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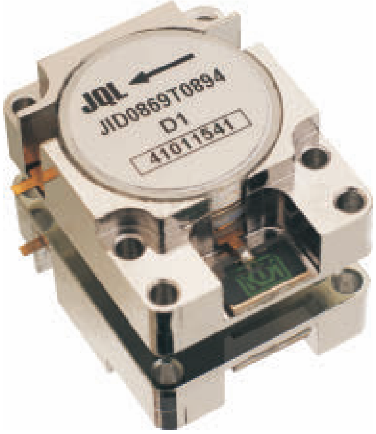

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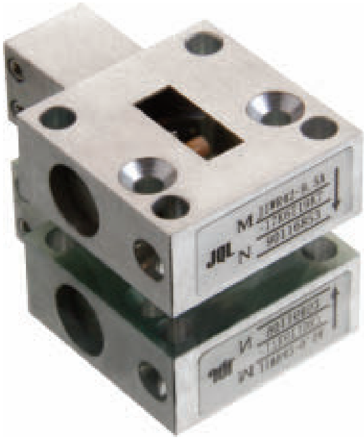

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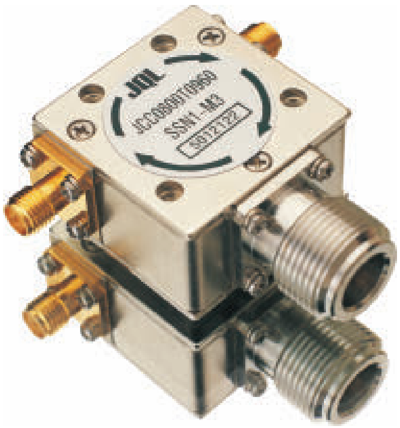

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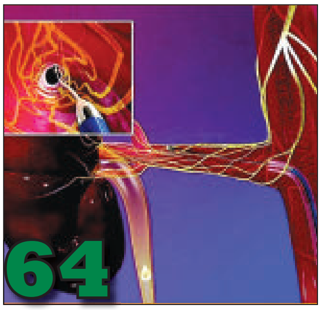

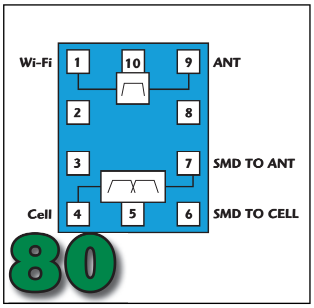

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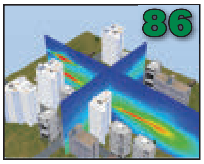

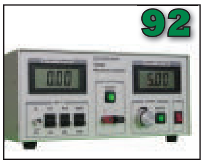

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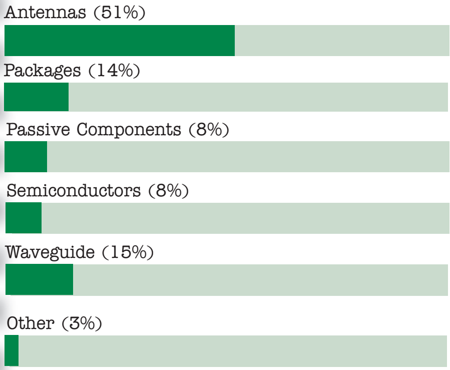

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Mergers Mold 2016

Patrick Hindle
Microwave Journal *Editor*

We have been talking about the great era of semiconductor consolidation since 2014 and it continued through 2016. There have been big moves in the industry such as the TriQuint and RFMD merger, Broadcom's acquistion of Avago and Analog Devices' acquisition of Hittite. And this year Analog Devices is also merging with Linear Technology—becoming a giant semiconductor player in the wireless and IoT markets.

Another big move was NXP's acquisition of Freescale, then NXP's RF power business spun off to become Ampleon. I thought things would slow down after that, but then Qualcomm came along to acquire NXP. And Infineon is acquiring Wolfspeed (formerly Cree) for its GaN technology. With the Chinese government still pumping billions into acquiring semiconductor companies and the pressure for the larger scale to provide low cost products, expect this trend to continue.

GaN has finally become mainstream and competitive with LDMOS in the lower cost commercial markets. A significant GaN milestone was the 36,000 GaN amplifiers that were shipped to Lockheed Martin for its Space Fence radar system. Our August supplement featured this system development which is one of the largest phased arrays and computing centers in the world today. Another milestone was the adoption of GaN in some cellular infrastructure applications. Our February 2017 issue will highlight Ericsson's progress in this area. GaN is addressing its higher cost with a 6-inch wafer fab coming online at Qorvo, and GaN on Si from MACOM possibly going to 8-inch wafers. Infineon tried to use GaN on Si for RF applications but was blocked by MACOM's acquisition of the rights in that market. Expect Infineon to beef up Wolfspeed's fab to compete in the higher volume commercial sectors.

The RF Energy Alliance continued to make progress in reducing the cost of solid-state amplifier technology with a standard, low cost 300 W, 2.45 GHz module with near 70 percent efficiency. The challenge will be mainly cost as the technology works for these applications but is far more expensive than the current solution.

3D packaging and printing for RF applications really took off in 2016. Our February cover story featured 3D packaging research at Leti, where they are creating a new generation of mmWave interposer packages with enhanced electrical and mechanical properties at a reasonable cost.

Our October cover story discussed The MITRE Corporation's work on a new generation of 3D printing techniques and materials that realize complex geometries for wideband phased array and metamaterial designs using low-cost, commercial desktop printers. They demonstrated the technology by making 3D printed monopole Wi-Fi antennas and are now working on a complex, electrically-functional phased array and metamaterial structure. And our August Fabs and Labs covered the Printed Electronics Research Collaborative at University of Massachusetts Lowell where they are using 3D printers to manufacture frequency selective surfaces, antennas, waveguides, phased arrays and even tunable devices printed on plastic materials.

One of the biggest happenings of the year was on July 14, when the FCC established rules for microwave and mmWave broadband operations above 6 GHz in the U.S. The move effectively quadrupled the amount of radio bandwidth available to the mobile industry and paved the way for future 5G systems. Professor Ted Rappaport of NYU WIRELESS was the first to show that mmWaves were viable for cellular communications with his past urban channel modeling tests, and this year he conducted similar tests in a rural setting showing the viability of line-of-sight and non-line-of-sight transmission of mmWave communications at 73 GHz. NYU WIRELESS used this data to generate the first rural path loss model for mmWave frequencies, demonstrating pretty remarkable distances that can be achieved using mmWaves (near theoretical limits). With 5G mmWave trials happening so quickly, it will be very interesting to see how fast companies can commercialize mmWave technology and bring the cost down to a level that is practical for wide use.

Microwave Journal launched two significant ventures this year. EDI CON USA took place for the first time Sept. 20-22 in Boston, Mass., with a successful event covering RF/microwave, high-speed digital and EMC/EMI design topics. We also launched the first *Signal Integrity Journal* online covering signal integrity, power integrity and EMC/EMI topics (www.signalintegrityjournal.com). This is the only industry journal available covering these topics that address the needs of the digital design community. We hope everyone had a good year. Happy Holidays! ■

COVER FEATURE
INVITED PAPER

Automotive Radar Sensors Must Address Interference Issues

Dr. Steffen Heuel
Rohde & Schwarz, Munich, Germany

Autonomous driving is a current global trend that will continue to accelerate in the future. A key enabling technology in this area is automotive radar sensors, which are a significant step toward more driving comfort, crash prevention and even automated driving. Driver assistance systems are already common and many are supported by radar.

Today's 24 GHz, 77 GHz and 79 GHz automotive radar sensors clearly need to be able to measure and resolve different objects while offering high range, radial velocity and azimuth resolution in any urban or rural environment. A very important feature is immunity to interference from other automotive radar sensors. This topic has not been greatly focused on since the market adoption of radar sensors is low at the present time. However, the proliferation and expected growth is continually increasing and the Advanced Driver Assistance Systems (ADAS) market is expected to grow by up to 10 percent per year.

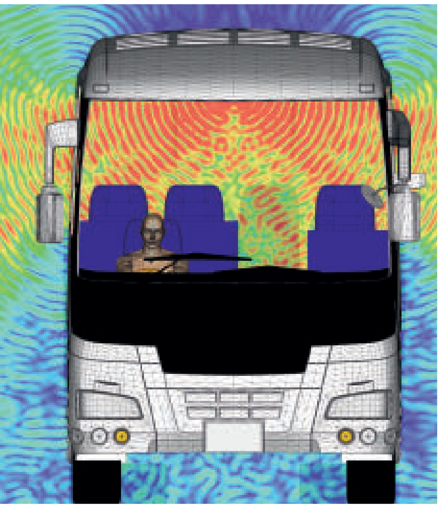
Considering that 72 million new cars are registered each year with a potential average of three (or more) automotive radar sensors per car, about 200 million more automotive radar sensors could be on the streets in the not too distant future. Consequently, the 24 GHz and 76 to 81 GHz spectrum will be heavily occupied. Automotive radar sensors will need to cope with mutual interference and offer signal diversity and interference mitigation techniques.

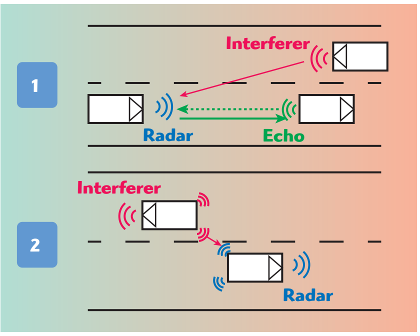
The occasional accidents involving automated cars that are under research and development have been reported in the press. In May 2016, questions about the security of self-driving cars and the safety of the technologies rose again after the first fatal accident involving a partially automated car. It is therefore essential to ensure the functionality of the sensing equipment in any environment in the presence of mutual interference.

This article presents the theoretical background of state-of-the-art and next generation automotive radar signals and sensors. It explains the impact of mutual interference and presents measurement possibilities to test and verify mitigation techniques in arbitrary RF environments with norm interferers. This approach helps researchers and developers engineer automotive radar sensors that function according to specification, even in harsh RF environments.

AUTOMOTIVE RADAR AND REGULATIONS

Several automotive radar sensors may interfere with each other when operating in the same portion of the frequency band[1] and in close proximity to each other (see ***Figure 1***). Possible scenarios are the creation of artificial ghost targets or decreased probability of detection. Ghost targets do not exist in reality, but appear as real targets to the radar sensor. This may be caused by a copy of the transmitted signal. The copy is not from the original radar transmitter, but falls into the receiver bandwidth and is processed as a real echo signal. For this scenario to occur, timing, waveform





▲ *Fig. 1 Interference scenarios.*

and frequency between two or more radars have to match and the echo power has to exceed a certain limit.

Also, arbitrary RF signals with a certain power level that fall into the receiver bandwidth may increase the noise floor of the radar and reduce the Signal-to-Noise Ratio (SNR) of a target. This may cause targets with a small Radar Cross Section (RCS) to disappear since the SNR of these echoes is reduced. For this scenario to happen, a signal that spreads over all frequencies after FFT signal processing has to fall within the receiver bandwidth.

The output power of automotive radar sensors is specified by the Electronic Communications Committee (ECC). Based on the ECC Decision (04) 03 entitled, "The Frequency Band 77 to 81 GHz to be Designated for the Use of Automotive Short Range Radars," the European Conference of Postal and Telecommunications Administrations (CEPT) designated the 79 GHz frequency range for Short Range Radar (SRR) equipment on a non-interference and non-protected basis. Moreover, a maximum mean power density of -3 dBm/MHz e.i.r.p. associated with a peak limit of 55 dBm e.i.r.p was defined, and the maximum mean power density outside a vehicle resulting from the operation of one SRR equipment shall not exceed –9 dBm/MHz e.i.r.p.

All standard automotive radar sensors operating in these bands have to fulfill this criteria. ETSI standards EN 301 091-1 and EN 301 091-2[2] already standardize several aspects related to test conditions, power emission and spurious emissions for 77 GHz radars, but do not mention anything about interference rejection. The same is true for the ETSI standards EN 302 264-1 and EN 302 264-2[3], which regulate the 79 GHz band.

In the maritime domain, for example, navigational radars have to adhere to the International Electrotechnical Commission standard IEC 62388,[4] which specifies the minimum operational and performance requirements, methods of testing and required test results conforming to performance standards of radiocommunications equipment and systems. One very important aspect in the IEC standard is the specification of interference rejection. However, for automotive radar specifications, there is no standard defining interference rejection or performance and test methods that navigational radars have been subject to for decades.

WAVEFORMS AND IMPACT OF INTERFERENCE

If an interfering signal falls into the radar receiver bandwidth, it should be detected as such and rejected in the signal processing. It is common for manufacturers to each have slightly

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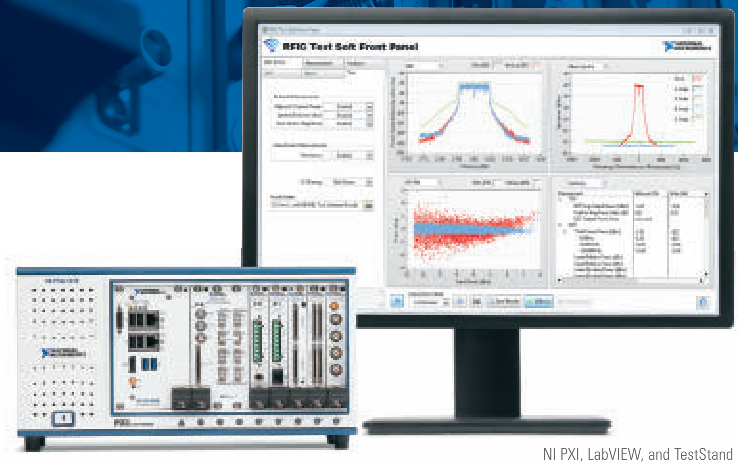

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different waveforms, timings, bandwidths, antenna patterns and signal processing. This is an advantage in terms of interference rejection, but also results in the radar responding differently to interference.

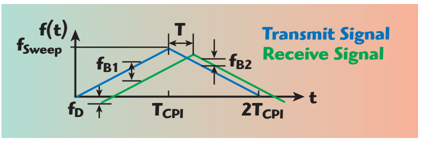
There are mainly two different types of waveforms used in today's automotive radar sensors. Blind Spot Detection (BSD) radars often use the Multi-Frequency Shift Keying (MFSK) radar signal and operate mainly in the 24 GHz band. Radars operating in the 77 GHz or 79 GHz band often make use of Linear Frequency Modulated Continuous Wave (LFMCW) signals or Chirp Sequence (CS) signals, which are a special form of LFMCW signals. Using LFMCW, the radar transmits a frequency modulated signal (chirp) with a specific bandwidth f_{sweep} within a certain time, called the coherent processing interval T_{CPI}, as shown in ***Figure 2***.

The radar down-converts the received signal with the instantaneous transmit frequency and measures the beat frequency f_B, which describes the offset from the original transmitted waveform. Both radar parameters, range, R and radial velocity, v_r, contribute to the measured beat frequency. In order to resolve the target unambiguously for v_r and R, two beat frequency measurements are necessary (see Figure 2, where the beat frequencies are denoted as f_{B1}, f_{B2}). In multitarget situations, range and radial velocity cannot be resolved unambiguously by two consecutive chirps measuring different beat frequencies. This can be resolved by an additional chirp with a different slope.

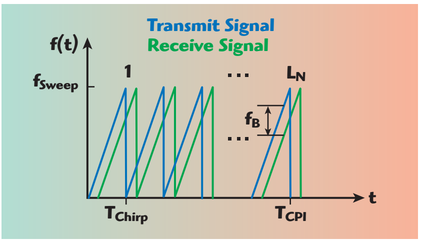
To enable a certain radial velocity resolution, T_{CPI} is typically in the region of 20 ms and the number of chirps for a single processing interval is greater than two. f_{sweep} defines the range resolution and varies between 100 MHz and above, and will be more than 1 GHz in the near future and probably 4 GHz or even 5 GHz in the distant future.

The chirp sequence waveform consists of several very short LFMCW chirps, each with a duration of T_{Chirp}, transmitted in a block of length T_{CPI} (see ***Figure 3***). Since a single chirp is very short, the beat frequency is mainly influenced by the signal propagation time and the Doppler frequency shift, f_D can be neglected.

Signal processing takes place following an initial down-conversion by the instantaneous carrier frequency and a Fourier transformation of each single chirp. Due to the high carrier frequency and the high chirp rate the beat frequency is mainly determined by range. The target range is calculated assuming a radial velocity, $v_r=0\frac{m}{s}$. The



▲ *Fig. 2 LFMCW radar signal with upchirp and downchirp.*



▲ *Fig. 3 Chirp sequence.*

TABLE 1
AUTOMOTIVE RADAR WAVEFORM COMPARISON

	LFMCW	CS (Fast LFMCW)
f_0 (GHz)	77	77
f_{Sweep} (GHz)	1	1
T_{CPI} (ms)	20	0.025
$f_{B,Upchirp}$ (MHz)	0.039027	10.6997
$f_{B,Downchirp}$ (MHz)	0.012342	–10.6484

radial velocity is not measured during a single chirp, but instead over the block on consecutive chirps with duration T_{CPI}. A second Fourier transformation is performed along the time axis, which results in the Doppler frequency shift. After obtaining the Doppler frequency shift, the target range is corrected.

While a single T_{Chirp} is typically in the region of 10 µs to 100 µs, the number of signals L_N should be so high that the entire coherent processing interval, $T_{CPI}=L_N\ T_{Chirp}$ is again in the region of several dozen ms to achieve the desired radial velocity resolution.

The signal bandwidth is high, and the receiver bandwidth is very small in comparison. This can be achieved due to the fact that only the maximum beat frequencies for which the radar is designed are measured. To give two examples, ***Table 1*** shows the resulting beat frequencies of two automotive radar waveforms when measuring a target in 40 m range with a radial velocity of 50 m/s.

These calculations are according to the LFMCW equations and show that the occurring beat frequencies are in the range of 100 kHz for LFMCW, but are much higher for CS radars (several MHz). This causes the receiver bandwidth to be higher and may require different mitigation techniques compared to techniques applied when using LFMCW.

The advantage of CS compared to LFMCW is the unambiguity and the increased update rate, because a single coherent processing interval is sufficient to measure and resolve all targets in the observation range. In LFMCW, at least three different chirp signals are necessary. On the other hand, in the CS waveform the processing complexity increases due to multiple FFTs and the receiver bandwidth scales according to the expected beat frequencies, which is why there is a need for interference rejection and mitigation techniques.

Figure 4 depicts the down-conversion and Fourier transformation process when an interference signal (red chirp) is present. The interfering chirp is down-converted together with the radar return of the object. In green is the constant beat frequency for a certain range as it would occur in an interference-free environment while measuring a single target. With the introduction of an interference signal, a time-dependent beat frequency is generated (red curve), which appears in addition to the wanted echo. Hence in the Fourier domain, the spectrum shows not only a single beat frequency but several frequencies.

In the optimal solution, the signal-to-noise ratio of the echo signal (green bar) is maximum. When the interference signal is present, the noise floor rises and the signal-to-noise ratio decreases depending on the receiver bandwidth, f_{LP} as indicated in the sketch. Aside from a decreased probability of detection, the lower signal-to-noise of an echo signal results in a

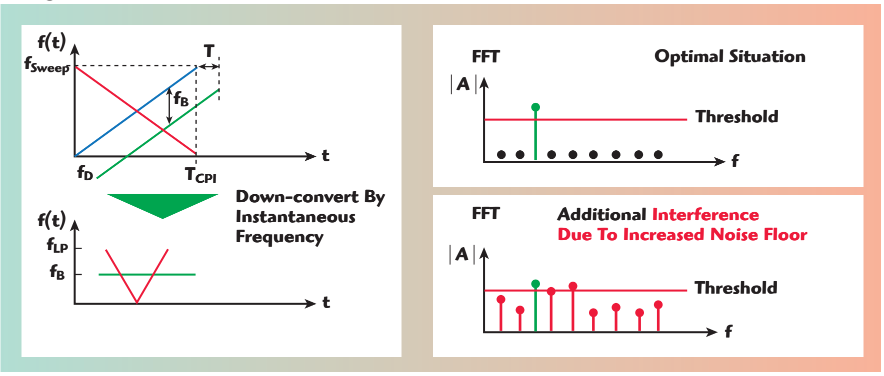


Fig. 4 Effect of interference signals.

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The receiver noise floor and the signal-to-noise ratio of the object depend on the hardware, software and the object's RCS. Typical noise floor levels are about –90 dBm for an automotive radar operating at 77 GHz. One trend is to combine chirp sequence waveforms with other methods such as frequency shift keying in order to reduce the computational effort. However, at present, there are no common definitions on normative interferers and interference rejection written in standards for automotive radar sensors.

T&M INTERFERENCE REJECTION

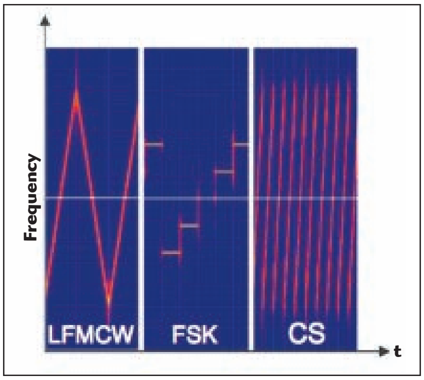
In order to verify the performance of interference rejection methods and to test the interference robustness of a radar sensor, a measurement was set up in the laboratory that allowed the generation of arbitrary RF signals. These signals can even include, for example, transmitter position, antenna motion and pattern.

Figure 5 shows typical radar interference signals generated by Pulse Sequencer software, such as LFMCW, frequency shift keying and chirp sequence. It should be mentioned that the software is not limited to these signals or sequences, but can also create complex RF environments to the laboratory.[5]

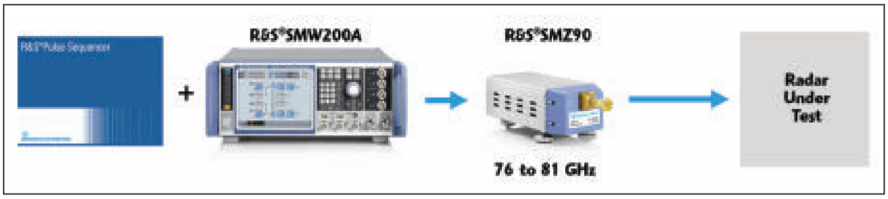
Although these signals can be generated in the baseband, bringing these signals up to E-Band frequencies is a challenge. As most automotive radars use only frequency-modulated signals, one way is to use a state-of-the-art vector signal generator together with a multiplier. The advantages of this setup are less complex test setups and high signal bandwidth that can be reached more easily since the multiplier also scales the signal bandwidth.[6] The scaling factor can easily be considered when designing the waveforms in the baseband.

Figure 6 shows a typical test setup for automotive radar sensors, using a vector signal generator in combination with a multiplier. The Pulse Sequencer software is used to generate the arbitrary RF environment in which signals are transferred to the vector signal generator over the local network or via a USB stick. The RF signals produced by the vector signal generator at 12.6 to 13.5 GHz are multiplied by a factor of six. An E-Band horn antenna can be connected to the output of the multiplier so that the E-Band signal can then be transmitted over the air towards the Device Under Test (DUT).

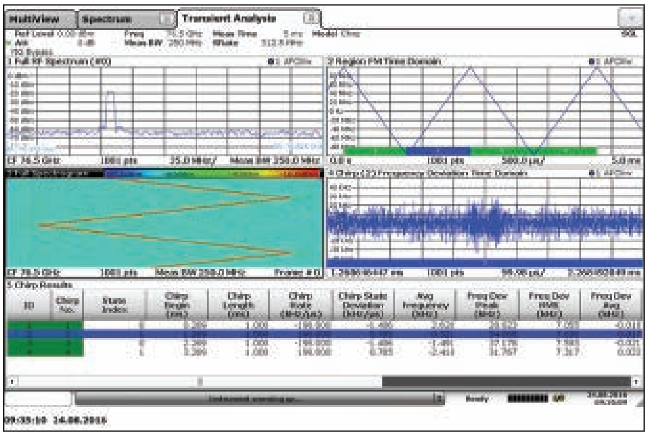
In this setup, the bandwidth applied at the vector signal generator also scales by a factor of six. To generate radar chirps with a signal bandwidth of 5 GHz, a baseband bandwidth of



▲ *Fig. 5 Typical CW radar signals.*



▲ *Fig. 6 Interference test setup using a vector signal generator and multiplier.*



▲ *Fig. 7 Radar interference signal.*

833.3 MHz is required (833.3 MHz × 6 = 5 GHz). With the setup shown in Figure 6, a baseband bandwidth of 2 GHz is possible, which results in an RF signal bandwidth of up to 12 GHz (2 GHz × 6 = 12 GHz).

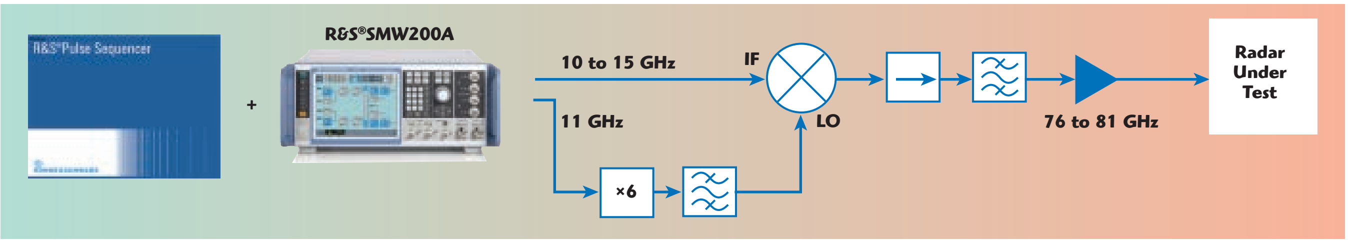
The spectrum of the interference signal is in ***Figure 7***. It is possible to observe the spectrum and the LFMCW signals with upchirps and downchirps. All chirp signal parameters have been analyzed directly with a signal analyzer equipped with transient analysis software. The chirp length is 1 ms and the signal frequency linearity is in the domain of several kHz, which is comparable to automotive radar sensor signals.

Researchers have already investigated using communications signals like OFDM in automotive radar[7] and designed interference rejection algorithms.[8] However, it may be complicated to process these extremely wideband OFDM signals in a price-sensitive sensor in real time. This will make it complicated to apply OFDM signals in the near future. This is also one of the reasons why it is so important to verify interference rejection algorithms, waveforms and the entire processing chain, starting with the mmWave region.

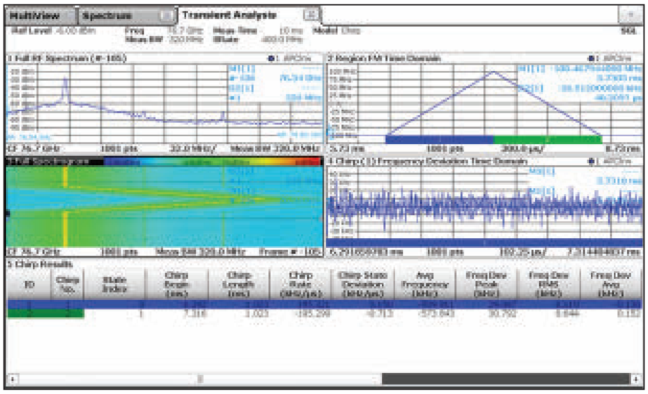
Not only is the cost-effective, real-time processing of very wideband OFDM signals challenging, generating amplitude-modulated interference signals in mmWave also requires a more complex setup. One approach is depicted in ***Figure 8***, which shows the IF and LO signals generated by a two RF channel vector signal generator. The LO signal is multiplied by a factor of six and shifts the IF signal to 76 to 81 GHz. A vector signal generator with an internal wideband baseband then allows the generation of arbitrarily modulated RF signals in the E-Band with a signal bandwidth of up to 2 GHz. Using vector signal generators incorporating calibrated internal wideband baseband hardware has benefits over solutions using multiple instruments since there is no need for calibration nor compensation of the I/Q frequency modulator response.

MEASUREMENT RESULTS

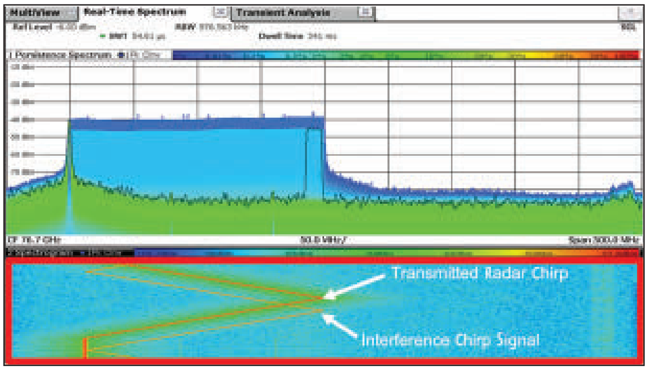
To verify the impact of additional radar signals that are present, a state-of-the-art 77 GHz sensor was used. The advantage of this sensor is the availability of IF and FFT raw data. This makes it possible to immediately verify the impact of interference signals on the FFT spectrum. As explained, one should see an increase in the noise floor depending on how much interference signal power is downconverted and falls into the receiver bandwidth. In these measurements, the sensor was configured to transmit an LFMCW signal with 200 MHz signal bandwidth as depicted in ***Figure 9***, where the transient analysis option shows the duration, signal bandwidth, the linearity (frequency



▲ *Fig. 8 Interference test setup using a mixer.*



▲ *Fig. 9 Radar sensor analyzed with the transient analysis option.*

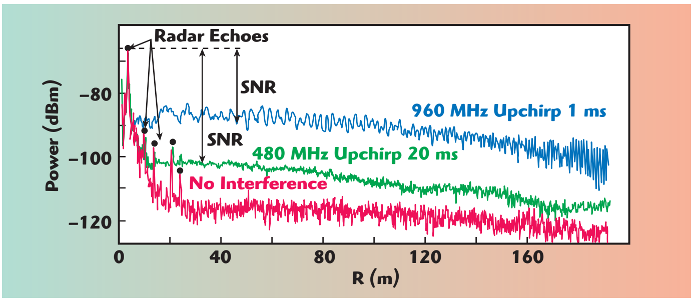


▲ *Fig. 10 Real-time spectrum showing wanted signal (on left with single chirp) and continuously chirping interferer.*

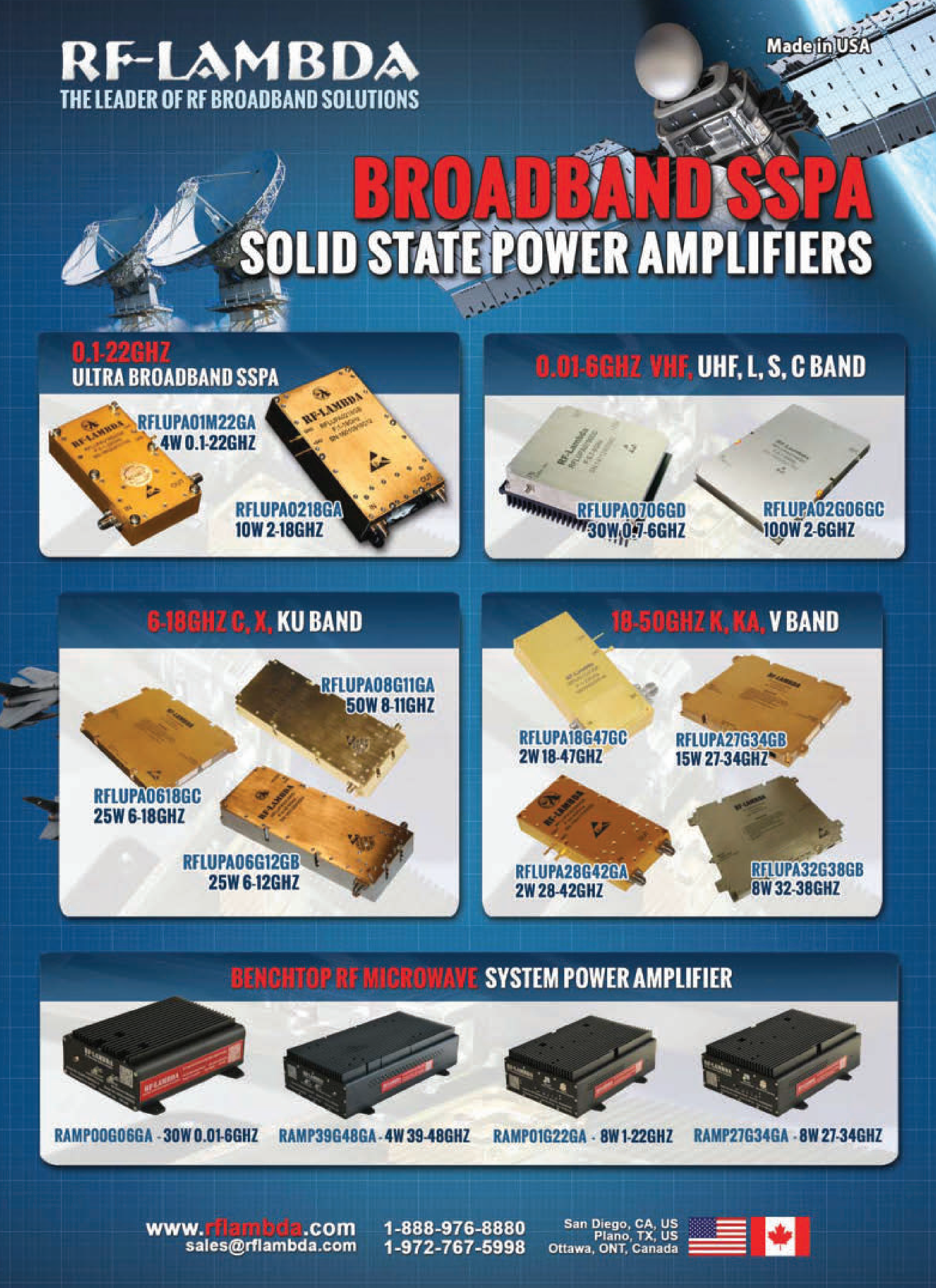
deviation time domain) of the transmitted chirps and spurious emissions in the RF spectrum.

The Pulse Sequencer software was used to emulate the waveform and test the radar with an additional interference waveform. The real-time spectrum in persistence mode can be used to verify the two signals. ***Figure 10*** shows two RF signals, the chirp which is transmitted by the radar sensor and the interference signal generated by the vector signal generator. While the radar sensor transmitted an upchirp and downchirp followed by an unmodulated CW signal, the interference signals just transmit upchirps and downchirps. The power level of the interfering chirp is about 5 dB less than the transmitted radar signal as shown in the persistence spectrum.

Figure 11 depicts a sample of spectrum measurements where the amplitude level over the range is plotted with and without interfering signals present. While measuring into free space without interference, this radar sensor measures a spectrum at a pow-



▲ *Fig. 11 Radar sensor spectrum.*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25W 6-18GHZ
RFLUPA06G12GB
25W 6-12GHZ
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er level in the range of -115 dBm and some radar echo signals in close range.

When an interfering signal is present, the noise floor increases to about -102 and -90 dBm depending on the interfering signal itself. It should be mentioned that this radar sensor does not apply any interference cancellation. Also, the noise floor increase strongly depends on the interference signal level and the interfering waveform itself as can be seen in the measurements. A decrease of 10 to 25 dB SNR has been proved, which can cause objects to be very easily lost during tracking or objects with low RCS, like pedestrians, going undetected.

CONCLUSION

Automotive radar supports the trend towards additional driving comfort, safety and even automated driving. The number of automotive radar sensors on the streets is increasing rapidly and will grow further in coming years. As a consequence, the allocated spectrum in the 24 GHz, 77 GHz and 79 GHz bands needs to be shared among different types of sensors and signals. As a safety critical element, the radar sensor needs to cope with mutual interference, offer signal diversity and interference mitigation techniques to measure, detect, resolve and classify radar echo signals even in the highly occupied frequency spectrum. Regulations and standards on interference test and mitigation are available for navigational radars, for example, but are not yet required for automotive radars.

To address these needs, this article explained the theoretical background and impact of interference on state-of-the-art and next generation automotive radar. Test and measurement possibilities to verify interference mitigation techniques in arbitrary RF environments have been presented. The impact of interference has been verified using a state-of-the-art commercial 77 GHz radar sensor. These test setups should help researchers and developers ensure the functionality of their radar according to specification even in harsh RF environments.■

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For wireless infrastructure applications, IDT has developed a family of transmit (Tx) variable gain amplifiers (VGA) with high gain and high linearity. Incorporating a new constant linearity K_{LIN}™ RF VGA, the family provides a nominal 32 dB maximum gain with 29.5 dB gain control, and an output IP3 of +38.5 dBm. The devices incorporate a digital step attenuator (DSA) with 0.5 dB step resolution. Three parts cover the bands from 700 to 2950 MHz (see ***Table 1***), all with similar gain, OIP3 and P_{1dB} performance. Device linearity is optimized over the respective frequency ranges for each VGA; however, gain flatness is optimized over a broader frequency to account for systems with extended digital predistortion (DPD) bandwidth requirements.

In wireless infrastructure base stations and remote radio units (RRU), RF VGAs are used in the transmit paths connecting the data converter to the power amplifier (PA) stages. The typical requirements for the components in the Tx path are:

- Low distortion
- High efficiency
- High ACLR
- Low spectral noise
- High signal-to-noise ratio
- Low DC power consumption
- Small PCB footprint
- Low cost

TABLE 1

VGA FAMILY

Part #	Frequency Range (MHz)	Max Gain (dB)	OIP3 (dBm)	P_{1dB} (dBm)
F1451	700 to 1100	33.0	40	23.5
F1455	1400 to 2300	32.8	38.5	23
F1456	2100 to 2950	32.1	40	23

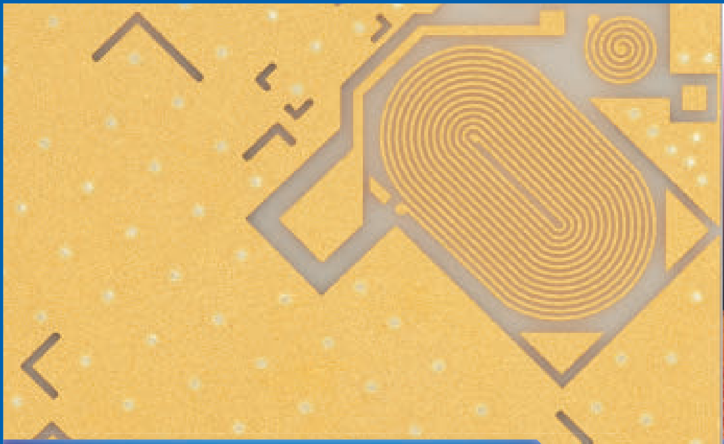
The IDT Tx VGAs meet or exceed wireless infrastructure requirements. Each Tx VGA in the F145x family consists of a K_{LIN} RF amplifier, DSA and a PA driver amplifier (see ***Figure 1***) that are configured to provide an optimum balance between noise and linearity performance over the gain control range.

Common features of the three Tx VGAs include:

- Broadband operation
- 32 dB maximum gain, flat and temperature invariant
- 4 dB noise figure at maximum gain
- 23.4 dBm P_{1dB}, which is constant for the first 12 dB of gain reduction
- 38.5 dBm OIP3, also constant for the first 12 dB of gain reduction
- 29.5 dB total gain control range in 0.5 dB steps
- Serial peripheral interface (SPI) for gain control
- Internal matching and biasing
- High reliability MSL1 package with low thermal resistance
- Single +5 V supply voltage and 220 mA of DC current
- Standby feature for TDD applications
- High reliability, due to the assembly of a monolithic silicon die in a QFN package

K_{LIN} FEATURE

Unique to these Tx VGAs is the K_{LIN} feature. The K_{LIN} amplifier extends the OIP3 and output P_{1dB} performance over a wider range of input and output powers than conventional competitive devices. Unlike other products, the F145x Tx VGAs separate



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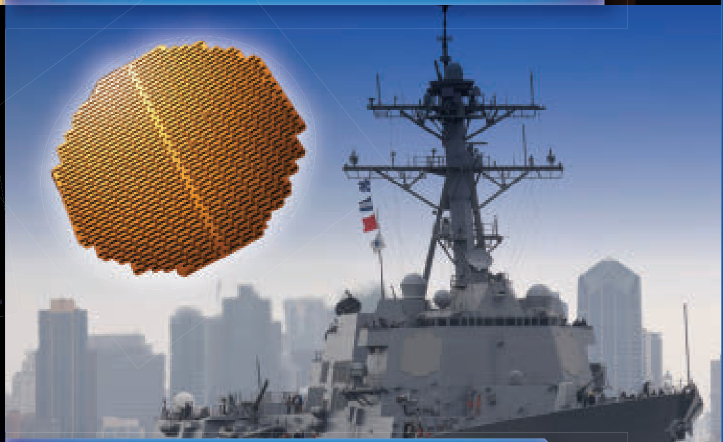

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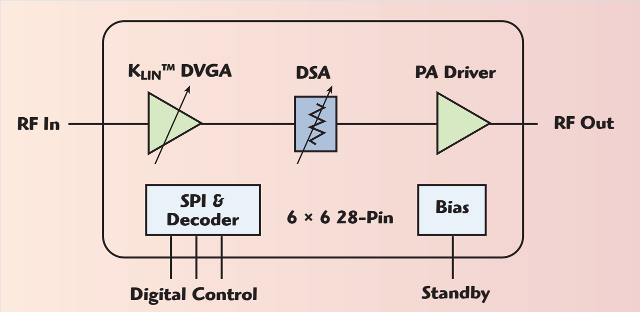

Fig. 1 Functional block diagram of Tx VGAs with the K_{LIN} constant linearity feature.

the gain control between both the K_{LIN} amplifier and the DSA. The first amplifier incorporates circuitry to improve the linearity of the device as gain is reduced from its maximum value. This results in an output IP3 characteristic that remains constant for approximately 12 dB of gain reduction (see ***Figure 2***), providing greater dynamic range for the system. With this added dynamic range, the device is able to operate over a wider range of input power levels while maintaining a constant output P_{1dB} and OIP3. A conventional VGA, whose OIP3 characteristic falls off more steeply as gain is reduced, has a more limited range of acceptable input power levels, i.e., for which the desired intermodulation performance is met.

The same applies to the P_{1dB} performance. The first F145x stage tolerates higher input power as a function of gain reduction before contributing to the overall compression performance of

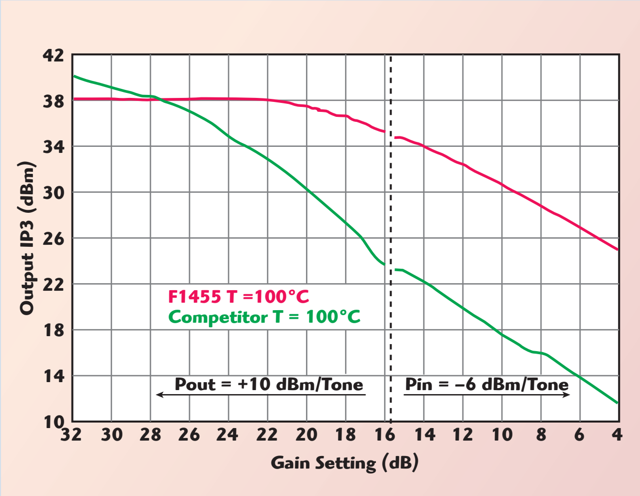

Fig. 2 Output IP3 vs. gain, showing the flatness of the K_{LIN} feature compared to a competing product.

the device. In contrast, the first stage amplifier of some competitive parts compresses early. With degrading P_{1dB} and OIP3 as a function of gain reduction, these competitive devices only allow a relatively small window of acceptable input power. ■

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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	+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	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
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	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+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
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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	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	2.0 MAX, 1.5 TYP	+10 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, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Cliff Drubin, Associate Technical Editor

Raytheon Developing Next-Gen Human/Machine Interface for Armored Ground Vehicles

Raytheon Co. is developing new technology to provide comprehensive situational awareness to troops inside windowless armored vehicles, as part of the Defense Advanced Research Projects Agency's (DARPA) Ground X-Vehicle Technologies (GXV-T) program.

The goal of GXV-T is to improve the mobility and survivability of armored vehicles without adding more armor and weight. DARPA is funding advanced technology development in four related areas: mobility enhancement, agility for survivability, crew augmentation and signature management. Raytheon BBN Technologies is developing crew-augmenting technologies.

"Our team is developing a virtual experience that gives the crews of armored military vehicles greater awareness of what's going on outside the vehicle, while also reducing their vulnerability to attack," said David Diller, GXV-T program manager for Raytheon BBN. "We're creating a three-dimensional model of the environment in real time that gives users views of their outside environment that would not normally be possible from inside the vehicle."

The Raytheon BBN technology uses lidar data to create a 3D model of the environment, employing high-definition video to produce a detailed, natural rendering of the surroundings. Additional sensors provide the precise location of any incoming hostile fire, while blue-force position updates locate friendly forces. Presenting all this sensor data in a natural, intuitive interface improves situational awareness while reducing the workload for the crew and allowing them to focus on the most relevant threats and challenges.

Source: DARPA Image

Advanced Space Surveillance Telescope Has Critical Military Applications

The most sophisticated space surveillance telescope ever developed is ready to begin tracking thousands of space objects as small as a softball. It's a boon to space surveillance and science and a new military capability important to the nation and the globe, an Air Force general says.

"It's not often we get an opportunity to witness the beginning of an entirely new military capability," Air Force Maj. Gen. Nina Armagno, director of strategic plans, programs, requirements and analysis for Air Force Space Command headquarters at Peterson Air Force Base in Colorado, said at the transfer event, "but that's exactly what we're doing here today."

The telescope, developed by the Defense Advanced Research Projects Agency, was turned over to the Air Force Oct. 18 at the Space Surveillance Telescope site atop North Oscura Peak on the northern part of the Army's 3,200 square mile White Sands Missile Range in New Mexico. The formal transition of the SST from a DARPA-led design and construction program to ownership by the Air Force begins the telescope's operational phase. The Air Force will move the SST to Harold E. Holt Naval Communication Station in Western Australia, operating and maintaining the telescope jointly with the Royal Australian Air Force. The SST also will be a dedicated sensor in the U.S. Space Surveillance Network, operated by the Air Force Space Command.

According to DARPA, SST represents breakthroughs in telescope design, camera technology and image analysis software, and allows much faster discovery and tracking of previously unseen or hard-to-find small space objects. SST has increased space situational awareness from a narrow view of a few large objects at a time to a widescreen view of 10,000 objects as small as softballs, DARPA says. The telescope also can search an area larger than the continental United States in seconds and survey the entire geosynchronous belt in its field of view—a quarter of the sky—multiple times in a night. "From a military perspective, any one of those objects could put satellites at risk," Armagno said. "That's why this capability is so important to us in Air Force Space Command."

The world and the threat have changed, she noted, adding, "We no longer have the luxury of assuming that we operate in a benign environment (or) that conflict will only be on land or at sea or in the air. Now we must concern ourselves with a conflict that may extend into space."

This calls for an in-depth understanding of what's go-

Source: DARPA Image

For More Information Visit mwjournal.com for more defense news ing on in space, she added—what objects are there, what they are doing, what their intentions are and what they will do next. SST will provide such information to the United States and its allies, Armagno said, characterizing it as "the ability to better understand the space domain in order to identify and predict the actions of others. In turn this knowledge will help us deter others from reckless behavior, and [allow us] to posture ourselves to react if needed."

Cognitive EW Development Contract

DARPA has awarded BAE Systems a $13.3 million contract modification to extend its work on the Adaptive Radar Countermeasures (ARC) project.

Current EW systems are limited in their ability to quickly adapt to new and advanced threats because they rely on a database of known threats with predefined countermeasures. To ensure mission success in future anti-access/area denial environments, EW systems will need to isolate unknown hostile radar signals in dense electromagnetic environments, and then rapidly generate effective electronic countermeasures. The cognitive EW technologies developed for the ARC program employ advanced signal processing, intelligent algorithms and machine learning techniques.

Under the contract modification, for Phase 3 of the ARC program, BAE Systems will perform work that includes the planned completion of algorithm development, advanced readiness testing, and key milestones for transitioning the ARC technologies to critical airborne warfare platforms, such as fifth-generation fighter jets.

"The Phase 3 award from DARPA recognizes the progress our team delivered at the end of Phase 2," said Louis Trebaol, ARC program manager at BAE Systems. "In Phase 2, we successfully demonstrated the ability to characterize and adaptively counter advanced threats in a closed-loop test environment. We will now continue to mature the technology and test it against the most advanced radars in the U.S. inventory in order to successfully transition this important technology to the warfighter."

Source: BAE Image

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Newtec HTS Solution to Provide Connectivity to Sub-Saharan Africa

The Newtec Dialog® platform, including a Wi-Fi hotspot solution, has been selected by Avanti Communications Group as the High Throughput Satellite (HTS) ground segment technology platform for its ECO project. The project, which is a public-private partnership between the European Space Agency (ESA) and Avanti, will provide affordable and reliable satellite broadband connectivity in its first phase to 1,400 schools and community sites across Sub-Saharan Africa within the next two years.

Newtec's optimized ECO terminals will deliver the ECO satellite broadband services to all identified sites through Avanti and its service providers. These Wideband DVB-S2X 500 Mbaud terminals combine the satellite connectivity with a Wi-Fi hotspot, including optional solar panels, and are part of the Newtec Dialog multiservice platform. The ECO service will initially be deployed in 32 Ka-Band spot beams out of multiple gateways in Europe and Africa.

> "...reduce the digital divide..."

"We are pleased to be able to use Newtec's technology on this vital project," said David Williams, CEO of Avanti. "The partnership is a significant step towards creating a solution for the endemic lack of affordable broadband connectivity across Sub-Saharan Africa."

The ECO satellite broadband services will benefit thousands of schools, communities and health centres, as well as Internet cafes and community area networks. The connectivity will also be used by local governments, telecom providers, mobile network operators and Internet service providers.

"One of Newtec's long-term objectives has been to reduce the digital divide and projects such as ECO are essential to this goal," said Didier Tymen, VP Sales EMEA of Newtec. "Our technology, including the Wi-Fi hotspot solution, delivers well against Avanti's network philosophy of Quality & Flexibility. It plays an important role in delivering the initiative's goals and makes reliable, but also affordable broadband a reality for millions across the region."

EU-US Agreement Offers New Opportunities for Research Cooperation

An agreement between the European Commission and the U.S. Government will enable European and American researchers to work together more closely on projects funded under Horizon 2020, the European Union's research and innovation programme.

Carlos Moedas, European Commissioner for Research, Science and Innovation, said, "Bright ideas should know no boundaries, so European research and innovation is open to the world for collaboration. This agreement means that the best talent on both sides of the Atlantic will be able to work even closer together on tackling the global challenges that our societies are facing."

The agreement, known as the "Implementing Arrangement," facilitates cooperation between U.S. organizations and Horizon 2020 participants in cases where the U.S. organizations are funded by the U.S. and do not receive any funding from the Horizon 2020 programme. It simplifies cooperation between a selected Horizon 2020 project and a U.S. entity by enabling researchers to organise their cooperation outside the formal Horizon 2020 Grant Agreement signed for each project, in accordance with applicable laws, rules, policies and regulations of their respective funding programmes.

> "Bright ideas should know no boundaries..."

With a budget of €77 billion for 2014 to 2020, Horizon 2020 is one of the largest multinational programmes dedicated to research and innovation. Research and innovation cooperation between the EU and the U.S. is governed by the Agreement for Scientific and Technological Cooperation, which entered into force in 1998. On 18 June 2014 the EU-US S&T cooperation agreement was renewed for an additional five years with retroactive effect and is now valid until 14 October 2018.

European Commission to Invest €9.1 Million in SMEs

Small and medium-sized enterprises (SME) from 24 countries have been selected for funding in the latest round of the Horizon 2020 SME Instrument. The funding is provided under Phase 1 of the instrument, which means that each project will receive €50,000 to finance feasibility studies for new products that can disrupt the market. The enterprises can also ask for up to three days of free business coaching.

The 189 SMEs that will receive funds proposed 182 projects in total (multiple SMEs can be involved in one project) and between them will receive €9.1 million in total. Italian SMEs were particularly successful with 34 companies accepted for funding, followed by firms from Spain (30) and the UK (18). Most of the projects funded (29) will be in the area of Information and Communications Technology (ICT), followed by transport and low-carbon energy systems (both 24).

> "...new products than can disrupt the market..."

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For the third cut-off of the SME Instrument Phase 1 this year, EASME received 1,938 project proposals from 40 countries. Since the launch of the programme on 1 January 2014, 1840 SMEs have been selected under Phase 1 of the SME Instrument.

WTSA-16 Gives ITU Impetus to Power Smart 5G Era

The World Telecommunication Standardization Assembly 2016 (WTSA-16) held in Hammamet, Tunisia from 25 October to 3 November, has given further impetus to the International Telecommunication Union (ITU) standardization work aimed at supporting government, industry and academia in achieving their priorities for year 2020 and beyond.

ITU membership has called for ITU's standardization arm to expand its study of the wireline networking innovations required to achieve the ambitious performance targets of smart 5G systems. This call has come in parallel with ITU members' reaffirmation of the importance of ITU's standardization work to drive the coordinated development of ultra-high-speed transport networks, the Internet of Things, future video technologies, and smart cities and communities.

The conference, which takes place every four years, gathered up to 1000 delegates from 92 countries to deliberate on a wide range of standardization topics critical to the next phase of innovation in ICT. The Assembly also reviews the structure and working methods of the ITU Telecommunication Standardization Sector (ITU-T) and elects the teams that will lead ITU-T's expert groups.

"...a range of victories for international collaboration..."

"WTSA-16 has achieved a range of victories for international collaboration," said Moktar Mnakri, Chairman of WTSA-16. "The diverse membership of ITU-T has reached a series of agreements to assist all regions of the world in their efforts to share in the social and economic benefits that will be accelerated by ICTs in coming years."

"The deliberations of WTSA-16 have demonstrated the great spirit of collaboration for which ITU membership is well known," said Chaesub Lee, director of the ITU Telecommunication Standardization Bureau. "Our members have worked tirelessly to reach agreement on the future shape of ITU-T, ensuring that it is fit for purpose to deliver standards capable of providing an equitable basis for ICT innovation worldwide.

Cliff Drubin, Associate Technical Editor

UWB Indoor Location Technology is Finally Ready for Prime Time

Ultra-wideband (UWB) indoor location technology is on the cusp of substantial market growth. ABI Research forecasts that there is huge opportunity for the high-accuracy, low-cost ultra-wideband radio technology in industrial and IoT markets, with total RTLS/asset tracking revenues to reach $15 billion by 2021.

"High-precision UWB technologies are nothing new, with companies like Time Domain, Ubisense and Zebra Technologies being long-established vendors in the RTLS/asset tracking market, says Patrick Connolly, principal analyst at ABI Research. "Though no one ever doubted UWB's accuracy or ability to perform in challenging RF environments, the cost/accuracy trade-off previously limited this technology to very niche applications. But big change is now happening as start-ups invent ways to cost effectively implement the technology without compromising on performance."

A number of companies are predicted to be very disruptive in this space. Decawave remains the biggest influencer, now shipping UWB ICs for less than $15 at scale. This opened the floodgates for a host of start-ups working with the technology for the first time to contend in the market.

"...start-ups invent ways to cost effectively implement the technology without compromising on performance."

Partners Decawave and Quantitec are making significant progress with the likes of Bosch; while Nanotron is a "20-year-old start-up" that offers a well-thought-out embedded location platform. UWINLOC is another new startup that created a semi-passive UWB solution that can ultimately compete on price with passive RFID, while also providing similar benefits to active technology through energy harvesting.

Not only will UWB disrupt the existing market, it will also open up new opportunities around compliance, traceability, fleet management, pallet tracking, staff management, fulfillment and inventory management. The major competitive threat stems from Bluetooth; while it comes with a range of cost/accuracy trade-offs, its major advantage is its easy integration with smartphones and industrial wearables. Companies like Bluvision, Kontakt.io, MIST and Quuppa lead the way in this space.

"It is still very early," concludes Connolly. "But the ability to deliver consistently on the impressive pricing, accuracy, and performance parameters that vendors are touting today will be what really differentiates Bluetooth and UWB technologies from one another."

IoT Partner Programs Expand to Combat Ecosystem Complexity

In its recent analysis ranking more than 450 companies on their IoT service capabilities, ABI Research finds that IoT partner programs and their member companies are evolving their IoT offerings. IoT partner programs are ecosystems of companies focused on assembling end-to-end solutions around a supplier product portfolio. The programs streamline the IoT adoption process by enabling collaboration among hardware, software, and service providers across different technology sectors to deliver comprehensive IoT solutions for enterprises.

"IoT partner programs are critical, as supplier diversity and offer complexity is not lessening and no one company can deliver a complete end-to-end IoT solution," says Ryan Harbison, research analyst at ABI Research. "Over the past year, companies like Dell and Intel continued to grow their programs to target additional verticals like manufacturing and energy. IoT partner programs 'un-fragment' the market for end-users and drive awareness to hardware, software and service providers that combined can deliver an end-to-end IoT solution."

Dell is expanding its partner program ecosystem with its series of IoT gateways, relying on partners like Action Point and Datatrend Technologies. Through a portal, Dell customers can search for the partners that will best fit their needs, based on a variety of metrics like vertical offerings and location. The initial program success is so strong that Dell aims to double its program members by the end of 2016.

"...successful partner programs are the ones striking the right balance between their number of partners and the overall product offering..."

Similarly, Intel's IoT Solution Alliance continues to create interoperable, secure solutions to drive efficiencies and deliver device system performance insights. Program members like Advantech and relayr help Intel differentiate its devices and the value they provide to end users.

Partner programs drive value for parent organizations, like Dell and Intel, by expanding their ecosystem user base through their member company connections. The programs, in turn, drive value for member companies through incremental business opportunities. Finally, enterprises acquiring IoT capabilities enjoy faster time to market and potentially a more integrated solution.

"Today's successful partner programs are the ones striking the right balance between their number of partners and the overall product offering," concludes Harbison. "It is not about having the biggest partner program; it

For More Information Visit mwjournal.com for more commercial market news is about working to forge new alliances with like-minded partners across multiple sectors and consistently delivering valuable IoT services to a broad range of customers. It is about learning how to adapt in the expanding IoT universe."

IoT Gateway Shipments to Exceed 64 Million Units in 2021

IoT gateways, which manage and control complex connected environments by aggregating and transmitting sensor data, as well as translating communication protocols, are on the rise. ABI Research forecasts IoT gateway shipments will grow to exceed 64 million units in 2021. While home automation and security market components will account for well over 50 percent of all IoT gateway shipments over the next five years, it will be the mobility and transportation segments, as well as industrial and infrastructure, which generate the most revenue.

"The home automation and security market relies on gateways for aggregating and orchestrating communications between an increasing variety of home sensors and cloud services," says Dan Shey, managing director and vice president at ABI Research. "However, this segment will only represent around 30 percent of the market's five-year value. This is because gateways in the home do not have the same requirements for ruggedness, antenna design and processor requirements as gateways used in industrial and commercial settings."

The higher priced, albeit lower volume, sectors are mobility and transportation, as well as industrial and infrastructure. IoT gateway opportunities in fleet management are small, but growing. Companies such as Omnitracs, PeopleNet and Sierra Wireless and are offering gateways for multi-application communications in fleet vehicles, such as critical event reporting, fault monitoring, and navigation. The industrial and infrastructure market segment, meanwhile, relies on many traditional markets like smart grid and video surveillance. Looking ahead, this segment will also benefit from new higher growth markets through applications in the smart cities and manufacturing/process industries.

"There are many traditional names that have been serving the M2M/IoT gateway market for years, such as CalAmp, Cisco, Cradlepoint, Digi International, Eurotech and Sierra Wireless," concludes Shey. "But these big name players are just a small share of the total supplier base, which includes both branded and white label vendors. In this growing IoT market, consolidation is not expected anytime soon and suppliers are increasingly turning to software and services to differentiate."

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Qualcomm Inc. and **NXP Semiconductors N.V.** announced a definitive agreement under which Qualcomm will acquire NXP. Pursuant to the agreement, a subsidiary of Qualcomm will commence a tender offer to acquire all of the issued and outstanding common shares of NXP for $110 per share in cash, representing a total enterprise value of approximately $47 billion. NXP is a leader in high-performance, mixed-signal semiconductor electronics, with innovative products and solutions and leadership positions in automotive, broad-based microcontrollers, secure identification, network processing and RF power. As a leading semiconductor solutions supplier to the automotive industry, NXP also has leading positions in automotive infotainment, networking and safety systems.

Analog Devices Inc. announced the acquisition of **Innovasic Inc.**, a leading provider of deterministic Ethernet semiconductor and software solutions. The acquisition adds a suite of multiprotocol industrial Ethernet solutions and key enabling technologies to ADI's Smart Automation Solutions portfolio for industrial automation and Industrial Internet of Things (IoT). With the industrial automation market already transitioning from serial fieldbus to Ethernet connectivity, and with the simultaneous push toward a ubiquitous Industrial IoT, there is a clear need for highly reliable, real-time Ethernet connectivity for sensitive industrial automation applications. The acquisition of Innovasic will give ADI customers immediate access to a set of innovative solutions for today's Industrial Ethernet applications.

Linear Technology has announced that, based on a preliminary vote at their Annual Stockholders Meeting, the merger agreement under which **Analog Devices**, will acquire Linear Technology, has been approved. Stockholders also approved the election of the seven Linear Technology directors that were nominated for election and other proposals relating to the transaction. Approximately 99 percent of voting LLTC stockholders cast their votes in favor of the proposal to approve the merger agreement, representing approximately 79 percent of LLTC's outstanding common stock as of the record date for the Annual Meeting of Stockholders. The final vote results will be reported on a Current Report on Form 8-K that Linear Technology will file with the Securities and Exchange Commission.

Altamira Technologies Corp., a provider of technology solutions to the U.S. Intelligence and Defense Communities, announced its acquisition of **APG Technologies**, a Northern Virginia-based advanced engineering company supporting various customers in the United States DoD, Space, and Intelligence Community (IC). APG supports the DoD, Space and Intelligence Communities in overcoming the complex challenges of today's mission critical information systems and responding to the ever-increasing velocity, variety and volume of data while maintaining focus on the continually expanding complexity of missions. APG transforms data into clear information that enables U.S. national security leaders to act with confidence.

COLLABORATIONS

NI announced a collaboration with **DARPA** to supply core infrastructure for a path-breaking channel emulation testbed, called Colosseum, which will play a central role in the DARPA Spectrum Collaboration Challenge. NI will provide USRP software defined radios (SDR) that support a wide variety of open source and proprietary tool flows including GNU Radio, RFNoC and LabVIEW system design software. The Colosseum channel emulation testbed supports up to 256×256-channel, real-time channel emulation, calculating more than 65,000 channel interactions at up to 80 MHz of real-time bandwidth per channel.

Airbus Defence and Space and **Orbital ATK** have been selected by Eutelsat to partner to build the company's latest video satellite, EUTELSAT 5 West B. According to the terms of the contract signed between the three companies, Airbus Defence and Space will lead the team and be co-prime contractor with Orbital ATK for the development and construction of EUTELSAT 5 West B. Airbus Defence and Space will provide the communications payload operating in Ku-Band and the satellite will be based on Orbital ATK's GEOStar platform. Scheduled for launch in 2018, EUTELSAT 5 West B will have a launch mass of around three tonnes and 5 kW of power.

Analog Devices Inc. and **Dell EMC** unveiled a proof of concept (POC) for an Internet of Things (IoT) solution that tracks the health and location of first responders. The POC IoT solution is designed to improve the safety and effectiveness of first responders when involved in an emergency situation, especially those in harsh environments. According to the National Fire Protection Association, more than 60,000 fire fighter injuries in North America alone are reported annually, of which 25 percent are as a result of overexertion or strain. The POC IoT solution tracks the location and vital signs of first responders at all times in or outside of buildings.

ACHIEVEMENTS

Anritsu Co. announced it has earned the 2016 Global Product Line Strategy Award—Manufacturing Test Software for IoT from Frost & Sullivan. In making the announcement, Frost & Sullivan stated that newly released software packages from Anritsu uniquely position the company's Universal Wireless Test Set MT8870A as an all-in-one instrument with unmatched solutions that support a wide range of wireless technologies to conduct high-volume production tests on IoT devices. In its report, Frost & Sullivan stated that Anritsu enjoys a prominent position in the global wireless manufacturing test and measurement equipment market, capitalizing on its extensive breadth of software packages supporting manufacturing tests for IoT devices.

The National Science Foundation (NSF) has announced 11 awards, worth a total of $12 million, to support activities aimed at enhancing the public's access to the radio frequency spectrum i.e., the part of the electromagnetic spectrum used

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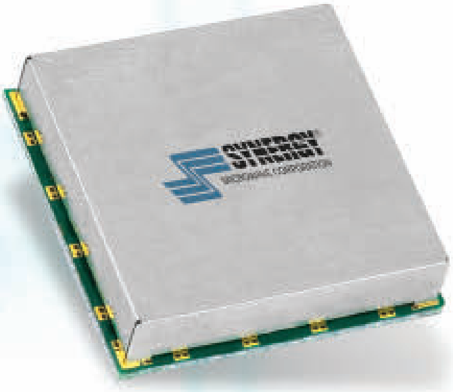

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HFSO745R84-5	745.84	0.5 - 12	+5 VDC @ 35 mA	-147
HFSO776R82-5	776.82	0.5 - 12	+5 VDC @ 35 mA	-146
HFSO800-5	800	0.5 - 12	+5 VDC @ 20 mA	-146
HFSO800-5H	800	0.5 - 12	+5 VDC @ 20 mA	-144
HFSO800-5L	800	0.5 - 12	+5 VDC @ 20 mA	-142
HFSO914R8-5	914.8	0.5 - 12	+5 VDC @ 35 mA	-139
HFSO1000-5	1000	0.5 - 12	+5 VDC @ 35 mA	-141
HFSO1000-5L	1000	0.5 - 12	+5 VDC @ 35 mA	-138
HFSO1600-5	1600	0.5 - 12	+5 VDC @ 100 mA	-137
HFSO1600-5L	1600	0.5 - 12	+5 VDC @ 100 mA	-133
HFSO2000-5	2000	0.5 - 12	+5 VDC @ 100 mA	-137

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to facilitate telecommunications and modern information systems essential for public safety, transportation and national defense. The research activities supported by these awards represent bold new approaches with the potential to contribute to improvements in the efficiency of radio spectrum utilization while protecting passive sensing services, and allowing traditionally underserved Americans to benefit from current and future wireless-enabled goods and services.

Doodle Labs announced global regulatory approvals of its embedded Industrial Wi-Fi product portfolio. The transceivers have been certified as fully compliant for the U.S. (FCC), Canada (IC) and Europe (ETSI) as DFS Master and Client devices. While Doodle Labs' technology is known for its flexibility and customizability, these certifications provide customers with a streamlined path to release and deploy standardized, government-approved products. Doodle Labs' Industrial Wi-Fi product portfolio has been designed to provide customers with the industry's best-in-class performance, particularly those addressing challenging applications.

Fractal Antenna Systems has been issued a patent for a fundamentally new approach to power gathering and transport, as well as heat transfer, with the innovation of metamaterials based on fractal geometry. They were issued U.S. patent 9,482,474, entitled "Radiative Transfer and Power Control with Fractal Metamaterial and Plasmonics." Fractal metamaterials are collections of detached resonators, themselves intricate structures made from repeated and scaled designs. Each fractal resonator lies close to another, collecting and transferring its energy along with adjacent ones, without actual physical connection. The process happens at the speed of light and is a man-made form of 'radiative transfer'.

CONTRACTS

CACI International Inc. announced it has been awarded a prime position on a five-year, multiple-award, indefinite delivery/indefinite quantity contract with a $900 million ceiling value to continue providing services in program management, engineering and technical support, and professional services for the **U.S. Special Operations Command** (SOCOM) on the SOCOM-Wide Mission Support (SWMS) program. The contract spans several CACI market areas, enabling the company to provide a wide range of mission-essential solutions and services to Special Operations Forces (SOF). SOCOM synchronizes the planning of special operations and provides SOF to support persistent, networked and distributed Global Combatant Command operations in order to protect and advance our nation's interests.

The Naval Sea Systems Command awarded **Science Applications International Corp.** a contract to manufacture MK 48 Mod 7 heavyweight torpedo afterbody/tailcone sections. The work to be performed will increase the quantity of the MK 48 Mod 7 heavyweight torpedoes for operational use. The contract has a 27-month base period of performance from award to final acceptance and includes options for the procurement of spares, production support material, engineering services, test equipment design and manufacturing, and hardware repair services. If all options are exercised, the total contract value will be more than $383 million with an expected completion date of January 2020. Work will be performed in Bedford, Ind.; Marion, Mass.; Middletown, R.I. and Indianapolis, Ind.

BAE Systems has been awarded a **U.S. Army** contract modification valued at $146.5 million to construct and commission a new facility that will increase the capacity for producing insensitive munitions at the Holston Army Ammunition Plant in Kingsport, Tenn. The project to build the Insensitive Munitions Weak Nitric Acid Recovery Facility is a major part of a multi-year effort to increase the production capacity of Insensitive Munition eXplosives (IMX), which are designed to be robust but more stable and safer to handle than conventional munitions. The plant, operated by BAE Systems, produces a wide range of explosive formulations for multiple applications to support the military, as well as commercial mining and oil operations.

Engility Holdings Inc. announced it was awarded a $71 million contract by the **Naval Air Warfare Center Aircraft Division** (NAWCAD) to deliver systems engineering on U.S. naval aircraft and weapons systems. NAWCAD is responsible for advancing research and development, engineering, and test and evaluation of all Navy and Marine Corps air vehicle systems. As part of the contract, Engility will assess the technical performance, suitability and risks of aircraft, weapon and integrated systems. The team will perform systems engineering, analysis, development, integration and testing for the introduction of warfare systems into naval aircraft.

Harris Corp. has received a four-year, $55 million contract to perform sustainment work on the electronic warfare system used by the **U.S. Air Force** to protect B-52s and C-130s from radar-guided threats. The contract was received during the first quarter of Harris' fiscal 2017. Harris will redesign one of the ALQ-172's Line Replaceable Units (LRU-1) as part of wider efforts to increase the electronic warfare suite's reliability and supportability. In addition to a new LRU design, Harris will develop software, support customer testing and other solutions for the U.S. Air Force.

The **U.S. Air Force Research Laboratory** and the **Office of the Secretary of Defense** have awarded **Raytheon** a $14.9 million contract to further enhance its process for producing gallium nitride-based semiconductors. The new agreement follows a previous GaN Title III contract, completed in 2013, and aims to increase the performance, yield and reliability of Raytheon GaN-based, wideband, monolithic, microwave-integrated circuits and circulator components. Gallium Nitride (GaN) is a semiconductor material that can efficiently amplify high power RF signals at microwave frequencies thereby enhancing a system's range, while reducing size, weight, power consumption and cost.

Mercury Systems Inc. announced it received a $6.3 million follow-on order from a leading defense prime contractor for microwave transceivers for a precision guided munitions application. The order was booked in the company's fiscal 2017 first quarter and is expected to be shipped over the next several quarters.

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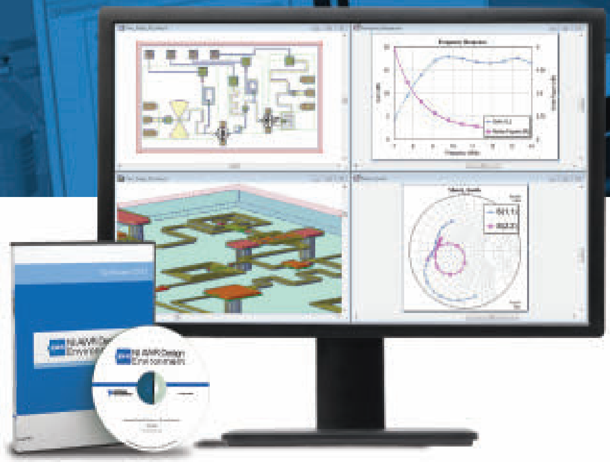

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Around the **Circuit**

PAR Technology Corp. announced that its subsidiary, **Rome Research Corp.** (RRC), has been awarded a $5.2 million subcontract from **Delta Solutions & Strategies LLC** of Colorado Springs, Colo. to provide operation and maintenance of the USAF Air Combat Command (ACC) High Frequency Global Communication System – Puerto Rico Station (HFGCS-PRS). HFGCS-PRS is one of 13 worldwide high powered, high frequency stations that make up the USAF's Command and Control (C2) network.

Comtech Telecommunications Corp. announced that its Tempe, Ariz.-based subsidiary, **Comtech EF Data Corp.**, which is part of Comtech's Commercial Solutions segment, received a $1.2 million equipment order from **General Dynamics Mission Systems—Canada** in support of the Canadian Armed Forces (CAF) Mercury Global project. This is the initial order of Comtech EF Data's DMD2050E WGS-certified Universal Satellite Modem to support General Dynamics Mission Systems—Canada's implementation and In-Service Support of the Mercury Global Anchor Segment. The DMD2050E complies with MIL-STD-188-165A and NATO standard STANAG-4486, Edition 3 Super High Frequency (SHF) Military Satellite Communications (MILSATCOM) Frequency Division Multiple Access (FDMA) Modem.

Thales Alenia Space has signed a contract with the **Korea Aerospace Research Institute** (KARI) to supply a satellite navigation system known as the Korea Augmentation Satellite System (KASS). KARI, on behalf of the South Korean Ministry of Land, Infrastructure and Transport (MOLIT), will receive the KASS System relying on the European Geostationary Navigation Overlay System (EGNOS) developed by Thales Alenia Space as prime contractor for the European Commission, with ESA as the contracting authority. The EGNOS system has been operating in Europe since 2009 for Safety of Life (SoL) services.

The Royal Malaysian Navy (RMN) has selected the **Terma** SCANTER 6000 radar as the combined navigation and helicopter control radar for its two Lekiu-class frigates mid-life modernization and service life extension. The SCANTER 6000 is a coherent X-Band 2D solid state radar that has been specifically designed as an affordable all-weather sensor solution to plug the gap between standard marine navigation radars and more expensive military surveillance radar systems. It is very versatile, and has the capability to control aircraft and increase tactical options and safety.

PEOPLE

▲ *Vincent E. Pelliccia*

Anokiwave Inc., an innovative company providing highly integrated IC solutions for mmWave markets and active antenna based solutions, announced the appointment of **Vincent E. Pelliccia** as vice president, business development. This appointment comes at a strategic time for Anokiwave with tremendous opportunities to grow its business into the rapidly developing mmWave 5G, radar, sat-

Innovation Amplified.

Mercury Systems offers gallium nitride (GaN) power amplifiers from 100 MHz to 40 GHz with power to 4 kW.

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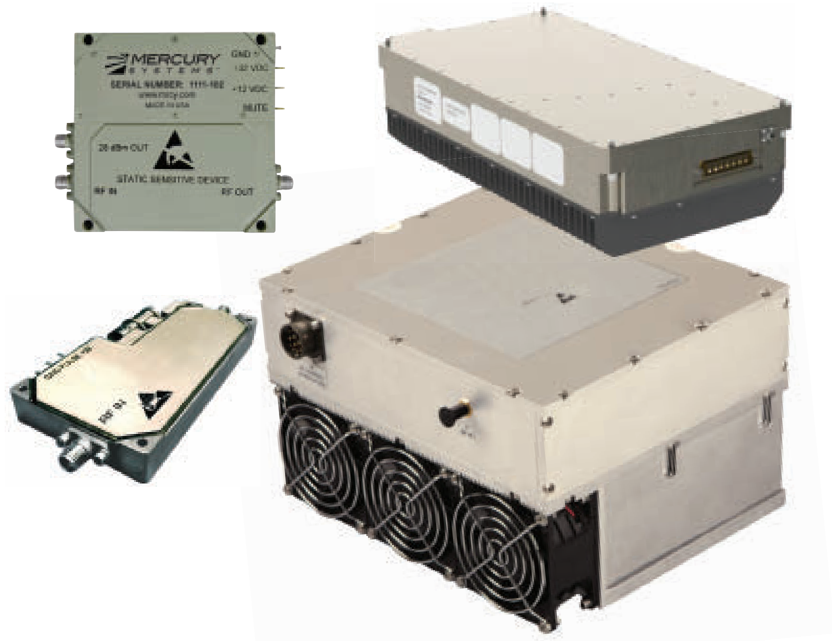
- High-power linear amplifiers for communication systems
- All of our amplifiers are designed and manufactured in the USA



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Learn more and download our amplifier brochure at mrcy.com/amplifier com and stratellite markets. Pelliccia joined Anokiwave in March 2016, and brings 30 years of industry experience starting with E-Systems designing Null Steered Phased Arrays and then at M/A-COM working on Ku-Band VSAT and LMDS systems.

The board of **Resonant Inc.** appointed **Jeff Killian** as chief financial officer (CFO), effective October 24, 2016. Killian will succeed Ross Goolsby, who has been serving as the interim CFO of the filter start-up. Killian has almost 30 years of relevant financial, filter and semiconductor industry experience. He was CFO at Cascade Microtech since 2010. During his eight years at Cascade, company revenue grew from $77 million to $144 million, with an attendant market cap from $25 million to $258 million. Cascade was acquired by FormFactor in 2016. Prior to Cascade, Killian was at TriQuint Semiconductor, where he held several roles over 11 years, including director of financial planning and analysis.


▲ *Rainer Lorger and Oliver Herzberger*

Quintech Electronics & Communications Inc. and **DEV Systemtechnik** announced the promotions of **Rainer Lorger** and **Oliver Herzberger** each to the position of co-managing director for DEV Systemtechnik. Together, they will guide the company, with Lorger focusing on administrative and sales functions, while Herzberger will head up the engineering and technology responsibilities. Herzberger has been with DEV since 1998 and Lorger joined in 2009. The co-managing directors possess a familiar and focused understanding of the goals and direction of the company and will provide the leadership necessary to serve and grow the satellite and telecommunications industry businesses of DEV Systemtechnik.


▲ *Jingya Huang*

Indium Corp. announced that **Jingya Huang** has joined the company as marketing communications assistant manager. Huang is responsible for creating and managing promotional and branding activities that support the company's worldwide sales and marketing programs. She manages Indium Corp.'s global trade show program, internal communications, social media and the expansion of its web presence. Huang has several years of experience in advertising, marketing and communications. In her last position, she focused on digital marketing for Chinese markets. Huang has also worked as an account planner at a full-service advertising agency, where she performed strategic planning, market research, project management and sales support.

REP APPOINTMENTS

Agile Microwave Technology Inc., a product innovator in RF and microwave component and sub-system market announced the appointment of **TriLight MICROWAVE AB** as its sales representative in the UK and Russia. TriLight MICROWAVE is a sales representative and distribution company focused on RF components for radar,

10 MHz Rubidium Frequency Standard

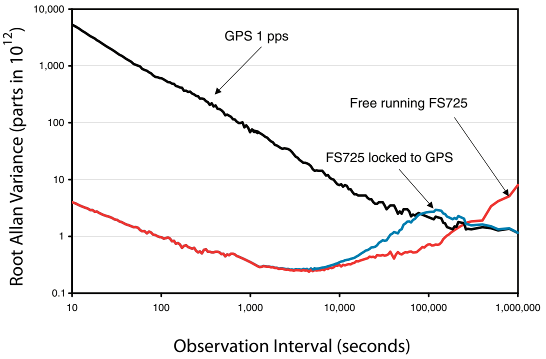
- ***5 MHz and 10 MHz outputs***
- ***Ultra-low phase noise (<–130 dBc/Hz at 10 Hz)***
- ***0.005 ppm aging over 20 years***
- ***Built-in distribution amplifier (up to 22 outputs)***
- ***1 pps input and output***

The FS725 Benchtop Rubidium Frequency Standard is ideal for metrology labs, R&D facilities, or anywhere a precision frequency standard is required.

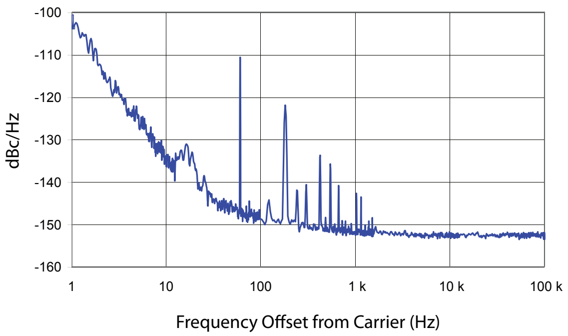
It has excellent aging characteristics, extremely low phase noise, and outstanding reliability. A 1 pps input is provided for phase-locking to GPS, providing Stratum 1 performance.

With a built-in 5 MHz and 10 MHz distribution amplifier, the FS725 is the ultimate laboratory frequency standard.

Allan Variance vs. Time



FS725 Single Sideband Phase Noise



FS725 rear panel

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avionics, EW, military defense, space and oil exploration markets. Teamed with Agile MwT factory sales engineers, TriLight MICROWAVE AB will provide sales and technical support to RF and microwave product designers and manufacturers.

Bliley Technologies has signed a distribution agreement with **Avnet**. Effective immediately, Avnet will offer a broad lineup of standard and custom crystal oscillators, precision AT, SC, IT and FC cut crystals, piezoelectric transducers and GPS disciplined modules from Bliley Technologies to customers in the Americas through its broadline components Electronics Marketing group and Avnet USI, Avnet's defense/aerospace specialty distribution business unit. Bliley Technologies provides quality frequency generation solutions for SATCOM/space, defense/aerospace electronics, wired and wireless communication, industrial and medical instrumentation and consumer electronics. The company is among a select few vertically integrated manufacturers in the U.S. designing and manufacturing both crystals and oscillators in a single facility.

Richardson RFPD will distribute **Tagore Technology Inc.'s** portfolio of high-power RF switches to customers worldwide. Tagore Technology has developed innovative switch products using proprietary technology that significantly reduces total board area. These switches handle 1 W to 50+ W CW input RF power and operate from 10 MHz to 6 GHz. They are available in SPDT, SP3T and SP4T configurations. Compared to traditional PIN diode solutions, Tagore's switches offer lower power consumption, with current draw in microamps instead of milliamps. These fully-integrated switches operate from 2.7 V and do not require external negative voltages or external passive components.

PLACES

Ampleon announced the opening of its RF Energy Competence Center in Hefei, PRC. The company is recognized as a leader in the RF Energy market and continues to invest in the emerging use of this technology. While RF energy covers a broad range of applications (domestic and professional cooking, heating and drying, ignition and lighting), the new competence center's current focus is on solid-state cooking. Key to the success of solid-state cooking in both consumer and professional applications is providing white goods manufacturers with local integration and application support. Ampleon closely works with leading companies in this market, having their design and production sites in China.

EnSilica has further expanded its network of specialist design centers with the establishment of a new facility near Oxford, UK, focusing on RF and low power sensing applications. The new design centre will be headed by Alan Wong, formerly the IC design director at Frontier Microsystems, who joins EnSilica with immediate effect as director of RF IC Design. Wong brings with him a design team whose pioneering experience in ultra-low power RF and sensor interfaces significantly extends EnSilica's skills-base in addressing the needs of wireless connected IoT and wearable products.

INVITED PAPER

Advances in RF Energy for Medical Applications

Franck Nicholls and Jose Fernandez Villasenor, M.D.
NXP Semiconductors, Chandler, Ariz.

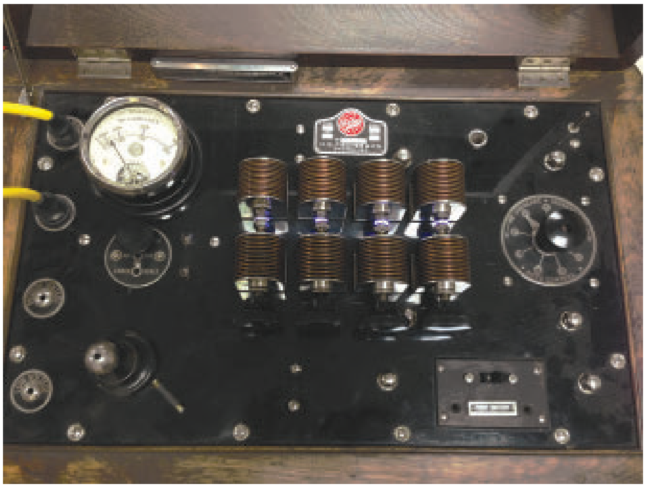
The benefits of electromagnetic energy for treating medical conditions have been recognized since the late 19th century. Today, although probably only magnetic residence imaging (MRI) is familiar to most people, many other medical applications exploit its unique abilities. They include reducing the size of tumors, aiding cardiac surgery, rejuvenating skin and treating muscular conditions. Medical systems based on RF energy are continually advancing, thanks in large measure to the transition from vacuum tubes to solid-state. Semiconductor devices such as LDMOS bring flexibility, enable advanced modes of operation and offer advantages at microwave frequencies.

SPARK OF INSPIRATION

The benefits of RF energy in almost all medical applications are gained from heat generated by some form of RF generator. Although the first recorded evidence of heat from any source used for medical purposes dates to prehistoric times, when heated rocks were used to reduce or stop blood flow (hemostasis), it was the prodigious inventor and scientist Nicola Tesla who first proposed, in 1891, that the application of electricity could produce heat in a human body. This was dangerous territory, as electricity caused electric shock. Shortly after Tesla's results were presented, French physician and biophysicist Jacques Arsene d'Arsonval discovered that when the frequency of this energy was above 10 kHz, rather than shocking the patient, it caused the skin to heat. He proposed ways of applying this "high frequency" current to the body using contact electrodes, capacitive plates and inductive coils.

The use of RF energy to heat deep tissue was first suggested by Austrian chemist R. von Zaynek, who noted that production of heat in tissue was a function of both frequency and current density. In 1908, German physicist Karl Franz Nagelschmidt coined the name "diathermy" for this, during what were the first extensive experiments on humans. Nagelschmidt is considered to be the pioneer in the field, writing the first textbook on the subject in 1913. Important developments in later years included those of Harvey Cushing and William T. Bovie, in which an electrosurgical device developed by Bovie was used to cause homeostasis during the resection of a vascular brain tumor.

The initial use of RF energy for diathermy was impeded by the lack of devices to generate it, as spark-discharge Tesla coil machines could reach frequencies of only 2 MHz. This type of diathermy was called longwave diathermy, because of the long wavelengths at these frequencies. The invention that broke this logjam was the vacuum tube, revealed in 1904 by John Ambrose Fleming, which ultimately increased the frequency to about 300 MHz (see ***Figure 1***).



▲ *Fig. 1 A Fischer diathermy machine, circa 1920.*

TABLE 1

ADVANTAGES OF LDMOS FOR MEDICAL

LDMOS vs. Vacuum Tubes	LDMOS vs. BJT and VMOS
• Flexibility: greater control of power, frequency and phase because of low voltage power supply • Consistency: small part-to-part variation • Reliability: greater lifetime with no performance degradation over time	• Performance above 100 MHz • Extremely rugged • No carcinogenic BeO in packages

Diathermy machines operating at this frequency were called shortwave diathermy. Like many RF and microwave technologies, the advancement of vacuum tube technology dramatically accelerated during the world wars, and new types of vacuum electron devices were created. The most noteworthy was the magnetron, which made it possible for emerging radar systems to generate high power at higher frequencies. One of the beneficiaries of the magnetron has been the medical profession, and many of the initial applications are still in use today and still use magnetrons for generating RF energy.

Like vacuum tubes before them, transistors further extended the reach of RF energy medicine. The earliest examples of transistor-based power generation appeared in the 1950s, although these devices generated minimal power and were extremely fragile. As their limitations were mitigated in subsequent years, semiconductor technologies such as the bipolar junction transistor (BJT) and vertical metal oxide semiconductor (VMOS) transistor were adopted for medical devices. Today, laterally-diffused metal oxide semiconductor (LDMOS) power transistors are proving to be the preferred solid-state technology, producing power levels up to 1500 W. LDMOS transistors have advantages that make them well suited to be the alternative to their vacuum tube and transistor predecessors (see ***Table 1***).

The primary benefit transistors have over vacuum tubes for medical applications is flexibility. The output power can be tightly controlled over their full dynamic range, which enables heat transferred to human tissues to be reduced when required. They support sweeping frequencies within an ISM band (from 902 to 928 MHz, for example), which helps to maximize the energy transferred to the body. For advanced systems that use multiple probes to combine wave fronts, the phase can be controlled to move the areas that must be targeted. While vacuum tubes require potentially dangerous high voltages, generated by large and heavy power supplies, transistors operate at 32 to 50 V_{DC}. The biggest advantages of LDMOS transistors over previous semiconductor technologies are their ability to operate at higher frequency, such as 915 and 2450 MHz, and ruggedness. LDMOS power transistors will survive when almost all the transmitted energy is reflected back, because of an impedance mismatch such as a short or open circuit. This is important in medical applications because human tissue can present a variable load to the probe.

Originally, the capabilities of available RF power sources determined the frequencies where electromagnetic energy-based systems were used. The first operating frequencies were very low, with both frequency and

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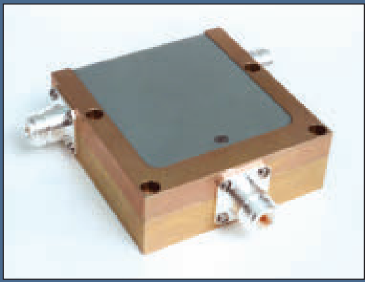
100 MHz
to 20 GHz



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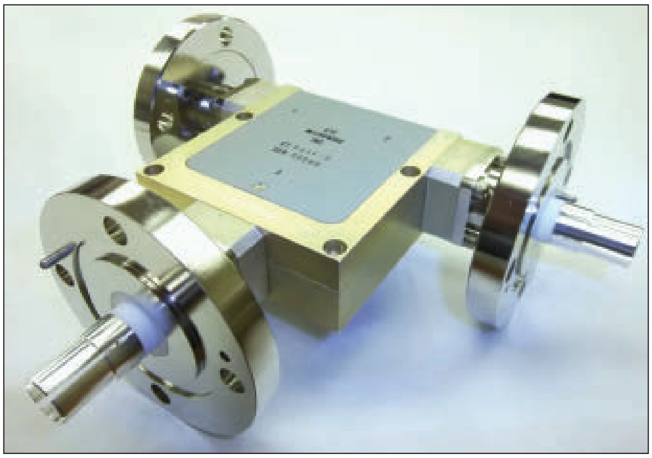
325 MHz NEW HIGH POWER Circulator for Radar & UHF Frequencies



Model CT-1864-S is rated at 60kW peak and 600W average power at 325 MHz. The unit provides 20 dB minimum isolation, 0.2 dB insertion loss and 1.20:1 maximum VSWR. Its extremely compact design has flange to flange insertion length of only 6-3/4" and a height of 5-1/4". For use in radar applications, it has 1-5/8" EIA connectors. It is also available at other UHF frequencies and connector types.

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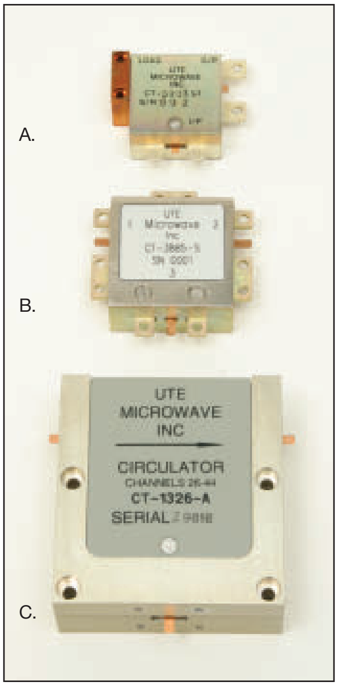
B) 1.2–1.4 GHZ 3 kW pk, 300 W av

C) UHF TV Band 5 kW pk, 500 W av



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Model No.	Power	Connectors	Freq. Range
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CT-3877-S	2.5 Kw Pk 250 W Av	"Drop-in"	2.7–3.1 GHz
CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
CT-1645-N	250 W Satcom	N Conn.	240–320 MHz
CT-1739-D	20 Kw Pk 1 Kw Av	DIN 7/16	128 MHz Medical

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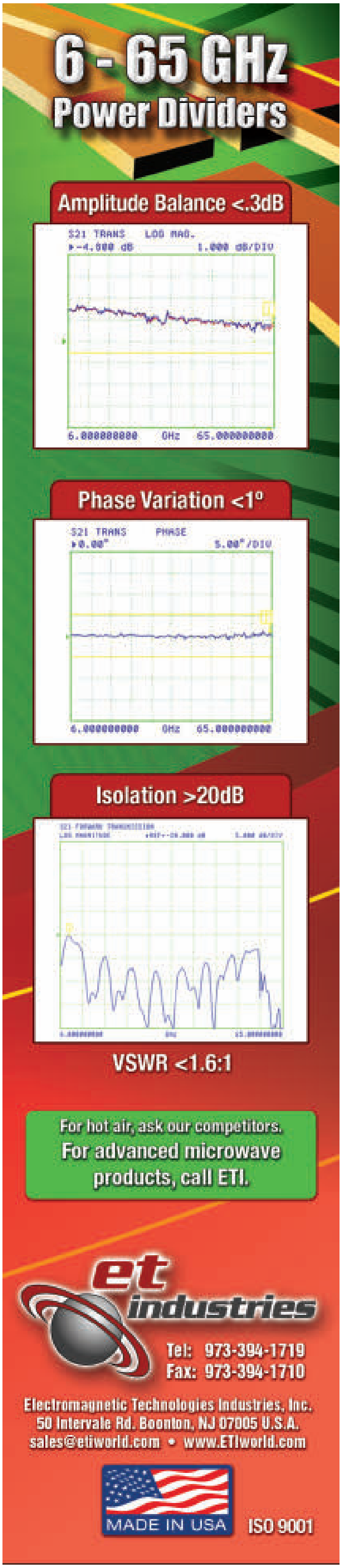


TABLE 2

ISM FREQUENCIES FOR MEDICAL APPLICATIONS

	ISM Band (MHz)				
	13.56	27.12	40.68	915	2450
	High Frequency (HF)			Microwave	
Diathermy	✗	✗	✗	✗	✗
Skin Rejuvenation	✗	✗	✗		Emerging
Ablation	✗			✗	✗

output power increasing over time. However, as medical, scientific and industrial systems began to proliferate, it became necessary to specify areas of the electromagnetic spectrum for operation. These industrial, scientific and medical (ISM) bands for the U.S. are shown in ***Table 2***, and are widely accepted throughout the world. Some countries use additional frequencies. Many other systems operate in these same bands, including Wi-Fi, Bluetooth, microwave ovens and RF-based industrial equipment. With ISM bands unregulated, equipment must prevent or tolerate interference generated by nearby applications.

RF HEATING OF TISSUE

With the exception of MRI—which uses an intense electromagnetic field for imaging, not heating—all medical applications use RF to create heat. The electromagnetic field applied at high frequencies forces the water dipole to move with every cycle, creating friction between the molecules and generating heat. The frequencies at which this heat is generated and the hardware used to apply the heat largely determine the utility for specific medical uses. Generalizing about the use of electromagnetic energy for medical applications:

- Changes in tissue occurring at the molecular level differ with frequency
- Lower frequencies penetrate deeper into the skin than higher frequencies
- Lower frequencies penetrate fewer types of tissue than microwave frequencies
- Systems operating at microwave frequencies can more precisely direct energy to specific areas
- Medical systems operating at lower frequencies have been in use far longer than microwave-based systems that operate above 900 MHz
- The advantages of systems operating at microwave frequencies are gaining importance and becoming more thoroughly understood.

After the early efforts by Tesla and others suggested an interaction between radiated electromagnetic energy and the human body, the mechanism was further clarified and extended to all non-conducting materials. It was shown that the depth of penetration is determined by the frequency of the radiation and the insulating properties of the material. When microwave generators became available, it was demonstrated that because of their short wavelengths, specific areas could be targeted precisely. Greater penetration at lower frequencies (to about 2 inches) makes lower frequencies desirable for applications such as diathermy, in which the goal is often to soothe aching muscles. Microwave frequencies offer benefits such as faster heat delivery, more precise targeting of specific areas (a tumor, for example) and more accurate control.

At low frequencies, the electromagnetic field is generated between two or more electrodes, the shape dictating the characteristics of the field. The most common types of electrodes are rods and plates, between which the target material is placed. With increasing electrode distance, the voltage to maintain the electric field strength also increases, and the maximum distance between the electrodes and, thus, the maximum thickness of the target material is determined. When microwave frequencies are used, the energy is launched from a small emitter and guided through space to the target; a set of plates, used with lower frequency applications, is not required.

Arguably, there are dozens of medical applications that use RF energy, either alone or in combination with light or a laser at various wavelengths.

However, they generally fall into the following categories: MRI, diathermy, ablation and skin rejuvenation. MRI will not be discussed, because its benefits are not derived from heat.

▲ *Fig. 2 Microwave diathermy treatment.*

DIATHERMY

As the first treatment to use electromagnetic energy, diathermy has a long-established track record of effectiveness, and its use has expanded dramatically over the years. Today, diathermy either applies heat directly to the skin (shortwave diathermy) or heats it using a probe situated a short distance from the body that directs energy to the skin (microwave diathermy). Shortwave diathermy operates at 13, 27 or 40 MHz, and microwave diathermy operates at either 915 or 2450 MHz. Although vacuum tubes have long been used as the RF power source for both shortwave and microwave diathermy, LDMOS power transistors are replacing them, due to their longevity; precise control of power level, frequency and phase; simpler control mechanisms; smaller amplifier size and lower operating voltage (see Table 1).

Shortwave diathermy employs either two plates, placed on either side of the area of the body to be treated, or induction coils, molded to fit the body or wrapped around a limb. As the high frequency waves travel through the body tissues between the plates or coils, they generate heat. The degree of heat and depth of penetration partially depend on the absorptive and resistance properties of the tissues that the waves encounter. Shortwave diathermy is most effective for treating pain caused by sinusitis, kidney stones and pelvic infections, as well as conditions that cause muscle spasms.

Microwave diathermy is very effective for evenly warming tissues without heating the skin. Unlike shortwave diathermy, microwave diathermy does not apply heat directly to the body, rather beams RF energy into it from a probe to generate heat within the targeted tissues (see ***Figure 2***). As it cannot penetrate deep into muscles, the primary applications are for areas closer to the skin, such as shoulders. The probe focuses the RF energy field directly on the targeted tissue in a more concentrated area than shortwave diathermy. Absorption of the energy causes heating in the tissues, deeper than infrared treatments but not as deep as shortwave diathermy.

As heat increases, so does blood flow, which can improve flexibility in joints and connective tissue. As pain and inflammation are reduced, arthritis sufferers can increase the range of motion. Other applications include treatment of sprains, strains, lesions, degenerative joint disease, rheumatoid arthritis, stiffness in the joints, hematoma, bursitis, synovitis, infected surgical incisions, carbuncles and abscesses. Diathermy can be used for surgical procedures, where a probe is applied to a blood vessel to cause the blood to coagulate, cauterizing the area. It is also effective in removing tumors in cases where traditional surgical techniques are impractical, such as the prostate, bladder, cervix, brain, ovaries, bowels and tonsils.

ABLATION

Ablation, in medical terms, applies to any technique (including surgery) that destroys tissue for a specific beneficial purpose. Two types of ablation systems use RF energy: RF ablation typically operates between 450 and 500 kHz and microwave ablation operates at either 915 or 2450 MHz. RF and microwave ablation are principally employed for heart surgery and tumor reduction and removal. Increasingly, they are considered a first-line treatment. RF ablation is the most widely used technique, while microwave ablation treatment is growing as studies

show where its operating frequency provides unique benefits. The ablation procedure is typically guided by images generated by MRI, computed tomography (CT) or ultrasound, enabling the surgeon to precisely address a specific location with the ablation electrode. The electric current produced by the RF power source causes tissue heating around the probe at temperatures high enough to cause tissue death.

There are two types of RF ablation: monopolar and bipolar. In monopolar RF ablation, a single group of electrodes delivers energy at the tumor site using a ground pad to complete the circuit through the body. The pad, which acts as a return path for the RF current, is generally located on the patient's thighs or back. Bipolar RF ablation allows current to flow between multiple groups of electrodes and does not require the use of grounding pads.

The procedure is performed by inserting the probe into the target tissue to be destroyed. Tissue is heated by applying current between the probe and the ground pad or other electrodes. To ensure that tissue heating occurs only where desired, some parts of the probe may be insulated. Cell death depends on temperature and application time, ranging from a few minutes to kill cells at 50°C and just a few seconds at higher temperatures.

In many cases, microwave ablation has advantages over its low frequency counterpart. Molecules continuously realign as the microwave energy field oscillates, which increases kinetic energy and tissue temperature. Because of its small wavelength, the amount of energy delivered around the probe is denser and makes the procedure faster. Unlike lower frequency currents, energy at microwave frequencies can permeate all biological tissues, including bone and lungs that resist electric current. Consequently, microwave ablation generates a greater volume of energy around the probe, expanding the ablation zone and potentially reducing the number of required applications. The design of the microwave probe is a major determinant of the shape and size of the ablation zone. Researchers have produced many types of probes with varying degrees of effectiveness at controlling the transfer of RF energy. More than one probe can be used to create a larger ablation zone that precisely conforms to the target area. The phase of the signal at each probe can be varied to create zones of constructive and destructive wave interaction, yielding a positive effect on the results.

The benefits of microwave ablation versus RF include reduced application time (as little as a few minutes), higher temperatures, reduced sensitivity to various types of tissue, reduced need to reposition the probe and the ability to treat tumor types where RF ablation cannot be used.

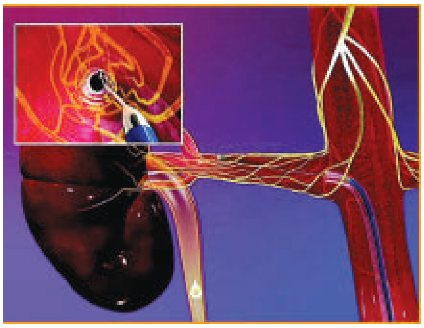
Another use of ablation is renal denervation (see ***Figure 3***), the subject of research for its potential to treat hypertension in patients for whom medication and other traditional remedies are not effective. It is a minimally-invasive procedure that reduces blood pressure by ablating the renal nerves. A small catheter is placed in the femoral artery, which provides ac-

cess to the nerves serving the renal artery. The nerves are ablated by passing electromagnetic energy into the artery through the catheter tip placed in the kidneys. The energy is transmitted through the vessel wall to damage the renal nerves.

SKIN REJUVENATION

Many techniques that fall within the broad term of cosmetic therapy (also called esthetic therapy) employ RF energy, either alone or in combination with a laser or other source of light (see ***Figure 4***). Optical energy has been used for many years for treating dermatologic problems, sometimes combining lasers and intense pulse light (IPL) for epilation, removal of vascular and pigmented lesions, reduction of fine wrinkles and acne treatment. In most cases, the laser's power is generated by an RF source; power levels of several kilowatts at a frequency of 100 MHz create a plasma in a chamber, from which the laser light is extracted.

The limitations of optical techniques caused researchers to investigate the use of RF energy, which has become very popular. RF treatments rely on the tissue's electrical properties rather than on the concentration of molecules in the skin for thermal destruction. RF technology transfers energy to the skin at relatively low



▲ *Fig. 3 Microwave ablation used for renal denervation.*

▲ *Fig. 4 Before (a) and after (b) skin rejuvenation using RF energy.*

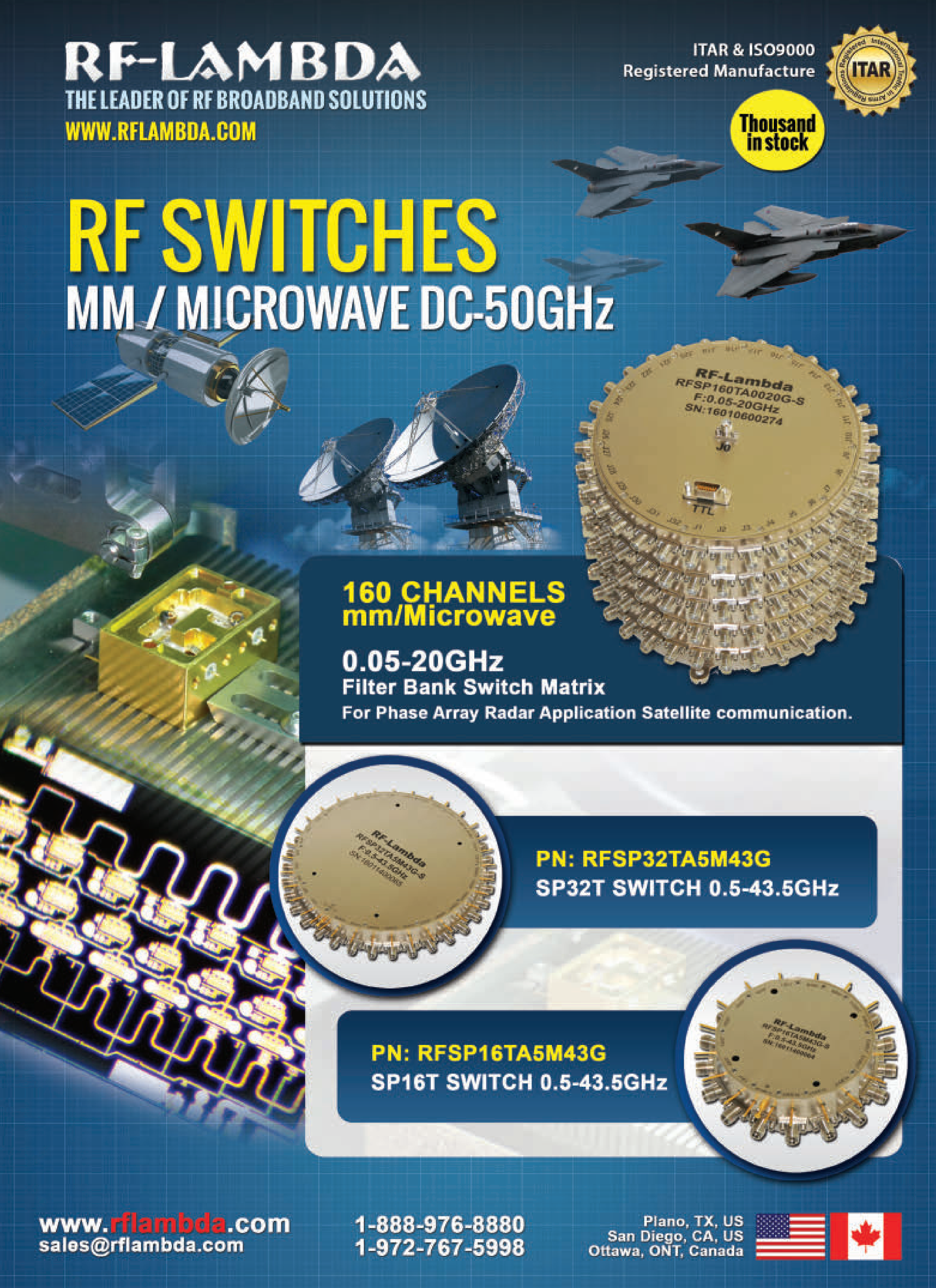
temperatures, so it is well suited for acting on dermal collagen without affecting the epidermis, which enables more effective wound healing and provides effective skin rejuvenation in a short time (see ***Figure 5***). As it does not affect epidermal melanin, patients of all skin types can be treated, including those with darker skin and those prone to developing post-inflammatory hyperpigmentation.

There are several approaches to RF-based treatments: Monopolar RF applies a single electrode tip to the target area, and another plate serves as a ground pad. Bipolar RF targets tissue using two points on the tip of a single probe, and tripolar RF employs multiple electrodes to heat both shallow and deep layers of the skin at the same time. A relatively new technique, called fractional RF, uses a very thin, needle-type electrode that can service multiple zones of tissue without affecting the epidermis and adnexa, which results in faster healing. Another approach, called unipolar RF, works without delivering current to the skin. Rather, it uses energy to induce rotational oscillations in water molecules, targeting the reticular dermis and subcutaneous junction, in contrast to the bipolar technique that affects the papillary and mid-level dermis.

One skin rejuvenation application can reduce or eliminate telangiectasia (commonly called varicose veins), a skin condition that can be benign or a symptom of underlying and sometimes serious illness. Often referred to as spider veins owing to its web-like appearance, it is recognized by tiny blood vessels that cause a threadlike appearance on the skin and can form in clusters. Studies show that RF and possibly microwave ablation can reduce the plaques typical of this disease, using lower temperatures and with fewer side effects. The technique called VNUS Closure, introduced by VNUS Medical Technologies in 1998, is a similar approach that uses an injected saline solution to numb the leg, squeeze blood from the vein and protect surrounding tissue. After the procedure, blood is naturally rerouted through other healthier veins.

A cosmetic procedure called body contouring allows reshaping of the body without surgery and has resulted in numerous noninvasive and often proprietary techniques. RF energy is used to deliver current deep into areas of fat cells to destroy them. Connective tissue and fat both contribute to the development of cellulite, for which RF energy has proven to be effective in minimizing. The heat produced causes collagen proteins in connective tissue to change and tighten. Studies have shown that it may also increase blood flow and fat metabolism at the treatment site. RF energy also affords its noninvasive capabilities for liposuction. Radio frequency assisted liposuction (RFAL), a technique developed by one manufacturer, uses RF energy to produce heat using two electrodes, one external and one internal and connected to a handheld controller.

Electro-optical synergy (ELOS), also called E-light technology, combines bipolar RF and optical energy to reduce the intensity and potential side effects of optical energy. Studies



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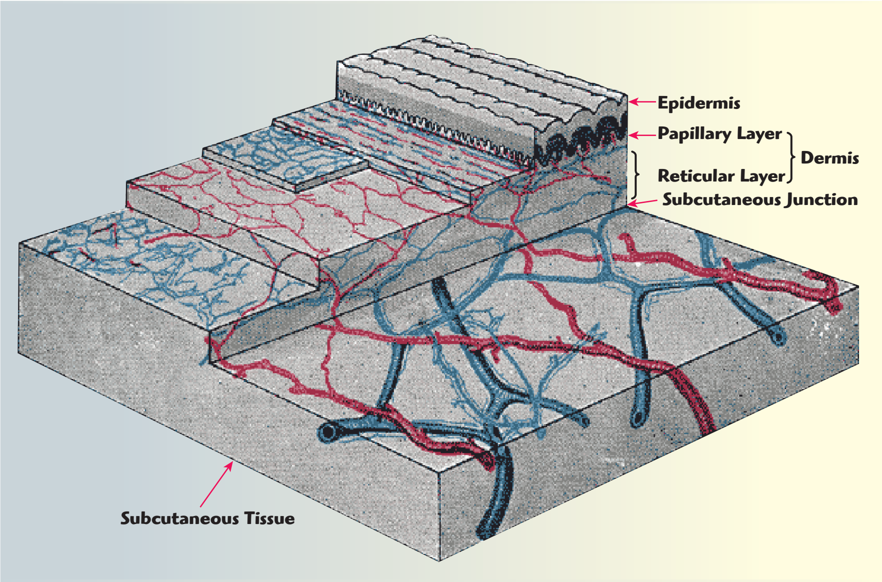

▲ *Fig. 5 Cross section of human skin. Source: Henry Gray, "Anatomy of the Human Body," 1918.*

have shown that it can be used with all hair types and is effective in removing white hair.

EMERGING APPLICATIONS

RF technology is being used to treat other pathologies, and many rely on RF ablation. It is being used to treat various heart conduction disorders, of which there are many. The procedure has been demonstrated to be safe, with a mortality rate of less than one per 2,000 procedures. RF ablation is also being used to treat hepatocellular carcinoma, the most common type of liver cancer. Electrodes are inserted into the liver tumor using percutaneous, laparoscopic or open surgery with guidance from ultrasound imaging. As it is a local treatment with minimal effects on normal healthy tissue, it can be repeated multiple times. The technique has proven to have four-year survival rates like those of surgical resection. Barrett's esophagus, a serious complication of gastroesophageal reflux disease, is also being treated using RF ablation. The RF energy is delivered through an endoscope inserted into the esophagus that allows abnormal cells to be destroyed while protecting the healthy cells underneath.

CONCLUSION

The use of RF energy in medicine has a long history and has proven its effectiveness, either alone or used with a laser for diathermy, ablation and skin treatment. Advances in solid-state device technology enable better control and flexibility, especially LDMOS RF power transistors that extend treatment options to microwave frequencies. ■

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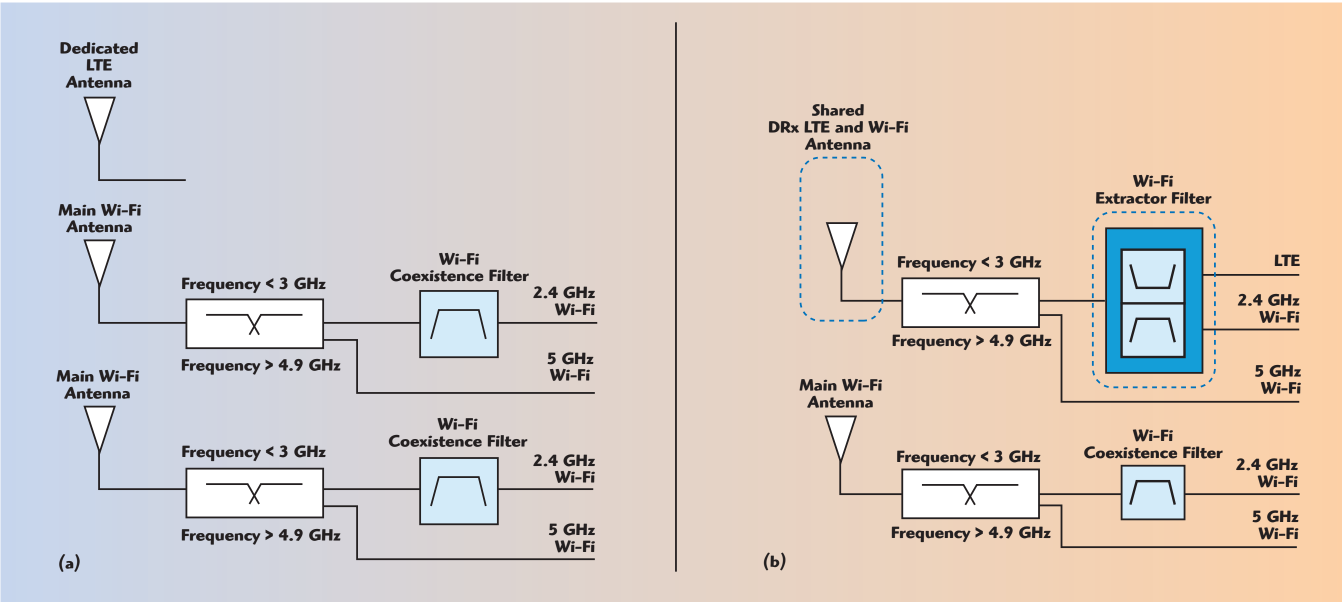
INVITED PAPER

Filter Technology Trends in Mobile Wi-Fi Modules

Kevin Gallagher
Qorvo, Chelmsford, Mass.

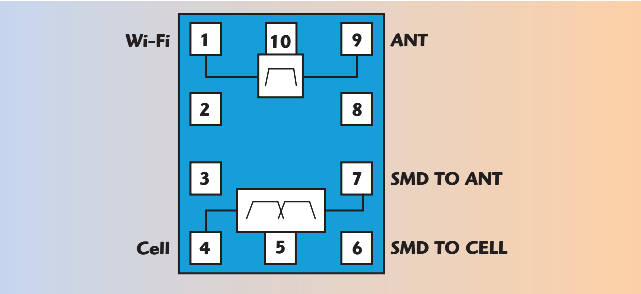
In smartphones, high performance Wi-Fi is key to satisfying the ever-growing demand for mobile data, because Wi-Fi offloads traffic from operators' LTE networks. Trends in 2017 will include the growing prevalence of 2×2 multiple-input-multiple-output (MIMO) in handsets, which enables dual simultaneous data streams. IEEE 802.11ac, which utilizes the 5 GHz band and offers greater throughput than its predecessors, will continue to proliferate, while the industry prepares for the next standard, 802.11ax, which will further improve performance.

The drive to continually increase Wi-Fi performance creates design engineering challenges requiring the use of advanced RF filters, typically incorporated into integrated modules to maximize performance, simplify design and save space. One of these challenges is antenna sharing, which facilitates the addition of 2×2 MIMO Wi-Fi alongside increasingly complex LTE functionality in the limited space available

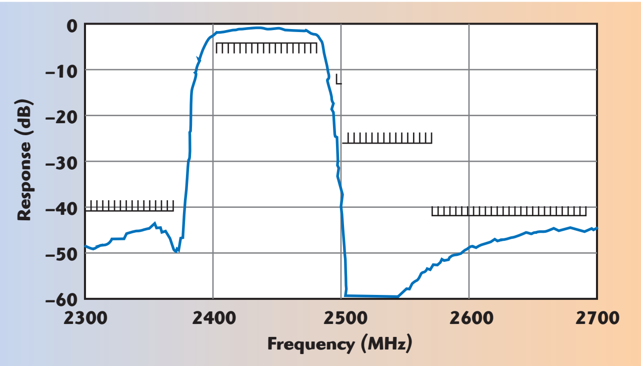


▲ *Fig. 1 Simplified smartphone architecture with 2×2 MIMO Wi-Fi and separate LTE antenna (a) and shared Wi-Fi/LTE antenna (b).*

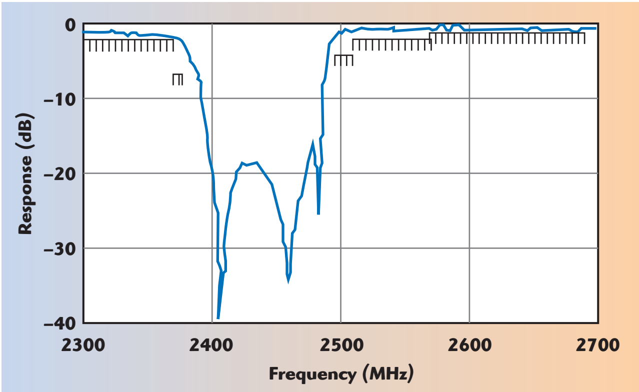
within the handset. Other challenges: Designs must avoid interference with neighboring LTE bands, including bands that use the new Class 2 standard for higher output power, and support simultaneous dual-band Wi-Fi operation.



▲ *Fig. 2 A diplexer module enables Wi-Fi and LTE to share a common antenna (e.g., Qorvo's 885060).*



▲ *Fig. 3 Response of the Wi-Fi bandpass filter in the diplexer module.*

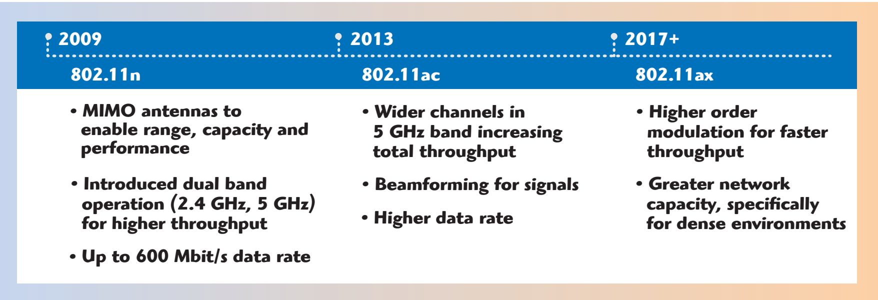


▲ *Fig. 4 Response of the Wi-Fi notch filter, including the adjacent LTE bands.*

ANTENNA SHARING

The number of antennas in smartphones has grown to support faster data services as well as a growing range of RF technologies. Today's handsets may require as many as six or seven antennas for primary cellular and diversity receive (DRx), Wi-Fi, near-field communications (NFC) and other technologies. It becomes increasingly difficult to squeeze still more antennas into the limited physical space available within a typical high performance smartphone. Antenna sharing alleviates this problem (see ***Figure 1***), as it allows handsets to accommodate 2×2 MIMO Wi-Fi by sharing the cellular DRx antenna between Wi-Fi and LTE.

Antenna sharing requires two advanced filters to avoid interference between 2.4 GHz Wi-Fi and adjacent LTE bands (7, 38, 40 and 41), while diplexing the LTE and Wi-Fi paths to a single antenna port. A 2.4 GHz notch filter is used to remove the Wi-Fi signal from the LTE path, while a 2.4 GHz bandpass filter removes LTE interference from the Wi-Fi path. The use of temperature-compensated bulk acoustic wave (BAW) filters enables designs to minimize insertion loss, meet attenuation requirements for Wi-Fi and LTE, use the full Wi-Fi spectrum and operate across temperature.



▲ *Fig. 5 Evolving Wi-Fi standards.*

One example of a commercial product is Qorvo's 885060 Wi-Fi extractor filter module (see ***Figure 2***), which combines the notch and bandpass filter into a single module and reduces the need for external matching. The BAW bandpass filter provides high performance Wi-Fi and meets out-of-band attenuation requirements (see ***Figure 3***). The notch filter meets the Wi-Fi attenuation requirements and achieves low insertion loss for the adjacent LTE bands (see ***Figure 4***).

LTE POWER STANDARD

Whether or not the handset uses antenna sharing, all handsets require filters to ensure coexistence between 2.4 GHz Wi-Fi and the adjacent LTE bands. A new coexistence challenge is presented by Power Class 2, an emerging standard for higher output power in TD-LTE band 41 (2.5 GHz) and potentially other high frequency bands. Band 41 is increasingly being used in the United States, China and other countries. Power Class 2 increases handset output power to 26 dBm, double the previous 23 dBm maximum defined by power class 3. The goal of increased output power is to compensate for greater propagation losses at higher frequencies. Raising handset output power enables carriers to maintain cell coverage without adding expensive infrastructure.

The filtering challenge is to attenuate these higher power LTE signals sufficiently to protect the neighboring 2.4 GHz Wi-Fi spectrum. The Wi-Fi filter that is required will depend on the filter that the handset manufacturer chooses for band 41. If a high performance filter is used for band 41, the Wi-Fi attenuation requirements will be less stringent; however, if a lower performance filter is used, greater attenuation will be required to avoid interference, meaning a higher performance Wi-Fi filter will be needed.

CONCURRENT DUAL-BAND OPERATION

Another emerging Wi-Fi filtering challenge is presented by the trend toward concurrent dual-band

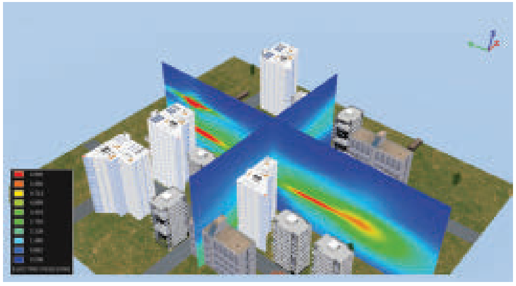
operation. Today's handsets support both 802.11ac (5 GHz) and the older Wi-Fi standards that use 2.4 GHz (802.11n, b and g). As Wi-Fi becomes more prevalent and is incorporated into more households, wearables and other devices, it will be valuable for a handset to simultaneously communicate on both Wi-Fi bands. The 5 GHz band provides the highest performance, so it may be used for internet access via a local, high bandwidth access point. The 2.4 GHz band will be used because it provides greater range and enables communication with devices that support only the 2.4 GHz band. Wi-Fi filters need to support this concurrent usage, ensuring adequate attenuation of 2.4 GHz signals in the 5 GHz band and vice versa.

Wi-Fi filters are being incorporated into integrated front-end modules (iFEM) with other components in the Wi-Fi transmission chain, such as power amplifiers and switches. Modules provide better performance, reducing matching losses, simplify design complexity, save space, limit the number of discrete components and reduce time to market for the handset manufacturers.

CONCLUSION

Advanced filters and iFEMS are essential components, needed to enable future Wi-Fi performance improvements. 2×2 MIMO in handsets will increase during 2017, particularly among the fast-growing manufacturers in China. This will drive adoption of iFEMs and antenna sharing, as manufacturers seek to add a second Wi-Fi RF chain within the limited space available in increasingly complex handsets.

The upcoming 802.11ax standard will further improve throughput, especially in dense user environments such as stadiums and airports (see ***Figure 5***). Performance improvements will be achieved, in part, by using more complex modulation coding (i.e., 1024-QAM compared with the 256-QAM maximum in 802.11ac), which will tighten the error vector magnitude (EVM) specification from 1 percent to 0.5 percent. To support 802.11ax, Wi-Fi iFEMs will need to improve linearity without sacrificing filter performance.■



Electromagnetic Exposure Simulation Software

Microwave Vision Group (MVG)
Paris, France

Across the globe, telecommunication regulatory bodies are paying more and more attention to human exposure to RF emissions, with the result that nowadays gaining authorization for installing new antennas is often dependent upon proof of compliance with local reference levels. Compliance becomes dependent on accurate simulation of human exposure to electromagnetic fields, which is the only way to calculate and assess the cumulated level of exposure generated by new antennas in their future installation sites together with all those already in place that are used for cellular networks or radio services.

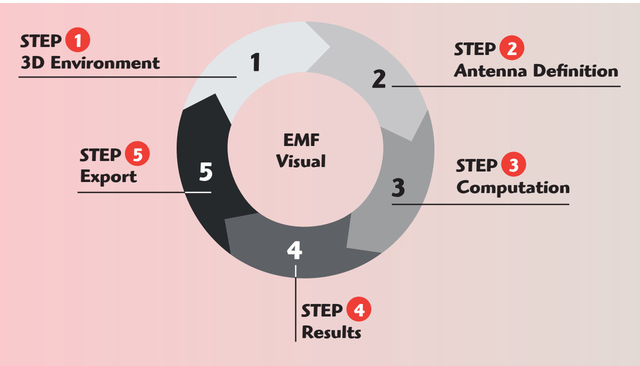
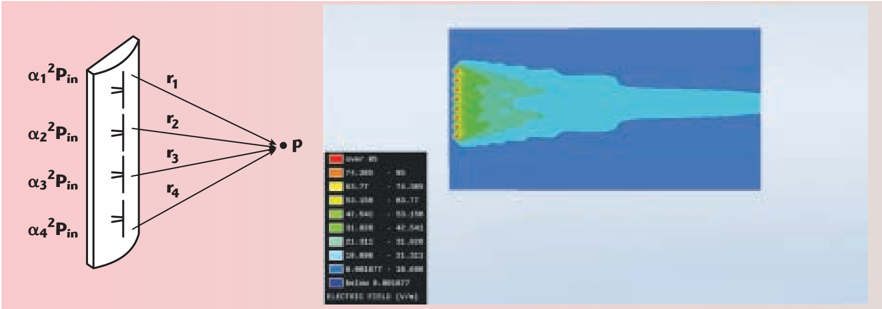


Fig. 1 Process utilized by EMF Visual.

To address this issue a new version of the EMF Visual software has been developed. The existing version offers reliable and fast calculations and enables the visualization of electromagnetic fields in a determined zone (near-field/far-field), taking into account the multiple emitters and their interaction with surrounding buildings. The simulation results can be compared directly with reference levels given by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), Safety Code 6, FCC. Therefore, providing clear and



▲ *Fig. 2 The E-field calculated at each point in the mesh is the superposition of the fields emitted by each sub-antenna of the radiating element.*

easy-to-understand evaluations of the compliance of a site.

The new version of EMF Visual is even more powerful thanks to advanced features. It now uses GPU resources, which provide coverage of larger areas for exposure evaluation and enables the use of the Geographical Information System (GIS) database or 3D objects conversion for direct loading of virtual 3D scenes, while interfacing with SketchUp software. In addition, the new version allows users to assign material properties to the entire surrounding 3D environment in order to take into account their impact on exposure levels, while still making fast calculations.

The simulation tool is based on a five step process as shown in ***Figure 1***. The first is the definition of the complete 3D scenario. In this phase, the user can define or build a complete 3D scenario based on existing components provided with the software (buildings, ground profiles, etc.) There is a wide range of choice included in the software representing different types of buildings, roads, masts, towers, houses and indoor objects and the user can select different electromagnetic properties for the materials.

Once the scenario is defined, the second step is the antenna selection and installation within the specific scenario. EMF Visual provides a wide database of generic antennas which can be used. In addition, the BSA synthesis module can be used to add custom antennas based on user defined specifications such as: frequency, beamwidth, tilt, input power, gain, etc. The user defined antennas can be exported to the EMF Visual database for use in different scenarios.

The third step is the definition of the computation volume inside the area of interest. Once this is identified the calculation is launched, taking into account the surrounding environment and the interaction with other radiation elements present. The computation is based on ray tracing techniques. The user can select the mesh size of the computation volume and use a non-uniform grid in order to improve the resolution around the antennas and save computation time.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LOW NOISE FIGURE
HIGH POWER HANDLING
LOW POWER CONSUMPTION
SMALLEST FORM


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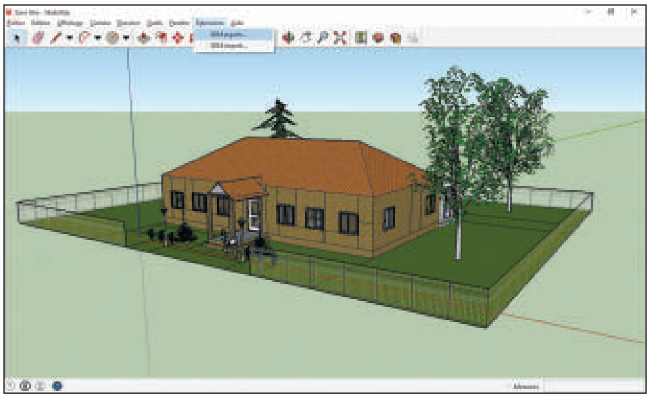


Fig. 3 SketchUp import example.

The E-field calculated at each point in the mesh is the superposition of the fields emitted by each sub-antenna of the radiating element (see ***Figure 2***). Once the input power (P_{in}) and phase (α) of each sub-element is known, the total E-field can be calculated at any point (p) in the 3D space as the sum of the individual contributions.

Once the simulation of the scenario is complete, the next step is to visualize the results. The user can define surface or cut-planes to visualize the E-field levels inside the scenario contained within the user defined computation volume. In addition to E-field, the software can display H-field, power density, percentage of power or percentage of field for multi-frequency sources. The software can also automatically determine the safe distance from the radiating element based on the standards/recommendations defined by the European Union, ICNIRP or other regulatory and governing bodies. The user can also change the color and transparency of the results for an optimal view.

The scenario definition setup in the software package provides several possibilities. It contains the standard EMF Visual tool with CPU or advanced GPU option. For a precise and rapid creation of a 3D environment, several options are available. The user can use the internal generic database, which is quite comprehensive and provides a wide range of buildings, ground floors, towers, masts, indoor objects, etc.

The user can also opt for a plug-in for SketchUP using the SE-SKP-EMF option whereby the user can import custom structures into the EMF Visual software using the SDM format as shown in ***Figure 3***. Another option is the 3D creation tool (SE-AGETIM-Light-EMF) that generates a complex 3D terrain using the GIS user interface. The detail of the final output depends on the quality of input data.

The third option is the 3D conversion tool (SE-FFT-EMF) that can be used to convert files from VRML, TDF, OpenInventor and OpenFlight formats to the SDM format, which is used by the EMF Visual. This tool is a package of several tools each used to convert to a specific file format.

Microwave Vision Group (MVG)
Paris, France
www.mvg-world.com

High Voltage and High Current Waveform Amplifier

Accel Instruments
Irvine, Calif.

Many test and measurement applications require a driver amplifier that provides high voltage, high current or any combination. Typical benchtop signal sources — function generators, arbitrary waveform generators, signal generators and data acquisition systems — are unable to provide high voltage or current. The output of most benchtop generators is limited to about ±5 V into 50 Ω and 100 mA drive current. With a typical output resistance matched to 50 Ω, they can't drive low resistance loads that draw high current. To address these needs, Accel Instruments developed the benchtop TS250 high voltage and high current waveform amplifier for general laboratory and test and measurement applications. The TS250 will provide an output voltage to 65 V and can drive more than 6 A. The TS250 is used to amplify function generators and other weak signal sources (see ***Figure 1***), extending the function generator's capabilities.

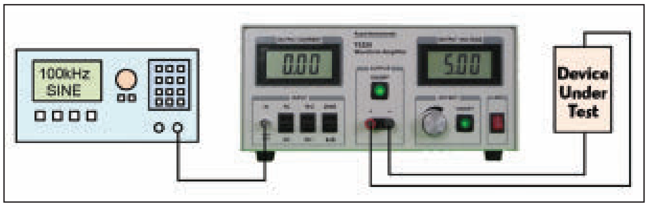
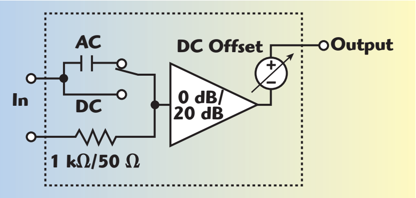


Fig. 1 Typical use of a waveform amplifier.

The TS250 power amplifier (see ***Figure 2***) has a selectable voltage gain of 0 or 20 dB. 20 dB is normally used for applications that require high voltage, while 0 dB supports high current applications. The input impedance of the TS250 can be set to either 50 or 1 kΩ. The TS250 amplifier has very low output impedance (approximately 50 mΩ) to maintain signal integrity without distortion. A DC offset voltage can be added to the output signal, similar to the DC offset feature with most function generators. It can generate an AC signal on the DC voltage, which is useful for power supply ripple or ripple rejection tests.

WAVEFORM DISTORTION

Using a signal generator to drive a non-50 Ω load can attenuate and distort the desired waveform. When driving low resistance loads, the signal will be attenuated by the voltage division from the higher source impedance, as shown in ***Figure 3a***. A square wave from a function generator may be distorted by capacitive or inductive loads (see ***Figures 3b*** and ***3c***). With a capacitive load, the source generator output resistance and load capacitance form a lowpass filter. With an inductive load, such as a relay or a magnetic coil, the generator output resistance and load form a highpass filter. Driving

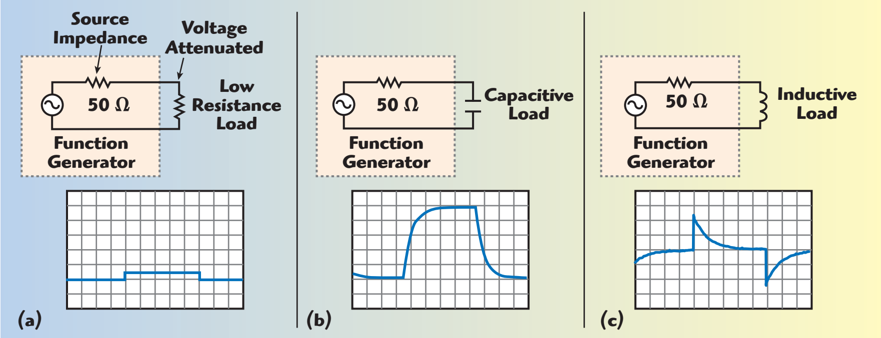


▲ *Fig. 2 Functional block diagram of the TS250 waveform amplifier.*

such loads from the TS250 waveform amplifier will not distort the waveform because of the TS250's low source resistance and high current capacity.

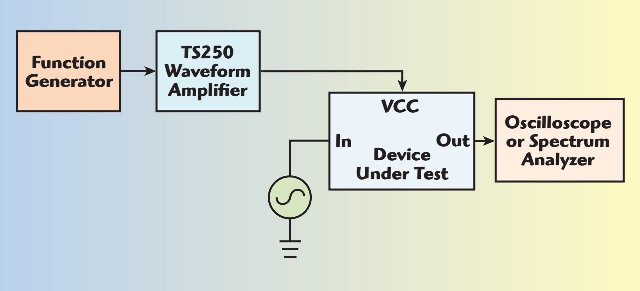
APPLICATIONS

Piezoelectric transducers, electromechanical relays and power supplies are three applications that require higher voltage than is available from most function generators, i.e., from 10 to 65 V. Other applications present low impedance loads and require high current, such as generating a high magnetic field in a coil. Yet other cases — voltage transient and pulsed thermal transient testing — require both high current and high voltage. Some signal sources are weak and require amplification, such as data acquisition systems (DAQ).



▲ *Fig. 3 Examples of waveform distortion when a 50 Ω function generator drives low resistance (a) capacitive (b) and inductive (c) loads.*

The output impedance of a DAQ is low, 1 Ω or so, with a limited current drive of 1 mA. DAQ analog outputs are designed to see a load of 1 kΩ or greater. In all of these applications, a waveform amplifier is needed.



▲ *Fig. 4 Test setup for power supply ripple rejection.*

A common product development test is power supply ripple injection and rejection, to identify amplifier spurs or phase and amplitude noise caused by noise from the power supply. This requires generating an AC ripple voltage on top of the DC supply voltage and sweeping the ripple frequency from near DC to 1 MHz. The AC ripple is usually a sine wave, although it can be any waveform, such as a square or triangle wave or random noise. The test is particularly difficult when the device being tested draws high DC current. ***Figure 4*** shows how the TS250 waveform amplifier is used for ripple injection testing. Using a network analyzer in place of the function generator and oscilloscope or spectrum analyzer enables measurement of the power supply ripple rejection ratio (PSRR).

Helmholtz coils are commonly used to generate uniform magnetic fields; however, producing high frequency and high magnetic fields is challenging, requiring high current drive. Using a series capacitor to tune the Helmholtz coils to resonance cancels the coils' reactance, reducing the coils' impedance from 10 kΩ to less than 1 Ω, or just the parasitic resistance of the coils. The TS250 amplifier can drive up to 6 A through the coils to produce high magnetic fields at high frequencies.

Accel Instruments
Irvine, Calif.
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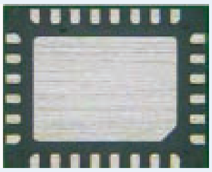

24 GHz Transceiver for Industrial Sensors and Automotive Radar

United Monolithic Semiconductors has utilized its expertise on the design, manufacture and marketing of leading edge RF and millimeter wave components and solutions to develop the newly introduced CHC2442-QPG, a state-of-the-art, fully integrated 24 GHz transceiver solution for industrial sensor and automotive radar applications. Designed specifically to address sensor applications in the 24 GHz ISM band, the transceiver provides a fully integrated front-end. It offers a high level of flexibility, which can make it the basis for a wide range of industrial sensors, from short range car applications to robotic and peripheral security systems.

LEADING EDGE PERFORMANCE

The CHC2442-QPG includes a signal generation Tx and a dual reception Rx in a single component. This solution is claimed to offer leading edge performance due to a low phase noise voltage controlled oscillator (VCO), a high transmit power level, dual Rx with very low noise figures, all combined with a high level of isolation between Tx and Rx channels. The versatile transceiver also includes power and temperature monitors and a programmable pre-scaler.

The CHC2442-QPG is fully compatible with standard digital interfaces through a serial interface (SPI) with data read and write capabilities. It is available in a surface-mount 28L-QFN4X5 SMD plastic package, is qualified to AEC-Q100 and is also available in high production volumes.

INTEGRATION

A high level of integration and state-of-the-art performance make the CHC2442-QPG a more than suitable solution for industrial sensor and automotive applications. Operating in the -40° to +125°C temperature range, features include maximum Tx power of >13 dBm with a Tx power control range of 12 dB, Rx gain of 37 dB and an Rx gain control range of 24 dB.

United Monolithic Semiconductors (UMS)
Paris, France
www.ums-gaas.com

6.5 to 40 GHz Microwave Power Modules

For defense and communications applications that require high power, L-3 Electron Devices offers two microwave power modules (MPM) that lead in size, weight and power (SWaP). Integrating a solid-state driver, TWT and power supply, each MPM is housed in a compact package designed for rugged military environments.

The M1245 MPM provides 200 W minimum output power across 6.5 to 18 GHz, with spurs no greater than –50 dBc and a maximum noise power density of –35 dBm/MHz. The power amplifier's small-signal gain is 60 dB minimum. The RF input connector is SMA female, and the output interface is WRD-650 double-ridged waveguide. The MPM operates from a +270 VDC supply, per MIL-STD-704E, and has 900 W maximum power dissipation. The housing size is 8.5" × 9.75" × 1.5".

The M2842 MPM is designed to provide 60 W minimum output power from 18 to 40 GHz and 100 W minimum from 20 to 36 GHz. Spurs are no greater than –45 dBc, the maximum noise power density is –30 dBm/MHz and the minimum small-signal gain is 40 dB. The RF input connector is a 2.9 mm female, and the output interface is WRD-180 double-ridged waveguide. This MPM operates from a +28 VDC supply and dissipates a maximum of 400 W. The housing size is 8.5" × 9.75" × 1.75".

Both MPMs have individual on/off controls for supply voltage and RF, with visual indicators for warm-up, high voltage and a fault condition. The units are cooled by conduction and can operate from –40° to +85°C.

L-3 Electron Devices
San Carlos, Calif.
www.L-3com.com/edd

Tunable Frequency and Bandwidth Filter

K&L is shipping a digitally-controlled bandpass filtering system that tunes anywhere from 700 MHz to 6 GHz and has continuously adjustable bandwidth. The system simplifies LTE and Wi-Fi testing by eliminating the large number of fixed filters required to cover all the bands. This single filter can be tuned to any of the cellular and Wi-Fi bands between 700 MHz and 6 GHz and the filter bandwidth set to the appropriate channel bandwidth. For a center frequency between 700 MHz and 2 GHz, the 1 dB bandwidth can be set from 5 to 40 MHz. For a center frequency between 2 and 5 GHz, the 1 dB bandwidth can be from 10 to 40 MHz, and between 5 and 6 GHz, the bandwidth can range from 12 to 40 MHz. The filter's harmonic rejection is 60 dBc from DC to 13 GHz.

The filter system has Ethernet, GPIB, USB and RS-232 interfaces with compatible software for automated testing. The user interface works with smartphones, tablets and traditional PCs. The filter system measures 27" × 31" × 22" and weighs approximately 200 lbs.

K&L Microwave
Salisbury, Md.
www.klmicrowave.com

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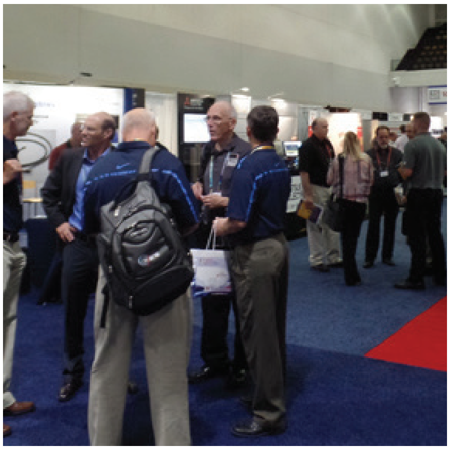

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component and system simulation ■ materials/PCB boards ■ devices and foundry services ■ components cables and connectors ■ test and measurement ■ verification ■ RF and microwave ■ 5G ■ IoT autonomous cars ■ radar ■ signal integrity ■ power integrity ■ EMC/EMI

Benchtop Power Amplifier

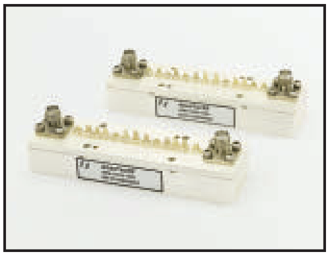
VENDORVIEW

The 350S1G6 provides wideband high linear output power over a frequency band of 0.7 to 6 GHz. Over 350 W of output power is achieved with only 1 mW of input power. This amplifier is designed using "Hybrid Microelectronics Technology" resulting in an amplifier with greater power density, smaller size and lower production cost than previously possible. For a full product demo, visit www.arworld.us/html/video-AR350S1G6%20Amplifier.asp.

AR RF/Microwave Instrumentation
www.arworld.us

Build Your Own Bandpass Filter

VENDORVIEW



AtlanTecRF launched its second 'build your own' web tool, specifically designed for people looking to customize bandpass filters. Every web tool is designed by engineers with the aim of simplifying the product specification process by guiding each user through a range of simple questions. Once completed, the form provides the AtlanTecRF customer services team with the information needed to deliver a customized quote that matches each customer's bandpass filter specifications.

AtlanTecRF
www.atlantecrf.com

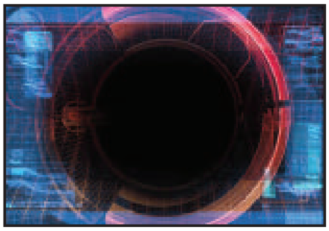
Improved Navigation and Support

K&L Microwave's website provides information and tools, such as the Filter Wizard® web application, to speed the identification of custom design solutions from a full range of company products. The latest web update features a new look, mobile device support, social media links and improved LTE band navigation to test set components for broadband emission monitoring. Customers can also research capabilities, access datasheets, submit quote requests and download catalog sections.

K&L Microwave
www.klmicrowave.com

Unlocking Millimeter Wave Insights

VENDORVIEW



Sit down with Keysight millimeter wave experts in a new video, "Unlocking Millimeter Wave Insights," as they discuss the challenges and the commercialization of tools for millimeter wave design, simulation, measurement and analysis. As you reach up to millimeter wave, it's easy to underestimate the complexities at these frequencies. See how Keysight is taking the mystique out of millimeter waves and unlocking new insights in this short video. Visit https://youtu.be/mVJCZ5wAU0Y to learn more.

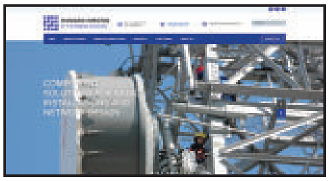
Keysight Technologies Inc.
www.keysight.com

New Look and Content

Kuhne electronic's new website features a new look and new content that is clear, modern, informative and responsive. Simply download the datasheets of the company's modules with just one mouse click, or browse various applications to find a solution for your project. Using dedicated specification filters allows customers to immediately locate the respective module. Also, take a look at the new products including bidirectional amplifiers, signal generators for RF heating and plasma applications, linearized amplifiers and much more.

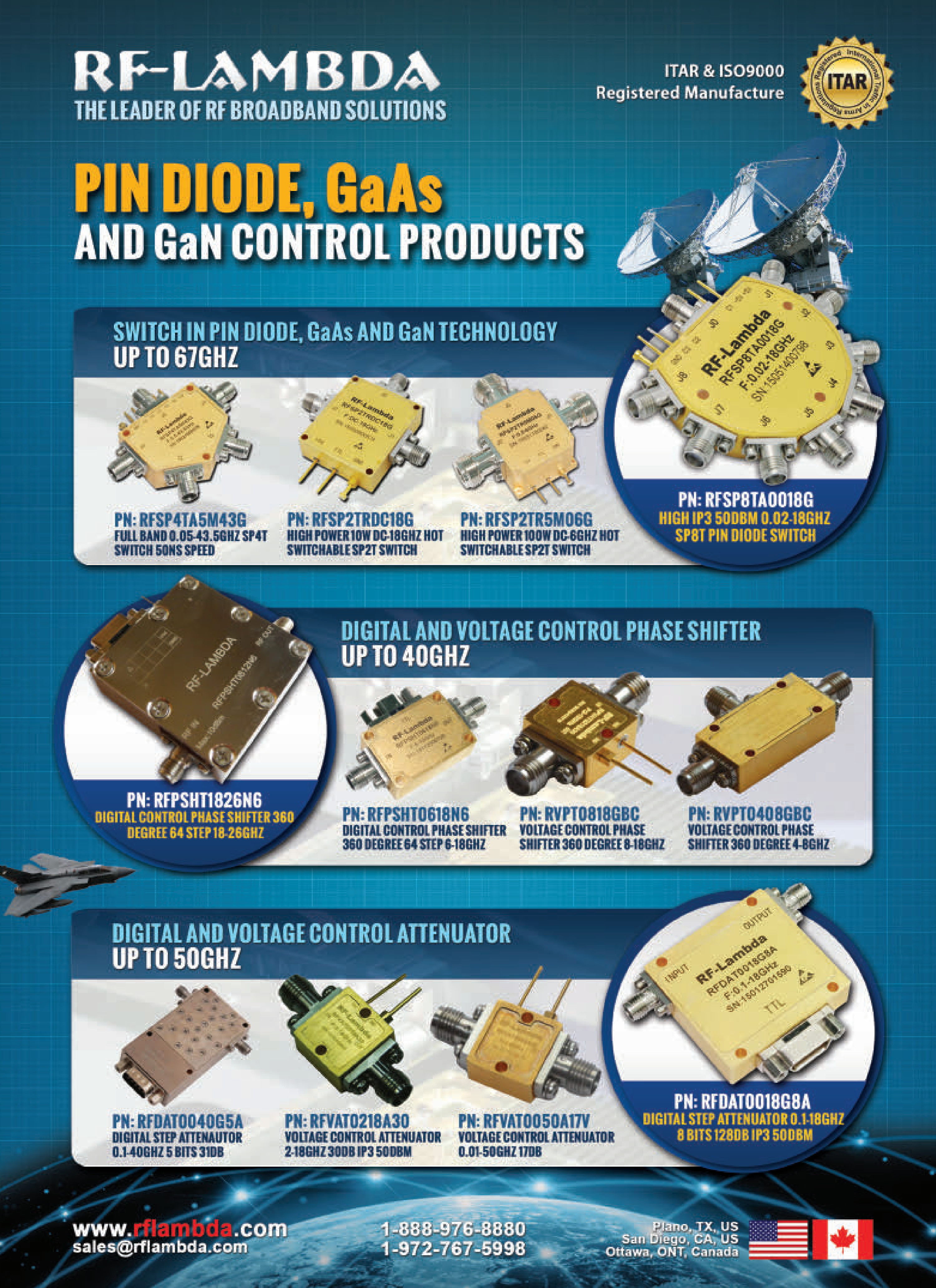
Kuhne electronic GmbH
www.kuhne-electronic.de

Added Functionality and Value Features



Microwave Marketing's new website has been designed to offer greater functionality and access to manufacturer/product information. It now offers more product and market focus, enabling customers to view synergistic products across multiple brands, either within the same application set or product group. Added value features help customers find solutions to fit their requirements for multiple building blocks within the same system. Further features that will be launched soon include technical and applications support via live chat, and a web store for direct purchases.

Microwave Marketing
www.microwavemarketing.com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HIGH POWER 10W DC-18GHZ HOT SWITCHABLE SP2T SWITCH
PN: RFSP2TR5M06G
HIGH POWER 100W DC-6GHZ HOT SWITCHABLE SP2T SWITCH
RF-Lambda
RFSP8TA0018G
F:0.02-18GHz
PN: RFSP8TA0018G
HIGH IP3 50DBM 0.02-18GHZ
SP8T PIN DIODE SWITCH
DIGITAL AND VOLTAGE CONTROL PHASE SHIFTER
UP TO 40GHZ
RF-LAMBDA
PN: RFPSHT1826N6
DIGITAL CONTROL PHASE SHIFTER 360 DEGREE 64 STEP 18-26GHZ
PN: RFPSHT0618N6
DIGITAL CONTROL PHASE SHIFTER 360 DEGREE 64 STEP 6-18GHZ
PN: RVPT0818GBC
VOLTAGE CONTROL PHASE SHIFTER 360 DEGREE 8-18GHZ
PN: RVPT0408GBC
VOLTAGE CONTROL PHASE SHIFTER 360 DEGREE 4-8GHZ
DIGITAL AND VOLTAGE CONTROL ATTENUATOR
UP TO 50GHZ
PN: RFDAT0040G5A
DIGITAL STEP ATTENAUTOR 0.1-40GHZ 5 BITS 31DB
PN: RFVAT0218A30
VOLTAGE CONTROL ATTENUATOR 2-18GHZ 30DB IP3 50DBM
PN: RFVAT0050A17V
VOLTAGE CONTROL ATTENUATOR 0.01-50GHZ 17DB
INPUT
OUTPUT
RF-Lambda
RFDAT0018G8A
F:0.1-18GHz
TTL
PN: RFDAT0018G8A
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8 BITS 128DB IP3 50DBM
www.rflambda.com
sales@rflambda.com
1-888-976-8880
1-972-767-5998
Plano, TX, US
San Diego, CA, US
Ottawa, ONT, Canada

New Cable Design Tool

VENDORVIEW

Pickering Interfaces' new graphics-based Cable Design Tool allows users to create customized cable assemblies using detailed design characteristics that include a selection of connector types, wire type, pin definitions, pin and cable labeling, cable bundling, length selection, sleeving comments and more. It also features a built-in library of standard cable sets for customization, or cables can be designed from scratch. The tool runs on all modern browsers and is fully supported on all major tablet operating systems.

Pickering Interfaces Ltd.
www.pickeringtest.com

Field Replaceable Connectors

Signal Microwave has updated their website. Recently added is a new line of 2.92 mm field replaceable connectors with typical VSWR under 1.10:1. These are available in standard 2 and 4 hole flange sizes. Test board offerings now include 40 and 70 GHz boards for VNA calibration verification. These boards can be used as a measurement verification tool. The basic version consists of a 50 Ω through line, a 25 Ω "Beatty" line and a 100 Ω differential pair line.

Signal Microwave
www.signalmicrowave.com

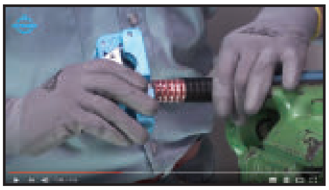
Smart Front-End Module

VENDORVIEW

Skyworks introduced a highly integrated 470 to 510 MHz front-end module (FEM) that is ideal for smart energy, smart metering (electric, gas, water, heat), security, RFID, industrial and other Internet of Things (IoT) applications. The SKY66115-11 FEM operates over a wide variety of supply voltages at low power consumption and comes in a small 4 mm × 4 mm × 0.9 mm, 16-pin multichip module solution. Its extended range more than doubles when compared to a stand-alone system-on-chip solution. Visit www.skyworksinc.com/Product/3138/SKY66115-11.

Skyworks Solutions Inc.
www.skyworksinc.com

Connector Installation Videos



VENDORVIEW

The SPINNER MultiFit™ and SPINNER Cut And Fit (CAF®) monobloc connectors have been a big hit with installers. Their easy handling, fast, reliable installation and excellent technical values put them in a class of their own. And now SPINNER has released installation videos to supplement the written instructions. The installation videos show the connectors for the following cable types and sizes: SF 3/8", SF 1/2", LF 1/2", LF 7/8", LF 1 1/4" and LF 1 5/8".

SPINNER GmbH
www.youtube.com/spinnergmbh

Website Launch

VENDORVIEW

Smiths Microwave Subsystems announced that TRAK Microwave has launched a new website. The site has been designed to allow easy navigation through a library of time and frequency systems, integrated microwave assemblies and high performance ferrite components. Users can download datasheets, request pricing with attachments, check out the factory, find a local sales representative, submit questions and view all new items posted on the site in the updates section—including product releases, tech briefs, company news, events and insightful blogs.

TRAK Microwave Corp.
www.trak.com

Ferrite Bead Impedance Calculator

Vishay Intertechnology Inc. has introduced the industry's first online ferrite bead impedance calculator. Available at www.vishay.com/inductors/ferrite-bead-calculator/, the time-saving online tool makes it simple to find the impedance of Vishay's most popular surface-mount ferrite beads at any given frequency and calculate the effective impedance at the stated frequency with DC bias applied. The new calculator eliminates the need to determine impedance information from the Z vs. frequency graph in product datasheets, plus it also removes the guesswork in determining how much impedance is reduced.

Vishay Intertechnology Inc.
www.vishay.com

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Innovations in EDA
Presented by: Keysight Technologies
- How to Design Phased Arrays for 5G, Radar and Satellite
- Advances in High Power RF Design

Keysight Wireless Communications and Connectivity Series
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NEW PRODUCTS

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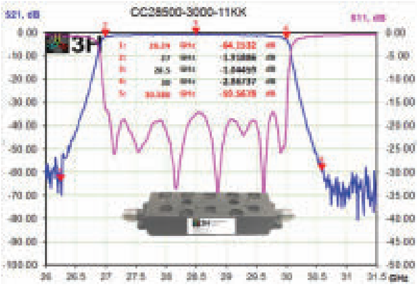
COMPONENTS

Bandpass Filter



3H's Ka-Band, bandpass filter has a center frequency of 28.5 GHz with a 3 dB bandwidth of 3 GHz. Insertion loss at Fo is >1.5 dB with a VSWR of 1.5:1 while offering >50 dB selectivity. This filter is capable of handling 50 W CW within a package size of 1.65" × 0.63" × 0.50". Please contact 3H Communication Systems at (949) 529-1583 or send an email to sales@3hcomm.com.

3H Communication Systems
www.3Hcommunicationsystems.com

SP5T Absorptive Switch, Drop-In

Amplical's SW5A203 SP5T miniature broadband coaxial absorptive PIN diode switch features low insertion loss, low VSWR, high isolation and fast switching speed. J1, J2, J3, J4 and J5 ports are terminated in 50 (when switched in the isolation (off) state. All RF ports incorporate DC blocks. An on-board TTL-compatible driver provides convenient logic control. The switch operates from +5 V DC and a negative DC supply ranging from -12 to -20 V. The ultra-compact package is designed for drop-in microstrip or strip line applications.

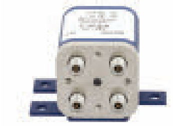
Amplical
www.amplical.com

PIN Diode SP8T Switch Reflective

Ducommun's 18 to 40 GHz PIN diode SP8T switch reflective, Model CP8-29225040-01, features low insertion loss/high isolation, fast switching and complete solid-state solutions. The specifications are frequency: 18 to 40 GHz, insertion loss: 3 dB (goal), 5 dB (max) 18 to 30 GHz, 4 dB, (goal), 6 dB (max) 30 to 40 GHz, isolation: 40 dB (min) and return loss: 10 dB (min).

Ducommun
www.ducommun.com

Electromechanical Relay Transfer Switches

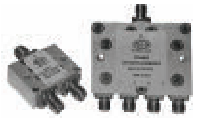


Fairview Microwave introduced a line of 43 electromechanical transfer switches that cover frequency bands from DC to 40 GHz. These products can be used as "drop-out switches" for signal reversal or to bypass a component under test. Superior performance includes insertion loss as low as 0.2 dB and isolation greater than 80 dB. Some models feature power handling capability up to 700 W (CW) at 1 GHz. These transfer switches are in-stock and ship same-day.

Fairview Microwave
www.fairviewmicrowave.com

mmWave Power Dividers

VENDORVIEW



MECA's 2-way and 4-way, 30 W Wilkinson power dividers operate across microwave and mmWave bands covering 6 to 40 GHz with 2.92 mm connectors. The 2-way has typical numbers of 1.3:1 input and 1.17:1 output VSWRs and isolation of 22 dB Typ. The 4-way also has excellent typical specs of 1.2:1 VSWRs and isolation of 19 dB typ. Made in the U.S. and 36-month warranty.

MECA Electronics Inc.
www.e-MECA.com

ISM Band Bandpass Filter

This TX/RX filter dramatically reduces adjacent and out-of-band interference to the ISM Band (902 to 928 MHz), allowing higher data rates and improved range. It features high Q, low loss and extremely sharp lowside cutoff limits 800 MHz cellular-band noise and interference. Available with SMA adapter board or stand-alone, it is designed for infrastructure ISM-Band users. It features automated data collection, dedicated monitoring and data links.

Integrated Microwave Corp.
www.imcsd.com

YIG-Tuned Band Reject Filters

Micro Lambda Wireless Inc. announced the production release of YIG-tuned band reject filters with 50 dB notch depths at 500 MHz and 60 dB notch depths starting at 2 GHz. Standard models cover the 500 MHz to 2 GHz, 2 to 6 GHz, 6 to 18 GHz and 2 to 18 GHz. The standard model operates over the 0 to +65°C temperature range, but Military versions covering -40° to +85°C are available on special order.

Micro Lambda Wireless
www.microlambdawireless.com

Power Splitter/Combiner

VENDORVIEW

Mini-Circuits' ZN2PD2-14W+ is a 2-way 0° high-power splitter/combiner providing up to 35 W power handling as a splitter (1 W as a combiner) and low insertion loss across the entire 500 to 10500 MHz frequency range. Its outstanding combination of high power handling and low loss minimize power dissipation and excellent signal power transmission from input to output. The ZN2PD2-14W+ comes housed in a rugged aluminum alloy case measuring 4.5"× 2.5" × 0.67" with SMA connectors.

Mini-Circuits
www.minicircuits.com

18 to 40 GHz Down-Converter

Model N15-5356 is a millimeter wave frequency converter with a single RF input and two IF outputs at 4 to 18 GHz. The unit has integrated LO sources and down-converts 18 to 26.5 GHz and 26.5 to 40 GHz simultaneously. A positively sloping gain across the frequency range compensates for other system losses.

Norden Millimeter
www.nordengroup.com

ULTRA-REL™

CERAMIC MMIC AMPLIFIERS

10 MHz to 7 GHz

Low NF from 0.5 dB *High IP3 up to +42 dBm* *Low DC current 65 mA* from $7.45 ea. (qty 20)

When failure is not an option! Our CMA family of ceramic MMIC amplifiers is expanding to meet your needs for more critical applications. Designed into a nitrogen-filled, hermetic LTCC package just 0.045" high, these rugged models have been qualified and are capable of meeting MIL standards for a whole battery of harsh environmental conditions:

Qualified for: *(see website for complete list and details)*

Gross and Fine Leak	*HTOL (1700 hours @ +105°C)*
Mechanical Shock	*Steam Aging*
Vibration	*Solder Heat Resistance*
Acceleration	*Autoclave*
PIND	*And More!*

*Gross leak only

Robust performance across wide bandwidths makes them ideal for military and defense applications, hi-rel instrumentation, and anywhere long-term reliability adds bottom-line value. Go to minicircuits.com for all the details today, and have them in your hands as soon as tomorrow!

Electrical Specifications *(-55 to +105°C)*

3 x 3 x 1.14 mm

Model	Freq. (GHz)	Gain (dB)	P_{OUT} (dBm)	IP3 (dBm)	NF (dB)	DC (V)	Price $ ea. (qty 20)
CMA-81+	DC-6	10	19.5	38	7.5	5	8.95
CMA-82+	DC-7	15	20	42	6.8	5	8.95
CMA-84+	DC-7	24	21	38	5.5	5	8.95
CMA-62+	0.01-6	15	19	33	5	5	7.45
CMA-63+	0.01-6	20	18	32	4	5	7.45
CMA-545+	0.05-6	15	20	37	1	3	7.45
CMA-5043+	0.05-4	18	20	33	0.8	5	7.45
CMA-545G1+	0.4-2.2	32	23	36	0.9	5	7.95
CMA-162LN+	0.7-1.6	23	19	30	0.5	4	7.45
CMA-252LN+	1.5-2.5	17	18	30	1	4	7.45

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503 Rev J

NewProducts

Active Frequency Multipliers

VENDORVIEW

Pasternack, a leading provider of RF, microwave and millimeter wave products, has released a new series of active frequency multipliers that simplify system designs by offering high output power levels. These active frequency multipliers are important building block components used in local oscillator (LO) chains for radar, communication receivers and frequency sources to extend frequencies and achieve optimal performance. They support multiple markets and applications including electronic warfare, electronic countermeasures, point-to-point radio, VSAT radio, test instrumentation and telecom infrastructure.

Pasternack
www.pasternack.com

Transfer Switch

VENDORVIEW

PMI model no. PXS-1G2G-80-T-SFF is an absorptive, high speed, two pole transfer switch capable of switching within 100 ns max. The frequency range is 1 to 2 GHz. This switch has > 80 dB isolation. Features include SMA female connectors. Unit size is 1.2" × 1.2" × 0.5" with painted blue finish.

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

Reflective DC to 18 GHz Coaxial SP2T Switch

RF Lambda's reflective DC to 18 GHz coaxial SP2T switch features wide band operation DC to 18 GHz with TTL compatible driver included. Fast switching speed 50 ns, low insertion loss and high isolation, temperature ranges from -45° to +85°C. Customization is available upon request. Hermetically sealed packages up to 60,000 ft are available. Primary applications are military, airborne, wireless infrastructure, satellite communications and medical applications.

RF Lambda
www.rflambda.com

300 W Bidirectional Coupler

VENDORVIEW

Richardson RFPD Inc. announced the availability and full design support capabilities for a new bidirectional surface-mount coupler from Innovative Power Products Inc. The IPP-8036 is one of the featured surface-mount products from IPP's full line of dual directional couplers. It is a 300 W, 50 dB dual directional coupler that operates from 20 to 1000 MHz. IPP has leveraged soft-board laminate technology and embedded internal terminations in order to offer the IPP-8036 in a surface mount package.

Richardson RFPD Inc.
www.richardsonrfpd.com

High Power Cavity Filters

RLC Electronics is currently manufacturing high power cavity filters for military and commercial applications. Filters can accommodate any high power connector desired, including but not limited to N, SC, HN or 7/16. The benefits of this type of filter include sharp attenuation, low loss and consistent performance unit-to-unit. The unit pictured above is a 1280 MHz bandpass filter with 65 dB rejection at 1000 MHz and 1800 MHz. The filter is rated for 400 W avg and 2000 W cW (20% duty cycle) and exhibits low loss (0.3 dB).

RLC Electronics Inc.
www.rlcelectronics.com

E-Band Waveguide Diplexer

VENDORVIEW

Model SWY-74384355-12-I1 is an E-Band waveguide diplexer with a low passband of 71 to 76 GHz and a high passband of 81 to 86 GHz. The nominal insertion loss of the diplexer is 0.5 dB and the minimum isolation is 55 dB. Since both low and high passband frequencies can be changed by modifying the design, custom designs are available under different model numbers.

SAGE Millimeter
www.sagemillimeter.com

Wide Bandwidth Triple-Balanced Mixer

Synergy introduced its "Spur Tamer" series of mixers with the release of the first model in this series. The STM-6000 is a broadband triple balanced mixer covering the LO and RF frequency band from 1 to 6000 MHz and the IF port bandwidth is from 1 to 4000 MHz. The even mode spurious rejection are significantly improved over conventional triple balanced mixers, making this product ideal for applications in high performance frequency converters where low spurious and high LO rejection are desirable.

Synergy Microwave Corp.
www.synergymwave.com

NewProducts

CABLES & CONNECTORS

VNA Test Port Extension Cables

These phase stable alternatives to overpriced OEM test cables provide the utmost precision in vector measurements in the lab and during calibrations. The cable is constructed with an armor assembly to protect the cable and connectors, ensuring consistent performance in VNA, PNA and scalar test calibrations. Fewer calibrations means less downtime, resulting in the MegaPhase promise of lowest cost per measurement. Cable assemblies are available in any user-defined length up to 25 feet.

MegaPhase
www.megaphase.com/tm/vna

AMPLIFIERS

Wideband Medium Power Amplifier

Covering a frequency range of 0.1 to 20 GHz and more than 1 W output, Advanced Microwave's wideband medium PA comes with universal AC input, 95 to 250 V AC. This model is super linear and is ideal for multi-tone, radar and fiber-optic applications. It accepts narrow pulses less than 1 nano-sec.

Advanced Microwave Inc.
www.advmic.com

1 to 6 GHz, 350 W Benchtop PA

VENDORVIEW

AR's 350S1G6 provides wideband high linear output power over 0.7 to 6 GHz. Over 350 W of output power is achieved with only 1 mW of input power. This amplifier is designed using "Hybrid Microelectronics Technology," resulting in an amplifier with greater power density, smaller size and lower production cost than previously possible.

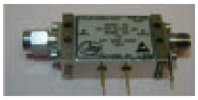
AR RF/Microwave Instrumentation
www.arworld.us

GaAs Low Noise FETs

CEL is offering new GaAs low noise FETs to replace the discontinued Renesas Electronics FET devices. These new drop-in replacements support frequencies of 12, 20 and 24 GHz (K- and Ku-Bands). They are ideal for low noise blocks (LNB) for communications satellites including Direct Broadcast Satellites (DBS), VSAT systems and others.

CEL
www.cel.com/RF

1 to 40 GHz AMP with Detected Output



Ciao Wireless Inc. introduced an ultra-broadband amplifier which features an integrated wideband detector for communication applications. This amp comes with two min gain options of 30 dB min (35 dB TYP) and 15 dB min (20 dB TYP). The gain flatness is ±3.25 maximum. The typical output power is +13 dBm across 1 to 28 GHz. The input and output VSWR is 2.3 or better. The typical noise figure is 6 across the full band (1 to 40 GHz).

Ciao Wireless Inc.
www.ciaowireless.com

C-Band RF Power Modules

VENDORVIEW

High efficiency, high power and compact with proven GaN technology, the VSC3645 can be easily combined to create high power C-Band radar transmitters. CPI BMD's solid-state power amplifiers are reliable, highly-efficient and easy to maintain. The VSC3645 solid-state power amplifiers are designed for use in maritime surveillance and weather radar transmitters covering 5.2 to 5.9 GHz. GaN transistors are combined into a 4.2 kW output and are air cooled.

Communications & Power Industries, Beverly Microwave Division
www.cpii.com/BMD

SSPA Module

VENDORVIEW

Exodus introduced the ultra-wide band AMP1074 compact SSPA covering the full 2 to 20 GHz frequency band at 10 W min. The AMP1074 uses C&W hybrid GaN devices, and operates from a 32 VDC supply at 4.5 A with gain flatness of 5 dB max peak-to-peak. Covering multiple bands, this SSPA is suitable for use with all modulation standards and features a small form factor, lightweight construction and high reliability. Typical applications include EMI/RFI testing, EW and communications systems.

Exodus Advanced Communications
www.exoduscomm.com

GaN-on-SiC HEMT Transistors

Integra Technologies' models IGN0912L45 and IGN0912L125 are designed for L-Band avionics applications. These high-power GaN-on-SiC HEMT transistors supply > 45 W and > 125 W of output power at 50 V drain bias, with up to 20 dB of gain and 57% of efficiency at 444 × (7 μs on, 6 μs off), 22.7% pulse conditions.

Integra Technologies Inc.
www.integratech.com

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PHOTO BY NEAL MIYAKE

The IEEE Microwave Theory and Techniques Society's 2017 International Microwave Symposium (IMS2017) will be held 4 - 9 June 2017 at the Hawai'i Convention Center in Honolulu, Hawai'i as the centerpiece of Microwave Week 2017. IMS2017 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. As usual, the Microwave Week 2017 technical program also comprises the RFIC Symposium (**www.rfic-ieee.org**) and the ARFTG Conference (**www.arftg.org**).

With over 8000 participants and 500 industrial exhibits of state-of-the-art microwave products, Microwave Week 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. IMS2017 offers something for everyone:

- The first-ever IMS Hackathon and IMS 3-Minute Presentation Competitions
- A 5G Summit showcasing next-generation wireless technologies
- An Executive Forum to discuss the latest in 5G and Internet of Things (IoT)
- RF Boot Camp – a three-quarter day course on RF/microwave basics
- The first-ever IMS Exhibitor Workshops for exhibitors to present the technology behind their products
- Networking events for Young Professionals and Women in Microwaves
- Student Design, Student Paper, Best Industry Paper, and Best Advanced Practice Paper Competitions
- Project Connect for under-represented minority engineering students, and the PhD Student Initiative for new PhD students
- *Teaching that inspires...students that aspire* – an exciting STEM program exposing middle school and select high school students, as well as their teachers, to RF/microwave technology

IMS2017 will include a comprehensive portfolio of events featuring recent 5G developments, including a plenary session, focus session, workshops, panel session, and a technology-development pavilion.

Paper Submission: Authors are invited to submit technical papers describing original work and/or advanced practices on RF, microwave, millimeter-wave, and terahertz (THz) theory and techniques. The deadline for submission is 5 December 2016. 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 at **www.ims2017.org**. Papers will be evaluated on the basis of originality, content, clarity, and relevance to IMS.

Emerging Technical Areas: IMS2017 enthusiastically invites submission of papers that report state-of-the-art progress in technical areas that are outside the scope of those specifically listed in this Call for Papers, or that may be new to IMS, but are of interest to our attendees.

Workshops, Short Courses, Focus and Special Sessions, Panel and Rump Sessions: Topics being considered for these areas include Next-Generation Wireless Systems (5G and beyond), Internet of Space, Latest Technologies for RF/Microwave Measurements, and Advances in RFIC Technology. Please consult **www.ims2017.org** for a more detailed list of topics and instructions on how to prepare a proposal. Proposals must be received by 6 September 2016.

MicroApps and Exhibitor Workshops: The Microwave Application Seminars (MicroApps) serve as a forum for IMS exhibitors to present technology behind their commercial products and special capabilities. New for IMS2017 are Exhibitor Workshops, which offer IMS exhibitors a chance to present in-depth technical topics, via two-hour sessions, in a meeting room off the exhibit floor. Both presentation formats are open to all conference and exhibit attendees – MicroApps are free of charge and Exhibitor Workshops require a nominal fee. Please visit **www.ims2017.org** for details on submitting MicroApps and Exhibitor Workshop presentation ideas.

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Innovative Integration
www.innovative-dsp.com

SOURCES

OEM Signal Generator Platform

VENDORVIEW

Berkeley Nucleonics (BNC) released a user-customizeable OEM signal generator platform for RF/microwave systems requiring brand singularity or system integration. The platform leverages proven designs at 20 and 26.5 GHz, low phase noise, phase coherence and robust modulation features. Fast frequency switching speeds ensure a broad range of applications can be addressed. The Fast Switching (FS) option allows for extremely fast digital sweeps at a minimum rate of 10 µs.

Berkeley Nucleonics
www.berkeleynucleonics.com

Wideband Microwave Signal Source

DS Instruments introduced a redesigned version of its highest-end microwave signal generator with output past 22 GHz. Phase noise has been driven below - 90 dBc at 10 KHz offset. New internal variable attenuators compliment the standard stepped power output level settings. Active harmonic filtering to -30 dBc typical and dual-control put this device in a league with equipment priced thousands more.

DS Instruments
www.dsinstruments.com

Low Phase Noise OCXO

VENDORVIEW

Morion has released the improved MV269, low noise OCXO in a small DIL14 package, measuring just 21 mm × 13 mm × 9.5 mm. Available at 60 to 120 MHz, the MV269 has phase noise of -153 dBc/Hz @ 1 kHz offset and <-170 dBc/10 kHz ; sinewave or HCMOS. It works at 5 or 3.3 V. Temperature stability is at < 5E-8 from 0 to 60°C; frequency adjustment for external synchronization provided, but due to excellent <1E-7/year aging unit may work as a stand-alone unit; Ideal as a reference oscillator in synthesizer and PLL circuits.

Morion
www.morion-us.com

Compact Active Multiplier

QuinStar's model QMM-753012040 is a compact active (x4) multiplier designed for E-Band RF front-ends, driving LO ports of E-Band mixers and up-converters with 13 dBm typical power from 60 to 87 GHz. It is featured with a 2.9 mm coaxial connector at input, WR-12 output embedded with a waveguide window, and two side slots for mounting screw access. The multiplier has in-band harmonics rejection at 30 dBc or better and spurious signal rejection 60 dBc or better.

QuinStar Technology Inc.
www.quinstar.com

Voltage Controlled Oscillator

VENDORVIEW

The DRO series voltage controlled oscillator is a fundamental, narrowband signal source utilizing a high-Q dielectric resonator for optimal phase noise performance. The DRO VCO solution is currently being offered for frequencies operating within 7 to 14 GHz. This customizable, ultra-low noise oscillator series is available with both electrical tuning and mechanical tuning for fine frequency precision.

Z-Communications
www.zcomm.com

ANTENNAS

Filtered Omni-Directional Antennas

VENDORVIEW

Southwest Antennas' new filtered omni-directional antennas with integrated goosenecks give users an easy plug-and-play solution for enhanced radio performance without complicating their radio setup. This can be particularly useful for handheld or body worn tactical radio systems, which are often deployed in areas with crowded RF environments and powerful co-located transmitters. These antennas feature custom electronics inside of the antenna to ensure the filter performs optimally across the antenna's entire operating frequency range, and are available with several RF connector options.

Southwest Antennas
www.southwestantennas.com

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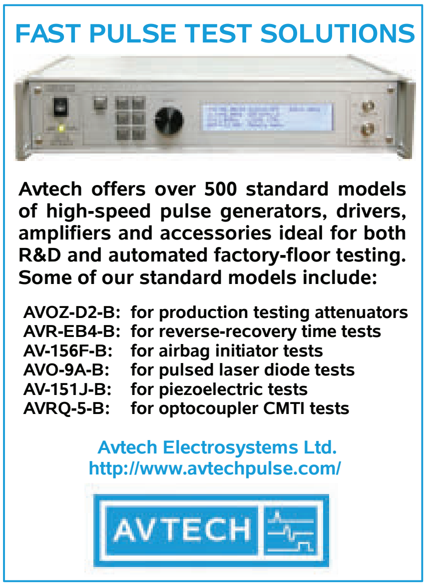

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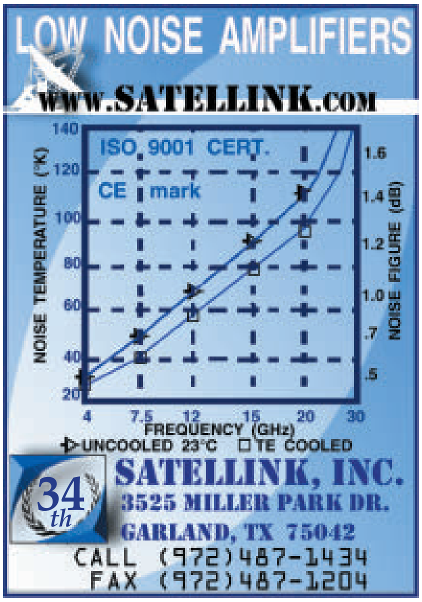

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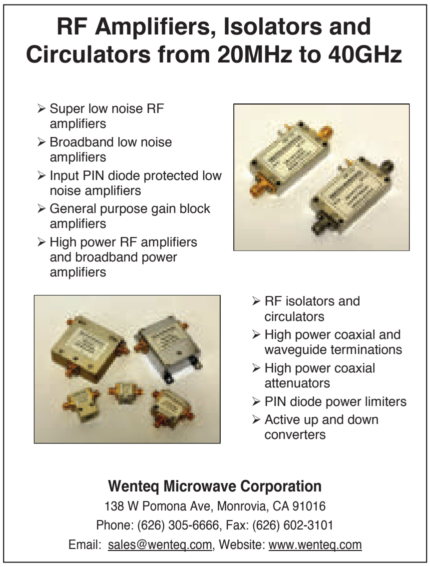

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Program Highlights

KEYNOTE SPEAKER

Tuesday, 17 January 2017

"5G on the Road to WRC-19"
Jayne Stancavage, Senior Manager-Spectrum Policy (ITU-R), Intel Corporation

Abstract: Significant progress is being made on the road to 5G via research and development, the creation of new standards, network trials, and product designs. Two major efforts are currently underway in the International Telecommunication Union – Radiocommunication Sector (ITU-R). First, ITU-R Working Party 5D is undertaking a wide range of tasks culminating in the development of the specification(s) for IMT-2020. The second major effort revolves around spectrum access. Demand for mobile broadband spectrum continues to grow due to an increasing number of users (~3.6 billion mobile broadband subscriptions in 2016) and more bandwidth-intensive traffic such as video. Join us for a discussion on key milestones on the 5G road to WRC-19.

WORKSHOPS

Sunday, 15 January 2017 and Monday, 16 January 2017

Inkjet and 3D printed electronics for the Internet of Things and 5G communication systems
Chairs: Apostolos Georgiadis, Heriot-Watt University and
Manos Tentzeris, Georgia Institute of Techology

Techniques for High Efficiency Linear Power Amplification of 5G Signals
Chair: Roman Maršálek, Brno University of Technology

High speed Optical Communications and Opto-electrical Component Technologies for 400 Gbit/s and Beyond
Chairs: Koichi Murata, GigPeak Inc. and
Noriaki Kaneda, Nokia Bell Labs

Shaping the Career with Next Generation RF Technologies
Chairs: Tushar Sharma, University of Calgary and
Ibrahim Khalil, NXP Semiconductors

PANEL SESSION

Monday, 16 January 2017

Linearization of Power Amplifiers in 5G
Chair: Neil Braithwaite, Consultant

MTT-S DISTINGUISHED LECTURER TALKS

Monday, 16 January 2017

Design of millimetre-wave multifunction integrated circuits for data communication and remote sensing applications
H. Zirath, Chalmers University

Millimeter-wave and Terahertz Applications Enabled by Photonics
T. Nagatsuma, Osaka University

Gallium Nitride Power MMICs – Fact and Fiction
C. Campbell, Qorvo

IEEE Topical Workshop on the Internet of Space

Tuesday, 17 January 2017 and Wednesday, 18 January

Introducing a new co-located conference at RWW, that will feature keynote talks "The Challenges of Space" and "Creating Iridium" as well as several presentations from industry and academic leaders in this booming field.

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EXHIBITS AND DEMO SESSIONS

Monday, 16 January 2017 and Tuesday, 17 January

http://www.radiowirelessweek.org/

Telecommunication Networks for the Smart Grid

Alberto Sendin, Miguel Sanchez-Fornie, Iñigo Berganza, Javier Simon and Iker Urrutia

Telecommunication networks enable the so-called smart grid to be smart, relaying usage data to the utility and, when required and enabled, controlling usage to prevent demand from exceeding generation capacity. "Telecommunication Networks for the Smart Grid" was written to help the electric power industry understand the telecommunications technologies and services that underpin the smart grid. It is equally useful for telecommunications professionals called to deploy or support smart grid networks.

Since readers won't likely have a full understanding of the topic, the first three chapters provide a foundation. The authors begin by defining the smart grid concept, identifying the standards for smart grids and discussing the requirements for the attendant networks. The second chapter provides a tutorial on telecommunications networks for power systems engineers who are not familiar with networking. For telecommunications engineers not familiar with power systems, the third chapter offers a similar tutorial.

The remainder of the book (chapters 4 through 9) covers smart grid applications and requirements, typical telecommunications technologies used, a networking architecture for meeting smart grid requirements and power line communications (PLC) and wireless approaches for relaying data. The final chapter has guidelines for implementing a "pragmatic" smart grid project, including the end-to-end process, system design and requirements (e.g., EMC and environmental). The authors conclude with a smart grid example, beginning with the network design and showing the actual data traffic at key points in the network.

Collectively, the authors bring extensive experience in the power industry, telecommunications and smart grids. They all work for Iberdrola, a global electric utility based in Spain, with operations in Brazil, Scotland and the U.S.

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MAR	Test and Measurement	Microwave & RF EDI CON China Expo Electronica
& SUPPLEMENT	Cables and Connectors	IWCE IEEE MTT-S IMS
APR	Amplifiers and Oscillators	WAMICON AUVSI Xponential
MAY	IEEE MTT-S IMS Show Issue	IEEE MTT-S IMS Space Tech Expo Aerospace Electrical Systems Expo
JUN	Semiconductors/MMICs/RFICs	Sensors Expo
& SUPPLEMENT	Aerospace & Defense Electronics	Sensors Expo EDI CON USA
JUL	RF & Microwave Software and Design	IEEE EMC & Signal/Power Integrity
AUG	High Frequency Components and PCBs + EDI CON Show Issue	IEEE Autotestcon EDI CON USA
SEP	European Microwave Week Show Issue	EuMW IEEE CSICS
& SUPPLEMENT	Military Microwaves	EuMW MILCOM
OCT	Passive and Control Components	AMTA COMCAS Asia Pacific Microwave Conference
NOV	Government and Military Electronics	
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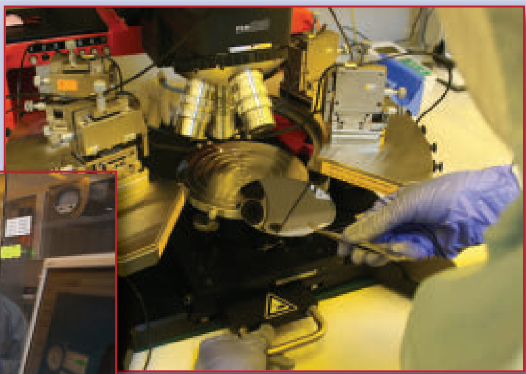

Exhibiting passion and professionalism like James Bond, Micran has grown a hundredfold from its origins in 1991 as a private firm of eight people into a modern innovative company with a strong team of specialists, utilizing their expertise in the fields of microwave electronics, communications, radio location, test and measurement equipment, and information security.

Now one of Russia's leading manufacturers of solid-state EHF and SHF electronics, the company grew out of the Tomsk State University of Control Systems and Radioelectronics (TUSUR) lab. The links between the two remain strong. In cooperation with the University, Micran has created a Telecommunications Scientific-Research Institute, Nanoelectronics Educational Research Center and Siberian Solid-State SHF Electronics Competence Center.

From 2013 to 2015, Micran and TUSUR developed and organized high-tech production of solid-state millimeter wave radar using electronic components of its own design, which laid the groundwork for the development of an interconnected surveillance system for selected areas.

In addition to its links with academic and commercial research bodies, Micran's key strengths are the full cycle of its in-house research and development. All of the company's products are developed and manufactured in compliance with international standards and recommendations, including ETSI, IEC, IEEE, DIN, ITU, ANSI, EIA and ETS, which are covered by the corresponding patents. The company's flexible manufacturing facility is geared up for both low-volume and high-volume production, meeting all the needs of the market.

Micran's MMIC Design Center began its activity in 2008. Since that time the team has gained substantial experience through joint activity with the company's Internal III-V Foundry and successful projects with popular foundries in Europe and Asia. Subsequently, MMICs can be manufactured using proven foundry processes from OMMIC, United Monolithic Semiconductors (UMS) and WIN Semiconductors.

Micran's MMIC Design Center, working in cooperation with the company's Internal III-V Foundry, has the capability to design and fabricate a variety of III-V microwave devices, producing both off-the-shelf products or custom designed MMICs. Micran can offer competitive vertical diode processes, which are claimed to offer superior performance and extended functionality. The offering includes the QZBD process that is based on a vertical GaAs zero bias diode. This process is suited primarily for ultra-wideband, wide dynamic range power detectors with no DC bias required.

Another is the QSBD process, which has at its core a vertical GaAs Schottky barrier diode with high reliability and excellent performance. Various types of passive microwave devices can be designed based on the QSBD process, including limiters, mixers, multipliers and detectors.

The QPIN process is based on a vertical GaAs PIN diode that simplifies the design of different passive microwave devices such as switches, limiters, attenuators and phase shifters.

Micran uses proven microwave design software from leading companies and focuses on quality control for the manufacturing of quality products. On-wafer device characterization can be carried out using the company's test and measurement capabilities, including the measurement of S-parameters, power, noise figure and load-pull.

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C5725	Dual	0.1-1000	500	40	0.5	1.25:1	0.5	5.2 x 2.67 x 1.69
C9688	Dual	1-1000	800	40	0.5	1.20:1	1.0	6 x 2.2 x 2.2
C7734	Dual	30-2500	100	43	0.35	1.25:1	1.5	3.5 x 2.6 x 0.7
C8188	Uni	30-3000	20	20	2.4	1.35:1	1.0	6 x 1.5 x 1.1
C3910	Dual	80-1000	200	40	0.2	1.20:1	0.3	3 x 3 x 1.09
C8373	Bi	100-2500	200	20	0.8	1.25:1	1.75	9.58 x 1.48 x 0.88
C7711	Dual	100-3000	100	40	0.35	1.25:1	1.0	3 x 2.2 x 0.7
C7058	Bi	200-2000	200	10	0.3	1.25:1	1.0	6.4 x 1.6 x 0.72
C8060	Bi	200-6000	200	20	1.1	1.40:1	2.25	4.8 x 0.88 x 0.5
C7248	Bi	300-3000	100	6	0.35	1.25:1	1.0	6 x 2 x 0.85
C8000	Bi	600-6000	100	30	0.4	1.25:1	1.0	1.8 x 1 x 0.56
C8214	Bi	700-2500	100	6	0.35	1.25:1	1.0	6 x 2 x 0.85
C10462	Dual	700-4200	250	40	0.2	1.30:1	1.0	2 x 2 x 1.06
C10525	Dual	700-4200	700	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10537	Dual	700-4200	700	60	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10536	Dual	700-4200	1000	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10751	Dual	700-4200	1000	60	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10006	Dual	700-4200	2000	50	0.2	1.35:1	1.0	3 x 3 x 1.59
C10117	Dual	700-6000	250	40	0.2	1.30:1	1.0	2 x 2 x 1.06
C10364	Dual	700-6000	500	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10762	Dual	1000-6000	300	40	0.2	1.30:1	0.5	2 x 2 x 1.06
C10958	Dual	1000-6000	400	40	0.2	1.35:1	0.5	2 x 2 x 1.06
C10761	Dual	1000-6000	600	40	0.2	1.35:1	0.5	2.15 x 2 x 1.36
C8644	Bi	1800-6100	60	20	0.4	1.25:1	1.0	1.1 x 0.75 x 0.48
C10743	Dual	2000-6000	500	40	0.2	1.30:1	0.5	2.15 x 2 x 1.36
C10746	Dual	2000-6500	500	50	0.2	1.35:1	1.0	2.15 x 2 x 1.36
C10748	Dual	2000-6500	500	60	0.2	1.35:1	1.0	2.15 x 2 x 1.36

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