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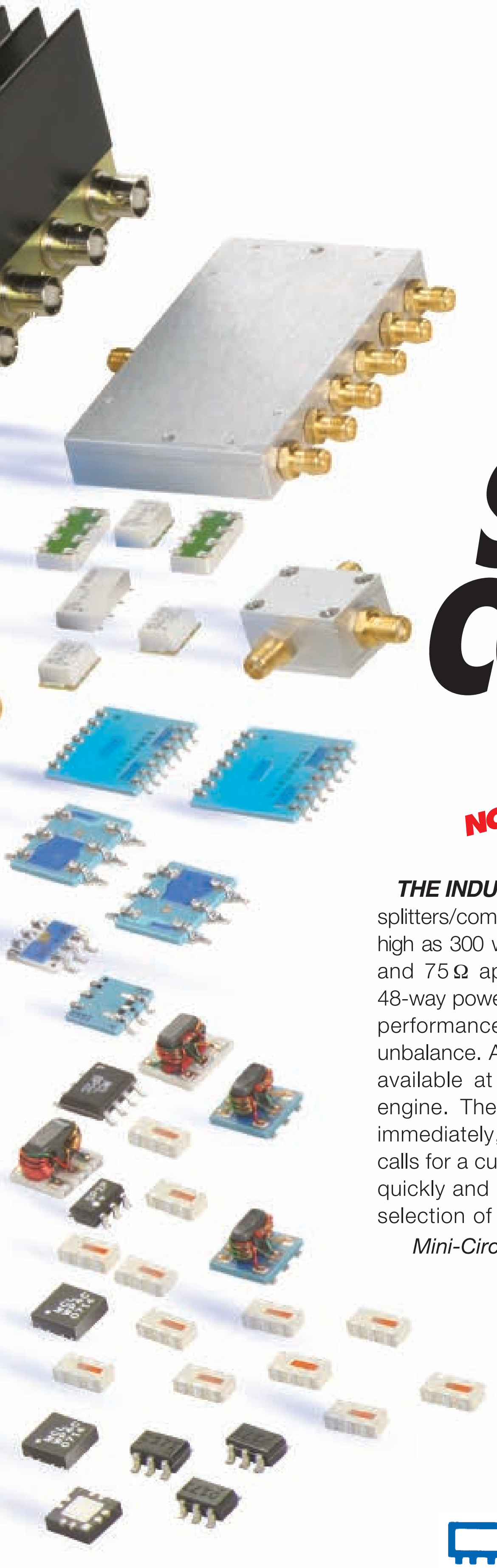

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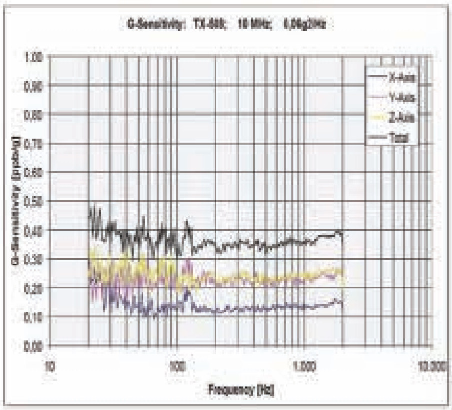

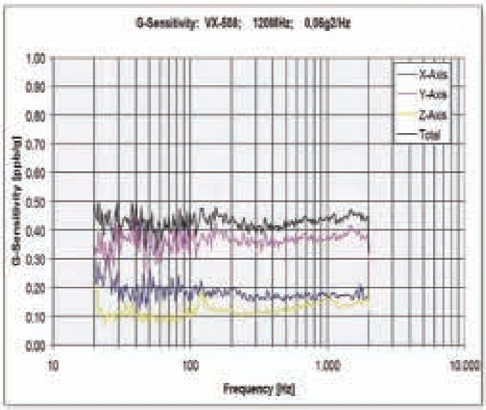

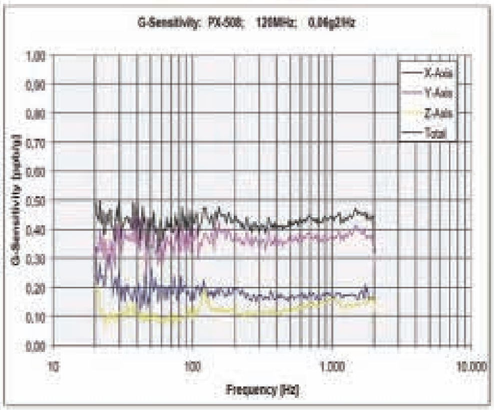

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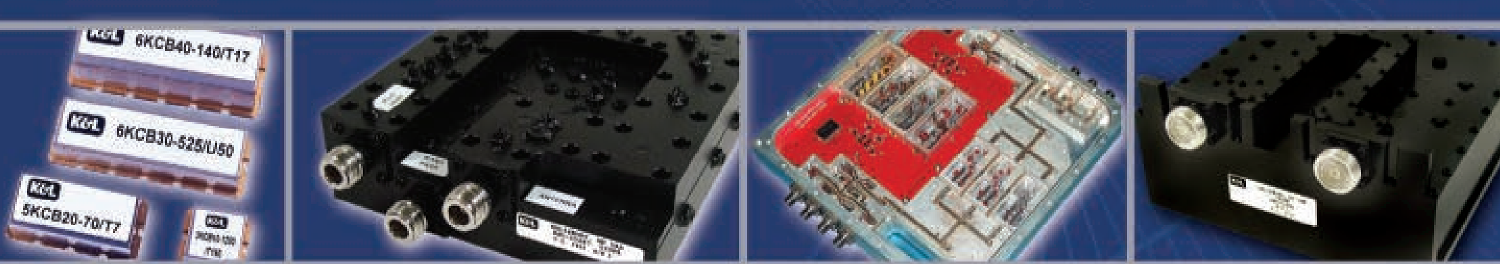

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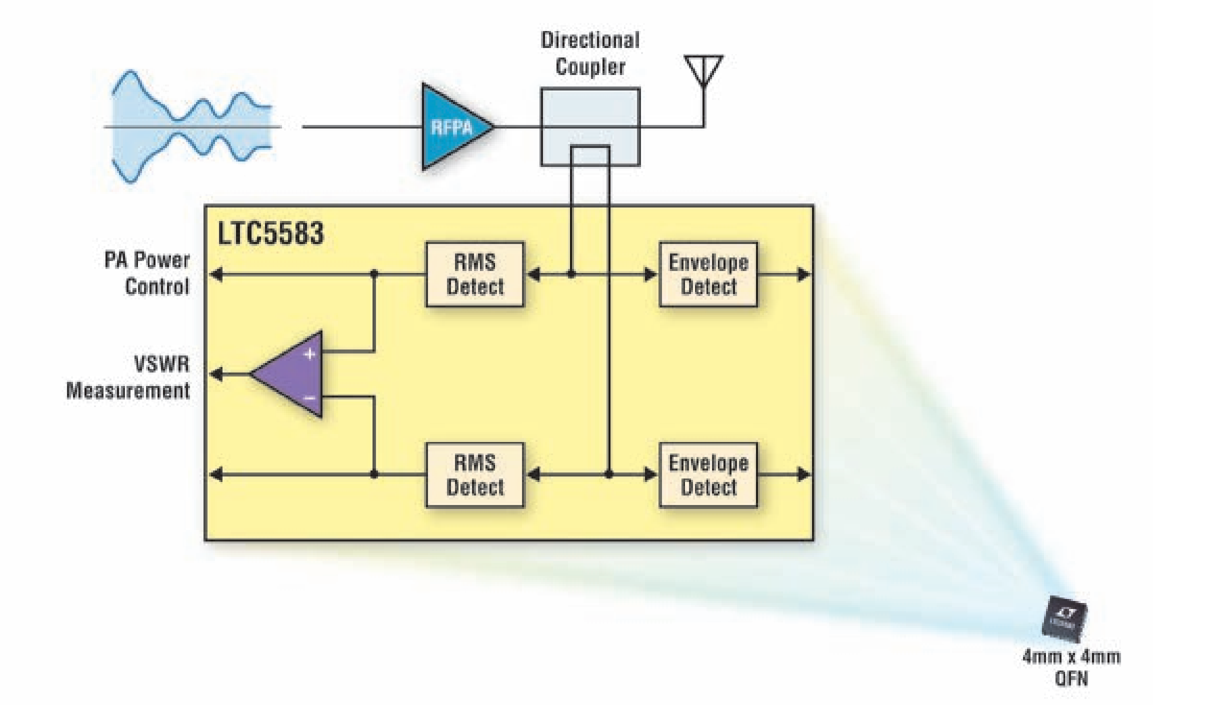

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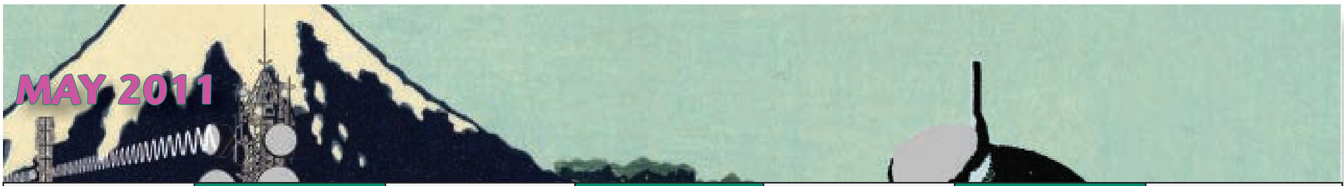

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8	9	10	11	12	13	14
15	16 **Asia-Pacific EMC Symposium** Jeju Island, Korea	17 **MWJ Besser Webinar: Mixers and Frequency Conversion** Sponsored by Mini-Circuits **Agilent RF and Microwave Fundamentals** Las Vegas, NV	18 CST **European User Group Meeting** Munich, Germany	19	20	21
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29	39	31 **ECTC 2011 Electronic Components and Technology Conference** Lake Buena Vista, FL	1	2	3	4

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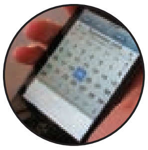

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MAVC-110000-000626	536 - 716	0.5	11.5	-115	4.8	17
MAVC-130000-000986	896 - 1076	2.5	10.5	-114	4.8	13
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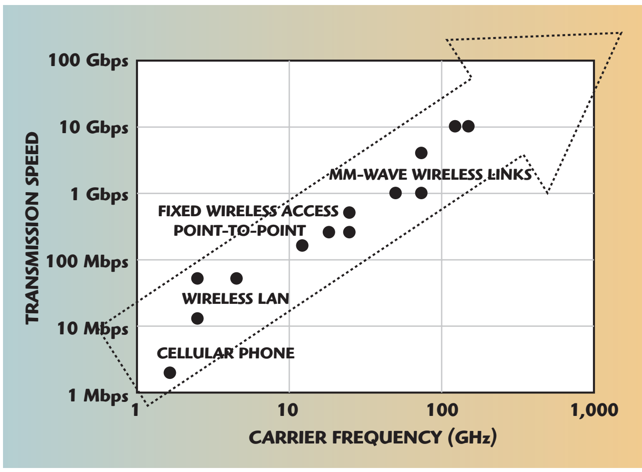
Future Opportunities and Challenges for mm-Wave Amplifier MMICs

The consumers' appetite for wireless data transfer is seemingly inexhaustible. This is pushing up the operating frequency of point-to-point links and leading to increased opportunities for microwave monolithic integrated circuit (MMIC) mm-wave amplifiers. The link between carrier frequency and data rate is illustrated in ***Figure 1***. Unfortunately, as operating frequencies increase, component availability decreases, while the costs of both components and equipment rises.



▲ *Fig. 1 Relationship between data rate and operating frequency (reproduced with permission from[1]).*

The largest application for mm-wave amplifier MMICs is point-to-point links for mobile communications backhaul. Microwave point-to-point links in the 6 to 40 GHz range are a well established technology for this application. In terms of mm-wave (> 30 GHz) amplifiers, products targeting the point-to-point bands at approximately 38 GHz are currently shipping in very high volumes. Looking to the immediate future, there is a lot of interest in the 40.5 to 43.5 GHz frequency range (also called the 42 GHz band), which is viewed as a likely extension to the current range of fixed link frequency allocations. In Europe, CEPT guidelines provide recommendations for the accommodation and assignment of multimedia wireless systems (MWS) and point-to-point links in this band.

E-band spectrum at 71 to 76 GHz and 81 to 86 GHz is also receiving a lot of interest. The use of E-band offers worldwide availability of a large amount of spectrum under a 'light license' basis. This scheme operates in the US, the UK and many other countries, and allows

L. Devlin, A. Dearn, G. Pearson and T. Richards
Plextek Ltd., Great Chesterford, UK

licenses to be obtained quickly and cheaply while retaining the benefits of interference protection.[1]

Despite the attractions of E-band, deployment in very high volumes will only happen once the price of equipment falls to an acceptable level. This requires wider availability of component parts with adequate performance at acceptable costs. While it is possible to manufacture E-band MMICs in high volumes at a low cost, the current range of commercially available parts is limited and the unit cost could not be described as low. The problem is that the development of E-band MMICs is complex and time consuming and is therefore very costly. Unless the MMIC supplier has confidence that volume orders will come through, it can be difficult to justify the NRE costs to develop E-band components.

The test equipment used to evaluate mm-wave MMICs (shown in ***Figure 2***) is also very expensive and adds to the cost of development activity. While the implementation and evaluation of components targeting the 42 GHz band is less of an issue than for E-band, the current range of available components is still limited. This is starting to change, with suppliers actively developing MMICs targeting the 40.5 to 43.5 GHz band, which will lead to increased component availability and reduced component cost.

▲ *Fig. 2 Evaluation of a mm-wave amplifier MMIC in Plextek's RFOW test laboratory.*

There is also a significant allocation of mm-wave spectrum at approximately 60 GHz. The most extensive and flexible allocation is in the US, where the 57 to 64 GHz band is available for unlicensed use. Two applications are normally cited for the 60 GHz spectrum: medium range point-to-point outdoor links and very high data rate WLANs or wireless personal area networks (WPAN).

One feature of the 60 GHz spectrum is high atmospheric attenuation, caused by oxygen absorption. This reduces practical propagation distances, but is often presented as offering benefits in terms of interference reduction and ease of frequency re-use. However, to term the oxygen absorption an advantage seems like an attempt to change a vice into a virtue and the 60 GHz bands look a less attractive option for outdoor point-to-point links than E-band.

The 60 GHz spectrum, however, is an attractive option for very high data rate WLAN/WPAN applications. In this case, the potential product volumes would be extremely high, the required performance (NF, linearity and transmit power) less stringent than for point-to-point links and the cost targets very low. These factors lead to the conclusion that this is an application that is likely to be dominated by highly

integrated Si transceivers.

There may be a role for small, low-cost transmit amplifier MMICs capable of modest output power levels. However, increased confidence in high production volumes is needed before the work required to drive down the size and cost to the levels required for WLAN/WPAN applications will be undertaken.

This article considers the challenges in designing amplifier MMICs for operation above 40 GHz, using commercially available foundry processes and offers some guidelines for achieving optimum performance and reduced risk.

PROCESS AVAILABILITY AND SELECTION

The first consideration when choosing a process for the realisation of mm-wave amplifier ICs is to identify which commercially available, fully released processes can offer useful gain across the required frequency range. With E-band operation, the number of potential processes is relatively modest. Transistors realised on short geometry CMOS and SiGe processes have a high enough Ft to provide gain at E-band and numerous circuits at high mm-wave frequencies have been demonstrated using these technologies.

However, all current commercially available mm-wave links for wireless backhaul incorporate GaAs-based front-end MMICs. The reason behind this is that acceptable NF and adequate linearity are essential requirements and GaAs technology offers superior performance in these respects.[2] GaN technology shows a lot of promise for the future,[3] in particular for the realisation of mm-wave PAs. However, the GaN foundry processes that are commercially available today are only suitable for operation to approximately 20 GHz and, for the immediate future, GaAs technology is the best candidate for the realisation of mm-wave amplifiers for point-to-point applications.

Other advantages of the GaAs technology for the realisation of mm-wave amplifiers include the semi-insulating substrate material and the ready availability of low inductance through substrate vias. The absence of these features on most Si processes means that the design approaches that must be adopted tend to sacrifice gain. Available gain decreases with increasing operating frequency and at E-band the available gain of transistors on commercially available processes is very limited. In the 42 GHz band, the available gain is much higher, which eases the design process and increases the linearity and output power that can be achieved. However, the same range of candidate processes can be considered for both frequency ranges.

The commercially available GaAs processes that can provide useful gain up to E-band can be split into three categories:

- 0.15 or 0.13 µm gate length PHEMT
- 0.15 µm gate length MHEMT
- 0.1 µm gate length PHEMT

There is a minimum level of available transistor gain below which it is not practical to consider realising am-

plifier blocks. In the authors' experience, 6 dB is a realistic lower limit. The available gain of a transistor is not only dependent on the process, it is also dependent on device geometry (number of gate fingers and unit gate width), substrate thickness (actually parasitic inductance of through substrate vias used as RF grounding) and the bias point.

As the total transistor gate width increases (more gate fingers and/or wider unit gate width), the parasitic effects increase (that is gate inductance and phase delay between gate fingers). This reduces the available high frequency gain of the transistors. For a given process and bias point, there is thus a maximum transistor size that can be considered for a particular frequency range, which limits the maximum RF power handling and linearity of the transistor.

Most commercially available 0.15 or 0.13 μm gate length PHEMT processes can provide a good level of gain across the 42 GHz band. However, at E-band, the maximum practical transistor size that can be used in these processes (in order to retain an acceptable level of available gain) is relatively small. Larger device sizes can be considered with a 0.1 μm gate length process, which means that the achievable linearity and output power levels are higher. Bias conditions and breakdown voltage must also be assessed when comparing the linearity available from different processes, but, even with this consideration in mind, it is possible to say that of today's commercially available GaAs processes, the best choice for output power and linearity at E-band is the 0.1 μm gate length PHEMT.

Obviously process costs also need to be considered. GaAs processes with 0.1 μm geometries tend to utilise e-beam written gates, which can push up process costs. Some 0.13 and 0.15 μm processes have optically defined gates, which should result in lower production costs. This difference is likely to change over time and it is expected that GaAs processes with optically defined gates at lengths of 0.1 μm and below will become commercially available in due course.

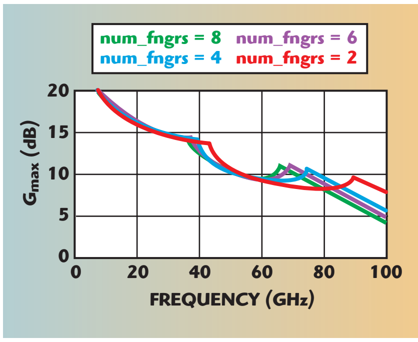
The available substrate height (thickness) also needs to be considered when selecting the preferred process. Most commercially available GaAs processes have a substrate thickness of 100 μm. However, some processes are available with a thinner substrate thickness of 50 μm, which can provide a performance advantage at mm-wave frequencies. The advantage stems from the reduced via inductance inherent in the thinner substrate. The via inductance acts as series inductive feedback around the transistor and can degrade performance and stability.

This is apparent by inspection of the simulated maximum available gain (MAG) versus frequency curves found in ***Figure 3***.[4] These curves are for a 0.15 μm gate length process with a 100 μm substrate height. At low frequencies, the device is conditionally stable (or potentially unstable with K<1) and the gain response plotted is actually the maximum stable gain (MSG). The kink in the traces, at ap-

proximately 40 GHz, marks the point at which the transistor transitions to being unconditionally stable (K>1). This behaviour is well understood.

The more curious aspect to the curves is the second higher frequency kink, which shows the transistors reverting to a region of potential instability. If operated in this region, some gain must be sacrificed to stabilise the transistor and it is likely that the practical performance that can be obtained from the device would not be adequate.

This occurs because the reverse isolation is reducing with increasing frequency (feedback is increasing), but the transistors still have significant forward gain. If the source inductance of the transistors can be reduced, this reversion to potential instability can be suppressed. The use of a thinner substrate height can allow this. The availability of intersource grounding (through substrate vias directly under the fingers of the transistors) can also help reduce source grounding inductance.



▲ *Fig. 3 MAG/MSG for 0.15 μm PHEMT process, 50 μm finger width and varying number of fingers on a 100 μm thick substrate.*

DESIGN, SIMULATION AND EXAMPLE MMICS

Once the process has been selected, detailed investigations into the design can commence. At E-band frequencies, the first challenge is achieving adequate gain as the transistors have little in hand to be sacrificed. At each stage of the design process, care must be taken to ensure as little gain as possible is lost, with practical implementation issues such as biasing the device and realising a practical matching network.[4]

Obviously, stability must also be considered. The transistors have a lot of low frequency gain and care must be taken to ensure the design is stable in this region. If transistors are used that revert to a region of potential instability at higher frequencies, care must also be taken in this region. In both cases, any components added to ensure stability must not add any significant in-band loss.

The other challenge with gain is linked to linearity. Larger transistors at higher bias currents must be used, if increased power handling and/or linearity is required. These larger transistors have reduced gain and for a given process and operating frequency range there will be a maximum transistor size that can be considered if practical levels of gain per stage are to be achieved.

This effect will be evident at both 40.5 to 43.5 GHz and at E-band, but the use of larger transistors will be more practical in the 42 GHz band and higher power/linearity amplifiers can be

realised. Obviously, linearity and power handling can be increased by RF power combining of multiple transistors, but the losses of the combining structures make this a process of diminishing returns. However, it is still the most appropriate route to designing high power/linearity mm-wave amplifiers.

The PHEMT processes that are best suited to mm-wave operation generally have very good NF performance. The NF exhibited by a given transistor is set by the impedance presented to the transistor and the losses at its input (that is the input matching network losses). The impedance required to achieve best NF is different from that required to achieve good input return loss and so optimise the gain of the device. One approach to achieving improved NF is to simply match for optimum noise and live with the degraded input match (and reduced gain). Other approaches aimed at simultaneously achieving good input return loss and NF performance include adding series inductive feedback or adopting a balanced design.

Unfortunately, these techniques all require some loss of gain and while they can be considered for 40.5 to 43.5 GHz operation, they are not practical at E-band using current commercially available processes. The only practical approach is to select a device size and bias point with a lowest NF in mind and then to conjugately match for maximum gain and to accept the resulting performance.

It is normal to start the amplifier design process with ideal passive elements and active device models. Once acceptable performance is achieved, the design is moved to a practical implementation with the incorporation of representative passive models, including those required to simulate parasitics and discontinuities. With mm-wave circuits, it is always essential to perform an EM simulation to accurately account for all proximity and discontinuity effects associated with the layout. Many 3D and 2.5D EM simulation packages are now available. In the authors' experience, the use of a 3D simulator for simulation of a MMIC does not guarantee superior performance to that using a 2.5D simulator.

Figure 4 is a photograph of an E-band gain block, together with a comparison of the measured and EM

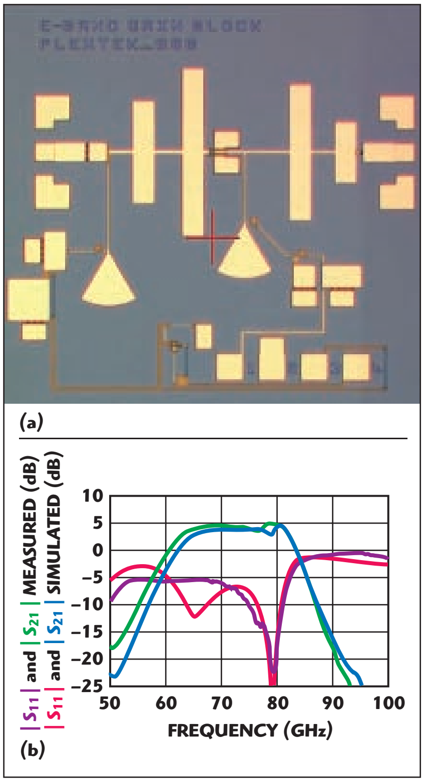


Fig. 4 E-band gain block realized with a 0.15 μm PHEMT process: (a) photograph and (b) measured and simulated performance.

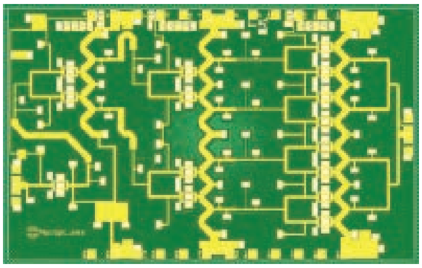
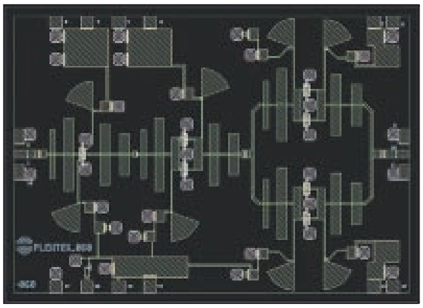


Fig. 5 Plextek designed 1 W, 40.5 to 43.5 GHz power amplifier.

simulated performance.[4] This was fabricated on the PP15-20, 0.15 μm gate length PHEMT process of WIN Semiconductor. This process has a 100 μm thick substrate and is probably not the ideal choice for E-band MMICs, but it demonstrates over 4 dB of gain per stage in the 71 to 76 GHz band and, perhaps more importantly, shows a reasonably good match between simulated and measured performance. In addition to accurate EM simulation, this requires good device models, which are valid across the frequency range of interest.

Figure 5 shows a Plextek designed 1 W, 40.5 to 43.5 GHz PA, designed for a 0.15 μm gate length PHEMT process. The approach taken for this design was to identify the transistor geometry and bias capable of offer-



▲ *Fig. 6 Plextek designed, low-cost E-band, 20 dBm driver amplifier.*

ing the highest linearity while still achieving 8 dB of available gain. Eight transistors were then power combined in the output stage, using a compact matching and combining network. The driver stages were designed to have adequate linearity to ensure a limited output stage performance of the complete amplifier.

As previously mentioned, many short gate length PHEMT processes are fabricated using direct write e-beam machines to define the gate fingers. This is a convenient means of defining very short geometry gates, but adds time and cost to the processing compared to processes using optically defined gates. The availability of short gate length processes that make use of optical gate definition is currently limited but expanding. ***Figure 6*** shows the layout of a 71 to 76 GHz driver amplifier having a 12 dB gain and an output power capability of 20 dBm, realised on a low cost 0.13 μm gate length process, which uses optically defined gates (TQP13 from TriQuint).

CONCLUSION

This article has discussed the future opportunities and challenges for the realisation of MMIC mm-wave amplifiers. It has primarily considered MMICs for point-to-point links, which is considered the largest potential market for this technology. MMIC amplifiers, at 40.5 to 43.5 GHz and E-band, represent a very significant opportunity. The development of MMICs for these bands, using commercially available foundry processes, has been discussed and practical design examples have been presented.

The successful development of MMICs operating at these very high frequencies is a complex and time consuming task. The range of suitable commercial processes is limited and, at E-band in particular, the inherent gain available from the transistors is modest and great care must be taken to avoid losing performance during the detailed design and simulation process. Larger transistors have less gain, which presents restrictions on the practical output power and linearity performance that can be achieved. The absence of excess gain also restricts the use of conventional LNA design techniques and limits the designer's ability to reduce the NF. The commercial development of MMICs targeting the 40.5 to 43.5 GHz band is already well underway. Development work at E-band is less well progressed, but E-band MMICs can be developed with current commercially available processes. The main barrier preventing wider availability of E-band MMICs is the commercial leap of faith to believe that the volume of the market will justify the development costs. ■

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Liam Devlin *is the Director of RF Integration with Plextek. He joined the company in 1996 to develop the RF and microwave IC design capability and since then has led the design and development of over 50 custom ICs on a range of GaAs and Si processes at frequencies up to 90 GHz.*

Andy Dearn *joined Plextek in 1997, and is currently a Senior Technology Consultant within the RF Integration group. His primary focus is on the design of GaAs MMICs. He also has experience in designing discrete-based RF and microwave components and subsystems for a range of technologies, including DAB radio, GSM and military hardware.*

Graham Pearson *joined Plextek in 1999, and is currently a Senior Technology Consultant within the RF Integration group. His current role includes the detailed design and development of mm-wave and microwave components and modules in a range of technologies including GaAs MMIC.*

Tony Richards *joined Plextek in 1999, and is currently a Senior Technology Consultant within the RF Integration group. He has helped to design several single chip radio ICs for multinational silicon vendors such as National Semiconductors. He has also worked on the development of SMT-based RF products and X-band microwave PAs, and is currently designing GaAs MMICs at microwave and mm-wave frequencies.*

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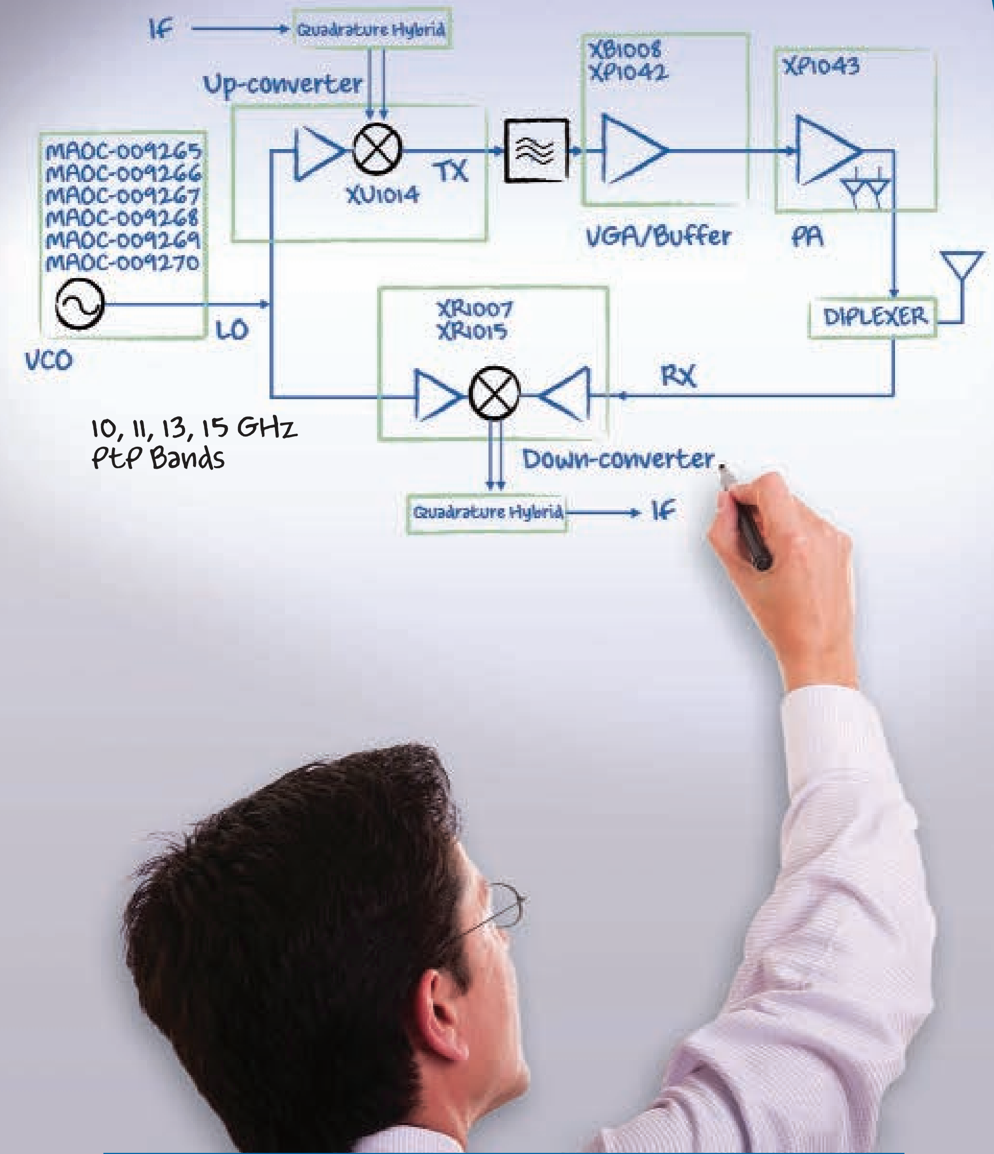

Part Number	Frequency (GHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	Pout (dBm)	PN at 100 kHz (dBc/Hz)	Current (mA)	Package (mm)
XP1043-QH	12.0-16.0	21.5	30.0	41.0			700	4x4
XP1042-QT	12.0-16.0	21.0	25.0	38.0			500	3x3
XB1008-QT	10.0-21.0	17.0	19.0	32.0			100	3x3
XU1014-QH	8.0-18.0	-10.0	2.0	12.0			80	4x4
XR1007-QD	10.0-18.0	13.5		4.0 (I/P)			150	7x7
XR1015-QH	10.0-16.0	12.0		2.0 (I/P)			170	4x4
MAOC-009265	9.0-10.3				6.0	-110	175	5x5
MAOC-009266	10.2-11.3				9.0	-114	185	5x5
MAOC-009267	11.2-12.6				3.5	-110	165	5x5
MAOC-009268	12.7-14.2				7.0	-105	175	5x5
MAOC-009269	11.4-12.8				3.0	-110	165	5x5
MAOC-009270	12.2-13.8				6.5	-105	155	5x5

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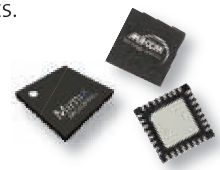

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The PowerCore LUT allows the RFRD6460 to meet multiple market/mobile operator needs. For example, in standard set-up the controller can bias the power amplifiers at a total battery current of 440 mA in order to deliver 23.5 dBm at an ACLR of -35 dBc into a poorly matched load (VSWR of 3:1), or the controller can be set for either relaxed mode (battery current of 390 mA) for the same output power and -38 dBc ACLR into a 50 ohm load, or the battery current can be reduced to under 300 mA to operate in relaxed power out mode (Pout = 22.5 dBm, -38 dBc ACLR into a 50 ohm load), all through the LUT control.

RFRD6460

The RFRD6460 is comprised of two separate component placements: The RF6260 (power amplifier module) and the RF6560 (boost-buck DC-to-DC converter) integrated into a single module. This device features the first RF configurable power core, designed to seamlessly merge RFMD's VSWR-tolerant, quadrature power amplifier technology with its patented power management technology. The technology dramatically reduces the size of the front-end solution by enabling replacement of discrete configurations using traditional PAs operating with DC-DC converters, commonly used in 3G front-ends (see ***Figure 2***).

With scalable band coverage up to five 3G bands (penta-band),

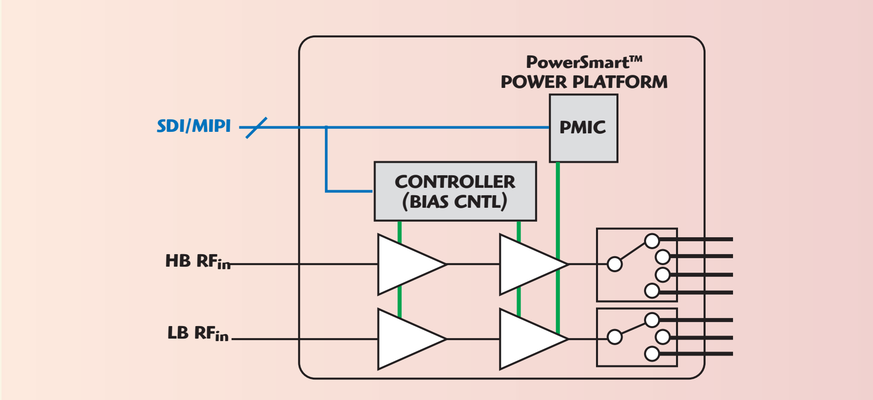

Fig. 1 PowerSmart™ platform with PowerCore technology.

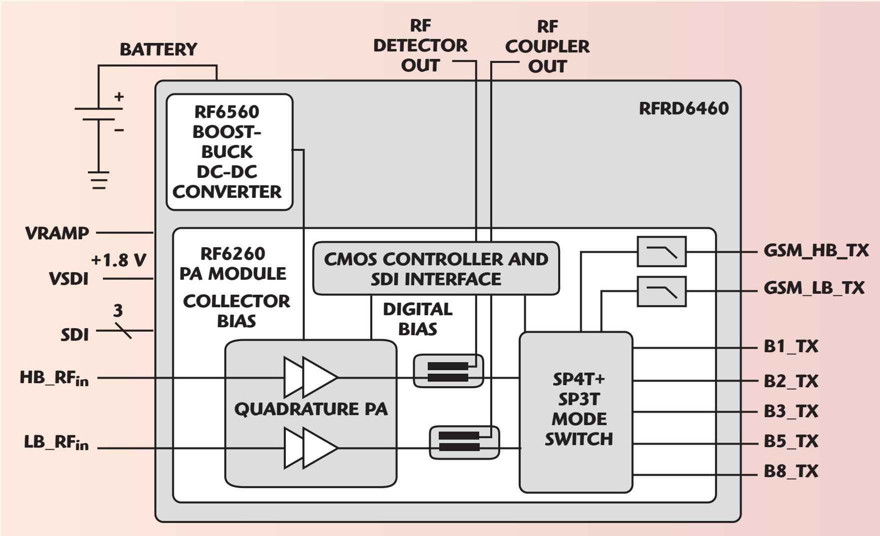

Fig. 2 Functional block diagram of RFRD6460 front-end module.

2 LB, 3 HB (Bands 1-6 and 8-10) of W-CDMA/HSPA+ operation and/or other linear modes of operation (CDMA, TD-SCDMA, LTE, WiMAX), the RFRD6460 provides extensive flexibility and customization, accelerating the time to market for OEMs targeting smartphones and mobile Internet devices (MID). The RFRD6460 is able to meet OEM and mobile operator band requirements with no hardware changes and no post-power platform matching, saving both time and R&D investment.

SUMMARY OF FEATURES

- Best-in-class 3G current consumption at all power levels (24, 22 and 10 dBm, DG.09)
  - No PA Matching required
- Scalable band coverage: Up to five 3G bands (penta-band), 2 LB, 3 HB (Bands 1-6 and 8-10)
- WLAN, Bluetooth®, GPS coexistence
- Quad-band GSM/EDGE
- Modes: GSM, EDGE and W-CDMA/HSPA with capability for other linear modulations (CDMA, TD-SCDMA, LTE, WiMAX)
- SDI Interface for ease of programming and control
- Exceptional 2G TRP performance
- Fully adjustable performance via firmware changes not hardware
- "Future-proof" to accommodate unforeseen changes:
  - Post-PA component changes (ex. Duplexer IL changes, ASM IL changes, return loss performance from antennas)
  - Already accommodates LTE modulation with no MPR
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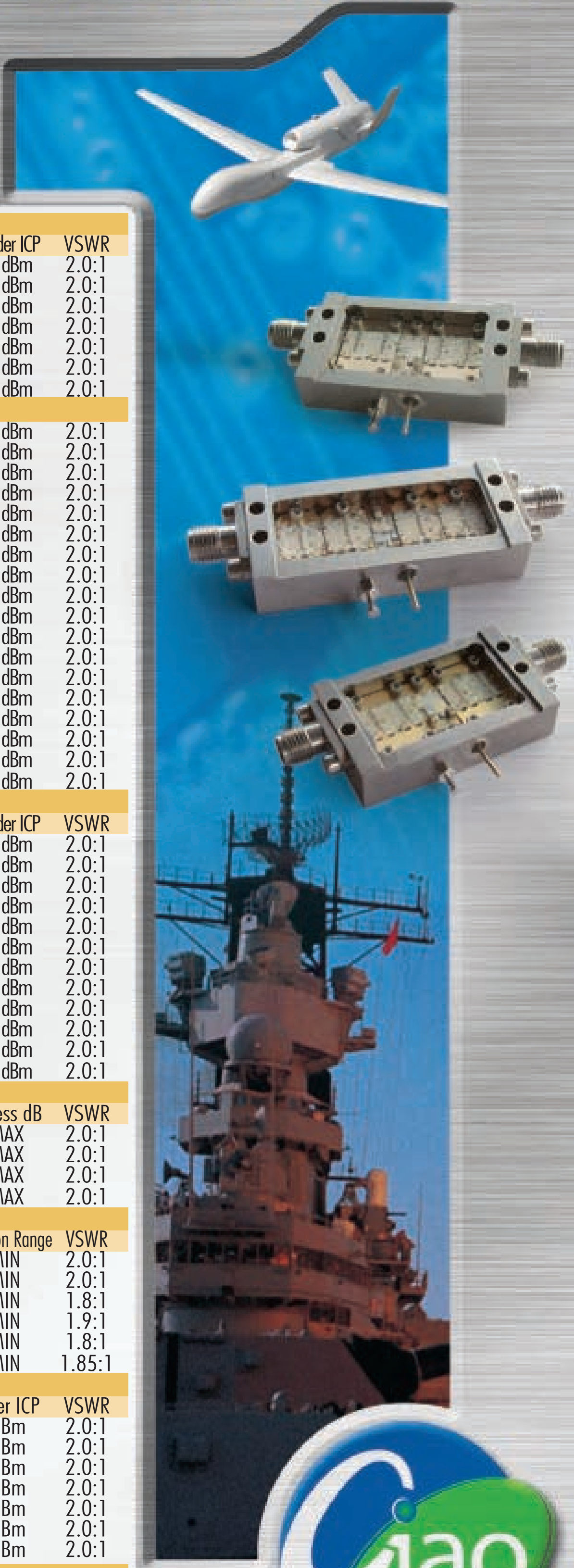

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+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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Defense News

Dan Massé, Associate Technical Editor

Boeing and Northrop Grumman Submit Proposal for Missile Defense Contract

The Boeing Co. and industry partner Northrop Grumman Corp. submitted their joint proposal for the competitive development and sustainment contract for future work on the Ground-based Midcourse Defense (GMD) element of the United States' ballistic missile defense system.

"This development and sustainment contract proposal is backed by the full commitment of Boeing, Northrop Grumman and all of our team members," said Dennis Muilenburg, President and CEO, Boeing Defense, Space & Security. "We have been privileged to have been partners with the Missile Defense Agency through the development and deployment of the GMD system, and now with Northrop Grumman, we will bring to GMD over 50 years of experience in sustaining and modernizing the Minuteman ICBM weapon system. We look forward to continuing that partnership in this next phase of the GMD program."

The Boeing-Northrop Grumman GMD proposal submitted to the Missile Defense Agency brings together a broad industry group, selected for extensive heritage GMD capability and relevant expertise, to deliver the best offering for the future of the program. The team has worked for the past year to prepare the expansive proposal, which includes an overview of past performance and outlines future program support. "With over half a century of experience and success on the nation's ICBM system, Northrop Grumman continues to demonstrate its unmatched capabilities in developing, managing and integrating the complex and mission-critical systems that defend our country and its allies," said Wes Bush, President and CEO, Northrop Grumman. "Our partnership with Boeing on this GMD proposal brings together the very best minds in the industry to help the nation improve its defenses against a threat that affords no margin for error."

"Our partnership with Boeing on this GMD proposal brings together the very best minds in the industry…"

Boeing will lead the industry team in the development, deployment, integration and testing of the GMD weapon system, building on its experience of supporting the Missile Defense Agency as prime contractor for the GMD program since 2001. Following a presidential directive in 2002, Boeing led a team of more than 300 suppliers and delivered a limited operational GMD capability in just two and a half years. The Boeing-led team currently operates and sustains the deployed weapon system while actively developing and testing innovative technologies to provide increased reliability and meet evolving customer needs and requirements.

"GMD remains the nation's only defense against long-range ballistic missile threats and as we look to GMD's future, our proposal is focused on supporting the program's current capability while offering innovative solutions for future program evolution at the lowest cost to the customer," said Norm Tew, Boeing Vice President and Program Director of GMD. "Only the Boeing-Northrop Grumman team has the unmatched GMD experience to bring the best value to the customer, without sacrificing operational readiness and future performance capabilities. This knowledge base enables us to offer the US government substantial cost savings with minimal risk."

Raytheon Delivers 250th APG-79 AESA Radar

Raytheon Co. has delivered its 250th APG-79 active electronically scanned array radar to Boeing. The APG-79 radar is flown on US Navy F/A-18E/F and EA-18G aircraft, and on the Royal Australian Air Force F/A-18F Super Hornet.

"As we recognize this milestone of the 250th APG-79 AESA delivery, it is also significant to note that 85 radar systems were completed for the US Navy in just the last 12 months," said Eric Ditmars, F/A-18 Program Director, Tactical Airborne Systems. "The APG-79 radar has revolutionized fighter combat capabilities and dramatically improved situational awareness for aircrews. This combat-proven, advanced radar technology also has logged more than 175,000 operational flight hours."

The APG-79 AESA hardware offers 10 to 15 times greater reliability than mechanically scanned array radars, which results in lower life-cycle costs. In addition, it provides capabilities that allow warfighters to detect and identify targets beyond the reach of most missiles. The APG-79 AESA radar is in operation with more than a dozen US Navy squadrons. Internationally, the Royal Australian Air Force received the radar system in 2010, marking the delivery of the first foreign military sale of Super Hornets equipped with the APG-79.

"The APG-79 radar has revolutionized fighter combat capabilities and dramatically improved situational awareness for aircrews."

Hughes Wins US Air Force Satellite Study Contract

Hughes Network Systems LLC, a leader in broadband satellite technologies and services, and a provider of managed network services, announced it was award-

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ed a $495,000 contract by the US Department of Defense (DoD) to conduct an architectural study of commercial communications satellite (COCOMSAT) systems capabilities. The report, which will focus on meeting the future tactical communications-on-the-move (COTM) needs of the US military, is expected to be delivered to the US Air Force Space and Missile Command Center's Military Satellite Communications (MILSATCOM) Systems Directorate by July 2011.

Under the terms of the agreement, Hughes will conduct research on DoD COTM requirements and scenarios using processing satellite architectures such as those employed by the Hughes commercial SPACEWAY® 3 satellite, which today provides service to more than 400,000 Ka-band terminals in North America. Additionally, Hughes will study COTM applications using transponded satellite architectures such as those being employed by the high-capacity Hughes commercial Jupiter™ satellite, a 100+ Gbps Ka-band satellite system, which is under development for launch in 2012.

Ground segment and terminal analysis will include Multi-Frequency, Time Division Multiple Access (MF-TDMA) technologies as employed in the commercially successful Hughes HX satellite modem/router platform, currently available for multi-band COTM operations worldwide. The study also includes analysis of commercial satellite system acquisition processes and how they may be applied to future satellite acquisitions by the military, including various lease or buy options.

"Hughes is… pleased to be working with the DoD and US Air Force to study how commercial satellite architectures… can help achieve its tactical communications missions."

"Hughes is extremely pleased to be working with the DoD and US Air Force to study how commercial satellite architectures and acquisition approaches can help the military achieve its tactical communications missions," said Rick Lober, Vice President and General Manager of Hughes Defense and Intelligence Systems Division. "We have a world-class technology team at Hughes. They will be working with their military partners to deliver a report that will help the DoD determine how industry can better meet the increasing need for satellite communications technologies and, more specifically, the requirements of warfighters at home and in theater."

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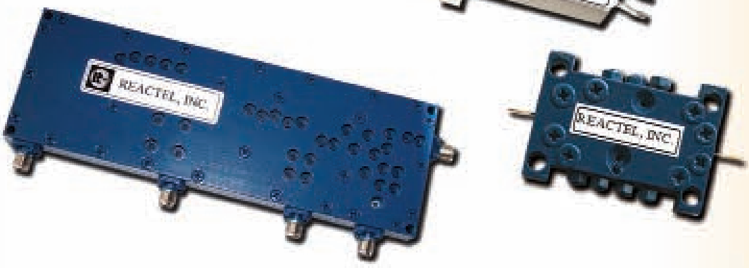

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Microwaves to Help Transport Systems DRIVE Forward in Europe

VTT Technical Research Centre of Finland and Mercedes-Benz are leading a project to create the transport system of the future, in which cars communicate with each other, receive real-time information about traffic, and also gather and forward information. A test area is currently being built in Tampere, Finland, that will help establish which services Finnish drivers want, and what sort of effect these services would have on the safety and fluency of traffic as well as environmental effects.

The development is part of the recently launched European DRIVE C2X Project, which has a total budget of around €19 M. European research institutes and major European car manufacturers—particularly Daimler as the project's coordinator—are carrying out this three-year project. VTT is the largest partner in the project, both by budget—€2.1 M—and volume of work. In addition to Finland, other countries taking part in the project are Germany, the Netherlands, Sweden, Italy, France and Spain.

The DRIVE C2X Project, which commenced in January 2011, follows on the work of the PRE-DRIVE C2X Project that was completed in June 2010. Based on the overall description of a common European architecture for an inter-vehicle and vehicle-to-infrastructure communication system, PRE-DRIVE C2X developed a detailed system specification and functionally verified prototype. The new systems will be trialled in about a year's time in Tampere, when the test area is up-and-running.

FP7 Programme Update

The DRIVE C2X Project is part of the Seventh Framework Programme, which bundles all research-related EU initiatives together to help reach the goals of growth, competitiveness and employment. The DRIVE C2X Project is set to run from January 2011 to December 2013. To discover the project's objectives, participants, funding, etc., visit: www.mwjournal.com/FP7APR2011.

EADS to Open Research Facility in Russia

EADS and the Skolkovo Foundation have signed a Memorandum of Understanding (MoU) on research collaboration that underlines the intention of EADS to participate in the Russia-based Skolkovo Innovation Centre. Dubbed 'Russia's Silicon Valley,' the Centre is a high technology business hub that is being built in the Moscow region.

According to the MoU, EADS will establish a centre that will conduct research in the areas of: aerospace technology, including telecommunications and navigation; efficient energy technologies; and information technology. The Centre will also collaborate with the Skolkovo Institute of Technology and other Russian scientific institutions in order to identify technologies and competences of mutual interest.

"Establishing relationships with esteemed groups like Skolkovo is part of EADS' long-term strategy…"

EADS also intends to investigate the possible participation in programmes to support the development of Russian start-up companies in relevant areas. Based on its long-standing experience, the company intends to support development of educational programmes in technology of the Skolkovo Institute of Technology and also to provide advisory services to the Skolkovo Foundation in respect to establishing internal regulations, corporate solutions and governance, technical support, security and IP rights.

Jean Botti, EADS CTO, said, "I am very pleased to sign this cooperation agreement with Skolkovo. Establishing relationships with esteemed groups like Skolkovo is part of EADS' long-term strategy to build a global integrated research capability to meet the demanding needs of our customers."

Viktor Vekselberg, Executive President of the Skolkovo Foundation, added, "The partnership with EADS allows us to do a strategic outlook on the space technology cluster which is to be set up at Skolkovo. The Russian United Aircraft Corp. (UAC) will play a leading role in this project from the Russian side."

Thales Alenia Space Creates German Subsidiary

Thales Alenia Space has created a separately owned German subsidiary, Thales Alenia Space Deutschland GmbH, located in the Stuttgart area. This strategic move demonstrates the company's intention to play a growing role in Germany, a country committed to strongly supporting European institutional and national R&D space programmes. The opening of the subsidiary will also enable the company to strengthen current relationships with German customers and partners, such as DLR, ESA, OHB-System and Astrium.

"[Germany] plays a very important political and financial role today in shaping Europe's Space policy."

Thales Alenia Space Deutschland will first integrate activities focused on EGNOS and Galileo ground systems for navigation activities and, then, gradually expand its portfolio of activities to additional space busi-

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ness domains. The new company will be led by CEO, Sven Carstensen, previously in charge of the Thales Air Systems entity within Thales Deutschland and staffed by a team of engineers transferred from within Thales Deutschland's existing ranks.

Carstensen commented, "In creating a fully German incorporated company, Thales Alenia Space, one of Europe's leading space equipment, sub-systems and prime contracting companies, will be able to directly invest in a country that plays a very important political and financial role today in shaping Europe's Space policy."

ETSI and ATIS are Global Standard Bearers

The European Telecommunications Standards Institute (ETSI) and the Alliance for Telecommunications Industry Solutions (ATIS) have entered into a Memorandum of Understanding (MoU) to promote regional and international standardization, with the aim of contributing to the establishment of a global information and communications technology (ICT) infrastructure.

The agreement formalizes an already successful collaboration in 3GPP, the global collaboration for the development of standards for advanced mobile communication technologies, in which ATIS and ETSI are two of six Organizational Partners. The new, formalized relationship serves to align various common activities and to enable an exchange of knowledge and expertise.

"This agreement... reflects a shared vision regarding the importance of standards in global commerce."

Both organisations are committed to avoiding duplication of technical work and both benefit from adopting a complementary approach to the standardization process in their areas of mutual interest. The MoU's scope includes data-sharing agreements and calls for both organizations to participate in joint meetings with the principal goal of developing and deploying next generation networks.

"This agreement further strengthens ATIS' relationship with ETSI and reflects a shared vision regarding the importance of standards in global commerce," said Susan Miller, ATIS President and CEO. "The areas of mutual interest between our two organizations have been strategically mapped to allow more effective collaboration and reflect the fact that standardization efforts increasingly have a global impact. From wireless to broadband to emerging applications such as Smart Grid, standardization is vital to ensuring that new ICT products and services can be deployed."

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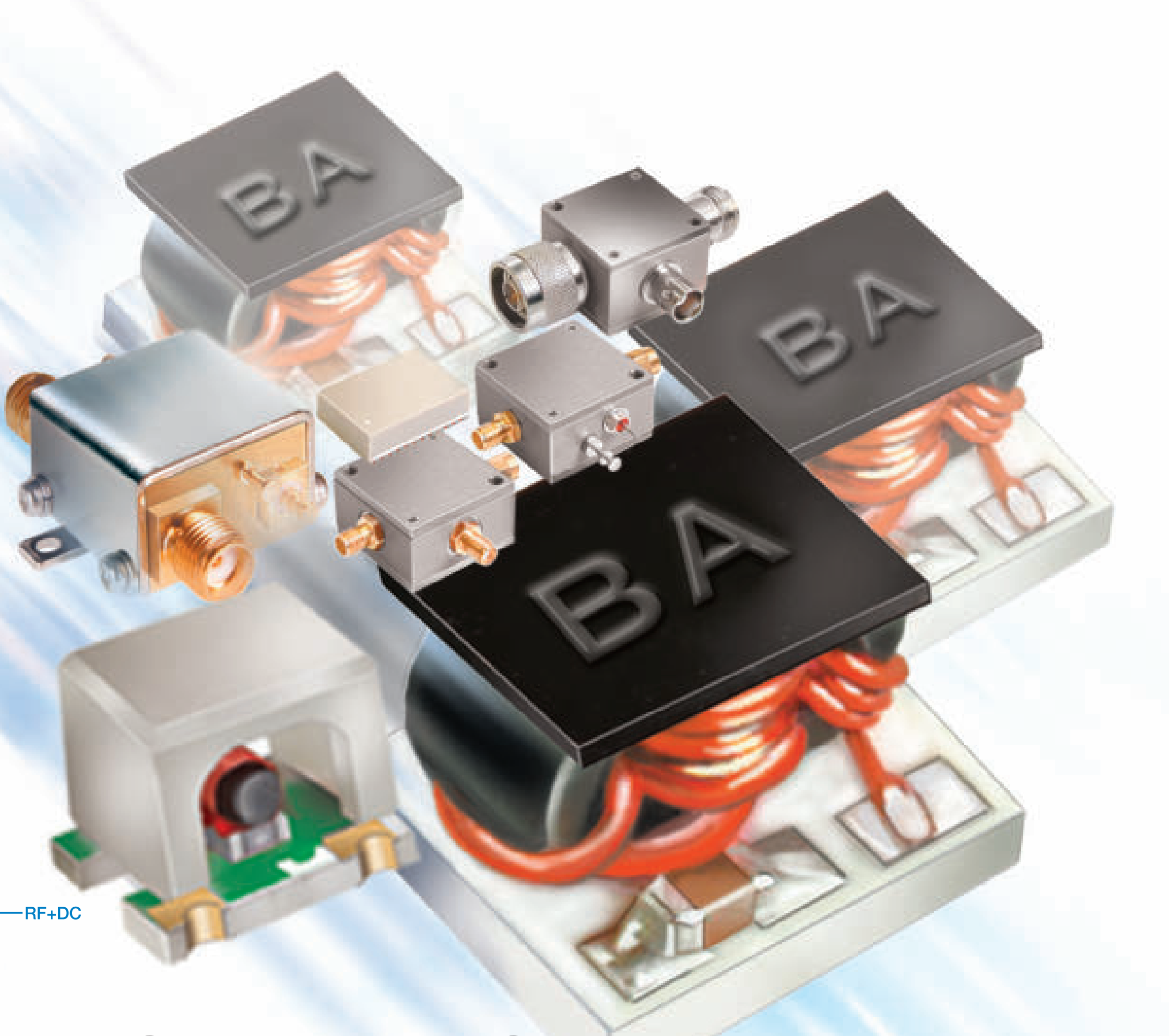

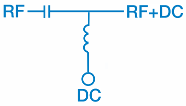

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TCBT-6G+	50-6000	0.7	28	200	9.95
TCBT-14+	10-10,000	0.35	33	200	8.45
TCBT: LTCC, Actual Size .15" x .15", U.S. Patent 7,012,486.					**Qty.1-9**
JEBT-4R2G+	10-4200	0.6	40	500	39.95
JEBT-4R2GW+	0.1-4200	0.6	40	500	59.95
PBTC-1G+	10-1000	0.3	33	500	25.95
PBTC-3G+	10-3000	0.3	30	500	35.95
PBTC-1GW+	0.1-1000	0.3	33	500	35.95
PBTC-3GW+	0.1-3000	0.3	30	500	46.95
ZFBT-4R2G+	10-4200	0.6	40	500	59.95
ZFBT-6G+	10-6000	0.6	40	500	79.95
ZFBT-4R2GW+	0.1-4200	0.6	40	500	79.95
ZFBT-6GW+	0.1-6000	0.6	40	500	89.95
ZFBT-4R2G-FT+	10-4200	0.6	N/A	500	59.95
ZFBT-6G-FT+	10-6000	0.6	N/A	500	79.95
ZFBT-4R2GW-FT+	0.1-4200	0.6	N/A	500	79.95
ZFBT-6GW-FT+	0.1-6000	0.6	N/A	500	89.95
ZFBT-282-1.5A+	10-2800	0.6	45	1500	56.95
ZFBT-352-FT+	30-3500	0.4	23	4000	48.95
ZNBT-60-1W+	2.5-6000	0.6	45	500	82.95
ZX85-12G+	0.2-12000	0.6	N/A	400	99.95

ZX85: U.S. Patent 6,790,049.

Note: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports.

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IF/RF MICROWAVE COMPONENTS

Footwear and Fashion to Drive UHF Passive RFID Item-level Tagging Growth

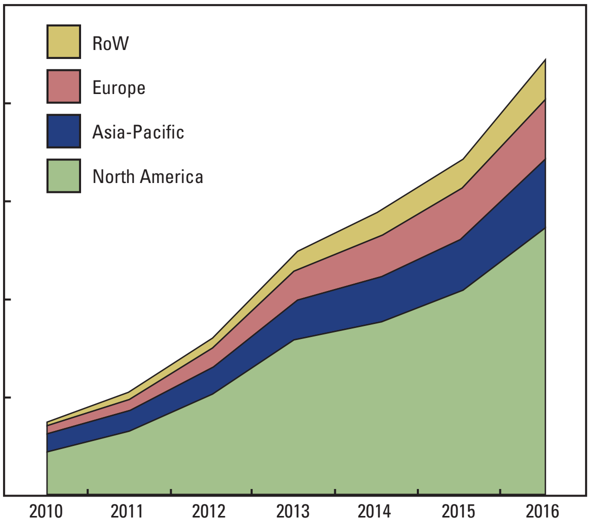
RFID Item-level Tagging (ILT) is being deployed very rapidly in apparel and footwear markets. Item-level passive UHF tags now make up an increasing share of the total world market for RFID tags. ABI Research forecasts that more than three quarters of a billion RFID tags will be used in global apparel markets in 2011. Major retailers such as Macy's, JCPenney and Wal-Mart are leading the charge to make RFID systems commonplace in the retail environment.

RFID systems allow apparel retailers to get a better handle on inventory, reducing costs and preventing out of stock situations that result in loss of sales. The growth in retail item-level tagging is huge, both in shipments and in total spending. The average growth rate is close to 60 percent for the next three years. In fact, the number of tags that will be used for retail ILT in apparel alone is likely to exceed the total number consumed over the past five years for all RFID markets combined.

- How does ILT differ from previous retail "mandated" projects?
- Why is ILT so "hot" right now?
- What does ILT mean for the overall passive UHF RFID market?

To learn more about the ILT market and how it may affect various business models now and in the future, please visit ABI Research's new study "The Retail Apparel RFID Item-level Tagging Market," which provides current analysis and a five-year forecast of UHF adoption at the item-level in the retail apparel market. It discusses market drivers and inhibitors, along with a summary of the key RFID solution providers and product suppliers.

Retail ILT Revenues by Geographic Region
World Market, Forecast: 2010–2016



Source: ABI Research

Dual-platform 4G Strategy Rewards Mobile Networks Operators, Chips and Device Makers

There's no question that in the long term LTE will become the mainstay 4G network technology, although its universal use is still in the future. Until then, says ABI Research, some service providers will benefit from a dual-platform strategy based on both LTE and WiMAX. According to Research Director Philip Solis, "Intel and others are pushing the idea of heterogeneous networks. This is not to deny LTE's long-term position as the leading 4G platform, but to recognize that a small part of the ecosystem will still be characterized by diversity for some time."

Who stands to benefit?

"Some operators, such as Sprint and Clearwire, KDDI and UQ Communications, and KT, will use both technologies for some time," says Solis. "By using both standards, they will have access to more spectrum, which helps with capacity issues."

Multi-standard base stations now being deployed support several generations of technologies as well as both 4G standards. Alvarion, Huawei, NEC, NSN, Samsung and ZTE are some vendors supporting both technologies in the same flexible base station. There will also be multimode 4G chipsets in devices. Prior to its acquisition by Broadcom, Beceem was already planning such chipsets. Chipmaker Sequans recently announced a similar product initiative it calls 4Sight, with software allowing for handoffs between multiple networks if carriers choose to implement it. According to Solis, these solutions "provide the ecosystem with the flexibility it needs."

"Intel and others are pushing the idea of heterogeneous networks."

Intel already has WiMAX/Wi-Fi chipsets and in the near future it will focus designs on HSPA+/LTE. Longer term, it will likely combine those into one solution along with short-range wireless technologies. Multi-mode chipsets also benefit mobile device manufacturers interested in reducing the number of their SKUs; by creating devices compatible with multiple networks, they ensure product longevity and allow MNOs to migrate without stranding their subscribers.

With 24 Percent Share of Smartphones, Android Will Outshine "Nokisoft"

Smartphone markets are on a roll. Shipments grew from 177 million in 2009 to 302 million in 2010, a remarkable 71 percent growth rate. Meanwhile, handset OEMs' market shares have fluctuated widely; Nokia's dropped from 39 to 33 percent, even as the collective share held by manufacturers of Android-based phones increased from 4 to 24 percent. "In short," says ABI Research Vice President Kevin Burden, "the market has been disrupted during a period of record growth."

Today's smartphone includes a long and growing list of technologies, components and software. Some combinations of these find favor with consumers, others do not. Smartphone OEMs' strategies determine how these components are stitched together into cohesive products. With the rise of Android, the number of handset OEMs with significant smartphone market share increased in 2010. This competitive landscape is forcing handset OEMs to consider their device and portfolio strategies carefully as they jockey for position. Many are placing their bets on Android. Are they right?

Senior Analyst Michael Morgan elaborates: "Motorola has pinned its entire turnaround strategy on Android. As competitors flood the Android ecosystem, Motorola wants to become known as the OEM that brings Android devices to business. Meanwhile Samsung is hoping that it can convert its feature phone customers to smartphones, on the backs of both Bada and Android. And Nokia has now moved away from a purely proprietary OS strategy."

How are these strategies working? It appears that handset OEMs choosing Android have had success that is both driven by and limited to the reach of their distribution networks and operator partnerships. "Unfortunately," Morgan says, "OEM-specific Android 'enhancements' have not yet created a clear differentiation in consumers' minds. Smartphone OEMs adopting Android as a key platform must produce meaningful innovation or risk losing significance."

Shipments grew from 177 million in 2009 to 302 million in 2010, a remarkable 71 percent growth rate.

ABI Research's new "Smartphone Technologies and Markets" study explores the leading IC and OS platforms and the outlook for these competing technologies. In addition, it examines technologies that are being integrated into smartphones as competitive differentiators by smartphone OEMs.

The firm's "Smartphone Market Data" provides quarterly/annual global and regional data for smartphone operating systems, ASPs, vendor market shares, revenues, air interface protocols and technology attach rates.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Around the Circuit

Jennifer DiMarco, Staff Editor

INDUSTRY NEWS

Herley Industries Inc., a leader in the design, development and manufacture of microwave technology solutions for the defense, aerospace and medical industries worldwide, announced that the company has signed a definitive agreement to be acquired by **Kratos Defense & Security Solutions Inc.** for $19.00 per share in cash. The transaction will be accomplished through an all-cash tender offer and second-step merger, and will have a total value of approximately $270 M.

Anaren Inc. and **AML Communications Inc.** jointly announced the signing of a definitive merger agreement whereby Anaren, through a subsidiary, has agreed to acquire all of AML's outstanding shares of common stock for $2.15 per share in an all-cash transaction, representing an equity value of approximately $29.3 M and an enterprise value of approximately $22.6 M. AML is based in California and is a provider of microwave amplifiers and integrated assemblies for defense electronics applications. Upon completion of the acquisition, AML will become a wholly owned subsidiary of Anaren and will be reported within Anaren's Space & Defense Group.

GigOptix Inc., a supplier of high performance electronic and electro-optic components that enable next generation 40G and 100G optical networks, announced that it has signed a definitive merger agreement to acquire **Endwave Corp.**, a provider of high frequency RF solutions and semiconductor products for the wireless mobile backhaul communications, satellite communications, electronic instruments, and defense and security markets. The combined company will retain the name GigOptix Inc. to become a high speed, high frequency leader for optical and wireless communications. The acquisition is expected to close in the second quarter of this year.

ITT Corp. announced that its board of directors has unanimously approved a plan to separate the company's businesses into three distinct, publicly traded companies. Under the plan, ITT would execute tax-free spinoffs to shareholders of its water-related businesses and its Defense & Information Solutions segment. Following completion of the transaction, ITT will continue to trade on the New York Stock Exchange as an industrial company that supplies highly engineered solutions in the aerospace, transportation, energy and industrial markets. Under the plan, ITT shareholders will own shares in all three corporations following the completion of the transaction.

Rohde and Schwarz, a supplier of solutions in the fields of test and measurement, announced that it has formed a relationship with **Tektronix Service Solutions** to offer customers in North America a single-source for calibration services. This represents the first time that two major test and measurement manufacturers have joined forces to provide customers with a comprehensive solution for all their calibration needs.

Agilent Technologies Inc. and **Altair Semiconductor** announced they will jointly conduct interoperability testing and validation testing using Altair's 4G LTE chipset in conjunction with the Agilent PXT wireless communications test set and N6070A-series signaling conformance test software. The joint effort will accelerate the development of LTE devices and testing solutions into new operating bands.

Skyworks Solutions Inc., an innovator of high reliability analog and mixed signal semiconductors enabling a broad range of end markets, and **Ember Corp.**, a provider of low power, wireless mesh networking technology, introduced innovative solutions for ZigBee® applications targeting the growing energy management, home area network and industrial automation markets. ZigBee is a wireless network standard that solves the unique needs of remote monitoring and control, and sensor-network applications. Specific wireless applications range from lighting control, to door and window sensors, to appliance and temperature controllers.

Remcom announced its participation on a team led by **Raytheon Co.**, who has been competitively selected by the US Department of Homeland Security (DHS) to develop an advanced software tool to model and assess the effects of wind turbines on radar systems used throughout the United States. At the completion of the 24-month effort, Remcom and its partners, Raytheon and Analytical Graphics Inc. (AGI), will deliver to DHS's Directorate of Science and Technology, Special Projects Division a modeling and simulation tool that will assist DHS in the evaluation process for new wind farm applications.

Boeing announced that it successfully conducted its first over-the-air ground test of a Ka-band satellite communications (SATCOM) phased-array antenna system that will enable wideband SATCOM on aircraft, providing increased bandwidth for networking in flight. The test demonstrated the new system's ability to support a range of applications, including file transfer and a Voice over Internet Protocol video conference.

Ducommun Inc. announced it has received a 2010 Outstanding Supplier Award from **Tektronix**. Tektronix identified four key areas of distinction as the main reasons behind Ducommun's Technologies unit (DTI) being selected for this award. These were: 1) Engineering excellence; 2) Consistent on-time delivery of quality hardware; 3) Customer relationship; and 4) Being reactive to customer requests. DTI engineers have worked closely with Tektronix on a number of new product development initiatives.

For up-to-date news briefs, visit www.mwjournal.com

With its unique, non-hierarchical, team-based culture, global manufacturing company **W.L. Gore & Associates** has once again earned a spot on *FORTUNE* magazine's annual list of the 100 Best Companies to Work for in America. The company is ranked No. 31. This marks Gore's 14^{th} consecutive appearance on the list, making it one of a select few workplaces to appear in every edition of the rankings.

CONTRACTS

KOR Electronics announced that it has received contracts from the government in excess of $12 M in Q4 2010. The awards include major releases against the previously announced USN IDIQ contract that supplies advanced digital jamming systems for the US Navy and Air Force. The awards also include a significant contract for the final phase of KOR's development of its next generation digital exciter receivers that will provide advanced capabilities to the warfighter.

Comtech Telecommunications Corp. announced that its Melville, New York-based subsidiary, **Comtech PST Corp.**, has received $1.4 M of orders for high power amplifiers from a provider of aviation electronics and communication systems. The amplifiers are utilized as part of satellite communications systems that provide commercial mobile airborne-to-satellite-to-ground communications service.

Crane Aerospace & Electronics, Crane Electronics Inc., Microelectronics Solutions, a segment of Crane Co., signed another five-year contract with **Cochlear Ltd**.

FINANCIAL NEWS

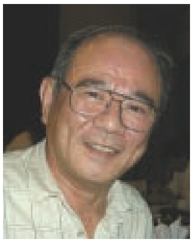
RF Micro Devices Inc. (RFMD) reported financial results for its fiscal 2011 third quarter, ended January 1, 2011. RFMD's quarterly revenue increased approximately 11 percent year-over-year and decreased approximately 2 percent sequentially to $278.8 M. On a GAAP basis, gross margin equaled 37.0 percent, quarterly operating income totaled $43.3 M, and quarterly net income was $36.7 M, or $0.13 per diluted share. On a non-GAAP basis, gross margin equaled 38.7 percent, quarterly operating income totaled $54.0 M, and quarterly net income was $52.6 M, or $0.19 per diluted share. During the quarter, RFMD generated $54.2 M in free cash flow.

TriQuint Semiconductor Inc. announced its financial results for the quarter and year ended December 31, 2010. Revenue for the fourth quarter of 2010 was $253.4 M, up 31 percent from the fourth quarter of 2009 and 7 percent sequentially. Revenue for 2010 was $878.7 M, up 34 percent from 2009. Networks continued to enjoy a strong rebound from the lows of 2009, with quarterly revenue growing 50 percent year over year. Mobile Devices showed robust growth, with quarterly revenue increasing 12 percent sequentially and 34 percent year over year.

NEW MARKET ENTRY

Thunderline-Z, a supplier of feedthrus and hi-rel packages for the RF/microwave industry, has announced its new laser services for hermetic sealing of high frequency devices, components and subassembly packages. By employing the precise control of high power lasers, including advanced power ramping and pulse-shaping techniques, Thunderline-Z provides reliable hermetic seals for both standard and custom packages—even for package designs that incorporate posts or pedestals for stability.

OBITUARIES



▲ *Nobuhiko Kawamoto*

Nobuhiko Kawamoto, past President of Tecdia Inc., recently lost his battle with leukemia in Kyoto, Japan, at the age of 69. He was a pioneer in thin film termination technology for microwave capacitors, who created Tecdia's Kyoto Technology Center (KTC) for the design and production of single layer ceramic chip capacitors and other thin film products. He joined Tecdia in 1978, and served as a Company Director and its Chief Technology Executive for the KTC until his retirement in 2004. Prior to joining Tecdia, Kawamoto was a Chief Development Engineer at Murata Manufacturing Co., Chief Design Engineer at Nichicon Corp., and a member of the Research Staff in the Semiconductor division of Japan Physics and Chemistry Laboratory in Tokyo, Japan. He was a member of the Japan Society of Applied Physics, and published a number of papers and articles on thin film technology for high frequency capacitors and resistors.

Thomas P.M. Couse, 75, of Jackson, NJ, passed away, February 8, 2011, at home. Couse was born in Neptune and resided in Freehold before moving to Jackson seven years ago. He was an electrical engineer and was the President of Advanced Control Components in Eatontown for 26 years before his retirement in 2008. He graduated from Monmouth College with a BS in Electrical Engineering and then went on to earn his master's degree in Electrical Engineering from New York University. Couse proudly served his country in the US Navy.

PERSONNEL

M/A-COM Technology Solutions announced a realignment of its management and reporting structure that positions the company for continued industry leadership. M/A-COM Tech Chief Executive Officer **Joseph G. Thomas** announced that he is retiring after more than 35 years of distinguished service. Thomas, who had served as CEO of M/A-COM Tech since March 2009, has held a number of senior management positions throughout his career with M/A-COM Tech, Cobham Defense Electronic Systems and Tyco Electronics. M/A-COM Tech concurrently announced the appointment of **Chuck Bland** as its new Chief Executive Officer. Bland has served as M/A-COM Tech's Chief Operating Officer since June 2010, with responsibility for the company's worldwide business units and operations. M/A-COM Tech announced that **Robert S. Donahue** has been appointed its new Chief Operating

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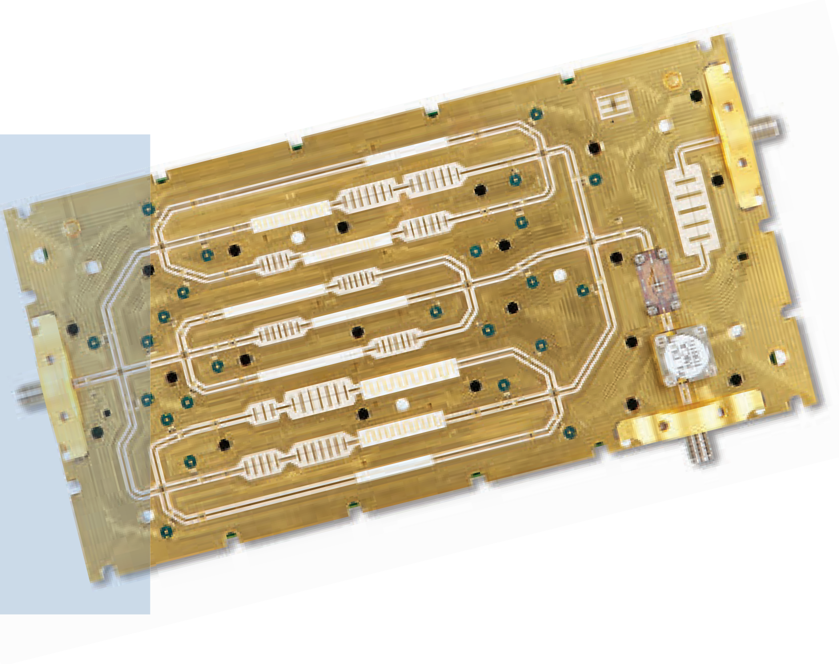

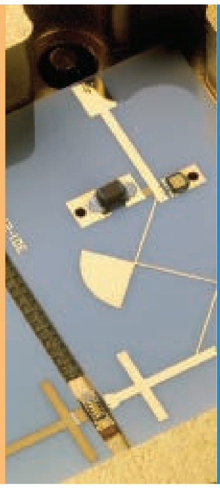

Maxtek is now Tektronix Component Solutions, offering a variety of services—including customization, design, assembly and test—for RF and microwave components and modules.

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Officer, reporting to Bland. Donahue has served as M/A-COM Tech's Chief Strategy Officer since August 2009. M/A-COM Tech also announced that it is increasing the scope of responsibility of Vice President and General Manager **Suja Ramnath** to include leadership of all the company's market-facing businesses.

SkyCross announced the appointment of **Bami Bastani**, PhD, to its Board of Directors. Bastani is the Chairman and CEO of B_2 Global Consulting LLC, a management consulting firm focused on enabling corporate transformation. His expertise is in leading high-growth, multi-national communications businesses. From 1998 to 2008, Bastani was President and CEO of ANADIGICS Inc. Under his leadership the company became a recognized innovator in semiconductor RF solutions for the wireless and broadband communications equipment markets. During a three-year period from 2005 to mid-2008, ANADIGICS reported 13 consecutive quarters of growth at 38 percent CAGR, delivering both positive cash flow and solid profitability.

Peregrine Semiconductor Corp. announced the appointment of two new members to its Board of Directors. Intellectual Property (IP) expert **Carl Schlachte** and former Qualcomm President and Chief Operating Officer **Anthony (Tony) Thornley** bring broad experience and expertise in the areas of global IP/patent licensing and growth company executive leadership to Peregrine's nine-member board.

Kaben Wireless Silicon Inc. announced the appointment of **Ian Roane** as its Chief Executive Officer. As an accomplished high-tech executive and entrepreneur, Roane brings over 30 years of experience in managing and growing technology companies. This includes his roles as CEO of Sound Design Technologies, General Manager of the Audio and Wireless Division of Gennum Corp., head of National Semiconductor's Canadian IC operations and Vice President of Engineering of Sirific Wireless.

▲ *Maty Pardo*

Norden Millimeter Inc. is pleased to announce that **Maty Pardo** has joined the company as the Director of Sales. Pardo brings over 30 years experience in the microwave industry, in engineering, management and sales. He holds BS and MS degrees in Electrical Engineering and an MBA. Previously, Pardo was the Vice President of Sales and Marketing at L-3 Com Narda West and Director of Sales at KOR Electronics. He will be responsible for expanding Norden business in the military, scientific, commercial, scientific and test equipment markets. Norden designs and manufactures amplifiers, transceivers, frequency multipliers, frequency converters and oscillators covering the frequency range from 500 MHz to 110 GHz. He can be reached at (530) 642-9123 or e-mail at mpardo@nordengroup.com.

Valpey Fisher Corp. announced **Malcolm J. Lomer** has joined the company as Europe and Middle East Business

▲ Malcolm J. Lomer

Development Manager. His office is located near Colchester, UK. Lomer has over 23 years of experience in the RF and wireless semiconductor industry. Most recently, he spent three years at SiGe Semiconductor (Europe) Ltd. as Product Marketing Manager for GNSS RF IC products. Lomer also held key product-management positions at SiRF Technology Inc., Zarlink Semiconductor and Mitel Semiconductor.

REP APPOINTMENTS

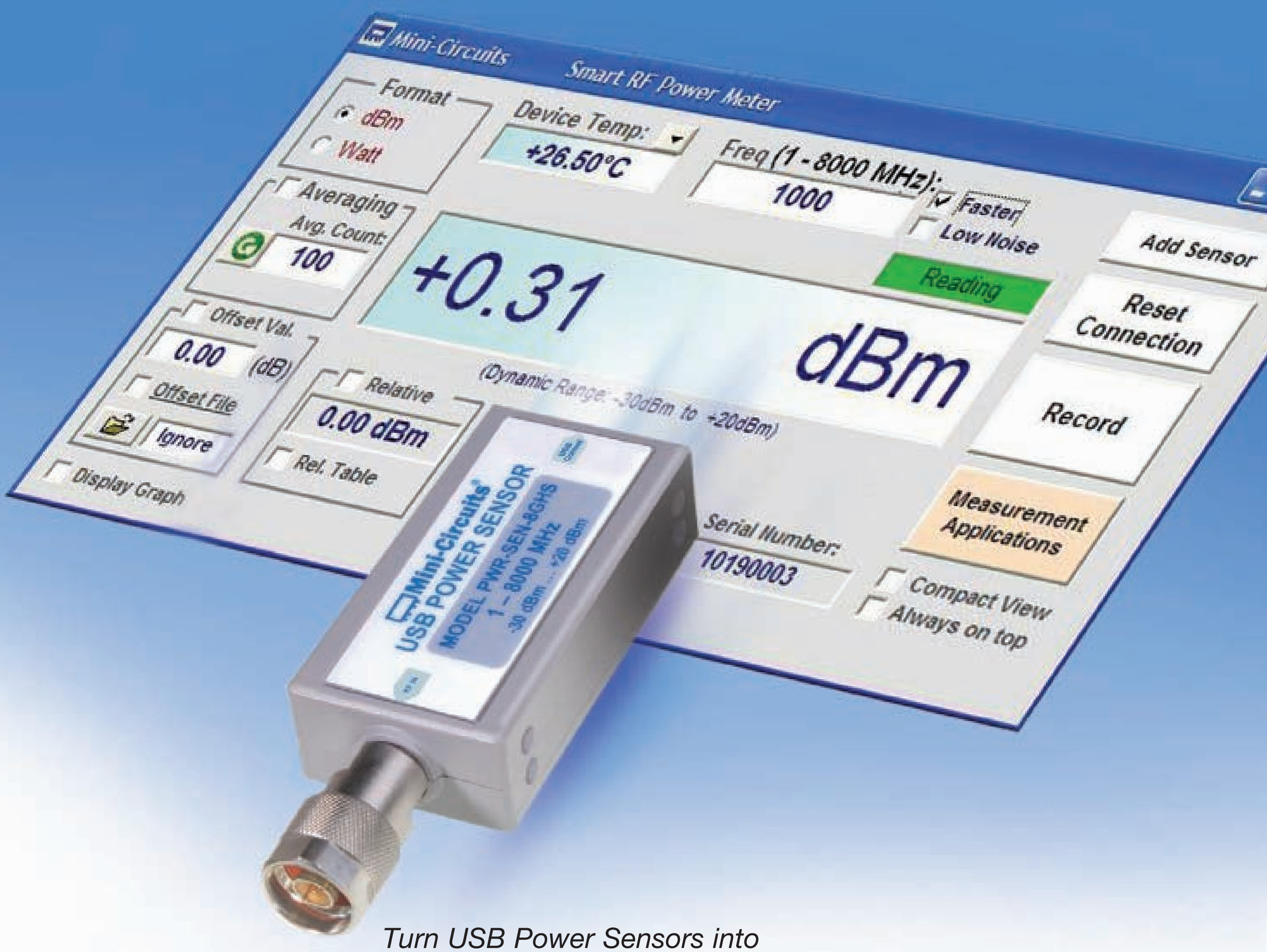
RFMW Ltd. and **TriQuint Semiconductor Inc.** announced a distribution agreement for Europe, the Middle East and Africa. TriQuint is a manufacturer of high performance components for communications applications. RFMW Ltd. is a specialized distributor that provides customers and suppliers with focused distribution of RF and microwave components as well as specialized component-engineering support. To reach RFMW in Europe, the Middle East and Africa, customers can call the UK headquarters at +44 20 8848 4732 or e-mail: europe@rfmw.co.uk.

Richardson RFPD Inc. and **Maxwell Technologies Inc.** announced the expansion of their mutual business agreement to now include distributing ultracapacitors in the European markets. Richardson RFPD carries a substantial inventory of Maxwell ultracapacitor products, with stocking locations throughout the world. Richardson RFPD's global field sales engineering team can recommend the proper ultracapacitor considering a customer's specific electrical design requirements and mechanical constraints. Richardson RFPD offers Maxwell's complete line of ultracapacitors from individual cells (1F to 3,000F) to multicell modules (up to 500F). Richardson RFPD also has the engineering capabilities to design and build custom ultracapacitor banks and assemblies.

Mouser Electronics Inc. launched a major global distribution partnership with **Maxim Integrated Products Inc.** This worldwide agreement between two of the industry's premier solutions and service providers gives design engineers immediate access to Maxim's vast array of advanced semiconductor components and tools.

WEBSITE

Amphenol RF, a leader in RF interconnect solutions, is pleased to announce the availability of IGS File downloads for the majority of its connectors. There are currently over 1,100 files available for immediate download, with more added on a daily basis. Visit www.amphenolRF.com to browse the extensive selection of cable connectors, adapters and PCB configurations.



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PWR-4GHS	9 kHz-4 GHz	30 ms	50	795.00
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AN ANALOG APPROACH TO POWER AMPLIFIER PREDISTORTION

Davin Lee, CEO of Scintera.

Visit www.mwjournal.com to read this in-depth interview.

More than ever, linearization schemes for radio frequency (RF) power amplifiers (PA) have become a necessity. Modern PAs are facing ever-increasing challenges in terms of power efficiency (PE) and performance requirements. Solutions relying heavily on digital signal processing are mature and readily available today, but are not without their drawbacks. Besides, new standards, markets and applications are creating new challenges that these state-of-the-art techniques called digital predistortion (DPD) are not always able to solve.

One of the most exemplar challenges for DPD is the linearization of low power PAs that can be found in multi-antenna arrays or femtocell applications. For those applications, relying on a 5 to10 W DPD system to linearize a 5 W PA, for instance, does not make much sense.

With the need for alternative and simpler linearization methods, one needs to take an orthogonal approach, or what is called the analog approach. Analog predistortion (APD) faces unusual design challenges, even for the seasoned designer. First and foremost, textbooks do not cover it in much detail. The simplest questions arise but stay unanswered: How do you model the system? What do you need to specify? How do you perform simulation? How does a circuit specification translate into system performance?

While the most common analog blocks such as phase-locked loops, mixers or bandgap voltage references have been extensively analyzed and reported, little can be found on analog signal processing, or on analog computing building blocks. This article describes the peculiar aspects of APD in terms of requirements and provides a few pointers on the analog techniques of choice to implement an analog linearizer.

THE PA AND ITS NEED FOR LINEARIZATION

Among the PA parameters, designers must fulfill three that are all equally important and difficult to meet at the same time. Other equally important parameters, such as gain, have less relevance to PD techniques and are therefore not mentioned in this article. The first goal is to transfer all the electrical energy from the power plug into RF energy that will be radiated through the air. The ratio of the RF energy to the consumed power is power efficiency.

The second goal, which is intimately related to the first, is the linearity. It defines the quality of the signal that will be transmitted and also the amount of interferences generated into neighboring channels. For the present

FREDERIC ROGER
Scintera Networks, Sunnyvale, CA

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SPECIFICATIONS

Part Number	*Architecture*	*Block Diagrams A, B, C*	*LO Freq (MHz)*	*Phase Noise (dBc/Hz) at 2 GHz*		*Mixer RF/IF Port Freq Range (MHz)*	*Mixer IIP3 (dBm)*	*Supply Voltage (V)*	*Supply Current (mA) with one mixer active*	*Multi-Slice Mode*
				1 kHz	**10 kHz**					
RF2051	Frac-N PLL, VCO, 2 mixers	A	300 to 2400	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	—
RF2052	Frac-N PLL, VCO, 1 mixer	B	300 to 2400	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	—
RF2053	Frac-N PLL, 1 mixer	C	external VCO	-85	-90	30 to 2500	23	2.7 to 3.6	45 to 65	—
RF2056	Frac-N PLL, VCO, 2 mixers	A	50 to 500	—	—	30 to 500	25	2.7 to 3.6	50 to 65	—
RF2057	Frac-N PLL, VCO, 2 mixers	A	1900 to 2400	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	—
RF2059	Frac-N PLL, VCO, 2 mixers	A	1550 to 2050	-85	-90	30 to 2500	18	2.7 to 3.6	55 to 75	—
NEW RFFC2071	Frac-N PLL, VCO, 2 mixers	A	85 to 2700	-95	-102	30 to 2700	23	2.7 to 3.3	100 to 130	✓
NEW RFFC2072	Frac-N PLL, VCO, 1 mixer	B	85 to 2700	-95	-102	30 to 2700	23	2.7 to 3.3	100 to 130	✓
NEW RFFC5071	Frac-N PLL, VCO, 2 mixers	A	85 to 4200	-95	-102	30 to 6000	23	2.7 to 3.3	100 to 135	✓
NEW RFFC5072	Frac-N PLL, VCO, 1 mixer	B	85 to 4200	-95	-102	30 to 6000	23	2.7 to 3.3	100 to 135	✓

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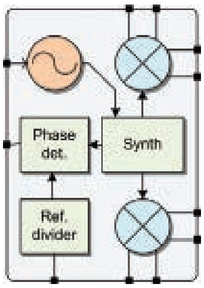

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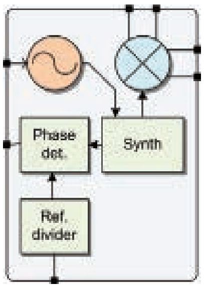

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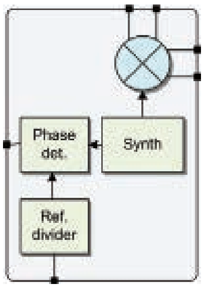

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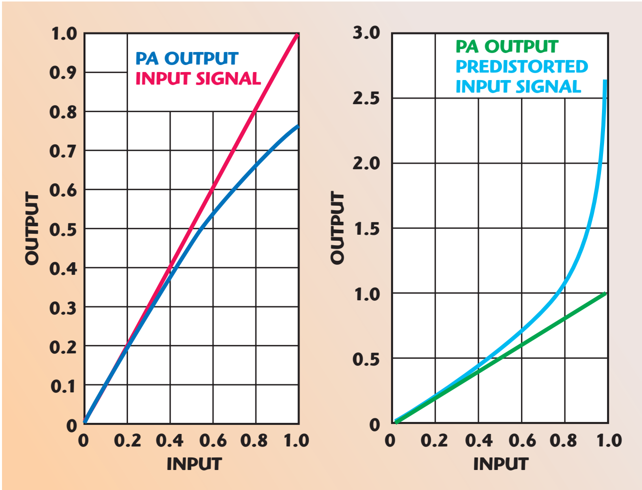
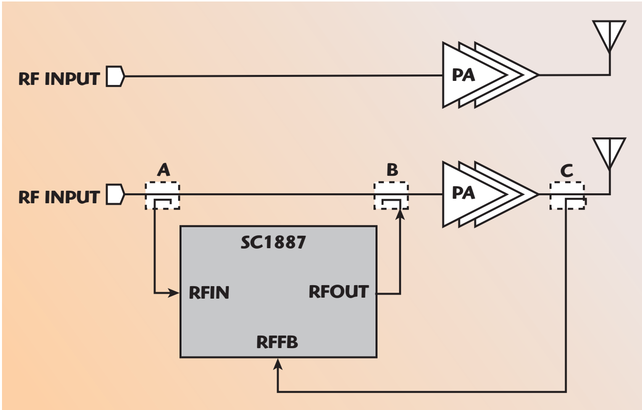
purpose, linearity can be defined as a metric that measures the quality of the signal after being distorted by an amplifier.

The last goal is the video bandwidth (VBW). In a nutshell, higher VBW means more users and higher data rates from the end user's favorite smartphone.

While the first cellular standards like GSM were created to simply make phone calls, modern standards like 3G and 4G have been primarily developed to handle greater data transmission and ultimately give users access to new services such as video streaming. The shift to those modern air interfaces has changed the PA requirements quite substantially. W-CMDA, for instance, calls for VBWs that are at least ten times greater than GSM. Worse, in order for a 3G-PA to be properly linearized, its VBW should be even greater because the linearizer will expand the signal, as will be discussed later in this article.



▲ *Fig. 1 PA distortion.*



▲ *Fig. 2 Predistorter (SC1887) application schematic.*

PREDISTORTION'S PRINCIPLE AND IMPLEMENTATION

Principle

Predistortion (PD) is basically a way of improving the linearity of the PA. Why is that a good thing? Because linearity can be traded for power efficiency. A good PD system allows the PA designer to make the PA less linear but more efficient, knowing that the lost linearity can be recovered by the linearizer. The PD principle is extremely simple and has given its name to the technique. The idea is to preprocess, or predistort, the signal applied to the PA, rather that trying to improve the PA itself.

Figure 1 shows this principle. On the left-hand side, the red signal is the input applied to the PA. The blue curve shows the output of the PA. Where a straight line following the red line is expected, one can see that as the signal becomes larger, the amplifier is not able to follow the input anymore; it is compressing. On the right-hand side, the input signal is predistorted (cyan) and the output of the PA (green) is now a straight line; the PA is said to be more linear. It is interesting to note that while the blue line was pointing down, the green line is pointing up; it is expanding.

Implementation

Following the predistortion principle, the actual implementation of an analog PD solution is very straightforward and can be hooked up in a few minutes to any existing PA. ***Figure 2*** illustrates the simplicity of such a system. The RF input signal RFIN is connected to the analog predistorter's input, called RFIN (coupler A). The predistorted signal coming out of RFOUT is added (coupler B)

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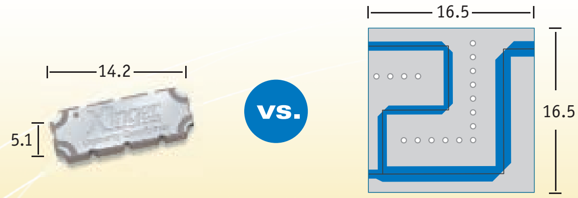

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to RFIN at the input of the PA. A last signal called RFFB (coupler C) is used to analyze the output of the PA and adapt the predistortion signal. It should be noted that unlike in a digital PD system, all of the inputs and outputs are RF/analog signals. Among other things, this makes it independent of protocol. Any adaptive PD system, analog or digital, requires two main subsystems: an analyzing and processing engine and a correction engine.

Analyzing and Processing Engine

The first thing that needs to be done is analyzing the signal to extract metrics that describe the quality of the incoming signals RFIN and RFFB. These metrics are called cost functions (CF). RFIN is the signal sent by the transceiver to the input of the PA. As such, this signal has the highest spectral purity, that is free of distortion and only limited in quality by the transmitter baseband and upconverter. RFFB is basically the output of the PA, only attenuated to accommodate the power levels at the input of the linearizer. This signal is strongly distorted by the PA. It is the signal that must be improved. Having these two inputs allows a few operations, such as subtracting them to obtain the error introduced by the PA (see ***Figure 3***).

It is also possible to take a look at RFFB and measure its spectral purity by measuring the energy in the band of interest and out of the band. ***Figure 4*** shows the measured adjacent channel leakage ratio (ACLR) output of a PA for a single-carrier W-CDMA signal.

Correction Path

The correction block is the heart of the system. Its role is to apply mathematical transformations to the incoming RF signal. These transformations are called the work function (WF). The work function is an approximation of the PA's inverse transfer function. Ideally, the predistorting transformation is cancelled out by the amplifier's distorting transformation, resulting in an undistorted, amplified output signal. Due to the nonlinear behavior of the PA, its inverse function can be approximated by a polynomial function; the higher the order of the polynomial, the better the approximation of the mathematical transformation. ***Figure 5*** demonstrates a possible implementation of such a polynomial. The input signal X is passed through a number of multipliers to generate its harmonics: X, X^2, …, X^n. Those harmonics are then multiplied by a series of coefficients c_1, c_2,…, c_n and finally summed together to create a polynomial of the form: $c_1X + c_2X^2 + \ldots + c_nX^n$.

In DPD, these operations are realized in the digital domain. Analog predistortion is using analog multipliers and digital-to-analog-converters (DAC) for the coefficients.

One fundamental mechanism of the PA is the so-called memory effect. In a nutshell, the PA transfer function is not constant over time and will vary. In other words, the output of the PA

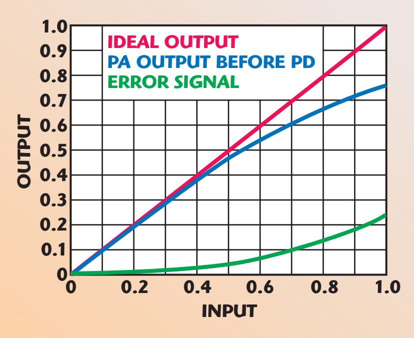

Fig. 3 Error measurement.

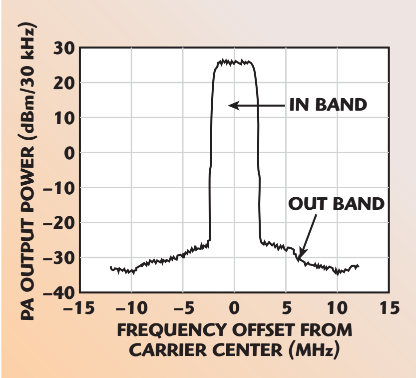

Fig. 4 In-band vs. out-of-band.

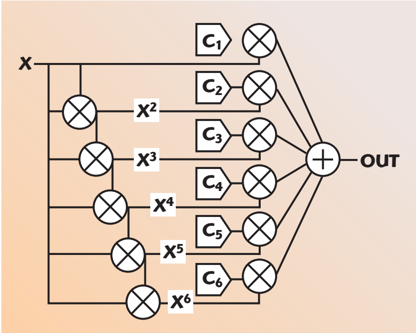

Fig. 5 Polynomial generation.

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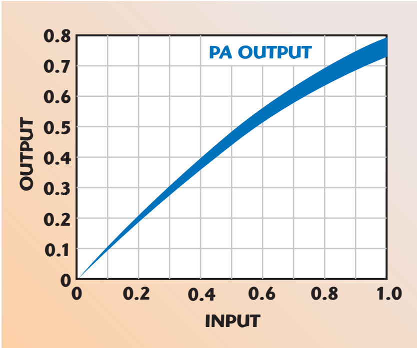
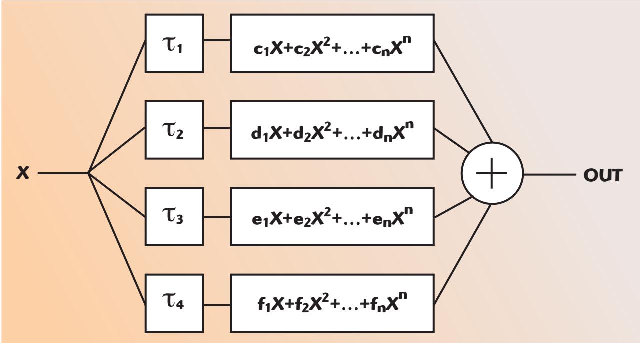
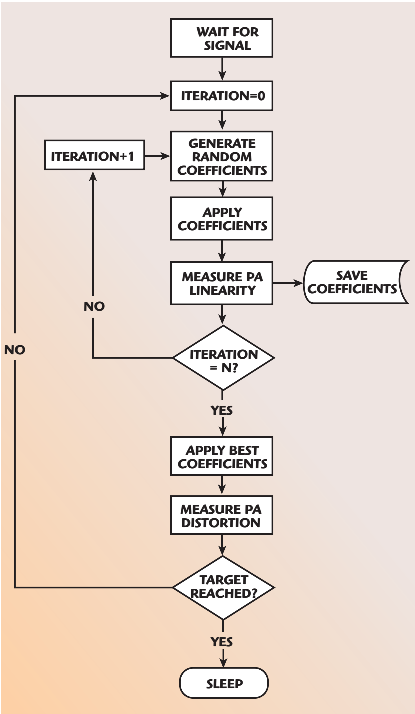


▲ *Fig. 6 Memory effect.*



▲ *Fig. 7 Memory compensation.*



▲ *Fig. 8 Adaptation algorithm.*

depends on its input at all times. ***Figure 6*** shows how the PA characteristic is affected by the memory effect; its output spreads.

To accommodate for these memory effects, the polynomial has to be replaced with a set of polynomials (see ***Figure 7***). Each of the polynomials is identical, but is fed by a time shifted version of the input signal X. Such a mathematical representation is called a Volterra Series and was developed by Vito Volterra in 1887. The analog predistorter contains four memory terms. Each of them is made of a programmable delay, followed by a 6^{th} order polynomial.

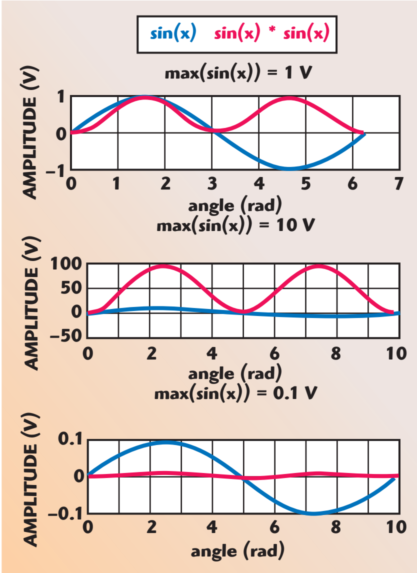
Adaptation Related Issues

The system must be continuously adaptive to compensate for changes. It basically learns from its mistakes and becomes better over time. When the device starts, it waits for an input signal and then goes through an adaptation loop (see ***Figure 8***). When the adaptation is over after a few seconds, the device will go into power saving, but will keep looking at the incoming signal regularly and immediately go back to adaptation if necessary.

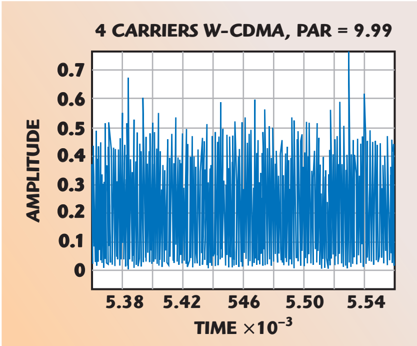
The adaptation principle is quite simple. Starting with some random coefficients, a few sets of random coefficients are applied and the result measured. Out of these trials, the best coefficients are selected, and the loop is repeated until the linearity target is reached.

This algorithm, while being robust and simple, puts a high burden on the analog blocks on the chip. When the device enters the ‘sleep state’, the on-chip temperature drops by a few tens of degrees Celsius. These temperature changes are happening many times per second and should have no impact on the analog path in order for the PD signal to stay constant.

Also, during adaptation, the algorithm applies random coefficients on the online signal, the signal sent to the PA. If too much of the perturbation energy is applied, the PA linearity will degrade and violate the spectrum requirement. On the other hand, if the applied perturbation is too small, the cost function will not change significantly enough to be meaningful, hence useful for adaptation. In order for this mechanism to work, the gain settings throughout the chip have to



▲ *Fig. 9 Compression vs. expansion.*



▲ *Fig. 10 Peak to average ratio.*

be tightly controlled over process, voltage and temperature (PVT). Only a tight control will ensure that the perturbation energy is controlled.

DESIGN ISSUES EXPLAINED

Bandwidth Expansion

Predistortion is all about signal expansion, hence bandwidth expansion. For a given input signal at a frequency f_0, the PA will generate distortion products at multiples of this frequency: $2f_0$, $3f_0$, $4f_0$, $5f_0$, $6f_0$, $7f_0$, etc. While this is a good thing for a rock guitar, modern telecommunication PA spectral output requirements are very stringent and do not tolerate too much distortion. The higher order harmonics' energy is high enough to significantly degrade the spectrum up to the 7^{th} order.

This means the linearizer should be able to generate frequencies at least up to $7f_0$ to cancel this distortion product at the output of the PA. In other words, for a 40 MHz VBW input signal, the linearizer should have a 280 MHz VBW. This also implies that the PA has a VBW high enough to allow the correction signal to be passed to its output.

Square-cube Law Factor Dilemma

While being extremely simple, the square-cube law has dramatic consequences on all physics phenomena. This law teaches that certain forces will matter more or less depending on the magnitude of a particular physics quantity. What does this all have to do with the topic? Take a 1 V sinusoid and square it. This would be the simplest way to generate the second harmonic of the signal. The output signal will be 1 V (see ***Figure 9***). Now, do the same thing with a 10 and 0.1 V signal. The outputs will be 100 and 10 m V, respectively. In the first case, the output of the multiplier expanded — 100 V > 1 V — and in the second, the signal has been severely compressed — 10 mV < 0.1 V.

What this means is that for 'larger' input signals, the polynomial generator output will be rapidly overwhelmed while smaller signals will virtually vanish. Solutions to the expansion are two-fold: increasing the dynamic range and increasing the resolution of the coefficient DACs. The compression issue can only be resolved by amplifying the signal, that is adding gain. A high gain can be achieved using a cascade of amplification stages with the drawback that each stage requires power and adds noise. Low noise amplification is therefore a must.

Peak-to-Average Ratio Burden

The peak-to-average ratio (PAR) is the ratio between the peak of the signal and its average. In ***Figure 10***, a short time sample of a four carrier W-CDMA signal with a 10 dB PAR is shown. A single peak above 0.7 can be seen, while most of the signal (the average) is much lower. Multicarrier applications, modern standards and OFDM, in particular, lead to very high PAR. What is important to understand from a design standpoint is that the analog circuits within the linearizer basically have the same problem as the PA. They have to support a high dynamic range to accommodate the PAR. Worse, because the linearizer has to create high order correction terms for the polynomial, it will actually expand

TABLE I

PAR

Signal	PAR (dB)	PAR	Peak (V)	Average (V)
1st order	10	3.16	1	0.316
2nd order	20	10	1	0.1
4th order	40	100	1	0.01
6th order	60	1000	1	0.001

TABLE II

GAIN VARIATION OVER TEMPERATURE

Temperature (°C)	Gain	X (V)	X^2 (V)	X^3 (V)	X^4 (V)
-40	25	0.1	0.25	0.6	1.5
25	15	0.1	0.15	0.22	0.34
125	10	0.1	0.1	0.1	0.1

the PAR. ***Table 1*** demonstrates this expansion for a 10 dB PAR signal.

As can be seen, when the order of the signal increases, the average signal drops at a very fast pace because each time the input signal is squared, the output is an order of magnitude smaller than the input. In order to compensate for these losses, at least 20 dB gain must be added after each squaring function.

CIRCUIT LIMITATIONS AND CONSIDERATIONS

Linearity of the MOS Device

With all its advantages, the MOS transistor is not a very linear device; its well-known square law V-I relationship limits its usability where linear transconductance stages are needed. In other words, independent of the load or type of circuit used, one cannot apply a 1 V signal at its gate and expect 60 dB linearity at its output; 10 to 20 dB is all one will get.

The most widely used techniques to overcome this limitation are to use the transistor in a closed-loop circuit. Closing the loop reduces the input signal seen by the transistor to a few tens of a mV, while keeping a large output signal and ultimately improving its linearity. As everything in life, however, this does not come for free. Closed-loop circuits are relying on feedback to work and feedback always comes too late. Given BW and gain requirements, applying feedback would have been difficult, and perhaps even impossible. To rely exclusively on open-loop circuitry was preferred.

Process, Voltage and Temperature Variation Impact

Dealing with process, voltage and temperature variations is the essence of an analog designer's job. Process variations come from the imperfect manufacturing of silicon structures. The outcome is that the devices that are fabricated will vary from wafer to wafer.

Voltage variation can be mostly handled by architecture choice and has little impact on most of the important design parameters other than

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With Heat Sink/Fan										
LZY-1+	20-512	43	+45.7	+47.0	8.6	+54	26	7.3	1995	1895
LZY-2+	500-1000	46	+45.0	+45.8	8.0	+54	28	8.0	1995	1895
ZHL-5W-1	5-500	44	+39.5	+40.5	4.0	+49	25	3.3	995	970
ZHL-5W-2G+	800-2000	45	+37.0	+38.0	8.0	+44	24	2.0	995	945
ZHL-10W-2G+	800-2000	43	+40.0	+41.0	7.0	+50	24	5.0	1295	1220
ZHL-16W-43+	1800-4000	45	+41.0	+42.0	6.0	+47	28	4.3	1595	1545
• ZHL-20W-13	20-1000	50	+41.0	+43.0	3.5	+50	24	2.8	1395	1320
ZHL-30W-252+	700-2500	50	+44.0	+46.0	5.5	+52	28	6.3	2995	2920
• ZHL-50W-52	50-500	50	+46.0	+48.0	6.0	+55	24	9.3	1395	1320
• ZHL-100W-52	50-500	50	+47.0	+48.5	6.5	+57	24	10.5	1995	1920
NEW										
ZVE-3W-183+	5900-18000	35	+34.0	+35.0	5.5	+44	15	2.2	1295	1220
ZVE-3W-83+	2000-8000	36	+33.0	+35.0	5.8	+42	15	1.5	1295	1220
• ZHL-100W-GAN+	20-500	42	+49.0	+50.0	7.0	+60	30	9.5	2395	2320
ZHL-30W-262+	2300-2550	50	+43.0	+45.0	7.0	+50	28	4.3	1995	1920

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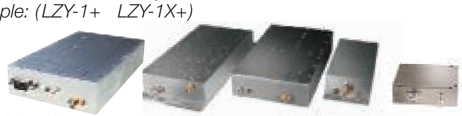
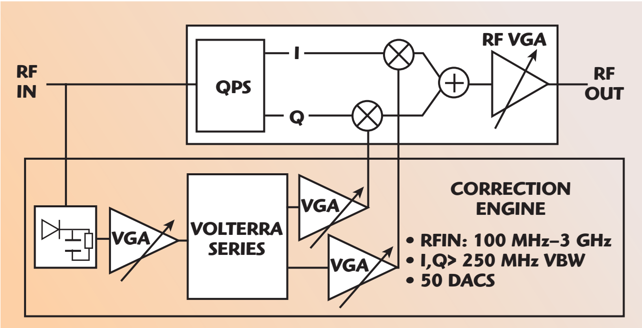
*For models without heat sink, add **X suffix** to model No.*
Example: (LZY-1+   LZY-1X+)





▲ *Fig. 11 Signal path.*

power consumption. Temperature, on the other hand, is a real beast. The characteristics of a transistor on a chip will change a lot with temperature. The gain of an analog multiplier can easily change by a factor of 2.5 (8 dB) between -40° and 125°C (industrial temperature range). For reference, ***Table 2*** shows how the temperature affects the harmonics' amplitude coming out of the polynomial generator. As can be seen, the signal amplitude after subsequent multiplications will vary greatly. Further, non-idealities will actually make the situation even worse.

A FEW ANSWERS

Design Partitioning

Proper design partitioning is key to such a complex analog processing architecture. The wrong partitioning can quickly lead to losses such as signal degradation, high power consumption, linearity degradation, and high noise figure or bandwidth degradation. Also, while certain design techniques can be applied in exceptional cases, their implementation is often heavy in terms of real estate, complexity or power consumption, and is therefore not suitable for circuits like multipliers and DACs that need to be replicated tens of times on a chip.

- A few simple rules can be used as a guide through the architecture choices and tradeoffs:
  Combine functions:
  –Amplification should never be made stand-alone but be part of another function
  –And its corollary: the signal should not be attenuated without good reason
- Use passive circuits as much as possible
- Minimize the hardware
- Limit the number of active stages
- Control all the circuit parameters
- Make the physical design (layout) part of the design process
- Reuse building blocks and/or make them scalable

Implementation of the Analog Signal Processing Path

Figure 11 depicts a simplified version of an implementation of the analog signal path. The RF signal is fed to the RF signal processor (RFSP) and to the correction engine (CORR). The signal path can handle RF frequencies going from 700 MHz to 3 GHz.

RFSP's first stage is a quadrature phase shifter (QPS). It is an analog polyphase filter, whose purpose is to extract the in-phase (I) and quadrature (Q) signals; having I and Q signals allows one to change both the phase

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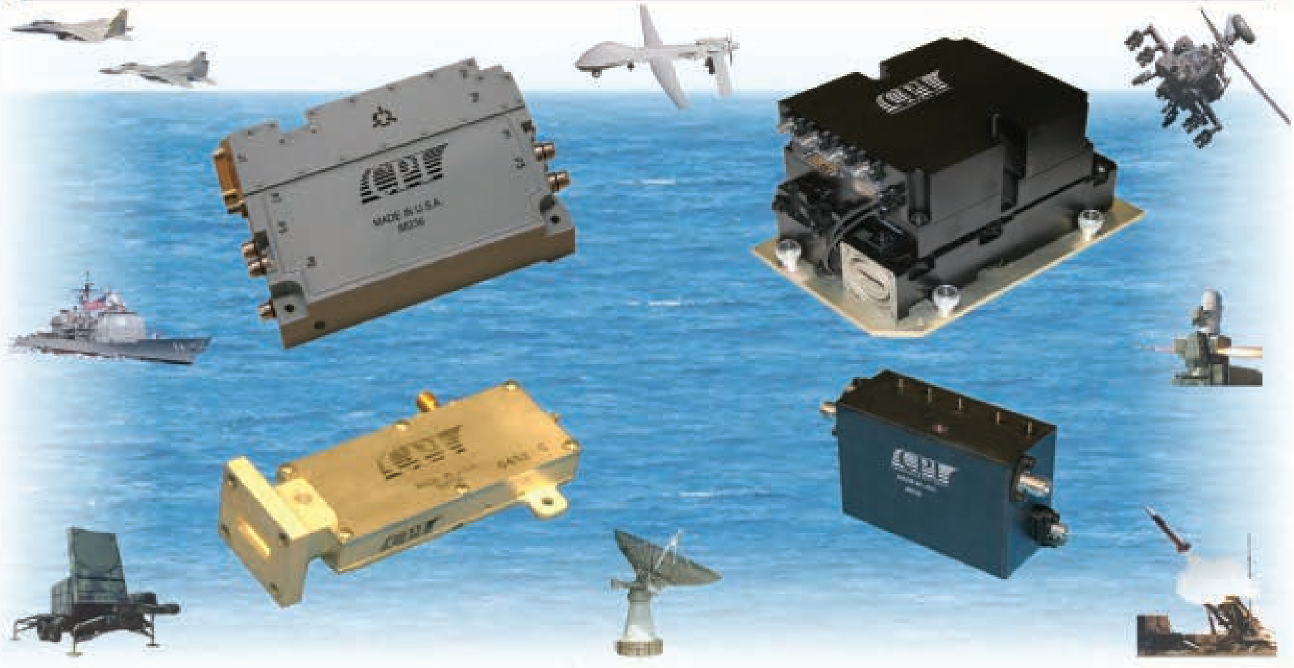

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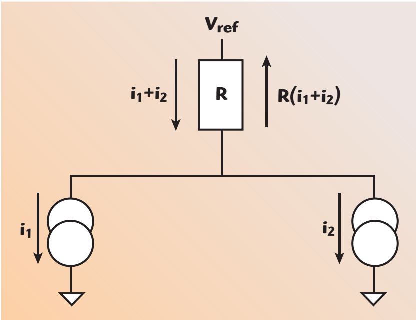
and amplitude of RFIN. I and Q are multiplied by the corresponding I/Q signals generated by CORR. The outputs of the multipliers are then added together and connected to RFOUT. RF VGA acts as a driver and a voltage-controlled amplifier for finer control over the correction signal.

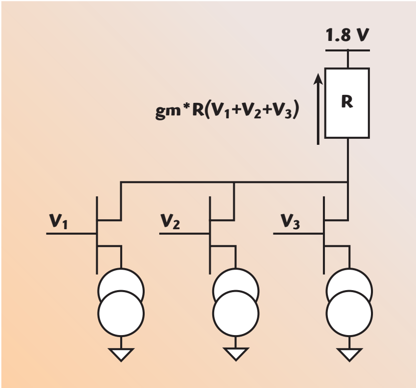
CORR is mostly a baseband analog processor. The first stage brings the RF signal down to baseband by extracting its envelope. The output is then buffered through another VGA that drives the Volterra series generator that was described previously. It actually generates two series to correct I and Q independently. The VGAs were added at the interface, instead of plain drivers, to gain flexibility and granularity.

Current Mode Approach

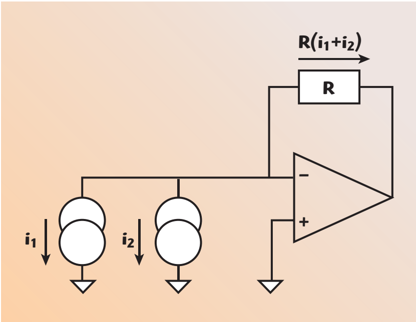
When it comes to summing and amplifying signals at high speed, current mode clearly outperforms voltage. Summing signals is as easy as connecting two nodes together, as shown in ***Figures 12*** and ***13***. Great amplification can be achieved by using a simple resistor. However, when isolation and impedance transformation are required, a transimpedance amplifier (TIA) will do the job nicely (see ***Figure 14***). High gain can be achieved by increasing the resistance of feedback resistors. For example, for $i_1 = i_2 = 50$ µA and R = 1 kΩ, Vout = 100 mV.



▲ *Fig. 12 Current summing.*[1]



▲ *Fig. 13 Current summing.*[2]



▲ *Fig. 14 Current summing with amplification.*

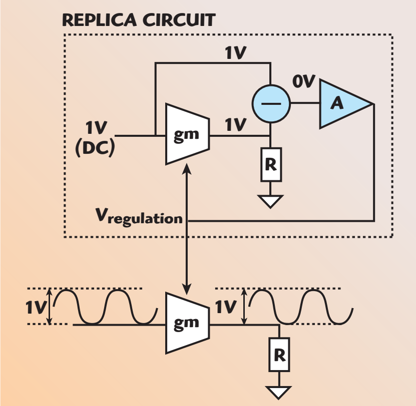
Replica Biasing

As was seen before, it is critical to control the gain of the circuits over PVT. It was also concluded that it was not possible to use closed-loop circuits to do so, mainly because of the BW requirements. A common way of regulating parameters over PVT is to use what

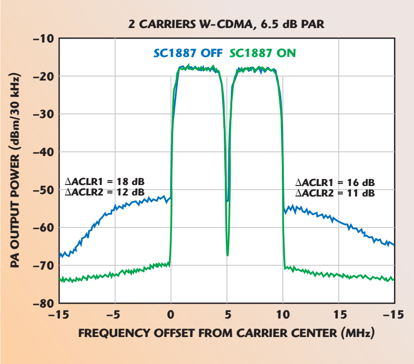
is called replica biasing. Replica biasing consists of making a perfect copy (see ***Figure 15***) of an active circuit. This replica is then included in a regulation loop that will control a specific parameter of this circuit. The output signal of the control loop V regulator is connected to both replica and active circuits. The replica circuit is using copies of the devices gm and R. In this case, it is forcing the equation: gm·R = 0.

Replica circuits are not new and are far from perfect. First, they are additional circuitry that serve no functional purpose. They take real estate and consume power. The achievable accuracy is therefore limited.

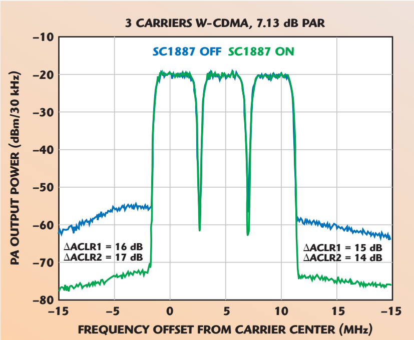
The outlined approach makes extensive use of replica biasing to control every single circuit in the CORR path. However, one particularity is that while different replicas are used, the same control circuit is employed everywhere.



▲ *Fig. 15 Replica biasing.*



▲ *Fig. 16 Two carriers W-CDMA.*



▲ *Fig. 17 Three carriers W-CDMA.*

CONCLUSION

Figures 16 and ***17*** show typical measurements taken with an implementation in standard CMOS of some of the techniques described and a Doherty PA for W-CDMA waveforms. The center frequency is 2.19 GHz. This demonstrates that analog predistortion can be successfully used for PA linearization. Complex GHz signal processing can be done in the analog domain by carefully selecting the architecture and design techniques. While being a new technology, it is also very robust. This design is scalable and flexible and can be easily adapted to other applications. ■

Reconfigurable GaAs MMIC Power Amplifier Design Methodology Using a Tunable Interstage Network

A tunable matching network (MN) integrated into the interstage of a two-stage power amplifier (PA) to provide the capability for center frequency tuning is described. The tunable π-section interstage topology is used to match the first and second amplifier stages. This enables the amplifier to reach a high Q-factor, thus resulting in a narrow bandwidth. The M-probe method is used to analyze the amount of mismatch loss in the interstage to compensate for roll-off and equalize the gain between tuning states. The power amplifier and tunable interstage network, which were fabricated on three GaAs MMIC die, was chosen to realize a prototype. The reconfigurable amplifier offers the advantage of center frequency tuning from 1.37 to 1.95 GHz or 35 percent tuning bandwidth in four switched bands, which covers standards for analog and digital cellular telephony. The maximum measured output power and OIP3 are 16.62 and 28.25 dBm, respectively.

The next generation of wireless applications requires tunable or reconfigurable components to realize multifunctional RF systems. In current broadband RF systems, filtering dominates size and cost.[1,2] These filters are not tunable and hence limit the usable frequency range of most RF front-ends. An alternative to the use of static filters located before or after the power amplifier is a reconfigurable PA, which can be difficult to design for high performance. A multiband PA with narrow bandwidth was achieved by employing a tunable T-section or π-section interstage matching network whose structure is a bandpass filter. These topologies transform the impedances to intersect with high Q-factor contours on the Smith chart, resulting in narrower bandwidth.[3]

Integrating the tunable impedance matching network into the interstage of the amplifier has several advantages. The rapid impedance variation provided by the first and second amplifier stages results in a narrow bandwidth. The resistance in the lower-Q tuning inductors also helps to stabilize the second amplifier

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Cellular Infrastructure LNA	400–1200	900	17.5	0.5	34	19	4	54	DFN 8L 2 x 2 x 0.75	**SKY67101-396LF**
Cellular Infrastructure LNA	1200–2300	1950	17.5	0.7	34	18.5	4	55	DFN 8L 2 x 2 x 0.75	**SKY67100-396LF**
Cellular Infrastructure LNA	2300–2700	2500	16.5	0.7	35.5	18	5	75	DFN 8L 2 x 2 x 0.90	SKY65066-360LF
GPS and ISM Band SiGe LNA	400–3000	1575	16.5	0.8	19.5	0	3.3	7	DFN 8L 2 x 2 x 0.90	SKY65047-360LF
Broadband Low Noise FET	450–6000	2400	15.5	0.65	23.5	10.5	3	20	SC-70 4L 2.2 x 1.35 x 1.1	SKY65050-372LF
Broadband High Linearity Low Noise FET	450–6000	2400	16.5	0.8	33.5	15.5	5	55	QFN 4L 2 x 2 x 0.55	SKY65053-377LF
5.8 GHz WLAN and ISM Band LNA	4900–5900	5800	13	1	20	9	3	11	QFN 1.5 x 1.5 x 0.45	**SKY65404-21**

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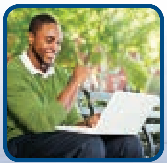





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stage. Exploitation of interstage mismatch loss is used for gain equalization to compensate for the gain roll-off of the active devices used in stages 1 and 2. The reflections in the interstage are acceptable because they allow the input and output of the amplifier to be conjugately matched. Also, by including the tunable matching network into the interstage of the PA, the resulting switch and inductor losses do not affect the input noise figure or output power of the amplifier. Finally, when multiband operation is required, a reconfigurable amplifier requires less die space than many single-band amplifiers typically used in the conventional approach.

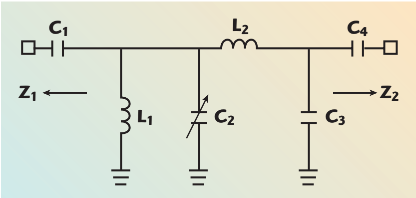
A CMOS PA, described in the literature,[4] also uses the interstage for tuning purposes. However, each tuning state has a broad bandwidth and considerable gain fluctuation. In an earlier work,[3] a reconfigurable power amplifier with a tunable interstage matching network was realized by using a two-stage MMIC PA and discrete components for the interstage matching network. The devices are placed on a three-layer prototype board with 50 Ω lines with dimensions of 4 cm × 5 cm. The MMIC PA is located at the center of the board and 25.4 μm diameter gold wire bonds are used to connect the bond pads on the die to the board microstrip line runners. The input and output matching networks were kept fixed while the switching function of the interstage matching network was implemented using a Skyworks AS204 SP4T switch.

At higher frequencies, the size of discrete components becomes large compared to the wavelength and the surface-mount components (SMT) can self-resonate or the parasitic effects begin to dominate. Electromagnetic coupling and parasitic effects from the prototype board become more evident, which cause difficulties in the design process. Therefore, the results from the earlier discrete design suggest that a MMIC implementation of the tunable interstage matching network becomes necessary for higher frequency operation.[3] This is due to fewer parasitics being present and better control over component values in the MMIC implementation.

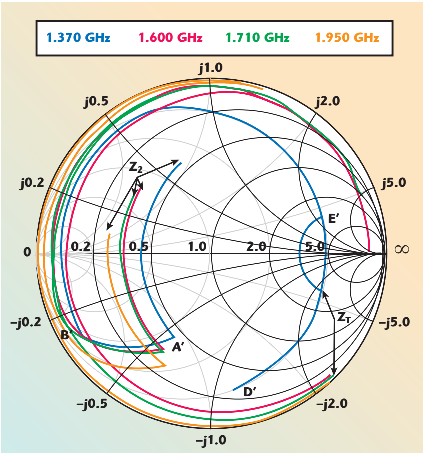
In this article, a reconfigurable power amplifier fabricated using three MMICs is described. The two-stage PA occupies a single MMIC die and the tunable interstage matching network occupies two MMIC die. GaAs FETs are used in the design to provide the switching function instead of varactor diodes or MEMS switches. Varactor diodes have limited linearity and low power handling capability, while MEMS switches are high cost and require a high DC supply voltage. These components cannot be realized monolithically and lead to larger circuit size and higher cost. Therefore, GaAs FETs are used to perform switching in the interstage matching network.

MMIC DESIGN METHODOLOGY

The reconfigurable PA, including the MMIC tuner design, can be used for applications covering GSM, CDMA, Bluetooth and WiMAX for frequencies from 0.9 to 2.4 GHz. Circuit design and DC analysis were performed using the Agilent Advanced Design System (ADS).



▲ *Fig. 1 Simplified schematic of the interstage matching network.*



▲ *Fig. 2 Impedance matching transformation using a Smith chart.*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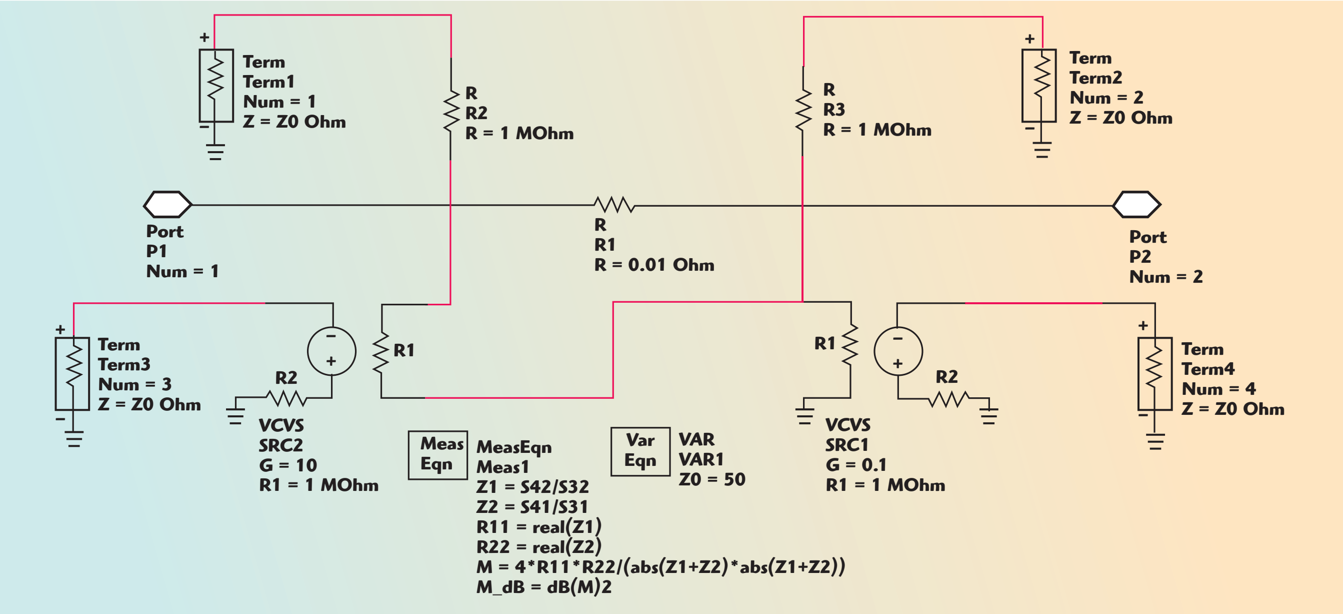

▲ *Fig. 3 Schematic diagram of M-probe for implementation in ADS.*

Circuit Design and Small-signal Performance

The first step in the design is the selection of the first- and second-stage BJTs, including biasing and ballast networks, and input and output matching for 1 to 2 GHz operation. This initial design uses simple high-pass and low-pass L-section matching networks for the input and output. A blocking capacitor is used in the interstage and some resistive loading is used to improve stability. The output impedance of the first-stage amplifier (Z_1) and the input impedance of the second-stage amplifier (Z_2) were then calculated. ***Figure 1*** shows the π-section impedance matching network used in the interstage. This network has a bandpass response. Impedance matching using a Smith chart was used to determine the initial components values.

Figure 2 shows the impedance transformations used to reach the high-Q contour on the Smith chart. The series capacitor C_4 transforms the input impedance of the second-stage amplifier, Z_2 to A'. The shunt capacitor C_3 then transforms A' to B', the series inductor L_2 transforms B' to C', the shunt capacitor C_2 transforms C' to D', the shunt inductor L_1 transforms D' to E' and finally the series capacitor C_1 transforms E' to Z_T. Ideally, to ensure maximum power transfer through the network, the impedance should be transformed from Z_2 to the exact conjugate match Z_1^*. However, the transformed impedance is Z_T, whose difference from Z_1^* results in mismatch loss that is exploited to equalize the gain between the states.

Transformation to the high resistance region of the Smith chart (E') is also necessary for minimum bandwidth.[5] In addition to the transformation purpose, the series capacitors (C_1 and C_4) also behave as DC blocking capacitors. The shunt capacitor C_2 is realized by using four shunt capacitors with FET switches placed in series for frequency control. Here, the center frequency switching takes place by varying the capacitance

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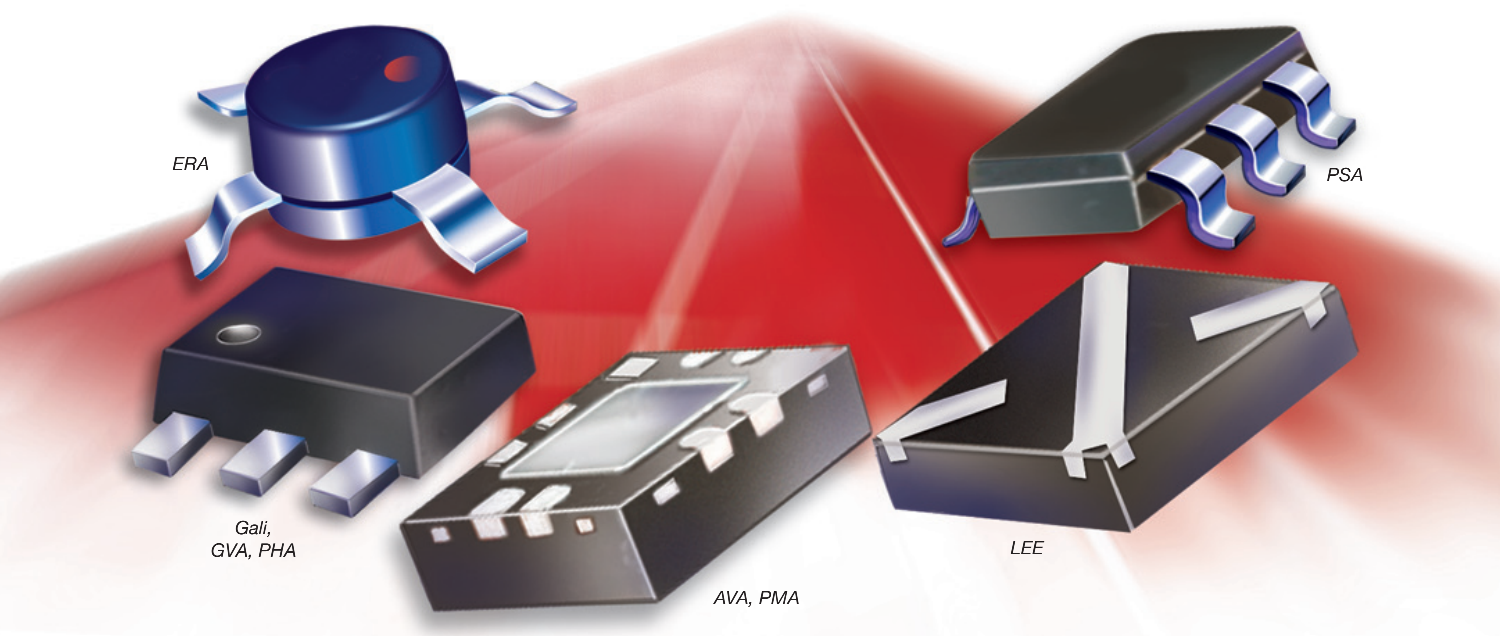

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value and thus changing the mismatch loss in the interstage.

Mismatch loss in the interstage matching network was calculated using the mismatch probe or M-probe. ***Figure 3*** shows the schematic diagram of the M-probe used with ADS, which is adapted from the S-probe tool.[6] The M-probe is a non-invasive analysis that can be placed at an arbitrary point within the circuit.[7] The M-probe uses Equation 1 to compute the mismatch loss or mismatch factor between two complex impedances $Z_1 = R_1 + jX_1$ and $Z_2 = R_2 + jX_2$.[8]

$$M = \frac{4R_1R_2}{\left|Z_1Z_2\right|^2} \quad (1)$$

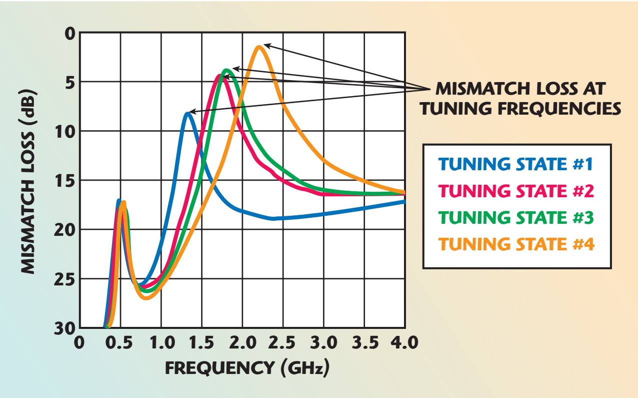
TABLE I INTERSTAGE MISMATCH LOSS	
Frequency (GHz)	***Interstage Mismatch Loss (dB)***
1.32	8.218
1.72	4.264
1.80	3.768
2.18	1.439

Since M-probe is non-invasive, it is easy to implement and can be computed quickly. It is particularly useful in circuit design, where only a specific part of a large circuit is analyzed, that is the interstage. ***Figure 4*** shows a plot of the interstage mismatch loss calculated at the input to the interstage of the amplifier for four different FET switch states. The interstage mismatch loss has a response that is bandpass and decreases monotonically with increasing tuning frequency.

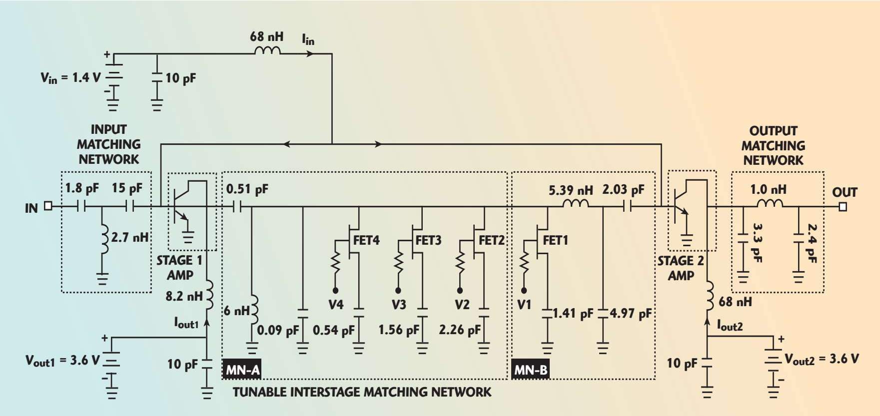
The mismatch loss in the interstage for each tuning state is tabulated in ***Table 1***. The circuit was designed with higher mismatch loss at lower frequency since the gain of the two amplifier stages rolls off with increasing frequency. Therefore, the gain roll-off from stages 1 and 2 are compensated or equalized by this mismatch loss.

In the initial design, the decrease in S_{21} over the design bandwidth was approximately 4 dB. After obtaining the initial component values using the Smith Chart, the interstage was re-tuned and analyzed for flat amplifier gain (S_{21}) response using the M-probe. Finally, the input and output matching networks for the PA were tuned to provide for wideband low input and output return losses. In the final design, the measured gain (S_{21}) variation was only ± 0.7 dB.

A detailed schematic diagram of the final reconfigurable MMIC power amplifier using tunable interstage matching network



▲ *Fig. 4 Interstage mismatch loss.*

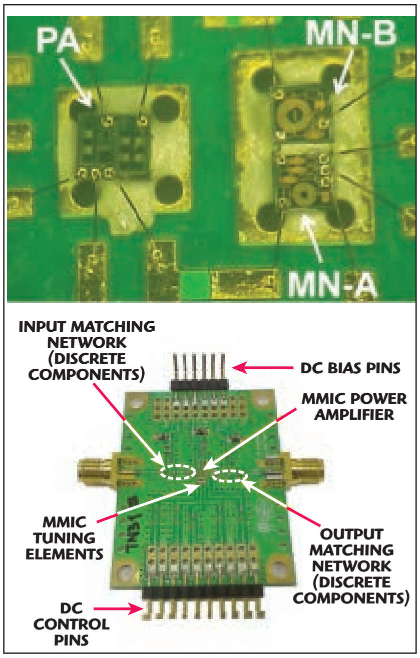


▲ *Fig. 5 Detailed schematic diagram of a GaAs MMIC reconfigurable PA.*

is shown in ***Figure 5***. This shows the two-stage amplifier, fixed input and output matching network, tunable interstage matching network and the DC biasing network.

DC Analysis

The circuit is biased using the input bias V_{in} = 1.4 V (I_{in} = 1.32 mA), output1 bias V_{out1} = 3.6 V (I_{out1} = 25.4 mA) and output2 bias V_{out2} = 3.6 V (I_{out2} = 137 mA), which are required to operate the two-stage amplifier. Series RF chokes and shunt bypass capacitors are placed between each DC power supply and the circuit to provide adequate isolation between each of the amplifier stages. The center frequency tuning is performed by changing the control voltage of the four FET switches (V_1, V_2, V_3 and V_4) for turn on or off. Changing the FET switch state varies the overall shunt capacitance value (C_2). To limit the current flow into each FET switch,



▲ *Fig. 6 Fabricated prototype of the reconfigurable power amplifier.*

a 1.96 kΩ resistor is placed in series with each gate terminal and control line.

The DC bias networks included RF chokes and bypass capacitors to provide isolation between the amplifier stages and improve the stability. Broadband stability analysis was performed on each amplifier stage and also at each tuning state to ensure unconditional stability. Rollet's condition, where $K > 1$ and $|\Delta| < 1$, is satisfied to achieve stability.[8]

FABRICATION

Figure 6 shows the fabricated prototype of the reconfigurable power amplifier, including the two-stage power amplifier and the tunable interstage matching network and the prototype board. The MMIC PA and MMIC tuner were fabricated on three different die and co-located on the prototype board. The die shown on the left side is a two-stage power amplifier (PA) having dimensions of 720 μm × 660 μm and the two tuner die shown on the right side are 600 μm × 600 μm (MN-A and MN-B). These die are the tunable interstage matching network that provides center frequency tuning function. Separate die for the tuner were necessary because of limited wafer space. The input and output matching networks were fixed and realized using surface-mount components (0402 and 0805 SMT). For the

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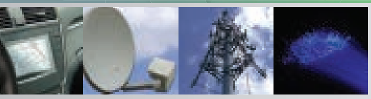

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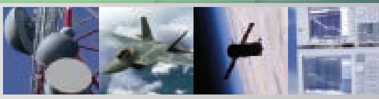

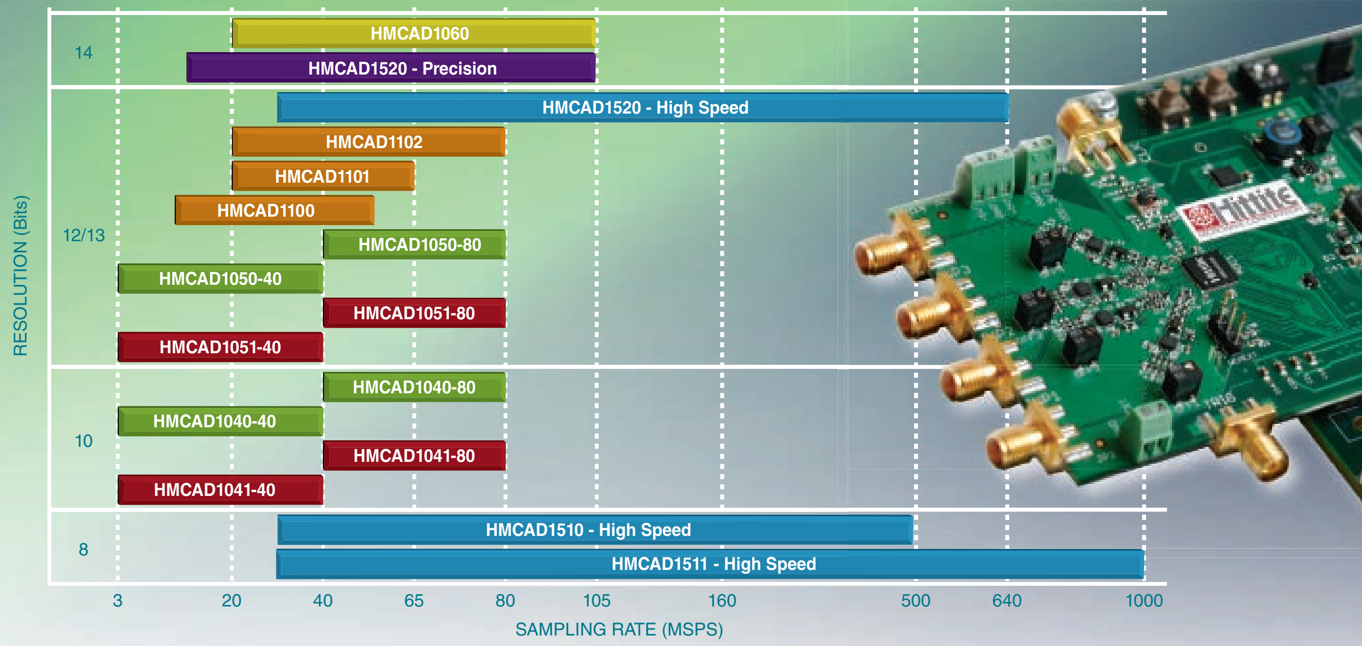

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HMCAD1060	14-Bit	105 MSPS	4	157 mW / Channel	74.3	80	LP7D	EKIT01-HMCAD1060
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HMCAD1040-80	10-Bit	80 MSPS	2	78 mW	61.6	75	LP9	EKIT01-HMCAD1040-80
HMCAD1040-40	10-Bit	40 MSPS	2	43 mW	61.6	81	LP9	EKIT01-HMCAD1040-40
HMCAD1041-80	10-Bit	80 MSPS	1	46 mW	61.6	75	LP6H	EKIT01-HMCAD1041-80
HMCAD1041-40	10-Bit	40 MSPS	1	25 mW	61.6	81	LP6H	EKIT01-HMCAD1041-40

[1] Excluding Interleaving Spurs. [2] Supply Voltage (Vdd): +1.8 Vdc Analog Supply (AVdd) and +1.8 Vdc Digital Supply (DVdd). [3] Output Supply Voltage (OVdd): +1.7 to +3.6 Vdc.

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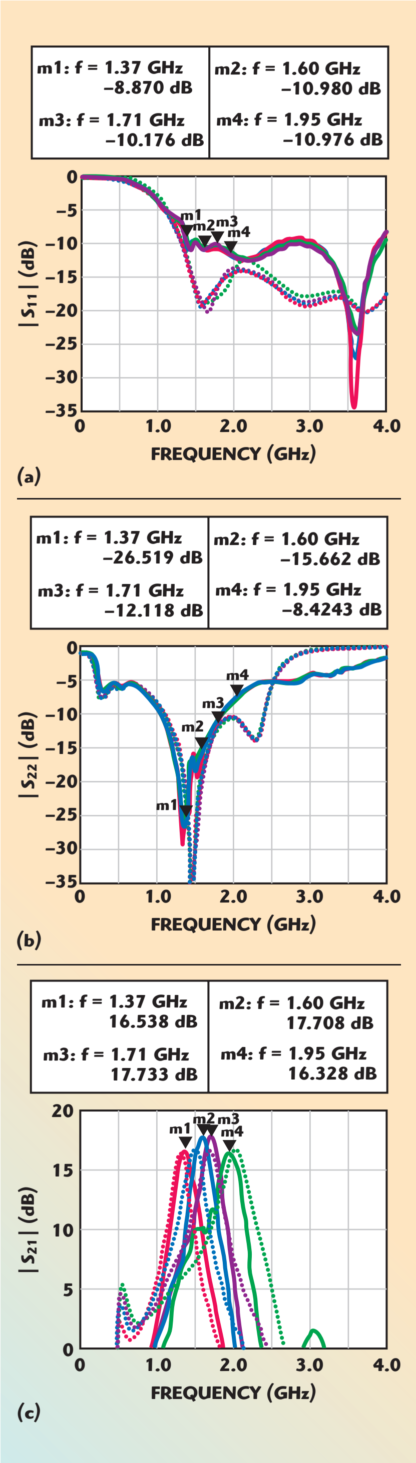
TABLE II

BINARY COMBINATIONS FOR FET TUNING STATES

FET1	FET2	FET3	FET4	Total Shunt Capacitance	Operating Frequency (f_o)
on	on	on	on	5.86 pF	1.37 GHz
on	off	off	on	2.04 pF	1.60 GHz
on	off	off	off	1.50 pF	1.71 GHz
off	off	off	off	0.09 pF	1.95 GHz

low tuning bandwidth (35 percent), the optimum load impedance for maximum power transfer is assumed to be independent of frequency.



▲ *Fig. 7 Measured and simulated S-parameters of the GaAs MMIC reconfigurable power amplifier.*

The three-layer prototype board has dimensions of 4 cm × 5 cm and 50 Ω microstrip lines. The top DC pins are used to supply the DC bias to operate the two-stage amplifier and the bottom DC pins are used to switch the control voltages (V_1, V_2, V_3 and V_4).

TABLE III

3 dB BANDWIDTH AT VARYING OPERATING FREQUENCIES

f_o (GHz)	1.370	1.600	1.710	1.950
3 dB BW (MHz)	260	260	270	320
Q= f_o/BW	5.269	6.154	6.333	6.094

TABLE IV

MEASURED P_{1dB} AND OIP3 FOR THE RECONFIGURABLE MMIC PA

f_o (GHz)	1.370	1.600	1.710	1.950
Meas P1dB (dBm)	16.62	16.35	14.95	13.85
Meas OIP3 (dBm)	28.25	25.89	24.83	22.61

SIMULATION AND MEASUREMENTS

The circuit simulation was performed using the Agilent Advanced Design System (ADS) and the effects of parasitics from the prototype board were modeled using Sonnet™. The SMT S-parameter data that are available from the vendors were also included in the circuit simulation. A sensitivity analysis was used to consider any effects due to possible variations in the prototype board on the circuit performance. The length and width of the microstrip lines in the circuit simulations were varied to ensure that any effects due to these variations were minimal.

Small-signal Measurement

The small-signal response of the reconfigurable MMIC PA was simulated and measured. An Agilent E5071C Network Analyzer was used to measure the S-parameters. ***Table 2*** shows the combination of FET switch tuning states and the total shunt capacitance value used to tune the center frequencies to 1.37, 1.60, 1.71 and 1.95 GHz.

Figure 7 shows the measured (solid lines) and simulated (dotted lines) S_{21}, S_{11} and S_{22}, at four different center frequencies. The fabricated prototype shows 17 dB (± 0.7 dB) measured gain and gives reasonable agreement with the simulated gain. The measured input reflection coefficient (S_{11}) is less than -10 dB at most of the operating frequencies. The output reflection coefficient (S_{22}) varies between -8.5 and -26.5 dB for the different switch states. The minimum reverse isolation (S_{12}) is -50 dB for all states.

Table 3 shows the measured 3 dB bandwidth at each operating frequency and its corresponding Q-factor. The Q-factor is nearly constant for all tuning states. The measured 3 dB bandwidth varied from 260 to 320 MHz between the tuning states.

Large-signal Measurement

The Agilent MXA N9020A Spectrum Analyzer and Agilent MXG N5181A Analog Signal Generator were used to measure the large-signal power performance. OIP3 and P_{1dB} for each state were measured at the corresponding operating frequency (f_o) and are tabulated in ***Table 4***. The maximum measured OIP3 and P_{1dB} at 1.370 GHz are 28.25 and 16.62 dBm, respectively.

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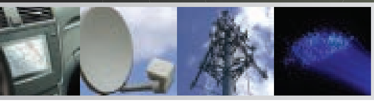

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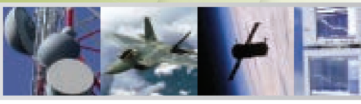

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CONCLUSION

This article presents the design methodology for a reconfigurable power amplifier with a tunable interstage matching network. The fabricated prototype operates at center frequencies between 1.37 to 1.95 GHz, which cover several standards of digital telephony. The reconfigurable PA was fabricated using 3 MMIC die and a test board. The measured gain (S_{21}) of the reconfigurable amplifier is 17 dB (± 0.7 dB) over the tuning bandwidth. Future work includes the development of an integrated MMIC including the power amplifier and tuning elements onto a single die to achieve a broader tuning range and higher frequency of operation. ■

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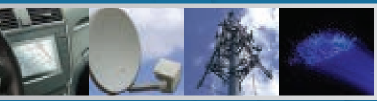

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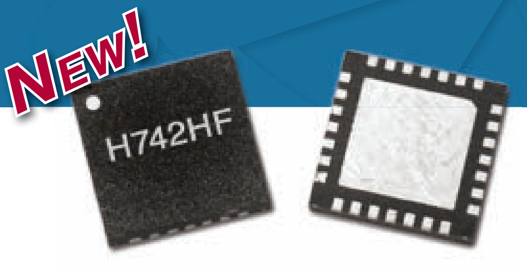

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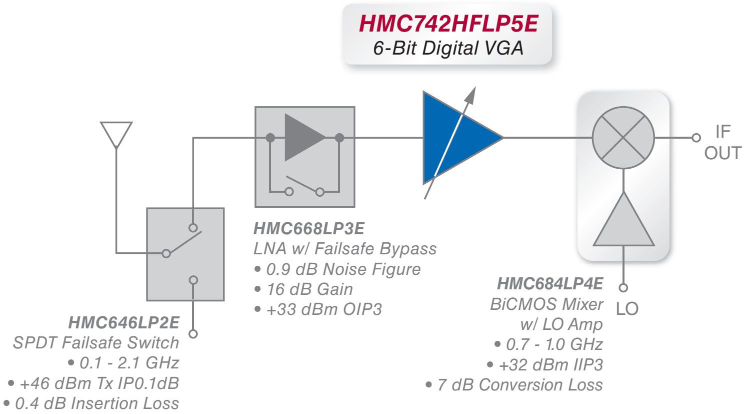

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	2.3 - 2.5	Analog VGA	-9 to +21	2.5	7	3	+3V @ 9mA	**HMC287MS8E**
	6 - 17	Analog VGA	0 to +23	6	30	22	+5V @ 175mA	**HMC694LP4E**
	0.7 - 2.7	5-Bit Digital, Serial Control	+1 to +32.5	4.4	45	25	+5V @ 218mA	**HMC926LP5E**
	DC - 1	6-Bit Digital, Serial & Parallel Control	-11.5 to +20	4.3	36	20	+5V @ 90mA	**HMC627LP5E**
	DC - 1	6-Bit Digital, Parallel Control	+8.5 to +40	4	36	20	+5V @ 176mA	**HMC626LP5E**
	DC - 1	6-Bit Digital, Serial Control	+13.5 to +45	2.7	36	20	+5V @ 176mA	**HMC681LP5E**
	DC - 6	6-Bit Digital, Serial & Parallel Control	-13.5 to +18	6	33	19	+5V @ 88mA	**HMC625LP5E**
	0.07 - 4.0	6-Bit Digital, Serial & Parallel Control	-19.5 to +12	4	39	21.5	+5V @ 150mA	**HMC742LP5E**
NEW!	0.5 - 4.0	6-Bit Digital, Serial & Parallel Control	-19 to +12.5	4	39	21.5	+5V @ 150mA	**HMC742HFLP5E**
	0.7 - 1.2	6-Bit Digital, Serial & Parallel Control	-2.9 to +29	0.8	38	21	+5V @ 236mA	**HMC707LP5E**
	1.7 - 2.2	6-Bit Digital, Serial & Parallel Control	-2.9 to +29	1.0	37	21	+5V @ 252mA	**HMC708LP5E**
	DC - 4	Dual 6-Bit Digital, Serial Control	-45 to +18	6	33	18	+5V @ 82mA	**HMC743LP6CE**

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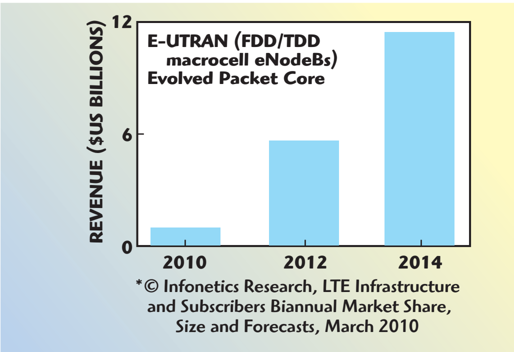
LINEARITY LOOMS LARGE FOR NEXT GENERATION RF SYSTEMS

The emergence of Long Term Evolution (LTE) as the next generation mobile wireless standard beyond 3G renews the importance of broadband, highly linear RF systems and components. The deployment of LTE in the 700 MHz spectrum in the United States only increases an already crowded spectrum, raising the bar even higher for systems engineers to ensure that co-existence and co-location requirements are met, adjacent channel bands are not corrupted and the signal bands of interest have sufficient dynamic range.



▲ *Fig. 1 Worldwide LTE infrastructure revenue forecast.*

The gradual transition from lower data rate 3G to 4G is highlighted by the TD-LTE rollout expected in China in 2012. Infonetics Research predicts that the LTE infrastructure market will exceed $11 B in 2014 (see ***Figure 1***).[1] The demand for faster, more efficient devices is driving this steep growth curve in LTE as consumers want to access more data on-demand from their laptops, smartphones, tablets and other portable devices.

LTE extends the performance of 3G to much higher data rates by using two different access schemes. Single-carrier frequency-division multiple access (SC-FDMA) is used on the uplink (base station receive, mobile station transmit) and orthogonal frequency-division multiple access (OFDMA) is used on the downlink (base station transmit, mobile station receive). In addition, data throughput is increased by the use of Multiple Input, Multiple Output (MIMO) technology.

From a linearity standpoint, the implementation of LTE poses several challenges in the

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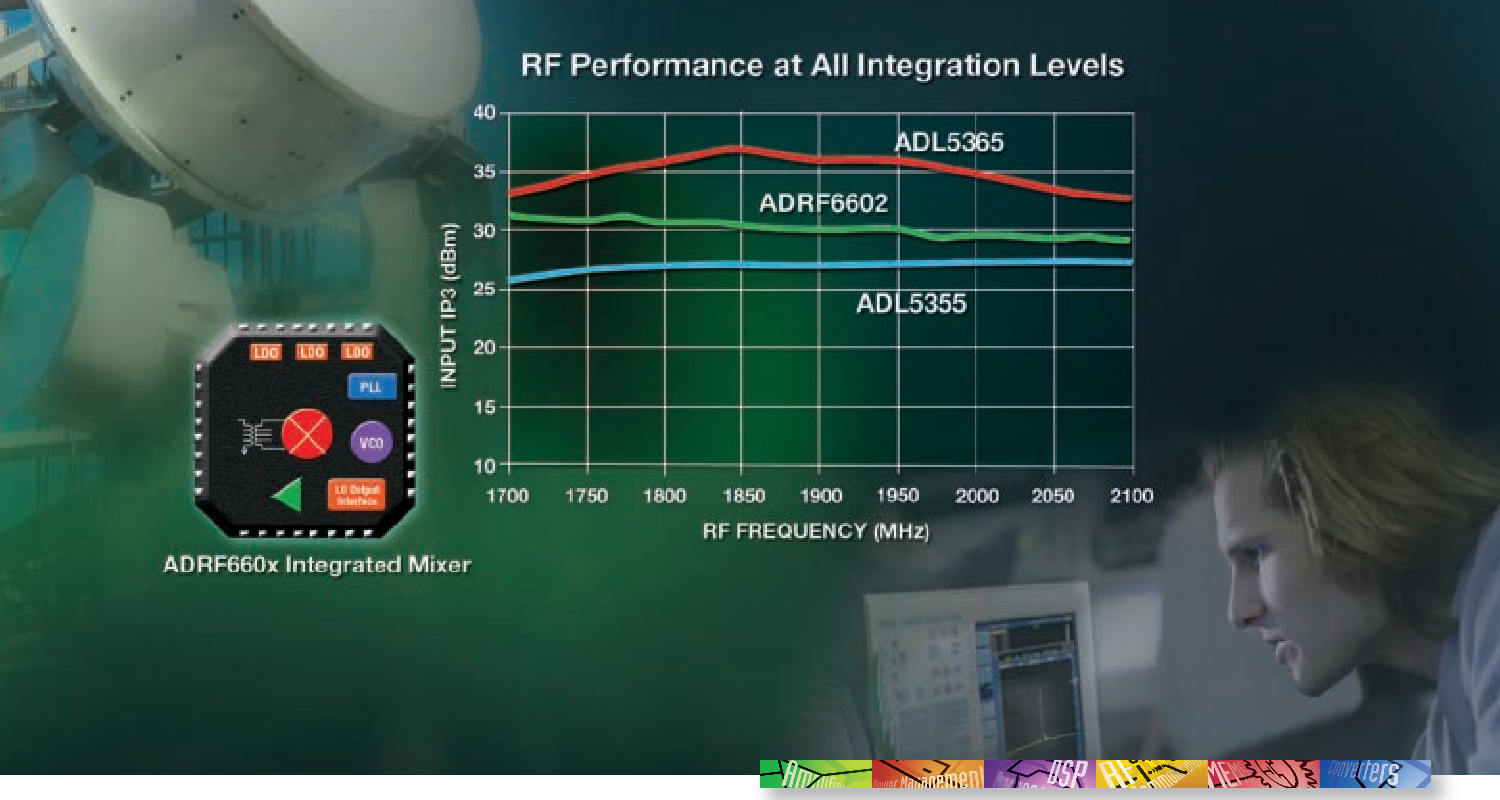

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system design. The use of an adaptive modulation scheme that varies from QPSK to 64 QAM necessitates reducing the amplitude and phase distortion of the modulated RF signal. The transmitter is required to meet specific spurious emissions requirements and minimize adjacent channel leakage. On the flip side, the receiver has to account for a worst-case sensitivity degradation from the mixing of an out-of-band interferer with its own transmit signal or a transmit signal from a separate antenna. Coupled with the use of closely spaced (15 kHz wide) orthogonal subcarriers and the limited transmit band to receive band spacing, LTE raises the complexity of the overall system linearity requirements.

For most components such as switches and digital step attenuators used in mobile wireless and wireless infrastructure systems, the out-of-band distortion products are quantified in terms of Harmonic Distortion (HD) and Intermodulation Distortion (IMD). To better analyze the impact of IMD with respect to the modulated RF carrier, second- and third-order distortion terms IMD2 and IMD3 are specified as second- and third-order intercept points IP2 and IP3. In addition, Cross Modulation Distortion (CMD) is a critical in-band consideration when multiple transmitters and receivers co-exist in the same geographic area.

Examining one scenario in LTE, the second harmonic of the 'C' Block (777 to 787 MHz) uplink signal will fall into the GPS 'L1' band of 1575.2 MHz, making HD2 an important consideration. In another scenario in W-CDMA, the operating band I (1950 MHz) uplink signal will intermodulate with a GSM1800 out-of-band interferer at 1760 MHz, causing a de-sense of its own receiver.[2] In this case the component IIP3 would be the critical specification.

Designing highly efficient, highly linear systems has always been a challenge. Even with current 3G networks, the systems used in the back-end infrastructure typically use some form of linearization, be it analog pre-distortion or digital pre-distortion (DPD). For example, remote-radio heads, a cost-effective way to extend cell coverage without the addition of more base stations, often contain a multi-carrier power amplifier embedded in a DPD loop. The main goals of digital pre-distortion are to meet the stringent adjacent channel power ratio (ACPR) requirements by reducing odd order intermodulation distortion and to maximize power amplifier efficiency.

In wideband, multicarrier systems such as W-CDMA, there is also the concept of UTRAN sharing where two network operators actively share the same network infrastructure to reduce capital and operating expenses.[3] For the systems engineer, that can translate to a more complex receive front-end that has to meet the sensitivity requirements of two co-located receivers operating simultaneously within the same band.

Sorting through the standard specifications can be challenging enough besides having to select components that enable the designer to meet the stringent system requirements. In most cases, simply meeting the technical requirements may not be enough; it has to be done at a low cost and with as little power consumption as possible.

ULTRACMOS™ TECHNOLOGY ADDRESSES MARKET DEMANDS

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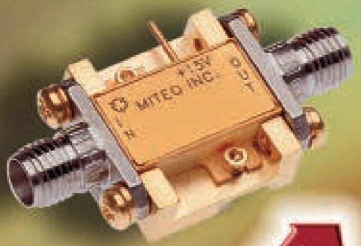
With the progression of mainly voice communication (2G networks) to data intense communication requiring different multiplexing and modu-



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OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	0.12-.25	38	0.50	0.9	2.0:1	2.0:1	+10	125
AFS3-00250050-08-10P-4	0.25-0.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-06-10P-6	0.5-1	38	0.75	0.6	2.0:1	1.5:1	+10	150
AFS3-01000200-05-10P-6	1-2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-06-10P-6	1.2-2.4	34	1.00	0.6	2.0:1	2.0:1	+10	150
AFS3-02000400-06-10P-4	2-4	32	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6-5.2	28	1.00	1.0	2.0:1	2.0:1	+10	125
AFS3-04000800-07-10P-4	4-8	32	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8-12	28	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8-16	28	1.00	1.5	2.0:1	2.0:1	+8	100
AFS4-12001800-18-10P-4	12-18	28	1.50	1.8	2.0:1	2.0:1	+10	125
AFS4-12002400-30-10P-4	12-24	24	2.00	3.0	2.0:1	2.0:1	+10	85
AFS3-18002650-30-8P-4	18-26.5	18	1.75	3.0	2.2:1	2.2:1	+8	125
MULTIOCTAVE BAND AMPLIFIERS								
AFS3-00300140-09-10P-4	0.3-1.4	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS2-00400350-12-10P-4	0.4-3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	0.5-2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-10-10P-4	1-4	30	1.50	1.0	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2-8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-24-10P-4	2-18	35	2.00	2.4	2.5:1	2.5:1	+10	175
AFS4-06001800-22-10P-4	6-18	25	2.00	2.2	2.0:1	2.0:1	+10	125
AFS4-08001800-22-10P-4	8-18	28	2.00	2.2	2.0:1	2.0:1	+10	125
ULTRA WIDEBAND AMPLIFIERS								
AFS3-00100100-09-10P-4	0.1-1	38	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-00100200-10-15P-4	0.1-2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS1-00040200-12-10P-4	0.04-2	15	1.50	1.2	2.0:1	2.0:1	+10	50
AFS3-00100300-12-10P-4	0.1-3	32	1.00	1.2	2.0:1	2.0:1	+10	125
AFS3-00100400-13-10P-4	0.1-4	30	1.00	1.3	2.0:1	2.0:1	+10	125
AFS3-00100600-13-10P-4	0.1-6	30	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	0.1-8	28	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	0.1-12	34	1.50	2.2	2.0:1	2.0:1	+10	150
AFS4-00101400-23-10P-4	0.1-14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-S-4	0.1-18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	0.1-20	20	2.50	3.0	2.5:1	2.5:1	+10	125
AFS4-00102650-42-8P-4	0.1-26.5	24	2.50	4.2	2.5:1	2.5:1	+8	135

Note: Noise figure increases below 500 MHz.

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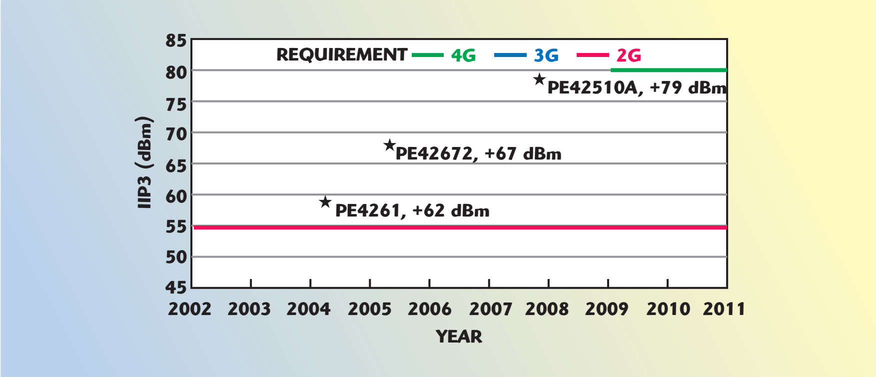

▲ *Fig. 2 Evolving IIP3 market requirements for handset antenna switches.*

lation schemes (3G and beyond), the market requirements for a high linearity RF front-end (RFFE) switch have evolved. For example, W-CDMA required a high linearity RFFE as some or all W-CDMA bands had to be routed through a specially designed multimode antenna switch. The antenna switch, typically connected directly to the antenna port without any filtering, had to be linear enough to cope with any unwanted interferes without degrading the receiver sensitivity.

Figure 2 shows the mobile handset antenna switch Input IP3 requirements as a function of time. For each technology transition, as the linearity requirements increased, an UltraCMOS switch solution was delivered to the market. One of the first devices to be released on the HaRP-enhanced UltraCMOS process was a SP7T switch for quad-band GSM and GSM/W-CDMA handset applications, featuring an IIP3 of +67 dBm.

As next generation mobile phones integrate LTE with quad-band W-CDMA (850, 900, 1900, 2100) and quad-band GSM (850, 900, 1800, 1900), the antenna switch linearity requirements will only get more demanding. To support the transition to LTE and LTE-Advanced, multi-throw switches requiring an IIP3 greater than +80 dBm will likely become a reality.

MEASUREMENT CHALLENGES

Besides designing and manufacturing such a switch, the challenge extends to validating the high linearity in the lab. An +80 dBm IIP3 translates to an extremely low IMD3 level, with the IIP3 expressed as the RF input power plus half the difference between the desired fundamental output and undesired IMD3 output. The distortion produced from the test system itself would have to be at least 18 dB below the IMD3 output in order to prevent the system from limiting the measurement.[4] That translates to a system IIP3 requirement of at least +89 dBm to accurately measure the true linearity of the switch.

Most engineers are familiar with the traditional two-tone test for measuring the intercept point, expressed as Input or Output IP3.[5] In this setup, two CW tones (f_1, f_2) typically of equal amplitude spaced at a specific frequency offset are combined and driven into a nonlinear device under test, producing IMD3 products at the frequency offset below and above the fundamental tones. The output is then driven directly into a spectrum analyzer for intercept point measurement using the f_1, f_2 and $2f_1 - f_2$ and $2f_2 - f_1$ frequencies. In fact, many spectrum analyzers even have a third-order intercept point "TOI" measurement built-in.

The reality is such a conventional technique will be limited by the system dynamic range. To measure the distortion of a highly linear component, the two test tones would need to have large amplitudes to raise the IMD tones out of the measurement noise floor. To process the large desired output signals, the spectrum analyzer requires its RF input attenuation to be optimized to function in the linear range of operation. Doing so, however, raises its noise floor, increasing the minimum signal level that can be measured. This dynamic range limitation leaves the user with balancing the system distortion and system noise floor even if the signals are individually measured in a narrow

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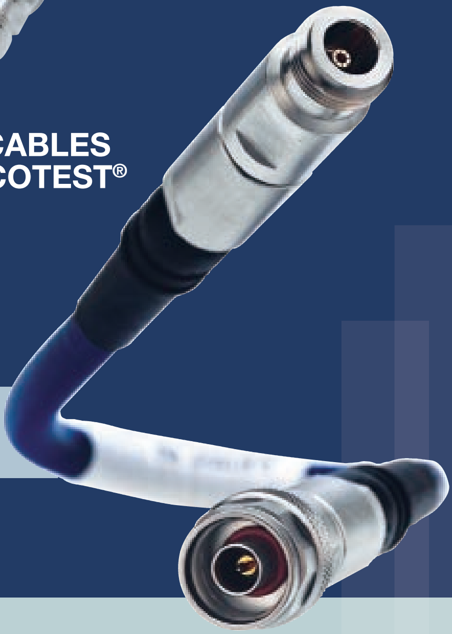

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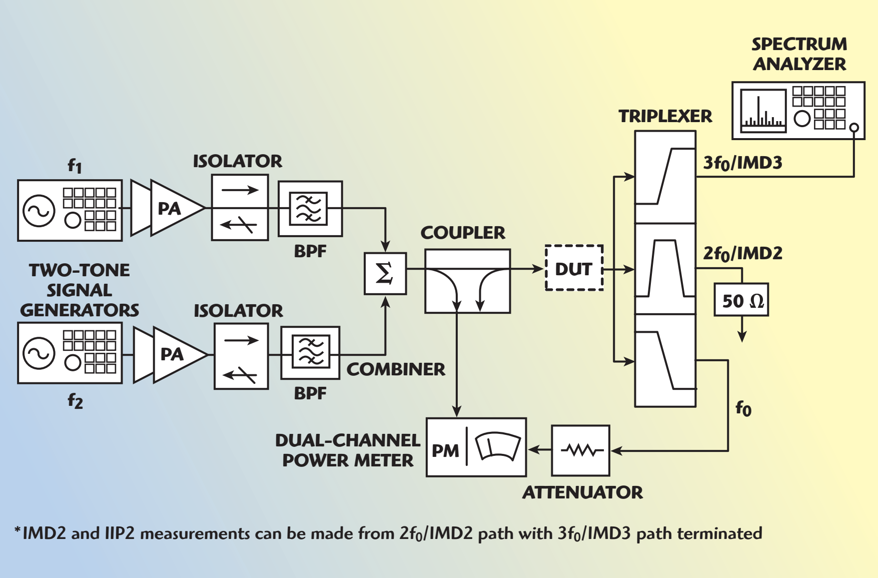
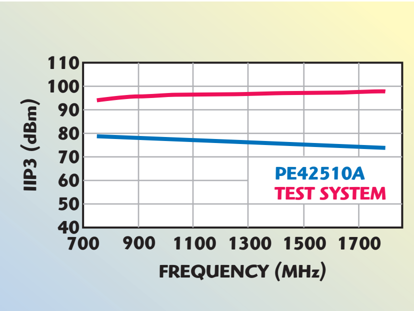


▲ *Fig. 3 Two-tone IIP3 measurement setup for sum IMD3 measurement.*



▲ *Fig. 4 UltraCMOS SPDT performance in the LTE band.*

span by optimizing the resolution and video bandwidth filter settings.

For example, with two tones at +18 dBm/tone, an +80 dBm IIP3 would place the IMD3 tones at -106 dBm, a dynamic range of 124 dB. Most high-performance spectrum analyzers today cannot meet this requirement, system limiting at 110 dB levels for third-order intercept measurement.[4] If the requirement to keep the measurement uncertainly to less than 1 dB is applied, then the dynamic range is closer to 100 dB levels.

OVERCOMING SYSTEM LIMITATIONS

An approach to work around this limitation is to measure the distortion at the sum frequencies rather than the difference frequencies. Since the distortion products at the sum frequencies are mathematically equivalent to the distortion products at the difference frequencies, the test system can focus on capturing the desired and undesired outputs separately and is no longer required to simultaneously process both sets of signals.

The sum IMD3 products occur at $2f_1 + f_2$ and $2f_2 + f_1$ frequencies and can be captured using a diplexer or triplexer at the DUT output, with each path capturing a specific frequency band. As shown in ***Figure 3***, a dual-channel power meter is used to accurately measure the fundamental input and output power levels, with the spectrum analyzer measuring the sum IMD3 tones. All tones (fundamentals and distortion) are terminated to 50 Ω thru filters and attenuators, eliminating any sensitivity to phase angles. In addition, all setup losses and DUT losses at the sum IMD3 frequencies are included in the final IIP3 calculations.

A new SPDT switch was measured in this setup with tones at +18 dBm/tone. It features a 50 W P1dB compression point and an insertion loss of < 0.4 dB below 1 GHz. As shown in ***Figure 4***, it measures an IIP3 close to +80 dBm in the LTE band. Competing SOI and GaAs technologies have struggled to demonstrate this level of broadband linearity at these power levels. With GaAs technology, while the linearity may be acceptable for lower power levels, the distortion increases at high power due to the gate voltage being modulated.[6] Finding a multi-throw antenna switch that can meet the high linearity, insertion loss

and isolation requirements of an integrated LTE RFFE can be extremely challenging.

As the next generation RF systems continue to develop, one thing is for sure—high linearity will always be a premium. The co-existence of multiple bands and the sharing of existing network infrastructure to alleviate CapEx and OpEx costs will only increase the challenges for RF system designers. Coupled with the need for high linearity components arises the dilemma of how to accurately measure their performance as conventional techniques fall short. ■

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BATTLING PHASE NOISE AT RF AND MICROWAVE FREQUENCIES

Over the past 20 years, RF and microwave signal generators have grown in capability and complexity in order to keep pace with the swift advances of vector modulated communications and advanced radar systems. One of the most critical performance parameters for these applications is phase noise.

Purchasing an off-the-shelf signal generator for an application that demands low phase noise can be costly. Low phase noise is often the most expensive performance option available with a high-end signal generator. There are several steps that can be used to improve and optimize the phase noise performance of a signal generator, provided it allows access to the reference hardware, voltage-controlled oscillators (VCO) and phase lock loops (PLL) that make up the synthesizer chain. Before these steps are explored, it will be helpful to have a quick look at how the phase noise is specified.

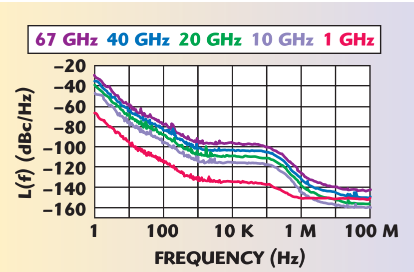

Fig. 1 Absolute SSB phase noise at various carrier frequencies.

Phase noise is random fluctuations in the phase of a signal, contributed by the various components and circuits within a generator, which disperses the output power to the surrounding frequencies. Ideally, the power of a synthesized continuous wave (CW) signal is all located at a single frequency. This can be modeled as random phase modulation. The units of phase noise (referred to as L(f)) are measured in dBc/Hz or dB down from the measured carrier power in a 1 Hz bandwidth for frequency offsets from the CW output. For example, the phase noise of a generator may be specified as -97 dBc/Hz at 100 kHz offset from a CW frequency at 20 GHz. The phase noise is generally plotted on a log-log chart to easily examine both the close-in phase noise (offsets < 1 kHz) and the far-out phase noise (offsets > 10 kHz). See ***Figure 1*** as an example.

SOURCES OF PHASE NOISE WITHIN A SIGNAL GENERATOR

There are four main contributors to phase noise in a signal generator: The frequency reference, the synthesizer (phase detectors and PLLs), the oscillator and the broadband noise floor. ***Figure 2*** indicates which section of the signal generator hardware dominates the different portions of the phase noise characteristics.

At frequency offsets below approximately 1 kHz, the stability and phase noise are determined by a reference section that is usually

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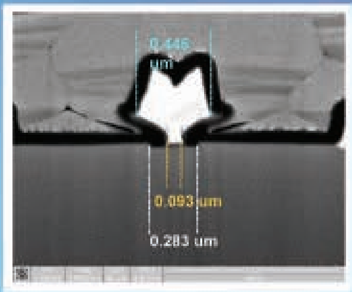

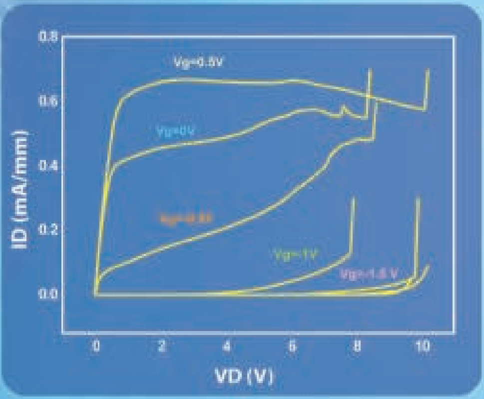

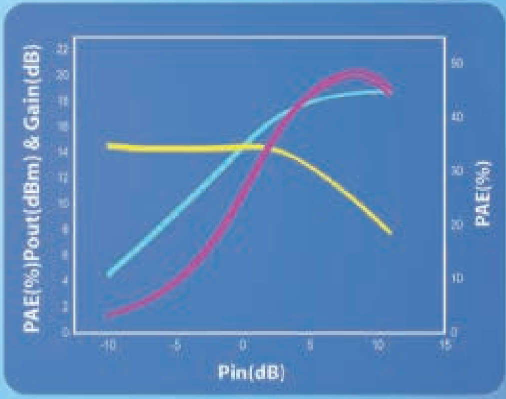

Comparison of WIN's millimeter wave pHEMT technologies

	PP-15	PL-15	MP-15	PP-10
Vto (V)	-1.2	-0.7	-0.8	-0.9
Idss (mA/mm)	500	260	400	460
Idmax (mA/mm)	650	500	600	660
GM (mS/mm)	495	550	700	700
VGD (V)	10	9	12	10.5
fT (GHz)	85	95	105	128
Fmax (GHz)	180	160	180	180
P1dB (mW/mm)	670 (5V)	242 (3V)	--	380 (3.5V)
Psat (mW/mm)	820 (5V)	312 (3V)	--	500 (3.5V)
Gain (dB)	11	12.6	--	14.6
PAE (%)	50	39	--	47

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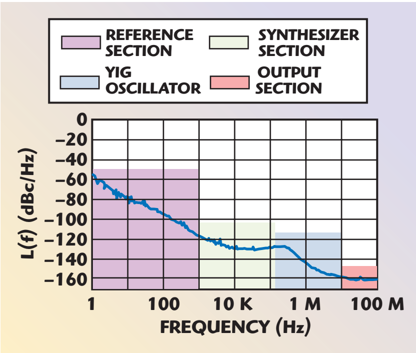
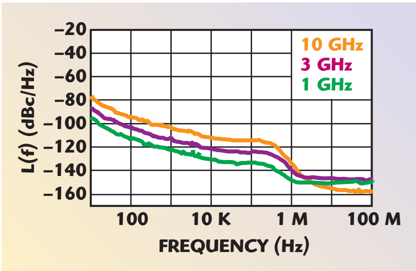
driven by an initial 10 MHz signal. The 10 MHz frequency reference can be generated internally or supplied externally. The frequency reference section multiplies the fall-off initially as $1/f^3$ and transitions to a $1/f^2$ dependence, which on a log-log plot represents a slope of 20 dB per decade.

Generally, low phase noise signal generators use an yttrium iron garnet (YIG)-based oscillator, which has better performance than typical VCOs. The phase noise of YIG oscillators falls off more quickly for far from carrier offsets above 100 kHz. They exhibit a wide tuning range, meaning there is less multiplying of the signal required to achieve the desired frequency, leading to lower phase noise, particularly at higher frequencies. The bandwidth of the PLL determines the point at which the YIG oscillator contribution to the overall phase noise becomes suppressed. For frequency offsets inside the PLL bandwidth, the overall phase noise of the generator is dependent upon contributions from the phase detector and the reference oscillator.



▲ *Fig. 2 Source of phase noise within a signal generator for different offsets.*



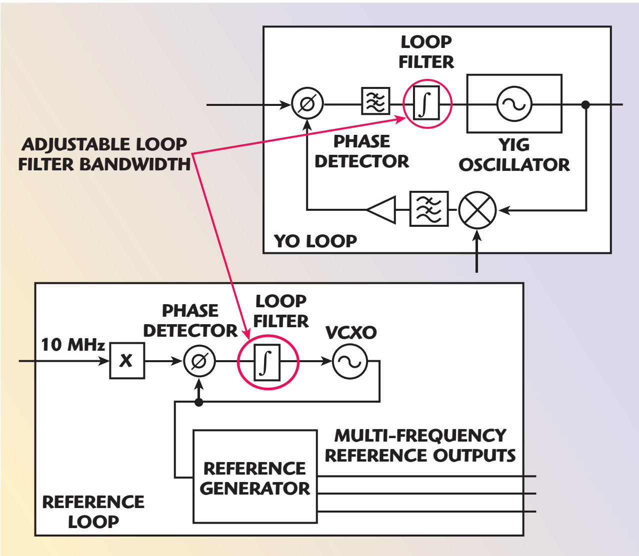
▲ *Fig. 3 Residual phase noise of a signal generator.*

The broadband noise floor results primarily from the thermal noise present in the generator; most of this is contributed by the power amplifier in the output section. Generally, the phase noise at offsets greater than 10 MHz is limited by this noise floor. This far from carrier noise most affects wideband communication systems, particularly those using orthogonal frequency division multiplexing (OFDM). The closely spaced multiple carriers can begin to interfere with one another, if the phase noise at offsets that approach the carrier spacing is too high.

SUPPRESSING PHASE NOISE INSIDE THE SIGNAL GENERATOR

Test equipment manufacturers are always looking to make advances in signal generator architecture that will suppress phase noise to new lows. One of the most basic ways to improve phase noise, particularly close-in, is to install a lower noise 10 MHz reference. These are normally oven controlled crystal oscillators (OCXO) that are stabilized with respect to temperature. Research laboratories are constantly looking to improve reference technology and these advances have quickly made their way into signal generator products available today.

New and innovative designs are emerging to suppress phase noise to new levels in the areas of the phase noise plot dominated by the synthesizer section and the YIG oscillator. These advanced architectural improvements to the reference and synthesizer design include well devised frequency plans to minimize spurious signals, multiple loop design for enhanced stability and the ability to drive the loops harder, enabling a higher signal-to-noise as the signal traverses the synthesizer chain.



▲ *Fig. 4 Adjusting the PLL integrator/filter bandwidth of the reference and YIG oscillator loops within the signal generator.*

TAKING ADVANTAGE OF LOW RESIDUAL PHASE NOISE

The residual phase noise represents the phase noise of a signal generator, not including the reference section. The plots in ***Figure 3*** show the residual phase noise levels of the same signal generator as the absolute phase noise plots in Figure 1. The absolute phase noise in the plot indicates the typical and total phase noise of the signal generator from one end of the block diagram to the other. How can this low residual phase noise be used to our advantage?

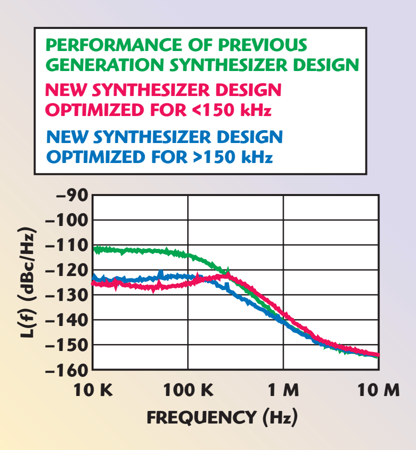
Most signal generators provide a port to supply an external 10 MHz reference. This way, using a very clean reference can help reduce close to carrier phase noise, although it will remain far above the residual levels. The reference section of a signal generator consists of much more than the 10 MHz reference. It includes a phase detector and PLL as well as multipliers to supply multiple frequencies in a range usable by the rest of the synthesizer chain (see ***Figure 4***). In order to bypass the reference, a higher frequency reference must be supplied externally.

A higher frequency external reference can be used to drive the phase noise of the signal generator down toward residual levels. The signal generator would have to allow for access to the reference path past the reference section and the external high frequency reference source used would have to have lower intrinsic phase noise than the signal generator's internal reference. Many high performance signal generators have internal references that already provide excellent phase noise characteristics. The new reference would have to exhibit exceptional phase noise performance.

OPTIMIZING PHASE NOISE PERFORMANCE FOR YOUR APPLICATION

The loop bandwidth of the PLLs within a signal generator refers to the bandwidth of the integrating filter that follows the phase detector (see Figure 4). There are multiple PLLs within the reference and synthesizer paths, each of which affects the phase noise in its own way. In most signal generators, these bandwidths are fixed at a point considered optimal for most use cases. The loop bandwidth of the reference oscillator and the YIG oscillator (YO) PLLs may be used to optimize the phase noise in certain areas of offset from the carrier. This requires that the signal generator provide adjustment of the bandwidth.

Adjustment of the reference loop bandwidth is generally enabled in fixed steps for either an internal or external frequency reference, usu-



▲ *Fig. 5 Optimizing the YIG oscillator loop bandwidth.*

ally ranging from 25 to 650 Hz. This adjustment affects the slope of the phase noise curve up to an offset of approximately 2 kHz. The higher the reference loop bandwidth, the lower the phase noise at very low offsets, less than approximately 200 Hz. For a lower reference loop bandwidth, there is a small reduction of the phase noise in the offset range from approximately 200 Hz to 2 kHz. Optimizing for one offset range is at the expense of the other.

New synthesizer designs enable access to the YO loop bandwidth in addition to the reference loop, where previous designs did not. Adjustment of the YO loop bandwidth affects an entirely different part of the phase noise plot. With this adjustment, the phase noise at offsets from approximately 1 kHz to 1 MHz is affected. Setting the YO loop bandwidth to a wide range of approximately 240 kHz optimizes the phase noise at offsets greater than 150 kHz. Setting the YO loop bandwidth to a narrow range of approximately 130 kHz optimizes phase noise for offsets below 150 kHz (see ***Figure 5***).

USE OF DIVIDERS AT LOWER FREQUENCIES, INSTEAD OF HETERODYNE MIXING

Signal generators often use dividers to provide their coarse frequency adjustment. When a carrier signal is routed through a frequency divider, the carrier frequency is reduced by the divide number (n):

$$F_{out} = F_{in}/n \qquad (1)$$

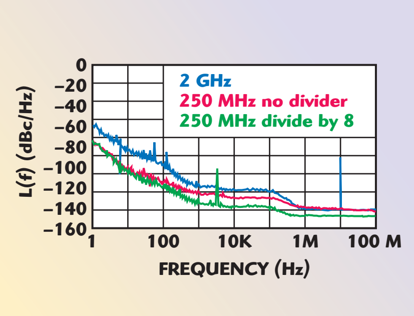
where F_{in} is the input frequency and n is the divide number.

In the case of a divider where n = 2, the output frequency is one half of the input frequency.

In addition to the reduction in the carrier frequency, the carrier phase noise is reduced by a 20log(n) factor:

$$L(f)_{out} = L(f)_{in} - 20\log(n) \quad (2)$$

For the example of a divide-by-two divider, the output frequency's phase noise will be 6 dB lower (20 log 2) than the phase noise of the input frequency, as indicated by the phase noise plots shown in Figure 1. When using frequency or phase modulation (FM or PM) in a signal generator, dividing a carrier frequency will reduce the FM deviation and the PM deviation by a factor of 1/n. At lower carrier frequencies, the modulation deviation can become too small to be useful. Many signal generators switch to a heterodyne mixing scheme instead of dividing at lower frequencies in order to preserve modulation bandwidth. Note that heterodyne mixing to lower frequencies does not provide phase noise reduction. In ***Figure 6***, the phase noise of a 250 MHz signal is shown both divided down from a 2 GHz signal and mixed down.



▲ *Fig. 6 Phase noise advantage of using dividers.*

Frequency dividers can be used externally and some signal generators have integrated dividers. When enabled, the generator uses a dividing technique to output signals at low frequencies. This results in improved phase noise at all offsets for these frequencies. The dividers can be disabled, returning the signal generator to a standard mode of creating low frequencies with a heterodyning technique. This mode provides wider deviation bandwidth for FM and PM signals.

CONCLUSION

Test and characterization of RF and microwave components and systems, particularly receivers, generally requires the presence of a clean test stimulus. Classic test engineering methodologies dictate that the signal stimulus must have performance fidelity of at least an order of magnitude better than the device or system being characterized. Otherwise the risk is run of contaminating the results with the anomalies of the stimulus source. Some of the steps that can be taken to ensure the best possible performance from a signal generator have been discussed. More information on measurement science and test instrumentation can be found on manufacturer's websites such as Agilent. ■

FULLY AUTOMATED PHASE NOISE MEASUREMENT SYSTEMS

Holzworth Instrumentation has an excellent reputation for its versatile product offering of phase coherent, ultra low phase noise RF synthesizers. What many engineers do not realize is that the RF synthesizer products have been a fundamental building block to Holzworth's premier line of products. Customers are pleasantly surprised to learn that Holzworth Instrumentation was originally founded to create the industry's most innovative phase noise analysis products.

Holzworth engineering designs every product from the ground up, right down to each subsystem allowing for full control of the most necessary performance variables. Review of a Holzworth product specification reveals that the design did not originate from a textbook architecture. The key to Holzworth's success in a market saturated with mature competition is to provide highly reliable, innovative products that offer unique performance advantages.

PRODUCT INCEPTION

For decades, phase noise has been a performance parameter that is often avoided (even ignored), being written off as something that "only radar companies need to worry about." The primary concerns with making phase noise measurements include: test complexity, capital costs and support costs. When considering incorporation of phase noise test into a manufacturing test line, "throughput" is added to the top of the list of concerns.

From initial inception to date, Holzworth has been working with phase noise test engineers throughout many industry sectors. Beyond accuracy, reliability, etc., market research consistently revealed three things: First, can you make it extremely easy to operate? Second, can you improve the measurement speed while hitting ultra low noise floors? Third, can you price it so that one can justify a purchase for multiple test lines? The HA7400 series specifically addresses these three needs with some additional benefits. Product highlights include:

- 0.1 Hz to 1 MHz, adjustable offset
- -180 dBc/Hz$^{1/2}$ in 20 sec (1 Hz to 1 MHz)
- Auto-calibration, self-test
- Integrated frequency counter
- Integrated power meter
- Low noise DUT power supplies

CORE DESIGN

At the core is a fast, spur-free, cross correlation engine. There are many phase noise analysis solutions available today that provide single channel analysis. Some are better than others. Someone who understands the intricacies of the measurement could even use a high end audio card to setup a valid measurement system, but with a limited floor and frequency offsets.

The need for lower measurement floors is driven by DUTs that exhibit very low phase noise characteristics. It is not good enough to have a measurement system with a noise floor that is close to that of the DUT as there are tolerances and variables that contribute to the measurement, resulting in incorrect data. Spur-free cross correlation provides a measurement floor that is lower than that of the DUT, resulting in accurate measurements without question-

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able artifacts. As outlined in ***Table 1***, the HA7400 series are speedy cross correlators. More details on the advantages of cross correlation analysis can be referenced in the Holzworth authored article: "Cross Correlation in Phase Noise Analysis," *Microwave Journal*, February 2011.

INTUITIVE INTERFACE

One of the most fundamental elements of Holzworth analyzers is a software interface (see ***Figure 1***) that is so intuitive that a user with zero knowledge of phase noise test can be taking valid data after 15 minutes of instruction. There is no need to have a phase noise expert on staff to constantly support the test process.

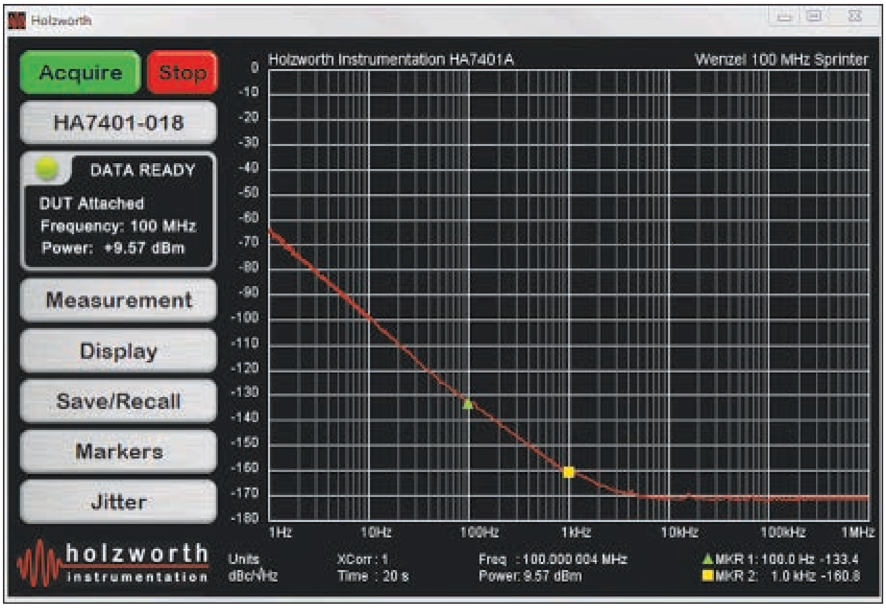
The interface for the HA7400 series is a quantum leap in the industry in terms of ease of use. Embedded diagnostic hardware provides the information the software needs to auto-detect, lock, calibrate, acquire data and even warn if the data is "out of character" or if more correlations are required. Interface highlights include drag and drop markers, user defined test limit, overlay ASCII data from other instruments and a touch screen compatible GUI.

Often, a proprietary PC and/or integrated front panel is the failure mechanism to a test system. Holzworth analyzers are virtual instruments that can be controlled by any standard PC (driver free) to further eliminate potential technical issues.

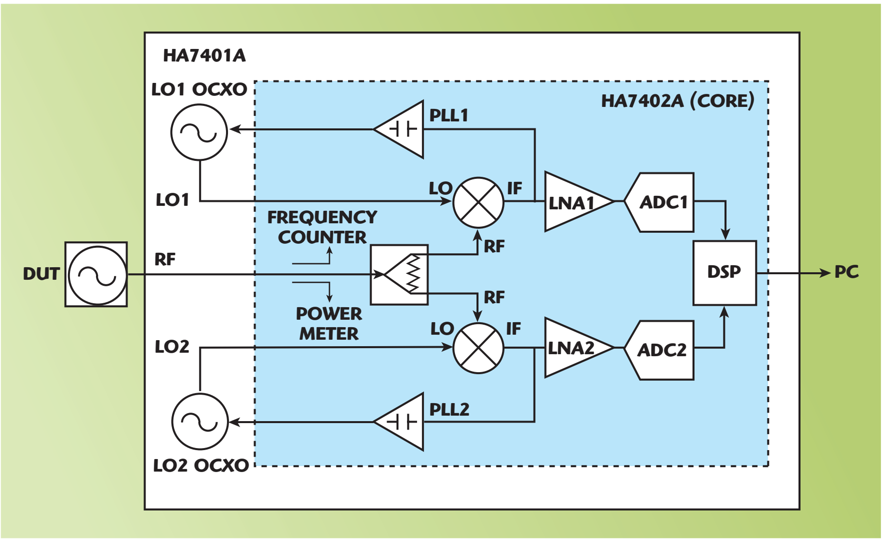
APPLICATION DRIVEN DESIGNS

Many phase noise analyzers available today are loaded with internal hardware settings that are well beyond phase noise (and jitter) test. Added functionality makes for a higher level of system complexity, slower acquisition times, potential system instabilities and a greater price tag. Holzworth currently offers three phase noise analyzer products within the HA7400 series that are individually priced at under $25,000 US. Each model targets dedicated phase noise measurements.

FIXED CRYSTAL MEASUREMENTS (Model HA7401A): Crystal references are the thread that tie all instruments together and often set the frequency accuracy and the phase noise of an entire system. It is also one of the more difficult measurements because of the extreme low noise



▲ *Fig. 1 The HA7400 series are speedy cross correlators.*



▲ *Fig. 2 HA7401A/HA7402A absolute measurements.*

that many oscillator designs exhibit. ***Figure 2*** contains a block diagram of the HA7401A fixed frequency analyzer for making absolute phase noise measurements at fixed frequencies. 10 MHz, 100 MHz and other common frequencies are available.

ABSOLUTE MEASUREMENTS (Model HA7402A): For those applications (crystals, DROs, synthesizers, etc.) where variable test frequencies are necessary, the HA7402A is a more versatile solution. The HA7402A allows for two LO input ports instead of having a factory set fixed frequency (refer to the "CORE" outlined in Figure 2). The user sets the test frequency by supplying two identical, non-coherent source signals for making DUT measurements between 10 MHz to

TABLE I

HOLZWORTH DATA ACQUISITION TIME

Frequency Offset Range	*Acquisition Time (sec)*
0.1 Hz to 1 MHz	114
1 Hz to 1 MHz	18.7
10 Hz to 1 MHz	5.3
100 Hz to 1 MHz	2.2
1 kHz to 1 MHz	1.4
10 kHz to 1 MHz	1.0

1.2 GHz. Measurements to 18 GHz will be available by June 2011.

RESIDUAL (ADDITIVE) MEASUREMENTS (Model HA7403A): Residual phase noise measurements are of a completely separate classifica-

High power, small footprint broadband power amplifiers

BROADBAND POWER AMPLIFIERS

MODEL NUMBER	FREQUENCY (GHZ)	GAIN (DB)	POWER (DBM)	OIP3 (DBM)	NF (DB)	SUPPLY/CURRENT V/MA
PA020180-3922	2.0 - 18	38	Psat > 39	48	-	+28 / 1200
PA020180-3025	2.0 - 18	30	P1dB> 30	40	9	+12 / 2000
PA002005-21	0.2 - 0.5	20	P1dB> 21	35	1.1	+5 / 100
PA001002-22	0.1 – 0.2	19	P1dB> 23	37	1.5	+5 / 100
PA001040-27	0.1 – 4.0	25	P1dB> 27	40	5	+10 / 290

2 to 18 GHz 8W power amplifiers
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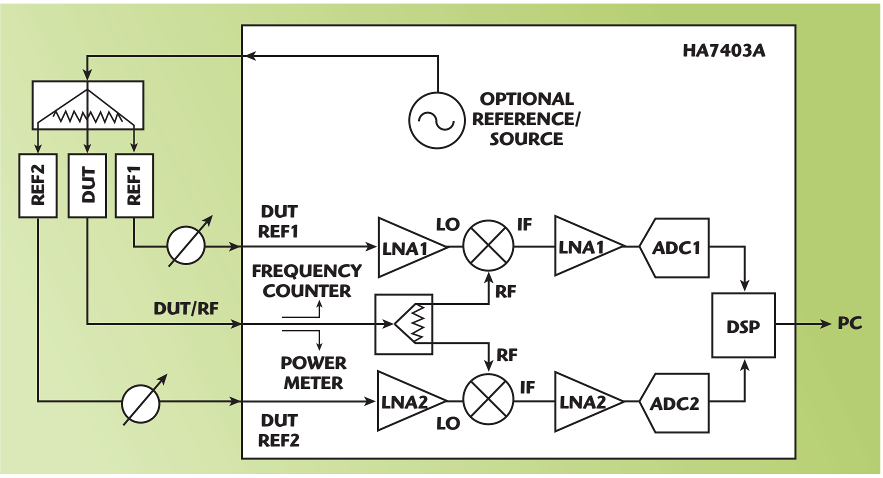
tion. Low noise amplifiers, frequency dividers, frequency multipliers, etc., can all be measured with the self calibrating, HA7403A residual phase noise analyzer. ***Figure 3*** contains a basic block diagram of the residual analyzer.

RELIABLE

Cooling fans and ground loops are typical culprits of performance issues amongst traditional test systems. Holzworth analyzers utilize a fan-less chassis that offers significant advantages in terms of noise floor and spurs. A centralized heat sink is used to efficiently dissipate internal heat, while doubling as a common ground to completely eliminate ground loops. The 20 lb (9 kg) chassis is fully sealed, rugged and uniquely portable for field applications, providing consistent results from location to location without the worry of recalibration support or repair.

Time is money. If the need for support were to arise, the HA7400 series GUI maintains a detailed system log file that can be used for remote diagnostics. The user simply exports the file and e-mails it to the factory.



▲ *Fig. 3 HA7403A residual (additive) measurements.*

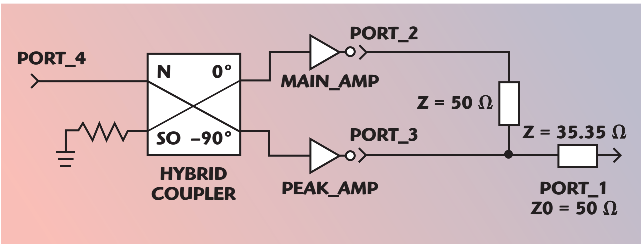
Real time trouble shooting eliminates questions relative to the analyzer so that the user can be up and running as quickly as possible.

Engineers are becoming more and more aware of how the effects of poor phase noise performance can ripple through an entire system. The result is an increasing trend for mandatory phase noise test being specified at the subsystem and component levels. Holzworth's expanding line of fast, cost-effective phase noise analyzers provides an excellent fit for dedicated manufacturing phase noise test with the added benefit of having the accuracy necessary for product development.

Holzworth Instrumentation, Boulder, CO (303) 325-3473, www.holzworth.com.

XINGER®-III DOHERTY COMBINER OFFERS ADVANTAGES OVER A PCB COMBINER

First introduced in the late 1930s by a Bell Telephone Laboratories electrical communications engineer named W.H. Doherty and deployed in numerous broadcast radio station transmitters for years thereafter, the Doherty amplifier has been widely adopted in recent years by wireless infrastructure manufacturers seeking to squeeze every dB, W and penny out of today's base station equipment. The attractiveness of the Doherty design is largely due to its inherent efficiency in managing input signals with a high peak-to-average ratio (PAR), which are typical of today's systems (e.g. W-CDMA, CDMA2000, and emerging systems structures like WiMAX and LTE).



▲ *Fig. 1 Typical Doherty amplifier configuration.*

A typical implementation of a Doherty amplifier is shown in ***Figure 1***, wherein a "main" amplifier runs at all times and a "peak" amplifier switches on only when a certain power threshold is needed. When the main and peak amplifiers (both matched to 50 ohm) are turned on and delivering maximum output power, the combining circuit functions as a 1:1 combiner.

When peak amp is off and presents high output impedance, the main amp port sees 100 ohms and the combining circuit functions as a 2:1 impedance transformer. This unique combiner is called a Doherty combiner, and it is today typically printed on premium-quality printed circuit board (PCB) that is 20 or even 30 mils thick in order to minimize insertion loss.

Unfortunately, some of the performance and efficiency gains achieved in the overall Doherty amplifier execution are lost in the PCB-based combiner, unless a thicker, higher-end board is used and there is ample real estate available. One new approach to recapturing real estate

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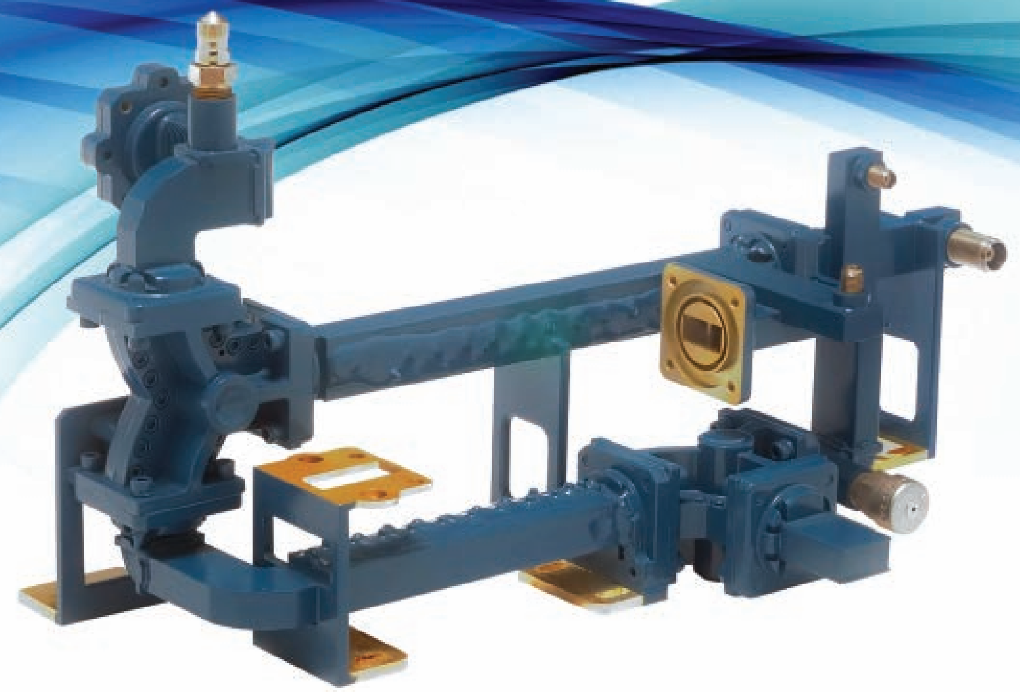

Typical Specifications

Frequency.............16.0 - 17.0 GHz

Waveguide............WR62

Transmit VSWR ....1.50 Max.

Transmit Loss ....1.0 DB Max.

Receive VSWR ......1.50 Max.

Receive Loss ....1.0 DB Max.

Power (CW).........150W

Power (Peak) 300W

Pressure................15 PSIG

Material ....Aluminium/Iridite

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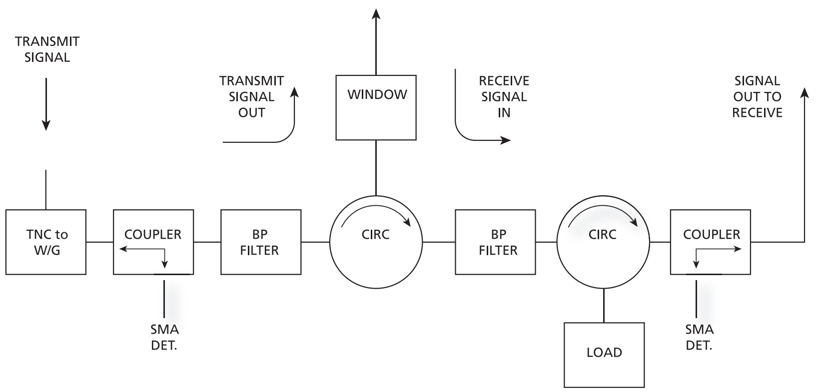
Precision manufacturing has made MDL the industry leader in passive waveguide components and subassemblies. And we have remained the leader for 50 years because of our attention to detail and our single source capabilities. Our engineers use the latest in SolidWorks, Ansoft HFSS and our proprietary software to design to your specifications – precisely. Call an MDL specialist today or visit us online at **mdllab.com**.



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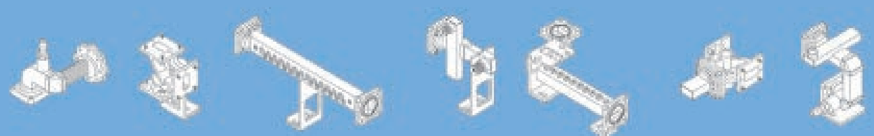

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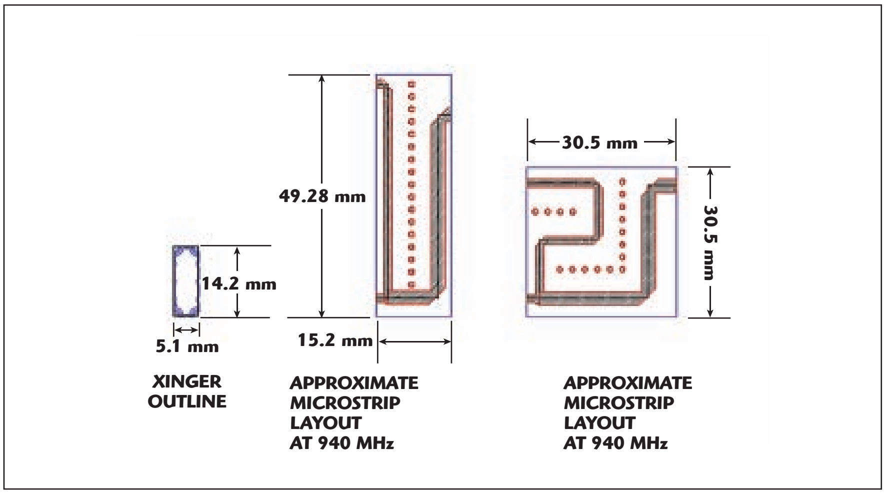
TABLE I

ANAREN'S DOHERTY COMBINER PRODUCTS

Part Number	Size (mm)	Size (in)	Frequency (MHz)	Power (W)	Ins. Loss (dB)	Return Loss (dB)	Phase Balance (degrees)
X3DC07E2S	14.2 × 5.1	0.56 × 0.20	728-768	200	0.15	21	90 ± 3.0
X3DC08E2S	14.2 × 5.1	0.56 × 0.20	869-894	200	0.15	21	90 ± 3.0
X3DC09E2S	14.2 × 5.1	0.56 × 0.20	925-960	200	0.15	21	90 ± 3.0
X3DC18E2S	14.2 × 5.1	0.56 × 0.20	1805-1880	200	0.15	21	90 ± 3.0
X3DC19E2S	14.2 × 5.1	0.56 × 0.20	1930-1990	200	0.15	21	90 ± 3.0
X3DC21E2S	14.2 × 5.1	0.56 × 0.20	2110-2170	200	0.15	21	90 ± 3.0
X3DC19P1S	6.35 × 5.08	0.20 × 0.25	1700-2000	50	0.2	22	89 ± 4.0
			1805-1880	50	0.17	25	88 ± 4.0
			1930-1990	50	0.2	25	94 ± 4.0
			1880-1920	50	0.17	25	90 ± 4.0



▲ *Fig. 2 Size comparison of Xinger and typical microstrip layouts at 940 MHz.*

or performance lost via PCB-based Doherty combiners is a new line of Xinger®-III brand Doherty combiners from Anaren (currently nine part numbers covering bands from 728 up to 2170 MHz; see ***Table 1***).

Like all 'Xingers,' this new combiner is a standardized, softboard SMT component that offers a range of both physical and performance advantages for infrastructure OEMs seeking continuous improvement of transmitter performance and cost management.

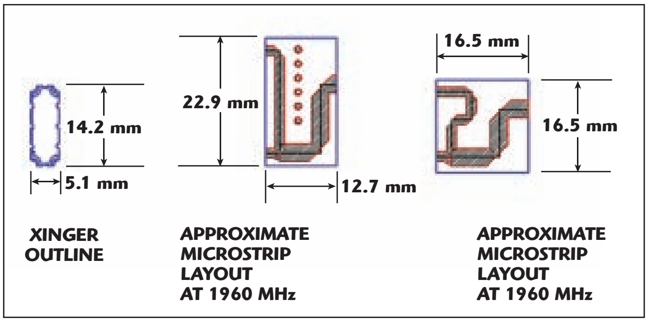
SMT COMBINERS SAVE SPACE AND IMPROVE MANUFACTURING RELIABILITY

The most self-evident benefit of the Xinger Doherty combiner is its compact packaging. Currently available in a P-size footprint (6.35 × 5.08 mm) and an E-size footprint (14.2 × 5.1 mm), these new components are approximately 1/10th the size of their equivalent PCB-based printed combiner layouts. ***Figure 2*** shows the E-size Xinger combiner relative to a best-case 940 MHz microstrip lay-

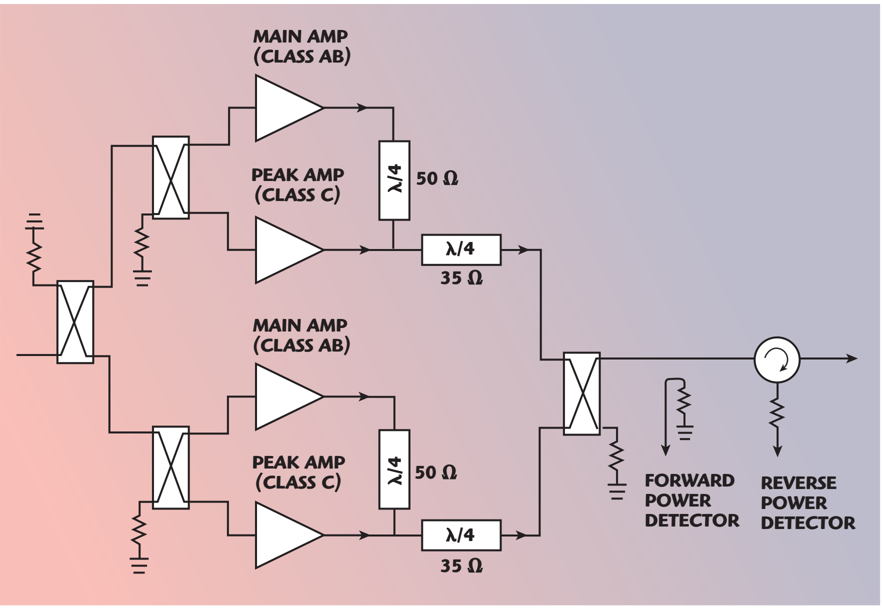
out for a printed Doherty on 30 mil RO4350 (measuring 49.28 × 15.2 mm or 30.5 mm square), while ***Figure 3*** shows the Xinger beside a best-case 1960 MHz printed Doherty on the same board (measuring 22.9 × 12.7 mm or a layout of 16.5 mm square).

For the design engineer, this reduction in size translates into added space for other functionalities, the potential use of smaller amplifiers, or cost savings associated with using a smaller PCB. The smaller, SMT-style Doherty combiner's footprint can also mean an opportunity to adopt a well-known approach in amplifier designs, a balanced Doherty amplifier that would otherwise not be possible due to the size of PCB-printed Doherty combiners (see ***Figure 4***). This configuration should help achieve better stability and gain flatness, as is typically seen with balanced amplifiers. In addition, as smaller transistors are used compared to a "single Doherty amplifier," the transistor impedance is higher and making the device easier to match, improving bandwidth and manufacturing.

Additionally, the Xinger Doherty combiner's standardized footprints



▲ *Fig. 3 Size comparison of Xinger and typical microstrip layouts at 1960 MHz.*



▲ *Fig. 4 Balanced dual-Doherty amplifier.*

TABLE II

COMPARISON OF XINGER DOHERTY COMBINER TO OTHER PCB DESIGNS

Fc	Xinger Doherty Combiner Ins. Loss	RO 4350 (30 mil) (Raw Copper) IL	RO4350 Ins. Loss (w. ENIG Plating)	FR4 (35 mil) (Raw Copper) IL	FR4 Ins. Loss (w. ENIG Plating)
940 MHz	0.12 dB (E-size)	0.10 dB	0.11 dB	0.176 dB	0.179 dB
1960 MHz	0.10 dB (E-size) 0.13 dB (P-size)	0.09 dB	0.10 dB	0.167 dB	0.169 dB
2145 MHz	0.10 dB (E-size)	0.09 dB	0.10 dB	0.166 dB	0.168 dB

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Model	Frequency Range	Type	Typical Phase Noise 10	100	1K	10K	100K	1M	Output Frequency	Output Power (dBm, Min.)
XTO-05	5-130 MHz	Ovenized Crystal	-95	-120	-140	-155	-160	-	100 MHz	11
PLD	30-130 MHz	P.L. Crystal	-95	-115	-140	-155	-155	-	100 MHz	13
PLD-1C	130-1000 MHz	P.L. Mult. Crystal	-80	-100	-120	-130	-135	-	560 MHz	13
BCO	.100-16.5 GHz	P.L. Single Loop	-65	-75	-80	-90	-115	-	16.35 GHz	13
VFS	1-14 GHz	Multiple Freq. Dual Loop	-60	-75	-110	-115	-115	-	12.5 GHz	13
DLCRO	.8-26 GHz	P.L. CRO Dual Loop	-60	-85	-110	-115	-115	-138	10 GHz	13
PLDRO	2-40 GHz	P.L. DRO Single/Dual	-60	-80	-110	-115	-120	-145	10 GHz	13
CP	.8-3.2 GHz	P.L. CRO Single Loop	-80	-110	-120	-130	-130	-140	2 GHz	13
CPM	4-15 GHz	P.L. Mult. Single Loop	-60	-90	-105	-110	-115	-130	12 GHz	13
ETCO	.1-24 GHz	Voltage Tuned CRO	-	-	-70	-100	-120	-130	2-4 GHz*	13

* Octave band.

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help OEMs migrate toward system-level standardization to account for global market distinctions. And, as is the case with most discrete SMT components, repeatability of performance from unit to unit is superior to printed PCB executions, which can vary significantly based on materials used, manufacturing conditions and expertise of the PCB printing processor.

Another advantageous physical characteristic is the Xinger's softboard construction. Because these parts are manufactured using materials with coefficients of thermal expansion (CTE) compatible with common PCB substrates such as FR4, Rogers 4350, RF-35 and polyimide among others, they expand and contract at the same rate as the PCB they are mounted on, which improves reliability.

LOWER LOSS IMPROVES AMPLIFIER EFFICIENCY

In addition to physical and dimensional advantages, Anaren's Doherty combiner takes sizeable steps toward recapturing performance losses seen with printed Doherty's. Chief among these are very low insertion loss.

Table 2 starts with a conservative comparison between the two approaches, which assumes the printed Doherty combiner is executed on a very high quality board material such as RO4350 in 30 mil thickness. In this head-to-head comparison, the much smaller Xinger combiners' 0.10 to 0.13 dB losses are nearly on par with the 0.10 to 0.11 dB loss range typically achieved with a Doherty printed on high-end PCB. It then compares the Xinger combiners with Doherty combiners as they would perform when printed on a more common 'cost conscious' board, such as FR4 (with ENIG plating). Here, the Xinger part's 0.10 to 0.13 dB loss range compares very favorably with the 0.168 to 0.179 dB losses typical of the printed solution. In today's systems, this is a significant performance gain. Another performance advantage of the Xinger Doherty combiner is the repeatable low return loss, made possible by the component's high performance materials and precision etching.

On the cost front, Anaren's Xinger Doherty combiner will be in the range of $1.65 each for the E-size units (in higher quantities) and $1.49 each for the P-size in like quantities. Additional savings can be realized through the minimization of PCB size and by eliminating design time and other resources needed to maintain a standing and current library of PCB-based Doherty designs to account for various applications.

Even more significant may be the cost savings made possible in the selection of PCB material. As discussed previously, there are some instances when a premium board material becomes the only way to achieve low insertion loss given the inherent inefficiencies of a printed Doherty; in other instances, higher insertion losses are tolerated as a trade-off for using a lower cost board. With Anaren's softboard Doherty combiner, the equipment manufacturer achieves the best of both worlds—excellent Doherty performance with a more competitively priced board.

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www.anaren.com.

A MULTI-PURPOSE 'NO STRINGS' AMPLIFIER

AtlanTecRF has introduced a new broadband amplifier module with very versatile characteristics, which makes it suitable for a variety of applications. One such application is the BOX battery-powered multipurpose portable amplifier, which lends itself to laboratory and measurement tasks where a single very wide bandwidth AC power-independent amplifier offers the advantages of being convenient and cost effective.

The heart of the BOX battery-powered amplifier is the AOX multi-octave amplifier illustrated in ***Figure 1***. This is a 1.0 to 20.0 GHz small-signal amplifier that employs novel matching structures to deliver excellent performance over wide bandwidth. It is also capable of operating over a wide range of temperatures down to 4°K. It features low noise figure, good temperature stability and has a typical gain of 27 dB. It is housed in a small enclosure measuring 31.4 by 27.5 by 10 mm with SMA connectors.

Fig. 1 Model AOX multi-octave amplifier.

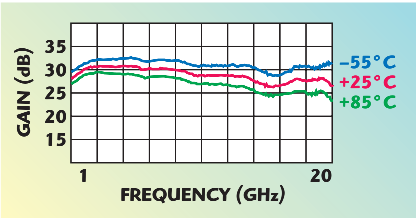

Fig. 2 Gain vs. frequency and temperature for the AOX.

There are three principal versions for differing temperature ranges: -20° to +85°C, -55° to +85°C and 4° to 358°K, the differences being in the design of the enclosure. ***Table 1*** illustrates the main characteristics and ***Figure 2*** shows the gain variation with frequency and temperature.

The extra versatility provided by the broad bandwidth and temperature range offers benefits in cost and logistics, making the AOX suitable for many applications in test and measurement, telecoms, radar, countermeasures and other demanding military and civil applications. The 4°K model is ideal for radioastronomy and other instrumentation situations where high gain is required at low temperature, together with the ability to perform reliably at the higher temperatures experienced during setting-up and during the transition down to the operating temperature.

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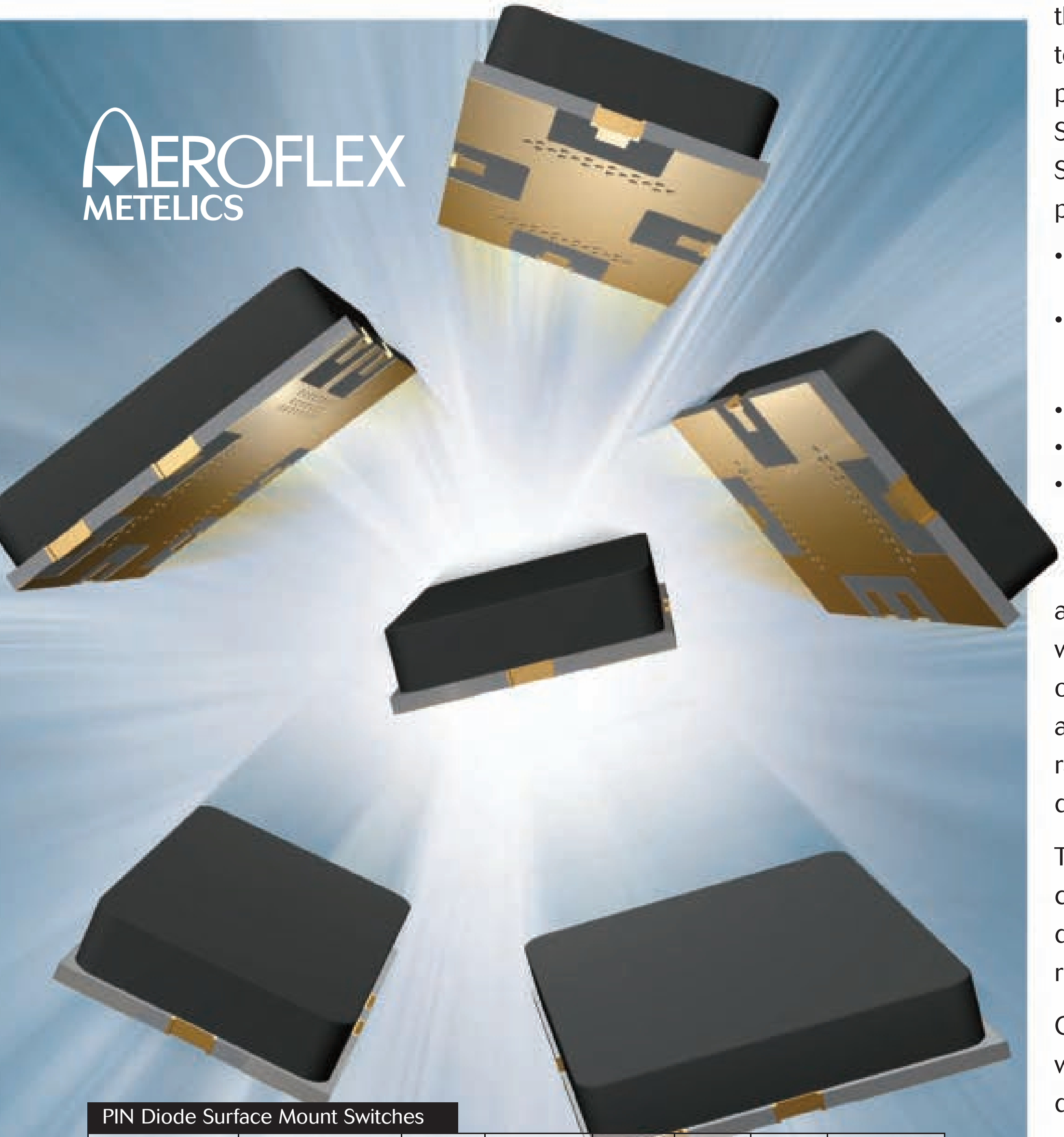

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Part Number	Configuration	DC Power	F (MHz)*	Loss (dB)	VSWR	Isolation (dB)	C.W. Incident Power (dBm)
MSW2000–200	SP2T T-R Switch	+V Only	20–1000	0.2	1.2:1	57	+ 51
MSW2001–200	SP2T T-R Switch	+V Only	200–4000	0.3	1.3:1	45	+ 51
MSW2002–200	SP2T T-R Switch	+V Only	2000–6000	0.4	1.5:1	40	+ 51
MSW2022–200	SP2T T-R Switch	+V & -V	10–1000	0.2	1.2:1	52	+ 52
MSW2050–205	SP2T T-R Switch	+V Only	20–1000	0.2	1.2:1	52	+ 52
MSW2051–205	SP2T T-R Switch	+V Only	200–4000	0.3	1.3:1	40	+ 52
MSW2030–203	Symmetrical SP2T	+V Only	20–1000	0.2	1.2:1	55	+ 51
MSW2031–203	Symmetrical SP2T	+V Only	200–4000	0.4	1.3:1	45	+ 51
MSW2032–203	Symmetrical SP2T	+V Only	2000–6000	0.5	1.5:1	40	+ 51
MSW2040–204	Symmetrical SP2T	+V Only	20–1000	0.2	1.2:1	54	+ 52
MSW2041–204	Symmetrical SP2T	+V Only	200–4000	0.3	1.3:1	44	+ 52
MSW2060–206	Symmetrical SP2T	+V & -V	20–1000	0.2	1.2:1	55	+ 51
MSW2061–206	Symmetrical SP2T	+V & -V	400–4000	0.4	1.3:1	45	+ 51
MSW2062–206	Symmetrical SP2T	+V & -V	2000-6000	0.5	1.5:1	40	+ 51
MSW3100–310	Symmetrical SP3T	+V Only	20–1000	0.3	1.2:1	57	+ 51
MSW3101–310	Symmetrical SP3T	+V Only	200–4000	0.5	1.4:1	43	+ 51
MSW3200–310	Symmetrical SP3T	+V & -V	20–1000	0.3	1.2:1	57	+ 51
MSW3201–310	Symmetrical SP3T	+V & -V	400–4000	0.5	1.4:1	43	+ 51

* 20-1,000 MHz specs at 500 MHz, 400 – 4,000 MHz specs at 2000 MHz, 2000 – 6,000 Specs at 4,000 MHz

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BOX AMPLIFIER

The BOX battery-powered amplifier (see ***Figure 3***) incorporates the AOX module in a self-contained and portable product with the same electrical specification as the AOX itself. Housed in a die-cast aluminium enclosure, the BOX also contains a NiMH rechargeable battery, which gives approximately 24 hours of operation between charges. A battery charger is supplied with each unit.

Table 2 illustrates the general specifications; the detailed electrical parameters are similar to the AOX figures given in Table 1.

Two connector configurations are available—axial, in which the connectors are mounted on the ends of the housing, and radial, in which they are mounted on one face. Rugged, high performance Type N male and female connectors are supplied as standard, but, optionally, SMA can be provided.

TABLE I

AOX CHARACTERISTICS

Parameter	Typ.	Min.	Max.
Small-signal Gain (dB)			
@ -55°C	30	27	
@ +25°C	27	24	
@ +85°C	25	22	
@ 4°K	32		
Gain Variation (dB)			
Over any 50 MHz	0.15		
Over any 500 MHz	0.50		
Over any 1 to 20 GHz			±2.5
Noise Figure (dB)			
@ +25°C	2.5 @ 5 GHz		
	4.5 @ 15 GHz		
@ 4°K			0.5 @ 5 GHz
			2.0 @ 15 GHz
Output Power (dBm)			
1 dB GCP @ +25°C	+11 @ 1 GHz	+8 @ 1 GHz	
	+14 @ 5 GHz	+11 @ 5 GHz	
	+14 @ 10 GHz	+11 @ 10 GHz	
	+13 @ 15 GHz	+10 @ 15 GHz	
	+12 @ 20 GHz	+9 @ 20 GHz	
Output Power (dBm)			
Saturated @ +25°C	+12 @ 1 GHz		
	+15 @ 5 GHz		
	+15 @ 10 GHz		
	+14 @ 15 GHz		
	+13 @ 20 GHz		
Third-order Intercept			
@+25°C	+28 @ 1 GHz		
	+20 @ 5 GHz		
Input VSWR	2.0:1		2.5:1
Output VSWR	2.3:1		2.8:1
DC Supply			
Voltage (V)	+5		+8
Current (MA) @ +25°C	140		150
@ 4°K	125		

▲ *Fig. 3 Model BOX battery-powered amplifier.*

All models have a threaded hole in one face to enable the amplifier to be mounted on a tripod or other support. There is an 'Amplifier On/Off/Charge' switch and the charger accepts an AC input voltage range of 80 to 240 V at 50 to 60 Hz.

There are many measurement applications for a broadband amplifier such as antenna-testing and EMC evaluation. The battery-powered BOX amplifier offers the benefit of freedom from ground potential; thus, it can be used to overcome ground loop problems. In field applications such as antenna testing there is a clear advantage in independence from an AC power supply and the unit may be used in conjunction with the increasing numbers of battery-operated field-portable test instruments such as VNAs and spectrum analysers. Furthermore, the very broad bandwidth means that 'one size fits all' when it comes to making provision for different antennas on the test range. This saves time, cost and logistics.

Often antenna test ranges entail the use of long interconnecting cables and this invites ground loop issues. Battery operation means that it is much easier to 'float' parts of the circuit to identify and overcome these problems. Similar issues may affect EMC measurements which, again, often entail field operation and long cable runs. The BOX can be used as an effective and trouble-free antenna-mounted amplifier and its low noise figure makes it suitable for reception applications in addition to roles in transmission. Battery life is sufficiently long to allow the completion of many test routines and, typically, recharging can be carried out overnight or during other downtimes.

Even in conventional desk-top applications there are times when a readily-available, AC power-independent amplifier can solve problems. For instance, it is a convenient way of making up cable losses in large hook-ups involving an isolated test chamber or screened room and the broad bandwidth ensures great flexibility.

The very broad bandwidth and 'no strings' freedom from AC power of the BOX amplifier makes it an ideal component of the test engineer's toolkit, yet this very simple concept has not hitherto been very readily available off-the-shelf. The applications are numerous and limited only by the imagination. The AOX multi-octave amplifier module featured in the BOX portable battery-operated amplifier embodies proprietary matching circuits that enable stable operation to be achieved over a wide range of temperatures and it offers economic and versatile solutions to a wide range of civil and military applications.

TABLE II

BOX GENERAL SPECIFICATIONS

General Specifications	
Frequency Range	1 to 20 GHz
Operating Temperature Range: Model BOX-010200	0 +50°C Ambient Conditions
RF Connector	Type N, Stainless Steel MIL-C-39012
Connectors: Standard	Male Input, Female Output
Optional	Type N Male or Female
	SMA Male or Female
Housing	Die-cast Aluminum Alloy
Finish	Matt Black
Dimensions	175 × 80 × 60 mm (6.89 × 3.15 × 2.36 ins.)
Tripod Mounting Point	1/4" UNC Threaded Hole in Base

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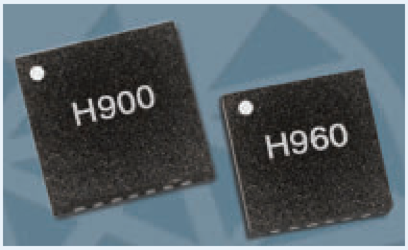
HITTITE LAUNCHES IF/BASEBAND PROCESSING PRODUCT LINE



Hittite Microwave has launched a new IF/Baseband Processing integrated circuit product line, introducing two new baseband compatible products that combine excellent performance with flexibility at a low cost. Both the HMC960LP4E dual digital variable gain amplifier and the HMC900LP5E dual programmable low pass filter meet the demand for a universal, multi-standard and wideband/multi-carrier transceiver, which is compact and capable of processing complex high density constellation signals.

The HMC960LP4E is a dual-channel, digitally programmable, differential variable gain amplifier. It supports discrete gain levels from 0 to 40 dB, in 0.5 dB steps that are smooth and precise. The dual differential HMC900LP5E filter features 0 or 10 dB input gain settings and supports arbitrary bandwidths from 3.5 to 50 MHz. Once calibrated, the accuracy is within ±2.5 percent of the desired bandwidth. The 6th order Butterworth transfer function delivers superior stop band rejection while maintaining both a flat pass-band and minimal group delay variation.

The HMC960LP4E can be combined with the HMC900LP5E to provide a complete direct down conversion baseband line-up that drives Hittite I/Q channel Analog-to-Digital Converters such as the HMCAD1520 12-bit ADC with its dual channel, 320 MSPS sampling rate. The HMC960LP4E has an externally controlled common mode output voltage feature that greatly simplifies the ADC interface. Both devices offer high linearity, high precision, very low noise and superior RF isolation between channels. These features enable the receiver designer to overcome the challenge of rejecting out-of-channel interferers while maintaining a perfect noise versus linearity trade-off. Matched I and Q paths provide excellent quadrature balance, which is an important feature in direct conversion architectures.

The HMC960LP4E is housed in a 4 × 4 mm plastic leadless surface-mount package; the HMC900LP5E is housed in a 5 × 5 mm plastic leadless surface-mount package. Both products provide excellent temperature stability from -40° to +85°C. The HMCAD1520 is housed in a 48-pin, 7 × 7 mm QFN package.

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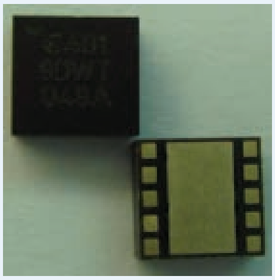

W-CDMA/HSPA Power Amplifiers for 3G China Markets

Epic Communications has developed a series of its next generation W-CDMA/HSPA power amplifiers (PA) that are specifically designed for 3G portable devices and mobile phones, and are compatible with industry leading 3G chipset solutions. This latest series of W-CDMA/HSPA PAs are designed specifically for the most popular UMTS/W-CDMA frequency bands (Bands I, II, V and VIII). They feature high linearity, high power added efficiency, ultra-low quiescent current, excellent temperature stability and very attractive performance/cost ratio. Epicom's PAs are provided in 3 × 3 mm packages with the same dimensions, pin-out assignments and features as other major suppliers, and are compatible with the next generation 3G PA standards.

Based on the most advanced BiFET wafer process, all key features and functional blocks of Epicom's 3G PA are integrated into a single cost-effective chip while still delivering superior performance. Epicom's 3G PAs feature digitally controlled tri-power mode operation and ultra-low quiescent current. The compact package form factor includes both the required directional coupler and all matching circuits, and is fully compliant with next generation 3G/4G PA footprint, feature and performance requirements.

EPA8100A, EPA8200A, EPA8500A and EPA8800A are W-CDMA/HSPA PA products that support the most popular 3G bands: EPA8100A for Band 1 (1,920 to 1,980 MHz), EPA8200A for Band 2 (1,850 to 1,910 MHz), EPA8500A for Band 5 (824 to 849 MHz) and EPA8800A for Band 8 (880 to 915 MHz), respectively. The PAs are designed to operate from a single DC supply voltage ranging from 3.2 to 4.2 V. At a Vcc of +3.4 V, they achieve 35 to 40 percent power added efficiency at 28 dBm when operating in high-power mode, 30 percent in medium-power mode at 18 dBm and greater than 10 percent power added efficiency in low-power modes at 8 to 10 dBm. No external DC-DC converter is required since the built-in voltage regulators eliminate the need for any external reference voltage. The quiescent current is 10 mA when operating at low-power mode.

The PAs utilize Epicom's patent pending temperature compensation design, which provides temperature stability from -40° to +85°C, allowing smart phones, wireless data cards and other 3G-equipped MIDs such as tablet PC and e-books to operate in extreme environmental conditions. These PAs are also provided as bare dies to volume SiP module makers for custom module design requirements. Epicom plans to offer more advanced PA products for other 3G standards such as TD-SCDMA, CDMA2000/EV-DO, and 4G standards of LTE and TD-LTE.

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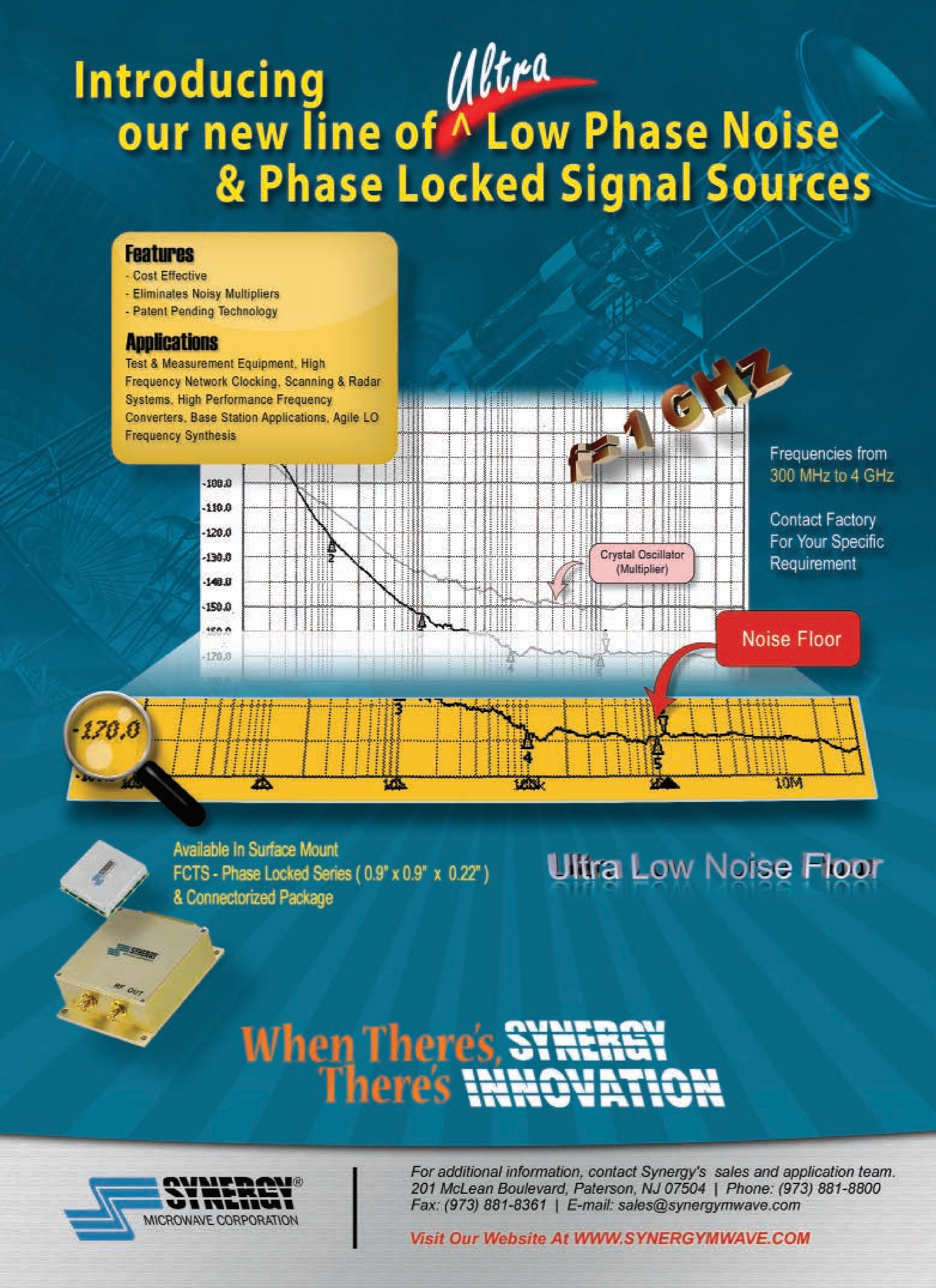
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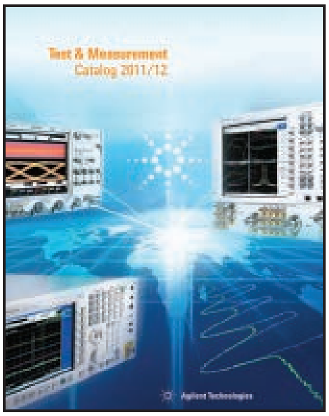

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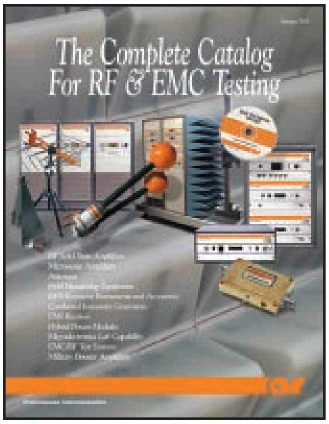

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Product Selection Guide

VENDORVIEW

Hittite is pleased to announce the release of the March 2011 Product Selection Guide summarizing over 925 products including 57 new products and two new product lines. This selection guide organizes Hittite's portfolio by product line as well as by market applications. Full specifications for each product are available at www.hittite.com. Click on "My Subscription" to receive the latest product releases.

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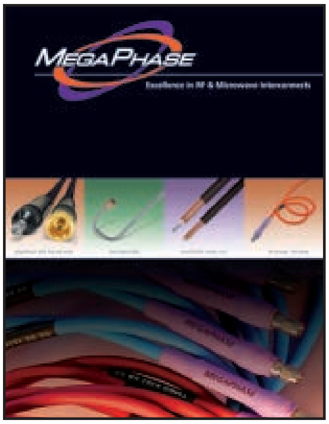
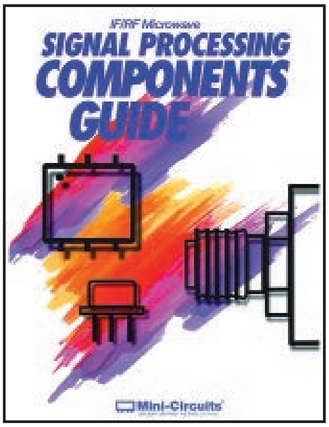
Keithley Instruments,
Cleveland, OH (440) 248-0400, www.keithley.com.



RF and Microwave Interconnects

MegaPhase is an ISO-9001:2008 certified manufacturer of RF/microwave coaxial cable, cable assemblies, connectors and RF components through 70 GHz. MegaPhase products include GrooveTube® test cables, semi-rigid and flexible coaxial cables for advanced systems, test adapters and coaxial connectors. For more information, contact MegaPhase at (570) 424-8400 or by e-mail at fastquote@megaphase.com.

MegaPhase LLC,
Stroudsburg, PA (570) 424-8400, www.megaphase.com.

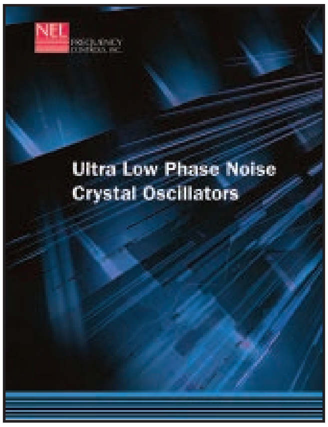


IF/RF Microwave Signal Processing Components Guide

VENDORVIEW

Mini-Circuits' new 164-page catalog includes over 750 new products and the industry's most comprehensive listing of RF/IF and microwave components and subsystems with more than 4100 products and over 25 product lines, including state-of-the-art amplifiers, mixers, VCOs, synthesizers, filters, test accessories and USB Power Sensors. Mini-Circuits' website provides additional data, application notes, design tools and its powerful YONI search engine, which searches actual test data on over thousands of units.

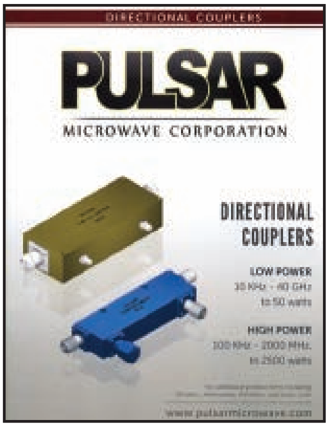
Mini-Circuits,
Brooklyn, NY (718) 934-4500, www.minicircuits.com.



Product Selector Guide

This product selector guide features the company's ultra-low phase noise crystal oscillators. The brochure is available online at www.nelfc.com. The oscillators in the catalog are shown at scale. Low phase noise solutions for OCXO, TCXO, VCXO and XO are available.

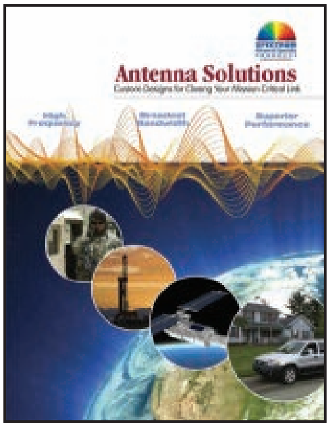
NEL Frequency Controls Inc.,
Burlington, WI (262) 763-3591, www.nelfc.com.



Directional Couplers

Pulsar Microwave's directional couplers include lump element, microstrip, stripline and airline techniques in surface-mount, drop-in and connectorized configurations. The enormous library of designs makes it practical to offer modifications of catalog items quickly and as cost effective as standard parts.

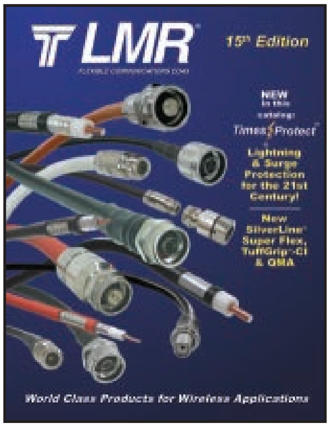
Pulsar Microwave Corp.,
Clifton, NJ (973) 779-6262, www.pulsarmicrowave.com.



Antenna Solutions Brochure

The antenna solutions brochure from Spectrum Advanced Specialty Products outlines Spectrum's complete vertical integration and extensive custom capabilities for antennas and antenna assemblies. The superior performance, high frequency and broadest bandwidth of Spectrum's antennas make them ideal for mission-critical applications. Antenna types include aperture, spiral, slot, planar, beam-forming static, switched array and more.

Spectrum Advanced Specialty Products,
Fairview, PA (814) 474-1571, www.specemc.com.

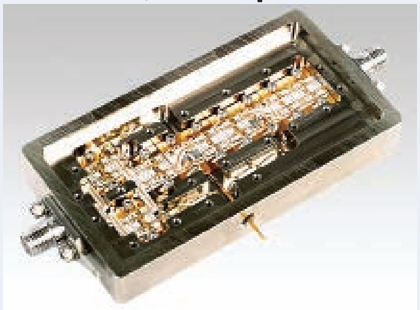


LMR Wireless Products Catalog

Times Microwave Systems announces the availability of the 15^{th} edition of the LMR® Wireless Products Catalog. The new catalog includes the entire range of LMR cables including LMR-DB, LMR-FR, LMR-Ultraflex, LMR-LLPL and LMR-75 as well as TCOM® (low PIM cable), FBT® low loss, high power cables, T-RAD™ leaky feeder cables and SilverLine® test cables. Also included in this latest edition is the new Times-Protect™ line of innovative lightning surge protector products for RF equipment.

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

6 to 18 GHz, 3 W Amplifier

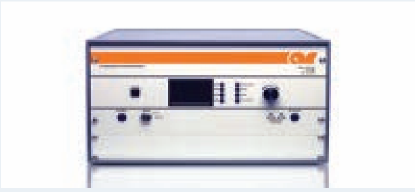


AML announces the immediate availability of a high power broadband amplifier model AML618P4202. This amplifier operates over 6 to 18 GHz with industry best DC to RF efficiency. Output P1dB is +35 dBm (3 W) minimum. Gain is 42 dB minimum with flatness within ±2.5 dB maximum. DC current at +12 VDC is under 2.5A. Dimensions are 2.85"L × 1.5"W × 0.5"H. Operating temperature range of -54° to +85°C is available as an option.

AML Communications Inc.,
Camarillo, CA (805) 388-1345,
www.amlj.com.

0.8 to 4.2 GHz Solid-state Amplifier

VendorView



AR has introduced a new solid-state microwave amplifier, model 175S1G4, that covers 0.8 to 4.2 GHz and has a power output of 175 W. This amplifier employs a new design that delivers more than twice the power of older models. The new, more efficient design consumes less power and incorporates both USB and Ethernet interfaces in addition to the standard IEEE and RS-232 interfaces. With these improvements, AR has maintained the superior rugged design for load tolerance and excellent linearity.

AR RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.ar-worldwide.com.

Voltage-controlled Oscillators

Crystek's CVCO55FLM voltage-controlled oscillators (VCO) contain an extra modulation port (TX modulation), making the family an ideal choice for transmitter applications. The modulation port has a negative slope and a typical modulation sensitivity of -20 KHz/V. The CVCO55FLM-0172-0210 operates from 172 to 210 MHz with a control voltage range of 0.2 to 4.8 V. This VCO features a typical phase noise of -119 dBc/Hz at 10 KHz offset and has excellent linearity. Output power is typically 0 dBm.

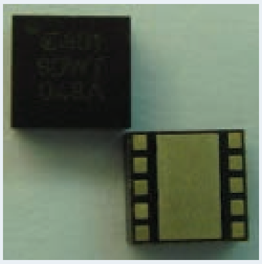
Crystek Corp.,
Fort Myers, FL (239) 561-3311,
www.crystek.com.

Low Noise Amplifier

Model ALN-85305020-H1 is a W-band low noise amplifier that operates in a frequency range from 65 to 100 GHz with a maximum 6 dB noise figure and minimum 20 dB gain. The amplifier incorporates the internal integrated voltage regulator and operates at +8 to +12 VDC and typically draw 80 mA current. The RF connectors for the amplifier are standard WR-10 waveguide with UG387/U Mod flange and measures 1.60" long, 1.2" wide and 0.6" tall. This amplifier is an excellent choice for instrumentation, lab testing and wideband receiver applications. Nominal gains of 10 to 50 dB are available upon request.

Ducommun Technologies Inc.,
Carson, CA (310) 847-2859,
www.ducommun.com.

3G Power Amplifier

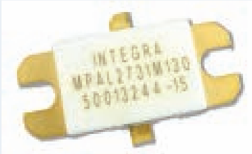


The EPA8100A 3G power amplifier is aimed at the Chinese TD-SCDMA market. The PA targets all TD-SCDMA/HSDPA platforms and is packaged in the industry standard 3 by 3 by 1 mm form factor. It has a built-in 20 dB directional coupler, integrates all matching and biasing circuitry, and is fully compatible with mainstream PAs used in TD-SCDMA mobile phones and data cards in terms of package form factor, pin-out assignments and performance. It features high linearity and output power, high power added efficiency, low quiescent current consumption, ultra-low temperature sensitivity over voltage from -40° to +85°C, digitally controlled power mode operation, as well as 100 percent compatibility with other mainstream 3G PAs.

Epic Communications Inc. (Epicom),
Hsinchu City, Taiwan 886-3-577-5776,
www.epic.com.tw.

Miniaturized Power Amplifier

Integra Technologies announced its highest power MPA, part number MPAL2731M130. It is a miniaturized power amplifier that is internally matched to 50 ohms. It is designed for S-band radar systems and operates over the instantaneous bandwidth of 2.7 to 3.1 GHz. It utilizes gold metal LDMOS transistor technology operating in common source configuration. It may be operated in class B, AB and A mode. It is operable over nearly any pulse width and duty factor. Under 300 µs/10 percent pulsed operation it can be used to supply a minimum of 130 W of peak pulse power over the instantaneous frequency range of 2.7 to 3.1 GHz. All devices are 100 percent screened for large-signal RF parameters. Sampling now.



Integra Technologies Inc.,
El Segundo, CA (310) 606-0855,
www.integratech.com.

High Power Amplifier Module

With a frequency range of 1,280 to 1,300 MHz, the new MKU PA 131000 CU power amplifier utilizes the latest LDMOS-technology to provide excellent efficiency, together with good linearity. It is suitable for analog and digital transmission systems as well as scientific/medical applications such as linear accelerators. The input power is 20 to 30 W and the output power is 1,000 W CW. Safe operation is provided by a built-in sequencer that controls internal procedures or external components, e.g. a coaxial relay. Other key features include protection against overheating, a milled copper case for optimum heat transfer; special versions and accessories are deliverable on demand.

Kuhne electronic GmbH,
Berg, Germany +49 (0) 9293 800939,
www.kuhne-electronic.de.

Highly Linear RF Driver Amplifier

VendorView

The MAAM-009560 is a HBT driver amplifier for cellular and WiMAX infrastructure applications. This driver amplifier covers a broad frequency range of 250 to 4000 MHz with excellent linearity of 42 dBm OIP3 over a greater than 20 dB input power range, as well as features a typical gain of 15 dB. The lead-free SOT-89 surface-mount plastic package is RoHS compliant and compatible with solder reflow temperatures up to 260°C. The ESD susceptibility achieves a Class 2 ESD rating.

M/A-COM Technology Solutions Inc.,
Lowell, MA (978) 656-2539,
www.macomtech.com.

NEW WAVES

Low Noise Amplifiers

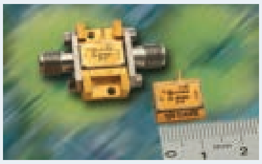
Maxim Integrated Products introduces the MAX2686/MAX2688, low noise amplifiers (LNA) designed for GPS-enabled applications operating in the 1575 MHz band. Packaged in a 0.86 × 0.86 mm, 0.4 mm-pitch wafer-level package (WLP) with only four pins, these LNAs minimize solution footprint for today's continually shrinking handheld designs. Maxim's advanced SiGe BiCMOS technology enables this space-saving design. Device specifications outperform GaAs and PHEMT LNAs and integrated RF CMOS receivers, and performance surpasses today's larger competitive options.

Maxim Integrated Products,
Sunnyvale, CA (800) 998-8800,
www.maxim-ic.com.

Low Noise Amplifier

VENDORVIEW

MITEQ Inc. introduces a new addition to its family of ultra-broadband LNAs. The model JS4-00104000-58-5P is very low noise, lightweight, and has a small profile and



footprint. The Kovar housing is a hermetically sealed package. This unit has a low noise figure of 5.8 dB maximum. The input and output port VSWR is a maximum of 2.5:1. Small-signal gain is 30 dB minimum and P1dB is +5 dBm minimum. The JS4-00104000-58-5P comes with various options such as various bandwidths, and input/output DC block. Operating temperature is -54° to +85°C case.

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

Wideband Gain Blocks

The BGA28xx series of gain blocks is a recent addition to NXP's portfolio of RF products, and these gain blocks offer best-in-class linearity versus current consumption. Optimized for satellite LNBs, the BGA28xx products are also well suited for general-purpose applications. These devices join other NXP discrete and integrated building blocks, including oscillators, amplifiers, switches and biasing, to provide complete coverage for all LNB architectures. As a key benefit, the new BGA28xx gain blocks do not require an output inductor when using them at the output stage. Features of this product family include: performance up to 3 GHz (optimized for 250 to 2150 MHz); internally matched (50 Ω); and small 2×2 mm 6-pin SOT363 plastic SMD package.

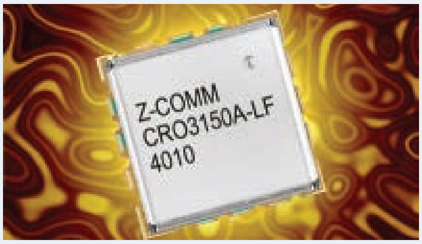
NXP Semiconductors,
San Jose, CA,
www.nxp.com.

Phase-locked Oscillator

The PLS-17000-P100I is a high performance, low noise, 17 GHz phase-locked oscillator (PLO) with a 100 MHz OCXO internal reference. The design of this PLO's primary source consists of a low noise, bipolar-silicon-transistor oscillator. In addition, a frequency doubler and a buffer amplifier in the output path provides the desired frequency, power output and load isolation. Power output is 13 dBm minimum into a 50 ohm load. Phase noise at 10 kHz and 100 kHz offsets is better than -110 dBc/Hz. The PLS-17000-P100I is housed in a compact (2.25" × 2.25" × 0.92") connectorized package. Phase Matrix's PLOs are available in frequencies up to 50 GHz and up to 1 W of power output with internal or external reference oscillators. These products are designed for use in commercial as well as high-reliability military applications.

Phase Matrix Inc.,
San Jose, CA
(408) 428-1000,
www.phasematrix.com.

Low Phase Noise VCO



Z-Communications Inc. announces a new RoHS compliant voltage-controlled oscillator (VCO) model CRO3150A-LF in S-band. The CRO3150A-LF operates at 3125 to 3175 MHz with a tuning voltage range of 0.5 to 4.5 VDC. This VCO features a typical phase noise of -108 dBc/Hz at 10 KHz offset and a typical tuning sensitivity of 21 MHz/V. CRO3150A-LF is well suited for fixed wireless and digital radio applications that require ultra low phase noise performance. The CRO3150A-LF is designed to deliver a typical output power of 4.5 dBm at 5 VDC supply while drawing 25 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -19 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22".

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

IMS 2011 MicroApps

Nonlinear Characterization Expert Forum

Baltimore, Maryland, June 8, 12:00 – 1:30 pm

A 90 minute forum and webcast, featuring experts in RF nonlinear device measurement and characterization.

Our panel of experts will discuss solutions and trends in nonlinear device characterization from the perspective of new measurement equipment, techniques and device representation in EDA tools. An open panel discussion session will follow the presentations with audience questions from both live and online participants.

SPEAKERS:

- Loren Betts, Research Scientist/Senior Engineer, Agilent Technologies
- Steve Reyes, Product Marketing Manager Network Analyzers, Anritsu
- Marc Vanden Bossche, Founder and CEO, NMDG Engineering
- Johannes Benedikt, CTO, Mesuro

Sponsored by:

Agilent Technologies Anritsu ROHDE&SCHWARZ Tektronix

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Microwave Journal
Frequency Matters.

Components

RF Connectors

HD-BNC™ is the newest line of small form factor RF connectors designed to support rapidly growing demand for high bandwidth, high reliability interconnection in the broadcast and telecommunications industries. The high-density BNC series (HD-BNC) is based on the familiar quarter-turn BNC coupling connector pioneered by Amphenol in the late 1940s, but with patented design advancements that permit a four-fold reduction in footprint and more than 20 percent reduction in weight while maintaining true 75 ohm performance and the robust mechanical properties expected from a BNC interface. The Amphenol HD-BNC was developed in close collaboration with leading industry equipment makers and system integrators to address the most common issues with conventional high density solutions including interface robustness and signal loss related to long cable runs.

Amphenol RF,
Danbury, CT (800) 627-7100,
www.amphenolrf.com.

Cavity Bandpass Filter

VENDORVIEW

The model Wifi2437-6A is a ruggedized, weatherproof cavity bandpass filter for outdoor WiFi installations that has excellent rejection, handles up to 40 W of RF input power and is extremely selective. The Wifi2437-6A has a center frequency of 2437 MHz and a bandwidth of more than 30 MHz (2427 to 2447 MHz), along with maximum insertion loss of less than 2 dB and passband ripple of less than 0.2 dB. The filter has rejection of at least 60 dB at 2412 and 2462 MHz and return loss of more than 18 dB. The unit measures 108 × 56 × 29 mm and uses SMA female connectors. The Wifi2437-6A is ruggedized and weatherproofed for use in outdoor environments, and has an operating temperature range of -40° to +70°C.

Anatech Electronics,
Garfield, NJ (973) 772-4242,
www.amcrf.com.

42 GHz Bandpass Filter

VENDORVIEW

Model EWT-31-0245 is a coaxial bandpass filter with a center frequency of 42 GHz. With a 3 dB bandwidth of 1000 MHz minimum, the insertion loss at center frequency is 1.5 dB. Rejection at 40 GHz is greater than 50 dB and the VSWR is 1.5:1. This compact filter design has an overall size of 1.20" × 0.5" × 0.5". This model is supplied with 2.4 mm connectors.

Eastern Wireless TeleComm Inc.,
Salisbury, MD (410) 749-3800,
www.ewtfilters.com.

Surface-mount Fixed Attenuators

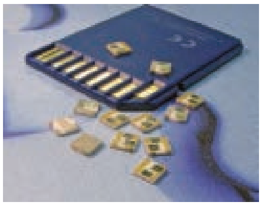
VENDORVIEW

This new wideband surface-mount fixed attenuator is optimized for performance from DC to 20 GHz. Utilizing EMC's 40 plus years of experience in refining attenuation solutions, the TS09 offers the best performance to date for high frequency applications in an SMT package. These devices have been noted for their excellent performance and small size, measuring only 0.070" × 0.060" (1.78 × 1.62 mm). The TS09 wideband fixed attenuator handles 200 mW of input power and is available in dB values from 0 to 10 dB in 1 dB increments.

EMC Technology,
Stuart, FL (772) 600-1620,
www.emc-rflabs.com.

Broadband Resistive Couplers

IMS announced the expansion of its line of low loss broadband resistive couplers to include wire bondable terminals and alternate configurations. The IMK Series couplers now come in both forward and reverse facing directions, coupling values from 6 to 30 dB and are rated at 1 W dissipated power and 5 W through power. The IMK Series resistive couplers are compact (0.120" × 0.120") alternatives to more complex narrow band couplers. They have been characterized to 20 GHz and can exhibit insertion loss less than 1 dB loss for nominal values greater than 18 dB.



International Manufacturing Services Inc.,
Portsmouth, RI
(401) 683-9700,
www.ims-resistors.com.

Three-way Power Dividers

Marki Microwave announced the release of a new line of broadband three-way power dividers. These power dividers are constructed using a unique design approach that enables industry leading isolation and amplitude/phase balance. The three-way power divider line launches with two models: the 0.4 to 12 GHz PD3-0R412 and the 0.6 to 16 GHz PD3-0R616. Custom designs are also available. Contact the factory for more information.

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

+12 to +33 dBm Limiter

VENDORVIEW

The Mini-Circuits VLM-63-2W+ is a +12 to +33 dBm limiter that operates in a frequency range from 30 to 6000 MHz. This limiter features low insertion loss, 0.4 dB typical. The limiters offer fast recovery time, 5 nsec typical; excellent VSWR, 1.05:1 typical; and low leakage power, 11.5 dBm typical. Applications include: protects low noise amplifiers and other devices from ESD or input power damage and military, hi-rel applications. This limiter is RoHS compliant in accordance with EU Directive (2002/95/EC). Price: $51.95 (1-9).

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

SP6T Switch

VENDORVIEW

The SEM163 SP6T electromechanical switch is designed for operation from DC to 18 GHz. The switch is a normally-open configuration and includes an indicator circuit. Insertion loss is less than 0.5 dB, VSWR is less than 1.5:1 and isolation is as high as 80 dB. It employs SMA female connectors and measures 2.5 high by 1.1 in. square. It operates from 28 VDC and requires 140 mA of actuating current. Other models in the DC-to-18 GHz SEM163 family include latching configurations, TTL control, suppression diodes, and self-energizing and de-energizing capabilities. The model SEM163 and all other members of the SEM163 family are in stock and available for immediate delivery.

Narda Microwave-East,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com/east.

Digital Phase Shifter

Model number PS-360-3237-5-292FF is a 32 to 37 GHz digitally-controlled phase shifter with capability for phase shifting from 0 to 349°. Five logic lines allow various phase shift with a LSB of 11.25°. Key specifications include an operating frequency of 32 to 37 GHz; insertion loss of 8 dB; VSWR of 2.0:1; LSB of 11.25 degrees; maximum phase shift of 348.75 degrees; control bits of 5-Line TTL; switching speed of < 500 nsec; and 2.92 mm connectors. Size: 1.29" × 1.75" × 0.5".

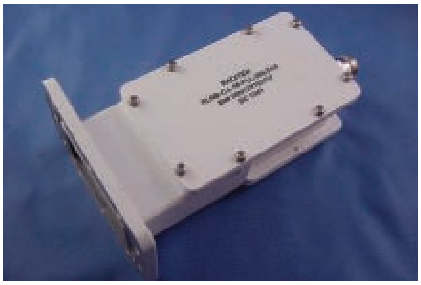
Planar Monolithics Industries Inc.,
Frederick, MD (301) 662-5019,
www.pmi-rf.com.

Directional Coupler

Pulsar model C40-22-481/6N covers the frequency range of 200 to 2000 MHz with a

power rating of 200 W, 40 ± 1 dB coupling, 0.4 dB insertion loss and 20 dB directivity. Coupling flatness is ± 1.0 dB and VSWR is 1.2:1. Outline dimensions are 3.0" × 2.6" × 1.0".
Pulsar Microwave Corp.,
Clifton, NJ (973) 779-6262,
www.pulsarmicrowave.com.

Low Noise Block Down Converter

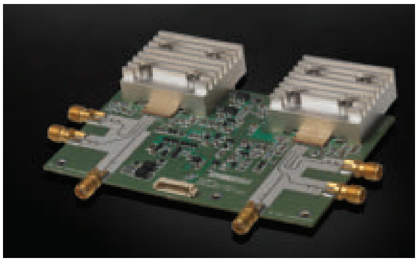


These high stability C-band PLL low noise block (LNB) down converters are the company's latest addition to its SATCOM products. The down converters feature input frequency from 3.4 to 4.2 GHz, LO frequency of 5.15 GHz and output frequency from 950 to 1750 MHz. Typical specifications include noise temperature of 20K to 30K, and LO stability ±2 to ±25 kHz over temperature, excellent offset. Phase noise is -73 dBc/Hz at 1 kHz and input/output VSWR is 2.2:1. The temperature range is between -40° to +60°C.
Raditek,
San Jose, CA (408) 266-7404,
www.raditek.com.

Programmable Step Attenuators

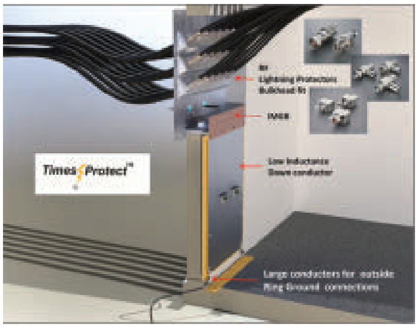
RLC Electronics' PA series attenuators are binary programmable step attenuators designed to operate from DC to 20 GHz. Two basic models offer attenuation ranges of 15 and 70 dB. Control is in standard format: 1-2-4-8, etc. The attenuators are available with failsafe or latching operation, 12 or 28 V coils and optional TTL drivers, with a choice of frequency ranges.
RLC Electronics Inc.,
Mount Kisco, NY
(914) 241-1334,
www.rlcelectronics.com.

mm-wave Converters



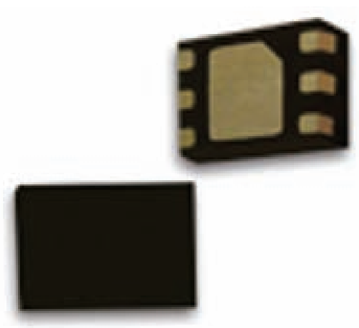
The FC1001V V-band converter platform and the FC1001E E-band converter platform are designed to enable radio link manufacturers to slash time to market for next generation radio links with a transfer rate up to 10 Gb/s, and at low cost. Applications other than point-to-point and point-to-multipoint radios include WLAN, measurement systems and defense and secure communications. These high performance converters can easily be customized and are available in several configurations including with or without internal LO synthesizers or optional diplexer.
Sivers IMA AB,
Kista, Sweden +46 87036800,
www.siversima.com.

Times-Protect Smart-Panel



Times Microwave Systems has introduced the Times-Protect Smart-Panel™, a revolutionary concept in shelter and base station entrance panels. Intelligently designed to eliminate traditional entrance panel shortcomings and vastly improve the protection of expensive base station equipment, the Smart-Panel is truly a product for 21st century needs. The Smart-Panel provides for highly desirable single point grounding while eliminating the expense and potential incorrect installation of external grounding kits. The Smart-Panel design provides for bulkhead mounting of the surge protectors directly on the panel for superior surge performance.
Times Microwave Systems,
Wallingford, CT
(203) 949-8400,
www.timesmicrowave.com.

Monolithic 90 Degree Hybrids

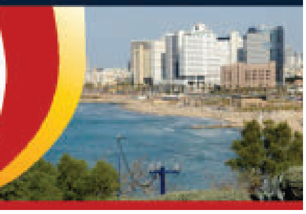


Valpey Fisher Corp. Microwave Products Group introduces a new product family of miniature monolithic 90 degree hybrids. The VFHY100 series consists of eight different models spanning the frequency range of 600 MHz to 4 GHz and are offered in a miniature 1.5 × 2 mm leadless package. Valpey Fisher's RF/microwave passive products utilize a custom design and monolithic manufacturing process offering outstanding electrical performance and part to part repeatability when compared to existing solutions. Samples are available upon request.
Valpey Fisher Corp.,
Hopkinton, MA
(508) 435-6831,
www.valpeyfisher.com.

IEEE COMCAS 2011

The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems

David Intercontinental Hotel, Tel Aviv, Israel, November 7-9, 2011



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Call for Papers

COMCAS 2011 continues the tradition of providing a multidisciplinary forum for the exchange of ideas in the areas of microwaves, antennas, communications, solid state integrated circuits, sensing and electronic systems engineering. The conference re-visits the venue which has proven to be attractive and enjoyable, with many opportunities for networking, candid exchange of ideas and the building of a strong sense of community. This year we will continue to expand the program to include RF and microwave photonics, biomedical technologies, cognitive radios and networks, radio frequency identification, electron devices and photonic means for IC inspection among other topics.

A diverse assembly of researchers, engineers and scientists will be invited to present their ideas and discuss new results, providing a unique opportunity for attendees to view a variety of interesting and innovative technologies in one location. Invited papers and tutorial talks from international experts will be presented in key topical areas.

Technical Topics:

- Antennas (components, modeling, phased array, etc.)
- Biomedical Technologies
- Circuit Modeling / Theory
- Cognitive and Software-Defined Radios
- Communications Systems Modeling, Simulation and Analysis
- Electromagnetic Compatibility
- Energy Harvesting
- MEMS Modeling, Devices, Applications
- Mixed Signal Analog/RF/Digital Circuits and Systems
- Microwave and MM-Wave Circuit Technologies
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- Plasmonics
- Radar and Electronic Systems
- Remote Sensing
- RFID Devices, Technologies and Systems
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- Terahertz and Applications
- New and Emerging Technologies

Regular oral presentations will be 20 min. in length; there will also be Poster sessions. All submitted papers will be peer reviewed and assessed on key accomplishments, technical contribution, advancement of the state-of-the-art, originality and interest to the attendees. Accepted papers will be published in the COMCAS 2011 Proceedings which will be available through IEEE Xplore® after the conference.

Papers should first be submitted as a 1 to 2 page summary to
http://www.mtt-tpms.org/symposia_v6/COMCAS2011/start.html

Please refer to the detailed author instructions provided on the conference web site
www.comcas.org
The official language of the Conference is English

Deadline for summary submission: 15 June 2011
Final manuscript submission: 1 September 2011

The technical program will be complemented with a technical Exhibition, which will be held on November 7-8, offering companies and agencies a unique opportunity to visit Israel and present related products and services in display and printed advertisement.
For further details please contact the Conference Secretariat.

Antenna

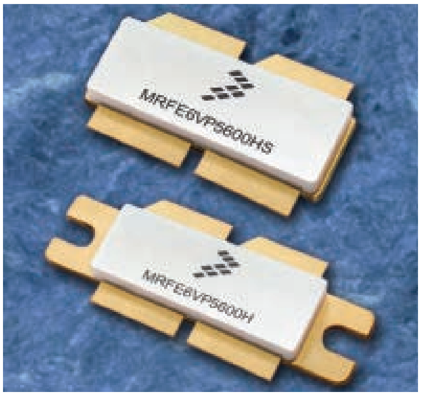
Patch Antenna Elements

Spectrum Advanced Specialty Products' patch antenna elements now meet Iridium Satellite Communications' "Iridium Compatible Equipment (ICE) Certification" requirements. This certification saves customers time when using Iridium-certified antennas in their applications by eliminating the need for re-certifying equipment when using the patch antennas according to Iridium's guidelines. Currently, the PA25-1621-025SA and PA45-1621-1575SA patch antennas are ICE-Certified; however, several of Spectrum's antennas and assemblies are in the approval process and certification is expected in 2011.

Spectrum Advanced Specialty Products,
Fairview, PA (814) 474-1571,
www.specemc.com.

Semiconductor/IC

LDMOS Power Transistor



Freescale Semiconductor has introduced a 50 V, 600 W LDMOS power transistor that continues to deliver its full rated gain and output power even after withstanding a load mismatch of 65:1 VSWR. This ruggedness capability supports harsh RF circuit environments in highly mismatched applications such as CO_2 laser exciters, plasma generators and MRI power amplifiers. The MRFE6VP5600 is also well-suited to be used in defense/aerospace amplifiers (pulsed operation or CW), HF/VHF radio amplifiers, RF plastic welding amplifiers, particle accelerator amplifiers, and various other industrial, medical and broadcast amplifiers. This high-gain LDMOS transistor operates over the frequency range from 1.8 to 600 MHz.

Richardson Electronics for
Freescale Semiconductor, (800) 737-6937,
www.rell.com/RFPD.

Source

SMT Frequency Synthesizer

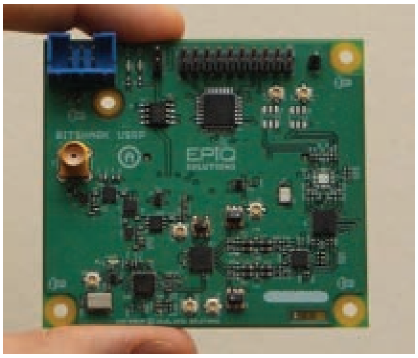
The HFS-2500 operates over 2000 to 2500 MHz for advanced electronic warfare applications. This unit features exceptionally-low phase noise (<-121 dBc/Hz at 100 KHz offset), fast switching (<5 mSec), 10 MHz step size, +5 dBm output power; supply voltages are +5 V DC A-VCC/+8

VDC D-VCC and programming is via three-wire serial interface. The HFS-2500 is housed in a small, surface-mount package (1.25" × 1" × 0.24") and operates in harsh environments over the temperature range of -40° to +85°C.

EM Research Inc., Reno, NV (775) 345-2411, www.emresearch.com.

System

Bitshark Family

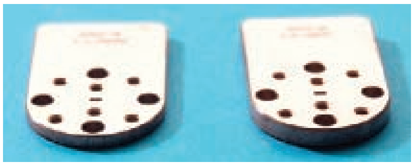


The Bitshark family of products provide small form-factor, high performance reconfigurable radio solutions that integrate with different host platforms. This family has been specifically designed to handle many different waveforms, including 2G/3G/4G cellular. These platforms are capable of operating from 300 MHz to 4 GHz, handling RF channel bandwidths up to 50 MHz. Total power consumption for a single Rx tuner solution is < 1 W.

EPIQ Solutions, Schaumburg, IL (847) 598-0218, www.epiq-solutions.com.

Test Equipment

Millimeter & Sub-millimeter Cal Kits



The new Series 704, 721 and 741 range of millimeter and sub-millimeter Thru-Reflect-Line (TRL) calibration kits have applications in millimeter and sub-millimeter waveguide vector network analyzer calibration and precision measurements. With three metrology grades and with models from 110 to 500 GHz, the calibration kits utilize National Physics Laboratory (NPL) applied technology, which uses line lengths of $3/4\lambda g$ or $5/4\lambda g$. In the 110 to 330 GHz frequency range, two lines (offsets) are used that each give a nominal $3/4\lambda g$ phase change at a point in the band. In the 260 to 500 GHz frequency range, three lines (offsets) are used that each give a nominal $5/4\lambda g$ phase change at a point in the band.

Flann Microwave Ltd., Bodmin, Cornwall, UK +44 (0)1208 77777, www.flann.com.

Signal Generator

VENDORVIEW

The HMC-T2220 is a new and easy to implement 10 MHz to 20 GHz synthesized signal generator that provides high output power, low harmonic levels and broad frequency range for only $9,998.00. Ideal for use in automated test and measurement environments, research, and development laboratories, the HMC-T2220 is a compact and lightweight frequency generator that delivers up to +28 dBm of CW output power in 0.1 dB steps over a 60 dB dynamic range. Harmonic rejection is better than -30 dBc and spurious products are better than -57 dBc across the entire bandwidth. Phase noise is -99 dBc/Hz at 100 kHz offset at 10 GHz with insignificant deviation over the temperature range of 0 to +35°C. The broad frequency range of 10 MHz to 20 GHz covers all major communication bands with frequency resolution of 1 Hz and fast switching speed of 300 μs.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.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Modco offers a low-noise general purpose amplifier. Model Number WB100-6000DJ covers a frequency range of 100MHz through 6000MHz. The amplifier is housed in an Iridite Gold finished aluminum housing measuring 1.25" x 1.25" x 0.60". It is supplied with three SMA F Connectors. The device operates from a single +5V supply and consumes 60mA
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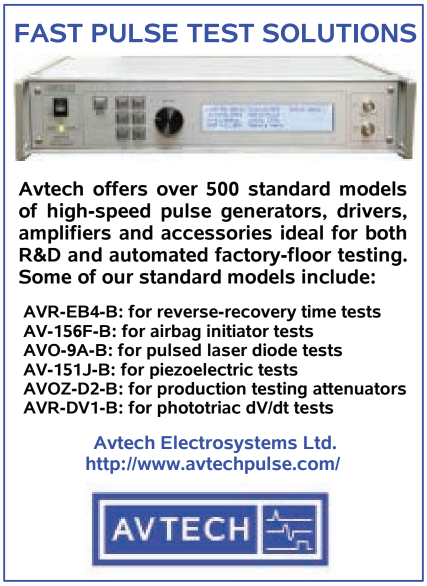
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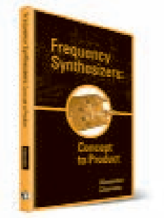

Frequency Synthesizers: Concept to Product

Alexander Chenakin

Frequency Synthesizers: Concept to Product offers RF and microwave engineers a thorough overview of both well-established and recently developed frequency synthesizer design techniques. As a critical component found in many modern devices like radio receivers, mobile phones and GPS systems, frequency synthesizers provide a clean and stable signal at various frequencies. Professionals will find expert guidance on all design aspects, including main architectures, key building blocks and practical circuit implementation. Engineers will learn the development process and gain a solid understanding of how to build a synthesizer from a basic diagram to the final product.

Starting with a simple single-loop PLL example, the book progressively examines various alternatives—fractional-N, DDS, frequency offset, multi-loop and more—to achieve required performance objectives. It first covers basic frequency synthesizer concepts, control interfaces and building blocks. It then moves on to synthesizer construction, the design process, improving performance and finally advanced functions.

Written by industry expert Dr. Alexander Chenakin of Phase Matrix, *Frequency Synthesizers: Concept to Product* is for practical engineers and others in the design field. It is primarily intended for engineers in their first years of practice and serves as a quick and effective guide to mastering professional skills, but is also helpful to other professionals such as consultants, researchers, technical marketers and sales.

This unique book gathers a collection of block diagrams, circuits, design recipes and other hard-to-find information, all of which are often treated as "design secrets". Written in a simple yet rigorous style with numerous illustrations, the book is an all-in-one reference for both beginner and experienced designers.

To order this book, contact:

Artech House
685 Canton St., Norwood, MA 02062
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16 Sussex St., London SW1V 4RW, UK
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215 pages; $129, £86
ISBN: 978-1-59693-230-2

2011 Microwave Industry Exhibition in China (MIE 2011)

2011 National Conference on Microwave and Millimeter Wave in China

MIE 2011

For detail information, Please visit www.cnmw.org www.mws-cie.org

Sponsors: Chinese Institute of Electronics (CIE)

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Collaborating journals:
Journal of Microwaves(Chinese)
Chinese Journal of Radio Science
Mobile Communications(Chinese)
Microwave Journal(English)
Rfeda, Mrfn, Eefocus, Kilomega and Wbsp.

Conference / Exhibition Date: June 1 - 4, 2011 **Conference / Exhibition Venue: Qingdao, P.R. China**

Microwave Industry Exhibition has been held for over 10 years. It is held every year, with the National Conference on Microwave and Millimeter Wave in China (Microwave Annual Conference of China) every odd year and with the International Conference on Microwave and Millimeter Wave Technology every dual year.
MIE 2011 will be another grand exhibition after MIE 2010 in Chengdu, MIE 2009 in Xi'an, MIE 2008 in Nanjing China!

Exhibitors to be attended:

- Fabricator / distributor for RF / microwave / millimeter wave devices / components: solid state device and circuits (including MMIC): amplifiers, mixers, oscillators, etc. and passive components: filters, duplexers, couplers, attenuators, and antennas etc.
- Designer / distributor for RF / microwave / millimeter wave software.
- Fabricator / distributor for RF / microwave / millimeter wave equipments.
- Fabricator / distributor for RF / microwave PCB and connectors.
- Fabricator / distributor for microwave absorber.
- Fabricator / distributor for microwave / millimeter inductor, capacitor and high power resistor.
- RF / microwave / millimeter related press and media.

Why you should attend?

- MIE 2011 is the largest event of microwave field in China, which is sponsored by Chinese Institute of Electronics(CIE) .
- MIE 2011 is where to provide a platform for enterprises engaged in Microwave Millimeter wave and RF field to publicize your company/ products in China .
- MIE 2011 will provide a chromatic company introduction page (210mm×285mm) for each exhibitor in List of Exhibitors, which is free.
- MIE 2011 is where to provide a nice opportunity for the scientists and engineers specialized in Microwave and Millimeter wave field to present your new ideas and learn from each other .

There are two kinds of booths: Standard booth and Customized booth:
Standard booth: 3 m x 3 m,
Consist of one headboard with company name (limited in 30 characters), one table, two chairs and so on.
Customized booth: From 36 m^2
Empty area, you can customize the booth to highlight your company / products

Background of National Conference on Microwave and Millimeter Wave in China (NCMMW)

NCMMW is China's largest conference on microwave and millimeter wave technologies. It is Sponsored by Chinese Institute of Electronics (CIE) and held every two years (every odd year).

NCMMW 2011 will be held in Qingdao International Conference and Exhibition Center, P.R. China, on June 1-4, 2011(Decoration June 1), The proceedings of the conference will be published by Publishing House of Electronics Industry of China.

NCMMW 2011 will surely attract a large number of scholars and industry companies of China Mainland, Hong Kong, Macao and Taiwan. It is a great opportunity for publicizing your company / products.

Contact: Mr. Wei, Ms Xu
Tel: 86-755-83655339, Fax: 86-755-83629073
Email: mwrf@vip.163.com kingradio@163.net
www.cnmw.org www.mws-cie.org/ncmmw2011

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- Analysis of 3G Noise to GPS in 3G Handsets
- Test Methods for Characterizing Microwave Materials
- Considerations for Measuring Pulsed Active Devices

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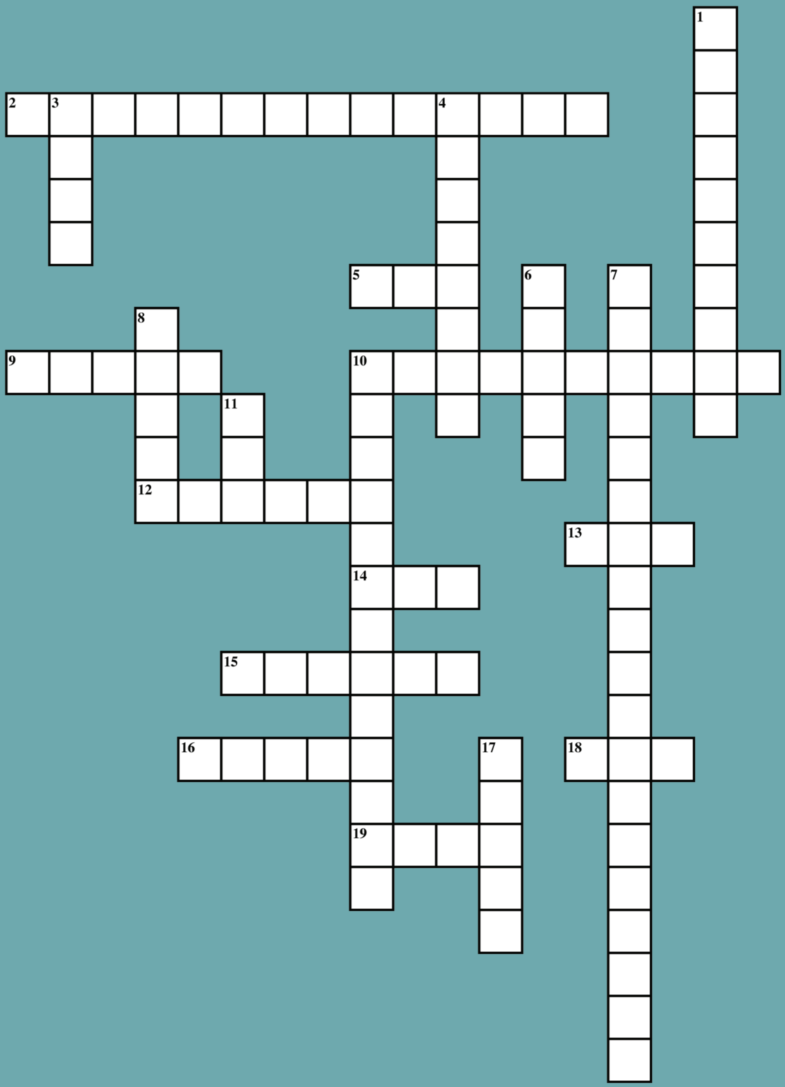

Across

2 A polynomial model for nonlinear behavior that accounts for memory effects (2 words)
5 Short for digital pre-distortion
9 mm-wave frequency best suited for high bandwidth, short-range applications due to high atmospheric attenuation
10 Random fluctuations in the phase of a signal (2 words)
12 mm-wave band of interest at 71-76 and 81-86 GHz for backhaul
13 Short for peak to average power ratio
14 Short for surface-mount components
15 The PA transfer function is not constant over time; this is called the ____ effect
16 Device process currently best suited for today's mm-wave MMICs according to the cover story
18 Low phase noise signal generators usually use ____ based oscillators, which have better performance than typical VCOs
19 Modulation scheme that has high peak to average power ratios

Down

1 The loss of signal power resulting from the reflection caused at a discontinuity (2 words)
3 Short for output third-order intercept point
4 ______ phase noise represents the phase noise of a signal generator not including the reference section
6 Device process that tends to offer a little more gain and slightly lower minimum NF than PHEMT, but has lower breakdown voltages and power densities
7 Results primarily from the thermal noise present in the generator; most of this is contributed by the PA in the output section (3 words)
8 Inductor designed to block (have a high reactance to) higher frequencies
10 Preprocessing the signal to a PA in order to improve its linearity
11 Using a divide-by-2 divider with a signal generator, the output frequency's phase noise will be ___ lower than the phase noise of the input frequency
17 Generally the phase noise at offsets greater______ is limited by this noise floor

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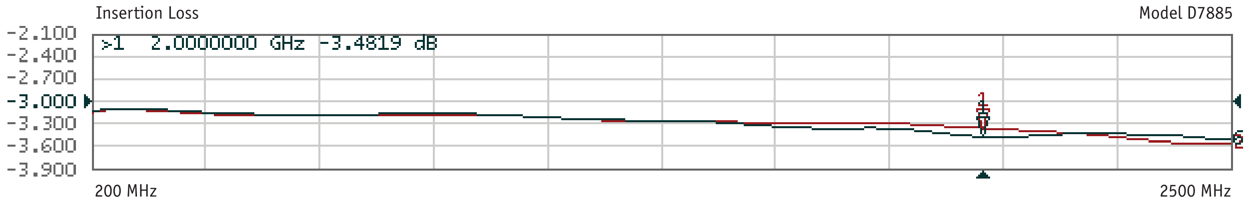

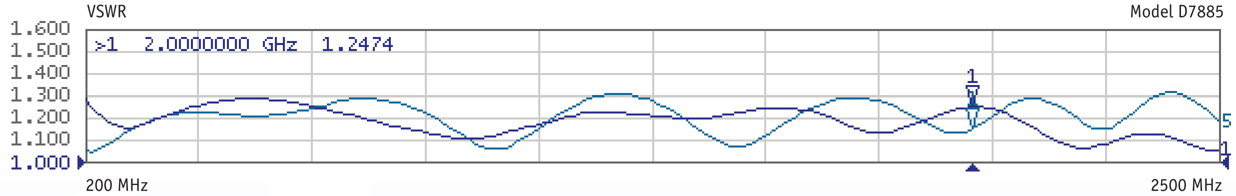

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D7630	2-Way	800-3000	200	0.4	1.35:1	15	3.7 x 1.9 x 0.87
D7539	4-Way	800-2800	200	0.6	1.35:1	17	5.5 x 4.1 x 1.1
D7695	4-Way	900-1300	100	0.4	1.30:1	20	4.0 x 3.3 x 0.8