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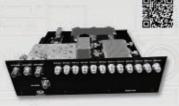
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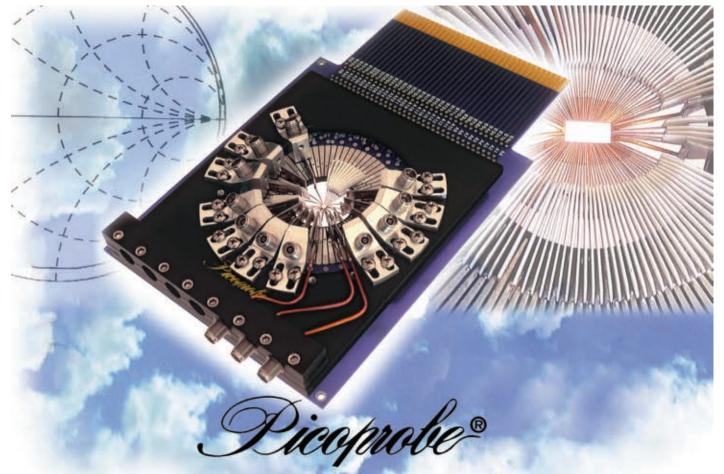
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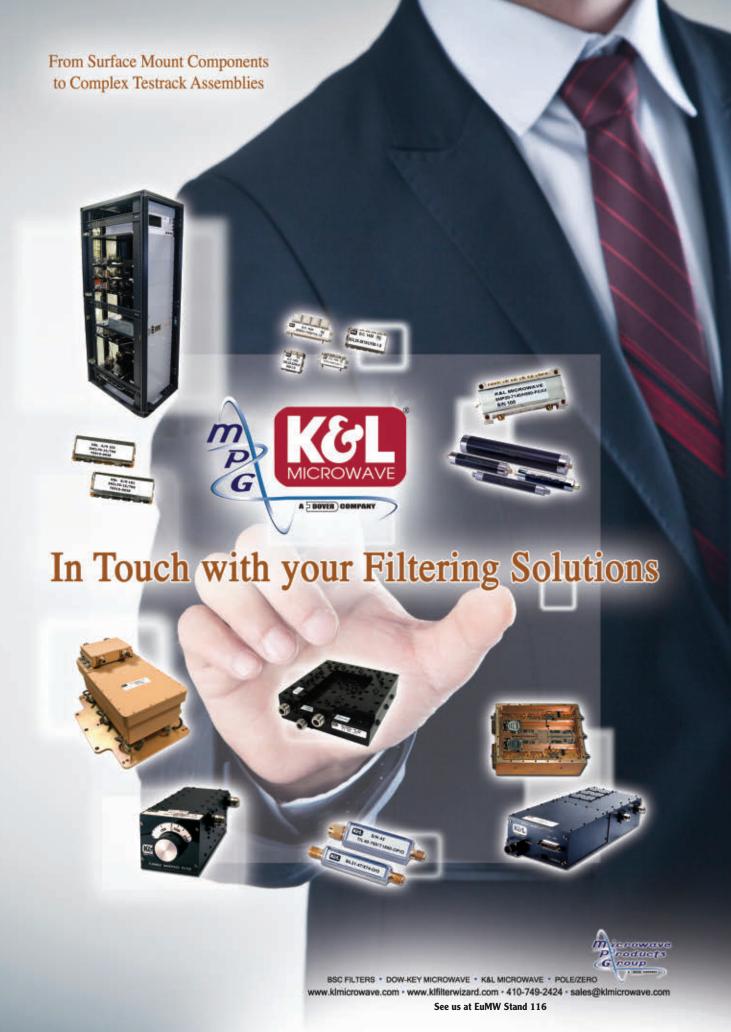


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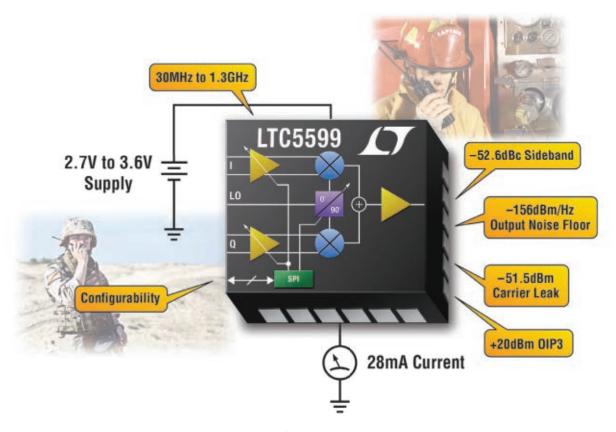
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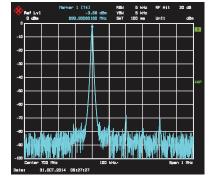
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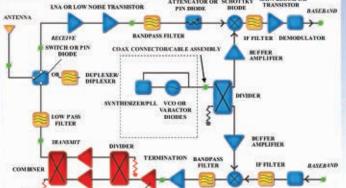
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Mixer (12%)

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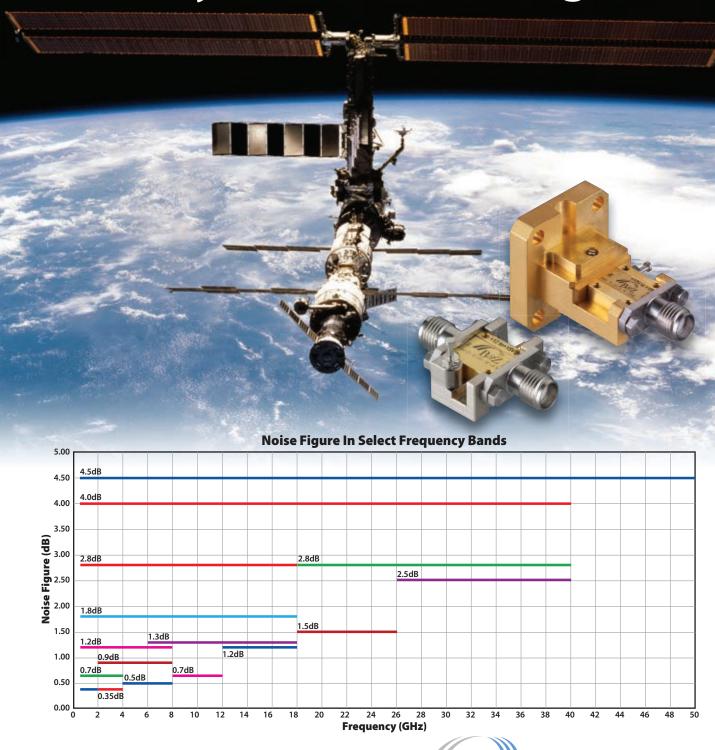
Other (2%)



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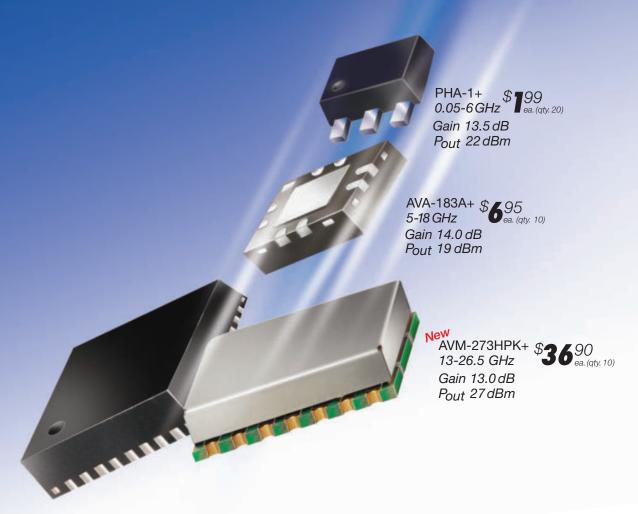




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MILRAD 2015

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August 26-28, 2015 • Sendai, Japan www.rfit2015.org





SEPTEMBER

EuMW 2015

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Metamaterials 2015

September 7-12, 2015 • Oxford, UK www.congress2015.metamorphose-vi.org

The 2015 Defence, Security and Space Forum at European Microwave Week

September 9, 2015 • Paris, France www.eumweek.com

CTIA Super Mobility 2015

September 9-11, 2015 • Las Vegas, Nev. www.ctiasupermobility2015.com

Tower & Small Cell Summit

September 9-11, 2015 • Las Vegas, Nev. www.towersummit.com

ION GNSS+ 2015

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OCTOBER

ICUWB 2015 IEEE International Conference on

Ubiquitous Wireless Broadband October 4-7, 2015 • Montreal, Canada www.icuwb2015.org

CSICS 2015

IEEE Compound Semiconductor IC Symposium

October 11-14, 2015 • New Orleans, La. www.csics.org

AMTA 2015

October 11-16, 2015 • Long Beach, Calif. www.amta2015.org

IME/China 2015

International Conference & Exhibition on Microwave and Antenna

October 21-23, 2015 • Shanghai, China www.imwexpo.com

MILCOM 2015

October 26-28, 2015 • Tampa, Fla. www.milcom.org

ITC/USA 2015

October 26-29, 2015 • Las Vegas, Nev. www.telemetry.org





NOVEMBER

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November 2-4, 2015 • Tel Aviv, Israel www.comcas.org

IEEE AUTOTESTCON 2015

November 2-5, 2015 • National Harbor, Md. www.ieee-autotest.com

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DECEMBER

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December 6-9, 2015 • Nanjing, China www.apmc2015.org

IEDM 2015

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December 7-9, 2015 • Washington, DC www.ieee-iedm.org



JANUARY 2016

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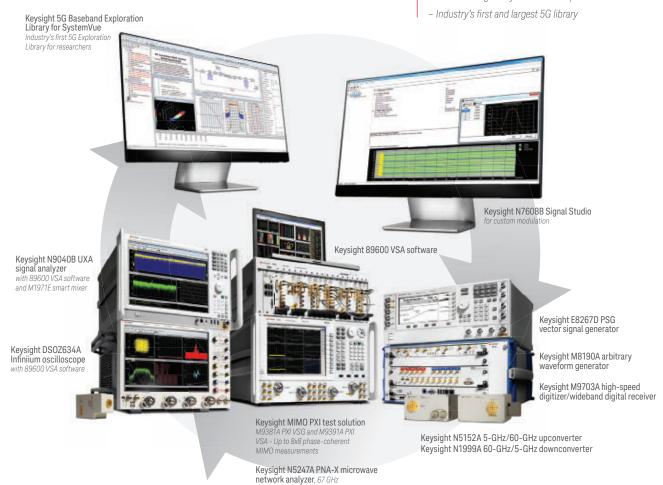
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Multi-Sensor Approach for Non-Segregated Airspace Insertion of RPAS

Patrick Garrec Thales, Paris, France

emotely piloted air systems (RPAS) are vital to the execution of military operations, as recently borne out by Europe's near neighbours in Libya, Mali, Syria and Iraq. Proliferation of RPAS is anticipated in the near future for 3D (dull, dirty, dangerous) missions (see Figure 1). Militarily, RPAS capabilities are being successfully applied to paramilitary applications such as border surveillance, maritime surveillance, crisis management and civil protection. Within the civil domain, RPAS usage is experiencing exponential growth from a small base of early adopters and a variety of markets: farming, filming, fire detection and a number of applications we haven't yet discovered, as their costs are still prohibitive for RPAS or because the legislation doesn't allow them yet.

The RPAS market is forecast to grow continuously and multiply by roughly five times ev-

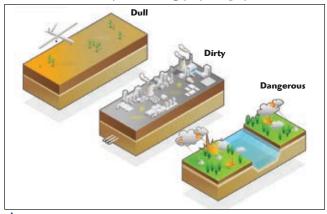


Fig. 1 RPAS favoured operations: dull, dirty and dangerous.

ery five years.¹ The opportunity for Europe is significant, with a conservative, lower estimate of the accessible RPAS sensor payload market of €17.4 billion and a higher growth estimate of €23.6 billion in the period from 2015 to 2035. Of course, this will only be possible if a sense and avoid capability is designed and manufactured in compliance with the dedicated requirements.

The higher growth case for civil and security RPAS sensor payloads predicts a pronounced market shift away from the historical military dominance of the RPAS market sector towards a more balanced market demand between military, security and civil – albeit over the longer term. The needs are identified but the means are missing.

For military RPAS, flying in a segregated area set up by a Notice to Airmen (NOTAM) is acceptable as long as the number is not tremendously high. However, with the growing market, cohabitation will become a major concern. This is the reason why the European Defence Agency (EDA) has launched the mid-air collision avoidance system (MIDCAS)² study. To address the expected increase in numbers, more electronics will have to be devoted to safety concerns, at the cost of endurance.

For civil RPAS, France is the pioneer in Europe, creating the *Conseil des Drones Civils* RPAS civil councils in November 2014. The three newly created committees deal with regulation, technology and safety uses. A survey carried out by the Direction générale de l'aviation civile (DGAC) has counted more than 800 operators in France. There are now

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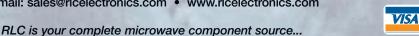
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rules in France for mini and micro RPAS, which is also the case in 14 European countries. The number will continue to increase.

For mini/micro RPAS, the technology is mainly obtained by a spin-out from the toy and smartphone market. The command and control stations are derived directly from the phone or tablet world, as well as the payloads themselves (stabilized camera, low energy computer, MEMS, Wi-Fi communication, etc.). Existing applications are 2D and 3D maps or imagery and thermal models for building isolation assessment as well as land surveying, mining, mapping, agriculture, forestry, littoral conservation, media, site inspection, civilian safety and linear inspection of pipelines, railway and electric cables. The service market will grow in parallel.

Today, manufacturers are building optionally piloted vehicles (OPV) as mission systems that they intend to turn into true RPAS as soon as the certified solution for sense and avoid is available. Currently, no OPV has been certified for flying without a safety pilot on board. The only demonstration programme to be completed to date is SESAR,³ which was underwhelming as the safety case was "simple and it's not a real unmanned aerial vehicle (UAV)." OPVs remain piloted aircraft, and their certification is not comparable with that of UAVs.

Being obliged to have a pilot has a direct impact on the size of the air-

craft, which is obviously oversized, especially at the level of medium altitude long endurance (MALE) RPAS. Compared to tactical solutions which are optimized for the mission and can land on a semi prepared area, OPVs have to cope with pilot constraints (i.e., additional weight, instruments and human factors) as well as needing airports for landing.

RPAS are limited by the maximum take-off weight. The balance between the payload that can be flown and the carburant (i.e., petrol, batteries, etc.) that is needed to ensure a decent time on station is the parameter that has to be adjusted for efficiency. Regulation will force the incorporation of additional sensors to take care of collision avoidance or even better achieving "pass well clear," a natural concern with the forecast in the number of aircraft increasing. No one wants to be responsible for RPAS casualties.

The only solution for staying competitive is to have light sensors, and integrated sensors are the best option. This article will now consider the different RPAS classes, the rules and certification constraints, the different solutions for sense and avoid and the weight estimation for separate sensors. The discussion will show how the performance and size, weight and power (SWaP) consumption of a multi-sensor suite could be improved thanks to collaborative tasks and resource sharing, and it will provide recommendations

for decreasing the weight and increasing the functionalities.

ALL OF THEM ARE RPAS, BUT...

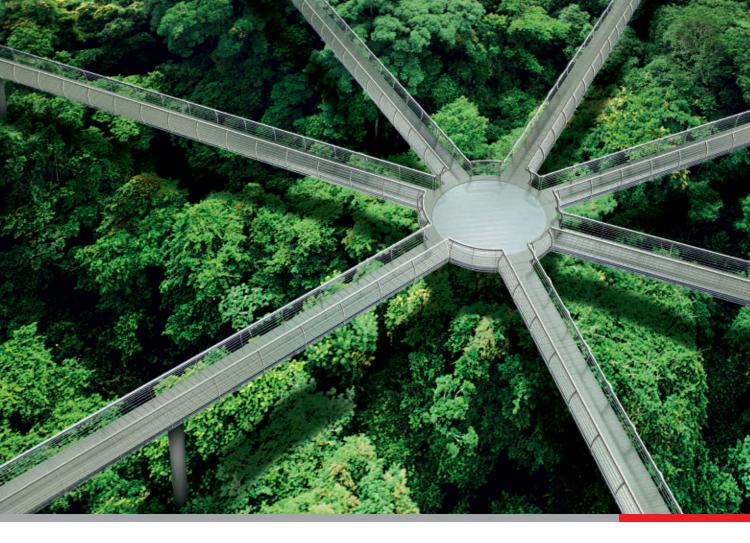
Today there are too many classes of RPAS – also called drones (from the low continuous humming sound produced when flying), unmanned aircraft systems (UAS) and UAVs. The way the classification is presented indicates the interest of the user, the manufacturer or the market development.

- Size: nano, micro, mini, small, medium, large
- Aerodynamic type: fixed wings, rotating wings, vertical take-off and landing (VTOL)
- Altitude: low, medium or high
- Altitude and endurance: medium altitude long endurance (MALE), high altitude long endurance (HALE) and low altitude long endurance (LALE)
- Level of operation: tactical, operative, strategic
- Mission: ISR, combat, support, etc.
- User: military, commercial, civilian
- Class: I, II, III, IV, etc.
- Operation mode: line-of-sight (LOS), beyond line-of-sight (BLOS)

However, these categories often include aircraft with very heterogeneous performance.

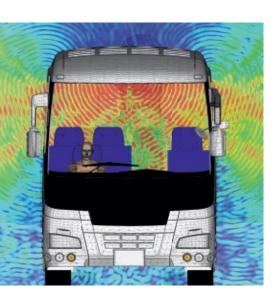
The performance characteristics of speed, endurance and maximum takeoff weight are totally different and no one can expect that the same sense and avoid system can satisfy a 2 kg aircraft as well as a 4 ton one.





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Also, the operating altitude is different and so are the missions. For example, being capable of detecting and avoiding overhead cables is required for low altitude missions but not for midair anti-collision systems. The small RPAS want to use the sense and avoid function to operate in a swarm; maneuverability, speed and detection range are not the same for all aircraft.

The segmentation is very wide, and different scenarios and rules are imposed according to the size and application of these kinds of systems. The requirements are not the same and the solutions will be different.

GOVERNING RULES

As per the International Civil Aviation Organization (ICAO) definition, the visual flight rules (VFR) are a set of regulations under which a pilot operates an aircraft by visually controlling the attitude and trajectory of the aircraft, navigating and maintaining separation with obstacles such as land, clouds and other aircraft. This must be done in visual meteorological conditions (VMC).

VMC are usually defined by certain visibility conditions, cloud ceilings (for take-off and landing) and cloud clearances. The exact requirements vary by type of airspace, whether it is day or night (for countries that permit night VFR) and from country to country. Typical visibility requirements vary from 1.5 to 8 km. VMC are the weather conditions required for flight under

VFR (using outside visual references). The boundary criteria between VMC and instrument meteorological conditions (IMC) are known as the VMC minima.

In France, regarding small aircraft, RPAS under 150 kg are segmented depending on different scenarios:

- S1: direct visual line-of-sight above non populated area, with 100 m maximum distance from the pilot
- S2: above non-populated areas, with 1 km maximum from the pilot and with a height under 50 m from the ground or artificial obstacles
- S3: flights above populated areas, in direct line-of-sight of pilot, with a maximum distance of 100 m from the pilot
- S4: particular activities (geographic, video, aerial surveillance, etc.) above non-populated area and not included in the S2 scenario.

Regarding large RPAS, the U.S. Federal Aviation Administration (FAA) wrote an order (8130-34: Airworthiness Certification of Unmanned Aircraft Systems), then a UAS roadmap and a UAS comprehensive plan in October 2013; European rule 216/2008 defines the competency.

A wide range of scenarios can exist with widely varying performance characteristics, along with different types of aircraft in an operational environment when defining, size, speed, type of control and other flight capabilities, material properties and structural design standards, system reliabil-

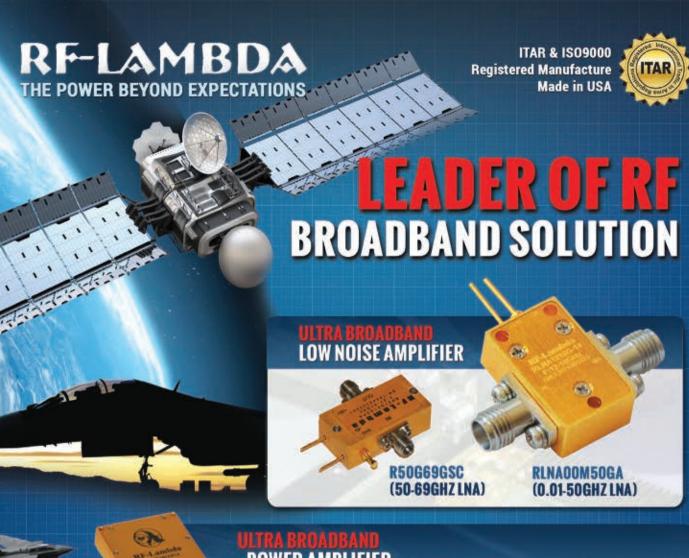
ity and other aircraft performance (at system and subsystem levels).

For the European RPAS steering group – the European group providing milestones for integrating RPAS into non-segregated airspace, following EDA study AIR4ALL – studies have to be carried out in relation to allowing flights in non-segregated airspace: data communication links, including spectrum issues; operational procedures; security issues; operational contingency procedures and systems; surface operations, including take-off and landing; detect and avoid systems.

The European EDA MIDCAS study has established sets of sensor capabilities to ensure flying in nonsegregated airspace regarding detect and avoid capabilities. A demonstrator of this system has recently flown with electro-optic/infrared (EO/IR) combined with radar capacities for detecting non-cooperative intruders. This is complemented by automatic dependent surveillance broadcast (ADS-B) and identification, friend or foe (IFF) equipment to detect cooperative intruders – at the same time taking into account the non-cooperative tracks by means of heterogeneous data fusion. The best combination of only noncooperative sensors was proven to be radar plus electro-optic.

It is envisaged that RPAS will operate in airspace and air traffic management (ATM) environments, in conjunction with a variety of manned

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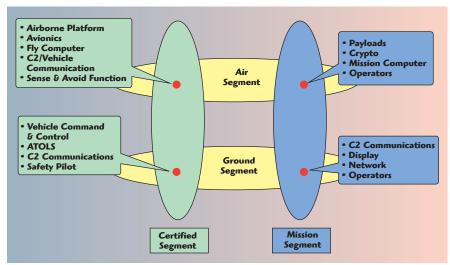
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▲ Fig. 2 Main functions required for RPAS.

aircraft (e.g., from gliders to large airliners), both under IFR or VFR, adhering to the requirements of the specified airspace in which they are operating – that is to say mainly by providing the pilot in command with information of distance to clouds. Formally speaking, according to the rules of the air, VFR flight encourages getting the distance to clouds in order to avoid entering instrument meteorological conditions (IMC).

A flight conducted under VFR must maintain a minimum distance from clouds and requires a minimum distance from the ground and surrounding obstacles. In a manned aircraft this is ensured by visual recognition and instruments. For RPAS, this should be achieved through an

adequate set of sensors with enough distinctiveness to make valid decisions. This set of sensors will have to include multi-function radar capabilities for weight saving.

With regards to the functional architecture, the main functions needed for the RPAS are allocated to several segments as shown in *Figure 2*. Part of what was considered as a whole entity is now spread between the air segment and the ground segment, creating a rupture. There is a pilot, but he is on the ground, which means that the situation assessment, the reaction time and the consequences are not the same for him.

Comparing the RPAS architecture to an aircraft, there is a notion of "green aircraft" and a mission system

that can be highlighted. The airworthiness constraints are now spread among the air and ground segments, making the certification more complex. Legally, in an aircraft, the pilot is responsible for the see and avoid. For an RPAS, it may not be the case as the pilot is on the ground and the data link could be interrupted. Sense and avoid must be achieved even when the data link is perturbed. An autonomous function is thus compulsory.

Today, without the sense and avoid function, the only legal solution is the segregation with a NOTAM and the use of a primary radar for situation assessment. STANAG 4671 2009 ⁴ states "It is recognized that 'sense & avoid' is a key enabling issue for UAV operations."

HOW TO SENSE AND AVOID

Sense and avoid detection is based on two kinds of function: cooperative and non-cooperative.

Cooperative Function: Among the possible cooperative sensors, ADS-B is particularly suitable for implementing sense and avoid. ADS-B is based on the publication of the UAV's position on a dedicated network. It assumes that the Global Navigation Satellite Systems (GNSS) information is available, that the communication to the network is updated correctly and that all the flying systems are all equipped. The main characteristics are:

 Automatic: there is no interrogation needed to start the data or



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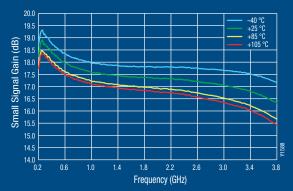
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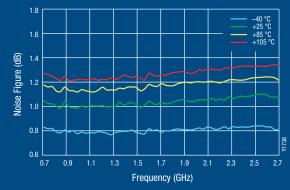
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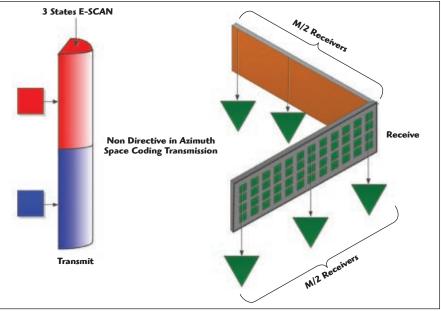
- Dependent: it relies on on-board navigation (GNSS, altimeter, barometric altitude, inertial system) and broadcast equipment to provide information to other ADS-B users
- Surveillance: automatic surveillance and traffic coordination are required
- Available at long range, provided that aircraft are in line of sight
- · All weather

One of the main problems in using ADS-B is linked to knowledge of the integrity of received data and that it only provides the published data, assuming that the surrounding aircraft are all fitted with ADS-B. The traffic collision avoidance system (TCAS) function is the automatic avoidance system used for manned aircraft and is the way forward for the big RPAS, when weight is less critical associated with a non-cooperative sensor. The IFF in Mode S is used for providing aircraft parameters (range, altitude, azimuth) and for ADS-B confirmation. Spoofing may be a concern in the future. Link 16 is used for situation as-

These systems are L-Band with separate boxes, antennas and with filters and blanking boxes to cope with compatibility. Building a single piece of equipment capable of all these functions will save weight and will simplify integration and will help with certification. The cables' weight for aircraft installation has been measured and represents 15 percent of the total weight of the boxes. Building a multifunction L-Band system is clearly a challenge that could save half the weight by having common transmitters, common multifunction receivers and shared computer resources. It will also naturally take care of EMI/EMC compatibility. There is no risk of one of the L-Band transmitters polluting the other, if you only have one.

Non-Cooperative **Function:** Non-cooperative sensors are segmented into two solutions: electrooptical/infrared sensors and radar. Among possible non-cooperative sensors, the natural solution is optical detection as it mimics the pilot's eyes, with the same advantages and limitations. Cameras are cheap, small and light and can easily be spread around the aircraft structure. This is true for mini RPAS, when the distance detection is increasing the weight and consumption growth proportionally. But the system is not all-weather and the speed measurement of the incoming objects is quite difficult to obtain; only the increasing number of pixels is no-

Radar complements the imaging sensors: EO/IR sensing provides angular measurements with great accuracy and has a good data rate update, while the radar also provides distance and speed measurements. Data fusion achieves the best of both sensors.



▲ Fig. 3 X-Band radar antenna system for the sense and avoid function.

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Moreover, the cooperative information is used for the data fusion.

For radar sensors there are two possible antenna technologies that can be selected. The first is mechanical scanning along the azimuth axis with digital beam forming along the elevation axis on receive. This approach is also referred to as the "moving solution." The second is coloured emission combined with quantized E-scanning along the elevation axis on transmit, with digital beam form-

ing along the azimuth axis on receive. This is also referred to as a "static solution." 5,6

Considering the band choice, X- and Ku-Band offer the best compromises between accuracy, weather robustness, available spectrum, cost and system weight. Ka-Band has been discarded as unsuitable for all-weather use. C-Band and lower frequencies have also been discarded, due to the available bandwidth for the sense and avoid function. Moreover, they are

heavier and consume more space than X- and Ku-Band.

RADAR IMPLEMENTATION

One of the most advanced existing radars uses a patented Thales design based on electronic scanning (E-SCAN) and digital beam forming (DBF) (see *Figure 3*). The techniques and technologies which have ruled the proposed design all favoured decreasing the drag by minimizing the antenna footprint, easing the installation on board the aircraft and decreasing the weight compared to standard solutions. The result is a good, yet complex, fully integrated solution, which offers the best compromise within an affordable SWaP budget.

The radar system operates in X-Band with an architecture based on multiple-input-multiplecoherent output (MIMO) principles.^{5,6,7} To decrease the size of the antenna, coloured transmission is implemented for measurement of elevation angles, which otherwise would not be possible. One of the advantages of operating in X-Band, rather than Ku-Band, is that the signal of the weather radar from airliners can be detected and the information incorporated in the fusion system to enrich detections. Cloud detection is also a most valuable function that needs to be included in future designs. Medium RPAS cannot afford to carry both the sense and avoid function and weather radar.

The signal processing can be installed at the back of the receiving antennas, for cable optimization, and the use of smartphone processors are a possible solution in the future. The use of conformal antennas as promoted by EDA⁸ can be envisaged; as the tools for building conformal antennas are not yet mature, they will probably be the next step after having certified the radar sensor for sense and avoid.

SWAP: LIGHT IS BEAUTIFUL

The figures shown in *Table 1* are based on separate sensors and data fusion after detection. Three possible approaches can reduce these values. The first is through technology improvements, for example the use of new radar technology planned for AESA architectures. The second is a multi-sensor approach, using strong interaction and cooperation between the sensors, including compacting the sensors in





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| TABLE 1 |
|---|
| FUTURE SENSE AND AVOID AIRBORNE SEGMENT (SYSTEM WOULD USE EITHER EO OR IR SENSOR, NOT BOTH) |

| | Weight (kg) | Volume (L) | Power (W) | Total Weight (kg) | Total Volume (L) | Total Power (W) | |
|---------------------------------|----------------|---------------|--------------|----------------------|---------------------|--------------------|----------------------------|
| EO Sensor | 4 | 4 | 70 | | | | |
| IR Sensor | 4 | 4 | 60 | 19 | 14 | 410 | Non-Cooperative Sensors |
| RADAR Processing | 15 | 10 | 350 | | | | |
| ADS-B IFF Interrogator | 3 | 3 | 35 | 3 | 3 | 35 | Cooperative Sensors |
| Main Computer | 3 | 1.5 | 25 | 3 | 1.5 | 25 | Data Fusion |
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the same units (direct gain) or offering increased functionalities while avoiding new sensors (indirect gain).

- Capacity for the radar system to detect clouds and give a measurement of the distance to clouds to the pilot in command, in order to fly VFR
- Detection of weather radar from airliners to compare with standard detection
- Use of optical technology, if possible merged within the radar panel⁹ The third approach is resource management sharing, e.g., RF chains or computing resources.

As most fixed wing RPAS are gliders, the consumption is small and could be just kilograms per hour – as little as 5 kg. The key parameter for the RPAS is the time on station. Takeoff and landing, the time to travel to and from the mission area are not the interesting part of the flight, although necessary. The only parameter that can be adjusted is the time on station. If the payload weight is inflated by 5 kg, at least one hour of time on station is impacted (not taking into account the weight impact on the platform performance).

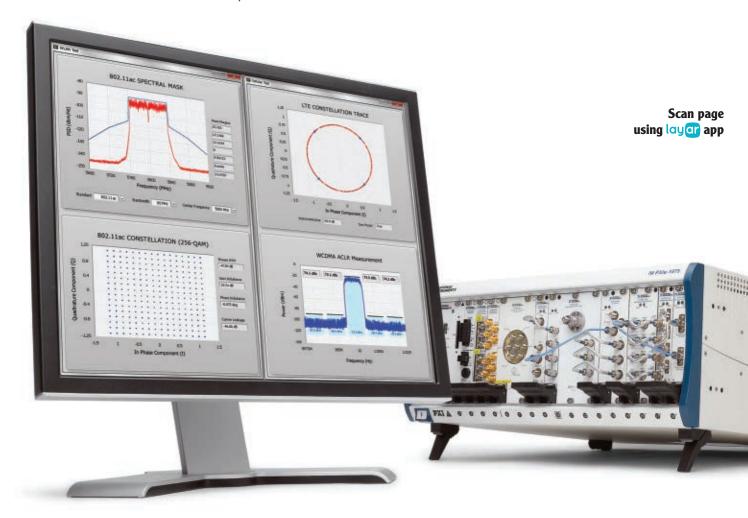
Although significant technological and regulatory advances have been made by the RPAS community, technology improvements and regulation development are still needed to fully understand the impact of RPAS operations in the non-segregated airspace.

Of course depending on the RPAS class, the problem is not the same, and thus the solution will have to be adapted. Technologically, efforts have to be made to decrease the weight of cabling and connectors, as the ratio of these elements is not negligible compared to the mission payloads. It represents more than 20 percent of the payload.

Another approach is sensor physical integration, being able to insert all

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NATIONAL INSTRUMENTS cameras (EO/IR) within the antenna will save weight. In addition to SWaP benefits, smooth sharing of the processor resources between the EO/IR and the radar would improve system efficiency.

In clear visibility, detection from the radar giving Doppler detection and range could be managed without other refined computation. The optical sensor could then give the refined angular detection, getting rid of the burden of measuring the distance and the speed, which is quite complex for EO/IR and requires additional computation. Moreover, the distance being known, the focalization of the camera can be pre-adjusted to the correct value. For poor visibility, the camera computer resources will be fully allocated to the radar, preventing unused CPU resources.

For small aircraft with a weight less than 5 kg, the target weight for the sense and avoid function must be reduced to 200 g maximum; hope-

fully, the platform speed will also be reduced to less than 30 m/s. For these platforms, the only radar technology will be millimeter wave, which is also the technology selected by the automobile industry. Allocating 76 to 77 GHz frequencies to helicopters is now under discussion.

We could have envisaged simple equipment or a set of equipment ensuring RPAS airworthiness certification, enhancing system performance and physical SWaP characteristics and even being compatible with existing manned airplanes. However, this is a chimera and the specificity of each class of platform forces a dedicated solution by type of class.

FUTURE DEVELOPMENT

Performance trade-offs and development of standards will be the next step to be achieved, as the certification cost is too high for every aircraft manufacturer to achieve. The only pragmatic solution is to go through a standardization process, which will ease the approval by the regulation authority.

Sharing the requirements will allow technology driven improvement, e.g., by using MMIC designs, merging RF and optical front-ends as well as improved performance by cooperation at low level, thus drastically improving the SWaP of the sense and avoid function. Advanced studies still need to be funded at the European level to miniaturize critical components and increase the efficiency for decreasing the consumption.

This will be even more critical for small RPAS where the ratio of the sense and avoid function compared to the possible payload weight is the same order of magnitude. Here, using mass production elements and devices designed for smartphones, computers or cameras are credible options.

The use of standards will also simplify the regulatory approvals, together with their development, their tests and the performance validation. The use of standards will allow the building of representative simulation models, in turn simplifying the integration of the sense and avoid function in the RPAS.

The EDA will be a major player in facilitating an industrial standard for promoting an indigenous solution. The RPAS expansion is being held back by this function which is not yet available. Moreover, when it does be-

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come available it will be more likely be implemented in manned aircraft. Thus, the market for this product will not be limited to RPAS but will benefit all aircraft.

For European industry, it is necessary to promote innovation and competiveness in high-end engineering and technologies and to aggregate competencies to stimulate sustainable growth in the economy. Most of the leading edge technical and industrial capabilities already exist. This sense

and avoid function is an essential condition for RPAS deployment.

Globally competitive sense and avoid systems can – through European governments and industry acting together – be delivered by the European industry affordably and to a schedule which will meet member states' military requirements and respond to expected civil demand, thus facilitating a real growth in RPAS business. However, what is missing and difficult to achieve is the stan-

dardization (to obtain critical mass), a stronger cooperation between industries and the political will that is required if Europe wants to be liberated from RPAS dependencies. ■

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Patrick Garrec is RF sensors architecture expert at Thales Systèmes Aéroportés in Pessac, France. He is in charge of innovative development for UAV systems in Thales aerospace, including radar-based automatic

take-off and landing systems. With more than 32 years experience in radar, Garrec's main focus has been radar design, including air traffic control (ATC), battlefield and meteorological systems. He holds more than 30 radar patents. He received the Thales Innovation Award in 2008 and is a Senior Member of the Société de l'Electricité, de l'Electronique et des Technologies de l'Information et de la Communication. He received the Dipl.-Ing degree from the INSA Rennes and the Diplôme d'études approfondies (DEA) from the ENSM (now Ecole Centrale Nantes).





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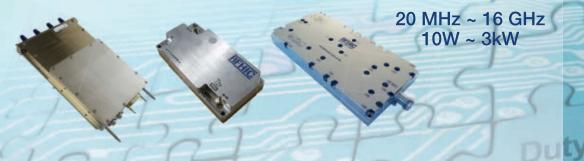
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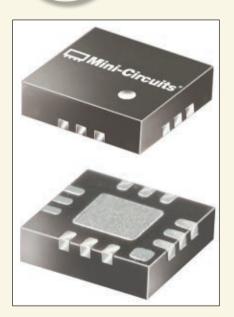
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ilters are fundamental building blocks of nearly every modern RF/microwave system, used to eliminate unwanted signals in receiver and transmitter architectures. Until recently, study and research in practical filter design has been largely devoted to topologies in which rejection of stopband frequencies is accomplished by reflecting undesired signals back to the source. Meanwhile, there are many applications in which these reflections produce intermodulation products, gain ripple and other problems in system performance. For example, nonlinear devices such as mixers, multipliers and high-gain amplifiers which respond to outof-band frequencies are highly sensitive to the reflections caused by conventional filter designs. This becomes especially challenging as filters are often needed near or adjacent to active devices in the signal path to better define bandwidth or suppress unwanted harmonics.

While RF system designers have used several brute-force approaches to manage these adverse effects, such as inserting attenuators or isolation amplifiers around sensitive components, these techniques are known to degrade overall system signal-to-noise ratio (SNR) and dynamic range. Absorption of stopband signals has been achieved by terminating one port of a diplexer (or all but one port of a multiplexer), but this approach is demanding on space requirements and still results in reflections due to mismatch in the transition. Balanced filters with quadrature hybrids at the input and output can also be used to buffer the circuit from reflective elements, but the bandwidth of the filter is then limited by that of the hybrids, which makes this

technique unsuitable for broadband applications.

Thus, there is a clear need for new filter topologies in RF and microwave systems in which stopband energy is absorbed into the circuit rather than reflected back to the source. This need has led to advanced research and development of a novel, patented topology of reflectionless filters, which Mini-Circuits will release to the market for commercial use this year.

FILTER THEORY AND EXTENSIONS

The reflectionless filter topology assumes a two-port symmetric network and is derived based on even/odd mode analysis. This approach allows the two-port network to be divided (in theory) into two single-port networks, each of which contains half the elements of the two-port network. In the even mode equivalent circuit, the nodes that lie on the symmetry plane are assigned to an open circuit, while in the odd mode equivalent circuit, nodes that lie on the symmetry plane are assigned to ground (or virtual short). The S-parameters of the two-port symmetrical network are therefore defined as the superposition of the even and odd mode reflection coefficients, such that:

$$\begin{split} \mathbf{S}_{\text{II}} &= \mathbf{S}_{22} = {}^{\text{I}}/{}_{2}(\Gamma_{\text{even}} + \Gamma_{\text{odd}}) \text{ and } & \text{(I)} \\ \mathbf{S}_{2\text{I}} &= \mathbf{S}_{12} = {}^{\text{I}}/{}_{2}(\Gamma_{\text{even}} - \Gamma_{\text{odd}}) & \text{(2)} \end{split}$$

Given the requirement that the circuit be reflectionless, S_{11} must be equal to zero (normalized to the characteristic impedance of the network). It follows that:

$$\Gamma_{\text{even}} = -\Gamma_{\text{odd}} \tag{3}$$

This condition is satisfied when the corre-



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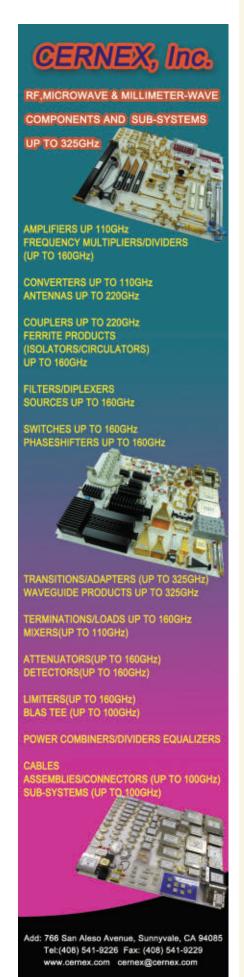
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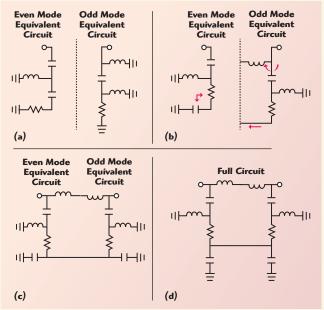








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▲ Fig. 1 Derivation of a lowpass reflectionless filter topology: even and odd mode equivalent circuits that satisfy Equation 3 (a) rearranged elements (b) added inactive elements to achieve symmetry (c) and final circuit topology (d).

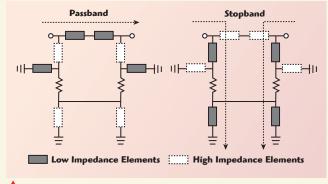


Fig. 2 Passband and stopband signal paths through the reflectionless lowpass filter.

sponding elements of the even and odd mode equivalent circuits are duals of one another. The derivation of a reflectionless lowpass filter following this methodology is illustrated in *Figure 1*.

In the resulting circuit, signals in the filter's passband travel directly through, from input to output. Signals in the filter's stopband are routed directly to the resistors, which terminate the signal internally (see *Figure 2*).²

Figure 3 shows the typical performance of a single pole lowpass reflectionless filter of this class. The filter exhibits a third order inverse Chebychev-type response but is distinct from traditional filters in that the reflection coefficient is zero for all frequencies. While this example shows a reflectionless lowpass filter, the same technique has been used to derive a wide variety of highpass, bandpass and bandstop filters.

Extensions of this design approach include higher order filters in which the terminating resistors are replaced with matched subnetworks to achieve improvements stopband rejection and steepness in the transition. For example, a series of third order lowpass filters (the NRLP3 series) has been developed in which three reflectionless filters are nested. each into the last. These designs exhibit steeper transitions and higher rejection in the first octave of the stopband relative to that of first order lowpass reflectionless filters.

As another extension, cascading filters are used in many applications to enhance stopband rejection or to combine highpass and lowpass filters to create a bandpass response. While cascading traditional fil-

ters can introduce in-band ripple and phase instability, reflectionless filters can be cascaded without adding these effects to the filter's performance. Figure 4 compares the typical insertion loss, return loss and group delay of a traditional filter to that of a reflectionless filter when cascaded. These curves show that cascading traditional filters creates in-band ripple, degrades return loss and generates phase instability. By

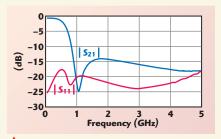


Fig. 3 Typical performance of a single pole lowpass reflectionless filter.

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| Td | 360°C | 360°C | 360°C | 390°C | 360°C | | |
| Dk @ 10 GHz | 2.80 - 3.45 | 3.38, 3.45 & 3.56 | 3.45* | 3.45* | 3.00 | | |
| Df @ 10 GHz | 0.0028 - 0.0036 | 0.0028, 0.0031 & 0.0034 | 0.0031* | 0.0030* | 0.0017 | | |
| CTE Z-axis (50 to 260°C) | 2.90% | 2.80% | 2.80% | 2.90% | 2.90% | | |
| T-260 & T-288 | >60 | >60 | >60 | >60 | >60 | | |
| Halogen free | No | No | No | Yes | No | | |
| VLP-2 (2 micron Rz copper) | Available | Available | Available | Standard | Standard | | |
| Stable Dk & Df over the temperature range | -55°C to +125°C | -55°C to +125°C | -55°C to +125°C | -55°C to +125°C | -40°C to +140°C | | |
| Optimized global constructions for Pb-free assembly | Yes | Yes | Yes | Yes | Yes | | |
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| Low PIM < -155 dBc | Yes | Yes | Yes | Yes | Yes | | |

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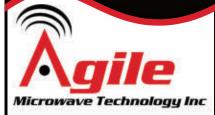
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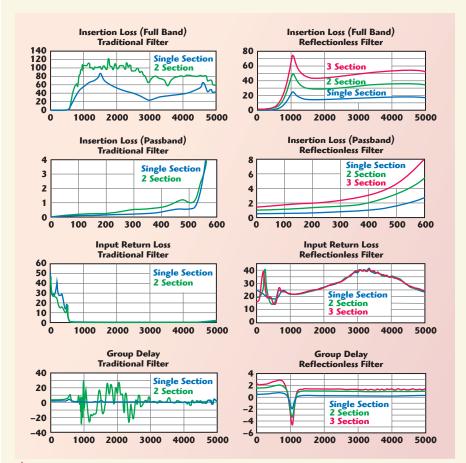
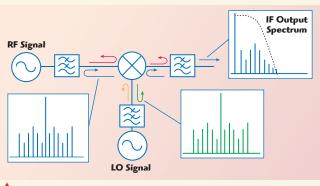
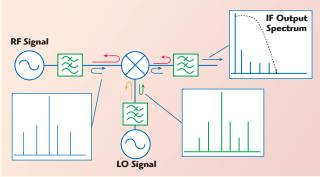


Fig. 4 Performance comparison of traditional and reflectionless filters.



▲ Fig. 5 Typical intermodulation expansion due to reflections from multiple filters.

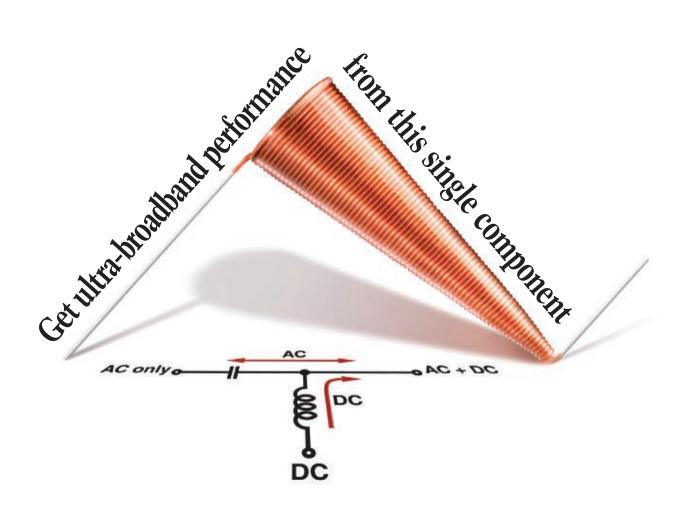


▲ Fig. 6 Minimizing the effect of intermodulation expansion by using reflectionless filters on mixer ports.

contrast, the reflectionless filters exhibit none of these detrimental effects, even when cascaded in three sections.

PRACTICAL APPLICATIONS

Reflectionless filters are particularly useful for pairing with sensitive nonlinear devices. where traditional filters are notoriproblematic. One such case is a filter cascaded with a mixer in the signal chain. Mixers generate spurious mixing products, higher LO harmonics and other unwanted signals that must be filtered out. However. with a conventional filter, these spurious tones are reflected



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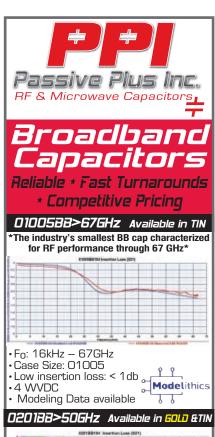
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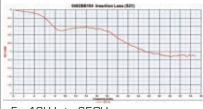
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back into the mixer where they can convert again or re-mix with the intended signals to create a multitude of unintended signals that may fall within the desired passband (see Figure 5).

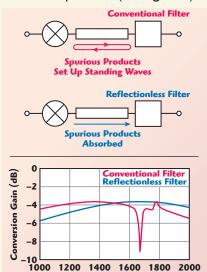


Fig. 7 Simulation of a mixer and filter separated by a transmission line, comparing traditional and reflectionless designs.

Frequency (MHz)

Reducing intermodulation ucts generated by the nonlinear mixer has always been a design goal, and the industry has had various levels of success with high dynamic range FET based mixers. However, even the best mixers produce intermodulation products at some level from each port which then react with the neighboring elements in the RF chain. When these adjacent elements are filters, the out-of-band intermodulation products are fully reflected back into the mixer to recombine with the fundamental signal and produce additional "family members" of unwanted spurious products. These spurious products make their way to the output IF, and several end up in-band, limiting the overall dynamic range of the system. When out-of-band reflections from filters are minimized, those "family member" spurious products are reduced, resulting in a net reduction of in-band unwanted intermodulation products and improvement in overall system dynamic range (see Figure 6).

Additionally, these unwanted spuri-

ous products can be

substantial in magnitude and of an undetermined phase. Therefore, in certain phase relationships, they can interfere destructively the down-conversion signal, resulting in a "suck-out" at some point in the frequency band (see the red curve in the response in Figure 7). This occurs commonly in broadband systems, in part because of the greater likelihood of a destructive phase relationship between the reflection and the desired signal over a wide bandwidth. Even in cases where this effect does not occur, the overall shape of the conversion loss curve will change and develop ripples as the electrical length of the line between the mixer and filter

changes. In effect, this

mixer-filter

TABLE 1

INITIAL CATALOG OF REFLECTIONLESS FILTERS (PASSBAND DEFINED AS INSERTION LOSS < 3 dB)

| Filter Type | Model Number | Passband (GHz) |
|-------------|--------------|----------------|
| | NRLP-151+ | 0 – 0.3 |
| | NRLP-221+ | 0 - 0.38 |
| | NRLP-421+ | 0 - 0.62 |
| | NRLP-551+ | 0 - 0.79 |
| | NRLP-861+ | 0 – 1.20 |
| Lowpass | NRLP-122+ | 0 – 1.56 |
| | NRLP-192+ | 0 – 2.50 |
| | NRLP-252+ | 0 - 3.31 |
| | NRLP-332+ | 0 – 4.20 |
| | NRLP-732+ | 0 – 10.2 |
| | NRLP-982+ | 0 – 13.8 |
| | NRLP3-63+ | 0 - 8.2 |
| | NRLP3-73+ | 0 – 10.0 |
| | NRLP3-762+ | 0 – 11.3 |
| Lowpass | NRLP3-962+ | 0 – 12.8 |
| (3rd Order) | NRLP3-14+ | 0 – 13.6 |
| | NRLP3-123+ | 0 – 15.7 |
| | NRLP3-133+ | 0 - 16.9 |
| | NRLP3-173+ | 0 – 21.1 |
| Highpass | NRHP-23+ | 1.65 – 15.9 |
| | NRHP-252+ | 2.03 – 17.5 |
| | NRHP-392+ | 3.28 – 19.5 |
| Bandpass | NRBP-282+ | 2.3 – 3.15 |

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combinations sensitive to environmental conditions as well.

The reflectionless filter, however, causes no such effects to the mixer performance because the spurious mixing products are absorbed, rather than reflected back into the mixer where they can interfere. The conversion loss curve for the mixer in this setup not only lacks the suck-out effect shown by the traditional filter, but is also entirely insensitive to the line

length between the filter and the mixer.

These same properties make reflectionless filters suitable for use with other types of sensitive components, such as multiplier chains, where reflections can contribute to unwanted harmonic multiplication and conversion gain ripple. They have also been used to extend the spurious-free dynamic range (SFDR) in analog-to-digital converters (ADC) by absorbing clocked spurs before they can re-enter the

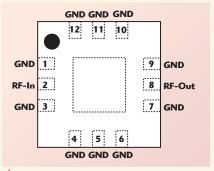


Fig. 8 NR-series reflectionless filter pinout.

ADC. Similarly, they can eliminate unintended feedback in high gain amplifiers and avoid stability problems, without the need for additional attenuators to buffer stopband reflections.

CONCLUSION

The development of the reflectionless filter topology represents a revolutionary advance that will enable significant improvements in RF system performance in many applications. This technology solves a number of longstanding problems related to embedding filters in transmit and receive chains. Some of the applications which will benefit - or have already - from replacing traditional filters with reflectionless filters have been discussed in this article, but the full scope of their usefulness in practical applications has yet to be realized. Mini-Circuits will release an initial offering of 23 models to the market, featuring first and third order lowpass, highpass and bandpass designs covering passbands from DC to 21 GHz (see **Table 1**). The filters are fabricated on GaAs using integrated passive device (IPD) process technology and packaged in tiny 3 × 3 mm QFN cases (see Figure 8).



- Protected by U.S. Patent No. 8,392,495 and Chinese Patent No. ZL201080014266.1. Patent applications 14/724976 (U.S.) and PCT/US15/33118 (PCT) pending.
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| | | | | | 0 10 1 100 | 1.001110 |
| Model No. | Freq (GHz) | Gain (dB) MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
| CA01-2110 | 0.5-1.0 | 28 | 1.0 MAX, 0.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-2110 | 1.0-2.0 | 30 | 1.0 MAX, 0.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA24-2111 | 2.0-4.0 | 29 | 1.1 MAX, 0.95 TYP 1.3 MAX, 1.0 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA48-2111 | 4.0-8.0 | 29 | 1.3 MAX, 1.0 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA812-3111 | 8.0-12.0 | 27 | 1.6 MAX, 1.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1218-4111 | 12.0-18.0 | 25 | 1.6 MAX, 1.4 TYP 1.9 MAX, 1.7 TYP 3.0 MAX, 2.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1826-2110 | 18.0-26.5 | 32 | | | +20 dBm | 2.0:1 |
| NARROW B | AND LOW | NOISE AND | MEDIÚM POV | VER AMPLIF | ERS | |
| CA01-2111 | 0.4 - 0.5 | 28 | 0.6 MAX, 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA01-2113 | 0.8 - 1.0 | 28 | 0.6 MAX, 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-3117 | 1.2 - 1.6 | 25 | 0.6 MAX, 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA23-3111 | 2.2 - 2.4 | 30 | 0.6 MAX, 0.45 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA23-3116 | 2.7 - 2.9 | 29 | 0.7 MAX, 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA34-2110 | 3.7 - 4.2 | 25 30 29 28 | 1.0 MAX, 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA54-2110 | 5.4 - 5.9 | 40 | 1.0 MAX, 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA78-4110 | 7.25 - 7.75 | 27 | 1.0 MAX, 0.3 III | +10 MIN | +20 dBm | 2.0:1 |
| CA910-3110 | 9.0 - 10.6 | 25 | 1.2 MAA, 1.0 III 1 4 MAV 1 2 TVD | +10 MIN +10 MIN | +20 dBm | 2.0.1 |
| CA1315-3110 | 13.75 - 15.4 | 2.5 | 1.0 MAX, 0.5 TYP 1.2 MAX, 1.0 TYP 1.4 MAX, 1.2 TYP 1.6 MAX, 1.4 TYP | | +20 dBm | 2.0.1 |
| | 10./0-10.4 | 20 | 1.0 MAA, 1.4 III | +10 MIN | | |
| CA12-3114 | 1.00 - 1.00 | 30 | 4.0 MAX, 3.0 III | +33 MIN | +41 dBm | 2.0:1 |
| CA34-6116 | 3.1 - 3.5 | 40 | 4.0 MAX, 3.0 III | +35 MIN | +43 dBm | 2.0:1 |
| CA56-5114 | 5.9 - 6.4 | 30 | 5.U MAX, 4.U IYP | +30 MIN | +40 dBm | 2.0:1 |
| | 8.0 - 12.0 | 30 | 4.5 MAX, 3.5 TYP 5.0 MAX, 4.0 TYP 4.5 MAX, 3.5 TYP 5.0 MAX, 4.0 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA812-6116 | 8.0 - 12.0 | 3U | 5.0 MAX, 4.0 IYP | +33 MIN | +41 dBm | 2.0:1 |
| CA1213-7110 | 12.2 - 13.25 | 28 | 6.0 MAX, 5.5 TYP | +33 MIN | +42 dBm | 2.0:1 |
| CA1415-7110 | 14.0 - 15.0 | 30 | 5.0 MAX, 4.0 TYP | +30 MIN | +40 dBm | 2.0:1 |
| | 17.0 - 22.0 | 25 | 3.5 MAX, 2.8 TYP | +21 MIN | +31 dBm | 2.0:1 |
| ULTRA-BRO | | | TAVE BAND AN | APLIFIERS | | |
| Model No. | Freq (GHz) | Gain (dB) MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
| CA0102-3111 | 0 1-2 0 | 28 | 1.6 Max, 1.2 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0106-3111 | 0.1-6.0 | 28 | 1.9 Max, 1.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0108-3110 | 0.1-8.0 | 26 | 2.2 Max 1.8 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0108-4112 | 0.1-8.0 | 32 36 | 3.0 MAX, 1.8 TYP | +22 MIN | +32 dBm | 2.0:1 |
| CA02-3112 | 0.5-2.0 | 36 | 4.5 MAX, 2.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA26-3110 | 2.0-6.0 | 26 | ') () () () () () () () () () () () () () | . IO MIN | +20 dBm | 2.0:1 |
| CA26-4114 | 2.0-6.0 | 22 | 5 0 MAX 3 5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA618-4112 | 6.0-18.0 | 25 | 5.0 MAX 3.5 TYP | +23 MIN | +33 dBm | 2.0:1 |
| CA618-6114 | 6.0-18.0 | 35 | 5 0 MAX 3 5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA218-4116 | 2.0-18.0 | 30 | 3.5 MAX, 0.5 TTP | +10 MIN | | 2.0:1 |
| CA218-4110 | 2.0-18.0 | 30 | 5.0 MAX, 3.5 TYP 5.0 MAX, 3.5 TYP 5.0 MAX, 3.5 TYP 5.0 MAX, 3.5 TYP 3.5 MAX, 2.8 TYP 5.0 MAX, 3.5 TYP | +20 MIN | +30 dBm | 2.0:1 |
| CA218-4112 | 2.0-18.0 | 29 | 5.0 MAX, 3.5 TYP | +24 MIN | +34 dBm | 2.0:1 |
| LIMITING A | | L 7 | J.U MAX, J.J 111 | +24 ///// | +34 UDIII | 2.0.1 |
| | | nnut Dunamic Da | ngo Output Dower I | D . D | | |
| Model No. CLA24-4001 | ried (GHZ) | npor bynaniic ka | ilide Outbut Fower i | | r Elatroca dD | VCMD |
| CLAZ 4-400 I | 20 40 | 30 to 10 db | m . 7 to . 11 | Range Psat Powe | er Flatness dB | VSWR |
| (1427,0001 | 2.0 - 4.0 | -28 to +10 dB | m + 7 to + 11 | Range Psat Power I dBm +/ | er Flatness dB /- 1.5 MAX | 2.0:1 |
| CLA26-8001 | 2.0 - 6.0 | -28 to +10 dB -50 to +20 dB | m + 7 to + 11 | Range Psat Powe dBm +/ 8 dBm +/ | er Flatness dB /- 1.5 MAX /- 1.5 MAX | 2.0:1 2.0:1 |
| CLA712-5001 | 2.0 - 6.0 7.0 - 12.4 | -28 to +10 dB -20 to +20 dB -21 to +10 dB | m +7 to +11 m +14 to +1 m +14 to +1 | l dBm +, 8 dBm +, 9 dBm +, | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX | 2.0:1 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 | -50 to +20 dB | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 | Range Psat Powe dBm +/ 8 dBm +/ 9 dBm +/ 9 dBm +/ | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX | 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS N | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR | -50 to +20 dB ATED GAIN A | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX | 2.0:1 2.0:1 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS \ Model No. | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) | -50 to +20 dB ATED GAIN A Gain (dB) MIN | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS \ Model No. CA001-2511A | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freg (GHz) 0.025-0.150 | -50 to +20 dB ATED GAIN A Gain (dB) MIN | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range 30 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS \ Model No. CA001-2511A CA05-3110A | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP 5 MAX 1.5 TYP | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 VSWR 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS 1 Model No. CA001-2511A CA05-3110A CA56-3110A | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freg (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 23 28 28 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 ITTENUATION Noise Figure (dB) Pow .0 MAX, 3.5 TYP .5 MAX, 1.5 TYP | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 22 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS 1 Model No. CA001-2511A CA05-3110A CA56-3110A CA612-4110A | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 23 28 28 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 ITTENUATION Noise Figure (dB) Pow .0 MAX, 3.5 TYP .5 MAX, 1.5 TYP | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 20 dB MIN 22 dB MIN 15 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS 1 Model No. CA001-2511A CA05-3110A CA56-3110A CA612-4110A CA1315-4110A | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 28 2 24 2 25 2. | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow .0 MAX, 3.5 TYP .5 MAX, 1.5 TYP .5 MAX, 1.5 TYP .5 MAX, 1.5 TYP .2 MAX, 1.6 TYP | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 22 dB MIN 15 dB MIN 15 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 1.8:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS V Model No. CA001-2511A CA05-3110A CA6-3110A CA612-4110A CA1315-4110A CA1518-4110A | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 28 2 24 2 25 2. 30 3 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow .0 MAX, 3.5 TYP .5 MAX, 1.5 TYP .5 MAX, 1.5 TYP .5 MAX, 1.5 TYP .2 MAX, 1.6 TYP | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 20 dB MIN 22 dB MIN 15 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS 1 Model No. CA001-2511A CA05-3110A CA56-3110A CA612-4110A CA1315-4110A | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 28 2 24 2 25 2. 30 3 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (4B) Pow 0 MAX, 3.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 2 MAX, 1.6 TYP 0 MAX, 2.0 TYP | dBm | 7-1.5 MAX 7-1.5 MAX 7-1.5 MAX 1-1.5 MAX Attenuation Range BO dB MIN 20 dB MIN 22 dB MIN 15 dB MIN 20 dB MIN 20 dB MIN 20 dB MIN 20 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 1.8:1 1.85:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS 1 Model No. CA001-2511A CA05-3110A CA56-3110A CA612-4110A CA1315-4110A CA1518-4110A LOW FREQUE Model No. | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 5 28 2 24 2 25 2. 30 3 ERS Gain (dB) MIN | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 2 MAX, 1.6 TYP 0 MAX, 2.0 TYP | dBm | /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX /- 1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 22 dB MIN 15 dB MIN 15 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.8:1 1.85:1 VSWR |
| CLA712-5001 CLA618-1201 AMPLIFIERS N Model No. CA001-2511A CA05-3110A CA56-3110A CA612-4110A CA1315-4110A CA1518-4110A LOW FREQUE Model No. CA001-2110 | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 28 2 24 2 25 2 30 3 ERS Gain (dB) MIN 18 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP -5 MAX, 1.5 TYP -5 MAX, 1.5 TYP 2 MAX, 1.6 TYP 0 MAX, 2.0 TYP Noise Figure dB 4.0 MAX, 2.2 TYP | dBm | 7-1.5 MAX 7-1.5 MAX 7-1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 22 dB MIN 15 dB MIN 20 dB MIN 20 dB MIN 20 dB MIN 3rd Order ICP +20 dBm | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 1.8:1 1.85:1 VSWR 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS 1 Model No. CA001-2511A CA05-3110A CA56-3110A CA612-4110A CA1315-4110A CA1518-4110A LOW FREQUE Model No. | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 NCY AMPLIF Freg (GHz) | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 5 28 2 24 2 25 2, 30 3 ERS Gain (dB) MIN 18 24 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 2 MAX, 1.6 TYP 0 MAX, 2.0 TYP Noise Figure dB 4.0 MAX, 2.2 TYP 3 5 MAX, 2.7 TYP | dBm | 7- 1.5 MAX 7- 1.5 MAX 7- 1.5 MAX 7- 1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 22 dB MIN 15 dB MIN 15 dB MIN 20 dB MIN 20 dB MIN 3rd Order ICP | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 1.8:1 1.85:1 VSWR 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS N Model No. CA001-2511A CA05-3110A CA6-3110A CA612-4110A CA1518-4110A LOW FREQUE Model No. CA001-2110 CA001-2211 CA001-2215 | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 NCY AMPLIFI Freq (GHz) 0.01-0.10 0.04-0.15 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 5 28 2 24 2 25 2, 30 3 ERS Gain (dB) MIN 18 24 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 2 MAX, 1.6 TYP 0 MAX, 2.0 TYP Noise Figure dB 4.0 MAX, 2.2 TYP 3 5 MAX, 2.7 TYP | dBm | 7- 1.5 MAX 7- 1.5 MAX 7- 1.5 MAX 7- 1.5 MAX Matenuation Range 80 dB MIN 20 dB MIN 22 dB MIN 15 dB MIN 20 dB MIN 20 dB MIN 3rd Order ICP +20 dBm +23 dBm | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.8:1 1.85:1 VSWR |
| CLA712-5001 CLA618-1201 AMPLIFIERS N Model No. CA001-2511A CA05-3110A CA6-3110A CA612-4110A CA1518-4110A LOW FREQUE Model No. CA001-2110 CA001-2211 CA001-2215 | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 NCY AMPLIFI Freq (GHz) 0.01-0.10 0.04-0.15 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 28 2 24 2 25 2 30 3 ERS Gain (dB) MIN 18 24 23 28 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 2 MAX, 1.5 TYP 0 MAX, 2.0 TYP Noise Figure dB 4.0 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP | dBm | 7- 1.5 MAX 7- 1.5 MAX 7- 1.5 MAX 1- 1.5 | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 1.8:1 1.85:1 VSWR 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS N Model No. CA001-2511A CA05-3110A CA56-3110A CA612-4110A CA1315-4110A CA1518-4110A LOW FREQUE Model No. CA001-2110 CA001-2211 CA001-2215 CA001-3113 | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 NCY AMPLIFI Freq (GHz) 0.01-0.10 0.04-0.15 0.01-1.0 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 28 2 24 2 25 2 30 3 ERS Gain (dB) MIN 18 24 23 28 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 TTENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 2 MAX, 1.5 TYP 0 MAX, 2.0 TYP Noise Figure dB 4.0 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP | dBm | 7-1.5 MAX 7-1.5 MAX 7-1.5 MAX 7-1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 15 dB MIN 15 dB MIN 20 dB MIN 20 dB MIN 20 dB MIN 21 dB MIN 22 dB MIN 23 dB MIN 24 dB MIN 25 dB MIN 26 dB MIN 27 dB MIN 28 dB MIN 29 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.9:1 1.8:1 1.85:1 VSWR 2.0:1 2.0:1 2.0:1 2.0:1 |
| CLA712-5001 CLA618-1201 AMPLIFIERS N Model No. CA001-2511A CA05-3110A CA56-3110A CA1315-4110A CA1518-4110A LOW FREQUE Model No. CA001-2110 CA001-2215 CA001-3113 CA002-3114 | 2.0 - 6.0 7.0 - 12.4 6.0 - 18.0 WITH INTEGR Freq (GHz) 0.025-0.150 0.5-5.5 5.85-6.425 6.0-12.0 13.75-15.4 15.0-18.0 NCY AMPLIF Freq (GHz) 0.01-0.10 0.04-0.15 0.01-1.0 0.01-2.0 | -50 to +20 dB ATED GAIN A Gain (dB) MIN 21 5 23 2 28 2 24 2 25 2. 30 3 ERS Gain (dB) MIN 18 24 23 28 27 | m +7 to +11 m +14 to +1 m +14 to +1 m +14 to +1 m +14 to +1 ITENUATION Noise Figure (dB) Pow 0 MAX, 3.5 TYP 5 MAX, 1.5 TYP 5 MAX, 1.5 TYP 2 MAX, 1.5 TYP 2 MAX, 1.6 TYP 0 MAX, 2.0 TYP Noise Figure dB 4.0 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP 4.0 MAX, 2.8 TYP 4.0 MAX, 2.8 TYP | dBm | 7-1.5 MAX 7-1.5 MAX 7-1.5 MAX 7-1.5 MAX Attenuation Range 80 dB MIN 20 dB MIN 22 dB MIN 20 dB MIN 20 dB MIN 20 dB MIN 20 dB MIN 21 dB MIN 22 dB MIN 24 dB MIN 25 dB MIN 26 dB MIN 27 dB MIN 28 dB MIN 28 dB MIN 29 dB MIN 20 dB MIN 21 dB MIN 22 dB MIN 23 dB MIN 24 dB MIN 25 dB MIN 26 dB MIN 27 dB MIN 28 dB MIN 28 dB MIN 29 dB MIN 20 dB MIN | 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 2.0:1 1.8:1 1.8:1 1.8:1 1.8:1 1.85:1 VSWR 2.0:1 2.0:1 2.0:1 2.0:1 |
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DefenseNewsCliff Drubin, Associate Technical Editor

vs.

Value of Global Military Satellite Market to Increase By Over 70 Percent

ccording to a new report by Strategic Defence Intelligence (SDI) the global military satellite market is expected to grow from \$5.7 billion in 2015 to \$9.7 billion in 2025 – an increase of over 70 percent in value terms. Global expenditure on military satellites will accumulate to \$94.3 billion over the next 10 years. With a share of 36 percent, intelligence, surveillance and reconnaissance (ISR) satellites will lead the market, followed by communications (32 percent) and navigational (31 percent) satellites. "Many existing ISR satellites are about to reach the end of their operational life cycle, meaning that leading defense spenders need to replace these satellites in the next five to 10 years. Moreover, satellites are an alternative to expensive UAVs or reconnaissance aircraft, which is also driving growth," says Bharathi Bajaj, analyst at SDI.

According to SDI, the U.S. will continue to dominate the global military satellite market, occupying 41 percent

Global spending on military satellites will accumulate to \$94.3 billion over the next 10 years.

of the global market share with cumulative spending of \$38.4 billion during the next decade. "The increasing effort of the U.S. Department of Defense to reorient military forces towards network-centric warfare is driving expendi-

ture," says Bajaj. "The U.S. is also trying to counter growing investments by countries such as Russia and China in the military satellite sector." Prominent programs boosting investments include the satellite bandwidth for the UAVs, Evolved Expendable Launch Vehicle (EELV) and MIL-SATCOM programs.

The report also finds that manufacturers are focusing on developing cheaper alternatives such as microsatellites to counter the global defense budget cuts. "Microsatellites are faster to design, develop and launch using commercial off the shelf technology (COTS), although their reliability and longevity are yet to be proven," says Bajaj. Countries such as the U.S., Russia, Israel, Japan, Brazil and China are among those investing significantly in microsatellites.

GD Receives \$219 M for U.S. Army's WIN-T Increment 2 Systems



eneral Dynamics received the first full rate production order from the U.S. Army to build additional Warfighter Information Network – Tactical (WIN-T) Increment 2 systems. The \$219 million order includes the production of more than 300 vehicle-based network communication nodes along with related equipment and materials. WIN-T Increment 2 is the Army's communications backbone providing secure, on-the-move communications,

mission command and situational awareness for commanders and their soldiers. The order allows the Army to continue fielding WIN-T Increment 2 to Army units currently scheduled to receive the system.

"WIN-T Increment 2 puts the power of the Soldier's Network into soldiers hands down to the company level, which is vitally important as the Army evolves into a more expeditionary force," said Chris Marzilli, president of General Dynamics Mission Systems. "As full-rate production

begins, our engineering teams will continue working closely with the Army to upgrade technology and human-factors design, giving soldiers a decisive information advantage wherever they are called to serve."

WIN-T Increment 2 is integrated into Mine-Resistant Ambush Protected (MRAP), High Mobility Multipurpose Wheeled Vehicles (HMMWV) and Stryker vehicles. To date, four division headquarters and 12 brigade combat teams have WIN-T Incre-

WIN-T Increment
2 is the Army's
communications
backbone providing
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for commanders and
their soldiers.

ment 2. The system successfully served Army units supporting the Security Force Assistance Brigades in Afghanistan by replacing the fixed communications infrastructure that was dismantled when the U.S. military closed its operating bases. Last summer, WIN-T provided the 'communications grid' for humanitarian operations responding to the Ebola epidemic in West Africa.



Source: U.S. Army Photo

Raytheon Completes Milestones on Path to Production-Ready GaN-Based AESA Patriot

ilitaries of the future will soon have access to a single radar capable of protecting troops' backs from threats such as ballistic and cruise missiles, and

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drones. Raytheon Co. recently completed a series of milestones, bringing the combat-proven Patriot Air and Missile Defense System with 360-degrees of coverage, one step closer to production readiness.

The milestones involve upgrading the Patriot's radar main array with gallium nitride (GaN) Active Electronically Scanned Array (AESA) technology. Completion of those milestones keep Raytheon engineers, who are currently building a GaN-based AESA full size main panel radar array, on track to having the system up and running in early 2016.

"A GaN-based AESA radar benefits netted sensors, and gives Patriot greater capability and reliability while significantly reducing operations and sustainment costs," said Ralph Acaba, vice president of Integrated Air and Missile Defense at Raytheon's Integrated Defense Systems business. "Raytheon recognizes how important this capability is for the warfighter and is investing its own resources to bring Patriot's GaN-based AESA radar to the point where it can enter engineering and manufacturing development with low risk."

The main AESA array is a bolt-on replacement antenna that measures roughly 9 feet wide × 13 feet tall, which is oriented toward the primary threat. Patriot's new rear panel arrays, which are a quarter the size of the main array, let the system look behind and to the sides of the main array, enabling Patriot to engage threats in all directions. Earlier this year, Raytheon built a GaN-based AESA Patriot rear-panel array, integrated it with the current Patriot radar using the

existing, recently modernized, backend processing hardware and software, and tracked targets of opportunity to seamlessly create a 360-degree view.

The milestones accomplished to date include fabricating the main radar array's superstructure, and completing development work on the power and cooling subsystems. In the months ahead, additional upgrades will focus on integrating the

"A GaN-based
AESA radar benefits
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subsystems and populating the array superstructure with GaN-based transmit-receive line replaceable units (TRLRU). The GaN TRLRUs are the heart of the radar, are identical to the ones used for the rear-panel arrays, and are made in the same Massachusetts-based GaN foundry currently producing GaN chips for Navy and Air Force defense systems.

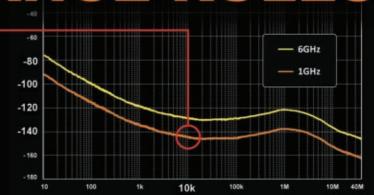
The GaN-based AESA Patriot radar will work with an open-architecture common command and control (CC2) node and retain backwards compatibility with the current Patriot Engagement Control Station. The CC2 node will be fully interoperable with NATO and the Integrated Air and Missile Defense Battle Command System.

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he UK Ministry of Defence (MoD) has launched Project MORPHEUS to develop and consider options to replace the current Bowman communications system and meet the requirements of the British Army, Royal Marines and RAF Regiment. It is seeking anyone involved in areas such as telecommunications, wireless, IT, networks and security – as well as trainers in these areas – to feed expertise and ideas on new technological approaches into the project whether working in the defence or commercial world.

The MORPHEUS Systems House – led by PA Consulting with QinetiQ, Roke Manor Research and CGI – is tasked with drawing together different ideas into potential options, so those with partial solutions and research are strongly encouraged to submit them. MORPHEUS provides a way for academics and businesses, especially small to medium enterprises (SME), to inform the future of communications, as well as presenting significant long-term business opportunities for innovators in this area. Companies wishing to register an interest can do so via the MORPHEUS website.

The range of options, outlining which technologies and software are needed to get information from point A to B securely, will be addressed, with the most appropriate long-term business models (acquisition and operating). The selection process will take into account security, speed of communication, range, ease of use and cost – both of deployment and manpower required for operation.

... a capability to securely integrate new technologies...

These options also need to plan for the pace of change of operational demands and technical development. They must reflect a capability to securely integrate new tech-

nologies as they come onto the market, including commercial technologies. The selected option(s) will form the basis for MoD competition for design of the new system.

Rick Mather, project lead for MORPHEUS at QinetiQ said, "We know there are lots of really exciting technology and security SMEs, as well as academics, doing exactly the kind of research and innovation this project needs. We also know a lot of them think that these kinds of contracts always go to the same old defence companies. That's not the case here, we're really open to innovative, and even unusual solutions to ensure that the final options are the best possible."

University of Warwick Eyes Potential of Terahertz Sensor

new type of sensor, that is said to be much faster than competing technologies used to detect and identify hidden objects, has been developed by scientists at

the University of Warwick, UK. Called 'Q-Eye', the invention senses radiation across the Terahertz (THz) spectrum. It works by detecting the rise in temperature produced when electromagnetic radiation emitted by an object is absorbed by the Q-Eye sensor, even down to the level of very small packets of quantum energy (a single photon).

The device could help address the weaknesses reported in July in America's airport security, where mock weapons and explosives were smuggled through airports, undetected in 95 percent of cases. It may also prove useful in discover-

ing concealed goods in the retail industry or for non-destructive monitoring. Other applications include astronomical and climate science observations and medical diagnosis.

Professor Evan Parker of Warwick University's Nano-Silicon Group, "...our initial calculations indicated world-beating detector capability..."

Physics Department commented, "We were very surprised when our first very crude prototype showed such impressive speed and detection performance and our initial calculations indicated world-beating detector capability – all this and using silicon."

Made using standard silicon processes, large numbers of detector chips containing designs matched to a particular application can easily be fabricated on large (300 mm) wafers with great uniformity, which is claimed to set it apart from existing technologies.

The patented device involves a thin film of aluminium deposited on top of a silicon layer placed under strain, used to create an electronic cooling (e-cooling) process. The electrons in the silicon layer are so isolated from the silicon lattice they become highly sensitive to incoming radiation. This e-cooling process is the secret to Q-Eye sensor's exceptional performance, enabling fast imaging and material identification.

Bell Labs and Technische Universität Dresden Collaborate on 5G

ell Labs, the industrial research arm of Alcatel-Lucent has become a research partner of the Technische Universität Dresden's 5G Lab Germany. Under the research collaboration agreement the two organizations will develop and test technologies that will help to define the capability of 5G mobile networks in meeting the massive connectivity demands of the future, with the high-performance required by end-users.

Opened in September 2014, the 5G Lab Germany brings together 20 professors from the Technische Universität Dresden with more than 500 scientists. It is a recognized technology consortium and industry leader in the collaborative effort required to develop and deliver 5G networks. It comprises four separate tracks which al-

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low members to focus on areas of interest, while providing a holistic view of 5G networks. As a new member of the 5G Lab Germany, Alcatel-Lucent will initially focus its research efforts on the Wireless & Networks track of the program.

The Alcatel-Lucent collaboration with 5G Lab Germany will initially focus on two sectors. The first is the use of multiple device-to-radio connections to enhance reliability for mission-critical communications. Studies will investigate how network capacity and reliability could be enhanced by connecting a device like a smartphone to multiple radios simultaneously. It will focus on how multiple 5G radio links or a combination of 5G and 4G LTE radio links could enhance reliability for mission-critical communications, where disruption to the network will cause a failure in operations.

The second area is the definition of a 5G air interface where the organizations will jointly analyze new air interface – or radio frequency link – proposals for 5G concept/prototype networks and propose them in the upcoming 5G standardization process. The newly-developed Bell Labs Universal Filtered-Orthogonal Frequency-Division Multiplexing (UF-OFDM) waveform for 5G networks is a leading contender for standardization and will enable enhanced performance and new services, while dramatically increasing the number of users (both human and machine) as well as reduce the complexity of 5G networks.

Infineon Heads Three European Electromobility Research Projects

The European Commission is launching three new research projects aimed at making electromobility cheaper, more efficient and more reliable in order to facilitate more environmentally-friendly vehicles on Europe's roads. Europe will be the site for the continued development and production of electric vehicles under these projects, which will be headed by Infineon Technologies and run until 2018.

As a result of the three research projects 3Ccar, OSEM-EV and SilverStream, electrical systems used in electric vehicles will benefit from being approximately one-fifth more compact and lighter, their range improved, and their cost lowered by about 25 percent. The three projects will collaborate to research and develop environmentally-friendly, safe and robust electric vehicles. The entire automotive value chain is contributing to this effort, from chip producers to car manufacturers.

With a research budget of €54 million the Integrated Components for Complexity Control (3Ccar) project involves 48 partners from 14 countries are participating in the 3Ccar Project. Twelve partners are involved in the Optimised and Systematic Energy Management in Electric Vehicles (OSEM-EV) project, which has a research budget €8 million, while ten partners from five countries are involved in the €4.5 million SilverStream project.





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Demand Rising in Millimeter Wave Bands for Mobile Backhaul

TE network expansion across different regions is driving the acceleration of LTE mobile adoption worldwide. According to ABI Research, in 2014, the global LTE subscriber base increased threefold from 2013 to 628 million. "Increasing LTE adoption combined with growing adoption of smartphones, tablets and bandwidth hungry applications is continuously putting pressure on the capacity of backhaul networks across different markets," comments Jake Saunders, VP and practice director of Core Forecasting.

In many countries, telecommunication regulators are considering efficient allocation of spectrum for mobile backhaul. Many are in the process or have completed the consultation with telecom operators for spectrum planning for mobile backhaul. The selection of backhaul network solution, whether it is fixed or wireless and the topology and spectrum bands for the backhaul links, vary market to

A combination of fiber-optic and mmWave will represent approximately half of total backhaul links in 2019.

market based on the several conditions and the capacity requirements by each market.

While fiber-optic is an attractive medium to support high capacity backhaul links, it is not the best solution in a number of scenarios, due to its cost and time required to install. "Microwave spec-

trum bands are still the most widely used for backhaul links and equipment vendors are also providing various solutions to enhance the capacity of microwave backhaul links. Based on ABI Research's backhaul spectrum data analysis, microwave spectrum bands will remain the important option for mobile backhaul links," says Khin Sandi Lynn, industry analyst.

Spectrum bands in the sub 20 GHz bands are increasingly experiencing congestion—a number of countries have taken steps to make the spectrum in the higher bands available for backhaul use. Millimeter waves (mmWave), which include V-Band (60 GHz) and E-Band (70/80 GHz), are proving of interest to operators for small cell backhaul deployment. ABI Research expects a combination of fiberoptic and mmWave will represent approximately half of total backhaul links in 2019.

Mobile Data Traffic Growth Built on Emerging Market Strength

obile operators in developed markets experiencing a slow-down in traffic growth may want to look to emerging markets for ideas on unlocking growth in more cost-conscious segments. According to the Strategy Analytics' Wireless Operator Strategies report, "77 Percent Mobile Data Traffic Growth in Q1 as Emerging Market Momentum Builds," micro-bundles for data, device and

data plan combinations, and affordable smartphones have a role to play in any cost-conscious customer segment, irrespective of location.

These findings are based on data from Strategy Analytics' Wireless Operator Performance Advanced 4G markets should look to developing economies for growth ideas.

Benchmarking database, which tracks the financial and operational performance of 247 active wireless operators, which collectively account for 80 percent of the world's cellular subscriptions. Other key findings of the report include:

- The top operators in terms of traffic growth in Q1 2015 were AIS Thailand (192%), Geocell Georgia (176%), Play Poland (163%), Indosat Indonesia (159%) and China Mobile (158%).
- 2G traffic growth is still strong in India, where low-cost smartphone models remain in use. 2G accounted for 44% of total data traffic at Idea Cellular in Q1 2015 and recorded 68% annual growth, compared to the 135% growth seen on Idea's 3G network.
- 4G is dominant in markets such as the U.S., where Verizon Wireless saw 86% of its traffic on the LTE network, and South Korea, where operators carried 96% of their data traffic on 4G.
- Advanced 4G markets reported slower traffic growth in Singapore (25%) and Hong Kong (34%).

These results are in line with the 26 percent growth in U.S. mobile data traffic recently reported by the CTIA for 2014.

U.S. Wireless Market to Add 100 Million Subscribers by 2020

he U.S. wireless market has entered into a new phase, evolving from voice to text to data and now to constant connectivity and what you do with it—according to the Strategy Analytics Wireless Operator Strategies (WOS) service report, "U.S. Wireless Outlook: Can T-Mobile and Sprint Disrupt AT&T and Verizon Wireless?"

With fewer new subscribers to sign up for wireless service for the first time, carriers have focused on transitioning consumers to smartphones, 4G LTE and monetizing their data use. Now carriers are focusing on adding value and content as they jockey for position.

Key findings:

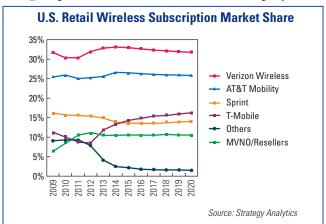
 While growth has slowed, nearly 100 million wireless connections (including consumer electronics connections but excluding M2M) will be added through 2020, reaching a 128 percent penetration rate (of the U.S. population).

For More Information

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CommercialMarket

- Mobile service revenue will grow 0.2 percent to reach \$197 billion in 2020, up slightly from \$195 billion in 2015, spurred by a 5.7 percent growth in prepaid service revenue and 3.3 percent growth in data revenues.
- Verizon Wireless and AT&T are diversifying their revenue streams but will remain strong leaders, even as challengers T-Mobile USA and Sprint gain ground.
- No major shifts are anticipated in market share among the top four carriers, as T-Mobile has already surpassed Sprint in terms of total subscribers by mid-2015. The wholesale/MVNO/reseller market will gain a slightly higher percent of net adds over the next couple years.



LTE Capable Antennas Push Market Towards \$4B

he global market for LTE capable antennas for wireless infrastructure, including passive and active types, is set to reach almost \$4B in 2015, according to the latest forecast from ABI Research.

Multi-band antennas are the hot segment of this market. "LTE does not have the formal spectrum standardization of previous air interfaces such as 3G," according to research director Lance Wilson, "so multi-band antennas that can operate over a number of different frequency slots offer a solution to the problem of rapidly growing LTE wireless data traffic."

Active antennas are certainly part of the overall mix but their cost-other than remote electrical tilt antennas (RET)has certainly limited market penetration for now. The antenna vendor ecosystem is slightly unusual in that there are multiple tiers and many participants. The bulk of these vendors are small companies that command only fractional percentages of the total available market. ABI Research believes that some market consolidation is likely. The scenario for active antennas is a bit different, with antenna manufacturers normally partnering with equipment builders.

Has 4G provided stimulus to the antenna market? "LTE-capable antennas are now driving overall market growth," says Wilson, "and this scenario should continue over the next few years."



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Around the **Circuit** Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Keysight Technologies announced its Netherlands subsidiary will acquire the entire issued and to be issued ordinary share capital of **Anite**, a U.K.-based leading supplier of test and measurement solutions to the international wireless market. At 126 pence per share, the acquisition values Anite (on a fully diluted basis) at approximately £388 million (US\$606 million based upon an exchange rate of 1.56 USD:GBP). This cash acquisition has been unanimously recommended by the board of directors of Anite.

API Technologies Corp., a provider of high performance RF, microwave, millimeter wave, power and security solutions announced the successful completion of its acquisitions of Aeroflex/Inmet Inc. and Aeroflex/Weinschel Inc. from Cobham plc for a total purchase price of \$80 million. Combined, Inmet and Weinschel generated revenue of \$51.4 million and EBITDA margins over 20 percent for the year ended December 31, 2014. The closing of the acquisition of Inmet and Weinschel adds breadth to API's RF, microwave and microelectronics product portfolio, extends the company's subsystems offering and furthers API's reach in key end markets, including defense, space, commercial aviation and wireless.

NXP Semiconductors N.V. announced an agreement to sell its RF power business to **Jianguang Asset Management Co. Ltd.** Under the terms of the agreement JAC Capital will pay \$1.8 billion for the business. The NXP RF power business is one of the market leaders in high performance RF power amplifiers primarily focused on the cellular base station market, but with potential future growth applications in the areas of industrial lighting, next generation cooking and automotive electronic ignition systems.

GLOBALFOUNDRIES has completed its acquisition of **IBM's Microelectronics Business.** With the acquisition, GLOBALFOUNDRIES gains differentiated technologies to enhance its product offerings in key growth markets, from mobility and Internet of Things (IoT) to big data and high-performance computing. The deal strengthens the company's workforce, adding decades of experience and expertise in semiconductor development, device expertise, design and manufacturing. The addition of more than 16,000 patents and applications makes GLOBALFOUNDRIES the holder of one of the largest semiconductor patent portfolios in the world.

COLLABORATIONS

Cobham AvComm, formerly Aeroflex AvComm business unit, has announced an agreement with **Tait Communications** to provide automated test capabilities for Tait P25 series radios on the Cobham 3920B Digital Radio Test Set. Initial test capabilities will be focused on

the Tait TP9100 and TM9100 series radios. The program will be later expanded to provide automated testing of Tait TP9400 and TM9400 series radios. With a proven track record for speed and accuracy, this application uses the precision instrumentation with the 3920B to quickly perform automated tests to specifications defined by the manufacturer.

Exelis has signed agreements with four **Federal Aviation Administration** (FAA) designated unmanned aircraft systems test sites for airspace situational awareness and research. The research will focus on using the Exelis Symphony® RangeVueTM sense-and-avoid tool towards safe integration of unmanned aircraft into the national airspace system. Under the terms of the agreements, the test sites will gain valuable real-time and historical situational awareness of the range airspace via Symphony RangeVue, while Exelis gains critical product feedback through operational usage.

Systems under which BAE Systems will provide non-exclusive third-party foundry services in support of the company's "Lab-to-Fab" transition plan. The current phase of the work will be performed between March 2015 and August 2015. Key objectives of the collaboration include process transfer, prototype builds and design enablement kit development. Using BAE Systems' ISO certified manufacturing facility will improve the quality, process control and analytical capacity of prototype builds. The result will be both a more manufacturable process and improved optimization of the device structures in the planar-opto-electronic technology.

NEW STARTS

Pasternack Enterprises Inc. recently launched two new eCommerce websites, one in China and one in Japan, providing engineers and component buyers in those countries easier access to the largest selection of in-stock and readyto-ship RF products. With the recent launch of www.pasternack.cn and www.pasternack.jp, Pasternack has greatly expanded its reach into two key Asian markets for RF components. Both websites are translated into the local language and offer local eCommerce options, previously not available from the company's U.S. website, Pasternack. com.

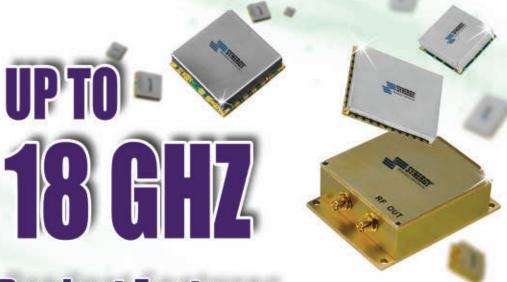
ACHIEVEMENTS

Five Arlington, Texas Independent School District seniors gave their final project reports marking the completion of their high school engineering internship at **Lockheed Martin's** Aeronautics business. Upon their high school graduation, they will become college interns for the summer. Lockheed Martin developed the program in partnership with Arlington ISD as part of its efforts to prime the pipeline for engineering talent. In addition to a mature internship program, Arlington ISD incorporates the Project Lead the Way engineering curriculum in its schools. Project Lead the Way is a nationwide experiential engineering

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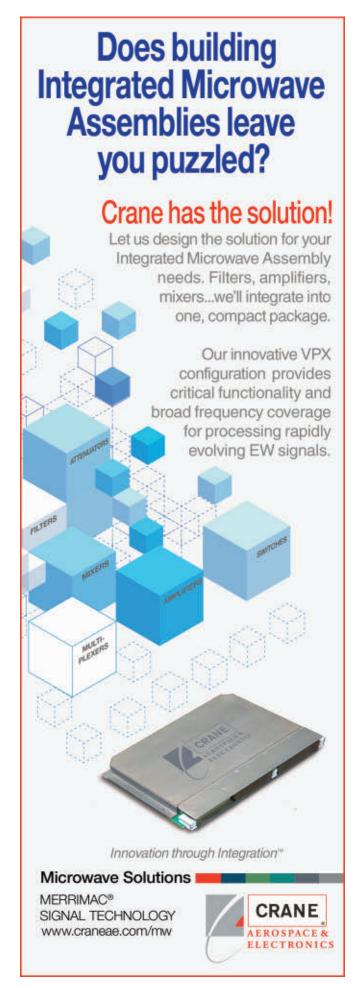
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Around the Circuit

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TRM Microwave of Bedford, N.H. has been certified as a woman-owned small business. The decision to transfer the future of TRM, a major supplier of defense-related passive RF components, from Anthony Tirollo to current CEO Wendy Tirollo coincides with the company's 45th anniversary. Wendy Tirollo joined TRM in April 1994 and played a key role in the company's initiative to become one of the first RF manufacturers to achieve ISO certification, where she was exposed to all aspects of the business.

CONTRACTS

The Missile Defense Agency awarded Raytheon Co. an undefinitized contract action for a fiscal year 2015 contract valued at \$559 million for Standard Missile-3 Block IBs, which are guided missiles used by the U.S. Navy to provide regional defense against short to intermediate range ballistic missile threats. Under this contract action, which was announced April 30 by the Department of Defense, Raytheon will deliver an initial quantity of 44 Standard Missile-3 Block IB all-up rounds and provide the work required to produce and deliver the third stage rocket motor reliability growth and design enhancements.

Teledyne Technologies Inc. announced that its subsidiary, Teledyne Brown Engineering Inc., was awarded the Target Execution, Asset and Material Development, Lethality Testing and Analysis (TEAM DELTA) Task Order with the U.S. Army Space and Missile Defense Command/Army Forces Strategic Command (USASMDC/ARSTRAT) under the Test Execution Services and Launch Augmentation (TESTLA) contract. This task order under an indefinite delivery, indefinite quantity contract has a value of up to \$67.4 million over a period of 36 to 48 months, depending on the exercise of contract options.

Harris Corp. announced a one-year, \$10 million followon production contract for its portion of production of the Small Tactical Terminal, a co-developed product with ViaSat. This latest award brings the overall contract value for Harris to more than \$25 million since 2010. The Small Tactical Terminal (STT) was jointly developed by ViaSat and Harris, to enable soldiers at the tactical edge of the battlefield to access real-time situational awareness, location, and command and control information using a single radio terminal sized to fit space-constrained, mobileground and light-aircraft platforms.

Mercury Systems Inc. announced that it has been awarded a \$7.1 million indefinite quantity/indefinite delivery (IDIQ) contract by the U.S. Naval Warfare Center, Crane Division (NSWC) to supply advanced radio frequency (RF) tuners, digital receivers and related equipment to be used as spares during the installation of the AN/SLQ-32(V)6 electronic countermeasure system on U.S. Navy and Coast Guard ships. Work will be performed at the company's headquarters in Chelmsford, Mass., and is expected to be complete by May 2020. The AN/SLQ-

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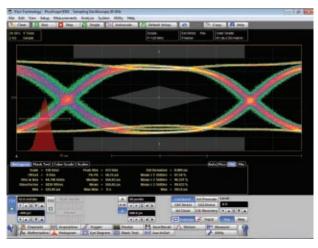


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The clock recovery trigger derives a timing reference directly from the NRZ waveform to be measured. The clock recovery trigger covers the most popular electrical standards used today from 6.5 Mb/s to 11.3 Gb/s bit rates.



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Around the Circuit

32(V)6 was developed as part of the Navy's Surface Electronic Warfare Improvement Program (SEWIP), which is an upgrade to the AN/SLQ-32 electronic warfare anti-ship missile defense system.

PEOPLE



A D :15 K (

Anaren Inc. has named David E. Kopf as the new president of the company's Space & Defense Group. Most recently, Kopf was vice president of engineering and operations at Astronics Aerosat, based in Amherst, N.H. Prior to that, he held executive, business development and engineering management posts at Cobham Defense Electronics, Tyco Electronics M/A-Com, and Sanders (a

Lockheed Martin Company) and BAE. Kopf earned his MBA at New Hampshire College, his BSEE (with a minor in economics) from Case Western Reserve University, and his MSEE in Microwave Engineering from the University of Massachusetts.



▲ Jacqueline Williams

Microwave Journal welcomes Jacqueline Williams as event coordinator, a new position that was created based on MWJ's expanding event portfolio. She will coordinate activities around the European Microwave Week event, EDI CON China and our newest launch, EDI CON USA as well as manage Microwave Journal's participation at various industry exhibitions. Williams

recently graduated with an M.S. in Organizational and Professional Communication from Regis College, where she also gained experience in planning and organizing events as programming and leadership coordinator.

REP APPOINTMENTS

Digitaltest Inc., global provider of advanced in-circuit test, flying probe and process software solutions announced that it has appointed **Torenko Associates** as its exclusive manufacturers' representative for the Texas and Mexico regions. Torenko Associates will represent Digitaltest's complete product line in Texas, Mexico, Oklahoma, Arkansas and Louisiana. Headquartered in Sunnyvale, Texas, Torenko Associates has a team across the U.S. and Mexico dedicated to helping its customers make the right decision.

DiTom Microwave has signed up **Chesapeake Advanced Technologies** for exclusive representation in the Mid-Atlantic States to include Maryland, Delaware, Virginia, West Virginia, Washington D.C., South New Jersey and Eastern Pennsylvania.

Custom MMIC announced the appointment of **JS Commtech** as its new technical representative covering the country of Korea. JS Commtech was founded in 2006 and has an established team of technical sales professionals offering state-of-the-art components and related technologies of the RF/microwave and wireless markets.



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VDI's mini-modules are reduced in size, but yield the same industry leading performance as our original designs. Also the power supply is simplified and the cooling fans have been eliminated. Mini-modules are currently available for WR15, WR12, and WR10, with higher frequency bands coming soon.

| Waveguide Band (GHz) | WR15 50-75 | WR12 60-90 | WR10 75-110 | WR6.5 110-170 | |
|---|-------------------|----------------------|-----------------------|-------------------------|--|
| Dynamic Range (BW=10Hz, dB, typ) (BW=10Hz, dB, min) | 120 100 | 120 100 | 120 100 | 120 90 | |
| Magnitude Stability (±dB) | 0.15 | 0.15 | 0.15 | 0.25 | |
| Phase Stability (±deg) | 2 | 2 | 2 | 4 | |
| Test Port Power (dBm) | 6 | 6 | 6 | 0 | |



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Around the Circuit

Electro Rent and **Anritsu Co.** announced that the two companies have signed a formal agreement whereby Electro Rent is a preferred reseller for Anritsu test solutions throughout the United States and Canada. Under terms of the agreement, industry-leading Anritsu benchtop and field instruments will be available through Electro Rent. In other news, **Electro Rent** and **ART-Fi** have announced that Electro Rent is now the sole provider of the ART-MAN SAR measurement system. The ART-MAN, which reduces SAR testing time from weeks to days, will be used by North American test labs, and wireless equipment and design manufacturers.

Cobham AvComm, formerly a division of Aeroflex and manufacturer of advanced test solutions for military and commercial aviation, along with military and commercial radio test solutions, announced the selection of **Integrated Procurement Technologies** (IPT) as a global stocking distributor partner. This new stocking agreement allows IPT to stock and sell pre-determined items globally. Cobham AvComm selected IPT due to their reputation in providing quality sales, service and support service worldwide. IPT provides a one-stop solution that includes sales, ITAR compliance, and customer support to the military and commercial international market space.

PLACES

Skyworks Solutions announced that it is opening a state-of-the-art design center and laboratory facility in San Diego, Calif. The design center will focus on the development of leading edge technologies targeting 4G/5G protocols and the Internet of Things. Skyworks' design center was slated to become operational in July and is strategically situated to enhance collaboration among Skyworks' design centers in Newbury Park and Irvine, Calif., its advanced packaging team in Irvine, its manufacturing facility in Mexicali, Mexico as well as its filter joint venture with Panasonic in Japan, which designs and produces innovative RF filters and duplexers.

Haigh-Farr increases its in-house environmental testing capabilities with the construction of a dedicated facility adjacent to its existing building. The first phase of the project hosts state-of-the-art vibration equipment that tests both shock and vibration limits on antenna designs, with additional testing capabilities planned for later in the year. The new facility will initially focus on vibration and shock testing. When completed, the new environmental test facility can grow to 40,000 square feet, giving Haigh-Farr the capacity to take a project from virtual simulation design and manufacturing through to final physical testing. This gives the company the ability to serve its customers better by offering tighter quality-control protocols and faster turnaround times for successful project completion.





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US patent 6,943,629

*Low frequency cut-off determined by coupling cap. For GVA-60+, GVA-62+, GVA-63+, and GVA-123+ low cut off at 10 MHz. For GVA-91+, low cut off at 869 MHz.

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Non-Linear Simulation Models for ADS
http://www.modelithics.com/mvp/Mini-Circuits.asp





European Microwave Week

Welcome to European Microwave Week 2015

Hervé Aubert

General Chairman, EuMW 2015

Ivar Bazzy

President, Horizon House Publications

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/eumw2015.

elcome to Paris, La Ville Lumière – the City of Light - where the spotlight will fall on the RF and microwave industry when the Palais des Congrès de Paris stages the 18th European Microwave Week from 6 to 11 September 2015. During the week the focus will be on the three conferences: the 45th European Microwave Conference (EuMC), the 10th European Microwave Integrated Circuits Conference (EuMIC) and the 12th European Radar Conference (Eu-RAD, together with the European Microwave Exhibition and affiliated workshops and short courses.

The motto for 2015 is "Freedom through Microwaves," which addresses the concept of modern living, where microwave technologies are opening up new frontiers that will govern how individuals and objects communicate, sense and move. In particular, there is major interest in the development and evolution of the "connected humans" concept, where there is potential for the micro-

wave community to play a significant role as we look towards Horizon 2020.

Technologically, connecting humans may be relatively new but European Microwave Week has been doing so on a personal level for many years, priding itself on building relationships between academia and industry, the young and the more experienced and across continents. Such interaction is epitomized by the Welcome Reception on Tuesday evening, which provides networking opportunities and a convivial atmosphere that actively encourages delegates and industry to interact and socialize.

On Wednesday evening socializing will move from the Palais des Congrès to the River Seine for a cruise, including a cocktail reception on board a charming Paris Bâteaux Mouches, which will tour the Paris landmarks after dark. Mixing business and pleasure can be enjoyed throughout the week through the strong calendar of social events.

Not content with just land and water, EuMW 2015 will also offer the opportunity for attendees to discover

space, as it is a major focus for the event and the subject of key presentations. For example, the opening session on Tuesday morning will feature two keynote lectures when Bruno Le Stradic from Airbus DS Space Systems will consider: "Space Antennas on Satellites, for Telecommunications and Earth Observation Missions: Past Evolutions and Future Trends." He will be followed by Laurent Phalippou from Thales Alenia Space (TAS) who will present: "30 Years of Innovation in TAS Radar Altimetry Product Line for Earth Climate Monitoring."

During the EuMW closing session, Clément Dudal and Céline Loisel from the French Space Agency (CNES) will consider the ESA/CNES/DLR Rosetta mission, which successfully reached the 67P Churyumov-Gerasimenko comet after a 10 year journey. They will offer an insight into the embedded RF electronics, which led to the success of the mission.

Not forgetting the Defence, Security and Space Forum, which will take place on Wednesday, 9 September, and feature executives from indus-

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European Microwave Week

try, academia, the military and space agencies. This year the focus will be on the design and deployment of RF systems for unmanned aerial vehicles. More information on the Forum can be found on page 90.

Paris is renowned for glamour, so it is appropriate that the well-established Women in Engineering event, co-sponsored by the IEEE MTT-Society, will include a panel session focused on exploiting microwaves in the area of fashion (fashionable and wearable technology), arts and gastronomy that will end with a guided tour of a fashion workshop.

The catwalk where the latest RF and microwave trends and innovations can be found will be at the European Microwave Exhibition. The show floor offers a platform for companies from Europe and across the globe to demonstrate the developments they are making and the products they are producing that will enable engineers to design, develop and fulfill their goals. The exhibition spans the middle of the week from 8 to 10 September, with 265 exhibiting companies taking up 9460 square metres of gross space on Level 1 of the Palais des Congrès.

The exhibition will also be the home of the conference poster sessions and coffee breaks, feature the Publisher's Corner and the ever popular Cyber Café, as well as being the location for the European Microwave Week Microwave Application Seminars (MicroApps). MicroApps will take place in the MicroApps Auditorium on the show floor the entire three days of the exhibition, offering a platform for education and discussion.

Maintaining EuMW's commitment to education and the development of young engineers, two student competitions will take place during the week. The Student Challenge, sponsored by Thales Nederland B.V., is a competitive event where teams of bachelor's, master's and doctoral students are invited to propose an appealing topic or idea in the wide and challenging field of microwaves, inspired by papers presented at EuMW. The Student Design Competition involves master's and doctoral students designing and measuring a piece of equipment developed during the conference. It is sponsored by Cobham Aerospace Communications, with measurement facilities provided by Keysight Technologies.

The Career Platform continues, with the aim of fostering the dynamic between young researchers, engineers and the job market within the field of microwaves. A dedicated area will be reserved for sharing and exchange, and new special sessions will be held on industrial market analysis, career development and recruitment strategies. EuMW 2015 will also launch a unique e-platform initiative with the ambition of offering the RF and microwave community a job portal on a European scale.

Putting together such a major event is never easy, but the 2015 EuMW team faced the added complication of finding a suitable alternative venue at the eleventh hour and had to bring the schedules forward to accommodate an early September time slot. Bringing this to fruition, from paper submission and review to the on-site organization at the venue, has been a major undertaking. So, on behalf of the local organizing committee, we would like to thank the technical programme committees of the three conferences, along with the reviewers who worked tirelessly to shape the conference programmes. We would like to acknowledge the EuMA board for its continued advice and guidance and thank the Horizon House personnel assigned to EuMW for their indispensable expertise and support in organizing this major event. Recognition should also go to the organizers of workshops, special sessions and student events and we also acknowledge the significant financial and in-kind sponsorship of many industrial companies and organizations.

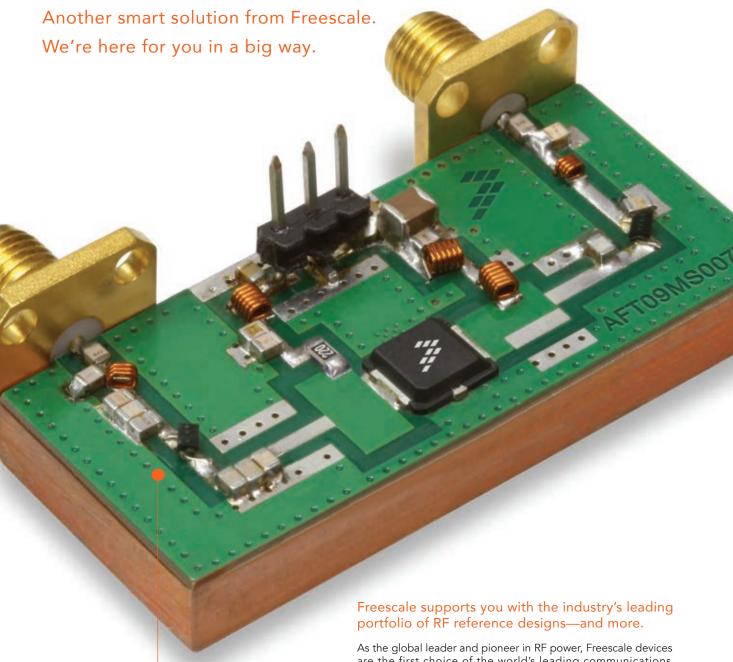
We hope and expect La Ville Lumière to be illuminating on all levels and we look forward to seeing you in Paris. ■







Ivar Bazzy



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European Microwave Week

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Attending European Microwave Week 2015

Richard Mumford Microwave Journal International Editor

he gourmet capital of the world, Paris is renowned for its delicious food and fine wines. In early September the city will also serve up a mouth-watering array of technology and innovation as the Palais des Congrès plays host to the 18th European Microwave Week. The event has been organized to satisfy the appetite of its global attendees and visitors eager to learn about and discuss new developments, view the latest products and take the opportunity for professional and personal networking. Not forgetting, too, the opportunity to taste the delights of a sophisticated, vibrant and diverse city.

But, just what is on the European Microwave Week menu this year? The offering is quite substantial, covering six days and containing three cutting edge conferences and one extensive trade and technology exhibition featuring leading players from across the globe.

Around 1,000 papers were submitted for review to the three conferences from more than 50 countries. The technical programme includes 86 technical sessions, 424 oral papers and 96 posters, five special sessions and seven focused sessions. The global reach and

influence of EuMW is illustrated by the fact that the opening and closing plenary sessions of each of the three conferences will feature keynote lectures delivered by internationally renowned leaders in their respective fields.

Firmly established as the premier RF and microwave event in Europe, EuMW 2015 is expected to attract in the region of 1,600 conference delegates, around 3,500 attendees, with the exhibition featuring over 265 exhibiting companies, spread over about 9,460 square metres (gross).

A vital ingredient of European Microwave Week is its endeavour to create a structure and atmosphere that encourages industry and academia to network and interact – not only during the conference sessions, workshops and on the show floor, but also socially in the form of the ever popular EuMW Welcome Reception. On Tuesday, 8 September, the reception will be held in Espace Maillot, Level 2 of the Palais des Congrès. The evening will begin with a cocktail reception at 18:30, when guests will be addressed by the 2015 EuMW chairman, who will hand over to the 2016 EuMW chairman for London, followed by Platinum Sponsor Key-



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European Microwave Week

sight Technologies, after which a three course seated buffet for 1,000 people will be served.

Although convivial interaction is essential to a successful event, the main aim is to ensure that attendees have a productive and informative week. To help visitors achieve these aims, the following quick reference guide is designed to complement the

Conference Programme and Exhibition Show Guide, where you will find more detailed information.

THE CONFERENCES

Each with their own dedicated time slots throughout the week, the three focused conferences are the

• 45th European Microwave Conference (EuMC) – 7 to 10 September

- 10th European Microwave Integrated Circuits Conference (EuMIC) 7 and 8 September
- 12th European Radar Conference (EuRAD) 9 to 11 September
- Workshops and short courses from 6 to 11 September
- Defence, Security and Space Forum on Wednesday, 9 September

Rohde & Schwarz sponsored online registration that opened on 25 May and remains open to and during the event, until 11 September. Onsite registration will be available from 16.00 to 19.00 on Saturday, 5 September and from 7.30 each morning from Sunday, 6 September to Friday, 11 September. The registration area will be located on Level 1 of the Palais des Congrès de Paris.

All those who have pre-registered should bring their badge barcode and confirmation with them to the conference where they can print out their badge by scanning their barcode at the Fast Track desk onsite.

For those who have not pre-registered, onsite registration terminals will be located within the registration area, where delegates can enter their details and pay immediately by swiping their credit or debit cards through the card readers attached to the terminals. Alternatively, there is a cashier desk for those who require a printed receipt.

Once in possession of their badges, delegates can collect their delegate bags, sponsored by Infineon Technologies, from collection points in the registration area. The bags will include a USB stick, sponsored by UMS, that contains the conference proceedings.

THE EUROPEAN MICROWAVE CONFERENCE

EuMC is Europe's leading forum for presenting the current status and future trends in the field of microwave, millimeter wave and terahertz systems and technologies. These high frequency related topics, from materials technologies to integrated circuits, systems and applications are addressed in all respects: theory, simulation, design and measurement.

The EuMC TPC received 640 submissions; 56 percent were selected to build a very high quality and strong



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European Microwave Week

conference programme, which consists of workshops and short courses on Sunday, Monday and Wednesday, and regular, special and focused sessions, mainly on Tuesday, Wednesday and Thursday. The EuMC opening session will be held on Tuesday at 10:50.

EuMC shares nine sessions with EuMIC, in the fields of active devices, circuits and subsystems. It also shares

11 sessions with EuRAD in the fields of millimeter wave, THz technologies and systems, and antennas and propa-

Focused sessions have been selected in the following domains: advances in THz and opto-nanoelectronics, advances in scanning probe microwave and millimeter wave microscopy, microwaves in agriculture environment and earth observation (MAGEO) and modal analysis of electromagnetic structures.

Three special sessions have been selected based on subjects of specific interest to the microwave community. These are: system modelling and optimization, additive manufacturing techniques for RF modules and autonomous driving in a worldwide changing society - between silver agers and Y-generation. Also, as a result of an agreement between EuMA and the organizers of the Asian Pacific Microwave Conference, a special session is devoted to enabling the exchange of speakers between the two conferences.

The closing session on Thursday at 16:10 will include three distinguished keynote speakers and the award ceremonies, when the EuMC Microwave and the EuMC Young Engineer prizes

will be presented.

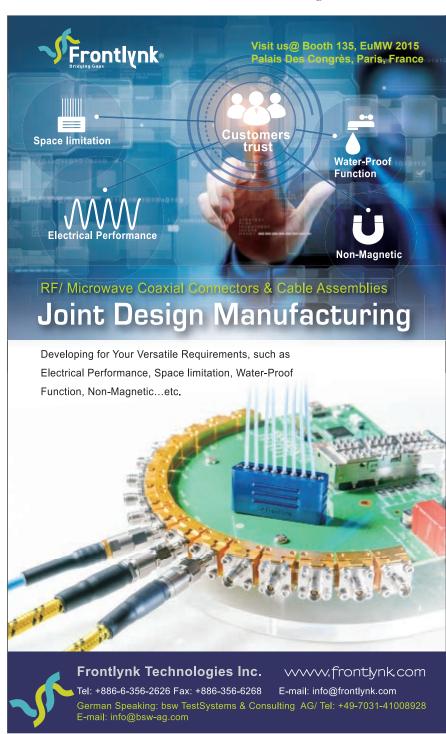


Jointly organized by the GAAS® Association and EuMA, the aim of the conference is to promote the discussion of recent developments and trends and to encourage the exchange of scientific and technical information covering a broad range of high frequency related topics, from materials and technologies to integrated circuits and applications.

The EuMIC opening plenary session will feature two keynote speeches by world leaders in their fields. Andreia Cathelin from STMicroelectronics will present the planar UTBB FD-SOI technology for highly energy efficient devices, while Thomas Roedle from NXP Semiconductors will focus on GaN technology, modelling and applications.

The closing session will include the traditional foundry session, gathering key representatives from RF and microwave semiconductor foundries, as well as speeches given by two eminent plenary keynote speakers. The session will also feature a panel discussion on: "The Impact of Advanced GaN and Silicon Technologies for Military and Space Applications."

During the closing session, the prize for the best contributed paper to EuMIC 2015 will be awarded and



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European Microwave Week

the EuMIC Young Engineer Award will be presented to a young engineer or researcher who authored an outstanding paper presented at the EuMIC Conference. Three GAAS® Ph.D. student fellowships will also be celebrated.

On Monday, 7 September, all EuMIC delegates are invited to the EuMIC Cocktail Reception that will take place in the lounge area on Level 1 of the Palais des Congrès at 18:30.

THE EUROPEAN RADAR CONFERENCE

This conference is the major European event addressing the present status and future trends in radar technology, system design and applications and covers a wide variety of topics,



Photo courtesy of Shmuel Auster.

from radar components and systems, radar echo modelling, advanced signal processing techniques, the most innovative radar architectures and concepts and the latest applications.

This year, 190 papers were submitted, with the accepted papers organized into 16 oral sessions and one poster session. Three focused sessions proposed by renowned experts on very innovative and interesting fields will deal with: 3D SAR imaging of complex environments, measurement and processing techniques for system diagnostic and calibration, and advanced modeling, processing and inversion applied to ground penetrating radar. There is also one special session addressing advances in T/R modules for AESA applications. These sessions are complemented by expert workshops and short courses, presented on Wednesday and Friday, covering advanced radar concepts, techniques and applications.

The opening session will be on Wednesday at 10:50 and will include two keynote presentations. Marc Lesturgie, from Sondra-Supélec, will consider recent and important innovations in his talk on "Breakthroughs and New Concepts in SAR and Radar," and Fabio Rocca, from Politecnico di Milano will give a presentation on "Geosynchronous Synthetic Aperture Radars: Systems and Applications," introducing the potential, risks and applications of a multi-sensor geosynchronous spaceborne SAR mission.

During the closing session, to be held on Friday at 13:50, Albert Huizing, from TNO, will give a presentation entitled "Radar Horizon 2030: Challenges and Emerging Technologies," addressing some of the future challenges for radar and presenting the state of the art and new developments in signal processing techniques.

On Friday, 11 September, all Eu-RAD delegates are invited to the







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EuRAD lunch that will take place at 12:30 in Room Maillot on Level 2 of the Palais des Congrès.

THE EXHIBITION

Central to the week both chronologically and metaphorically, the European Microwave Exhibition will be housed in four connected halls – Passy, Neuilly, Ternes and Paris – which to-

European Microwave Week

gether form one continuous, uninterrupted exhibition space. Taking place from Tuesday, 8 September to Thursday, 10 September, and larger than in 2014, it will be the hub of activity generated by the multitude of companies eager to display and demonstrate their latest introductions.

The exhibition is free to attend and will feature companies large and small, established and emerging. Of course, European companies are to the fore, taking advantage of France's central location and easy access. Local French companies are supporting the event, and the Spanish Pavilion continues to be popular. As always, the U.S. and Asia are well represented with the Chinese Pavilion expanding in 2015, demonstrating the country's continued emergence as a force in the RF and microwave sector.

The exhibition is a vibrant shop window for companies wanting to reach the international audience which EuMW attracts. It has also become an event that leading manufacturers often choose to launch new products onto the European and global market. To find out which companies will be exhibiting at the Palais des Congrès see the latest exhibitor list, on page 166.

The established and popular exhibitor workshops offered by leaders in their respective fields, including Keysight Technologies, Rohde & Schwarz, National Instruments and Anritsu will offer attendees the opportunity to see live demonstrations and gain handson experience.

The educational/instructional theme will continue on the show floor with the fifth European Microwave Week Microwave Application Seminars (MicroApps). The National Instruments, Rohde & Schwarz and Horizon House sponsored free-to-attend seminars will take place in the MicroApps auditorium for the entire three days of the exhibition. Designed to provide engineers with insight into products and techniques that will aid them in their everyday work, EuMW exhibitors will present 20 minute technical presentations describing state-of-the-art applications, products, design techniques and processes of interest to the RF and microwave community.

The exhibition space will also be the home of the conference poster sessions, coffee breaks sponsored by Copper Mountain and the Publisher's Corner. Once again, CST is sponsoring a Cyber Café, located on the show floor, for all delegates, exhibitors and visitors to use, as well as free Wi-Fi access to email for delegates in all conference areas.



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EXHIBITION OPENING HOURS

- **Tuesday, 8 September:** 9:30 to 18:00 (followed by the Welcome Reception)
- Wednesday, 9 September: 9:30
- Thursday, 10 September: 9:30 to 16:30

European Microwave Week

GETTING TO THE PALAIS DES CONGRÈS

Paris is easily reached by plane, train or car. It is served by two international airports and a very convenient railway system. Shuttle buses run from Charles de Gaulle or Orly airports to the city centre.

By Plane

Paris has two international airports. Most international flights use the larger Roissy Charles de Gaulle Airport, 30 km northeast of Paris. The other one is Orly Airport, 18 km south of the city. Both are well connected by public transport to central Paris.

From Roissy-Charles de Gaulle **Airport:** RER B, stop at Chatelet Les Halles then take RER A to Charles de Gaulle/Etoile then line 1 of the metro to Porte Maillot/Palais des Congrès.

By Air France or ADP shuttle **bus**: take line 2 (buses go directly to Porte Maillot/Palais des Congrès or to the Opéra in the city centre). Departure is every 15 minutes from 05:45 to 23:00 with an approximate journey time of one hour.

From Orly Airport: Take the high speed shuttle (Orlyval) to Antony RER B, stop at Chatelet Les Halles then take RER A to Charles de Gaulle/ Etoile then line 1 of the metro to Porte Maillot/Palais des Congrès. The approximate journey time is one hour.

By the Cars Air France: go to Terminus Etoile, then take line 1 of the metro to Porte Maillot/Palais des Congrès. Departure is every 30 minutes from 06:00 to 23:00, with an approximate journey time of 40 minutes to one hour. By taxi the approximate journey time to central Paris is 40 minutes to 1 hour depending on the traffic.

Porte Maillot is reached via the inner/outer ring road, taking Boulevard Periphérique Ouest (West Beltway) exit. There is direct access to the underground parking at the Palais des Congrès via Porte Maillot, which is open 24 hours a day.

Public Transport

Train: Line C of the RER Commuter trains provides direct access to Porte Maillot station.

Metro: The metro is probably the best way to travel within the city. The Palais des Congrès is above the Porte Maillot metro station. It runs from 05:30 to 01:00. Keep your ticket until you leave the metro as you may need to show it/have it with you at some exit doors. Line 1 of the metro (La Défense-Château de Vincennes) crosses the city from east to west and provides direct access to the Palais des Congrès Porte Maillot station.

Bus: Slower than the metro at certain hours of the day depending on



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traffic. However, the bus services are frequent during the day but are less regular after 20:00 on some routes. Lines to Porte Maillot: 82 (Luxembourg-Neuilly), 73 (Concorde-La Défense), and PC1, PC2, PC3 (beltway lines).

Public Transport Tickets: Paris public transport is operated by the RATP and includes the metro subway

system, RER trains, buses, night buses, Montmartre bus and the Montmartre funicular railway, all of which accept the same tickets and passes. You can purchase individual tickets, or a Paris Visite Metro Pass, available for two, three or five consecutive days of unlimited travel. They also include special offers and discounts of up to 35 percent at a variety of attractions in the

Paris area. Tickets for public transport are available at subway stations, some bus terminals and registered retailers, displaying the RATP sign.

Taxi: There are approximately 500 taxi ranks on the city's major avenues and boulevards. There is an initial fee for each ride. The average fare from the city centre to the Palais des Congrès is €15.00. For the return journey, there is a taxi station located on the Avenue de la Grande Armée, right next to the Palais des Congrès: +33 (0)1 45 72 61 84.

HOTEL RESERVATIONS

Horizon House has teamed with Hotelzon to offer a wide range of accommodation at competitive rates. To make a booking, visit Hotelzon's booking page www.hotelzon.com/en/ uk/events-eumw and make your booking, or email sally.garland@hotelzon. co.uk.

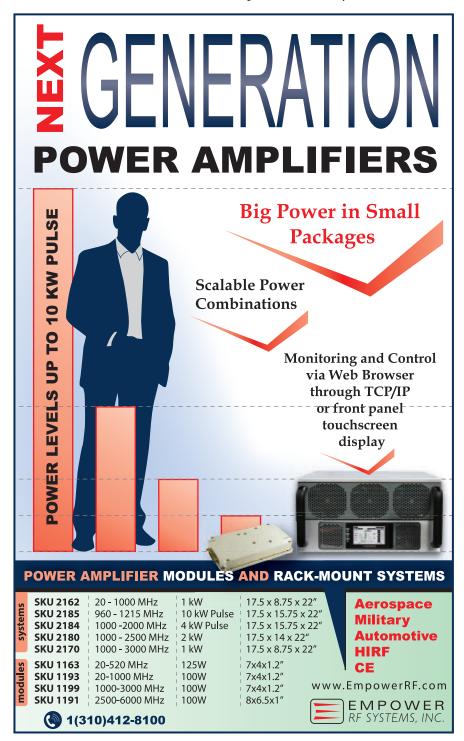
SHOPPING & SIGHTSEEING

Paris has so much to offer visitors. Some of the most famous Parisian landmarks include Notre Dame de Paris, the Arc de Triomphe and the Eiffel Tower, along with the Tuileries Gardens, the Champs-Élysées, the Invalides museum, the Panthéon church, the Palais Garnier, the Sainte-Chapelle palace chapel and the Église de la Madeleine.

The Louvre is one of the most famous museums featuring the Mona Lisa and the Venus de Milo statue. Other museums include Musée Picasso, Musée Rodin, Musée du Montparnasse, Musée National d'Art Moderne, Musée Cluny, Musée d'Orsay and the Musée du quai Branly. For cultural entertainment, opera houses include Opéra Garnier and the Opéra Bastille, along with theatres such as Bobino, Théâtre Mogador and the Théâtre de la Gaîté-Montparnasse.

For shopping, few places in the world can beat the size and range of shops along the boulevard Haussmann. Other good shopping areas include the rue de Rivoli, on the Left Bank and the Madeleine.

There are various tours and excursions organized as part of the EuMW Social Events & Partner Programme or visit www.en.parisinfo.com.



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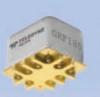
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European Microwave Week

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The 2015 EuMW Defence, Security and Space Forum

Richard Mumford Microwave Journal *Internat<mark>ional Editor</mark>*

A forum on Wednesday, 9 September, from 10:50 to 18:45 focused on RF systems and microwave technology for unmanned aerial vehicles Room Maillot, Palais des Congrès

efence and security impact at all levels – international, cross border, regional and on individuals. Those charged with securing the safety of citizens need the tools, the finances and the technology to be able to defend sovereignty, resolve regional conflicts and fight global terrorism, together with the ability to effectively guard against threats that can be enacted by armies, small groups or a single terrorist.

The nature of conflicts has evolved and so too is how they are being addressed. Surveillance, reconnaissance and the use of technology to reduce numbers on the front line and keep human casualties low have come to the forefront. In particular unmanned aerial vehicles (UAV) are being developed and

utilized in all regions of conflict and are increasingly being applied to general security applications.

The EuMW Defence, Security & Space Forum has always endeavoured to reflect and discuss prevalent initiatives, so this year the emphasis will be on RF systems and microwave technology for UAVs, covering specifics such as: synthetic aperture radar (SAR) for UAVs, ESM and EW for UAVs, operational use of integrated RF systems for UAVs, along with airborne SARs.

The forum will feature executives from industry, academia, the military and from space agencies. It will be held in combination with the opening of EuRAD. The technical sessions will conclude with a round-table discussion, followed by a cocktail reception for attendees.



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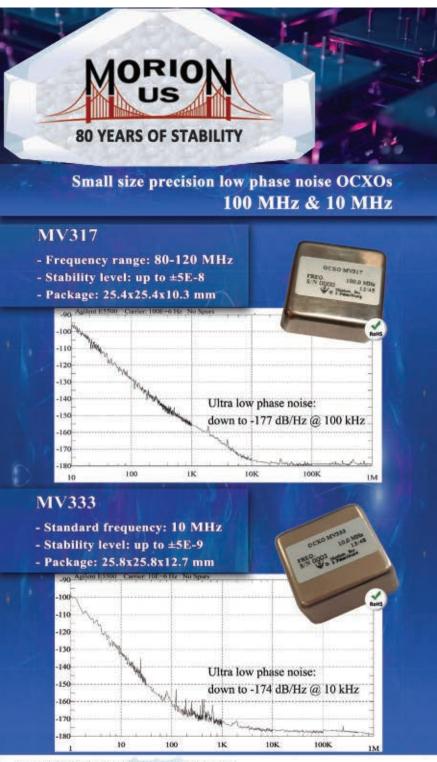




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European Microwave Week

THE FORUM FORMAT

Below is a brief outline of each session. A full listing of the presentations at the time of going to press can be found on pages 94 and 95.

For the fourth year, the EuMW Defence, Security and Space Forum will incorporate the EuRAD Opening Session (10:50 to 12:30), followed by the Strategy Analytics Lunch & Learn Session (12:40 to 13:40), which will add a further dimension by offering a market analysis perspective, illustrating the status, development and potential of the market.

The afternoon will begin with the *Microwave Journal* Industry Panel Session (13:50 to 15:30) that will offer an industrial perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2015, the panel will address RF and Microwave Development for UAVs.

Completing the technical sessions the EuMW Defence & Security Executive Forum (16:10 to 17:50) will provide a platform for speakers from leading European defence industries to proffer their views on RF and microwave technology trends for the next generation UAV platforms and systems. The industrial speakers are complemented by speakers from government, agencies and research organizations who will offer their perspective of military and security needs, programmes, budgets and scientific research for next-generation systems.

The event will conclude with a cocktail reception (18:00 to 18:45) that will afford delegates the opportunity to network and discuss the issues raised throughout the forum in an informal setting.

REGISTRATION AND UPDATES

Registration fees are €10 for those who have registered for a conference and €50 for those not registered for a conference. Register online at www. eumweek.com. As information is formalized, the Conference Special Events section of the EuMW website will give further details and will be updated on a regular basis. ■



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Wednesday, 9 September, 10:50 – 18:45

A focused Forum addressing the application of RF integrated systems for UAVs.

The emphasis of the 2015 EuMW Defence, Security and Space Forum will be on RF systems and technology for Unmanned Aerial Vehicles (UAVs), covering specifics such as: Synthetic Aperture Radar (SAR) for UAVs, ESM and EW for UAVs, operational use of integrated RF systems for UAVs, along with Airborne SARs. It will feature executives from industry, academia, the military and from space agencies. It will be held in combination with the opening of EuRAD and will conclude with a round-table discussion.

Programme:

10:50 - 12:30 EuRAD Opening Session

12:40 - 13:40 Strategy Analytics Lunch & Learn Session

• Expanding the Mission Envelope for UAS Platforms Asif Anwar, Strategy Analytics

13:50 - 15:30 Microwave Journal Industry Panel Session

- Flexible RF Signal Generation and Wideband Analysis for Testing Future Unmanned Vehicle Sensors
 - Dr. Steffen Heuel. Rohde & Schwarz
- How Intelligent Integration Improves Antenna Resolution and Allows Rapid Array Re-Configuration in SAR and AESA Systems Andrew Christie, Peregrine Semiconductor
- How Improvement in GaN Technology and Device Packaging Leads to Smaller, Higher Performance RF Systems for UAVs Roger Hall, Qorvo Inc.
- The Analog vs. Digital Conundrum: Mixed Signal Integration Solutions and Challenges for **Unmanned Systems** Duncan Bosworth, Analog Devices

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Room Maillot, Palais Des Congrès, Paris



16:10 - 17:50 EuMW Defence & Security Executive Forum

- RPAS Sensor Payloads: Making the Business Case for European Non-Dependence Neil Whitehall, Selex ES
- Critical RF Technologies for Multi-Function Sensor Payload Patrick Garrec, Thales Systemes Aeroportes
- An EDA Perspective on the RPAS Sensor Payloads Challenge Ignacio Montiel-Sánchez, European Defence Agency (EDA)
- Compact and Distributed Radar Concepts on UAV: Trends and Vision for a New Paradigm in Air and Ground Surveillance
 Marc Lesturgie, Director of SONDRA Lab ONERA - The French Aerospace Lab

18:00 - 18:45 Cocktail Reception

The opportunity to network and discuss the issues raised throughout the Forum in an informal setting.

Registration fees are €10 for those who registered for a conference and €50 for those not registered for a conference.

Details in this programme are correct at the time of going to press – updates will be posted on eumweek.com.

Organized by:







Microwaves in Europe: Driving Forward?

Richard Mumford Microwave Journal International Editor

After economic false starts and a stalled recovery can the European RF and microwave industry change gears and show the drive needed to move forward? Can European Union initiatives, allied to the skills, expertise and knowledge that our industry possesses fuel innovation and investment? This report considers the roadmap being pursued and the course being taken.

The European RF and microwave industry is a small cog in a giant economic, bureaucratic and regulatory wheel that, in recent years, has had to revolve around depressed markets, austerity measures and the vagaries of the global market. However, the EU is endeavouring to put mechanisms in place to drive innovation and provide a research, production and trading environment that will accelerate competiveness and growth.

At the 6th European Innovation Summit at the end of last year, Carlos Moedas, EU Commissioner for Research, Science and Innovation stated, "This is an exciting time in Europe. We have a new Parliament and a new Commission in Brussels. The discussions which happen now, will significantly impact the course we choose to take over the next five years. It is now that we define our priorities, our relationships with

define how we will

take European
innovation forward."

Co
cus
sig
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"It is now that we

member states and each other. It is now that we define how we will take European innovation forward."

He added, "I want to grow an innovationresponsive society in Europe. An environment conducive to home-grown, 21st century, disruptive innovation, based on three distinct pillars: Adequate public and private funding of research, development and innovation; a unified research area open to the world, with firm foundations in the Internal market; and a market environment quick to respond to innovation – making it easier for great ideas devised here to become commercial products and services – creating entirely new markets and transforming existing ones, through disruptive innovation."

Such enthusiasm is commendable but out there in the real Europe, what economic, legislative and technological hoops are those in the semiconductor clean room, the RF component design house, microwave lab, test house or production line having to jump through and what incentives and support is being offered in general, and to the RF and microwave industry in particular, to ensure that these goals are achievable? What is the climate that companies/institutes are currently operating in?

An indicator of the current state of innovation in Europe is the European Commission's annual Innovation Union Scoreboard. Last year's report showed positive signs for innovation performance – improved and less innovative countries were catching up on Europe's innovation leaders. Although the *Innovation Union Scoreboard 2015* indicates that the EU's overall level of innovation has remained stable, it offers a mixed message, with 13 Member

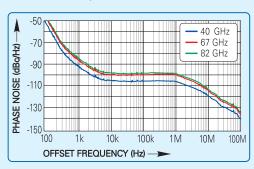
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| Phase Noise at 100 kHz | -108 dBc/Hz at 40 GHz | -105 dBc/Hz at 67 GHz | -103 dBc/Hz at 82 GHz |
| Power (min) dBm | +17 | +17 | +10 |
| Output Connector | 2.92 mm | 1.85 mm | WR-12 |

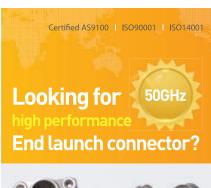


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States presenting a declining innovation performance and 15 improving their performance compared to the previous year.

Sweden continues to be the innovation leader, followed by Denmark, Finland and Germany, with the fastest growing innovators being Malta, Latvia, Bulgaria, Ireland, the UK and Poland. In global comparison, the EU continues to be outperformed by the U.S., Japan and South Korea. However, the 2015 scoreboard shows that, since 2008, the EU has managed to close almost half of its innovation performance gap with the U.S. and Japan but the gap with South Korea is still widening. The EU has maintained a performance lead over Australia and Canada and to a greater extent over the BRICS (Brazil, Russia, India, China and South Africa) countries. This lead is stable or even increasing for all BRICS countries except for China, which is bridging the gap quickly.

Innovation is often perceived as the economic "Holy Grail" – a medium for growth, a catalyst for expanding existing markets and a driver for new ones. There is no doubt that the economic downturn has had an impact on the activity of the European private sector: the statistics show that the number of innovative firms is in decline, as is the innovative activity of small and medium-sized enterprises (SME). On the plus side there has been improved business investment in research and development.

Public investment in research and innovation is key to creating the knowledge and talent that innovative firms need, and it spurs business R&I investment and growth. The latest Research and Innovation performance in the EU: Innovation Union progress at country level report, published by the European Commission late in 2014 concluded that in the first period of the crisis, many member states protected their R&I expenditure. Some even increased their R&I budgets, such as Germany, Denmark and several Central and Eastern European countries. However, in recent years, other member states such as Bulgaria, Romania, Croatia and Hungary cut their R&I budgets further, even though their public R&D activity had already been well below the EU average.

The report also stated that analysis points to the persistence of a clear

'East-West' science divide in Europe, with a weaker science base in all Central and Eastern European countries (as well as Cyprus and Malta). This is alongside a 'North-South' differential: Greece, Portugal, Spain and Italy perform just below the EU average and hold an intermediate position between Central and Eastern European countries and Northern/Western Europe.

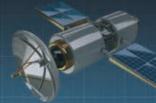
More industry specific, the World Trade Semiconductor **Statistics** (WSTS) released in May 2015 anticipates the world semiconductor market will show a moderate growth of 3.4 percent to \$347 billion in 2015. All major product categories are forecast to have positive growth rates in 2015, with the significant drivers being smartphones and automotive. However, the dollar based WSTS forecast predicts that not all regions will grow from 2014, with Europe and Japan forecast to show a decline in 2015, which is mainly based on the current Euro/\$ and Yen/\$ rates.

This is backed up by the latest figures available from the European Semiconductor Industry Association (ESIA), which were for April 2015. They showed that semiconductor sales in Europe in April 2015 amounted to \$2,889 billion. The figure reflects a slight decline in sales compared to the previous month, in line with sales developments in the other regions, with the exception of Asia-Pacific. However, in April, exchange rate developments affected significantly the European sales picture when comparing market growth in euros and in dollars. Application specific semiconductors performed well in April, with devices designed to be used in consumer and wireless communication growing by 3.2 percent and 1.7 percent respectively compared to March.

These are the circumstances in which the RF and microwave industry in Europe has to operate from large corporations to SMEs, from established businesses to start-ups, those operating in countries with relatively stable economies to those facing financial uncertainty.

As an entity the European Union has to take a cross-continent view and legislate for the collective good of all. It has long been an assertion of the EU that a key driver for growth is research and development and great emphasis has been given to putting

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RF Switch 67GHz RFSP8TA series

Θ

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RF TRANSMITTER

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RF Mixer

INPUT

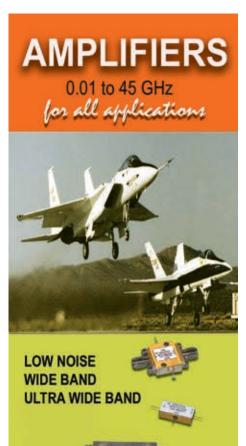
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the technological, economic and practical mechanisms in place to support innovation and create an environment where European industry can evolve and compete on the global stage.

A cornerstone of this activity has been the European Framework Programmes, which were launched in 1984. They have played a lead role in funding multi-disciplinary research and cooperative activities in Europe and were an anchor of support through difficult periods of trade.

Set to run from 2014 to 2020, Horizon 2020 is designed to build on the Framework Programmes and move the quest for viable EU research and innovation forward. For Horizon 2020's inception last year, this annual report comprehensively specified its structure and goals, so the following is only a brief outline.

HORIZON 2020

With over €80 billion dedicated to research, industrial leadership and key societal challenges Horizon 2020 is the biggest EU research and innovation framework programme ever launched. As well as refunding research it also aims to mainstream funding for activities in all stages of the innovation cycle and support and encourage the participation of businesses.

Significantly for our industry, this includes supporting SMEs through the *Innovation in SMEs* initiative, which takes a company-focused and market-driven approach. It funds additional activities intended to support entrepreneurship and internationalization and improve access to markets through the Competitiveness of Enterprises and Small and Mediumsized Enterprises (COSME) programme, which has a planned budget of €2.3 billion.

In parallel, billions are being invested in innovation-driven public-private partnerships, with instruments in place aimed at easing access to finance, including reinforced debt and equity facilities and the venture capital passport.

Also, the European Research Area (ERA) aims to reduce the fragmentation of the knowledge base in Europe, by putting in place measures aimed at facilitating the mobility of researchers across borders and across business and academia.

"...Horizon 2020

funds innovation as

well as research..."

Examples of other measures that both strengthen Europe's knowledge base and reduce its fragmentation through better connection between industry and academia include activities by the European Institute of Innovation and Technology Knowledge and Innovation Communities (EIT KICs), the Knowledge Alliances, the development of the Innovative Doctoral Training Principles and the Maria Skłodowska Curie actions under Horizon 2020.

There is also strengthened cooperation between the policy directorates of the European Commission and the Joint Research Centre (JRC) as well the work of the European Forum for Forward Looking Activities (EFFLA).

Significantly for the RF and microwave industry, Horizon 2020 funds innovation as well as research and is actively encouraging and investing in key enabling technologies including information and communications technology (ICT), nanotechnology, materials and production technology. In addition, money is available for testing, prototyping, demonstration and pilot type activities, for business-driven R&D, for promoting entrepreneurship and risk-taking, and for shaping demand for innovative products and services.

LEADING INITIATIVES

These are the foundations, so how are they being built upon? In an industry so diverse as RF and microwave, it is impossible to cover every activity but there are certain fields such as mobile communications, the space industry and materials development where, through Horizon 2020 and FP7 before it, the EU is encouraging and supporting Europe to take the lead. The following is a snapshot of the activity in these specific sectors, highlighting key projects.

Give your next amp a boost with

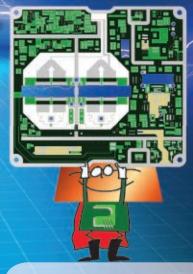
RO4360G2

6.15 Dk High Frequency Laminates



When amplifier designers asked, Rogers listened and developed RO4360G2™ high-frequency laminates. These thermoset materials feature a powerful balance of high performance, low cost and ease of processing in a laminate with a dielectric constant of 6.15.

RO4360G2 laminates deliver the low loss and high thermal conductivity sought by amplifier designers. Suitable for a variety of commercial and industrial applications, RO4360G2 laminates can be processed similar to FR-4 & support lead-free, RoHS-compliant manufacturing practices.



Features

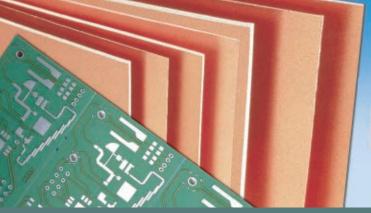
- High dielectric constant
- Low loss
- High thermal conductivity
- Low Z-axis CTE (30 PPM/°C) for reliable PTHs

Total Cost Solution

- Priced better than alternatives
- Low fabrication cost

Ease of Fabrication

- Ideal for multilayer circuits
- Suitable for automated assembly lines
- Processes similar to FR-4
- Lead free, RoHS compliant







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|---------------------|--------------------|--------------------------|
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| NTWPA-0000010011000 | 0.00001-0.01 | 60 |
| NTWPA-0000010013000 | 0.00001~0.01 | 65 |
| NTWPA-0000010015000 | 0.00001-0.01 | 67 |
| NTWPA-001011000 | 0.01~0.1 | 60 |
| NTWPA-001013000 | 0.01-0.1 | 65 |
| NTWPA-001015000 | 0.01~0.1 | 67 |
| NTWPA-008031000 | 0.08~0.3 | 60 |
| NTWPA-008032000 | 0.08~0.3 | 63 |
| NTWPA-0310700 | 0.3~1.0 | 58 |
| NTWPA-03101000 | 0.3~1.0 | 60 |
| NTWPA-00305100 | 0.03-0.512 | 50 |
| NTWPA-00305200 | 0.03~0.512 | 53 |
| NTWPA-000110100 | 0.001-1.0 | 50 |
| NTWPA-00810100 | 0.08~1.0 | 50 |
| NTWPA-00810200 | 0.08-1.0 | 53 |
| NTWPA-0510100 | 0.5~1.0 | 50 |
| NTWPA-0510200 | 0.5~1.0 | 53 |
| NTWPA-0510500 | 0.5~1.0 | 57 |
| NTWPA-05101000 | 0.5~1.0 | 60 |
| NTWPA-0710100 | 0.7~1.0 | 50 |
| NTWPA-0710200 | 0.7~1.0 | 53 |
| NTWPA-0710500 | 0.7~1.0 | 57 |
| NTWPA-1822100 | 1.8-2.2 | 50 |
| NTWPA-1822200 | 1.8~2.2 | 53 |
| NTWPA-1822500 | 1.8~2.2 | 57 |
| NTWPA-2327100 | 2.3-2.7 | 50 |
| NTWPA-2327200 | 23-27 | 53 |
| NTWPA-2327500 | 2.3-2.7 | 57 |
| NTWPA-0822100 | 0.8~2.2 | 50 |
| NTWPA-0822200 | 0.8-2.2 | 53 |
| NTWPA-0822500 | 0.8~2.2 | 57 |
| NTWPA-0727100 | 0.7~2.7 | 50 |
| NTWPA-0727200 | 0.7~2.7 | 53 |
| NTWPA-2560100 | 2.5-6.0 | 50 |
| NTWPA-2560200 | 2.5~6.0 | 53 |
| NTWPA-2060100 | 2.0~6.0 | 50 |



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Mobile Communications

The European Commission is already laying down the legislative and technical foundations for the introduction of 5G. Through the proposal for the *Telecoms Single Market* and the forthcoming *Digital Single Market* package, the Commission aims to develop a common approach to managing radio-spectrum use across Europe.

The EU Commission signed a landmark agreement with the '5G Infrastructure Association' on 17 December 2013, representing major industry players, to establish a Public Private Partnership on 5G (5G-PPP). This is the EU flagship initiative to accelerate research developments in 5G technology. The European Commission has earmarked public funding of €700 million to be complemented by a minimum of €3.5 billion by the EU industry. As part of the €700 million, a new wave of 5G research projects worth €125 million has just been announced that will be launched in July 2016.

At the 2015 Mobile World Congress (MWC), the European Commission and Europe's tech industry presented the EU's vision of 5G technologies and infrastructure, which was written by members of the 5G Infrastructure Association, the industry part of the 5G PPP. The EU vision will feed into a global debate which aims to agree by the end of 2015 on the scope of 5G, its main technological constituents, and the timetable for putting it in place. Many European operators predict 5G commercial availability in 2020 to 2025.

EU investment in 5G technology is also an essential factor in reinforcing EU leadership in the field of ultrafast broadband. It is not only necessary to support the traffic volume expected by 2020 but also to boost networks and Internet architectures in emerg-

"...a common
approach to managing
radio-spectrum use
across Europe."

ing areas such as machine-to-machine (M2M) communication and the Internet of Things (IoT).

To this end the €3.3 million EU Funded Full-Duplex Radios for Local Access (DUPLO) project has sought to develop practical solutions to cope with the increase in mobile traffic volumes and the number of wireless devices.

The solution devised by DUPLO aims to make better use of available bandwidth in an energy efficient manner through full-duplex radio transmission. This technology enables the same carrier frequency to be used for data transmission and reception and paves the way to integrated reconfigurable multiband front-end modules for frequency-division duplexing in next-generation mobile phones.

Space

The main aim of the EU's space policy is to use space-related technology to stimulate technological innovation. In the period from 2014 to 2020, over €12 billion will be spent on the implementation of the EU's three space programmes: The Galileo and EGNOS programmes provide positioning, navigation and timing information worldwide, while the Copernicus programme provides Earth observation data and information. Thirdly, part of the Horizon 2020 programme focuses specifically on space technologies, applications (e.g., GNSS and Earth observation), weather, sciences, exploration and other space related topics.

A recent initiative that has come to fruition is the €1.51 million budget Terahertz heterodyne receiver components for future European space missions (Teracomp) project, led by Chalmers University of Technology, Gothenburg, Sweden, which has developed a state-of-the-art 'terahertz receiver' that may help detect traces of life in space. The technology could even be used in a 'sub-millimetre spectrometer' for measuring wavelengths of light during the first ESA mission to Jupiter's moons, planned for launch in 2022.

The project team focused on developing Schottky diodes and also worked to integrate complementary circuits such as a local oscillator within the same receiver. This enabled them to push the frequency response as high as possible and optimize the components so that they work well together.



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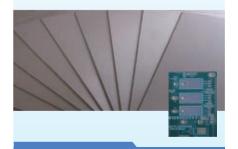


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Materials Technology

With a budget of €1 billion the Graphene Flagship is the EU's biggest ever research initiative. It is tasked with bringing together academic and industrial researchers to take graphene from academic laboratories into European society in the space of 10 years, thus generating economic growth, new jobs and new opportunities.

Launched in 2013, the Graphene Flagship is one of the first of the European Commission's Future and Emerging Technology (FET) Flagships, whose mission is to address the big scientific and technological challenges of the age through longterm, multidisciplinary R&D efforts. As a result of an open Expression of Interest, 11 new industrial partners, including Infineon Technologies have now joined the Graphene Flagship to bring in complementary competences and capabilities in specific areas. The new partners will be incorporated in the scientific and technological work packages of the core project under the

"...take graphene from academic laboratories into European society..."

planned Horizon 2020 phase (1 April 2016 – 31 March 2018).

As part of the Graphene Flagship, a team led by Philippe Lambin from the Université de Namur in Belgium has found that a graphene plane can provide an effective absorbent shield against microwaves. Lambin and his colleagues demonstrated that the conductivity of several graphene layers adds arithmetically when thin polymer spacers separate them. Maximum microwave absorption in the Ka-Band between 26.5 and 40 GHz is achieved with six graphene planes separated by layers of poly-methyl methacrylate (PMMA).

Multilayer microwave barriers constructed by researchers based at the University of Eastern Finland in Joensuu start with a first graphene layer deposited on a copper foil substrate by chemical vapour deposition. This layer is then covered with a 600 to 800 nanometre PMMA spacer obtained by spin coating, following which the copper is etched away with ferric chloride, and the graphene/PMMA heterostructure transferred to a quartz substrate. The procedure is repeated until the required number of graphene layers is reached.

SECTOR OVERVIEWS

The initiatives outlined above are offered as examples of the headline grabbing 'pioneering' work being carried out in the RF and microwave industry in Europe. Just as significant are the smaller scale efforts of engineers and designers endeavouring to: make a difference, push the boundaries just a little bit further and thus contribute to the technological development of our industry.

The 2015 European Microwave Week in Paris in September is a platform for the RF and microwave community to network, share ideas, take stock and look forward. Therefore, this report has enlisted the Chairmen of the three 2015 EuMW conferences: the European Microwave Conference (EuMC), the European Microwave Integrated Circuits Conference (EuMIC) and the European Radar Conference (EuRAD) to offer an insight into key areas of development and identify future trends.

RF and Microwaves



Sector overview by Serge Verdeyme, EuMC 2015 Chair

With contributions from Almudena Suarez, Jean-Yves Dauvignac, Philippe Ferrari, Raphaël Gillard, Luc Lapierre, Jean-François Villemazet, EuMC TPC members.

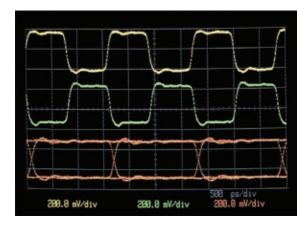
Microwaves remain a core technology in the 21st century for civilian, defence and security application systems, such as wireless communications, sensor networks and radar systems. Based on the material being presented during the 2015 EuMC

2 GHz Clock Generator





- Square wave clocks from DC to 2.05 GHz
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Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).

The CG635 generates clock signals—flawlessly. The clock signals are fast, clean and accurate, and can be set to standard logic levels.

How fast? Frequency to 2.05 GHz with rise and fall times as short as 80 ps.

How clean? Jitter is less than 1 ps and phase noise is better than -90 dBc/Hz (100 Hz offset) at 622.08 MHz.

How accurate? Using the optional rubidium timebase, aging is better than 0.0005 ppm/yr, and temperature stability is better than 0.0001 ppm.

You would expect an instrument this good to be expensive, but it isn't. You no longer have to buy an rf synthesizer to generate clock signals. The CG635 does the job better—at a fraction of the cost.



Stanford Research Systems

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conference, this overview aims to outline the trends in European RF and microwave research and development.

Microwave/millimetre wave component performance and flexibility is a constant and major topic in the field of passive devices, influenced by the steady improvement of MEMS components and the introduction of new emerging materials like graphene, carbon nanotubes

and GeTe materials. Low cost materials or technologies like paper, inkjet printing or 3D additive manufacturing for instance are also currently being assessed.

CMOS and BiCMOS technologies are increasingly being used for millimetre wave applications. Distributed components are mixed with lumped ones, and 'IC designers' have to work with 'microwave designers' to develop efficient CAD tools.

"Microwaves remain a core technology in the 21st Century...."

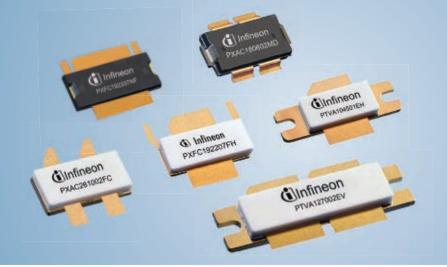
The current trends in packaging and interconnection remain focused on achieving compactness and maintaining frequency capabilities up to millimetre waves through the increasing use of organic materials, even for the implementation of GaN devices for power applications.

In the front-end and transceiver domain, researchers are working on innovative designs of both components and subsystems. Applications include next generation wireless radios with adaptive beamforming networks, dedicated short range communications at 5.8 GHz, the Square Kilometre Array (SKA) radio astronomy project and the second European Meteorological Operational Satellite Programme.

Research to obtain the best efficiency is the main objective of studies of solid-state power amplifiers, with particular emphasis being focused on harmonic matching techniques. To increase the performance of signals with variable envelopes such as telecommunication, Doherty techniques and envelope tracking are being researched extensively. There is significant technological and design development with regards to GaN, even if LDMOS is a widely exploited technology.

EuMW 2015 reflects the degree of activity in the antenna sector with more than 100 papers presented on the subject during the week. A large part of this activity is related to integrated antennas (including a transmitter and receiver co-design approach) and also new materials used in antenna design and fabrication, in order to realize new tunable functionalities or agile antennas. Arrays and phased array antennas are also widely being utilized for digital beamforming, MIMO, radar, microwave imag-







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|-----------------|--------------------|----------|----------------------|-------------------|---------|----------------------|-------------------|---------|---------------|------|
| | Frequency (MHz) | | P _{OUT} (W) | Gain (dB) | Eff (%) | P _{OUT} (W) | Gain (dB) | Eff (%) | | |
| PTVA030121EA | 390 – 450 | No | 12 | 25.0 | 69 | 14 | 22.0 | 73 | 12μs, 10% DC | 13:1 |
| PTVA035002EV | 390 – 450 | No | 400 | 19.5 | 65 | 500 | 17.5 | 67 | 12μs, 10% DC | 13:1 |
| PTVA104501EH | 960 – 1215 | I/O | 450 | 17.0 | 57 | 490 | 15.0 | 55 | 128μs, 10% DC | 10:1 |
| PTVA101K02EV | 1030 / 1090 | I | 920 | 18.0 | 56 | 1090 | 16.0 | 57 | 128μs, 10% DC | 10:1 |
| PTVA120251EA | 500 – 1400 | No | 30 | 16.0 | 56 | 40 | 14.0 | 59 | 300μs, 10% DC | 10:1 |
| PTVA120501EA | 1200 – 1400 | I | 54 | 16.5 | 55 | 63 | 14.5 | 57 | 300μs, 10% DC | 10:1 |
| PTVA123501EC/FC | 1200 – 1400 | I/O | 375 | 16.0 | 56 | 415 | 14.0 | 57 | 300μs, 12% DC | 10:1 |
| PTVA127002EV | 1200 – 1400 | I/O | 700 | 16.0 | 55 | 800 | 14.0 | 58 | 300μs, 10% DC | 10:1 |

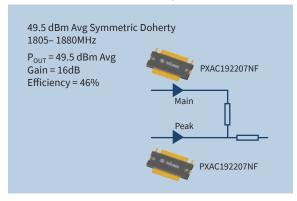
ISM (2.45GHz) Product Line

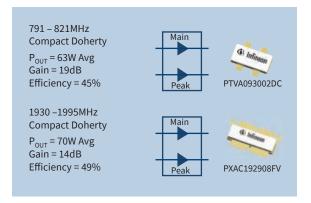
| Product | | | | @P _{1dB} | | @P _{3dB} | | | Test Signal | VSWR |
|--------------|--------------------|-----|----------------------|-------------------|---------|----------------------|-----------|---------|-------------|------|
| | Frequency (MHz) | | P _{OUT} (W) | Gain (dB) | Eff (%) | P _{OUT} (W) | Gain (dB) | Eff (%) | | |
| PTFC253002EV | 2400 – 2500 | I/O | 260 | 14 | 51 | 280 | 12 | 53 | CW | 10:1 |

New Cellular Doherty Solutions

| | Product | Doherty-in- Package | Operating Frequency [MHz] | P _{1dB} Typ [W] | Gain Typ [dB] | Eff Typ [%] | Supply Voltage Typ [V] | Package T | ype |
|----|--------------|------------------------|---------------------------------|--------------------------------|---------------------|-------------------|------------------------------|---------------|-------------|
| | PTVA093002TC | Yes | 700 – 960 | 2X50 | 19.0 | 50.0 | 50 | H-49248H-4 | G lebour |
| | PXAC180602MD | Yes | 1800 – 2000 | 21+28 | 18.0 | 50.0 | 28 | PG-HB1DSO-4-1 | |
| EW | PXAC192908FV | Yes | 1930 – 1995 | 110+120 | 14.0 | 49.0 | 28 | H-37275G-6/2 | 1 |
| EW | PXAC203302FV | Yes | 1880 – 2025 | 140+220 | 16.5 | 46.0 | 28 | H-37275-4 | Ser. |
| EW | PXAC243502FV | Yes | 2300 – 2400 | 150+200 | 15.5 | 44.0 | 28 | | |
| EW | PXAC260622SC | Yes | 2496 – 2690 | 25+50 | 17.0 | 45.0 | 28 | H-37248H-4 | G) fedorest |

Cellular Doherty Reference Designs





General Purpose Transistors (700MHz - 2200MHz)

| | Product | Operating Frequency [MHz] | Matching | P _{1dB} Typ [W] | Gain Typ [dB] | Eff Typ [%] | P _{out} Avg [W] | Test Signal | Supply Voltage Typ [V] | θJC [°C/W] | Package Type | |
|-----|-------------|---------------------------------|-----------|--------------------------------|---------------------|-------------------|--------------------------------|-------------|------------------------------|---------------|--------------|-----|
| NEW | PTFC270051M | 900 – 2700 | Unmatched | 7.3 | 20.3 | 60 | - | CW @ 2170 | 28 | 3.84 | PG-SON-10 | MAN |
| NEW | PTFC270101M | 900 – 2700 | Unmatched | 12 | 20.0 | 60 | - | CW @ 2140 | 28 | 4.04 | | m |

LDMOS Integrated RF Power Amplifiers (700MHz - 2200MHz)

| Product | Operating Frequency [MHz] | Matching | P _{1dB} Typ [W] | Gain Typ [dB] | Eff Typ [%] | Р _{оит} Avg [W] | Test Signal | Supply Voltage Typ [V] | (c/w) | Package Type |
|-------------|---------------------------------|----------|--------------------------------|---------------------|-------------------|--------------------------------|-------------|------------------------------|----------|---|
| PTMA080152M | 700 – 1000 | I | 20 | 30 | 34 | 8 | GSM/EDGE | 28 | 8.5/2.5 | PG-DSO-20-63 |
| PTMA080302M | 700 – 1000 | I | 32 | 31 | 36 | 15 | GSM/EDGE | 28 | 6.7/1.7 | hunning the state of the state |
| PTMA180402M | 1800 – 2200 | I | 40 | 30 | 16 | 5 | CDMA | 28 | 3.6/1.5 | Infrance 1 |
| PTMA210152M | 1800 – 2200 | I | 20 | 28.5 | 33 | 7 | WCDMA | 28 | 10.7/2.9 | Helitalia |

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"...energy efficiency continues to be a hot topic of research."

ing and hyperthermia applications. Printed antennas for wideband and multi-band communications are still prolific. Nowadays, antennas are often taken into account in the model of whole RF systems, sensors, sensor networks, radars, etc., that require the system designer to have good antenna expertise or to work together with the antenna designer.

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ICs & Semiconductors



Sector overview by Eric Kerhervé, EuMIC 2015 Chair In collaboration with Didier Floriot, Co-Chair and Eric Tournier, TPC Chair

The 10th European Microwave Integrated Circuits Conference (EuMIC) offers a perspective of the state of the art of integrated circuits, covering frequencies from the microwave to the submillimetre wave region.

One of the main applications for RF integrated circuits is mobile communication, where 3G, 4G and shortly 5G, will see the transceiver market continue to exhibit high growth. This will be driven by increased volumes of connected mobile platforms and higher complexity of transceiver functionality.

The key factors for the transceivers in the next decade will be the reconfigurability for multi-mode, linearity for complex modulations, tuning functionality for multi-frequencies, millimetre wave capability for Gbps wireless, along with a small size and power efficiency aimed at reducing power consumption. The silicon technologies supporting such applications should enable these constraints to be solved. During EuMIC, several contributions will demonstrate the remarkable progress in RF systems achieved through RF CMOS or similar technologies.

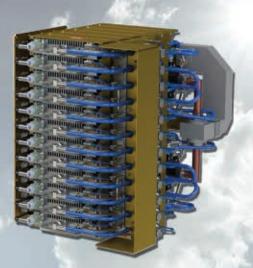
Apart from classical mobile communication, there are also many other RF activities in high-growth areas, such as Wi-Fi (802.11ac) and potentially WiGig (802.11ad), RF infrastructure including femtocells, picocell base stations and backhaul communications infrastructure. This can be achieved by wireless communication systems operating at millimetre wave frequencies as well as by optical data transmission.

As most of the power in a communication system is dissipated in the power amplifier, energy efficiency continues to be a hot topic of research. For RF power amplifier design, III-V

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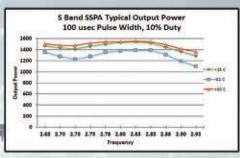
Field Replaceable Modules

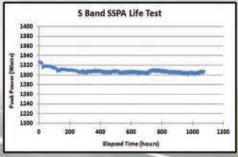
9.0 - 9.2 GHz X-Band: 1 kW Modules

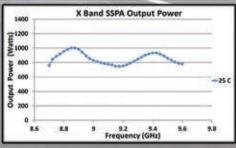
2.7 - 2.9 GHz S-Band: 1.3 kW Modules

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and nanoscale silicon, circuits are being investigated at RF and millimetre wave frequencies.

There is also increased interest in GaN technologies. These technologies have been developed in Europe for the last 20 years, providing a strong groundbase from material substrate to qualified industrial sources. Previously limited to roughly 20 GHz in terms of application, progress is underway to extend to 40 GHz at the industrial level, and up to E/W frequency bands at the R&D academic level.

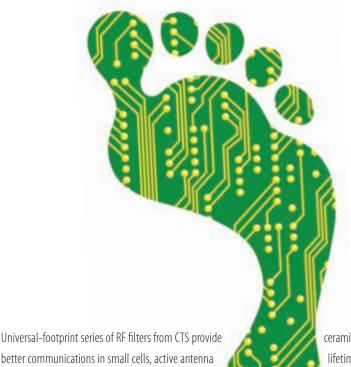
National and European administrations are committed to the objective of progressively achieving the complete GaN supply chain inside Europe. As a result, players in Europe are now able to address the substrate, epitaxy, foundries and packaged products. Space evaluated technology covering applications up to C-Band has been available for several years in the EPPL list of the European Space Agency (ESA). This domain will be extended up to Ku/Ka-Bands in the coming years.

At the product development level, there is a clear trend to make compatible power GaN technologies and plastic based packaging through management of the thermal heating and the reliability. This is mainly motivated by a cost reduction approach. Another trend is a mixing of different technologies inside the same package (GaN/GaAs/SiGe/CMOS) to offer full functionality inside a single package (SiP), creating more added value and so mitigating the access cost of such technologies at system level.

The trends that have been outlined indicate the direction that RF and microwave research and applied technologies are taking in the integrated circuits and semiconductor arena.

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^{*} Note: "Difficult" bands may have 2dB lower worst case Rx band isolation.













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Radar



Sector overview by Laurent Ferro-Famil, EuRAD 2015 Chair

The radar sector is a continuously growing area of research and development, with numerous and very productive interaction between institutional, industrial and academic partners, centered on technological breakthroughs, high level signal processing concepts and techniques and innovative applications and products.

Besides the historical defence-orientated use of radar, the most dynamically expanding radar activities relate to civil applications, where diversities of operating scales, from micro-local to worldwide; of products, i.e., devices, data and expertise; and of topical domains, ranging from environmental sciences to safety and security, encompassing medicine and industrial needs, have generated a wide and active market.

This growth is clearly illustrated by the high scientific and technological contributions presented in the framework of the 12th European Radar Conference, in particular with regards to three areas of intense development: multi-channel radar systems and processing techniques, imaging radar, and mmWaves and THz radar.

Multi-channel radar systems play a key role in the rapid increase in the number of applications and market opportunities in the radar sector. The joint use of several sources of passive or active radar information operated over one or more modes of diversity, such as space, time, frequency or polarization, results in significantly improved global capabilities, in terms of detection performance, unambiguous operating domains, hardware complexity and cost, and estimation accuracy.

Such high performance systems appear in a wide range of applications from mass market local measurements through to satellite missions. The evolution, in terms of hardware solutions and applications, of multichannel systems deeply depends on



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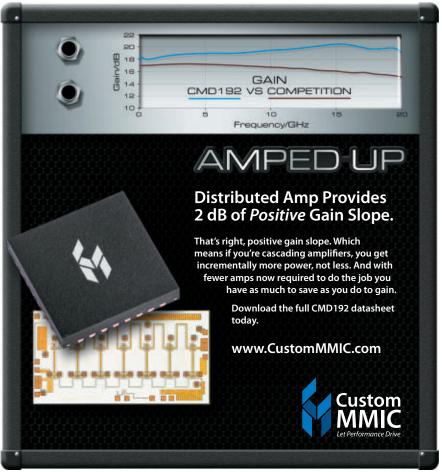
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the current capabilities of RF components and on the development of new multi-dimensional signal processing methodologies, orientated towards MIMO and cooperative network techniques, waveform design, sparse sampling and signal reconstruction and robust processing.

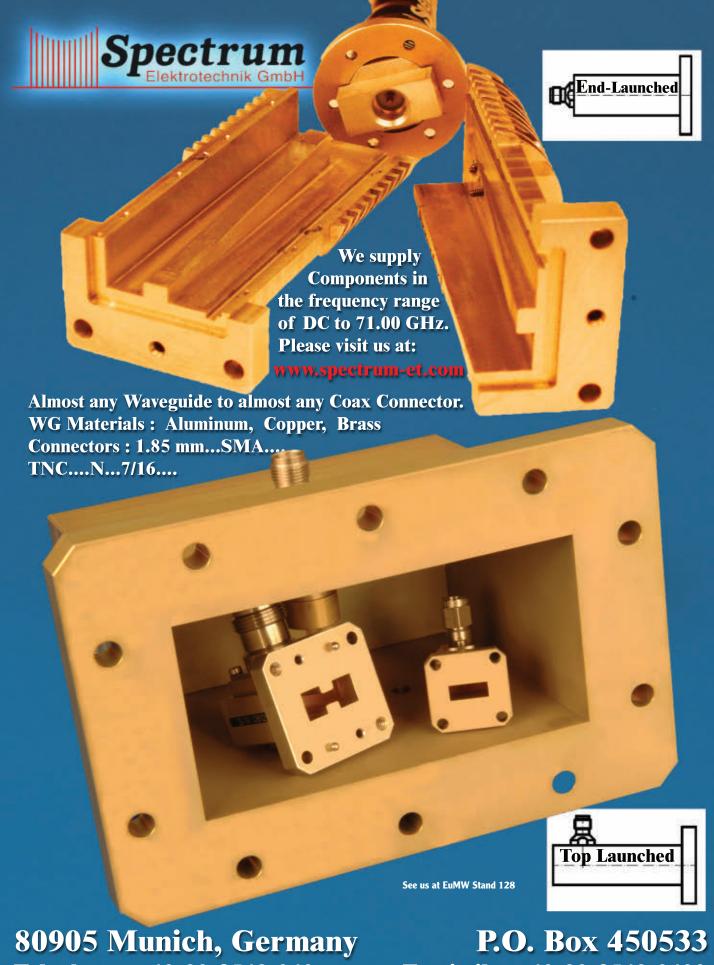
Imaging, considered as the precise localization of sources of signals in a multidimensional space, is becoming an essential feature of new radars. Besides its traditional use for large-scale mapping, imaging is widely addressed in non-destructive testing, localization, physical parameter estimation, and automatic target detection and recognition applications.

Signal focusing techniques may also be used to characterize RF components, electronic cards or devices, like complex antenna systems, anechoic chambers, in order to check local field distributions, look for potential defects or resolve EM compatibility problems. Imaging can be coupled to a large range of signal processing techniques aimed at enhancing the resolution of analysis, reduce acquisition requirements in terms of SNR, time and spectral occupation.

"Imaging can be coupled to a large range of signal processing techniques..."

mmWave and THz radar represents one of the most promising fields of the sector. The use of higher frequencies provides many advantages, such as more refined spatial and Doppler resolutions and significant potential for integration through the drastic reduction of the size of the systems.

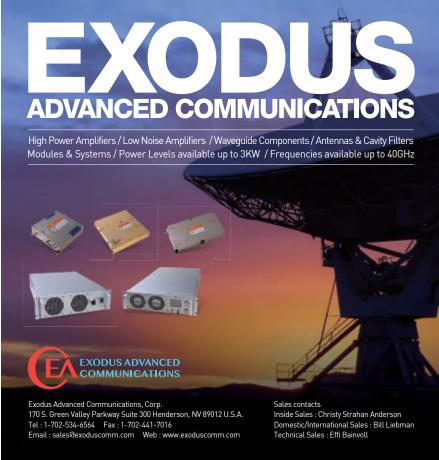
On-chip radars or miniaturized array-based systems will provide multiple and high-performance functionalities at a reduced cost, well adapted to short range applications. The combined use of such devices together with digital com-



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ponents similar to those introduced in the telecommunications domain should enable very appealing, software defined or reconfigurable types of applications.

The radar sector is in a period of rapid and deep growth. It is not only benefiting from technological development itself but often inspires other fields of activity such as RF component and device design or signal processing.

CONCLUSION

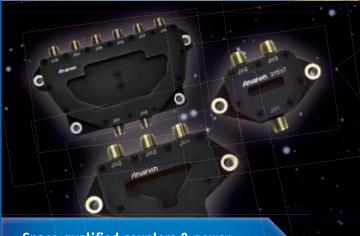
Like other market sectors in Europe the RF and microwave industry has to steer a course through the economic downturn and address the issues of skills shortages, funding cuts and reluctant investors. However, like a skilled car mechanic it has the right tools to engineer positivity and progress – an educated workforce, a strong tradition of academic excellence and a long history of technological and industrial development.

As we turn the corner and exit the economic downturn, research and innovation is becoming increasingly important. It is seen as an investment in the future that is at the heart of the EU's blueprint for smart, sustainable and inclusive growth and jobs. Those countries that invested in R&I before and during the crisis have often been most resistant to economic hardship, which is a good reason why more should be striving to reach the EU target to invest 3 percent of GDP in R&D.

As can be seen from the examples given in this report, the European RF and microwave industry, helped by Horizon 2020 and other initiatives, is at the forefront of the latest technologies, with a significant role to play in shaping the future and influencing global markets. Not all initiatives have to be large scale – SMEs are the backbone that collectively supports the RF and microwave skeleton in Europe, able to use their inherent flexibility and economies of scale to be agile and adaptable to changing market conditions.

Whatever the source, cutting edge engineering and design and innovative entrepreneurship that has the ability to turn research into technology and bring technology to market will be a key driver for future prosperity.





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Meeting 5G Test and Measurement Challenges

Martin Schmaehling Rohde & Schwarz, Munich, Germany

The boom in mobile Internet access due to smartphones and tablet PCs has made LTE and LTE-Advanced the fastest growing mobile technologies. Because of the requirements of smartphones and tablet PCs, LTE and LTE-Advanced have been optimized for high data throughput to wireless users. However, when it comes to the requirements for 2020, it is foreseen that many new scenarios and applications need to be supported. These requirements and possible solutions are a topic of 5G research. Traditionally, the official definition of next-generation mobile communications systems comes from the ITU. Today, the future 5G requirements are being studied.

The Internet of Things (IoT) is a concept whereby more and more devices such as emergency systems, robots and home automation equipment will increase the number of connected devices many times over. The requirements of these devices will differ vastly from those of smartphones or PCs. Some will require extremely high data rates, while

others will send or receive minimum amounts of data and require the simplest possible radio access procedure and many years of battery lifetime. The "tactile" Internet aims to support steering and control via the Internet. Examples range from mobile gaming and remote control of robots to healthcare applications. For consistent user perception, round trip times in the order of 1 ms are required.

Today's cellular technology cannot meet these requirements. We therefore anticipate that 5G will require much wider frequency bandwidth, which is only available in the millimeter wave domain. Bandwidths up to 2 GHz are being discussed. New waveforms and new modulation schemes are also being demanded. While mobile network operators and network vendors have experience in frequencies from 700 MHz to 3 GHz for cellular networks, millimeter wave technology and signal propagation is a new field.

Exploiting the required frequency bandwidths will require mining these new frequency bands. One area of 5G study is exploring radio wave propagation characteristics at higher carrier frequencies, also referred to as channel sounding. Universities in the U.S. have conducted early research on the propagation characteristics of a 28 GHz signal in an urban environment. Recent investigative work

by several research initiatives all over the world now includes using the 60 GHz ISM bands and frequencies around 73 GHz. A network operator in South Korea has announced that it will run a 5G network at the 2018 Winter Olympics in Pyeongchang in the 28 GHz range.

The LTE air interface does not efficiently meet all 5G

requirements. The 10 ms frame duration is too long for round trip times to meet the requirements of tactile applications. The cyclic prefix is considered overhead and causes latency. Therefore, other means are needed to avoid intersymbol interference (ISI) and intercarrier interference (ICI). A filtered multicarrier approach is being studied in order to achieve synchronous and asynchronous traffic types, with loss of orthogonality in some cases. Different techniques are being investigated, such as filter bank multicarrier (FBMC), universal filtered multicarrier (UFMC) and generalized frequency division multiplexing (GFDM).



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ULTRA-WIDEBAND SIGNAL ANALYSIS

Mobile devices require physical layer conformance tests in line with their specific standards. The required trans-



▲ Fig. 1 R&S FSW signal and spectrum analyzer with R&S RTO oscilloscope.

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▲ Fig. 2 Simplified block diagram of signal and spectrum analyzer with oscilloscope for wideband signal analysis.

Application

mission test parameters and procedures with LTE, for example, are defined in the standards 3GPP 36.141 (for base stations) and 3GPP 36.521 (for mobile devices). These parameters and procedures include spectral measurements at frequencies up to 12.75 GHz and signal demodulation with up to 20 MHz analysis bandwidth. Signal and spectrum analyzers are used for these tests. However, because of the required frequency range and analysis bandwidth, the foreseen requirements for 5G testing cannot be met in the same straightforward way as with LTE.

In order to digitally demodulate signals, spectrum analyzers are the instrument of choice. Spectrum analyz-

ers with demodulation bandwidth up to about 500 MHz are commercially available today. Combining the advantages of high-end spectrum analyzers for spectral measurements with those of cost-efficient midrange oscilloscopes is a concept in signal analysis that extends the analysis bandwidth to up to 2 GHz. The analyzer downconverts to an intermediate frequency (IF). The IF of the spectrum analyzer must be high enough to support the required frequency bandwidth. In addition, it must still be low enough for the oscilloscope to fulfill the Nyquist sampling theorem.

Such a combination is shown in *Figure* 1, with the block diagram of the combination in *Figure* 2. The signal and spectrum



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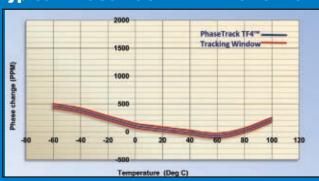


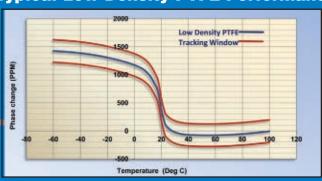
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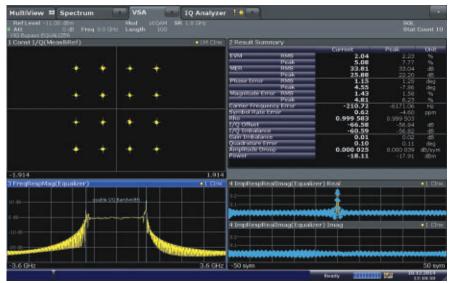


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▲ Fig. 3 Demodulation of a signal with a 1.8 GHz symbol rate.

analyzer features an IF of 2 GHz. The oscilloscope digitizes the signal and transfers it back to the analyzer over a local area network (LAN). The analyzer equalizes and resamples the signal and mixes it into the digital baseband. The measurement software options on the signal and spectrum analyzer receive equalized I/Q data at a user-defined sample rate. This concept allows the analysis of signals up to the maximum frequency of the signal and spectrum analyzer,

e.g., 67 GHz for the instrument shown.

The setup of a signal and spectrum analyzer with an oscilloscope as external analog-to-digital converter is straightforward. The analyzer firmware fully controls the oscilloscope. The user operates the measurement characteristics in the same way as with classical internal analog-to-digital converters.

Figure 3 shows the demodulation of a signal with a symbol rate of 1.8 GHz at a center frequency of 9 GHz. With the equalizer function of the measurement application, an error vector magnitude (EVM) value of 2 percent is measured. The measurement application for vector signal analysis now offers many functions for in-depth digital signal analysis. The result summary table displays EVM, phase error, magnitude error, carrier frequency error, symbol rate error and constellation distor-

tion values. The display of the equalizer function helps to detect effects of a non-equalized frequency response or filter mismatches of the device under test.

While 5G is not yet defined, many research projects and early initiatives call for high modulation bandwidth at frequencies greater than 20 GHz. Signal and spectrum analyzers with up to 2 GHz demodulation bandwidth up to 85 GHz are commercially available today for straightforward measurements of spectrum and modulation parameters.





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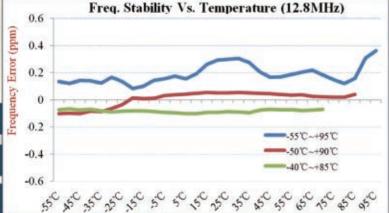
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[†]Flatness specified over 0.5 to 7 GHz.



E-Band Front-End Module for Multi-Gbps Radio Links

Jagjit Singh Bal Infineon Technologies North America Corp.

t is projected that in 2019, global data demand will grow to 24.3 exabytes (1 billion gigabytes) per month from the present

2.5 exabytes per month with 97 percent of this growth due to smart mobile devices. An average smartphone user currently uses 800 MB/month and this is projected to rise to roughly 4000 MB/month in 2019. With the growing number of apps, cloud computing, video streaming and other bandwidth consuming services the demand for mobile data services will continue to grow rapidly.

Even though mobile devices are getting faster by incorporating new technologies like LTE-Advanced, to provide good quality-of-service (availability, fast speed, connectivity) at reasonable prices to the end customers the network operators also need the backhaul networks which have low latency, much higher capacity and lower total cost of ownership.

Optical Fiber is preferred for backhaul because of the high capacity and scalability it can provide but the total cost of ownership (TCO) is quite high. Sometimes it is not feasible to install the fiber in urban areas; longer deployment time, expensive leases and the required approvals from the relevant authorities often make this solution unattractive to carriers.

Microwave radios connect more than 60 percent of all the base stations today but their capacity has been pushed to the limits by using higher modulations, wider channels, polarization multiplexing techniques and radio link bonding.² The limited channel bandwidth of up to 56 MHz will not be sufficient in future to provide multi-Gbps capacity for the backhaul and fronthaul. On the other hand, in E-Band there is 10 GHz of spectrum available, where even simple modulation schemes can be implemented to achieve several Gbps capacity.

E-Band has worldwide availability, is lightly licensed, interference free, has much wider channel bandwidths (250 MHz and above) available and also low oxygen absorption, allowing much longer hops. Wireless links can be deployed quite quickly compared to optical fiber and also now the technology exists that makes the total cost of ownership of the point-to-point radio link lower than optical fiber. A number of IC manufacturers have developed chip sets for E-Band transceivers, some in silicon and others in GaAs. This article discusses the radio link design and performance that can be achieved at E-Band with a front-end design using Infineon SiGe transceivers.

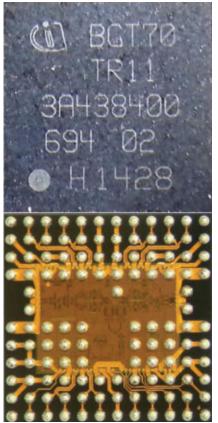


Fig. 1 Package view (top and bottom) of the 71 to 76 GHz transceiver.



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E-BAND TRANSCEIVERS

E-Band transceivers which can be used for multi-Gbps point-to-point radio links have been developed in SiGe technology. High capacity macrocell backhaul, small cell backhaul, fiber extension or replacement, common public radio interface (CPRI) interconnection are some of the applications which are addressed by the E-Band links. *Figure 1* shows an E-Band transceiver for the 71 to 76 GHz band.

In this example, the transceiver chip is fully differential and features a direct up and down-conversion architecture for the Tx/Rx chain. The transmitter, depending upon frequency, can deliver up to +14 dBm saturated output power. The receiver has a double sideband noise figure of 8 dB for the 71 to 76 GHz band.

The transmitter includes a single sideband modulator, a variable gain amplifier and a power amplifier. The transceiver is controlled with a serial peripheral interface (SPI), which can

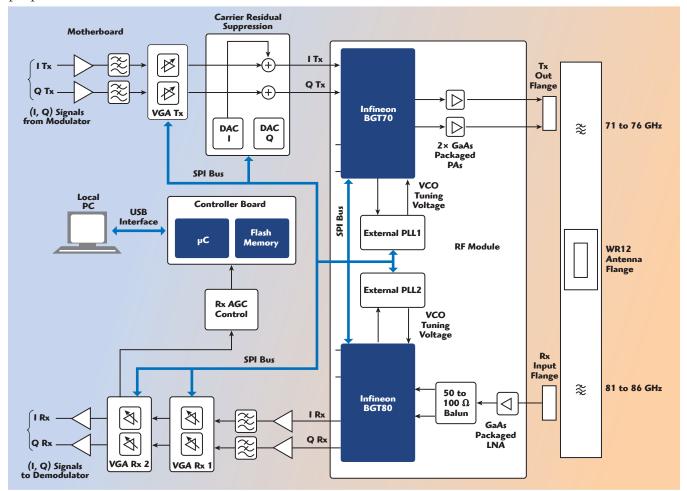
be used to set the variable gain amplifier (VGA) gain in the Tx chain, calibrate the carrier leakage at the Tx output, read the integrated power and temperature sensor. The transceiver can be used in both time division duplex (TDD) and frequency division duplex (FDD) systems. The chip can be switched between Tx and Rx modes in under 1 µs via SPI to enable it to be used in TDD mode. The internal VCO of the transceiver has phase noise better than -80 dBc/Hz at 100 kHz offset from the carrier, which enables radio links with complex modulation schemes to work even in narrower channels to achieve greater than 1.3 Gbps capacity with 256-QAM in the $250\ \mathrm{\overline{MHz}}$ radio channel.

SiGe bipolar technology offers excellent flicker noise performance in comparison to CMOS based technologies, which enables the realization of oscillators with high purity outputs. This in turn helps to achieve higher order modulation schemes and also excellent receiver noise figures at lower IF frequencies. The E-Band transceivers require only single supply voltage of 3.3 V and consume 1.5 W in Tx mode and 1.2 W in Rx mode.

E-BAND FRONT-END MODULES

Based on these mmWave transceivers, front-end modules (FEM) have been designed which could be used for radio links with greater than 1 km long hops and over 3 Gbps data rates. The block diagram of an E-Band FEM is shown in *Figure 2*. In order to cover a longer range (> 1 km) with higher order modulation schemes (up to 256-QAM) using this reference design, a packaged power amplifier (PA) is used at the output of the Tx chain. The saturated output power at the antenna port can be as high as +21 dBm. This topology provides sufficient power at the antenna port to account for the back-off for higher order modulation schemes, the transition losses on board and the losses in the diplexer, as well as having the required fading margin.

On the receiver side, an external



▲ Fig. 2 Block diagram of the E-Band front-end module.

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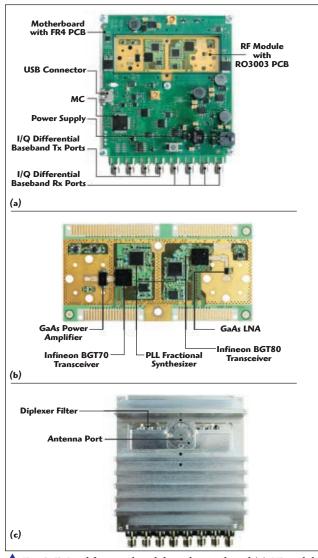
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▲ Fig. 3 E-Band front-end module evaluation board (a) RF module (b) diplexer filter and antenna port (c).

variable low noise amplifier (LNA) is placed before the E-Band transceiver in order to increase the system sensitivity. The receiver section features automatic gain control circuitry with two stages of external VGA. These are used to deliver a constant level IF signal to the modem even in the case of variations in the received signal at the antenna port. The dual channel differential VGAs are able to cover around 2 GHz of baseband bandwidth. A microcontroller is used to control the E-Band transceiver and the on board PLLs via SPI interface.

For E-Band transceivers, it sets the Tx/Rx mode, Tx VGA control, LO leakage calibration, reading chip ID, reading power and temperature detector, real time Rx AGC. For the PLLs it is used to set the

center frequency, charge pump current and reference oscillator offset. An interactive graphical user interface allows the user to control various settings of the E-Band transceiver and PLL via USB connection.

EVALUATION BOARD FOR E-BAND FRONT-END MODULE

The RF circuitry of the FEM is implemented on a substrate (Rogers RO3003) that was chosen because of relatively low losses at 71 to 86 GHz, lower coefficient of thermal expansion (CTE) in the XYZ plane and low tensile modulus, and the rest of the baseband and control circuitry is designed on an FR4 board. The FEM has an SMA interface for the differential I/Q baseband signals, which allow easy interfacing with an external modem. The diplexer is mounted into the heat sink beneath the motherboard. The evaluation board is powered from an external +12 V supply. The step down converter and low dropout voltage regulator are used to convert +12 V into lower voltages required by various blocks on the evaluation board. The top and bottom views of the FEM are shown in **Figures 3a** through 3c.

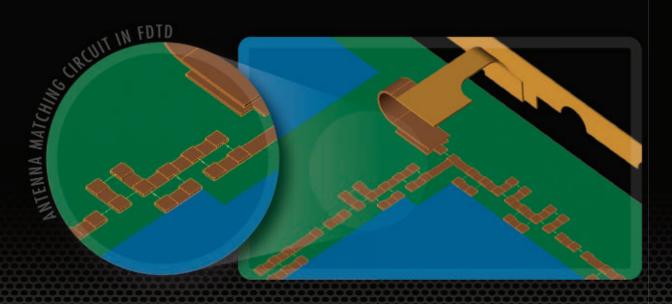
TRANSMIT CHAIN

The chipset integrates an on-chip voltage-controlled oscillator whose output frequency is controlled by an external PLL circuit available on the module. The E-Band transceivers have an internal divider; divide-by 32,



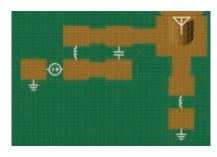


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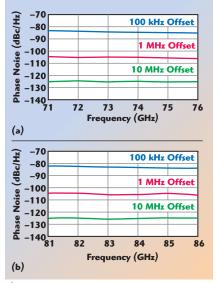
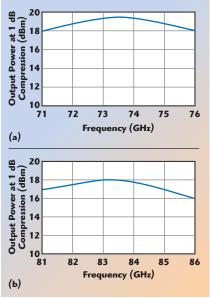


Fig. 4 Phase noise performance across 71 to 76 GHz (a) and 81 to 86 GHz (b).

which provide the RF signal to the external PLL. An onboard crystal is used to provide the reference signal to the PLL. A fractional PLL is used to lock the carrier to the specific channel in a band. The measured phase noise at the antenna port of the FEM is shown in *Figures 4a* and *4b*.

The baseband bandwidth for the E-Band transceiver is specified to be 1 GHz, which translates into RF bandwidth of 2 GHz. The IF levels fed into the Tx chain of the FEM can be adjusted by the VGA in the IF Tx chain or to some extent by the modem itself. The E-Band transceivers have an internal DAC at the transmitter side to suppress the LO leakage at the Tx port. The onboard microcontroller runs the algorithms, which are used to do LO leakage calibration. External DC biasing at the modulator inputs of the E-Band transceivers allow further suppression of the LO leakage for higher order modulation schemes.

In order to have a higher capacity link for longer hops the output of the E-Band transceiver is fed into two external packaged GaAs power amplifiers. A low loss microstrip to waveguide (WR12) transition is designed at the



▲ Fig. 5 Output power at 1 dB compression across 71 to 76 GHz (a) and 81 to 86 GHz (b).

output of power amplifiers to feed the signal to the diplexer. The integrated diplexer on the module has low insertion loss (under 0.5 dB) and higher isolation (greater than 70 dB) in order to prevent any kind of desensitization of the receive chain. The output P1dB, measured at the antenna port, for the 71 to 76 GHz and the 81 to 86 GHz band is shown in *Figures 5a* and *5b*. *Table 1* lists the measured output power at the antenna port with different modulation schemes in channel bandwidth of 500 MHz.

RECEIVER CHAIN

On the Rx side an LNA is placed before the E-Band transceiver in order to improve system sensitivity for higher order modulation schemes (> 64-QAM). A low-loss waveguide-to-microstrip transition and balun are used to convert the single-ended output of the LNA to the differential interface of the E-Band transceiver on the board. The differential IF output of the E-Band transceiver is connected to the automatic gain control chain consisting of the external VGAs and power detector. The measured noise figure

TABLE 1 MEASURED OUTPUT POWER VS. FREQUENCY AND MODULATION Output Power (dBm)

| | Output Power (dBm) | | | | |
|----------------------|--------------------|--------|--------|---------|--|
| f _c (GHz) | 4-QAM | 16-QAM | 64-QAM | 256-QAM | |
| 73.5 | 18 | 14 | 12 | 8 | |
| 83.5 | 18 | 14 | 12 | 8 | |



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Insertion Loss: 4.5 dB typ. 80 dB min. Switching Speed: 200 ns max. 2.0:1 max.

25 Watts CW 10 MHz to 6.0 GHz



P2T-10M6G-45-R-5V-SFF-HIP20W

Insertion Loss: 2.5 dB typ., 2.8 dB max. 1solation: 25 dB typ., 20 dB min. Switching Speed: 100 ns max.

VSWR: 2.0:1 typ.

5 kW Peak 100 Watts CW

1.0 to 1.1 GHz



P2T-1G1R1G-25-R-TFF-100W

Insertion Loss: 0.8 dB max. 25 dB min. Switching Speed: 275 ns typ... 1.5:1 max.

5 Watts Peak 2 Watts CW

9.25 GHz (+/- 30



P1T-9D25G-90-T-SFF-5W

Insertion Loss:
Isolation:
Switching Speed:
VSWR:
1.5 dB goal
80 dB min.
10 ns max.
1.9:1 max.

4 Watts CW 500 MHz to 18.0GHz



P2T-500M18G-80-T-515-SFF-4W

Insertion Loss:
 Isolation:

Switching Speed:
 VSWR:

3.5 dB typ. 70 dB min. 200 ns max. 2.0:1 max.

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and conversion gain of the receiver at the antenna port across frequencies is shown in *Figures 6a* and *6b*.

The FEM is currently able to achieve up to 256-QAM in the 500 MHz channel bandwidth, providing a data rate of 3.18 Gbps in a bi-directional link. The measured 256-QAM constellation for this FDD link operating at 83.5 GHz is shown in *Figure* 7. The link is working with a signal-tonoise ratio (SNR) of greater than 33 dB for the bidirectional link.

The data rate is limited in this demo due to the limited symbol rate from the baseband generator. The E-Band transceivers are specified to work up to 2 GHz RF bandwidth. A modem capable of delivering higher symbol rates (> 500 Msymbols/s) can provide higher capacity radio links but with lower order modulation schemes, e.g., 32 or 64-QAM.

Using much wider channel bandwidth will increase the integrated noise in the band thus reducing the SNR required to sustain higher order modulations (> 32-QAM). As an example, comparing the measured SNR for the 83.5 GHz link operating in the 250 MHz RF channel bandwidth from *Figure 8* with the SNR of the link from Figure 7, it can be seen that doubling of the RF channel bandwidth reduces the SNR by 2.5 dB.

For the E-Band FEM, link distance simulations are performed for 99.99 percent link availability. A vertically polarized antenna with 43 dBi of gain is considered, per the minimum antenna







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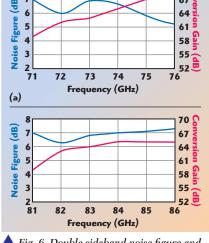




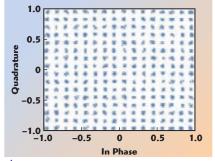




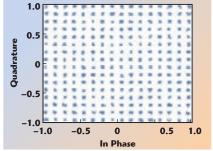




▲ Fig. 6 Double sideband noise figure and conversion gain across 71 to 76 GHz (a) and 81 to 86 GHz (b).



▲ Fig. 7 I/Q constellation of a 3.18 Gbps link using 256-QAM with a 500 MHz channel bandwidth at 83.5 GHz. The SNR is 33.5 dB.



▲ Fig. 8 I/Q constellation of a 1.37 Gbps link using 256-QAM with a 250 MHz channel bandwidth at 83.5 GHz. The SNR is 36 dB.

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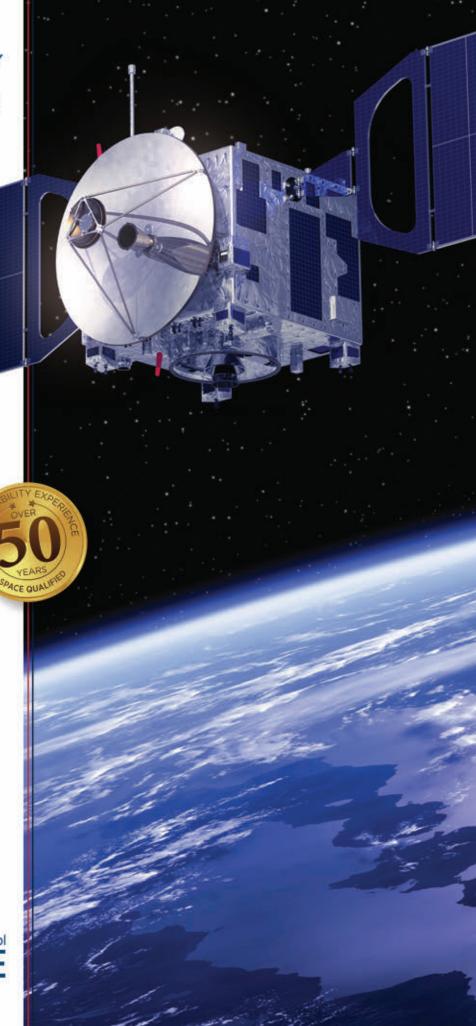
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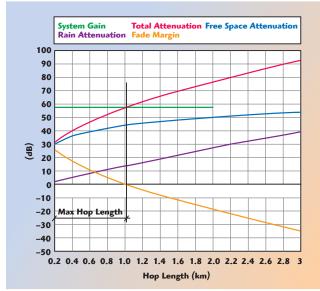
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gain requirements of the FCC. The ITU-R P.837-6 K-region rain model with rain rate of 42 mm/h exceeded for 0.01 percent of the average year is considered for this simulation. The fade margin is calculated from the following equations:

System Gain (dB) = Transmit Power - Receiver Threshold Power for BER of 10⁻⁶



▲ Fig. 9 Fade margin vs. hop length for a 256-QAM signal at 83.5 GHz with 500 MHz channel bandwidth and +8 dBm power at the antenna port.

- Total Attenuation (dB) = Free Space Attenuation + Attenuation Due to Rain and O₂
- Fade Margin (dB) = System Gain Total Attenuation
 The measured receiver threshold for a BER of 10⁻⁶ is
 -50 dBm for 256-QAM in a 500 MHz RF channel bandwidth. Using the above equations, *Figure 9* shows a hop length of 1 km is achieved for a 3.18 Gbps radio link. Under similar conditions, the link operating with 64-QAM will cover 1.3 km and 4-QAM will cover 2.4 km.

CONCLUSION

The E-Band FEM reference design is able to achieve a 3.18 Gbps radio link using 256-QAM in a 500 MHz RF channel bandwidth with +8 dBm of output power at the antenna port. The module is able to cover 1 km with standard antennas using 256-QAM and even longer distances with lower order modulation. The FEM is an all-SMT solution offering excellent performance in a compact form factor with a flexible interface, which can easily be used with an external modem. ■

ACKNOWLEDGMENT

The author would like to thank the RF team at GreenWaves S.r.L. for their inputs on the E-Band frontend module.

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Comparing Nonlinear Vector Network Analyzer Methodologies

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cattering parameters (S-parameters) were first mentioned in articles and textbooks in the 1950s and 1960s by Matthews, Collins and Kurokawa and popularized by the release of Hewlett Packard's first network analyzers in the 1960s. Since then, S-parameters have been used to describe the complex characteristics of a network by quantifying the RF power flowing between its ports. S-parameters are essentially the ratio of the reflected and transmitted signal at a given port to the incident signal at a given port under perfect match conditions (see *Figure 1*). When referring to a transistor, these parameters can be used to calculate return

loss, gain and isolation.¹

It is important to understand that Sparameters are only truly valid for linear networks, where the characteristics of the network are independent of the level of the signal being network. When considering a semiconductor application such as a transistor, this refers to its small-signal operating condition, in which the input drive power does not affect the S-parameters of the transistor. Under small-signal oper-

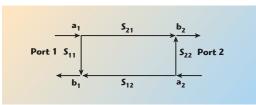
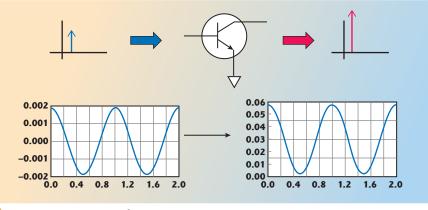


Fig. 1 Generalized two-port network.



driven into the A Fig. 2 Linear operation of a transistor.



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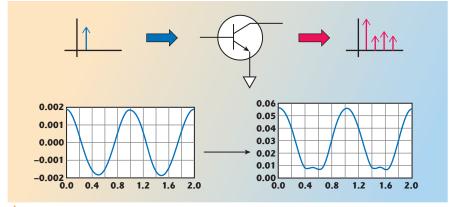


Fig. 3 Nonlinear operation of a transistor.

ating conditions, a transistor will have linear gain at the fundamental drive frequency and not excite additional powers at the harmonic frequencies. Linear operation of a transistor and the associated input and output waveforms are shown in *Figure 2*.

The question arises how to thoroughly describe and model a transistor operating under nonlinear largesignal conditions. These conditions occur commonly for high power and high efficiency power amplifiers operating in advanced classes of operation. Under these operating conditions, powers are induced at harmonic frequencies when excited by a sine wave, and in-band and out-of-band modulation products are created under modulation excitation. Considering a simple sine wave excitation, a transistor's characteristics are dependent on the level of the input drive signal, shown in both frequency and time domains in Figure 3.

When the transistor is in deep compression and its output is composed of multiple harmonics, the device behavior cannot be described correctly by S-parameters, which are frequency domain quantities. It is much more natural to analyze the behavior of the device under test (DUT) in terms of time domain RF voltage and current waveforms. Clear evidence of this is provided by the theoretical description of the different modes of operation of power amplifiers, which is completely done in time domain. In this case, a nonlinear vector network analyzer (NVNA) can be used to measure the incident and reflected a- and b-waves at the transistor input and output, in both amplitude and phase. The data can then reconstruct the time domain RF voltage and current

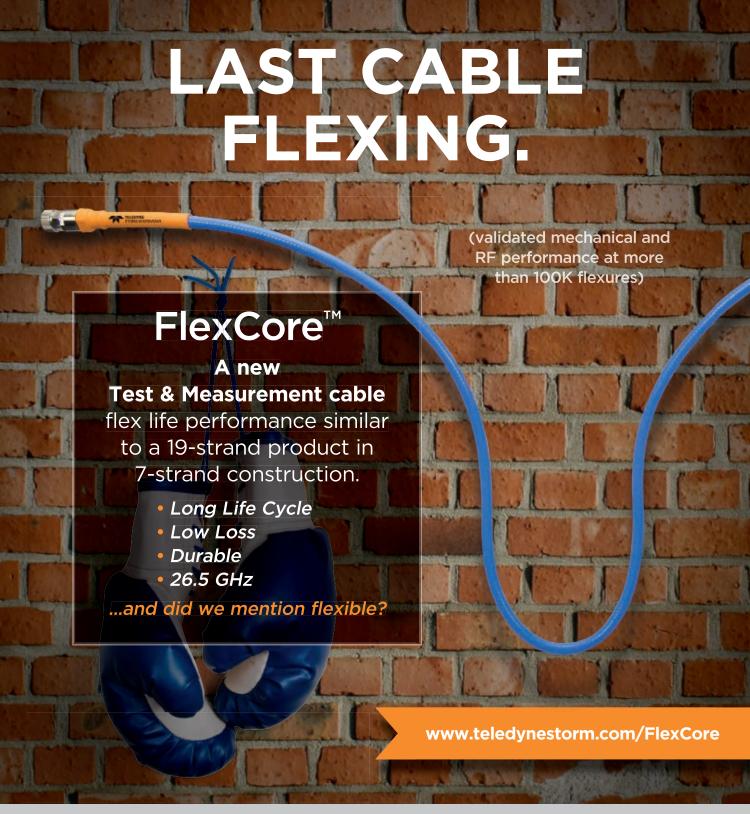
waveforms and RF load lines as well as all the conventional performance parameters of the device, such as input and output power, gain and efficiency.²

Several commercial solutions exist to measure nonlinear transistor performance. This article will compare Maury Microwave's MT4463 large signal network analyzer (LSNA) and the MT2000 mixed-signal active load-pull system (MSALP). The MT4463 LSNA was offered in conjunction with Agilent's Network Measurement and Description Group between 2003 and 2008. The MT2000 is currently offered as an integrated non-50 Ω measurement system, in conjunction with Anteverta-mw.

MT4463 LARGE SIGNAL NETWORK ANALYZER

The LSNA concept was first introduced in the 1980s by researchers using oscilloscopes to measure voltage and current waveforms at the gate and drain of a transistor. Research continued through the late 1980s and early 1990s with the goal of improving the capabilities of the technique. The breakthrough that led to the commercialization of the LSNA product occurred in 1994 with the release of the Hewlett Packard (HP) microwave transition analyzer (MTA). In 1996, HP designed the nonlinear network measurement system (NNMS), the precursor to the first LSNA, which was commercialized in 2003 by Maury Microwave.

The goal of the LSNA is to measure the wideband incident and reflected waves of a DUT at fundamental and harmonic frequencies using a periodic CW or periodically modulated signal, as shown in *Figure 4*. The injection



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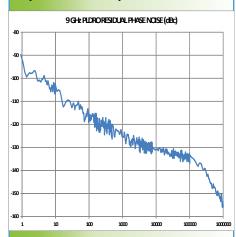


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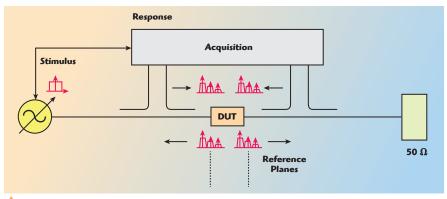


Fig. 4 Signal flow of LSNA with exemplary 50 ohm termination.

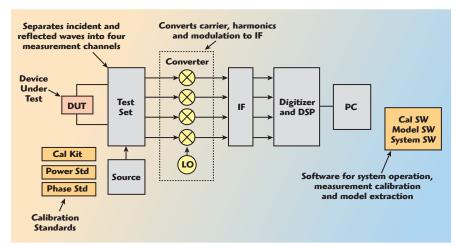


Fig. 5 Functional block diagram of the LSNA.

signal is external to the core measurement instruments and, depending on the model selected, can be used to synthesize single-tone CW, pulsed CW or periodically modulated signals (i.e., multi-tone).

The hardware architecture of the LSNA is shown in *Figure 5*. The DUT has an associated input and output signal which can be represented by waves. The LSNA

test set separates the incident and reflected waves into four measurement channels. A harmonic-sampler coherently down-converts the carrier and the harmonic and modulation frequencies to IF. A 14-bit digitizer and digital signal processor provides the raw signal data, and a computer performs error correction to represent

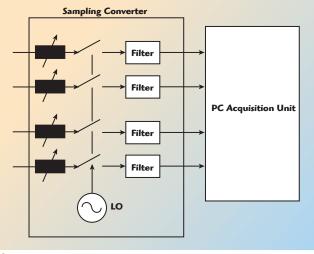


Fig. 6 LSNA sampling converter.

the incident and reflected waves in the reference plane at the DUT. Additional software can plot the data in multiple formats (A/B, V/I, time, frequency or envelope).

The enabling technology of the LSNA lies in the HP MTA and its sampler-based technology, or sampling converter, as shown in *Figure* 6. With a sampler, all frequencies

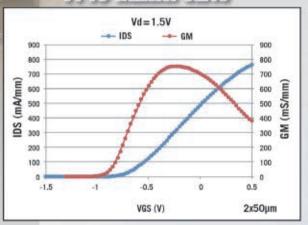




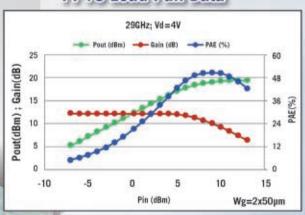
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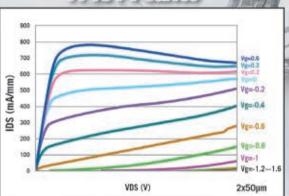
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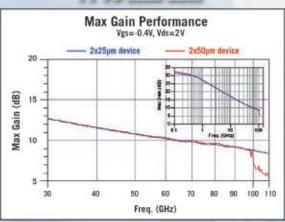
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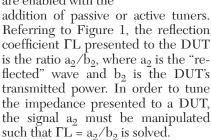
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are acquired in the same measurement using a fixed LO, including the fundamental, harmonics, modulation and intermodulation frequencies.

In the default configuration, the LSNA is terminated with 50 Ω . Non-50 Ω measurements are enabled with the



Passive mechanical tuners may be used to vary the impedance presented to the DUT. A passive slide-screw tuner (see **Figure** $\bar{7}$) consists of a precision 50 Ω slab line, with two parallel plates and a center conductor, and a metallic probe (or slug). When the probe is completely withdrawn from the slab line, the signal entering the tuner passes through with minimal interference, resulting in a low a2 signal. As the probe is lowered into the slab line, the electric field of the signal is interrupted, part of the signal is reflected back towards the DUT, and the a₂ signal increases. As the probe's horizontal position changes, the distance between the tuning element (probe) and the DUT changes, changing the phase of the reflection. By moving the probe up and down, left and right, nearly any impedance can be presented to the DUT, represented by full coverage of the Smith Chart (see Figure 8).

With open loop active load-pull, instead of using a passive tuner to reflect the signal back towards the DUT to manipulate a_2 , the signal is terminated, and a new signal a_2 is introduced back towards the DUT. In this manner, the magnitude of reflection can be as large as the new a_2 signal allows – even outside the Smith Chart – and created at the fundamental and harmonic frequencies.

One advantage of sampler-based measurements is speed, since the

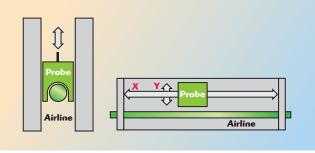


Fig. 7 Cross section and side view of the tuner, slab line and probe.

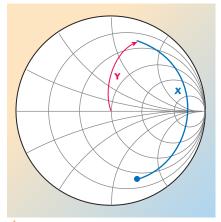


Fig. 8 Impedance change by varying the horizontal (X) and vertical (Y) probe position.

signal across the entire frequency spectrum is captured at once. Another advantage is signal type, since any periodic signal can be sampled. A disadvantage of sampler-based measurements is dynamic range, which is typically limited to approximately 60 to 70 dBc. The LSNA has been designed as a network analyzer using wideband receivers to measure vector corrected incident and reflected waves, allowing different types of external stimuli, including tuners, to be configured depending on the application. Therefore, external synthesizers are needed to create the injection signals to complete the network analyzer architecture. Also, any non-50 Ω analysis requires additional tuning networks, such as passive or active tuners. Passive tuners can be used with any injected signal, however they provide a wideband response which can distort wideband signals and degrade measurement results. Open loop active load-pull can be used with CW or pulsed-CW signals only.

The MT4463 LSNA covered two frequency ranges, 0.6 to 20 GHz or 0.6 to 50 GHz. The IF bandwidth was 10 MHz, RF frequency resolu-

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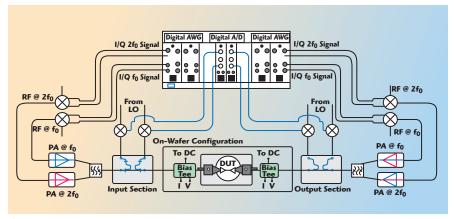
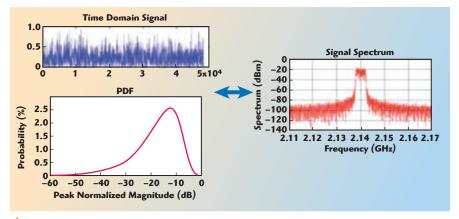


Fig. 9 Functional block diagram of the MT2000.



📤 Fig. 10 Realistic wideband signal.

tion was 1 kHz and the measurement dynamic range was 60 to 70 dB.³ Additional signal sources were necessary for multi tone or modulated signal synthesis, and passive or active tuners were needed for load-pull measurements.

MT2000 MIXED-SIGNAL ACTIVE LOAD-PULL SYSTEM

The MT2000 MSALP is a NVNA with integrated wideband sources (two, four or six) that is capable of measuring a- and b-vector waves and S-parameters and with inherent wideband impedance control capabilities. The MT2000 covers between 300 MHz and 40 GHz, with 2, 4 or 6 active tuning loops, modulation bandwidths up to 240 MHz and a measurement dynamic range of 80 dB.⁴

The hardware architecture of the system is shown in *Figure 9*. Wideband arbitrary waveform generators (AWG) are used to create a wideband signal around baseband, which is then up-converted in the RF test set. The RF test set consists of local oscillators (LO) combined with I/Q mixers to up-convert the baseband signal to

the fundamental and harmonic RF frequencies and inject source and load I/Q signals into the DUT. The resulting RF signal output is then down-converted back to baseband, and its a- and b-waves are analyzed by wideband analog-to-digital converters (ADC). Because both the AWGs and ADCs are wideband, a signal with up to 240 MHz of bandwidth can be generated and analyzed.

To generate a wideband signal, a repetitive time domain modulated signal, compliant with industry standards, is generated and then analyzed in the frequency domain. The signal is composed of thousands of tones, as shown in *Figure 10*. The wideband signal is up-converted and injected into the DUT as a₁. The resulting output signal b₂ consists of a modified version of the original signal, including an amplified signal at the fundamental frequency (with the possibility of signal distortion if modulated) and signals at the harmonic and baseband frequencies. Because the device may not be physically matched at the input, part of the signal may be reflected as b₁. The signal flow is shown in **Figure 11**.











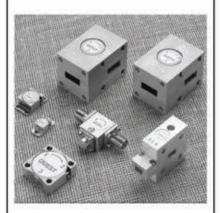
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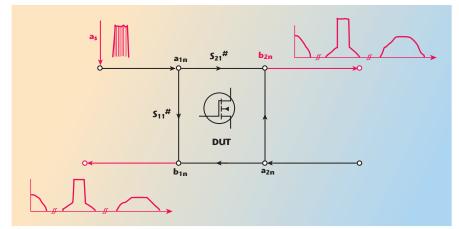
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📤 Fig. 11 Signal flow of the original injected signal, reflected signal and amplified signal.

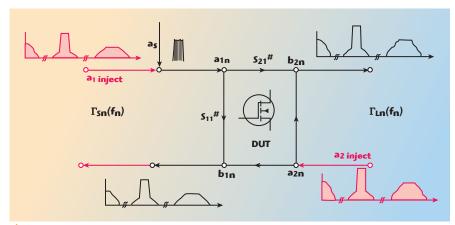
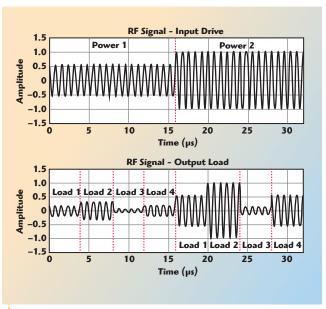


Fig. 12 Signal flow of the original injected signal, reflected signal and amplified signal (black) and the generated signals for active tuning (red).

Wideband pedance load-pull (see **Figure 12**) is achieved by varying a₂ at Hz tone spacing to satisfy $\Gamma L =$ a₂/b₂ throughout the wideband signal. The wideband AWGs are used to create the pre-distorted CW, pulsed CW or modulated a signal at baseband, so the up-converted fulfills the signal desired wideband impedance grid at fundamental and harmonic frequencies. The same used on the input ments. to adjust the source

impedances presented wideband at the fundamental and harmonic frequencies.



technique can be A Fig. 13 Time slotting of a CW signal for fast load-pull measure-

The wideband signal generation and analysis can also be used with single tone signals where the signal is divided in time. The record contain-



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| CT-3838-N | 5 Kw Pk 500 W Av | N Conn. | 2.7-3.1 GHz |
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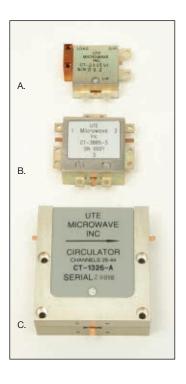
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| TABLE 1 COMPARISON OF LSNA AND MSALP | | | | | |
|--|---|--|--|--|--|
| | Advantage | Limitation | | | |
| MT4463 Large Signal Network Analyzer (LSNA) | Sampler-Based Results in Faster Measurements Waveform Reconstruction of Modulated Signal Flexibility Quasi-Open Source Code | Modulation Bandwidth Limited to 10 MHz No Wideband Impedance Control Dymanic Range Limited to 60 to 70 dB External Sources Required External Impedance Tuning Required Discontinued Platform | | | |
| | Advantage | Limitation | | | |
| MT2000 Mixed-Signal Active Load-Pull System (MSALP) | 80 dB Dynamic Range 240 MHz of Modulation Bandwidth (Plans for Higher Bandwidths in Future) Internal Sources Wideband Impedance Control for Modulated Signals Fast Impedance Tuning (1000 Impedance/Power States per Minute in CW or Pulsed-CW) Actively Supported and Expanded | No Waveform Reconstruction of Modulated Signals | | | |

ing the wave modulation for a single modulated impedance can contain several wave magnitudes and phases representing many single tone impedances. *Figure 13* shows an example of time slotting. In this manner, it is possible to load-pull 1000 impedance/power states per minute.

CONCLUSION

NVNA is a powerful tool to investigate, characterize and model transistor technologies operating under nonlinear conditions. Several commercial solutions offer NVNA capabilities, built around sampler or mixer technologies and each with their own advantages and limitations. A comparison of the two NVNA methodologies discussed in this article is in *Table 1*. In determining which approach to use, consider the type of injection signal required (CW, pulsed

CW, single-tone, multi-tone or modulated), the level of measurement dynamic range, measurement speed, impedance control methodology (passive, narrowband active or wideband active), impedance control speed and system availability and support. It is clear that as measurement and signal-processing technologies evolve, newer solutions are overcoming the limitations of the past.

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| USB-4SPDT-A18 | 4 | 0.25 | 1.2 | 85 | 10 | 1180.00 |
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| RC-8SPDT-A18 | 8 | 0.25 | 1.2 | 85 | 10 | 2595.00 |

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PI Weinschel's model 8512 switch matrix series provides users with access to multiple individual switches that can be locally or remotely controlled. Instead of using a custom switch assembly where all of the coaxial interconnections between switches are embedded within the unit, the 8512 programmable switch matrix offers the flexibility to customize the switch architecture by externally interconnecting the individual switches.

The 8512 series can be configured with up to 14 failsafe or latching SP3T, SP4T, SP5T or SP6T switches in one 19 inch enclosure. The switches cover DC to 18 GHz (Options A and B) or 26.5 GHz (Option C). Maximum inser-

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▲ Fig. 1 The GUI of the LabVIEW-based switch control center software (SCCS) enables independent control of each installed switch to any desired position.

tion loss is 0.5 dB at 18 GHz or 0.8 dB at 26.5 GHz, with maximum VSWR of 1.5:1 and 1.7:1 respectively. Isolation is 60 dB or greater at 18 GHz (Options A and B) and 70 dB or better at 26 GHz (Option C). Switching speed is 15 msec. Switch life is a minimum of 5 million cycles (Option C). Each option includes an integrated switch cycle counter.

The front panel local control and display make the switch matrix easy to use in the lab and manual test environments. For automated testing, Ethernet 10/100 BaseT, USB 2.0 and RS-232 are standard control interfaces. A GPIB/IEEE-488 interface is available as an option.

SWITCH CONTROL CENTER SOFTWARE

LabVIEW-based switch control center software (SCCS) supplied with each unit controls the operation of the Weinschel 8512 series, enabling the user to set up and control the programmable switches in one of three modes. Through a graphical user interface (GUI), Mode 1 enables independent control of each installed switch to any desired position (see *Figure 1*). Mode 2 is a virtual switch controller that allows the user to define multiple channels, where each channel path flows through several switches. Customized channels can be designated by an input label and an output label (see *Figure 2*). For example, the path from "ANTENNA 1" to "TEST 5" sets Switch 1 to



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| 2.4 Male - 2.4 Female | 50 |
| 2.4 Male - 2.4 Male | 50 |
| 2.4 Female - 2.92 Female | 40 |
| 2.4 Female - 2.92 Male | 40 |
| 2.4 Male - 2.92 Female | 40 |
| 2.4 Male - 2.92 Male | 40 |
| 2.4 Female - 3.5 Female | 33 |
| 2.4 Female - 3.5 Male | 33 |
| 2.4 Male - 3.5 Female | 33 |
| 2.4 Male - 3.5 Male | 33 |
| 2.4 Female - N Female | 18 |
| 2.4 Female - N Male | 18 |
| 2.4 Male - N Female | 18 |
| 2.4 Male - N Male | 18 |
| 2.4 Female - SMA Female | 27 |
| 2.4 Female - SMA Male | 27 |
| 2.4 Male - SMA Female | 27 |
| 2.4 Male - SMA Male | 27 |

| Description | Frequency (GHz) | | | |
|---------------------------|--------------------|--|--|--|
| 2.92 Female - 2.92 Female | 40 | | | |
| 2.92 Male - 2.92 Female | 40 | | | |
| 2.92 Male - 2.92 Male | 40 | | | |
| 2.92 Female - 3.5 Female | 33 | | | |
| 2.92 Female - 3.5 Male | 33 | | | |
| 2.92 Male - 3.5 Female | 33 | | | |
| 2.92 Male - 3.5 Male | 33 | | | |
| 2.92 Female - N Female | 18 | | | |
| 2.92 Female - N Male | 18 | | | |
| 2.92 Male - N Female | 18 | | | |
| 2.92 Male - N Male | 18 | | | |
| 2.92 Female - SMA Female | 27 | | | |
| 2.92 Female - SMA Male | 27 | | | |
| 2.92 Male - SMA Female | 27 | | | |
| 2.92 Male - SMA Male | 27 | | | |

| Description | Frequency (GHz) | | |
|-------------------------|--------------------|--|--|
| N Female - N Female | 18 | | |
| N Male - N Female | 18 | | |
| N Male - N Male | 18 | | |
| N Female - SMA Female | 18 | | |
| N Male - SMA Female | 18 | | |
| N Female - SMA Male | 18 | | |
| N Male - SMA Male | 18 | | |
| SMA Female - SMA Female | 27 | | |
| SMA Male - SMA Female | 27 | | |
| SMA Male - SMA Male | 27 | | |

| Description | Frequency (GHz) |
|--|--------------------|
| 3.5 Female - 3.5 Female | 33 |
| 3.5 Male - 3.5 Female | 33 |
| 3.5 Male - 3.5 Male | 33 |
| 3.5 Female - N Female | 18 |
| 3.5 Female - N Male | 18 |
| 3.5 Male - N Female | 18 |
| 3.5 Male - N Male | 18 |
| CONTRACTOR OF THE PERSON NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TRANSPORT NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TRANSPORT NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TRANSPORT NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TRANSPORT NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TRANSPORT NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TRANSPORT NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TRANSPORT NAMED IN COLU | |

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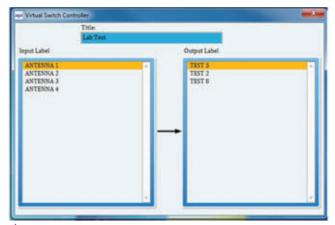
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ProductFeature



▲ Fig. 2 Mode 2 of the SCCS enables the user to define multiple channels, routing a channel's path through several switches.

position 3, Switch 2 to position 5 and Switch 8 to position 2. Mode 3 enables switch matrix control, allowing the user to configure the unit to an N \times M full-blocking switch matrix. *Figure 3* shows an example of the control interface for a 3×3 switch matrix.

Custom switched RF paths are required for many wireless standards, such as Wi-Fi, WiMAX and LTE. The flexibility of Weinschel's 8512 series switch matrix makes it ideal for use in multiple applications, as well as test environments with:

 Signal routing from multiple instruments to single or multiple devices being tested



 \blacktriangle Fig. 3 SCCS GUI for a 3 × 3 switch matrix.

- Multiple tests using the same test setup, reducing production test time
- Applications requiring configuration flexibility and agility.

VENDORVIEW

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Active Steering Antenna System Improves 5 GHz Wi-Fi Connectivity

Ethertronics Inc. San Diego, Calif.

here has been a significant shift in consumers accessing movies, television shows, sporting events and other video via wireless devices in recent years. While this new trend is growing, streaming high-definition (HD) video wirelessly to multiple screens has not come without challenges. There is nothing more frustrating than trying to watch your favorite HD video and getting a tiled picture, or worse, being interrupted by an error message saying that you've lost connection.

While the topics of on-demand content and the Internet of Things (IoT) grace almost every tech headline, delivering a stronger, faster and more reliable Wi-Fi signal is still a huge component to the equation. Connectivity is the heartbeat that enables these 5 GHz and IoT applications, yet meeting the rigorous demands of OEMs, service providers and consumers has proven increasingly steep and far more challenging than the industry anticipated.

ACTIVE STEERING SYSTEM SOLUTION IMPROVES CONNECTIVITY

One solution that solves these challenges is Ethertronics' Active Steering System for 5 GHz – a new plug-and-play configuration that enables Ethertronics' Active Steering technology. The solution combines an antenna, Ether-

tronics' recently announced EtherChip EC482 multiple-input-multiple-output (MIMO) RFIC (or the EtherChip EC614 four-port RF switch) and an algorithm into a single system module (see *Figure 1*). For the burgeoning streaming HD video applications, the Active Steering System for 5 GHz can be easily integrated into a variety of products, including access points, set-top boxes, smart appliances, Wi-Fi extenders, wearables and other IoT devices.

Ethertronics' Active Steering technology generates multiple radiation patterns from a single antenna structure. The EC482 MIMO RFIC (see *Figure 2*) enables beam steering by sampling and switching between the antenna's multiple radiation patterns to select the pattern that provides the best RF link performance. This capability improves range and data throughput, reduces interference and increases robustness and connection reliability in multipath environments. Ethertronics' technology achieves ubiquitous coverage regardless of the box's orientation or location, which eases installation and improves quality.

SOLVING THE MARKET CHALLENGE

With MIMO becoming more prevalent for Wi-Fi, the need for two or more antennas collocated in a mobile device or small form fac-



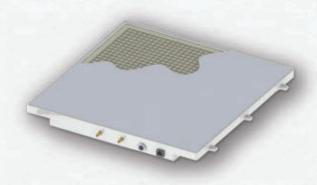
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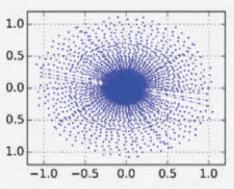
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ProductFeature



▲ Fig. 1 Components of the MIMO Active Steering System Solution.

tor access point is becoming common. These groups of antennas need to have high – and preferably equal – efficiencies with good isolation and low correlation. With access point applications, the multipath environment is constantly changing, which affects the throughput performance of the communication link. Ethertronics' new Active Steering System Solution for 5 GHz, with the embedded EC482 RFIC, addresses these challenging



▲ Fig. 2 The EC482 RFIC comprises the RF switches, control circuitry and algorithm to select the antenna pattern that optimizes system performance.

RF environments by dynamically tuning and optimizing the antenna system parameters for the MIMO system to provide greater throughput. In addition to solving the MIMO challenges associated with the 5 GHz band, this system enables a single gateway to stream video, data and voice – from a single box or access point – since these components are co-developed and optimized as a system to provide a solution that is cost effective and easy to integrate.

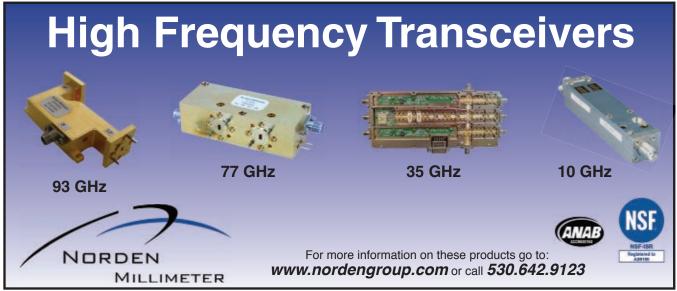
OEMs can realize time-to-market and cost benefits with the Active Steering System Solution. The embedded EtherChip EC482 is designed for the high frequency and fast RF switching environment that Wi-Fi systems demand. The EtherChip EC482 contains the RF switch, which adjusts the antenna pattern, as well as the al-

gorithm and communication and control conduits that sample and switch among the patterns, adaptively making the optimal selection. For MIMO Wi-Fi applications, the master EC482 can control multiple Active Steering antennas in concert with EtherChip EC614s. An EC482 is used for the first Active Steering element, and an EC614 is utilized for each additional Active Steering element. This combination provides the most cost-effective solution for customers.

With the Active Steering System, an OEM can replace one of the existing antennas, all 5 GHz antennas or a subset of them in a single box, since the antenna, chip and algorithms are configured as one system. To further ease integration, the Active Steering System for 5 GHz is available as a 2D antenna on a flexible circuit that can be placed anywhere in the box, or it can be printed on the host PCB to further reduce cost. With an operating frequency of 100 to 7000 MHz, the Active Steering System Solution has a small footprint and minimizes power consumption.

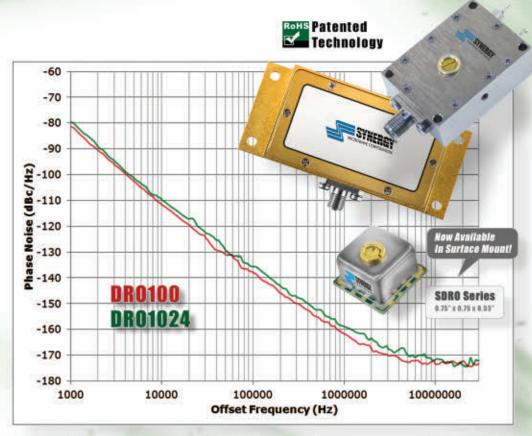
Active Steering provides a host of benefits, including uninterrupted service, faster data throughput for video streaming and no video tiling.

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| Model | Frequency (GHz) | Tuning Voltage (VDC) | DC Bias (VDC) | Typical Phase Noise @10kHz (dBc/Hz) |
|------------------|-----------------|-------------------------|-----------------|--|
| Surface Mount Mo | odels | | | |
| SDRO1000-8 | 10 | 1 - 15 | +8 @ 25 mA | -107 |
| SDRO1024-8 | 10.24 | 1 - 15 | +8 @ 25 mA | -111 |
| Connectorized Mo | odels | A | V. | W |
| DRO100 | 10 | 1 - 15 | +7 - 10 @ 70 mA | -111 |
| DRO1024 | 10 | 1 - 15 | +7 - 10 @ 70 mA | -109 |

| Model | Center Frequency (GHz) | Mechanical Tuning (MHz) | Supply Voltage (VDC / Current) | Typical Phase Noise @10kHz (dBc/Hz) |
|---------------------|---------------------------|----------------------------|-----------------------------------|--|
| Mechanical Tuning C | Connectorized Model | | | |
| KDRO145-15-411M | 14.5 | ±10 MHz | 15 V / 130 mA (Max.) | -88 |

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TechBrief



ntegrated Device Technology (IDT) has expanded its RF portfolio with two new Glitch-FreeTM digital step attenuators (DSA) and the first product in a new family of voltage variable attenuators (VVA). Designed in RF silicon, these attenuators achieve wide bandwidth, low insertion loss, high linearity, pinpoint attenuation accuracy and a wide temperature range from -40° to 105°C. The products meet the stringent demands of wireless infrastructure, point-to-point microwave links, satellite communications and general-purpose communication applications.

The DSAs feature IDT's industry first Glitch-Free technology, reducing attenuation switching overshoot dur-

Low-Loss, Ultra-Linear, Wideband Variable Attenuators

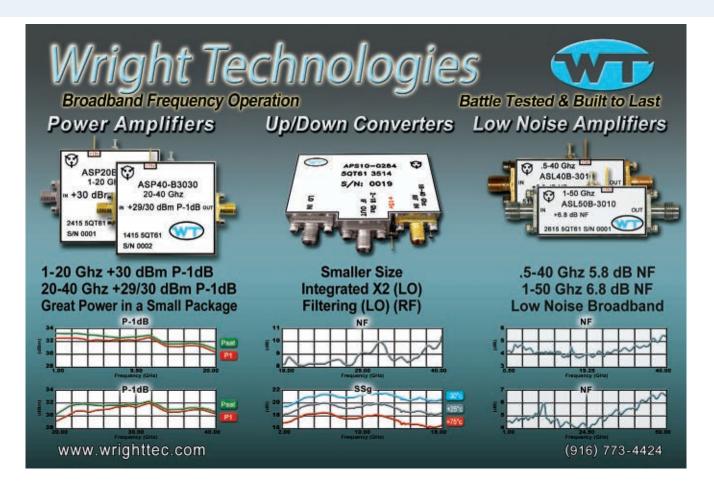
ing the most significant bit transitions by up to 95 percent. This feature simplifies the control software, improves reliability, prevents damage to downstream components such as power amplifiers, and limits over-ranging of data converter inputs. Covering 1 MHz to 4 GHz, the F1912 DSA is a 6-bit device with 0.5 dB step size and 31.5 dB attenuation range. Attenuation step error is 0.1 dB, with 1.4 dB insertion loss at 2 GHz. The F1956 is a 7-bit device that also covers 1 MHz to 4 GHz, with 0.25 dB step size and 31.75 dB attenuation range. Attenuation step error is 0.1 dB with 1.3 dB insertion loss at 2 GHz. The input IP3 of both DSAs is 64 dBm. The F1912 has a 0.1 dB compression point of 31

dBm, 34.5 dBm for the F1956.

The F2250 VVA covers 50 MHz to 6 GHz and has a highly linear (in dB) analog attenuation range of 33.6 dB. Insertion loss is 1.4 dB at 2 GHz, input IP3 measures 65 dBm and the 1 dB compression point is 34.4 dBm. The design includes a "Vmode" feature that allows either positive or negative attenuation control.

Pin compatible with competitor products, IDT's new attenuators are assembled in TQFN packages: 3×3 mm for the F2250, 4×4 mm for the F1912 and 5×5 mm for the F1956.

Integrated Device Technology Inc. San Jose, Calif. www.idt.com







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Software and **Mobile** Apps

Altium Designer 15.1

Altium Ltd. announced the next update to its flagship PCB design tool, Altium Designer. Altium Designer 15.1 introduces several new features for improved design productivity, documentation outputs and high-speed design efficiency including: improved support for xSignals, expanded rigid-flex sup-



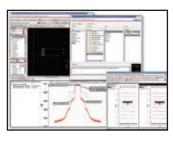
port, new output documentation options and new design re-use tools. Now is a great time for designers to make the switch to Altium Designer. Visit the company's website to start your free trial today.

www.altium.com



Spectre RF Simulator

Building a multi-band wireless chip? Worried about LO leakage from one transceiver to another? Cadence's newest release of Spectre RF Simulator enables the harmonic balance analysis of multiple transceivers each with a different frequency divider. The new 14.1



version also adds LTE, Wi-Fi 802.11ac and 802.11af to the rich set of supported wireless standards. The tight integration of Spectre RF Simulator into the Virtuoso Analog Design Environment provides you with a cockpit to easily drive multi-test simulation and post-process the results, enabling robust verification.

Cadence Design System Inc. www.cadence.com/products/rf

UCAMCO Integr8tor

Cirexx International acquired and installed the UCAMCO Integr8tor pre-CAM software. With the Integr8tor tool, Cirexx is able to process more quotes, more quickly, and with a greater degree of confidence in having identified all of the challenging attributes of printed circuit fabrication build. The software delivers a "cleaner" CAM-ready package that merges directly into the CAM platform for tooling and planning once the or-



der is placed. A simple and intuitive user interface makes the system easy to learn and accessible for CAM engineers.

Cirexx International Inc. www.cirexx.com

Mobile Device App

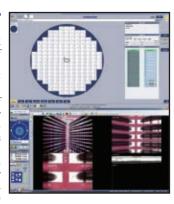
AR RF/Microwave Instrumentation's mobile app is now available as a free download from Apple iTunes and Google Play. This application is a quick and easy tool to access a variety of content from AR. The home screen icons allow easy navigation to view basic and full product descriptions, app notes, AR's literature library, You-Tube videos, contact information and social media activity - all from your mobile device. To download the app, visit www.arww-rfmicro. com/html/ar-moblie-app.asp.



VVFNDOR**VIEW** AR RF/Microwave Instrumentation www.arworld.us

Velox 2.0

Cascade Microtech announced Velox 2.0, their latest version of probe station control software. Combining the ease of NucleusTM with the power of ProberBenchTM, Velox 2.0 delivers new levels of test and measurement efficiency to accelerate time to job completion. This latest release supports collaboration on critical projects, enabling several users to work on a single recipe and share wafer maps across multiple stations. A unified platform accelerates the



time to data for process design kits, saving time for the designers and fab engineers. Wafer handling, alignment, temperature control, Z-profiling and stepping perform as a single automated test flow using the Velox-Pro[™] test automation software option.

Cascade Microtech Inc. www.cascademicrotech.com

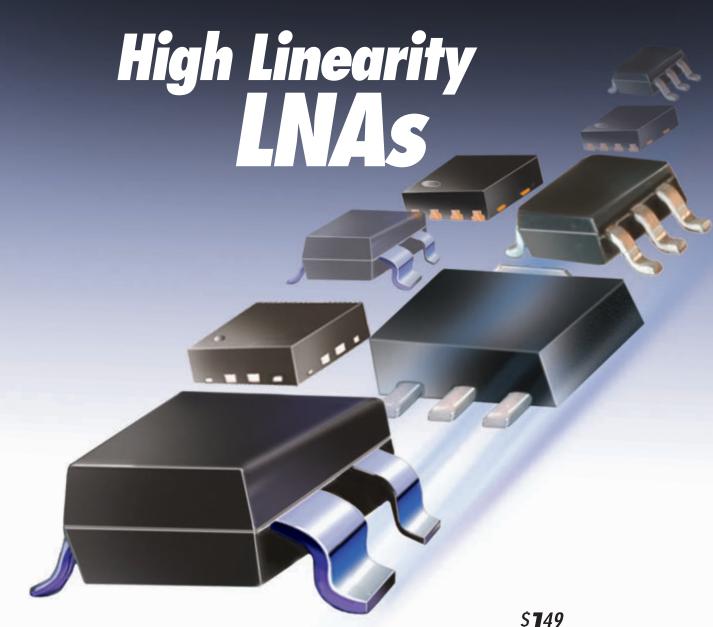
RF Tools in Your Pocket

The iPhone app 'RF Tools' has been enhanced with the assembly calculator. More than 270 cables and assemblies from HUBER+SUHNER can be easily calculated on the iPhone - anytime and anywhere. This useful app provides an easy comparison of up to three HUBER+SUHNER radio frequency cables and assemblies in different configurations



and environments. It offers straight access to technical specifications such as insertion loss and power rating. The app is available for free in English and Chinese in the App Store at https://itunes.apple.com/app/ id525678686.





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| Model | Freq. (MHz) | Gain (dB) | NF (dB) | IP3 (dBm) | P _{out} (dBm) | Current (mA) | Price \$ (qty. 20) |
|-------------|----------------|--------------|------------|--------------|---------------------------|--------------------------|--------------------|
| PMA2-162LN+ | 700-1600 | 22.7 | 0.5 | 30 | 20 | 55 | 2.87 |
| PMA-5452+ | 50-6000 | 14.0 | 0.7 | 34 | 18 | 40 | 1.49 |
| PSA4-5043+ | 50-4000 | 18.4 | 0.75 | 34 | 19 | 33 (3V) 58 (5V) | 2.50 |
| PMA-5455+ | 50-6000 | 14.0 | 8.0 | 33 | 19 | 40 | 1.49 |
| PMA-5451+ | 50-6000 | 13.7 | 8.0 | 31 | 17 | 30 | 1.49 |
| PMA2-252LN+ | 1500-2500 | 15-19 | 8.0 | 30 | 18 | 25-55 (3V) 37-80 (4V) | 2.87 |
| PMA-545G3+ | 700-1000 | 31.3 | 0.9 | 33 | 22 | 158 | 4.95 |
| PMA-5454+ | 50-6000 | 13.5 | 0.9 | 28 | 15 | 20 | 1.49 |
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| Model | Freq. (MHz) | Gain (dB) | NF (dB) | IP3 (dBm) | P _{out} (dBm) | Current (mA) | Price \$ (qty. 20) |
|------------|----------------|--------------|------------|--------------|---------------------------|--------------------|--------------------|
| PGA-103+ | 50-4000 | 11.0 | 0.9 | 43 | 22 | 60 (3V) 97 (5V) | 1.99 |
| PMA-5453+ | 50-6000 | 14.3 | 0.7 | 37 | 20 | 60 | 1.49 |
| PSA-5453+ | 50-4000 | 14.7 | 1.0 | 37 | 19 | 60 | 1.49 |
| PMA-5456+ | 50-6000 | 14.4 | 8.0 | 36 | 22 | 60 | 1.49 |
| PMA-545+ | 50-6000 | 14.2 | 8.0 | 36 | 20 | 80 | 1.49 |
| PSA-545+ | 50-4000 | 14.9 | 1.0 | 36 | 20 | 80 | 1.49 |
| PMA-545G1+ | 400-2200 | 31.3 | 1.0 | 34 | 22 | 158 | 4.95 |
| PMA-545G2+ | 1100-1600 | 30.4 | 1.0 | 34 | 22 | 158 | 4.95 |
| PSA-5455+ | 50-4000 | 14.4 | 1.0 | 32 | 19 | 40 | 1.49 |
| | | | | | | | |



Software and Mobile Apps

SW Selector Mobile App

Keysight Technologies offers over 230 test and measurement soft-ware applications based on innovative algorithms and up-to-date standards for use with bit error rate testers, oscilloscopes, signal generators, signal analyzers, vector network analyzers and more. The new Keysight SW Selector Mobile App provides a quick and easy way to search by application, technology or measurement platform to find the right stand-alone

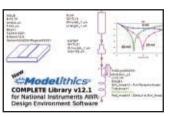


or embedded test and measurement software for a specific application. The app can be downloaded for iOS or Android at www.keysight.com/find/swselector.



COMPLETE Library v12.1 for NI AWR

Modelithics released the latest version (v12.1) of the Modelithics® COMPLETE Library $^{\rm TM}$ for NI AWR Design Environment software. The new release includes over 50 new high accu-



racy simulation models, representing over 1,500 individual devices. New models have been added for components from AVX, Cobham Aeroflex, Würth Elektronik, ATC, Passive Plus, Piconics, Skyworks, Freescale, Qorvo, CoilCraft, Murata, Darfon, Taiyo Yuden, TDK and IPDIA. The Modelithics COMPLETE Library now represents over 50 vendors and over 11,000 RF and microwave devices. Visit www.modelithics.com for details.

Modelithics Inc. www.modelithics.com

Microwave Calculator Mobile App

Mini-Circuits' new Microwave Calculator app for Android mobile devices gives engineers a quick and easy tool to perform three common calculations on the fly: the effect of VSWR/return loss on



transmitted power, cascaded noise figure and power to voltage conversion. It also provides the formulas for each of these computations as a convenient reference. It is the perfect tool to simplify and expedite problem-solving whether you're working in the lab or in the field. The app is available for FREE download from the company's website and on Google Plav $^{\text{IM}}$.



V12 NI AWR Design Environment

V12 NI AWR Design Environment $^{\text{TM}}$ software, the first major release in 2015, includes new amplifier, antenna and radar-specific features as well as ease-of-use im-

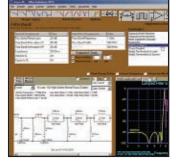


provements, speed enhancements and third-party flows that benefit designers of MMICs, RF PCBs, modules and more. V12 NI AWR Design Environment software consists of Microwave Office/Analog Office circuit design software, Visual System Simulator $^{\rm TM}$ (VSS) system design software, AXIEM planar EM simulator and Analyst $^{\rm TM}$ 3D EM simulator. Learn more at awrcorp.com/v12.



Asymmetrical Band Pass Filter Design

Nuhertz announces improved capability in FilterSolutions®, synthesis software. The program now instantly and accurately automates design of asymmetric band pass filters which do not require symmetric attenuation response on each side of the pass band. Rather than utilizing optimization or manual pole-zero tuning, FilterSolutions provides an accurate, automated



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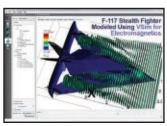


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includes electromagnetic and particle modeling features for magnetrons, klystrons, gyrotrons, traveling-wave-tubes and similar devices, as well as antenna design, photonics and semiconductors. Visit https://www.txcorp.com/vsim for more information.

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RF Cable Builder

SV Microwave released their Rapid Response RF Cable Assemblies that are built-to-order and ready to ship within 5 business days. These cables can be custom configured and purchased on the company's website using their new interactive RF cable



builder application. Customers can choose from a variety of in-stock standard connector series and cable types for miniature and low loss co-axial assemblies. The RF Cable Builder will generate a custom datasheet complete with part number, data drawing, technical specifications and pricing. Go to www.svmicrowave.com/products/rf_cable_builder.

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Online Simulator

X-Microwave introduced its Online Nonlinear System Simulator powered by Keysight's Genesys Spectrasys. Simulate with hundreds of models of real system components using the intuitive user interface. X-parameter or Sparameter models are extracted from X-Microwave's drop-in com-



ponents (X-MWblocks) using Keysight's PNA-X analyzer. An X-parameter model of an amplifier serves as a live datasheet to determine the P1dB or IP3 at a given operating point of interest. Quickly cascade microwave components and simulate to view the spectral content at any node of the block diagram.

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Past Webinars On Demand

RF/Microwave Training Series

Presented by: Besser Associates

- MMIC Design Overview
- Mixers & Frequency Conversion
- RF and Microwave Filters

Technical Education Training Series

- New Thermoset PCB Materials Improve mmWave Performance and Reliability at Reduced Cost
- Bonding Layer Material Selection for Use in High Performance Multilayer Circuit Board Design: Thermoset and Thermoplastic Options
- Narrowband Planar Filter Design with NI AWR Design Environment Software
- Simulating MRI Heating of Medical Implants
- GaN Going Mainstream
- Internet of Things (IoT) and Over-the-Top (OTT) Applications How to Quantify Signaling Impact and Power Consumption
- Linearity: The Key to Successful Data Transmission in Cable and Beyond
- Narrowband Combline Filter Design with ANSYS HFSS
- Advanced Multi-Emitter Radar Simulation with Off-the-Shelf T&M Equipment
- Multipactor Basics and How Numerical Analysis Can Safely Increase Margins
- Understanding Filter Technology and the Selection Process Including Qorvo's Specialized LowDrift™ and NoDrift™ Filters
- EMIT 4.0 The Next Generation in RF Cosite Interference Modeling and Simulation
- Effect of Laminate Properties on PIM Distortion in Microstrip Transmission Lines
- Modern Trends in Broadband Diode Mixers
- Practical Antenna Design for Advanced Wireless Products
- RF and Microwave Heating with COMSOL Multiphysics
- Tips & Techniques for Making Microwave Vector Network Analysis Measurements in the Field

CST Webinar Series

- CST STUDIO SUITE 2015 Update Webinar on MW&RF Simulation
- CST STUDIO SUITE 2015 Update Webinar on EDA/EMC Analysis

Innovations in EDA

Presented by: Keysight Technologies

- Avoid Design Hazards and Improve Performance with Electro-Thermal Simulation
- How to Design an RF/Microwave Power Amplifier: The Basics
- Understanding 5G and How to Navigate Multiple Physical Layer Proposals

Keysight in LTE/Wireless Communications Series

- A Flexible Testbed for 5G Waveform Generation and Analysis
- 802.11ah, Bluetooth LE, Zigbee and Wi-SUN Test for IoT/M2M

Keysight Technologies Webcast

- Seven Best Practices to Avoid Damaging Power Meters and Sensors
- Multiport and Multi-Site Test Optimization Techniques
- Addressing Multi-Channel Synchronization for MIMO and Beamforming Test
- Bridging the Gap from Benchtop to PXI: A Common Software Strategy
- MVG-Orbit/FR μ-Lab A Compact Integrated Test Facility for mm-Wave Antenna Testing
- One Size Does Not Fit All Choose the Right Instrument Form Factor

Keysight in Aerospace/Defense

- Test and Measurement Trends for Aerospace and Defense
- Closed Loop Adaptive EW Simulation

FieldFox Handheld Analyzers Series

Presented by: Keysight Technologies

 Transmission Line Theory and Advanced Measurements in the Field

RF and Microwave Education Series

Presented by: Keysight Technologies

- Understanding New Pulse Analysis Techniques
- RF/μW Switching Solutions
- Understanding Available Measurement Techniques for Spurious or Unknown Signals

EuMW Product Showcase



The following Stand numbers are complete as of July 14, 2015.

Hall Passy

Stands 272/E110

Rosenberger North America LLC Stand C303 Intermodulation Site Analyzer



Rosenberger presents its brand new broadband passive intermodulation site analyzer for multi-function on-site tests and measure-

ments of active and passive elements. The Rosenberger site analyzer features PIM detection over CPRI (including cancellation function), broadband Rx and Tx base model 700 to 2700 MHz with exchangeable filter units, continuous wave signal (no pulse), portability with a rugged design, sunlight readable 12" touch screen, antenna isolation measurement, DTF measurement (VSWR vs. distance; PIM vs. distance), VSWR/return loss measurement and battery, and 110/220 V AC operation.

www.rosenberger.de

Mician Stand C308 **u**Wave Wizard[™] Version 8.0



Mician shows the latest release of the company's software tool μ Wave WizardTM. Version 8.0 comes with a ribbon based graphical user interface. Speed up of GUI launch for very large projects is now up to 10 times faster. It includes a new direct and iterative solver and parallelization is possible. This new release now includes a modeler for user defined elements.

www.mician.com

CST Stand D311 EM Simulation Software



CST STUDIO SUITE® is the culmination of many years of research and development into the most accurate and efficient computational solutions for electromagnetic designs. It offers con-

Keysight Technologies
Measurement Accelerator



Keysight Technologies' M9451A PXIe measurement accelerator, a high performance FPGA processing card, speeds envelope tracking and digital predistortion (DPD) characterization for power amplifier test. With the M9451A, closed/open loop DPD and envelope tracking measurements can be made in tens of milliseconds for up to a 100 times speed improvement. The M9451A with Option DPD is now integrated with the RF PA/FEM characterization and test, reference solution, which provides even higher throughput while maintaining highly accurate S-parameter, harmonic distortion, power and demodalation measurements. The reference solution enables full characterization of next-generation power amplifier modules, including power amplifier-duplexers.

www.keysight.com/find/m9451a

High Performance Spectrum Analysis



Accelerate spur searches by up to 500 times with new high performance spectrum analysis integrated in PNA and PNA-X vector network analyzers. Keysight recently introduced a new high performance spectrum analyzer capability to its PNA and PNA-X series microwave vector network analyzers (VNA). This new capability: improves test times by a factor of 10 to 500 times with fast spur searches over a wide frequency range up to 67 GHz, provides unparalleled insight by measuring spurious signals simultaneously from all

ports on mixers and frequency converters, unlocks true device performance by removing cable and fixture effects with using VNA calibration and de-embedding techniques, and simplifies test stations with the PNA-X's expanded single-connection, multiple-measurement capability. www.keysight.com/find/pna-sa

12-bit PCIe High Speed Digitizer



The U5303A is a 12-bit PCIe digitizer, sampling up to 3.2 GS/s, with on-board real-time processing. It delivers unprecedented analog fidelity, high ENOB and very low noise. New dedicated options are available: CSR continuous simultaneous acquisition and readout allows engineers to perform acquisition and readout simultaneously and continuously. CB0 digitizer streaming implements real-time digitizer data recorder. CB1 digital down-converter streaming provides the same functionality as CB0 and adds real-time digital down-converter functionality. Recording performances up to 180 MHz instantaneous bandwidth are ensured in a specific qualified system. www.keysight.com/find/digitizers

VENDORVIEW

siderable product to market advantages such as shorter development cycles, virtual prototyping before physical trials and optimization instead of experimentation. CST STUDIO SUITE is comprised of multiple modules for high frequency, low frequency, charged particle and multiphysics applications. Visit CST in Stand D311 to learn more.



www.cst.com

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/eumw2015.

Maury Microwave Product Showcase





Exceptional companies have superior labs – complete your lab with Maury Microwave. Maury, a leader in measurement and modeling device characterization solutions, VNA calibration accessories and interconnections, will be showcasing active and hybrid-active harmonic load-pull solutions, LXTM-certified mechanical impedance tuners, pulsed IV/RF compact transistor modeling as well as coaxial and waveguide VNA calibration kits and metrology adapters, in-stock color-coded precision and daily-use adapters, and test-port, phase-stable and value cable assemblies. Visit Maury for details, demos, deals and NPIs.

www.maurymw.com

New! HIGH POWER, LOW LOSS! SPLITTER/COMBINERS



Up to 100W 2 Way-0°

- ✓ Low insertion loss, 0.5 dB
- ✓ Amplitude unbalance, 0.15 dB
- ✓ Good isolation, 22 dB
- ✓ Excellent VSWR, 1.2:1



Up to 100W 4 Way-0°

- ✓ Low insertion loss, 0.8 dB
- ✓ Amplitude unbalance, 0.2 dB
- ✓ Excellent VSWR, 1.15:1
- ✓ Good isolation, 22 dB



Up to 100W 8 Way-0°

- ✓ Low insertion loss, 1.0 dB
- ✓ Amplitude unbalance, 0.4 dB
- ✓ Good isolation, 23 dB
- √ Good VSWR, 1.2:1



Up to 25W 2 Way-0°

- ✓ Up to 20W as combiner
- ✓ Low insertion loss, 0.17 dB
- ✓ Low amplitude unbalance, 0.05 dB
- √ High isolation, 30 dB
- ✓ Excellent VSWR, 1.1:1

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MMW Amplifiers

Ducommun has more than 45 years of experience with the design, testing and manufacturing of standard and custom millimeter wave amplifiers.



• High Power, Single DC power supply/ internal sequential biasing



32 to 36 GHz Power Amplifier

- · AHP-34043530-01
- · Gain: 30 dB (Min)
- Gain Flatness: +/-2.0 dB (Max)
- P-1dB: 34 dBm (Typ), 33 dBm (Min)
- Broadband, Low noise with high gain



26.5 to 40.0 GHz Low Noise Amplifier

- ALN-33144030-01
- · Gain: 30 dB (Min)
- Gain Flatness: +/-1.0 dB across the band
- Noise Figure: 4.0 dB (Typ)

For additional information, contact our sales team at 310.513.7256 or rfsales@ducommun.com

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NI AWR Stand E112 Design Environment Software



Visit NI at Stand E112 to explore the new features in V12

NI AWR Design Environment software. Demonstrations include new amplifier, radar and antenna specific features as well as ease of use, performance improvements and third-party flows such as ANSYS HFSS.

www.awrcorp.com/v12

National Instruments FPGA Programmable Solutions



National Instruments, provider of RF and commercial wireless test equipment, will be featur-

ing new LabVIEW FPGA programmable solutions for spectrum monitoring and electronic warfare applications. These solutions include a real-time spectrum analysis demonstration using NI's new controller for FlexRIO. The NI Controller for FlexRIO combines with wideband RF transceiver adaptor modules to produce a rugged and deployable radio platform. The new FlexRIO solution complements NI's PXI high-performance signal analyzers such as the PXIe-5668R – the industry's widest bandwidth 26.5 GHz real-time spectrum analyzer.

www.ni.com

NI Microwave Components Synthesizers



QuickSyn synthesizers are now extended to mmWave. NI Microwave Component's new QuickSyn mmWave synthesizer

modules use the same QuickSyn technology that allows fast switching, low phase noise and compact size. These CW sources cover popular frequency bands, 27 to 40 GHz, 50 to 67 GHz and 76 to 82 GHz for a variety of applications including a backhaul for digital radio, point-to-point and point-to-multipoint wireless HDMI, WiGig, IEEE802.11ad, wireless gigabit Ethernet and automotive radar for collision avoidance.

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www.ni.com

SPINNER GmbH Going the Extra Mile



At European Microwave Week, SPINNER will present a selection of superior rotary joints for satellite communications as well as test and measurement

Stand 274

products for calibration and PIM. SPINNER will also be launching its low PIM switch and rotary joint, which will help to save further costs in automated RF test and measurement environments. SPINNER is a global leader in developing and manufacturing state-of-the-art RF components. Since 1946, the industry's leading companies have

Rohde & Schwarz GmbH & Co. KG Vector Signal Generator

Stand E113



With its new microwave frequency options, the R&S SMW200A vector signal generator supports development applications requiring complex multichannel scenarios up

to 40 GHz. It is the only instrument on the market to combine a baseband generator and RF generator with fading, AWGN and MIMO capabilities in a single box. Offering an RF modulation bandwidth of 160 MHz with excellent 1/Q flatness and EVM, the R&S SMW200A generates signals of the highest modulation quality in the microwave range.

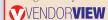
www.rohde-schwarz.com

USB and **LAN** Diode Sensors



The completely redesigned R&S NRPxxS and R&S NRPxxSN USB three-path diode power sensors offer unprecedented

measurement speed and accuracy, even at low levels. The sensors enable 10,000 triggered measurements per second with a minimum trigger resolution of 100 µs. A special mode permits 50,000 equidistant measurements per second. The improved design decreased the lower measurement limit to -70 dBm, resulting in a very wide dynamic range of 93 dB.



www.rohde-schwarz.com

trusted SPINNER to provide them with innovative products and outstanding customized solutions.



www.spinner-group.com

Anritsu Stand E305 5G Wideband Modulated S-Parameter VNA Measurements



VectorStar VNA paired with Chalmers University software to demonstrate power amplifier measurements under modulated conditions. Instantaneous receiver

bandwidth of up to 200 MHz utilizing the NLTL sampler and high speed IF digitizer option to evaluate device and amplifier characteristics under 5G conditions. The interface provides a display of ACPR, adjacent channel intermodulation and AM/AM characteristics. Performing these measurements up to 70 GHz provides the first-ever capability to analyze device and component performance under real world conditions including future 5G networks.



www.anritsu.com

Hall Neuilly

Dow-Key Microwave Stand 116 High Power & Lightweight T-Switch



Dow-Key Microwave presents its high power T-switch 511H-series, which has been qualified and supplied to various domestic and international space

programs, for both military and commercial use. Today's design is offered with 1.5 kW peak power at UHF-Band, 300 W peak power both at L-Band and S-Band, and 200 W peak power at C-Band. In addition to its superior RF performance and lightweight design, the 511H-series minimizes the switching time by using random access drive and it is available in various mounting configurations.



www.dowkey.com

K&L Microwave Lowpass Filters





Using a proprietary approach for power handling, K&L has developed a series of cleanup lowpass filters for high power applications. High

power amplifiers often create spurious responses that are undesirable, K&L's lowpass filters enable a spurious free response as much as ten times the fundamental frequency. With power handling currently up to 2500 W and frequency coverage from 0.5 to 100 MHz, these lowpass filters enable spurious free HPA performance. To discuss your application visit K&L at Stand 116.

www.klmicrowave.com

Pole/Zero Tunable Bandpass Filter

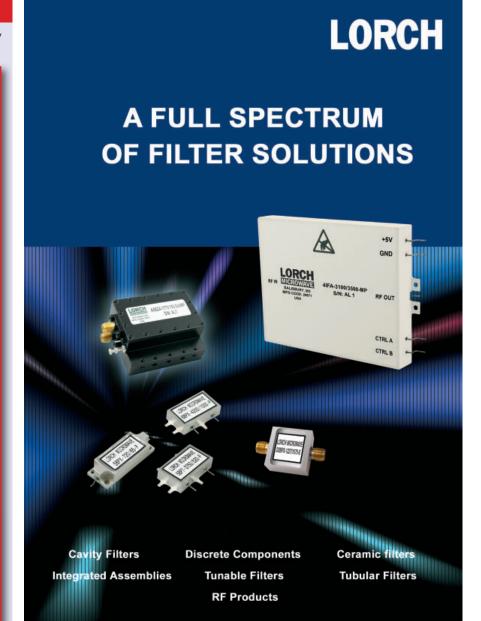




Pole/Zero's new NANO-ERFTM tunable bandpass filter covers the military tactical radio band of 30 to 520 MHz while fitting in a package measuring 1.1" × 1.1"

 \times 0.216" (28 \times 28 \times 5.5 mm). The NANO-ERF combines SMT capability with +6 dBm in-band and +20 dBm out-of-band RF power handling, +16 dBm IIP3, low insertion loss (5 dB typical in a 6% filter), 27 μs typical tune time and selectivity of 20 dBc at fc \pm 15 percent for 6 percent bandwidth.

www.polezero.com



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Spectrum Elektrotechnik GmbH

Stand 128

Phase Shifters



Phase shifters or phase adjusters of Spectrum Elektrotechnik GmbH are passive devices, being used to change the phase of an RF signal. Key parameters include consistent amplitude across all phase states and low insertion loss. The units are used in phased array antennas, phase modulators, frequency converters, testing and instrumentation. Frequency ranges start always at DC, with operation to 2, 12, 18, 26, 40, 50 and 63 GHz. New are the mini phase adjusters.

www.spectrum-et.com



Southwest Microwave Stand 141 SuperMini Board-to-Board DC to 67 GHz Connectors



SuperMini board-toboard DC to 67 GHz blind-mate connectors optimize transmission line reliability for board-to-board applications, assuring interconnect performance

connect performance for PCBs stacked as tightly as 3 mm. Unique bullet and receptacle designs accommodate 0.010" axial and ± 5° radial misalignment. Low mating insertion force allows an increased density of interconnections per board. Superior bullet design enables extended mating and de-mating cycles. Available vertical and end launch configurations for microstrip and grounded co-planar launch transitions, plus direct solder cable assemblies to simplify high performance push-on test connection to board-to-board receptacles.

www.southwestmicrowave.com

Greenray Industries Inc. Stand 143 Temperature Compensated Oscillator



Greenray Industries
Inc. announced the
availability of the
T1220 TCXO. The
new, high performance
T1220 temperature
compensated oscilla-

tor, available from 10 to 50 MHz with square-wave, CMOS output, features ultra tight frequency stability vs. temperature performance. The T1220 offers a low g-sensitivity option (down to $< 7 \times 10^{-10}/g$) while maintaining superior frequency stability. The T1220's tight stability makes it an ideal choice for mobile radio applications where OCXO performance is required but at low power consumption.

www.greenrayindustries.com

Ducommun Inc. Stand 144 60 to 90 GHz Block Down-Converter



Model SNG-12-01 is a full E-Band block down-converter. Its primary function is to extend the testing capability of low cost, low frequency noise figure meters. It also allows noise figure testing of E-Band devices with-

out a noise figure meter, using the Y-factor method. The block down-converter is also versatile for use with various other applications. With a low cost design, Model SNG-12-01 is an affordable expansion to millimeter-wave labs that do not have the budget for large scale equipment.

www.ducommun.com



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API Inmet Stand 152 Higher Shift Temperature Variable Attenuators



API Inmet expanded the temperature variable attenuator offering by introducing the -.009 dB/dB/°C series for applications up to 12 GHz and 2 W inci-

dent power. This addition to the Powerfilm™ brand of resistive components eliminates the need for gain control circuitry and bias or control voltages. The initial release consists of values 2 thru 5 dB. More information and data sheets can be found at www.inmet.apitech.com. Sample requests can be made at inmetsales@apitech.com or call (734) 426-5553.

www.inmet.apitech.com

API Technologies Corp. Hybrid Driver Amplifier



The QB-904 is a 4 W hybrid driver amplifier operating over the 2 to 6 GHz frequency range utilizing the latest in GaN

die technology. It features a wide DC input voltage range, 38 dB of small signal gain and a saturated output power of +36 dBm, minimum. The QB-904 is packaged in a small, hermetically sealed copper nickel housing with an optional heat sink.

www.apitech.com

API Weinschel Programmable Attenuator Units

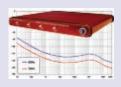


Weinschel, an API Technologies company, announced a new series of programmable attenuator units that offer a new streamlined approach in programmable attenuation for bench test and subsystem applications. Models 8320/8321, house and control various Weinschel programmable attenuator models (3200-XE, 3400, 150T and 4200 Series) via front panel controls, Ethernet, USB 2.0 and serial communications interfaces. A GPIB (IEEE-488) interface is also available as an option. This series is available in single or up 12 channel configurations and can be configured for front or rear connectors.

VENDORVIEW

www.weinschel.apitech.com

Holzworth Instrumentation Signal Generators

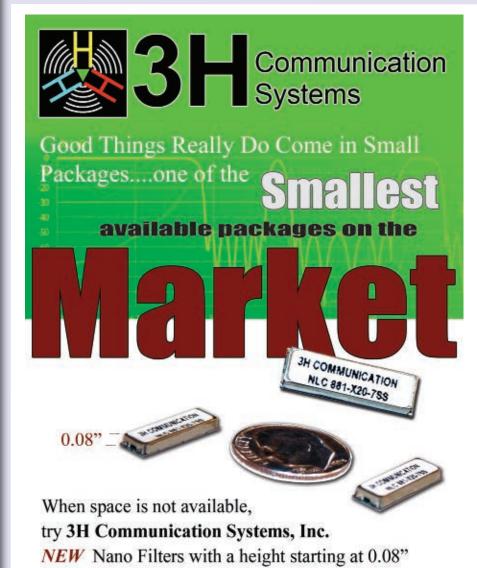


Stand 144

Holzworth Instrumentation's HSX Series signal generators exhibit industry leading phase noise and spectral purity performance coupled with an accurately calibrated dynamic range of +23 to -110 dBm. 1, 2, 3 or 4 channel models are available in a 1U form factor; each providing the ultimate in frequency accuracy, channel-to-channel stability and phase coherency. The 10 MHz to 6 GHz CW source product is currently available with 12 and 20 GHz models available as beta evaluation units. Experience a demo at EuMW Stand 144.

VENDORVIEW

www.holzworth.com



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3H Communication Systems offers a complete line of RF and microwave filter products and frequency conditioning solutions from DC to 50 GHz. Our product listings include Cavity, Lumped Component, and Ceramic topologies. All our products are available in connectorized and or SMT formats. Our expertise is second to none for low PIM, high power filters. We design filters that yield the most optimum performance with the smallest size possible. 3H offers complete help in coming up with the most optimum filter solutions for your system's unique needs. Working together with our customers will lead to high value cost effective solution over the life of the products.

EuMW Product Showcase

Hall Neuilly and Hall Ternes

RFMW Circulator

Stand 146

The RFCI RFCR8934 is a wideband, drop-in circulator spanning 8 to 18 GHz with 250 W peak/25 W average forward power handling. Part of the RF Circula-Isolator family (RFCI)

broadband, octave and octave plus drop-in circulators, the RFCR8934 provides >16 dB typical port-to-port isolation while maximum insertion loss is 0.7 dB. Octave and octave plus circulators are a robust, drop-in alternative to broadband coaxial designs used to protect active components from distortion or potentially damaging reflected power.

VENDORVIEW

www.rfmw.com

AR RF/Microwave Instrumentation **Amplifier**



Stand 154

Model 100S1G6AB is a solid-state; 100 W Class AB amplifier design that instantaneously covers 1 to 6 GHz in one unit. The 100S1G6AB will

provide Pout of 100 W minimum at Psat with infinite mismatch tolerance housed in approximately half the size of a traditional Class A design at a much more economical price.



www.arworld.us

HUBER+SUHNER

Stand 198

RF-over-Fiber Series

The market is evolving at a significant pace. With customers requiring that new solutions



and systems combine various technologies, HUBER+SUHNER has positioned itself to be able to provide its customers with end-toend solutions.

benefits of combining radio frequency and fiber optics in a single solution: no changes required to existing RF infrastructure, secure, lightweight, covers greater distances with less loss, wide frequency ranges available, flexible connectivity options, reduced total cost of ownership and future-proof.



www.hubersuhner.com

Ingun Prufmittelbau GmbH Stand 198 RF Probe up to 12 GHz



German equipment manufacturer INGUN has developed a new radio frequency probe HFS-856 for contacting

switch-connector (MM8030, MM8430, MS-156 and MS-180) and also miniature plug connectors (U.FL). During the contacting process the outer conductor is contacted first, whereupon it then aligns optimally on the connector due to its floating mounting and ultimately makes contact to the signal conductor. Using the new design, frequencies up to 12 GHz can be transferred. The assembly is carried out by means of a flange with a centering bolt and two screws. The HFS-856 is connected via a SMA plug.

www.ingun.com

RFHIC GaN SMD Module

Stand 205

RFHIC's GaN SMD Module, HI2425-15A is specially designed for wireless power transfer (WPT), plasma lighting system (PLS), thermal therapy applications. And more high power and beam switching system can be accomplished by employing array antenna. Using an advanced high power density GaN semiconductor process, this high performance amplifier achieves efficiency of 80

dBmCorp, Inc 32A Spruce Street ◆ Oakland, NJ 07436 Tel (201) 677-0008 ◆ Fax (201) 677-9444 www.dbmcorp.com percent and powers 5 to 15 W at 2.45 GHz



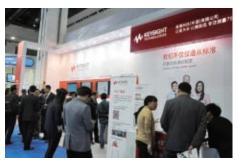


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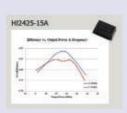
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EuMW Product Showcase

Hall Paris



of ISM band. HI2425-15A is 50 ohm input/output matched in a very small form-factor $15 \times 10 \times 5.4 \text{ mm}$ on aluminum nitride (AlN) board that provides ex-

cellent thermal dissipation. www.rfhic.com

Coilcraft **High Q Air Core Inductors**



ance surface-mount "spring" :- 1 combine the exceptionally high O of an airwound coil with the convenience of surface-

Stand 217

mounting. Their flat tops make them suitable for automatic placement and reflow or vaporphase processing. The SQ Family of square air core inductors is offered in seven sizes with Q factors up to 230 and current ratings as high as 5.7 amps. Visit Stand 217 to learn more. Also be sure to ask about their ultra-broadband conical inductors

www.coilcraft.com/prod_smspring.cfm

Isola Group Laminates



Astra MT laminates and prepreg are breakthrough, ultralow-loss dielectric materials for patch antenna designs and RF front-end

PCBs for 76 to 81 GHz

Stand 219

radar applications. Astra MT materials enable a higher yield in RF-hybrid PCB manufacturing, reducing production costs. Astra MT features a Dk that is stable between -55° and +125°C at up to 20 GHz. In addition, Astra MT offers a lower dissipation factor (Df) of 0.0017, making it a cost-effective alternative to PTFE and other commercial microwave laminate materials.

www.isola-group.com

Norden Millimeter Stand 230 **Block Frequency Converters**

Norden Millimeter produces a variety of block frequency converters converting 18 to 26.5, 26.5 to 40, 40 to 60, and 60 to 70 GHz bands



into the 2 to 18 GHz band. These converters are usable to extend the frequency range of existing systems with 18 GHz capability. Norden makes both

down and up converter versions for each of these bands. These converters can have variable gain, 0.03 to 18 GHz bypass paths, and common IF input/output. Shown is an 18 to 40 GHz down-converter presently in production with 14.4 GHz LO frequency and 0.5 to 18 GHz converter bypass.

www.nordengroup.com

OML Inc. **Down-Converter**

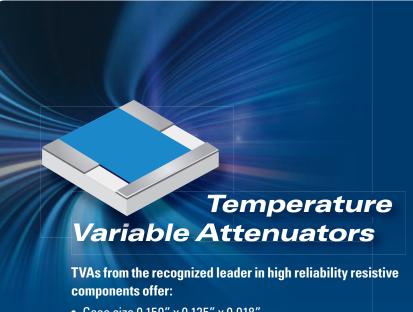




OML introduced its first down-converter (CxxLNDC) that directly interfaces with a analyzer spectrum without the need of an

external LO source. With a typical conversion loss of 12 dB, excluding IF amplifier gain, and a compression of 0 dBm typical, this down converter covers both V-Band (50 to 75 GHz) and E-Band (60 to 90 GHz). These two models can help to provide solutions in IEEE 80211.ad (Y-Gig), point-to-point radios and automotive radar.

www.omlinc.com



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APMC2015

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December 6-9, 2015 Jinling Hotel, Nanjing, China

2015 Asia-Pacific Microwave Conference (APMC2015) is intended to provide an international forum for the exchange of information on the research progresses and developments in electromagnetic wave theory, microwave and antenna technology, microwave & millimeter wave integrated circuit technology, THz frequencies technology, wireless communication technology and related fields. It is also an important objective of this meeting to promote mutual-interaction among participants.

APMC2015 will be held in Nanjing, China on December 6-9, 2015. Nanjing was awarded the title of "Famous Historic and Culture City" because it was the capital of China ten times. Today, Nanjing is Capital of Jiangsu Province and one of the important hubs of communications in China. APMC2015 is organized by Southeast University, co-sponsored by CIE Microwave Society and IEEE MTT-S, and technically co-sponsored by EuMA, IEEE AP-S, Science and Technology on Antenna and Microwave Laboratory, IEEE MTT-AP-EMC Joint Nanjing Chapter, etc.

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The APMC 2015 exhibition will be organized at the same venue with the conference on December 7-9. The exhibition is held in conjunction with the Technical Symposia and offers an excellent opportunity for all segments of the microwave community to meet. It is the synergy of the Exhibition and the Technical Symposia for everyone involved in technologies associated with RF, microwave, millimeter wave, and THz frequencies.

Companies including the sponsors of APMC 2015 will exhibit the latest microwave products and technologies. Also, some exhibition booths will be provided for universities to present their latest research outcomes.

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EuMW 2015

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Freescale Semiconductor RF Power Integrated Circuit





Size, weight and power are critical parameters for avionics applications. Freescale's AFIC10275N is the industry's first RF power

integrated circuit covering the 978 to 1090 MHz band, and helps customers address these market

criteria by enabling much smaller and lighter power amplifier (PA) transponders. The AFIC10275N integrates two amplification stages in a plastic package, delivering 250 W with 31 dB of gain and 64 percent drain efficiency. The device also embeds temperature and RF sensing capabilities, reducing the need for external components. www.freescale.com

Exodus Advanced Communications Solid-State Power Amplifier

Stand 233



Exodus Advanced Communications announced the release of a new high power ultra broadband solid-state power amplifier: AMP1062 operates over 6 to 18 GHz in-

stantaneous bandwidth with 40 W minimum in CW and 30 W P1dB typical output power using state of the art Class AB GaN devices. Featuring 46 dB of gain and 32 V DC supply voltage at 14 amp maximum current consumption, this amplifier is suitable for use in multiple platforms including communication, jamming, radar transmitter systems and TWTA replacement.

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| BCF040T | 0.3 x 400 | DC - 26.5 | 120 | 32 | @12GHz: 13.0 @18GHz: 10.4 | @12GHz: 23.0 @18GHz: 22.5 |
| BCF060T | 0.3 x 600 | DC - 26.5 | 170 | 32 | @12GHz: 12.5 @18GHz: 10.0 | @12GHz: 25.0 @18GHz: 24.6 |
| BCF080T | 0.3 x 800 | DC - 26.5 | 240 | 27 | @12GHz: 11.2 @18GHz: 9.7 | @12GHz: 26.0 @18GHz: 25.8 |
| BCF120T | 0.3 x 1200 | DC - 26.5 | 340 | 31 | @12GHz: 11.2 @18GHz: 9.3 | @12GHz: 28.0 @18GHz: 27.9 |
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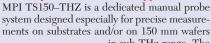




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MPI Corp. Stand 237







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sign can be specified at the time of order to include any number of combiner configurations. Each interchangeable module may include four 2-ways, three 3-ways, two 4-ways, or one 8-way (each assembly holds up to six modules).

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The IEEE Microwave Theory and Techniques Society's International Microwave Symposium (IMS2016) will be held 22 - 27 May 2016 in San Francisco, California as the centerpiece of a week dedicated to RF and Microwave Technology. IMS2016 offers technical sessions, interactive forums, plenary and panel sessions, workshops, short courses, industrial exhibits, application seminars, historical exhibits, and a wide variety of other technical and social activities including a guest program.

Co-located with IMS2016 are the RFIC symposium (www.rfic-ieee.org) and the ARFTG conference (www.arftg.org).

With over 10,000 participants and 1000 industrial exhibits of state-of-theart microwave products, IMS2016 is the world's largest gathering of Radio Frequency (RF) and microwave professionals and the most important forum for the latest research advances and practices in the field.

PAPER SUBMISSION:

Authors are invited to submit technical papers describing original work and/ or advanced practices on Radio-Frequency, microwave, millimeter-wave, and terahertz (THz) theory and techniques. The deadline for submission is 5pm Central Standard Time 7 December 2015. Papers should be 3 pages in length (PDF format), and should not exceed one megabyte in file size. Hardcopy and email submissions will not be accepted. Please refer to the IMS2016 website (www.ims2016.org) for detailed instructions concerning paper submission. Authors must adhere to the format provided in the conference paper template available on the symposium's website. It is the authors' responsibility to obtain all required company and government clearances prior to submission. Please don't wait until the last day to start using the paper submission process. Those unfamiliar with the process may encounter paper formatting or clearance issues that may take time to resolve.

A double blind review process will be used to ensure anonymity for both authors and reviewers. Detailed instructions on submitting a double-blind compliant paper can be found on the IMS2016 website (www.ims2016.org). Papers will be evaluated on the basis of originality, content, clarity, and relevance to the symposium. For accepted papers, the electronic submission of a final manuscript along with a copyright assignment to the IEEE will be required no later than 29 February 2016. Accepted papers will be included in the Symposium Proceedings and submitted for inclusion in the IEEE Digital Xplore Library. Authors of accepted papers should consider submitting an extended version of their symposium paper for possible publication in the IEEE Transactions on Microwave Theory and Techniques.

EMERGING TECHNICAL AREAS:

IMS2016 enthusiastically invites submission of papers that report state-of-theart progress in technical areas that are outside the scope of those specifically listed in this Call for Papers, or that may be new to the symposium, but are of interest to our attendees.

SPECIAL SESSIONS, WORKSHOPS, PANEL AND RUMP SESSIONS, AND SHORT COURSES:

Topics being considered for these areas include Next Generation Wireless Systems, Latest Technologies for RF/Microwave Measurements, and Advances in RFIC Technology. Please consult the IMS2016 website for a more detailed list of topics and instructions on how to prepare a proposal. Proposals must be received by 8 September 2015.

STUDENT PAPER AND STUDENT DESIGN COMPETITIONS:

Eligible students are encouraged to submit papers for the student paper competitions. The papers will be evaluated using the same standards as all contributed papers. In addition, eligible students or student teams are invited to consider taking part in student design competitions during the IMS2016, which are organized and sponsored by various Technical Committees (TC) of the MTT-S Technical Coordination Committee (TCC). Please visit the IMS2016 web site for full details.

MICROAPPS:

The Microwave Application Seminars serve as a forum for exhibitors at the IMS to present the technology behind their commercial products and their special capabilities. The presentations are open to all conference and exhibit attendees. Please refer to the IMS2016 website (www.ims2016.org) for more information on submitting MicroApps technical papers.

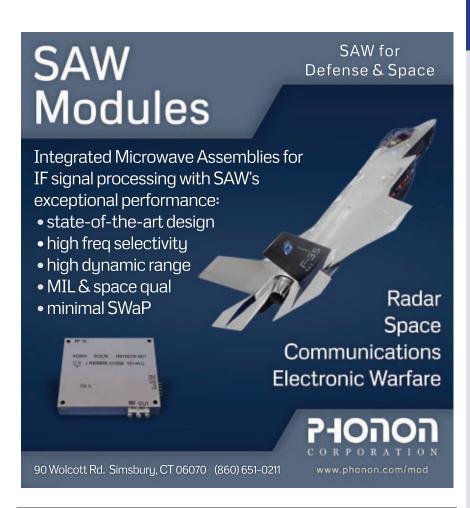


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EuMW Product Showcase **Hall Paris**

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Teledyne Relays RF Relay

Stand 260



Teledyne Relays announced its new 121 relay. The RF121 is a high repeatability, SPDT. broadband, magnetic-latching RF relay with performance

to 12 GHz. The RF121 is ideal for switchable RF attenuators, RF switch matrices, high frequency spectrum radios, ATE and applications that require dependable high frequency signal fidelity and performance. The RF121 is available in through-hole, surface-mount stub pin (GRF121) and J-lead configurations. The GRF121 has a frequency range of DC to 16 GHz. www.teledynerelays.com

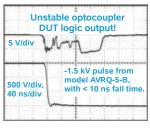
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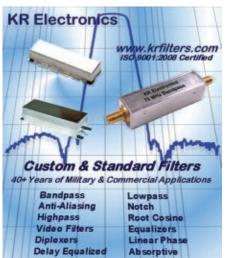


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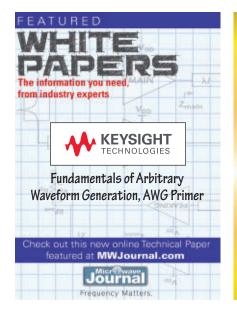
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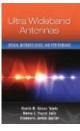
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BookEnd

Ultra Wideband Antennas: Design, Methodologies, and Performance

Giselle M. Galvan-Tejada, Marco A. Peyrot-Solis and Hildeberto Jardón Aguilar



he RF semiconductor industry is always eager to claim credit for enabling the tremendous growth in wireless networks and their applications. The antennas that propagate the signals between the semiconductor transceivers are often overlooked, perhaps because their designs remain an art, notwithstanding the mystery of Maxwell's equations being reduced to numerical computation.

With the growth of ultra wideband (UWB) wireless systems, from automotive radar to body area networks, "Ultra Wideband Antennas" provides a comprehensive treatment of the theory and design of UWB antennas. The authors don't assume the reader has a foundation in antenna design; after presenting the scope of their book, they address general concepts, such as the various types of antennas, radiation

patterns, gain, directivity, polarization and impedance.

Shifting to UWB antennas, subsequent chapters survey R&D and delve into the practical design of directional and omnidirectional antennas. Chapter 3 describes recent advances and presents some 20 antenna types (e.g., volcano-smoke slot, tulip-shaped monopole, octagonal-shaped fractal, planar inverted cone, double ridged guide horn). Chapter 4 addresses UWB antenna theory, followed by chapters on phase linearity, the design of omnidirectional antennas for communications, design of directional planar and volumetric antennas, current trends and unresolved problems. The final chapter describes numerical methods, including finite difference, finite element and method of moments. The treatment of numerical analysis wouldn't be complete without discussing available software packages; although not exhaustive, the chapter does include NEC, HFSS and CST Studio Suite.

In addition to their common interest in wireless systems and UWB antennas, the three authors have combined their respective academic backgrounds and professional roles. Giselle M. Galvan-Tejada received her Ph.D. in electronics and telecommunications engineering from the University of Bradford, U.K. and is a lecturer and full-time researcher in the Communications Section of the Department of Electrical Engineering of the National Polytechnic Institute in Mexico City. Marco Antonio Peyrot-Solis received his Ph.D. in electrical engineering from the Center for Research and Advanced Studies of the National Polytechnic Institute. He works for the Mexican Navy Research Institute in Veracruz. Hildeberto Jardon-Aguilar received his Ph.D. in radio systems from the Moscow Technical University of Communications and Informatics in Russia. He is a full professor at the Center for Research and Advanced Studies of the National Polytechnic Institute and has written five books and more than 100 technical papers.

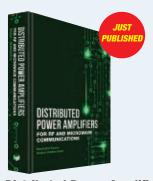
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MILCOM 2015 celebrates the 34th anniversary of the premier international conference for military communications. "Leveraging Technology – The Joint Imperative" gathers the leading minds of government, military, industry and academia in an interactive forum to further explore and define the benefits that joint-level collaboration bring to current and future communication challenges. Leaders from around the world will address the critical role communications plays in military readiness and operations. The Tampa location is ideal for this discussion, with close proximity to the MacDill Air Force Base military community, U.S. Special Operations Command (SOCOM), U.S. Central Command (CENTCOM) and the 6th Air Mobility Wing. MILCOM offers industry the opportunity to discuss communications technologies and services with decision makers from all branches of the armed forces, the Department of Defense, federal agencies and multinational forces.

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International Sales

Richard Vaughan International Sales Manager 16 Sussex Street London SW1V 4RW, England Tel: +44 207 596 8742 FAX: +44 207 596 8749 rvaughan@horizonhouse.co.uk Germany, Austria,

Germany, Austria, and Switzerland (German-speaking) WMS.Werbe- und Media Service Brigitte Beranek Gerhart-Hauptmann-Street 33, D-72574 Bad Urach Germany Tel: +49 7125 407 31 18 FAX: +49 7125 407 31 08 bberanek@horizonhouse.com

Korea Young-Seoh Chinn JES Media International 2nd Floor, ANA Bldg. 257-1, Myungil-Dong Kangdong-Gu Seoul, 134-070 Korea Tel: +82 2 481-3411 EAY., 829 481-3414 FAX: +82 2 481-3414 yschinn@horizonhouse.com China

Shenzhen Michael Tsui ACT International Tel: 86-755-25988571 FAX: 86-10-58607751 michaelt@actintl.com.hk

Shanghai ACT International Tel: 86-21-62511200 lindal@actintl.com.hk

Beijing Oasis Guo ACT International Tel: 86-13011108861 oasisg@actintl.com.hk Hong Kong, Taiwan, Singapore Mark Mak

ACT International Tel: 852-28386298 markm@actintl.com.hk

Japan Katsuhiro Ishii Ace Media Service Inc. Tel: +81 3 5691 3335 FAX: +81 3 5691 3336 amskatsu@dream.com

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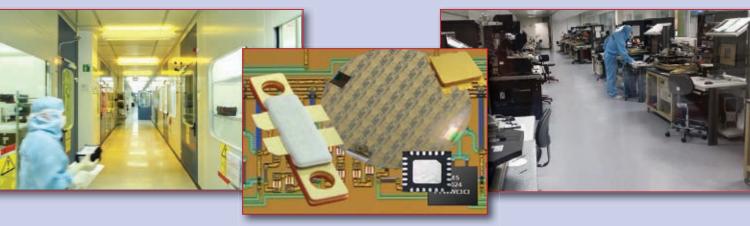
^{*120} dB models specified from 1-4000 MHz.

[†]No drivers required. DLL objects provided for 32/64-bit Windows® and Linux® environments using ActiveX® and .NET® frameworks.





UMS - a European Enterprise with a Global Focus



United Monolithic Semiconductors (UMS) was created in 1996 as a joint venture between Thales and EADS, to provide a European source of III-V technologies and products. UMS is the European leader in offering RF MMIC products and foundry services for specialized markets, including defense and space, telecommunications, automotive radar and industrial sensors to the worldwide market.

The company has two production sites:

Company headquarters in Villebon, France, is the site of the design center, foundry services and backend production and services. It also houses a 1400 m² state-of-the art clean room and labs that offer on-wafer testing, automatic visual inspection, dicing, picking, automated test of packaged devices and characterization.

The Ulm, Germany facility houses 1000 m² of labs and clean room where GaAs and GaN technology development and wafer manufacturing take place. UMS also has sales offices in Lowell, Mass. and Shanghai, China, along with a network of sales representatives supporting a global customer base.

UMS' comprehensive offer is based on the supply of either ASIC or catalogue products, mainly based on the company's internal III-V technologies, and through the provision of a comprehensive foundry service, allowing customers to directly create their own product solutions. The range of catalogue products from DC to 100 GHz is based on GaAs, GaN and SiGe technologies and encompasses power amplifiers up to 200 W, mixed-signal functions, very low noise amplifiers and complete transceiver systems.

In-house GaAs and GaN processes provide the technology platform to enable the design of leading edge products and form the basis of foundry services

to external design centers. The open foundry provides an integrated suite of services aimed at ensuring that ASIC designs are fabricated successfully on the first fabrication run. The flow from design to fabrication and delivery is optimized to offer designers the right process selection to meet design goals; design kits supported by extended, accurate and validated models available on familiar platforms; technical support at all stages of the project, including critical foundry design reviews to identify and solve issues early; fabrication using reliable and repeatable processes; optional early MMIC validation through onwafer test; dicing and known good die delivery.

UMS has strong relationships with many of the major R&D centers and universities throughout Europe. Recent innovations include multichip transceiver modules, using a combination of SiGe and GaAs technologies for the latest 24 GHz automotive radar sensors; and GaN high power devices, including general purpose transistors in SMD DFN packages and internally matched power quasi-MMIC amplifiers from L to C-Band in ceramic and QFN packages.

Power applications are the main drivers for in-house technology development. In addition to $0.5~\mu m$, a $0.25~\mu m$ GaN HEMT high power technology has recently been qualified and released. It has been used internally and by foundry partners to create new products up to 20~GHz.

In the future, the current GaN technology range will be extended to higher frequencies with the development of a 0.15 µm technology. GaAs technology will remain the optimum choice for some power applications, so UMS is releasing a high breakdown voltage GaAs PHEMT process (PPH15X-20) for linear power applications into Ka-Band. In addition to chip-and-wire assemblies, it will be compatible with standard QFN packaging.

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- Full Port-To-Port Isolation
- MISMATCH TOLERANT® DESIGNS
- Connectorized and Surface Mount

Model QH10089



90° Hybrid Coupler

EXCELLENT AMPLITUDE BALANCE

This High Power 90° Hybrid Coupler covers the **full 800 - 2800 MHz bandwidth**, at 200 W CW. Incurring just 0.35 dB of insertion loss, while providing a minimum of 20 dB isolation, this compact, surface mount design, measures just 1.25 x 0.55 x 0.08". The QH10089 is ideal for extreme military or commercial environmental conditions.

Model D10262



2-Way 0° Combiner

TOLERATES A FULL INPUT FAILURE

The D10262 is a 2-Way Combiner rated at 600 W CW, and operates with full port - to port isolation of 17 dB minimum. This high power combiner is **designed to handle an input failure,** at rated power, while operating at a +70°C baseplate temperature. Ideal for coherent and non-coherent combining, the D10262 is suitable for multiple military applications.

Model H10125



180° Hybrid Combiner

SMT 180° Hybrid

Our newest 180° Hybrid Combiner / Divider delivers best-in-class amplitude balance, typically \pm 0.2 dB, and operates with a maximum insertion loss of 0.5 dB. Supplied as a surface mount, stripline design, the H10125 is rated at 350 W CW, offers excellent phase tracking, and 30 dB typical port - to - port isolation.

Model D10118



4-Way Radial Combiner

Power Rating of 1500 W CW

The D10118 is the newest addition to our full line of **Radial Combiners & Dividers.** Ideal for Radar, EW, and Telecom systems, this 4-Way design is rated at 1500 W CW, and combines or divides a single stage through a radial transmission line structure. The D10118 generates low loss and requires minimal heat dissipation.

Model D9623



4-Way 0° Combiner

DESIGNED FOR MIL-STD-810

Werlatone provides several combiner designs, for high power applications, where the customer determines that port-to - port isolation is not required, or when an isolated design incurs too much loss. The compact and robust Model D9623, is a 4-Way Combiner, covers the full 1 - 3 GHz bandwidth, and is rated at 500 W CW.

Model H10253



180° Hybrid Combiner

CONNECTORIZED 180° Hybrid

The Model H10253 is the connectorized version of Model H10125. Rated at 350 W CW, and measuring just 2.31 x 1.21 x 0.25", this high power hybrid operates with 20 dB port - to - port isolation, an amplitude balance of \pm 0.2 dB maximum. Supplied with all N Female connectors, the H10253 is robust & compact.