data center can cause equipment failures, air conditioning is often run continuously at full power, wasting energy. Facilities managers are reluctant to jeopardize their internal networks, so Vigilent deploys wireless devices that do not interfere with regular operation. The facilities are also sensitive to security, so the wireless protocol is required to have end-to-end encryption of all packets and additional security at the network manager. Data center sense points are typically dense, and Vigilent has had success in deploying multiple overlapping networks to achieve the required number of sensors.

CONCLUSION

Multichannel time-synchronized mesh networks based on 802.15.4 radios address many of the challenges involved in building flexible, reliable, low-power wireless sensor networks. There are a growing number of new applications that are utilizing these types of sensor networks to reduce costs and provide enhanced services around the world. ■

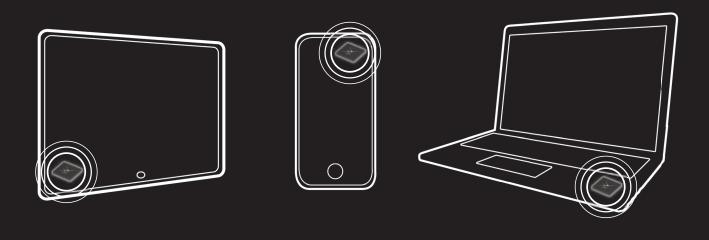
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wo of the most important trends in the last 50 years have been Moore's law and the proliferation of software. As a result, we have seen our technology get faster, smaller and lower cost while becoming much more flexible and customizable to each user's needs. National Instruments has built upon these trends with significant industry introductions such as the release of NI LabVIEW system design software that empowered engineers and scientists to extend their fixed functionality instrumentation by connecting them to the PC with productive software that enables data collection, signal processing, automation and also the introduction of PXI 15 years ago. As a leading modular instrumentation standard, PXI has ushered in a new era of instrumentation that is faster, smaller and lower cost than traditional instruments without sacrificing performance.

National Instruments has now redefined testing instrumentation with a new class of instrument, the vector signal transceiver. Combining a vector signal analyzer, a vector signal generator and high-speed digital I/O in one three-slot PXI module, the NI PXIe-5644R vector signal transceiver is a fraction of the size and cost of traditional solutions while offering orders of magnitude faster speed and maintaining industry-leading measurement performance. Even more important, the NI PXIe-5644R is a software-designed instrument. With an open, user-programmable FPGA at its core, users can modify its LabVIEW-based software and firmware to create an instrument specific to their exact needs.

FLEXIBILITY OF A SOFTWARE DEFINED RADIO ARCHITECTURE

The fundamental elements that compose a vector signal transceiver are the combination of a vector signal generator (VSG) and vector signal analyzer (VSA) and a shared FPGA for real-time signal processing and control. This differs from traditional solutions, which use either two discrete instruments or wireless test sets that just combine the instruments in a common chassis (see *Figure 1*).

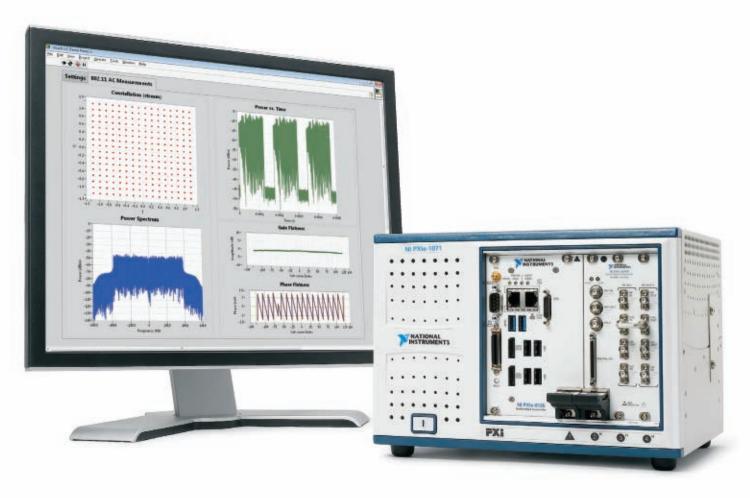
By replacing fixed, vendor-defined hardware with a flexible, software-designed approach, the vector signal transceiver empowers engineers to design exactly the instrument functionality they need. The NI PXIe-5644R vector signal transceiver also features the following:

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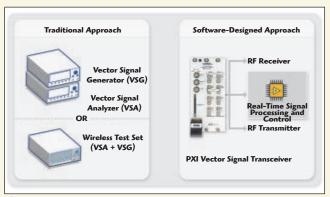
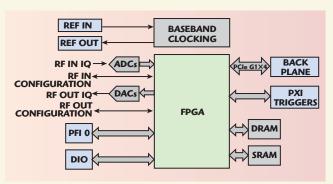


Fig. 1 Comparison of vector signal transceiver to traditional instrumentation.



▲ Fig. 2 Block diagram of the NI PXIe-5644R FPGA basecard.

One way the potential of these features is immediately realized is by the significant reduction in test time. With most of the processing offloaded to the onboard FPGA, and data transfers occurring over the high-throughput PCI Express bus, measurement times are 10 to 100 times faster than traditional instruments.

Also, due to its small size and modular nature, the vector signal transceiver can be used in a multitude of configurations. For example, one vector signal transceiver can be used in a four-slot PXI chassis as a small bench-top instrument, or up to five vector signal transceivers can be combined in one 18-slot chassis to address parallel testing needs and multiple input, multiple output (MIMO) applications 5×5 in that specific example, see **Figure 3**).

SOFTWARE-DESIGNED INSTRUMENT

Out of the box, the vector signal transceiver provides a software experience similar to other instruments with a quick time to first measurement/generation and a programming interface for the most common functions. However, the true power comes from the fact that all LabVIEW software and firmware source code is provided to enable users to modify their instruments to their specific needs (see *Figure 4*).

LabVIEW is suited to this new class of RF instrumentation because it empowers any engineer or scientist with basic RF knowledge to successfully design new features or modify existing ones deep within the instrument. As system design software, LabVIEW is capable of abstracting the processing implemented on an FPGA and the microprocessor (in the PC environment) in a way that does not require extensive knowledge of computing architectures and data ma-

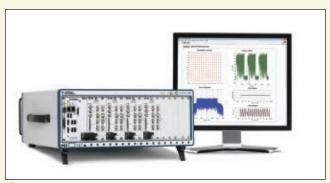


Fig. 3 Scale up to 5 input and output channels in one PXI system.

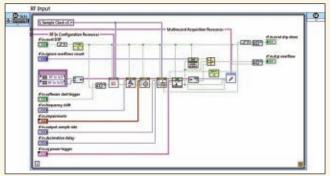


Fig. 4 All LabVIEW software and firmware source code is provided to enable the user to modify the instrument to their specific needs.

nipulation. This frees the user to focus on the functionality of algorithms and instrument control to meet their specific application needs.

A NEW WAY TO THINK ABOUT INSTRUMENTATION

After years of learning to program vendor-defined instruments and decades of manual work, engineers can now use the NI PXIe-5644R vector signal transceiver and LabVIEW to define their instrumentation.

Early access users of the NI PXIe-5644R are customizing the device in many different applications:

- Embedded protocols inside the instrument to build protocol-aware testers
- Integrated, real-time channel models to emulate wireless device testing in the field
- Hardware-in-the-loop techniques to servo the nonlinearity of RF power amplifiers
- Software defined radios to prototype future communication standards

With a software-designed approach, engineers no longer have to ask, "How do I make this box do what the vendor intended?" Instead, they can start asking, "What do I need this instrument to do?" and easily make it happen. This is a significant change in the way testing instrumentation can be used in the future.

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IW's Re-Flex Cables were designed to offer an alternative to standard semirigid & conformable cables. The unique design of these cables features a laminated PTFE dielectric, as ilverplated copper foil shield, and a tightly woven copper braid. They have the same leakage characteristics and mechanical dimensions as standard semi-rigid cable. Stock assemblies use shell style & direct solder SMA plugs. Non-stock assemblies are available with relevant popular RF connector styles. Standard cable diameters are RF .085 & .141, with RF .047 & .250 Now Available! An FEP jacket is also available for all four cable types to eliminate any risk of a shorting hazard.

 50Ω Impedence:

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copper per ASTM B-298

1.4 ns/ft Time delay:

Cut off frequency: 60 GHz for RF 085

34 GHz for RF 141

RF leakage: Equivalent to

Dielectric

Multi-ply PTFE laminate

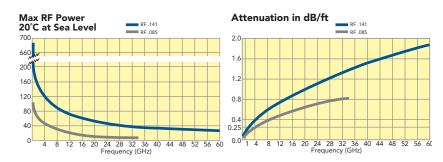
per ASTM D-1457

semi-rigid cable

Temp range: -55°C to 135°C

Bend radius: 1/16 inch for RF 085

1/8 inch for RF 141



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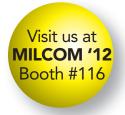
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Shield

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	Model No.	Freq (GHz)	Gain (dB) MII		Power -out @ P1-dB		VSWR
	CA01-2110 CA12-2110	0.5-1.0 1.0-2.0	28 30	1.0 MAX, 0.7 TYP 1.0 MAX, 0.7 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 2.0:1
	CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
	CA48-2111 CA812-3111	4.0-8.0 8.0-12.0	29 27	1.3 MAX, 1.0 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 2.0:1
	CA1218-4111	12.0-18.0	25	1.6 MAX, 1.4 TYP 1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
	CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1
	NARROW B CA01-2111	0.4 - 0.5	NOISE AN	O.6 MAX, O.4 TYP	VER AMPLIF +10 MIN	+20 dBm	2.0:1
	CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
	CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
	CA23-3111 CA23-3116	2.2 - 2.4 2.7 - 2.9	30 29	0.6 MAX, 0.45 TYP 0.7 MAX, 0.5 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 2.0:1
	CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
	CA56-3110 CA78-4110	5.4 - 5.9 7.25 - 7.75	40 32	1.0 MAX, 0.5 TYP 1.2 MAX, 1.0 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 2.0:1
	CA76-4110 CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN +10 MIN	+20 dBm	2.0.1
	CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
	CA12-3114 CA34-6116	1.35 - 1.85 3.1 - 3.5	30 40	4.0 MAX, 3.0 TYP 4.5 MAX, 3.5 TYP	+33 MIN +35 MIN	+41 dBm +43 dBm	2.0:1
	CA54-6116	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
	CA812-6115	8.0 - 12.0	30	5.0 MAX, 4.0 TYP 4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
	CA812-6116 CA1213-7110	8.0 - 12.0 12.2 - 13.25	30 28	5.0 MAX, 4.0 TYP 6.0 MAX, 5.5 TYP	+33 MIN +33 MIN	+41 dBm +42 dBm	2.0:1 2.0:1
	CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
	CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1
	Model No.	Freq (GHz)	Gain (dB) MI	CTAVE BAND AN Noise Figure (dB)	Power-out@P1-d8	3rd Order ICP	VSWR
	CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
	CA0106-3111 CA0108-3110	0.1-6.0 0.1-8.0	28 26	1.9 Max, 1.5 TYP 2.2 Max, 1.8 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 2.0:1
	CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
	CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
	CA26-3110 CA26-4114	2.0-6.0 2.0-6.0	26 22	2.0 MAX, 1.5 TYP 5.0 MAX, 3.5 TYP	+10 MIN +30 MIN	+20 dBm +40 dBm	2.0:1 2.0:1
	CA618-4112	6.0-18.0	25	5.0 MAX. 3.5 TYP	+23 MIN	+33 dBm	2.0:1
	CA618-6114 CA218-4116	6.0-18.0 2.0-18.0	35 30	5.0 MAX, 3.5 TYP 3.5 MAX, 2.8 TYP	+30 MIN +10 MIN	+40 dBm +20 dBm	2.0:1 2.0:1
	CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
	CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1
	LIMITING AI Model No.		nput Dynamic	Range Output Power I	Range Psat Pov	ver Flatness dB	VSWR
	CLA24-4001	2.0 - 4.0	00 1 10	ID ' 7 . 1	1 dBm →	-/- 1.5 MAX	2.0:1
	CLA26-8001 CLA712-5001	2.0 - 6.0 7.0 - 12.4	-28 to +10 c -50 to +20 c -21 to +10 c	IBm +14 to +1 IBm +14 to +1	8 dBm +	-/- 1.5 MAX -/- 1.5 MAX	2.0:1 2.0:1
	CLA618-1201	6.0 - 18.0	-50 to +20 c	1Bm + 14 to +1	9 dBm +	-/- 1.5 MAX	2.0:1
	AMPLIFIERS V Model No.	VITH INTEGR Freq (GHz)	ATED GAIN Gain (dB) MIN	ATTENUATION Noise Figure (dB) Pow	ver-out@P1-dB Gain	Attenuation Range	VSWR
	CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
	CAO5-3110A	0.5-5.5	23 28	2.5 MAX, 1.5 TYP	+18 MIN +16 MIN	20 dB MIN	2.0:1
	CA56-3110A CA612-4110A	5.85-6.425 6.0-12.0	24		+10 MIN +12 MIN	22 dB MIN 15 dB MIN	1.8:1 1.9:1
	CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
	CA1518-4110A Low Freque t	15.0-18.0		3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1
	Model No.		Gain (dB) MIN		Power-out@P1-dB	3rd Order ICP	VSWR
	CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
	CA001-2211 CA001-2215	0.04-0.15 0.04-0.15	24 23	3.5 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP	+13 MIN +23 MIN	+23 dBm +33 dBm	2.0:1 2.0:1
	CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
	CA002-3114 CA003-3116	0.01-2.0 0.01-3.0	27 18	4.0 MAX, 2.8 TYP 4.0 MAX, 2.8 TYP	+20 MIN +25 MIN	+30 dBm +35 dBm	2.0:1 2.0:1
	CA003-3110	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1
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Dan Massé, Associate Technical Editor

High Resolution X-Band Radar Provides Photo-links Imagery in Any Weather

Lockheed Martin airborne reconnaissance radar that provides high resolution, photographic-like imagery, even in inclement weather or darkness, is now available to customers worldwide. Lockheed Martin's AN/APY-12, a dual mode, X-Band synthetic aperture radar (SAR) with moving target indication capability, has been cleared for export to certain countries, including Taiwan, Italy, Sweden and Korea.

"Intelligence operations depend heavily on the ability to quickly locate and track targets in every weather condition," said James Quinn, vice president of C4ISR Systems with Lockheed Martin IS&GS-Defense. "Our AN/APY-12 radar is tailor-made for customers who need real-time situational awareness 24 hours a day, seven days a week."

Developed for surveillance and reconnaissance missions, the AN/APY-12 can transmit airborne processed images and moving target detections to ground-based exploitation stations in real-time via secure data links. This high resolution SAR delivers photographic quality images

"Intelligence operations depend heavily on the ability to quickly locate and track targets in every weather condition."

of areas of interest as well as ground moving target indicator (GMTI) detections of moving surface vehicles, taxiing aircraft, and hovering helicopters. A new mode incorporated into the radar produces GMTI detections with increased sensitivity and improved geo-location accuracy. The radar also incorporates a wide area moving

target indicator (WAMTI) mode that can scan thousands of square-kilometers, detect ground movement, then overlay that moving target data onto a map in less than one minute.

Since inventing SAR in the early 1950s, (Lockheed Martin owns the original SAR patent titled 'Simultaneous Doppler Build Up'), Lockheed Martin has continued to refine this imaging technology. Resolution that had been measured in feet can now be measured in inches in certain applications. More than 500 SAR systems have been developed for 30 different types of aircraft, including the development of all SAR systems for the SR-71 Blackbird.

Today, Lockheed Martin continues its pursuit toward the development of next generation SAR technologies. Recent Lockheed Martin SAR innovations include dual-band VHF/UHF synthetic aperture radar for imaging concealed targets, foliage penetrating radar, reconnaissance sensors encased in pods to enable fighter aircraft to collect imagery, and an all weather, passive detection and tracking system suitable for real-time 3D air surveillance.

Northrop Grumman's F-35 DAS and Radar Demonstrate Ability to Detect, Track and Target

orthrop Grumman Corp. demonstrated the ballistic missile detection, tracking and targeting capabilities of the company's AN/AAQ-37 distributed aperture system (DAS) and AN/APG-81 active electronically scanned array (AESA) radar, both of which are featured on the F-35 Joint Strike Fighter (JSF) aircraft.

Leveraging NASA's Science Mission Directorate-sponsored Anomalous Transport Rocket Experiment launch operation, the demonstration was coordinated with NASA and the U.S. Air Force to ensure that it did not impact NASA's primary science mission goals. The systems were demonstrated in flight onboard the company's BAC1-11 test bed aircraft. Northrop Grumman's DAS and APG-81 autonomously detected, tracked and targeted multiple, simultaneous ballistic rockets. The DAS autonomously detected all five rockets, launched in rapid succession, and tracked them from initial

launch well past the second stage burnout.

"Northrop Grumman demonstrated these ballistic missile tracking modes with only minor modifications to the baseline F-35 JSF radar and DAS software," said Jeff Leavitt, vice president of Northrop Grumman's combat avionic systems business unit. "Since DAS is always staring simultaneously in every

The DAS
autonomously
detected all five
rockets, launched
in rapid succession,
and tracked them
from initial launch
well past the second
stage burnout.

direction, an operator does not have to point the sensor in the direction of a target to gain a track. The F-35 pilot could continue the primary mission, while the sensors automatically observe ballistic missile threats."

The APG-81 AESA radar demonstrated the ability to provide acquisition and weapons quality tracks independently, and also via pointing cues from DAS for expedited and extended range target acquisition. The radar maintained each track from initial acquisition until the rocket exited the radar's field of view. Leavitt added that Northrop Grumman is currently exploring how the existing DAS technology could assist in several additional mission areas, including irregular warfare operations.

The multifunction AN/APG-81 AESA radar is capable of the full range of air-to-air and air-to-surface capabilities complemented by significant electronic warfare and intelligence, surveillance and reconnaissance functions. The AN/AAQ-37 DAS provides passive spherical awareness for the F-35, simultaneously detecting and tracking aircraft and missiles in every direction, and providing visual imagery for day/night navigation and targeting purposes.

X

Raytheon Awarded \$636 M for EKV

aytheon Co. was awarded a \$636 million development and sustainment contract to provide the Exoatmospheric Kill Vehicle (EKV) to The Boeing Co., which is the prime contractor for the Ground-based Midcourse Defense program. Raytheon booked the award during its second quarter.

EKV represents the centerpiece for the Missile Defense Agency's GMD as the intercept component of the Ground Based Interceptor, also known as GBI, which is designed to engage high-speed ballistic missile warheads in space.

"When it comes to developing, testing and deploying technologies that enable the intercept of threats in space, Raytheon is a world leader," said Dr. Taylor W. Lawrence, Raytheon Missile Systems president. "We are proud to contribute to our nation's first line of defense against the threat of ballistic missiles."

Under conditions of the contract, which extends through November 2018, Raytheon will provide EKV development, fielding, testing, system engineering, integration, configuration management, equipment manufacturing and refurbishment, and operation and sustainment.

Leveraging more than two decades of kill vehicle technology expertise, the EKV is designed to destroy incoming ballistic missile threats by colliding with them, a concept often described as "hit to kill."

Harris Corp. Awarded U.S. Army Order

arris Corp. has received an initial order to provide the U.S. Army with Harris Side Falcon (SRW-SF) Soldier Radio Waveform appliqué systems. The order, via the GSA, FAS Assisted Acquisition Services, is in support of the Army's Network Integration Evaluations (NIE) at White Sands Missile Range.

The Harris Side Falcon integrates the Falcon III® AN/PRC-152A handheld radio with a small-form factor wideband power amplifier for increased range and reliability. Side Falcon systems will be installed in vehicles to address Army requirements for a vehicular single-channel radio that operates the JTRS Soldier Radio Waveform. The appliqués will be deployed to move voice and data seamlessly between dismounted soldiers, their command centers and higher headquarters.

The Harris Side Falcon supports SRW as well as the Harris Adaptive Networking Wideband Waveform (ANW2). In addition, Side Falcon also operates SINCGARS, VHF/UHF Line-of-Sight, HaveQuick, IW for tactical satellite communications and other combat net radio waveforms, making it fully interoperable with existing DoD radios — providing the Army with maximum flexibility in combat. The Army has indicated it intends to acquire as many as 5000 SRW Appliqué systems through a series of competitive procurements over the next several years.

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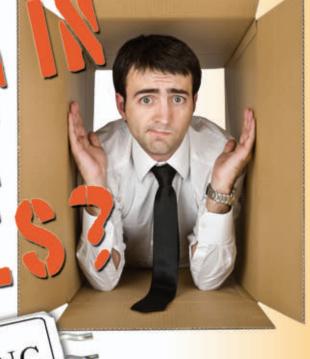
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Industrial Perspectives – Newly developed microwave technology for pivotal defence, security and space applications.

Late Morning Session: 10:40 – 12:20

EuRAD Opening Session – Overview of prevalent issues and synergies between industrial defence and space sectors.

Lunch and Learn: 12:30 - 13:30

Data and analysis of global defence market, presented by Strategy Analytics.

Afternoon Session: 13:50 – 15:30

Industry and agency expert panels share insights on defence and space trends and developments.

Executive Forum: 16:00 – 18:00

Executives from space and defence agencies and leading defence contractors consider the issues faced by their organizations and the role of technology.

A Q&A session will conclude the forum.

Cocktail Reception: 18:00 – 19:00

Opportunity to network and discuss issues raised throughout the forum in an informal setting.



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International Report Richard Mumford, International Editor



NEC Participates in DRIVE C2X

Demonstration

EC Laboratories Europe announced that its vehicular communication system has become part of the European Commission sponsored DRIVE C2X research project to make traffic and transportation safer, more efficient and more environmentally friendly.

NEC's vehicular communication system, including the LinkBird-MX communication platform and the company's C2X-Software Development Kit, which is part of

"NEC's participation in large-scale European trials is the result of more than a decade of innovation in vehicular communications, developing research ideas and successfully bringing them onto reliable pre-commercial platforms."

the DRIVE C2X vehicle reference system, were recently part of a demonstration to a global audience at the Dutch Integrated Testsite for Cooperative Mobility in Helmond, the Netherlands

The trial event demonstrated nine applications for safety and traffic efficiency. It also provided insights into the test management centre and procedures for Carto-Car and Car-to-Infrastructure (Car-2-X) communications. Additionally, the event validated the functionality of the reference system.

The NEC system has become a leading platform in European vehicular communications activities thanks to its small form factor, high reliability, communication stack performance and compliance with standards.

"NEC's participation in large-scale European trials is the result of more than a decade of innovation in vehicular communications, developing research ideas and successfully bringing them onto reliable pre-commercial platforms," said Dr. Heinrich Stuettgen, vice president of NEC Laboratories Europe.

DRIVE C2X Project Update

DRIVE C2X is a European Commission sponsored research project that brings together car manufacturers, research institutes, authorities and information technology providers to provide a pan-European reference platform for communication among cars, and between cars and the infrastructure. Following the Dutch demonstration, the DRIVE C2X reference system has been made available to seven European test sites where further tests will be conducted.

ITU and ETSI Renew MoU

he International Telecommunication Union (ITU) and the European Telecommunications Standardization Institute (ETSI) have agreed on a new Memorandum of Understanding that will smooth the way for regional standards, developed by ETSI, to be recognised internationally. The two organisations possess complementary roles as Standards Development Organizations (SDO), with ITU recognized as an international standardization body in the ICT field and ETSI as the European standardization organization for telecommunications.

Mutual cooperation between SDOs is key to ensuring a coordinated approach to standards development. International standardization re-engineers regional stan-

dards to allow them international reach, or reconciles regional standards to form cohesive international standards.

Clear, coordinated action from standards bodies will provide the business community with greater clar"Mutual cooperation... is key to ensuring a coordinated approach to standards development."

ity regarding standards under development. This increased certainty will promote a faster, more efficient adoption of standards in products manufactured, leading to greater economies of scale and lower costs to consumers.

Hamadoun Touré, secretary-general, ITU, stated, "ITU standards allow international access to the innovations progressing our Information Society. This is achieved through cooperation with national and regional standards bodies to uncover the most valuable innovations and standards, no matter where they originate. It is thus very encouraging to see an extension of ITU's MoU with ETSI, an action which will ensure ITU standards reflect the current 'state of the art' in European ICT standardization at the international level."

NGMN and GTI Cooperate to Support LTE

he Next Generation Mobile Networks (NGMN) Alliance and Global TD LTE Initiative (GTI) have finalised a cooperation agreement to jointly collaborate on progressing LTE. Both organisations share the view that LTE is one single technology and together will work to support the convergence of both FDD and TDD. The cooperation will lead to the exchange of information and commonly identified projects avoiding duplication of work.

In order to achieve these objectives, the two organisations have agreed to align technical requirements, share experiences, and identify and carry out joint technical co-operation projects, which will lead to aligned public messages, actions and requirements, including commu-



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"GTI is committed to deliver one global LTE standard."

nications to Standards Development Organisations (SDO).

Peter Meissner, operating officer of the NGMN Alliance under-

lined: "The cooperation will aim to enable and support timely delivery to market of next generation mobile broadband technology, both of LTE TDD and LTE FDD. It will also enable synergies between LTE TDD and LTE FDD and convergence of LTE TDD/ LTE FDD solutions, while avoiding fragmentation of the market."

Craig Ehrlich, chairman of the steering committee of GTI added: "GTI is committed to deliver one global LTE standard. GTI will work with the NGMN Alliance and the mobile industry to achieve this goal."

UK Government Invests to Stimulate Innovation

sixteen major new research and development projects that will help to stimulate innovation in the UK's manufacturing sector are to share government funding of over £6.5 million. The Technology Strategy Board (TSB) and the Engineering and Physical Sciences Research Council (EPSRC) are to provide grant funding to support the development of new technologies that have the potential to underpin new produc-

tion processes in a wide range of industrial applications and market sectors.

The focus of the R&D will be on production technologies that can create high value through novel processes, advanced product manufacture, and/or resource efficiency

"Investment in cutting edge manufacturing research... is the key to economic success."

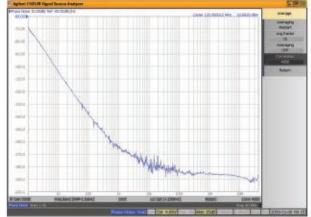
improvements. The projects will also encourage the development of technologies that will facilitate greater environmental sustainability through efficient disposal, recycling or remanufacture of assets at the end of their useful life.

Iain Gray, chief executive of the Technology Strategy Board, said: "The Technology Strategy Board has an important role to play, through funding for such collaborative research and development, helping UK businesses to accelerate the development of new equipment, processes and expertise brought about by technology innovation. Manufacturing capability is often built on, and strengthened by such new-found technology and this can be a significant driver of economic growth."

Professor Dave Delpy, EPSRC chief executive said: "Investment in cutting edge manufacturing research and the translation of that into commercial applications is the key to economic success. EPSRC has a portfolio of 350 live projects and an investment of £380 million in the manufacturing sector."

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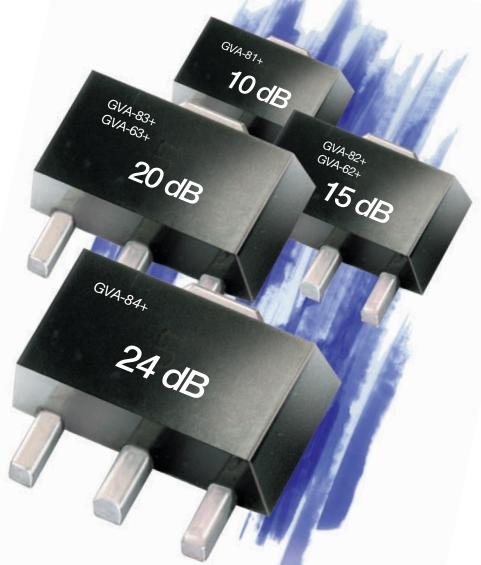
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*Low frequency cut-off determined by coupling cap, except for GVA-62+ and GVA-63+ low cutoff at 10 MHz.

US patent 6,943,629

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Commercial Market

Dan Massé, Associate Technical Editor



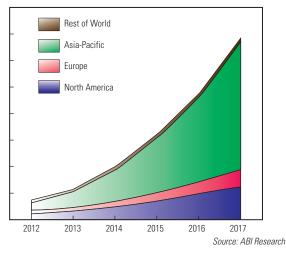
Carrier Wi-Fi Equipment Market to Grow 8× Its Current Size to \$2.2 B by 2017

lobal revenue for carrier Wi-Fi access points and controllers will reach \$2.2 billion in 2017, a level equivalent to almost one-half of the traditional enterprise or consumer/SoHo Wi-Fi segments in the same period. The majority of the total market in 2011 was accounted for by Cisco, Ruckus Wireless, and Ericsson/BelAir, and as traditional mobile infrastructure vendors add Wi-Fi to their portfolios, these early market share rankings will fluctuate. Carrier Wi-Fi is defined as Wi-Fi that is provided as a service to mobile carrier customers, owned and operated directly or indirectly by the carrier, e.g., a third-party hotspot provider.

Nick Marshall, principal analyst, mobile networks, comments, "While carrier Wi-Fi is still in relative infancy today, the drive by mobile operators to off-load data traffic is providing a significant boost to this segment of the market."

The rollout of carrier Wi-Fi has been hampered up until now by the lack of standards which make the process seamless and transparent for the subscriber. "We believe that with standardization initiatives well under way, like Hotspot 2.0 and the almost universal inclusion of Wi-Fi in every smartphone, PC, and tablet being built today, carrier controlled Wi-Fi is expected to see wide-scale adoption, especially in markets like North America, Japan and South Korea," continues Marshall. Additionally, the use of increasingly sophisticated connection managers, which aggressively seek out validated Wi-Fi access in accordance with the service provider's policies, will accelerate this trend. Thanks to this trend, carrier Wi-Fi data traffic offloaded is expected to grow to around 30 percent by 2017.





High Inventory and Low Burn Rate Stalls Femtocell Market in 2012

BI Research's latest forecasts for Enterprise and Consumer Femtocells, also referred to as Indoor Small Cells, estimate largely flat volume shipments in 2012 relative to 2011. The shipments in 2012 are expected to contain 2.44 million units, similar to the 2.47 million units shipped in 2011. In total, ABI Research estimates 5.3 million units will be deployed by the end of 2012.

"We believe there is a large inventory of femtocells sitting with operators right now with operators having a slow burn rate, which has led to limited fresh orders in

the first half of 2012," says Aditya Kaul, practice director at ABI Research. "Silicon component suppliers have suggested that 1Q 2012 shipments were down 30 to 40 percent compared to 1Q 2011."

Some of the slack in volumes can be attributed to attention Some of the slack in volumes can be attributed to attention shifting from indoor femtocells to outdoor metrocells.

shifting from indoor femtocells to outdoor metrocells. Also, the recent consolidation in the market including Mindspeed's acquisition of picoChip and Huawei's exit from the femtocell market suggest that the indoor small cell market has been under some strain. In spite of lackluster volume shipments of residential and enterprise femtocells plaguing the indoor small cell market in 2011 and 2012, ABI Research forecasts that growth is likely to pick up from 2013 onwards. Some of this growth stems from a refresh of inventory levels, with operators like AT&T, Vodafone, Telefonica, Softbank and Sprint being at the forefront of driving shipments in both enterprise and residential settings.

The recently concluded Small Cell World Summit in London also provided some encouraging signs. Vodafone's Femtoplug announcement, which is sourced directly from French ODM, SagemCom, and is expected to be driven by Vodafone's Connected Home division, suggests some level of maturity in value chain dynamics and operator go to market strategies.

The Enterprise and Consumer femtocell market will grow at a CAGR of 63 percent to reach almost 28 million units in 2017 for revenue of \$3.4 billion. Consumer femtocells are the largest class of femtocells representing a 68 percent share of units in 2012 and 70 percent in 2017.



Commercial Market

Unstoppable Rise of the Smartphone Will Drive Analog IC Market

echnologies essential to the latest smartphones and tablets mean that the analog integrated circuit (IC) industry can look forward to guaranteed expansion over the next few years, states a new report by business intelligence providers GBI Research. Analog ICs are used in a wide range of applications including third and fourth generation (3G/4G) radio base stations and portable device batteries, as well as medical imaging scanners and electric cars.

GBI Research predicts that the sales revenue from the general purpose analog IC industry, responsible for the production of amplifiers and voltage regulators, will grow from a 2012 value of \$20.41 billion at a Compound Annual Growth Rate of approximately 9 percent to reach \$31.35 billion by the end of 2016. The application-specific analog IC industry, which makes power management and communications chips, is expected to increase its sales revenue from \$27.47 billion in 2012 to \$38.15 billion in 2016, climbing at a CAGR of 6.8 percent.

GBI Research anticipates smartphone sales to play a major role in the expansion of the overall analog IC market. Last year, the number of smartphones in existence was over 417 million – a staggering figure that is expected to grow further to just under 1 billion by 2016,

as the customer appetite for new and more advanced features and applications ues to swell. The Asia Pacific region will play a big part in this growth due to increases in both consumption and manufacturing. Over the next four years, large wafer manufacturing plants will be developed by semiconductor companies such as Intel Corp. and Semiconductor

Last year, the number of smartphones in existence was over 417 million – a staggering figure that is expected to grow further to just under 1 billion by 2016...

Manufacturing Co., reducing costs and therefore increasing consumption for analog ICs.

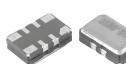
The industry, however, is not without its concerns. The huge demand for the latest features and applications, combined with the ceaseless march of technological innovation, has resulted in short product life cycles. Regular shifts in customer interests make demand difficult to predict, so by the time ICs are developed and ready to be shipped, their application areas are already at risk of being replaced. Such a scenario is a potential nightmare for businesses in the analog IC market.

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INDUSTRY NEWS

Mercury Computer Systems Inc. announced that it has signed a definitive agreement to acquire Micronetics Inc., a designer and manufacturer of microwave and radio frequency (RF) subsystems and components for defense and commercial customers. Pursuant to the terms of the agreement, Mercury will acquire Micronetics via merger for \$14.80 per share. This represents a fully diluted equity value of approximately \$71.7 million and an enterprise value of approximately \$75.4 million, including \$3.7 million of net debt as of March 31, 2012. The acquisition will be funded with available cash and is expected to be immediately accretive to EBITDA.

Murata Electronics North America Inc. and its parent company Murata Manufacturing Co. Ltd. announced that it has closed the deal to acquire RF Monolithics Inc. (RFM). The cash transaction paid the holders of RFM common shares \$1.78 per share. RFM, headquartered in Dallas, TX, will continue to market its broad range of solutions-driven, technology-enabled wireless connectivity for wireless applications — including individual standardized and custom components, modules for comprehensive industrial wireless sensor networks and machine-to-machine (M2M) technology — under the RFM brand as a whollyowned subsidiary of Murata Electronics North America Inc.

Gowanda Electronics, a U.S.-based designer and manufacturer of precision electronic components and inductors for power, RF, and high frequency (HF) applications, teamed up with its newly acquired sister company, Instec Filters, to provide a range of passive electronic components to the global marketplace. Instec Filters is a global supplier of EMI/RFI filters, feedthroughs and filter assemblies. The company was located in CA but recently moved its operations to Arcade, NY, near Gowanda.

Diamond Antenna Europe BVBA has been formed as a joint venture between **AML Microtechnique Lorraine S.A.** and **Diamond Antenna and Microwave Corp.** to manufacture rotary joints in Metz, France. The venture will provide production, customer service, and sales to designated European markets.

Pole/Zero Corp. and Delcross Technologies announced a partnership to offer a "turnkey" source for solutions to the challenges of antenna placement optimization and RF cosite interference mitigation in shipboard, airborne and vehicular applications. Delcross Technologies is a recognized industry leader in simulating installed antenna patterns and antenna-to-antenna coupling characteristics on complex military platforms. In conjunction with Pole/Zero's RF cosite interference analysis software and mitigation equipment, the Pole/Zero and Delcross Technologies team will provide developers of new or modified radio communications platforms first-time success in fielding these systems.

Agilent Technologies Inc. announced that its ongoing collaboration with Thales, a global technology leader for the defense and security and aerospace and transport markets, has expanded the reach of X-parameters technology to wideband super-heterodyne receiver applications. Agilent's collaboration with Thales on nonlinear behavioral models began in 2005. The primary goal of the effort was for Thales to validate the use of the technology for RF system design. As a result of this collaboration, Thales successfully developed a high-accuracy spurious analysis methodology based on X-parameter models. The Thales technique supports arbitrary topology and has been tested for RF systems with single-frequency conversion. Subsequent spurious analysis of such systems has yielded excellent results.

Researchers at **MIT** have found a new way of making complex three-dimensional structures using self-assembling polymer materials that form tiny wires and junctions. The work has the potential to usher in a new generation of microchips and other devices made up of submicroscopic features. Although similar self-assembling structures with very fine wires have been produced before, this is the first time the structures have been extended into three dimensions with different, independent configurations on different layers, the researchers say.

Versatile Power Inc., a technology leader in the design and manufacture of custom electronic subsystems, announced it has been awarded U.S. Patent Number US 8,115,366 B2, entitled "System and Method of Driving Ultrasonic Transducers" by the USPTO. This patent covers a unique method for electronically driving an ultrasonic transducer used in a variety of applications including medical, dental and many other applications requiring ultrasonic energy.

NEC Corp. announced that **Mobile TeleSystems OJSC**, the leading telecommunications provider in Russia and the CIS, together with **NEC Neva Communications Systems**, a subsidiary of **NEC Europe**, is providing a new femtocell service in Siberia. The service aims to establish or improve the 3G coverage of corporate customers in facilities where thick walls and steel beams may otherwise obstruct the signal coming from the base stations. NEC Neva is providing MTS with a multi-function femto-solution and ensures the technical support of the femto-network.

Cobham Sensor Systems celebrated a production milestone June 14th when it produced its 200th Low Band Transmitter Antenna Group (LBT-AG), part of the AN/ALQ-99 Tactical Jamming System used on U.S. Navy and Marine Corps EA-6B Prowler and EA-18G Growler aircraft. **Naval Air Systems Command** exercised the second option of the third full-rate production lot of the LBT-AG this past February for nearly \$39 million. This award brings the total number of production transmitters ordered to 281 of the 315 required trans-

X

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Model Number	Frequency (MHz)	Impedance Ratio	Schematic
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TM1-0	0.3 - 1000	1:1	JE.
TM1-1	0.4 - 500	1:1	JE
TM1.5-2	0.5 - 550	1.5:1	JE
TM2-1	1 - 600	2:1	JE
TM1-6	5 - 3000	1:1	0-ww-0
TM2-GT	5 - 1500	2:1	75
TM4-GT	5 - 1000	4:1	Ţſ
TM8-GT	5 - 1000	8:1	Ţ
TM4-1	10 - 1000	1:4	
TM4-4	10 - 2500	1:4	*
TM1-2	20 - 1200	1:1	ĴË
TM1-9	100 - 5000	1:1	00
TM1-8	800 - 4000	1:1	0-mm-0



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Around the Circuit

mitters. The LBT-AG has been in production since 2005 and is designed to protect strike aircraft, ships, and ground troops by disrupting enemy radar and communications.

CONTRACTS

Astrium continues to drive the implementation of the European Data Relay System (EDRS). As prime contractor, Astrium Services has contracted the German Aerospace Centre (DLR) to implement and operate major parts of the ground network. The agreement covers the design, implementation, delivery and operation of four ground stations: two receiving stations for the EDRS-A satellite in Weilheim, Germany and one in Harwell, United Kingdom, as well as a transmitting and receiving station for EDRS-C in Weilheim, Germany, and a back-up station in Redu, Belgium. As part of the agreement, DLR will also implement and operate the payload control center for EDRS-A and the satellite control center for EDRS-C in Oberpfaffenhofen, Germany. The contract covers the entire nominal lifetime of the EDRS-A and EDRS-C missions until 2030 and has a value of around €65 million.

Harris Corp. has been awarded a two-year, \$19 million contract by the U.S. Department of Veterans Affairs Office of Information and Technology to create a wireless network infrastructure for medical centers nationwide. Harris will design, install, validate and provide training for a secure wireless infrastructure to accommodate the voice, video, and real-time-location-services necessary for mobility. With all options exercised, Harris will deploy this infrastructure to 26 customer sites as part of one of the largest healthcare mobility infrastructure deployments — which will be among the largest wireless deployments in the world.

The French Defense Procurement Agency (DGA) has awarded **Thales** the development contract for the CONTACT programme, which is designed to equip the majority of the French forces' platforms with next-generation tactical radios incorporating innovative software-defined radio technology. Future CONTACT radio products will be fielded with the French Army, Air Force and Navy, providing faster transmission speeds, better security and heightened interoperability. They will be interoperable with the communication systems of other nations to support coalition operations.

PERSONNEL

CAE announced the appointment of **Gene Colabatistto** as its new group president, military simulation products, training and services. Colabatistto has held leadership positions within the industry and the military. Prior to joining CAE, he was a senior vice president in the intelligence, surveillance and reconnaissance (ISR) group at Science Applications International Corp. (SAIC). He will be replacing Martin Gagné who, after 16 years at CAE, has decided to retire. Gagné has agreed to stay on as a consultant in order to ensure a smooth transition and support a number of key strategic initiatives.

ATW Companies Inc. announced that it has appointed Matthew Underhay as sales manager for A.T. Wall, its









Times Microwave Systems manufactures high performance test cables used in a broad range of test and interconnect applications. SilverLine test cables are cost effective, rugged, and have provided long life and excellent stability in applications where they are repeatedly flexed and mated/unmated.





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Model	Frequency	Power	Size (H x W x L)
5304024	100-1000MHz	200W	1.5" x 3.0" x 12.0"
5304025	800-3000MHz	200W	1.5" x 3.0" x 12.0"
5304043	2500-6000MHz	50W	1.1" x 5.0" x 7.0"
5303084	500-3000MHz	50W	6.0" x 5.0" x 1.1"
5303129	700-4000MHz	8W	9" x 5.2" x 1.8"
Model	Frequency	Power	Size (RU)
5227	80-1000MHz	500W	5U
5228	80-1000MHz	1000W	11U
5136A	800-2000MHz	500W	6U
5194	2000-6000MHz	100W	5U



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Around the Circuit

precision stamping and tube drawing subsidiary. Underhay, a successful industry veteran, is responsible for supporting the development of A.T. Wall's sales and marketing processes by leveraging his technical background and market knowledge. He will be leading a team of account executives and sales representatives, and working with his colleagues in ATW's other subsidiaries to implement a growth plan for A.T. Wall.

Analog Devices Inc. named four strategic advocates to the Analog Devices University Program. Strategic Advocates provide insight and guidance to the company's ongoing mission to promote and support hands-on, active learning at engineering universities. The new advocates are Robert Bowman, professor of electrical and microelectronic engineering at the Kate Gleason College of Engineering at Rochester Institute of Technology; Kenneth Connor, professor, Department of Electrical, Computer, and Systems Engineering, education director of the Smart Lighting Engineering Research Center and director of the Mobile Studio Project at Rensselaer Polytechnic Institute; Kathleen Meehan, associate professor, Bradley Department of Electrical and Computer Engineering, Virginia Tech; and **John Robertson**, professor, Department of Engineering, College of Technology and Innovation, Arizona State University.

REP APPOINTMENTS

CRFS is building a rep network across North America and announced the appointment of **Testforce Systems Inc.** as the Canadian distributor of its RFeye® products. The RFeye is a cost effective solution for continuous radio spectrum monitoring.

Global electronic components distributor **Digi-Key Corp.** announced it has entered into a global distribution agreement with **Anaren** and will distribute Anaren's Integrated Radio (AIR) modules.

IF Engineering (IFE) has joined forces with **East Coast Microwave Distributors Inc.** (ECM). ECM will stock and distribute IFE's line of VHF, L-Band and broadband power dividers, couplers, transformers and a new line of switches.

LadyBug Technologies, manufacturers of USB RF power sensors, announced **VigVen Tech Mark Pvt. Ltd.** Bangalore as authorized distributors in India for LadyBug's entire range of USB power sensors covering average power measurement, pulse power measurement, pulse profile measurement and a unique data logger.

Richardson RFPD Inc. announced it has completed an agreement to distribute product from **Sapa Group**, a global manufacturer of aluminum solutions. Through this agreement, Richardson RFPD is able to support its customers in China with thermal management solutions from the **Sapa Profiles** (**Jiangyin**) **Co. Ltd.** plant that opened in February 2012.

RFMW Ltd. and **Aeroflex/Metelics**, a wholly owned subsidiary of **Aeroflex Holding Corp.**, announced a distribution agreement covering Europe, the Middle East and Africa (EMEA) along with the Americas.



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Tackling Satellite Interference

The satellite industry loses millions of dollars per year due to cases of interference and a great deal of manpower has to be given over to discovering its causes. Radio frequency interference (RFI) is caused by human error, bad installation, lack of training, poor equipment or system design and a lack of adherence to industry standards and guidelines. Occasionally, interference may be malicious, but this is rare and the main issues of interference lie largely within the heart of the satellite industry itself. The orbital spacing of satellites is being reduced and the fill rate is getting higher. It is getting crowded up there, leading to increased interference. The Satellite Interference Reduction Group (sIRG) is aiming to turn this around.

The effects of satellite interference are felt throughout the industry, yet it is

throughout the industry, yet it is we, the industry, that is causing the problem. Everything, from components and subsystem design, right through to the end user, affects satellite interference, so we need to work together for the resolution.

REF = 35.00 dBm ATT 40 dB -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 CENTER = 12.5226608 GHz DRAIN 20.269 MHz RBW 34.7 kHz SWP 1.3 ms

▲ Fig. 1 Masks can be used to detect unauthorized carriers occupying spectrum reserved for another user.

TYPES OF INTERFERENCE

There are several causes of interference and, as mentioned most of these are caused by the industry and can be avoided. There are of course some malicious attacks, but they only account for a very small percentage of the interference cases. By far the most significant cause of interference is human error. According to Ron Busch, VP Network Operations, Intelsat, as much as 90 percent can be attributed to human error. To follow is a quick rundown of the main types of interference. Satellite radio interference events may be generally categorized into eight main groups. These are:

Human Error

This is usually accidental, due to user error (transmitting at the wrong time, wrong frequency or transmitting through the antenna instead of into a dummy load), equipment malfunction or due to poor cable shielding, causing retransmit of terrestrial signals (see *Figure 1*). Intelsat's measurements show that 47 percent of satellite interference is due to unauthorized carriers, which is often caused by human error.

Adjacent Satellite Interference

This type of interference is also generally accidental, due to operator error or poor system design or installation practices. This type of

MARTIN COLEMAN The Satellite Interference Reduction Group (sIRG), Douglas, Isle of Man, UK

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Special Report

interference is becoming more prevalent as a 2° spacing between satellites in the geostationary arc becomes more common. Smaller antennas mean larger beamwidths, so pointing the antenna correctly becomes more critical. Typical 3 dB beamwidths approach $\pm 0.75^{\circ}$ or greater, so it does not take much to miss pointing the antenna such that it starts to illuminate an adjacent satellite at 2° spacing.

Terrestrial Interference

The use of RF spectrum is increasing and now traditional satellite frequency bands, such as the satellite downlink frequencies of 3.4 to 4.2 GHz, are being used terrestrially for the last mile broadband data networks. Tests carried out by sIRG, in conjunction with other groups, have demonstrated this to be a major issue. These frequencies are of paramount importance in the tropical regions

as they are less prone to attenuation from weather effects. So the expansion of WiMAX and other BWA systems has limited the use of spectrum for satellite users.

Many satellite ground stations use intermediate frequency of either 70 MHz or L-Band (950 to 2150 MHz). These IF signals are upconverted to the satellite frequency bands, using block upconverters (BUC). Often, such IF frequencies are used for terrestrial services, such as FM broadcast radio or cell phone networks (GSM 3G and 4G). Badly planned or maintained ground stations retransmit these terrestrial signals to the satellite. Certainly, the increase in 3G and 4G services has seen a greater number of cell towers, which allied with an increasing number of small low cost satellite terminals, has led to increased retransmission of terrestrial signals.

Deliberate Interference

This type of interference is usually caused by a state or large commercial user that objects to some content in the transmission that they are intentionally jamming. It is, generally, relatively easy to locate, but almost impossible to remove without political intervention, and even then this may prove difficult.

Cross Polarization Interference

Satellites increase the available spectrum by using polarity diversity. The RF signals are transmitted to the satellite in two polarities at the same frequency. A well aligned antenna should have greater than 30 dB of rejection of the opposite polarity (both transmit and receive). which is more than enough to ensure interference free communication. According to Intelsat, as much as 33 percent of interference is due to cross polarization leakage of signals from one pole into the other.

There are two main causes of cross polarization interference, the obvious one being that the antenna becomes misaligned. This may be due to several factors, ranging from being pushed around by high winds or other weather effects, to poor installation in the first place. Another is perhaps not so obvious and comes down to planning practices; that is incompatible modulation types (such as FM TV) being transmitted in the opposite polarization, analogue services such as FM or analogue video that generally, at some



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Pallet Amplifier

Part Number	Frequency (MHz)	Gain (dB)	Pout (W)		Pulse Droop (dB)	Duty (%)		VDD (V)	Dimension (mm)
RRP03250-10	135 ~ 460	31	300	45	0.5	20	500	50	114.3 x 25.4 x 28
RRP10350-10	1030 ~ 1090	28	350	50	0.5	5	200	50	53.2 x 28 x 8
RRP13330-10	1200 ~ 1400	14	330	65	0.5	20	500	50	85 x 40 x 10
RRP29280-10	2700 ~ 3100	9	280	50	0.5	20	500	50	86 x 39 x 10

kW SSPA

Part Number	Frequency (MHz)	Gain (dB)	Pout (W)		Pulse Droop (dB)	Duty (%)		VDD (V)	Dimension (mm)
RRP131K0-10	1200 ~ 1400	53	1000	45	0.5	20	500	50	250 x 150 x 28
RRP291K0-10	2700 ~ 3100	60	1000	32	0.5	20	500	50	220 x 145 x 27

T/R Module

Part Number	Frequency (GHz)	Tx Pout (W)	Rx NF (dB)	Rx Gain (dB)	Tx Gain (dB)	Duty Cycle (%)			
RFUD95-X15-200	9.3 ~ 9.5	15	3.5	30	32	10	100	6 Bit, 31.5dB	N/A
RFUD31-STRM	2.7 ~ 3.5	200	3.5	25	53	20	500	6 Bit, 31.5dB	6 Bit, 360deg
RFUD13-LTRM	1.2 ~ 1.4	250	3.5	35	54	20	500	6 Bit, 31.5dB	6 Bit, 360deg

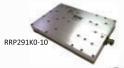
GaN Hybrid Amplifier

Part Number	Frequency (MHz)	Gain (dB)	Pout (W)	Eff. (%)	Pulse Droop (dB)	Duty (%)	Pulse Width (µs)	VDD (V)	Dimension (mm)
RRC13050-10	1200 ~ 1400	36	50	60	0.5	10	100	50	20.5 x 15 x 4.8
RRC29050-10	2700 ~ 3100	26	50	55	0.5	10	100	50	20.5 x 15 x 4.8
RRC31050-10	2700 ~ 3500	25	50	50	0.5	10	100	50	20.5 x 15 x 4.8
RRY56025-10	5400 ~ 5900	20	25	42	0.5	10	100	50	20.5 x 15 x 4.8
RRC94030-10	9300 ~ 9500	17	25	40	0.5	10	100	50	20.5 x 15 x 4.8
RNP04006-A1	400 ~ 450	33	4	72	0.5	10	100	24	20.5 x 15 x 4.8

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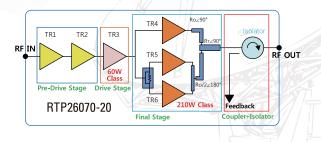
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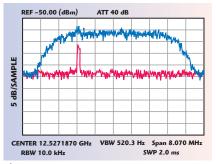
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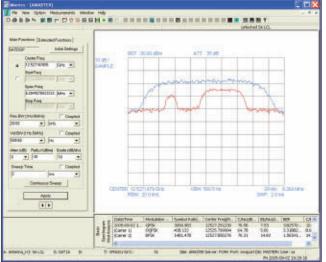
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instance in time, collapse back to being un-modulated or a CW carrier.

The power, which normally spreads across the bandwidth by the modula-



▲ Fig. 2 Modern digital signal analysis can now separate multiple signals occupying the same frequency space and measure the interference.



▲ Fig. 3 Detecting and analyzing interference is the first step in reducing the effects.

tion, is now concentrated in the CW carrier. Even with 30 dB of cross pole signal rejection, there can still be sufficient power in the cross pole to disrupt digitally modulated (*PSK) signals (see *Figure 2*).

Intermodulation

Intermodulation occurs when two or more RF signals meet and merge, the sums and the differences of their harmonic frequencies cause intermodulation products. Most common is the third order harmonic for different products. This form of interference in generally caused by users "creeping" up their power for a perceived link budget advantage. The reality is that, when all users resort to power creep,

it becomes self defeating, as the satellite TWTA moves toward a nonlinear state and intermodulation in the form of spurious signals and what appears to be an increased noise floor actually reduces the link margin. Power creep can also result in ground equipment becoming compressed and spectral re-growth is seen, which can result in adjacent carrier interference (ACI) as the carrier now expands beyond its allocated bandwidth (see *Figure 3*).

Sun Interference

Sun Interference is due to the satellite, the Sun and the Earth station (E/S) antenna being aligned. Solar heavy noise will be received with the satellite signal, due to the satellite, the sun and the E/S being aligned, as shown in *Figure 4*, which occurs twice a year.

Scintillation (Level Variation)

Scintillation occurs due to the turbulent mixing of air masses in the ionosphere, as shown in *Figure 5*. The satellite signal fluctuates in level (by up to 12 dB) at affected Earth Stations, while neighboring Earth Stations may not experience the same effects. It often occurs between 19:00 and 23:00 Earth Station local time

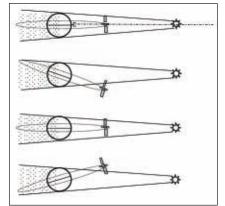


Fig. 4 Sun interference due to the satellite, the sun and the earth station antenna being aligned (courtesy of Arabsat).





Special Report

and mainly affects lower frequencies, such as C-Band. It is unpredictable, so affected E/Ss are recommended to disable normal auto tracking once noticed and engage in manual tracking using received traffic levels as the basis of keeping on track.

WHAT IS CAUSING THESE CASES OF INTERFERENCE?

There is a whole range of different causes of interference. A number of years ago, it was believed that the biggest cause was deliberate signal jamming. However, now it is known that it is not the case and in fact, the deliberate sabotage of satellite signals is a very small percentage of the problem and that is not currently the highest priority.

Indeed, our industry is the main cause. One factor is that crowded geostationary satellites are leading to closer spacing of satellite. The biggest reason right now is sub-standard equipment, lack of trained technicians,



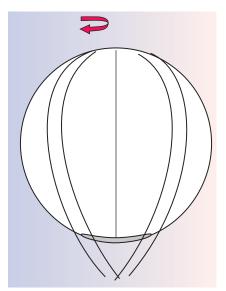


Fig. 5 Scintillation occurs due to turbulent mixing of air masses in the ionosphere (courtesy of Arabsat).

poor installations and consequently equipment failure, as well as human error. There is still a lot of unidentified carriers and insufficient incident coordination.

The Global VSAT Forum (GVF) comments that with VSAT terminal costs dropping well below \$1000, the margin available for installation services is falling. Add to that the fact that installers are no longer necessarily experienced engineers spending days on site, but instead often junior technicians paid as little as \$50 for a complete VSAT installation. There are a vast number of VSAT terminals being installed, over 100,000 per year, any of which can cause serious interference. GVF also comments that spot beams make satellites more sensitive to uplink signals and although this helps reduce VSAT size and cost, it makes transponders more sensitive to interference.

SO WHAT IS THE INDUSTRY CURRENTLY DOING?

sIRG is working together with other industry organizations and major players in the satellite industry to resolve interference and is supported by the key satellite operators. Indeed, Intelsat's Ron Busch commented: "At Intelsat, we are very much aware that Radio Frequency Interference continues to be a problem. Indeed, our metrics continue to show a steady rate of interference events on our fleet." Intelsat, like others, has its own Intelsat Inter-

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ference Management Initiative, which concentrates on training, technology and processes, both internally and with the entire satellite community.

There are a number of ways to reduce interference and eventually it would be nice to eradicate it altogether. The only way this can be achieved is by working together. A lot of work has already been done with satellite operators, broadcasters and equipment manufacturers across the globe,

establishing a number of initiatives and good working practices to tackle this growing problem.

Carrier Identification

Carrier ID has been the major initiative for sIRG thus far in the world of broadcasting. It is an industry-wide initiative and it is the most effective tool for tracking the source of interference quickly and efficiently. In fact, (at the time of this writing) we

are working closely with satellite operators, broadcasters and equipment manufacturers to have the NIT Carrier ID in place in time for the 2012 Olympics.

The purpose of Carrier ID is to tag an RF carrier with a unique identity, in the form of an alphanumeric string. This unique identifier is tracked by the satellite operator after the carrier is commissioned. That way if that carrier were to be the cause of interference, the unique identifier could be read and the satellite operator contacted to rectify the problem.

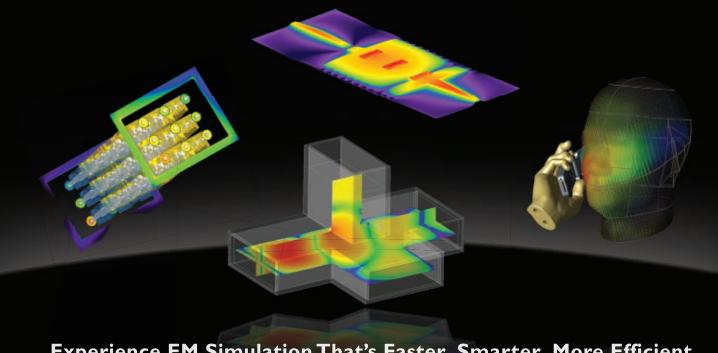
There are currently two technologies available for Carrier ID. The first makes use of the Network Information Table (NIT) within DVB streams of satellite digital TV transmissions. A standard DVB stream analyzer can be used to extract the NIT from the DVB stream. The other method uses a Meta Carrier or sub-carrier developed by Comtech and is transmitted at the same frequency as the carrier. The Meta Carrier is transmitted at low power, approximately 22 dB below the actual carrier, so as not to impact the link budget. The Meta Carrier uses a spectrum spreading technique, such that a receiver can correlate and pull the Meta Carrier out of the noise and read the unique identifier. The industry has come together and suppliers of communication system monitoring (CSM) equipment now supply systems capable of extracting and displaying the unique identifier from both systems.

At the time of this writing, Intelsat plans to use Carrier ID for DVB and SCPC carriers during the 2012 Olympic Games. "We are prepared for the NIT version and are hopeful we can also include Comtech's Meta Carrier ID technology. The idea is to get the community used to using Carrier ID and for satellite operators to test databases and processes to communicate with each other, when identifying an offending carrier" commented Ron Busch.

Bob Potter of SAT Corp. says, "Our goal is to support our customer base in meeting their target of using Carrier ID for the Olympics in 2012. To that end, we have CSM systems deployed in Europe and North America detecting and displaying Carrier ID information."

Another piece of the puzzle for Carrier ID is the equipment manufacturer. A large number of the equip-





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ment manufacturers have integrated NIT Carrier ID capabilities into their products and we are now working with them to test those products in time for the Olympics and, of course, beyond. While at NAB, sIRG focused on making that happen and, as a result of our efforts, we now have encoders to test from Ericsson, Fujitsu, Harmonic, IDC, NTT and Vislink and, recently, a new modulator from Newtec that was launched at that show. SiS Live are as-

sisting with test transmissions using the Vislink encoder, along with test carriers provided by Eutelsat, Intelsat and SES. In addition, Comtech is supplying various sub-sets of equipment and decoders for the new Meta Carrier ID technology. This testing is absolutely crucial for ensuring not only that there are encoders and modulators on the market able to handle NIT Carrier ID, but also to ensure interoperability between equipment. The

tests we are currently carrying out will mean that carrier monitoring specialists and manufacturers alike can iron out any issues, as well as allowing time to develop the interfaces and decoding techniques for both NIT and the new ID technology. Once we have gathered the results from these tests, and after any necessary modifications, we will convey this information to all those involved with the Olympic transmissions. At that point, we can begin applying ID to all applicable carriers ready for the Olympics this summer.

The next stage will be to encourage those manufacturers to upgrade to the new Meta Carrier ID technology, which is currently with the DVB. In addition, users need to ensure they are purchasing only equipment with Carrier ID capability and replacing any existing equipment which does not allow Carrier ID. This is our single biggest challenge. Through open debate and educating our audiences, broadcasters and uplinkers are gradually getting on-board with Carrier ID. After all, they are arguably the biggest sufferers of satellite interference.

A major effort is coming from satellite operators. The various announcements and active support from key operators Eutelsat, Inmarsat, Intelsat and SES have ensured that Carrier ID continues to progress and the initial Carrier ID will be used for the Olympics. sIRG actively encourage all operators to commit to this program as they have the power and influence to ensure users can employ Carrier ID within their transmission systems.

Carrier ID essentially means that any carrier can be quickly identified, so when interference occurs, a satellite operator can identify instantly who is causing the problem. *Figure 6* shows a synopsis of the Carrier ID and QA process.

Detecting and Locating Interference

For those instances, which still exist when there is no Carrier ID, operators can call upon geolocation to find the source of the problem. Integral Systems Europe (ISE) is one of the companies providing geolocation tools. The company uses a monitoring tool to spot when interference occurs on a satellite. In this case, two signals



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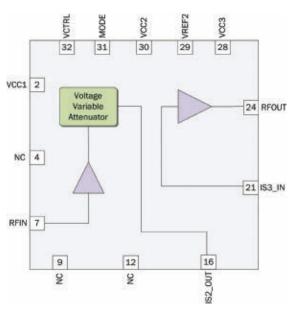


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400	2700	26	5	24	40	5	185	MCM	RFVA0016

RFVA0016 BLOCK DIAGRAM



FEATURES

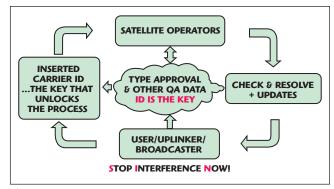
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▲ Fig. 6 Carrier ID and QA process.

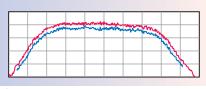


Fig. 7 A retransmit signal causing interference.

with the same characteristics can be separated and characterized (see *Figure 7*).

These signals can then be geolocated by satID, the companies integrated geolocation product, to identify where the offending carrier is located. This can be further backed up by more accurate geolocation using its plane based system, Moscito. Before takeoff, the mission is prepared from a laptop. Once in the air, the pilot engages autopilot and records GPS, video and spectrum power. If communication is possible, the pilot will also receive live data, which is then downloaded to the laptop after landing and processed using ISE's software (see *Figure 8*).

CASE STUDY

The interference detected by the Monics CSM system is shown in *Figure* 9. The CSM system was used to measure cross polarization and found no matching carrier. Monics continued to monitor and characterize the interference. The signal that was causing ACI inter-

ference put the transponder close to a nonlinear mode and blocked a fee paying service from accessing the satellite. The carrier was not employing Carrier ID technology.

While the CSM continued to monitor the signal, it was decided the quickest form of action was to use a geolocation tool to locate the source of the transmission and then further determine the reason for interference (see *Figure 10*). Generally, ground based satellite signal geolocation systems need to monitor the target signal (interferer) through two satellites. The primary satellite being the satellite that is experiencing interference and the secondary satellite is close by and has a similar frequency plan.

The signal is monitored through the two satellites and analyzed to produce two lines of position, TDOA, a Time Difference of Arrival, which is generally a north south line and FDOA, Frequency Difference of Ar-

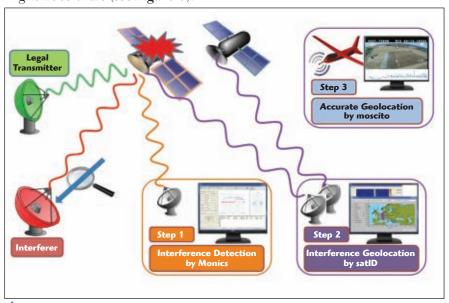
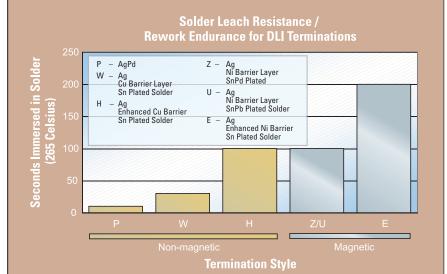
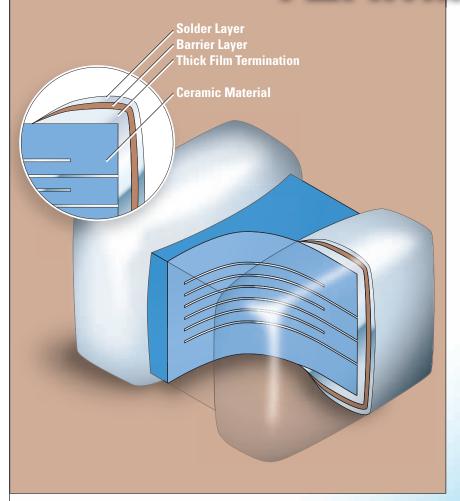


Fig. 8 Unauthorized source identification.



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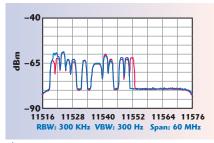


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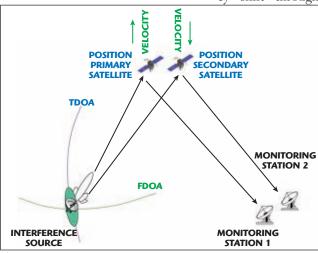
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📤 Fig. 9 Interfering carrier detected.

rival, which generally is an east west line. The TDOA is generated based on the different distances to the two satellites and FDOA is generated based on the different frequency shift through



▲ Fig. 10 Basic geolocation two satellites technique.

the two satellites based upon their relative motion to each other. Through geolocation, the offending ground station is found relatively easily (see *Figure 11*) and, after a few phones calls, found that the reason for the interference was simply human error. The problem was quickly rectified and the carrier was removed from the satellite.

TX SPECTRUM MONITORING

As discussed, Carrier ID is by far the most effective solution for monitoring and resolving interference quickly and efficiently. However, this is not yet common practice and in those instances where it is not in place, operators are therefore forced to use other methods to combat this costly and challenging problem. Geolocation is one solution and Satellite Operator Arabsat urges that regularly monitoring the uplink can be a crucial "tool" for spotting interference. Arabsat has observed that any undesired signal above the noise threshold but low enough (typically more than 26



Fig. 11 Interfering antenna found.

dBc below the desired carrier level) will affect adjacent users.

Talal Mahfouz, Arabsat
Operations Center (AOC) expert, commented,
"More crucially,
it can be hard





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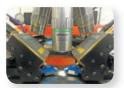
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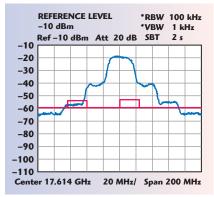
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▲ Fig. 12 TX spectrum monitoring.

to determine the source by a satellite operator, even if it is clearly visible on the downlink spectrum." He added, "HPA re-growth, HPA intermodulation, retransmission MRN and converter harmonics are part of the undesired signals RFI types. However these could easily be detected in the early stages by the Uplinker, once the output spectrum has been checked. Indeed, L-Band analyzers, which are the most commonly available, can monitor MRN and converter harmonics if connected to the upconverter in-

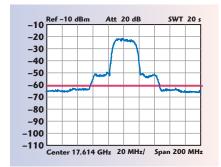
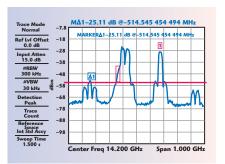


Fig. 13 TX spectrum monitoring.

put test point." Arabsat would like to see every Earth Station uplink operators apply transmit spectrum monitoring. The graphs shown in Figures 12 to 14, supplied by Arabsat, show TX spectrum monitoring at work.

CONCLUSION

The RF environment is becoming ever more crowded with ever increasing competition for bandwidth, and satellite communication is very much a part of that conundrum. Satellites in the geostationary arc are moving closer together (2°); more people are accessing satellites than



igtriangle Fig. 14 TX spectrum monitoring.

ever before and thus interference is very much a fact of life. However the industry, through innovation, technology and a willingness to cooperate, is fighting back against interference. Carrier ID is a proven technology and another tool to use in reducing interference.

ACKNOWLEDGMENTS

The author thanks the support from Bob Potter, President, Sat Corp., Ron Busch, Vice President, Network Operations, Intelsat and Talal Mahfouz, Operations Center (AOC) expert, Arabsat.

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IMS 2012 By the Numbers

he IEEE MTT-S International Microwave Symposium (IMS) 2012 is a fading memory for approximately 7600 attending exhibitors and delegates, but is sure to be remembered for the celebration of the society's 60th anniversary and the Montréal venue. While concern among some exhibitors over export restrictions and ITAR regulations may have resulted in a 12 percent lower turnout than 2011, the efforts by IMS 2012 chair Ke Wu and this year's steering committee made sure the event ran smoothly.

The symposium reported 841 paper submissions from 49 different countries and a total of 569 exhibitors from 21 countries. Among the non-exhibitors, 2635 delegates were registered for the technical program and 1464 registered for the exhibition only. In all, 57 countries were represented, with the United States and Canada leading in participation with 46 percent and

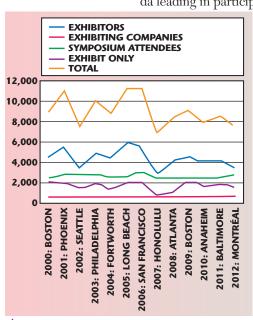
17 percent, respectively. Along with reported increases in attendees from Europe – notably Germany, France, UK and the Netherlands – the MTT-S also reported a 200 percent increase in attendees from China.

A look at the IMS attendance numbers over the past dozen years (see *Figure 1*) shows a direct correlation between the number of exhibitors, exhibit visitors and total attendees, which since Hawaii (2007) has hovered between this year's 7600 and a 9165 high set in Boston (2009). According to the data, exhibiting companies have

demonstrated a good sense of knowing which markets will attract more local (exhibitor only) visitors and responded with higher staffing levels. Contrary to these fluctuations, the number of symposium attendees and exhibiting companies has held steady year-to-year, averaging 2500 delegates and 550 exhibiting companies over the past five years. The ratio of delegates (symposium and exhibit only) to exhibitors is also relatively flat (approximately 1 to 1), varying from a low of 0.78 (Long Beach, total attendance 11,405) to a high of 1.26 (Seattle, total attendance 7598).

Apart from macro-economic factors such as the recent recession, the location of IMS strongly influences show attendance. Many exhibitors often ask how a host city gets selected. Every year, the MTT-S chooses the site for the symposium eight years ahead based on proposals from local chapters vying for hosting rights. The society takes into consideration the adequacy of the proposed site with regard to the proximity of a regional microwave industry and research community, adequate housing and convention hall facilities, available local steering committee leadership/management and exhibitor survey data (if available). The society is solely responsible for weighing these factors and deciding the location from among its chapters. Back in 2004, the winning proposal for 2012 went to Ke Wu and his team in Montréal.

While the notion of crossing the border may have discouraged certain U.S. companies from participating, Montréal did have a positive effect on the international make-up of new exhibitors, which accounted for 10 percent of this year's 550 individual vendors. New exhibitors mostly hailed from one of four regions (see *Figure 2*). Not surprisingly, Canadian-based companies



▲ Fig. 1 IMS attendance numbers and exhibitor information from 2000 to 2012.

DAVID VYE Microwave Journal *Editor*

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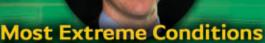


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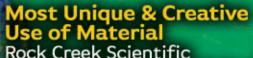
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Special Report



Fig. 2 Profile of new exhibitors at IMS

took advantage of their local status resulting in a larger presence this year. Vendors from the U.S., Europe and China represented most of the remaining new exhibitors.

Chinese companies have definitely been increasing in numbers at both IMS and European Microwave Week (EuMW) for several years now. With subsidies from the Chinese government to exhibit at international trade shows, these vendors are financially supported (up to 40 percent of their costs) to market a wide range of microwave products outside of China. Offering all types of components from SAW filters, power amplifiers, crystal oscillators, passives components and cables, their presence provided visitors with a unique opportunity to compare and contrast products from a sizable portion of the global supply chain, from North America and abroad.

Being new to IMS, many of these exhibitors were situated toward the far right, left and rear of the long, Lshaped exhibition hall of the Palais de Congrès de Montréal. Visitors seeking out new exhibitors could find them in these quieter regions where many start-ups, foreign companies and some noteworthy technology companies relatively new to exhibiting at a microwave show shared neighboring real estate. Notable companies off the beaten path included Teseq, Mathworks (although not their first year), Texas Instruments and Chinese test equipment manufacturer, CETC 41.

Scattered throughout the exhibition were many lesser known companies that provide critical manufacturing services to the industry. When it comes to physical design and manufacturing, microwave components are finicky and so many attendees were on the look-out for helpful suppliers. Dozens of vendors offered a range of specialized parts, services and materials, from custom RF/EMI shielding enclosures to epoxy pre-forms and

advanced ceramics. Small and nimble manufacturing specialists play a very important role supporting the highmix, low-volume products developed by many businesses in the microwave industry. Having these companies present at this event provides engineers with an excellent opportunity to talk face-to-face with a very broad range of experts.

Of course, mainstay companies dominated the show floor with large, well-staffed booths, multiple demo stations, in-booth workshops and/or organized press conferences. These familiar companies supply the industry with test and measurement equipment (Agilent, Anritsu, Aeroflex, National Instruments, Rohde & Schwarz, and Maury Microwave), software (ANSYS, AWR, CST, Sonnet), semiconductors/RFICs/MMICs (M/A-COM, ADI, RFMD, TriQuint, Skyworks, NXP, Hittite, Freescale, Mitsubishi). cable/connectors/components (Carlisle, Emerson Connectivity, Teledyne, Anaren, K&L, Trak, RFMW) and subsystem/subassemblies (Cobham, MITEQ). The show floor also hosted the 2012 MicroApps, which was sponsored by Agilent and has become an excellent forum for application based presentations given to exhibition attendees. On Wednesday, Microwave Journal hosted the MicroApps Device Characterization and Advanced RF/Microwave Design Forum featuring talks from Agilent, Anritsu, AWR and Maury Microwave.

With approximately 550 exhibiting companies, it has become an impossible task for one individual to visit them all. Microwave Journal's comprehensive IMS coverage is posted on the MWI website and in the Microwave Flash Online Show Daily newsletters. The combined coverage features all the show-related product releases and editor reports from press conferences and vendor visits that took place in Montréal. The Microwave Journal IMS wrap-up article features news from nearly 100 different companies compiled by our editors and is available on the *Microwave* Journal website (www.microwavejournal.com/IMS2012WrapUp). addition to product news, the IMS online show daily features reports on special events such as a recap of the business opportunity for GaN panel, the MicroApps Device Characteriza-

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Special Report

tion panel, summary of Richardson RFPD expert presentations/Q&A, video interviews/demos and our IMS 2012 photo gallery.

TEST AND MEASUREMENT HIGHLIGHTS

The larger exhibitors, mainly representing test and measurement suppliers, simulation/design software and semiconductor manufacturers, were located toward the center exhibition entrance. Among them, Agilent was surrounded by its technology partners at "Agilent Avenue" demoing a wide variety of new products including ADS 2012, EMPro 2012, GoldenGate for RFIC simulation (v 2012.07) and SystemVue 2012.06. New test and measurement equipment was also on display and included a USB peak power sensor and the latest PNA-L network analyzer. Anritsu focused attention on solutions for accurate, broadband Vector Network Analyzer (VNA) measurements with multiple demo stations highlighting their state-of-the-art equipment. The company unveiled their unique broadband VNA system capable of conducting single sweeps from 70 kHz to 140 GHz.

Rohde & Schwarz demonstrated the R&S FSW-K6 pulse measurement option for the R&S FSW series of high-performance signal and spectrum analyzers, which is particularly suited to evaluating the performance of radar systems and all other applications that employ pulsed signals. Available in three models for frequency ranges up to 26.5 GHz, the FSW has an analysis bandwidth of 160 MHz, making it well suited for measuring very narrow pulses and broadband systems such as emerging IEEE 802.11ac networks. National Instruments announced early access support for testing next-generation 802.11ac wireless local area network (WLAN) chipsets and devices. NI's 802.11ac WLAN test solution provides flexibility in testing 802.11ac devices in addition to testing 802.11a/b/g/n devices.

Aeroflex added IEEE 802.11ac capability to its S-Series RF signal generator and analyzer product line. The S-Series was designed for use by engineers in WLAN research, design, and manufacturing, specifically targeting top-of-the-range performance at a mid-range price. At 200 MHz, the S-Series offers the industry's widest bandwidth, along

with other standard features such as level and frequency settling times that are $5\times$ faster than competitors at $100~\mu s$ and very low phase noise performance (–135 dB/Hz at 1 GHz, 20 kHz offset).

EDA HIGHLIGHTS

CST announced enhancements to the Microwave Studio transient solver addressing memory efficiency and the robustness of explicit time domain methods and the accuracy of the Perfect Boundary Approximation. The upcoming 2013 release will allow users to solve more than 20 billion unknowns, using cluster computing and a message passing interface. Remcom was featuring the new capabilities in its XFdtd release 7 (FDTD-based modeling and simulation software), which now supports twisting structures such as a waveguide during a missile flight.

Other software vendors such as AWR, ANSYS, Agilent and Sonnet were touting new integration capabilities in their software, allowing circuit designers easier access to 3D and planar EM simulation from within their circuit design products such as ADS, Microwave Office (MWO) and ANSYS Designer or through third-party tools from Cadence and Mathworks.

Closing the gap between test verification and simulation software, Agilent and AWR were demonstrating tighter integration between their simulation and measurement software platforms. AWR was featuring demos of data exchanges between MWO and its parent company NI's flagship product, LabView. AWR was also demonstrating its latest version of a 3D FEM simulator called Analyst, which will support EM simulation of parameterized 3D structures such as wirebonds and ball grid arrays from within MWO. ANSYS was also addressing the need for 3D EM simulation at the circuit designer's fingertips with HFSS Solver-on-Demand available in ANSYS Designer and Cadence Allegro and Virtuoso products. Agilent also surprised many attendees by announcing the pending support for Xparameters by ANSYS Designer.

SEMICONDUCTOR AND INTEGRATED DEVICE MANUFACTURERS (MMICS/RFICS)

No less than a dozen companies were featuring new products based on Gallium Nitride (GaN). RFMD



Less is More







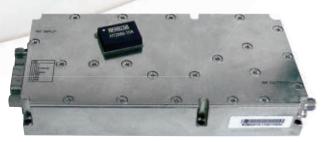


Go ahead and measure it; this is the actual size GaN Technology

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RUM43010-10 5.12 x 2.52 x .84 (Inch)

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Radar Application

	Part Number	Frequency (MHz)	Power (W)	Gain (dB)	PAE (%)
ſ	RRC13050-10	1200 ~ 1400	50	36	60
	RRC31050-10	2700 ~ 3500	50	25	50
ſ	RRC29050-10	2700 ~ 3100	50	26	50
	RRC94030-10	9300 ~ 9500	25	17	40
ſ	RRY56025-10	5400 ~ 5900	25	20	42

Wideband Application

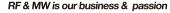
Part Number	Frequency (MHz)	Power (W)	Gain (dB)	PAE (%)
HM0005-10A	20 ~ 520	10	30	50
HM0525-10A	500 ~ 2500	10	20	35
TG2000-10	30 ~ 2000	10	14	45
TG2000-03	200 ~ 2000	3	35	45
TG2000-05	200 ~ 2000	5	35	38

Telecom Application

Part Number	Frequency (MHz)	Power (W)	Gain (dB)	PAE (%)
HT0808-15A	869 ~ 894	10	35	55
HT2008-15A	2065 ~ 2080	10	33	55
HT0808-30A	869 ~ 894	25	28	45
HT1919-30A	1930 ~ 1995	25	35	45
HT2121-30A	2110 ~ 2170	25	35	45

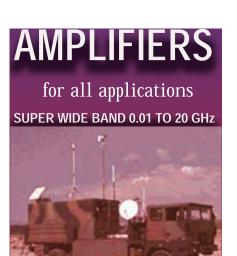
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AF0118193A	0.1 - 18	19	±0.8	2.8
AF0118273A		27	±1.2	2.8
AF0118353A		35	±1,5	3.0
AF0120183A	0.1 - 20	18	±0.8	2.8
AF0120253A		25	±1.2	2.8
AF0120323A		32	± 1.8	3.0
AF00118173A	0.01 - 18	17	±1.0	3.0
AF00118253A		25	±1.4	3.0
AF00118333A		33	±1.8	3.0
AF00120173A	0.01 - 20	17	±1.0	3.0
AF00120243A		24	±1.5	3.0
AF00120313A		31	±2.0	3.0

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Special Report

announced a highly-efficient 280 W pulsed GaN RF matched power transistor. The company also announced multiple new products including four high-performance front end modules integrating the power amplifier, LNA, and switch functionality into a single plastic QFN package for next generation WiFi applications.

TriQuint showcased newly-released GaN products including a packaged 20 W Ku-Band GaN power amplifier fabricated on TriQuint's production-released, 0.25 µm GaN on SiC process that operates from 14 to 16 GHz and typically provides 43 dBm of saturated output power, 30 percent power-added efficiency and 23 dB of small signal gain.

Just prior to IMS, Freescale Semiconductor announced that it was introducing its first GaN devices, initially targeting the cellular infrastructure market, with potential future applications including avionics, radar, ISM and software-defined radio. Freescale was also highlighting their Airfast RF power product line, which now includes at least one solution for each cellular band and supports both small and large cell base station deployments. These products range from 900 MHz to 2.2 GHz with various powers and configurations.

Skyworks Solutions unveiled two new series of high performance and low power LNAs for multiple industrial, scientific, medical (ISM) bands and next generation cellular infrastructure applications. The company also introduced a line of high power RF switches – up to 100 W – supporting diverse market applications including TD-LTE infrastructure base stations, repeaters and low frequency military/microwave UHF and UVF radios

Hittite Microwave featured 24 new products at the show including a low noise, wideband, fractional-N phase-locked-loop (PLL) with integrated VCO capable of generating continuous frequencies from 25 to 8400 MHz and featuring a synthesizer Figure of Merit of –230 and –227 dBc/Hz in integer and fractional modes, respectively. Double sideband RMS jitter is less than 180 fs and the noise floor is –170 dBc/Hz in fundamental mode at 2 GHz.

M/A-COM Technology Solutions showcased new products for wireless backhaul, CATV, optical communications, and aerospace and defense applications, including a 42 GHz SmartSet chipset for point-to-point wireless backhaul with a 1 W power amplifier with 22 dB gain and 38 dBm OIP3, 350 W GaN Smart Pallet designed for S-Band air traffic control radar with over 60 percent drain efficiency, and a highly linear Edge QAM VGA designed for CATV head-end modules.

NXP Semiconductors demonstrated its full portfolio of first-generation GaN products and discussed its vision and roadmap related to GaN. Currently the company offers engineering samples of its first-generation GaN products including amplifiers for 50 and 100 W broadband applications. Live demonstrations included a multistage GaN line-up covering a 200 to 2700 MHz frequency band with best-in-class linearity. With the high-impedance 50 V GaN process, broadband amplifiers can be designed on a single transistor.

Peregrine Semiconductor Corp. introduced the company's SP3T RF switch, featuring low insertion loss of 0.45 dB at 1 GHz and 0.55 dB at 2.5 GHz, and high isolation of 40 dB at 1 GHz and 30 dB at 2.5 GHz. Additionally, it provides excellent ESD tolerance of 4500 V HBM and 250 V MM on all ports, and is available in a miniature, 8-lead 1.5 × 1.5 mm DFN package.

IN THE BEGINNING

Since 1972, when 19 vendors with table-top displays were allowed to co-locate with the symposium, the exhibition has provided an invaluable opportunity to discover the latest and greatest in microwave components, semiconductors, materials, test and simulation technology and related manufacturing services. MWI Editorin-Chief, Ted Saad noted the occasion in his editorial, The 1972 IEEE-GMTT International Microwave Symposium: "Despite the largest attendance since 1957, the IEEE-GMTT International Microwave Symposium in Arlington Heights, IL was a lively, well-run affair. The meeting was highlighted by a number of provocative items, stimulated by a competent Steering Committee. It was the first MTT Symposium to have paid exhibits by microwave companies. Despite misgiving on the part of at least one diehard, it appears the experiment was a success."

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Frequency	50 MHz – 100 MHz & 100 MHz – 1.0 GHz	500 MHz - 2.0 GHz & 500 MHz - 2.5 GHz	2.0 – 6.0 GHz	6.0 – 18.0 GHz	2.0 – 18.0 GHz
Frequency Accuracy	±2.0 MHz MAX.@+25°C	±2.5 MHz MAX.@+25°C	±2.0 MHz MAX.@+25°C	±2.5 MHz MAX.@+25°C	±2.0 MHz MAX.@+25°C
Frequency Drift	±0.1 MHz/°C	±0.1 MHz/°C	±0.1 MHz/°C	±0.1 MHz/°C	±0.1 MHz/°C
Frequency Settling	±2.0 MHz MAX. (within 1μS)	±2.0 MHz MAX. (within 1μS)	±2.5 MHz MAX. (within 1µS)	±4.0 MHz MAX. (within 1μS)	±3.0 MHz MAX. (within 1µS)
Modulation Bandwidth	DC - 3.5 MHz MIN.	DC – 9 MHz MIN.	DC – 14 MHz MIN.	DC – 10 MHz MIN.	DC – 9 MHz MIN.
Modulation 2.0:1 TYP. (50-100MHz) Sensitivity 3.0:1 TYP. (100MHz-1GHz) Variation		1.1:1 Max.	1.1:1 Max.	1.1:1 Max.	1.1:1 Max.
Modulation Frequency Deviation BW	40 – 100 MHz TYP.@2V P-P	100 MHz MIN.@2V P-P	200 MHz MIN.@2V P-P	200 MHz MIN.@2V P-P	400 MHz MIN.@2V P-P
RF Output Power	+10 dBm MIN.	+10dBm MIN.	+2 to +8dBm MIN.	+10dBm MIN.	+10dBm MIN.
RF Output Variation	±3.0 dB MAX. over Temp & Freq.	±2.0 dB MAX. (0.5-2.0GHz) ±3.0 dB MAX. (0.5-2.5GHz) Over Temp & Freq.	±2.5 dB MAX. over Temp & Freq.	±3.0 dB MAX. over Temp & Freq.	±3.0 dB MAX. over Temp & Freq.
Phase Noise	-60 dBc/Hz Typ@100 kHz Offset	-60 dBc/Hz Typ@100 kHz Offset	-65 dBc/Hz Typ@100 kHz Offset	-60 dBc/Hz Typ@100 kHz Offset	-60 dBc/Hz Typ@100 kHz Offset
Harmonics	-20dBc TYP.	-20 dBc MAX	-45 dBc MAX	-55 dBc MAX	-20 dBc MAX
Spurious	-55dBc MAX.	-55 dBc MAX	-45 dBc MAX	-55 dBc MAX	-55 dBc MAX
Linearized Frequency Tuning Step Size	LSB 2.0 MHz Nominal for Full Band	LSB 0.5 MHz Nominal for Full Band	LSB 1.0 MHz Nominal for Full Band	LSB 0.5 MHz Nominal for Full Band	LSB 0.5 MHz Nominal for Full Band
DC Power	±15vdc / +5vdc / +28vdc	±15vdc/+5vdc/+28vdc	±15vdc / +5vdc / +28vdc	±15vdc / +5vdc / +28vdc	±15vdc / +5vdc / +28vdc



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Antennas, the mmWave Advantage

perators of backhaul networks are facing more and more problems when it comes to new installations. In congested areas, the site acquisition is a substantial part of the cost and house owners and planners are often hesitant to allow access to rooftops, etc. Also, for aesthetic reasons, antennas can be disguised to blend in with the environment and take shape as part of the chimney, brick walls and the like. Furthermore, from a practical point of view, a minimized wind load and weight is advantageous, especially during installation. *Figure 1* offers a comparison between standard and mmWave antennas.

SIZE

Antenna size is always something that must be related to the wavelength and thus the frequency. Higher frequencies can utilize smaller



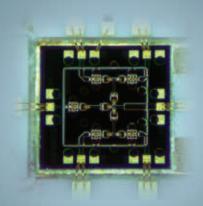
▲ Fig. 1 Parabolic reflector for a point to point microwave link, compared to small flat array for mm-wave.

antennas but antennas cannot be made arbitrarily small and still perform without detriment to performance. There are two main constraints when it comes to antennas and size. One is the radiation resistance and the antenna feeding impedance and the other is radiation pattern. The first issue, impedance and matching for electrical small antennas has been successfully addressed by antenna and circuit designers, with virtually all antennas used in handsets being small from an electrical point of view, yet they perform well for their application.

The other constraint, antenna radiation pattern, is not so easy to compensate for as the fundamental laws of physics apply. In order to direct the electromagnetic energy from an antenna, it must have a certain shape and size. To be able to gain some insight into this, let us take a look at the most fundamental antenna, the isotropic radiator. A point source that serves as the basic antenna element for theoretical analysis will radiate equally in all directions. A hypothetical point source in (free) space will thus radiate in all directions in a spherical fashion – an isotropic antenna.

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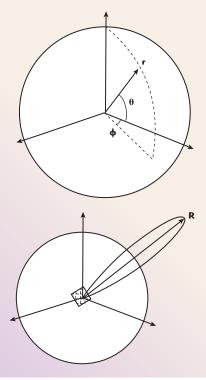


Fig. 2 Spherical coordinates of the isotropic radiator and pencil beam antenna.

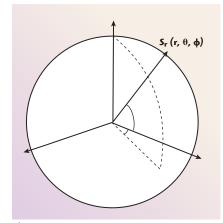


Fig. 3 Definition of coordinates, Poyntings vector.

Of course, even the remote presence of a ground surface or conductors to this antenna element will cause a disturbance in its radiation pattern, and it will no longer radiate equally in all directions. However, as an analysis tool the isotropic point source is very useful and most, if not all, antenna structures can be treated as a combination of isotropic radiators.

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DIRECTIVITY

When dealing with antennas, there are a number of parameters to consider. This article will focus on antennas that have an appreciable size compared to wavelength, and where matching and radiation efficiency is generally not a big concern. Most of the energy supplied to the antenna from the transmitter is transformed to radiated energy, in one direction or another.

If we consider the directive gain first, the term implies that we seek a measure of the antenna's ability to concentrate its energy in a certain direction. This is compared to the isotropic radiator as shown in *Figure 2*.

The isotropic radiator sends all its energy equally distributed in all directions, but any other physical reliable antenna will concentrate its energy in specific directions. For a point to point link, the preferred pattern is to direct all the energy in a small cone towards the receiving antenna. Other radiation patterns can also be desirable, such as broadcast antennas radiating their energy in a doughnut shaped pattern with the antenna in the center. Another example is a radar antenna that has a narrow horizontal beam and a broad beam in azimuth.

For a given antenna with a spatial dependency of the power density, Poyntings vector $\mathbf{S_r}$ has only a radial component in the far field. $\mathbf{S_r}$ [W/m²] is a function of θ , φ and r as shown in **Figure 3**.

Total radiated power from the source is:

$$P_{rad} = \iint \mathbf{S}_{r} (\theta, \phi) r^{2} \sin(\theta) \partial\theta \partial\phi \qquad (1)$$

For the isotropic radiator, the power density S_i is equally distributed over the area of the sphere, and thus

$$S_{i} = \frac{P_{rad}}{4\pi r^{2}} \tag{2}$$

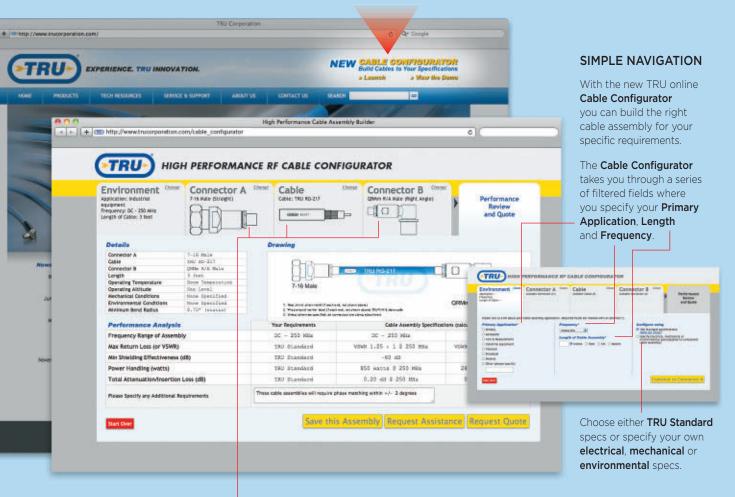
For the general case when there is a spatial dependence, S_r is given as a product of its maximum value S_m , and a function of the spherical coordinates $F(\theta, \varphi)$.

The two dimensional function $F(\theta, \varphi)$ is the antenna pattern and can be illustrated in several ways. Quite often the antenna pattern is presented as a projection in either θ or φ plane and the \mathbf{E} and \mathbf{H} vector is aligned with

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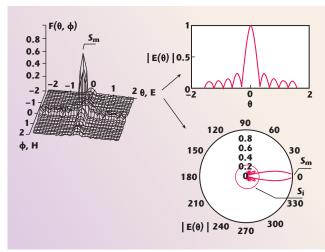


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lacktriangleq Fig. 4 Antenna diagram as two dimensional contour plot showing E and H field components, and projection of the E-field pattern on θ plane in rectangular and polar plot. All scales are normalized to the maximum value of each parameter.

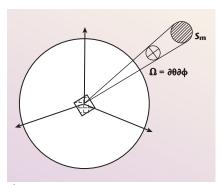


Fig. 5 Equivalent cone shaped antenna diagram, useful for pencil antennas.

either coordinate, see **Figure 4**. Note that for the isotropic radiator $F(\theta, \varphi) = 1$, and the maximum value $S_m = S_i$ everywhere on the sphere as shown in the polar plot in Figure 4.

The directivity is defined as the ratio of the maximum value of $S_r \, (= S_m)$ to the average value of the power density, or

$$D = \frac{S_{\rm m}}{S_{\rm i}} = \frac{4\pi}{\iint F(\theta, \phi) \sin \theta \, \partial\theta \, \partial\phi}$$
 (3)

In words, the directive gain (D) is defined as the ratio of maximum power density to the average power density from the antenna. The average power density can be found by carrying out the integration of power at each infinitesimal area element on the imaginary sphere with radius R, or much easier, by calculating the equivalent power from an isotropic antenna,

 $S_i = P_{rad}/4\pi R^2$.

So far, the power P_{rad} used in the equations is the power that is actually

radiated by the antenna, to signify this the suffix rad is used. The input signal power to the antenna is generally different (higher). At this point, it may be convenient to discuss antenna gain, Ga. Any electrical structure is exposed to losses, even if very small there are some ohmic losses and also losses from reflection (mismatch) in most cases. If P_{rad} is all the power actually emitted from the antenna in all directions, then the antenna efficiency

can be written as $\eta = P_{rad}/P_{in}$. Then the antenna gain is defined as $G_a = \eta D$. In most cases, the antenna gain is almost the same as directive gain. From a system point of view the antenna gain is, of course, the interesting quantity since it goes directly into the link budget.

Another useful concept is the beamwidth. For the moment, the discussion is confined to pencil beam shaped patterns, the antenna pattern is basically symmetrical around the main axis of the beam as shown in Figure 2.

If the antenna radiation angle Ω_A [sR] is defined as the imaginary solid angle through which all power would be concentrated if the power density was constant over that solid angle and equal to the maximum power density at boresight (the axis of the main lobe), we would find that: $\Omega_A = 4\pi/D$, and since $\Omega_A \cong \varphi 1.01$ for very small angles (see **Figure 5**), there is a simple and useful expression to approximately determine the beamwidth in either **E** or **H** plane,

Beamwidth
$$\cong \sqrt{\frac{4\pi}{D}}$$
 radians

The approximation is good for small angles as found in highly directive antennas for point to point radios. For example, for a 36 dB antenna, the approximation will yield a beamwidth of

$$\sqrt{\frac{4\pi}{10^{36/10}}} \approx 0.056 \text{ radians or } 3.2^{\circ}$$

As an analogy, the antenna can be

viewed as the spatial equivalent to the time-frequency concept for signals. The radiation pattern is the equivalent to the frequency plane and the physical distribution or separation of antenna elements is the time equivalence. Hence, like a short pulse gives rise to a broad frequency spectrum, a small antenna will have a broad spatial distribution of its energy (a broad beam). The underlying mathematics correspond and main lobe and side lobes can be calculated in a similar fashion.

RECEIVING SIGNALS

So far the discussion has revolved around the antenna as a radiator in the transmitting case. It would be a pity if we could not pick up the hopefully intelligent transmission in a complementary receiving antenna. To do this, two concepts are introduced: the effective antenna area and reciprocity.

The effective area of an antenna is defined as the power delivered on the antenna's terminals divided by the power density that the receiving antenna is exposed to. In mathematical terms,

$$P_{r} = A_{e}S_{r} \tag{4}$$

where P_r = Received signal power [W] on antenna terminals and A_e = effective antenna area [m²].

As mentioned earlier, we know that the power density from a transmitting antenna is

$$S_{r} = \frac{P_{tr}G_{tr}}{4\pi R^{2}} [W/m2] \text{ or,}$$

$$S_{r} = \frac{P_{tr}\eta D}{4\pi R^{2}} = \frac{P_{tr}G_{tr}}{4\pi R^{2}}$$
(5)

where P_{tr} = input power to transmitting antenna and G_{tr} = transmitting antenna gain.

The power delivered from the receiving antenna can now be calculated as:

$$P_{\rm r} = A_{\rm e} \frac{P_{\rm tr} G_{\rm tr}}{4\pi R^2} \tag{6}$$

It is obvious that the amount of received power is directly proportional to the effective area of the receiving antenna and this equation is valid regardless of frequency or wavelength.

We can now also appreciate the meaning of effective antenna area. As usual, whatever is introduced to measure or collects energy from a system will affect that system. This is also true for an

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antenna. The field in the vicinity of the antenna must deviate from the planar wave condition to fulfil the boundary conditions on the antenna surface. The concept of effective area takes this into consideration and this is why the effective area differs from the physical area.

This constraint can take some odd turns. A wire antenna, like a dipole or a Yagi antenna, will present a much larger effective area than its projected area would suggest. A parabolic reflector on the other hand will show a very obvious physical area but in this case, the effective area is smaller than the projected area.

It is now time to introduce the concept of reciprocity. A transmitting antenna that produces a certain field pattern will have an identical 'sensitivity' pattern when used as a receiving antenna. If we have a particular antenna with $G=10~\mathrm{dBi}$ (i in dBi means $10~\mathrm{dB}$ over a comparative isotropic antenna) we will in boresight have $10~\mathrm{dB}$ higher power density when transmitting and

a 10 dB higher output signal from the antenna when receiving a signal compared to the isotropic antenna.

So now, how is the antenna gain calculated? We can start to work with Maxwell's equations and realize why we pay a disproportionate amount of money for a bent wire, a piece of shaped metal plate or a PCB with some seemingly haphazardly placed patches. Of course, computers and software will come to our aid, but to make a better design, a good theoretical understanding is necessary. The subject of antenna design is far beyond the basics covered in this article. However, a very simple equation can help us to understand antennas and particularly the relationship between effective antenna area, A_e, and antenna gain:

$$G_{a} = \frac{4\pi A_{e}}{\lambda^{2}} \tag{7}$$

If you know either the gain or effective area then the other can be calculated and for some structures, the effective area can be closely approximated by just observing physical dimensions. The equation for G_a and A_e assumes an idealized situation where the antenna is situated in free space and is exposed to a field produced by a distant point dipole. Any perturbation of that field in the environment where the antenna is situated will affect the result.

Some directive gain values for common antennas are listed in $Table\ I$ and the effective antenna area can be calculated from those values. Note that losses are not included; hence D instead of G_a . Note also that area, A_p , in Table 1 is the physical area.

FRIIS EQUATION, TRUTH AND CONSEQUENCE

One of the most useful equations for a telecommunication engineer can be found by combining the expression for effective area of a receiving antenna with the power density from a transmitting antenna, and calculating the apparent path loss $P_{\rm r}/P_{\rm tr}$,

$$\begin{aligned} P_{\rm r} &= A_{\rm e} S_{\rm r} \\ S_{\rm r} &= \frac{P_{\rm tr} G_{\rm tr}}{\left(4\pi R\right)^2} \end{aligned} \tag{8}$$

$$A_{e} = \frac{G_{r}\lambda^{2}}{4\pi} \tag{9}$$

 G_r =receiver antenna gain



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AWS	2010 ~ 2155 MHz	1710 ~ 1755 MHz
DCS (1800)	1805 ~ 1880 MHz	1710 ~ 1785 MHz
E-GSM (900)	925 ~ 960 MHz	880 ~ 915 MHz
E-TETRA	420 ~ 430 MHz	410 ~ 412 MHz
GSM	935 ~ 960 MHz	890 ~ 915 MHz
IMT-E (2600)	2620 ~ 2690 MHz	2500 ~ 2570 MHz
LTE-JPA	1488 ~ 1520 MHz	1456 ~ 1480 MHz
LTEJPC	1475 ~ 1511 MHz	1427 ~ 1463 MHz
LTE-US (700-L)	728 ~ 759 MHz	698 ~ 716 MHz
LTE-US (700-U)	728 ~ 759 MHz	776 ~ 788 MHz
. ==		776 ~ 788 MHz
LTE-US (700-UL)	728 ~ 759 MHz	698 ~ 716 MHz
PCS (1900)	1930 ~ 1990 MHz	1850 ~ 1910 MHz
TD-SCDMA (2000)	2010 ~ 2025 MHz	1900 ~ 1920 MHz
TETRA	390 ~ 400 MHz	380 ~ 390 MHz
UMTS / WCDMA (2100)	2110 ~ 2170 MHz	1920 ~ 2060 MHz
WCDMA-JP	2150 ~ 2170 MHz	2110 ~ 2140 MHz
WiDee I/D	2110 ~ 2170 MHz	4040 4000 MU-
WiBro-KR	2300 ~ 2390 MHz	1910 ~ 1990 MHz
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NEW!	HMC941LP4E	0.1 - 33	5-Bit Digital	4	0.5 to 15.5	45	0 / +3 to +5V
	HMC939	0.1 - 40	5-Bit Digital	3.5	1 to 31	43	0 / +3 to +5V
	HMC973LP3E	0.5 - 6.0	Analog VVA	2.5	0 to 26	35	0 to +5V
	HMC346	DC - 20	Analog VVA	2.2	0 to 25	10	0 to -3V
	HMC712LP3CE	5 - 26.5	Analog VVA	3.5	0 to 28	32	0 to -3V
	HMC712	5 - 30	Analog VVA	2.5	0 to 30	32	0 to -3V
	HMC812LC4	5 - 30	Analog VVA	2	0 to 28	28	0 to -3V
NEW!	HMC985LP4KE	10 - 40	Analog VVA	3	0 to 35	33	-3 to 0V
	HMC-VVD102	17 - 27	Analog VVA	1.5	0 to 22	17	-4 to +4V
NEW!	HMC985	20 - 50	Analog VVA	3	0 to 35	33	0 to +3V
	HMC-VVD104	70 - 86	Analog VVA	2	0 to 14	-	-5 to +5V

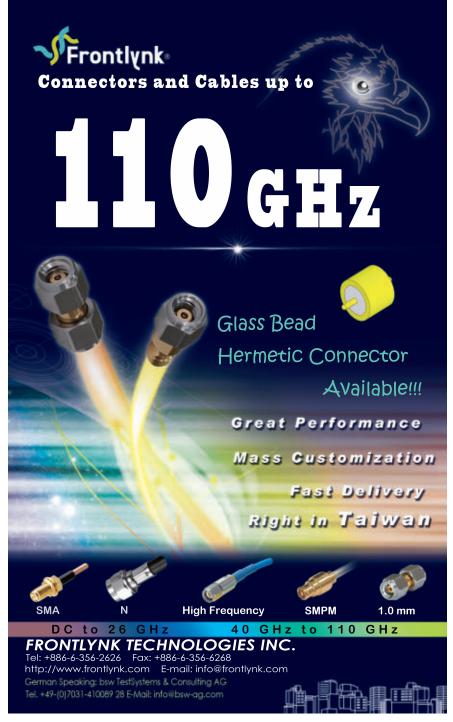
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TABLE I SOME ANTENNA STRUCTURES, DIRECTIVE GAIN AND EFFECTIVE AREA								
Antenna	Dimensions	Directive Gain	Effective Area (A _e) Compared to Physical Area (A _p)					
Half Wave Dipole	λ/2	D ≈ 1.6	$A_{\rm e} \approx 0.13/\lambda^2$					
Horn Antenna	□ □ □ b □ a □ b	$D \approx \frac{10ab}{\lambda^2}$	$\mathrm{D}\approx 0.8~\mathrm{A}_p$					
Parabolic Reflector	(0	$D = \frac{7\pi r^2}{\lambda^2}$	$A_e \approx 0.6A_p$					
Rectangular Array	a b	$D = \frac{4\pi ab}{\lambda^2}$	$A_e = A_p$					



Combining the three equations above leads to Friis equation,

$$\frac{P_r}{P_{tr}} = \frac{G_r G_{tr} \lambda^2}{(4\pi R)^2} \tag{10}$$

Friis equation is very useful for link budget calculations; however it has sometimes been interpreted to suggest that the spatial attenuation increases with shorter wavelengths. This is not true and probably is a consequence of the embedded expression for the effective area. Friis equation assumes that the power density produced by the transmitter is constant and since $P_{\rm r}=A_{\rm e}\!\cdot\!S_{\rm m}$, the received power must vary as $A_{\rm e}$ is proportional to λ^2 .

The spatial dependence on wavelength is only true if the antenna gain is held constant when comparing different systems but is there any reason to keep the antenna gain constant? A constant antenna gain requires the effective antenna area to vary with the wavelength as

$$A_e = \frac{G_a \lambda^2}{4\pi} \tag{11}$$

Consequently the effective area, A_e, must be decreased for a constant gain as the frequency is increased (see *Figure 6*). This is actually a benefit with higher frequencies since the aim is to have as small and yet as efficient antennas as possible.

In Friis equations, the antenna gain is kept constant but it is particularly important to keep the ratio between transmitter power and received signal constant and let the antenna size vary. As an example and for convenience let us consider a symmetrical link setup, with the same antenna used for transmitting and receiving. By using the relationship between effective area and gain and modifying Friis equation, we get

$$\begin{split} &\frac{P_{r}}{P_{tr}} = \frac{A_{e} 4\pi A_{e} 4\pi \lambda^{2}}{\lambda^{2} \lambda^{2} \left(4\pi R\right)^{2}} \Longrightarrow \\ &A_{e} = \sqrt{\frac{P_{r}}{P_{tr}}} \lambda & (12) \\ &\text{and since we want } \sqrt{\frac{P_{r}}{P_{tr}}} = \text{a constant} \end{split}$$

and since we want $\sqrt{P_{tr}}$ a constant and equal for all frequencies, A_e is kept proportional to the wavelength, λ .

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This is actually what we are looking for: The antenna area can be allowed to decrease linearly with the inverse of the used frequency and provide the same system link budget regardless of frequency used (This assertion overlooks the actual path loss that is present from absorption, foliage blockage, etc. All effects must be included and the atmospheric absorption can be quite high at certain frequency bands such as 24 and 60 GHz).

PARABOLIC REFLECTORS

Parabolic reflectors are popular for radio links and a typical parabolic reflector antenna with a diameter, d, may have an aperture efficiency of 60 percent and thus the effective area can be expressed as

$$A_e = kd^2 \tag{13}$$

where k is a factor depending on antenna physical constraints in compari-

LOW FREQUENCY, A IS LARGE AND ANTENNA MUST BE LARGE HIGHER FREQUENCY, THE SAME BEAMWIDTH IS OBTAINED WITH A **SMALLER ANTENNA**

Fig. 6 Antenna size for different wavelengths. Antenna area scales in principle with wavelength for circular symmetric antenna

diagrams.

son to wavelength, but to a good ap-

proximation can be set to 0.4. Now, if we compare two systems working at different frequencies but let the antenna size (diameter, d) be proportional to the square root of the wavelength, $d \propto \sqrt{\lambda}$, then the effec-

tive area will be proportional to the wavelength and as mentioned above, we will find that the ratio between received power and transmitted power will always be equal regardless of frequency used.

Example: Compare a link at 15 GHz to a link at 80 GHz with equal transmitter power. The space loss will be equal in both cases. To get the total loss between transmitter and receiver, atmospheric attenuation and other contributions must be added or compensated for.

Assume that the antenna gain for the 15 GHz link is 36 dBi, and is the same for transmitter and receiver. The equations above yield

$$d = \sqrt{\frac{G\lambda^2}{k4\pi}} \tag{14}$$

The antenna diameter for the 15 GHz link is thus

$$d_{15} = 0.56 \text{ m}$$

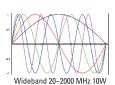
If the antennas for the 80 GHz system are scaled proportionally to the square root of the wavelengths, the

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HM0525-104	500 ~ 2500	40	20	30	2	CP-7D				

CATV, G-PoN,	FTTH, RFoG E	Е-рНЕМТ	MMIC		SOIC-8 5×6×1.52mm
Part Number	Gain (dB)	N.F (dB)	Vdd (v)	CH @Vo (Flat / dBµV)	Package (Type)
AE618	20	3.0	12	79@107	SOIC-8
AE607	13	3.5	8	79@100	SOIC-8
Activo Dividor	E BUEMT MMI	_			QFN3x3

Active Divider E-	PHEMT MMIC				QFN3x3 3×3×1 mm
Part Number	Gain (dB)	N.F (dB)	Vdd (V)		Package (Type)
AD274	5.5	3.5	3~5	2 Way	QFN3x3

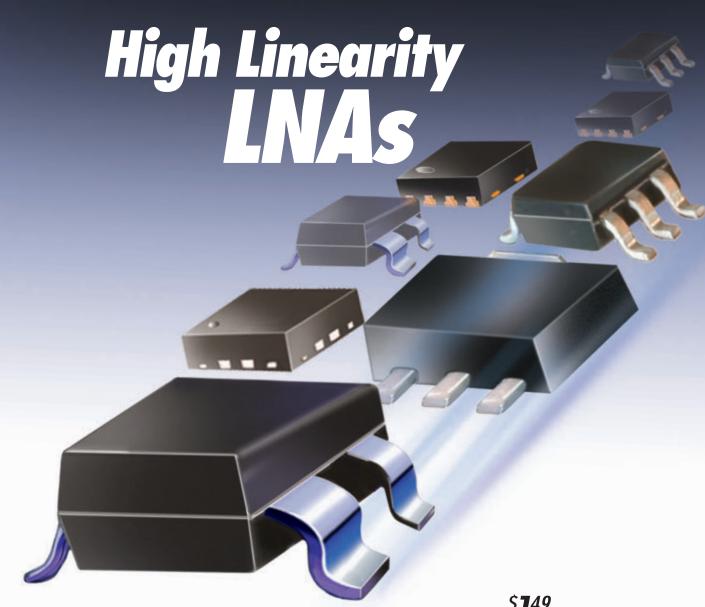
BTS / RRH / Repe	eater E-pHEN	MT MMIC		SOIC-8 5×6×1.52mm	SOT-89 4.5×4×1.5mm
Part Number	Gain (dB)	N.F (dB)	Pout (dBm)	WCDMA 4FA (dBm)	Package (Type)
AE379	12	2.3	33	23	SOIC-8
AE367	15	3.5	27	18.5	SOT-89

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PMA-5452+	50-6000	14.0	0.7	34	18	40	1.49	PMA-5453+	50-6000	14.3	0.7	37	20	97 (5V) 60	1.49
PSA4-5043+	50-4000	18.4	0.75	34	19	33 (3V) 58 (5V)	2.50	PSA-5453+	50-4000	14.7	1.0	37	19	60	1.49
PMA-5455+	50-6000	14.0	0.8	33	19	40	1.49	PMA-5456+	50-6000	14.4	8.0	36	22	60	1.49
PMA-5451+	50-6000	13.7	0.8	31	17	30	1.49	PMA-545+	50-6000	14.2	8.0	36	20	80	1.49
PMA2-252LN+	1500-2500	15-19	8.0	30	18	25-55 (3V) 37-80 (4V)		PSA-545+ PMA-545G1+	50-4000 400-2200	14.9 31.3	1.0 1.0	36 34	20 22	80 158	1.49 4.95
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antenna diameter will be

$$\mathrm{d}_{80}=\mathrm{d}_{15}\sqrt{\frac{\lambda_{80}}{\lambda_{15}}}$$

$$d_{80} = 0.24 \text{ m}$$

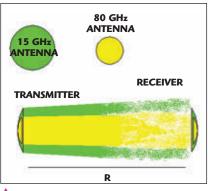
Less than half the diameter compared to the 15 GHz antenna, and yet the same link budget is attained. Also note that the antenna gain will be proportional to the inverse of the wavelength, or in this case,

$$G_{60} = \frac{80 \text{ GHz}}{15 \text{ GHz}} G_{15}$$

and consequently the antenna gain at 80 GHz will be 43.3 dBi.

However, the atmospheric attenuation must be added at roughly 2 dB/km higher for 80 GHz compared to 15 GHz. If we assume a distance of 3 km between transmitter and receiver, the 80 GHz transmit and receive antennas must each have an additional 3 dB

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▲ Fig. 7 Relative size between 15 and 80 GHz antennas for equal link budget levels.

gain to compensate for attenuation, i.e., a total antenna gain of 46.3 dBi.

The antenna diameter will then be $d_{80} = 0.34 \text{ m}$

Comparing the beamwidth for the two cases, 15 GHz and 80 GHz using the approximate formula given earlier (see *Figure 7*),

 $\begin{array}{l} bw_{15\mathrm{GHz}}=3.2^{\circ}\\ bw_{80\mathrm{GHz}}=1^{\circ} \end{array}$

CONCLUSION

This article has very briefly described some concepts that are well known, but are well worth further examination. One example is Friis equation that sometimes leads to the misinterpretation that radiation loss is higher for higher frequencies. This is due to the 'free space loss' term $\lambda^2/(4\pi R^2)$ – a strange designation, especially in a lossless medium.

With the aid of a few simple equations, it is shown that millimeter-wave frequencies can offer significantly smaller antennas without any sacrifice in link budget performance. And if the benefits of superior bandwidth and lower cost for licensing are added, millimeter-wave radio is a very attractive alternative for fixed access service.

Christer Stoij received his BSEE in 1975 and MSEE 1981 from Chalmers University of Technology. He has been active in the microwave field throughout his career, since starting with Ericsson AB, and he has cofounded and founded several microwave companies including Microsystemgruppen AB and Gigatec AB. Stoij has been with Sivers IMA AB since 2000 in leading positions, and is currently acting as CTO. He remains active in engineering and is involved in design and research work in many product areas with special interest in electromagnetics, filters and structures.

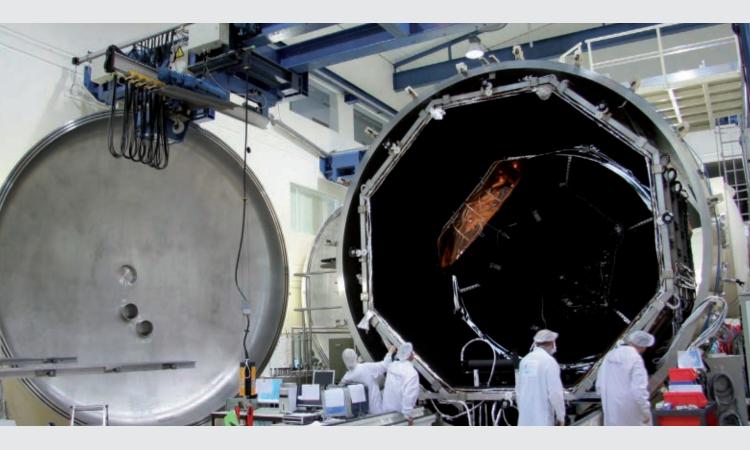


■ Frequency Converters, LNAs, BUCs & SSPAs

■ EW, Radar, Radio and SATCOM Applications

■ Pin Diode Switch Products





SUCOFLEX® TVAC

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- Low out gassing according ECSS-Q-ST-70-02 C
- Superior mechanical and electrical stability
- Vented connectors for fast evacuation and venting
- Excellent performance to price ratio
- Perfect matched cables and connectors from one manufacturer
- Worldwide assistance and support





L-Band Switch Matrix

rane Aerospace & Electronics, Microwave Solutions, has recently introduced a new high-performance switch matrix covering L-Band aimed at satellite communications ground station applications. This system provides new breakthroughs in signal fidelity preservation and built-in-test features allowing for critical communications to be preserved. It offers a flexible architecture, which can be configured from 12 antenna ports and 48 modem ports to as large as 24 antenna ports to 192 modem ports, and can be upgraded in the field. There are separate transmit and receive units that pass the signals to and from the modems and frequency converters.

The receive switch matrix is built around a classic architecture with power dividers being fed from each input, feeding multi-throw switches to select the feed to the appropriate output. This technique results in what is called a Full-Fan-Out architecture. Full-Fan-Out refers to the fact that one input signal can drive any, some or all outputs simultaneously without loss of signal fidelity. Losses from the power division are overcome through the use of custom-designed amplifiers. To ensure that proper performance is achieved, the amplifiers selected for this application have critical band flatness, noise figure, intercept point and compression performance specifications. A simple functional block diagram of the configuration is shown in *Figure 1*.

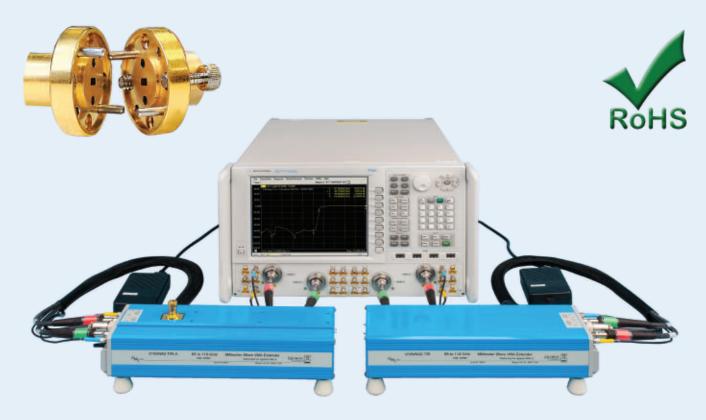
Components used in this system design, due to the critical performance required for the unit, were created within Crane Aerospace & Electronics. Power dividers in two-, four- and 24-way configurations are utilized. These are built using a traditional Wilkinson structure with stripline technology as the basis. Excellent frequency flatness and VSWR performance is achieved. Frequency slope compensating equalizers are included to insure that the entire design meets the overall flatness performance window.

RF switch cards were designed and also manufactured internally by Crane Aerospace & Electronics. These are based on GaAs PHEMT technology for the switch elements. Utilization of a well-matched, terminated switch design ensures that the prescribed isolation, power handling and intercept performance is achieved. Control to the switch assemblies is achieved using a parallel data bus, which is addressable for each card in the switch assembly.

To achieve the ultimate configuration of the system required, the components have been integrated into 12×24 matrix building blocks. These are rack-mount, fully integrated assemblies containing the amplifiers, power dividers and switch cards along with digital control and DC power supply regulation. To achieve a 12×48 switch ma-

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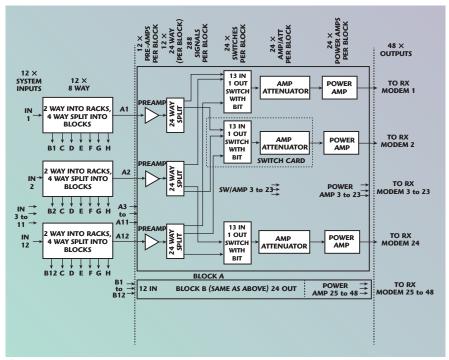
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Product Feature



📤 Fig. 1 L-Band switch matrix block diagram.

trix, two of these 12×24 matrix blocks are used along with an input power divider (two-way) assembly, splitting the 12 inputs to the two switch block assem-

blies. Their outputs directly drive the user's system.

An advanced built-in-test system is included in the system. Under com-

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mand of the system controller are signal generators and receivers, available on each of the signal paths, which pass through the system and test for RF continuity from input to output. If signals are not detected at certain points in the prescribed path, the internal controller can provide trouble-shooting information to service personnel indicating which assemblies are the most likely failure points. This process helps with the ability to rapidly service the system and get it back to full operation following a failure.

Another feature to enhance system reliability is the incorporated redundant power supply system. Each rack of equipment contains duplicate power supplies with a sophisticated summing and monitoring system. The system can operate on one of these power supplies. Should one power supply fail, the system will continue operating on the single supply. The internal diagnostics provide an alarm indication through the command controller. The system operator can remove the failed power supply and replace it with a new one without taking the system off-line.

Unit control is achieved using a single-board PC architecture. The controller receives commands through the TCP/IP Ethernet. These commands are then executed by selecting the appropriate switches to connect the signals from the desired input to prescribed output. Additional support commands, such as status polling, configuration information, etc., are available in response to a command. A front panel character display and keypad also allow local control and configuration.

A companion to the receive matrix, a transmit path matrix, is also provided. This system operates in an opposite manner of the receive system described above. In this case, multiple modems are connected to the desired number of upconverters. This matrix combines these signals so that they are available within the IF bandwidth to drive the upconverter. Individual control of the modem signal level is provided so that no overdrive condition is experienced.

Crane Aerospace & Electronics, Beverly, MA (978) 524-7200, www.craneae.com/mw, mw@crane-eg.com.



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setups with ease! And the rugged aluminum cases house our patented mechanical switches, the only ones available anywhere, at any price, that offer up to 10 years and 100 million cycles of guaranteed performance.[†] Just go to minicircuits.com for technical specifications, performance data, pricing, and real-time availability—or give us a call to discuss any custom programming needs—and think how much time and effort you can save!

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Thermal Vacuum Assemblies for Space Applications

In general, space engineered components have to meet strict requirements regarding qualification and measuring/testing. Whole satellites or space components are tested in thermal vacuum chambers to simulate conditions found in space. They are exposed to vacuum and temperature variations from extremely cold to extremely hot. The devices under test are connected to the measuring instruments outside



Fig. 1 Thermal vacuum chamber.

the chamber using special RF assemblies. *Figure 1* shows a thermal vacuum chamber.

Simulating the conditions found in space places extreme demands on all components, from the test subject inside the thermal vacuum chamber through to the measuring installations outside. To address these issues, HUBER+SUHNER has developed SUCO-FLEX® TVAC (thermal vacuum) assemblies for vacuum chamber applications, which ensure that the test data arrives perfectly at the measuring instruments.

A specific requirement is that the assemblies used within the vacuum chamber must meet the outgassing standard set out, e.g. by the European Space Agency (ESA) within ECSS-Q-ST-70-02 C, to prevent contamination of the chamber or equipment with solvents evaporating from certain materials.

HUBER+SUHNER AG Herisau, Switzerland



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Product Feature

TABLE I TECHNICAL DATA FOR SF 103F/EA					
Assembly: SUCOFLEX 103E/103EA with straight male SK (2.92 mm) connectors					
Frequency Range	DC to 33 GHz				
Connectors Vented	11_SK-312_TVAC				
Cable	SUCOFLEX 103E (jacket material: polyurethane)				
VSWR/Return Loss (Assembly)	1.25/19 dB (DC to 18 GHz) 1.34/16 dB (18 to 33 GHz)				
Insertion Loss (Assembly)	nom./max. 2.1/2.3 dB (incl. connectors, 1000 mm assembly length @ 33 GHz)				
Temperature Range	-30° to +80°C				
Outgassing	Acc. (European Space Agency) ECSS-Q-ST-70-02 C				
Note	Available with or without steel spring armouring				

TABLE 2 FEATURES AND BENEFITS OF SUCOFLEX TVAC ASSEMBLIES AND ADAPTORS						
Assemblies and ad	Assemblies and adaptors for thermal vacuum applications					
Features	Features					
	 Extended temperature range Low outgassing according to ECSS-Q-ST-70-02 C 					
Assemblies	 Superior mechanical and electrical stability Vented connectors for fast evacuation and venting Not vented connectors also available Different connectors, frequency range, electrical features Other configurations according to customer requirements 					
Adaptors • Hermetically sealed • Superior return loss performance						
Benefits						
	 Longer lifetime, lower costs Excellent performance to price ratio Perfect matched cables and connectors from one manufacturer Assistance and support everywhere 					

To protect the assemblies from stress and to provide extended life, the TVAC connector contains venting holes for easy air flow into and out of the components during the pressurization/depressurization cycles. The venting holes are shown in *Figure 2*.

MATCHED COMPONENTS

Especially in such demanding environments, it is important that the complete run of cables and connectors be perfectly matched, which makes SUCOFLEX cables, with their excellent mechanical properties, a good solution for TVAC applications. Also, the SUCOFLEX TVAC venting holes

offer the right compromise between smooth air flow and good shielding, while defined evacuation paths in the components allow the pressure changes to be balanced quickly, resulting in less stress.

Thanks to the robust design, the electrical performance is very good. All materials used comply with ESA's ECSS-Q-ST-70-02 C standard and have been approved by an independent test lab. The TVAC portfolio comprises assemblies using SUCOFLEX 103, 104, 404 and 106 cables, covering all kinds of applications, including low and high power/frequencies, and with or without armour.



Fig. 2 Connector with venting hole.

INCREASING REQUIREMENTS

Especially developed to address the market trend towards higher frequencies and greater bandwidth, HUBER+SUHNER has developed and qualified the new SUCOFLEX TVAC SK connector (2.92 mm) that operates up to 33 GHz. Together with the SUCOFLEX 103E cable (available with or without armour), the company guarantees the best-in-class performance with this configuration and excellent long-term behaviour. The technical data for these assemblies is provided in *Table 1*.

The SUCOFLEX TVAC assemblies and adaptors have been developed to enable customers to perform measurements to the highest industry and space standards and a summary of the products' key features and benefits are shown in *Table 2*.

For applications outside the thermal vacuum chamber, HUBER+SUHNER also offers a wide variety of high-quality SUCOFLEX assemblies for space applications that are not subject to outgassing restrictions. Also, as a result of its longstanding collaboration with leading satellite manufacturers and test institutions, the company has gained extensive experience in this field and can design customer-specific solutions and cable assemblies on request and under clean room conditions (DIN ISO 14644-1 class ISO 5).

The new HUBER+SUHNER TVAC product portfolio provides optimal coverage for the commonly used frequency bands L, S, C, X and K (up to 33 GHz) relevant in the space sector, and are characterised by their extra high level of robustness and reliability. All assemblies have been designed and tested for use in the temperature range from -30° to +80°C but higher temperature requirements can be met.

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Multi-User, Multi-Mission Remote Real-Time Spectrum Monitoring

RFS saw a gap in the market and set out to create a new type of spectrum intelligence system, combining the best features of benchtop spectrum analyzers and high performance SIGINT systems in a neat ruggedized package that is very fast, simple to deploy and infinitely scalable – so the RFeye® was born. The philosophy of CRFS was to create a single "little white box" with built-in intelligence that is capable of performing a whole series of tasks usually reserved for multiple different specialist systems – multi-user, multimission. At the outset, all the potential applications for the RFeye were not fully known, so CRFS designed it to be as flexible and versatile as possible with an architecture that allows easy overlay of new functionality.

The RFeye is a radio receiver, spectrum sensor, interference detector, direction finding system, signal demodulator and security system, all rolled into one. The unit runs fast with 10 MHz to 6 GHz spectrum sweeps in less

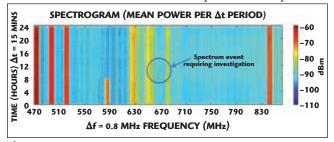


Fig. 1 Example spectrogram from RFeye system.

than 100 ms – allowing it to capture and analyze even short-burst transmissions or the most transient spectrum events (see *Figure 1*). The high performance radio is coupled with a Linux baseband so the unit can operate fully autonomously without the need for a computer server.

One of the unique benefits is how very large networks of RFeye nodes can be deployed (see *Figure 2*), each with its own remote distributed computing power. The fact that each node is intelligent means that it is able to act independently, process and analyze data, make decisions based on its programming, and communicate with and assign tasks to any other nodes in the network, all without the need to refer back to the center. This allows the whole system to run superfast – no data backhaul problems, no routing via a central server – making it ideal for dynamic real-time applications. The RFeye can simply be connected to an IP address and directly queried from any location.

The RFeye can be programmed remotely to perform a series of multi-layered missions with relative priorities assigned to each. These include general background monitoring and spectrum occupancy measurements, interference detection, transmitter geo-location, signal demodulation and classification. The idea is that a network of nodes is deployed – fixed or tempo-

CRFS INC. Yucaipa, CA





Hermetically **Sealed Adapters**

2.92mm, TNC, N. Feedthroughs with venting holes for Vacuum Test Chambers

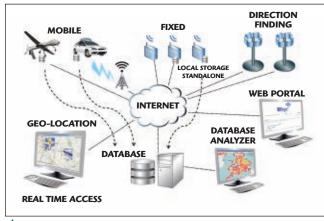




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Product Feature



▲ Fig. 2 RFeye system diagram.

rary — around a particular geographic area of interest. That could be a sensitive building like an embassy or state department, a city center, a sports stadium, a military proving ground, a critical installation like a power plant, a harbor, coastline or land border — whatever needs to be monitored. The RFeye makes measurements of the spectrum to provide information about both authorized and unauthorized activity in the area — real-time intelligence that

can be acted upon for example to resolve interference, frequenreassign cies, share spectrum between different users, detect intruders or bugging devices, whatever. The system architecture is designed to allow multiple users to access the network simultaneously and request multiple different missions and operations.

The RFeye nodes are all synchronized to a reference clock – either GPS for outdoors or CRFS's proprietary SyncLinc system for in-building – so that each node in the network sweeps at exactly the same time. Background masks are created for authorized or expected RF activity at the node – any detected signal that breaks the mask can trigger the RFeye to perform a closer investigation, sound an alarm, as appropriate, and send commands to the

nearest nodes in the network to locate the source using various techniques like time difference of arrival (TDOA), power on arrival (POA) or angle of arrival (AOA). The fact that it has such good RF performance and exceptionally low internal spurious elements means that the RFeye can reliably detect and locate even low power signals.

The RFeye is packaged in a ruggedized aluminium housing rated to IP67, fits in the palm of a hand and weighs less than 5 lbs. It is a low-power unit and can be powered from multiple sources including battery-backed solar cells. There is also a lightweight, extra low-power rack-mountable Vita format version of the RFeye, suitable for integration with other sensors.

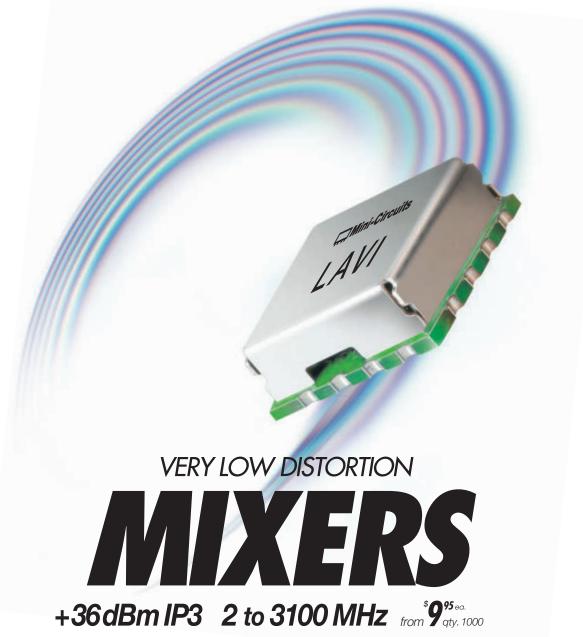
CRFS supplies not only the white boxes, but also a whole range of RFeye systems including backpacks, storm cases and roof boxes for portable and mobile use, as well as radome systems with built-in DF arrays for fixed mounting and vehicle mounting. The company also has a first-class application software team that works with customers, partners and integrators, to provide full turnkey solutions.

CRFS has recently launched a frequency extender for the RFeye - the BDC-18. The BDC-18 extends the range of the RFeye to 18 GHz which opens up a range of interesting new applications for customers who wish to monitor higher as well as lower frequencies, particularly in the military and non-civilian sectors. The BDC provides a simple and seamless extension of the RFeye making it suitable both for new installations and retrofit. A key advantage is the ability to mount the unit right next to the 18 GHz antennas, thus alleviating the problem of high cable losses at these frequencies.

The architecture of the BDC has been designed to ensure that the exceptional RF performance and speed of the RFeye is maintained up to the higher frequencies. Several of CRFS's customers would like to monitor and manage all frequencies "from DC to light." CRFS's latest development program is a BDC-50 based on the same technology which will further extend the range up to 50 GHz and is planned for launch by the end of 2012.







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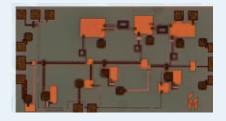
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26 to 34 GHz Low Noise Amplifier MMIC

ustom MMIC has released a new amplifier into its growing MMIC design library of standard products. The CMD162 is a GaAs MMIC low-noise amplifier (LNA) chip for applications from 26 to 34 GHz. Optimized for 30 GHz satellite communications, the CMD162 boasts a typical noise figure of 1.7 dB with a small-signal gain of 22 dB and an output 1 dB compression point of +7 dBm. This amplifier delivers high performance with high efficiency, reducing typical industry DC power dissipation for a device in this frequency band from approximately 340 mW down to 50 mW.

The CMD162 also offers subsystem and device designers a key cost reduction attribute. Implementation is simplified since the device only requires positive drain and gate voltages of +2 V, thereby eliminating the negative voltages and sequencer circuits commonly associated with LNAs in this frequency range. The CMD162 can be biased with a drain voltage ranging from +1 to +4 V and a gate voltage ranging from 0 to +3 V.

The amplifier die measures 2.3×1.3 mm, includes gold backside metallization, and has full nitride passivation for increased reliability and moisture protection. It can handle

input signal levels to +20 dBm. The GaAs MMIC amplifier has typical input return loss of 18 dB and typical output return loss of 20 dB, both at 30 GHz. It is a much smaller, lower-cost alternative to hybrid LNAs for this frequency range, and is uniquely suited for both narrowband and broadband applications requiring small size and low current consumption, including phased-array radar and point-to-point microwave radio systems.

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Software and Mobile Apps

Introducing...

As smartphones have penetrated the mobile market, mobile apps are exploding in popularity. It is only natural that mobile apps are starting to grow in use for the RF and microwave industry. In response to this trend, Microwave Journal will now be including mobile apps in our Software Update. As our editors covered IMS 2012, they found several new mobile apps that were recently released and those help kick off our first ever "Software and Mobile Apps" department.

RF Tools App

Huber+Suhner is proud to present its first iPhone App, which shows the relation between RF-specific values like impedance, wavelength, return loss (VSWR) and signal delay including their conversion. The RF Tools app is downloadable free of charge from the Apple store at http://itunes.apple.com/app/id525678686.



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Cable & Connector App

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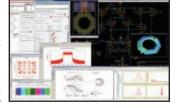
Reactel,

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



GoldenGate 2012 VENDORVIEW

Agilent introduced the latest release of its RFIC simulation, verification and analysis software, GoldenGate 2012. The 2012 release offers RFIC designers a host of technology enhancements for



accelerated design verification, extended design-for-manufacturing solutions and improved links to system design. The new GoldenGate 2012 X-parameters feature allows designers to capture the nonlinear behavior of active components such as amplifiers and save the data for quick use in simulation models in RF system or circuit designs, while also hiding all intellectual property.

Agilent Technologies Inc., Santa Clara, CA (800) 829-4444, www.agilent.com.

EMC Test SoftwareVENDOR**VIEW**

AR's EMC test software combines radiated susceptibility, conducted immunity and emissions testing into one package allowing more control and a more intuitive interface. Built-in standards include IEC, MIL-STD, DO160, auto-



motive standards and the ability to create your own test standards. The software has the ability to control more equipment and the report generating feature has been enhanced to offer more control and customization.

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HEWER

PRODUCTS

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2-WAY	0				79			
CSBK260S	20 - 600	0.28 / 0.4	0.05 / 0.4	0.8/3	25 / 20	1.15:1	50	377
DSK-729S	800 - 2200	0.5 / 0.8	0.05 / 0.4	1/2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1/4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1,1	0.05/0.2	1/2	28 / 22	1.2:1	5	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05/0.2	1/2	28 / 22	1.21	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1 / 0.3	1/3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1/2	27 / 23	1.2:1	5	331
DSK180900	1800 - 9000	0.4/0.8	0.05 / 0.2	1/2	27 / 23	1.2.1	20	330
3-WAY	74.574 (02).1571-25	0.000	1-03/11/07/07	111111	2.0400000	Jane 1		9/4/
S3D1723	1700 - 2300	0.2/0.35	0.3/0.6	2/3	22/16	1.3:1	5	316
In excess of theor	retical split loss of 3.0	dB		4000				

In excess of theoretical split loss of 3.0 dB
 With matched operating conditions

HYBRIDS

ALCOHOL: SHOWING			_					
Model #	Frequency (MHz)	Insertion Loss (dB) [Typ:/Max.] 0	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ.Max.]	(dB) [Typ./Min.]	VSWR (Typ)	Input Power (Watts) [Max.)	Package
90°								
DQS-30-90	30 - 90	0.3 / 0.6	0.8 / 1.2	1/3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6/0.9	1/3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1/1.5	4/6	23 / 18	1.40:1	5	102SLF
CSDK3100S	30 - 1000	0.8 / 1.2	0.05/0.2	0.2/3	25 / 18	1.15:1	50	378
DQS-118-174	118 - 174	0.3 / 0.6	0.4/1	1/3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2/5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2/0.4	0.5 / 0.8	2/5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1/1.6	1/4	22/20	1.20:1	40	326
MSQ100800	1000 - 8000	0.871.6	1/1.6	174	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2/0.3	0.2/0.4	2/3	22 / 18	1.20:1	50	226
180° (4-POR	rs)		11 0050000	1000				
DJS-345	30 - 450	0.75 / 1.2	0.3/0.8	2.5/4	23 / 18	1.25:1	5	301LF-1
0 in excess of theor	etical coupling loss of	3.0 dB						

COUPLERS

						The second secon	
Model #	Frequency (MHz)	Coupling (dE) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ.Max.]	Directivity (dB) [Typ./Min.]	Input Power (Wats) [Max.] -	Package
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255*
KFK-10-1200	10 - 1200	40 ±0.75	±1.0	0.4 / 0.5	22 / 15	150	376
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2/0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2/0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38/30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8/5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8/5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7/1	14/5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7/1	14/5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12/5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14/5	25	322

^{*} Add suffix - LF to the part number for RoHS compliant version.

Unless noted, products are RoHS compliant.



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Multicarrier TD-SCMA Feasibility

Brad Brannon, Bill Schofield, and Yang Ming, Analog Devices Presented by Richardson RFPD



Application Guide to RF Coaxial Connectors and Cables

Michael J. Hannon and Pat Malloy, AR RF/Microwave Instrumentation



Small-Signal Intermodulation Distortion in OFDM Transmission Systems

Application Note, RFMD

/Inritsu

Making Successful, Confident Noise Figure Measurements on Amplifiers

Application Note, Anritsu



Bringing Rapid Prototyping In-House

White Paper, LPKF

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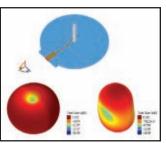


Frequency Matters.

Software and Mobile Apps

Antenna Magus 4.0 VENDORVIEW

MAGUS (Pty) Ltd., CST, and EMSS - EM Software & Systems-S.A. (Pty) Ltd. have released the fourth major version of Antenna Magus. The 4.0 release includes over 200 antennas. Antennas can be designed for a wide range of objectives and validated simula-



tion models of user-designed antennas can be exported to FEKO® and CST MICROWAVE STUDIO®. Antenna Magus 4.0 offers application-specific designs optimized for WLAN, GPS and other broadband applications.

Computer Simulation Technology AG, Darmstadt, Germany +49 6151 7303 0, www.cst.com.

Cable Configurator

With the new Tru online Cable Configurator, you can build the right cable assembly for your specific require-

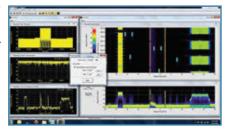


ments. The Cable Configurator takes you through a series of filtered fields where you specify your primary application, frequency, length, specs and connector and cable types. It is an easy-to-follow, prompted process that results in a completed review from which you can request assistance from an applications engineer or a quote.

TRU Corp., Peabody, MA (800) 262-9878, www.trucorporation.com.

Spectro-X 3.0

X-COM Systems introduces version 3.0 of its Spectro-X software, designed to search for signals of interest within long-duration recordings of signal activity in the RF and microwave spectrum.



The new features in Spectro-X Version 3.0 include a "zoom" function that lets users more easily focus on a specific point in time and frequency, and integrated pulse search and analysis capability that allows long pulse trains to be identified based on key signal characteristics. X-COM has also made enhancements to the software's user interface and has added automated key functions.

X-COM Systems LLC,

Reston, VA (703) 390-1087, www.xcomsystems.com.

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EXHIBITION & CONFERENCE REGISTRATION INFORMATION

October 28th - November 2nd 2012 Amsterdam RAI, The Netherlands























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The 7th European Microwave Integrated Circuits Conference Co-sponsored by







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European Microwave Week continues its series of successful events, with its 15th at the RAI, Amsterdam, The Netherlands. The EuMW 2012 team are excited to return to this superb city that offers the culture, entertainment and history of a big city, while also affording the charm and warmth of one much smaller. Bringing industry, academia and commerce together, European Microwave Week 2012 will see an estimated 1700 conference delegates, over 5000 visitors and 250 plus exhibitors.

THE EXHIBITION

Concentrating on the needs of engineers, the event showcases the latest trends and developments that are widening the field of the application of microwaves. Pivotal to the week is the **European Microwave Exhibition**, which offers YOU the opportunity to see, first hand, the latest technological developments from global leaders in microwave technology, complemented by demonstrations and industrial workshops. **Registration to the Exhibition is FREE!**

- International Companies meet the industry's biggest names and network on a global scale
- Cutting-edge Technology exhibitors showcase the latest product innovations, offer hands-on demonstrations and provide the opportunity
 to talk technical with the experts
- Technical Workshops get first hand technical advice and guidance from some of the industry's leading innovators

BE THERE

Exhibition Dates	Opening Times
Monday 29th October	12:00 - 18:00
Tuesday 30th October	9:30 - 18:00
Wednesday 31st October	9:30 - 18:00

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- Register as an Exhibition Visitor online at www.eumweek.com
- Receive a confirmation email with barcode
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www.eumweek.com



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Don't miss Europe's premier microwave conference event. The 2012 week consists of three conferences and associated workshops:

- European Microwave Integrated Circuits Conference (EuMIC) 29th 30th October 2012
- European Microwave Conference (EuMC) 29th October 1st November 2012
- European Radar Conference (EuRAD) 31st October 2nd November 2012
- Workshops 28th 29th October and 1st 2nd November 2012

The three conferences specifically target ground breaking innovation in microwave research through a call for papers explicitly inviting the submission of presentations on the latest trends in the field, driven by industry roadmaps. The result is three superb conferences created from the very best papers, carefully selected from close to 1,000 submissions from all over the world. Special rates are available for EuMW delegates. For a detailed description of the conferences, workshops and short courses please visit www.eumweek.com. The full conference programme can be downloaded from there.

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Conference Prices

There are TWO different rates available for the EuMW conferences:

- ADVANCE DISCOUNTED RATE for all registrations made online before 27th September
- STANDARD RATE for all registrations made online after 27th September and onsite

Please see the Conference Registration Rates table on the back page for complete pricing information. All payments must be in \in euro – cards will be debited in \in euro.

Online registration is open now, up to and during the event until 2nd November 2012

DELEGATES

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- Register online at www.eumweek.com
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- Bring your email, barcode and photo ID with you to the Event
- Go to the Fast Track Check In Desk and print out your delegates badge
- Alternatively, you can register Onsite at the self service terminals during the registration opening times below:
 - Saturday 27th October (16.00 19.00)
 - Sunday 28th October (07.30 17.00)
 - Monday 29th October (07.30 17.00)
 - Tuesday 30th October (07.30 17.00)
- Wednesday 31st October (07.30 17.00)
- Thursday 1st November (07.30 17.00)
- Friday 2nd November (07.30 10.00)

Once you have collected your badge, you can collect the conference proceedings on USB stick and delegate bag for the conferences from the specified delegate bag area by scanning your badge.

CONFERENCE PRICING AND INFORMATION

EUROPEAN MICROWAVE WEEK 2012, 28th October - 2nd November, Amsterdam, The Netherlands

Register Online at www.eumweek.com

ONLINE registration is open from 12th June 2012 up to and during the event until 2nd November 2012.

ONSITE registration is open from 4pm on 27th October 2012.

ADVANCE DISCOUNTED RATE (before 27 Sept), STANDARD RATE (after 27 Sept & Onsite)

 $Reduced\ rates\ are\ offered\ if\ you\ have\ society\ membership\ to\ any\ of\ the\ following:\ Eu\mbox{\it MA},\ gaas,\ iet\ or\ ieee$

EuMA membership costs: Professional: € 20/year Student € 10/year

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students less than 30 yrs of age and Seniors 65 or older as of 2nd November 2012)

ADVANCE REGISTRATION CONFERENCE FEES (BEFORE 27 SEPT)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE						
	Society Member	(*any of above)	Non-member				
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.			
EuMC	€ 420	€ 100	€ 550	€ 130			
EuMIC	€ 325	€ 90	€ 430	€ 120			
EuRAD	€ 255	€ 80	€ 340	€ 110			
2 Conferences		•					
EuMC + EuMIC	€ 600	€ 190	€ 790	€ 250			
EuMC + EuRAD	€ 550	€ 180	€ 720	€ 240			
EuMIC + EuRAD	€ 470	€ 170	€ 630	€ 230			
3 Conferences							
EuMC + EuMIC + EuRAD	€ 710	€ 270	€ 940	€ 360			

STANDARD REGISTRATION CONFERENCE FEES (AFTER 27 SEPT AND ONSITE)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE							
	Society Member	(*any of above)	Non-member					
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.				
EuMC	€ 550	€ 130	€ 720	€ 170				
EuMIC	€ 430	€ 120	€ 560	€ 160				
EuRAD	€ 340	€ 110	€ 450	€ 150				
2 Conferences			'					
EuMC + EuMIC	€ 790	€ 250	€ 1030	€ 330				
EuMC + EuRAD	€ 720	€ 240	€ 940	€ 320				
EuMIC + EuRAD	€ 630	€ 230	€ 810	€ 310				
3 Conferences			•					
EuMC + EuMIC + EuRAD	€ 940	€ 360	€ 1230	€ 480				

WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

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FEES	ADVANCE DISCOUNTED RATE				
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	Standard	Student/Sr.	Standard	Student/Sr.	
1/2 day WITH Conference registration	€ 80	€ 60	€ 110	€ 80	
1/2 day WITHOUT Conference registration	€ 110	€ 80	€ 150	€ 110	
Full day WITH Conference registration	€ 120	€ 90	€ 160	€ 110	
Full day WITHOUT Conference registration	€ 160	€ 120	€ 210	€ 150	

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 - 29th October 2nd November 2012

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FEATURING VVENDOR**VIEW** STOREFRONTS

Components

Connector Line

CarlisleIT added a new connector line to its push-on family – the TMP® series. The TMP family is designed to provide higher power handling capacity, similar to an SMA connector, for use in radar and other high power RF and microwave systems. The TMP interface enables mode-free operation to 23 GHz, and is rated to handle above 200 W of power in the S-Band. It features a PCB mount, field replaceable, microwave cable and custom connector configurations.

Carlisle Interconnect Technologies, St. Augustine, FL (800) 458-9960, www.carlisleit.com.

Quantizer ADC VENDORVIEW

The HMC9000 is a high speed, multi-GHz quantizer analog-to-digital converter (ADC) that provides up to 12-bit resolution to 500 MSPS. The HMC9000 provides excellent performance for microwave frequencies, including ultra high frequency wideband performance utilizing Hittite's track and hold amplifiers and ADCs. The HMC9000 also offers a robust and optimized PCB design and layout which includes a path to improve performance through integration, either MCM or monolithic. Hittite's data converters offer the lowest power consumption for best signal-to-noise ratio (SNR).

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

Power Sensors



LadyBug Technologies, manufacturer of the only No-Zero, No-Cal™ USB RF/uW power sensors, now offers new, optional 3.5 mm precision RF connectors (male and female) for all La-

dybug USB PowerSensor+TM units. Customers will be able to select their RF connector (male or female) from Type N, Super SMA, or 3.5 mm. Datasheets and ordering guides with the new 3.5 mm connector option are available for download at www.ladybug-tech.com/saleslit.html.

LadyBug Technologies, Santa Rosa, CA (866) 789-7111, www.ladybug-tech.com.

Directional Coupler

With the new CA-18, Marki Microwave is increasing the power handling of its high directivity air-line couplers to 200 W. CA-18 is a high power type N-connectorized bidirectional coupler capable of operation to 18 GHz. This coupler features a unique air-line construction that simultaneously enables extremely low loss and high directivity. This coupler can be used for low loss and high power applications. The useable operating frequencies extend below 1

GHz for applications where calibration of the frequency response is available.

Marki Microwave, Morgan Hill, CA (408) 778-4200, www.markimicrowave.com.

Hybrid Couplers VENDORVIEW



These highpower, 3 dB hybrid couplers are useful in BTS applications for combining two transmitters to

share one antenna or for use to distribute signals for in-building/DAS applications. Available in eight bands: 400 to 520 MHz, 698 to 1000 MHz, 800 to 1000 MHz, 969 to 1215 MHz, 1020 to 1040 MHz, 1070 to 1230 MHz, 1700 to 2200 MHz, and 1850 to 1990 MHz. Unique airline construction provides lowest possible insertion loss while delivering high isolation (30 dB typical), exceptional VSWR (1.10:1 typical) and superior phase balance (3 degrees max.).

MECA Electronics Inc., Denville, NJ (866) 444-6322, www.e-meca.com.

Cavity Filter VENDORVIEW



NIC introduces a Ku-Band cavity bandpass filter designed for use in airborne, ship-mount and vehicle-mount applications in

harsh military environments. This filter offers low insertion loss of < 1 dB and high selectivity in a small package size of approximately $1.4^{\prime\prime} \times 0.5^{\prime\prime} \times 0.35^{\prime\prime}$. These filters can be custom designed for center frequencies up to 20 GHz and 3 dB bandwidth from 1 to 50 percent. Custom designs are available up to K-Band.

Networks International Corp., Overland Park, KS (913) 685-3400, http://nickc.com.

Absorptive SwitchVENDOR**VIEW**



PMI model P2T-500M40G-USB is a stateof-the-art SPDT, absorptive switch that operates from 500 MHz to 40 GHz. This switch is powered and con-

trolled via USB 2.0 and is supplied with a Graphic User Interface (GUI) that gives you control of the switch via your PC. This model offers low insertion loss of 6 dB maximum and a minimum isolation of 60 dB. The package size is $2.25^{\circ} \times 1.0^{\circ} \times 0.33^{\circ}$.

Planar Monolithics Industries Inc., Frederick, MD (301) 662-5019, http://pmi-rf.com.

Connector Series



Part of the COMPEL series of connectivity products, the design of the SMP compatible connector series provides push-on mating characteristics and facilitates tight packaging

density due to its small diameter and low profile. All jacks incorporate an anti-rock ring to preclude radial movement and plugs are available in full detent, limited detent and smooth bore barrel configurations. Frequency coverage is from DC to 40 GHz in standard 50 ohm impedance. Custom variants are available upon request. Standard housings are manufactured in stainless steel with gold plating.

Response Microwave Inc., Devens, MA (978) 772-3767, www.responsemicrowave.com.

Hybrid Coupler VENDORVIEW



One of Werlatone's newest surface mount couplers, model QHS922, covers a full 150 to 2000 MHz band. Rated at 100 W CW, this bonded design

is utilized in applications requiring very small form factors and high repeatability. Measuring only $1.47"\times1.13"\times0.16",$ this unit is specifically designed for military and commercial environments. The unit provides exceptionally low loss (0.7 dB max.) and has an operating temperature of -55° to +85°C.

Werlatone Inc., Patterson, NY (845) 278-2220, www.werlatone.com.

Amplifiers

Low-Noise Amplifiers VENDORVIEW



Custom MMIC is offering two new devices: The CMD157 (die) and C M D 1 5 7 P 3 (packaged) are GaAs MMIC low-noise am-

plifiers (LNA) for applications from 6 to 18 GHz. These broadband devices boast an impressively low noise figure of 1.5 dB, deliver greater than 25 dB of flat gain, and have a corresponding output 1 dB compression point of +10 dBm. The CMD157 is suitable for chipand-wire applications, whereas the CMD157P3 is housed in a leadless RoHS compliant 3 × 3



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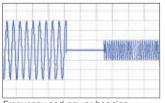
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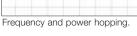
Sweep or hop across wide frequency and power bands, use a pair for third-order intercept tests, or slip one into your laptop case and take it on the road! Our easy-to-use GUI will have you up and running in minutes. Compatible with most test software,* they add capabilities and increase efficiency, all without busting your budget!

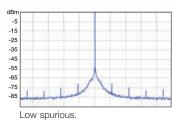
*See data sheets for an extensive list of compatible software.

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Model Frequency Power Harmonics Price (MHz) (dBm) (dBc typ.) (\$ ea.) SSG-4000HP 250-4000 -50 to +20 -40 1995.00 SSG-4000LH 250-4000 -60 to +10 -66 2395.00

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New Products

mm plastic surface mount package. Custom MMIC, Westford, MA (978) 467-4290, www.custommmic.com.

Amplifier VENDOR**VIEW**



Empower model BBM2E3KLP is a 20 to 520 MHz amplifier that is guaranteed to deliver 125 W output power and related RF performance under all specified temperature and environmental conditions. The amplifier module is $7" \times 4" \times 1.5"$. This amplifier is suitable for broadband jamming and high power linear applications in the UHF/VHF bands. This module utilizes high power LDMOS transistors and also features built in control and monitoring, with protection functions.

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

RF Power Amplifier

Freescale Semiconductor revealed its first RF power amplifier product built using GaN technology. The AFG25HW355S is a 350 W, high-performance-in-package (HiP), 2:1 asymmetric 2.3 to 2.7 GHz device with 56 dBm peak power, 50 percent efficiency, 16 dB gain and NI-780 packaging. The company's RF power GaN products will initially target the cellular infrastructure market, with potential future applications including avionics, radar, ISM and software-defined radio.

Freescale Semiconductor, Austin, TX (800) 521-6274, www.freescale.com.

Broadband Amplifier

Microsemi announced the immediate availability of a high power broadband amplifier, model AML618P4202. This amplifier operates



over 6 to 18 GHz with industry-best DC to RF efficiency. Output P1dB is +35 dBm (3 W) minimum. Gain is 42 dB min. with flatness

within \pm 2.5 dB max. DC current at +12 VDC is under 2.5 A. Dimensions are 2.85" \times 1.5" \times 0.5". Operating temperature range of -54° to +85°C is available as an option.

Microsemi Corp., Santa Clara, CA (408) 727-6666, www.microsemi.com/rfis.

SAW Modules SAW for Defense & Space Integrated Microwave Assemblies for IF signal processing with SAW's exceptional performance: • state-of-the-art design • high freq selectivity • high dynamic range • MIL & space qual Radar minimal SWaP Space Communications Electronic Warfare 90 Wolcott Rd. Simsbury, CT 06070 (860) 651-0211

Instrument Amplifier VENDORVIEW



The TVA-82-213 is an instrument amplifier that covers an exceptionally wide range of frequencies (0.8 to 21 GHz) while affording convenience, portabili-

ty, and ease of use. It features isolation of 75 dB typical and a self contained power supply with selectable 110 or 220 V AC supply and is thermally self protected.

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

MESFET MMIC Amplifier VENDORVIEW

RFMD's RFCA8818 is a low-noise, linear high performance GaAs MESFET MMIC amplifier. The RFCA8818 contains two amplifiers



for use in wideband push-pull CATV amplifiers requiring excellent second order performance. The second and third order nonlin-

earities are greatly improved in the push-pull configuration. Features include 75 Ω push-pull amplifier, 40 to 1008 MHz operation, internally matched input and output, 17 dB small signal gain, 2 dB noise figure, and single 5 to 8 V positive power supply.

RFMD, Greensboro, NC (336) 664-1233, www.rfmd.com.

Low-Noise Amplifier VENDORVIEW

Richardson RFPD introduced an 80 to 105 GHz balanced LNA from United Monolithic Semiconductors S.A.S. (UMS). The CHA1008-99F is a broadband, four-stage monolithic LNA designed



LNA designed for millimeter-wave imaging applications. The 3.40 × 1.60 × 0.07 mm device is manufactured on a 0.10 µm gate length PHEMT process, offering via holes through the

substrate, air bridges and electron beam gate lithography. Key features of the CHA1008-99F include 16 dB linear gain, 5 dB noise figure from 80 to 90 GHz, and a DC bias of $VD = 2.5 \, V$ at $ID = 115 \, mA$.

Richardson RFPD Inc., LaFox, IL (630) 208-2700, www.richardsonrfpd.com.

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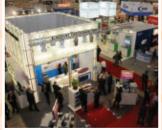
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- 5,000 key visitors from around the globe
- 1,700 2,000 conference delegates
- In excess of 250 exhibitors

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New Products

Variable Gain Receiver

TriQuint's new TAT6281 variable gain receiver for single family units employs proven PIN diode variable attenuation to provide a consistent, low-distortion method of adjusting gain. TriQuint's integrated module delivers reliable, low-noise RF performance while simplifying FTTH amplifier designs and reducing bills of materials. The TAT6281 builds on the success of TriQuint's TAT6254 product line, millions of which have been in CATV/FTTH networks deployed



world-wide. TriQuint's new devices are economical and built with market-tested GaAs technology, offering greater functional integration and higher efficiency.

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

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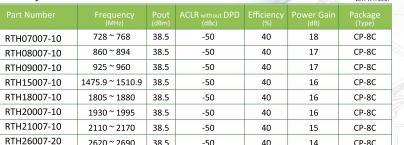
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14

Antennae

Mobile Antenna

ASC Signal unveiled a new 2.4 meter nomadic antenna that incorporates the company's advanced mobile features in the lightest, most agile package it has ever offered to defense and commercial customers. The antenna's one-, three- or nine-piece reflector panels allow for flexible configuration. The low-cost antenna enables cost-effective communications in L-, S-, X-, C-, K-, Ku-, Ka-, Q- and V-Bands as well as low PIM. The system's flexibility also ensures low on-going costs of operation and upgrades, and expandability for a variety of applications.

ASC Signal, Plano, TX (214) 291-7654, www.ascsignal.com.

SMT Antenna

PREMO launched a new family of its TP0702 standard, universally adopted by industry. This format provides up to 50 mV/Apk-pk/m (for 7.2 mH) sensitivity which gives it the best sensitivity in this transponder size. The new TP0702U and TP0702UCAP is an SMD antenna for low frequency 20 to 150 kHz receiver applications. TP0702UCAP provide an upper and lateral side protection with co-polyamide polyhexamethylene polymer walls, gamma radiated with high thermal stability (supports up to 290°C) and mechanical resistance (exceeds 150 Mpa of mechanical strength).

PREMO, Málaga, Spain +34 951 231 320, www.grupopremo.com.

Sources

Stick Synthesizers



Applied Radar Inc. announced the addition of the AR2010-5-10 and the AR2010-10-20 wideband models to its USB stick synthesizer product line. The AR2010-5-10 operates over the 5 to 10 GHz frequency band while the AR2010-10-20 operates over the 10 to 20 GHz frequency band. Both USB stick synthesizers offer adjustable output power and an onboard 20 MHz reference with a 10 to 200 MHz external reference input. Applied Radar's AR2010 USB stick synthesizer products are USB powered, USBT-MC compliant, and come with a control GUI.

Applied Radar Inc., N. Kingstown, RI (401) 295-0062, www.appliedradar.com.

HCMOS Clock Oscillator

Crystek Corp.'s ultra-low phase noise CCHD-950 Series HCMOS clock oscillator has a -168 dBc/Hz noise floor (100 MHz model). The CCHD-950 generates frequencies between 45 and 130 MHz, with 50, 80, 100 and 130 MHz offered as standard. A high-Q crystal and third overtone technology provide the ultra-low phase noise and low-jitter performance, making the CCHD-950 very useful in synthetic



August Short Course Webinars

Agilent in Wireless Communications

Addressing Measurement Challenges of 160 MHz 802.11ac MIMO

Live webcast: 8/9/12, 1:00 PM ET

Agilent in Aerospace/Defense

Measurement Challenges and Techniques for SATCOM

Live webcast: 8/16/12, 1:00 PM ET

Optimize Wireless Device Battery Run-Time

Innovative Measurements for Greater Insights

Live webcast: 8/22/12, 1:00 PM ET

Agilent in LTE

LTE-Advanced Design and Test Challenges - Carrier Aggregation

Live webcast: 8/23/12, 1:00 PM ET

Past Webinars On Demand

Masters of MIMO Series

- Over-the-Air (OTA) Signal Challenges and Implications Recommendation for LTE RAN
- MIMO OTA Measurements The Next Generation Platform for Wireless Testing



MicroApps Expert Forum

 Device Characterization Methods & Advanced RF/Microwave Design

RF/Microwave Training Series

Presented by: Besser Associates

- Mixers and Frequency Conversion
- LTE Broadband Wireless Access

Market Research Series

Presented by: Strategy Analytics

AESA Radar Market Trends: Fast-Jets and Beyond

Technical Education Series

- Improving GaN HEMT PA Design with Cree's Large Signal Models and AWR's Microwave Office™
- Understanding Radio Channel Part 2: Reaching a Data Rate of 100 Mbit/s with LTE
- RF and Microwave Heating with COMSOL Multiphysics
- Radar Fundamentals
- Using Highly Integrated RF ICs to Optimize Your Infrastructure and PTP Designs

Innovations in EDA/Signal Generation & Analysis Series

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- System-level Design and Verification for Advanced Satellite Comms
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- Comprehensive mmWave Design Solutions for TSMC's 60 GHz CMOS RDK
- Fast Characterization of Power Amplifier Performance with Modulated Signals

Agilent in Aerospace/Defense Series

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- Simulating Power Transients and Noise
- Mixed Signal Testing Challenges in FPGA-based Radar Systems
- Fast and Accurate Frequency Converter Characterization

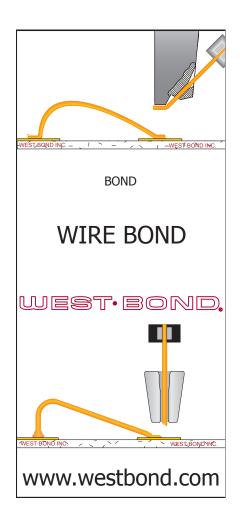
Agilent in LTE/Wireless Communications Series

Presented by: Agilent Technologies

- Wideband Digital Pre-Distortion Modeling for LTE-Advanced
- MSR Base Station Introduction and Measurement Challenges
- Next Generation 802.11ac WLAN MIMO Design and Test Challenges
- LTE Channel State Testing: An Overview of CQI, PMI, and RI for LTE
- Optimize UE Design for Greater Battery Run-Time







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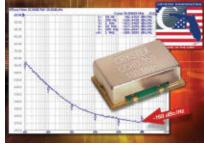
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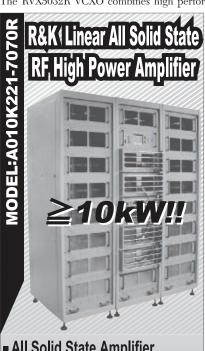
instrumentation such as VXI/PXI. Generating no sub-harmonics, the CCHD-950 requires an input supply voltage of 3.3 VDC consuming 15 mA of current.

Crystek Corp., Fort Myers, FL (800) 237-3061, www.crystek.com.

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Rakon introduced a high performance VCXO in a 5×3.2 mm surface mount package. The RVX5032R VCXO combines high perfor-



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Auckland, New Zealand +64 (9) 573 5554, www.rakon.com.

Voltage-Controlled Oscillator



The SMV5550B-LF, a high performance VCO, generates frequencies between 5000 and 6000 MHz, covering the 1000 MHz bandwidth within 0 to 10 V of control. Though the device covers a broad spectrum of bandwidth, the SMV5550B-LF comes in a compact package covering an area less than .10 sq. inches while exhibiting phase noise performance of -80 dBc/ Hz, typically, at 10 kHz from the carrier. It delivers 3 ± 3 dBm into a 50 Ω load with a nominal 5 V supply and drawing typically 24 mA.

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

Test Equipment

Signal Generator/Receiver



The TTG-7000 TCAS/transponder test set is a RF signal generator/receiver designed for testing TCAS and transponders. The TTG-7000 supplies a 10.4" touch screen LCD display. It can be remotely controlled via GPIB, LAN or USB. Some of the features include simulation of 32 dynamic and 400 static intruders; ADS-B squitters; 978, 1030 and 1090 MHz (in/out); top/ bottom four port antenna simulation (TCAS); hybrid surveillance, DO-181, 185, 260, and 300 testing; six independent transmitters; TX/RX data logging capability; data parsing for analysis; pulse and frequency measurement; and multilateration systems testing.

Advanced Technical Group Inc., Miami Lakes, FL (305) 556-1957, www.a-tg.com.



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The Site Master S331L is an all inclusive 1-port cable and antenna analyzer covering the 2 MHz to 4 GHz range, with a built-in InstaCal $^{\text{TM}}$ module and a built-in power meter. The S331L has been optimized for field conditions, is easy to use, and has efficient sweep management capabilities. It has an outdoor viewable 7" TFT touch screen display, new intuitive GUI, and classic mode that mimic the S331D basic measurement flow, and entire workday of battery operating time.

Anritsu Co., Richardson, TX (800) 267-4878, www.anritsu.com.

PIM Tester

The CCI PIMPro 900 is a full band unit, for use across the whole 900 band, which includes E-GSM, UMTS900 and LTE band 8. The PIMPro



1800 is a full band unit for the 1800 band, applicable for GSM1800, LTE Band 3 and LTE Band 9. PIMPro is a ruggedized field tool, with a flexible touch screen and icon-driven user interface, which enables PIM testing to be done swiftly, efficiently and with confidence by the field technician.

Communications Components Inc., S. Hackensack, NJ (201) 342-3338, www.cciproducts.com.

Phase Noise Analyzers

The HA7000 Series phase noise analyzers cover a DUT range of 5 MHz to 6.7 GHz. It currently consists of fundamental designs that respond to the demands from the marketplace: low noise floors, fast measurement speeds, reliability, ease of use and price. The HA7402A is a cross-correlation engine (dual core) with automated calibration of the DUT and the two external (user supplied) LO sources. It is capable of

measuring noise floors of below -190 dBc/Hz at acquisition speeds of less than a few minutes. Holzworth Instrumentation, Boulder, CO (303) 325-3473,

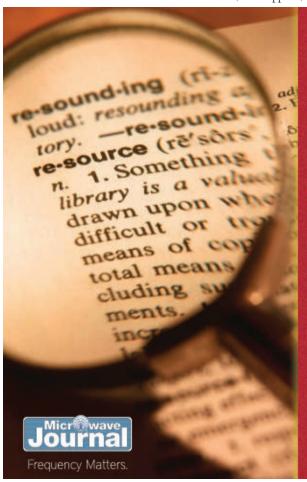
Optical Modulation Analyzer

www.holzworth.com.



Tektronix Inc. announced that its OM4000 Series optical modulation analyzer can now drive the DSA8300 Digital Sampling Oscilloscope to perform analysis on PM-QPSK, QAM, and other complex-modulation signals with higher vertical resolution than real-time based solutions at lower total system cost. Key capabilities provided by the DSA8300 in this application include 16-bit vertical resolution and 450 μV RMS noise floor at 60 GHz for added dynamic range and accuracy. It also features up to 60 GHz bandwidth on four channels to help future-proof the system for next generation baud rates.

Tektronix Inc., Beaverton, OR (800) 833-9200, www.tek.com.



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The Book End



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After an introduction, the first half of the book covers various passive and active devices including chapters on planar transmission lines, distributed and lumped elements, passive devices, control devices, duplexers and diplexers, lownoise amplifiers and mixers. The second half concentrates on systems for various applications covering different types of configurations including a chapter on design and fabrication. The book covers microwave front-ends of the following avionics systems: microwave landing system, radio altimeter, global positioning system, traffic collision avoidance system, transponder, distance measuring equipment, universal access transceiver, automatic dependent surveillance-broadcast and weather radar.

This book was primarily intended for RF and microwave

engineers just entering the field of integrated front-ends, but is a very good book for students in advanced electronics or aviation and is very useful for experienced engineers as a reference text. It is highly recommended for these uses as it thoroughly covers the important topics related to microwave frontends and many practical examples and references.

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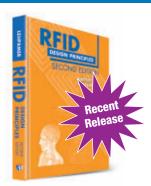
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The theme for the 80th ARFTG Conference is in the test and measurements for the rapidly expanding fields of the diverse Wireless Communication applications. We encourage submission of original papers demonstrating your approach to measurements of wireless and broadband communications on topics including:

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- Performance of new technologies such as Ultra-Wideband communication systems and High- Rate Wireless LAN Standards
- Adjacent & co-channel interference and their effects on power amplifier design, linearity and receiver sensitivity
- Measurement of bit error rate, including eye diagrams and constellation diagrams
- Applications of Digital Signal Processing to communications signal measurements
- Signal-to-noise ratio of microwave and broadband signals
- Vector Signal Measurements and Complex Waveform Analysis
- Nonlinear Measurement Techniques in Time Domain and Envelope Domain
- Time-domain measurement, characterization, and models of communication systems
- Relationships between baseband and RF systems performance and measurements
- Experimentally-based behavioral modeling
- Measurement techniques for RF Nanotechnologies

Deadlines

September 10, 2012 Electronic Abstract/Summary due in Adobe PDF format, to:

http://www.mtt-tpms.org/symposia_v6/ARFTG_Fall/start.html

October 19, 2012 Publication-ready paper due in PDF format.

Paper acceptance and classification will be communicated by September 28, 2012

Instructions for authors are outlined briefly below. More details can be found on the ARFTG web-site at: http://www.arftg.org/instructions for authors.html.

Instructions for Authors

Contributed papers will be presented as 20-minute talks or in an interactive poster session, and published as part of the ARFTG proceedings. You can express a preference for an interactive poster session.

We request that authors submit a 1000 word summary with supporting figures of both experimental setups and measurement results to enable evaluation with regard to the interests of the participants and novelty of the work.

Exhibit

The 80th ARFTG Conference also offers an outstanding exhibition opportunity. Please contact our Exhibits Chair directly for further information (exhibits@arftg.org).

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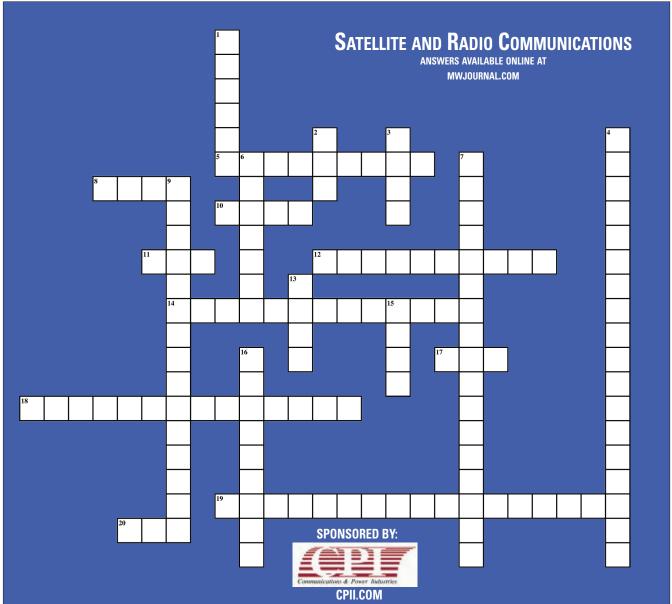
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Across

- 5 ____ can provide a cost-effective strategy for replacing obsolete test instruments
- 8 Short for Digital RF Memory
- 10 AESAs did not become feasible until _____ technology became mature enough to package the necessary volume of circuitry into compact T/R modules
- 11 Short for Automated Test Equipment
- 12 90 percent of satellite interference issues can be attributed to _____ (2 words
- **14** PHY (2 words)
- 17 Short for Wireless Sensor Network
- **18** AoA (3 words)
- 19 33 percent of interference is due to______ leakage of signals (2 words)
- 20 Short for Arbitrary Waveform Generator

Down

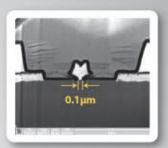
- 1 Another name for IEEE 802.15.4
- 2 Future AESA radar should benefit from new high power semiconductor materials such as ____
- 3 Short for Commercial Off The Shelf
- 4 SIGINT (2 words)
- 6 First volume production radar designs to employ the idea of transmitting and receiving through an array of individual phase or delay controlled elements
- RCS (3 words)
- 9 Could be described as self-interference (2 words)
- 13 Short for Standard Commands for Programmable Instruments
- 15 Progressively displacing legacy Mechanically Steered Arrays and Passive Electronically Steered Arrays Industry driven solution for tracking and solving satellite interference (2 words)



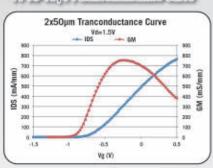
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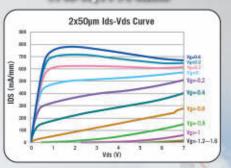
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fr	65 GHz	90 GHz	130 GHz
f _{max}	190 GHz	185 GHz	180 GHz
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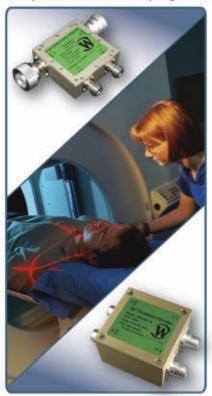
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C7286	40	72-78	400	4,000	0.15	1.15	20	6 x 3 x 1.09
C8429	50	100-500	200	5,000	0.1	1.20	20	3 x 3 x 1.09
C8212	50	100-500	1,000	10,000	0.2	1.10	20	3 x 3 x 1.09
C8653	60	121-125	1,000	10,000	0.15	1.20	25	3 x 3 x 1.09
C8895	50	123-133	200	45,000	0.15	1.20	27	6 x 3 x 1.09
C6504	50	123-133	2,250	20,000	0.15	1.20	25	6 x 3 x 1.09
C7134	60	125-130	2,000	35,000	0.15	1.20	25	3 x 3 x 1.09
C7560	40	126-128	400	4,000	0.15	1.15	25	3 x 3 x 1.09
C7633	50	126-128	400	4,000	0.15	1.15	25	3 x 3 x 1.59
C8406	60	126-129	3,000	35,000	0.15	1.20	25	3 x 3 x 1.59
C7020	60	127-129	2,000	35,000	0.15	1.20	25	3 x 3 x 1.09
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QH8180	2-Way (90°)	119-123	500	4,000	0.3	1.20	5	20	3 x 3 x 1.88
D8301	2-Way (0°)	121-124	500	8,000	0.25	1.20	3	20	4 x 2 x 1.5
D7801	8-Way (90°)	121-124	75	7,500	0.75	1.25	5	20	10 x 8 x 2.25
D7743	16-Way (22.5°)	125-128	400	8,000	0.85	1.40	5	20	12 x 12 x 4
QH8589	2-Way (90°)	126-130	500	5,000	0.3	1.20	5	20	3 x 3 x 1.88
D6861	8-Way (45°)	290-300	200	4,000	0.5	1.25	5	20	10 x 8 x 2.25
D7167	16-Way (22.5°)	290-300	400	8,000	0.65	1.30	5	20	12 x 12 x 4
D8066	4-Way (0°)	398-402	1,000	2,000	0.4	1.30	5	20	6 x 5 x 2.25
QH8065	4-Way (90°)	398-402	1,000	2,000	0.4	1.30	5	20	6 x 5 x 2.25

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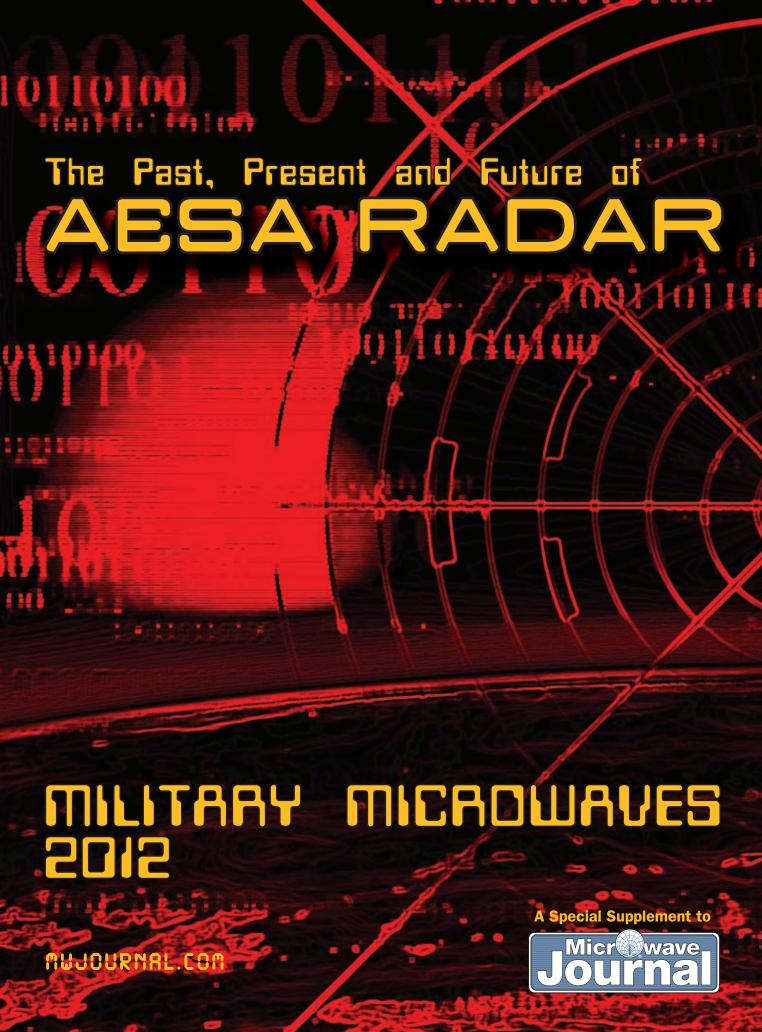
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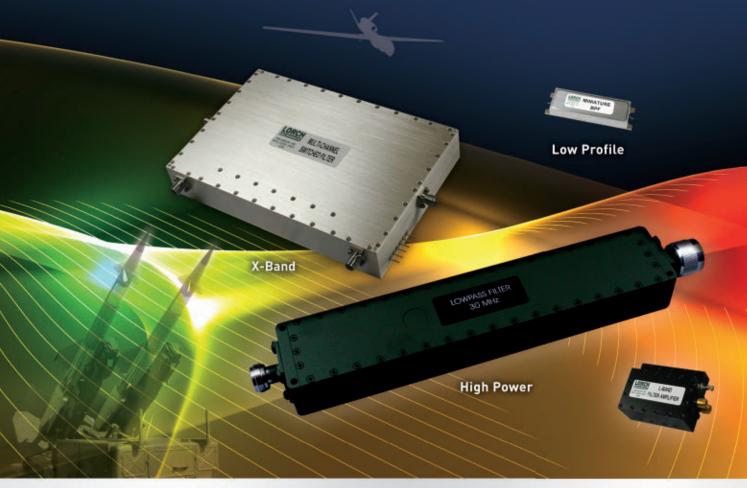
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Evolution of AESA Radar Technology

ctive Electronically Steered Array (AESA) X-Band radars are now the baseline in state of the art combat aircraft, progressively displacing legacy Mechanically Steered Arrays (MSA) and Passive Electronically Steered Arrays (PESA) in most new designs and some block upgrades of existing designs. The technology is now penetrating into other areas historically dominated by MSA and PESA technology, including Airborne Early Warning radars, Surface to Air Missile engagement radars, and volume search radars. This trend will continue for a number of very compelling reasons, which will be further explored.

The AESA is not a panacea for all radar applications and imposes a number of unique requirements on supporting hardware, which are lesser or indeed absent, in many legacy radar technologies. These requirements amount to costs in systems integration, which matter to varying degrees across applications. What is abundantly clear is that AESAs will become the dominant technology in many high volume radar applications over the coming years, as the technology matures and manufacturing costs progressively decline. To best appreciate why the AESA has been so successful, it is worth first exploring the evolution of ESAs or "phased arrays."

EVOLUTION OF ELECTRONICALLY STEERED ARRAY RADAR TECHNOLOGY

The first "modern" operational production phased array radars were the German VHF-Band GEMA FuGM41 Mammut or "Hoarding" series of air and sea surveillance radars, deployed during the latter part of the Second World War.¹ These revolutionary radars introduced the idea of electronic or "agile" beam steering, whereby the direction of the antenna main lobe was controlled not by physically pointing the antenna boresight, but by altering the relative phase or delay of the signals

passing through elements in an antenna array. Earlier British "Chain Home" radars, decisive during the Battle of Britain, exploited phase relationships between pairs of antenna elements for direction finding, but the Mammuts were the first volume production designs to employ the idea of transmitting and receiving through an array of individual phase or delay controlled elements.²

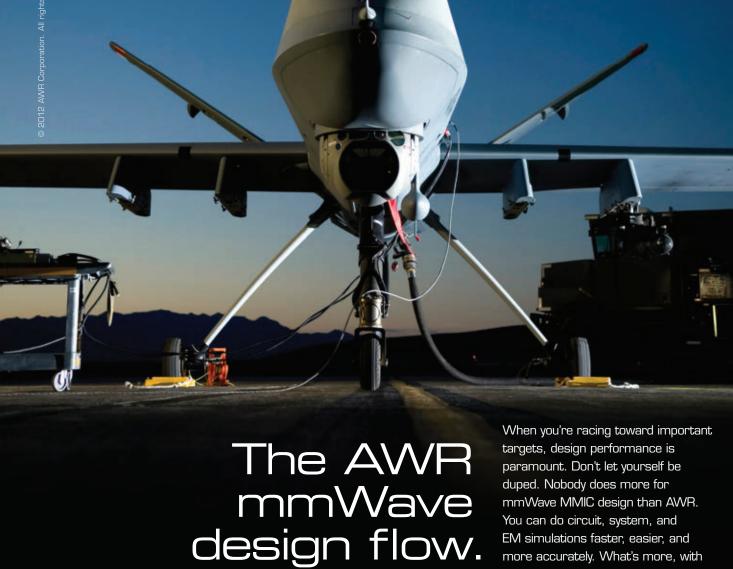
This presented a major advantage, in that the physically large and heavy antenna, necessary for high gain at such long wavelengths, did not have to be mechanically pointed to sweep across a volume of space. Agile beam steering via electronic control of beam direction remains the principal advantage of ESAs over MSAs, as it permits flexible control of beams for tracking individual targets or groups of targets, as well as scan rates over volumes of space. The penalties for designers and maintainers were complexity, volume and weight, compared to MSAs. Until recently, complexity, volume and weight have remained the principal obstacles to wider use of ESA technology. The need for complex feed networks, individual phase or delay control components, and supporting control hardware, is reflected accordingly.

The 1970s saw important advances in ESA technology, with the development of a number of important systems in the United States and the Soviet Union. In all instances, the motivation was the ability to track large numbers of fast targets concurrently, to support missile guidance applications, whether defending against tactical or strategic ballistic missiles, or cruise missiles at low or high altitudes.

In the critical strategic ballistic missile acquisition and tracking role, the 450 MHz Raytheon FPS-115 Pave PAWS³ and Soviet 150 MHz NIRI 5N15 series Dnestr/Hen House ESA radars were developed and deployed.⁴

CARLO KOPP Monash University, Victoria, Australia







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The later Pave PAWS variants delivered an average power of 145.6 kW, and peak power of 582.4 kW, using no less than 1,792 array elements, each rated at 325 W.

The U.S. Army/Raytheon C-Band MPQ-53 Patriot engagement radar and the Soviet X-Band 5N63/30N6 Flap Lid S-300PT/SA-10 Grumble and 9S32 Grill Pan S-300V/SA-12 Giant/Gladiator engagement radars were also PESAs, all developed to engage aircraft, cruise missiles, standoff missiles and tactical ballistic missiles. All three also shared the same design approach, using a passive optical space feed and transmissive primary antenna array of phase shift elements. The Soviet designs used an elaborate monopulse feed horn arrangement, placed behind a lens assembly.⁵

A similar space feed arrangement was adopted in the Soviet X-Band 9S19 Imbir/High Screen ABM acquisition radar, developed for the S-300 V/SA-12 Giant/Gladiator system, and the Janus-faced S-Band NIIIP 5N64/64N6 Big Bird battle management radar developed for the

later S-300PM/SA-20A Gargoyle.6

Similar operational requirements drove the development of the U.S. Navy's S-Band RCA SPY-1 Aegis PESA radar, with each antenna face comprising 4096 elements, divided into 140 modules, each with 32 elements, and complex feed network of waveguides to distribute transmit and receive signals. The SPY-1A qualified as a hybrid array, with 4352 solid state receivers embedded in each antenna face, and employed eight transmitters for a total of 132 kW peak power per face.⁷

Features shared by this generation of ESA radars were the use of passive transmissive ferrite technology phase shift elements and Travelling Wave Tube (TWT) transmitter stages, often ganged to increase total peak power. Optical space feeds were preferred in weight sensitive applications such as land based missile batteries, unlike the Aegis system and lower band BMD radars, which used feed networks. Variants or derivatives of all these radars remain in operational use and production today.

The 1980s saw a second generation of ESA radars emerge, for airborne applications, leveraging experience gained by designers during the early 1970s. In the United States, Westinghouse developed the X-Band APQ-164 radar for the B-1B Lancer bomber, a PESA design derived from the EAR demonstrator, which shared a single 1,526 element aperture for ground mapping, weapon targeting and automatic terrain following waveforms, with some Low Probability of Intercept (LPI) capabilities. The APQ-64 employed a redundant pair of TWTs, and redundant receiver chains, to match the reliability of the ESA antenna.8

It was soon followed in development by the Hughes Ku-Band APQ-181 LPI PESA "covert strike radar," developed for the B-2A Spirit stealth bomber. While the APQ-181 used similar antenna technology to the APQ-164 and provided similar navigation, targeting and automatic terrain following capabilities, an additional and challenging requirement was that the structural mode Radar Cross Section of the antenna face had to be compatible with the "small bird sized" signature of the host aircraft.9 The APQ-181 demonstrated a critical advantage of ESAs over MSAs, which was compatibility with low observable applications, a key long term driver of demand for AESAs, especially in airborne applications.

While early U.S. effort in airborne ESA radar focused on bomber radars, the first Soviet airborne X-Band PESA was the 1,700 element Tikhomirov NIIP BRLS-8B Zaslon or Flash Dance pulse Doppler air intercept radar, developed for the large MiG-31 Foxhound interceptor. This aircraft had the challenging role of intercepting low flying Boeing AGM-86B cruise missiles, GD BGM-109G Gryphon ground launched and RGM-109 naval cruise missiles. The Zaslon was built to concurrently guide four long range R-33 Amos missiles against low signature targets in ground clutter, and was the first volume production ESA fitted to a fighter aircraft. An interesting feature was that an L-Band IFF interrogator PESA was embedded in the X-Band array.¹⁰

Like the first generation of surface-based ESAs, features shared by this generation of ESA radars were



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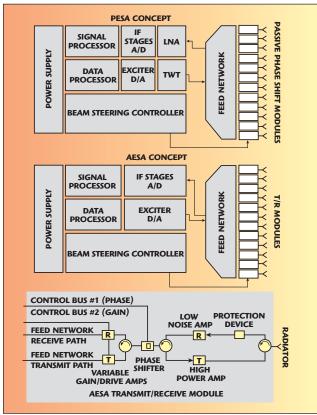


Fig. 1 Comparison of PESA and AESA designs.

the use of passive transmissive ferrite phase technology shift elements, and Travelling Wave Tube transmitter stages, but antenna feed networks were employed. typically in stacked row structures. Many ideas first employed in these radars have been since ployed in AESAs.

PESA technology continues to be used in a number of new production Russian designs, including the hybrid Tikhomirov **ESA** NIIP N011M BARS radar in the Su-30MKI/MKM Flanker H fighter, the derivative N035 Irbis E radar in the Su-35S

Flanker fighter, the Phazotron Zhuk-MFS/MFSE PESA for the Su-33 Flanker D naval fighter, the Leninets B004 multimode attack radar for the Su-34 Fullback bomber, modelled on the APQ-164, and the NIIP Ryazan GRPZ Pero PESA upgrade package for the N001VE Flanker radars. The Pero is curious insofar as it is a reflective space feed design, with an X-Band horn on a boom placed in front of the array. The technology is also used in the X-Band 9S36 engagement radar developed for the new 9K317 Buk M2/SA-17 Grizzly battlefield air defence missile system.¹¹

The 1990s saw a progressive transition in the United States and EU to AESA designs in key applications, with Russia and China now following. While the new AESAs exploited much of the technology previously developed for PESA radars, they introduced fundamentally different transmitter technology. The critical enabler was the maturation of GaAs planar monolithic processes, which permitted the production of power transistors and monolithic phase shifters. GaAs MESFETs with low noise figures (NF) for low power receiver applications were widely available 25 years ago, but AESAs did not become feasible until MMIC technology became mature enough to package the necessary volume of circuitry into Transmit-Receive Module (T/R module) volumes of sizes compatible with critical applications. That point was reached 15 years ago for L-Band and S-Band applications, and a decade ago for more challenging X-Band applications. Figure 1 shows a comparison of PESA and AESA designs, based on typical X-Band airborne radars. Whereas the PESA employs passive phase shift elements, the AESA T/R modules combine multiple MMICs to produce independently controlled receivers, transmitters and beamsteering controls, usually by phase. Figure 2 shows a Phazotron Zhuk AE X-Band Quad Module and MMIC dies, developed in 2006-2007. The Russian industry lags the United States in T/R module design, but can be expected to close the gap rapidly. Figure 3 shows an early United States quad module technology versus current single channel T/R module technology. Single channel modules permit better production yields in comparison with quad modules or multichannel "stick" designs.



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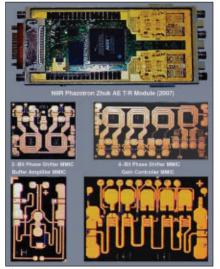


Fig. 2 Phazotron Zhuk AE X-Band quad module and MMIC chips.

At this time, AESA technology has penetrated into a number of key application areas, encompassing X-Band airborne and fire control radars, early warning and search radars between the VHF-Band and S-Band, and specialised S-Band and X-Band BMD radars. AESAs are appearing both as technology insertion upgrades into established



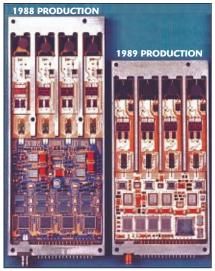


Fig. 3 Early U.S. developed quad T/R module technology.

operational radars, but also as entirely new designs displacing legacy radars.

In airborne applications for fighter and bomber aircraft, dominated by X-Band designs, the first volume production AESA was the 1,500 element Westinghouse, now Northrop-Grumman, APG-77 for F-22A Raptor. This radar was the trend setter in technology and is now in its second configuration, the APG-77(V)1 which uses common modules to the smaller 1,200 element APG-81 developed for the F-35. 12

A parallel development was the 1,100 element Raytheon APG-79, developed initially as a block upgrade to the extant APG-73 in F/A-18E/F Super Hornet, but eventually evolving into a unique design. The T/R module technology developed for the APG-79 was exploited for the subsequent APG-63(V)3 AESA upgrade to the F-15C and APG-82(V)1 AESA radar upgrade for the F-15E. Figure 4 shows the evolution of F-15 X-Band AESA radars. Early F-15 radars employed TWT driven MSA technology, exemplified by the APG (a). Some F-15Cs were later retrofitted with the early APG-63(V)2 AESA, which employed "stick" technology T/R modules (b). The most recent upgrade involves the APG-63(V)3/APG-82 configuration using single element T/R modules, based on the APG-79 design (c). The T/R module technology also migrated into a deep upgrade of the APQ-181 which, in its AESA incarnation, uses a pair of 2,000 X-Band element arrays. Northrop-Grumman concurrently developed the 1,000



Fig. 4 Evolution of the F-15 X-Band AESA radars.

element APG-80 as a block upgrade or new build design for the competing F-16 fighter, the APG-80 evolving into the Scalable Agile Beam Radar (SABR) design.¹³

While combat aircraft dominate the U.S. airborne X-Band AESA effort, the AN/ZPY-2 Multi-Platform Radar Technology Insertion Program (MP-RTIP) was launched, specifically to provide a dedicated surveillance imaging and Ground Moving Target Indicator capability, intended for the E-8 JSTARS, E-10 MC2A and RQ/MQ-4 Global Hawk. The MP-RTIP X-Band radar was intended for ISR. **Figure** 5^{14} shows a production RQ-4B Block 40 Global Hawk Remotely Piloted Vehicle, which will carry the MP-RTIP AESA under a ventral radome (a), and a prototype carried by the Scaled Composites Proteus demonstrator (b). AESA technol-



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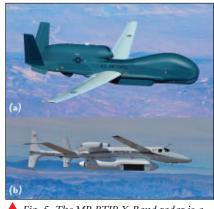
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ogy will also be central in the design of the Next Generation Jammer (NGJ) support jamming podset for the EA-18G Growler, intended to use GaN components. 15

European manufacturers lagged behind the U.S., but now offer several X-Band AESA products, including the Thales AESA RBE2 for the Dassault Rafale fighter, replacing the initial PESA design, the Euroradar Captor-E (ECR-90) for the Typhoon fighter,

and the smaller Selex Vixen 500E and 1000E AESA radars, the latter intended for Gripen NG. All designs leveraged experience gain in the collaborative Airborne Multirole Solid State Active Array Radar (AMSAR) program.16

Phazotron was the first Russian manufacturer to offer an X-Band AESA with the Zhuk AE for the MiG-35 Fulcrum fighter in 2007, soon followed by the competing Tikhomirov



▲ Fig. 5 The MP-RTIP X-Band radar is a

scalable design intended for ISR applications.

NIIP with a larger AESA for the SU-27/30 Flanker fighter, and the low observable Sukhoi T-50 PAK-FA.¹⁷

An interesting parallel development is a Tikhomirov-NIIP L-Band AESA intended for embedding in the leading edges of fighter wings and strakes, providing a dual role IFF and Counter Low Observable capability. 18

There have been no disclosures of substance on China's X-Band AESA technology, but it is known that the J-10B fighter has a radar bay shape and is sized for an APG-82 class AESA. While fighter applications are predominantly in the X-Band, the Northrop-Grumman AN/ASQ-236 AESA Radar Pod is a Ku-Band design developed specifically for precision ground mapping. 19 While X-Band AESAs for combat aircraft remain numerically dominant, AESAs penetrated into the Airborne Early Warning radar market during the 1990s. Israel's IAI/Elta developed the L-Band EL/M-2075 Phalcon on a Boeing 707-320, later selling the demonstrator to Chile. The technology evolved into the EL/W-2085 radar carried by the G550 airframe and is currently flown by Israel and Singapore.²⁰

The same technology was offered unsuccessfully to Australia in 1998 for the Wedgetail requirement, then sold to China, the order later cancelled under pressure from the Clinton Administration. Eventually India procured the system, with a three sided EL/W-2090 L-Band AESA installed inside a fixed radome, carried on a Beriev modified Ilyushin Candid airframe designated the A-50EI.²¹ Sweden has been highly successful in exporting its S-Band Érieye family of AEW&C radars, supplied to Swe-

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🛕 Fig. 6 Northrop-Grumman MESA radar.



Fig. 7 AN/TPY-2 THAAD-GBR/FBX-T

den, Brazil, Greece, Mexico, Pakistan, Thailand and the United Arab Emirates and carried on commuter sized airframes, jet or turboprop.

The only new U.S. AEW&C AESA design is the Northrop-Grumman L-Band Multi-Role Electronically Scanned Array (MESA) system, developed commercially and sold to Australia, Turkey and South Korea on the Boeing 737-600 airframe. *Figure 6* shows the Northrop-Grumman MESA radar. Operating in the L-Band, the design combines a pair of side looking arrays, with a cavity end-fire array to provide coverage over the nose and tail, in a surfboard shaped "tophat" radome. ²²

The cancellation of the Israeli order led China to initiate the development of the KJ-2000 system, which is modelled on the three sided EL/W-2090 L-Band AESA, and has been supplied to the PLA Air Force, on the Ilyushin Il-76 Candid airframe. The PLA Navy has been procuring the KJ-200, itself modelled on the Swedish Erieye design.²³

While airborne applications have been the primary target for AESA developers, niche surface based applications are seeing increasing use. One of these is acquisition and fire control radars for missile defense applications. The first of these was the Israeli L-Band Elta EL/M-2080 Green Pine, developed to support the Arrow ABM. It was soon followed by

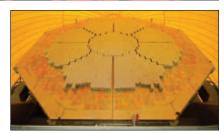


Fig. 8 The 22-meter diameter, 45,056 element SBX radar.



▲ Fig. 9 A 3,000 element four-sided THALES APAR.

the 25,344 element X-Band Raytheon AN/TPY-2 Theater High-Altitude Air Defense Ground-Based Radar/ Forward-Based X-Band - Transportable (THAAD-GBR/FBX-T) wideband AESA, (see **Figure 7**) developed as an acquisition and engagement radar for the THAAD anti-ballistic missile system. The largest and most powerful AESA in this domain is the 45,056 element Sea Based X-Band (SBX) radar, developed for the Ground-Based Interceptor (GBI) three stage exo-atmospheric ABM – the AESA antenna face is 22 meters in diameter (see Figure 8).24

X-Band acquisition and fire control radars for defending warships against sea skimming cruise missiles are another domain where AESAs have become prominent and will be central to the intended Air and Missile Defense Radar (AMDR) competition. Known examples include the Raytheon AN/SPY-3 Multi-Function Radar (MFR) developed for the Zumwalt class destroyer and Ford class carriers, the



Fig. 10 Australian CEA technologies 1,024 element CEAFAR/CEAMOUNT system developed for the ANZAC (Meko) class FFGs.

3,000 element four-sided Thales Active Phased Array multifunction Radar (APAR) deployed on the Dutch De Zeven Provinciën class FFG and German Sachsen class FFGs, (see Figure 9), and the Australian CEA Technologies 1,024 element CEA-FAR/CEAMOUNT system developed for the ANZAC (Meko) class FFGs, (see Figure 10) - all are intended to guide the RIM-162 Evolved Sea Sparrow Missile.²⁵

Search and acquisition radars are also seeing increasing use of AESA The Thales/Raytheon technology. Groundmaster series S-Band GM200 and GM400 are good examples, as was the developmental S-Band component of the Zumwalt's Dual Band Radar (DBR) system. The Chinese S-Band Type 305A/K/LLQ305A appears to be fundamentally influenced by the Thales designs.²⁶ No less interesting are the Russian Almaz-Antey/ NNIIRT 1L119 Nebo SVU and 55Zh6ME RLM-M Nebo M VHF-Band three-dimensional Counter Low Observable search and acquisition radars, (see Figure 11). The former employs 84 elements, each with 1.4 to 1.7 KW power ratings, the latter employs 168 elements, possibly of higher rating.²⁷ At this time, it is abundantly clear that AESA technology has invaded all traditional mainstream niches in military radar.

THE ADVANTAGES AND **LIMITATIONS OF ACTIVE ELECTRONICALLY STEERED ARRAYS**

There are some compelling reasons why AESAs are displacing PESA and MSA designs and will eventually relegate the latter to specialised niches.²⁸ The first and foremost is beam forming and beam steering agility which, in contemporary designs, permits chang-



Fig. 11 Russian Almaz-Antey/NNIIRT 55Zh6ME RLM-M Nebo M VHF-Band threedimensional counter low observable search and acquisition radar.

ing beam parameters at rates of up to kilohertz. This was the initial imperative in early ESA applications, as the antenna could track multiple targets with very high update rates, critical when intercepting fast targets like supersonic cruise missiles and aircraft, or re-entering warheads.

A byproduct of this agility is the ability to "timeshare," "multiplex" or "interleave" the antenna between different tasks. In fire control applications, this permits concurrent tracking of widely separated targets, or concurrent search and missile midcourse guidance or terminal guidance. In search applications, it permits the ability to concurrently perform volume searches while tracking and, in surveillance applications, the ability to interleave surface mapping and moving target detection. In combat aircraft, it offers the ability to interleave mapping, terrain following or avoidance, air target and surface target searches and data linking. A single AESA equipped multimode radar can thus replace two or more legacy single function radars.

The second critical driver is that AESAs are much more reliable than traditional radars, primarily due to the use of hundreds to thousands of independent T/R modules – the failure of even large numbers of T/R modules only degrades antenna performance. Catastrophic AESA failure only arises when a shared subsystem like a power supply or beam steering controller (BSC) fails. MSAs on the other hand are exposed to mechanical component wear out failures, and single point failures in highly electrically stressed components like TWTs, waveguides, feeds and high voltage supplies.

An important advantage of AESAs over PESAs is the ability to independently control per-element gain as well as phase. This has important impacts in several areas:

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The first is that beam forming can be more precise and different taper functions can be applied for different beams. This is most commonly used in side lobe suppression, which is a long running issue in clutter and jammer rejection, but more recently in achieving stealth, as very low side lobes reduce the probability of detection by hostile intercept or surveillance receivers. Other byproducts of this capability include the ability to make design trades between wavefront planarity in the main lobe, versus side lobe magnitude, or generate nulls within the main lobe to reject jammers.

AESAs can potentially be built with much greater bandwidth than PESAs or MSAs, facilitating Low Probability of Intercept (LPI) modes and enabling functions such as Electronic Attack (jamming) against in-band emitters. This capability is also exploited in some designs to permit the use of a radar AESA as an additional high gain antenna for a threat warning subsystem, or a data link with bandwidth potential of Gigabits/second, or LPI/covert capabilities, or both.

AESA receivers typically enjoy a 6 dB or better noise figure advantage over PESA/MSA receivers, as the loss between the antenna radiating element and first receiver stage contributes to the net noise figure or system level noise temperature. Higher power aperture AESAs also have significant potential as Directed Energy Weapons, to produce disruptive or electrical damage effects in electronically dense target systems. ²⁹ Fixed AESAs are inherently better than gimballed MSAs in terms of structural radar

cross section, which makes them inherently compatible with stealth vehicles, airborne or other.

These advantages do not come for free. Complex-

These advantages do not come for free. Complexity and development costs are higher for AESAs versus MSAs. Weight and volume can be significantly higher than MSAs. Power consumption and cooling are major issues for AESAs and have often presented "brick wall" barriers to integration in smaller platforms. Power density limitations in the semiconductor devices and T/R module level cooling architectures can set hard limits on AESA performance growth in many designs. AESAs are software intensive with rigid real-time processing demands, presenting many unique engineering challenges well outside the RF domain, with much potential for software gremlins and outright functional failures.

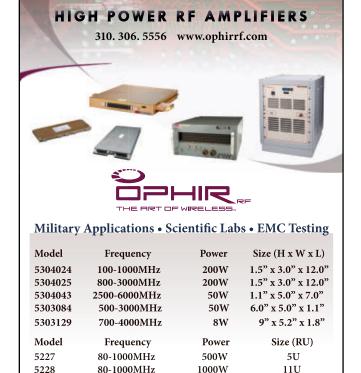
From a raw gain performance perspective, AESAs must confront the problem of aperture foreshortening for targets well off the antenna boresight, and hard limits on beam steering angles between 45° and 70°. Phase steered AESAs also suffer intrinsic bandwidth limitations arising from aperture fill and side lobe steering effects, which impact all high bandwidth demand applications, with varying severity.³⁰ In many applications, the only solution compatible with low structural RCS is the use of multiple AESA installations, incurring concomitant penalties in cost, complexity, weight, volume and cooling. Examples include the planned for but never fitted F-22A cheek arrays, or planned T-50 PAK-FA cheek arrays. AESAs are not a panacea for all microwave antenna applications, but present significant advantages in most applications, advantages which justify additional penalties incurred in using the technology.

ACTIVE ELECTRONICALLY STEERED ARRAY TECHNOLOGY TRENDS

The technology driving advances in AESA design is without doubt monolithic device technology, which determines bounds on power-aperture performance of AESAs, directly via power transistor performance and indirectly via cooling performance. The latter is also heavily impacted by packaging technology, which imposes limits on density and cooling systems.

The GaAs MMIC was the enabling technology for AESAs in the S-Band and above, and also the reason why L-Band AESAs were early entries in airborne applications as these were the least dependent on transistor f_T performance. The poor thermal performance of GaAs substrates, despite the excellent carrier mobility in the material, has been a persistent problem through much of the history of the AESA, and has been a strong imperative for the use of materials with better thermal properties, such as SiGe, or especially GaN.³¹ Packaging techniques have also evolved dramatically since the first X-Band AESA demonstrators were built. Array design theory dictates element spacing of a half wavelength or less, which presents increasing density challenges with increasing frequency. The contemporary power density benchmark is exceeding 4 W/cm² at the array face.

Early U.S. X-Band AESA designs and current Russian designs used a "stick" or "quad element" packaging design for T/R modules, with a single module containing a row or column of elements or channel in a "stick" or four in a quad. This approach presented persistent problems in



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production repeatability, as a defect in any channel required a rework of the whole stick or quad module, if that was feasible. Contemporary U.S. and EU AESAs employ a "single channel" approach where each element employs a stack of components (tile approach) normal to the antenna face. Backplane feed networks also present design challenges, especially in loss performance and bandwidth, despite the advantage versus the PESA in not

having to handle high power levels. In X-Band designs, the feed network may incur further complexity due to the need to segment the array to create multiple phase centers to accommodate dual plane monopulse tracking or GMTI displaced phase centres (DPCA).

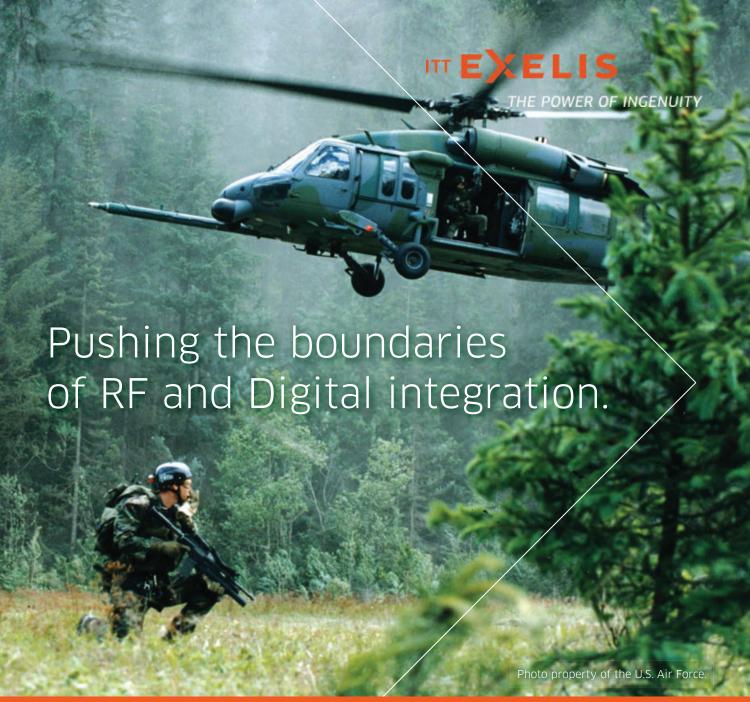
A single channel or element in an AESA must contain an LNA for the receive path, a power amplifier, a phase shifter, impedance matched low insertion loss interconnections, gain control blocks, RF buffer amplifiers if required, as well as the digital circuits and control logic required to latch downloaded gain and phase parameters into the T/R module phase shifter and gain control components. Modern AESA T/R modules will also include circuits for health monitoring and Built-In-Test (BIT), and calibration.

Heat from semiconductor components in the T/R module must be conducted out of the module and carried out of the antenna using a cooling system. X-Band AESAs typically employ a Poly-Alpha-Olefin coolant, dumping heat into aircraft fuel, or via a heat exchanger into surrounding air.

In assessing futures for AESA technology, advanced RF device materials and processes will comprise one part of the equation and exponentially growing density in photolithographically fabricated digital components is the other part. Brookner has recently identified the following benchmarks and trends in device and materials technology:³²

- Arrays using micro-electromechanical systems (MEMS) phase shifters
- Low cost 24 GHz phased-array car radars driving down T/R module costs through volume
- Extreme MMIC circuitry for 8 to 32 element arrays on single SiGe/ BiCMOS chips
- GaN technology offering tenfold higher power and higher efficiency, permitting >1000 W peak power with single transistor packages
- Low cost Silicon based SiGe single chip
- Purdue University low-cost S-Band two panel GaN Digital Array Radar having 700 MHz bandwidth, 25 W per element peak; gets wide angle scan through use of electromagnetic band gap (EBG) material for increased isolation between antenna elements (lower mutual coupling); has potential of eliminating circulator
- Arrays with instantaneous bandwidths of 10:1 up to 33:1
- 20 dB increased receiver dynamic range through improved A/D linearity and reduced intermodulation
- Exploitation of meta-materials in passive antenna components
- 3D micromachining technology for interconnections







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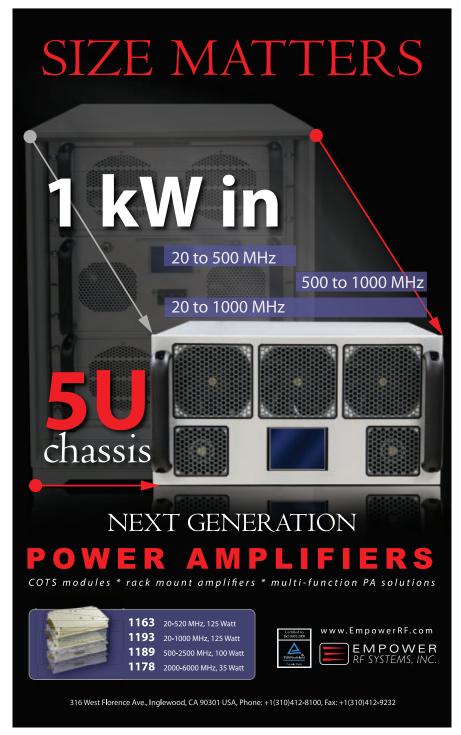
Exponential density growth is a well documented feature of the digital landscape, but is less prominent in RF components, due to the encumbrances of impedance matching and need for analogue components.³³ Growth, especially in parallel processing computer hardware, will impact radar across all categories, by providing abundant capability to perform floating point arithmetic. Current General Purpose Graph-

ics Processing Unit (GPGPU) chips have internal memory bandwidths in excess of 100 Gigabytes/sec and often in excess of 500 pipelined floating point optimized processing cores in a single chip. Density growth in this technology will yield larger numbers of cores and higher memory bandwidths, enabling signal and data processing algorithms which are currently computationally infeasible in realtime applications.

In conclusion, continuing advances in MMIC materials and fabrication technologies, advancing packaging technology and exponential growth in digital circuits open many possibilities for future AESA designs. ■

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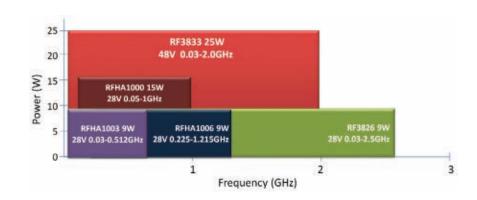
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0. 20								
Freq Range (Min) (MHz)	Freq Range (Max) (MHz)	Gain (dB)	OP3dB (dBm)	Power Added Efficiency (%)	V _D (V)	I _D (mA)	Package	Part Number
() ()	(11142)	(42)	(==)	(75)	(-)	(11111)	go	
30	2500	11.0	39.0	40.0	28	55	AIN SOIC-8	RF3826
30	2000	13.0	43.0	45.0	48	88	RF270-10	RF3833
50	1000	16.0	41.3	53.0	28	88	AIN SOIC-8	RFHA1000
30	512	18.5	39.5	70.0	28	55	AIN SOIC-8	RFHA1003
225	1215	16.6	39.4	62.5	28	88	AIN SOIC-8	RFHA1006

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Carlo Kopp is an academic at Monash University in Australia and also a co-founder of the independent Air Power Australia military think tank. Kopp completed his PhD at Monash University in 2000, his dissertation dealing with the adaptation of AESAs for Gigabit datalinking and networking. Prior to his academic career, he spent 15 years in industry, mostly as a design engineer, with design experience in ECL logic, high speed analog circuits, optical receivers, high speed logic, SPARC processor boards, graphics adaptors, cooling systems, embedded software and operating systems. Kopp has also actively published as a defence analyst since 1980, with over 650 publications in related areas, including a contribution to the third edition of Skolnik's Radar Handbook.



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SSHPS 2.7-2.9-1000	2.7-2.9 GHz	100 Watts	1000 Watts	0.8 dB	40 dB	1.7:1	4 µsec	3.5 x 3.5 x 1.0 inches
SSHPS 2.9-3.1-1000	2.9-3.1 GHz	100 Watts	1000 Watts	0.8 dB	40 dB	1.8:1	4 µsec	3.5 x 3.5 x 1.0 inches
SSHPS 2.7-3.5-1000	2.7-3.5 Ghz	50 Watts	1000 Watts	0.9 dB	40 dB	2.0:1	4 µsec	3.5 x 3.5 x 1.0 inches
SSHPS 0.020-1.000-200	20-1000 MHz	200 Watts	1500 Watts	0.7 d8	25 dB	2.0:1	5 µsec	3.0 x 3.0 x 1.0 inches
SSHPS 0.225-0.450-400	225-450 MHz	400 Watts	2000 Watts	0.7 dB	40 dB	2.0:1	5 µsec	3.0 x 3.0 x 1.0 inches
SSHPS 1.0-2.5-200	1000-2500 MHz	200 Watts	1000 Watts	0.9 dB	25 dB	1.5:1	4 µsec	4.0 x 6.0 x 1.3 inches

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Reducing the Cost of SIGINT ISR Test

development and upgrade of SIGINT ISR platforms is a time consuming and costly endeavor that must balance two somewhat conflicting requirements. On one end, the mission critical nature of a deployed system maximizes the importance of fielding a proven system, often creating a preference for existing systems that have been successful in the past. On the other end, the need to address rapidly evolving threats, many of which are based on quickly changing commercial technology, requires that a SIGINT ISR system must incorporate enough state-of-the-art functionality to adjust to new requirements. Exacerbating this challenge is the difficulty of testing ISR systems during development and integration. The final success of a SIGINT ISR solution is completely dependent on how it performs when deployed under real world conditions where the RF spectrum is increasingly crowded. As a result, the developer and/or buyer are often forced to rely on fully testing systems only once they are installed on the target platform.

While Field Tests have the benefit of replicating in-service conditions, complete control of the RF spectrum during flight is not possible. SIGINT ISR systems are tasked to operate against many environments including terrestrial point-to-point communication, SATCOM, wireless networks and a wide variety of commercial and military systems. Frequency reuse results in a densely overlapped spectrum when viewed from an ISR platform. Spectrum efficiency and interference mitiga-

tion have led to complexity of waveforms that are difficult to collect and decipher even when they are clearly received by ISR systems. The variety of transmitters and power levels as well as density leads to very high dynamic range requirements. A further complication is that most ISR platforms operate transmitters that are in-band with desired collection. With the variety of possible end-use environments and the expense and time required for testing on the target platform, Field Testing is best reserved for systems that have already been thoroughly tested against realistic collection environments representing multiple potential scenarios.

A-T Solutions, in collaboration with National Instruments (NI), has demonstrated the ability of a modular commercial-off-the-shelf (COTS) platform to generate realistic, complex test scenarios with signals that reflect relative motion, spectral overlap, frequency and time offset. This system can be used in a laboratory environment, in-lieu of field test installed on a platform. This article will briefly discuss the forces in the commercial sector that are driving applicable capability in COTS test equipment, the architecture of the COTS instrumentation selected and the results of the collaboration to produce a realistic SIGINT ISR collection environment codenamed LoBSTER (Low-Band System Test and Evaluation in Real-time).

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A TEST ENVIRONMENT THAT BENEFITS FROM ADVANCES IN COMMERCIAL TECHNOLOGY

At the end of 2011, the number of wireless mobile subscriptions in the world had exceeded 5.9 billion. Approximately 1.2 billion of these connections are capable of accessing third generation (3G) networks and the increased data rates and functionality they provide.1 The constant evolution of the use of wireless spectrum as methods of communication, whether it be voice, video, data, emergency information or command and control, is driving tremendous investment by commercial industry to create an infrastructure capable of supporting development of new wireless devices.

In test, this has translated to the need to provide new test methodologies and system architectures that enable faster product development cycles from concept to reliable product – meeting the requirements that are driven by current wireless standards but with the capability to quickly adapt to new technology. Over the last few years, this has resulted in various trends driving modern wireless test systems. Two of the most relevant trends in reducing the cost of testing SIGINT ISR systems are the development of modular instrumentation platforms based on COTS technology software-defined instrumenta-

Modular Instrumentation Based on COTS Technology

By modularizing the key functional blocks of traditional instrumentation, modular instrumentation platforms are built to take advantage of the rapid advancement of COTS technology in various functional areas.

 Processing elements – integration of different computational elements (heterogeneous computing) allows for the tasks comprising wireless test applications to be executed on the element offering best performance. General Purpose Processors (GPP), field-programmable gate arrays (FPGA), Graphical Processing Units (GPU) and digital signal processors (DSP) continue to be driven by Moore's law, offering increasing computational horsepower.

 Bus technologies – high speed point-to-point interconnects offering guaranteed bandwidth and deterministic latency. Modern instrumentation buses, such as PXI Express, enable individual modules to transfer data at rates of GBs/sec.

 Baseband elements – A/D and D/A components continue to evolve, enabling wider bandwidths and increasing dynamic range.

RF front ends – multiple implementations from super-heterodyne to wideband homodyne architectures provide options for maximizing RF performance in different areas. Separate local oscillators (LO) ease frequency/tuning constraints and enable phase synchronous, multi-channel systems.

One such modular instrumentation standard is PXI. *Figure 1* shows an example of a high level block diagram of a modular RF vector signal generator in a PXI chassis with an embedded host computer, programmable FPGA module and external RAID storage interface. The RF signal generator itself is broken into three separate modules: an IO modulator that translates an RF signal from baseband to RF, an arbitrary waveform generator that drives the IQ modulator with a user-defined waveform and an LO module. The other modules in the system provide shared resources for the RF generator to use, such as the display connected to the embedded controller or the massive storage available in the external RAID system, or additional resources to expand the functionality of the generator, such as the FPGA

module adding realtime processing to create waveforms on the fly. The modular nature of the platform allows for test systems to be easily reconfigured for additional channels of RF generation, greater computational power for embedded processing and larger data storage while maintaining the original investment.

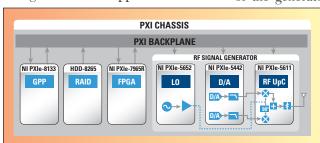
Software-Defined Instrumentation

Test environments are moving from closed, fixed capability to open, software-defined functionality. This has been driven by the need to test increasingly complex devices that are themselves defined more and more by software. Software-defined instrumentation allows a test environment to become a dynamic system that adopts functionality defined by the user.

In the context of wireless test, the ability to embed user-created software into the instrumentation platform provides the capability to reuse work done in the design stage of a wireless product or standard. During the development phase of new wireless standards, comprehensive simulation is done to determine how a receiver will perform under deployed conditions. Models are created for the protocol, the physical layer and the actual environment. Software-defined instrumentation provides a methodology to move these models from the simulation domain to hardware to generate and receive physical signals. Final functionality could include custom measurements, generation of RF signals previously recorded or generated from off-line modeling, and/or implementation of a full software defined radio or complex channel model to simulate a deployment environment in real time.

An important consideration with software-defined instrumentation is the potential complexity of programming the different elements within the system. A software environment/tool chain that simplifies the integration of hardware with abstraction, supports heterogeneous computing with a common programming paradigm for the different computational elements and is compatible with models generated from other languages and tools, is critical.

An ideal way to address this challenge is by using the graphical system design approach, which provides an integrated software and hardware platform that scales across design, simulation, deployment and test, from desktop to embedded systems. An example is NI LabVIEW system design



▲ Fig. 1 Example of a modular RF instrumentation system.



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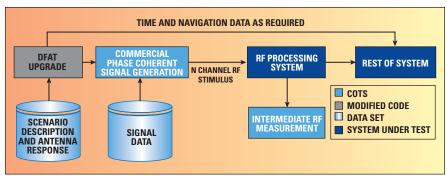
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software, which is the heart of the graphical system design approach, as it uses a graphical dataflow language to abstract hardware control functions. This unified abstraction combines user interfaces, models of computation, math and analysis, input/output signals, technology abstractions, and various deployment targets to greatly simplify any system.

ARCHITECTURE OF SIGINT ISR TEST PLATFORM (LoBSTER)

A-T Solutions' LoBSTER is designed for test and integration of complex ISR systems, providing multiple channels of RF stimulus conditioned to replicate the signal normally received at the antennas of the system(s) under test (SUT). Input to more than one collection platform can also be provided. The RF stimulus to the SUT is based on a scenario that describes the movement of collection platforms and the location and activity of emitters. Scenario time and navigation data are provided to the SUT as well as the ability to monitor and record their RF processing. Emitter signals can be defined strictly from simulation or can incorporate previously recorded signals. Output signals are individually adjusted for collection platform motion, propagation conditions, collection antenna patterns, angle of arrival at collection platform, and collection platform separation. LoBSTER provides up to eight coherent channels of RF stimulus with precise control of scenario signals. The overall architecture is given in *Figure 2*.

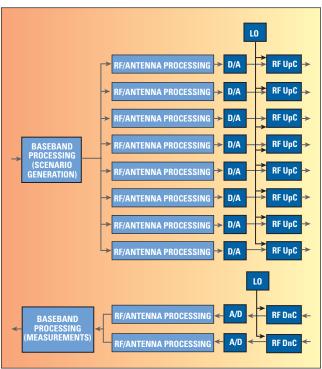
In order to generate an accurate representation of a realistic SIGINT ISR collection environment, multiple channels of phase-synchronous



▲ Fig. 2 LoBSTER system architecture.

RF generation with tight specifications on relative channelto-channel phase, amplitude and frequency accuracy are required. Using the modular nature of the RF signal generator in Figure 1, LoBSTER consists of up to eight channels of RF upconverters and ARBs driven by a shared LO. Each channel provides up to 100 MHz of generated bandwidth. The RF/antenna signal processing and hardware control necessary to align the channels and precise maintain phase, amplitude and frequency lev-

els is done in on-board FPGAs in the instrument modules. With a shared LO driving all upconverter stages and the PXI backplane driving the sample clocks for the digital-to-analog con-



▲ Fig. 3 COTS RF subsystem.

verters, normal contributors to inaccuracy, such as phase noise from the reference clock, affect each channel equally and therefore cancel out when examining relative channel-to-channel values. Along with the RF signal generation, LoBSTER adds two channels of coherent RF signal acquisition to monitor and record the RF processing done by the SUT. *Figure 3* illustrates the high-level diagram of the RF generation and signal processing elements.

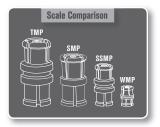
Performance values are derived from analysis of the phenomena to be modeled. The fundamental goal is to create a stimulus environment that will be good enough so that simulated signals will evaluate the performance of the SUT without simulation artifacts becoming a controlling factor in SUT performance assessment. *Table 1*

tipic chaim	tiple charmers of phase-synchronous clocks for the digital-to-analog con-						
TABLE I SUT PLATFORM EXAMPLES							
Collection Platform Example	Nominal V (Km/ second)	Nominal Target Range (Km)	Maximum Observation Angle Rate (degrees/ second)	Δτ (second)	$rac{\Delta \phi}{m{(degrees)}}$	Δω (Hz) @ 50 MHz (Hz)	
Low Altitude UAV @ 100 NM/hour	0.051	10	0.29	1.7×10 ⁻¹²	0.011	1.30×10 ⁻⁶	
Med Altitude Turbo Prop at 150 NM/hour	0.077	12	0.37	2.56×10 ⁻¹²	0.015	1.66× 10 ⁻⁶	
Business Jet at 300 NM/hour	0.154	25	0.35	5.13×10 ⁻¹²	0.014	1.57×10-6	

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TABLE II COTS TEST SYSTEM REQUIREMENTS						
Parameter	Adjustment Range	Precision	Accuracy			
Channel to Channel Phase Offset	0 to 360 Degrees	0.01 degree	0.1 RMS			
Received Signal Waveform Strength Channel to Channel	Noise floor to +5 dBM	0.1 dB	0.5 dB RMS			
Collector to Collector Time Delay (Narrowband)	0 to 100's of μseconds	2 ps	5 ps RMS			
Collector Frequency Offset (Narrow Band)	Determined by Radial Velocity Difference	Interpolation Limit ~.001 PPM	0.1 PPM RMS of Settling Frequency			

TABLE III						
TARGET EMITTER DESCRIPTIONS						
Emitter 1	Lat=34.639 deg Lon=118.088 deg Alt = 2401 ft. Signal amplitude = 0.35 Baseband RF = -383000 kHz Stepped frequency modulated signal Az = 153.3 deg and El = 93.4 deg during time of interest					
Emitter 2	Lat=37.266 deg Lon=117.010 deg Alt = 1200 ft. Signal amplitude = 0.25 Baseband RF = -225000 kHz Stepped frequency modulated signal Az = 175.6 deg and El = 93.2 deg during time of interest					
Emitter 3	Lat=34.736 deg Lon=114.390 deg Alt = 500 ft. Signal amplitude = 0.3 Baseband RF = -800000 kHz Stepped frequency modulated signal Az = 221.7 deg and El = 93.05 deg during time of interest					

shows incremental changes for selected conditions that are comparable to peak value of real collection scenarios, with the delta change assessed at 10 millisecond intervals.

This assessment is made at the point of maximum rate of change for the indi-

cated range and velocity. Using simple stimulus signals, the ability of the COTS RF signal generation hardware to meet the listed accuracies was validated. Derived COTS test system requirements for simulating these real world effects are shown in *Table 2*.

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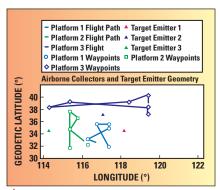
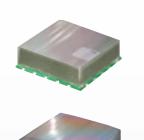


Fig. 4 Test scenario geometry.

RECREATING THE ENVIRONMENT

To validate the ability of the final test system to accurately reproduce flight scenarios, a scenario with three airborne ISR systems collecting multiple emitters is created. The scenario is illustrated in *Figure 4*, with the target emitter characteristics defined in *Table 3*.

The COTS test system, shown in Figure 3, was used to generate the RF signals from the defined scenario and the output was recorded with a multi-channel, phase-aligned RF measurement system. The results were compared with the original models. Figure 5 displays the spectrum of the simulated data versus the baseband recovered from the actual RF generated from the test system. The blue signals are the original baseband spectra, and the red spectra are the recovered baseband. As will be noted, the spectra are essentially indistinguishable.



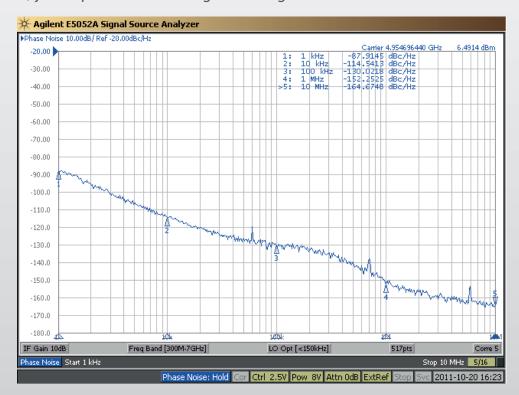






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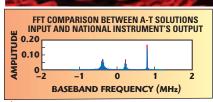
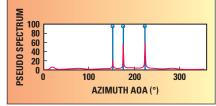


Fig. 5 Spectrum comparison: simulated versus generated RF.

To validate that the phase relationships remained consistent between the original models and the generated RF, the MUSIC algorithm² was applied to the four input channels for platform 1 defined in the scenario shown. Figure 6 depicts the pseudo spectrum which results from covariance and eigenvector analysis of the four channels of baseband data collected by platform 1. This shows three peaks of amplitude when plotted against the 360° range of angles of arrival around the collection platform. In Figure 6, the vertical blues represent the azimuth angle of arrival at platform 1 with pseudo spectrum plotted in red.

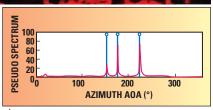
Figure 7 depicts the results of applying the same analysis to the recovered spectrum after RF conversion.



▲ Fig. 6 Angle of arrival simulated data.

As can be observed, the recovered angle of arrival and pseudo spectrum are essentially identical to that derived from the original simulated baseband. Further analyses included placing a beam former on the signal at 176° and recovering the spectrum. The desired spectrum was isolated and validated to be as simulated.

The key functionality of LoBSTER is based on the software Direction Finding Analysis Toolset (DFAT) which provides the key software components to compute incident angles and antenna responses to received signals, so that the SUT receives RF stimulus as though it were from system antennas. LoBSTER also uses the extensive library of geo location modeling codes and scenario simulation to address time offset, frequency shift



🛕 Fig. 7 Angle of arrival generated RF.

and channel-to-channel phase offset. *Table 4* gives some examples of these.

The signal generator is aligned to the first channel of the suite. This uses the embedded firmware to control the output waveforms, which achieves the necessary adjustment range accuracy and precision as shown. Because the scenario explicitly controls the waveforms, LoBSTER can provide signal environments that are difficult if not impossible to replicate during flight test. These signal environments can be merged with RF signals recorded off air or modeled on platform transmitter output, as desired, to provide a representative RF environment to SUT.

CONCLUSION

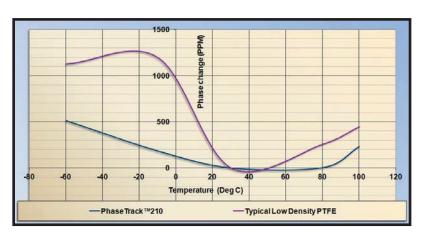
This ability to recreate a realistic SIGINT ISR collection environment



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TABLE IV						
EXAMPLE LoBSTER MODELING EFFECTS						
Emission Effects	Method					
Doppler Frequency Shift	Based on each SUT velocity and direction relative to each emitter	$f_0^*(1$ - $^{v_{emitter}}/C)$				
Time of Arrival	Based on SUT position relative to each emitter	$\tau = \tau_0 + (Emitter_{location} - SUT Antenna_{location})/C$				
Signal Amplitude	Controlled by scenario, adjusted for propagation loss and receive antenna pattern	$A = A_0 - 10 log (4\pi D/\lambda)^2$ + Antenna Pattern at (az, el, and frequency) ³				
Signal Phase for each Coherent Channel	Determined by distance from scenario emitter to each SUT antenna, azimuth and elevation of incident wave front modified by receive antenna response	Reflects pitch, roll, yaw of SUT platform, and offset from SUT location to each receive antenna location				
Signal On/Off Time Duration and Content	Specified in scenario					
Channel Effects – Fading, etc.	Available models					

in the laboratory can be used throughout system development, integration and verification. With more complete test coverage of real world conditions before Field Test, ISR development schedules are not tied to deployment platform availability and, when ready, the SUT can be installed on the target platform and proceed to operational verification with high confidence against real world environments. The ability of a COTS test environment to evolve efficiently with new technology driven by the commercial sector enables testing future requirements and provides support for ISR system updates, problem resolution, and similar activities over its lifecycle.

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Dave Giles holds a bachelor's degree from Stanford University, advanced studies and a Juris Doctorate from Santa Clara University. Giles has lead the development of several systems and provided engineering to multiple system developments during his career of more than 40 years in ISR, including software, system design, analysis, and field support. As the lead SIGINT System Engineer for A-T Solutions Colorado office, he leads the development of ISR tools for A-T Solutions

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Emulation Provides a Cost-Effective Strategy for Replacing Obsolete Instruments in ATEs

ypically, test systems used in aerospace and defense applications have a lifespan of 25 years or more – far longer than the lifespans of the individual measurement instruments that comprise the system. Replacing obsolete instruments can have major negative consequences for the deployed test program set (TPS) and for the maintenance, calibration and repair costs of Automated Test Equipment (ATE). However, by employing instrumentation with a sophisticated emulation strategy, the new test instruments can be successfully integrated, using a less expensive, more efficient migration path. For example, modern T&M

▲ Fig. 1 Instruments such as the R&S SMA100A can be controlled by commands other than the built-in SCPI commands.

instruments can be controlled by commands other than the built-in native SCPI commands. As shown in *Figure 1*, users can replace legacy signal generators in a test system without having to change the remote control code.

BILLIONS AT STAKE

Between 1980 and 1992, the U.S. Department of Defense spent over \$50 billion on ATS procurement. During this period, the standard practice was to develop a unique ATS or ATE to support a single military system, which resulted in a proliferation of hard-to-maintain test systems. Solving the problem of test equipment obsolescence is both difficult and necessary, because the cost of system ownership is greatly influenced by ATE calibration and repair costs and by the current maintenance procedure for TPSs. There is also an increasing risk of replacement parts becoming unavailable and of calibration and repair capabilities eroding during the system's lifetime once the instrument is no longer supported by the vendor.

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EMULATING OBSOLETE DEVICES

Test program sets used in ATE systems are generally certified, which makes it very time-consuming and costly to modify and reapprove them when an obsolete instrument is replaced. Replacement also triggers software modifications – and the cost of a TPS rewrite almost always exceeds the cost of instrument replacement. It is therefore very cost effective to manage instrument replacements without changing the existing TPSs. An attractive migration strategy is to deploy new measuring instruments that emulate the discontinued instruments. This approach saves time and is cost-effective but not trivial. The requirements for the new instruments are determined by the test programs themselves and by the electrical and functional features of the instruments to be emulated.

DIFFERENT STRATEGIES

There are three basic approaches to solving the obsolescence problem: ATEs can be maintained, modernized, or upgraded. The appropriate choice depends on remaining ATE system life and on cost. Maintaining an existing ATE by repairing its instrumentation has lower costs and is relatively simple, but is limited to the number of years the legacy instruments are available. Benefits are zero or few changes to hardware and software and minimal capital expense. Problems are the limited time span, higher downtime and the increased risk when the product is no longer supported.

Modernizing or replacing the entire ATE solves the code compatibility issue, but also has much higher costs and usually can be done only during major program updates or extensions. Advantages include greater reliability, faster tests and extended life. On the other hand, this approach requires major changes to hardware and TPS, which lead to higher complexity, compatibility issues, higher risk and high costs.

Upgrading the ATE with modern instruments is a middle way that has the potential to create modern systems at a reasonable cost. However, it requires that the line replaceable units (LRU), or units under test (UUT), give the same response when stimulated with the replacement instrument as they did with the legacy instrument. In other words, the replacement has to be done with codecompatible instruments.

ACHIEVING CODE COMPATIBILITY

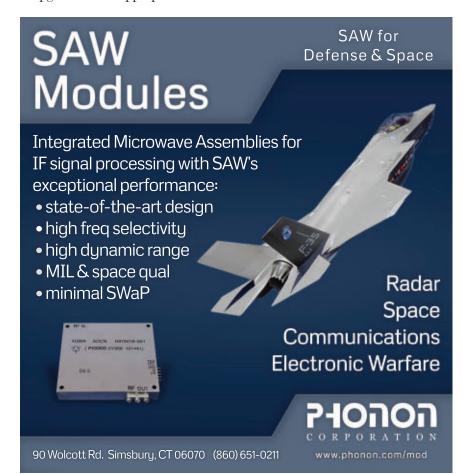
Usually, replacing legacy instruments with new instruments that emulate them exactly requires the same hardware interface (GPIB) used by the existing test system. It also requires adopting the existing command language (such as for frequency and measurement range setting, dynamic range setting and noise level setting for the replacement instruments). Fortunately, the Standard Commands for Programmable Instruments Standard (SCPI) has significantly reduced the problem of interchangeability. Footprint in most cases is not a problem because modern instruments tend to be smaller in size and have lower power consumption.

Faster testing (increased throughput, higher yield) may also be possible because the replacement instruments deliver higher accuracy and speed and this can lead to higher margins for the DUTs. Other benefits include minimal hardware and software changes, greater reliability and reduced cost of ownership.

Since the late 1990s, remote control of instrumentation has been based on the common SCPI standard. Before that, legacy instruments used vendor-specific command sets that had their own syntax and semantics. To make these instruments compatible with earlier generations at a minimum requires switching from the SCPI parser to a parser for the legacy commands that understands the old syntax. But just translating the legacy commands into SCPI is not enough. The right emulation mode has to be activated first, as well as the selection of the emulated instrument model. (Although most of the legacy instruments share a common set of remote commands, each model may respond to the commands quite differently.)

GETTING INTO EMULATION MODE

Activating emulation mode includes selecting the particular model of in-





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CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7-3.1 GHz
CT-1645-N	250 W Satcom	N Conn.	240-320 MHz
CT-1739-D	20 Kw Pk 1 Kw Av	DIN 7/16	128 MHz Medical

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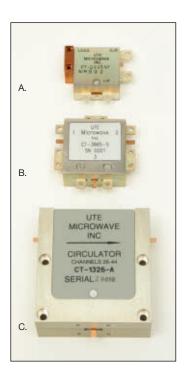
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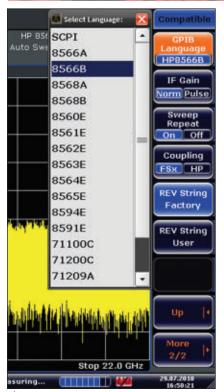
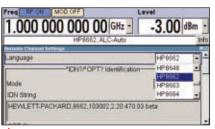


Fig. 2 Emulation mode: Selection of legacy signal analyzers to be emulated by the R&S FSV.

strument to be emulated. Instruments from an earlier family might have a common set of legacy commands but they can show considerable differences in many areas. Activating emulation mode includes selecting the particular model of instrument to be emulated. *Figure 2* shows the selection of legacy signal analyzers to be emulated



▲ Fig. 3 Emulation mode: Sample selection of a legacy signal generator to be emulated – example shown here is the R&S SMA 100A.

by the R&S FSV as an example. Figure 3 shows the sample selection of a legacy signal generator to be emulated by the R&S SMA100A and Figure 4 shows that power meters like the R&S NRP2 are often used in automated test applications. The remote emulation feature allows the user to control the R&S NPR2 by using the exact same commands that were implemented in the original instrument.

It is also very important for the emulation to function in both directions. Besides being able to understand and be capable of processing incoming commands, the new instruments must also deliver responses such as measurement or query results to the control program that are compatible with the emulated instrument.

In addition, activation of the emulation mode enables proper adaptation to the different preset settings of the instruments to be emulated (That is, for a spectrum analyzer: span, start and stop frequency, number of trace



Fig. 4 Power meters like the R&S NRP2 are often used in automated test applications.

points, reference level and bandwidth coupling).

Activation of emulation mode (or native mode) can also be handled automatically by means of a control command. This makes it possible for new control programs to take advantage of the features provided by state-of-the-art instruments, in addition to their emulation capabilities.

ID STRING EMULATION AND RESPONSE FORMATS

To address different members of the same instrument family, simply editing the ID string is often sufficient. For a valid ID string emulation, the response to a query for an instrument ID must match the original. ID strings should also be editable manually. In addition, preset settings need to be adjusted to match the legacy instrument.

Properly formatted instrument responses to queries by the control program are essential for proper emu-





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CHANGING THE STANDARDS

lation of previous instruments, along with identical formatting of all parameters (integer, float, ASCII strings) and an identical number of characters. When querying trace data from a spectrum analyzer, it is particularly important for the different query formats of previous instruments to be implemented to result in correct emulation. For example, legacy analyzers provide different formats for reading out trace data.

SERVICE REQUESTS AND STATUS REPORTING

Service requests are messages the instrument sends to the controller when specific conditions or events occur that require a response by the controller. An example would be a message indicating that the analyzer has completed a sweep. The controller analyzes the different events and status messages using status byte queries.

Service requests and status reporting present a tricky emulation problem. Although they are defined in the IEEE488.2 standard, legacy instruments implemented this functionality only partially and with different behaviors. Since the requirement is an identical response to service request, not only the status bits of the legacy instrument must be emulated, the behavior of the status bit combinations generated by the legacy instrument has to be emulated also. The responses of the status reporting (service requests) must be simulated as precisely as possible, including the response times and the related assignment of the status registers.



Sometimes a problem arises due to the different functional feature sets of the legacy instrument and the new instrument. The challenge is to replace a legacy instrument such as HP8340B by a new instrument, when the feature set of the legacy instrument is not a true subset of the new instrument. Normally, an emulation would implement the overlapping functions, but not those functions available in the newer instrument. This can lead to faults. The reason is that very often, during the initialization of the application, the legacy instrument calls for a function, which is not available in the new instrument and which is never needed during the rest of the application.

The following example illustrates this problem: The HP8340B, for instance, sends the command "PD0" to disable the pulse modulation in an application where no pulse modulation is needed. If the legacy instrument is replaced by an R&S SMB100A, for example, without a pulse modulation option, this command leads to an error message and possibly to a malfunction of the application. One solution is to implement the unavailable functions as "dummies" for the emulation. This means that set-up commands will be absorbed and polling commands will be answered with

default values.

HARDWARE AND TIMING ISSUES

In today's instruments, signal processing is fully digital. This means that





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the analog design of legacy instruments must be carefully taken into account, particularly with respect to timing, filters and level aspect. For example, reference level differences between modern and legacy spectrum analyzers can be adjusted with internal mixer levels. Emulation with digital filters must fit the shape factor of the analog filters in legacy instruments.

Modern instruments, such as analyzers, signal generators or power meters, are much faster than legacy instruments. In most cases, this is not an issue and even leads to better throughput. On the other hand, calibration and self-alignment may take much longer in modern instruments because it takes a larger number of correction steps to achieve higher accuracy. In this case, the solution is to reduce alignment to only a part of the procedure in emulation mode. Another problem on command execution may occur if test programs are not properly synchronized.

CONCLUSION

Many ATEs in use today are facing obsolescence problems in the short or mid-range term. Since modern instruments can now emulate legacy instruments and achieve code compatibility in many cases without modifications to the TPSs, migrating to the new generation of instrumentation makes it a strategy worth considering to keep system readiness at the highest level. Backward compatibility requires both command compatibility and true functional/behavioral compatibility. The advanced spectrum analyzers, network analyzers, signal generators, power meters and audio analyzers from test and measurement companies like Rohde & Schwarz and others offer built-in emulation to ensure the highest possible code compatibility. For example, the R&S Legacy Pro concept makes it feasible to use the migration approach in test systems, if desired, and replace obsolete measuring instruments. In many applications, it is possible to continue using existing control programs without any modifications.

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Jochen Wolle studied electrical engineering at the Technical Universities of Darmstadt and Munich before joining Rohde & Schwarz GmbH & Co. KG in Munich, where he is engaged in the development of T&M equipment. He is head of software development for spectrum and network analyzers, oscilloscopes and EMI test receivers.

Rainer Lenz studied electrical engineering at the University of Karlsruhe (TH) where he received his Dipl.-Ing. degree and PhD. After his studies, he worked for several years in RF engineering and in system engineering. In 2012, he joined Rohde & Schwarz GmbH & Co. KG in Munich as product manager for signal generators and power meters.



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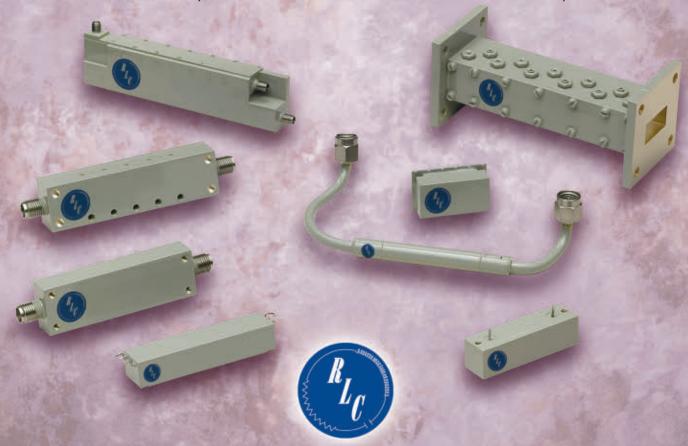
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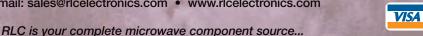
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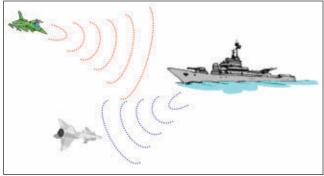


The Ins and Outs of Microwave Signal Capture and Playback

he capture and playback of microwave signals has a multitude of applications in the evaluation of communications, radar and electronic warfare systems. The stimulus and analysis requirements of system level testing differs from the functional testing of the various sub-systems, boards and components that make up the system for a number of reasons. For instance, these types of systems are becoming increasingly multi-role and multi-mode in nature, perhaps even perform-

ing multiple functions at the same time. The systems will need to automatically reconfigure themselves depending on the stimulus at one or more of their sensor ports. So, a benign or static test stimulus that may be sufficient to verify a lower level subsystem will not be sufficient to fully exercise the dynamic operation of the full system under all or even a few of its operating conditions.

To provide an environment adequate for functional evaluation of the system, the test stimulus must be long and unique – in other words, a complete, non-repetitive scenario. The issue is that these systems may internally operate in the realm of microwave frequencies and nanoseconds of time, but the environment in which the system lives is governed by real world events that can take seconds, minutes or even hours to unfold. In order to analyze or generate the scenario, the signal must be captured and/or played back at a sample rate that can recreate the highest frequency element



▲ Fig. 1 The reflected waveform is unique and changing at the receiver antenna during the entire flight.

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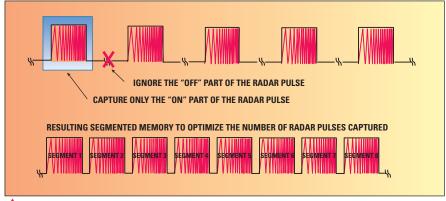


Fig. 2 Segmented capture of a long pulse train.

(usually the carrier) and the slowest changing or rarest event the system encounters.

For example, consider the flight of a radar guided missile as illustrated in **Figure 1**. The signal at the receiver of the missile will be constantly changing from the time it is launched to the time it reaches its target. It may begin in a bi-static mode, where the radar signal is transmitted at a certain frequency from the launching platform, like a fighter jet. During the flight, the missile and target will be accelerating or decelerating, putting a Doppler frequency shift on the carrier at a relatively low rate of change. The Radar Cross Section (RCS) changes constantly as the relative position of the missile and target changes. As the missile approaches the target, the pulses become more closely spaced. The mode of the radar may change to maintain optimal tracking of the target through changes in the pulse repetition frequency (PRF) and pattern. There will probably be an attempt to jam the signal. Finally, the radar seeker in the missile may take over at a different carrier frequency and PRF.

This requires a very deep memory in order to store all the samples need-

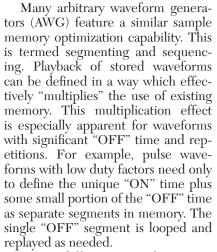
ed to capture or playback this type of scenario. For instance, if the radar operates in X-Band at 10 GHz, a sample rate of approximately 25 GS/s (GigaSamples per second) will be required (Nyquist frequency plus some margin) to accurately capture the signal. For the discussion here, a sample consists of a 32-bit I and Q sample pair. So a memory depth of 2 GS will only hold 80 ms of data at this rate. Fortunately, there are methods for optimizing the use of memory during capture and playback.

SEGMENTING AND SEQUENCING FOR CAPTURE AND PLAYBACK

When performing measurements on pulsed radar signals, capture and analysis of a large number of pulses is often required. For example, the Agilent 90000X oscilloscope has a deep capture depth of 2 GS. This is the same depth that was used in the example above. The amount of data in terms of time, of course, depends on the sample rate selected.

Segmented memory can further optimize the number of radar pulses that can be captured and analyzed with the available oscilloscope memory. Essentially, it enables the user to

zoom in on a pulse and capture only the "ON" portion of the pulse, while ignoring the "OFF" portion of the pulse as illustrated in *Figure* 2. This helps to optimize memory usage and maximizes the number of pulses that can be captured with the 2 GS of physical memory.

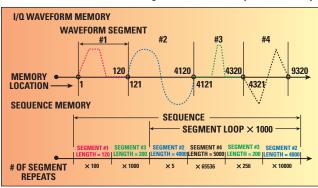


Many different waveform segments can be stored in the AWG waveform memory. Sequences are formed, using a contiguous series of segments. Because each segment has a specified start and stop address, sequence play is continuous and without gaps, when played from one segment to the next. Multiple segments can be grouped and looped for even greater memory compression. This waveform scenario construction is illustrated in *Figure 3*.

APPLICATIONS FOR CAPTURE AND PLAYBACK

In addition to the radar guided missile example, there are broad requirements in the aerospace and defense community for capture and playback of long, unique, non-repeating signals. One application example is interference testing. Interference is an undesired emitter, which could reduce or block the sensitivity of a receiver. Interfering emitters are often unpredictable: one does not know when they will occur, where in the spectrum they will appear or how long they will last. In order to fully understand the true nature of these interfering signals, many seconds, minutes or even hours of capture time may be required to guarantee that an event is captured.

What may be the most challenging application of signal capture and playback is radar target simulation. Here, the target return is coherent with the transmit pulse radar because the transmit pulse is captured and "immediately" played back to the radar receiver, with some fixed and perhaps added latency while maintaining a constant phase. Systems dedicated to



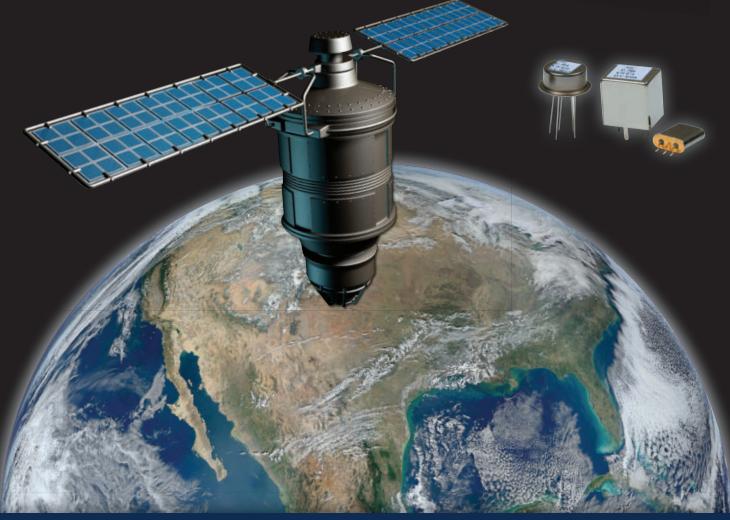
▲ Fig. 3 Example arrangement of segments in a loop and sequence.

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this function are termed Digital RF Memories (DRFM). Due to the relatively narrow use cases (radar target simulation and deceptive radar jamming) and custom nature of these DRFM systems, they are generally quite expensive. No solution using general purpose, off the shelf instruments currently exists. The requirements for such a capability include: a known, fixed signal latency through the system and the ability to act on the signal as it passes through the system (e.g., adding simulated Doppler).

For applications such as these, an extremely large amount of memory is needed. The ability to capture and perhaps playback without gaps at a very high data rate is also needed. So let's now discuss the concept of waveform streaming.

WAVEFORM STREAMING

Streaming is a flow of data that can be I and Q sample data, symbols, bits, waveform description, etc. The stream can last for an indeterminate, although generally finite, period of time, so there is not necessarily information about when the stream will end. The average data rate at the destination of the data is the same as at the source.

There are three basic use cases for streaming capture and playback of RF and microwave signals:

 Capture or playback of long waveforms to or from an extremely deep memory, which could be disk array of many Terabytes set up in a RAID configuration for faster write speeds.

CONTINUOUS STREAM OF IQ SAMPLES								
IQ SAMPLES								
BLOCKS OF IQ SAMPLES WITH META DATA								
TIMESTAMP, PHASE, CARRIER FREQUENCY IQ SAMPLES CARRIER FREQUENCY	• • •							
BLOCKS OF IQ SAMPLES TRANSMITTED FOLLOWING A HARDWARE TRIGGER SIGNAL								
IQ SAMPLES WAIT FOR TRIGGER IQ SAMPLES WAIT FOR TRIGGER								
BLOCKS OF META DATA THAT ARE CONVERTED INTO A WAVEFORM								
PULSE WIDTH, FREQUENCY SWEEP TRIGGER PULSE WIDTH, FREQUENCY TRIGGER TRIGGER TRIGGER								

A Fig. 4 Possible transmission over the streaming interface.

- Waveform to be defined dynamically during playback, based on the system's reaction to the current waveform.
 The next waveform segment to play is selected just prior to the current segment completing or it is created mathematically at run-time.
- Streaming allows a digitizer to capture a signal, optionally process it in a DSP and re-transmit it from an AWG in real time, as described in the DRFM application example above.

There are many different ways and types of data that can be utilized to stream a waveform in addition to just a continuous stream of I and Q samples. *Figure 4* shows the

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possible data transmissions over the streaming interface, which define a waveform. Meta data can be employed with waveform description data. Triggering enables control over the timing of the waveform.

THE STREAMING INTERFACE

The link or interface between the source of the data and its destination in a streaming configuration is, of course, critical for the rate that samples can be captured and the bandwidth of the signal that can be streamed. There are a few possibilities here, but one most promising is PCI Express (PCIe).

PCIe is a serial high speed interconnect, which replaced legacy bus-based PCI and PCI-X technologies, and is now migrating from desktop to embedded applications. PCI-Express operates more like a network than a bus. It utilizes a point-to-point topology, with separate serial links connecting peripherals to the processor. Data rates for PCIe 1.x ranges from 250 MB/s per lane to 4 GB/s using up to 16 lanes in each direction. The latest release version of the standard (3.0) can support 1 GB/s per lane to 16 GB/s for 16 lanes.

What kind of signal bandwidths can be accommodated in streaming over PCIe? With a data rate of 1 GB/s, this equates to 250 MS/s (32 bit I and Q pairs) and a capture/playback modulation bandwidth of 200 MHz. As can be seen from the evolution of PCIe, much wider bandwidths

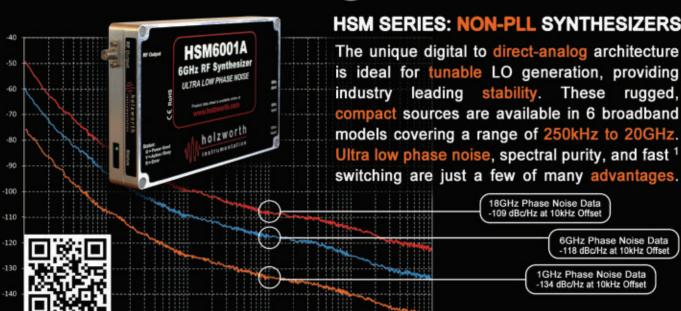
are possible. One difficulty might lie in the development of an interface driver to unlock the potential of the PCIe architecture and handle the flood of data over multiple lanes.

CONCLUSION

Streaming capture and playback of microwave signals is necessary for the development of advanced systems that operate in multiple modes, in a constantly changing environment. Solutions using off-the-shelf equipment have been lagging for this need, making it necessary for some to develop expensive custom solutions. It appears now that general purpose instrument manufacturers are beginning to implement the needed architectural features to stream waveforms at a high enough sample rate to address today's wide bandwidth applications. This is good news for our equipment budgets.

John Hansen is currently a senior application engineer for Agilent Technologies' Electronic Measurements Group. He has more than 20 years of experience in system engineering and new product development within the wireless, microelectronics and defense industries. At Agilent, he has been responsible for the launch of new high frequency microwave signal generator products and is currently involved in market analysis and generation of technical content for the aerospace & defense markets. Prior to joining Agilent, Hansen worked at Hughes Network Systems, where he participated in the development of terrestrial cellular and satellite communication products as an engineering test manager.

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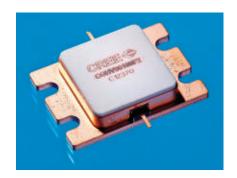
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50 and 100 W, X-Band Fully Matched Transistors

aAs MESFET and Traveling Wave Tube (TWT) amplifiers have long addressed high power X-Band applications from 10 W to multi-kW. GaAs MESFET solid state amplifiers deployed range from 10 to 100 W while TWT deployment range extends power to multi-kW; these amplifiers have served applications such as satellite communications, marine radar, medical imaging and military.

0.4 micron GaN HEMT transistors were first released into the market during the 2005 to 2006 time frame. The initial GaN HEMT offering focused on UHF through C-Band, primarily on CW broadband power and L- and S-Band pulsed power applications. Since the initial release, GaN HEMT suppliers have successfully fielded several million transistors. At Cree, the reported field FIT rates are less than 10 parts per billion hours of device operation. This FIT value rivals or is superior to any GaAs or Si power FET technology demonstrating GaN HEMT has established itself as a reliable and accepted technology.

Recently, a 0.25 micron GaN HEMT process technology has been released and to date includes product in die form, foundry service and X-Band fully matched packaged transistors. The X-Band matched device product family consists of four products:

- CGHV96050F1: 50 W, 50 Ω matched transistor tested under OQPSK at 25 W Pave from 7.9 to 8.4 GHz
- CGHV96100F1: 100 W, 50 Ω matched transistor tested under OQPSK at 50 W Pave from 7.9 to 8.4 GHz
- CGHV96050F2: 50 W, 50 Ω matched transistor tested from 7.9 to 9.6 GHz under 100 µsec, 10 percent duty cycle
- CGHV96100F2: 100 W, 50 Ω matched transistors tested from 7.9 to 9.6 GHz under 100 μsec, 10 percent duty cycle

The CGHV96050F1 and CGHV96100F1 are characterized for satellite communication linear power requirements under OQPSK. *Figures 1* and 2 show the linear features over frequency based on -30 dBc offset mask. Both the 50 and 100 W, X-Band GaN HEMT transistors show excellent linearity in the 30 percent power added efficiency (PAE) range while providing linear gain exceeding 12 dB. The spectral compliance is achieved while operating at 3 dB backed-off from Psat.

The CGHV96050F1 and CGHV96100F1 can be deployed in 25 to 100 W linear power solid state amplifiers (SSPA) which have ear-

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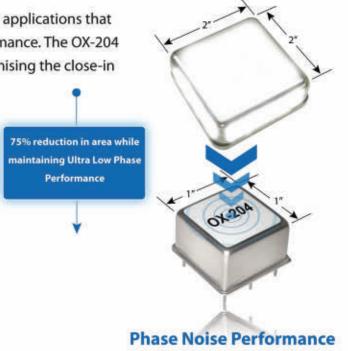
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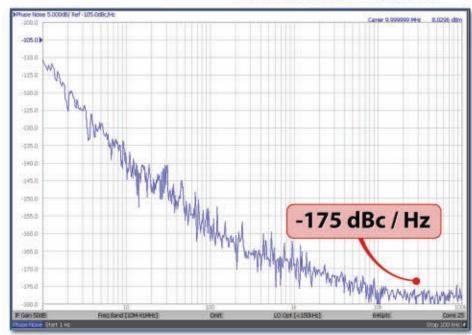
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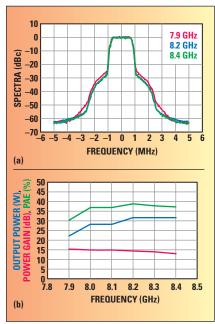
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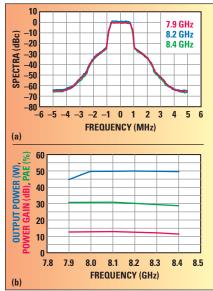


▲ Fig. 1 CGHV96050F1 typical performance spectral mask under OQPSK modulation, 1.6 Msps $V_{\rm DD} = 40~V$, output power = 44 dBm/25 W (a) and linear output power, gain and PAE, $V_{\rm DD} = 40~V$, $I_{\rm DQ} = 500~mA$, 1.6 Msps, OQPSK modulation at −30 dBc (b).

lier typically utilized GaAs MESFET technology. Devices are easily combined. For example, a high power SSPA could be developed with multiple combined 100 W transistors. Typical performance for a four-way combined 100 W transistor could realize a 200 W average power linear amplifier. TWTs typically operate at 6 dB backoff from their saturated power and in many cases require external linearization to be able to meet the linearity requirements for satellite communications. A 200 W GaN HEMT linear performance (400 W peak power) would be equivalent to a corresponding 800 W TWTA in terms of linear power performance capability.

The CGHV96050F1 and CGHV96100F1 offer the wide video bandwidth capabilities important for multi-carrier satellite communication applications. *Figure 3* shows tone spacing through 80 MHz separation while maintaining spectral stability in terms of IM3, IM5 and IM7.

The CGHV96050F2 and CGHV96100F2 GaN HEMT transistors have also been characterized for saturated power, pulsed applications such as weather and marine radar as shown in *Figure 4*. The transistors offer a minimum power gain of 10



▲ Fig. 2 CGHV96100F1 typical performance spectral mask under OQPSK modulation, 1.6 Msps $V_{\rm DD} = 40$ V, output power = 47 dBm/50 W (a) and linear output power, gain and PAE, $V_{\rm DD} = 40$ V, $I_{\rm DQ} = 1000$ mA, 1.6 Msps, OQPSK modulation at –30 dBc (b).

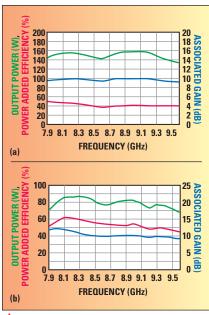
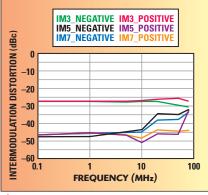


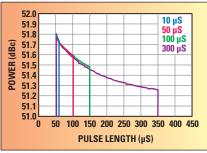
Fig. 4 CGHV96100F2: 100 W X-Band internally matched transistor (a) and CGHV96050F2: 50 W X-Band internally matched transistor (b) performance.

dB while offering 80 or 140 W output power over the 7.9 to 9.6 GHz frequency band and PAE offered is 45 to 50 percent. These features correspond to an average of two times improvement over comparable GaAs MESFET transistors at this frequency and power level.

The pulse droop demonstrated by the 50 and 100 W GaN HEMT transistors is excellent as shown in *Figure*



ightharpoonup Fig. 3 Intermodulation distortion performance vs. tone spacing, $V_{DD} = 40 \text{ V}$, frequency = 8.2 GHz, output power = 43 dBm/20 W.



Arr Fig. 5 Output power vs. time, $V_{DD} = 40 \text{ V}$, $P_{IN} = 41 \text{ dBm}$, duty cycle = 10%.

5. Short pulse width droop is extremely low and even a relatively long (for this application) 300 µsec pulse droop is a very good 0.5 dB as shown in the figure. The minimal pulse droop is due to the superior thermal properties of the Silicon Carbide (SiC) substrate used as a substrate material for the GaN-on-SiC HEMT structure.

These high power X-Band transistors offer excellent features for 50 thru 100 W requirements and can be combined into high power SSPAs exceeding 1 kW by deploying 100 W transistors into a multiple device combination scheme. The advantages of GaN HEMT transistors for X-Band will offer significant systems benefits in terms of power management, thermal management, power supply load, package size shrink of the SSPA unit size or offering significant reliability and cost advantages when compared with TWTA. GaN HEMT SSPA system advantages are overwhelming when compared with GaAs MESFETbased SSPA and TWTA.

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ilitary missions and natural disaster response share the need for rapid deployment of SATCOM infrastructure under very challenging conditions. Speed, performance and agility are critical, and until now, those capabilities largely have been viewed as incompatible. Greater bandwidth was available, but not in a form factor that could be fielded quickly or easily. Newer VSAT terminals offered more complex capabilities, but required lengthy set-up and adjustments.

Harris Corp.'s 1.3-meter Seeker™ terminal provides support for X-, Ku-, and Ka-Bands



Fig. 1 Transit case for 1.3-meter Seeker terminal.

in a single transit case that can be checked as airline baggage. Supporting throughput of 8 Mbps, Seeker offers the highest gain possible in a single-case (see *Figure 1*) antenna that is as small as many 0.9-meter systems.

What makes this possible? Seeker was designed to operate without an antenna controller unit or fans, drastically reducing weight, bulk and noise – as well as cost and power consumption. One battery can provide 80 minutes of airtime in the event of a power interruption.

An integrated RF receiver/transmitter is slice mounted directly to the back of Seeker's reflector hub, significantly reducing the number of cables required to just five: one input power, one output power, one input GPS, and two transmit/receive cables.

Seeker is self-contained, with a GPS receiver, inclinometer, flux gate compass and simpli-

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fied keyboard with a built-in display. Its large aperture size reduces the need for ESD spreading, thereby conserving up to 50 percent of satellite transponder bandwidth power compared with 0.6-meter solutions.

Ease of deployment and use are paramount in Seeker's design. The system can be set up by one person and operating in just 10 minutes. This is due not just to its innovative packaging and agility, but also to its user-friendly Acquisition Wizard. This embedded 'tool "coaches" the user through three simple steps to signal acquisition using elevation, azimuth and skew angle adjustments.

Even the novice user can acquire and join the satellite network in less than five minutes - something not possible with other VSAT systems, which still require the operator to pre-plan the mission, peak the terminal after acquiring, and fine-adjust the polarization skew angle to align to the target satellite.

Seeker excels in outdoor tactical



Fig. 2 Seeker 1.3-meter terminal with transit case.

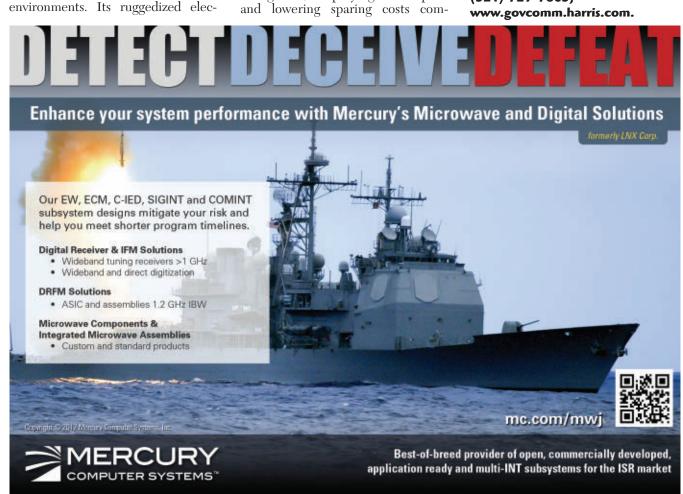
tronics can withstand challenging thermal, wind and water conditions with minimal degradation in throughput capability.

Seeker was designed in conjunction with other Harris terminals ranging in size from 0.45 to 3.8 meters. This "family" approach ensures efficient use of common, swappable components such as the modem, power supply, cabling and hardware. Each reflector panel also is interchangeable, simplifying field repairs pared with traditional, matched-set reflector panel configurations. Use of common elements has the added benefit of reduced training time. The product can be bundled with Harris CapRock satellite bandwidth and services to provide a complete endto-end SATCOM solution anywhere in the world.

Seeker has been demonstrated to several government organizations and companies that have recognized its unique benefits. During a recent demonstration, military attendees commented, "A 1.3-meter terminal in one case (see Figure 2). Seeker's terminal throughput is impressive for its class. It is so easy to use and the common receive/transmit unit across apertures ranging from 0.45 meters to 1.3 meters allows me to tailor my equipment for my specific mission needs."

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High Performance Airborne Router for Critical Defense ISR

Direct Government Technologies' (iGT) new satellite airborne router, the e8000 AR, is for government customers who want high speed communications on a variety of transport and intelligence, surveillance and reconnaissance (ISR) aircraft platforms. The new router is designed for easy roll-on, roll-off integration into both low-speed and high-speed military airframes, supporting multiple missions from a single satellite router or modem that can be connected into an existing iGT regional or global satellite internet protocol (IP) network.

The e8000 AR is a software-defined satellite modem that comes in a one RU rack-mount enclosure, 21 inches deep, and fits into the smallest portable flyaway cases. Weighing less than 16 pounds, the new router will not bust the operator's margin for weight. Also included are locking Ethernet, RF and 38-999 connectors that provide military-grade interfaces for high performance and secure connections that will

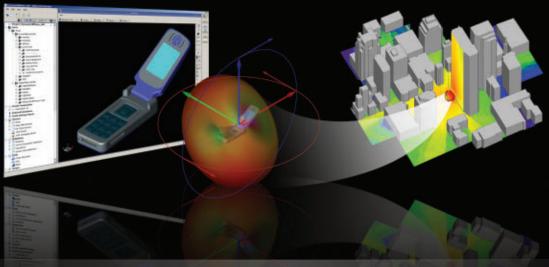
not loosen during operations where high vibration is present. With both AC (100 to 240 V, 50 to 400 Hz) and DC (28 V) inputs (see *Figure 1*), the router can be easily powered from an airplane's native power bus eliminating power converters that may produce dirty power. The entire unit is designed and tested to meet MIL-STD 810G airborne environmental standards and MIL-STD 461F standards for EMI and radiated emissions.

iGT routers have flown on multiple military airframes, from the low-speed King Air C12 surveillance aircraft to the high-speed C17 transport aircraft, supporting multiple military-specific applications. The e8000 AR router's highspeed communications-on-the-move (COTM) features along with the iDirect IP network, delivers voice, video and data applications to and from personnel on board the aircraft. The e8000 AR can be optimized for downstream or upstream data rates using either Deterministic Time Division Multiple Access (D-TDMA) or Single Channel Per Carrier (SCPC) operational modes. The router can be operated in either mode and switched by the operator depending upon the mission. For bandwidth intensive ISR applications, the e8000 AR can be operated in SCPC mode where up to 19 Mbps can



Fig. 1 e8000 AR back side inputs and connections.

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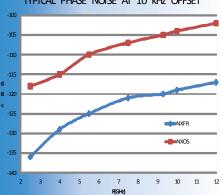
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be transmitted off the aircraft in the upstream path. These data rates can support multiple high-definition cameras for surveillance and sensor data from on-board video and sensor gathering equipment. The e8000 AR can also be operated in D-TDMA mode for improved bandwidth efficiency and achieve transmit data rates as high as 11 Mbps upstream from the aircraft, depending upon satellite link budget limitations.

Router data rate performance on aircraft platforms are antenna and satellite frequency band dependent. The e8000 AR is designed to operate in any combination of antennas and satellite frequency bands, including wideband global satellite (WGS) constellation, to provide optimum performance to the operator. The e8000 AR has a built-in open antenna modem interface protocol (OpenAMIP) to interface with airborne antenna's antenna control unit (ACU), which provides real-time location and pointing information during flight. For antennas without OpenAMIP, the e8000 AR includes an on-board CPU with an applications interface (API) for custom antenna interface development. The CPU comes with a thin-Linux operating environment that can be accessed through keyboard, video and mouse (KVM) interface, front-panel USB, or Ethernet port.

Some frequency bands, such as Ku-Band, have adjacent satellite interference (ASI) requirements due to decreased satellite spacing that can limit the power spectral density (PSD) transmitted from an airborne antenna system. The e8000 AR router has inherent COTM features that allow the operator to continue to optimize data rate performance, select operational modes and comply with ASI requirements. The router does this with spread spectrum technology that allows waveform spreading to meet PSD requirements, while maintaining the same data rate. The e8000 AR supports spreading factors 2, 4, 8 and 16.

On other satellite frequency bands such as X-Band and Ka-Band, ASI is less of an issue due to increased satellite spacing and allows much higher transmit power in the airborne antenna system. The e8000 AR takes advantage of this higher power operating environment and can be operated without waveform spreading, and uses

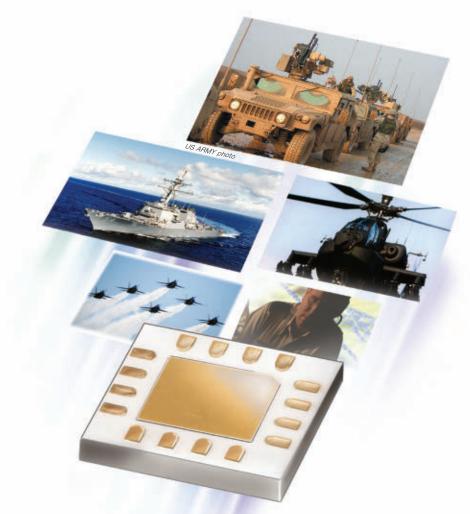
SCPC mode where iDirect routers have achieved data rates upstream from the aircraft as much as 14 Mbps from a 17-inch airborne antenna.

The e8000 AR also supports COTM features such as automatic satellite beam switching (ABS) and global roaming. Airborne networks can be regional, multi-regional or global as airplanes typically travel great distances and it can require more than one satellite or satellite beam to cover the traversed area. In order to maintain constant communications when the antenna needs to re-point or the modem needs to select a new beam, the e8000 AR and iDirect's Global Network Management System (GNMS) work together to make this physical transition nearly seamless. Along with on-board satellite beam maps, GPS input and an awareness of a multinode network, the e8000 AR provides the intelligence to transmit when it is safe, or legal to do so, and switch between satellites as the airplane moves from one satellite beam or coverage area to another satellite beam, reestablishes the connection and provides the optimum data rates that can be achieved for that link.

In addition to delivering high performance, the e8000 AR is certified to federal information processing standard (FIPS) Level 2 and can be operated in transmission security (TRANSEC) mode while operating in an airborne network. The iDirect system uses AES 256-bit key encryption and exchanges X.509 digital certificate authentication with automatic key management. The e8000 AR can be operated with TRANSEC in a regional or global network with the use of iDirect's unique global key distribution management system that allows roaming between secure networks.

The e8000 AR operates in a star topology and uses standards-based DVB-S2 with ACM waveform and can operate in networks with downstream rates up to 45 Msps and upstream rates up to 15 Msps in SCPC mode. Input frequency range is 950 to 2000 MHz and supports WGS frequencies. Modulation formats on the downstream are QPSK, 8 PSK and 16 APSK, and BPSK, QPSK and 8 PSK on the upstream.

iDirect Government Technologies, Herndon, VA (703) 648-8118, www.idirectgt.com.



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On land, sea, and in the air, demanding critical applications call for a switch that is a cut above the rest. Mini-Circuits rugged CSWA2-63DR+ ceramic RF/microwave SPDT switch is that switch. From 0.5 to 6 GHz this switch operates in the absorptive mode (good output VSWR in off state). From 0.3 MHz to 500 MHz in the non absorptive mode (output ports reflective in off state). The CSWA2-63DR+ at only 4 x 4 x 1.2 mm handles tight spaces, provides protection against high moisture environments, and offers outstanding performance. For tough RF/microwave switch requirements in commercial, industrial, or military applications, think Mini-Circuits' new ceramic switch. Visit our website to view comprehensive performance data, performance curves, data sheets, pcb layout, and environmental specifications. And, you can even order direct from our web store and have it in your hands as early as tomorrow! Mini-Circuits...we're redefining what Value is all about!

CSWA2-63DR+ In Stock

- Very High Isolation: 63 dB @ 1 GHz to 44 dB @ 6 GHz
- Low Insertion Loss: 1.2 dB
- High IP3: +45 dBm
- Integral CMOS Driver
- Supply current of only 18 micro amps
- 23 ns typical rise/fall time
- Operating temperature -55° to +125°C

4 mm Square Package









P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661



High Gain, 1 to 4.2 GHz Mixer

he MRA-42MH+ combines a double balance mixer with a highly linear, low noise IF amplifier to provide a high gain active mixer for efficient operation from 1000 to 4200 MHz. The LO power is +13 dBm, conversion gain is 11.5 dB typical, L-R isolation of 33 dB is typical and output IP3 of dBm is typical with an IF frequency range of 10 to 800 MHz. It is packaged in a small LTCC substrate that is 0.300" × 0.250" × 0.060". Maximum operation tem-

perature range is from -55° to 125°C. Typical applications include cellular, PCN, WCDMA, fixed satellite, defense radar and communications.

The MRA series, due to its ultra compact size, offers the additional flexibility to enable the user to install design specific components (i.e., filters, attenuators, switches, etc.) based upon the design needs. The Schottky diode and MMIC amplifier are bonded to a multilayer integrated LTCC substrate, and then sealed un-

der a controlled nitrogen atmosphere with gold plated covers and eutectic Au-Sn solder. These very compact active mixers have been tested to MIL requirements for gross leak, fine leak, thermal shock, vibration, acceleration, mechanical shock and HTOL.

VENDORVIEW

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



SPINNER | ROTARY JOINTS







SPINNER is a global leader in developing and manufacturing state-of-the-art RF components. Since 1946, the industries leading companies have trusted SPINNER to provide them with innovative products and outstanding customised solutions.

Headquartered in Munich, and with production facilities in Germany, Hungary, USA, China and Brazil the SPINNER Group now has over 1,300 employees worldwide.

Our subsidiaries and representatives are present in over 40 countries and provide our customers with an international network of support.

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SPINNER is a global supplier for rotary joints and slip ring assemblies. With more than 50 years of experience in RF Design and Engineering, SPINNER is your ideal partner for customised solutions. Our product range includes **coaxial**, **waveguide** and **fibre optic**, **single or multi channnel rotary joints**, **slip ring** and **media joint assemblies**. **Systems** are **available for** all **frequency bands**.

SPINNER offers superior rotary joints and slip rings for:

- Air traffic control radars
- Civil applications automotive, satellite tracking
- Defence applications air, sea, land
- SatCom
- Space applications
- Fibre optic single channel, multi channel (up to 21 channels)



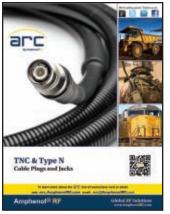
LITERATURE SHOWCASE



A/D Symposium DVD VENDOR**VIEW**

Get a complimentary copy of Agilent's 2012 A/D Symposium DVD that includes 20 technical papers on design tools and robust test solutions to help you build greater assurance in test system readiness. Areas covered include radar/EW, satellite, SDR/MilCom, general RF and microwave test. Also included are product and solution videos, application notes and additional resources. Get a copy at www.agilent.com/find/ad2012dvd.

Agilent Technologies Inc., Santa Clara, CA (800) 829-4444, www.agilent.com.



Ruggedized Connectors

Amphenol® RF's ARC line of ruggedized connectors literature and video training are now ready for download at arc.amphenolrf. com under the resource section. Download the cutsheet and watch the video training to learn more about how these connectors are fully submersible and are designed to handle the harshest of elements. The ARC line comes in Type N and TNC, as well as with or without cables.

Amphenol RF, Danbury, CT (800) 627-7100, www.amphenolrf.com.

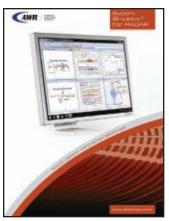


Resistive Components VENDOR**VIEW**

Precision-engineered and proven again and again in the toughest applications – Anaren's family of terminations, resistors, and attenuators addresses your needs. They are designed for high-power applications, from 4 to 800 W and are suitable for 'mission critical' applications from DC to 6 GHz, including beamforming networks, military radios, combiners/dividers, T/R modules, high voltage power supplies and high-power detectors. They have a range of packages (SMD, chip, flanged, and flangeless), accurate charac-

terization of performance and are available in low, 50-piece minimum order quantities.

Anaren Ceramics, Salem, NH (603) 898-2883, www.anaren.com.



VSS for Radar VENDOR**VIEW**

The new AWR Visual System Simulator Advanced Radar System Design Brochure details the capabilities of the software for behavioral modeling of radar RF and signal processing systems and 3D antenna patterns derived from synthesis or measurement. VSS Radar offers a wide variety of waveform options, as well as RF modeling, antenna and phased array models, DSP modeling, thirdparty connected verification solutions and a complete radar design library. Read more about VSS Radar online and download the brochure at www.awrcorp.com/VSS.

AWR Corp., El Segundo, CA (310) 726-3000, www.awrcorp.com.



VCO/CRO Solutions

Looking for high frequency, low phase noise, wideband VCO/CRO solutions to integrate successfully into your RF design? APA Wireless offers total engineering support and assistance that far exceeds competitors in helping you attain your system performance goals. Custom designs are the company's specialty. Its INSTA-SOURCE and ACCUSOURCE online ordering system allows you to tailor a product to your unique specifications while maintaining reasonable lead-time.

APA Wireless,
Oakland Park, FL (954) 563-8833, www.apawireless.com.



Connectors

CarlisleIT has added two new connector lines to its push-on family – the TMP® and WMP® series. The TMP family was designed to provide higher power handling capacity for radar applications, while the WMP line provides the smallest form factor for space restricted applications. Both connector series provide the benefits of a push-on interface (simple connection and ease of use in dense package configurations) and include PCB mount, field replaceable, microwave cable, and custom connectors.

Carlisle Interconnect Technologies, St. Augustine, FL (800) 458-9960, www.carlisleit.com.



LITARY MICROWAL

LITERATURE



Product Catalog

CPI's Beverly Microwave Division (BMD) designs and manufactures a broad range of RF and microwave products for radar, communications. electronic warfare and scientific applications. CPI/BMD is the world's largest manufacturer of receiver protectors and related products. Other product lines include magnetrons, TWTs, CFAs, transmitter assemblies, scientific systems, high power solid-state switches and switch assemblies, pressure windows and a wide variety of multifunction components and integrated microwave assemblies.

Communications & Power Industries (CPI), Beverly, MA (978) 922-6004, www.cpii.com/bmd.



Electromagnetic Fields Simulation Software

VVENDORVIEW

CST develops and markets software for the simulation of electromagnetic fields. Its products allow you to characterize, design and optimize electromagnetic devices all before going into the lab or measurement chamber. The extensive range of tools integrated in CST STUDIO SUITE® enables numerous applications to be analyzed without leaving the user-friendly CST design environment and can offer additional security through cross verification. CST's customers operate in industries as diverse as defense, telecommunications, automotive, electronics, and medical equipment.

Computer Simulation Technology AG (CST), Darmstadt, Germany +49 6151 7303 0, www.cst.com.



SSPA Family

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

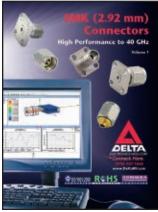
CTT Inc., Sunnyvale, CA (408) 541-0596, www.cttinc.com.



low noise and power amplifiers, semblies covering frequencies

from 1 MHz to 40 GHz with power handling up to 25 kW.

Delta Microwave, Oxnard, CA (805) 751-1100, www.deltamicrowave.com.



SMK Series Catalog

Delta Electronics Manufacturing's new 15 page SMK (2.92 mm) series catalog details over 65 part numbers that span 31 different configurations in this range of products that operate mode-free to 40 GHz. These products include: Cable plugs and jacks, field replaceable flange mount receptacles (jacks and plugs), thread-in "spark plug" receptacles, adapters within series, hermetic seals and accessory pins. In addition, the catalog features thorough information on materials and finishes, typical electrical performance,

assembly procedures, detailed mounting information and a competitive cross reference.

Delta Electronics Manufacturing Corp., Beverly, MA (978) 927-1060, www.deltarf.com.



Eastern Wireless TeleComm Inc., Salisbury, MD (410) 749-3800, www.ewtfilters.com.

Filter Catalog



Ruggedized RF Connectors for Mission-Critical Applications...





Amphenol® RF Ruggedized Connector Line is engineered for superior performance in extreme conditions. These connectors are fully submersible, water and dust protected to IP67 specifications in mated and unmated conditions. Robust, mechanical single-piece body construction is designed to withstand extensive shock and vibration. The line comes in Type N and TNC cable jacks and plugs. TNC connectors are available in standard and reverse polarity. These connectors can be configured with matte and black chrome finishes. Per specific customer's requirements the line can be supplied in waterproof, abrasion and chemical resistant cable assemblies.











To learn more about the arcline of connectors visit or email: web: arc.AmphenoIRF.com email: arc@AmphenoIRF.com

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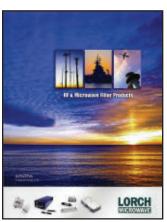


Midwest Microwave Catalog

The new Midwest Microwave catalog highlights passive microwave components for military, space and testing applications. The catalog features current product offerings along with an updated Qualified Parts Listing of attenuators, terminations and SMA connectors manufactured to meet or exceed the performance specifications set forth in the MIL Specification. Also contained within this release is an updated list of approved Defense Logistics Agency (DLA – Formerly DESC) specification

products. This list includes SMA, SSMA and BMA connectors and precision adapters.

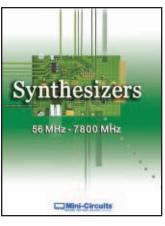
Emerson Network Power Connectivity Solutions Inc., Bannockburn, IL (847) 739-0300, www.emersonnetworkpower.com.



Short Form Product Guide

The Lorch Microwave short form product guide presents the complete product range in a clear and concise format. The products featured are used in a wide range of military and commercial applications. Also included are frequency range of operation, photographs and specific application information, charts and tables.

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



Synthesizers Brochure VENDOR**VIEW**

The Mini-Circuits design team can create a custom frequency synthesizer tailored to your requirements. They review your requirements and, following technical discussions between your engineers and Mini-Circuits designers, work closely with you to create final specifications that meet or exceed your requirements. To ensure high yields, they factor in component tolerances and even variations in manufacturing processes. You will have full access to performance data from sample

units, and can even evaluate sample units in your system to ensure that final production units fulfill your performance requirements.

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



RF Synthesizers and Generators

The ITT Exelis Microwave Systems business has been designing and manufacturing high performance DDS-based RF synthesizers and RF waveform generators for more than twenty years. If your radar, IFF, EW or SIGINT system requires fast switching and clean signals, please review ITT Exelis'

technical brief for a sampling of capabilities in low spurious, wideband solutions, tuning in less than 200 nanoseconds from DC to 26 GHz.

ITT Exelis, McLean, VA (703) 790-6300, www.exelisinc.com.



Components Catalog VENDOR**VIEW**

Celebrating its 51st anniversary, MECA (Microwave Electronic Components of America) designs and manufactures an array of RF/microwave components with industry leading performance. MECA is recognized worldwide as a primary source of supply for rugged and reliable components to commercial and military OEMs, service providers and installers by only providing products made in the USA.

MECA Electronics Inc., Denville, NJ (866) 444-6322, www.e-meca.com.



RF and Microwave Filters and Assemblies VENDOR**VIEW**

NIC celebrates 25 years of uninterrupted service to the military and space markets. This catalog features NIC's design and manufacturing capabilities from DC to 40 GHz and showcases a broad range of filter technologies including: LC, crystal, ceramic, cavity, delay equalized and phase matched filters, as well as NIC's integrated assemblies such as: switch filter banks, filter/amplifiers, and phase shifters. NIC is ISO 9001:2008 certified and AS-9100C

certified for aerospace applications. To request a copy, email sales@nickc.com or visit www.nickc.com.

Networks International Corp., Overland Park, KS (913) 685-3400, http://nickc.com.

PERFECTION

When you need perfection in satellite high frequency communication.



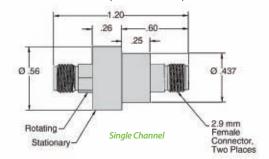
Family of Broadband High Frequency Coaxial Rotary Joints

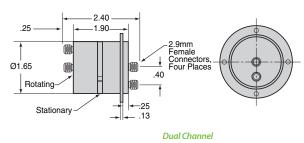
Single Channel & Dual Channel Rotary Joints — Frequency DC to 40.0 GHZ

MDL's short low torque, high performance coaxial rotary joints as well as our extensive line of waveguide rotary joints have set the standards of the industry .

You've never been in better hands.

Quality from CAD to crate, quick turnaround, and tight economy is what we're all about. Call an MDL specialist today at 800-383-8057 or visit us at mdllab.com. You'll find that we specialize in perfection.





SINGLE CHANNEL SPECIFICATIONS:

ELECTRICAL		
FREQUENCY	.DC - 18 GHz	
VSWR	.DC - 10 GHz	1.20 : 1 MAX.
	10 - 26 GHz	1.35 : 1 MAX.
	26 - 40 GHz	1.75 : 1 MAX.
WOW	.1.05 MAX.	
INSERTION LOSS	.DC - 10 GHz	0.2 dB MAX.
	10 - 26 GHz	0.4 dB MAX.
	26 - 40 GHz	0.6 dB MAX.
PEAK POWER	Equal to conne	ector rating

DUAL CHANNEL SPECIFICATIONS:

ELECTRICAL	Channel 1	Channel 2
FREQUENCY	7.0 - 22.0 GHz	29.0 - 31.0 GHz
VSWR	1.50:1 MAX.	1.70:1 MAX.
WOW	0.15	0.25
INSERTION LOSS	0.5 dB MAX.	1.0 dB MAX.
ISOLATION	Channel to Channel	50.0 dB MIN.



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Microwave Development Laboratories, 135 Crescent Road, Needham Heights, MA 02494





The AR-50 is a JITC-certified* booster amplifier for military transceivers. It's lightweight and portable, with automatic tuning that makes it easy to use.

And it provides the most extensive radio platforms

& waveform support available: SINCGARS, HAVEQUICK, DAMA, IW, ANW2 and more.



This battle-tested, 50-watt
RF amplifier covers the 30 – 512 MHz
frequency band supporting the Harris AN/PRC-117F,
Harris AN/PRC-117G*, Harris AN/PRC-152A,
Thales MBITR AN/ PRC-148 Raytheon AN/PSC-5D*,
Rockwell Collins AN/ARC-210 tactical radios plus others.
With protection against antenna mismatch, over-temperature
and accidental polarity reversal, the AR-50 has proven to be
durable and dependable in the toughest battle conditions.

If losing communications is not an option, then AR-50 booster amplifier is your best option.



To learn more, visit us at www.arworld.us/ar50 or call us at 425-485-9000.





modular rf

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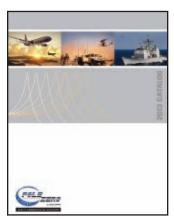
LITERATURE Showcase



Overview and Capabilities Brochure VENDOR**VIEW**

Planar Monolithics Industries (PMI) has released its latest product Overview and Capabilities Brochure. The brochure contains a listing of various RF components and RF module product types up to 40 GHz, including amplifiers, attenuators, phase shifters, detectors, DLVA/SDLVA's, filters, limiters, switches and switch matrices.

Planar Monolithics Industries, Frederick, MD (301) 662-5019, www.pmi-rf.com.



Product Catalog

RF Communications become more difficult in the presence of multiple interferers, as is common in today's Military ConOps where many radios are operating in close proximity. Pole/Zero's new product catalog provides a broad range of solutions to purify transmitters and protect receivers so you can achieve the clarity and range you need for your mission. Fast tuning, agile products are available in the tuning range of 1.5 MHz to 2 GHz. Contact Pole/Zero to resolve your interference issues.

Pole/Zero, West Chester, OH (513) 870-9060, www.polezero.com.



Filters, Multiplexers and Multi-function Assemblies

VVENDOR**VIEW**

This catalog features RF and microwave filters, multiplexers and multi-function assemblies. The catalog contains RF and microwave filters, multiplexers and multi-function assemblies for the military, industrial and commercial industries. To request a copy, please e-mail reactel@reactel.com, or visit www. reactel.com.

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



IF CABLE INTEGRITY IS CRITICAL AND YOU NEED PRODUCTS TO WITHSTAND HARSH ENVIRONMENTS... FAILURE IS NOT AN OPTION.

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MILITARY MICADWAVES

LITERATURE SHOWCASE



Analyzing Antenna Performance

VENDORVIEW

Successful integration of an antenna onto a vehicle platform poses many challenges, from vehicle features and motion impacting antenna performance to environmental factors, and radiation hazards. This paper provides a variety of examples on how modeling and simulation can be used to analyze antenna performance, identify problems and evaluate potential solutions. Download at www.remcom.com/antenna-platform-integration/.

State College, PA (814) 861-1299, www.remcom.com.



A&D Selector Guide **VENDORVIEW**

The June 2012 A&D Selector Guide includes the latest RF and microwave products for electronic warfare, communications, jammers, and radar (including commercial) applications. Featuring more than 30 new products, the Selector Guide is organized by ap-

plication and frequency bands. The Richardson RFPD A&D New Product Selector Guide is available on Richardson RFPD's website, updated monthly, and features direct hyperlinks for purchasing the latest products from the world's leading suppliers, along with links to the data sheet for each product.

Richardson RFPD Inc., LaFox, IL (800) 737-6937, www.richardsonrfpd.com.



Rohde & Schwarz GmbH & Co. KG, Munich, Germany +49 89 4129-12345, www.rohde-schwarz.com.



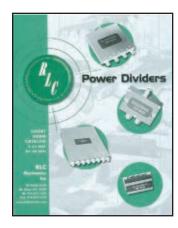
Product Selection Guide

VENDORVIEW

RFMD's 2012-2013 Product Selection Guide provides specifications for more than 750 products including more than 90 recently released products targeting multiple end-market applications. The 64-page guide allows customers to cross-reference and search products using end-market application diagrams. RFMD's Product Selection Guide lists products servicing more than 15 end-market segments including cellular, point-to-point microwave radio, WiFi, WiMAX,

LTE, CPE, smart energy AMI, Zigbee®, wireless infrastructure, military and space, broadband transmission, consumer, and others.

Greensboro, NC (336) 664-1233, www.rfmd.com.



Power Divider Short-Form Catalog

RLC Electronics introduces the release of its newest short-form catalog featuring power dividers. This catalog provides a comprehensive listing of DC to 40 GHz standard designs as well as the company's capabilities to customize in accordance with your specifications. RLC has designed and manufactured a wide variety of power dividers for both commercial and military applications. Please contact them to request a copy of this catalog, or to obtain information regarding any of RLC's products.

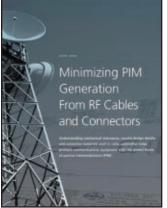
RLC Electronics Inc. Mt. Kisco, NY (914) 241-1334, www.rlcelectronics.com.



Test & Measurement Catalog

VENDORVIEW

This catalog will give you an overview of all Rohde & Schwarz's T&M products. It contains almost 200 pages full of information about the company's T&M instruments and systems as well as their software. Each product has a short description, photos, the most important specifications and ordering information. On the Rohde & Schwarz website, you can find this catalog as a PDF file for download. Order number: PD 5213.7590.42.



PIM White Paper **VENDORVIEW**

San-tron's latest white paper, "Minimizing PIM Generation From RF Cables and Connectors," explores passive intermodulation (PIM), its effects on modern communication systems, and how it can be minimized in high-frequency cables, connectors, and cable assemblies. In addition to exploring the different causes of PIM, this white paper also reviews San-tron's efforts to create connector interfaces with low-PIM mechanical structures and to minimize the use of paramagnetic materials in its connectors.

Ipswich, MA (978) 356-1585, www.santron.com.

Industry pros are talking about us behind our backs ...and we love it!



IW designs and manufactures high performance microwave cable and cable assemblies for both military and commercial markets. Applications include telecommunications, data links, satellite systems, airborne electronic warfare and counter measures, missile systems, UAV applications, avionics and instrumentation, fire control systems, medical electronics, and geophysical exploration.

We offer a wide variety of products providing extremely low attenuation at frequencies up to 67 GHz and ranging from .050 inch to 0.50 inch in diameter. Our unique PTFE lamination process, combined with our high performance shield design, has made us one of the leaders in low-loss microwave transmission lines. IW's broad range of microwave cables and connectors assures every customer the proper cable assembly for each of their specific application needs.

Our major products include:

- Low-loss microwave cables optimized for use to 11, 18, 26.5, 40, 50, and 67 GHz
- Microwave cable assemblies with connectors for SMA, TNC, N, SC, 7/16, 1.85mm, 2.4mm, 2.92mm, 3.5mm, 7mm, ZMA, SMP, SMPM & more
- RE-FLEXTM semi flexible assemblies
- TUF-FLEXTM assemblies improved crush resistance without using armor
- Water-blocked cables for submarines
- Composite cables combination microwave/signal/power/data
- PTFE insulated hook-up wires
- Multi-conductor cables
- Dielectric cores
- Twisted pair and triaxial cables
- Low smoke, zero halogen cable jackets
- Cable protection options such as armor, PEEK, NOMEX, Neoprene weatherproofing, PET monomer braid

ISO 9001:2008 certified with AS9100 pending.



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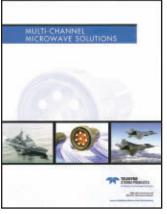
LITERATURE SHOWCASE



FleXtra Application

SV Microwave is proud to introduce the $FleXtra^{TM}$ line of cable assemblies – a new family of high performance flexible 0.047 style cable assemblies. Available in multiple variations, the new FleXtra cables will surely fit your needs. Choose from a wide variety of industry standard connector styles or custom designs to meet your performance requirements.

SV Microwave, West Palm Beach, FL (561) 840-1800, www.svmicrowave.com.



Harness Capabilities Brochure

Teledyne Storm Products' new Multi-Channel Microwave Solutions brochure details the company's capabilities in the design and manufacture of both standard and custom multi-channel microwave harness assemblies. The harnesses, found in a wide range of airborne, ground and sea-based military and commercial applications, are backed by Teledyne Storm's more than 30 years of microwave cable design and manufacturing expertise. It includes a case study.

Teledyne Storm Products, Woodridge, IL (630) 754-3300, www.teledynestorm.com.



RF Interconnect Solutions for DAS

Times Microwave Systems announces the availability of its RF Interconnect Solutions for Distributed Antenna Systems (DAS) brochure. Typical applications of DAS technology include large buildings, stadium venues and shopping malls where signals are either attenuated because of the surrounding building structure or large groups of people congregate to overload the otherwise limited capacity of carrier networks. Included in the brochure are the popular LMR® low loss, flexible coaxial cables, connectors and ca-

ble assemblies, low PIM plenum and non-plenum rated cables and jumpers and surge protection devices.

Times Microwave Systems,
Wallingford, CT (203) 949-8400, www.timesmicrowave.com.

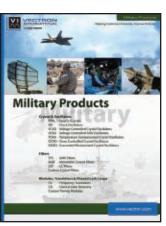


Werlatone 2012 Catalog

VENDORVIEW

Werlatone, in business since 1965, supplies a full range of high power combiners, dividers, 90° hybrid couplers, and directional couplers. The company's new catalog highlights some of its new products as well as several of its most popular designs. Werlatone's full library contains over 2000 models. Please note that 65 percent of the company's business revolves around custom designs.

Werlatone Inc., Patterson, NY (845) 278-2220, www.werlatone.com.

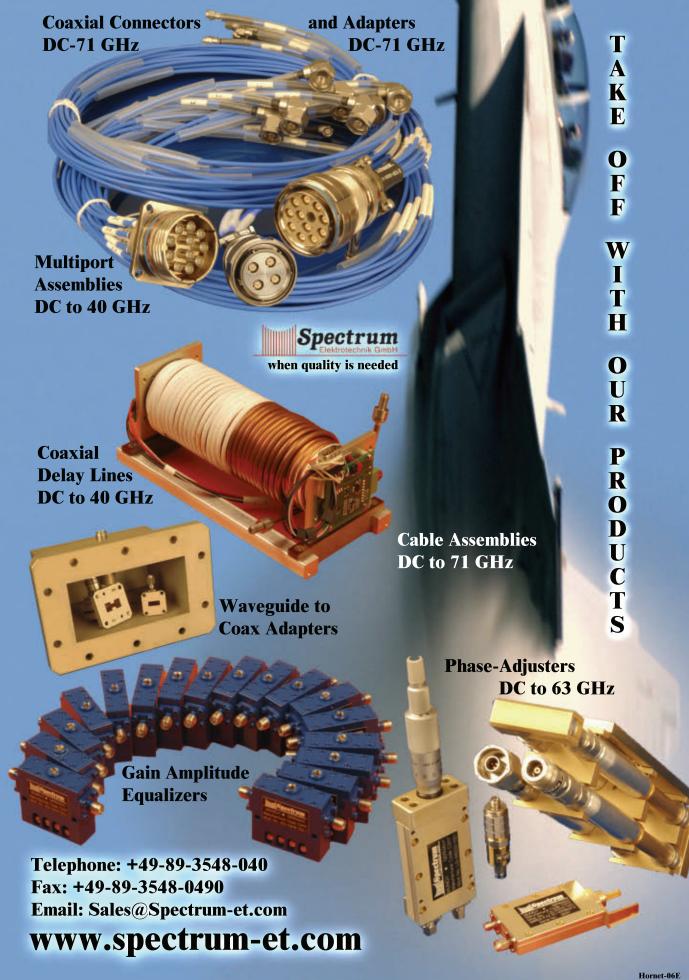


Military Products Catalog

Vectron International is both a product manufacturer and a solutions provider, leading with its unique technology but always prepared to design and engineer custom solutions where required. Vectron's core competency combines its classic crystal and SAW technology with sophisticated integrated circuits and advanced packaging. Aside from these capabilities, Vectron strives to be extremely flexible and focused on service, responding quickly and professionally helping customers innovate, improve and grow their business.

Vectron International, Hudson, NH (888) 328-7661, www.vectron.com.





MILITARY MICADWAVES

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Model	Type	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Isolation (dB)
D6233	2-Way	10-1000	25	3.25 x 2 x 1.1	0.75	1.35:1	20
D8632	2-Way	20-1000	50	2.2 x 2.02 x 1.5	0.7	1.40:1	20
D8300	2-Way	20-1000	100	2.45 x 2 x 0.91	0.5	1.35:1	20
D8544W*	2-Way	20-1000	100	2.85 x 2.5 x 1	0.5	1.35:1	18
D8682	2-Way	20-1000	500	5.2 x 2.65 x 1.8	0.6	1.35:1	15
D8851W*	2-Way	20-1000	500	5.6 x 3.05 x 1.8	0.6	1.35:1	15
D7365	4-Way	20-1000	100	5 x 2 x 1	0.75	1.35:1	20
D7439	4-Way	20-1000	250	5 x 5 x 1.5	0.75	1.35:1	18
D8746	4-Way	20-1000	500	7.2 x 3.5 x 1.4	0.7	1.35:1	15
D9048	4-Way	20-1000	500	5 x 4.7 x 1.4	0.6	1.35:1	17

^{* &}quot;W" references a Watertight Design

Dual Directional Couplers

Model	Coupling (dB)	Frequency (MHz)	Power (WCW)	Size (Inches)	Insertion Loss (dB)	VSWR	Directivity (dB)
C8858	40	10-1000	250	2.09 x 1.16 x 0.57	0.4	1.30:1	20
C8631*	40	20-1000	150	1.5 x 0.95 x 0.5	0.35	1.25:1	20
C8696	40	20-1000	150	1.76 x 1.16 x 0.57	0.35	1.25:1	20
C8686	40	20-1000	500	5.2 x 2.7 x 1.7	0.35	1.25:1	20

^{*} Non-Connectorized / Tabs

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