Vol. 48 • No. 8

August 2005

Microwave Journal

Satellite and mm-wave Applications

Millimeter-wave Satellite Remote Sensing

MTT-S 2005 Wrap-up

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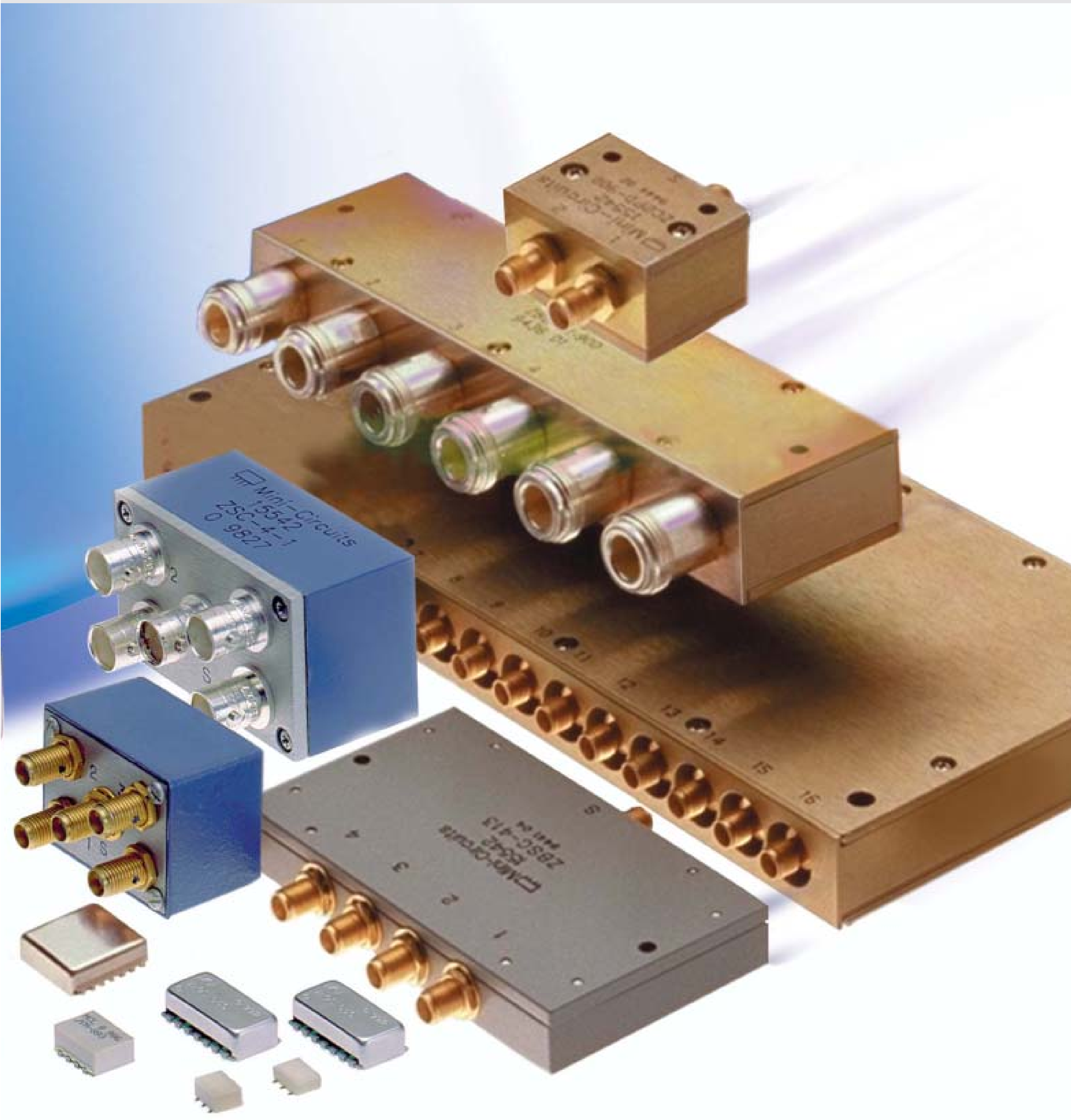

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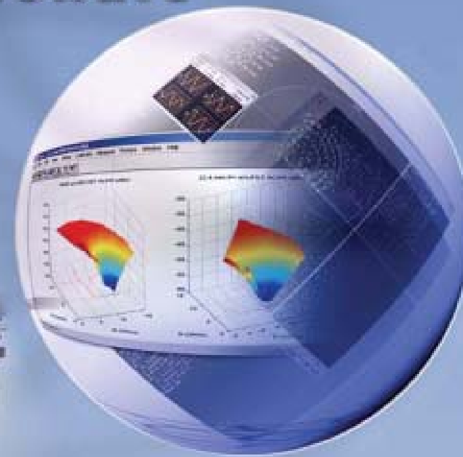

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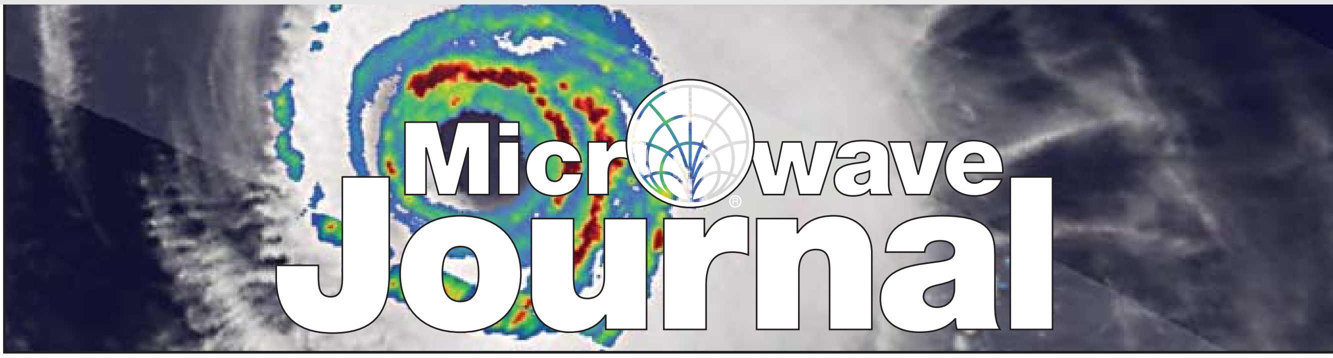

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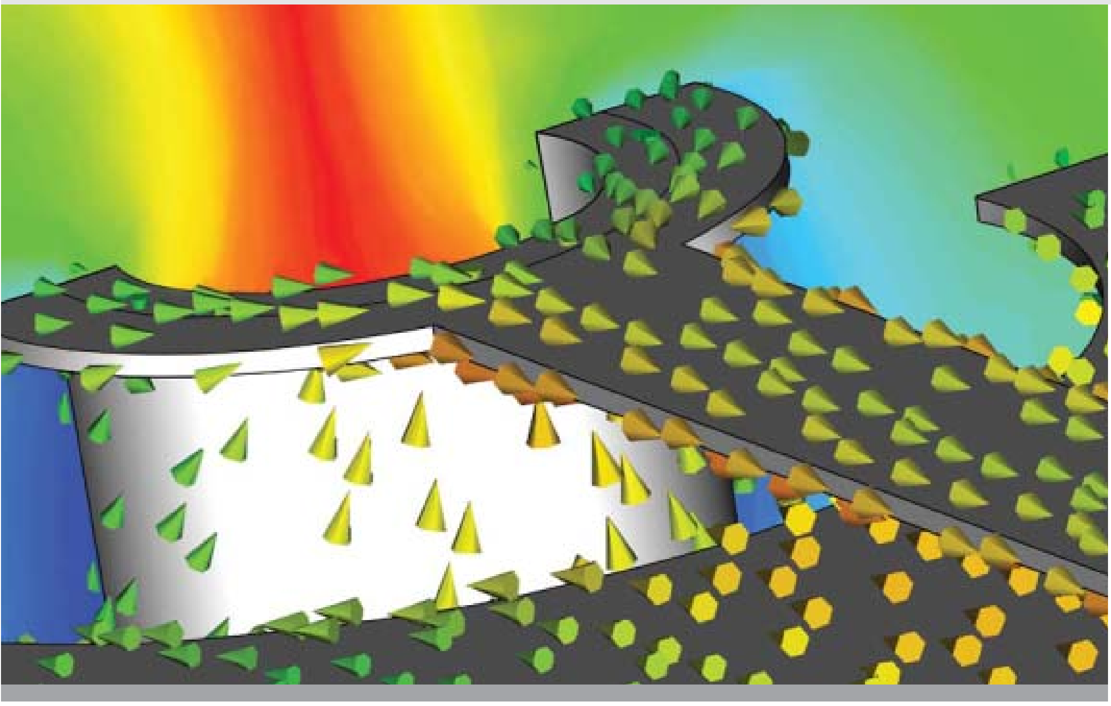
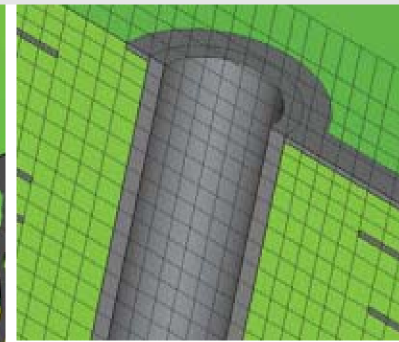
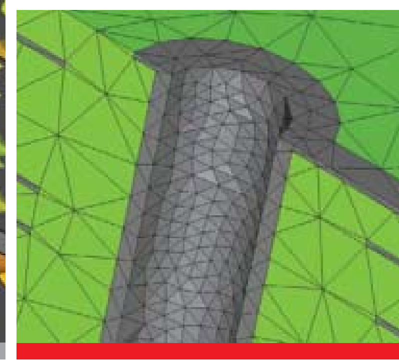

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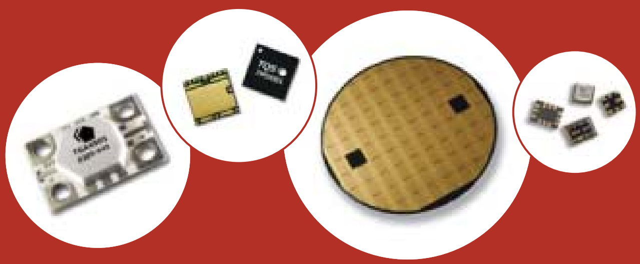

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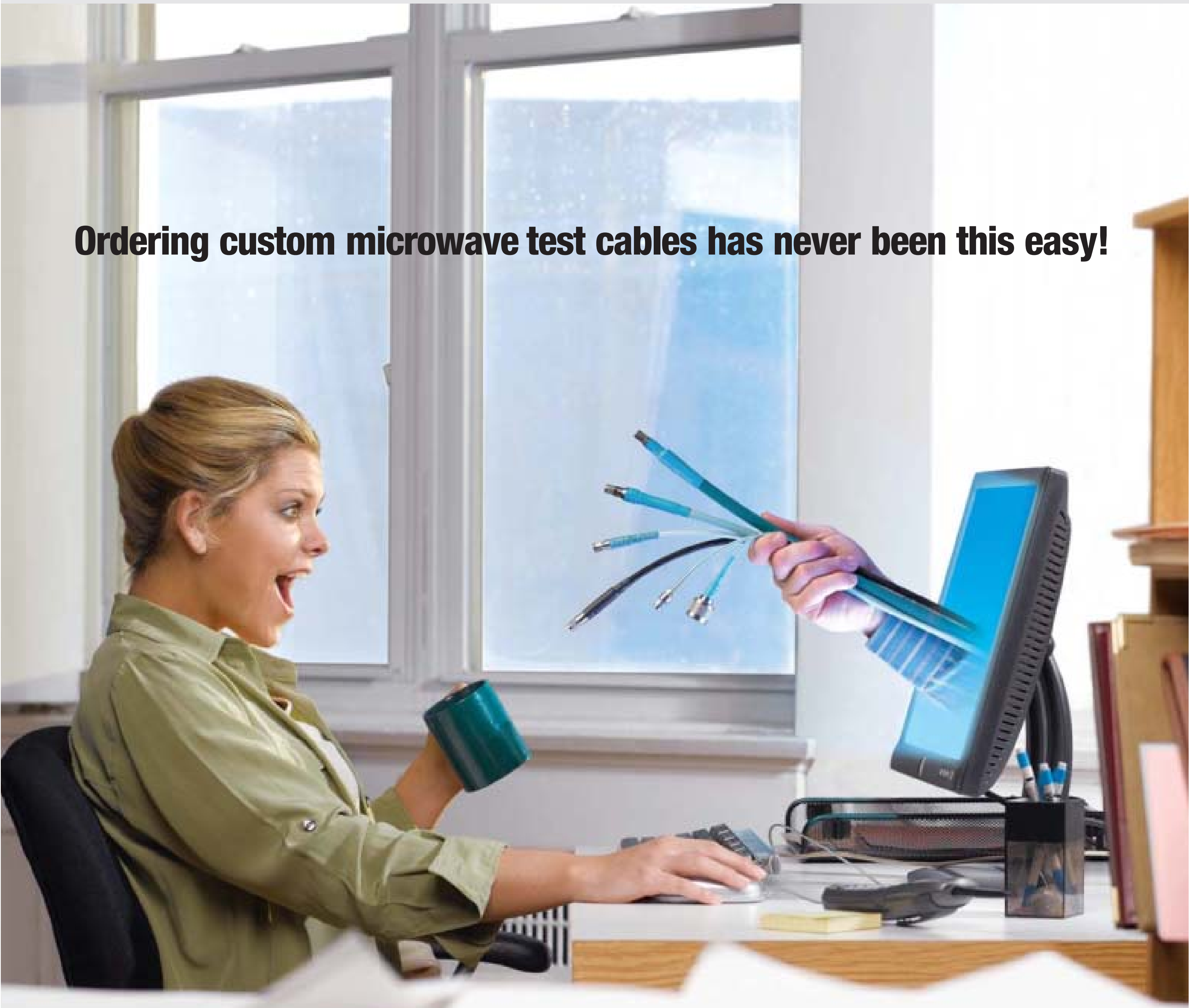

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COMING EVENTS

Military Antenna Systems
September 19–21, 2005
Arlington, VA

This event will address how the explosive growth of information technology has kept the United States military ahead in the battle for information superiority. However, with the proliferation of antenna systems, radars, jammers, radio transmitters and receivers, it has also caused a wide variety of problems; from interference and cost concerns to ship design troubles and operational problems. This conference is designed to launch the research and technologies that will ensure a smooth flow of the vast amount of battlefield data. For more information, visit www.idga.org/na-2362-01.

Antenna Systems 2005
September 22–23, 2005
Santa Clara, CA

Antenna Systems 2005 is a two-day international conference focused on the latest and most important advancements in antenna systems technology. The technical conference will serve OEM developers of products that utilize antennas and antenna systems, system operators, antenna integrators and manufacturers, and component and material suppliers interested in learning the latest capabilities and best practices in this rapidly changing field. For more information, visit www.antennasonline.com/ast_conf2005_index.htm or contact Jeremy Martin at (720) 528-3770 or e-mail: jeremym@infowebcom.com.

CTIA WIRELESS I.T. and Entertainment 2005
September 27–29, 2005
San Francisco, CA

CTIA WIRELESS I.T. and Entertainment 2005 focuses on integrating wireless technologies into the enterprise and vertical business markets such as healthcare, government and transportation. Additionally, the show reflects the explosive growth in wireless entertainment, encompassing everything from music downloads to digital cameras to interactive games. The capabilities of today's wireless devices continue to expand and improve across business sectors and personal entertainment. For more information, visit www.wirelessit.com.

European Microwave Week 2005
October 3–7, 2005
Paris, France

European Microwave Week 2005 (EuMW) features four major conferences, a three-day commercial exhibition that attracts international players, alongside technical workshops and short courses. **GAAS 2005** – The 13th Gallium Arsenide and other Compound Semiconductors Application Symposium (October 3–4); **ECWT 2005** – The European Conference on Wireless Technology (October 3–4); **EuMC 2005** – The 35th European Microwave Conference (October 4–6); **EuRAD 2005** – The 2nd European Radar Conference (October 6–7); and the **European Microwave Exhibition** (October 4–6). The exhibition is an international showcase for leading manufacturers in the RF, microwave, gallium arsenide, wireless and radar industries. For more information, visit www.eumw2005.com.

International Topical Meeting on Microwave Photonics (MWP)
October 12–14, 2005
Seoul, Korea

MWP 2005 is an international conference on microwave photonic devices, systems and applications. The meeting provides a forum for the presentation of new advances in this multidisciplinary research area, ranging from novel

devices to system field trials. It is held annually and rotates between North America, the Asia-Pacific region and Europe. For more information, visit www.mwp2005.org.

Compound Semiconductor IC Symposium
October 30–November 2, 2005
Palm Springs, CA

The Compound Semiconductor IC Symposium (formerly IEEE GaAs IC Symposium) is dedicated to providing an ideal forum for the presentation of gigahertz frequency state-of-the-art electronic circuits, devices and technologies. These areas include commercial wireless, power amplifiers, receivers, high speed digital communications, interface electronics, mm-wave defense and automotive systems. The symposium will again offer the primer course "Basics of GaAs, InP and SiGe RFICs," which is an introductory-level class intended for those wishing to obtain a broad overview of RFIC technology. For more information, visit www.csics.org.

AMTA 2005 Meeting and Symposium
October 30–November 4, 2005
Newport, RI

The Antenna Measurement Techniques Association (AMTA) is the international organization dedicated to the development, application and dissemination of advanced antenna, radar signature and related measurement technologies. The annual meeting and symposium consists of a short course, four days of technical sessions, social programs and an exhibit hall. For more information, contact Julie LaComb, chairperson, e-mail: julie@amta2005.com or go to www.amta2005.com.

IEEE Radio and Wireless Symposium
January 17–19, 2006
San Diego, CA

The IEEE Radio and Wireless Symposium (RWS 2006) continues the evolution of the successful Radio and Wireless Conference (RAWCON), most recently held in Atlanta, GA, September 2004. This conference maintains a focus on interdisciplinary aspects of wireless and RF systems and technology with an emphasis on how the elements fit together to shape the latest developments in communications technology and enable the convergence of applications. In addition to oral presentations and posters, RWS includes workshops, panels and a major exhibition. The inaugural RWS 2006 is held as part of a week-long major technical event – *MTT Wireless*. Also participating in *MTT Wireless* are the *Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems* (SiRF) and the *IEEE Topical Workshop on Power Amplifiers for Wireless Communications* (PA Workshop). Companies interested in the exhibition or in sponsorships should contact Kristen Dednah at (781) 769-9750 or e-mail: kdednah@mwjournal.com. For additional information, visit www.radiowireless.org.

IEEE MTT-S International Microwave Symposium and Exhibition
June 11–16, 2006
San Francisco, CA

The IMS Symposium will serve as the centerpiece of Microwave Week 2006. Topics will include: research, development and application of RF and microwave theory and techniques. In addition to IMS2006, a microwave exhibition, a historical exhibit, the RFIC symposium and the ARFTG conference will be held during Microwave Week 2006. The technical sessions will run Tuesday through Thursday of Microwave Week. Workshops will be held Sunday, Monday and Friday, and the ARFTG Microwave Measurements Conference will be held on Friday. For exhibition information, contact Kristen Dednah, Horizon House Publications, 685 Canton St., Norwood, MA 02062 (781) 769-9750 or email: kdednah@mwjournal.com.

Workshops & Courses

High Speed PCB, Systems Design and Use of Simulation Tools

■ **Topics:** This course will give participants the fundamental knowledge necessary to make the most efficient design-rule set for a high speed design, organize the design process to most efficiently execute the design, select the appropriate materials for the PCB itself and select the tool set that will make the design process most efficient. For more information, visit www.unex.berkeley.edu.

■ **Site:** Redwood City, CA

■ **Dates:** August 22–24, 2005

■ **Contact:** UC Berkeley Extension, 1995 University Avenue, Berkeley, CA 94720 (510) 642-4151 or e-mail: course@unex.berkeley.edu.

Linear Power Amplifier Design and Wireless Systems

■ **Topics:** This four-day Summer School, hosted by Sabanci University, Istanbul, offers intermediate sessions dealing with the fundamentals, theory and practical aspects of wireless systems, RF and microwave technology and power amplifiers. It will be of interest to graduate students, researchers, engineers and technical staff planning a career in these fields. Tutorials on RF integrated circuit design techniques with application examples and software tools are also included.

■ **Site:** Istanbul, Turkey

■ **Dates:** Aug. 30–Sept. 2, 2005

■ **Contact:** Prof. Yasar Gurbuz, Sabanci University, Istanbul, Turkey +90 (216) 483 9533 or e-mail: yasar@sabanciuniv.edu.

Basic Antenna Concepts

■ **Topics:** This course will provide a practical understanding of the fundamental principles of antennas. It consists of a combination of lectures, interactive computer simulations and laboratory demonstrations that allow a participant to obtain a basic understanding of modern antennas. The course will minimize mathematical explanations and emphasize intuitive physical explanations and laboratory demonstrations. For more information, visit www.pe.gatech.edu.

■ **Site:** Smyrna, GA

■ **Dates:** September 27–30, 2005

■ **Contact:** Georgia Institute of Technology, Professional Education, PO Box 93686, Atlanta, GA 30377 (404) 385-3500.

Complete 3D EM Technology — CST MWS

■ **Topics:** This one-day workshop is an introduction to the field of 3D electromagnetic simulation. It is intended for engineers, managers and technicians who are interested in improving productivity in the area of high frequency design. Various applications will be presented with the opportunity to work with the software. For more information, visit www.cst.com.

■ **Site:** San Bruno, CA

■ **Date:** October 11, 2005

■ **Contact:** CST of America Inc., 10 Laurel Avenue, Suite 300, Wellesley Hills, MA 02481 (781) 416-2782.

Microwave Measurements for High Performance Devices and Applications

■ **Topics:** This 1-1/2 day course covers microwave measurement fundamentals, including vector network analysis, scattering parameters, power and thermal noise. Practical issues such as cables, fixtures, probes and on-wafer measurements are covered. For more information, visit www.arftg.org.

■ **Site:** Washington, DC

■ **Dates:** November 29–30, 2005

■ **Contact:** David Walker, NIST, M.S. 818.01, 325 Broadway, Boulder, CO 80305 (303) 497-5490 or e-mail: dwalker@boulder.nist.gov.

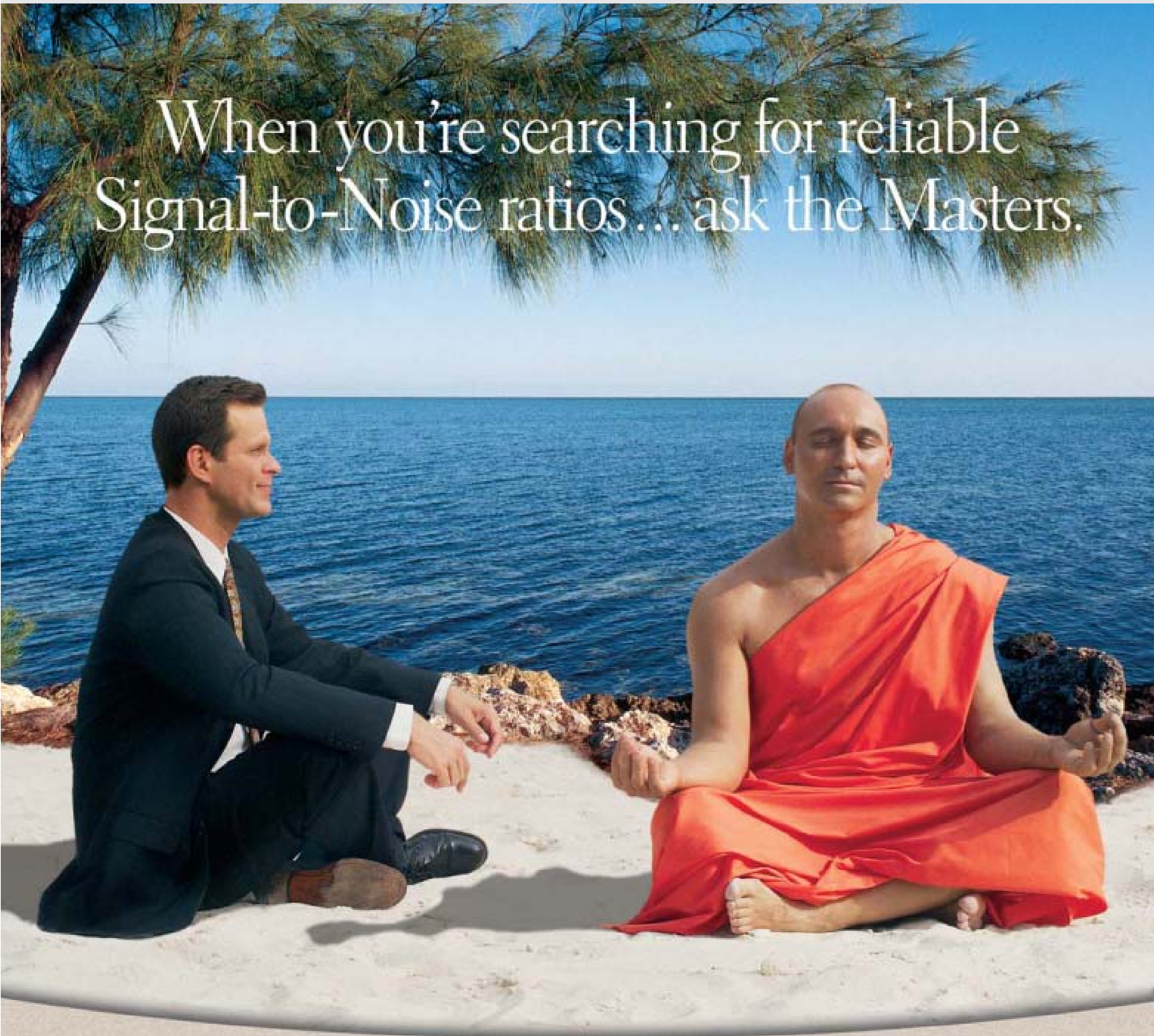
Symmetrical Components

■ **Topics:** This course discusses a variety of topics such as phasors and complex number mathematics, balanced and unbalanced three-phase systems, sequence networks, fault impedance and fault calculation methods. The course concludes by analyzing short circuit and open-circuit faults, including workshops on developing sequence networks and performing fault calculations. For more information, visit http://feeds.eng.usf.edu.

■ **Site:** Archived on-line course.

■ **Dates:** Archived on-line for anytime viewing.

■ **Contact:** FEEDS Office at the University of South Florida (813) 974-3783.



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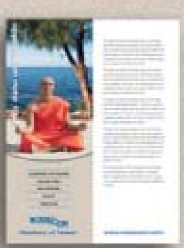

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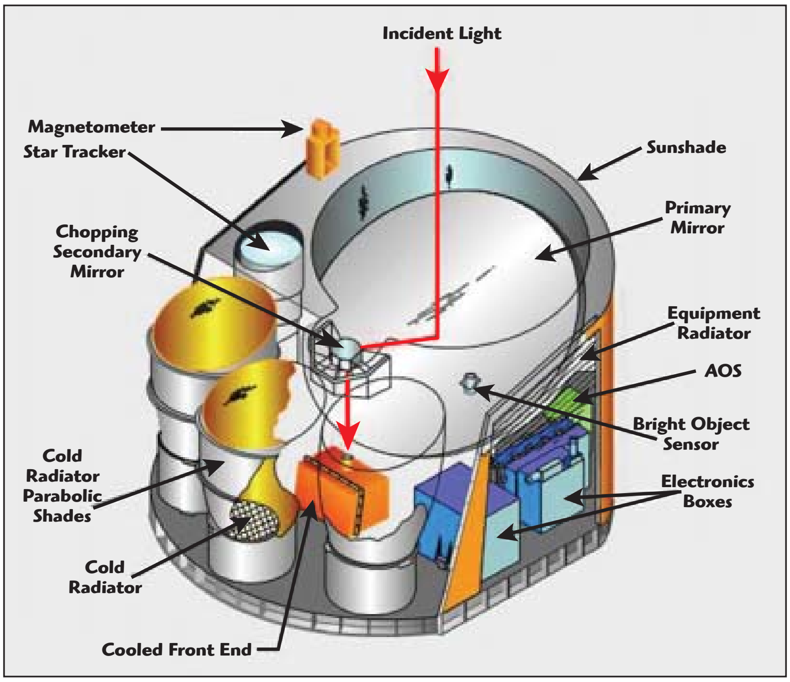
INVITED PAPER

COVER FEATURE

MILLIMETER-WAVE SATELLITE REMOTE SENSING

When the Hubble Satellite was launched in 1990, the joke was that it was the third best optical satellite in space, but that the two better ones were pointed in the opposite direction. While it is still true today that more satellites are looking downward than upward, satellites are now much more likely to include sensors for other than just the optical portion of the electromagnetic spectrum. They now involve many other bands, including millimeter-waves, for specific data collection tasks. While the heavy lifting for satellite-based data gathering is still accomplished at optical and infrared frequency ranges, the microwave and millimeter-wave ranges offer specific advantages that make them far better suited to certain satellite missions. Millimeter-wave remote sensing serves two main functions: spectral line detection (spectroscopy), to distinguish the spectral signature for a specific element or molecule and determine its relative abundance and speed; and radiometry, to ascertain the temperature of the radiating source. Because of this technology, millimeter-wave sensors on satellites have become extremely important tools for gathering data: astrochemistry and continuum noise measurements when the satellite is pointed upward, and weather forecasting (using a variety of measurements), oceanography, ozone and soil moisture measurements when pointed downward. A discussion of the more relevant satellite systems employing millimeter-wave technology follows.

Fig. 1 The Submillimeter-wave Astronomy Satellite (SWAS) instrument (courtesy of Harvard University).[1]



MILLIMETER-WAVE SPECTROSCOPY

The primary application for remote sensing at millimeter-wave frequencies is the detection of molecules of various substances. When molecules collide, they emit faint electromagnetic signals at specific frequencies called spectral lines. These signals are detected using a sensitive receiver equipped with an RF spectrometer centered on a frequency band near the spectral line of interest. Examples of a receiver and received spectrum are shown in ***Figures 1***

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Millitech Inc.
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Previous Page | Contents | Zoom In | Zoom Out | Front Cover | Search Issue | Next Page

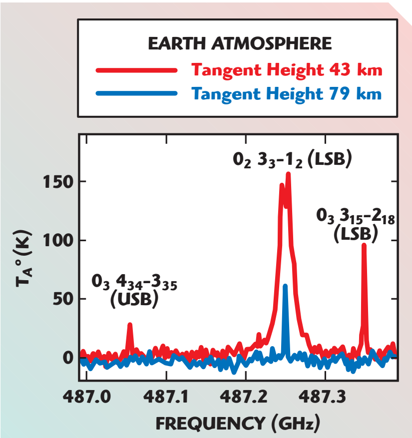

Fig. 2 Spectral lines measured by SWAS.[2]

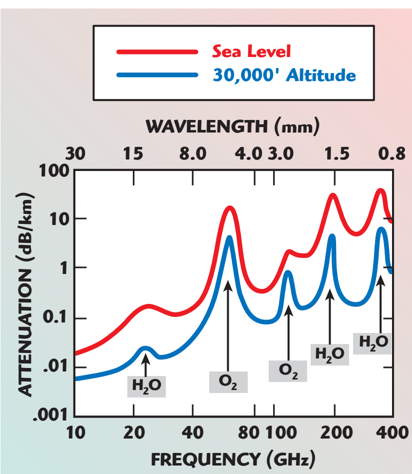

Fig. 3 Average atmospheric absorption of millimeter waves (horizontal propagation).[3]

and **2**. Molecules can also absorb energy at discrete frequencies. This is responsible for the absorption of millimeter-wave energy by the atmosphere, as shown in ***Figure 3***. Viewing gases against a broadband source such as the sun is another method of detecting molecule species by their absorption spectra. The absence of signal at a particular frequency indicates spectral line absorption associated with a particular energy state of a species.

For atmospheric monitoring by satellite, several molecules of interest have spectral lines at millimeter-wave frequencies, including oxygen (60, 180 GHz), water vapor (22, 183 GHz), ozone (184, 206 GHz) and chlorine monoxide (204 GHz). For certain molecules, millimeter-wave frequencies have advantages over infrared (IR) and near-IR, as millimeter-waves are not easily obscured by cloud cover. The width of spectral lines varies with pressure due to a phenomenon known as pressure-broadening. Since the atmospheric pressure changes with altitude, a spectral line measurement contains a combination, or superposition, of lines of various widths. Using sophisticated modeling techniques, the abundance of a species can be determined as a function of altitude in a given column of atmosphere. This technique is used to characterize a profile of water vapor versus altitude, which is in turn used by weather-modeling software along with many other data measurements, to forecast the weather.

Atmospheric measurement instruments aboard satellites have significant advantages over their earth-bound counterparts. For one thing, ground-based atmospheric measurements are mainly limited to landmass locations with little coverage of the oceans. Satellites that point toward the earth (nadir observations) are particularly effective at collecting oceanic data, since broadband radiation from the land reduces the sensitivity of these measurements. While all objects emit broadband radiation that is proportional to their temperature (blackbody radiation), the emissivity (the ratio of the radiation emitted by a surface to the radiation emitted by a blackbody at the same temperature) of the oceans is much lower than that of landmasses, thus lessening the effect. Measurements of the atmosphere can also be made against the cold (2.7 K) background of space by looking through the edge, or limb, of the atmosphere. The instruments that make these types of measurements are known as limb sounders, and are used for the most sensitive atmospheric measurements.

A principal goal for astronomers is to determine the chemistry of star formation from gaseous clouds. Water vapor, carbon monoxide, molecular oxygen and atomic carbon are of particular interest. These molecules are more likely to convert kinetic energy to radiation and their radiated spectra are important artifacts of stellar evolution. Radio astronomers have studied the chemical composition of molecular clouds for decades using earth-based telescopes. However, the earth's atmosphere tends to obscure many of these species from earth-bound instruments, particularly at submillimeter-wave and higher millimeter-wave frequencies. This limitation has led to the development of satellite-based radio telescopes such as Smithsonian Astrophysical Observatory's Submillimeter-wave Astronomy Satellite (SWAS). Using such satellites, astronomers have been able to measure the abundance of various molecule species that lead to star formation.

Spectral measurements require the use of RF spectrometers. A spectrometer is a specialized instrument that can simultaneously detect a series of multiple frequencies. Typical laboratory spectrum analyzer measurements sweep a narrow receiver across a band of interest, and only one frequency can be detected at any given time. Spectrometers are able to detect signals at all frequencies across their band simultaneously, greatly improving the sensitivity of the measurement.

There are three basic types of spectrometers: filter banks, autocorrelators and acousto-optic spectrometers. A filter bank, as the name implies, is simply a series of filters at successive frequencies with detectors at their outputs. The filters are multiplexed at their input and since each filter has its own detector, simultaneous spectral measurements can be made. This is the most effective solution when only a small number of channels are required, as in the case of atmospheric measurements. For astronomical applications, filter banks are less practical because the spectral line frequencies can undergo large Doppler shifts due to the relative motions of stellar and interstellar sources. The spectral line frequencies are not fixed and therefore require a greater number of channels. Conceptually, digitizing the RF band and applying a Fourier transform is another method of deriving the RF spectrum. Unfortunately, real-time fast Fourier transforms (FFT) are not practical much above audio frequencies. By mixing the RF with a time-delayed version of itself using logic circuits known as autocorrelators, a digitized RF can be autocorrelated in real time with significant bandwidths. The power spectrum can then be derived by transforming the integrated data. The biggest drawback of autocorrelators for satellite applications is their

significant power consumption requirements. The third type of spectrometer is an acousto-optic spectrometer (AOS). An AOS introduces RF signals into one end of a crystal structure known as a Bragg cell. Acoustic waves in the Bragg cell create a density distribution that mimics the RF signal and acts like a diffraction grating to a coherent light source used to illuminate the cell. The light emerges from the grating at different angles and intensities based on the respective frequency and amplitude of the RF input. The light is then detected on a charge-coupled device (CCD) that integrates, or counts, the power in respective frequency channels. An AOS makes an ideal choice for satellite-based radio astronomy applications since broad bandwidth and high resolution are possible with relatively low power consumption.

RADIOMETRY

As molecules coalesce into larger particles, they no longer emit radiation in spectroscopic lines; instead, they emit over a broad continuum of frequencies. Planck's function calculates the maximum emission magnitude from an object, based on the temperature of the object and the measurement frequency. The actual radiation magnitude from an object is reduced, however, by the emissivity of the object. An object that radiates exactly the Planck calculated value (emissivity = 1) is termed a blackbody. A radiometer is a very sensitive receiver that measures extremely low power radiation across a continuum of frequencies in order to determine the temperature and emissivity of an object. Radiometers are used on satellites for a variety of purposes. One application is to measure the temperature of dust in star-forming regions, or in the vast regions between stars. The degree of frequency shift of the radiation curve from Planck's function indicates the speed of the dust relative to our position in space. This is known as the red shift.

Another application is the calibration of space radars such as Ku-band altimeters. Sea surface mapping is of great interest to oceanographers and climatologists (not to mention the military), but even at Ku-band the atmospheric effects make it impossible to achieve the needed accuracy. The two factors are temperature and water vapor, which can be characterized very precisely with radiometers operating on or near the oxygen line at 60 GHz and the water line at 22 GHz. Using the reverse superposition technique mentioned earlier, the temperature of the pressure broadened oxygen in the atmosphere is characterized versus altitude, which can be assumed to be equal to the temperature of the air versus altitude. For water vapor content, all that is needed is the total collimated amount of water vapor to calibrate for the effective dielectric constant of the air in the column due to water vapor. With prior knowledge of the temperature profile and the water vapor content, the accuracy of a Ku-band altimeter is greatly improved.

ACTIVE SENSING

Both spectroscopy and radiometry are passive techniques, in that they

Fig. 4 *CloudSat Satellite at Vandenberg AFB (courtesy of CloudSat Web site).*[5]

only receive and do not transmit any RF energy. Active techniques, such as various types of radar from satellites, have been used in the microwave range but not the millimeter-wave range until the launch of CloudSat this summer (see ***Figure 4***). Millimeter-wave systems are relative newcomers to satellites, and while bringing enhanced resolution and reduced antenna size in comparison to microwave systems, they are also encumbered with lower power levels and higher attenuation levels through the atmosphere. Power levels delivered from millimeter-wave MMICs are continuing to rise, particularly with the advent of wide bandgap materials for MMIC substrates. Active sensing from satellites in the millimeter-wave band will first be realized by the CloudSat satellite, which will be used for the profiling of cloud condensation and precipitation. This is accomplished by a 94 GHz pulsed radar (2 kW pulses, 3.3 μs long, every 0.32 sec) with a vertical resolution of 500 m. As was the case with microwave space radars, other new areas of research will likely follow. One such example is the discovery of subsurface prehistoric river systems beneath the Sahara Desert by the Shuttle Imaging Radar system,[4] which constructed images of the ground from synthetic aperture radar scans at 1.3, 5 and 10 GHz. A future microwave active-sensing satellite of note is the US Air Force's Space-based Radar, which is a constellation of satellites for the tracking and targeting of ground-based targets using synthetic aperture radar. For a more detailed view of millimeter-wave systems on satellites, let us first review past satellite systems before exploring current and future projects.

PAST SYSTEMS

The history of millimeter-wave remote sensing from space began in December of 1972 when NASA launched the Nimbus-E, the fifth in a series of polar-orbiting meteorological satellites. Two millimeter-wave sensors were onboard: the Electrically Scanning Microwave Radiometer (ESMR) operating at 19.35 GHz, and the Nimbus-E Microwave Spectrometer (NEMS) operating five channels at 22.235, 31.4, 53.65, 54.9 and 58.8 GHz. These instruments allowed scientists to discover the "hidden" features of the earth and atmosphere, previously unavailable from established optical and IR instruments, as their measurements are hindered by cloud cover. Although these millimeter-wave instruments were experimental, they provided data to demonstrate that surface temperature, at-

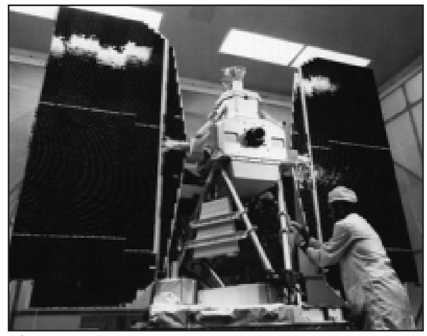

Fig. 5 Nimbus-E (courtesy of NASA).[6]

mospheric water vapor content and temperature profiles could be obtained globally from space. An additional advantage is the ability of these "hidden" characteristics, especially water vapor, to enhance the accuracy of IR instruments. Millimeter-wave instruments have been ever-present on meteorological satellites since the launch of Nimbus-E (see ***Figure 5***). The Nimbus-F was launched two and a half years later. This satellite had a different ESMR, which operated at 37 GHz, and the NEMS was replaced by a similar, but more advanced, Scanning Microwave Spectrometer (SCAMS). This also provided five channels in the same bands but utilized slightly different frequencies. The two ESMRs were both the first and last space-based, electrically-scanning millimeter-wave instruments. All subsequent millimeter-wave sensors have utilized mechanically-scanned mirrors, which provide optimal performance with respect to loss and beam efficiency. The seventh and last of the Nimbus satellites was G, launched in 1978 (see ***Figure 6***). It carried another breakthrough instrument, the Scanning Multispectral Microwave Radiometer (SMMR). One of the key characteristics of the SMMR was that it operated with a conical scan geometry, providing consistent size and shape of the field-of-view (FOV) or "footprint," as well as constant incidence angle on the earth's surface. This was important because its primary objective was to measure surface characteristics with frequencies of 6.6, 10.7, 18, 22 and 37 GHz, all dual-polarized (H&V) for ten channels of data.

The SMMR inaugurated a special class of instrument, the conical scanner. Conical scanners are configured with upward-firing feedhorns in which the reflector redirects the FOV back down toward earth. As previously mentioned, this provides a constant footprint, incidence angle and polarization throughout the scanning sector, an important factor when processing data and developing retrieval algorithms. This geometry has also enabled the use of larger reflector antennas in later instruments. However, the drawbacks of the conical scanner are:

- The scan track is an arc, which previously presented a challenge to mapping efforts.
- The arc and incidence angle introduce a Doppler shift, which varies with scan position. This issue is infrequent as it applies only to those channels that require frequency accuracy better than a few megahertz.

Fig. 6 Nimbus-G (courtesy of NASA).[7]

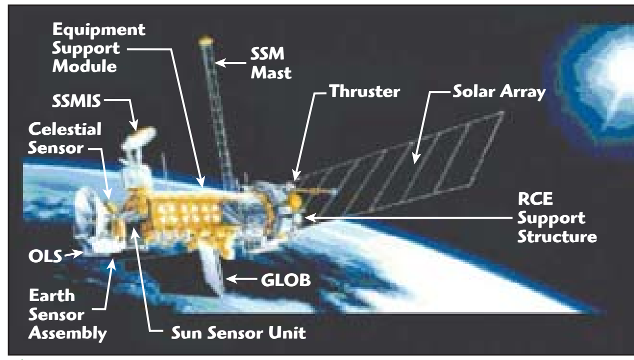

Fig. 7 View of the 5D-3 spacecraft (courtesy of DMSP).[8]

- The topside placement on a spacecraft leaves the instrument "hanging in the breeze" so to speak, leaving it without the support and protection of the spacecraft instrument platform and sun shades. These characteristics typically make conical scanners much more complex than their smaller counterparts, but also provide the ability for a larger antenna system and better spatial resolution.

Millimeter-wave instruments were incorporated on the NASA/NOAA upgraded next generation Television InfraRed Operational Satellite (TIROS-N). Ten TIROS-N satellites (A thru J) were launched between 1979 and 1994, each carrying the Microwave Sounding Unit (MSU) as part of the TIROS Operational Vertical Sounder (TOVS). The MSU, built by JPL, was essentially an improved SCAMS with four channels from 50 to 58 GHz, providing temperature profiles of the atmosphere. More MSUs have been put into orbit than any other millimeter-wave instrument.

In 1983, the USAF Defense Meteorological Support Programs (DMSP) incorporated its first millimeter-wave instrument with the Special Sensor Microwave/Temperature, built by Aerojet (see ***Figure 7***). The SSM/T implemented seven channels from 50 to 60 GHz, providing an atmospheric temperature profile superior to the TIROS-N MSU, with only four channels. The next launch in 1987 achieved another milestone, launching the Special Sensor Microwave/Imager (SSM/I) aboard the Block 5D2-F8 spacecraft. The SSM/I was built by Hughes and implemented the first total-power radiometers in space. It was a conical scanner similar to the SMMR but with seven channels: 19H, 19V, 22V, 37H, 37V, 85H and 85V. The SSM/I provided unprecedented results due to the improved sensitivity of the total power radiometers and the high spatial resolution of the 85 GHz channels. The last of six SSM/Is was put into orbit in 1997.

In 1991, NASA deployed the Upper Atmospheric Research Satellite (UARS) from the Space Shuttle. This was an extremely large platform, which included a Microwave Limb Sounder (MLS) built by JPL. The MLS features three channels at 60, 183 and 205 GHz. It measures the characteristics of the earth's limb where the FOV grazes through the atmosphere, without looking to the surface. In 2004, an updated version of the MLS was launched on NASA's Earth Observing Satellite (EOS) Aura. The 183 GHz channel was dropped and replaced by two submillimeter channels.

In 1991, the DMSP achieved yet another milestone when the Special Sensor Microwave/Temperature-2

(SSM/T-2) was launched with the SSM/I and SSM/T on a 5D2-F11. SSM/T-2, also built by Aerojet, has five channels: one at 91, one at 150 and three at 183 GHz. This represented the most comprehensive suite of millimeter-wave remote sensing instruments ever assembled on a single spacecraft.

In 1987, Japan joined the space age with respect to meteorology and millimeter-wave remote sensing with the launch of the first Marine Observation Satellite (MOS-1). MOS-1 carried IR sensors and the Microwave Scanning Radiometer (MSR), which provided K- and Ka-band channels for atmospheric water vapor measurements. MOS was then followed by the Tropical Rainfall Measuring Mission launched in 1997, a joint effort between NASA and Japan. The TRMM Microwave Imager (TMI) built by Hughes was similar to the SMMR and SSM/I with channels from 10.7 to 85.5 GHz. Meanwhile, microwave and millimeter-wave remote sensing had gained interest from the international community as manifested with the formation of the European Space Agency (ESA). ESA's first Remote Sensing Satellite (ERS-1) was launched in 1991 and ERS-2 in 1995, both with similar Ku-band altimeters for sea surface mapping and both including 23.8 and 37 GHz radiometers to calibrate the path length effect of the water vapor. In 1992, TOPEX/Poseidon was launched. It includes a 13.5 GHz sea surface radar altimeter and is now in the 12th year of its original three-year mission. Others have followed, such as GeoSat Follow-On (GFO) for the US Navy in 1998, Jason-1 in 2001 and EnviSat in 2002. The original GeoSat was classified in 1985 and GFO presented improvements in all aspects of the original. TOPEX/Poseidon and Jason-1 are both joint NASA/CNES projects, while EnviSat is an ESA satellite built by Astrium. Cooperative projects between NASA, ESA and other individual countries had been developed, and in 1998 NASA and NOAA launched the latest TIROS, NOAA-K, with several new sensors provided by ESA participants. The cornerstone of the millimeter-wave instruments was the Advanced Microwave Sounding Unit (AMSU), built by Aerojet. It was comprised of three modules: AMSU-A1, featuring the highest altitude temperature sounding with 12 channels from 50 to 58 GHz and another channel at 89 GHz; AMSU-A2, featuring 23.8 and 31.4 GHz with a larger antenna to provide a matching footprint; and AMSU-B, featuring 89, 150 and three 183 GHz channels similar to the SSM/T-2. The AMSU instruments have been launched on a total of four Advanced TIROS spacecraft (K, L, M and N) in 1998, 2000, 2002 and most recently in 2005. The latest launch replaced the AMSU-B with the Microwave Humidity Sounder (MHS), which has essentially the same features but is built by Astrium EU as part of furthering international cooperation. Additional AMSU instruments have been included on the EOS ADEOS-II, launched in 2002, and the EOS Aqua satellite in 2004. More recently, Japan has developed a conical scanning instrument, the Advanced Microwave Scanning Radiometer (AMSR). It is similar to the TMI except that its lowest channel is 6.9 GHz and a total of

▲ *Fig. 8 SWAS (courtesy of Harvard University).*[9]

nine channels extend to 89 GHz. The AMSR has been launched on the ADEOS-II and EOS Aqua satellites.

The DMSP has recently launched an upgraded satellite, the 5D-3. On this spacecraft the function of all three SSM instruments (SSM/I, SSM/T and SSM/T-2) has been consolidated into a single instrument, the SSMIS, built by Aerojet. The SSMIS represents yet another step forward in complexity and capability for a millimeter-wave sensor providing 24 channels spanning from 19 to 183 GHz simultaneously.

Millimeter-wave technology has also been implemented to observe the cosmos. The phenomena are the same: blackbody emissions of the targets resulting from the targets themselves and their specular absorption. Terrestrial radio telescopes are limited in their performance by the effect of atmospheric attenuation and distortion. A space platform above the atmosphere provides a clear view of celestial objects and features. In 1989, NASA launched the Cosmic Background Explorer (COBE) to map the temperature of the cosmos, looking for any possible pattern. One of three sensors, the Differential Microwave Radiometer (DMR), detected broadband noise temperature at 31.5, 53 and 90 GHz with six passively-cooled radiometers. The DMR discovered that there was significant anisotropy over the background, which had not been anticipated. Based on these results, a higher resolution instrument was developed, the Wilkinson Microwave Anisotropy Probe (WMAP), detecting with 23, 33, 41, 61 and 94 GHz. Launched in 2001, WMAP was a collaboration with Princeton and NASA GSFC, and was quite successful at enhancing the resolution of the measurement of the cosmic background anisotropy. NASA launched a series of Small Explorer (SMEX) missions, and in 1998 launched the Submillimeter-wave Astronomy Satellite (SWAS), the first of its kind (see ***Figure 8***). SWAS was a dual-channel spectrometer operating at 490 and 550 GHz, detecting the concentrations of five molecular constituents: O_2, H_2O, ^{13}CO, C and $H_2{}^{18}O$. SWAS was a wholly collaborative effort: The Smithsonian Astronomy Observatory led the science team; the entire radiometer receiver system was built by Millitech; the spectrometer, an acousto-optical Bragg cell (AOS), was provided by the University of Cologne; and the instrument platform and integration, incorporating a 0.6 m telescope mirror, was built by Ball Aerospace. SWAS discovered a much larger than expected water content throughout the cosmos and was also diverted to observe the atmospheres of Mars, Jupiter and Saturn, as well as take a brief look at the comet C/1999 H1. In all cases, SWAS provided information never before available, some of which contradicted previous theories. ***Table 1*** provides a summary of past millimeter-wave satellite sensors, the spacecraft on which they were used and the detection frequencies.

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Broadband Low Noise Amplifiers							
AML016L2802	0.1 – 6.0	28	±1.25	1.3*	+7	2.0:1	190
AML48L3001	4.0 – 8.0	30	±1.0	1.2	+10	1.8:1	150
AML412L3002	4.0 – 12.0	30	±1.5	1.5	+10	1.8:1	150
AML218L0901	2.0 – 18.0	9	±1.0	2.2	+5	2.5:1	60
AML0518L1601-LN	0.5 – 18.0	16	±1.0	2.7	+8	2.2:1	100
AML0126L2202	0.1 – 26.5	22	±2.25	3.5*	+8	2.2:1	170
AML1226L3301	12.0 – 26.5	33	±2.0	2.8	+8	2.5:1	200
Broadband Medium Power Amplifiers							
AML0016P2001	0.01 – 6.0	21	±1.25	3.2*	+23*	2.0:1	480
AML26P3001-2W	2.0 – 6.0	28	±2.5	6	+33	1.8:1	1500
AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
AML618P3502-2W	6.0 – 18.0	35	±2.5	4	+33	2.0:1	1850
Narrow Band Low Noise Amplifiers							
AML23L2801	2.8 – 3.1	28	±0.75	0.7	+10	1.8:1	150
AML1414L2401	14.0 – 14.5	24	±0.75	1.5	+10	1.5:1	130
AML1718L2401	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150

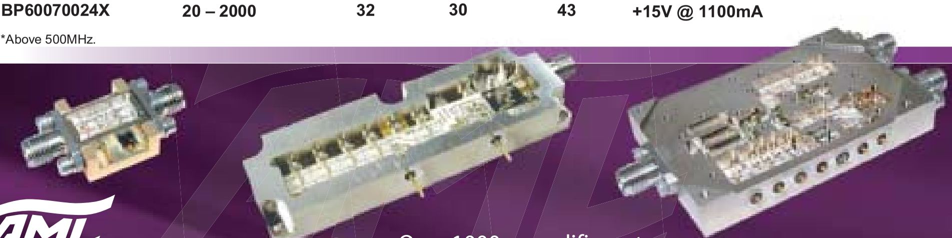
Low Phase Noise Amplifiers — Phase noise (dBc/Hz) at offset

Part Number	Frequency (GHz)	Gain (dB)	Output Power (dBm)	100Hz	1KHz	10KHz	100KHz
AML811PN0908	8.5 – 11.0	9	17	-154	-159	-167	-170
AML811PN1808	8.5 – 11.0	18	18	-152.5	-157.5	-165.5	-168
AML811PN1508	8.5 – 11.0	15	28	-145.5	-153.5	-158.5	-164.5
AML26PN0904	2.0 – 6.0	9	20	-150	-165	-165	-178
AML26PN1201	2.0 – 6.0	11	15	-155	-160	-160	-175

High Dynamic Range Amplifiers

Part Number	Frequency (MHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	DC
AR01003251X	2 – 32	21	32	52	+28V @ 470mA
AFL30040125	50 – 500	23	28	53	+28V @ 700mA
BP60070024X	20 – 2000	32	30	43	+15V @ 1100mA

*Above 500MHz.



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Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Gain (dB)	DC Current(A) @ +12V
Broadband Microwave Power Amplifiers						
L0104-43	1 - 4	42.5	17.8	41.5	45	14
L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0218-30	2 - 18	30	1	29	30	3
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-44	8 - 12	44	22	42	45	22
L1218-43	12 - 18	43	20	41.5	45	22
Millimeter-Wave Power Amplifiers						
L1826-34	18 - 26	34	2.5	33	35	4
L1840-27	18 - 40	27	0.5	26	30	2
L2632-37	26 - 32	37	5	36	38	10
L2640-27	26 - 40	27	0.5	26	30	2
L2630-37	26.5 - 30.5	37	5	36	38	10
L2732-35	27 - 32	35	2.8	33	35	6
L3040-30	30 - 40	30	1	29	35	4
L3236-36	32 - 36	36	4	35	40	12
L3640-36	36 - 40	36	4	35	40	10

High-Power Rack Mount Amplifiers

Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Pac (kW)	Height (in)
C071077-52	7.1 - 7.7	52.5	170	51.5	1.8	10.25
C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-40	26.5 - 30.5	40	10	39	0.25	5.25
C3236-40	32 - 36	40	10	39	0.25	5.25
C3640-39	36 - 40	39	8	38	0.24	5.25

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TABLE I

MILLIMETER-WAVE SATELLITE SENSORS EMPLOYED ON PAST SPACECRAFT MISSIONS

Instrument	Launch Date	Mission/Spacecraft	Frequencies (GHz)
ESMR-E	1972	NASA Nimbus-E	19.35
NEMS	1972	NASA Nimbus-E	22.235, 31.4, 53.65, 54.9, 58.8
ESMR-F	1975	NASA Nimbus-F	37
SCAMS	1975	NASA Nimbus-F	22.235, 31.4, 53.65, 54.9, 58.8
SMMR	1978	NASA Nimbus-G	6.6, 10.7, 18, 22.2, 37
MSU	1979–1994	NASA TIROS-N (A–J)	50–58
SSM/T	1983–1997	DMSP 5D2	50–60
SSM/I	1987–1997	DMSP 5D2	19, 22, 37, 85
MSR	1987, 1990	NASA-NASDA MOS-1/1b	23.8, 31.4
DMR	1989	NASA COBE	31.5, 53, 90
MLS	1991 2004	NASA UARS EOS Aura	60, 183, 205 118, 190, 240, 640
SSM/T-2	1991–1997	DMSP 5D2	91, 150, 183
TMR JMR	1992 2001	NASA-CNES TOPEX/Poseidon NASA-CNES Jason-1	18.7, 23.8, 34
MWR	1992 1995 2002	ESA ERS-1 ESA ERS-2 EnviSat	23.8, 36.5
TMI	1997	NASA-NASDA, TRMM	10.7, 19.4, 21.3, 37, 85.5
SWAS	1998	NASA-SAO, SWAS	490, 550
WVR	1998	US Navy, GFO	22, 37
AMSU-A	1998–present 2002 2002 2005–planned	NASA/NOAA ATN (K–N) ADEOS II EOS Aqua METOP-1	23.8, 31.4, 50–58, 89
AMSU-B HSB	1998–2002 2002	NASA/NOAA ATN (K–M) EOS Aqua (Brazil sponsored)	89, 150, 183 150, 183
WMAP	2001	NASA WMAP	23, 33, 41, 61, 94
MHS	2005	NASA/NOAA ATN (N) (replaces AMSU-B)	89, 157, 183
AMSR	2002	ADEOS II	6.925, 10.65, 18.7, 23.8, 36.5, 50.3, 52.8, 89
AMSR-E	2002	EOS Aqua	6.925, 10.65, 18.7, 23.8, 36.5, 89

CURRENT SYSTEMS

There are three major satellite systems currently in development with millimeter-wave sensors on board that Millitech has had involvement with: NPOESS, GPM/GMI and Herschel. Each represents several major steps forward in data gathering abilities.

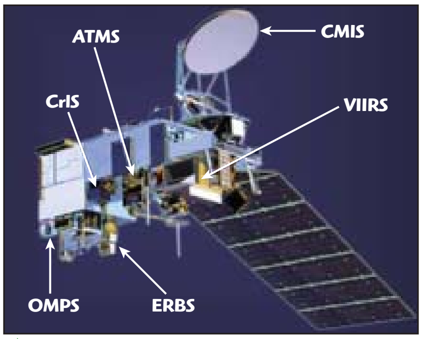

Fig. 9 NPOESS 1330 configuration (courtesy of NOAA).[10]

National Polar-orbiting Operational Environmental Satellite System (NPOESS)

NPOESS is a planned constellation of polar-orbiting satellites that contains several instruments providing data about the earth's atmosphere, oceans and land (see ***Figure 9***). Polar-orbiting satellites can observe the entire surface of the earth within a short period of time. Because the orbits of these satellites are low compared to geostationary satellites, the data they obtain has improved spatial resolution compared to higher (that is, geostationary) satellites.

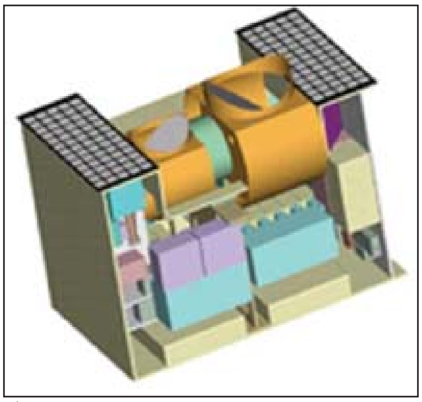

Fig. 10 ATMS conceptual illustration (courtesy of NOAA).[11]

TABLE II

ATMS CHANNEL SET[12]

Channel	Center Frequency (GHz)	Bandwidth (GHz)	Beamwidth (°)	Approx. FOV Size (km) for 833 km orbit
1	23.8	0.27	5.2	75
2	31.4	0.18	5.2	75
3	50.3	0.18	2.2	32
4	51.76	0.40	2.2	32
5	52.8	0.40	2.2	32
6	53.596 ± 0.115	0.17	2.2	32
7	54.40	0.40	2.2	32
8	54.94	0.40	2.2	32
9	55.50	0.33	2.2	32
10	57.290334	0.33	2.2	32
11	57.290334 ± 0.217	0.078	2.2	32
12	57.290334 ± 0.3222 ± 0.022	0.036	2.2	32
13	57.290334 ± 0.3222 ± 0.010	0.016	2.2	32
14	57.290334 ± 0.3222 ± 0.0045	0.008	2.2	32
15	57.290334 ± 0.3222 ± 0.048	0.003	2.2	32
16	88.2	2.0	2.2	32
17	165.5	3.0	1.1	16
18	183.31 ± 7	2.0	1.1	16
19	183.31 ± 4.5	2.0	1.1	16
20	183.31 ± 3	1.0	1.1	16
21	183.31 ± 1.8	1.0	1.1	16
22	183.31 ± 1	0.5	1.1	16

The broad coverage, coupled with high resolution, will provide continuous data for long-range forecasting and climate modeling. The NPOESS satellites have two instruments with millimeter-wave sensors: ATMS and CMIS. The first NPOESS satellite is scheduled to launch in 2009.

Advanced Technology Microwave Sounder (ATMS)

ATMS, shown in ***Figure 10***, represents the next generation in microwave sounders, with heritage from the AMSU instrument described above. It collects atmospheric data to calculate temperature and moisture profiles with high temporal resolution. This instrument has 22 radiometric channels, 21 of which are millimeter-wave (see ***Table 2***). Temperature and pressure profiles are obtained by observing the complex of oxygen absorption lines from 50 to 89 GHz with 14 channels, and with approximately 33 km resolution. Humidity and precipitation profiles are obtained with six channels observing the region near the water vapor absorption line at 183 GHz, with 15 km resolution. This information will provide improved accuracy for weather prediction models. ATMS can obtain useable data even if the footprint contains significant cloud cover. When the footprint has a minimum amount of cloud cover, ATMS works in conjunction with an infrared instrument, the Cross-track Infrared Sounder (CrIS), to obtain finer vertical resolution.

The ATMS channels are reflected by a flat, rotating reflector to a parabolic reflector, and then to a feedhorn. Channels are diplexed into separate channels and amplified by a low noise amplifier (LNA). The outputs of the LNAs are fed through bandpass filters and then to detectors. The signals are then integrated and sent

Fig.11 Full scale model of the CMIS instrument (courtesy of NOAA).[13]

to a signal processor. The types of algorithms used to obtain and retrieve the temperature and humidity profiles are based on the reverse superposition of pressure-broadened spectral lines, as described above. The first ATMS will be launched on the NPP mission in 2006.

Conical Scanning Microwave Imager/Sounder (CMIS)

CMIS, shown in ***Figure 11***, delivers measurements of ocean surface wind speed and direction, sea surface temperature, rain rate, the amount of water in clouds, soil moisture, and atmospheric temperature and moisture profiles. It has 77 channels from 6 GHz up to 183 GHz, with the majority operating near the 60 GHz oxygen absorption line spectrum (see ***Table 3***). CMIS rotates on an axis perpendicular to the ground, observing the surface along semi-circular arcs centered on the ground track. Successive arcs scanned by a single sensor channel are separated by approximately 12.5 km along-track. Calibration data is collected from a "hot" and "cold" scene viewed during a portion of the rotation cycle. The samples fall on one of three main reflector scan-arcs, or, for the 166 and 183 GHz channels, a single secondary reflector scan arc. Sea surface wind direction measurements, a key data product, are also available from CMIS.[15] The heritage instrument for this technique is WINDSAT, which was launched in 2003. The amount of blackbody radiation from the sea surface is a function of the water temperature, salinity and roughness. As winds on the surface increase, the surface becomes rougher, which increases the radiation levels. This effect is also a function of the wind direction. Data from the 10 VHLR, 18 VHPMLR and 37 VHPM channels, which avoid the water and oxygen absorption lines and are fully polarimetric, is processed to determine the wind vector. The 6 VH channel is most sensitive to the temperature of the sea surface, so data from that channel is used to calibrate out the error on the higher channels. In a similar fashion, the 23 VH channel is used to reduce the error induced from variations of water vapor above the surface.

Global Precipitation Measurement Program/GPM Microwave Imager (GPM/GMI)

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TABLE III

CMIS CHANNEL SET[14]

Channel Name	Polarization*	Center Frequency (GHz)	Bandwidth (MHz)	EFO (km × km)	T (ms)	EIA (°)	Scan Position
6V, H	VH	6.625	350	68.0 × 40.0	5.0	55.7	+1
10V, H, L, R	VHLR	10.65	100	48.0 × 28.0	2.47	58.1	+6
18V, H, P, M, L, R	VHPMLR	18.7	200	24.0 × 15.5	1.2	53.6	–3
23V, H	VH	23.8	400	18.0 × 12.0	1.2	53.6	–3
37V, H, P, M	VHPM	36.5	1000	16.0 × 12.0	1.2	55.7	+1
60VA	V	50.3	134	16.0 × 12.0	1.2	55.7	+1
60VB	V	52.240	1280	16.0 × 12.0	1.2	55.7	+1
60VC	V	23.570	960	16.0 × 12.0	1.2	55.7	+1
60VD	V	54.380	440	16.0 × 12.0	1.2	55.7	+1
60VE	V	54.905	350	16.0 × 12.0	1.2	55.7	+1
60VF	V	55.490	340	16.0 × 12.0	1.2	55.7	+1
60VG	V	56.660	300	16.0 × 12.0	1.2	55.7	+1
60VJ	V	59.380	280	16.0 × 12.0	1.2	55.7	+1
60VK	V	59.940	440	16.0 × 12.0	1.2	55.7	+1
60LL	L	60.3712	57.6	16.0 × 12.0	1.2	55.7	+1
60LM	L	60.4080	16	16.0 × 12.0	1.2	55.7	+1
60LU	L	60.4202	8.4	16.0 × 12.0	1.2	55.7	+1
60LV	L	60.5088	44.8	16.0 × 12.0	1.2	55.7	+1
60LFPT	L	60.434776	25	16.0 × 12.0	1.2	55.7	+1
89V, H	VH	89.0	4000	16.0 × 12.0	1.2	55.7	+1
166V	V	166 ± 0.7875	1425	16.0 × 12.0	1.2	55.5	+0.5
183A	V	183.31 ± 0.7125	1275	16.0 × 12.0	1.2	55.5	+0.5
183B	V	183.31 ± 3.10	3500	16.0 × 12.0	1.2	55.5	+0.5
183C	V	183.31 ± 7.7	4500	16.0 × 12.0	1.2	55.5	+0.5

*V = Vertical, H = Horizontal, P = +45°, M = –45°, L = Left-hand circular, R = Right-hand circular

ploration Agency (JAXA) are developing the "core" satellite upon which the

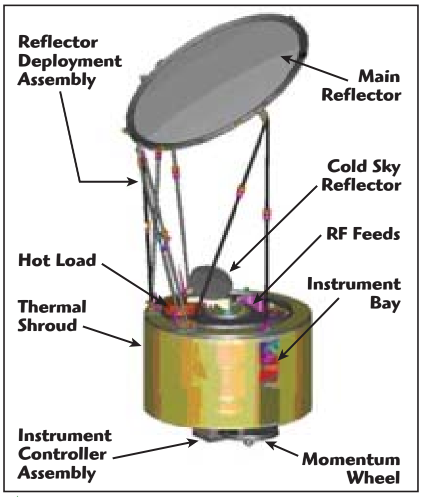

Fig. 12 GMI instrument (courtesy of NASA).[17]

GPM Microwave Imager (GMI) will be carried (see ***Figure 12***). The GMI will be a nine-channel microwave radiometer whose measurement frequencies are selected for measurement of rainfall amounts (see ***Table 4***). Like CMIS, it will have a conical scan to provide a large measurement swath (approximately 850 km wide). At 1.2 m, its antenna is smaller than the 2.5 m CMIS antenna, however, GMI will have improved resolution since it will be in a lower orbit at approximately 400 km.

Herschel

The European Space Agency (ESA) will be launching the Far-infrared and Submillimeter Telescope (FIRST, later re-named Herschel for William and Caroline Herschel) in 2007 (see ***Figure***

TABLE IV

GMI CHANNEL SET[16]

Channel	Center Frequency (GHz)	Polarization	Antenna 3 dB beam (°) (max)
1, 2	10.65	v, h	1.75
3, 4	18.70	h, v	1.75
5	23.80	v	0.90
6, 7	36.50	v, h	0.90
8, 9	89.00	v, h	0.40


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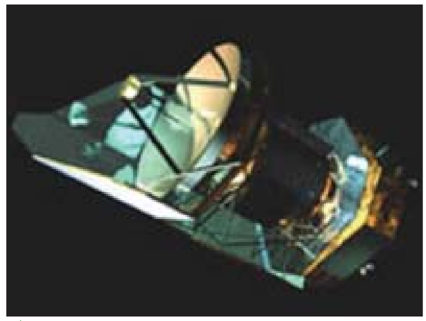

Fig. 13 Artist impression of Herschel (courtesy of ESA).[18]

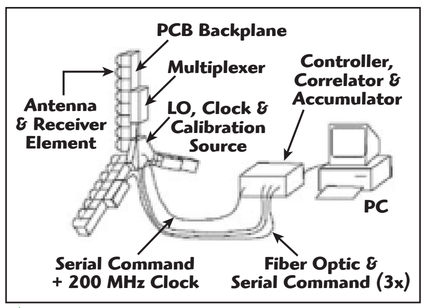

Fig. 14 Prototype GeoSTAR configuration.[19]

13). One of its instruments, the Heterodyne Instrument for FIRST (HIFI), is a submillimeter, high resolution spectrograph. It will measure radiation coming from the universe at 480 to 1250 GHz and 1410 to 1910 GHz, to study how the early galaxies and stars formed and evolved. While this satellite does its receiving at shorter wavelengths than the millimeter-wave region, it employs mixers as receivers with multiplier chains for the local oscillators, which are techniques normally used in millimeter-wave systems. The receiving system includes 14 LO chains from a common 23.7 to 35.55 GHz signal, with multiplication factors from X18 to X72, and 14 wideband receivers with contiguous bands to cover the extremely wide RF bandwidth. It will also use a 3.5 m mirror, which is the largest of any imaging space telescope.

FUTURE SYSTEMS

Two major satellite systems now under consideration with millimeter-wave sensors on board are the Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) and the Sky Polarization Observatory (SPOrt).

Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR)

As mentioned above, downward-looking satellites are in low earth orbit. If these kinds of instruments were to

Fig. 15 Photograph of the GeoSTAR prototype (courtesy of NASA-JPL/Cal Tech).[20]

be positioned on a geostationary satellite, measurements within its much larger field of view could be made almost instantaneously. However, a conventional reflector antenna would be quite large and heavy if the required resolution were to be maintained from that distance. GeoSTAR (see ***Figures 14*** and ***15***) would use an array antenna that has elements removed, or "thinned." The radiometric signals from each element are cross-correlated with each other. The closest pair of elements defines the overall field of view, while the furthest pairs set the resolution. The number of individual receivers and processors are high, but MMIC technology is progressing to the point where this approach becomes feasible. Researchers at NASA's Jet Propulsion Laboratory are currently developing this concept.

Sky Polarization Observatory (SPOrt)

Like COBE and MAPS before it, SPOrt is a satellite that will map out the cosmic background noise for more detail about how the early universe began to clump together. SPOrt is an Italian satellite which will cover the frequency range of 22 to 100 GHz with a 7° beamwidth and will measure in two polarization states. It is set to fly aboard the ISS later this year.

CONCLUSION

Millimeter-wave sensors have been used on satellites for the past 33 years and are designed into many of the next generation satellites currently in the development phase. The temperature and moisture altitude profiles from millimeter-wave sensors form the backbone of all the next generation weather forecasting satellites and are necessary for the calibration of microwave radar satellite systems. Future satellites will likely further these roles

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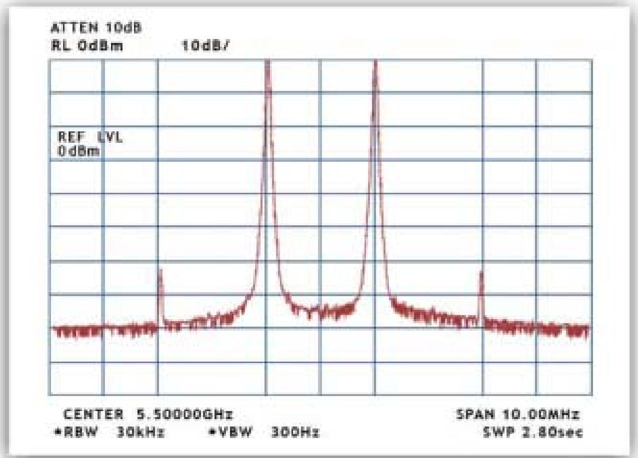

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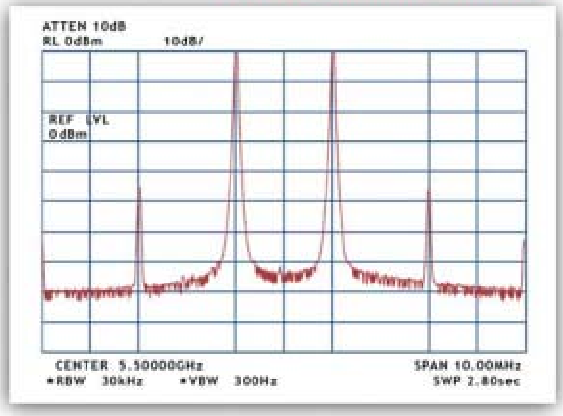

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both by the use of arrays, as in GeoSTAR, and by the use of active systems, as in CloudSat. The same techniques used to monitor the earth will eventually be used in the observation of other planets in the solar system by placing satellites in orbit around them. As the technology used for millimeter-waves continues to expand, the applications for millimeter-wave systems on satellites will expand as well. Millimeter-wave sensors will surely have a home on many future satellites, whether upward- or downward-looking, collecting data for a wide variety of scientific applications. ■

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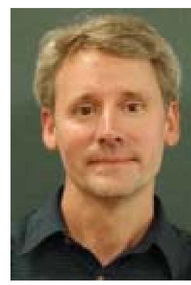

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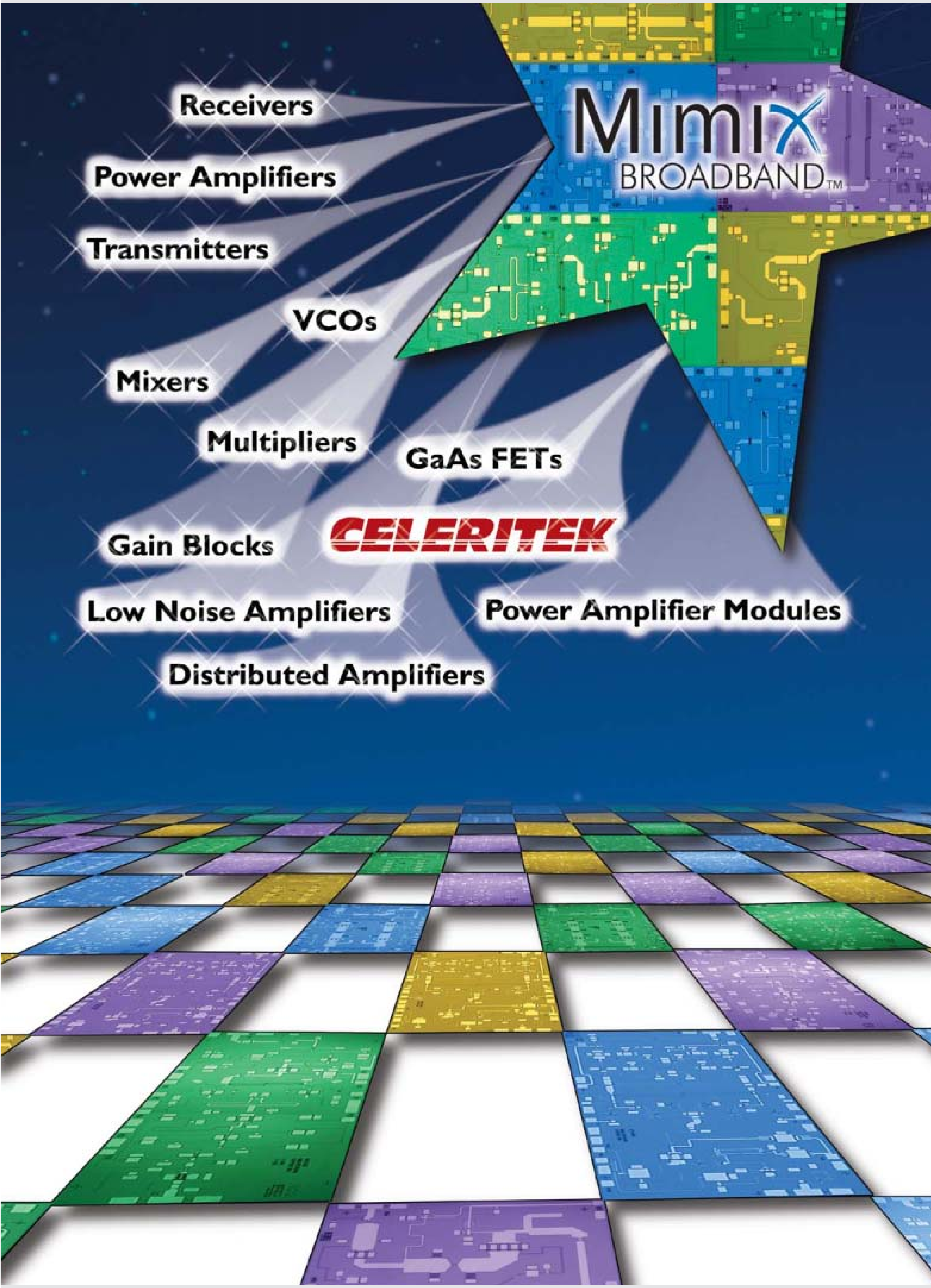
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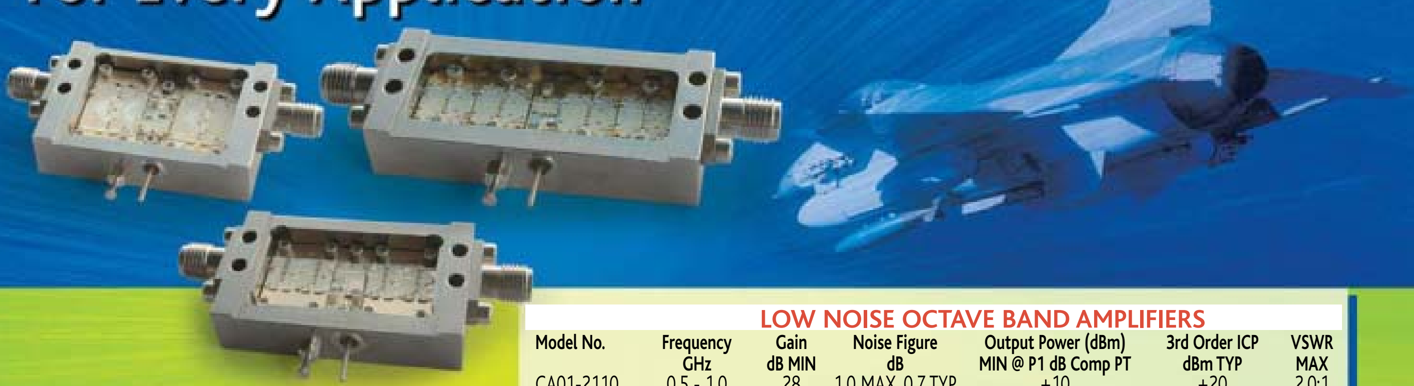

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CA26-3110	2.0 - 6.0	26	2.0 MAX, 1.5 TYP	+10	+20	2.0:1
CA26-3113	2.0 - 6.0	28	4.0 MAX, 3.0 TYP	+27	+37	2.0:1
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CA618-4112	6.0 - 18.0	25	5.0 MAX, 3.5 TYP	+23	+33	2.0:1
CA618-5113	6.0 - 18.0	24	5.0 MAX, 3.5 TYP	+27	+37	2.0:1
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CA218-4112	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+24	+34	2.0:1
CA218-4113	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+27	+37	2.0:1

NARROW BAND AMPLIFIERS

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
LOW NOISE:						
CA01-2110	0.4 - 0.5	28	0.75 MAX, 0.45 TYP	+10	+20	2.0:1
CA01-2112	0.8 - 1.0	28	0.75 MAX, 0.45 TYP	+10	+20	2.0:1
CA12-3116	1.2 - 1.6	25	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.2 - 2.4	30	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10	+20	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10	+20	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10	+20	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.5 TYP	+10	+20	2.0:1
CA1819-4110	17.7 - 18.3	20	2.0 MAX, 1.8 TYP	+10	+20	2.0:1
MEDIUM POWER:						
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA23-4110	2.7 - 2.9	32	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35	+43	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33	+41	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33	+42	2.0:1
CA1218-5116	12.0 - 18.0	35	6.0 MAX, 5.0 TYP	+30	+40	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21	+31	2.0:1
CA1718-4110	17.7 - 18.1	25	5.0 MAX, 4.5 TYP	+27	+37	2.0:1

COMPETITIVE PRICING OFFERED

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	Unit Price Qty 1-9 $US
CA12-A02	1.0-2.0	26	1.6	+10	$395
CA24-A02	2.0-4.0	26	1.8	+10	$395
CA48-A02	4.0-8.0	24	2.0	+10	$395
CA812-A02	8.0-12.0	22	2.5	+10	$395
CA1218-A02	12.0-18.0	16	3.5	+10	$395

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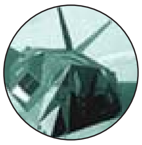


DEFENSE NEWS

Raytheon Awarded $260 M Contract for BMDS Radar Logistic Support

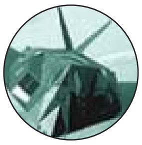
Raytheon Co. has been awarded a contract by the Missile Defense Agency (MDA) for contractor logistics support (CLS) of the Ballistic Missile Defense System (BMDS) radars. The contract has a potential value of $260 M over the five-year period of performance. Under the innovative contract, Raytheon Integrated Defense Systems (IDS) will be responsible for operating and maintaining Forward Based X-band Transportable (FBX-T) radars as part of the Missile Defense Agency's BMDS. The CLS contract covers all operations and sustainment of the forward based radars, including site surveys and site preparation; operational readiness certification; site operation and maintenance; mission preparation and support; radar performance reporting and analysis; depot support and administrative and physical security. Under this contract, Raytheon will provide the warfighter with "no doubt" reliability, ensuring that these radars work the first time and every time.

Titan Corp. and L-3 Communications Agree to $2.65 B Merger

The Titan Corp., a national security solutions provider, and defense contractor L-3 Communications have entered into a definitive agreement for L-3 to acquire Titan in an all-cash merger at a price of $23.10 per share. The total value of the transaction, including L-3's assumption of Titan's debt, is expected to be approximately $2.65 B at closing. The transaction, which has been approved by the board of directors of each company, is subject to approval by Titan shareholders, the execution and court filing of definitive settlements of the litigation described below, government regulatory reviews and other closing conditions contained in the merger agreement. Titan's board of directors is unanimously recommending that Titan shareholders approve the transaction. Dr. Gene W. Ray, Titan chairman, president and CEO, said, "During our 24-year history, Titan has grown by providing our military and government agency customers with effective, high quality products, services and solutions tailored to their specialized and ever-evolving needs. This merger with L-3 will create a company with greater resources and the operational flexibility to offer our customers an even broader spectrum of innovative systems and quality solutions." Concurrently with entering into the merger agreement, Titan entered into a Memoranda of Understanding (MoU) to settle securities law class actions and derivative suits pending in both Federal and State courts in California and the Delaware Court of Chancery. These settlements will become effective after the closing of the merger and receiving court approvals. Details of the settlements may be found in Titan's 8-K to be filed with the SEC. While no assurances can be made, Titan expects the merger to close prior to year-end and possibly by the end of the third quarter. Headquartered in San Diego, CA, the Titan Corp. is a provider of comprehensive information and communications systems solutions and services to the Department of Defense, intelligence agencies and other federal government customers. Headquartered in New York City, L-3 Communications is a provider of intelligence, surveillance and reconnaissance (ISR) systems, secure communications systems, aircraft modernization, training and government services, and is a merchant supplier of a broad array of high technology products. Its customers include the Department of Defense, Department of Homeland Security, selected US Government intelligence agencies and aerospace prime contractors.

Harris Corp. Awarded Space-based Radar Antenna Contract

Harris Corp. announced that it has been awarded a contract by Lockheed Martin to continue the development of the Flight Demonstration System (FDS) radar payload for the Innovative Space-based Radar Antenna Technology (ISAT) program. The ISAT program, under the direction of the Defense Advanced Research Program Agency (DARPA) Special Projects Office and the US Air Force Research Laboratory (AFRL) Space Vehicles Directorate, includes the development of technologies required to deploy extremely large antennas in space for tactical sensing of moving targets on the ground. Harris is responsible for the design of the radar sensor payload, which will provide Moving Target Indicator (MTI) surveillance of areas previously obscured from view by airborne assets. "We are pleased to have been selected to continue our support of this critical antenna technology initiative and to be given the opportunity to mature the innovative technologies we previously developed for the ISAT payload," said Russ Haney, president of the National Programs business unit of Harris Corp.'s Government Communications Systems Division (GCSD). "Performing complex MTI radar missions from space poses many technology challenges. With its collective years of innovation and leadership in this arena, however, the Lockheed Martin/Harris team is certainly up to the challenge." Harris successfully completed three prior contracts for earlier phases of the ISAT program. Under this phase of the program, Harris will complete the critical design of a scaled demonstration unit of the large, phased-array radar sensor that will be used to validate the technology and structural design concept for the full-size objective system. At nearly the height of the Empire State Building, the 300-meter objective system structure must be capable of being compressed to the size of an SUV for launch. This phase will take the payload design for the FDS radar payload through a tailored Critical



Design Review (CDR). The ISAT FDS is planned to launch in 2010.

NAS Modernization Program Goes into Full-rate Production

The National Airspace System Modernization Program received the green light from the new Undersecretary of Defense for Acquisition, Technology and Logistics, Kenneth J. Krieg, to move into full-rate production on June 7th. The program replaces older analog systems, some more than 40 years old, with state-of-the-art radar, communications and tracking systems at hundreds of Department of Defense and civilian air terminals throughout the United States. The FAA is serving as acquisition lead for civilian terminals. The Air Force Electronics Systems Center is the acquisition lead for all DoD sites. "This group of program managers, engineers, testers, logisticians, operators and many others from across the armed services, Federal Aviation Administration and industry has successfully collaborated to overcome many technical challenges," said Lt. Gen. Chuck Johnson, ESC commander. "This is a tremendous example of what can be achieved by a group to reach a common goal." This decision primarily impacts two of the three systems that comprise the NAS modernization effort:

- DoD Advanced Automation System, or DAAS (also referred to as STARS by the FAA), which is hardware and software that tracks and displays aircraft to air traffic controllers; and
- Digital Airport Surveillance Radar, or DASR, which is the actual radar and tower itself.

The last of the three components, the Voice Communication Switching System, which upgrades air-to-ground and ground-to-ground communications, was already in full-rate production. The program has been operating under low rate production, meaning annual authorizations were required, for the last five years. Going into full-rate production will allow the program office to execute the remainder of the modernization effort according to the original schedule, according to Lt. Col. Wayne Descheneau, NAS deputy program manager. The Air Force Operational Test and Evaluation Center (AFOTEC) completed its testing and issued a report recommending full-rate production to DoD in mid-December. The DoD Operational Test and Evaluation Directorate in turn studied the evaluation and concurred with the AFOTEC recommendation in March. This, in conjunction with DAAS and DASR's proven track record under operational conditions at already upgraded sites, cleared the way for Sec. Krieg's approval. ■

International Report

Richard Mumford, European Editor

QinetiQ Receives Almost £1 M to Go to Print

With separate backing from both the Department of Trade & Industry (DTI) and the Ministry of Defence (MoD) in the UK, QinetiQ is researching the potential for printing complete electronic circuits, including transistors, resistors and capacitors. In the defence field it could enable electronic functionality to be added to structural components of systems or to personal and protective clothing economically, with minimal increase in mechanical complexity and with negligible increase in weight. Unmanned air vehicles and battlefield communication systems are other likely defence sector candidates. In the consumer sector the technology being investigated could help reduce the cost of many electronic products.

The MoD, through its Electronics Systems' research budget, is providing over £750,000 for a three-year project to investigate emerging technologies for printing electronic circuits and their consequences for defence equipment. The DTI is providing parallel funding of around £200,000 for an initial two-year research programme to develop materials and processes and then look at applying the technology.

These research projects are based on using thin polymers, not silicon, as a semiconductor, adding the benefits of flexibility and improved robustness to the resulting circuits.

Thales to Supply Tactical Communication System for French Forces

The French defence procurement agency (DGA) has appointed Thales as prime contractor for the Melchior programme, which will provide the French armed forces with a new-generation high frequency tactical transit and access communication system. The €252 M contract calls for development and production of the system and subsequent through-life support.

The Melchior programme will provide French Army, Navy, Air Force and Special Forces units with a vital component of theatre communications that will be highly secure and interoperable with NATO systems. The contract also calls for migration to the Melchior standard of the Carthage and Matilde HF tactical communication systems in service and currently deployed in outside theatres of operations.

The system will also integrate commercial IP technology to provide highly secure voice, data and messaging services. It will provide long-range links and will complement SATCOM capabilities on joint and allied operations. In addition, new multimedia capabilities will enhance connectivity between HF terminals and other information and communication systems operated by the French armed forces.

Indra Ties Up Thai Satellite Control Station Deal

In recognition of Indra's satellite control technology the Spanish company has been appointed for the key-in-hand project to develop a follow-up, telemetry and telecontrol station of the Earth observation satellite THEOS, ordered from EADS-Astrium by the Thai government. Under the terms on the near €1 M project, the follow-up station's main objective is to act as a link between the satellite control centre in Bangkok and the THEOS satellite, located in orbit at a height of approximately 800 km above the Earth's surface.

Via this station the satellite parameter information (maintenance, location and operation indicators) will be received, sending telecommands or the necessary instructions to conduct its activity. The satellite itself is currently being manufactured by EADS-Astrium and will be operated and exploited by the Space Agency of the Thai Ministry of Science and Technology. It will be launched in 2007 and will be a key tool to prevent and deal with natural disasters in the South East of Asia.

It will provide georeferenced images of any part of the Earth to be used in cartography, supervision and management of the use of soil, control and follow-up of both agricultural activity and crop evolution and forest management. Furthermore, its surveillance activities will allow the prompt detection of fires, flooding or tsunamis and enable the appropriate action to be taken.

Ericsson Expands Microwave Transmission Network in Brazil

Vivo has selected Ericsson to expand and enhance its access transmission network in order to provide extra backhaul capacity and flexibility, as well as reducing operating costs.

Under the turnkey contract, Ericsson will enhance the Brazilian operator's access transmission network with the traffic node platform, MINI-LINK TN, as it expands coverage and services in the states of Bahia, Espírito Santo, Rio de Janeiro and Sergipe.

The system provides efficient traffic aggregation, with easy capacity expansion, and improved service quality and network control. The contract also covers the supply of over 1,500 microwave terminals and other equipment, together with professional services.

Javier Rodriguez, CTO of Vivo, said that this advanced microwave transmission solution gives his company the flexible network capacity needed to grow and evolve services effectively. He explained, "It not only strengthens our ability to manage traffic in the network, it also provides us with substantial cost savings. We're pleased with the quality of the relationship we have with Ericsson and the support we receive."

Siemens Delivers WiMAX-based Telemetering to Belarus

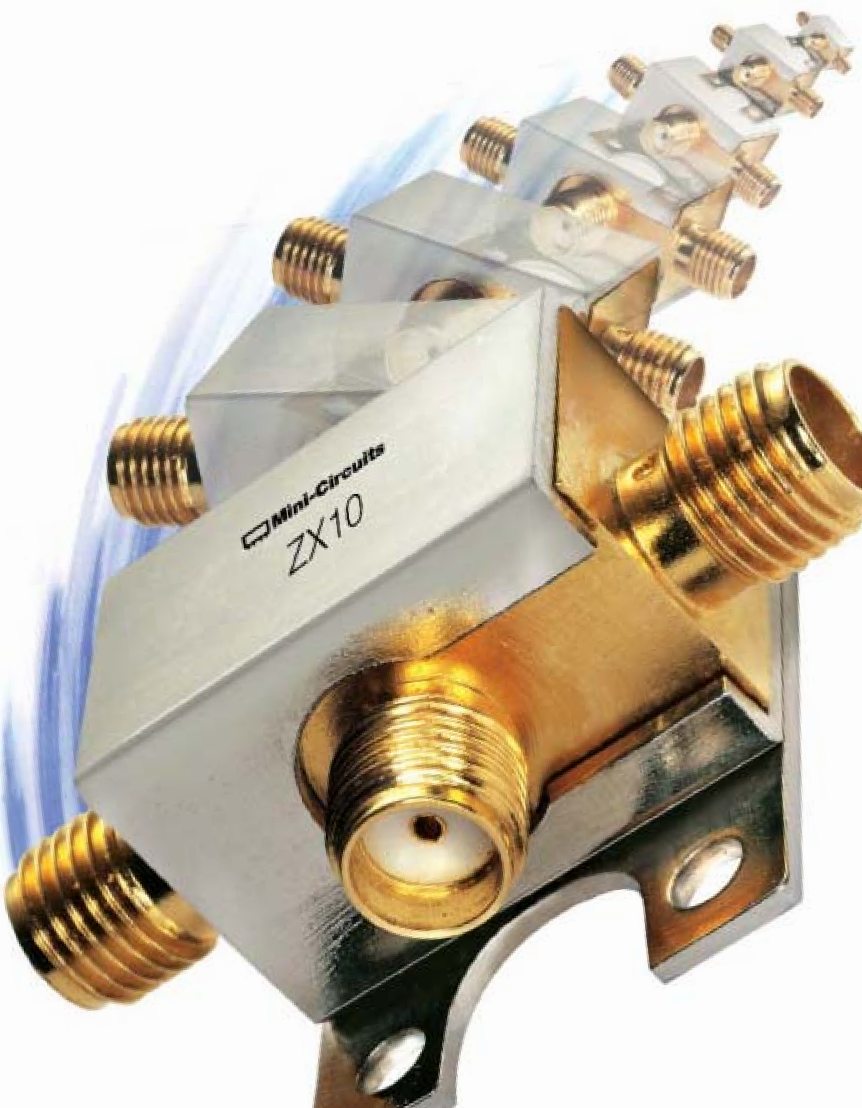
The Belarus government-owned telecommunications operator BEST and Siemens Communications have signed a Memorandum of Understanding (MoU) for the delivery of a WiMAX solution based on the company's SkyMAX products. The broadband radio network is part of a new initiative in the country designed to provide large parts of the population with Internet access.

In addition, the government wants to use the WiMAX network for an innovative telemetering solution through which all household consumption data for electricity, gas and water will be transmitted over the air to a central billing system. The network and the remote wireless meter reading system are scheduled to go live at the end of 2005. As well as the network infrastructure, Siemens will deliver special equipment capable of recording and transmitting the necessary measurement data.

Alcatel Venture Supports Chinese Technology Development

To speed up homegrown IT and telecom technology development in China and to deliver more user-centric broadband services to end users, Alcatel will launch a Corporate Venture Capital Partnership Program. This program, which will be managed directly by Alcatel Shanghai Bell, is a dedicated venture fund investing directly in IT and telecom technology start-ups in their early and even seed financing stages.

It will focus on innovative technologies, products, applications and services. The program supports start-ups using all technologies in the wireline and wireless arena. In addition, Alcatel will provide further support to the start-ups by granting them access to its research and development facilities in China for prototype testing and validation. The company will also offer marketing support to the companies and help them roll out their products or services to end users. ■



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ZX10-2-20	.2-2	20	0.8	24.95
ZX10-2-25	1-2.5	20	1.2	26.95
ZX10-2-42	1.9-4.2	23	0.2	34.95
ZX10-2-71	2.95-7.1	23	0.25	34.95
ZX10-2-98	4.75-9.8	23	0.3	39.95
ZX10-2-126	7.4-12.6	23	0.3	39.95
4WAY-0°			Above 6.0dB	
ZX10-4-11	.8-1.125	20	0.6	38.95
ZX10-4-14	1.1-1.45	20	0.8	38.95
ZX10-4-19	1.425-1.9	20	0.75	38.95
ZX10-4-24	1.675-2.35	20	0.9	38.95
ZX10-4-27	2.225-2.7	20	1.0	38.95

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Here Comes MIMO: Wi-Fi in the Home

According to In-Stat, the SOHO/consumer WLAN equipment market is becoming an increasingly difficult environment in which to compete. While shipment volumes have increased strongly since Apple first launched its AirPort line of 802.11b-compliant consumer WLAN gear in 2000, prices have eroded sharply over the past several years, and In-Stat believes that few vendors are making much money in this market segment at present. In 2004, the top three vendors by market share were Cisco's Linksys consumer product division, with roughly a third of AP unit shipments (including wireless routers and wireless Residential Gateways), D-Link at about a fifth and Netgear at a little over 15 percent. The top three vendors represented two-thirds of AP unit shipments in the SOHO/consumer WLAN market. Other key vendors included Apple, Belkin, Buffalo Technology and SMC. Shipment volumes are still expected to increase strongly over the forecast period, driven both by growing broadband adoption as well as increasing use of home networks. Importantly, WLAN equipment will increasingly be used to network consumer electronic devices as well as VoIP communications. Several SOHO/consumer WLAN equipment vendors have introduced audio and multimedia WLAN media adapters, including Linksys (Wireless-G Media Center Extender), D-Link (MediaLounge DSM-320 Wireless Player), Apple (the AirPort Express includes audio connectors), Buffalo Technology (LinkTheater High Definition Wireless Media Player) and SMC (E-Z-Stream Universal Wireless Multimedia Receiver). Likewise, it is expected that dual-mode WLAN/cellular telephony will gain significant traction in the consumer market starting in 2007.

A key market shift is the transition from the 802.11g air standard to MIMO-based products. In 2004, 802.11b and 802.11g effectively changed places in terms of percentage of total market shipments, with 802.11b falling from 63 percent of total SOHO/consumer AP shipments to only 30 percent in 2004. Likewise, 802.11g shipments increased from 34 percent in 2003 to 69 percent in 2004. However, unlike with the enterprise WLAN market, it is not believed that 802.11a/g is gaining traction in the SOHO/consumer WLAN market, nor will it become the logical successor to 802.11g. Instead, consumers appear to be responding to the range extension benefits of MIMO-based "pre-802.11n" products. While 802.11a/g is seeing some renewed interest for its clean 5 GHz spectrum for multimedia, the market will essentially skip 802.11a/g in favor of MIMO/802.11n. When the 802.11n standard is finalized in 2006, it will not only include the range and speed enhancements seen in today's MIMO products from the likes of Belkin, Linksys, Netgear and D-Link, but will also utilize both the 2.5 and 5 GHz spectrum, thus providing the same clean spectrum that is causing some renewed uptake of 802.11a/g. Key problems with the market adoption of 802.11a/g have been poor marketing/messaging by vendors, confusion about 802.11a/g benefits on the part of consumers and the stubbornly high price premium for 802.11a/g equipment compared to 802.11g.

RFID: Plug-and-Play to Save the Day

After the initial excitement around Wal-Mart's January 1, 2005 RFID deadline, things have gone a bit quiet. As ABI Research has noted in the past, a significant number of those suppliers have gone only as far as they absolutely had to in order to satisfy their mega-customer's basic requirements. If — as evidence from the consumer goods vertical market suggests — many end-users are currently in a "wait-and-see" holding pattern, why is that the case and what will it take to get the RFID ball rolling? According to ABI Research analyst Sara Shah, the answer can be summed up in three words: plug-and-play. "Leaving aside the important issue of cost and reliability," she says, "most of the RFID products available so far require a good deal of hard work for users to integrate them into their existing supply chain systems. Companies want to be able to plug an RFID reader or printer into their network and simply have it work." So far, solutions capable of doing that have been scarce. However, some RFID vendors are making a start. "A few startups have begun to address this need," notes Shah, "and new products from Symbol Technologies and Microsoft show this same trend of plug-and-play convenience." It is that kind of seamlessness, ABI Research believes, that will encourage end-users to move beyond "slap-and-ship" to the point where they will see a clear business case in favor of full-scale RFID implementation.

Continuous Wave UWB: Consider the "Other Ultrawideband"

The multiband OFDM technology proposed by the MBOA Alliance and a host of industry heavyweights, and its rival DS-UWB technology proposed by Freescale and the UWB Forum are well known. Lesser known is a UWB technology pioneered by Pulse-Link. Its Continuous Wave UWB uses no analog mixers or local oscillators, resulting in a less complex implementation. It employs variable spreading codes that can trade data-rate for range and its spectral characteristics allow flexibility to satisfy different regulatory constrains. It has some unique benefits that could make it a serious contender for in-home multimedia. "Do we really need another UWB technology?" asks ABI Research's principal analyst of semiconductor research, Alan Varghese. "Well, it depends." Any form of wireless communications can be described by its range and its data-rate at that range. Through the evolution of wireless, today we have three well-defined ranges — the Wireless Personal Area Network (WPAN), typically defined as within 10 meters, the Local Area (WLAN), defined at about 100 meters, and the Wide Area (WWAN), which can reach out to a few miles. There is a trade-off between range and data rate; you get the highest data rates at the smallest range and vice-versa. "What Continuous Wave UWB offers," says Varghese, "is a blurring of the segmentation between the personal area and the local area; the high data rate of 1 Gbps, which can typically only be offered at under three meters, will be offered at 10 meters, and at 80 meters we can still experience up to a 10 Mbps data rate. This lends itself nicely to bandwidth intensive applications such as distribution of in-home multimedia."

802.15.4 Could Grow 200 Percent by 2009

The market for 802.15.4, a wireless Personal Area Networking technology, or PAN, and the ZigBee specification network layer, is poised for skyrocketing growth, reports In-Stat. On an aggressive basis, 802.15.4 nodes/chipsets could grow by a compound annual growth rate (CAGR) of 200 percent from 2004 to 2009, the high tech market research firm forecasts, with annual shipments surpassing 150 M units in 2009. "In December 2004, the ZigBee Alliance completed a major milestone — final signoff of the ZigBee 1.0 specification. Even considering proprietary competition, the promise of many benefits of the 802.15.4 and ZigBee standardization still hold true. Although standardization takes longer, a major advantage of 802.15.4 and ZigBee offers OEMs a menu of multiple silicon sources and ZigBee networking layer suppliers," says Joyce Putscher, In-Stat research director and principal analyst.

A recent report by In-Stat found the following:

- This low cost, low power, low data-rate networking technology is receiving attention from many companies that are involved in industrial control, home automation and commercial building control, spanning everything from nuclear plants to hotels.
- Commercial building control is expected to capture the lion share of the 802.15.4 market, in terms of node/chipset volumes, but not design wins.
- Together, System-in-Package (SiP) and System-on-Chip (SoC) solutions will drive easier system/product development and lower the costs of adding this wireless capability to sensor networks. ■


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INDUSTRY NEWS

■ **MicroMetrics Inc.**, a manufacturer of semiconductor devices for commercial and military communications, announced the acquisition of **Knox Semiconductor**, Rockport, ME. The acquisition adds new products and customers to the company's portfolio. It also allows the company to expand its capabilities in ion implanted tuning varactors. Other technologies will allow expansion into additional commercial and military accounts. The two companies are privately held. The terms of the sale were undisclosed.

■ **Richardson Electronics**, a global provider of engineered solutions for the RF and wireless communications market, announced it has reached a global agreement with **American Technical Ceramics Corp.** (ATC), a manufacturer of high performance RF microwave electronic components. Under the terms of the agreement, Richardson has secured global distribution rights to ATC's current portfolio of EIA ceramic and signature ATC porcelain high Q capacitors.

■ **Focus Microwaves Inc.** and **Auriga Measurement Systems LLC**, providers of high frequency device characterization tools, announced an OEM agreement whereby Auriga will represent Focus for the eastern United States and the companies will work together to develop new products combining their technologies. Focus will bring to the partnership its electromechanical tuner technology and development of characterization instruments. Auriga will contribute its electronic tuner technology, systems integration capabilities and advanced modeling tools to the team.

■ **Agilent Technologies Inc.** and **Computer Simulation Technology** (CST) announced two major advances in the integration of the CST MICROWAVE STUDIO® (CST MWS) simulation tool with Agilent's Advanced Design System (ADS) electronic design automation software. The integration helps RF and microwave designers improve passive circuit performance with increasing confidence. These advances are implemented in the latest version of CST MWS as a direct result of the alliance and technical collaboration between Agilent and CST announced in June 2004.

■ **StratEdge**, a designer and producer of semiconductor packages for high speed wireless devices, announced the one year anniversary of transfer of control of the company to a management group headed by Tim Going. All long-term debts have been paid, the company is profitable, orders have increased and the company is achieving nearly 100 percent on-time delivery. Projections are for an increase in profit in 2005 with an anticipated 35 percent growth in the workforce. In March, the company was re-certified for ISO 9001:2000 by Det Norske Veritas with no non-conformances.

■ **Modelithics Inc.** has been awarded membership in **Cadence Design Systems'** Connections program in order to provide Cadence users full access to the power of Modelithics high accuracy and feature-rich models for active and passive components and IC devices. As part of its membership in the program, Modelithics will be developing an interface between its model library software products and the Cadence Virtuoso Spectre RF design and layout tool set.

■ **Linear Technology Corp.** announced the opening of its newest design center in Phoenix, AZ. This marks the company's tenth design center, as it continues to expand its resources for design of high performance analog integrated circuits.

■ **Spinner GmbH**, Munich, Germany, announced the establishment of a new, advanced engineering and production facility in the US for the manufacture of products used in wireless telephony systems, television broadcast and high power generation. Known as **Spinner Atlanta Inc.**, Norcross, GA, the new complex will incorporate precision fabrication equipment, field and laboratory test and measurement quality assurance, as well as design and engineering services.

■ **PCTEL Inc.** announced that it has relocated its antenna products group operations to a new facility in Bloomingdale, IL. The new facility will handle production for most of its major product lines, including those recently acquired. The company continues to have manufacturing capability in Tianjin, China. Effective immediately, PCTEL (formerly MAXRAD) antenna products currently manufactured in Hanover Park, as well as Antenna Specialists® and MicroPulse™ antennas will be manufactured at the new headquarters, located at 471 Brighton Drive in Bloomingdale, IL. Telephone, fax and Web site addresses remain unchanged.

■ **WJ Communications Inc.** announced that it has recently shipped the 100,000th CV series converter module reflecting the broad acceptance by major base station manufacturers throughout the world.

■ The president of **AR Worldwide** has been selected by the US Small Business Administration to receive the 2005 Exporter of the Year Award for eastern Pennsylvania. **Donald Shepherd** received the award at "SBA Day at Citizens Bank Ballpark" before a Philadelphia Phillies game.

■ **M2 Global Technology Ltd.** announced that the Association for Manufacturing Excellence (AME) recently recognized the company for its commitment to attainment of excellence in manufacturing and productivity. Every year AME selects some of the best-in-class companies to feature in its manufacturing workshop series. M2 has been selected for three consecutive years.

FEATURED MODELS

Model #	Frequency (MHz)	Typical Phase Noise (dBc/Hz)	
		@10 kHz	@100 kHz
FSW SERIES [DUAL SUPPLY VOLTAGE +5 & +15 VDC]			
FSW511-50	50 to 115	-103	-120
FSW1125-50	110 to 250	-100	-122
FSW1536-50	150 to 360	-100	-120
FSW1847-100	180 to 470	-98	-120
FSW SERIES [DUAL SUPPLY VOLTAGE +5 & +24 VDC]			
FSW514-50	50 to 140	-103	-120
FSW1129-50	110 to 290	-100	-122
FSW1545-50	150 to 450	-100	-120
LFSW SERIES [SINGLE SUPPLY VOLTAGE +5 VDC]			
LFSW514-50	50 to 140	-102	-120
LFSW35105-50	350 to 1050	-108	-130

Other models are available at our website.

FEATURES:
- Exceptional Phase Noise Performance
- Interactive Communication
- Selectable Interface
- Standard Programming Interface
- Single or Dual Supply Options
- Small Size, Surface Mount
- Lead Free - RoHS Compliant
- Patent Pending REL-PRO® Technology

RoHS COMPLIANT

For additional information,
contact Synergy's sales and application team.
201 McLean Boulevard, Paterson, NJ 07504
Phone: (973) 881-8800 Fax: (973) 881-8361
E-mail: sales@synergymwave.com

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i2s INTELLIGENT INTERACTIVE SYNTHESIZERS

CONTRACTS

■ **Aeroflex** has won a multi-million dollar order from **SGS**, an inspection, verification, testing and certification company. The order, which is expected to be performed over a two month period, is for a comprehensive suite of mobile handset and inter-system handover test systems and test cases, and marks SGS's decision to expand its existing operations for mobile handset conformance testing. The Aeroflex systems and test cases are designed to further allow these services to be offered by the two SGS mobile handset test laboratories located in Shanghai and Taiwan. The order enables Aeroflex to participate in the creation and development of value-added wireless communication design services in the region.

■ **EMS Technologies Inc.** Defense and Space Systems Division has announced the award of an antenna system for a US DoD program. This is a follow-on production for this program and will bring the total delivered antenna systems to over 250. The contract was awarded by a prime contractor and is valued at $9.6 M USD with deliveries continuing through 2007.

■ **Fairchild Semiconductor**'s model RMPA5255 WLAN RF power amplifier has been selected for use in **Broadcom**'s latest single-chip and PCI Express-enabled Wi-Fi reference designs. The selection is based on Fairchild's ability to optimize its product to meet Broadcom's strict size, cost and performance requirements. Broadcom's customers can now adopt the Wi-Fi module into their next generation designs.

■ **Rohde & Schwarz** received the follow-up order for supplying the Eurofighter Typhoon with radiocommunications equipment. For this second batch of 236 aircraft, the company will supply each platform with two VHF/UHF transceivers. In 1999, Rohde & Schwarz won the order for supplying the first batch of aircraft of the series with radio communications equipment. For the present batch, the radio communications equipment has been modernized and is now based on the successful airborne transceivers of the R&S M3AR family.

FINANCIAL NEWS

■ **Andrew Corp.** reports sales of $481.8 M for the second quarter ended March 31, 2005, compared to $447.1 M for the same period in 2004. Net income for the quarter was $3.1 M ($0.02/per share), compared to a net income of $10.2 M ($0.06/per share) for the second quarter of last year.

■ **Cascade Microtech** reports sales of $18.7 M for the first quarter of fiscal 2005 ended March 31, 2005, compared to $13.8 M for the same period in 2004. Net income for the quarter was $2.5 M ($0.21/diluted per share), compared to a net income of $0.3 M ($0.05/diluted per share) for the first quarter of last year.

■ **Merrimac Industries Inc.** reports sales of $7.3 M for the first quarter of 2005 ended April 2, 2005, compared to $7.6 M for the same period in 2004. Net income for the quarter was $84,000 ($0.03/per diluted share), compared to a net income of $231,000 ($0.07/per diluted share) for the first quarter of last year.

■ **RF Industries Ltd.** reports sales of $3.6 M for the second quarter ended April 30, 2005, compared to $2.8 M for the same period in 2004. Net income was $163,000 ($0.04/per diluted share), compared to $351,000 ($0.10/per diluted share) for the second quarter of last year.

NEW MARKET ENTRY

■ **Xceive Corp.** is a fabless semiconductor company founded in July 2001, headquartered in Santa Clara, CA. Xceive's mission is to become a leading producer of RF-to-baseband transceiver ICs for TVs and set top boxes, a $3 B dollar addressable market.

PERSONNEL

■ Peregrine Semiconductor announced that **Gary A. Monetti** has been appointed to its board of directors. Monetti brings a wealth of industry experience to Peregrine's board from his tenure at Sawtek. During his 22 year career with Sawtek, Monetti held a variety of management positions including VP sales and marketing, VP engineering, COO, and president and CEO. Monetti currently works as an industry consultant, board member and advisor to various private venture businesses.

■ Locus Microwave, a provider of RF amplifier and converter products, announced the appointment of **Jim Dixon** as CEO, **Dana Wilt** as president and **Gary McGovern** as executive vice president. All have worked together at the original Locus Inc., Maxtech and Paradise Datacom before the start of Locus Microwave in January 2005.


▲ Paul Minton

■ **Paul Minton** has been named CEO of California Eastern Laboratories (CEL), a supplier of NEC RF and wireless semiconductors, fiber optic communications components, optocouplers and solid-state relays. Minton has served CEL for nearly ten years. He held the post of executive vice president until his promotion to president in 2004. He also served for a number of years on the company's board of directors. Minton takes over the CEO position formerly held by Jerry Arden, who will remain active as chairman of the board of directors.

■ Park Electrochemical Corp. announced that **Fred E. Hickman III** has been appointed to the new position of vice president, OEM marketing. Hickman's new responsibilities will involve a more industry specific focus in the global OEM marketing of Park's advanced composite and RF/microwave materials. Hickman joined Park in 1991 as the engineering manager of Nelco Technology Inc. and has served in a variety of capacities since that time.

Around the Circuit

■ Auriga Measurement Systems LLC announced the addition of **Agostino Papetti** as director of global sales and marketing. Most recently, Papetti was employed by Agilent Technologies in a variety of sales and marketing positions focusing on the microwave and millimeter-wave business segments, the aerospace and defense market, and the GaAs foundry infrastructure. Papetti was also the co-founder of ATN Microwave.


▲ *Jimmy Wong*

■ MI Technologies announced the appointment of **Jimmy Wong** to director, Asia operations. In this new position, Wong will be responsible for all of the company's sales activities in Asia and the Pacific Rim. He will oversee the company's Asian manufacturer representatives and coordinate the company's product installations, customer training and support. Wong comes to MI with more than 20 years experience in the communications and RF/microwave industries.

■ Keystone Electronics Corp., manufacturers of interconnect components and electronic hardware, has appointed a new regional manager to concentrate efforts on the western states. **Joseph J. Schmalzried** will be headquartered in Houston, TX. Most recently he was director of materials for Bisco Industries.

■ Valpey Fisher Corp. announced that **Greg Arthur** has joined the company as a field applications engineer for frequency control products. Arthur has over ten years of experience in the electronics industry. Most recently he has spent the last year at Raltron as a regional sales manager.

REP APPOINTMENTS

■ **Telephus** announced that it has appointed **TechRep International** as its agent to represent the company's RF integrated passive devices (IPD) to the US market. Telephus is currently ramping up high volume production to customers in Japan and is looking to expand its business in the US.

■ **IKE Micro** has signed a manufacturer representatives agreement with **CALTECH Associates LLC**. Kevin Callery, president of CALTECH, will represent IKE Micro in the mid-west region of the US.

■ **Emerson & Cuming Microwave Products** has announced new sales reps and distribution networks in China, Japan and Taiwan. **Sanetronic Co. Ltd.** was named the exclusive sales rep and distributor for all business in China and Hong Kong. **Holy Stone Enterprises Co. Ltd.** has been appointed the exclusive sales rep and distributor for all business in Taiwan. The most recent addition to the Asian network is **M-RF Col Ltd.**, who will be the exclusive distributor in Japan.

AN UPBEAT IMS 2005 IN LONG BEACH

Four earthquakes and a tsunami warning not withstanding, the IMS 2005 Symposium and Exhibition in Long Beach, CA turned out to be a huge success. Cool ocean breezes and hazy days were the norm outside, while crowded technical sessions and a busy show floor were the norm inside the spacious Long Beach Convention Center (LBCC). The MTT-S International Microwave Symposium was held June 12 to 17 with an overall attendance topping 11,000. It is safe to say everyone had a good time.

Charlie Jackson, the General Chairman, and his superb team of volunteers did a great job of organizing and implementing this year's Microwave Week activities and the City of Long Beach played happy host to all of the attendees. The roomy Long Beach Convention Center was a short walk to the waterfront and its renowned Aquarium of the Pacific, while across the bay the elegant Queen Mary played host to many of our visitors.

In addition to the MTT-S International Microwave Symposium and Exhibition, the 2005 Radio Frequency Integrated Circuits (RFIC) Symposium and the 65th ARFTG Measurement Conference held their events during the week. The RFIC Symposium was chaired by Joseph Staudinger and held from Sunday through Tuesday; the ARFTG Microwave Measurement Conference was chaired by Tom Ruttan and was held on Friday. All three events were a solid success and their respective organizing teams are to be congratulated.

The Technical Program

The Technical Program kicked off with two inspiring Plenary Session keynote addresses. "Digitally Assisted Analog Design for Wireless SoCs and Its Future" was presented by Dr. Teresa Meng, professor of electrical engineering at Stanford University, and Mr. Ziqiang Hou, professor at the Institute of Acoustics China Academy of Science, presented "3G and Mobile Broadband Wireless Access."

In recent years the MTT-S technical program has become bigger and bigger and this year was no exception. There were 344 oral presentations and 149 interactive forums held under the guidance of Dave Rutledge, this year's TPC Chair, and Co-chairs Mike DeLisio and Bob York. In all, 2856 delegates attended the 87 technical program sessions and 38 workshops. The workshops this year were organized by Ethan Wang and the special sessions were organized by Alina Moussessian. In addition, there were lunch sessions organized by Emilio Sovero, and 20 student papers were nominated for the Student Competition.

Frank Bashore
Microwave Journal *staff*

HIGHLIGHTS OF THE *MWJ*/MTT-S

Social Events

The RFIC Symposium Reception in the Grand Ballroom of the Long Beach Convention Center Sunday evening kicked off the week's social program, followed Monday evening by the *Microwave Journal*/MTT-S Reception held at the Aquarium of the Pacific. Other events included the IEEE MTT Women in Engineering Reception and the Ham Radio Social, both held in the Hyatt Hotel. Wednesday was the traditional Industry-hosted Cocktail Reception followed by the IEEE MTT-S Awards Banquet. This year our own Harlan Howe, Jr. received the well-deserved 2005 Distinguished Service Award in recognition of his significant contributions and outstanding service to the MTT-S and the microwave profession. We here at *Microwave Journal* are very proud of Harlan's achievements over the years. The week's social program also included the IEEE MTT-S Student Awards luncheon and the Technical Attendees Breakfast in the LBCC.

The Industry Exhibition

In addition to the impressive technical program offered during IMS 2005, there is always the Industry Exhibition held Tuesday through Thursday in the LBCC. This year 513 companies were displaying their latest new products and services in 909 booths on the show floor. Also included with the exhibition was a very interesting display presented by the MTT-S Historical Society and 57 separate μAPS presentations by the various exhibitors. Some photographs of the Ex-

RECEPTION & EXHIBITION

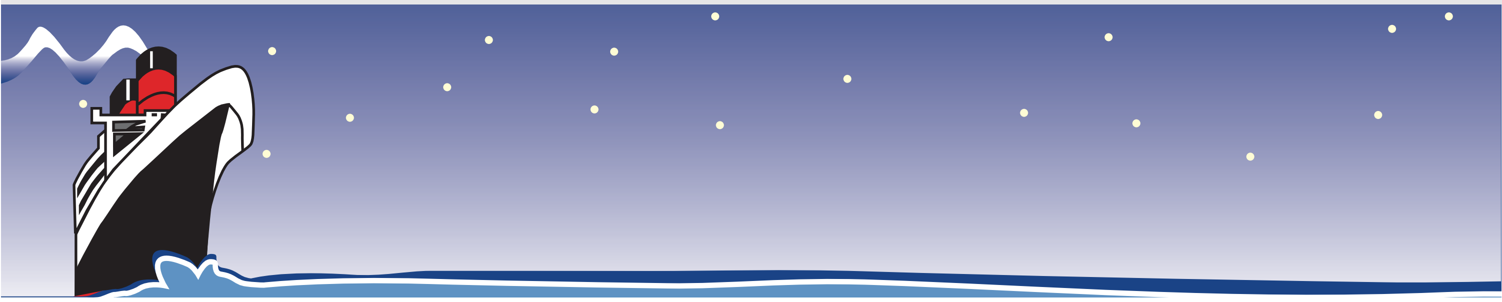
JUNE 13–16, 2005

hibition appear above and a sampling of some of the exhibitors and their offerings follows:

Aeroflex had on display its 2500 series frequency synthesizers that feature high speed, wide bandwidth and low noise, as well as increased reliability. The enhanced fast-switching synthesizers are faster, cleaner, smaller and more rugged than their predecessor. Also on display was its 1 to 40 GHz Microwave Downconverter that plugs into any Aeroflex PN9000 Phase Noise Analyzer or PN9500 Wideband Jitter and Phase Noise Analyzer. The PN9276 unit is billed as the highest bandwidth and lowest phase noise downconverter on the market, allowing noise measurements up to 200 MHz offset and allowing system sensitivity testing not possible here-to-fore.

Always on the leading edge of the market, Agilent Technologies announced an innovative 64-bit version of the Momentum 3D-planar electromagnetic software suite that significantly improves accuracy, capacity and speed for design and verification of passive components and interconnects for RFIC, MMIC and PCB/hybrid/module design. The new 64-bit capability eliminates memory limitations and cuts EM simulation and verification time in half. Also announced was a new capability to co-simulate using CST Microwave Studio® and Agilent's Advanced Design System.

Agilent's Test and Measurement group introduced a high performance Arbitrary Waveform Generator that generates waveforms for ultra-wideband



and multiple-input, multiple output radios and advanced DSL. The Agilent N60321A enables the creation of realistic orthogonal frequency division multiplexing UWB signals compliant with the Multiband OFDM Alliance (MBOA) proposal.

Also on display was a 14-bit, 40 MHz Bandwidth Digitizer for 6.7, 13.2 and 26.5 GHz PSA series spectrum analyzers. This new instrument provides low cost, high precision signal capture for designers of radar, satellite, military, emerging digital communications and 3G wireless systems employing high data-rate modulation.

AR Worldwide introduced two new models in its line of S-series broadband amplifiers. The model 700S1G4 operates from 0.8 to 4.2 GHz and features a power output of 700 W, while the model 800S1G3 provides 800 W over the 0.8 to 3 GHz frequency range. The new amplifiers represent a dramatic increase in power options within the S-series family. Both new amplifiers feature low levels of spurious signals and superior linearity. A new 20 W model 20S4G11 amplifier has also been added to the broadband solid-state amplifier line and three new high power, 1500 W models have been added to the traveling wave tube amplifier line. AR Worldwide also previewed a compact, high power microwave horn antenna that can supply high intensity fields for RFI/EMI field-testing.

Anritsu had several new items on display. A new version of the Signature™ MS2781A High Performance Signal Analyzer features up to 30 times faster operating speed, increased demodulation bandwidth, improved IQ vector output and improved amplitude accuracy. It is also now compatible with the company's MG3700A Vector Signal Generator. Three new CDMA2000 1xEV-DO options for the company's Cell Master™ MT8212B handheld analyzer were also on display, expanding its analysis capability to include RF, demodulation and over-the-air measurements. In addition, a UMTS Master for Node B analysis was introduced that offers unprecedented size, performance and cost advantages to 3G/UMTS applications.

Ansoft Corp. and TDK Ltd. released a new library for TDK's capacitor, inductor, common mode filter and ferrite bead components for use with Nexxim and Ansoft Designer. The new component library is free to Ansoft customers and will aid engineers in designing electronic equipment, such as wireless local area networks, car navigation systems, and cellular base stations and handsets. The device library contains S-parameters with proprietary equivalent simulation models of TDK's discrete products for use with high frequency designs.

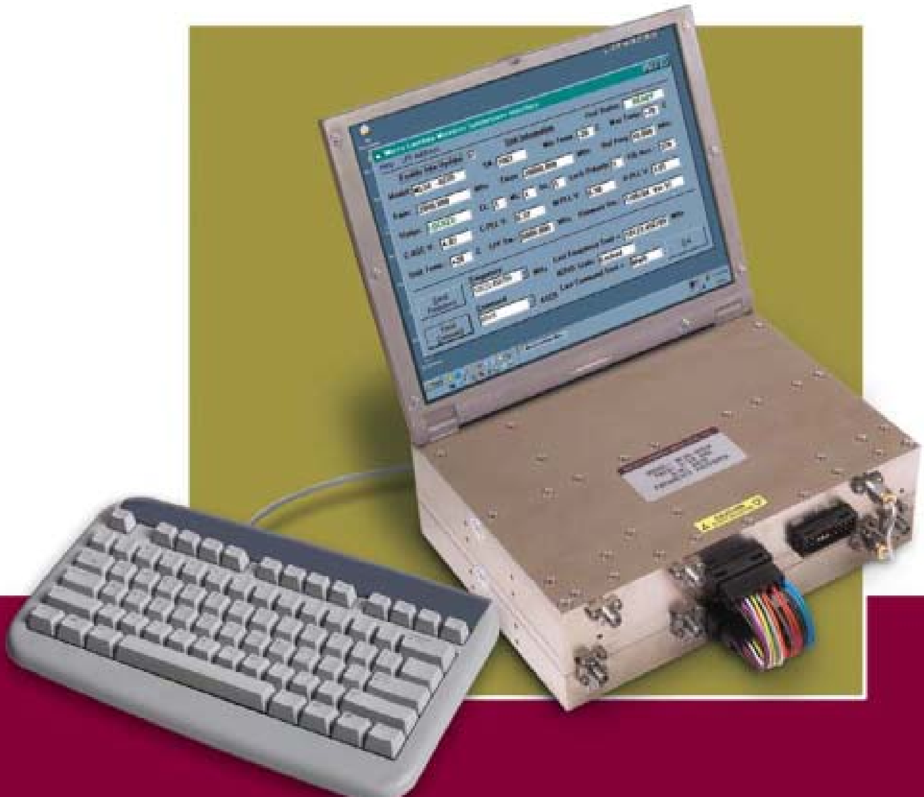
Applied Wave Research (AWR®) announced the release of a CDMA 2000 test bench for the company's Visual System Simulator™ (VSS) design suite. The new test bench is designed for RF system engineers who need to evaluate the impact of RF link impairments on frame error rate, bit error rate, symbol error rate and other metrics. The VSS design suite offers a rich set of behavioral RF models and integration with AWR's Analog Office™ circuit design software and popular industry instrumentation.

Boonton Electronics announced the release of its new 4500B Peak Power Analyzer. The new instrument captures, displays and analyzes RF power in both time and statistical domains, and can be used in applications involving pulsed RF such as radar, TDMA and GSM, and pseudorandom or noise-like signals such as CDMA and WLAN, and modulated time slotted signals such as GSM-EDGE and TD-SCDMA.

Dow-Key was showing its solid-state Canbus-based switch matrix that operates from 3.4 to 4.2 GHz and features an RS 422 interface. The switch matrix is available in full fan-out configurations from 32 × 32 to 32 × 64. The unit is designed with a focus on reliability and easy maintenance and is equipped with hot swappable redundant power sup-

microwave JOURNAL Previous Page | Contents | Zoom In | Zoom Out | Front Cover | Search Issue | Next Page

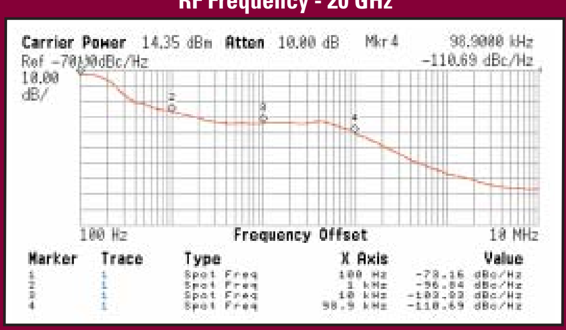
Test Equipment Performance at an Affordable Cost



FULL 2-20 GHZ AND 1-22 GHZ FREQUENCY COVERAGE IN SINGLE UNITS AND PORTABLE SIZE

Micro Lambda Wireless, Inc. a leader in the development of next-generation YIG devices introduces a new line of high performance frequency synthesizers covering the 2-20 GHz and 1-22 GHz frequency range. Designed specifically for wide band and low noise applications, these new frequency synthesizer/extenders rival the best lab-grade test instruments on the market.

Phase Noise
RF Frequency - 20 GHz



MLSE-SERIES WIDE BAND FREQUENCY SYNTHESIZERS.

This series of frequency synthesizers offer standard wideband tuning ranges covering 2-20 GHz and 1-22 GHz in standard models. RF Output power levels of +20 dBm and +17 dBm are offered respectively. Standard models provide output power leveling over the range of ±20 dB with 0.1 dB resolution. Frequency step size of 1 Hz is standard, but is programmable with software for customer specific requirements. External reference frequency of 10 MHz is utilized, but 5 to 50 MHz are offered as options.

Excellent phase noise performance of -73 dBc/Hz at 100 Hz offset , -96 dBc/Hz at 1 kHz offset, -103 dBc/Hz at 10 kHz offset, -110 dBc/Hz at 100 kHz and -131 dBc/Hz at 1 MHz is provided at 20 GHz. The units operate from +15V and +5V supply lines and frequency control is via a 5-wire serial (SPI & busy) input protocol.

Options include second RF output covering 4-11 GHz which can be used for down conversion, a low noise 2nd L.O. output tunable over specified frequencies and an auxiliary input to add an additional frequency input within the units range – into the synthesizer switch matrix. All units measure 5"x7"x2" and weigh 57 oz.

FEATURES

- 2.0- 20.0 GHz, 1.0 –22.0 GHz, Frequency Bands
- Excellent Phase Noise
- 1 Hz Step Size
- Output power Leveling / 0.1 dB resolution
- Fundamental RF Output available for downconverting

"Look to the leader in YIG-Technology"

MICRO LAMBDA WIRELESS, INC.

Visit mwjournal.com/info and enter 54 to request information

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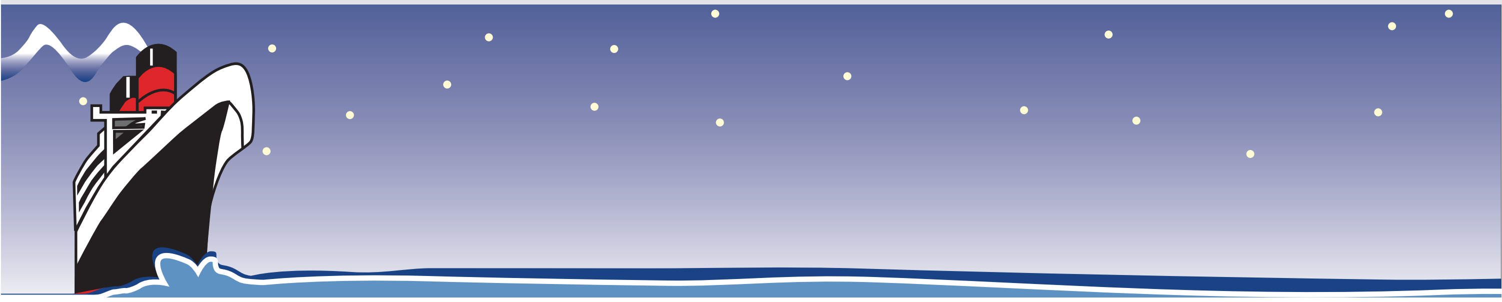


plies and hot swappable input and output cartridges.

Eagleware-Elanix Corp. announced its GENESYS™ 2005, a major new release of its popular RF and microwave design suite. The new version includes WhatIF, a new frequency planning tool, CAYENNE, a new time domain simulator, two new synthesis modules — AMPLIFIER and MIXER, plus enhancements to the linear, nonlinear, and system architecture simulators, new models and a revamped user interface.

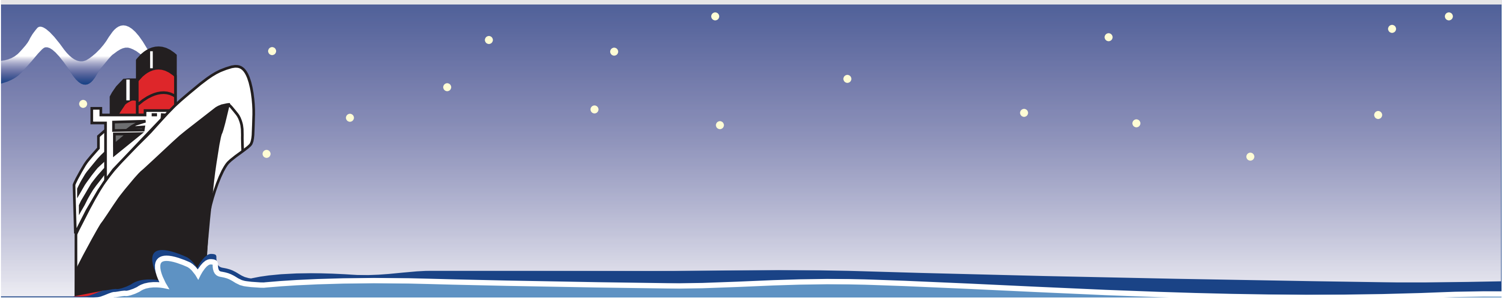
Fairchild Semiconductor was introducing its WCDMA/UMTS/HSDPA power amplifier modules that feature a dual-band PAM (RMPA2265) in a 3 × 3 mm footprint, a pin-compatible packaging that allows direct swapping with today's industry standard 4 × 4 mm as well as 3 × 3 mm PA modules, and compliance with emerging HSDPA standards. Also on display was an EDGE power amplifier module with high power-added efficiency in both GSM and EDGE modes in a 7 × 7 mm compact footprint, and the i-Lo™ CDMA/WCDMA power amplifier product family that uses novel proprietary circuitry to dramatically reduce amplifier current at low to medium RF output power levels.

Focus Microwaves was displaying its 100 MHz to 1.1 GHz Fast iTuner, the first automatic tuner that extends below 200 MHz. The new tuner features fast calibration, ultra fast tuning (360° at 100 MHz in less than 15 s) and high accuracy. The iTuner features automatic VSWR routines, user-developed test software, LabView+, Visual Basic+, Vee+, C and C++.

W.L. Gore introduced the GORE™ 100 series connectors, the newest addition to its Blindmate/Push-on connector family. The connectors are a super high density blindmate, high performance microwave interconnect system for operation through 100 GHz. GORE 100 connectors are an extention of the SMP and SMPM connector families and were developed to the industry's demand for increased package density, low mass and increased performance at higher frequencies. The new connectors are robust, durable and lightweight. A socket-to-socket bullet weighs less than 0.02 grams.

ITT Industries had on display its MINI RF series connector that combines miniaturization with durability and high performance. The new connector is intended for test and accessory use in conjunction with a wide range of telecommunications, consumer, automotive and industrial equipment.

Hittite Microwave introduced 18 new products that included the HMC247, HMC538LP4 and HMC-C010 analog phase shifters that operate from 6 to 21 GHz and provide up to 800° of continu-



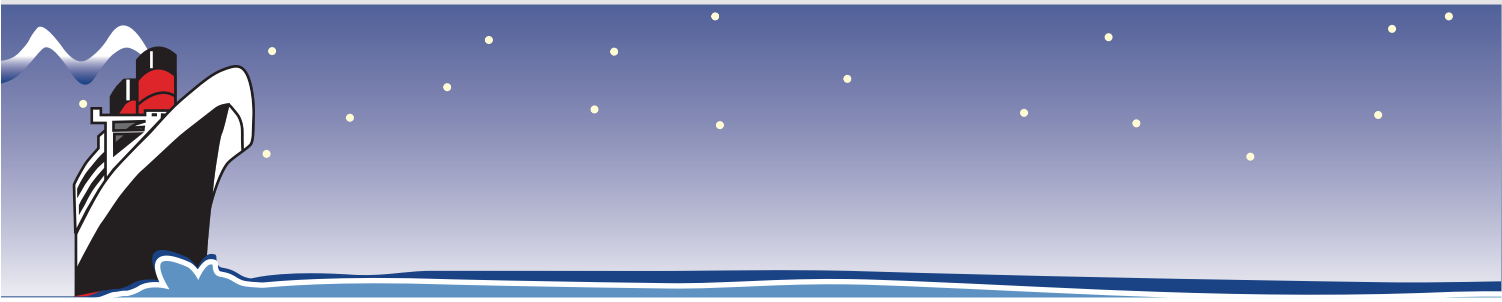
ously variable insertion phase. The phase is controlled by a positive analog DC voltage and the insertion loss is consistent versus phase shift. Also shown was the HMC535LP4 InGaP HBT phase-locked oscillator MMIC for VSAT subscriber equipment. The new PLO provides a single-ended RF output in the range of 14.6 to 15.4 GHz with 11 dBm output power and a low single-sideband phase noise of –110 dBc/Hz at 100 kHz offset.

Three new InGaP HBT VCOs have been added to its line. The HMC513LP5, HMC514LP5 and HMC533LP4 are fully integrated VCOs incorporating the resonator, negative resistance device and varactor diode. They cover the 10.43 to 11.46 GHz, 11.17 to 12.02 GHz and 23.8 to 24.8 GHz frequency ranges, respectively. The HMC260LC3B, HMC292LC3B and HMC329LC3B are passive MMIC double-balanced mixers offering IF bandwidths of DC to 8 GHz and covering all of the microwave radio bands from 14 to 32 GHz. The HMC523LC4, HMC526LC4, HMC527LC4 and HMC528LC4 are passive MMIC I/Q mixers providing RF/LO coverage from 6 to 23 GHz and delivering up to 28 dBm input IP3. The HMC383LC4 GaAs PHEMT MMIC driver amplifier, also shown, is rated from 12 to 30 GHz and delivers 15 dB of gain and +18 dBm of saturated output power while consuming only 100 mA from a single +5 V supply. In DBS downconverter applications, the HMC276LP4 GaAs MMIC 4 × 2 switch matrix is housed in a 4 × 4 mm leadless SMT package and is rated at 200 to 3000 MHz. The HMC374 GaAs PHEMT MMIC LNA was on display and is ideal for cellular/3G infrastructure, repeaters, WiMAX, broadband access and ISM applications from 300 to 3000 MHz. It exhibits 1.8 dB noise figure and +36 dBm output IP3 with 15 dB small-signal gain. Finally, the HMC-C011 is a DC to 20 GHz, non-reflective SPDT switch in a hermetic connectorized housing with field-replaceable SMA connectors. The switch offers 2 dB insertion loss, 35 to 65 dB isolation and +23 dBm input P1dB.

K&L Microwave was featuring its custom converter designs that employ state-of-the-art RF, analog and digital technologies to maximize performance and minimize size. The assemblies are configured from proven modular designs consisting of amplifiers, switches, multipliers, couplers and limiters. The new converters are compact, employing narrow and wideband filtering and feature integrated low noise amplifiers and a terminated IF diplexer for maximum IP3 performance. They are available in frequency ranges from 10 MHz to 18 GHz.

M/A-COM had many new products on display, including its 24 GHz SoC radar,


SIMULATION



a highly integrated SiGe design with multi-mode functionality in a low cost plastic package. Also featured was its line of RFID products that include a complete line of RFID antennas, RF components and value-added assembly services. The M/A-COM complete line of RF components for RFID readers includes a low barrier IQ modulator that replaces a discrete balun, as well as quadrature and Schottky diodes within a single monolithic device.

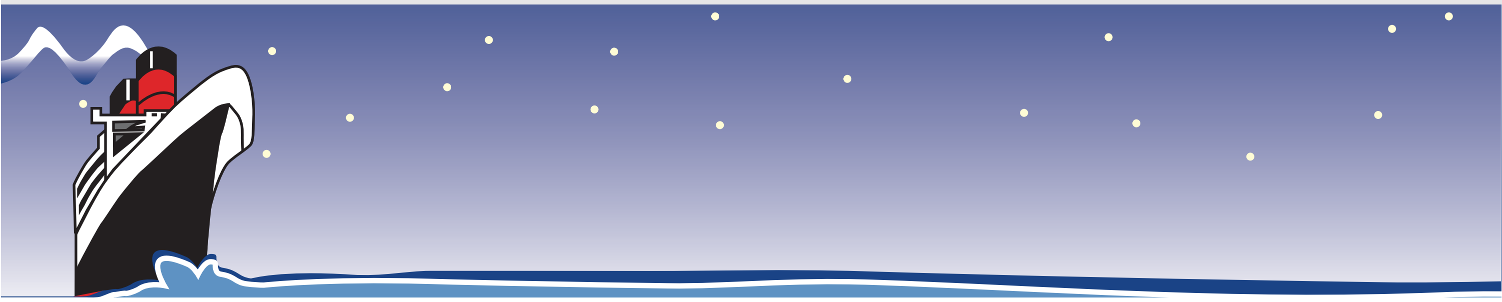
Maury Microwave had live demonstrations for power measurements, signal quality measurements, USB controlled tuners, LSNAs and noise measurements, and was displaying its Maury Automated Tuner System (ATS) Software's new features and functions. The ATS 4.00 software features an advanced sweep plan, electrothermal memory characterization tool, migration of ATN noise algorithm, and over 50 improvements and advanced features.

Mimix Broadband was talking about its recent acquisition of Celeritek Inc., while displaying its new line of highly linear GaAs MMIC power amplifiers that cover the 13 to 40 GHz frequency range with up to 39 dBm of output IP3 performance. The new PAs use a 0.15 μm gate length GaAs pseudomorphic high electron mobility transistor (PHEMT) device technology and are well suited for wireless communications applications. They also introduced a three-stage balanced GaAs MMIC power amplifier and complementary driver amplifier at 43.5 to 46.5 GHz that produces more than 26 dB of gain and 1 W of output power.

Noise Com had a number of its instruments on display including the DNG7500 digital noise generator that generates programmable, user-specified, pseudo-noise and CW signal spectrums for RF, microwave and fiber optic equipment testing. Also on display were the GPS7500 noise and interference generator for GPS interference testing, the UFX-EbNo series precision generators and the NBS-series primary noise standards.

Palomar Technologies was displaying its automated gold wire bonder that combines high net throughput and flexibility. The model 8000 gold ball-and-stitch thermosonic wire bonder is designed for precision gold wire bonding applications where flexibility, ease of programming and high throughput are desired such as in complex multichip applications, high I/O count devices and gold ball bumping for flip chip with planarBump™ technology. The unit features a large 12" × 6" x-y range linear motor actuated positioner carrying a dual axes voice coil driven bond head with a rectilinear z-stroke of 800 mils.

Peregrine Semiconductor was showing its new wireless UltraCMOS™ switches with extended performance to 3



GHz. The general use RF switches feature high isolation, high ESD tolerance and low insertion loss. The new switches provide an optimal solution for most wireless applications. The multi-throw switches were developed using Peregrine's patented UltraCMOS silicon-on-sapphire process technology and deliver an extraordinary combination of performance, price and monolithic integration. Also on display was the company's 75 Ω UltraCMOS switches and digital attenuators, as well as two integer-N phased-locked loops with embedded EEPROMs.

Remcom Inc. was demonstrating its XFDTD® 6.2 software suite that is an entirely new approach to EM modeling. The new automatic convergence check allows optimum run times and an adaptive meshing technique adjusts the FDTD mesh to one's geometry. For large problems, the MPI version of XFDTD can be utilized on 64-bit computers to facilitate calculations. Also featured was a powerful dimension-based geometric modeler, which can import complicated CAD objects, mesh in seconds, and view and edit the mesh before making the calculation.

RF Micro Devices displayed its Powerstar® EDGE Transmit module with four-port receive for large signal polar modulation. The RF3178 is RFMD's first low profile quad-band polar modulator-capable transmit module with four-port receive capability for GSM/GPRS/EDGE Class 12 operation. The TX module features integrated power control, PHEMT switch technology and integrated filters, resulting in a compact, high performance module that simplifies transmitter design. The RF3178 polar modulator features quad-band transmit capability and four RX ports, and can be used to design all geographical combinations of GSM/GMSK/EDGE handset configurations. It features controlled harmonic radiation from the antenna and can be used in multiple platforms.

Rogers Corp. showcased its high frequency laminates, including its RO4000® series high frequency circuit material, a glass-reinforced hydrocarbon/ceramic thermoset laminate system designed for performance sensitive, high volume commercial applications. Also on display was its RT/duroid® 6202 material for traditional microwave laminates and their R/flex® 3000 family of liquid crystalline polymer (LCP)-based circuit materials.

Rohde & Schwarz introduced the model ZVT8 eight-port vector network analyzer, that makes it easier and faster to measure multiport and balanced devices with high accuracy and wide dynamic range over a measurement range of 300 kHz to 8 GHz. The instrument has a reflectometer at each of its eight test ports, thus making it possible to perform measurements at all ports simultaneously. Also on display was its model FSL

microwave JOURNAL Previous Page | Contents | Zoom In | Zoom Out | Front Cover | Search Issue | Next Page

compact, low cost spectrum analyzer, a lightweight, portable instrument designed for field measurements as well as for product development and production test applications. The unit weighs only 15.5 lbs. The model SMJ100A vector signal generator was also introduced. This instrument is the latest in the SMx family of instruments and provides comprehensive baseband modulation capabilities, superior RF performance, fast frequency and level-setting times, and simple operation.

Times Microwave Systems was displaying its new TuffGrip™ for the SilverLine-TG™ test cables. The new grip enables the user to apply as much resistance as necessary in mating the connector. The SilverLine test cables are cost effective, durable, high performance cable assemblies designed for use in a broad range of test and interconnect applications. Also on display were its Zero dB™ coax cable assemblies that feature a unique design with no insertion loss, its SiO2 silicon dioxide hermetically sealed cable assemblies for use in extreme environments, and its BlindMate™ antenna solutions for "plug-in and forget" quick release antenna mount applications.

Trak Microwave introduced a new Ka-band isolator with an ultra miniature design that is ideal for defense and space applications. They also introduced a Ku-band switch assembly for antenna applications. The unit is extremely small, making it ideal for airborne application, especially aerial vehicles where size and weight are critical. In addition, a new C-band dielectric resonator oscillator was on display that was designed for rugged military applications that demand low phase noise, and new hybrid S- to C- and X- to Ku-band switch limiters were introduced that have a miniature, low profile design for defense applications. On the commercial side, Trak was showing a new Iso-Hybrid family for wireless applications that feature small size and low weight for use in micro base stations, and three new product families for RFID applications that include surface-mount circulators and drop-in isolators.

TriQuint Semiconductor introduced two new power amplifiers for 3.5 GHz WiMAX applications that are in low cost surface-mount packages and feature an instantaneous bandwidth of 200 MHz, and deliver high saturated power and PAE. Six new packaged millimeter-wave amplifiers for satellite and radio applications were also shown that comprise the output and driver stages for 27 to 31 GHz transmit chains and a power amplifier and low noise amplifier for the 17 to 27 GHz band. New power PHEMT transistors for DC to 20 GHz operation were also displayed that offer superior power, gain and efficiency for L- through Ku-band high power amplifier applications.

Valpey Fisher Corp. introduced integrated subsystems for demanding frequency control applications that are designed to offer the design engineer a complete solution. The basic building block is a very high frequency, very low noise reference oscillator and additional components are included to provide multifunctionality based on the user's unique requirements. The example shown was a high precision OCXO, power amplifier and an output filter/matching network, fitting neatly into a 2" × 2" × 0.75" package.

WJ Communications was showing its 12 V, 4 W power amplifier modules for PCS, UMTS and DCS band operation. The AP series amplifiers are multi-stage devices and are internally optimized for efficiency and linearity. Each of the devices include internal matching for input and output and operate from +12 V without requiring negative biasing voltages. The devices were developed using the InGaP HBT process.

San Francisco Next Year

Planning is already well underway for an even better IMS Week in 2006 in San Francisco, CA. The symposium and exhibition will run from June 11 to 16 and the city of San Francisco always offers a host of interesting activities to make your stay memorable. Mark you calendar and plan to join us there. ■

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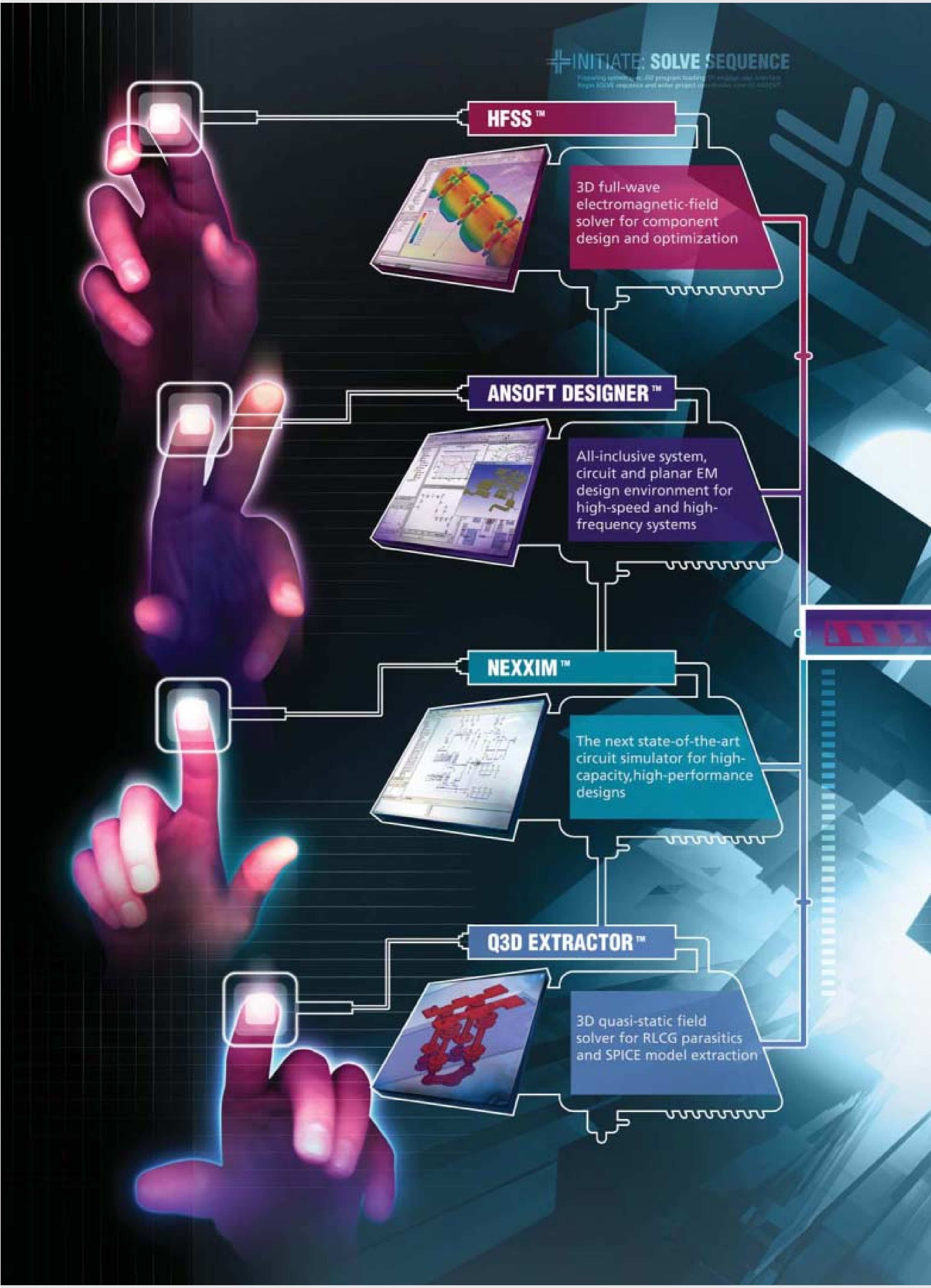
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TUTORIAL

A Brief Tutorial on Antenna Measurements

This article covers the basic concepts of antenna measurements, including definitions of the reactive near-field, radiating near-field and radiating far-field; primary antenna measurement parameters; and the various types of antenna measurements, including pattern, gain and polarization measurements. The most common types of measurement range configurations are detailed, including far-field range configurations such as the elevated range, slant range, ground-reflection range and compact range; and near-field ranges such as planar, cylindrical and spherical. A future article will focus on the applicability of different types of antenna measurement ranges to specific antenna measurement requirements.

> ***A summary of basic antenna properties and terms [is] presented, along with a description of the most often measured antenna parameters.***

BASIC ANTENNA CONCEPTS

Electromagnetic Waves

The radiation field from a transmitting antenna is characterized by the complex Poynting vector $E \times H^*$ in which E is the electric field and H is the magnetic field. Close to the antenna, at a distance r from the antenna, the Poynting vector is imaginary (reactive) and the fields decay more rapidly than 1/r, while farther away from the antenna, the Poynting vector is real (radiating) and the fields decay as 1/r. These two types of fields dominate in different regions of the space surrounding the antenna. Based on this characterization of the Poynting vector, three major regions can be identified (see ***Figure 1***).

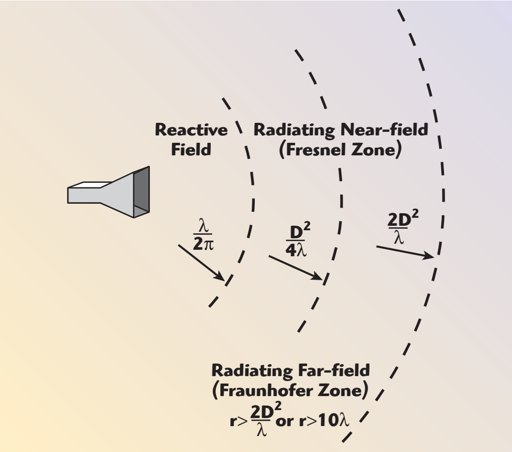

Fig. 1 Radiating regions.

JOHN F. AUBIN
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Horsham, PA

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Reactive Region

This region is the space immediately surrounding the antenna. The extent of this region is given approximately as $0 < r < \lambda/2\pi$, where λ is the wavelength. In this region, all three spatial components (r, ,θ, ϕ) decay more rapidly than 1/r.

Radiating Near-field

Beyond the reactive region, the radiating fields begin to dominate. The extent of the radiating near-field region is $\lambda/2\pi < r < 2D^2/\lambda$, where D is the largest dimension of the antenna. This region can be divided into two sub-regions. For $\lambda/2\pi < r < D^2/4\lambda$, the fields decay more rapidly than 1/r and the radiation pattern (relative angular distribution of the field) is dependent on r. For $D^2/4\lambda < r < 2D^2/\lambda$, the fields decay as 1/r and the radiation pattern is still dependent on r. The radiation pattern is given as the Fourier transform of the aperture distribution (with a phase error in excess of $\lambda/16$). The phase error is dependent on r (as $r \to \infty$, the phase error approaches zero). This region is often referred to as the Fresnel region.

Radiating Far-field

Beyond the radiating near-field region, for $r > 2D^2/\lambda$, the Poynting vector is real (only radiating fields are present) and has only two spherical coordinate components (θ, ϕ). The fields decay as 1/r and the radiation pattern is independent of r. The radiation pattern in this region is approximated by the Fourier transform of the aperture distribution (with a phase error of less than $\lambda/16$). This region is referred to as the Fraunhofer region.

Antenna Parameters

Polarization

Polarization is the property of the electric field vector that defines the variation in direction and magnitude with time. If the field is observed in a plane perpendicular to the direction of propagation at a fixed location in space, the end point of the vector representing the instantaneous electric field magnitude traces a curve. In the general case, this curve is an ellipse, as shown in ***Figure 2***. The ellipse is characterized by the axial ratio (AR), the ratio of the major and minor axes, and the ellipse major axis tilt angle τ. The polarization may be classified as linear, circular or elliptical according to the shape of the curve. Linear and circular polarizations are special cases of elliptical polarization, when the ellipse becomes a straight line or a circle, respectively. Clockwise rotation of the electric field vector is designated as right-

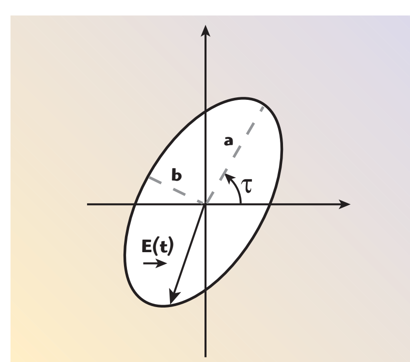


Fig. 2 Elliptical polarization.

hand polarization (RH) and counterclockwise rotation is left-hand polarization (LH), for an observer looking in the direction of propagation.

Input Impedance and VSWR

The input impedance is defined as the impedance presented by the antenna at its terminals. If the antenna is not matched to the interconnecting transmission line, a standing wave is induced along the transmission line. The ratio of the maximum voltage to the minimum voltage along the line is defined as the voltage standing wave ratio (VSWR). The effect of an impedance mismatch is to reduce the overall antenna efficiency and thus gain.

Directivity

The directivity is a parameter that quantifies the directional characteristics of the antenna pattern. It is defined as the ratio of the antenna radiation intensity in a specific direction in space to the radiation intensity of an isotropic source, assuming equal radiated power. Peak directivity is defined as the directivity at the angle of peak radiation of the antenna.

Efficiency

The antenna efficiency accounts for all the losses in the antenna, prior to radiation. The losses may be due to mismatch at the input terminals, conduction losses, dielectric losses and aperture illumination losses.

Gain

The gain of the antenna is defined as the product of the directivity and the efficiency. It thus takes into account the directional and loss characteristics of the antenna. The gain in a given direction is key in determining the ability of the antenna to provide an adequate link margin or to provide adequate sensitivity for the system under consideration.

Effective Isotropic Radiated Power

The effective isotropic radiated power (EIRP) is a figure of merit for the net radiated power in a given direction. It is equal to the product of the net power accepted by the antenna and the antenna gain.

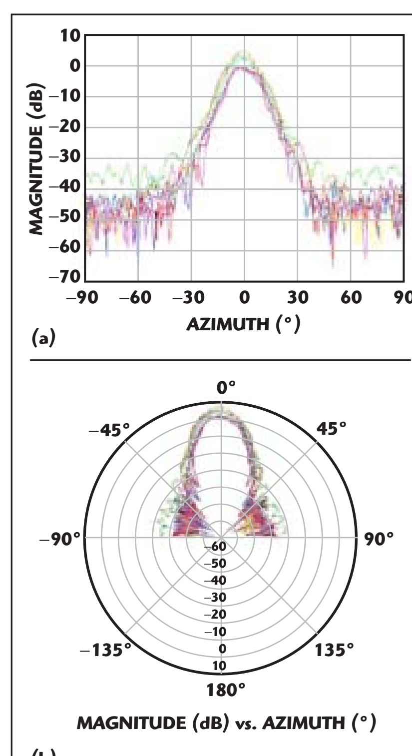
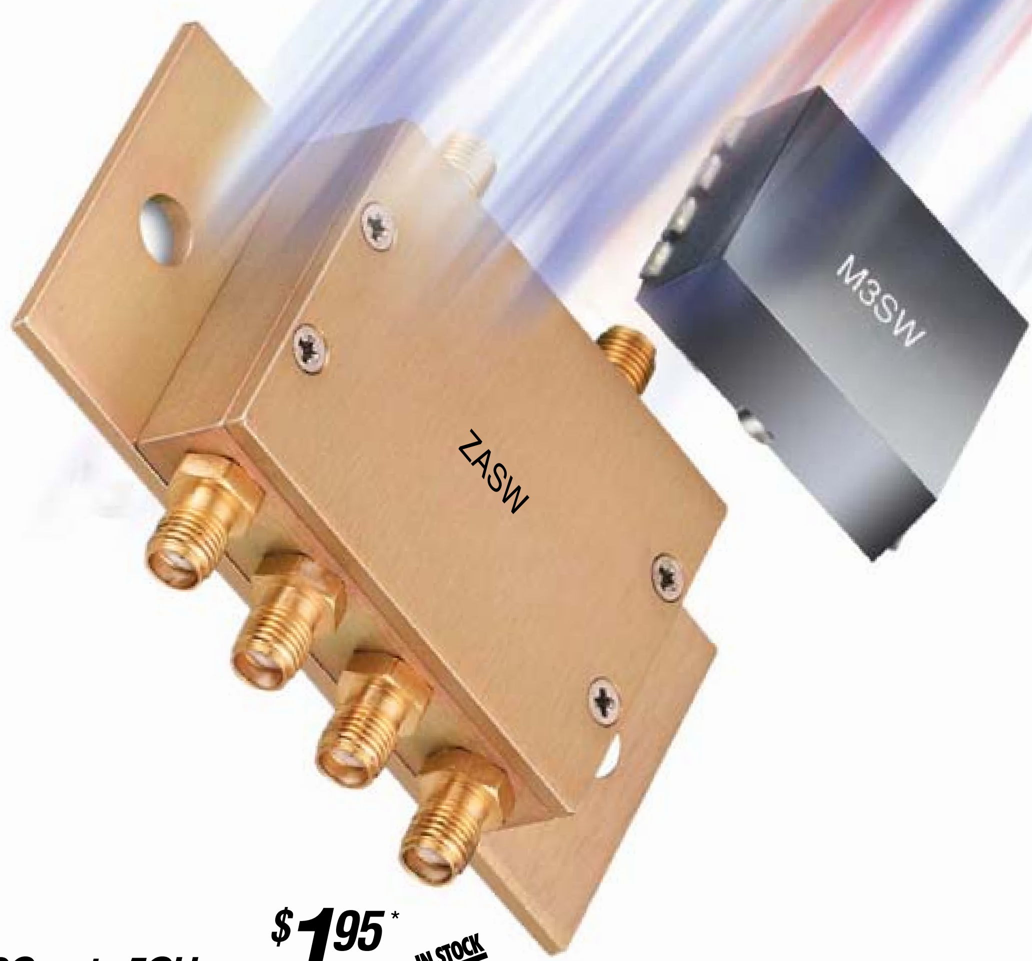


Fig. 3 Radiation patterns; (a) rectangular form and (b) polar form.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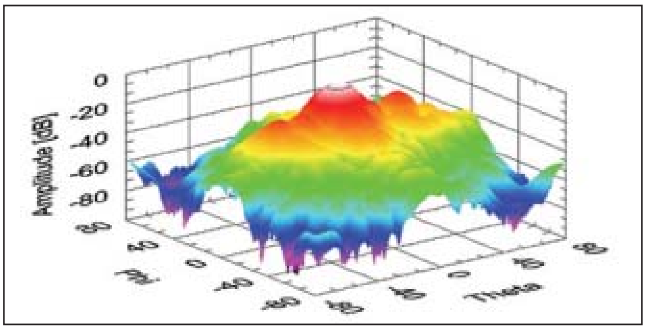


Fig. 4 Three-dimensional radiation pattern.

Radiation Pattern

The antenna radiation pattern is the mapping of the radiation levels of the antenna as a function of the spherical coordinates (θ, ϕ). In most cases, the radiation pattern is determined in the far-field region for constant radial distance and frequency. A typical radiation pattern is characterized by a main beam and a series of side lobes at different levels (see ***Figure 3***). The antenna performance is often described in terms of its principal E- and H-plane patterns. For a linearly polarized antenna, the E- and H-planes are defined as the planes containing the direction of maximum radiation and the electric and magnetic field vectors, respectively.

Antenna Noise Temperature

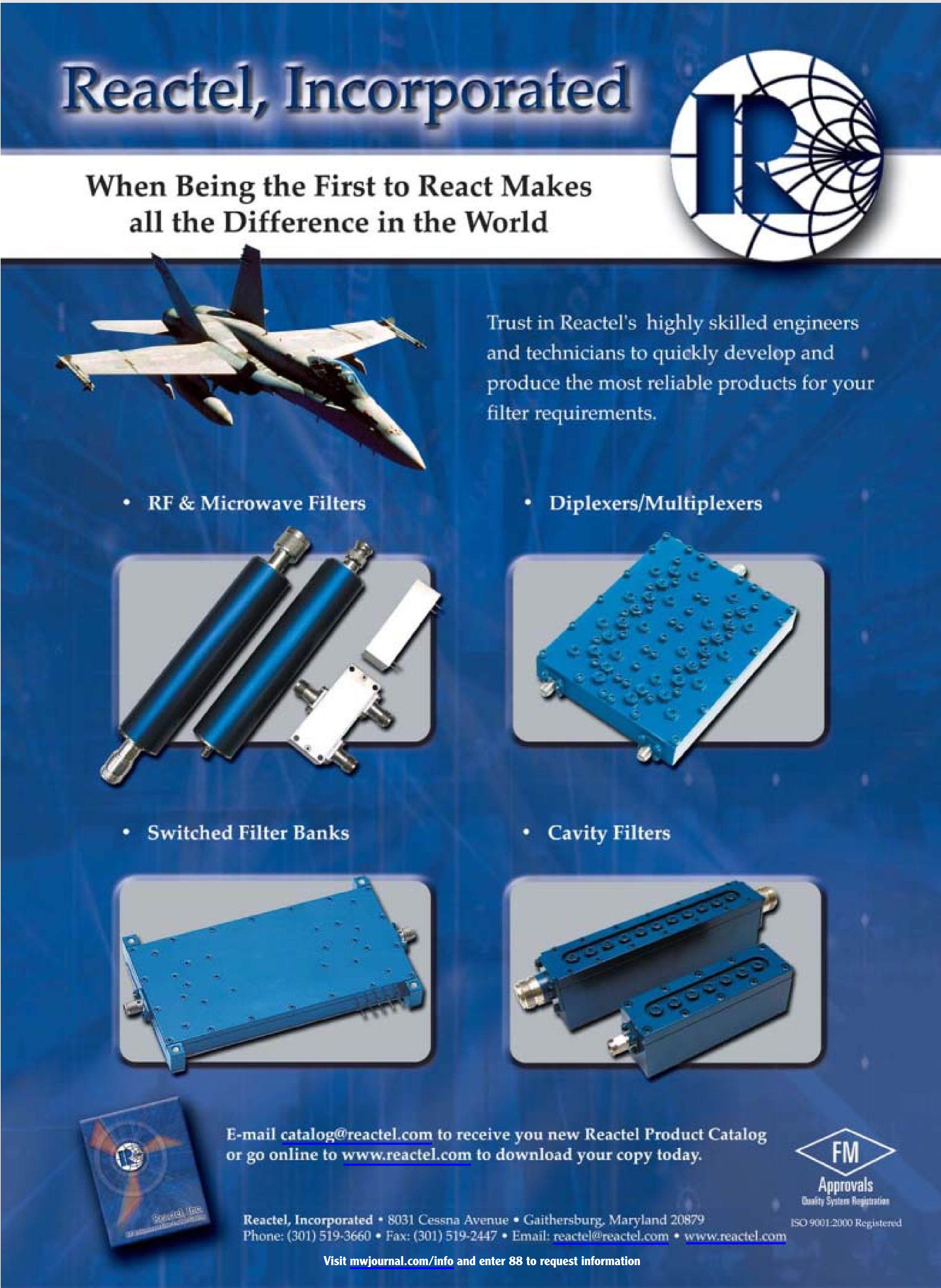
The antenna noise temperature is a parameter that describes the noise power received by the antenna. It can be obtained by integrating the product of the antenna directivity and the brightness temperature distribution of the environment over the entire space surrounding the antenna. The brightness temperature of the environment is dependent on many noise sources: cosmic, atmospheric, man-made and ground. The noise power received at the antenna terminals is equal to KTaB, where K is the Boltzman constant, Ta is the antenna noise temperature and B is the bandwidth of the system receiver. A convenient figure of merit, proportional to the signal-to-noise ratio received by the antenna, is G/T, where G is the antenna gain and T is the receiving system noise temperature in degrees Kelvin, and is given as the summation of the antenna noise temperature and the RF chain noise temperature from the antenna terminals to the receiver output.

ANTENNA MEASUREMENTS

Testing is performed on both indoor and outdoor ranges, with associated limitations for both. Outdoor ranges are not protected from environmental conditions, while indoor ranges are limited by space restrictions. Indoor ranges utilize anechoic chambers to provide a non-reflective environment in which to conduct the measurements. There are two basic forms of anechoic chambers: rectangular and tapered. Tapered chambers are generally used where low frequency performance is of high importance (typically for frequencies below 1 GHz).

Radiation Pattern Measurements

The radiation pattern of an antenna is three-dimensional over a sphere surrounding the antenna (see ***Figure 4***).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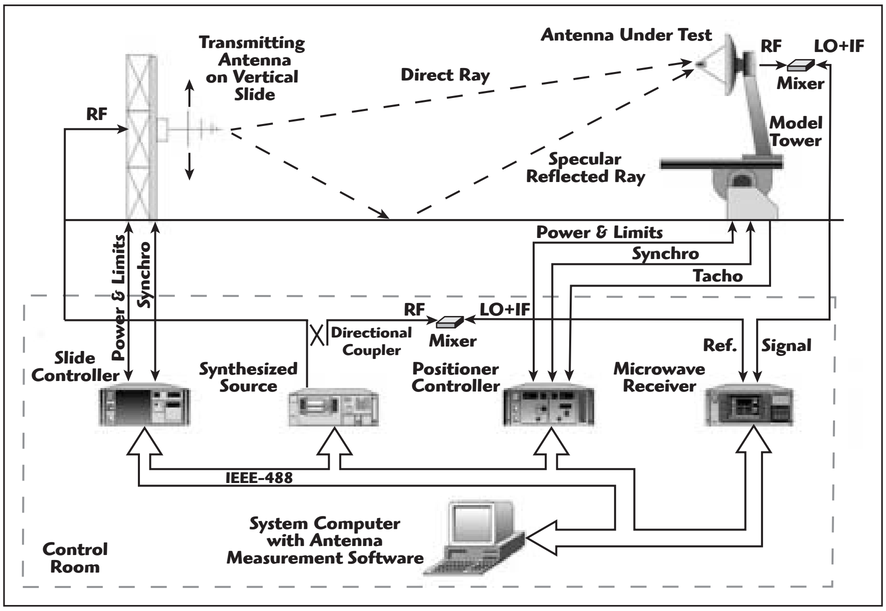

Fig. 5 Ground reflection range configuration.

Because it is not always practical to measure a three-dimensional pattern, a number of two-dimensional patterns (referred to as pattern cuts) are often measured. This can be accomplished by using different types of positioners, such as elevation-over-azimuth (EL/AZ), azimuth-over-elevation (AZ/EL), or roll-over-azimuth (Roll/AZ) mounts.

Directivity Measurement

The antenna directivity may be computed using measurements of the radiation pattern. This is often accomplished numerically by integrating the radiation intensity over the entire space of the surrounding sphere.

Gain Measurement

There are two basic methods that can be used to measure the gain of an antenna: absolute gain and gain comparison techniques. The absolute gain method requires no a priori knowledge of the transmitting or receiving antenna gain. If the receiving and transmitting antennas are identical, one measurement and the use of the transmission formula are sufficient to determine the gain. If the antennas are different, three antennas and three measurements are required to formulate a set of three equations with three unknowns to determine the gain of the antenna under-test (AUT). In the gain comparison method, standard gain antennas, whose gain is known, are used to determine the absolute gain of the AUT.

Polarization Measurement

Two methods are commonly used for polarization measurement. One is called the "spinning linear" method, where a linear source is rotated through all linear polarization states, thus yielding a direct measurement of the antenna under test axial ratio. The second common method is the dual-polarization method, where the response of the antenna under test is measured for two source illuminations characterized by orthogonal polarizations (typically linear vertical and linear horizontal). In this case, measuring the complex (amplitude and phase) response of the antenna under test yields, with appropriate analysis, the axial ratio, tilt angle and sense of the antenna.

FAR-FIELD MEASUREMENTS

Far-field Ranges

Far-field measurements can be performed using either outdoor or indoor ranges. In general, there are two basic types of far-field antenna ranges: ground reflection ranges and free-space ranges. In the ground reflection range, a constructive interference between the direct ray from the source

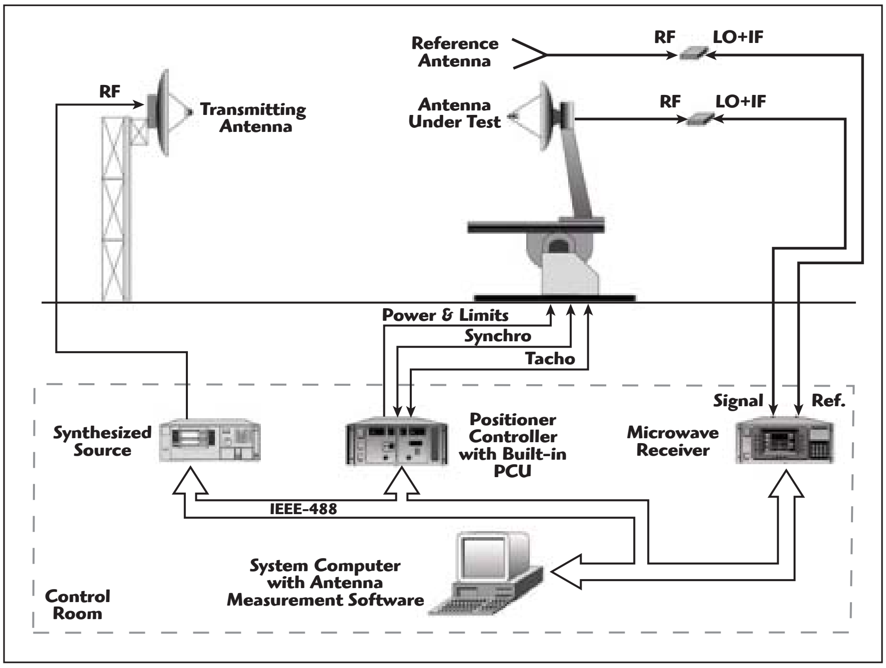

Fig. 6 *Elevated range configuration.*

antenna and the specular reflection from the ground is utilized to illuminate the test zone. In the free-space ranges, the reflections from the ground are minimized. There are several types of free-space ranges, primarily elevated ranges and slant ranges. A related type of range is a free-space class range that utilizes a compact range reflector to achieve a plane wave illumination that is approximated by other far-field measurement ranges.

Ground Reflection Range

In a ground reflection range, the specular reflection from the ground is used to obtain uniform amplitude and phase distribution over the AUT (see ***Figure 5***). This requires a smooth range surface. The range length r is designed to meet the far-field criterion. The interaction of the direct radiation from the source and the specular ground reflection over the test zone produces an interference pattern, with alternating maxima and minima. The heights of the source and AUT are chosen so that the AUT is centered on the first interference lobe. This criterion determines the relation between the source height, h_t, and the AUT height, h_r, to be $h_t \sim \lambda R/4h_r$. If the amplitude taper over the AUT is required to be no more than 0.25 dB, the height of the AUT should meet the criterion $h_r > 3.3D$.

Elevated Range

Elevated ranges are usually designed to operate mostly over terrain. The antennas are typically mounted on towers or on roofs of adjacent buildings (see ***Figure 6***). The range length r is designed to meet the far-field criterion $r > 2D^2/\lambda$, in which D is the largest dimension of the source or AUT. The height of the AUT, h_r, is determined by two criteria related to the source antenna. The source antenna is usually chosen so that the amplitude taper over the AUT is typically no greater than 0.25 dB. In addition, to minimize the range reflections, its first null points toward the base of the test tower. These two criteria determine the height of the AUT to be $h_r > 4D$. Occasionally diffraction fences are required to further suppress ground reflections. In some cases, the elevated range is implemented with the source and AUT site on local terrain peaks, with a valley in-between, which minimizes any contribution from ground reflections.

Slant Range

A slant range is one in which the source antenna is located close to the ground and the AUT is mounted on a tower (see ***Figure 7***). The source an-

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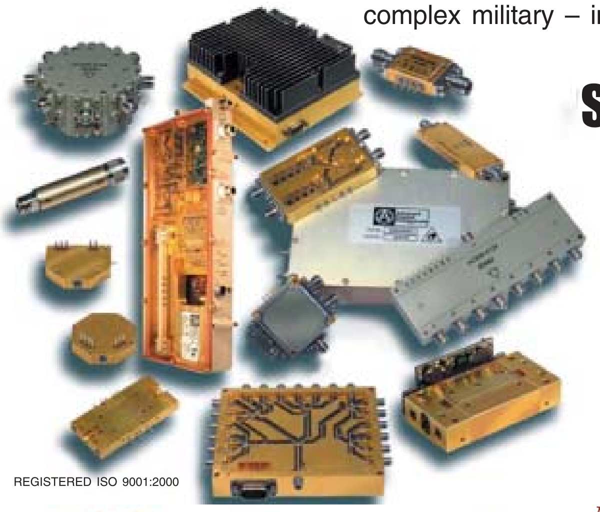

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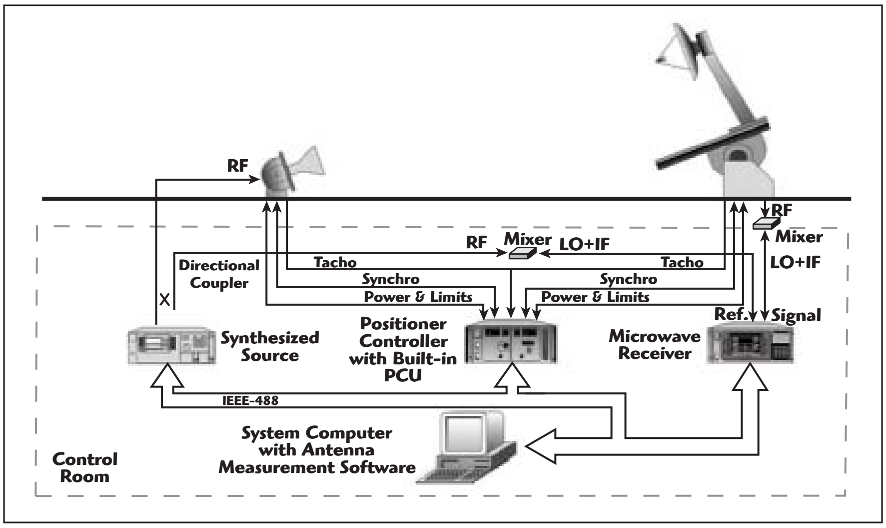

Fig. 7 Slant range configuration.

tenna points toward the center of the AUT and its first null points toward the tower base. It is desirable that the tower of the AUT be constructed of non-conducting materials to reduce reflections. Slant ranges, in general, require less real estate than elevated ranges.

Compact Range

Antenna measurements require that the AUT be illuminated by a uniform plane wave. This requirement is approximately achieved in the far-field for a range length $r > 2D^2/\lambda$, which, in many cases, dictates large distances. A compact range creates a plane wave field at distances considerably shorter than those required using the conventional far-field criteria. The plane wave produced by a compact range is generated by a large parabolic reflector (see ***Figure 8***). The parabolic reflector converts a spherical phase front from the illuminating feed into a planar phase front close to its aperture. There are several major factors that affect the compact range performance: aperture blockage and edge diffraction. The aperture blockage is reduced by utilizing an offset reflector system. The edge diffraction is reduced by using serrated or rolled edges.

NEAR-FIELD MEASUREMENTS

The required volume of an antenna test range may be reduced by making measurements in the near-field of the AUT, and then using analytical methods to transform the measured near-field data to the far-field radiation pattern.

Types of Near-field Set-ups

The measured near-field data (amplitude and phase) is acquired by using a probe to scan the field over a geometrical surface, which is typically a plane, a cylinder, or a sphere. The measured data is then transformed to the far-field pattern, using post processing.

Planar

In the planar scanning technique, a probe antenna is moved over a plane situated in front of the AUT. The position of the probe is characterized by the coordinates (x, y, z_0) in the coordinate system of the AUT. During the scanning process, z_0 is kept constant while x and y are varied. The distance z_0 is usually set within the range of 3λ to 10λ to avoid sampling of the reactive energy of the AUT. The dimensions of the near-field scanning aperture must be large enough to capture all significant energy from the AUT. The scan dimensions, Ds, also have to meet the criterion $Ds > D + 2z_0 \tan \theta$, where D is the largest AUT dimension and θ is the maximum processed radiation pattern angle (see ***Figure 9***). Three basic types of scans exist in planar near-field measurements: rectangular, plane-polar and bi-polar. In the plane-rectangular scan, the data is

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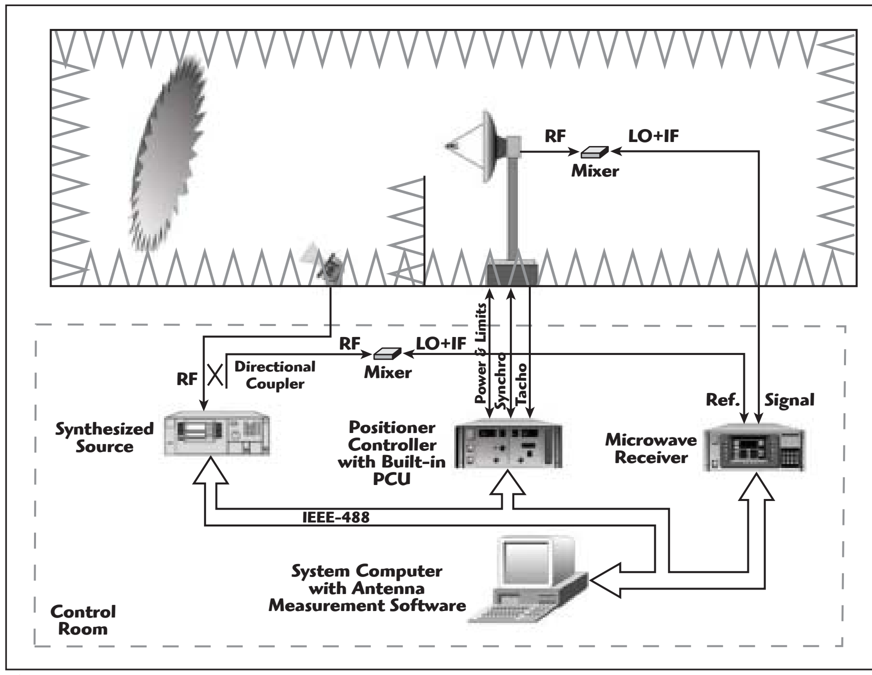


▲ *Fig. 8 Compact range configuration.*

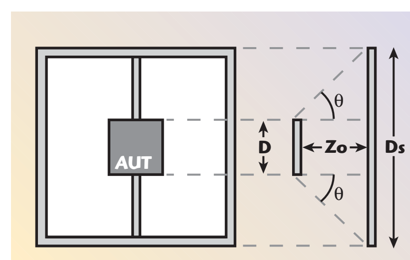
collected on a rectangular grid and processed by the conventional fast Fourier transform (FFT) algorithm. Sampling theory dictates a sample spacing of $\Delta x = \Delta y = \lambda/2$.

In the plane-polar technique, the AUT is rotated about its axis and the probe is attached to a linear positioner placed above the AUT (see ***Figure 10***). The combination of the antenna rotation and linear probe motion yields planar near-field data collected on concentric rings, with data points lying on radial lines. The polar near-field data is processed to the far-field by a Jacobi-Bessel transform or by interpolation to obtain a rectangular grid for an FFT algorithm.

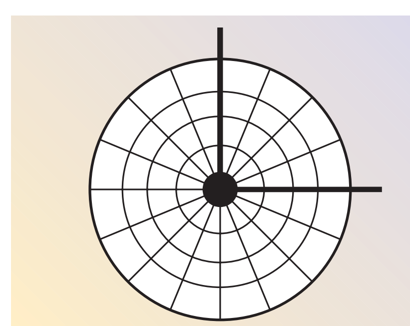
The bi-polar technique is similar to the plane-polar configuration in the sense that the AUT is rotated, but differs in the probe motion. The probe is rotated about a second axis and describes an arc that passes through the AUT axis (see ***Figure 11***). The combination of antenna rotation and probe arm rotation yields planar near-field data collected on concentric rings with data points laying on radial arcs. The near-field data is interpolated into a plane-rectangular grid. The rectangular data is then processed using the FFT to obtain the radiation pattern.

Cylindrical

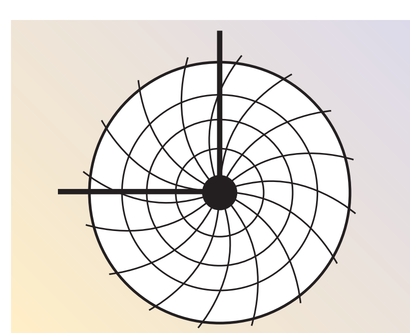
In the cylindrical scanning technique, the AUT is rotated around the z-



▲ *Fig. 9 Maximum scan size.*



▲ *Fig. 10 Plane-polar scanning geometry.*



▲ *Fig. 11 Bi-polar scanning geometry.*

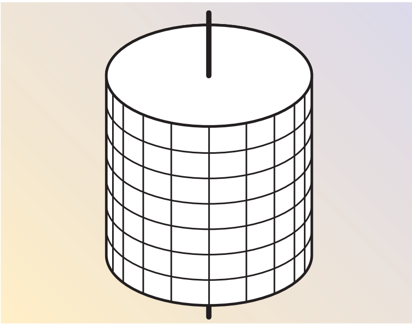


Fig. 12 Cylindrical scanning geometry.

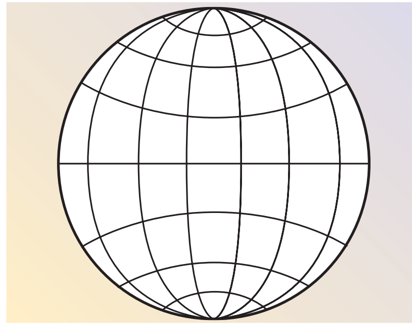


Fig. 13 Spherical scanning geometry.

axis of a xyz-coordinate system, while the probe is moved along a linear axis parallel to the z-axis (see ***Figure 12***). The probe is located at a distance a, typically chosen to be the smallest cylinder radius enclosing the AUT. The cylindrical scanning enables obtaining the exact azimuth pattern but only a limited elevation pattern due to the truncation of the scanning aperture in the z direction. In accordance with the sampling theory, the sampling spacing is given as $\Delta\phi = \lambda/2a$ and $\Delta z = \lambda/2$.

Spherical

In the spherical scanning technique, the AUT is rotated around the z-axis, and the probe is moved on a circular track in the θ direction (see ***Figure 13***). The radius of the rotation is "a" and is typically chosen as the smallest radius enclosing the AUT. An alternative is to keep the probe stationary and move the AUT in two axes, often chosen as a "roll-over-azimuth" positioner configuration. The advantage of spherical scanning is that it delivers the full extent of the AUT three-dimensional pattern. The sampling spacing is determined by the sampling theory to be $\Delta\phi = \Delta\theta = \lambda/2a$.

CONCLUSION

A summary of basic antenna properties and terms has been presented, along with a description of the most often measured antenna parameters. A review of the basic methods for measuring antennas has been outlined, with the highlights of each method noted. A wide variety of measurement range types and geometries are available. The fundamental differences between the far-field and near-field measurement methodologies were detailed. A future article will focus on the trade-offs of using each type of range and the types of ranges that are best suited to specific antenna types and measurement requirements. ■

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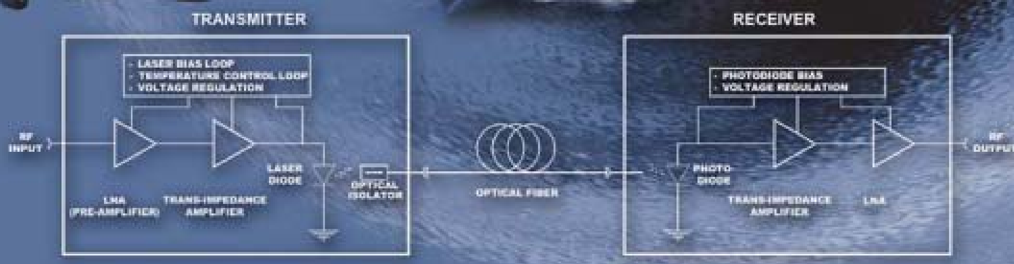
Gain (dB)	10-20 (17 Typ.)	10-20 (18 Typ.)	10-20 (18 Typ.)
Noise Figure (dB, Max.)	15 (10 Typ.)	20 (14 Typ.)	20 (18 Typ.)
Group Delay (ns ptp, Typ.)	0.1	0.1	0.1
VSWR (In/Out)	2:1	2:1	2:1
Phase Noise (dBc, Typ.)	>100	>100	>100
Input Power @P1dB (dBm, Min.)	-14	-14	-14
Spurious Free Dynamic Range (dB/Hz, Min.)	100 (105 Typ.)	101 (103 Typ.)	100 (104 Typ.)



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ELECTROFORMED FRONT-END AT 100 GHZ FOR RADIO-ASTRONOMICAL APPLICATIONS

The design of the front-end for a radio-astronomical receiver usually presents notable challenges in terms of large bandwidth and polarization purity and, more recently, for the very high frequencies investigated. In this article, the design of the whole front-end at 100 GHz (horn and backing ortho-mode transducer) is discussed and the critical aspects related to the mechanical structure due to the high frequency of operation are outlined. The article also discusses the aluminum electroforming technology chosen for manufacturing the front-end. Finally, the results of measurements taken on prototypes are shown.

The European Southern Observatory (ESO) is an intergovernmental European organization for astronomical research, coordinating many projects. The leading one in radio astronomy is the construction of the Atacama Large Millimeter Array (ALMA),[1,2] a project for an interferometer aimed at the study of microwave and sub-millimeter signals coming from space.

ALMA is expected to operate in the 30 to 950 GHz band, subdivided into ten sub-bands. It will comprise sixty-four dual reflector antennas that will be located in the Atacama Desert in northern Chile. This millimeter and sub-millimeter instrument will be very helpful in the study of some major challenges in modern astrophysics: the formation and evolution of galaxies and quasars in the early universe and the formation of stars and planets.

Due to the excellent atmospheric transparency at the site, the efficiency of the receiving system is of utmost importance; hence, the performance of the front-end is critical. As a first step, a cryogenic cooler will be used to reduce as much as possible the noise temperature. The most efficient design tools and fabrication techniques must then be used to guarantee optimal design, high dimensional accuracy and low surface roughness.

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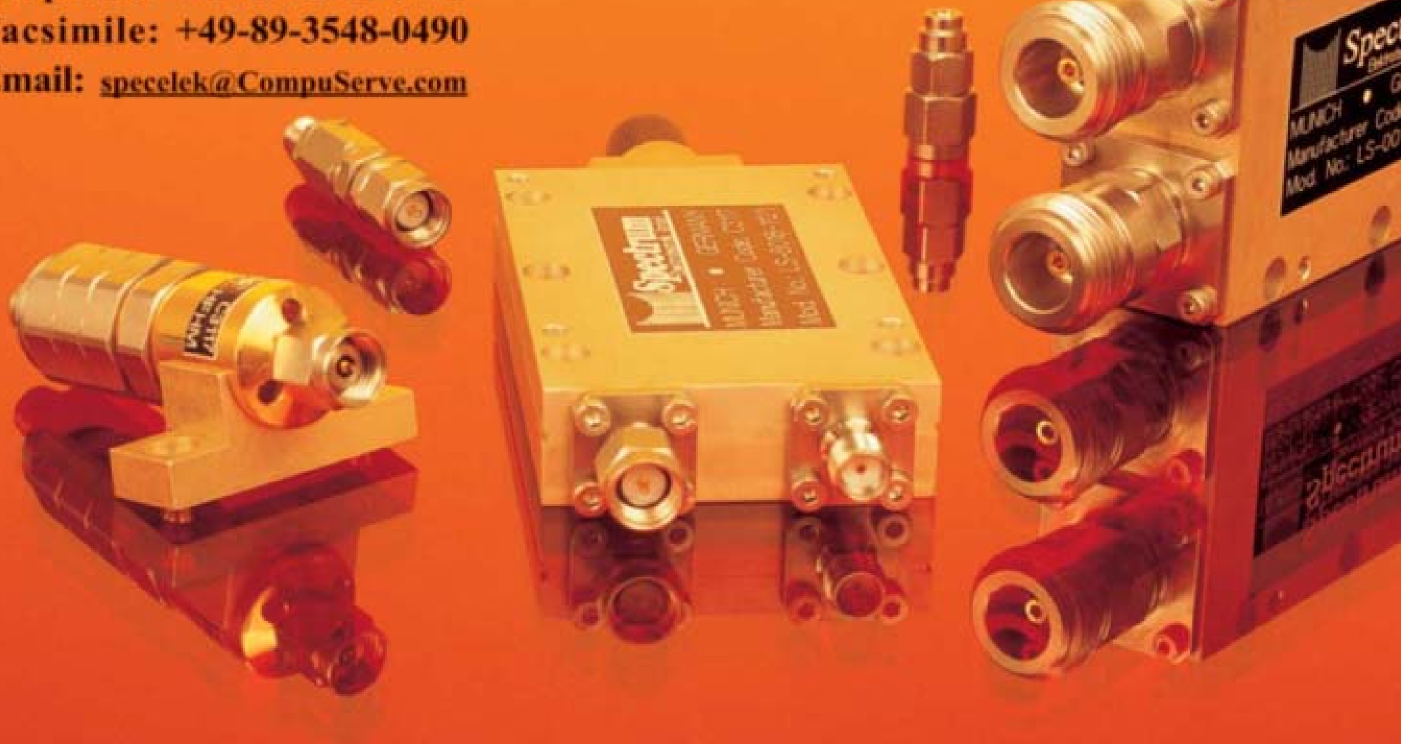

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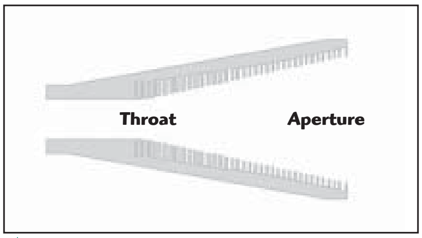
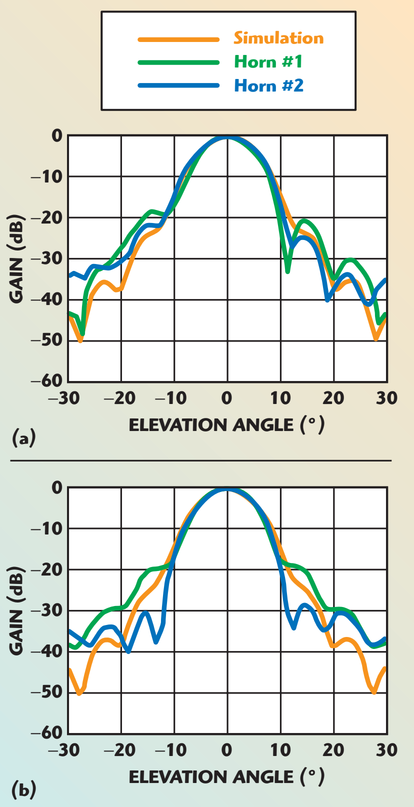
TABLE I

HORN SPECIFICATIONS

Type	*Value*
Frequency (GHz)	100
Bandwidth (%)	30
Beam waist (w_0) (mm)	$6 < w_0 < 7$
Cross-polar level (dB)	< –30
Return loss (dB)	> 30



▲ *Fig. 1 Circular corrugated horn geometry.*



▲ *Fig. 2 Simulated and measured radiation patterns of two 100 GHz horns; (a) E plane and (b) H plane.*

In this article, the design and fabrication aspects related to the front-end, horn[3] and backing ortho-mode transducer (OMT)[4] are presented. The device operates between 84 and 116 GHz, corresponding to sub-band number 3 of the ten sub-bands used to cover the overall ALMA spectrum. While the horn itself has been specifically designed for ALMA, and has already been tested by the Institut de Radioastronomie Millimetrique (IRAM),[5] the OMT has not been developed within the ALMA project but the ALMA specifications have been taken as guidelines. The OMT for ALMA has been produced with conventional machining, as reported in an ALMA memo by Wollak, et al.[6] The primary aim of this research was indeed to develop a new fabrication technique for the manufacturing of entire high frequency front-ends.

It is worth noticing that even if the described application is very specific, the design tools and technological solutions presented can have a mass-market follow-up in the near future. As a matter of fact, there are already European projects for wireless communication in the 90 GHz range, like the European Space Agency (ESA) Data and Video Interactive Distribution (DAVID) project, which may benefit from these results.

HORN DESIGN

The horn must illuminate the parabolic reflector according to the specification provided by the astro-physicists community. These specifications are reported in ***Table 1*** and are given in terms of beam waist. Typical requirements, related to horn antennas, are usually given in terms of gain, or of an equivalent parameter such as the edge taper, that is the direction from the horn axis at which the radiated power reaches a given level below the maximum. Alternatively, since the horn is a directive source, its main lobe can be modeled as a Gaussian beam. Since Gaussian beams are completely characterized in terms of their waist,[7] the latter is the specification given. The other design constraints are given in terms of return loss and cross-polarity level, and attaining such tight specifications over a 30 percent band is far from being trivial. These two latter specifications can be met only by resorting to a circular corrugated horn.

The horn design is then carried out by taking into account the fact that the main beam radiation is controlled by the aperture size and the horn's overall length. The first part of the corrugated region, the horn throat (see ***Figure 1***), principally determines the input matching (or return loss) and the proper excitation of the fundamental hybrid mode HE.[11] It is very important to take care in designing this part and very useful hints are given in the literature.[8] The corrugation geometry also governs the cross-polarity level,[9] an important parameter if the horn, as in this case, will be used in dual-polarization.

The first approach to the horn design is essentially similar to the method presented in detail by Clarricoats,[10] based on the use of formulas and graph charts, given a set of specifications. This procedure almost never leads to a structure whose behavior is rather close to the requirements. To improve the performance, numerical techniques are then necessary. An accurate full-wave solver, based on the Mode Matching (MM) and the Method of Moments (MoM) hybrid technique,[11] has been used to refine the first rough design.

Such a refinement can be carried out by a trial and error approach or by applying some sort of optimization technique. Automatic optimization allows for the unsupervised search of the horn that best matches the requirements in the geometrical parameters space. The algorithm can be based on both the Quasi-Newton method[12] and Genetic Algorithms,[13] suitably combined to prevent local minima problems and speed up the execution time. This approach has been already successfully applied to horn design.[14]

This procedure has lead to a horn design, which has been presented previously.[5] Prototypes were subsequently built by an electroforming process, which is basically the same as the one described below for the OMT. ***Figure 2*** shows the simulated and measured results taken on such prototypes.

OMT DESIGN

The OMT is based on a dual junction in rectangular waveguide, introduced and accurately described by Bøifot.[15] This design requires a thin septum and two matching pins, all of which would be too small at these high frequencies to be fabricated and to be mechanically stable. To make the OMT fabrication possible in the

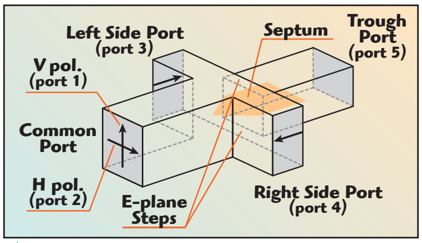


Fig. 3 Dual junction diagram.

original Bøifot configuration, the design has been revised with the aim to avoid such critical mechanical parts. The approach is quite similar to the one proposed by Narayanan.[16] Basically, a thick septum is adopted and the two side arm matching pins are eliminated. Matching is then obtained by using a pair of symmetrical E-plane steps (see ***Figure 3***).

Four physical ports are present, corresponding to five electrical ports: a common port CP carrying both the vertical (V, electrical port no. 1) and the horizontal (H, electrical port no. 2) polarization, two side ports (SP_L and SP_R, ports no. 3 and 4, respectively) that will be recombined in the whole OMT, and a through port (TP, port no. 5). The following scattering matrix gives the ideal electrical behavior of this junction

$$S = \begin{bmatrix} 0 & 0 & 0 & 0 & e^{j\alpha} \\ 0 & 0 & \frac{1}{\sqrt{2}}e^{j\beta} & \frac{1}{\sqrt{2}}e^{j\beta} & 0 \\ 0 & \frac{1}{\sqrt{2}}e^{j\beta} & \frac{1}{2}e^{j\gamma} & -\frac{1}{2}e^{j\gamma} & 0 \\ 0 & \frac{1}{\sqrt{2}}e^{j\beta} & -\frac{1}{2}e^{j\gamma} & \frac{1}{2}e^{j\gamma} & 0 \\ e^{j\alpha} & 0 & 0 & 0 & 0 \end{bmatrix} \tag{1}$$

where α, β and γ are phase terms whose value depends on the locations of the electrical port reference planes.

A 0.1 mm thick septum has been used, constituting a finite thickness septum from an electromagnetic point of view. This has a significant influence on the V-polarization channel, mainly in terms of return loss, and a symmetrical double E-plane step is used to control the input matching over approximately a 32 percent bandwidth. The septum shape is designed in order to have a good H-polarization return loss.

The dual junction has been designed using Ansoft HFSS, a finite element method (FEM)-based program able to accurately characterize the electromagnetic performances of such devices. In the design phase, a return loss better than 20 dB was achieved for both polarizations, as shown in the plots of ***Figure 4***, where the operating bandwidth is also highlighted.

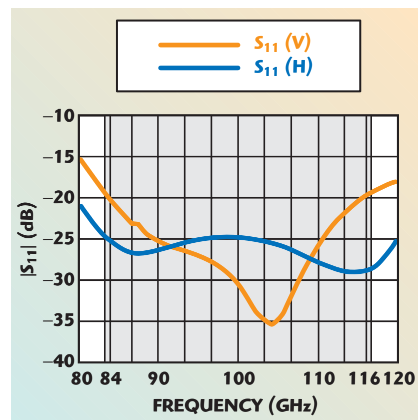


Fig. 4 Dual junction design results.

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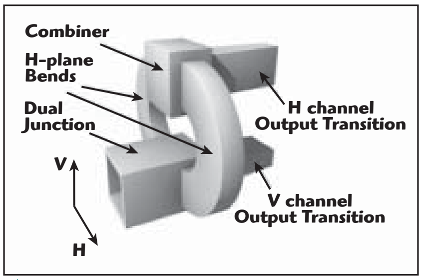
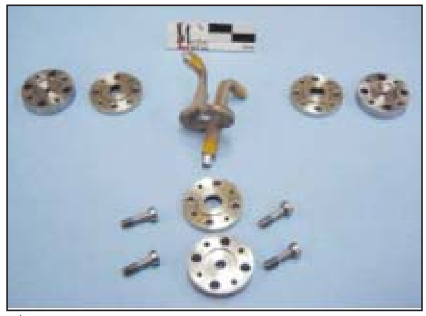


▲ *Fig. 5 OMT sketch.*

▲ *Fig. 6 OMT aluminum mandrel.*

To achieve the complete OMT configuration, the side arm ports need to be recombined by means of H-plane bends and a combiner. Furthermore, output transitions are used, both for the V and H channel, to allow standard WR10 flange connections to the device. The entire OMT is sketched in ***Figure 5***. To design the bends, the combiner and the transitions, different analysis techniques have been used, based on a hybrid mode-matching (MM)-FEM approach.



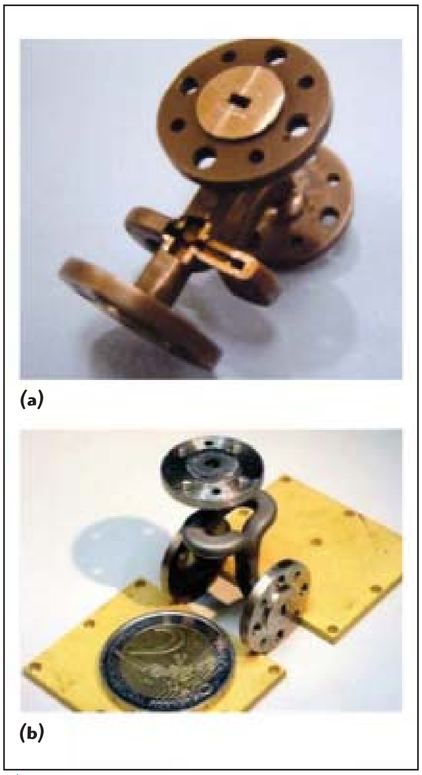
▲ *Fig. 7 Electroformed OMT with the mandrel still in place and with flanges and alignment tools.*

OMT FABRICATION

Electroforming consists in growing the item in a galvanic bath (usually nickel or copper) over a 'negative' of the desired shape, usually made of aluminum. The negative is dissolved later with a specific chemical solution and the final device is obtained.

Thanks to its intrinsic ability to reproduce any given shape with extremely high accuracy, it is a very interesting technique for the fabrication of metallic passive microwave components used at frequencies ranging from tens to a few hundred gigahertz (upper microwaves and far infrared).

At such high frequencies, the precision of common tool machining becomes comparable with the wavelength. The advantage of electroforming over direct machining is due to the fact that machining of the "negative" — or mandrel — of small waveguide objects is usually easier (and hence the accuracy is greater) than machining the object itself directly. This is particularly true for the OMT under study, where bends in the waveguides would require, for direct machining, to manufacture several separate parts to be assembled later on. Moreover, as opposed to direct machining, electroforming is a very slow process, giving no stress on the produced device and hence an



▲ *Fig. 8 OMT final devices; (a) sliced part for dual junction inspection and (b) ready for test.*

overall better behavior when the device undergoes thermal and pressure variations, as is the case for cryogenically cooled devices.

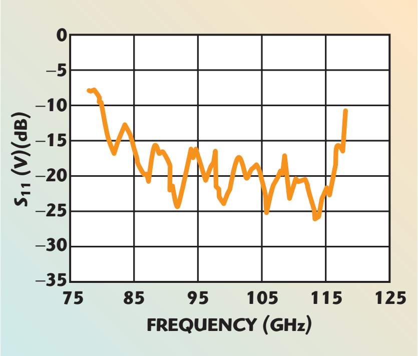
Electroforming has already given very good results in the fabrication of microwave devices such as ALMA reflector antennas, designed to work up to 900 GHz.[17,18] Although the OMT electroforming procedure requires two steps, a negative machining phase and the electroforming itself, the total procedure is simpler than direct machining and hence attractive from a cost-benefit point of view.

As a first step, a mandrel that is shaped as the inner empty space of the OMT is produced by machining an aluminum piece (see ***Figure 6***). Particular care has been taken to locate accurately the dual junction septum inside the mandrel, since its correct placement is very important for the electromagnetic performance. The gold-plated nickel septum exhibited two very little wings protruding from the mandrel so that it could be attached to the electro-deposited material during the electroforming process.

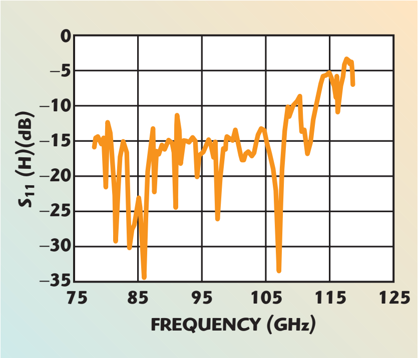
The electroforming process is subdivided into two parts, corresponding to different galvanic baths. First, a thin gold layer is electro-deposited on the aluminum mandrel to ensure good electrical performance; second, a thick nickel layer is electro-deposited to give a strong mechanical support to the device. In the electroforming phase, particular care has been devoted to preserve intact the end-points of the mandrel (two rectangular and one circular), since they will serve as very precise references for later flange alignment. The electroformed OMT is shown in ***Figure 7***, at the end of the nickel-deposition phase, together with the flanges and the related alignment tools. Two flanges are in standard WR10 rectangular waveguide while one is in circular waveguide for a through connection to the corrugated feed horn.

Once the flanges have been aligned and soldered, the inner aluminum part is dissolved with caustic soda. The final OMT appearance is shown in ***Figure 8***. An OMT prototype, cut to inspect the dual junction septum area, is also shown.

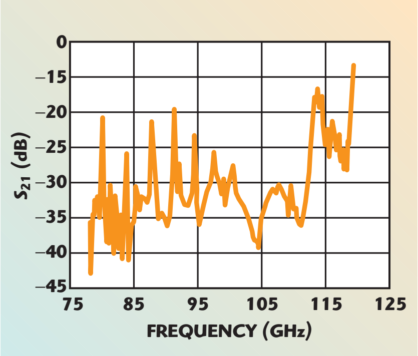
▲ *Fig. 9 OMT test setup.*



▲ *Fig. 10 OMT through port (V) reflection coefficient.*



▲ *Fig. 11 OMT side port (H) reflection coefficient.*



▲ *Fig. 12 OMT through port (V) to side port (H) isolation.*

MEASUREMENTS

The OMT prototype has been measured. The test setup was based on the Agilent 8757D scalar network analyzer, giving good accuracy measurements up to 110 GHz. As shown in the photograph in ***Figure 9***, the two OMT WR10 rectangular ports were connected to the ports of the instrument while the common port is connected to the feed horn. Since the feed horn is quite a good termination, with a return loss better than 30 dB over the whole band, the scattering parameter measurements directly read on the instrument are a quite accurate estimate of the return loss at the OMT rectangular ports (corresponding to the through port and the recombined side ports of the dual junction) and of the isolation between them. The reflection coefficient curves of the OMT are shown in ***Figure 10*** for the through port and in ***Figure 11*** for the side port, showing performance better than 15 dB over almost the whole band. The isolation between the two input ports is better than 30 dB, as shown in ***Figure 12***.

CONCLUSION

In this article, the design of a front-end receiver at 100 GHz, comprising a horn and an OMT, has been presented and a new design solution for a high frequency OMT has been discussed. Particular emphasis was given to the fabrication technique, which is of prime importance due to the small dimensions of the device parts. The electroforming process adopted to fabricate the prototypes has been discussed. Finally, some measurements on the device have been presented, showing very good performance and agreement with the simulated data. ■

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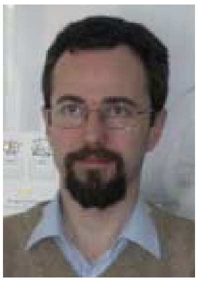
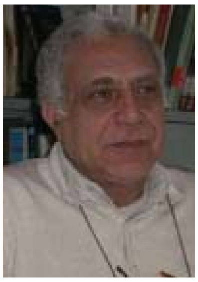
Guiseppe Pelosi *received his Laurea degree in physics (summa cum laude) from the University of Florence in 1976. He has been with the department of electronics and telecommunications at the same university since 1979, where he is currently a full professor. He was a visiting scientist at McGill University, Montreal, Canada, in 1994 and 1995. His current research activity is mainly devoted to the development of numerical procedures in h context of the finite element method, with particular emphasis on microwave and millimeter-wave engineering (antennas, circuits, devices and scattering problems). He is co-author of* Finite Elements for Wave Electromagnetics *(IEEE Press, 1994),* Finite Element Software for Microwave Engineering *(Wiley, 1996) and* Quick Finite Elements for Electromagnetic Fields *(Artech House, 1998).*



Stephano Selleri *obtained his Laurea degree (cum laude) in electronics engineering and his PhD degree in computer science and telecommunications from the University of Florence in 1992 and 1997, respectively. In 1992, he was a visiting scholar at the University of Michigan, Ann Arbor, MI, in 1992; a visiting scholar at McGill University, Montreal, Canada, in 1994; and a visiting scholar at the Laboratoire d' Electronique of the University of Nice, Sophia Antipolis, France, in 1997. From February to July 1998, he was a research engineer at the Centre National d' Etudes des Telecommunications (CNET), France Telecom. He is currently an assistant professor at the University of Florence, where he conducts research on numerical modeling of microwave devices and circuits with particular attention to numerical optimization. He is co-author of* Quick Finite Elements for Electromagnetic Fields *(Artech House, 1998).*



Enzo Natale *received his Laurea degree in physics from the University of Torino in 1967. From 1969 to 1988, he worked as a scientist at the Istituto di Ricerca sulle Onde Elletromagnetiche of CNR in Florence. Since 1988, he has been a senior scientist at the Istituto di Radioastronomia Sezione di Firenze. His research has dealt with the observation of diffuse galactic emission in millimetric and submillimetric regions and cosmic background radiation temperature and anisotropy. His current interests include the development of radio receivers and large bandwidth acousto-optical back-ends for millimeter and submillimeter astronomy.*

Renzo Nesti *received his Laurea degree in electronics engineering from the University of Florence in 1996 and his PhD degree in computer science and telecommunications in 2000. He joined the National Institute for Astrophysics at the Arcetri Astrophysical Observatory in Florence in 1999, where his main activity is in the area of passive microwave devices for radio astronomy receivers. His research interests include numerical methods for the analysis and design of millimeter-wave components.*

Gianni Tofani *received his degree in electronics engineering in 1964 and his PhD degree in radio astronomy in 1970. From 1964 to 1982, he worked at the Arcetri Astrophysical Observatory as a CNR research scientist, and served as an associate professor of radio astronomy at the University of Florence from 1982 to 1986. He is now senior astronomer and director of the Institute of Radio Astronomy-INAF in Bologna. His interests include radio telescope technologies and astrophysics of the stars formation.*

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05 ☐ Engineering
04 ☐ Management

01 ☐ GENERAL AND/OR CORPORATE MANAGEMENT

RESEARCH & DEVELOPMENT
07 ☐ Engineering
06 ☐ Management

MANUFACTURING & PRODUCTION
09 ☐ Engineering
08 ☐ Management/Supervision

10 ☐ ENGINEERING SUPPORT
(draftsman, lab assistant, technician)

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12 ☐ APPLICATIONS ENGINEERING, SALES AND MARKETING

13 ☐ EDUCATORS

14 ☐ OTHER PERSONNEL *(explain)*

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17 ☐ Cellular Systems & Equipment
26 ☐ WLAN, WiFi
10 ☐ Test & Measurement Equipment
27 ☐ Semiconductor, RFICs, MMICs, etc.
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12 ☐ Passive Components (including Antennas, Devices, Subsystems)
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04 ☐ Navigation, Telemetry Systems, GPS
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05 ☐ Electronic Warfare Systems
03 ☐ Ground Support Equipment, Aircraft/Missile
02 ☐ Weapons Control, Ordnance, Fusing Systems
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6 **YOUR WORK IS PRIMARILY:**
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02 ☐ 1–8 GHz
03 ☐ 9–18 GHz
04 ☐ 19–26.5 GHz
05 ☐ 26.6–40 GHz
06 ☐ Above 40 GHz
07 Other *(please specify)*

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02 ☐ $10,000 to $49,999
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02 ☐ Amplifiers (Power)
03 ☐ Tubes or Tube Amplifiers
04 ☐ Solid State Oscillators

07 ☐ ANTENNAS & ACCESSORIES
13 ☐ CAD SOFTWARE OR SERVICES

CABLE AND CONNECTORS
16 ☐ General Purpose
17 ☐ Precision or Laboratory

CONTROL COMPONENTS
20 ☐ Switches (Mechanical)
21 ☐ Switches (Solid State)
22 ☐ Attenuators & Phase Shifters

PASSIVE COMPONENTS
26 ☐ Couplers, Hybrids & Power Dividers
27 ☐ Attenuators & Terminations
28 ☐ Filters
29 ☐ Resistors, Capacitors & Inductors
30 ☐ Isolators & Circulators

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38 ☐ Signal & Sweep Generators
39 ☐ Synthesized Signal Sources
40 ☐ Spectrum Analyzers
41 ☐ Network Analyzers
44 ☐ Wave & Modulation Analyzers
42 ☐ Frequency Counters
43 ☐ Oscilloscopes
45 ☐ BER Testers

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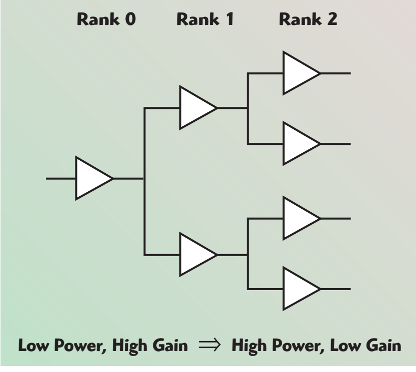
A SOLID-STATE, 1 TO 2 GHZ, 1 KW AMPLIFIER

Until recently, traveling wave tube (TWT) technology was the only technology capable of meeting the bandwidth and power requirements of high power L-band applications such as power testing radar components and for military/automotive RF immunity testing. Solid-state technology can, however, offer key performance advantages over TWT technology, particularly with regard to harmonic levels, linearity, gain flatness, mismatch tolerance and improved maintainability/reliability. But the task of developing octave band microwave power amplifiers that are cost competitive has been an elusive goal. That goal has been achieved by MILMEGA with the development of the AS0102-800, a solid-state amplifier delivering over 1 kW in the 1 to 2 GHz band.

Fig. 1 Corporate Structure Amplifier schematic.



THE AS0102-800 ARCHITECTURE

The unit was developed using the company's favored amplifier topology — the Corporate Structure Amplifier (CSA). It derives its name from the hierarchy of levels employed in its construction, which, ignoring the combining elements, gives the block diagram of the amplifier an appearance not dissimilar to that of a rotated company organizational chart (see ***Figure 1***).

The usual form of a CSA employs identical unit amplifier designs within each level, or rank, of the hierarchy, but designs may vary from rank to rank. Typically, a lower power, high gain, unit amplifier (a pre-amplifier) is employed at the front end of the amplifier system with higher power, lower gain units being employed in the output rank. All the useful power in a CSA is developed in the output rank, the preceding ranks being used only to develop the required drive levels.

The AS0102-800, which is available in forced-air or water-cooled versions, follows the CSA philosophy. The final design consists of 32 power modules in parallel, arranged in banks of eight, with each of these banks hav-

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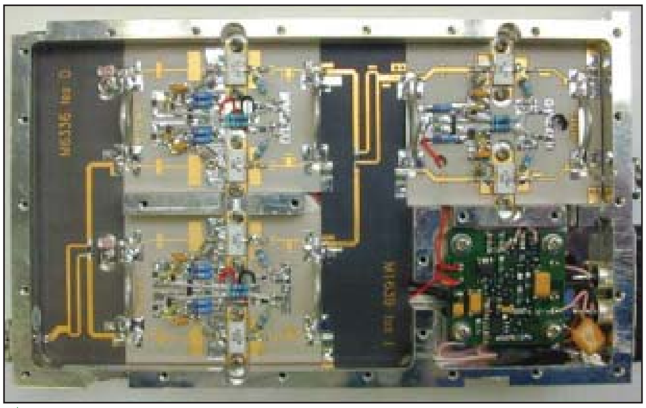
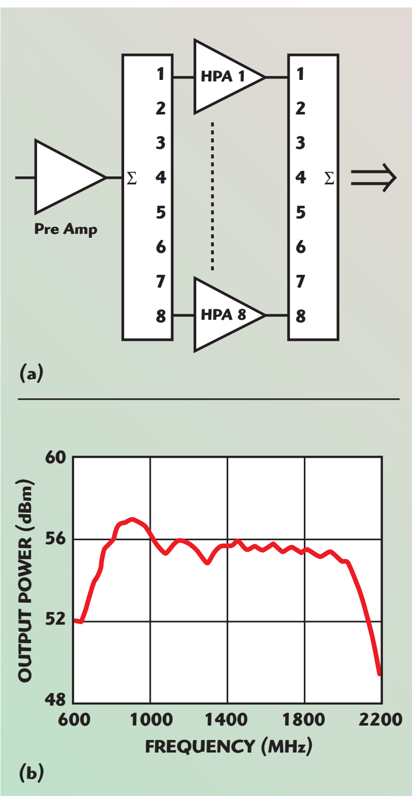


▲ *Fig. 2 35 W output rank power amplifier module construction.*



▲ *Fig. 3 The 250 W quarter section's (a) schematic and (b) performance.*

ing its own driver module, the four banks of eight being combined with a very low loss combiner. The key microwave components of the amplifier system are the output rank power modules and the final combiner that must be capable of handling in excess of 1 kW of CW power, across an octave bandwidth (1 to 2 GHz).

THE OUTPUT RANK POWER MODULE

The building block of the amplifier's output rank is the company's AS0102-35M, a GaAs FET-based 1 to 2 GHz 35 W power module, with a typical gain of 20 dB. Concentrating on the development of a single power module has the virtue that a high percentage of engineering resource, microwave, electrical, mechanical, thermal and reliability can be focused to design an outstanding component around which a system can then be built. ***Figure 2*** shows the module construction.

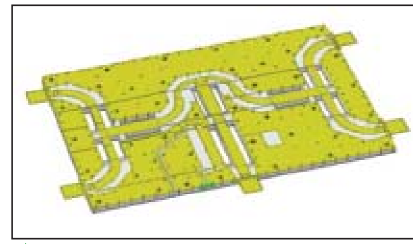
Power is developed within the module by combining two 20 W balanced pair amplifiers. Using one level of broadband quadrature combiners, plus the use of a robust GaAs FET technology, allows the modules to absorb 100 percent reflected power even when the module is operating at full output power. This can be a significant benefit to the system designer if the amplifier system is required to operate into high VSWR conditions.

DEVELOPING THE 250 W BLOCK

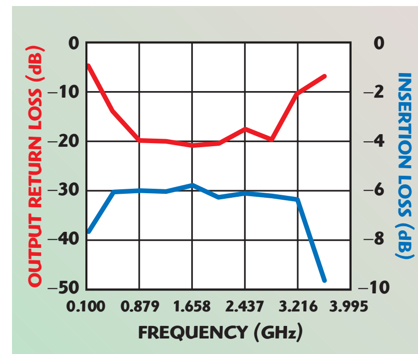
With the development of the output rank power module complete, the next stage was to develop a quarter section. This required the parallel combining of eight power modules. A schematic representation is shown in ***Figure 3***, along with the results achieved from combining eight modules by this method. Partitioning the final amplifier in this way greatly eases maintenance in the final system.

THE OUTPUT COMBINER

The development activity set out to improve on an existing MILMEGA design, which was implemented as a conventional stripline combiner using 2 × 0.25 inch thick Duroid slabs. The aim for the new combiner was to reduce losses and improve general manufacturability of the component. A 3D view of the board layout, showing routing slots, is illustrated in ***Figure 4***. The losses incurred in the existing 1 kW combiner were around 0.4 dB, which equates to a loss of 100 W of valuable microwave power. This power loss also created a heat problem, which required the use of a large heat sink to ensure effective dissipation, setting a limit on the physical size of the resultant structure.



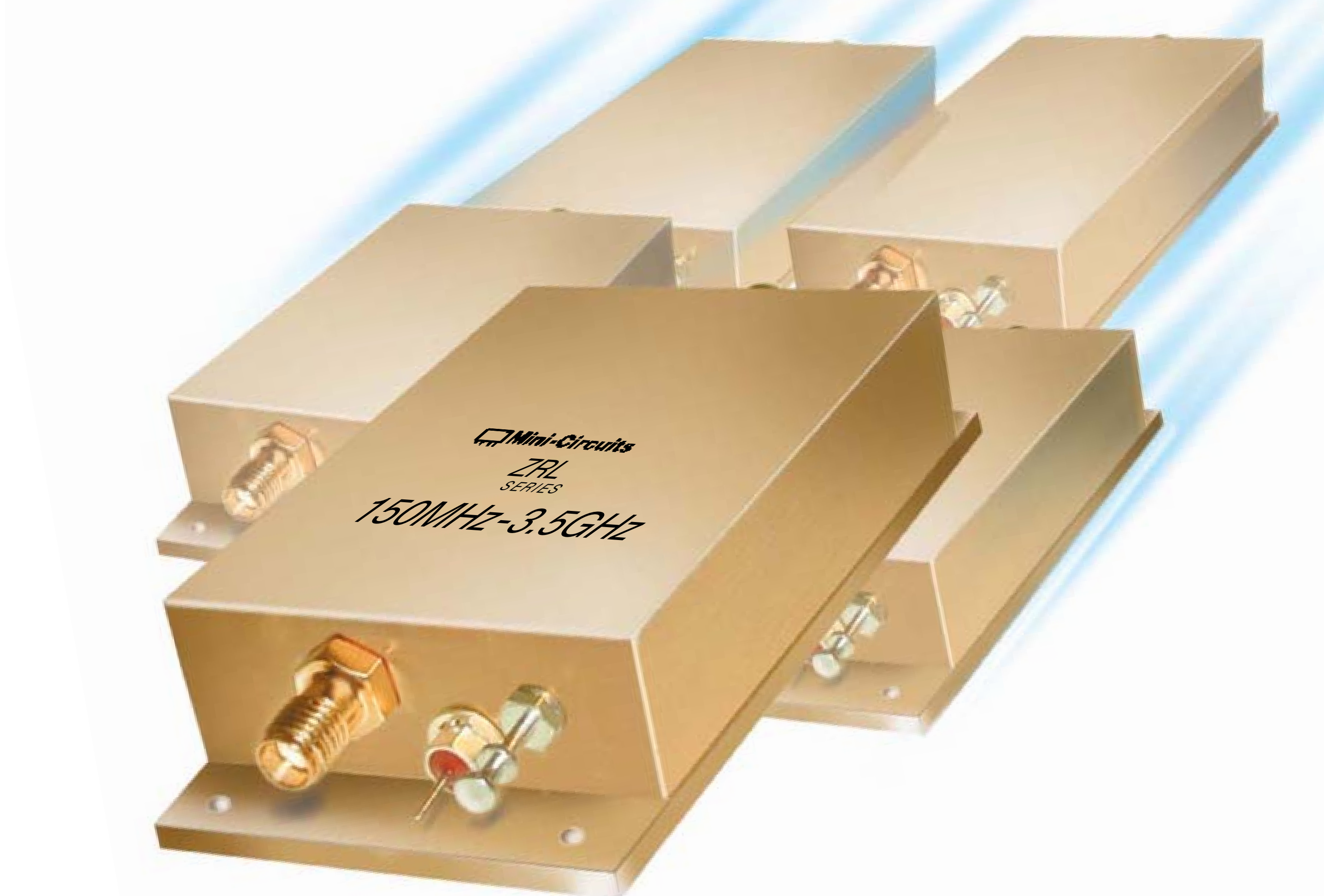
▲ *Fig. 4 3D view of the output combiner board layout.*



▲ *Fig. 5 Measured performance of the output, 1 kW combiner.*

In investigating an alternative design, the focus was on the causes of losses, which were recognized as substrate-dielectric losses, copper losses in the tracking and connector losses. After some investigation, it was decided that a suspended stripline solution would offer the best trade-off in terms of losses and mechanical dimensions. Air was the chosen dielectric.

Power combining of the four 250 W inputs is implemented using a two-layer cascade of two input resistorless Wilkinson style combiner structures. The resistors are not required in this application because all input signals are assumed to be matched in both phase and amplitude. The completed combiner/coupler operates over the 1 to 2 GHz range and has an integrated directional coupler, which provides forward and reverse outputs for sampling and measurement of incident/reflected power. Because of the high powers involved, each 250 W input connector is an N-type. The output connector is a 7/16-inch type. ***Figure 5*** shows the measured transmission responses of the combiner. Note the flatness of the amplitude response and the low insertion loss. This new combiner design produced less than half the loss of the existing design and, in tests with a full 1 kW of RF power be-



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ZRL-700	250-700	29.0	2.0	46	24.8	12	550	119.95
ZRL-1150LN	500-1400	31.0	0.8	40	24.0	12	500	119.95
ZRL-1200	650-1200	27.5	2.0	46	24.3	12	550	119.95
ZRL-2150	950-2150	25.0	1.5	33	22.0	12	300	119.95
ZRL-2300	1400-2300	23.5	2.5	46	24.6	12	550	119.95
ZRL-2400LN	1000-2400	27.0	1.0	45	24.0	12	550	139.95
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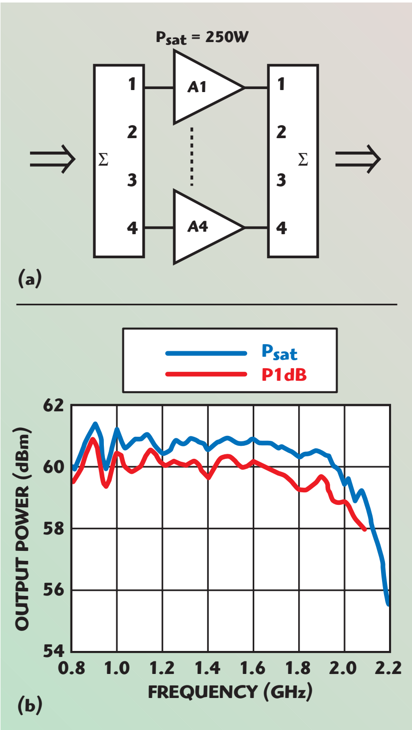

▲ *Fig. 6 Final stage of the 1 kW power amplifier; (a) schematic and (b) measured output power.*

ing produced, the heat dissipation in the component was negligible.

THE FINAL SYSTEM

The power achieved in the final system is shown in ***Figure 6***, with a minimum of 1 kW of saturated power achieved across the band 800 MHz to 1.95 GHz, which is in excess of an octave bandwidth. For a major proportion of this band, this power is of the order of 1.3 kW. Also of note is the close tracking of the 1 dB compression level to the saturated power level, allowing the amplifier to deliver up to 6 dB more linear power than the TWT equivalent.

INHERENT RELIABILITY

The multi-module combining approach in the output rank ensures that there is a low probability that a single random failure will cause the amplifier to cease operating in a satisfactory manner. It is more likely that failure modes will cause a gradual and predictable reduction of power over a period of time until a level is reached at which its performance has degraded below an acceptable threshold. This attribute is called 'graceful degradation' and is an intrinsic benefit of amplifiers developed with a CSA philosophy. For the output rank of the amplifier, the loss in microwave power is related to the number of failures by the equation:

$$\text{Power loss} = 10 \log [N_s/N_o]^2 \text{ (dB)}$$

where

N_s = the number of surviving modules
N_o = the number of original modules in the output rank

For the AS0102-800, which has 32 modules in the output rank, if one module fails the output of the amplifier drops by 0.28 dB. If one transistor fails the output power drops by only 0.07 dB, demonstrating the minimal effect that a single transistor failure has on an amplifier of this type. Both scenarios allow the user to continue using the amplifier until a suitable shutdown/maintenance period has been reached. This ability to defer maintenance to a time when cost is minimal is one of the major benefits of the amplifier when compared to a TWT equivalent.

CONCLUSION

The AS0102-800 is a unique, octave bandwidth, solid-state microwave power amplifier, competing successfully in technical and cost performance with TWTs for the delivery of 1 kW across the 1 to 2 GHz band. In addition, backed by the company's five-year warranty, it represents a major step forward for solid-state power amplifiers.

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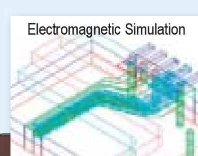

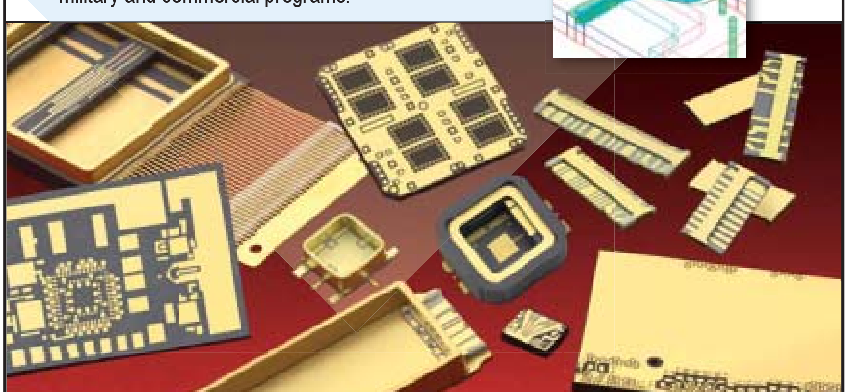

A NOVEL SUPER-ROBUST HANDGRIP FOR COAXIAL CONNECTOR ASSEMBLIES

Times Microwave Systems has introduced a new and unique addition to its popular SilverLine™ RF test cables. SilverLine-TG™ (TuffGrip™) is specifically designed to address the needs of cellular infrastructure, wireless Internet, and public mobile radio site installers and test technicians.

Extreme temperatures, foul weather, poor lighting, difficult to reach areas and severe time constraints are some of the obstacles with which site technicians must contend. Removal of weatherproofing materials in hot or cold weather can present other obstacles. Schemes to keep moisture from penetrating coaxial connections, such as butyl tape, shrink sleeves and electrical tape, become glue-like with age, requiring knives and cutting pliers to slice through and peel away multiple layers. Disconnecting coaxial cables to perform RF tests at a cell site can require a measure of physical strength and dexterity. Once extricated, the connector coupling nuts and threads often remain smeared with the tar-like weatherproofing materials, making them difficult to reconnect. ***Figure 1*** shows the end of an actual cell site jumper cable after having been disconnected for testing. The coupling nut on this cable no longer rotates freely, but requires a significant amount of applied torque. At low temperature, rotating the coupling nut would most likely be only possible with an open-ended wrench. Whether troubleshooting, repairing, or testing a repaired system, the goal is always the same: minimize the down time. In some cases, site technicians report the need of mating and demating cables at a rate of almost one per minute. Properly calibrated torque wrenches are not always available. Over-tightening can result in a ripped cable outer conductor either on the system side or the test side. Other problems include stripped threads or broken system components. The failure can be immediate or latent.

Fig. 1 Actual cell site disconnected jumper cable.

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Fig. 2 Connection between an analyzer test cable and a site jumper cable.

Fig. 3 Dented coaxial cable.

Fig. 4 Failed cable attachment.

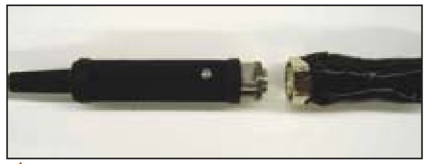


Fig. 5. TuffGrip-equipped cable ready to mate.

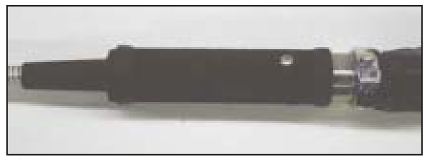


Fig. 6 Mated cable pair.

Due to their constant and repeated use, the RF test cables are often the first to fail. ***Figure 2*** shows the relative size of a typical site analyzer test cable with a 7-16 DIN female and a site jumper cable. While difficult to photograph, a close examination of the coupling nut shows the teeth marks from the use of a pipe wrench. The outside diameter of this analyzer cable is approximately 0.300", while the site cable is well over 1.5" in diameter with the weatherproofing. Test equipment manufacturers prefer small diameter cables because they coil more tightly and fit easily into the analyzer carrying case. While they are fine products for a laboratory, when used on-site, their small size makes them more difficult to handle and more easily damaged. Dented coaxial cables (see ***Figure 3***) and failed attachments (see ***Figure 4***) generate cables that exhibit unacceptable return losses or are unstable when flexed. Both are common test cable failure modes. In summary, harsh operating environments, glue-like weather-proofing, the use of improper tools and the hurried nature of the work add up to a need for a significant up-grade in RF test cable ruggedness.

SilverLine-TG (TuffGrip) addresses all these problems with the unique application of a novel, super-robust handgrip (patent pending) around the connector at the system interface end of the cable assembly. The grip allows the user to easily hand-apply as much resistance to a torque or pipe wrench as is necessary to mate to connectors that remain mired in weatherproofing materials.

The RF electrical connection is achieved via a field proven, solder-clamp approach. The clamping area transitions to a machined, solid metal sheath. The sheath envelops the RF cable. The sheath and cable are encased inside a rugged armor and an oversized crimp ferrule is added that increases connector retention to a pull force in excess of 200 lbs. This entire system is inside the grip. The inside of the grip is asymmetrical and matches an asymmetrical connector body to eliminate any possibility of connector rotation or twist. The strain relief behind the grip is similarly heavy duty and uses a material and tapered design that matches the flexibility of the armor. This strain relief results in a perfectly smooth transition to a highly flexible, high performance RF cable. The flexibility of the armor also matches the cable so it does not inhibit the minimum-bending radius.

The application of the handgrip and armor addresses the need to make and break RF connections both quickly and reliably under harsh conditions, while eliminating the most common failures that plague site technicians: test cable damage and failure of the connector-to-cable attachment area. The ability to securely manipulate TuffGrip also minimizes the risk of mistakes that damage system jumpers and difficult-to-replace system components.

Figure 5 shows a TuffGrip-equipped cable ready to be mated to the site jumper. ***Figure 6*** shows the mated pair. The functional diameters of both the test cable and jumper cable are similar, so the applied torque is similar. A cable so equipped makes it possible to easily manipulate both cables with gloved hands.

TuffGrip equipped connectors are available in 6 GHz, 7-16 DIN male or female connectors and 6 and 18 GHz Type N female connectors. The 7-16 DIN's have metrology grade interfaces for smooth, easy action. All connectors are high grade stainless steel for long life and all are capped for protection and cleanliness.

Popular part numbers for site installers include:

- SLA06-NM7MG-01.50M (6 GHz, armored, N male to 7-16 male with TuffGrip, 1.5 m long).
- SLA06-NM7FG-01.50M (6 GHz, armored, N male to 7-16 female with TuffGrip, 1.5 m long).
- SLA06-NMNFG-01.50M (6 GHz, armored, N male to N female with TuffGrip, 1.5 m long).

Three and 5 m lengths in each configuration are available as is an 18 GHz version of N to NF.

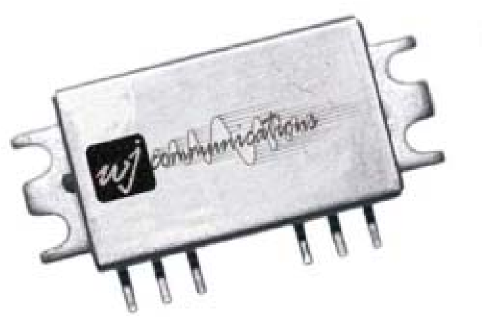
SilverLine™ test cables are rugged, high performance, highly flexible, phase stable test cables for use in a wide variety of both commercial and military OEM applications. They are available both armored and unarmored in the 6, 18 and 26.5 GHz frequency ranges. All connectors are stainless steel, captive contact construction. Connector selections include:

- BNC plug
- SMA male, female and right angle
- Type N male and female
- 7 mm
- 3.5 mm male, female and ruggedized 3.5 mm female (NMD-style)
- ETNC male and female (extended, 18 GHz range)
- 7-16 DIN male and female
- QMA male

All SilverLine test cables including SilverLine-TG come with Times's replacement guarantee.

Times Microwave Systems, Wallingford, CT (203) 949-8400, www.timesmicrowave.com.

RS No. 301



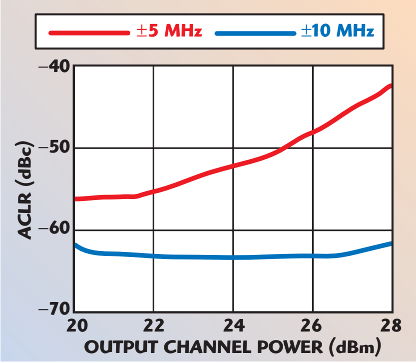
Highly Linear 12 V Power Amplifiers for Wireless Infrastructure Applications

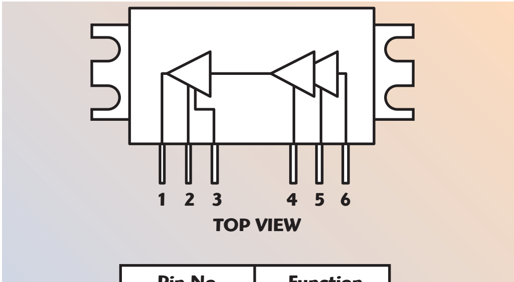
A new family of +12 V power amplifiers designed for use in wireless infrastructure applications has been introduced. The models AP501, AP502, AP503 and AP504 are targeted for driver and final stage amplifier applications where high linearity and high power are primary requirements. The combination of high power and high linearity makes these new amplifiers excellent candidates for multi-carrier 2.5/3G, PCS, UMTS and CDMA2000 base station use.

The new AP-series devices are multi-stage modules developed using the InGaP HBT process that are internally optimized for efficiency and linearity performance. Each of the PA modules includes internal matching for input and output 50 Ω operation and operates from a 12 V DC supply without requiring negative biasing voltages. In addition, an internal active bias allows the devices to maintain high linearity of a full range of operating temperatures.

The AP-series devices are designed to optimize the back-off linearity characteristics by setting the bias point to give a fast decrease of ACLR without backing-off too much in output power. A typical ACLR vs. output power curve of the AP-series is shown in ***Figure 1***. As a result, a lower P1dB device can be used to generate the same linear power with excellent ACLR. This is the most cost effective way to generate a linear power for the driver stage of the power amplifi-

Fig. 1 Typical ACLR vs. channel power performance for 3GPP W-CDMA operation at 2140 MHz.





Pin No.	Function
1	RF Output
2/4	V_{cc}
3/5	V_{pd}
6	RF Input
Case	Ground

Fig. 2 The AP-series PA module's functional block diagram and pinouts.

WJ Communications Inc.
San Jose, CA

microwave JOURNAL | Previous Page | Contents | Zoom In | Zoom Out | Front Cover | Search Issue | Next Page | qMags

PRODUCT FEATURE

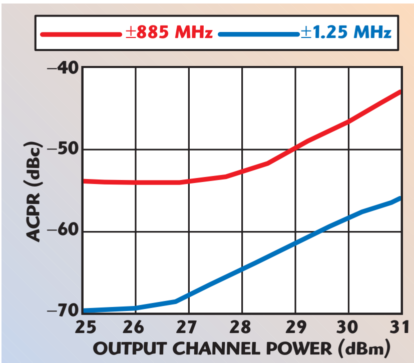


Fig. 3 Typical ACPR vs. channel power performance for IS-95 operation at 1960 MHz.

er where a stringent linearity is required.

The AP-series PA modules have the added feature of a +5 V power down control pin. A functional diagram and pin identification table of the AP-series PA modules is shown in ***Figure 2***.

PA PERFORMANCE

The AP501 PCS-band PA module uses a high reliability InGaP/GaAs HBT process technology and is designed to operate from 1930 to 1990 MHz with 30.5 dB of gain. The device features +36 dBm P1dB and +52 dBm output IP3. It is capable of +29 dBm IS-95 linear power at –50 dBc adjacent channel power ratio (ACPR) with 9 percent efficiency or +25.5 dBm W-CDMA linear power (–50 dBc adjacent channel leakage ratio (ACLR)) with 8.5 percent efficiency.

The AP502 UTMS-band PA module operates from 2110 to 2170 MHz with 28 dB of gain. It supplies +36 dBm at P1dB and +52 dBm at its OIP3. The device provides +27 dBm of W-CDMA linear power output (+45 dBc ACPR).

The AP503 DCS-band unit operates from 1805 to 1880 MHz with 31.5 dB of gain. Its CDMA2k linear power is +27 dBm (–60 dBc ACPR) and its IS-95A linear power is +26.5 dBm (–55 dBc ACPR). The AP504 DCS-band amplifier module operates from 1710 to 1785 MHz with 31.5 dB of gain and similar linear power performance to its AP503 sister amplifier.

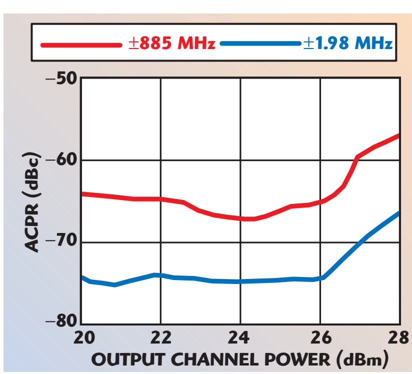


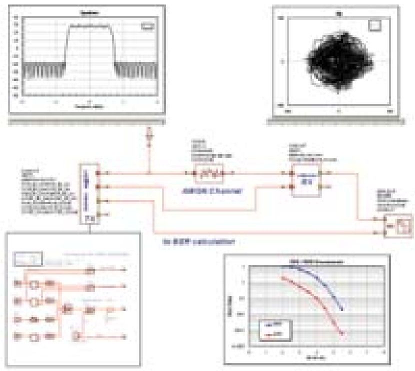
Fig. 4 Typical ACPR vs. channel power performance for CDMA2000 operation at 1840 MHz.

Figure 3 shows ACPR performance at 1960 MHz for IS-95, while ***Figure 4*** shows ACPR performance at 1840 MHz for CDMA2000 operation.

A low cost 29 × 13 × 4 mm metal housing with a bolt-down flange allows these devices to maintain a low thermal resistance and thus achieve an MTTF of over 100 years. In addition, the devices are 100 percent RF and DC tested. Fully assembled device samples are available upon request. Additional information can be obtained from the factory or from the company's Web site.

WJ Communications Inc.,
San Jose, CA (408) 577-6200, www.wj.com.

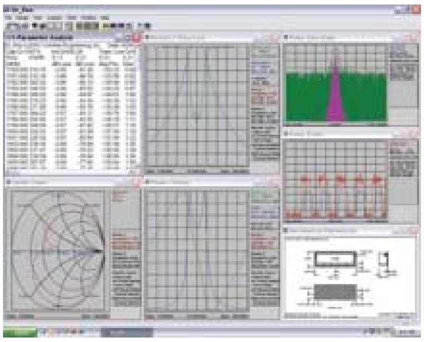
RS No. 305



TEST BENCH

The code division multiple-access 2000 (cdma2000) test bench for the company's Visual System Simulator™ (VSS) design suite has recently been released. This test bench is designed for radio frequency system engineers who need to evaluate the impact of RF link impairments on frame error rate, bit error rate, symbol error rate and other metrics. The VSS cdma2000 test bench modular design and interface offers flexibility in configuration and ease-of-use. This enables RF systems groups to be self-sufficient by providing a canvas to quickly and easily make changes and/or add functionality.

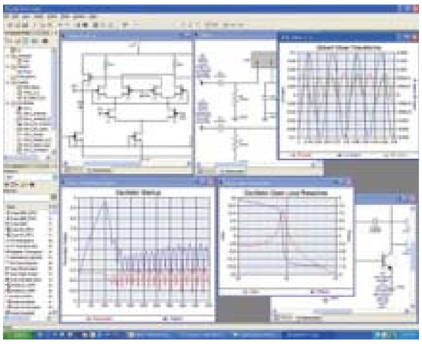
Applied Wave Research Inc.,
El Segundo, CA (310) 726-3000, www.appwave.com.
RS No. 310



DESIGN SOFTWARE

Dr. Rez is a free downloadable software program. User inputs will display tabular data, plotted data and outline drawings for products from 400 to 6000 MHz. Dr. Rez provides a quick and easy-to-use method of designing "puck" and coaxial dielectric resonator filters. This software features bandpass and notch filter design, dielectric and coaxial resonator design, mechanical outlines, return loss and transmission phase and delay analysis, automatic delay variation and phase linearity analysis.

ComNav Engineering Inc.,
Portland, ME (207) 797-4588, www.comnav-eng.com.
RS No. 311



RF AND MICROWAVE DESIGN SUITE

GENESYS™ 2005 is the most recent release of the company's RF and microwave design suite. The new version includes WhatIF (a new frequency planning tool), CAYENNE (a new time domain simulator), two new synthesis modules — amplifier and mixer, enhancements to the linear, nonlinear and system architecture simulators, new models, and a revamped user interface that offers ease-of-use.

Eagleware-Elanix Corp.,
Norcross, GA (678) 291-0995, www.eagleware.com.
RS No. 312

SIMULATION PACKAGE

The fifth suite of the 3D simulation package, FEKO has been released, and in keeping with the company's tradition, this new release represents a dramatic increase in the power of the product. In particular, the FEKO user interface has been overhauled and extended, making the power of the kernel significantly more accessible. Also, new solution features include the handling of tetrahedral meshes for the solution of dielectric regions and the solution of dielectric regions with the MLFMM.

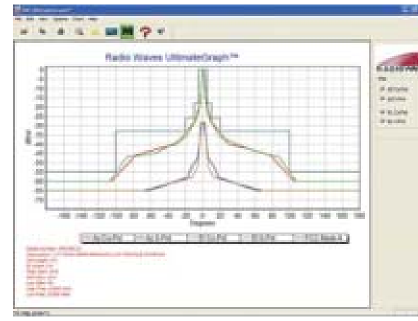
EM Software & Systems – SA (Pty) Ltd.,
Stellenbosch, South Africa +27-21-880-1880, www.feko.info.
RS No. 313

SOFTWARE UPDATE

FILTER SYNTHESIS AND SELECTION TOOL

Filter Wizard^{SM} has been enhanced to include low pass, high pass and band reject response types, with all-pole and elliptic solutions. In addition, the web-based selection tool's considerable bandpass search capabilities now include high Q ceramic puck options and a new class of dielectric resonator designs. Existing bandpass products include chip and wire filters, ceramic filters, cavity filters (combline and interdigital), and waveguide filters, as well as KeL-fil, KeL-com, Mini-Max and Mini-Pack options. Filter Wizard accelerates user progress from specs to RFQ for RF and microwave filters spanning an ever-increasing range of response types, bandwidths and unloaded Q values from 500 kHz to 50 GHz.

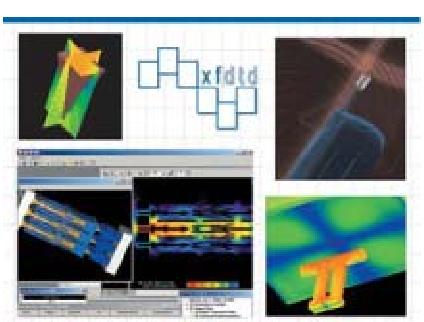
K&L Microwave Inc.,
Salisbury, MD (410) 749-2424, www.klfilterwizard.com.
RS No. 314



ANTENNA PATTERN SOFTWARE

The release of RW UltimateGraph version 1.05 is a software tool in the RW ToolBox series of software. By downloading RW UltimateGraph and microwave antenna pattern data, users of the software will be able to display microwave antenna patterns on a computer screen and print hard copies for reference. RW UltimateGraph contains useful features such as zoom, formatable labels and the ability to overlay FCC category A or FCC category B masks over antenna patterns. This version offers simpler management of FCC overlays, additional antenna patterns options and easier set up.

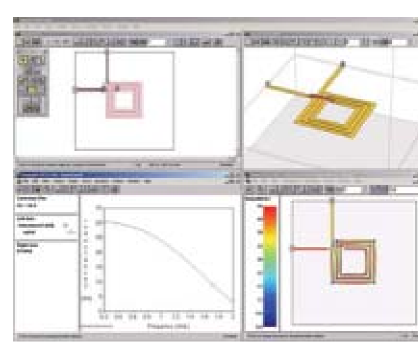
Radio Waves Inc.,
N. Billerica, MA (978) 459-8800, www.radiowavesinc.com.
RS No. 315



FULL-WAVE ELECTROMAGNETIC SOLVER

XFDTD, version 6.3, is now released and offers many new features and improvements, including enhanced PML boundary conditions, new multiple plane wave excitation, full 3D far zone plotting with extended data presentation, new CATIA interface, enhanced Pro-E and STEP interfaces, and greater flexibility in the adaptive meshing based on the Remcom FAST MESH algorithm. Further, a new Bio-Heat optional module is available for temperature rise due to SAR. Engineers, designers and scientists use the capabilities of XFDTD, a full-wave 3D electromagnetic simulation in such applications areas as microwave, RF, antennas, scattering, biological EM, photonics, packaging, EMC and specialized materials.

Remcom,
State College, PA (814) 861-1299, www.remcom.com.
RS No. 316



EM ANALYSIS SOFTWARE

Sonnet Lite is a free feature-limited version of Sonnet Suites Professional. This full-wave and fully functional electromagnetic (EM) field simulation software analyzes planar high frequency designs from 1 MHz through several THz. Sonnet Lite provides accurate and reliable planar EM analysis with an easy to learn interface with clear tutorials and extensive on-line help. Low cost upgrades are available starting at $495, which includes a DXF translator. Sonnet Lite contains many of the features and capabilities of the full Sonnet Suites Professional package, and uses the same user interface and EM analysis engine as the Sonnet Suites Professional.

Sonnet Software Inc.,
North Syracuse, NY (315) 453-3096, www.sonnetsoftware.com.
RS No. 317

SOFTWARE UPDATE

CASCADE DESIGN SUITE

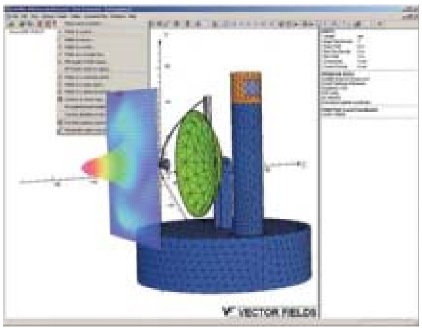
Cascade Design Suite allows a user to optimize a design by viewing individual component contribution, evaluate trade-offs in component selection (gain, noise and power, for example) and visualize a block diagram concept. Search the entire product line, including over 750 data sheets on amplifiers, mixers and oscillators. Cascade allows a user to save information as a spreadsheet for export into other software programs and to submit an RFQ to the company for a custom design. The software features a Pi and tee attenuator program, VSWR reduction tool and part number cross-reference. Cascade is available as a CD or as a download from the company's Web site.

Spectrum Microwave,
Delmar, DE (302) 846-2750, www.specwave.com.
RS No. 318

WEB TOOLS

These two new engineering tools aid in selecting optimal feedthrus and can be located on the company's Web site. The first tool is an advanced search engine of its entire database of previously designed feedthrus. This tool allows users to search over 2000 models of RF/50 Ω, DC and capacitor/filter feedthrus to find the model that most closely resembles a specific application. The second tool offered is a new impedance reference calculator. This tool allows engineers to calculate the opposing dimension of glass-to-pin, or pin-to-glass that will achieve optimal impedance in a specific package.

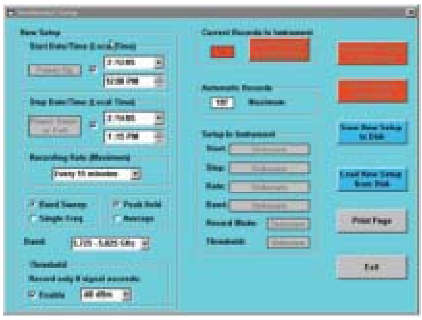
Thunderline-Z,
Hampstead, NH (603) 329-4050, www.thunderlinez.com.
RS No. 319



3D SOFTWARE

This recent version of the 3D software CONCERTO computes and predicts electromagnetic performance with confidence, giving users the ability to produce competitive and innovative products while keeping costs to a minimum. The diverse range of applications that can be analyzed with CONCERTO include antennas, waveguides, filters and cavities. This latest addition to CONCERTO is a Moment Method module that is ideal for antenna installed performance and radar signature prediction. Using the same geometric modeler, it complements the FDTD module that is recommended for component design.

Vector Fields Inc.,
Aurora, IL (630) 851-1734, www.vectorfields.com.
RS No. 320



UNATTENDED DATA RECORDING

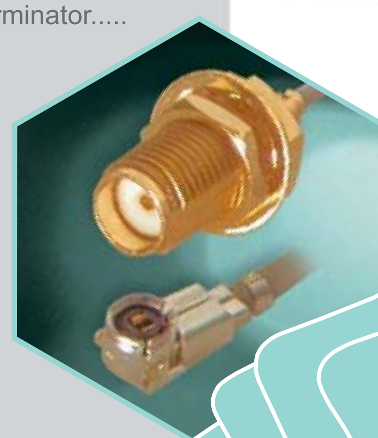
The unattended data recording is a new feature to the Analyze-R™ and Log View-R™ software. The Analyze-R can now be programmed to make unattended measurements at remote sites, allowing the instrument to operate on its own, recording and logging frequency spectrum and power data without the requirement of on-site personnel. Using the Log View-R software, a user can set the "Start Date/Time" and the "Stop Date/Time" for data collection as well as the "Recording Rate."

XL Microwave Inc.,
Oakland, CA (510) 428-9488, www.xlmicrowave.com.
RS No. 321

Main products:

> RF & Microwave Connectors:
SMP, 2.92 mm, MMCX, MCX, SSMA, SSMB, SMA (18 GHz, 26.5 GHz)
SMB, SMC, 1.0/2.3, 1.6/5.6, 7/16", N type, BNC, TNC, Mini-UHF, UHF
FME, Reverse Polarity Series, LMR® Series, BSA and Terminator.....

> Coaxial & Semi-Flexible cable assemblies



Production Capabilities:

> 20 sets of semi & auto assembly machines
80 sets of CNC screw machines
100 sets of fully automatic lathe machines
100 sets of secondary operating machines

> 8 million pieces of connectors per month

R & D Engineering Capabilities:

> Anritsu 37297D vector network analyzer (up to 65 GHz)
HP 8722C vector network analyzer (up to 40 GHz)

> 10 engineers with knowledgeable skill and experience in fields

> Sampling from a concept to prototype within 2 weeks

> Specialty in custom-built RF connectors and applications

On Time Delivery Capabilities:

> Within 4 weeks delivery time for mass production.

> 99.2 % shipments on time.

Quality Assurance Capabilities:

> ISO-9001 : 2000 certified by Lloyd's Register.

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EXTENDS YOUR REACH.

2006 MTT-S Radio & Wireless Exhibition 2006.
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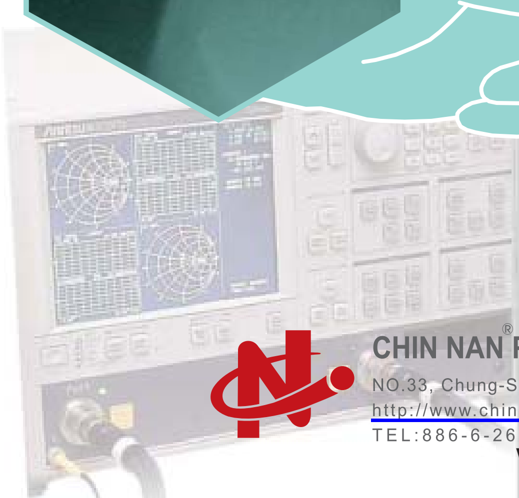
Jan. 17th ~ Jan. 19th 2006



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NEW WAVES: Satellite and mm-wave Applications

Frequency Multipliers

These millimeter-wave frequency multipliers operate in the output frequency range of 18 to 90 GHz. The multipliers feature 2.92, 2.4 and 1.85 mm connectors, power output of +7 dBm typical, fundamental isolation of 20 dB typical and low VSWR of 2.5 maximum. Standard waveguide output is available.

Antelope Valley Microwave Inc.,
Lancaster, CA (661) 726-9903,
www.avmicrowave.com.

RS No. 216

PHEMT Foundry Process

This proprietary 0.25 µm PHEMT process is designed to address millimeter-wave frequency applications. The process has been specifically developed for transceiver MMIC components. The device features high frequency characteristics of FT > 60 GHz and F_{max} > 150 GHz, with G_{max} > 15 dB at 30 GHz. It is ideal for PAs, gain blocks, LNAs, mixers, switches and other discrete or MMIC components with operations through Ka-band (or up to 40 GHz) frequency. This process utilizes optical gate lithography, which allows low cost manufacturing and short cycle time.

Global Communication Semiconductors Inc.,
Torrance, CA (310) 530-7274,
www.gcsincorp.com.

RS No. 217

Dielectric Resonator Oscillator

These phase-locked dielectric resonator oscillators (PLDRO) utilize MIC and SMT to provide crystal stability at microwave frequencies up to 40 GHz. Higher frequencies are achieved using a multiplier. The low profile and rugged construction provide good durability against harsh environmental conditions. These PLDROs feature a dielectric resonator, internal crystal oscillator reference, low phase noise and up to +25 dBm output power. The oscillators are designed for satellite communications, local area networks, global positioning systems, test equipment, up/down converters, and military, space and commercial applications.

Microwave Dynamics,
Tustin, CA (714) 505-0998,
www.microwave-dynamics.com.

RS No. 218

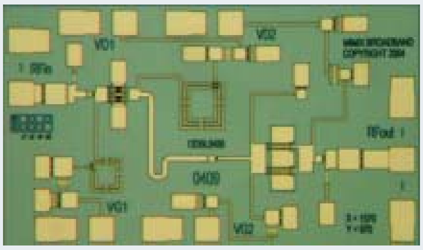
Tracking Antenna System

The Micro1600-M Dome is an advanced antenna system designed for mobile tracking voice communication applications and can be used over the MSAT/MSV networks. This system features a low profile, high gain and good overall performance. The Dome provides a reliable, secure two-way push talk voice communication system that can be used on a daily basis, earmarked specifically for emergencies, or used for both. This system operates in a 1525 to 1559 MHz receive frequency range and a 1626.5 to 1660.5 MHz transmit frequency range.

Micro-Ant Inc.,
Fall River, MA (508) 679-9300,
www.micro-ant.com.

RS No. 247

Two-stage Doubler



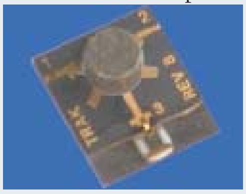
The model 12DBL0409 is a GaAs MMIC two-stage doubler that can be used to drive fundamental mixer devices. Using 0.15 micron gate length GaAs PHEMT device model technology, this doubler converts input signals in the 10 to 13 GHz frequency range to output signals in the 20 to 26 GHz frequency range, and has +15 dBm output power level. The doubler is ideal to drive the company's model XR1002 receiver, and is suitable for wireless communications such as millimeter-wave point-to-point radio, local multipoint distribution services and SATCOM applications.

Mimix Broadband Inc.,
Houston, TX (281) 988-4600,
www.mimixbroadband.com.

RS No. 219

Microstrip Isolator

The model D9A8031 is a microstrip isolator ideal for defense and space applications. This model operates in Ka-band with typical electrical specifications that include insertion loss < 0.7 dB, an operating frequency of 30 to 31 GHz and typical isolation of > 18 dB. This model operates at a temperature range of –54° to +85°C. Size: 0.238" × 0.28" × 0.13". Weight: 0.4 grams.



TRAK Microwave Corp.,
Tampa, FL (813) 901-7200, www.trak.com.

RS No. 220

RF Connectors

The Gore™ 100 series connectors are a super high density blindmate/push-on, high performance microwave interconnect system that offers performance through 100 GHz while offering good and repeatable RF properties. The connector series was developed as a response to the industry's demand for increased packaging density, low mass and increased performance at higher frequencies. The connectors are designed to accommodate both radial and axial misalignment with negligible VSWR change.

W.L. Gore & Associates Inc.,
Elkton, MD (800) 445-4673, www.gore.com.

RS No. 221

Desktop Microwave Preamplifiers

The NSP series desktop preamplifiers are high performance broadband (100 MHz to 40 GHz) fixed or variable gain control amplifiers. These preamplifiers include built-in CE approved power supplies along with an internal fan and rugged construction. Other options such as dual output, input limiter, DC block and temperature compensation are also available.

MITEQ,
Hauppauge, NY (631) 436-7400,
www.miteq.com.

RS No. 264

Ka-band Transceiver

The model TRKa-10 is a transceiver that covers the entire Ka-band spectrum of 26.5 to 40 GHz. The transmit and receive channels use a common phase-locked LO, typically designed at 42 or 44 GHz. Transmit power is ≥ +17 dBm and receive noise figure is 6 dB. Typical gain is 10 to 15 dB. The pulse performance capability of this unit is in the nanosecond range. The transceiver can be powered by either AC or DC input voltages and the system is integrated into a weatherized enclosure rated to NEMA 4X.

Spacek Labs Inc.,
Santa Barbara, CA (805) 564-4404,
www.spaceklabs.com.

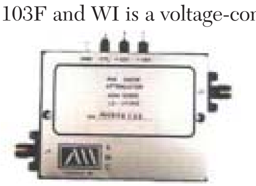
RS No. 265

NEW PRODUCTS

COMPONENTS

High Speed Variable Attenuator

The model AGH-1020D with options 004, 005, 103F and WI is a voltage-controlled linearized, high speed variable attenuator. This model operates from 1.2 to 1.4 GHz with 30 dB dynamic range, high accuracy, phase shift of ±20° (±15° goal), phase tracking of ±7.5° (±5° goal), a low insertion loss of 2 dB maximum and a rise/fall speed of 15 to 25 ns typical. Size: 2.6" × 2" × 0.5".



American Microwave Corp., Frederick, MD (301) 662-4700, www.americanmicrowavecorp.com.

RS No. 222

Circulators/Isolators

The SMC series of surface-mount coplanar, circulators and isolators is designed for high power applications and operates between 800 to 2500 MHz. These circulators are distinguished by good high power performance in congested multi-carrier environment. Models are available in typical bandwidths of 10 to 15 percent with isolation > 22 dB and insertion loss < 0.35 dB. Size: 1" square.

Renaissance Electronics Corp., Harvard, MA (978) 772-7774, www.rec-usa.com.

RS No. 231

Bi-directional High Pass Filter

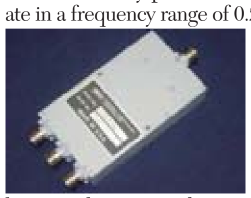
The model 4HPD-2000/A18000-SR is a broadband bi-directional high pass filter. This filter features a 1 dB typical cut-off of 2000 MHz. The insertion loss is 1 dB maximum from 2000 MHz to 18 GHz. The VSWR is 2.0 from 2200 MHz to 18 GHz. Size: 0.750" × 0.750" × 0.500" excluding SMA female removable connectors.

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

RS No. 226

Power Dividers/Combiners

These three-way power dividers/combiners operate in a frequency range of 0.2 to 18 GHz with either SMA or N connectors. These devices have a stripline construction and offer high isolation and low insertion loss. Delivery: within two weeks upon receipt of order.

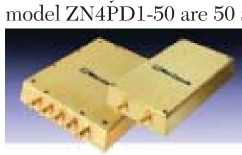


Microwave Communications Laboratories Inc., Saint Petersburg, FL (727) 344-6254, www.mcli.com.

RS No. 227

2- and 4-Way Splitters

The two-way model ZN2PD2-50 and four-way model ZN4PD1-50 are 50 Ω splitters that offer broad bandwidth and operate in a frequency range of 500 to 5000 MHz. These models provide high isolation of 22 dB (typical), low insertion loss of 0.9 dB (typical) and can handle up to 10 W input power. These splitters are designed primarily for lab and production set-up needs. Price: $74.95 each (1–9).



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

RS No. 228

4.7 GHz Diplexer

The part number 8DP7-4550/4850-X200S11 is a diplexer with a crossover frequency of 4.7 GHz. This unit has channels centered at 4.55 and 4.85 GHz with minimum 1 dB passbands of 200 MHz. Passband insertion loss comes in at less than 2.5 dB, with a passband VSWR of less than 1.5 and minimum channel-to-channel isolation of 40 dB. This unit can come with most any RF connector. Size: 0.75" × 1.75" × 6.3".

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

RS No. 230

Isolated Switch Filter Bank

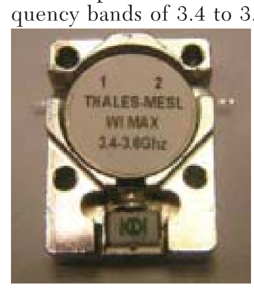
This isolated switch filter bank offers a compact, two-channel selectable filter suitable for IF filtering. This filter bank uses integral input and output isolators to achieve the required return loss (VSWR) without compromising its narrowband performance. The integrated assembly features input and output isolators to provide a consistent 50 Ω load, dual selectable bandwidths (85 and 50 MHz), lightweight aluminum housing, 40 dB reverse isolation and internal voltage regulation. Size: 6.5" × 1.75" × 1". Weight: eight ounces. Price: $865 (100).

Spectrum Microwave, Delmar, DE (302) 846-2750, www.specwave.com.

RS No. 232

WiMAX Isolators

These drop-in ferrite isolators cover WiMAX frequency bands of 3.4 to 3.6 GHz and 3.6 to 3.8 GHz. Power-handling is typically 60 W CW forward, 10 W CW reverse with minimum isolation and return loss of 20 dB, and maximum insertion loss of 0.3 dB. An IMD specification of –65 dBc maximum is achievable and parts are rated for use over –35° to +85°C. Size: 19 × 25.4 × 7.5 mm with tab-ended input and output ports.



Thales-MESL Ltd., Newbridge, Edinburgh, UK +44 131 333 2000, www.thales-mesl.com.

RS No. 233

High Power Circulators

The model CT-1713-S is a high power circulator that operates in the 400 MHz frequency range at a power level of 20 kW peak and 2 kW average power. This unit, supplied with 7/8 EIA connectors, is typical of other low loss VHF and UHF designs at similar power levels. Specifications include 23 dB isolation, 0.2 dB insertion loss and 1.15 max VSWR. Size: 3½" × 3⅜" × 1¼".

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

RS No. 235

AMPLIFIERS

Power Amplifiers

The AP series is optimized for driver or final stage amplifiers in mobile infrastructure. These devices are multi-stage, and are internally optimized for efficiency and linearity. Each PA module in the family features 50 Ω operation including internal matching for input and output and operates off +12 V without requiring negative biasing voltages. Additionally, an internal active bias allows the devices to maintain high linearity over temperature. Size: 29 × 13 × 4 mm.

WJ Communications,
San Jose, CA (800) 951-4401,
www.wj.com.

RS No. 245

Ultra-wideband RF Amplifiers

The model AF182093 is an ultra-wideband RF amplifier that operates in a frequency range of 0.5 to 18 GHz. This model provides a user with an amplifier in drop-in packaging. It offers a maximum gain of 15 dB, gain variation of ±1 dB, maximum noise figure of 5 dB, maximum VSWR of 2:1, and P_{out} at 1 dB compression is +3 dBm. Nominal DC current at +3.2 V is nominal 45 mA.

Herotek Inc.,
San Jose, CA (408) 941-8399,
www.herotek.com.

RS No. 238

ANTENNA

Slimline RFID Antennas

The model MAANAT0123, model MAANAT0133 and model MAANAT0134 are

new additions to the "RFID by M/A-COM" series, a family of slimline antennas for fixed RFID readers. The MAANAT0123 is for the US market (902 to 928 MHz), the MAANAT0133 is for the Japanese market (950 to 956 MHz) and the MAANAT0134 is for the European market (865 to 868 MHz). These compact antennas feature low VSWR of 1.25, high isolation of –33 dB, minimum weight of 2.5 pounds, unique feed network and DC short.

M/A-COM Inc.,
Lowell, MA (800) 366-2266,
www.macom.com.

RS No. 246

DEVICE

Fast Recovery Epitaxial Diodes

These DQ fast recovery epitaxial diodes (FRED) are available in 600, 1000 and 1200 V.

The diodes range in current from 8 to 100 amperes, in packages including TO-220, TO-247 and SOT-227s, or in chip form. The diodes feature soft recovery that reduces EMI and eliminates the need for snubbers, and fast reverse recovery for low switching losses. Price: $0.86 (1000).

Advanced Power Technology,
Bend, OR (541) 382-8028,
www.advancedpower.com.

RS No. 249

SOFTWARE

Test Bench

This code division multiple-access 2000 (cdma2000) test bench for the company's Visual System Simulator™ (VSS) design suite is designed for radio frequency system engineers who need to evaluate the impact of RF link impairments on frame error rate, bit error rate, symbol error rate and other metrics. The VSS cdma2000 test bench modular design and interface offers flexibility in configuration and ease-of-use. This enables RF systems groups to be self-sufficient by providing a canvas to quickly and easily make changes and/or add functionality.

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

RS No. 252

SUBSYSTEM

Integrated Subsystem

This 100 MHz high frequency reference module is an integrated subsystem that provides

+20 dBm of RF output power with low phase noise, –90 dBc/Hz at 10 Hz offset from the carrier and –170 dBc/Hz at 100 kHz offset. Its temperature sta-

bility is approximately 0.1 ppm over a 50°C range. Consisting of a high precision OCXO, power amplifier and an output filter/matching network, the entire subsystem fits neatly into a 2" × 2" × 0.75" package.
Valpey Fisher Corp.,
Hopkinton, MA (508) 435-6831,
www.valpeyfisher.com.
RS No. 258

TEST EQUIPMENT

Peak Power Analyzer

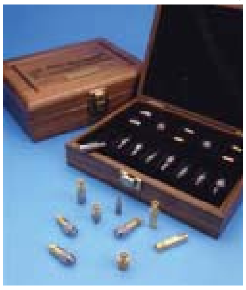
The model 4500B is a peak power analyzer that captures, displays and analyzes RF power in both time and statistical domains. This model can be used in many applications including RF such as radar, TDMA and GSM and pseudorandom or noise-like signals such as CDMA and WLAN. Some key features of the 4500B include 100 ps timebase resolution, automatic peak-to-peak triggering and delay-by-time and delay-by-events triggering.
Boonton Electronics,
Parsippany, NJ (973) 386-9696,
www.boonton.com.
RS No. 262

HSDPA Signaling Tester

The model MD8480C is a high speed downlink packet access (HSDPA) signaling tester that combines physical layer testing with call processing analysis functions, so it can simulate GSM/GPRS/WCDMA and HSDPA base stations. As a result, it is a single-instrument 3.5G tool that can be used by HSDPA chip set developers, manufacturers of HSDPA user equipment and carriers deploying HSDPA technology. Complying with all 12 HSDPA categories defined in 3GPP Release 5, the MD8480C fully supports the development of HSDPA chip sets and UE, and is scalable so it can support future UE enhancements. This model has high internal processing speed that supports the maximum HSDPA data rate of 14 Mbps. Delivery: six weeks.
Anritsu Co.,
Richardson, TX (800) 267-4878,
www.us.anritsu.com.
RS No. 261

Calibration Kit

The 8700-CALKIT is a connector calibration kit for the ZMA interface, a high coupling force bayonet connector used in microwave applications up to 12.4 GHz. The kit includes a full line of terminations, shorts and adapters that allow users to validate the performance of the ZMA interface. Developed for the frequency range from DC to 12.4 GHz, this calibration kit uses ZMA components with a 1.10 maximum VSWR over the entire frequency range. Price: $4,995.00 up, depending upon configuration.



SV Microwave Inc.,
West Palm Beach, FL (978) 465-9453,
www.svmicrowave.com.
RS No. 263

MICRO-ADS

Visit mwjournal.com/info and enter RS# to request information

New Literature

Selection Guide

This 20-page selection guide features the company's latest basic instruments. The guide displays product comparison tables for oscilloscopes, function generators, power supplies, counters and digital multimeters for easy evaluation and selection.
Agilent Technologies Inc.,
Palo Alto, CA (800) 829-4444,
www.agilent.com.
RS No. 200

Capabilities Brochure

This capabilities brochure, entitled "Power & Vision," provides an overview of the company's products and services. The company designs, manufactures and distributes RF amplifiers, amplifier modules and systems for OEM applications.
AR Worldwide Modular RF,
Bothell, WA (425) 485-9000,
www.ar-worldwide.com.
RS No. 201

Analyzer Data Sheet

This data sheet provides complete detail on the company's portable spectrum analyzer, model PSA-86A. The instrument is available in four versions and offers a frequency range of 3.2 to 7 GHz. A product photograph, accessories and technical specifications are also provided.
Avcom of Virginia Inc.,
Richmond, VA (804) 794-2500,
www.avcomofva.com.
RS No. 202

Product Catalog

This 86-page catalog provides an overview of the company's chokes and inductors for RF and EMC applications. The catalog describes the components with technical parameters and gives the corresponding ordering numbers for all products.
EPCOS Inc.,
Iselin, NJ (888) 768-2673, www.epcos.com.
RS No. 203

Antenna Testing Services

This brochure features the company's antenna testing services including nearfield and farfield capabilities. For larger antenna testing, the company offers an additional 1400 ft. farfield range that can handle up to several thousand pounds.
Micro-Ant Inc.,
Fall River, MA (508) 679-9300,
www.micro-ant.com.
RS No. 204

Microwave Diode Packages

This paper discusses the different types of microwave diode packages available, the attributes of each and the effects one might expect when used in some common circuit applications.
Microsemi-Lowell,
Lowell, MA (978) 442-5600,
www.microsemi.com.
RS No. 205

Coaxial and Fiber Optics Catalog

This catalog displays the company's coaxial and fiber optics products that include connectors, adapters, cables, attenuators, couplers, power dividers, switches, terminators and tools. A connector identifier and selection lists are provided to help locate specific products.
Pasternack Enterprises Inc.,
Irvine, CA (949) 261-1920,
www.pasternack.com.
RS No. 206

Product Brochure

This brochure features the company's passive and custom assemblies including filters, diplexers, multiplexers, subsystems and subassemblies. The brochure provides product overviews and a band coverage chart for the products highlighted.
SDP Components Inc.,
Quebec, Canada (514) 421-5959,
www.sdp.ca.
RS No. 207

Material Guide

This material guide features the company's high performance laminates that include PTFE/woven glass base materials for microwave, RF and high speed digital applications. Applications include LNAs, LNBs, PCS/PCN antennas, GSM and UMTS antennas, passive components, aerospace guidance telemetry and phased-array radar.
Taconic, Advanced Dielectric Division,
Petersburgh, NY (518) 658-3202,
www.taconic-add.com.
RS No. 208

Application Note

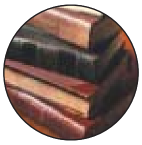
This application note features the company's RF522 relay – a compact, DPDT, surface-mount latching device characterized up to 10 GHz. The paper provides a detailed description of how the company mounts the RF522 onto evaluation test boards.
Teledyne Relays,
Hawthorne, CA (800) 284-7007,
www.teledynerelays.com.
RS No. 209

Cross Reference Guide

This comprehensive cross reference guide features over 100 industry-standard board level heat sinks. These cross-references are easily accessible on the company's Web site and include comprehensive thermal specifications including dimensional drawings and performance curves.
Thermshield LLC,
Gilford, NH (603) 524-3714,
www.thermshield.com.
RS No. 210

Test Cable Brochure

This updated SilverLine™ test cable brochure provides detailed information including connector mating life cycles (5000), connector attachment pull force (200 lbs. on the armored option), performance characteristics for 26.5 GHz cables and new connectors (3.5 mm and QMA).
Times Microwave Systems,
Wallingford, CT (203) 949-8400,
www.timesmicrowave.com.
RS No. 211



THE BOOK END

Raytheon Company: The First Sixty Years

Alan R. Earls and Robert E. Edwards
Arcadia Publishing
128 pages; $19.99
ISBN: 0-7385-3747-0

This book is not strictly a technical book, but shows how a small group of visionary entrepreneurs can start a company and lead it through much turmoil to achieve significant growth. Raytheon is now a well-known electronics industry leader, employing 78,000 people worldwide and involved in many and diverse government programs including radars, missiles, telecommunications, etc. Summarizing the rich history of such a company is no small task. This book is a pictorial history describing the company's growth from its inception through the 1980s. It uses some 200 photographs obtained mostly from the company archives by one of the authors, Robert E. Edwards. A group of three dedicated people, Laurence K. Marshal, Vannevar Bush and Charles G. Smith, later joined by brothers Percy and Al Spencer, provided an impression of quintessential technical entrepreneurship. The book is divided in five chapters. Chapter 1, "The Early Years," describes the founding in 1922 of the American Appliance Co., as Raytheon was originally called, and its first product, the S tube, which eliminated the use of batteries to operate radios. The name Raytheon was introduced in 1925 to avoid conflict with another company called American Appliance, based in the Midwest. Chapter 2, "The World War II Years," describes a period of rapid growth, generated by the demands of the military for microwave tubes and radar. By the end of the war, Raytheon was supplying 80 percent of all magnetrons in use by the Allies. Chapter 3, "Postwar Survival and Redirection," shows the transformation of the company into a diversified one, with products such as microwave ovens, microwave relays, sonars, TV transmitters and transistors. Chapter 4, "Growth and Diversification," describes the expansion of the company through acquisitions and the introduction of more complex military systems, including guided missiles. Chapter 5, "Winning the Cold War," shows Raytheon's contributions to the defense of the country with the development of early warning radars and several missile systems.

> ***"This book is a pictorial history describing the company's growth from its inception through the 1980s."***

To order this book, contact: Arcadia Publishing, 224 State St., Portsmouth, NH 03801 (603) 436-7564.

Microwaves and Wireless Simplified, Second Edition

Thomas S. Laverghetta
Artech House
284 pages; $79, £48
ISBN: 1-58053-943-2

This extensively updated and expanded second edition of *Microwaves and Wireless Simplified* is addressed to sales, marketing or management professionals whose work involves microwave or wireless communication technology. It offers non-technical professionals an edge in their careers by providing them with a thorough understanding of key concepts, components, devices, materials and applications. Since the publication of the first edition in 1998, microwave and wireless technology has evolved and this book will keep the reader up-to-date with the most recent advances in a particular field.

For a subject to be made truly simple, especially a technical subject like microwave, it must be intelligible and clear. This text does it without any mathematics or formulas of any kind. Chapter 1 has some clarification of microwave definitions and terms to bring them up-to-date with the rest of the book. Chapter 2 includes many applications, such as wireless local area networks (WLAN), radio frequency identification (RFID) and a section on the global positioning system (GPS). Chapter 3 now includes a section on waveguides and their applications in microwaves. Chapter 4 is expanded to include typical data sheets for each of the components that have been presented. When each of their parameters is defined, the use of the device will become more meaningful. Chapter 5 expands on the solid-state technology available in the 21st century and includes heterojunction bipolar transistors, radio frequency integrated circuits (RFIC) and microelectromechanical systems (MEMS). Chapter 6 is an update on the materials that are now available, including Teflon fiberglass, non-PTF materials and Thermoset composites. With the additions and deletions presented in this second edition, the reader will have at his or her fingertips a reference book that will provide all the information on microwaves and wireless components and systems necessary to become familiar with each of the topics.

> ***"...addressed to sales, marketing or management professionals whose work involves microwave or wireless communication technology."***

To order this book, contact: Artech House, 685 Canton St., Norwood, MA 02062 (781) 769-9750 ext. 4030; or 46 Gillingham St., London SW1V 1HH UK + (0) 207-8750.

Dan Massé

Dan Massé is a member of the Microwave Journal *staff.*

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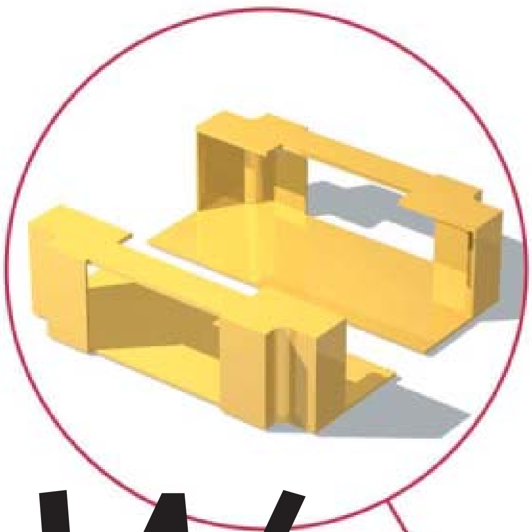

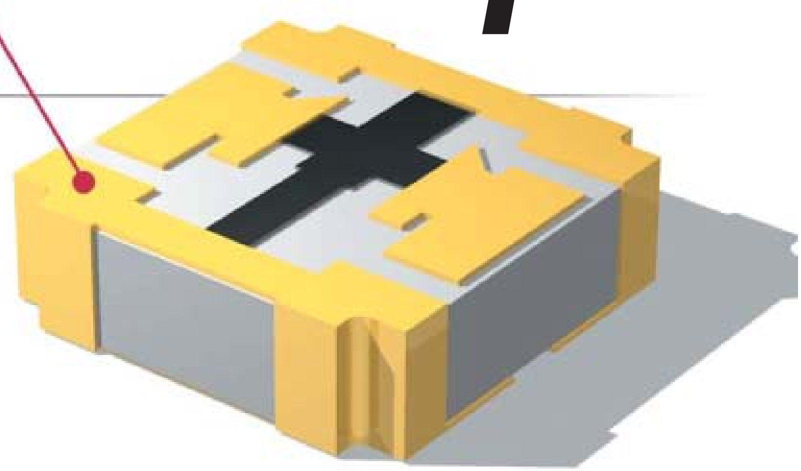

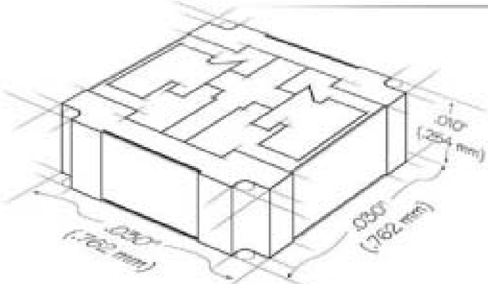
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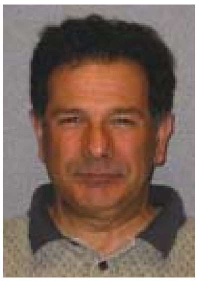
MILITARY MICROWAVES 2005 — CURRENT VIEWPOINTS ON TECHNOLOGIES FOR DEPLOYABLE FORCES

HARLAN HOWE, JR. – EDITOR, *MICROWAVE JOURNAL*
RICHARD MUMFORD – EUROPEAN EDITOR, *MICROWAVE JOURNAL*
MICHAEL PUTTRÉ – EDITOR-IN-CHIEF, *JOURNAL OF ELECTRONIC DEFENSE*

The editors of *Microwave Journal and Journal of Electronic Defense* interviewed some key executive and military leaders in the markets that we serve, both in the US as well as Europe. Selected questions and answers from those interviews are presented below. We would like to thank the participants who took the time and effort to present their views. As a result of space limitations some of the answers have been edited.

Lamberto Raffaelli
President and CEO
LNX Corp.



MWJ: *What are the roles of microwave technologies in light of current requirements for lighter, more deployable forces? How are these roles different from microwave technologies employed in the Cold War Era?*

LR: Certainly, in the recent past, our defense customers have been asking us to design microwave sub-systems with higher levels of integration than in the past. For instance, we are transferring more and more of the functionality from the RF side to the digital side. This is obviously possible because of the progress made in recent years in the area of high speed wide band digitizers, digital signal processing and field programmable gate arrays (FPGA). For example, we are now sampling at higher IF frequencies and doing more processing in the digital domain. Also, several RF compensation techniques are now realized with a look-up table in the digital section. As a result, we can reduce the size and cost of our microwave/digital subsystems. This is what our customers are really asking for.

MWJ: *Describe how the following military trends are affecting microwave technology programs: A. Transformation, B. Network-centric Warfare, C. Coalition Operations, D. Homeland Security and E. The Global War on Terrorism?*

LR: Even in this case, we believe that the major change compared to the past is our ability to integrate RF and digital technology to offer flexible systems that have the ability of adapting to different requirements with the same basic hardware. For instance, combining communication front-end RF products with digital capabilities allows us to offer software definable radios

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CA12-2110	1.0 - 2.0	30	1.0 MAX, 0.7 TYP	+10	+20	2.0:1
CA24-2110	2.0 - 4.0	32	1.2 MAX, 1.0 TYP	+10	+20	2.0:1
CA48-2110	4.0 - 8.0	32	1.4 MAX, 1.2 TYP	+10	+20	2.0:1
CA812-3110	8.0 - 12.0	27	1.8 MAX, 1.6 TYP	+10	+20	2.0:1
CA1218-4110	12.0 - 18.0	25	2.0 MAX, 1.8 TYP	+10	+20	2.0:1

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Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
CA0102-3110	0.1 - 2.0	28	2.0 Max, 1.5 Typ	+10	+20	2.0:1
CA0106-3110	0.1 - 6.0	28	2.0 Max, 1.5 Typ	+10	+20	2.0:1
CA0108-3110	0.1 - 8.0	26	2.2 Max, 1.8 Typ	+10	+20	2.0:1
CA0108-4112	0.1 - 8.0	32	3.0 MAX, 1.8 Typ	+22	+32	2.0:1
CA26-3110	2.0 - 6.0	26	2.0 MAX, 1.5 TYP	+10	+20	2.0:1
CA26-3113	2.0 - 6.0	28	4.0 MAX, 3.0 TYP	+27	+37	2.0:1
CA26-4114	2.0 - 6.0	22	5.0 MAX, 3.5 TYP	+30	+40	2.0:1
CA618-4112	6.0 - 18.0	25	5.0 MAX, 3.5 TYP	+23	+33	2.0:1
CA618-5113	6.0 - 18.0	24	5.0 MAX, 3.5 TYP	+27	+37	2.0:1
CA618-6114	6.0 - 18.0	35	5.0 MAX, 3.5 TYP	+30	+40	2.0:1
CA618-6115	6.0 - 18.0	35	6.0 MAX, 3.5 TYP	+32	+41	2.0:1
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CA218-4112	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+24	+34	2.0:1
CA218-4113	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+27	+37	2.0:1

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LOW NOISE:						
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CA01-2112	0.8 - 1.0	28	0.75 MAX, 0.45 TYP	+10	+20	2.0:1
CA12-3116	1.2 - 1.6	25	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.2 - 2.4	30	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10	+20	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10	+20	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10	+20	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.5 TYP	+10	+20	2.0:1
CA1819-4110	17.7 - 18.3	20	2.0 MAX, 1.8 TYP	+10	+20	2.0:1
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CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA23-4110	2.7 - 2.9	32	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35	+43	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33	+41	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33	+42	2.0:1
CA1218-5116	12.0 - 18.0	35	6.0 MAX, 5.0 TYP	+30	+40	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21	+31	2.0:1
CA1718-4110	17.7 - 18.1	25	5.0 MAX, 4.5 TYP	+27	+37	2.0:1

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CA24-A02	2.0-4.0	26	1.8	+10	$395
CA48-A02	4.0-8.0	24	2.0	+10	$395
CA812-A02	8.0-12.0	22	2.5	+10	$395
CA1218-A02	12.0-18.0	16	3.5	+10	$395

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and secure communications. These systems play a big role in today's homeland security and the global war on terrorism.

MWJ: *Do the trends listed above offer any opportunities for commercial suppliers of microwave components to find military markets?*

LR: My previous company, ARCOM, was mainly focused on commercial point-to-point radio applications. Today, my new company, LNX, is primarily dedicated to the defense market. This is mainly due to the following two reasons:

In the commercial communication market, we have been outsourcing most of the manufacturing and some of the engineering to the Far East. With the increased opportunities in the defense area, we have shifted our market focus to domestic military applications. Our defense customers are asking for more affordable microwave sub-systems. Our expertise in low cost, relatively high volume, commercial front-ends is the key to successfully meeting the cost reduction targets that are required today.

Dana Wheeler
Senior Vice President
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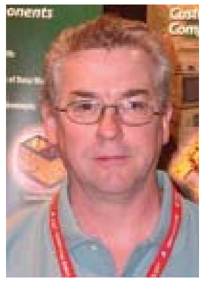
Terabeam Inc.



MWJ: *What are the roles of microwave technology in light of current requirements for lighter, more deployable forces? How are these roles different from microwave technologies employed in the Cold War Era?*

DW: There are a number of factors that come to mind:

Quickly deployable wideband communications – to support the transmission of high resolution imagery from unmanned platforms (UAVs) that, depending on the platform, can also deliver a weapon in real time versus the less readily available satellite surveillance imagery that relies on low data rate, (global) long distance relays to the command post.

Decreasing the cost of near-precision strike weapons – JDAMS, for example – adding low cost ubiquitous GPS to inertially guided "dumb" bombs with steerable tail fins to achieve near-precision accuracy versus optical or laser guided weapons that are spoofed by adverse weather or common battlefield obscurants, such as burning oil.

Decreasing the size/cost of automatic (unmanned) precision-approach/landing systems – miniature MMW systems for UAV and crippled pilot landings. Some systems incorporate differential GPS, which did not exist in the Cold War Era.

Providing more reliable identification (IFF) before lethal strike distance is attained by a potential threat. Possible use of interrogatable, smartcard-like devices for IFF at safe stand-off distances to provide greater reaction time.

Portable weapons detectors – man-portable to support door-to-door searches in an urban warfare environment versus large stationary systems.

MWJ: *Describe how the following military trends are affecting microwave technology programs.*

MILITARY MICROWAVES

DW: A. Transformation
After a recent visit to Tobyhanna Army Depot, it was obvious that our military equipment and facilities are being transformed into a new fighting force designed to fight the wars of today and not the wars of the past. The trend is moving to lighter, man-portable equipment that is designed to deter and defend against current and emerging threats of the 21st century. Microwave/MMW is needed to accelerate this transformation.

B. Network-centric Warfare
To me, network-centric warfare means that the new forces will depend on information gathering and dissemination to all troops, down to the lowest level. All of that data needs aggregation at higher bandwidths, so microwave/MMW radio technology is well suited to the task.

C. Coalition Operations
Coalition operations mean interoperability with foreign forces. The mix of troops, when coalition forces are used, make C3 more important than ever. Friendly fire issues, in the Gulf War and recently in operation Iraqi Freedom, shows the tragic result when these errors occur. Addressable encrypted microwave IFF tags would go a long way to improve this situation.

D. Homeland Security
Microwave/MMW technology exists to address needed improvements in homeland security. These include Smartcards for personal identification, which could be extended to vehicles. Weapons and explosive detectors and RFVID tags to track import/export crates and containers.

E. The Global War on Terrorism
Many of the requirements above are new opportunities for companies with the right technology.

MWJ: *Do the trends listed above offer any opportunities for commercial suppliers of microwave components to find military markets?*

DW: Absolutely! Commercial suppliers are needed to help in cost reduction and volume manufacturing to realize affordable military and security systems.

MWJ: *Does the trend toward defense acquisition reform, particularly in the area of COTS, offer any opportunities for commercial suppliers to find military markets?*

DW: Again, yes. The issue with COTS parts is ruggedness and security, both solved adequately and expeditiously by wrapping COTS parts in hardened enclosures and using external secure boxes. Additional testing over broader temperature ranges may be required in some cases.

MWJ: *Describe the important deployable military microwave technologies and programs for each of the following scenarios.*

DW: A. International Exercises
Interoperable communications systems (software configurable radios).

B. Expeditionary-force Operations
Man-portable, small, easy to set-up, broadband tactical ground/air communications including high resolution imagery upload to airplane/UAV loitering relays. Broadband air-to-air communications.

C. Peace-enforcement and Stabilization Operations
Personal ID (Smartcards)
Broadband wireless links
Ground penetrating radars
Portable weapons detectors
Disaster relief operations
GPS augmented cell phones
Broadband wireless links for telecommunications when existing infrastructure is not functioning.

THE EUROPEAN PERSPECTIVE

Europe is a diverse mixture of established military powers combined with emerging nations that have evolved since the end of the Cold War and the break up of the Eastern Block. Global issues such as the Iraq War and the War Against Terrorism weigh heavily on coalition forces and their allies while home and border security are a concern for all. To address these issues and remain effective and competitive microwave technology is having to adapt to changing circumstances and practices, while also having a significant role to play in bringing about these changes. As the following interviews elaborate the European microwave industry is actively addressing key issues such as: the transformation from heavy battalions to lighter, more deployable forces; the development of network-centric warfare; the need for greater integration and interoperability; and the exploitation of technologies emerging from non-defence markets.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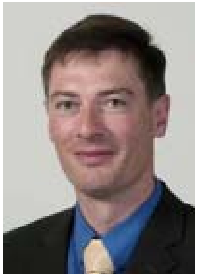
MILITARY MICROWAVES

Keith Burns
Product Line Manager for High Power Microwave Sub-Systems
Thales UK – Aerospace Division



MWJ: *What are the roles of microwave technologies in light of current requirements for lighter, more deployable forces? How are these roles different from microwave technologies employed in the Cold War Era?*

KB: As the Cold War threat diminished new, smaller, mobile, threats have taken their place, which require reduced sensor to shooter times. Microwave technology has also progressed to allow this to happen; the ability to network sensors has resulted in a significantly enhanced information capability with less systems. Lighter, faster deployable systems are now required to address the new threats and microwave technology has kept up with this change by the migration from large, heavy, waveguide systems and discreet components to integrated sub-systems in MIC and MMIC technology. The Thales Group, with over 40 years experience in developing microwave components, has progressed from the Cold War Era where we have seen the trend for OEMs to move away from procuring microwave components to procuring more integrated sub-systems. This trend of greater integration into smaller, lower power packages is likely to continue.

MWJ: *Describe how the following military trends are affecting microwave technology programs.*

KB: A. Transformation

Transformation from heavy battalions to lighter more deployable forces and a greater emphasis on special operations will result in the need for information superiority and enhanced situational awareness. This drives the requirement for the deployment of more advanced sensor platforms with SAR/GMTI capabilities and a combination of electro-optic sensors. The Watchkeeper UAV project is a good example of new developments in sensor platforms and of the type of microwave technology that will be incorporated into these platforms.

B. Network-centric Warfare

The migration to network-centric warfare will provide opportunities for microwave technologies that were developed for the telecom industries being adopted in the military sector; secure data links speeding up the flow of information in C4I environments is going to proliferate. The challenge with network-centric warfare is how the raw data is processed and disseminated to the appropriate personnel.

C. Coalition Operations

The challenge here is going to be interoperability of different communication and identification systems. Having common NATO standards only partially alleviate this if you are operating with other NATO countries, but if you are operating with countries outside NATO, these issues will still exist. Battlefield IFF systems that can be interrogated by all coalition forces will be an area of growth for microwave sub-systems.

D. Homeland Security

Homeland security is a growth market for microwave components. The need to increase border security will result in new opportunities for sensors and will provide opportunities for the microwave sub-system suppliers. The need to inspect freight and detect movement of radioactive material is resulting in an increased requirement for scanning machines; at Thales, we have been investing in developing high power microwave components for this type of application.

E. The Global War on Terrorism

Information flow is going to be one of the key requirements for identifying and tracking terrorist targets. Real time information will be a requirement, resulting in the need for fully integrated decision making systems, which can quickly analyse information, prioritise and communicate to those in the field. As engagements are more likely to take place in built up areas, accuracy of weapon systems is critical. Continual improvement of weapons guidance systems, using GPS and electro-optic sensors, will provide opportunities for microwave subsystem companies.

An interesting area for higher power microwave devices is going to be in non-lethal weapons; several field trials have already been conducted using high power microwave devices. Within Thales, we have been extending our high power microwave capabilities to address the future requirements in this market.

MWJ: *Do the trends listed above offer any opportunities for commercial suppliers of microwave components to find military markets?*

KB: The new trends have created opportunities in what was looking like a declining market for microwave components. The reduction in development funds from govern-

MILITARY MICROWAVES

ments and OEMs means that there is more of an incentive to look for components that are already developed. Commercial components have developed at a fast rate, driven by the telecoms market and offer technologies that are attractive to the defence industry.

MWJ: *Does the trend toward defence acquisitions reform, particularly in the area of COTS, offer any opportunities for commercial suppliers of microwave components to find military markets?*

KB: There is an industry consensus that all future designs of sensors will have to utilize a significant amount of commercial off the shelf products (COTS). COTS is the future direction of component procurement because many commercial developments are progressing at a faster technology rate than the equivalent military products. COTS offers innovative new modular systems with a faster time from concept to deployment since the component development work is done. Radars using COTS have demonstrated a reduction in development time and cost and, perhaps surprisingly in some circumstances, can offer an improvement in MTBF.

To address the issue of using commercial components in a harsher environment, COTS components will be subjected to upscreening. If by using COTS products there will be less time spent on development, there must be more time spent on testing by the OEM.

Future radar designs will adopt open system architecture; this enables modules to be redesigned as and when obsolescence occurs. Since the drawback of COTS is limited life cycle support, more redesigns of radar modules will occur providing opportunities for commercial suppliers throughout the life of the sensor.

MWJ: *Describe important deployable military microwave technologies and programs for each of the following scenarios: A. International Exercises, B. Expeditionary-force operations, C. Peace-enforcement and stabilization operations. D. Peacekeeping Operations, and E. Disaster-relief Operations.*

KB: All of the above requirements have common themes for the need for accurate, real time information. Each requirement has the need for some form of situation assessment, whether this is through satellite imagery, UAVs, some other sensor or from people on the ground. All of these requirements can benefit from using some form of microwave imagery. Similarly, the need to get this information to decision makers requires flexible communication systems, which will require some form of RF/microwave datalink. The processing and communication of information is a key requirement in all of the above scenarios.

MWJ: *Has the adoption of the new EU member states from Central Europe in May 2004 affected the dynamic of the European military microwaves market?*

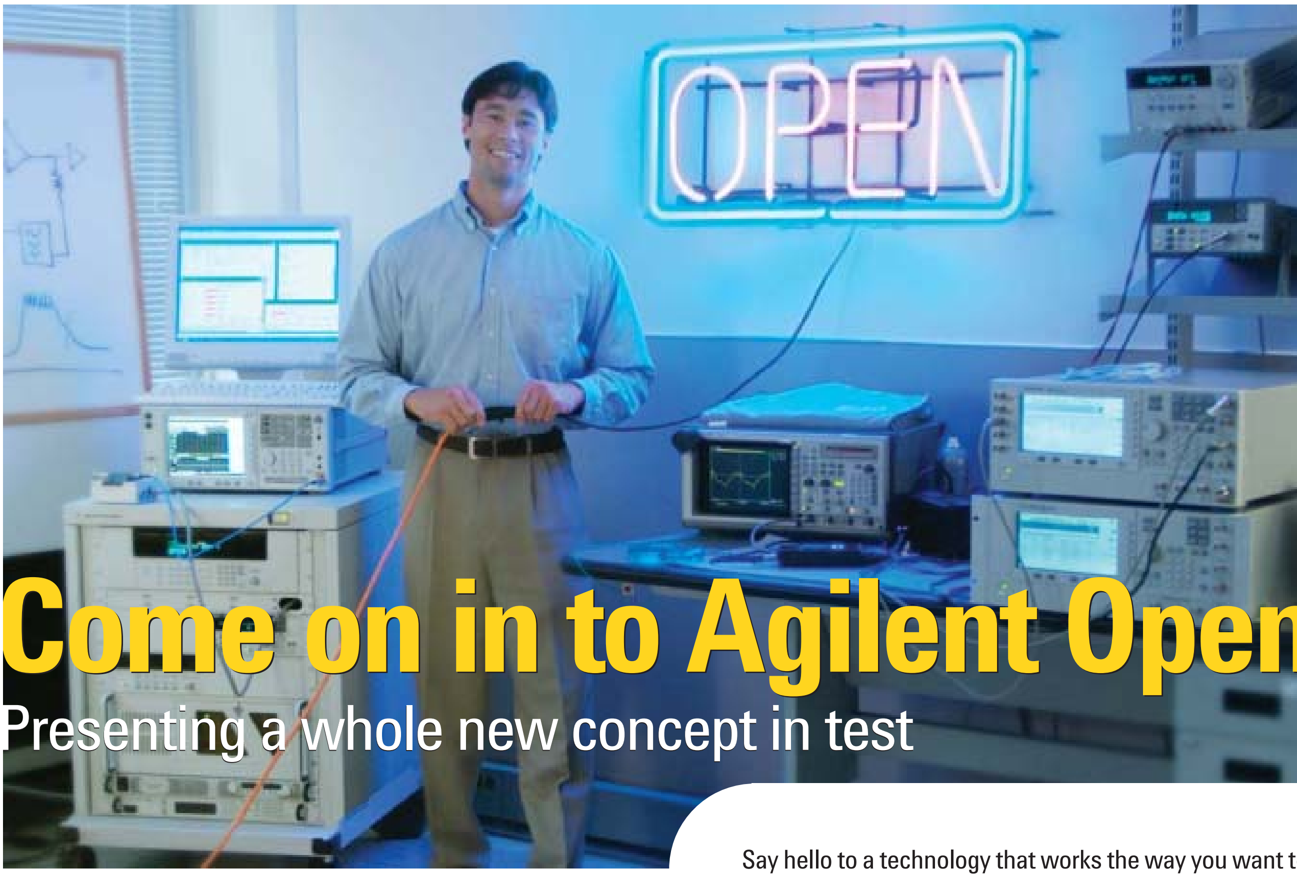
KB: Thales has yet to see the full impact of this, but central Europe will be a growth market for the future. There is a need to secure the extended EU border and a desire in these countries to either develop or procure systems that have improved interoperability with EU countries/NATO equipment and this is an area that will offer opportunities to the microwave component supplier.

There are microwave capabilities in these countries that may be attractive to Western Europe and partnerships may be one way of commercializing this technology in Western Europe. In the telecoms market, we have seen microwave sub-system assembly work being transferred from Western Europe to Central Europe, but due to security considerations this is less likely to happen for defence work.

Frank van den Bogaart
Business Unit Manager Knowledge; Observation Systems,
TNO Defence, Security and Safety, The Netherlands

MWJ: *What are the roles of microwave technologies in light of current requirements for lighter, more deployable forces? How are these roles different from microwave technologies employed in the Cold War Era?*

FvdB: Microwave technologies in the Cold War Era focused in particular on high-performance, stand-alone systems like radar and EW systems. As a consequence, microwave components in those systems were, in many cases, specially developed, designed, tailored and manufactured. This resulted in high cost technologies, with very little potential to sell them in other markets. The availability of communication systems in all forms will be extremely important for deployable defence forces. Such versatile communications include: short range and long range, low data rates and high data rates, secure and non secure, ad-hoc networks and fixed networks, low frequency bands and high frequency



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MILITARY MICROWAVES

bands, etc. This opens up a market for high volume microwave technologies.

Such high volume microwave technologies, emerging from communication applications, will also find their way into many other defence applications. In many cases, we will see that communication will be an integral part of the sensors in order to make the sensor data available in real time for command structures. On the other hand, we will see a new generation of new (networked) sensing systems. Phased array antennas will finally make a breakthrough to affordable radars and communication equipment.

MWJ: *Describe how the following military trends are affecting microwave technology programs: A. Transformation, B. Network-centric Warfare, C. Coalition Operations, D. Homeland Security, E. The Global War on Terrorism.*

FvdB: In line with my answer to the previous question, we will see a future of integrated sensor suites that are flexible and mobile and that can operate stand-alone, while operating more and more in (ad-hoc) networks. In addition, for example, as a result of lessons learned from coalition operations in not-well known territories or situations, I do see a need for sensor systems that can be integrated and adapted with existing building blocks in such a short time that they can still be deployed for ongoing missions. The result being more and more sensor systems that are made up of scaleable components.

MWJ: *Do the trends listed above offer any opportunities for commercial suppliers of microwave components to find military markets?*

FvdB: I would like to turn this question around. In my opinion, it is necessary for military manufacturers to try to understand the need to implement the technologies and processes that are used by companies that produce systems for non-defence markets. As a result, the purchase and common development of microwave components from commercial suppliers is necessary. Also, for military equipment, we will see an increased need for shorter development cycles and in-time introduction for military operations. However, we should realise that there is a continuing and existing need for high performance systems. In particular, radar systems will demand rugged high power capabilities. SiC and GaN semiconductor technologies, which are currently emerging in non-defence markets, are crucial for such systems in the future. In addition, there is a growing need for sensors and communications systems as a commodity in which high-volume low-cost SiGe semiconductor technologies will be utilised.

MWJ: *Does the trend toward defence acquisitions reform, particularly in the area of COTS, offer any opportunities for commercial suppliers of microwave components to find military markets?*

FvdB: I do think that the definition of COTS is, in many cases, misinterpreted. Just buying off the shelf involves the risk of ignoring adaptation, long-term availability and 'militarization' cost, which may turn out to be dominant in the end. Only if an early strategic involvement with the manufacturers of COTS components is effected will these components meet the buyer's future requirements, and enable their internal military system developments to be tweaked to the COTS components that become available when the systems go into production. Any alternative proposition is likely to result in a market introduction that is too late and too expensive. Also, the military will move to


pushing limits

standard components and scaleable subsystems for dedicated systems and for large volumes.

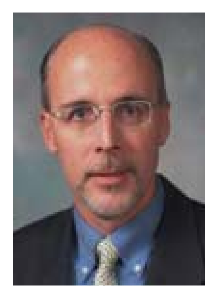
MWJ: *Has the adoption of the new EU member states from Central Europe in May 2004 affected the dynamic of the European military microwaves market?*

FvdB: I do feel that there are much more important global issues to consider, such as the US regulations and developments in the Far East, leading to new military powers. These will heavily influence the European Market.

THE JED PERSPECTIVE

Information is the new queen of battle, a throne previously occupied by airpower and artillery. Particularly as armed forces retool to become lighter and more mobile, information takes the place of numbers and armor. The ability to deploy, protect, and assure communications networks is a force multiplier of the highest order. Certainly, there are notable discrete technological developments that promise greatly enhanced capabilities, such as in the fields of imaging infrared sensors and electronically scanned phased array radar. However, integrating existing technologies into networked systems of systems is far and away the most important capability a military must consider when deciding on a major procurement program.

Joe Duthie
Director of Advanced Technology
Northrop Grumman's Defensive Systems Division
Rolling Meadows, IL



JED: *What are the roles of microwave technologies in light of current requirements for lighter, more deployable forces? How are these roles different from microwave technologies employed in the Cold War era?*

JD: In the Cold War, battlefield communications were structured and, more or less, strategic in nature. In today's war paradigm, communications are more ad hoc in nature. High-bandwidth, wireless links must form and dissipate along with the battlefield. Microwave technologies that support troop mobility and information flow will see added emphasis.

Lighter, more deployable forces require significantly lighter equipment with greater functionality. A radio can no longer be just a radio, but it must also allow for transmission of large amounts of digital data to provide greater situational awareness to the soldier and other mobile ground forces. Electronic equipment today is much more sophisticated and much more capable. One miniaturized personal digital assistant (PDA) is capable of data and voice communications. The same PDA can also provide GPS positioning information. It is not inconceivable that this same PDA will also provide identification-friend-or-foe (IFF) data back to friendly interrogators looking to prevent fratricide.

It will also be necessary to provide mobile forces with the ability to quickly and accurately understand their surroundings in battle. The micro-UAV will play a big role (and is playing a big role) with regard to battlefield awareness. Small hand-deployed UAVs with onboard cameras and radio links are being used to scan areas for unfriendly forces or to perform battle-damage assessment (BDA). These same UAVs will one day include miniaturized synthetic-aperture-radar (SAR) capability to overcome the bad-weather limitation of electro-optical (EO) sensors.

The bottom line is that the electronics of today are not our father's or our grandfather's electronics. All systems are expected to do more with less and to cost less (in today's dollars) than systems from the past. SAR imagery needs to be better and more accurate. The tracking of moving ground targets is a necessity. These radars need to be mobile (i.e., contained on UAVs like Global Hawk or brought in by Humvee) and quickly set up. There is a big push to be able to get payloads into space on short notice aboard micro- or mini-satellites that contain EO and RF sensor capability – sort of a satellite-on-demand capability that will not take weeks or months to deploy – the goal being one or two days to get the asset in place and providing the valuable information needed.

JED: *Describe how the following military trends are affecting microwave-technology programs: A. Transformation, B. Network-centric Warfare, C. Coalition Operations, D. Homeland Security and E. The Global War on Terrorism.*

JD: The mobile, ad hoc battlefield structures, coupled with "politics" that emphasize surgical precision, has driven the need for high-efficiency, broadband microwave power sources to support information flow; small covert, unattended microwave sensors to support targeting; and distributed microwave networks to support operations. Traditional fixed assets are beginning to disappear, and the need for lightweight and miniature technologies is prominent.

With regard to the global war on terror, the military is very interested in being able to deploy very low-cost micro-sensor technologies, based on commercial technologies, that could be used to perform persistent intelligent, surveillance, and reconnaissance (ISR) missions – the idea being that sensors could be widely deployed to monitor traffic through an area, and this information could then be used to trigger a response (i.e., attack and destroy or simply just track). It is not too hard to see how this same capability could be used in regard to homeland defense. In addition, the military is having a hell of a time with improvised explosive devices (IEDs), and there is a real need for devices (particularly microwave capability) that could prevent the detonation or even pre-

microwave JOURNAL Previous Page | Contents | Zoom In | Zoom Out | Front Cover | Search Issue | Next Page qMags

trigger these devices. These systems will need to be small and readily available in large quantity to support all our troops. Today, the protection available is very limited. Ultimately, the military would like to equip each solider with some sort of RF protection – something else for the solider to carry on his back.

JED: *Do the trends listed above offer any opportunities for commercial suppliers of microwave components to find military markets?*

JD: Yes, without a doubt. Providers of wireless communications technologies, sensors, and power sources should see increased demand from military users. The trend in military hardware has been to use more and more commercial hardware. The reason is simple: commercial suppliers have development cycles of two to three years, whereas the military have been working on the 10 to 20 year cycle. Military hardware is often antiquated before it is even deployed. Microprocessor capability has been doubling on a yearly basis. The military is pacing the commercial suppliers with regard to the development of electronics, and this trend will continue into the future. If the military hopes to have the best capabilities in their systems, they will have no choice but to embrace commercial electronics. The infrastructure will develop (actually, has developed) where a supplier base will purchase the commercial electronics and build them into ruggedized form-factors for use by military suppliers, particularly in regard to computers and microprocessors. Communications equipment (i.e., radios, PDAs, etc.) is also in this same situation with regard to secondary suppliers. Commercial electronics has also come a long way with regard to plastic-encapsulated microcircuits (PEMs), and they are finding more and more use in military electronics. Even the high-reliability space companies are using PEMs. Twenty to 30 years ago, this never would have been the case.

JED: *Does the trend toward defense-acquisitions reform, particularly in the area of COTS, offer any opportunities for commercial suppliers of microwave components to find military markets?*

JD: Yes, the trend is definitely toward leveraging what is commercially available, at least in terms of form and function. Fit often dictates adaptation to the military environment. The military really has no choice in the matter. The IRAD [internal research and development] funds being spent on the commercial side far outweighs that which is being spent on the military side, and if the military wants the best systems and electronics in the world, then they will have no choice but to get onboard with the commercial suppliers. Attention will still need to be paid to the military environment versus the commercial environment, though. It will do no good to use commercial hardware if it breaks as a result of the more severe environment being imposed by the military user.

JED: *Describe important deployable military microwave technologies and programs for each of the following scenarios: A. International Exercises, B. Expeditionary-force Operations, C. Peacekeeping and Stabilization Operations and D. Disaster-relief Operations.*

JD: International Exercises: JTRS and the wireless technologies that it embodies.

Expeditionary Forces: Compact, lightweight all-weather sensors, such as the US Army's Objective Lightweight Counter-Mortar Radar (O-LCMR).

Peacekeeping and Stabilization: Counter-fire technologies, like the AN/TPQ-36 radar, and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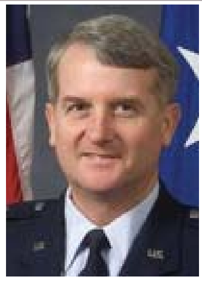
Brigadier General David J. Eichhorn
USAF, Deputy for Support, Electronic Systems Center
Hanscom Air Force Base, MA



JED: *What are the roles of microwave technologies in light of current requirements for lighter, more deployable forces? How are these roles different from microwave technologies employed in the Cold War era?*

DE: Certainly since the Wall came down it's a whole new world. Since 9-11, it's a whole new world. In the old days, I started flying B-52s. It was said during the Vietnam War that the electronic warfare (EW) officer never carried his own bags, never bought his own beer. He was taken care of. He was an important member of the crew. But it was self protection. You were being shot at and you didn't want to get hit. EW was critical to making sure that you didn't get hit, that there was nothing guided coming up at you.

Today, electronic warfare has really expanded to become kind of a virtual world through advances in technology. Our sensors can see things far beyond our human sight, even beyond the line of sight with the connections and stuff to where we can ascertain what is going on over the hill and figure out how we are going to deal with it before we ever get there. And so taking the information into a place – the command post, a combined air-operations center, and the like – and figuring out what you want to do is really the art of war today. Because the thing you want to do is put the right weapon on the right target at the right time. We want to minimize collateral damage. We want to maximize our effect on the enemy. That is not to say to maximize violence. That is not the intent. It is a maximum effect to where they cease the violence, where they cease their behavior determined to hurt us and run contrary to our national interest. So the kind of world with surgical strikes hitting strategic targets is really coming into effect now because of the intelligence, surveillance, and reconnaissance assets coupled with the command and control to use them properly is enabling us to put the right weapon on the right target at the right time to make the right things happen, which is to "cease and desist." Again, we don't want to do too much. We want to do just enough.

We get smarter and smarter about how to do these things. It used to be that the aim was to destroy a certain number of enemy aircraft, and the like. But today we realize that we do not necessarily have to destroy all of the enemy's assets . You just have to render him impotent. If his planes can no longer take off, they can no longer harm us. And so don't waste any more effort there. Worry about other things. It is a paradigm shift, and it's in part because of the information age that now we have better information and we can better use our resources. We can spread out and maximize that effect over all, because once a field is rendered ineffective, count it ineffective and move onto something else so you can do more with the same amount of forces than you could in the past.

It's funny. Some twenty-five years ago I was interviewed during a Golden Shield exercise while I was refueling and a reporter asked me at the time, "What do you think about the B-52 being around this long." It's still around, and it's still doing a great job. The old bird's got some life left. In Iraq, the B-52 was acting as a close-air support aircraft with the JDAM and in some cases dropping bombs closer to friendly ground forces than the airmen thought safe to do. But because the targeting was so precise we could lay down the effect near them, which got the bad guys off of them, close-air support from 30,000 ft. Thirty years ago you'd tell me I was crazy. Today with GPS-guided weapons you can do it. Like the pilots over Afghanistan, they're up there in orbit, waiting to be tasked on a close-air support mission. Here's what I want you to hit. Got it. Consent. Agreed. Whosh, bomb's on its way. Time of flight, and the target's gone.

JED: *Describe how the following military trends are affecting microwave-technology programs: A. Transformation, B. Network-centric Warfare, C. Coalition Operations, D. Homeland Security and E. The Global War on Terrorism.*

DE: The Electronic Systems Center (ESC) restructured about a year ago to wings, groups and squadrons. We always had an Airbase Support Wing and then the program offices. Now we have four new wings doing acquisition. We have the Network-Centric Systems Wing, the Operations Support Systems Wing, the Command & Control and ISR Systems Wing, and the Battle Management Systems Wing. What we've done to augment interoperability and commonality, is instead of having 26 different program offices, now we have four systems wings that are inherently common because we've grouped them that way. And now we've tasked the wing commanders and their staffs to start searching for those common solutions. So now Lt. Gen. Charles L. Johnson II, Commander of the ESC, has a much more doable task of integrating four wings instead of 26 different program offices. And I think we're seeing some big benefits in that. This is building momentum as we get smarter and smarter about what we can do with this. We're getting out of a program-centric mindset and into the capabilities mindset, where at Network Centric all these programs contribute to network-centricity. Some of the standards we are developing and have developed with the Navy are how to push toward a common solution to improve "jointness." The same thing with Opps Support: You can't go to war without the right supplies getting there at the right time. So how do we drive that? Really good stuff has been organized in that way.

We have the sensors mission: to develop the sensors to help the decision makers make better decisions. Be able to put the weapons on target. What has changed over time is more and more emphasis on the software algorithms for getting in that right information. Because what we're seeing is everybody has a piece of the puzzle. So then how do we bring those pieces together into a single, coherent operational picture so that decision-makers can see the whole thing and not miss anything and do the right thing. That gets into that virtual world. It's software intensive. Take the bits, the ones and zeroes – the best way to manipulate it is digital – bring it in and fuse it all together, figure our whether you're looking at one target or five targets; if they're mobile, then speed and direction; can you be a bit predictive on where it's going to be; so again you can make the right decision. Try to discern after all of this the enemy's intent. Because it may take five, six, seven different pieces in order to figure that out. Only when you bring them together can you do that. Our enterprise resource tools bring it all together so that we can see one coherent picture and make the right decision.

There's multiple pieces to creating a common integrated air picture. Where we see a lot of this coming together is in the air operations center (AOC). What we had in the past, through competitive bids, was different products from different vendors all optimized for their piece of the world. We did not foresee, nor could we, that eventually we'd be putting all this stuff together. Although that's becoming more obvious over time. We were happy to get pieces of it. Now we're seeing the benefits of a single picture. So, what we'd like to do, what I envision, is get down to a wide-screen view with overlays of whatever is pertinent to the picture. Overlays represent information that is published by somebody, so I can subscribe to it and get a real-time view of what the heck is going on. But it does come together in the AOC.

The desire is to have network-centric operations to where you can post the information on an Internet-like system. You have publishers to the system and then you have subscribers. You publish information to the system and those that need it can subscribe to the system and pull the information in, be it threat information in a certain geographic area or weather or tanker assets. All of the things that it would take to go into putting together an air strike. Doing that in an airborne environment is far more difficult than in a land-based environment.

In a land-based environment, the IP addresses don't change or they change minimally. Whereas what we're looking at is a self-forming, self-healing airborne network where you take off, you join up, and you're immediately a subscriber and a publisher at the same time. This is something that, in a dynamic environment, is not trivial. The net effect we want is like a ground-based network where the information is available, but in a land-based system the timeliness is not as critical. Packets are split up, they're sent around, and they get to you when they get to you. We really need some timestamps and some information assurance that the information that gets to us is not only accurate but timely so that we're not acting on old, decaying, no longer valid information. And so there's basic physics involved, because we're not going to have line-of-sight all the time, so go via satellite, and uplink and downlink with inherent delays. The speed of light's pretty fast but it's not instantaneous. So, how do we factor this in? Some of the software programs that we deal with were designed for continuous datalink, and we're finding out that when there's a break they don't just wait for the data they freeze. They go stupid. You have to reboot them. And obviously you can't have that. So we're sorting through that, what it means in an airborne networked environment. What we know intuitively is that it is an incredible force multiplier.

JED: *Do the trends listed above offer any opportunities for commercial suppliers of microwave components to find military markets?*

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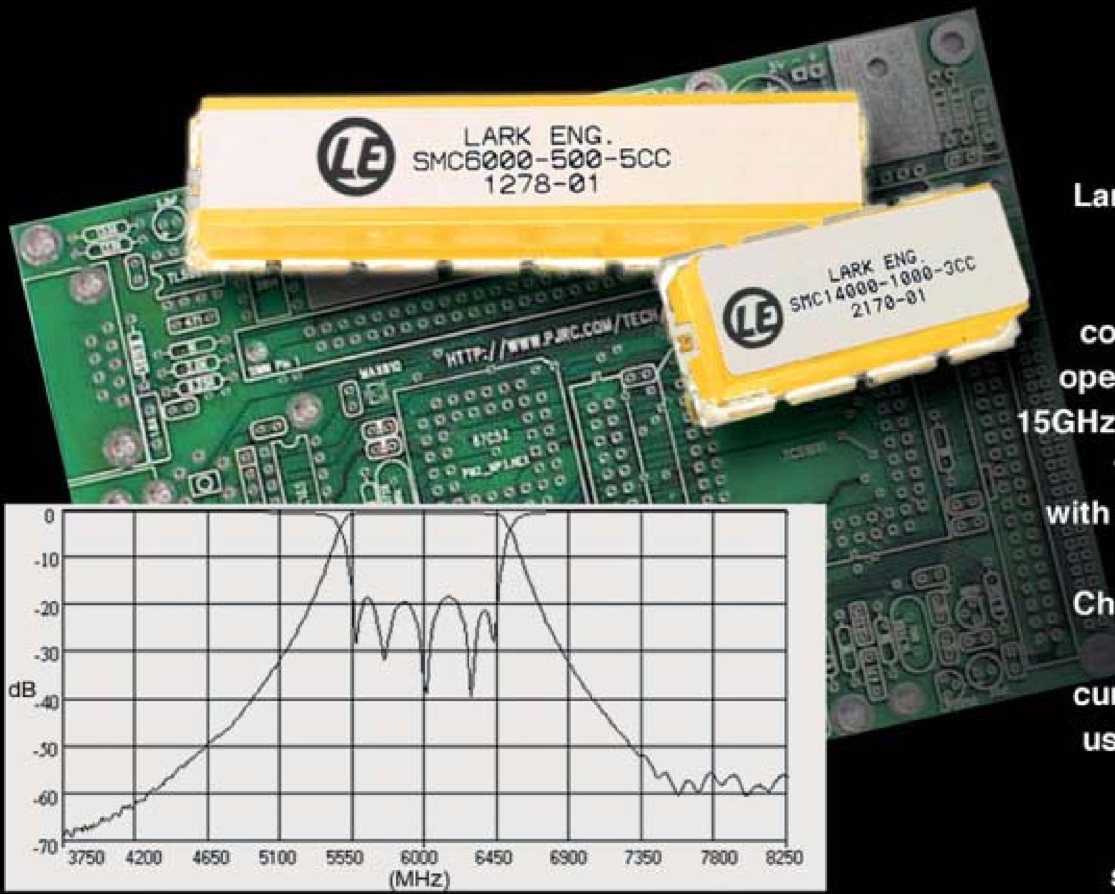

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DE: There's a volume aspect to the commercial marketplace that does not necessarily translate well to the military side. What a supplier makes this year may be totally different to what they made last year because they figured out a way to refine their process. I bought a pair of sunglasses to replace a previous pair: same brand, same thing, what the company says is the same model. But when I got them the ear pieces were different. They figured out a different way, no doubt a better way, for them to make it to increase their profit margin. I'm happy with the glasses but they're different. They're not exactly the same. So in a business where you're trying to, because it's life or death, lethal force is authorized, where you have a disciplined process to provide people with the same things consistently. Oh by the way, the American taxpayers don't like to have to pay for anything twice. So we buy things that we expect to last a long, long time. And then make them support them. And we don't have the volume of a car. I've had ten-year-old cars, I've had fifteen-year-old cars. I still expect to be able to get parts for them. So, there's those kinds of tradeoffs that make it harder.

Now, we are trying to build in some upgradability into some of these things. More modularity, for example. To where as these parts of it are improved over time that we could just swap out that part of it without having to rework the whole system. But it's hard. And some of that means you have to pay more up front to build in that modularity to begin with, and you've got to have the money. We don't always have enough. Everything's a tradeoff. Everything's coalition warfare in today's world and everything's a tradeoff. So, we try to make the best tradeoffs possible so we provide the best systems for the warfighter.

It's not uncommon in the course of your daily life to say, "Man, if I'd only known." Well, in a war you don't ever want to have people saying that. And so we try to set people up not with information overload but the right information, so you have to have the right filters. You want to have the right sensors to begin with and the right filters so that you're not just sending raw data to a decision maker but actually meaningful decision-quality information so that they know what's over the hill, what they're going to be facing. It's everything, from enemy threats, to weather, to order of battle, and it all plays together in "given this I can do that" kinds of scenarios so that you can have maximum effect to get the enemy to change his ways.

JED: *Does the trend toward defense-acquisitions reform, particularly in the area of COTS, offer any opportunities for commercial suppliers of microwave components to find military markets?*

DE: We are always looking at commercial off-the-shelf. We're all familiar with Moore's Law, with the computer's power doubling every eighteen months. We want to take advantage of that. With Internet technology, again, ten to fifteen years ago who would have thought that everybody would be using e-mail and that we would be referring to the US Post as snail mail. So, we want to take advantage of those things, but not all of it is a direct transfer. Because a lot of technology on the commercial side is not time sensitive. If you have wait a little bit to get your mail or to check the weather or whatever it is you are checking you can tolerate that. But if you're in the heat of battle, you can't. We're still working through what latency we can tolerate and where versus what is time critical. And then you have to figure out how to put the system together under an algorithm to make sure that the time-critical stuff really gets through and the stuff that can wait a while gets lower priority. There's a whole bunch of issues there.

We reserve the right to get smarter as we go along. We don't think we know everything today. So what we've seen is a change in the use of standards and specifications. It's interesting to me that the industry has gone to an ISO 9000 standards-based system for international trade. If you weren't ISO 9000 board-certified, then Rolls Royce didn't want to work with you. So what we're seeing now is, if we just changed the government's policy to where it's okay to use specifications and standards that's consistent to what we're seeing in commercial industry. Under acquisition reform, looking for consistently good suppliers to provide good products for the warfighter affordably in a timely way. And using what we know as a free-market-based system are the best tools to ensure the best. The best weapons systems at the best price are provided. So the competition contracting that, and all the things that go with that, we continue to try to streamline that understanding that inherently there are vying forces there competing for the business. Everybody trying to get that competitive advantage. That's the beauty of our system. Some folks have called it creative destruction. That has proved what's great about this country. We utilize that and keep trying to find out better ways of doing that. But no matter how we do it, and there's great good in it, there's some things that some people view as bad. It takes too long, why do you have to go through all this stuff? I think there's plenty of evidence as to why we have to go through that. This is because the end product for the nation is best.

JED: *Describe important deployable military microwave technologies and programs for each of the following scenarios: A. International Exercises, B. Expeditionary-force Operations, C. Peacekeeping and Stabilization Operations and D. Disaster-relief Operations.*

DE: It's not so much deployability of the hardware but of the information. If I can bring the information together in a timely manner with the experts who know what to do with it, then it's not so important where that command asset sits. Certainly they've got to understand the full environment, and there's more to the environment than just what you may see right there. There are always local considerations, humanitarian considerations: so you need those kinds of experts who really understand the whole global picture, if you will, not just their little corner. If I can bring all that into a cell somewhere, it may not be that important that the cell be deployable to the theater. On the other hand, once we get the systems down we're looking to minimize the number of databases, minimize the number of different systems, such that it is inherently deployable. On the Internet, you can be anywhere in the country and check your e-mail from any computer anywhere. So we want to set up that kind of secure network to where I sit down with a laptop wherever I happen to be, plug in, and as long as I've got that kind of super-net connection, boom, I can be up and running and with the proper wherewithal I could be running the operation. The situations we face today are complex to where you probably have teams working different aspects of an operation. But again, it's inherently deployable. Here's your computer, here's your workstation, help direct this portion of the operation.

Whatever type of operation we're conducting, we have an insatiable appetite for bandwidth. It's using it properly and setting it up with the right rules and priorities so that use of the available bandwidth is maximized. One area we're looking at to help with this is exploiting near space: from about 65,000 ft. to 300,000 ft. What if you were to put balloons up there with whatever platforms that you need? You'd have that long-duration, persistent ISR needs of the modern battlefield. We keep that profound knowledge of what is going on so that we can dictate what happens, doing the right thing at the right time. Using a command and control system for the rapid action. There's a whole lot you can do about reducing the cost of payload-to-orbit. We're using airborne assets and unmanned aerial vehicles (UAV) in unprecedented numbers. It's probably akin to what the cellular phone industry went through when Iridium was taking off. Everybody thought that cell sites were going to be limited to building towers. Now there are cells everywhere. There are certainly limits on what you can do with air, but we're doing a whole lot more. And now there's this in-between area that maybe we can better utilize. Once we put the whole thing together – from surface to geosynchronous orbit – there's an awful lot you can do. ■

SECURE PERSONAL COMMUNICATIONS ON THE BATTLEFIELD

The gulf between the technically possible and the practical is difficult to bridge.

ADAM BADDELEY

The development of Soldier Modernization Programs (SMP) across NATO and other countries poses challenges — not only through the extension of voice and data communications down to each infantryman, but the parallel need to define the level of security required to protect the information sent.

Communications security for individual soldiers cannot be addressed in a vacuum. The level of security needed has consequences at all levels of design. At a systems level it is important in terms of power and weight; doctrinally in terms of what level of interoperability is desired and at which echelon of command; procedurally in terms of the physical security of the device; and programmatically in terms of the individual cost which is multiplied by the tens of thousands of systems required.

Norway's NORMANS is one of several soldier communications programs proceeding internationally. Norwegian MoD photo

"On the one hand we all want secure communications throughout, but in practical and operational ways it makes things very difficult," stated Lieutenant Colonel Koos Meijer (Ret.), the recently retired former head of the Netherlands D2S2 SMP and Deputy Chairman, Topical Group 1 Soldier Systems Interoperability, NATO Army Armaments Group, responsible for the Alliance's work on the area and now head of the Elkoom Consultancy (Nunspeet, The Netherlands), outlining the balance that must be found between competing requirements.

TECHNICALLY 'DOABLE,' PRACTICALLY NOT

Two factors drive security classification: the status of the network that is being accessed and the classification of equipment that each soldier is cleared to carry. Today's individual Personal Role Radios (PRR) — a relatively new class of radio — are almost exclusively voice with limited security and range. As soldier systems begin to gain more intelligence and data, particularly location and basic messaging, then the information becomes more important and requires greater security. As a consequence, the complexity of the PRR-type radios and their cost will rise. However, for horizontal communications such at the lowest level, according to Richard Ransford, Systems Engineering Manager, Vehicle and Soldier Systems at Thales UK (Weybridge UK), "you do not need to go


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▲ *The H4855 Personal Role Radio began life as a voice solution using spread spectrum technology rather than encryption for security. As it develops its inherent data capability this is being increased by the addition of AES encryption for the SMP role.* Selenia Communications photo

up to a JTRS-style radio for communications at the section level."

For vertical communications, however, when sending aggregated section data upwards from platoon and company level or when connecting to larger secure networks to access battlefield CIS, the radio will need to have encryption and protection which is compatible with these larger networks. Discussions are underway throughout NATO on determining the level of encryption necessary for this information to leave the network to be then passed via the section leader's node to individual section members and the associated security needed to make this possible.

The security models that are implemented for high-level US Type 1 or UK High Grade Product hand-held and manpack Combat Net Radios (CNR) are inappropriate for such low level communications. "At the moment if I give a soldier a radio with a fully encrypted system, he has to be more secure with that radio than he is with his personal weapon. That is the problem," explained Colonel Meijer.

Further issues arise with the use of encryption keys. Colonel Meijer explained that although over the air solutions solve some of the encryption key issues, the associated physical security imposes unwanted rigidity on any solution and its implementation: "Each soldier has to be very secure. He has to carry the radio at all times. In order to operate crypto, you need crypto keys and the question arises as to who 'owns' these keys and where they are. In operations, unfortunately, you can guarantee they will not be where you need them to be when a change of crypto is required. The issue for SMPs now is whether they can solve those problems. I believe we can, but it will take time and mean the systems will be less flexible than the users believe they need." Col. Meijer noted that the addition of high level crypto also adds to the radio's weight and power consumption and at the same time decreases the bandwidth throughput possible in protected ECCM modes. This requires the radio to spend more time transmitting and thus drains the batteries more frequently, leading to the need for more batteries or more frequent recharge. All this has the effect of placing greater burdens on the individual soldiers and impacting on their ability to fight.

SECURITY TODAY

There are no easy answers and although prototype and pre-production SMP solutions exist and have seen some limited fielding, no absolute solutions to the problem have been produced. The most successful of the current radios is the Selenia Communications (Chelmsford, UK) H4855 Personal Role Radio. Over 100,000 sets have been sold to customers including the UK, USMC and USAF. There are 24 countries in total using the sets, with national differences limited to differences in connectors for headsets or the color of the radios.

The PRR has no encryption. Despite this, effective security has been achieved via several other approaches giving a layered solution that also points to methods that may be adopted by others in the near future. Firstly, the information sent in voice only is transient, according to Alan Heritage, Business Manager at Selenia Communications, offering little or no tactical benefit to an eavesdropping enemy. Secondly, the range is limited — 500 m in clear space but only 150 m in urban terrain or multi-story buildings — making it difficult to detect from a distance. This low range is coupled with low output, resulting in each PRR needing just two primary cell AA batteries for 24 hours of operation. Thirdly, the solution uses spread spectrum technology, which enables the transmission of wideband, noise-like signals which are widely used in the civil sector. These signals are hard to detect, intercept or demodulate and are harder to jam than their narrowband counterparts. These factors result in an effectively secure radio at reduced cost, so much so that the British Army acquired 45,000 items in 2001 in a contract worth approximately $36.5 M.

When discussing which programs are exploring this technology, Richard Ransford stated, "Spread spectrum technology allows you to disappear into the background noise and it lends itself very nicely to the 'front end' because the enemy cannot see you coming. It is very difficult to detect in the particular areas of the spectrum used to find information and so it is fairly difficult to spot. It is a good way forward."

Selenia Communications is now preparing a longer-range data capable version of the PRR to meet the requirement of SMP. This will be equipped with commercial 128-bit AES encryption with longer range and with moderate data throughput sufficient for section level situational awareness and low power consumption.

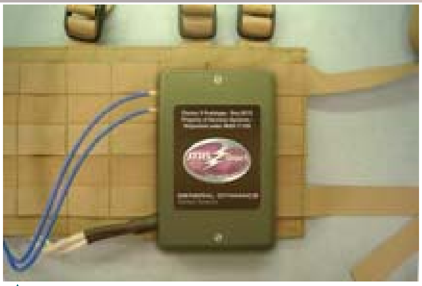
Other solutions competing in this nascent SMP oriented market are Thales' Soldier Advanced Radio (already in service with the Bundeswehr and deployed unencrypted) and the Tadiran Communications (Holon, Israel) PNR-500, which has adopted similar approaches. However, a key difference is the auto-synchronization feature of the PNR-500, which replaces the need for a nominated master station in 'PRR' networks.

Tadiran Communications is also allowing security options in its CNR range to enable greater bandwidth. The new CNR 9000 High Data Rate radio enables the user to switch between a standard 64 kbps CNR capability using an encrypted frequency hopping waveform, to a 115 kbps encrypted rate over a 25 kHz narrowband VHF/FM channel, thus better enabling ISR throughput at the manpack level for SMPs and others.

The US answer to the problems of security and low-level communica-

Land Warrior is addressing the issue of soldier security balancing the need to provide soldiers with a usable solution for mass use in the field that is certified to take information generated by higher-level systems. US DoD photo

tions has been to a large extent the Soldier Radio Waveform (SRW) being developed by DARPA and ITT under the Soldier Level Integrated Communications Environment program. This will be the dominant waveform for dismounted soldiers equipped with JTRS Cluster 5 radios. The SRW is designed from scratch to be a power



The Embedded SFF variants within JTRS Cluster 5 will use both NSA and lower grade NIST security depending on the radio variant's role in Land Warrior. General Dynamics photo

efficient and jam-resistant, agile network waveform providing both communications and geo-location information within difficult terrain. Equipped with four distinct nodes, data rates differ according to mode and circumstance. In Combat Communication Mode, burst rates at a 1.2 MHz allocation begin at 900 kbps rising to 2.4 Mbps, while at 4 MHz, these rise to 8 Mbps. In EW and LPD/LPI mode these are much less, ranging from 3.9 kbps to 187.5 kbps and 3.9 kbps to 46.9 kbps at 1.2 MHz, respectively. According to the prevailing security circumstance the SRW will adapt to deliver the best balance of bandwidth and security to deal with either a future peer competitor or urban insurgent.

While the SRW will provide some security, encryption will be determined by other means. Differing levels of security are manifest in the Land Warrior designs. The Cluster 5 'Leader' and 'Soldier' embedded radios operate the same five waveforms, but while the 'soldier radio' will support National Institute of Standards security, the Leader radio will have higher National Security Agency encryption.

Unique amongst SMPs, the US is providing all its Land Warrior ensembles with SATCOM, illustrating the 'foxhole to Pentagon' reach of the Global Information Grid and associated security requirements. All the Small Form Factor embedded communications — SFF B and C — for Land Warrior will support Mobile User Objective System UHF SATCOM when that comes on-line in 2010. In the meantime they will be able to operate with the

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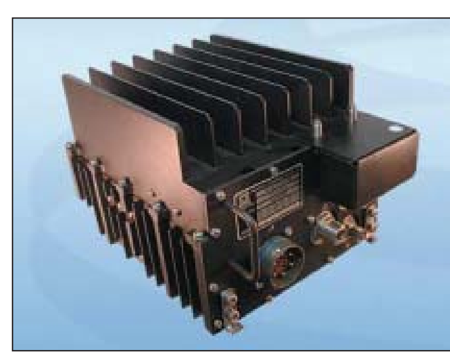

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181-3 DAMA SATCOM. The hand-held JTRS Cluster 5 radios have the Objective requirement for Mobile Satellite Services. With access to this Beyond Line Of Sight capability, low-level security is simply not an option.

BLUETOOTH ON THE BATTLEFIELD

Bluetooth solutions on an individual soldier level are being explored, not to link soldiers together but as a means to interconnect disparate pieces of equipment around the body. For this technology the term 'secure' not only means protected against eavesdropping or jamming but able to function in all environmental circumstances.

Power is a key limiting factor for wireless — while voice and data can be sent over the air, power cannot. It is not, however, the only factor. "There are some big health question marks around the effect of having wireless connections so close to the body and these are being studied," stated Colonel Meijer.

A wireless solution would be the optimum solution. Each cable that can be eliminated enables less restricted movement. Issues remain, however, on whether multiple wireless connections could cause interference and whether environmental conditions will impact performance. Independent of whether Bluetooth will work is the issue of the power consumption and power distribution. Power cannot be transferred to a device other than by physical connection. If a connection between a torso-mounted central power unit and the device itself, such as a hand-held computer, has to be wired anyway, the benefits of having a wireless system to exchange information round the soldier are cancelled out. If the external power source is eliminated then instead a battery has to be installed on the device. Such a policy writ large would see multiple battery types, one for each type of device, each requiring daily recharging, multiplied by several thousand soldiers — this obviously poses massive logistic challenges. That is not to say such devices are not being fielded and tested. The Dutch have examined a Bluetooth connection to link a wristwatch to a wider communication system. The watch vibrated in different ways to communicate high importance messages that needed to be widely disseminated such as incoming artillery or NBC attack. Germany's IdZ program has fielded a Bluetooth solution to link its NavIPad situation awareness display to the body mounted communications package. Sagem, leading France's FELIN program, has established a parallel solution to link the FAMAS assault rifle to body worn systems. While being carried, a wired connector links weapon and power sources enabling the central battery to power the system and charge the on board battery. In combat this connection can be pulled out and the battery on the weapon itself powers its functionality until reconnection. Looking further a field there are other commercial solutions. Tadiran Communications 'Radioos 100' allows multiple users to access a single CNR via a Bluetooth connection over 20 m via a headset.

Initially, Bluetooth applications appear to be limited. Steve Turner, VP

MILITARY MICROWAVES

Vehicle and Soldier Systems, Thales UK, gave his opinion on UK adoption of these systems. "During the FIST functionality trials in 2004, we leaned more toward wired rather than wireless. We might have a Bluetooth node on FIST, but the current configuration for what looks to be the in service capability for FIST looks like being wired gives us a better chance of managing the overall power budget."

INTEROPERABILITY

The security challenges of sharing information between section leaders and their units pale into insignificance compared to the security concerns for international interoperability. The interoperability picture is mixed and is currently quite limited. A desire to extend this interoperability imposes further restrictions. Interoperability amongst national CNRs is limited to either fixed frequency and unencrypted or in some cases the addition of an external crypto such as that demonstrated with Bowman VHF ADR+ plus the US KY99 module which can be achieved for a limited number of radios.

Further and deeper US-UK interoperability via Bowman-JTRS is now being explored. This will see roughly half of the UK's Bowman VHF modes having encryption and ECCM protocols embedded in a US JTRS radio. This process will start with Cluster 1 thanks to its use of the Sierra II software defined encryption chip. The UK security protocols embedded in the Cluster 1 radio will enable US radios to join UK networks rather than vice versa in a warfighting environment.

When fully implemented, communications routed from a British soldier equipped with today's PRR or the FIST communications solution would be able, via a Bowman VHF radio, to communicate with dismounted JTRS forces when Cluster 5 becomes available. Commonality is one way to go at this level for interoperability. The USMC in Iraq selected the PRR, as it would provide immediately interoperability with British and other users. Each PRR supports 16 groups of 16-networked users — 256 difference combinations — deliberately designed to provide a company-sized formation PRR communications system without interference. As there is no encryption of frequency hopping in each radio, a British, US Marine, Kuwaiti or Saudi soldier could form a network or join another simply by switching to the correct grouping.

Again, however, doctrinal and other issues nix technical possibilities. The UK's FIST studies concluded that interoperability is best achieved at the company level. According to Steve Turner, "There are doctrinal issues to making interoperability possible at lower levels. From a command structure perspective you do not want a section leader doing something with another section leader without going through the chain of command. The company level is where the exchange of information between nations or different companies should take place."

The ability to deliver security is not just a matter of technical solutions. It impacts on a wide range of other factors in SMP design and is unique to the dismounted soldier. Compromise and cooperation are not normally terms associated with information security but countries are increasingly turning to non-traditional but effective solutions to equip SMPs. ■

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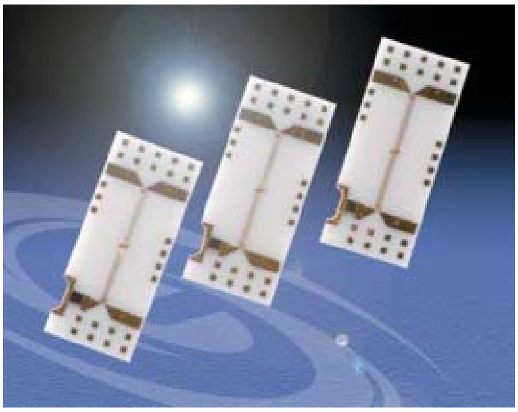
INNOVATIVE THIN FILM TECHNIQUES TO ELIMINATE FAULTY WIRE BONDS AND IMPROVE HIGH FREQUENCY CIRCUIT DENSITIES



ULTRASOURCE INC.
Hollis, NH

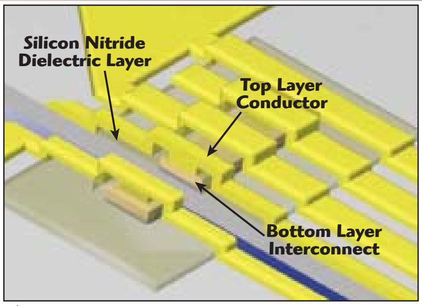
Thin film interconnects are a standard circuit technology used in high frequency design components and subsystems where transmission line widths of .005" and under are critical to performance as well as high power applications where thermal conductivity is of concern and materials such as beryllium oxide and aluminum nitride must be considered. This unique technology is employed in a variety of military and homeland security platforms from radar to EW and counter-measure applications, to missile and armament receivers and sensors.

Thin film is traditionally recognized as a single plane technology, where design engineers typically use wire bonds with eutectic solder or conductive epoxies to create interconnects from thin film circuits to various passive and active components and semiconductor devices in their systems. Engineers also use air bridges at some junctions. Although these methods are mature, and their performance over time predictable, industry sources suggest they are susceptible to failure, high assembly and tuning costs, and performance inconsistency due to the fragility of wire bonds, particularly as one considers that today's circuits have tiny bonding pads and require very short bond loops, and that it usually takes an operator with special skills to make those wire bonds. This is especially true of the center wire bonds.

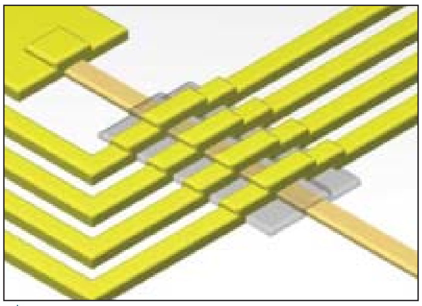
Another limitation of traditional thin film approaches is that until recently, the only additional passive element that could be cost effectively integrated on thin film was a resistor. However, a novel approach to designing and manufacturing with thin film has been

microwave JOURNAL Previous Page | Contents | Zoom In | Zoom Out | Front Cover | Search Issue | Next Page qMags


A new reality.

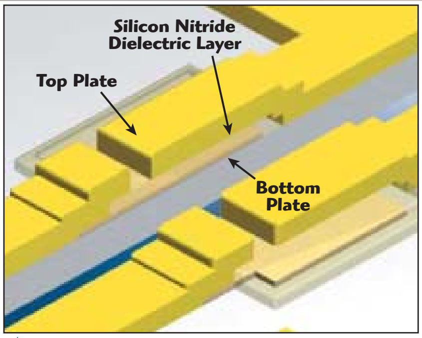


▲ *Fig. 1 UltraBridge™ layers.*



▲ *Fig. 2 The UltraInductor™*

developed to reshape the way microwave engineers employ it, and give them much needed improvements in reliability, repeatability and density.



▲ *Fig. 3 The UltraCapacitor™*

Modifying techniques traditionally reserved for costly MMIC fabrication, UltraSource has perfected a unique thin film multi-layering approach that has proven to provide repeatable, wire bond-less, cross-under bridges, and has allowed for further integration of not only resistors, but also inductors, capacitors and other circuit functions onto a single thin film substrate.

ULTRABRIDGE™

The key innovation from UltraSource is its UltraBridge technology. By eliminating the need for a wire bond, or an air bridge, this consistent, reliable, cost-effective solution is destined to become an important tool for circuit designers at high frequencies.

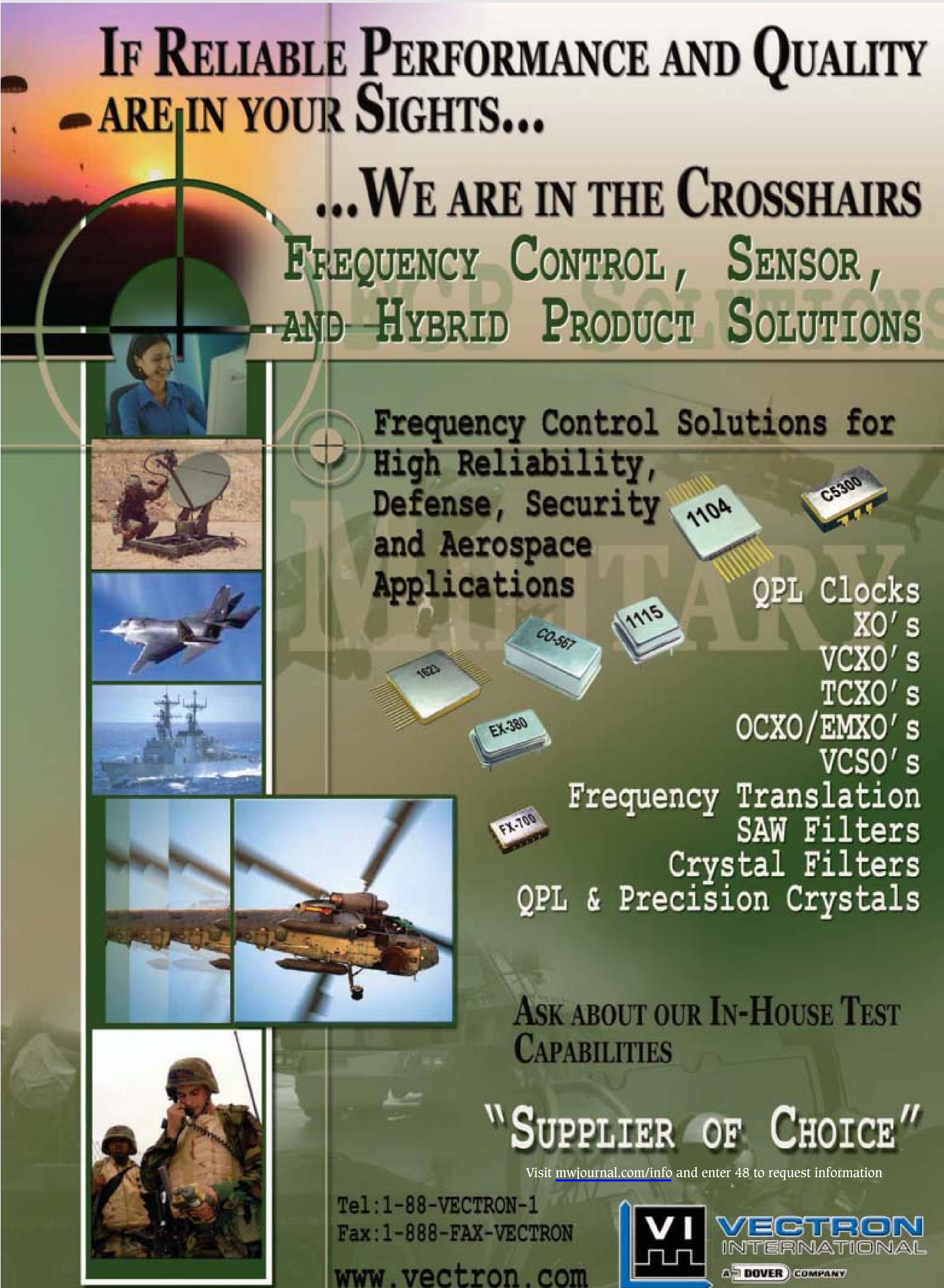
In this process, the interconnect conductor layer is applied and patterned right on the substrate surface as an under bridge. This is where this technique varies from an air bridge process, which applies the interconnect layer after the thin film conductor layer is complete. Next, silicon nitride (Si_3N_4) is applied over the interconnect layer to encapsulate it and to insulate it from the next metal layer. The silicon nitride features are then patterned and etched. Contact windows to the interconnect conductor are also made during the pattern and etch of the silicon nitride. Finally, the conventional thin film conductor and resistor layers are applied using standard techniques and processes. The result is a simple, cost-effective method for fabricating high frequency interconnects for Lange couplers, integrated capacitors and integrated spiral inductors.

The UltraBridge technique also reduces the number of mask steps by 30 percent over air bridges, resulting in reduced design complexity and increased reliability. The hardness of the silicon nitride creates a robust interconnect design unaffected by accidental compression during inspection or assembly. ***Figure 1*** shows a sample of UltraBridge layers.

IMPROVING DENSITY WITH THIN FILM INTEGRATION

Until now, the only element available for integration into complex RF and microwave thin film interconnects has been the thin film resistor. This is facilitated by a layer of resistive metallization of either nichrome or tantalum nitride in a predetermined sheet resistivity and etched or laser trimmed to the value and tolerance required by the design.

As the next step to complete integration of all passive elements into a single thin film circuit, the UltraInductor™ and UltraCapacitor™ have been introduced. UltraInductor technology uses the silicon nitride in the same configuration used for the UltraBridge to facilitate interconnects with the center tap co-located on the circuit with other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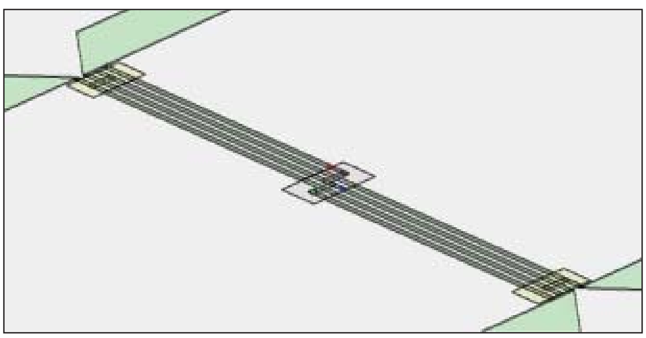
critical components, minimizing the parasitic components and variability. ***Figure 2*** shows an example of an UltraInductor.

The UltraCapacitor, shown in ***Figure 3***, uses the same process steps as the UltraBridge and UltraInductor and offers the designer the ability to integrate capacitors with values of 2 to 250 pF right onto the substrate. Silicon nitride is the ideal dielectric for this application with the thickness of the silicon nitride controlling the capacitance density of the dielectric, lending to flexibility in the capacitor layout.



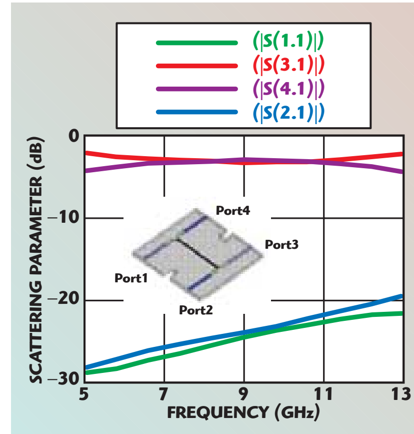
▲ *Fig. 4 HFSS model of a Lange coupler.*

A LANGE COUPLER APPLICATION EXAMPLE

UltraSource's approach has been successfully employed in the design and fabrication of Lange couplers, offering layout of line widths and spaces as precise as 0.0004" (10 µm) and controlled to tolerances of 1.5 µm.

Lange couplers are common circuits used in microwave applications. They provide equal power division and 90° of phase shift between the coupled ports. They are widely used as power combiners and splitters in microwave amplifiers and mixers/modulators. They are based upon interdigitated lines with narrow lines and tight spaces.

Figure 4 shows an HFSS model of a Lange coupler fabricated using the UltraBridge technology. Note how there are no wire bonds. The connections between fingers of the coupler are made by the metal traces, which are isolated from the fingers. This creates a highly reliable connection. Another benefit is that the connection is very repeatable. This is important for obtaining repeatable performance from circuits such as balanced amplifiers and modulators.



▲ *Fig. 5 HFSS simulated performance of the coupler.*

The circuit was modeled in HFSS and the predicted performance is shown in ***Figure 5***. Note how insertion loss is nearly the ideal 3 dB value. Also, the return loss and isolation are very good. The performance goal is 7 to 11 GHz with an equal power split. This was easily obtained with good electrical match and isolation. Lange couplers provide a simple example of the varied potential for employing multilayer thin film techniques in next generation high frequency designs.

GETTING STARTED

UltraTechnology should be looked at for advanced interconnect designs which would benefit from combining microstrip transmission lines, filled vias, resistors, capacitors, spiral inductors, under-bridges, and selectively deposited gold-tin all on a single substrate device.

To begin the design process using UltraTechnology, a designer should talk to the factory to decide on the level of integration desired and to procure design assistance on high frequency models. Additional information may be obtained by e-mailing Robert St. Pierre at rstpierre@ultrasource.com. ■

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

RS No. 306

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Previous Page | Contents | Zoom In | Zoom Out | Front Cover | Search Issue | Next Page


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A Combined Naval RESM, ELINT, CESM, COMINT and SIGINT System

MRCM GmbH
Ulm, Germany

To efficiently deal with modern day threats, the commander of a naval vessel requires a system that will provide him a highly effective communications and radar threat profile in near real-time. Even better, of course, is if that system can also provide automatic surveillance, together with operational flexibility leading to the reduction of the work of intelligence operators and ease of installation all on one mast. That is just what the MAIGRET S 5800 combined naval RESM, ELINT, CESM, COMINT and SIGINT system can deliver.

This system combines RADAR ESM and COMMS ESM inputs in the frequency range of 10 kHz to 40 GHz, with the radar and communications signal data intelligence information being fused into a single tactical EW database. With this data, an overview of the tactical situation can be shown on a tactical polar display and/or a map display. Also, special automatic threat warning filters are implemented to classify the signals into threat categories. The consequence of the action of these filters is that the load of the intelligence operator is dramatically reduced, effectively making the system an automatic surveillance system.

DATA RECORDING AND ANALYSIS

All collected data can be recorded and a shore-based, post mission analysis tool is available for analyzing offline the data recorded from different vessels. As was mentioned earlier, the system also has the capability of providing extended roles, such as electronic

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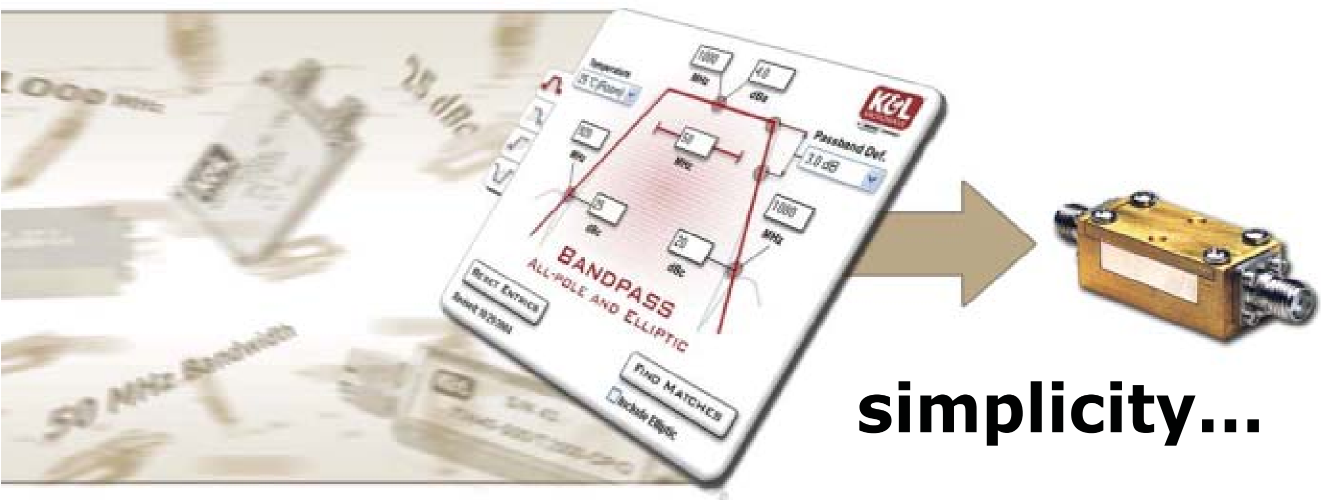

Designing a communications network, RF sub-assembly or military system requires finding and integrating components offering the highest quality, advanced features and competitive pricing.

K&L Microwave understands that each application is unique. To simplify your search, we've provided Filter Wizard™, an online tool that places response graphs, outline drawings and downloadable s-parameters at your fingertips.

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Fig. 1 Combined antenna array for radar and COMMS signals.

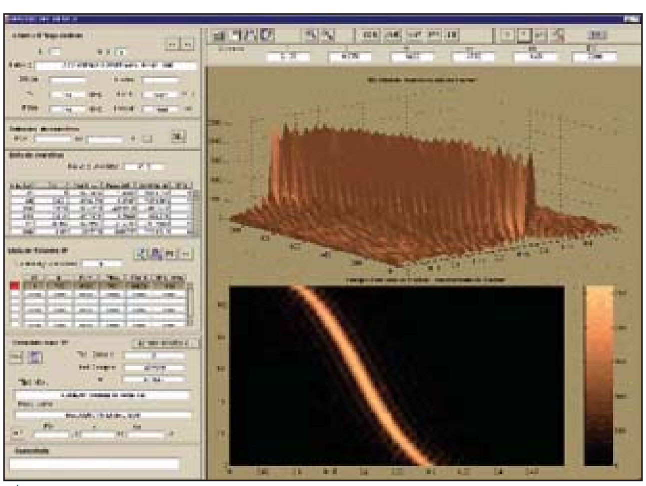

Fig. 2 Intra-pulse analysis display for the ELINT module.

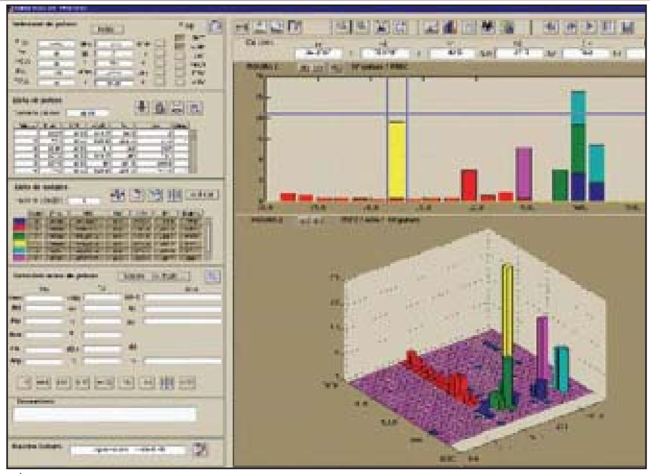

Fig. 3 Pulse train analysis display for the ELINT module.

intelligence (ELINT), communications intelligence (COMINT) and signal intelligence (SIGINT). It is a wideband digital reception technique, which is the core of the RESM that enables it to double as an ELINT system.

Taking COMMS ESM and RADAR ESM in turn, the former has a frequency range of 10 kHz to 3000 MHz, features azimuth selective wideband search and occupancy detection, and digital map display. The frequency range of the RADAR ESM, however, extends from 2 to 18 GHz with the capability of extending it to as low as 0.5 GHz and as high as 40 GHz. For this purpose MAIGRET S 5800 offers a one-mast antenna solution with an outstanding sensitivity and bearing accuracy. ***Figure 1*** shows the combined antenna array for radar and COMMS signals. Other key capabilities include automatic emitter activity detection, data reduction by emitter tracking, automatic emitter-type classification, manual signal analysis and the tracking of 512 emitters simultaneously.

The system has an ELINT capability mode with high sensitivity (better than –80 dBm), extensive data collection, including intrapulse parameters and no degradation of wideband characteristics while collecting ELINT data. To illustrate the operation, ***Figure 2*** shows an intrapulse analysis display for the ELINT module and ***Figure 3*** the pulse train analysis display for the same module.

FUTURE PROOFED

Other features include a software structure that enables the system's operation to be managed from the Multi-function Console (MFC) of the dedicated operation consoles. The system uses state-of-the-art, new generation (wideband) technology and significantly provides functional upgrades for new signals and future threats. Another important attribute is the capability to interface with many combat systems and customer databases, making the system easily adaptable to the specific needs of the customer.

As well as meeting the essential operational criteria, the system has also been designed to meet the physical demands of installation on naval vessels. The antenna is completely operationally proven for the naval environment and the basic version is installed in a standard 19 inch rack. This makes it ideally suited to compact vessels and submarines and easy to install, both for new build and retrofitting.

CONCLUSION

The MAIGRET S 5800 system offers the operational capability and flexibility required by the modern navy. It delivers a one-mast antenna solution providing automatic surveillance, flexible and comprehensive operation, together with ease of installation even in the most restricting and demanding naval environments. ■

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www.mrcm.net.

RS No. 302

A Small 4 GHz Antenna Suitable for Military Applications

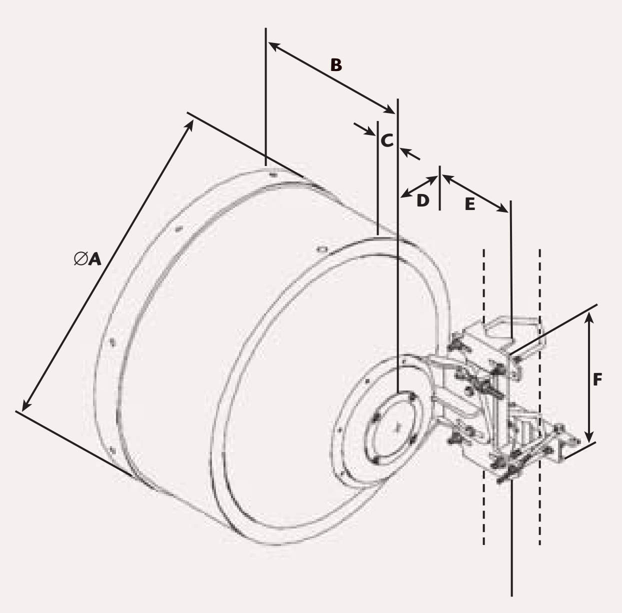
Radio Frequency Systems
Hannover, Germany

With the increasing volume of data that government authorities and the military have to handle, it is becoming more and more important to have high speed connection for short as well as long haul ranges. Combined with the fact that in many countries the 4 GHz frequency band is reserved for government authorities and military institutions, it is understandable that RFS has developed a small antenna to fill the gap in its product portfolio for the short haul range – the 2 ft. diameter, SB2-44AN CompactLine antenna, which is the first available in the range below 6 GHz.

The antenna's development took into consideration that wireless radio links are very efficient because they are more flexible to install and require less attention than fixed wired connections. In general, their availability is also greater, which is very important for applications such as fire departments and police stations. As for military applications, it is important for an antenna to be lightweight, rugged and resistant to mechanical loading, as well as being easy to install, especially if it is used for mobile operations.

MAIN FEATURES

The technical features of this ultra high performance antenna are broad: the low band gain is approximately 25.6 dBi, the mid-band gain, 26.6 dBi and the high band gain,



2 ft mount outline (all dimensions in mm)

∅A	B	C	D ∅114	D ∅51	E	F
700	289	114	273	231	63	350

▲ *Fig. 1 The SB2-44AN antenna's compact dimensions.*

27.6 dBi. The azimuth fine adjustment and the polarization adjustment are each of the order of ±5°, while the elevation adjustment is approximately ±15°. The mounting pipe diameter ranges from a minimum of 51 mm to a maximum of 114 mm. Also, the survival wind speed averages 250 kph (156 mph) and the operational wind speed 230 kph (143 mph).

To make the antenna as adaptable as possible, it is offered with two different interfaces. The SB2-44AN has a female N-connector to connect a coaxial foam cable, which, due to its flexibility, is the preferred solution for military mobile operations. For fixed point-to-point applications, with longer cable runs between active equipment and antenna, an elliptical waveguide is preferred because of the lower attenuation in comparison to a coaxial cable. Therefore, the SB2-44AD antenna has an integrated waveguide flange IEC 154 PDR-48 and is the perfect solution in combination with the company's Flexwell waveguide.

PROPERTIES

What are the main practical advantages of this new antenna? First, the use of the Cassegrain principle for the feed system minimizes the deviation caused by the metallic waveguide in the radiation area. The antenna is shielded to achieve high side lobe suppression and is covered by a rigid plastic radome, which protects the antenna feeder from external influences. The use of a special aluminum alloy and stainless steel hardware for all the mounting parts also makes the antenna resistant to corrosion. In addition, the weight and size reductions are significant (see ***Figure 1***) as the load on the tower is decreased, resulting in less, and thus lower cost, steelwork. Freight costs are reduced as well.

AESTHETICS

Color is not something that would immediately come to mind when considering antennas, but RFS receives requests for advice about refinishing weathered antenna radomes or changing the radome color for aesthetic or non-aesthetic reasons such as camouflage. Any paint selection should be compatible with the radome materials and not interfere with the antenna's electrical performance. However, there are two primary considerations regarding the choice of paint. The first one is adhesion, since a variety of radome materials are used in the antenna construction and consequently the surface texture will vary (some paints having the best durability may be dangerous to work with and require an EPA-qualified application facility). Preparation is important and all surface contamination must be removed. The second one is the choice of pigment. RF transparency is crucial, so conductive coloring materials such as carbonblack, lead and metallic powders cannot be used. Lighter colors are preferred where practical, to reduce internal temperature extremes which could occur on hot, sunny days. Whatever its color, the SB2-44AN has a low visual impact and simplifies getting authorization for its installation, which can be an important consideration.

CONCLUSION

To meet the demand for short haul connections and for fixed point-to-point applications, the CompactLine SB2-44AN is the ideal solution because of its small size and lightweight, combined with excellent electrical performance and low visual impact. It operates at frequencies in the 4 GHz frequency band, which, in many countries, is reserved for government authorities and military institutions. This antenna also offers a compact form factor and unrivalled side lobe suppression – a vital attribute in today's military networks. ■

Radio Frequency Systems,
Hannover, Germany,
+49 (0) 511 676 2731, www.rfsworld.com.

RS No. 303

NEW LIGHTWEIGHT CABLE ASSEMBLIES FOR HIGH PERFORMANCE AIRBORNE APPLICATIONS

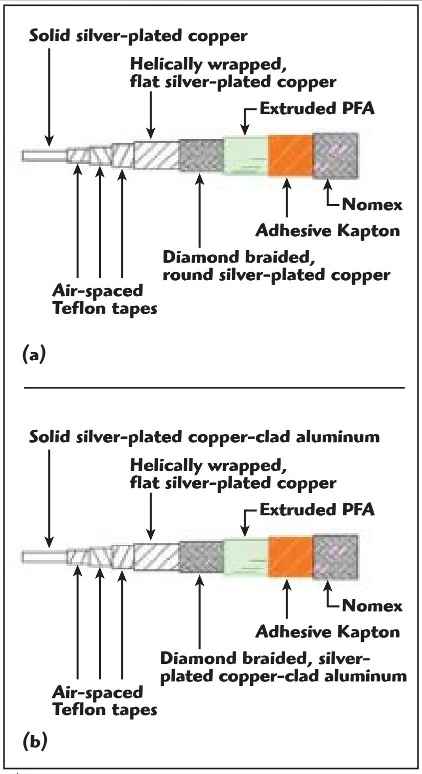
M/A-COM INC.
Lowell, MA

M/A-COM is now offering new lightweight cable assemblies utilizing the FN34RXLW cable, a lightweight version of its proven FN34RX cable assemblies. This new product offering is intended for use in high performance military airborne applications. All popular assembly configurations are readily available with reduced mass at competitive prices. Weight reductions of over 30 percent are available compared to traditional cable designs.

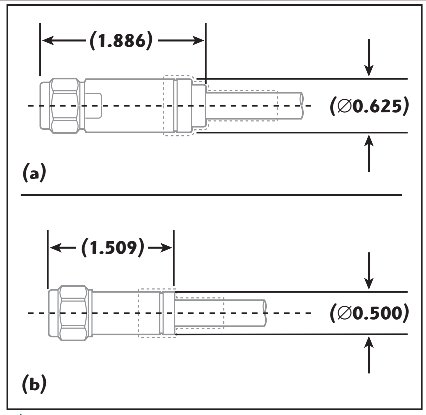
The FN34RX assembly is a DC to 18 GHz, 0.34" diameter cable, operational at temperatures up to +200°C and used for electronic warfare and other special purpose applications. The new, reduced weight version FN34RXLW, using a silver-plated copper-clad aluminum center conductor and a silver-plated aluminum shielding, exhibits a greater than 32 percent weight reduction with no impact on performance. ***Figure 1*** compares the construction of these two cables showing the difference in materials; other FN-RX assemblies can also be provided in lightweight versions.

Complementing the lighter FN34RXLW cable, all assemblies now feature new, reduced weight and volume connectors. The connectors retain the conventional ETNC, SMA and N interfaces while incorporating new materials. Excess bulk has been excluded to decrease both weight and space. ***Figure 2*** compares the traditional and reduced weight ETNC male, non-replaceable connectors showing the reduction in material used in their fabrication. Cables are available with ETNC, SMA, N, or other connector interfaces, and all incorporate new materials and have excess material removed to save weight. ***Table 1*** compares the weights of a 10 ft. cable assembly with traditional ETNC plug NR connectors and FN34RX cable to that of the lightweight FN34RXLW cable and redesigned ETNC plug NR connectors.

The electrical specifications for assemblies based on the new lightweight cable and connectors remain unchanged. In particular, there is no change in VSWR or insertion loss. ***Figure 3*** shows that the insertion loss speci-



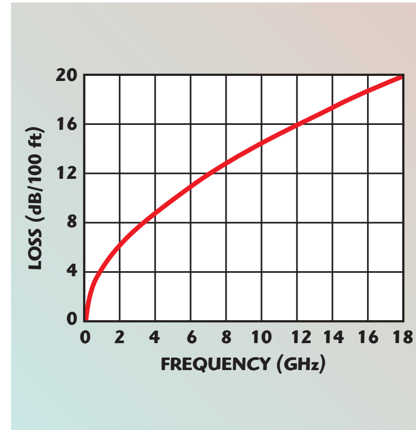
▲ *Fig. 1 Cable construction details; (a) standard cable FN-RX and (b) reduced weight FN-RXLW cable.*



▲ *Fig. 2 ETNC plug NR connector; (a) standard FN34RX and (b) lightweight FN34RXLW.*

TABLE I
WEIGHT COMPARISON OF TWO 10 FEET LONG CABLE ASSEMBLIES

	FN34RX	*FN34RXLW*
Cable (lbs)	1.01	0.71
Connectors (lbs)	0.20	0.11
Assembly (lbs)	1.21	0.82
Weight savings (%)	reference	32



▲ *Fig. 3 Insertion loss at 25°C for the two cables, FN34RXLW and FN34RX.*

fication is valid for both cable types. Similarly, the environmental characteristics remain unchanged. The lightweight assemblies can withstand the same harsh environment as the traditional assemblies. This includes altitudes from ground level to over 70,000 feet and temperatures from –55° to +200°C.

The mechanical characteristics of the lightweight cable assemblies are similar to those of the existing assemblies. The minimum bend radius remains the same. There is approximately a 10 percent reduction in the number of flexure cycles the cable can withstand; however, this is not significant for most applications, including fixed airborne applications.

The lightweight cables are highly recommended for all airborne applications including UAVs. In commercial applications, the weight savings translates into improved fuel efficiency or increased cargo capacity. In military applications, the reduced weight enables improved flight characteristics or provides margin for the inclusion of additional systems or armament.

In summary, M/A-COM has developed a line of lightweight cable assemblies that are over 30 percent less in weight compared to traditional designs. This is accomplished by using different construction materials in the cable assembly and reduced weight connector designs. The lightweight cables are ideal for use in airborne applications without sacrificing performance. ■

M/A-COM Inc.,
Lowell, MA (800) 366-2266,
www.macom.com.

RS No. 304

MILITARY MICROWAVES

Literature Showcase

Open CD-ROM

This CD-ROM contains the company's latest Open tools, application information, new product demos, articles, the System Development World-Wide Seminar presentations and LXI information to help simplify test-system development. The catalog also features system components and how they can be easily integrated into specific system solutions.

Agilent Technologies Inc., Palo Alto, CA (800) 829-4444, www.agilent.com.

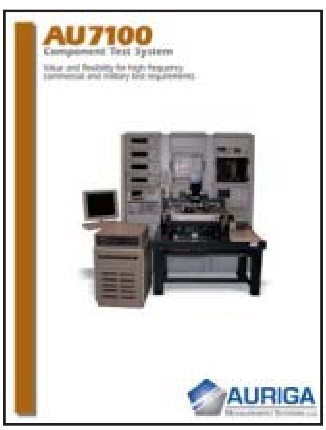
RS No. 322

Product Catalog

This catalog on CD-ROM features the company's design, manufacture and supply of communications equipment, services and systems. A comprehensive reference source of product specifications and data sheets for satellite broadband (VSAT), earth station antennas, electronics and accessories are also included.

Andrew Corp., Orland Park, IL (800) 255-1479, www.andrew.com.

RS No. 323



Product Brochure

This product brochure features the company's three product families for RF, microwave and millimeter-wave test solutions. It includes active/passive device modeling, parameter extraction, noise parameter and power characterization test systems, DC and RF pulsed IV test systems, load-pull and noise parameter test systems, on-wafer test, solid-state and mechanical tuners, custom manufacturing test systems, T/R modules, multi-state modules and components.

Auriga Measurement Systems LLC, Lowell, MA (978) 441-1117, www.auriga-ms.com.

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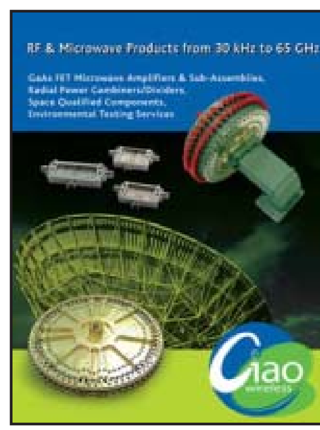

Product Catalog

This catalog details the company's design and manufacture of RF and microwave FET amplifiers from 10 MHz to 30 GHz. The company offers one to two week ARO delivery for most amplifiers, whether custom or from the catalog/Web site. Amplifier types include: low noise (as low as 0.35 dB); medium power (up to 5 W); broadband (2 to 18 GHz, 6 to 18 GHz) and narrowband/radar band amps. The company's newest product offerings include low frequency, high IP3/IP2 amplifiers.

Ciao Wireless Inc., Camarillo, CA (805) 389-3224, www.ciaowireless.com.

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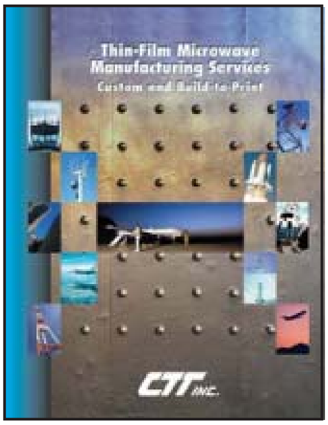

Product Brochure

This brochure highlights the company's new thin-film microwave manufacturing services including custom and build-to-print. CTT's facility was specifically designed to accommodate the unique requirements of hybrid microwave integrated circuit manufacturing conforming to MIL-PRF-38534C. The company has developed an automated and optimized thin-film hybrid manufacturing process especially suited to the production of microwave integrated circuits using chip and wire bond techniques.

CTT Inc., Sunnyvale, CA (408) 541-0596, www.cttinc.com.

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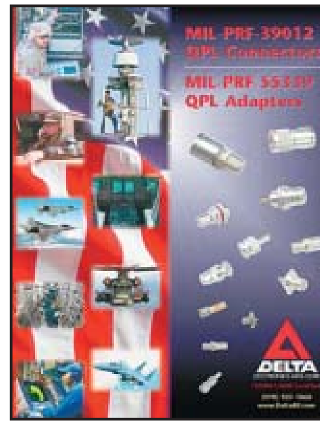


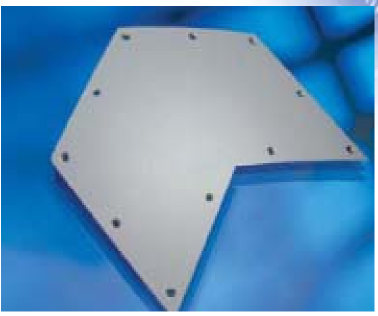
Product Brochure

This brochure presents the company's recently-expanded line of MIL-PRF-39012 QPL connectors and MIL-PRF-55339 adapters. This line now includes over 220 QPL configurations in the BNC, N, SMA and TNC series. The M39012 QPL connectors are available in a wide range of cable connector configurations with clamp, crimp and solder type cable attachments, as well as bulkhead- and panel-mounted receptacles. The company's M55339 QPL adapters include with- and between-series types in BNC and N interfaces.

Delta Electronics Manufacturing Corp., Beverly, MA (978) 927-1060, www.deltarf.com.

RS No. 327


M/A-COM



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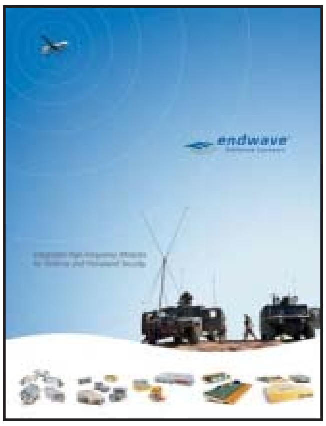

Defense Systems Brochure

As defense and homeland security systems move up in frequency and down in budget, companies turn to Endwave Defense Systems. Advanced technology, quick time-to-market, and consistent, high quality manufacturing are the hallmarks of the company's business philosophy. The brochure features its library of circuit building blocks that can customize nearly any integrated assembly imaginable.

Endwave Defense Systems,
Sunnyvale, CA and Diamond Springs, CA (408) 522-3170, www.endwave.com.

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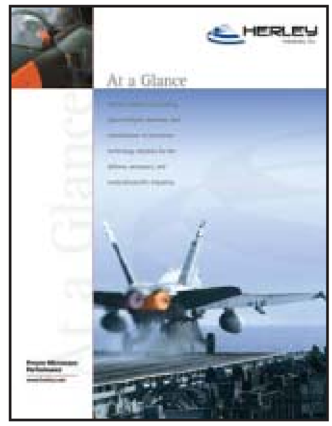


Product Catalog

This catalog displays the company's solid, innovative and sophisticated RF, microwave and millimeter-wave components and subsystems used by the defense and aerospace industries. Based in Lancaster, PA, the company has nine manufacturing facilities that offer design, development and manufacture of microwave technology solutions worldwide.

Herley Industries Inc.,
Lancaster, PA (717) 735-8117, www.herley.com.

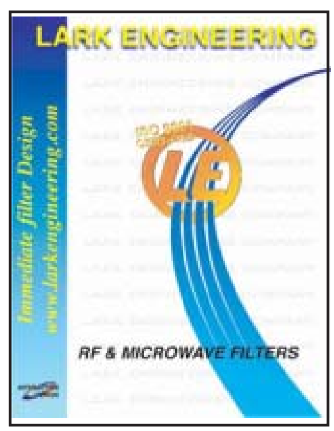
RS No. 329

Components and Subsystems Brochure

This brochure details the company's manufacture of RF and microwave filters used in defense electronics systems. The company supplies multi-function assemblies and a wide assortment of lumped component, cavity, ceramic and suspended substrate filters. This brochure features products from K&L and four other Dover Electronics companies serving military and homeland security needs.

K&L Microwave,
Salisbury, MD (410) 749-2424, www.klmicrowave.com.

RS No. 330



RF/Microwave Filters and Multiplexers Catalog

This 114-page catalog contains the company's ISO9001-certified RF and microwave filters that offer an extensive product mix with filters and multiplexers ranging from 100 kHz to 18 GHz. These products are currently being used in digital and analog wireless communications systems, test equipment and military systems. Typically, samples can be shipped within ten working days.

Lark Engineering Co.,
San Juan Capistrano, CA (949) 240-1233,
www.larkengineering.com.

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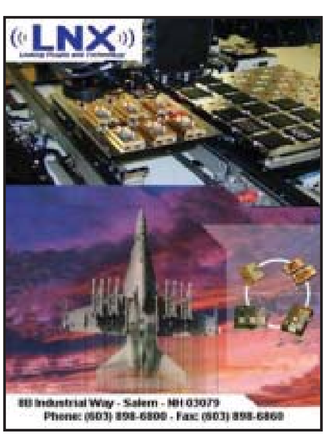

Product Catalog

This catalog features the company's design and manufacture of sophisticated defense related components and subsystems. The catalog displays microwave and digital design manufacturing from 20 MHz to 96 GHz. It utilizes and combines advanced concepts in the design and manufacturing of analog RF/microwave and digital signal processing. The catalog also highlights RF/microwave products and designs, analog and digital signal processing for EW and ECM applications, digital RF memory, and test and measurement.

LNX Corp.,
Salem, NH (603) 898-6800, www.lnxcorp.com.

RS No. 331

RF and Microwave Filter Catalog

This catalog includes the company's complete line of RF and microwave filter products. Also featured in this new edition are integrated filter assemblies, which include switched filters and filter amplifiers. Other RF products included are phase comparators, manual and digital phase shifters, voltage-controlled phase shifters, voltage-controlled attenuators and broadband mixers.

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

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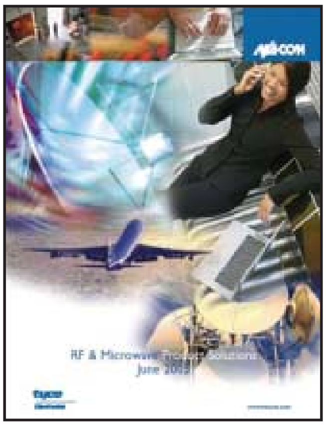

Product Solutions Guide

This product solutions guide contains information on over 1000 standard microwave and RF products. It contains parameters for each part number organized by product category. RoHS compliant products and off-the-shelf distribution products are noted for easy reference. Most standard products can be up-screened to meet defense and space applications or parts can be customized to meet certain specifications.

M/A-COM,
Lowell, MA (800) 366-2266, www.macom.com.

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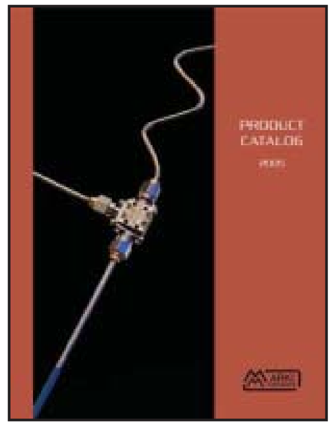

Product Catalog

This redesigned catalog features the company's standard product data sheets and useful application notes. Standard products include RF/microwave mixers, doublers, multipliers and specialty components up to 65 GHz. Outline drawings, including information about new surface-mount packaging technology and performance specifications are provided for each component.

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

RS No. 334

Product Data Sheet

This data sheet features the company's new low cost Schottky ring quads. The MFA series ring quads are designed for high volume applications requiring repeatable wideband performance. The quads feature good lot-to-lot uniformity, good matching of junction capacitance and tight forward voltage matching. The MFA series also features low series resistance, low junction capacitance and low leakage currents. Several low, medium and high barrier models are available in 1,000 piece quantity for $1.99 each.

MicroMetrics Inc.,
Londonderry, NH (603) 641-3800, www.micrometrics.com.

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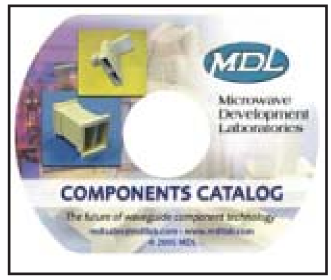


Components Catalog CD-ROM

This catalog CD-ROM features the company's cast components and other passive waveguide products. The CD also highlights the company's commitment to total control for perfection, engineering capabilities, quality manufacturing capabilities and guaranteed reliability.

Microwave Development Laboratories–MDL,
Needham Heights, MA (800) 383-8057, www.mdllab.com.

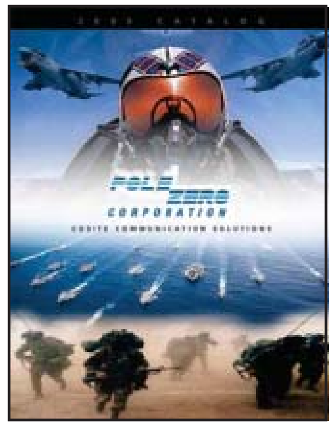
RS No. 336

SATCOM Amplifier Catalog

The company's AMFW catalog line of SATCOM waveguide amplifiers offer low noise figures available in the various frequency bands associated with S-band satellite communications. Achieving noise temperatures as low as 30 K, these amplifiers have been designed using state-of-the-art technology and can be used in either fixed or transportable applications. The high reliability design of these S-band amplifiers allows the company to offer a standard two-year warranty on units.

Miteq Inc.,
Hauppauge, NY (631) 436-7400, www.miteq.com.

RS No. 337



Cosite Solutions

This catalog features a complete line of tunable cosite filter products in the 1.5 MHz to 2 GHz range. The subsystem products were developed for specific platforms in order to mitigate cosite interference and enable clear channel communications. The specific tunable filter, low noise amplifier (LNA), power supply and control elements for each subsystem were chosen as part of a detailed development effort including an analysis of platform antenna isolation, cosite interferer levels and output power requirements.

Pole/Zero Corp.,
West Chester, OH (513) 870-9060, www.polezero.com.

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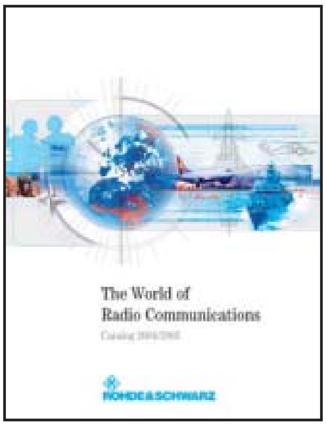
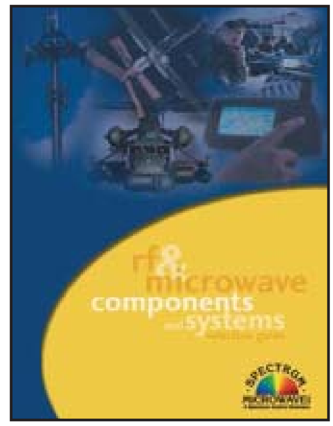


Radiocommunications Catalog

This catalog provides a comprehensive guide to all of the manufacturer's current equipment and systems, and reflects the company's position as a leading supplier of radiocommunications equipment for mission-critical environments. Included are solutions for global communications, tactical communications, LOS communications, direction finding, avionics equipment, together with system processor and IT software.

Rohde & Schwarz GmbH, Munich, Germany +49 89 4129-13779, www.rohde-schwarz.com.

RS No. 339



RF/Microwave Filter Selection Guide

This selection guide features control components, including amplifiers, mixers, VCOs/DROs and attenuators; ceramic bandpass filters and resonators and patch antenna elements/assemblies. Microwave filter components include lumped element, waveguide, tubular and cavity filters, suspended substrates, and base station products. Microwave systems include integrated assemblies, switched filter banks, frequency multipliers and synthesizers.

Spectrum Microwave, Delmar, DE (302) 846-2750, www.specwave.com.

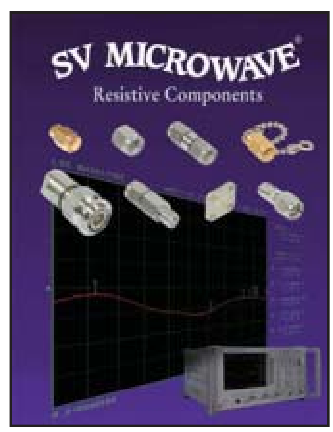
RS No. 340

High Performance Solutions

This newly updated catalog covers high performance microwave interconnect solutions to 50 GHz for defense and aerospace applications: phase stable, low loss and miniature flexible assemblies; semi-rigid cable and assemblies; capabilities; custom applications and solutions; and case studies. Product selection grids, performance graphs, tables, charts, tutorials, photos and ordering and service information are also included.

Storm Products–Microwave Group, Woodridge, IL (630) 754-3300, www.stormproducts.com.

RS No. 341

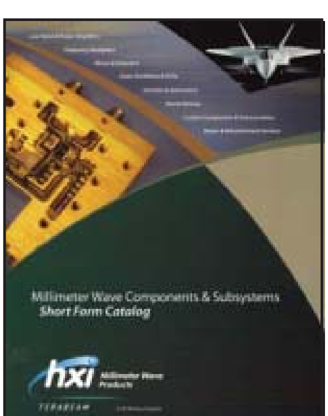


Resistive Components Catalog

This 24-page catalog provides specifications and outline drawings for some of the company's most popular fixed coaxial and chip attenuators as well as coaxial terminations. QPL attenuators to MIL-A-3933/14, /16, /18 and /25 are included, as well as QPL terminations to M39030/3. It also includes short circuit terminations and resistance cards.

SV Microwave Inc., West Palm Beach, FL (561) 840-1800, www.svmicrowave.com.

RS No. 342



Short Form Catalog

This short form catalog highlights the company's millimeter-wave (MMW) products that include a complete line of components from 18 to 110 GHz. The millimeter-wave product availability includes low noise amplifiers, medium/high power amplifiers, mixers, detectors, Gunn oscillators and VCOs, frequency multipliers, pin switches and attenuators, isolators and circulators, and custom subassemblies.

Terabeam/HXI, North Andover, MA (978) 691-7400, www.terabeam-hxi.com.

RS No. 343

Test Cable Brochure

This brochure features the company's heavy-duty armored *SilverLine*™ *TuffGrip*™ test cable series for wireless infrastructure and wireless Internet cell site RF field testing applications. These test cables employ a robust hand grip at the system test end enabling the user to apply as much hand resistance as necessary to make or break heavily weatherproofed RF connections quickly and easily without the use of wrenches and without damaging the test cable.

Times Microwave Systems, Wallingford, CT (978) 887-3033, www.timesmicrowave.com.

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