Vol. 52 • No. 11

November 2009

Microwave Journal

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PASSIVE COMPONENTS

N-way Power Divider with Dual-frequency
Yang, Shi, Wang, X.Q. Chen, D.Z. Chen

Ultra-broadband Wilkinson Power Divider
Peláez-Peréz, Alónso, Almorox-González, González-Martin

Dual-band Wilkinson Power Divider
Li, L. Yang, Gong, Y.J. Yang, Hong, Chen

Multilayer Filter with Skew-symmetric Feeds
Zhu, Li, Xie, Yang

Dual Ring Balun-BPF
Kang, Hwang

Microstrip Bandpass Filter with Slotted Hexagonal Resonators
Li, Liu

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2 – 8	SW1-020080RN1NF	2	80	1.7:1	10/10	20	35	35/70
4 – 12	SW1-040120RN1NF	2.2	80	1.7:1	10/10	20	35	35/70
2 – 18	SW1-020180RN1NF	3	80	2:1	10/10	20	35	35/70
1 – 18	SW1-010180RN1NF	3	70	2:1	10/10	20	35	35/70
SP2T								
0.2 – 2	SW2-002020RN1NF	1.5	70	1.6:1	10/10	20	35	60/60
2 – 8	SW2-020080RN1NF	1.8	80	1.7:1	10/10	20	35	60/60
4 – 12	SW2-040120RN1NF	2.2	80	1.7:1	10/10	20	35	60/60
2 – 18	SW2-020180RN1NF	2.8	80	2:1	10/10	20	35	60/60
1 – 18	SW2-010180RN1NF	3	70	2:1	10/10	20	35	60/60
SP3T								
0.2 – 2	SW3-002020RN1NF	1.6	70	1.6:1	20/20	150	180	85/85
2 – 8	SW3-020080RN1NF	1.9	80	1.7:1	20/20	150	180	85/85
4 – 12	SW3-040120RN1NF	2.4	90	1.7:1	20/20	150	180	85/85
2 – 18	SW3-020180RN1NF	3	80	2:1	20/20	150	180	85/85
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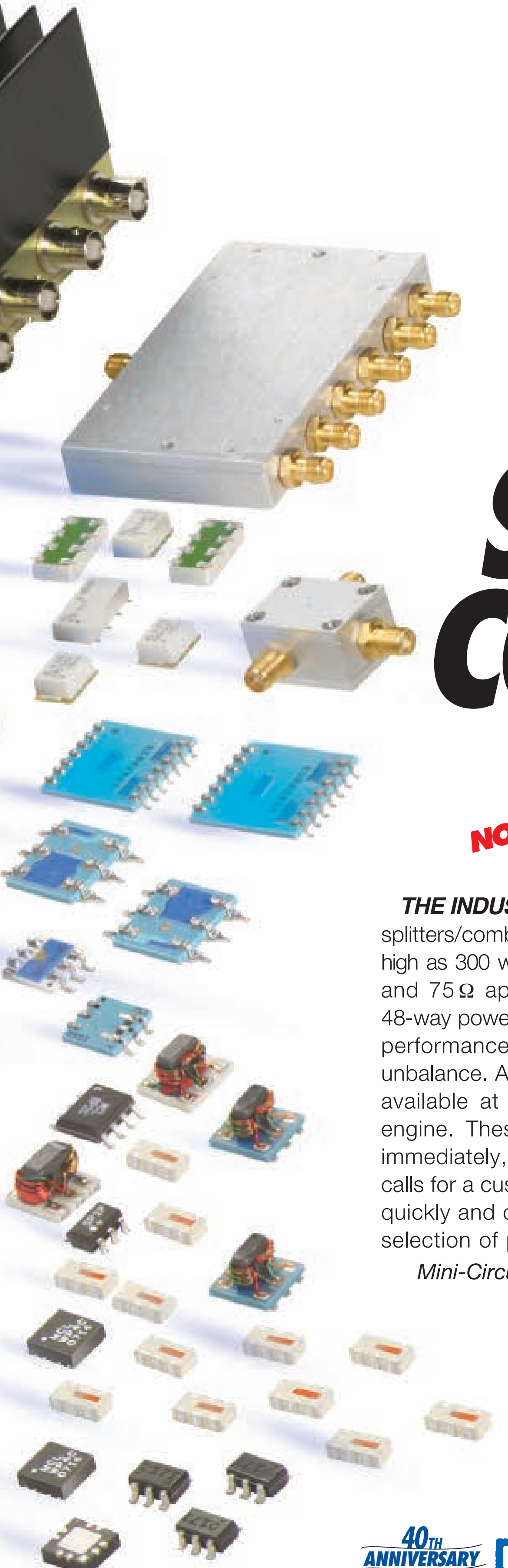

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Microwave Journal talks with **David Whitaker**, Passive Product Line Manager, **Anaren Microwave Inc**. Whitaker discusses his group's recent strategic acquisitions and the resulting impact on the company's competitiveness in the active assemblies and advanced PCB arenas.

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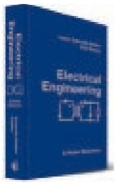
Greg Friesen is the Director of Product Management at **DragonWave**, a global supplier of packet microwave radio systems for mobile and access networks. Friesen will discuss "Network Engineering with Adaptive Modulation."



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SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
29	30	1 **Fall 2009 ARFTG Microwave Measurement Symposium** Boulder, CO (Dec. 1–4)	2	3 **INAS 2009 IEEE Conference on Antennas, Propagation and Systems** Johor, Malaysia (Dec. 3–5)	4	5
6	7 **APMC 2009** **Asia-Pacific Microwave Conference** Singapore (Dec. 7–10)	8	9 **RFIT 2009** **IEEE Radio Frequency Integration Technology Symposium** Singapore (Dec. 9–11)	10	11	12
13	14 **AEMC 2009** **IEEE Applied Electromagnetics Conference** Kolkata, India (Dec. 14–16)	15 **MWJ/Besser Webinar: RF Board Design** Besser Associates The Worldwide Leader in RF & Wireless Training	16	17	18	19 **ICMARS** (Dec. 19–21)
20 **ICMARS** **5th International Conference on Microwaves, Antenna, Propagation and Remote Sensing** Jodhpur, India	21	22	23	24	25	26
27	28	29 **MMWaTT** **First Conference on Millimeter-wave and Terahertz Technologies** Tehran, Iran (Dec. 29–31)	30	31	1	2

Next month:
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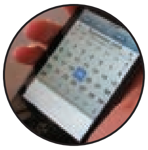

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NOVEMBER

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Antenna Measurement Techniques Association
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COMCAS 2009
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November 9–11, 2009 • Tel Aviv, Israel
www.comcas.org

Mediterranean Microwave Symposium
November 15–17, 2009 • Tangiers, Morocco
www.ieee.ma/mms2009/

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November 18–20, 2009 • Shanghai, China
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DECEMBER

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JANUARY

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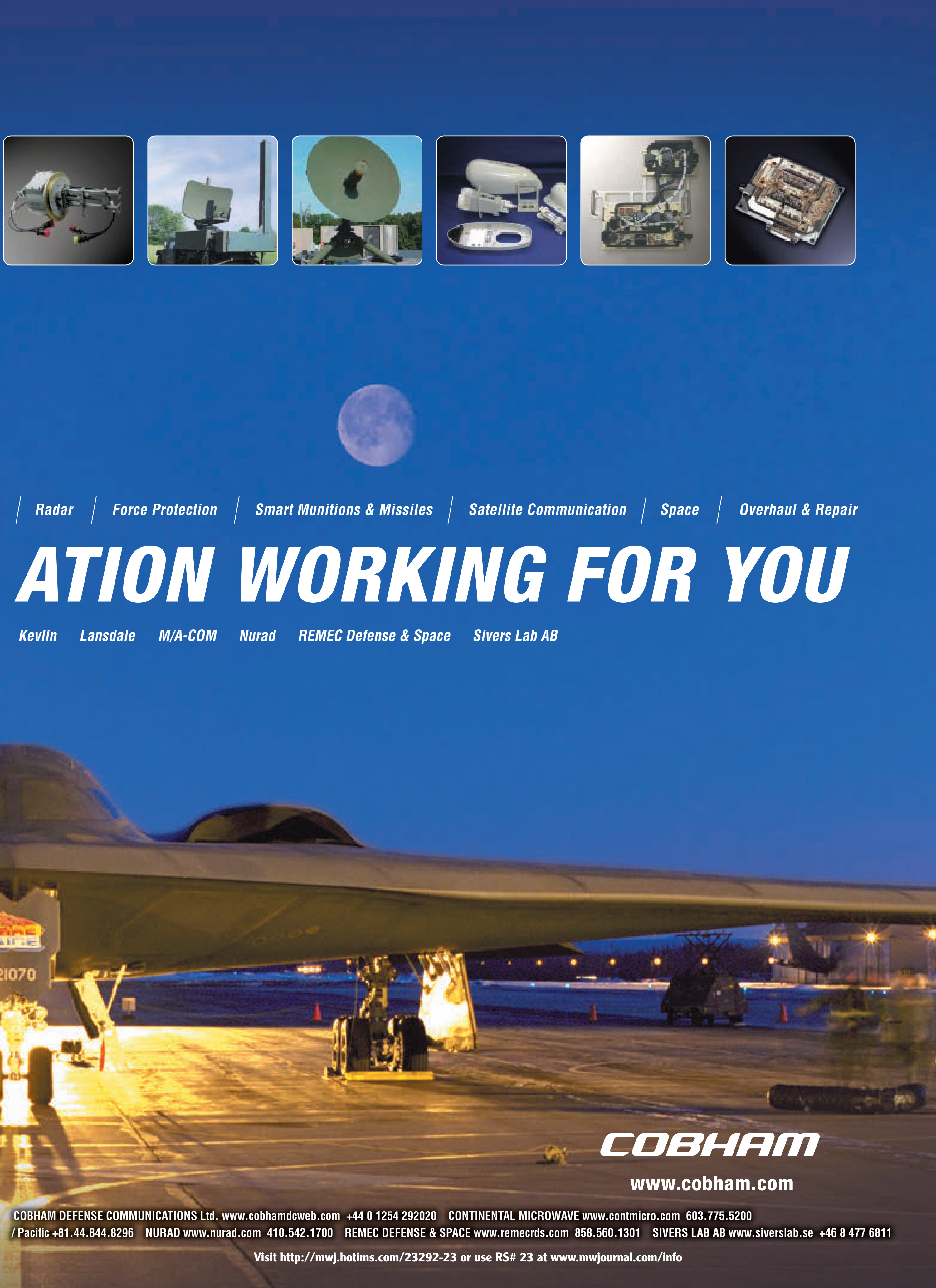
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PASSIVES: MAKING AN IMPACT

Passive microwave components are electrical elements without gain or directionality, yet they perform a range of functions such as signal attenuation, filtering, dividing/combining and routing. Designed for every medium from RF boards to System in Packages (SiP) to integrated circuits (MMIC/RFIC), passives are ubiquitous and essential. Driven by complex communication systems, today's passives must address high performance and unprecedented miniaturization at the lowest possible cost. Given these demands, considerable engineering effort is focused on developing enhanced passive devices.

As a result, *Microwave Journal* receives numerous papers detailing the use of new materials and circuit topologies. Among the various types of passives, the majority of submitted papers discuss novel technologies applied to filters and power combiners/dividers/couplers. This month, we are publishing a number of papers from our editorial backlog that address these types of passive designs.

From our divider/combiner/coupler files, we offer three board designs. Two of these tackle multi-band operations: one with an enhanced bandwidth Wilkinson power divider, the other with an N-way power divider. Both board designs demonstrate easy, low cost fabrication with minimal bill of materials and reasonable performance at the dual frequencies of 915, 2450 MHz and 1, 2.5 GHz. Our third divider paper is based on an ultra-broadband Wilkinson power divider operating from 15 to 45 GHz. This paper provides an excellent tutorial on basic multi-section divider theory and its implementation. Each of these three papers offers practical design information that should prove beneficial to our readers.

With multi-band radios and crowded frequency bands, filter performance is also important and therefore garners a good deal of engineering effort. While many filter companies keep quiet about their product's "secret sauce," the academic world is extremely generous in supplying *Microwave Journal* with content. Among these, we offer four technical papers this month.

A bandpass filter (BPF) can take many shapes as demonstrated in one paper discussing a compact elliptic-function BPF with slotted hexagonal resonators and open stubs for capacitive loading. Alternatively, an ultra-wideband (UWB) BPF operating from 3.1 to 10.6 GHz with a notched band from 7.5 to 7.6 GHz is achieved with two cascaded inter-digital hairpin resonators and four semi-circle defected ground structures (S_DGS). Improved selectivity and miniaturization are both addressed with a compact multi-layer filter design utilizing split-ring resonator (SRR) metamaterials and skew-symmetric feeds. Lastly, we offer a paper that integrates a balun and BPF with a center frequency of 2.45 GHz and a 90 MHz bandwidth utilizing a dual-ring structure to improve the balanced port characteristics.

If you design either type of passive, we hope this issue is particularly useful. If you currently don't, save this *Journal* for the day that you might. After all, even though these devices are passive, their impact on system performance is anything but inert.

DAVID VYE
Editor, Microwave Journal

Design Method of an N-way Power Divider with Dual-frequency

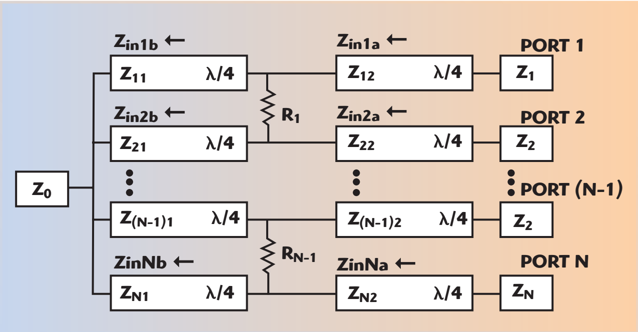
A novel planar N-way dual-frequency power divider is presented. The topology of the circuit consists of two sections of N transmission lines and 2N-2 planar isolation resistors, which provides enough isolation at two arbitrary frequencies. The structure of the power divider and the formulas used to determine the design parameters are derived. For verification purposes, a three-way power divider with a power split ratio of 1: 2: 3 at both frequencies 915 and 2450 MHz has been fabricated using microstrip technology. The measured results are in good agreement with the predicted ones.

A power divider is one of the most important passive circuits used in microwave and millimeter-wave applications. In 1960, Wilkinson proposed an N-way in-phase power divider.[1] He described a circularly symmetric power divider, which split a signal into N-equiphase and equiamplitude signals with an even or odd number N. Since then, several different N-way power dividers have been proposed.[2,3] All of them are for equal power dividers. In 2004, an N-way power divider with an arbitrary power split ratio was proposed by Ahn.[4] In Ahn's article, the circuit and design formulas are given, resulting in high isolation between ports. However, the structure of the divider is difficult to fabricate and it operates at a single frequency. In 2003, a small dual-frequency transformer section was introduced by Monzon,[5] which operates at any two arbitrary frequencies, f_1 and f_2. In this article, an extension of Monzon's analysis to the design of an improved N-way dual-frequency power divider is presented. The proposed power divider operates at two arbitrary frequencies f_1 and f_2, and with an arbitrary power split. The design equations are given and a new circuit is proposed, which is easy to fabricate and also has a high isolation. To verify the design method, a three-way power divider, with a power split ratio of 1: 2: 3 at both frequencies 0.915 and 2.45 GHz, which can be used in RFID applications, has been simulated and fabricated using microstrip technology. The validity of this analysis is demonstrated by experimental results.

Analyses and Design Equations

The configuration of an N-way arbitrary power divider with arbitrary power division ratio is depicted in ***Figure 1***, where all the transmission lines are $\lambda/4$ long, $Z_{11}, Z_{12}, Z_{21}, \ldots, Z_{N2}$ represent the characteristic impedances of 2N transmission lines, respectively. If the power

Y.Y. Yang, X.W. Shi, X.H. Wang, X.Q. Chen and D.Z. Chen
Xidian University, Shanxi, China



▲ *Fig. 1 Diagram of an N-way arbitrary power divider.*

split ratio is P_1: P_2: P_3…: P_N = K_1: K_2: K_3…: K_N, the following equations can be obtained:

$$Z_{inja} = \frac{Z_s}{K_j}, j = 1, 2, \ldots, N \qquad (1)$$

$$Z_{j1} = \sqrt{Z_{inja} * Z_{injb}}, j = 1, 2, \ldots, N \qquad (2)$$

$$Z_{j2} = \sqrt{Z_0 * Z_{inja}}, j = 1, 2, \ldots, N \qquad (3)$$

$$\frac{1}{Z_{in1b}} : \frac{1}{Z_{in2b}} : \frac{1}{Z_{in3b}} \ldots : \frac{1}{Z_{inNb}} = K_1 : K_2 : K_3 \ldots : K_N \qquad (4)$$

$$\frac{1}{Z_{in1b}} + \frac{1}{Z_{in2b}} + \frac{1}{Z_{in3b}} \ldots + \frac{1}{Z_{inNb}} = \frac{1}{Z_0} \qquad (5)$$

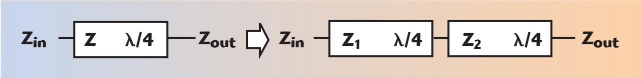
where Z_s is an arbitrary design impedance, which can be determined by the design situation, Z_{in1b}, Z_{in2b},…, Z_{inNb} are the final output termination impedances and Z_{j1}, Z_{j2} are the characteristic impedances of additional impedance transformers. By solving Equations 1 to 5, the design equations can be obtained:

$$Z_{injb} = \frac{K_1 + K_2 \ldots + K_N}{K_j} Z_0, j = 1, 2, \ldots, N \qquad (6)$$

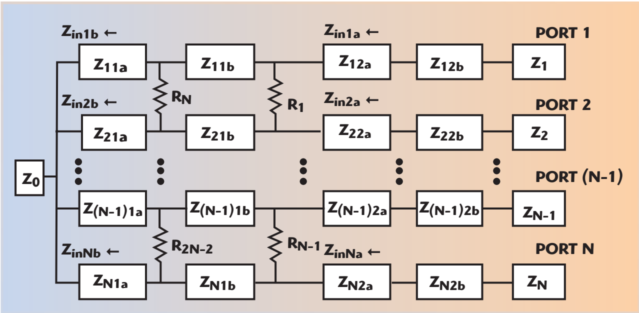
$$Z_{j1} = \frac{\sqrt{K_1 + K_2 \ldots K_n * \sqrt{Z_0 Z'}}}{K_j}, j = 1, 2 \ldots, N \qquad (7)$$

$$Z_{j2} = \frac{1}{\sqrt{K_j}} Z_{0,} j = 1, 2 \ldots, N \qquad (8)$$

By using Equations 1, 6, 7 and 8, a power divider with arbitrary split ratios can be designed. The isolation resistor R can be determined by



▲ *Fig. 2 An equivalent transformer using two quarter-wave sections.*



▲ *Fig. 3 N-way arbitrary dual-frequency power divider.*

$$R_j = Z'\left(\frac{1}{K_j} + \frac{1}{K_{j+1}}\right), j = 1, 2, \ldots, N-1 \qquad (9)$$

In 2003, Monzon[5] proposed a transformer operating at two different frequencies by splitting each quarter-wave branch into two sections with characteristic impedances Z_1 and Z_2 and length L, respectively. This could operate at any two arbitrary frequencies f_1 and f_2, as shown in ***Figure 2***. Here, an extension of Monzon's analysis to the design of an improved N-way dual-frequency power divider is presented. A schematic diagram of the proposed Wilkinson unequal power divider, which operates at two arbitrary frequencies and with an arbitrary power split, is shown in ***Figure 3***.

It is necessary to determine the input and output impedances of each branch (Z_{in} and Z_{out}) of the unequal power divider using Monzon's theory. Using Equations 1 to 6, Z_{inLa} and Z_{inLb} can be determined. Since Z_0 is known, Z_{in} and Z_{out} are determined. The parameters of the unequal power divider can be determined by Monzon's theory (here, f_2 greater than f_1 is assumed):

$$L = \frac{\pi}{\beta_1 + \beta_2} \qquad (10)$$

$$Z_1 = \sqrt{\frac{Z_{in}}{2\alpha}(Z_{out} - Z_{in}) + \sqrt{\left[\frac{Z_{in}}{2\alpha}(Z_{out} - Z_{in})\right]^2 + Z_{in}^3 Z_{out}}} \qquad (11)$$

$$Z_2 = \frac{Z_{in} Z_{out}}{Z_1} \qquad (12)$$

$$\alpha = (\tan(\beta_1 L))^2 \qquad (13)$$

$$\beta = \frac{2\pi}{\lambda} \qquad (14)$$

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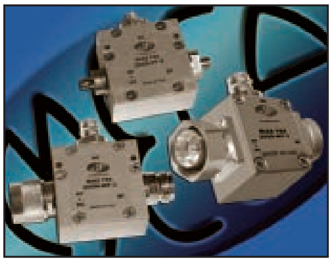

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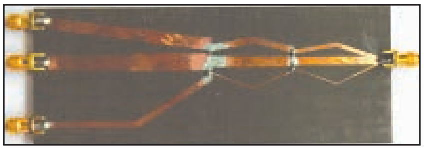
TABLE I
DESIGN DATA FOR A THREE-WAY POWER DIVIDER

	Ω	*W (mm)*	*L (mm)*
Z11a	134.2	0.27	32.0
Z11b	111.7	0.50	32.0
Z12a	50.0	2.65	32.0
Z12b	50.0	2.65	32.0
Z21a	44.8	3.15	29.8
Z21b	37.3	4.11	29.8
Z22a	27.1	6.28	29.3
Z22b	30.7	5.34	29.3
Z31a	67.1	1.61	30.5
Z31b	55.9	2.22	30.5
Z32a	33.9	4.67	29.6
Z32b	36.8	4.17	29.6



▲ *Fig. 4 Photograph of the fabricated dual-frequency unequal power divider.*

EXPERIMENT AND RESULTS

The three-way dual-frequency power divider was fabricated on a 1 mm thick substrate, with a relative permittivity of 2.65. The power divider is designed for f_1 = 0.915 GHz and f_2 = 2.45 GHz, with power division ratios of $K_1{:}K_2{:}K_3$= 1: 2: 3. The simulation, with models of a real lumped component and a real substrate, was done with AWR2006 software, and the measured data was collected from an Agilent N5230A network analyzer.

The design parameters of the power divider are calculated first. Using Equation 10, the length of each transformer section is L = 30.04 mm. Let $Z_s = Z_0 = 50\ \Omega$. Using Equation 1, the input impedances of the four transformer sections can be determined as Z_{in1a} = 50 Ω, Z_{in2a} = 16.67 Ω, Z_{in3a} = 25 Ω and Z_{in1b} = 300 Ω, Z_{in2b} = 150 Ω, Z_{in3b} = 100 Ω<, respectively. The resistances R_1, R_2, R_3 and R_4 of the planar isolation resistors are selected as R_1 = 82 Ω, $R_2 = R_3 = R_4$ = 39 Ω. The characteristic impedances and their widths and optimized lengths of the microstrip lines on Teflon substrate are given in ***Table 1***.

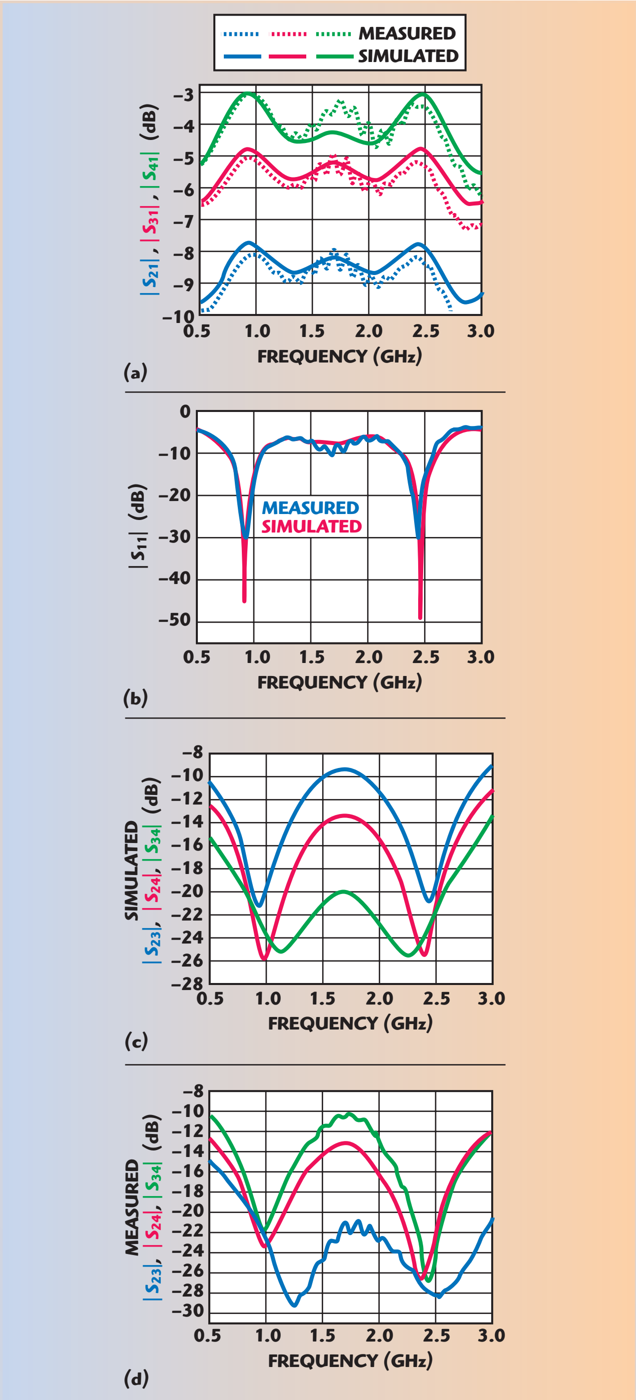
Figure 4 shows a photograph of the fabricated power divider. The measured and simulated S-parameters are shown in ***Appendix A***. The measured insertion loss results are approximately S_{21} = 8.20 dB, S_{31} = 5.10 dB, S_{41} = 3.08 dB at 0.915 GHz and S_{21} = 8.36 dB, S_{31} = 5.31 dB, S_{41} = 3.47 dB at 2.45 GHz, respectively. These indicate that the designed power divider can successfully separate an incoming signal into three parts with the power ratio of 1:2:3. The measured isolation is greater than -20.5 dB at 0.915 GHz and -26.7 dB at 2.45 GHz. The measured isolation between port 2 and port 4 are also greater than -21 dB at 0.915 GHz and -28.2 dB at 2.45 GHz.

CONCLUSION

An N-way dual-frequency arbitrary power divider is presented in this article, which fulfills an arbitrary unequal power split at two arbitrary frequencies. The structure, consisting of two sections of N transmission lines and 2N-2 planar isolation resistors, is easily fabricated. The design formulas, which are used to determine the design parameters, have been given. A good agreement between the simulation and measurement has been achieved. ■

References

1. E.J. Wilkinson, "An N-way Hybrid Power Divider," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 8, No. 1, January 1960, pp. 116-118.
2. U. Gysel, "A New N-way Power Divider/Combiner Suitable for High Power Applications," *1975 IEEE MTT-S International Microwave Symposium Digest*, pp. 116-118.
3. F.A. Ahargan, "Circular and Annular Sector Planar Components of Arbitrary Angle for N-way Power Divider/Combiners," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 42, No. 7, July 2001, pp. 1617-1623.
4. H.R. Ahn, K. Lee and N.H. Myung, "General Design Equations of N-way Arbitrary Power Dividers," *2004 IEEE MTT-S International Symposium Digest*, Vol. 1, pp. 65-68.
5. C. Monzon, "A Small Dual-frequency Transformer in Two Sections," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, No. 4, April 2003, pp. 1157-1161.



▲ *Appendix A Simulated and measured S-parameters for a power split of 1, 2, 3 at 0.915 and 2.45 GHz.*

ULTRA-BROADBAND MMWAVE WILKINSON POWER DIVIDER

The frequency spectrum is currently used for many applications and this resource is limited. There is also a growing demand for the use of higher frequencies, resulting from the demand from electronic warfare systems. Therefore, it is necessary to use the high band spectrum. The main advantages of working at high frequencies include more available bandwidth, smaller circuits, less interference with other services, and a less saturated spectrum.[1] In this context, ultra-wideband microwave circuits have gained prominence in radiocommunications systems because many applications demand the use of large bandwidths and these kinds of circuits are of great relevance in microwave technology.

The advantage of working at high frequencies is making the development of radio-communications systems possible at frequencies of up to 30 GHz. This implies the resolution of new technological problems in addition to the design, assembly and manufacturing problems in these frequency bands. There are currently multiple applications that work in the millimeter-wave band. Specifically, there are very interesting applications in the area of electronic warfare, such as high resolution radar or in the area of communications, such as LMDS or WiMAX systems.

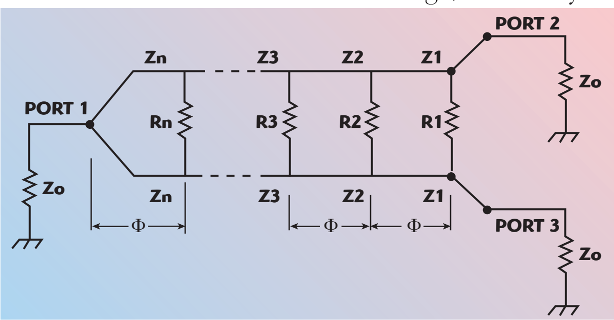


Fig. 1 Multisection Wilkinson power divider.

Power dividers are key circuits used in many microwave applications. The function of these circuits is to divide the input signal into two or more output signals of lower power. In this article, a two-section Wilkinson power divider in microstrip technology, which covers a bandwidth of 1.585 octaves (15 to 45 GHz), has been designed, developed and measured. The measured results show good agreement with the simulations.

BASIC THEORY

Multi-section Wilkinson power dividers consist of λ/4 transmissions line sections loaded with end resistances. This structure is shown in ***Figure 1***. In such circuits, as the number of sections is increased, the bandwidth and isolation substantially increase, although insertion losses become higher. The characteristic impedances of each section can be obtained from the normalized impedances for λ/4 transformers with a transformation ratio of 2:1.[2]

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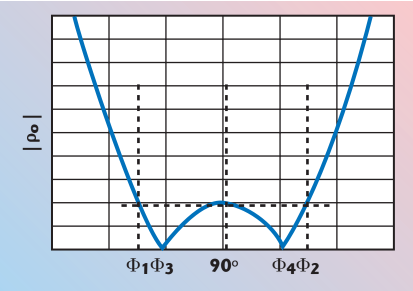
The nominal value of each end resistor depends on the characteristic impedances, and the lower and higher frequencies of the operating band.[3]



▲ *Fig. 2 Reflection coefficients ρ_o and ρ_e.*

Two-section Wilkinson Power Divider Design Techniques

The odd reflection coefficient, ρ_o, of a two-section Wilkinson power divider depends on the electrical length Φ of each section and can be represented as a symmetric function of approximately $\Phi = 90°$. The location of the odd and even reflection coefficients for a two-section Wilkinson power divider is shown in ***Figure 2***. If the design process is particularized for two sections, the input admittance ($Y_{in,o}$) and the reflection coefficient ρ_o can be easily determined through the transmission line theory. These expressions are:

$$Y_{in,0} = 2G_1 + Y_1 \frac{Y_1 + (2G_2 + Y_2 s)s}{2G_2 + (Y_1 + Y_2)s} \tag{1}$$

$$\rho_0 = \frac{1 - Y_{in,o}}{1 + Y_{in,o}} = \frac{2G_2\left(1-2G_1\right) - Y_1^2 - Y_1Y_2s^2 + \left[\left(Y_1+Y_2\right)\left(1-2G_1\right) - 2G_2Y_1\right]s}{2G_2\left(1+2G_1\right) + Y_1^2 + Y_1Y_2s^2 + \left[\left(Y_1+Y_2\right)\left(1+2G_1\right) + 2G_2Y_1\right]s} \tag{2}$$

$$s = -j\cot\varphi \tag{3}$$

where G_1 and G_2 are the conductances of the resistors making up the divider, and Y_1 and Y_2 are the admittances of the transmission lines.

To achieve the cancellation of the reflection coefficient ρ_o at points Φ_3 and Φ_4, the real and imaginary parts of the numerator of Equation 2 must be zero. Therefore, the following expressions are obtained for the real and imaginary parts:

$$2G_2\left(1-2G_1\right) - Y_1^2 - Y_1Y_2s^2 = 0 \tag{4}$$

$$\left(Y_1+Y_2\right)\left(1-2G_1\right) - 2G_2Y_1 = 0 \tag{5}$$

From Equations 3, 4 and 5, the values of the resistors that are part of the Wilkinson power divider can be obtained. Therefore, the resistor expressions are given by Equations 6 and 7

$$R_2 = \frac{2Z_1Z_2}{\sqrt{\left(Z_1+Z_2\right)\left(Z_2 - Z_1\cot^2\Phi_3\right)}} \tag{6}$$

$$R_1 = \frac{2R_2\left(Z_1+Z_2\right)}{R_2\left(Z_1+Z_2\right) - 2Z_2} \tag{7}$$

The expression that relates Φ_3 with Φ_1 can be obtained through the second degree Chebyshev polynomial: T2(x) =

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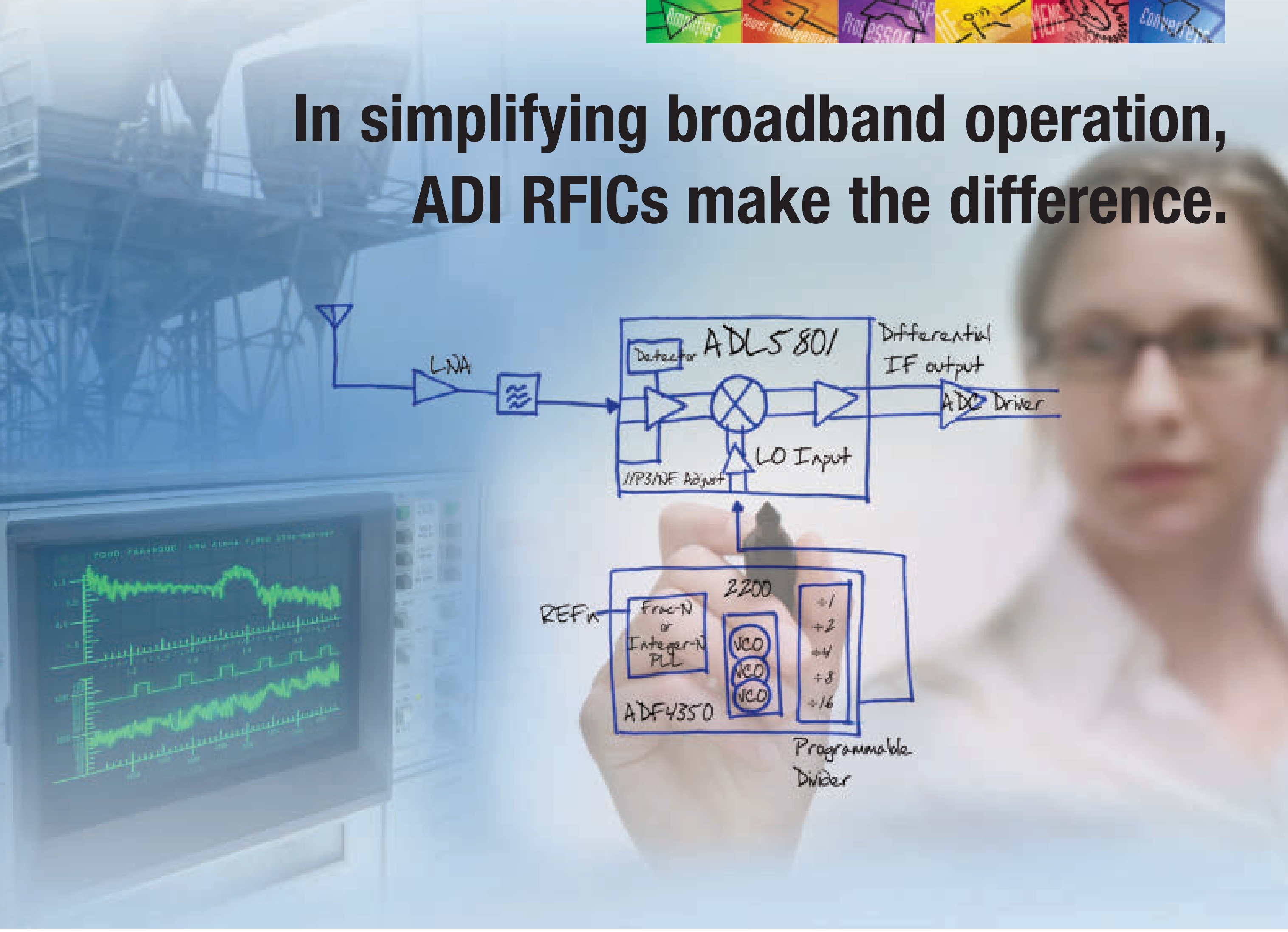

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$2x^2$-1, where x = (90° - Φ)/ (90° - Φ_1). The result is shown in Equation 8:

$$\Phi_3 = 90 - \frac{1}{\sqrt{2}}\left(90 - \Phi_1\right) = 90\left[1 - \frac{1}{\sqrt{2}}\left(\frac{f_2/f_1 - 1}{f_2/f_1 + 1}\right)\right] \quad (8)$$

where f_2 and f_1 are the higher and lower frequencies of the operating band, respectively.

The design process of the two-section Wilkinson power divider can be systematized in three steps (see ***Figure 3***):

- Calculation of the characteristic impedances Z_2 and Z_1. These impedances can be obtained from the tables for cascade λ/4 transformers.[2] For an impedance transformation ratio R = 2 and a bandwidth W = 2(f_2-f_1)/ (f_2+f_1), the characteristic impedances of the transmission line sections of a two-section Wilkinson power divider can be obtained.
- Calculation of the value of Φ_3 from Equation 8.
- Calculation of the resistor values at the end of each transmission line section through Equations 6 and 7.

TWO-SECTION WILKINSON POWER DIVIDER

Taking into account the considerations of the last section, an ultra-wideband power divider has been designed, with a successful response up to 40 GHz. The power divider operation specifications consist of getting insertion losses lower than 1 dB and return losses higher than 10 dB.

A two-section Wilkinson power divider was designed and developed, and is shown in ***Figure 4***. A 0.254 mm thick alumina substrate, with a relative dielectric constant of ε_r = 9.9 is used, because of the requirements of the electronic warfare systems developed by Indra Sistemas S.A. This design uses an impedance transformation ratio R = 2; the selected bandwidth is W = 2(48-12)/(48+12) = 1.2. For these values and for a Chebyshev design, a normalized impedance Z_1 = 1.29545 is obtained. Therefore, the second section impedance is: Z_2 = R/Z_1 = 2/1.29545 = 1.5439.

The second step is to calculate Φ_3 to determine the resistor's values. Therefore, Φ_3 = 90° {1-1/√2) [(f_2/f_1-1)/ (f_2/f_1+1)]} = 51.816°, and the resistor values can be obtained from Equations 9 and 10

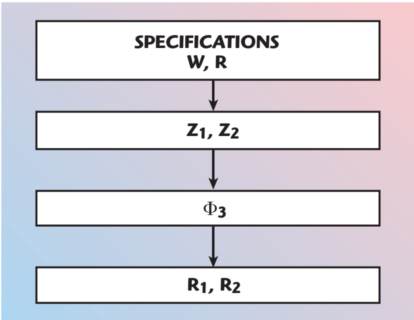
$$R_2 = \frac{2Z_1Z_2}{\sqrt{\left(Z_1+Z_2\right)\left(Z_2 - Z_1\cot^2\Phi_3\right)}} = 2.7548 \quad (9)$$

$$R_1 = \frac{2R_2\left(Z_1+Z_2\right)}{R_2\left(Z_1+Z_2\right) - 2Z_2} = 3.3046 \quad (10)$$

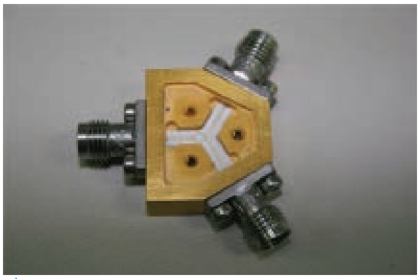
The Wilkinson resistors will be realized with printed resistors because it is not possible to use chip resistors at millimeter-wave frequencies. Printed resistors are obtained by depositing a certain material layer on the substrate used. The printed resistor value depends on different parameters, the resistivity and thickness of the material and the size of the resistor. An expression to calculate the resistor value in accordance with the physical dimensions is given in Equation 11

$$R = r_0 \frac{l}{e \cdot w}\,\mathrm{res}\left(\Omega/\mathrm{square}\right)\frac{l}{w} \quad (11)$$

where w is the width of the resistor, l its length, r_0 the material resistivity, e its thickness and res(Ω/square) is the



▲ *Fig. 3 Wilkinson power divider design flow chart.*



▲ *Fig. 4 Photograph of the developed Wilkinson power divider.*

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resistance in ohms per square. Resistors of 50 Ω/square will be used in the manufacturing process because it is the most common value. This fact implies that the resistor size determines the nominal value of the resistor. A crucial aspect in the circuit design is to choose the appropriate dimension of the resistors. Therefore, the discontinuities between the power divider branches can be avoided. Thus, the width of the selected resistor is the minimum set out by the manufacturing process (5.9 mils). The length of the resistor is determined by the resistor nominal value desired (13.8 mils).

Other important aspects are the discontinuities and the bends in the output branches, which must be carefully designed because these discontinuities can significantly degrade the response of the circuit. The proposed design in this article is made up of circular transmission line sections to avoid coupling between the branches.[4] The discontinuity caused by the angle between the two transmission line sections does not have an equivalent circuit model and its parameters are optimized through electromagnetic simulation with the Momentum tool of the Advanced Design System software.

The bend in the output transmission line has also been optimized using Momentum to get the best circuit response. The design of the output bend is extremely important because its response affects the output return losses. In the literature, there are different bend models in microstrip technology. The most usual case is the bend whose union between the two lines is 90°. However, for this design, one of the conditions required is that the angle of the output transmission lines should be 60° on the x-axis (for mechanical considerations). Therefore, the literature models cannot be used and electromagnetic optimizations have to be used to design the bend that introduces the best possible return losses in the output ports.

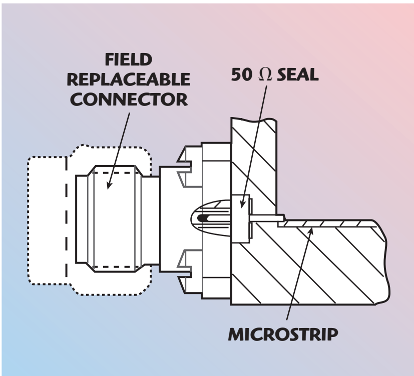
Another problem in the design of the power divider is the size of the circuit transmission lines, because the substrate determines an inappropriate dimension of the second transmission line. To solve this problem, the second section of length λ/4 was replaced by a line 3λ/4 long, because the substrate could not be changed, as Indra Sistemas S.A. imposes the use of alumina to make the integration of the divider in its systems easier; this splitter is part of a wafer, where different integrated circuits for electronic warfare are developed. Although the introduction of a 3λ/4 transmission line will change the theoretical response of the divider, in particular the minimum positions, the new design continues to fulfill the bandwidth specifications.

SIMULATIONS AND MEASUREMENTS

To perform measurements in the millimeter-wave band, equipment, connectors and cables that work correctly up to 50 GHz are required, but it is difficult to have the equipment work properly at these high frequencies. The most sensitive elements are the connectors, whose response degrades considerably as the operating frequency of the device increases. Therefore, it is necessary to choose connectors that work up to high frequencies and to make a suitable design of the coaxial to microstrip transition to improve the device's operating range.

In this project, the vector network analyzer PNA5230A, the N4693A calibration kit (both from Agilent) and connectors with a 50 Ω seal of 9 mils from SouthWest Microwave, model 1414-06SF 2.4 mm,[5] have been used (see ***Figure 5***). Reliable measurements can be taken with this measurement bench up to 50 GHz, if the effects of coaxial cables and connectors are eliminated through proper calibration.

The power divider assembly process has been done carefully, because a poor welding can significantly degrade the circuit response. Despite



▲ *Fig. 5 Connector with seal.*

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0.78 - 0.87	-120 dBc/Hz	-147 dBc/Hz	+12	190	-221 / -226	0.05 deg rms	**HMC824LP6CE**
0.99 - 1.105	-118 dBc/Hz	-145 dBc/Hz	+10	190	-221 / -226	0.07 deg rms	**HMC826LP6CE**
1.285 - 1.415	-116 dBc/Hz	-142 dBc/Hz	+10	190	-221 / -226	0.10 deg rms	**HMC828LP6CE**
1.25 - 1.62	-115 dBc/Hz	-142 dBc/Hz	+10	190	-221 / -226	0.10 deg rms	**HMC822LP6CE**
1.72 - 2.08	-113 dBc/Hz	-140 dBc/Hz	+10	190	-221 / -226	0.12 deg rms	**HMC821LP6CE**
1.815 - 2.01	-112 dBc/Hz	-141 dBc/Hz	+9	190	-221 / -226	0.13 deg rms	**HMC831LP6CE**
2.05 - 2.5	-110 dBc/Hz	-139 dBc/Hz	+10	190	-221 / -226	0.17 deg rms	**HMC820LP6CE**
3.365 - 3.705	-107 dBc/Hz	-135 dBc/Hz	0	190	-221 / -226	0.25 deg rms	**HMC836LP6CE**
7.3 - 8.2	-102 dBc/Hz	-140 dBc/Hz	+15	196	-221 / -226	0.55 deg rms	**HMC764LP6CE**
7.8 - 8.5	-102 dBc/Hz	-139 dBc/Hz	+13	193	-221 / -226	0.58 deg rms	**HMC765LP6CE**
11.5 -12.5	-100 dBc/Hz	-134 dBc/Hz	+11	181	-221 / -226	0.78 deg rms	**HMC783LP6CE**
12.4 - 13.4	-98 dBc/Hz	-134 dBc/Hz	+8	175	-221 / -226	0.81 deg rms	**HMC807LP6CE**

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	Frequency (GHz)	Function	Output Power (dBm)	10 kHz SSB Phase Noise (dBc/Hz)	100 kHz SSB Phase Noise (dBc/Hz)	Frequency Drift (ppm/°C)	Bias Supply	Package	Part Number
NEW!	8.0 - 8.3	Dielectric Resonator Oscillator	14.5	-124	-140	2	+6 to +15V @ 125 mA	C-18 / SMA	**HMC-C200**

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this, problems have been detected in the assembly of the box with the connectors. One of them has been the irregularity of the pearl outer ring, which causes a bad contact between the connector and the microstrip transmission line. Furthermore, the connectors are very delicate and deteriorate easily, because the circular section of the inner conductor connector can be deformed, causing important attenuation peaks in the circuit transmission response. The circuit simulation takes into account the effects of the connectors, which have been modeled with the equivalent circuit shown in ***Figure 6***. In the equivalent circuit, the first coaxial represents the seal; the third coaxial simulates the pin, and the second coaxial is introduced to decrease the discontinuity effect between the seal and the pin. The capacity C1 simulates the discontinuity between the seal coaxial (CX1) and the compensation coaxial (CX2), because of a change in the outer diameter and in the permittivity of the medium. The capacity C2 models the discontinuity between the compensation coaxial (CX2) and the pin coaxial (CX3), because of a change in the outer diameter. The capacity C3 simulates the discontinuity between the pin coaxial (CX3) and the pin, resulting from a change in the propagation medium. Finally, the coaxial-to-microstrip transition is modeled by the inductor L1, the capacity C4, the resistor R and the transmission line TL1. The 2.4 mm connector 1414-06SF has been characterized previously[6] through electromagnetic simulations with the CST software and by means of connector measurements. The connector equivalent circuit values are shown in ***Table 1***. ***Figure 7*** shows a close view of the developed Wilkinson power divider. Comparisons between the Momentum electromagnetic response and the measurements of the developed Wilkinson power divider are presented in ***Figures 8, 9*** and ***10***.

TABLE I
CONNECTOR EQUIVALENT CIRCUIT VALVES

C1 (pF)	0.0001
C2 (pF)	0.0001
C3 (pF)	0.005
C4 (pF)	0.018
L1 (nH)	0.081

The measured responses are very similar to the Momentum simulations. The transmission response has a peak-to-peak ripple amplitude of 1 dB up to 38.3 GHz. Above this frequency, the response falls slightly and the peak-to-peak ripple amplitude is 2 dB in the operating band: 15 to 45 GHz. The input reflection is better than 10 dB up to 38.7 GHz. The output reflection is better than 10 dB up to 40 GHz. The response deterioration at 40 GHz is the result of the connectors mismatch.

CONCLUSION

An ultra-broadband power divider for the millimeter-wave band has been designed, developed and measured. The main problems of using millimeter frequencies have been studied and solved. The designed circuit presents good performance in a wide band (15

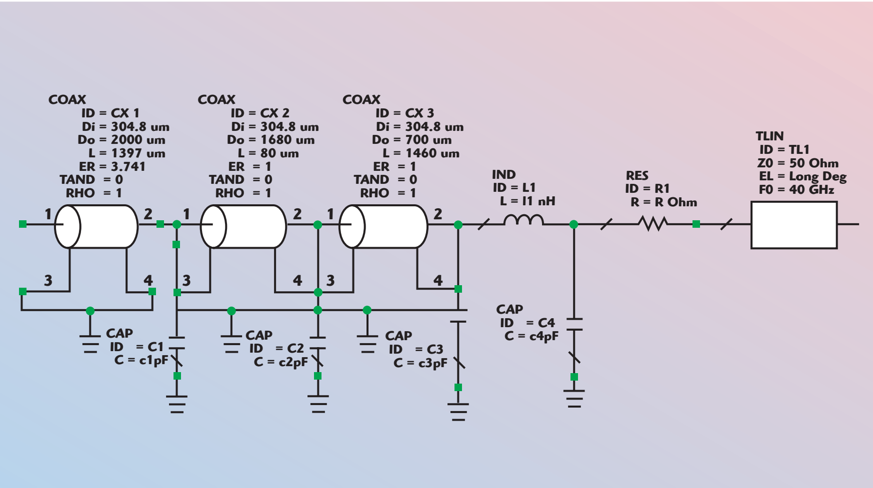

Fig. 6 Equivalent circuit of the connector.

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IN-STOCK HIGH SPEED COMPARATORS

	Analog Input B/W (GHz) / Clock Rate (Gpbs)	Function	Deterministic Jitter (ps)	Propagation Delay (ps)	Output Voltage Swing (Vdc)	DC Power Consumption (mW)	Vcco / Vterm [2] Power Supply (Vdc)	Package	Part Number
NEW!	10 / 20	Clocked Comparator - RSPECL	<3	120	0.4	150	+3.3 / +1.3	LC3C	HMC874LC3C
NEW!	10 / 20	Clocked Comparator - RSCML	<3	120	0.4	130	0 / 0	LC3C	HMC875LC3C
NEW!	10 / 20	Clocked Comparator - RSECL	<3	120	0.4	150	0 / -2.0	LC3C	HMC876LC3C
	9.7 / [1]	Latched Comparator - RSPECL	2	85	0.4	140	+3.3 / +1.3	LC3C	HMC674LC3C
	9.7 / [1]	Latched Comparator - RSCML	2	100	0.4	100	0 / 0	LC3C	HMC675LC3C
	9.7 / [1]	Latched Comparator - RSECL	2	100	0.35	120	0 / -2.0	LC3C	HMC676LC3C

[1] Note that HMC674/675/676LC3C is a family of Level Latched Comparators
[2] Vee = -3.0V & Vcci = +3.3V

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	Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	Part Number
	0.2 - 4.0	Low Noise, High IP3	13	40	2.2	22	+5V @ 155mA	ST89	HMC636ST89E
NEW!	0.04 - 1.0	50 / 75 Ohm Differential Gain Block	16	40	2.5	23.5	+5V @ 270mA	LP4B	HMC770LP4BE
	DC - 1	HBT Gain Block, 75 Ohm	14	38	5.5	21	+5V @ 160mA	S8G	HMC754S8GE
	0.05 - 3.0	HBT Gain Block	15	40	3.5	18	+5V @ 88mA	ST89	HMC740ST89E
	0.05 - 3.0	HBT Gain Block	20	42	2.5	18	+5V @ 96mA	ST89	HMC741ST89E
NEW!	0.7 - 2.8	High IP3 HBT Driver Amplifier	18	42	3.8	25	+5V @ 125mA	ST89	HMC789ST89E

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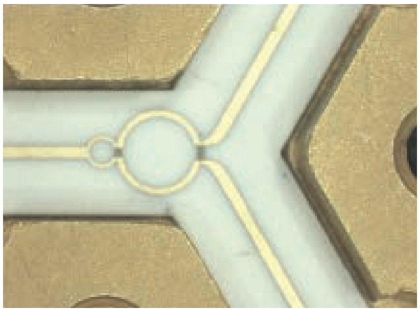

Fig. 7 *Close view of the developed Wilkinson power divider.*

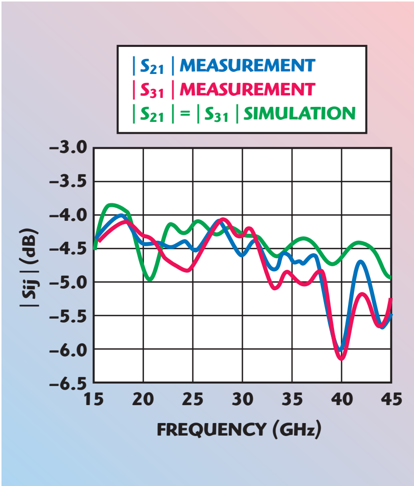

Fig. 8 *Insertion losses of the two-section Wilkinson power divider.*

to 45 GHz). This power divider can be used in more complex circuits for electronic warfare or other applications.

ACKNOWLEDGMENT

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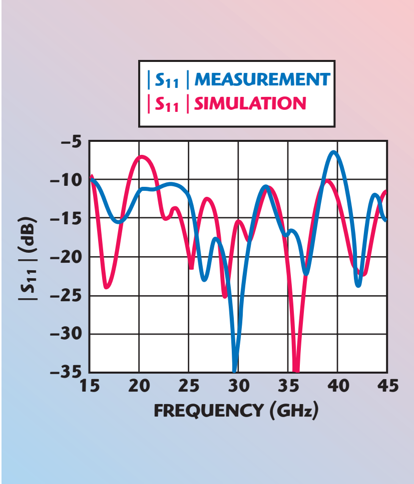

Fig. 9 *Input return losses of the two-section Wilkinson power divider.*

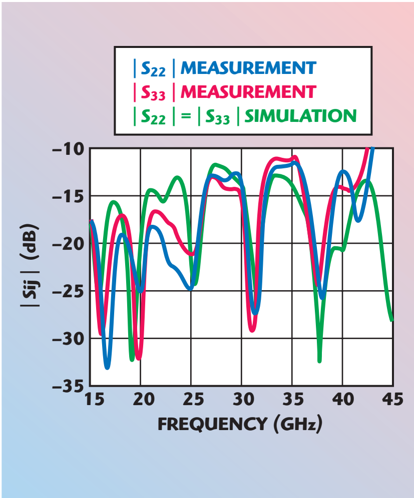

Fig. 10 *Output return losses of the two-section Wilkinson power divider.*

References

1. M. Alexander Morgan, "Millimeter-wave MMICs and Applications," Thesis, California Institute of Technology, Pasadena, CA, March 2003.
2. L. Young, "Tables for Cascade Homogeneous Quarter-wave Transformers," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 7, No. 2, April 1959, pp. 233-237. Corrections, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 8, No. 2, March 1960, pp. 243-244.
3. S.B. Cohn, "A Class of Broadband Three-port TEM-mode Hybrids," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 19, No. 2, February 1968, pp. 110-116.
4. M. Hamadallah, "Microstrip Power Dividers at mm-Wave Frequencies," *Microwave Journal*, Vol. 31, No. 7, July 1988, pp. 115-127.
5. Southwest Microwave website, available: http://www.southwestmicrowave.com.
6. L.A. Tejedor-Alvarez, J.I. Alonso, J. González-Martín and P. Almorox-González, "Consideraciones Sobre el Montaje de Conectores para Optimizar su Respuesta en Bandas Milimétricas," *XXIII Simposium Nacional de la Unión Científica Internacional de Radio* (URSI 2008), Book of Summaries, September 22-24, 2008, Madrid, Spain, p. 80.

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NEW!	0.01 - 20	Signal Generator	0.01	+27	+27	-113	-101	-80	<300	HMC-T2100
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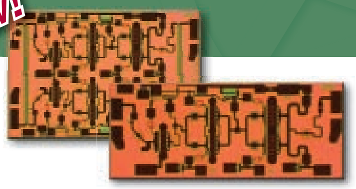

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	Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	NF (dB)	P1dB (dBm)	Bias Supply	Package	Part Number
	6 - 9.5	Power Amplifier, 1 Watt	21	40	-	30.5	+7V @ 820mA	LP5	HMC590LP5E
	6 - 9.5	Power Amplifier, 2 Watt	18	41	-	33	+7V @ 1340mA	LP5	HMC591LP5E
	7 - 9	Power Amplifier, 2 Watt	26	40	6.5	33.5	+7V @ 1.3A	Chip	HMC486
	7 - 9	Power Amplifier, 2 Watt	22	40	7	32	+7V @ 1.3A	LP5	HMC486LP5E
	9 - 12	Power Amplifier, 2 Watt	20	36	8	32	+7V @ 1.3A	LP5	HMC487LP5E
	10 - 13	Power Amplifier, 1 Watt	19	38	-	31	+7V @ 750mA	Chip	HMC592
	12 - 16	Power Amplifier, 1 Watt	13	34	9	31	+7V @ 1.3A	LP5	HMC489LP5E
NEW!	16 - 24	Power Amplifier, 1 Watt	23	41	-	31	+7V @ 790mA	Chip	HMC756
NEW!	16 - 24	Power Amplifier, 1/2 Watt	22	37	-	29	+7V @ 395mA	Chip	HMC757

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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

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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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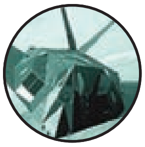


Final Lockheed Martin-built GPS Satellite Begins Operations

The last in a series of eight modernized Global Positioning System IIR (GPS IIR-M) satellites built by Lockheed Martin has been declared operational by the US Air Force for military and civilian navigation users around the globe. The satellite, known as GPS IIR-21(M), was launched successfully from Cape Canaveral Air Force Station on August 17th. Lockheed Martin's operations team assisted the Air Force with the launch and early on-orbit maneuvers.

"The team once again executed a smooth and disciplined on-orbit deployment and checkout of all spacecraft systems and we are extremely pleased to have another high-performance GPS IIR-M satellite in our robust constellation," said Col. Dave Madden, the US Air Force GPS Wing Commander. "I salute the entire government-industry GPS IIR-M team for their talent and determination to provide advanced navigation accuracy and reliability for GPS users worldwide."

Lockheed Martin and its navigation payload provider ITT of Clifton, NJ designed and built 21 IIR spacecraft and subsequently modernized eight of those spacecraft designated Block IIR-M. Each IIR-M satellite includes a modernized antenna panel that provides increased signal power to receivers on the ground, two new military signals for improved accuracy, enhanced encryption and anti-jamming capabilities for the military, and a second civil signal that will provide users with an open access signal on a different frequency.

"Reaching this milestone is a critical step in the mission to provide advanced position, timing and navigation capabilities for the warfighter and civil users," said Don DeGryse, Lockheed Martin's Vice President of Navigation Systems. "The successful launch and operational turnover is a testament to the capabilities of our entire GPS team. Working together with our Air Force partner is a source of tremendous pride for Lockheed Martin."

GPS provides essential services including situational awareness and precision weapon guidance for the military. It is also an information resource supporting a wide range of civil, scientific and commercial functions—from air traffic control to the Internet—with precision location and timing information.

Building upon a legacy of providing progressively advanced spacecraft for the current GPS constellation, Lockheed Martin, along with ITT Corp. and General Dynamics, will produce the next generation of global positioning satellites, designated GPS III. This program will improve position, navigation and timing services for the warfighter and civil users.

The team is progressing on-schedule in the Critical Design Review (CDR) phase of the program and is on track to launch the first GPS IIIA satellite in 2014.

Headquartered in Bethesda, MD, Lockheed Martin is a global security company that employs about 140,000 people worldwide and is principally engaged in the research, design, development, manufacture, integration and sustainment of advanced technology systems, products and services.

New Satellite Broadband Services for Military Personnel and Defense Contractors

TS2 Satellite Technologies is introducing new satellite link products to the international market. These types of telecommunication products are mainly used by the companies that execute contracts in the Middle East and Asia, as well as by soldiers that are stationed in Iraq and Afghanistan.

"Purchased bands give us unlimited possibilities of configuration and setting any telecommunication connections from the Middle East region and South-Western Asia. We can now build networks of any size on such satellites as Intelsat 10-02, Intelsat 901, ABS-1, ArabSat Badr-4 and NSS-6," said Marcin Frackiewicz, President of TS2.

The new TS2 Satellite Technologies offer is a broadband Internet and corporate networks based on satellites. The operator's broadband services enable two-way data transfer within the network and simultaneous Internet access. The company provides all dedicated VSAT services for demanding customers: VSAT Private Network, broadcasting services, SCPC/SCPC, SCPC/DVB, MESH services, STAR/DAMA, VSAT Mini Hub Solution and VNO.

"We provide secure and encrypted satellite connections particularly for the military sector, for any military units, literally in any part of the world, on the national firing ground and during all international trainings," said Frackiewicz. "We have mobile and stationary solutions dedicated to work in difficult conditions."

TS2 satellite services are used by the US Department of State, the United States Marine Corps (USMC), the US Army Corps of Engineers, the Australian Defense Force (ADF), the Command of the Polish Navy, the Air Force Institute of Technology, Lockheed Martin Information Technology, Halliburton Energy Services, KBR, General Dynamics Information Technology, General Atomics Aeronautical Systems, L-3 Communications Vertex Aerospace, and the US Naval Research Laboratory.

The TS2 staff is monitoring the performance of the satellite network 24 hours a day, in order to enable immediate help in case of breakdown or receipt of alert. Due to technical conditions and favorable weather, the Teleport is located in Jeddah, Saudi Arabia. Therefore, the signal from the aerial is not disturbed by the weather conditions and all connection users of TS2 receive services of the highest availability. The Teleport configuration is fully redundant and the services are also available on the national market.

Northrop Grumman to Continue Development of GPS-free Inertial Navigation System

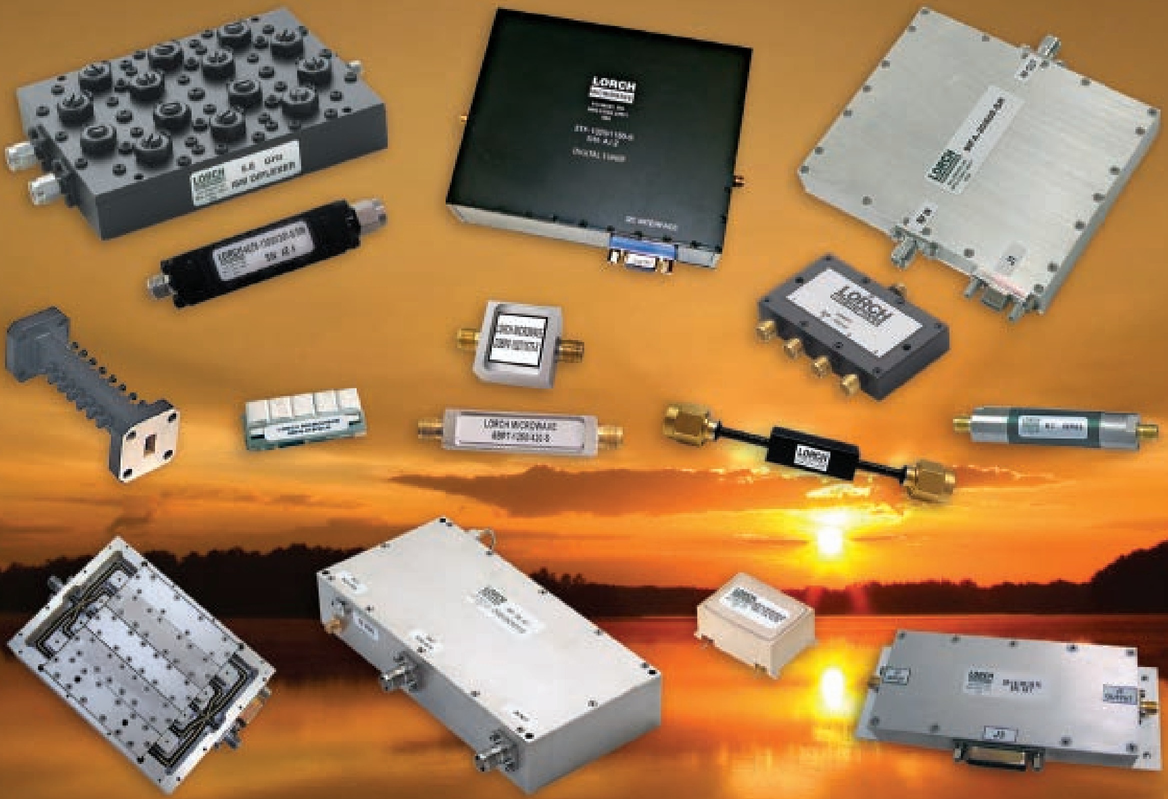
Northrop Grumman Corp. has received a contract modification from the US Department of Defense to further demonstrate a revolutionary advance in inertial navigation. The demonstration project makes use of traditional electro-optic (EO) cameras, atomic clocks, and advanced vision processing technologies to provide inertial navigation system (INS) updates to aircraft, ground vehicles and ground troops without the need for continuous Global Positioning System (GPS) input to maintain precise position and time.

Called LEGAND, for LADAR EO GPS/INS atomic clock navigation demonstration, the project aims to provide ground troops, aircraft, and ground vehicles the capability to maintain precision navigation in places not currently possible due to challenged or denied access to GPS, thus sustaining their operations. The LEGAND system processes visual motion observations to provide INS updates while the atomic clock maintains time synchronization, providing users precision navigation while rapidly re-acquiring partial or complete GPS input.

"When GPS access is denied, our warfighters in urban or indoor environments are often unable to maintain mission engagement. This inability to update the inertial navigation system with GPS causes a gradual loss of its precision navigation capability, resulting in mission degradation or cancellation," said Gorik Hossepian, Vice President of Navigation and Positioning Systems for Northrop Grumman's Navigation Systems Division. "This translates into less time focused on potential hostile targets of interest."

Hossepian noted that LEGAND's small size, weight and power requirements make it highly adaptable to current unmanned aircraft and will provide ground commanders critical battlespace awareness. "The innovative inertial navigation system can also benefit individual soldiers operating in remote areas on the ground," he added.

Two successful studies of the core LEGAND technologies were completed by Northrop Grumman in September 2008 and February 2009 and the current demonstration hardware development phase funded by this contract modification is expected to continue through September 2010.



GSMA Initiative Aims to Save Lives in Europe

The GSMA, the body representing the worldwide mobile communications industry, has signed a Memorandum of Understanding (MoU) to secure the deployment of a single, in-vehicle emergency call service, known as eCall, across Europe.

eCall is an emergency call generated either manually by vehicle occupants or automatically via in-vehicle sensors in an emergency situation. When activated, the eCall system establishes a voice connection with the emergency services. At the same time, it sends the critical data including time, location, direction of travel and vehicle identification, to speed response times by the emergency services.

The MoU creates a framework for the introduction of eCall and is designed to encourage co-operation between vehicle manufacturers, telecommunications operators, the European Commission and the EU Member States, together with other relevant parties such as the insurance industry, automobile clubs and other industry partners. eCall, like emergency calls, will be offered free of charge to users. In addition to the free eCall service, vehicle manufacturers and service providers can provide additional commercial services to supplement eCall.

According to the European Commission's research, a service such as eCall can save up to 2,500 lives every year, reduce the severity of injuries by 10 to 15 percent and reduce emergency response times by up to 50 percent in rural areas and 40 percent in urban centres.

New ETSI Industry Group Searches for Identity

The European Telecommunications Standards Institute (ETSI) has announced the creation of the ETSI Industry Specification Group for 'Identity and access management for Networks and Services' (ISG INS) to develop a common industry view on Identity Management (IdM) protocols and architectures, relating mainly to networks and services for the Internet of the future.

The Group will focus on architectures and protocols that are the key to new networks and services by capturing the results of IdM research and development activity and formulating an industry consensus.

Much of the input to the group will be derived from European Union 7th Framework Project (FP7) R&D activities on Identity Management with a specific focus on networks and services, languages for access control and privacy policies. The Industry Specification Group plans to create a series of commonly agreed Europe-wide specifications, which can be further developed by standardization groups such as ETSI and 3GPP™ as formally adopted standards for European or global use.

At the first meeting of ISG INS, Amardeo Sarma (NEC) was elected as Chairman and Ricardo Pereira (Portugal Telecom) and Peter Scholta (Deutsche Telecom) as Vice-Chairmen. Membership of the group currently consists of two network operators (Deutsche Telekom and Portugal Telecom), two manufacturers (NEC and Nokia Siemens Networks) and two technical institutes (Fraunhofer Institute and Waterford Institute of Technology). This membership is expected to grow rapidly, as participation is open to all ETSI members, as well as to non-members of ETSI subject to signature of a participation agreement.

ITU, Inmarsat and Vizada Take Emergency Action

The International Telecommunication Union (ITU), Inmarsat and Vizada SAS have reached an agreement to improve emergency communications for disaster preparedness and to coordinate relief activities in the aftermath of a disaster.

Inmarsat and Vizada provide satellite-based solutions that are critical in supporting activities aimed at helping countries better respond to disasters and have agreed to donate 70 BGAN mobile satellite terminals, highly portable devices capable of delivering voice and broadband data, to the ITU.

The equipment will enhance the ITU's capacity in deploying mobile telecommunications to assist countries in preparing for disaster and in strengthening response and recovery mechanisms. As part of the agreement, the two companies will also provide the ITU with preferential airtime rates and technical training support.

The agreement supports the ITU's recently launched global initiative that seeks to bring together partners from all domains to cooperate towards disaster mitigation through the use of information and communication technologies.

Linear Technology and C-MAC MicroTechnology Partner

C-MAC MicroTechnology and Linear Technology Corp. have formed a strategic partnership to provide the European, Canadian and Asian space markets with space qualified radiation hardened (rad-hard) monolithic devices and hybrid modules. This key partnership forms part of C-MAC's strategy for growth within the space market following its accreditation to MIL-PRF-38534 Class K in 2007.

The company will assemble, test and qualify Linear Technology's rad-hard (RH) die in a new range of package outlines at its plant in Great Yarmouth, UK. This relationship will combine C-MAC's vast range of microelectronic packaging and test services with Linear's state-of-the-art portfolio of high performance analogue integrated circuits. Thus, for the first time, customers outside the US will be able to purchase high reliability, space grade monolithic and multichip modules incorporating Linear's RH IC designs from a European manufacturer.

The product range will be available with qualification to ESA's ECSS-Q-ST-60-5C hybrid procurement specification or to MIL-PRF-38534 Class K and will undergo radiation testing for total dose accumulation and single event effects. The two companies combine a wealth of design and manufacturing expertise in microelectronic technology and this partnership confirms their position at the forefront of space grade microelectronic solutions.

VTT Provides Roadmap for Centre of Excellence

A centre of excellence for printed intelligence is to be built in the Navarre region in Spain and the VTT Technical Research Centre of Finland is delivering a roadmap study on printed intelligence to the Asociación de la Industria Navarra for this purpose. The study outlines what kind of expertise will be required for research and development in printed intelligence in the future and what kind of applications are to be expected in the selected branches of industry. The new centre of excellence is expected to generate significant new business while supporting sectors in which the region is already strong.

For the Asociación de la Industria Navarra, the roadmap offers a comprehensive and multi-dimensional operating guide. It features three future scenarios for each of the selected sectors, a listing of the technologies that best fit each of these scenarios and their feasibility for commercial use. The roadmap has been prepared by a team of experts at VTT with an exceptionally broad range of cross-discipline expertise enabling the gauging of the potential and practical applications of the technology.

Development has also been pursued in cooperation with local experts. The final stage of the project started in August with the selection of the principal technologies to be developed and their practical applications, together with the securing of the expertise necessary for their development. A total of €4.2 M has already been invested in the building of the centre. A total of €900,000 will be invested in equipment up until 2010 and the operating budget for 2011 will be €1.1 M.

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Military Spending and GaN Driving Power Semiconductor Markets

Although the spending on RF power semiconductors in wireless infrastructure markets has continued to stagnate, other markets—notably the military—are seeing increased activity. Also, according to a new study from ABI Research, gallium nitride—long seen as a promising new "material of choice" for RF power semiconductors—is finally starting to gain some market traction. The research indicates that total available market for RF power semiconductors in 2009 approaches $1 B.

"Gallium nitride (GaN) has markedly increased its market share in 2009 and is forecast to be a significant force by 2014," notes ABI Research Director Lance Wilson. "It bridges the gap between two older technologies, exhibiting the high-frequency performance of gallium arsenide combined with the power handling capabilities of silicon LDMOS. It is now a mainstream technology which has achieved measurable market share and in future will capture a significant part of the market."

The vertical market showing the strongest uptick in the RF power semiconductor business has been the military, which Wilson describes as being "now a very significant market." While the producers of these devices are located in the major industrialized countries, the military market is now so global that end equipment buyers can be from anywhere.

"RF Power Semiconductors" examines RF power semiconductor devices that have power outputs of greater than 5 W and operate at frequencies of up to 3.8 GHz, which represent the bulk of applications in use today. The last study ABI Research published on this topic appeared late in 2007.

With the current release, analysis of the six main vertical segments (wireless infrastructure; military; industrial, scientific and medical (ISM); broadcast; commercial avionics and air traffic control; and non-cellular communications), which was previously subdivided into 24 sub-segments, is expanded to 29 sub-segments. This study is part of the firm's Semiconductors Research Service, which also includes other Research Reports, Market Data, ABI Insights and analyst inquiry support.

Power Amp Market to Double with Multi-stream MIMO

Adoption of 802.11n MIMO with multiple transmit streams will help boost the market for Wi-Fi power amplifier modules to twice its 2008 size despite continued pricing pressure. "As prices for single-stream 802.11n (1x1) chips dropped to match 802.11g, OEMs have quickly begun to switch from 802.11g to 802.11n in new products. Consequently, 802.11n will ship in more than half of all Wi-Fi systems by the end of 2010," says Christopher Taylor, Director of the RF and Wireless Components service.

Not only will 802.11n quickly replace 802.11g, but as Wi-Fi continues to proliferate in new devices and applications, multi-stream MIMO configurations of 802.11n (that is 2x2, 3x3 and 4x4, transmit x receive) will rapidly grow in support of demand for greater range, faster file transfers and streaming multimedia in many of these applications. Taylor notes, "According to the Strategy Analytics forecast model, which considers MIMO stream adoption rates by application, 802.11n will push the Wi-Fi power amp market to almost $1 B over the next five years."

SiGe Semiconductor has established a firm lead in power amplifiers despite increasing competition from GaAs PA module specialists such as Skyworks, RFMD, TriQuint and Anadigics. "A relatively small and nimble company, SiGe Semiconductor owes much of its success to concentrating its resources almost exclusively on Wi-Fi PA modules," notes Asif Anwar, Director of the Strategy Analytics GaAs and Compound Semiconductor market research service.

Strategy Analytics has published its latest findings on WiFi and Wi-Fi power amplifiers and ICs in two reports: "Wi-Fi Radio Component Forecast 2009—2013: New Applications & MIMO Drive Growth," and "Wi-Fi Radio Component Vendor Share and Outlook: Broadcom & SiGe Semi Positioned to Maintain Leads," both published by the Strategy Analytics RF & Wireless Components market research service. The historical and projected data in the forecast report is also available in EXCEL format as a spreadsheet.

Top EMS/ODM Vendors Gain Stability

Following alarming revenue plunges in late 2008 and early 2009, the global electronics contract manufacturing business showed signs of stabilization in the second quarter, with the top players experiencing a collective return to growth, according to iSuppli Corp.

Based on a review of second-quarter sales data, the Top-10 Electronics Manufacturing Service (EMS) providers achieved revenue growth of 1.6 percent compared to the first quarter. While this may not appear to be much of an increase, it represents a dramatic swing from the 25 percent sequential revenue contraction in the first quarter. The Top-10 Original Design Manufacturers (ODM) performed much better, with second-quarter revenue rising by 12 percent compared to the first quarter. This contrasts with a 14 percent sequential decline in the first quarter.

"The year 2009 could not have started any worse for contract manufacturers," said Adam Pick, director and principal analyst for EMS/ODM at iSuppli. "However, during the second quarter, senior managers at EMS and ODM companies hinted that performance was stabilizing as demand firmed, cost structures adjusted and inventory decreased. iSuppli's research confirms that the market did regain its footing in the second quarter. Despite these positive signs, it is still too early to celebrate an electronics manufacturing recovery. Several factors continue to cloud the outlook for EMS/ODM."

One major factor is the global recession, which remains severe. Although revenue is rising on a sequential basis, the effects of the economic downturn can still be seen when making a year-over-year comparison. Second-quarter revenue for the Top-10 EMS providers was down 15 percent from 2008, and sales remain significantly lower than the normal seasonal pattern. Quarterly revenue for the Top-10 EMS providers, compared to a year earlier, has performed dismally since the fourth quarter of 2008.

Furthermore, certain OEMs are adopting strategic and recessionary manufacturing strategies, hindering growth for contract manufacturers. As evidenced by the moves of Nokia and NCR, some OEMs are taking back manufacturing operations from their outsourcing providers. For example, iSuppli estimates that Nokia has reclaimed as much as $5 B worth of spending from its EMS/ODM partners during this recession.

Other OEMs are acquiring assets from EMS providers to ensure continuity of supply. OEM Ericsson has taken this action with contract manufacturer Elcoteq.

Another market inhibitor is overcapacity, which continues to plague contract manufacturers by pressuring margins. Finally, ongoing shortages for devices, including optical disk drives and display panels, are negatively impacting the electronics supply chain in Taiwan and China. To adjust to these market realities, managers at EMS/ODM firms are taking appropriate actions to right-size their cost structures and to collaborate with OEMs and suppliers to establish realistic expectations for the future. Wall Street also has corrected its expectations for the contract manufacturing market, with the industry's second-quarter results conforming with or slightly exceeding financial analysts' expectations. However, four of the Top-10 EMS providers failed to improve revenues on a sequential basis during the second quarter. Furthermore, when Foxconn's sales are excluded, revenues of the Top-10 EMS providers actually contracted in the second quarter on a sequential basis.

Finally, when examining forward-looking guidance against historical datasets, it is apparent that a true bottoming out of the market remains elusive for some EMS providers. Despite the various adjustments that EMS providers have had to make, a resurgence of notebook and netbook orders to the ODMs has inspired bullish sentiment among a number of companies, including Quanta, Compal, Wistron and Inventec. Even with component shortages and lackluster guidance from Hewlett-Packard, Lenovo and Dell, certain ODMs have suggested that second-half shipments will greatly outpace first-half production given macroeconomic trends and the introduction into the market of products with new features.

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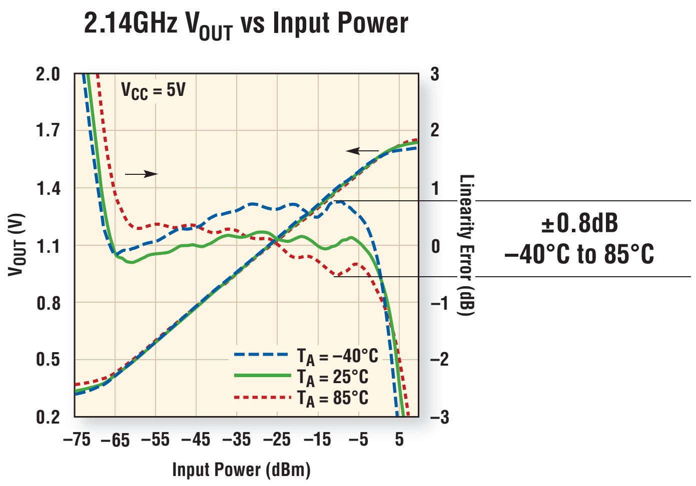

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	LT5538	75dB	40MHz to 3.8GHz	29mA @ 3V	3mm x 3mm DFN
RMS Detector	LT5570	60dB	40MHz to 2.7GHz	26.5mA @ 5V	3mm x 3mm DFN
	LT5581	40dB	10MHz to 6GHz	1.4mA @ 3.3V	3mm x 2mm DFN
Schottky Peak	LTC®5505	34dB	0.3GHz to 3GHz	0.5mA @ 3.3V	SOT-23
	LTC5532	35dB	0.3GHz to 12GHz	0.5mA @ 3.3V	TSOT-23, 2mm x 2mm DFN

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INDUSTRY NEWS

■ **TriQuint Semiconductor Inc.**, an RF front-end product manufacturer and foundry services provider, announced its acquisition of **TriAccess Technologies**, a provider of Cable TV (CATV) and Fiber-to-the-Premise (FTTP) integrated circuits for the amplification of high quality multimedia content, effective immediately. Previously, TriQuint served as TriAccess' foundry supplier. In related news, TriQuint announced it has signed a memorandum of understanding (MOU) with **Huawei**, a leader in providing next-generation telecommunications network solutions for operators around the world, to supply driver amplifiers and related products for new optical transport systems. As a strategic partner, TriQuint will work closely with Huawei to develop higher-speed and wider-bandwidth network solutions with lower power consumption for operators worldwide. TriQuint was selected due to its comprehensive product portfolio and green technologies. In addition to the MOU, the product development roadmaps of both TriQuint and Huawei will be aligned to enhance the competitiveness of their products.

■ The power of one multi-intelligence aircraft collecting, correlating then distributing diverse types of intelligence to those who needed it was demonstrated by **Lockheed Martin** during the US Army's C4ISR On-The-Move exercise. Lockheed Martin's Airborne Multi-intelligence Laboratory (AML) demonstrated how its onboard sensors, interacting with the Army's intelligence and battle command enterprises can dramatically improve the speed and quality of situational awareness available to friendly forces.

■ **Agilent Technologies Inc.** announced that **Simplay Labs** in Shenzhen, China, has selected Agilent's HDMI test solution for source, sink and cable certification at its new test center opening there this month. This purchase continues the long-term relationship between Simplay Labs and Agilent to further develop devices for current and future HDMI technology standards. The test center at Simplay Labs is designed to promote industry-wide interoperability among products using HDMI and High-bandwidth Digital Content Protection (HDCP).

■ **RF Micro Devices Inc.** (RFMD), a leader in the design and manufacture of high-performance semiconductor components, announced that it has successfully demonstrated industry-leading reliability performance with its high-power Gallium Nitride (GaN) process technology.

■ **Janco Electronics Inc.** (JEI) is now certified for ISO 13485:2003. ISO 13485:2003 is a quality-management standard for medical device manufacturing developed by the International Organization for Standardization. ISO 13485 certification will ensure that JEI has the required level of Quality Management systems in place to properly service the medical electronics services industry. It covers fundamental Good Manufacturing Practice (GMP) principles, which apply during the manufacture of medical devices.

CONTRACTS

■ The US Department of Defense announced that **Aeroflex** won a five-year, $40.5 M contract with the US Marine Corps to supply Ground Radio Maintenance Automatic Test Systems (GRMATS). For this contract Aeroflex will supply its newly developed test platform, the 7200 Configurable Automated Test Set (CATS). The 7200 is a commercial off-the-shelf (COTS) platform for testing software-defined radios, including military tactical radios and other high technology devices.

■ **Tektronix Inc.**, a provider of test, measurement and monitoring instrumentation, announced it has won a contract award from the US Navy to supply Digital Phosphor Oscilloscopes (DPO). The $10.75 M contract has a Best Estimated Quantity (BEQ) of 5000 units over a five-year period. The Naval Inventory Control Point (NAVICP), the Navy's primary equipment purchasing and inventorying agent for the Naval Supply Systems Command (NAVSUP), will use the Tektronix 100 MHz, 2-channel TDS3012C oscilloscopes for its General Purpose Electronic Test Equipment (GPETE) program. This contract follows two similar oscilloscope programs awarded by the US Navy in recent years—100 MHz, 2-channel TDS3012B (six-year program) and the 500 MHz, 4-channel TDS5054B oscilloscopes (five-year program).

■ **Channel Microwave Corp.** has recently been awarded $3.1 M in contracts for components and subsystems used for military and homeland defense applications. These contracts will be completed next year with expected follow-on orders.

■ **MicroWave Technology Inc.** (MwT Inc.), Fremont, CA, a wholly owned subsidiary of IXYS Corp., announced that it has been awarded a contract from **BAE Systems** with total amount over $2.5 M. MwT has been a well known supplier to the military and defense industry for the past 25 years. MwT manufactures high performance and high quality microwave semiconductor devices, MMICs, modules and subsystems for wireless communication infrastructure, defense, industrial and medical equipment applications. The contract that MwT has won consists of a large volume of custom connectorized microwave amplifiers with military electrical specifications and high reliability requirements.

■ **Skyworks Solutions Inc.**, an innovator of high reliability analog and mixed signal semiconductors enabling a broad range of end markets, announced that **Samsung** is leveraging both quad-band GSM/EDGE and next-generation WCDMA front-end solutions to power a variety of new 3G smart phones including the Pixon12, a 12 megapixel touchscreen camera phone. Skyworks has also secured EDGE and WCDMA power amplifier design wins for more than 15 additional Samsung smart phones currently in production.

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MFSH400800-100	4000 - 8000	1000	-75	-93
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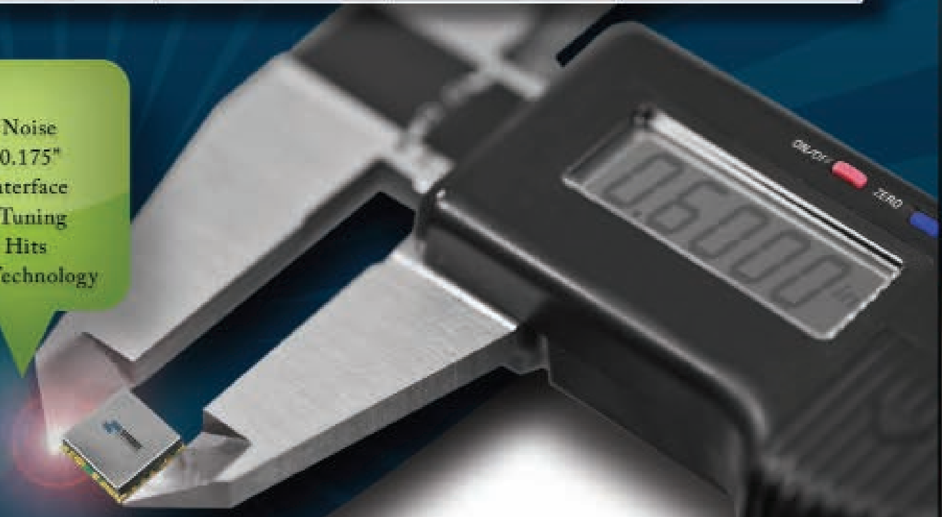

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■ **Rohde & Schwarz America** announced that it has received a contract from the US Naval Inventory Control Point (NAVICP) in Mechanicsburg, VA, for the purchase of 800 R&S SMB100N analog signal generators over a five-year period. The instruments will replace existing instruments throughout the Navy, and will also be available for purchase by other government agencies as well as defense contractors through NAVICP along with various options if desired.

■ **Strand Marketing** has been awarded a contract to manage the rebranding strategy of a leading digital and RF component manufacturer, **LNX Corp.** of Salem, NH, and related procurement business, Solynx. The contract calls for new corporate logos, websites and brochures.

■ **RFaxis**, a fabless semiconductor company focused on innovative, next-generation RF solutions for the wireless and connectivity markets, announced that **Helicomm Inc.** has chosen RFaxis' RF Front-end Integrated Circuits (RFeIC) and embedded antennas for integration into its family of Zigbee and other wireless networking modules.

■ **HRL Laboratories LLC** announced it has received Phase 2 funding to continue developing the Cognitive Technology Threat Warning System, or CT2WS. Funded by the Defense Advanced Research Projects Agency (DARPA), the goal of the CT2WS program is to improve warfighter situational awareness in a variety of operations, including reconnaissance, surveillance and standard infantry tactical fighting.

NEW MARKET ENTRY

■ **Fujitsu Microelectronics America Inc.** (FMA) has entered the mobile phone RF transceiver market with commercial production of a new highly integrated transceiver module supporting 3GPP WCDMA/EGPRS wireless phones. The MB86L01A is the industry's first multi-mode transceiver to eliminate 3G TX and RX inter-stage SAW filters and low noise amplifiers (LNA). The transceiver features a high-level programming model for controlling the radio using an open standard digital interface (3G DigRF/MIPI), which is compatible with a wide range of industry basebands. The MB86L01A is available in volume shipments now.

PERSONNEL

■ TRAK Microwave Corp., a Smiths Interconnect business, appointed **Rick Walsh** as Senior Staff Engineer, Technical Business Development. Walsh joins TRAK Microwave from Tampa Microwave, where his last position was Vice President of Engineering. Prior to that appointment, he spent 15 years at TRAK Microwave in various positions including Director of Business Development for Time and Frequency Systems. Walsh has over 30 years of ex-


▲ *Rick Walsh*

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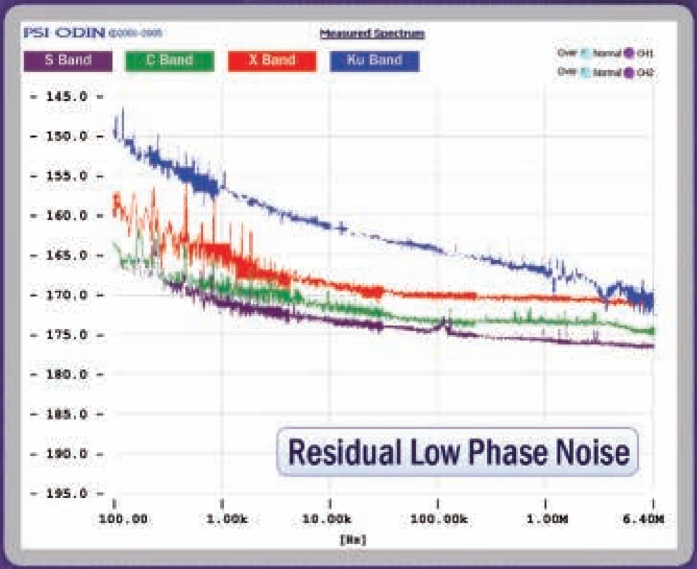

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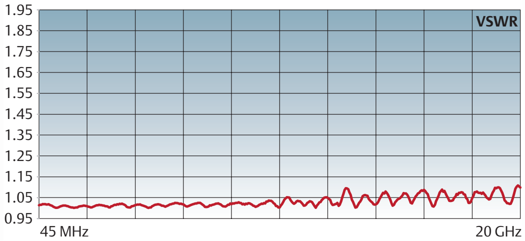

perience in the RF/microwave industry, including design engineering, business development and operations.

REP APPOINTMENTS

■ **Crystek** has been named the exclusive franchise USA distributor of Rubidium and GPS Time Sources from **AccuBeat** of Israel. AccuBeat's line of Frequency Standards provide precision signal timing for applications such as test and measurement equipment, military and satellite communications, and wireless technology. Crystek is offering four AccuBeat models: two Rubidium Frequency Standards and two GPS-Disciplined Rubidium Frequency Standards, in a number of configurations.

■ **Reactel Inc.**, a manufacturer of RF and microwave filters, multiplexers, switched filter banks, and subassemblies to the commercial, military, industrial, and medical industries, announced the appointment of **J/34 MICROWAVE** as the company's exclusive representative in Pennsylvania. For more information about J/34 MICROWAVE, please telephone Jim Shea at (443) 340-7705.

■ **Asymtek,** a Nordson company and leader in dispensing, coating and jetting technologies, announced a new manufacturer's representative company to provide sales, technical expertise, service, parts, and support for Asymtek's dispensing and coating products in Mexico—the **Rich Sales Co**. Rich Sales has 30 years of experience representing manufacturers throughout Mexico. They have eight outside sales engineers covering Mexico along with four service personnel to support Asymtek's Mexican's installation base. With its highly trained technical team, Rich Sales is able to help Asymtek customers find the best solution for their dispensing and coating applications.

WEB SITE

■ **AWR Corp.**, a leader in high frequency EDA, and **Modelithics Inc.**, a premier provider of precision measurements and models for RF and microwave design simulation, announced that a one-click option enabled on the AWR web site for trial evaluation requests for AWR's Microwave Office® software now also includes Modelithics' highly accurate active and passive model libraries. This cooperative partnering gives microwave designers the opportunity to use Modelithics' active and passive simulation models on a trial basis and see how they can impact their designs from within AWR's Microwave Office design environment. The Modelithics libraries are available for a growing number of components and ICs from various manufacturers, ranging from passive components to nonlinear diode and transistor models, and shortly, system-level components.

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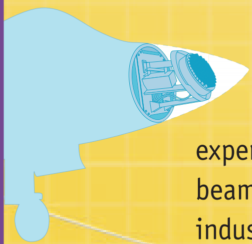

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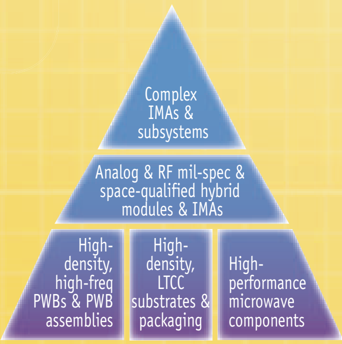

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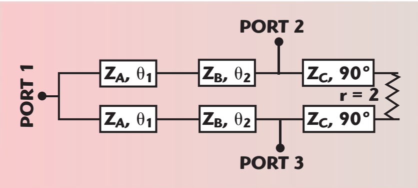
DESIGN OF A DUAL-BAND WILKINSON POWER DIVIDER WITH BANDWIDTH ENHANCEMENT

A novel Wilkinson power divider without additional lumped and distributed elements other than a single resistor for a dual-band operation is presented in this article. In this design, the measured bandwidth of the proposed structure can be enhanced for small band-ratios. The formulas used to determine the design parameters are given. Both simulated and measured results of the dual-band Wilkinson power divider are presented to validate the design approach and the derived equations.

Power dividers are very important components in microwave and millimeter-wave circuits. In recent years, there has been increasing demand for dual-frequency equipment due to the development of multiband technologies. Various power dividers operating at two or more frequencies based on lumped and distributed elements have been reported,[1-5] but they use increased circuit complexity and introduce parasitic effects. In this article, a novel design of a dual-band Wilkinson power divider, without additional lumped and distributed elements other than a single resistor, is presented. Moreover, the designed structure can enhance the bandwidth for small band-ratios. The two frequency bands of operation are selected by varying the electrical lengths and impedance values of three transmission lines. The proposed circuit also features a simple structure with realistic impedance values and a distributed design with reduced parasitic effect. The design parameters of the dual-band power divider are presented in explicit closed form. The validity of this analysis is confirmed through the design, simulation and experimental results for a power divider operating at 1 and 2.5 GHz.



▲ *Fig. 1 Schematic of a dual-band Wilkinson power divider.*

THEORY AND DESIGN EQUATIONS

Figure 1 shows the schematic representation of the proposed Wilkinson power divider for dual-band operation. The proposed impedance transformer, which is composed of two-section transmission lines and a shunt element, is depicted in ***Figure 2***. Mathematically, the Z-parameters of this half-circuit can be derived as:

$$M_1 = \begin{pmatrix} 0 & jZ_1 \\ jY_1 & 0 \end{pmatrix} \quad (1)$$

$$M_1 = M_2 M_3 M_4 \quad (2)$$

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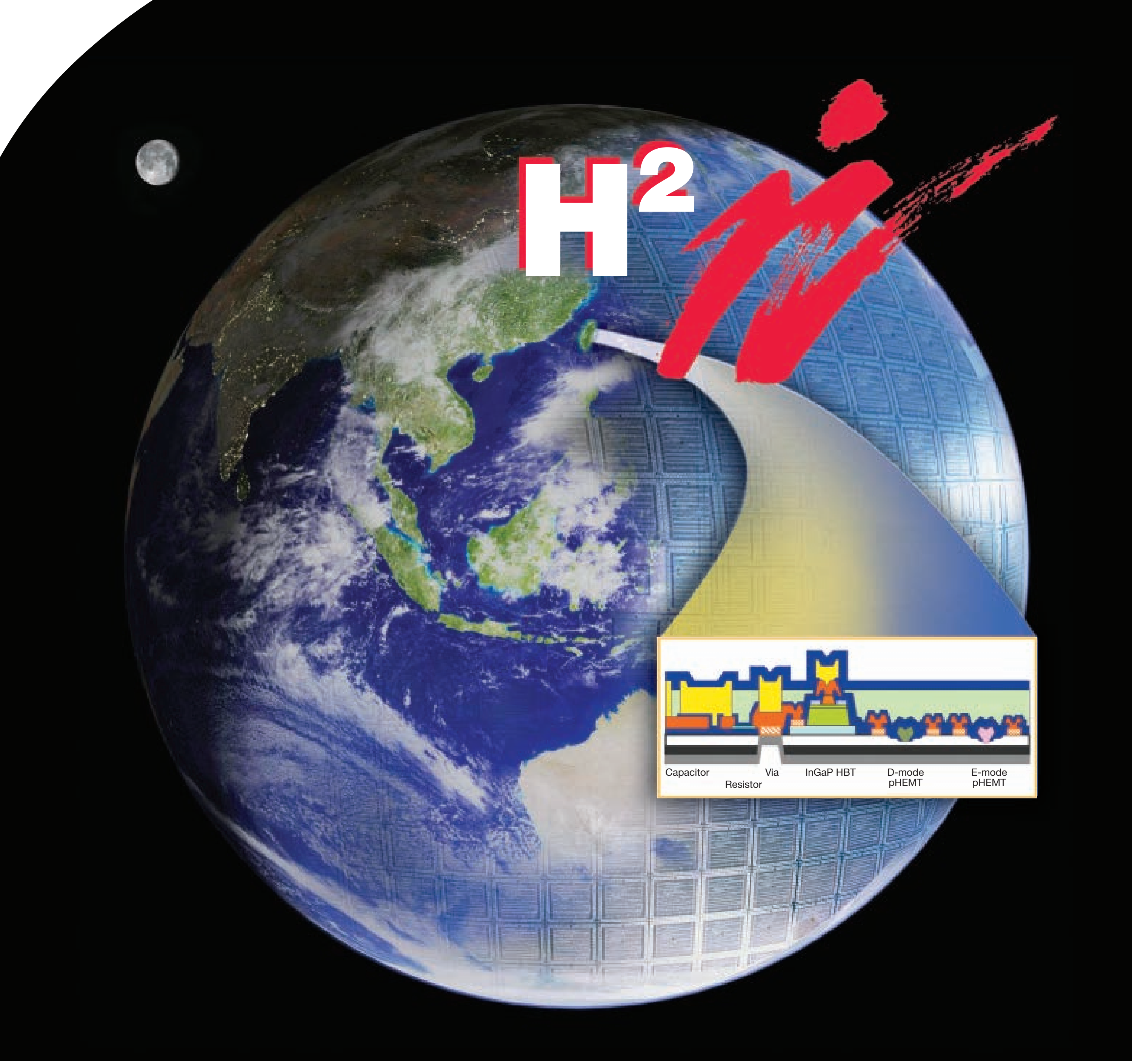

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HBT	Fmax	110 GHz
HBT	BVceo	19 V
e-pHEMT	Gm_Peak	500 mS/mm
e-pHEMT	Idss	0.01 uA/mm
e-pHEMT	BVdg	21 V
e-pHEMT	Vth	0.35 V
e-pHEMT	Fmin	0.44 dB
e-pHEMT	Ft	30 GHz
e-pHEMT	Fmax	90 GHz
d-pHEMT	Gm_Peak	330 mS/mm
d-pHEMT	Idss	230 mA/mm
d-pHEMT	BVdg	20 V
d-pHEMT	Vp	-1.0 V
d-pHEMT	Ron	2.0 Ohm-mm
d-pHEMT	Fmin	0.31 dB
d-pHEMT	Ft	30 GHz
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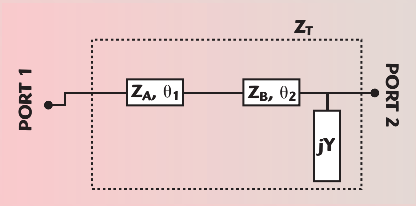


▲ *Fig. 2 Proposed dual-band transformer structure.*

where M_2, M_3 and M_4 are defined as:

$$M_2 = \begin{pmatrix} \cos\theta_1 & j2Z_A \sin\theta_1 \\ j\sin\theta_1 / 2Z_A & \cos\theta_1 \end{pmatrix} \quad (3)$$

$$M_3 = \begin{pmatrix} \cos\theta_2 & jZ_B \sin\theta_2 \\ j\sin\theta_2 / Z_B & \cos\theta_2 \end{pmatrix} \quad (4)$$

$$M_4 = \begin{pmatrix} 1 & 0 \\ jY & 1 \end{pmatrix} \quad (5)$$

Subsequently, these expressions can be simplified as

$$Z_A = \pm Z_T \frac{\sin\theta_1}{\cos\theta_2} \quad (6)$$

$$Y = \frac{\cos(\theta_1+\theta_2)\cos(\theta_1-\theta_2)}{\pm Z_T \cos\theta_1 \cos\theta_2} \quad (7)$$

Since θ_1 and θ_2 are both functions of the two operating frequencies f_1 and f_2 ($f_2 > f_1$), θ_1 and θ_2 can be expressed as

$$\theta_1(f_1) = \theta_2(f_1) = \frac{\pi}{2} - \frac{\pi}{2}\frac{R-1}{R+1} \quad (8)$$

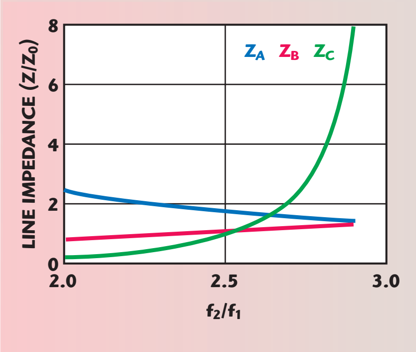
$$\frac{f_2}{f_1} = R \quad (9)$$

Consequently, the corresponding design parameters can be calculated by the following formulas:

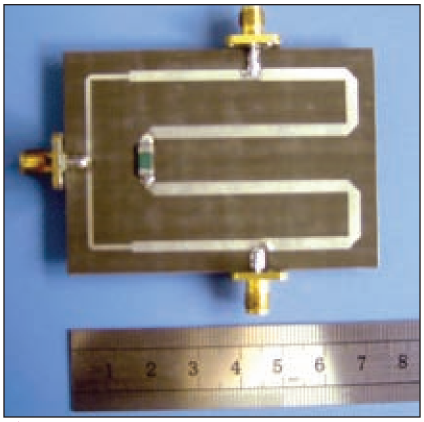
$$Z_A = \sqrt{2}Z_0 \mathrm{ctg}\frac{\pi}{2}\frac{R-1}{R+1} \quad (10)$$

$$Z_B = \sqrt{2}Z_0 \tan\frac{\pi}{2}\frac{R-1}{R+1} \quad (11)$$

$$Z_c = \frac{Z_0}{2}\frac{\tan\pi\frac{R-1}{R+1}}{\sqrt{2}}\tan^2\frac{\pi}{2}\frac{R-1}{R+1} \quad (12)$$



▲ *Fig. 3 Circuit parameters vs. frequency ratio.*



▲ *Fig. 4 Photograph of the proposed dual-band power divider.*

Figure 3 shows the transmission line impedances versus the band-ratio f_2/f_1 of the dual-band operation. It is observed that the designed power divider can easily operate at frequency ratio ranging from 2.3 to 2.74 with normalized line impedance from 0.6 to 2.4.

EXPERIMENT

A dual-band Wilkinson power divider prototype has been fabricated on a substrate with a dielectric constant ε_r = 2.65 and a thickness h = 1 mm for operation at 1 and 2.5 GHz. The impedances at all ports are 50 Ω. Based on the design formulas, the impedance values of Z_A, Z_B, Z_C can be determined as Z_A = 88.7 Ω, Z_B = 113 Ω and Z_C = 49.3 Ω, respectively, with electrical lengths $\theta_1 = \theta_2 = 0.29\pi$.

The model simulation was performed with HFSS software and the measured data are obtained with a Wiltron 37269A network analyzer. ***Figure 4*** shows the photograph of the designed power divider, which has an area of 72 × 51.28 mm.

The measured performance of the designed power divider is shown in

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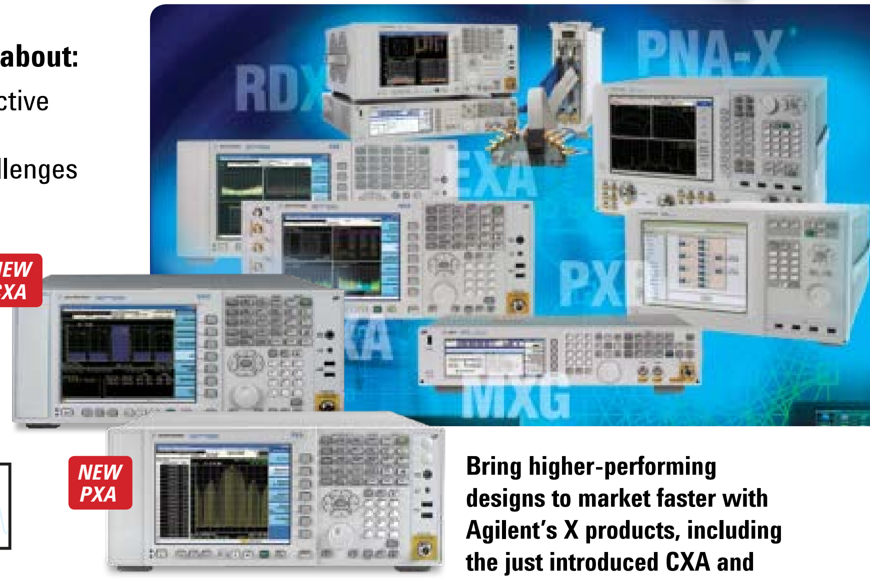

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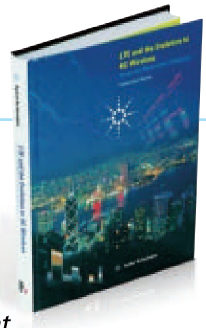

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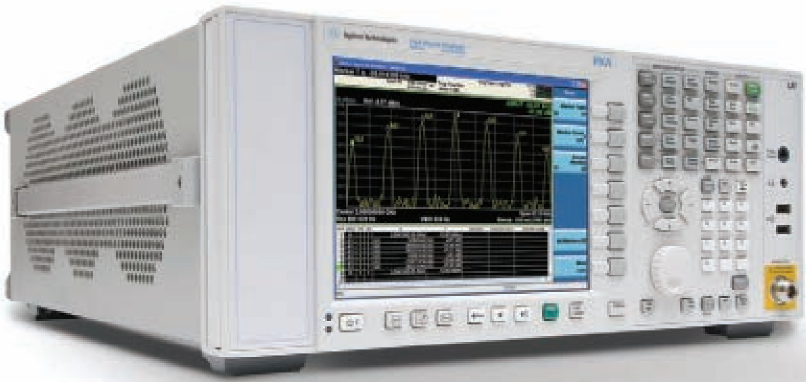

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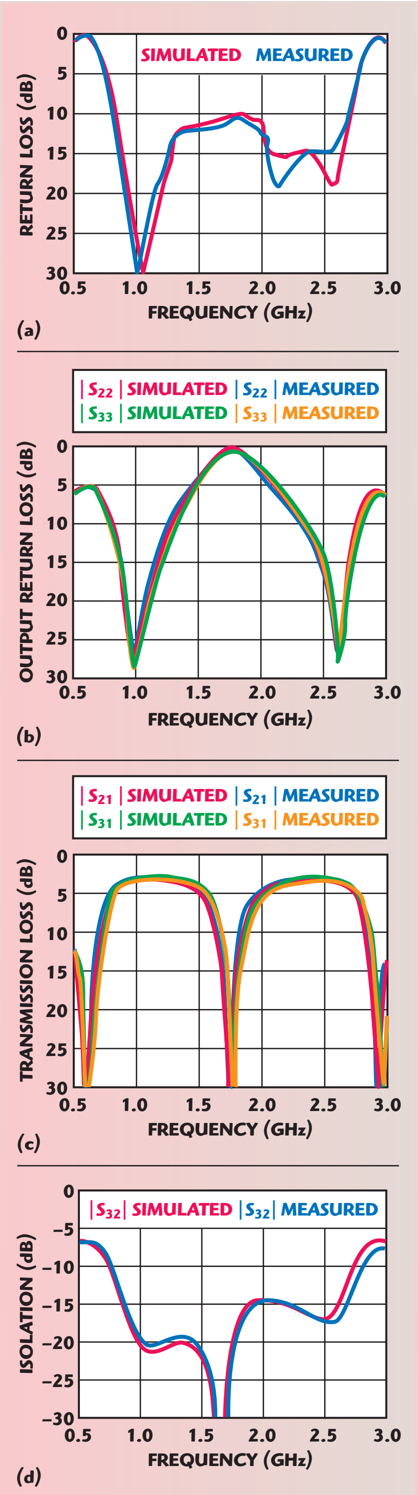

▲ *Fig. 5 (a) Input return loss, (b) output return loss, (c) transmission loss and (d) isolation.*

Figure 5. There is good agreement between the simulated and measured results with the dual-band operation at 1 and 2.5 GHz. The input return loss is 30.39 dB at 1 GHz and 15.01 dB at 2.5 GHz. The measured S_{21} values are 3.06 dB at 1 GHz and 3.28 dB at 2.5 GHz; S_{31} values are 3.08 dB at 1 GHz and 3.36 dB at 2.5 GHz. The isolation between ports 2 and 3 is more than 20 dB at 1 GHz and 16.88 dB at 2.5 GHz.

The designed power divider also improves the bandwidth for small band-ratios. The measured bandwidth is 240 MHz for S_{11}, S_{22}, S_{33} and S_{32}, all better than 20 dB. The theoretical bandwidth proposed by Park[6] is less than 60 MHz. The bandwidth enhancement using the proposed method becomes more pronounced as the band-ratio decreases.

CONCLUSION

This article presents a novel dual-band Wilkinson power divider without additional lumped and distributed elements other than a single resistor. The design procedure and closed-form equations are described. Good agreement between the simulated and measured results has been observed. The proposed structure can enhance the bandwidth as the band-ratio decreases. This simple topology makes the proposed circuit suitable for dual-band application, which will be more in demand in the near future. ■

References

1. R.J. Cameron, M. Yu and Y. Wang, "Direct-coupler Microwave Filters with Single and Dual Stopbands," *IEEE Transaction on Microwave Theory and Techniques*, Vol. 53, No. 11, November 2005, pp. 3288-3297.
2. K.K.M. Chen and F.L. Wong, "A Novel Approach to the Design and Implementation of Dual-band Compact Planar 90° Branch-line Coupler," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 52, No. 11, November 2004, pp. 2458-2463.
3. J.H. Sung, G.Y. Kim, S.H. Son, H.J. Lee, Y.J. Song, Y.W. Jeong, H.S. Park and D. Ahn, "Design Method of a Dual-band Balun and Divider," *2002 IEEE International Microwave Symposium Digest*, Vol. 2, pp. 1177-1180.
4. S. Avrillon, I. Pele, A. Chousseaud and S. Toutain, "Dual-band Power Divider Based on Semiloop Stepped-impedance Resonators," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, No, 4, April 2003, pp. 1269-1273.
5. C. Monzon, "A Small Dual-frequency Transformer in Two Sections," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, No. 4, April 2003, pp. 1157-1161.
6. M.J. Park and B. Lee, "A Dual-band Wilkinson Power Divider," *IEEE Microwave and Wireless Components Letters*, Vol. 18, No. 2, February 2008, pp. 85-87.

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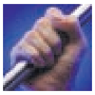

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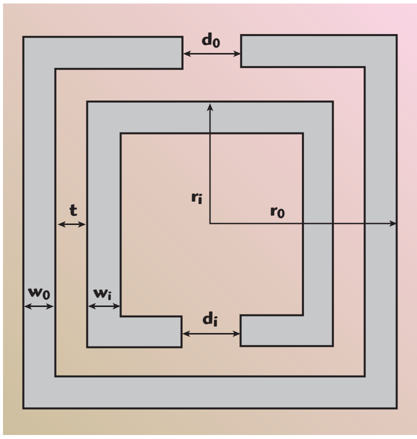
METAMATERIAL-BASED COMPACT MULTILAYER FILTER WITH SKEW-SYMMETRIC FEEDS

Split-ring resonator (SRR) metamaterials are introduced in the design of a multilayer filter. Considering the electric coupling to the magnetic resonance, careful examination of the SRR orientations to the external stimulation is presented through full wave analysis. With the skew-symmetric feed scheme, the compact multilayer filter has a center frequency of 6.07 GHz and 7 percent fractional bandwidth with two transmission zeros at 5.79 and 7.1 GHz. Compared with a conventional microstrip filter, the proposed filter shows a significant size reduction and improved selectivity.

Microwave filters are essential components in modern wireless communications systems. It is important to reduce their size and weight in order to integrate them with other components in a single chip system.[1] A main trend in filter design is a multilayer filter, which has a much better quality than a planar one.[2] At microwave frequencies, a negative permeability over a given frequency range can be realized in the magnetic resonance frequency of a periodic array of SRRs.[3] In this article, a multilayer technology and an SRR structure are combined for the design of a novel multilayer filter. Compared with the conventional microstrip filter, the proposed filter shows a significant size reduction and improved selectivity. The measured and simulated results are in good agreement.



▲ *Fig. 1 Split-ring resonator schematic.*

THEORY

Shown in ***Figure 1***, the SRR is made of two concentric rings separated by a gap, both having splits at opposite sides. The geometrical parameters, such as the split width, gap distance, metal width and radius are represented by d, t, w, and r, respectively. The subscripts i and o denote the inner and outer rings. Besides the electric and magnetic coupling, the incident field also induces the magnetoelectric coupling. An SRR not only has an electric resonance, but also has a magnetic resonance. In addition, the magnetic resonance frequency is lower than the electric resonance frequency.[4] Using the magnetic resonance of the SRR in the filter design, a significant size reduction can be obtained.

The magnetic resonance of the SRR depends on its orientation with respect to the

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	CD-501-102-30S	30 ±1.25	0.75	0.2	20	1.2:1	1.2:1	50	50	3
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	CD-102-202-20S	20 ±1.25	0.75	0.25	20	1.25:1	1.25:1	50	50	3
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7–12.4	CD-702-1242-6S	6 ±1.25	0.5	2	17	1.3:1	1.3:1	50	5	3
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12.4–18	CD-1242-183-10S	10 ±1.25	1	1.2	12	1.5:1	1.5:1	50	5	1
	CD-1242-183-20S	20 ±1.25	0.75	0.55	15	1.5:1	1.5:1	50	50	1
	CD-1242-183-30S	30 ±1.25	0.5	0.5	15	1.5:1	1.5:1	50	50	1
1–10	CD-102-103-10S	10 ±1.5	1	1	15	1.5:1	1.5:1	50	5	1
	CD-102-103-20S	20 ±1.5	0.8	0.8	15	1.5:1	1.5:1	50	50	1
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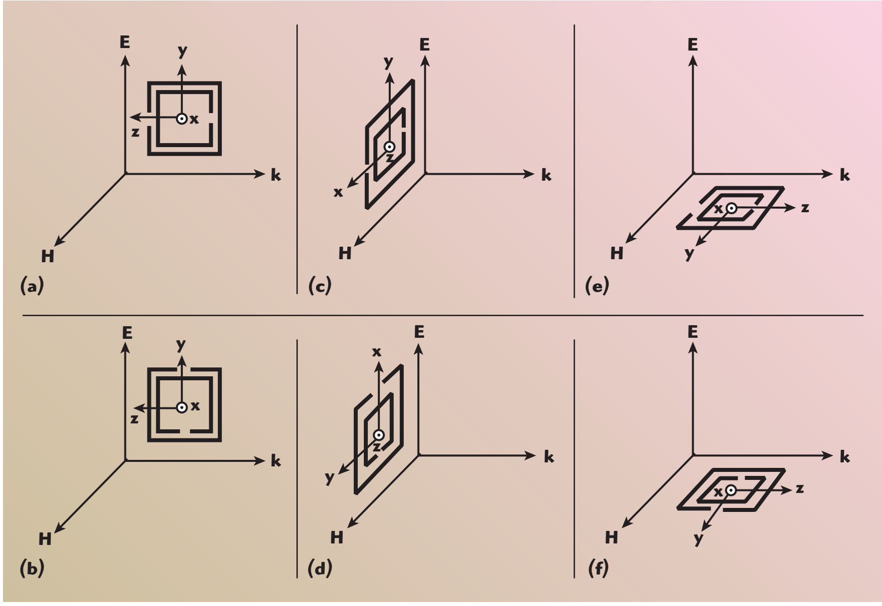


▲ *Fig. 2 Six orientations of the SRR with respect to k, E, H, of the incident TEM field.*

external electric field E and the direction of propagation k, which implies six distinct orientations. In the first two cases of ***Figure 2***, in which the magnetic field penetrates through the rings, the magnetic resonance of the SRR is excited by the magnetic field. The electric field can also excite the magnetic resonance when the incident wave penetrates through the rings and the external electric field E is parallel to the split-bearing sides.[5] However, when the external electric field E is rotated perpendicularly to the split-bearing sides, no magnetic response is produced, as in the two cases c and d. In the other two cases, the external electric field E penetrates through the rings. No magnetic response is produced.

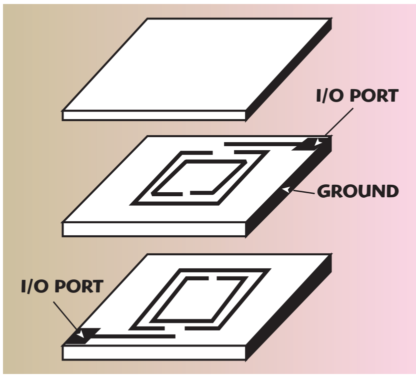
To account for the magnetoelectric coupling in Maxwell's equations, the SRR metamaterials can be described by the constitutive relations[6]

$$D = \varepsilon_0 \left(\bar{\varepsilon} \cdot E + Z_0 \bar{\kappa} \cdot H\right) \qquad (1a)$$

$$B = \mu_0 \left(-\frac{1}{Z_0} \bar{\kappa}^T \cdot E + \bar{\mu} \cdot H\right) \qquad (1b)$$

with $Z_0 = \sqrt{\mu_0 / \varepsilon_0}$, where $\bar{\varepsilon}$ and $\bar{\mu}$ are the relative electric permittivity and relative magnetic permeability tensors, and $\bar{\kappa}$ is the magnetoelectric coupling dimensionless tensor. For different axes fixed to the SRR as shown, only certain components of $\bar{\varepsilon}$, $\bar{\mu}$ and $\bar{\kappa}$ tensors are of significance.

Considering the forward plane wave propagation of the form exp (-iβz'), for case c, which will be used in the following filter design,



▲ *Fig. 3 Structure of the two-pole SSR filter with skew-symmetric feed.*

$$\beta^2 = \varepsilon_{yy}\mu_{xx} \qquad (2)$$

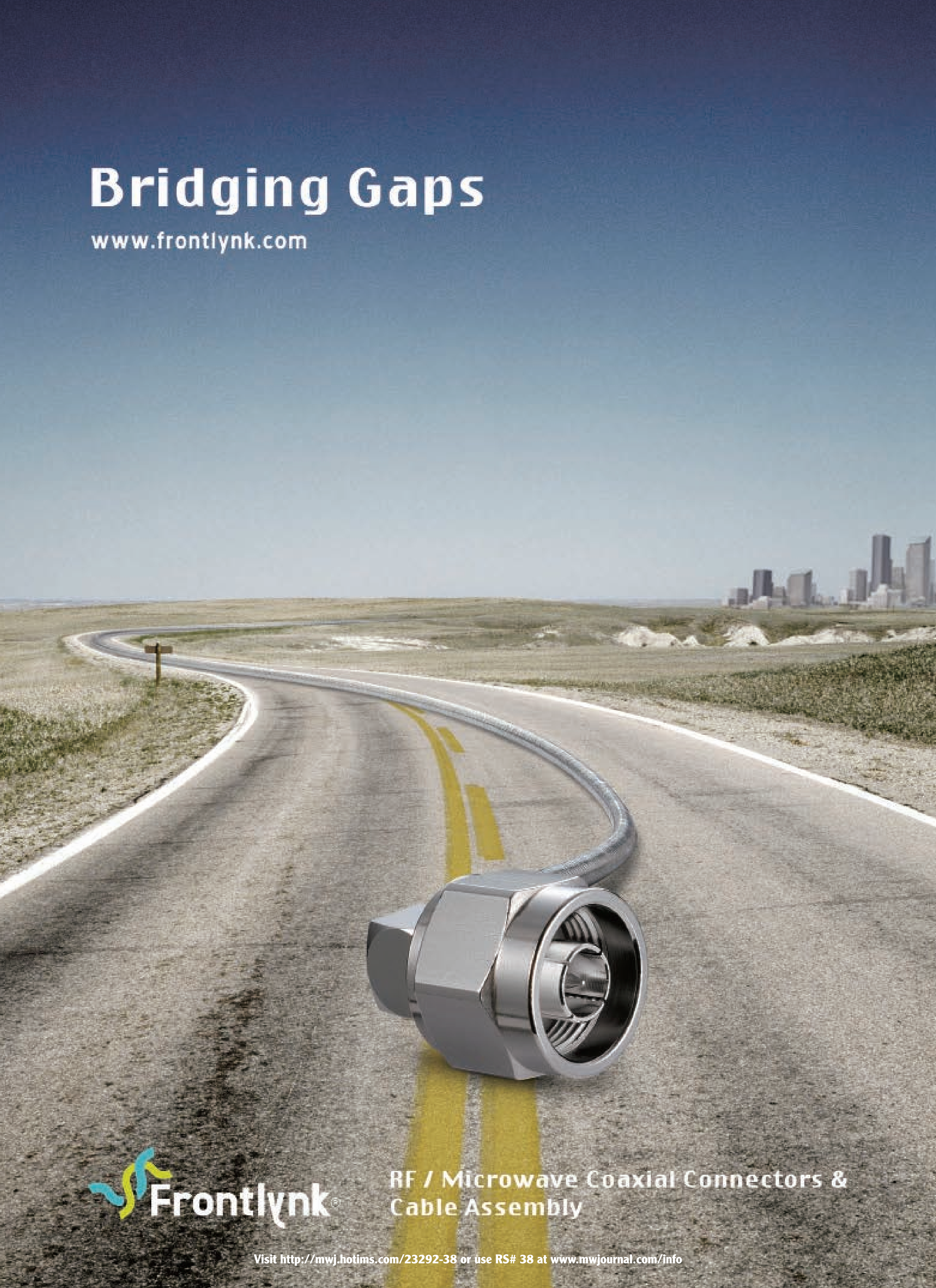
where

$$\varepsilon_{yy} = a + \frac{b\omega^2}{(\omega_0^2 - \omega^2)} \text{ and } \mu_{xx} = 1$$

When $\varepsilon_{yy} < 0$, a transmission stop band occurs. Through a similar analysis, the other cases can be proved.

DESIGN AND SIMULATION

Figure 3 shows the proposed filter, which is composed of a three-layer medium with the same relative permittivity $\varepsilon_r = 2.2$ and two SRRs metal layers embedded between the medium layers in the same plane but with splits laid in opposite directions. The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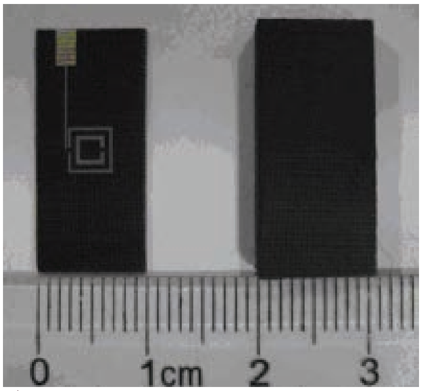
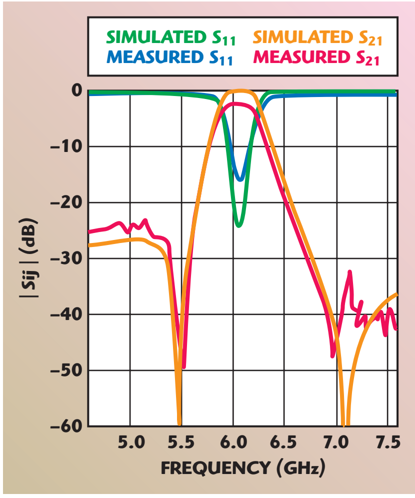


▲ *Fig. 4 Photograph of the fabricated filter.*



▲ *Fig. 5 Simulated and measured responses of the SRR filter.*

most important innovation here is the ground, which is located in the right and left as shown. This design makes the external electric field E parallel to the split-bearing sides and makes sure the magnetic resonance of the SRR take place, according to case c. The SRR filter with skew-symmetric input and output feed lines coupling on the first and last resonators possesses two extra transmission zeros, lying on either side of the passband, because the delays of the upper path and the lower path are the same. A photograph of the fabricated filter is shown in ***Figure 4***. The thickness of the first and third layers is 0.8 mm and the middle layer is 2.5 mm thick. The width of the feed line is 0.2 mm. In the photographs, the left is the inner structure of the filter and the right is the whole structure.

The simulated and measured results are shown in ***Figure 5***. From the EM simulation, the filter has a fractional bandwidth of 7 percent at 6.07 GHz, an in-band return loss of 20 dB and a minimum out-band loss of 25 dB. The transmission zeros are obtained near the passband at f_1= 5.49 GHz and f_2 = 7.1 GHz. This structure offers a good transmission characteristic and a compact size, which is less than one third of the wavelength in free space. From the measured data, the two transmission zeros, 5.53 and 6.96 GHz, are found in the passband response of the filter. Good agreement can be observed between the simulated responses and measured results.

CONCLUSION

In this article, the relationship between the magnetic resonance of an SRR and its orientation relative to the incident wave has been analyzed. A filter using two resonators with compact size, low insertion loss and sharp-rejection has been successfully designed. Furthermore, with the skew-symmetric feed structure, transmission zeros can be achieved. Good agreement between measured and simulated data has been demonstrated. ■

ACKNOWLEDGMENT

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References

1. W. Menzel, H. Schumacher, W. Schwab and X.K. Zhang, “Compact Multilayer Filter Structures for Coplanar MMICs,” *IEEE Microwave and Guided Wave Letters*, Vol. 2, No. 12, December 1992, 2, pp. 497-498.
2. W.S. Tung, Y.C. Chiang and J.C. Cheng, “A New Compact LTCC Bandpass Filter Using Negative Coupling,” *IEEE Microwave and Wireless Components Letters*, Vol. 15, No. 10, October 2005, pp. 641-643.
3. M. Shamonin, E. Shamonina, V. Kalinin and L. Solymar, “Properties of a Metamaterial Element: Analytical Solutions and Numerical Simulations for a Singly Split Double Ring,” *Journal of Applied Physics*, Vol. 95, No. 7, April 1, 2004, pp. 3778-3784.
4. K. Aydin, I. Buly, K. Guven, M. Kafesaki, C.M Soukoulis and E. Ozbay, “Investigation of Magnetic Resonances for Different Split-ring Resonator Parameters and Designs,” *New Journal of Physics*, Vol. 7, No. 168, August 2005, pp. 1-15.
5. N. Katsarakis, T. Koschny, M. Kafesaki, E.N. Economou and C.M. Soukoulis, “Electric Coupling to the Magnetic Resonance of Split Ring Resonators,” *Applied Physics Letters*, Vol. 84, No. 15, April 1, 2004, pp. 2943-2945.
6. C. Krowne, “Electromagnetic Theorems for Complex Anisotropic Media,” *IEEE Transactions on Antennas and Propagation*, Vol. 32, No. 11, November 1984, pp. 1224-1230.

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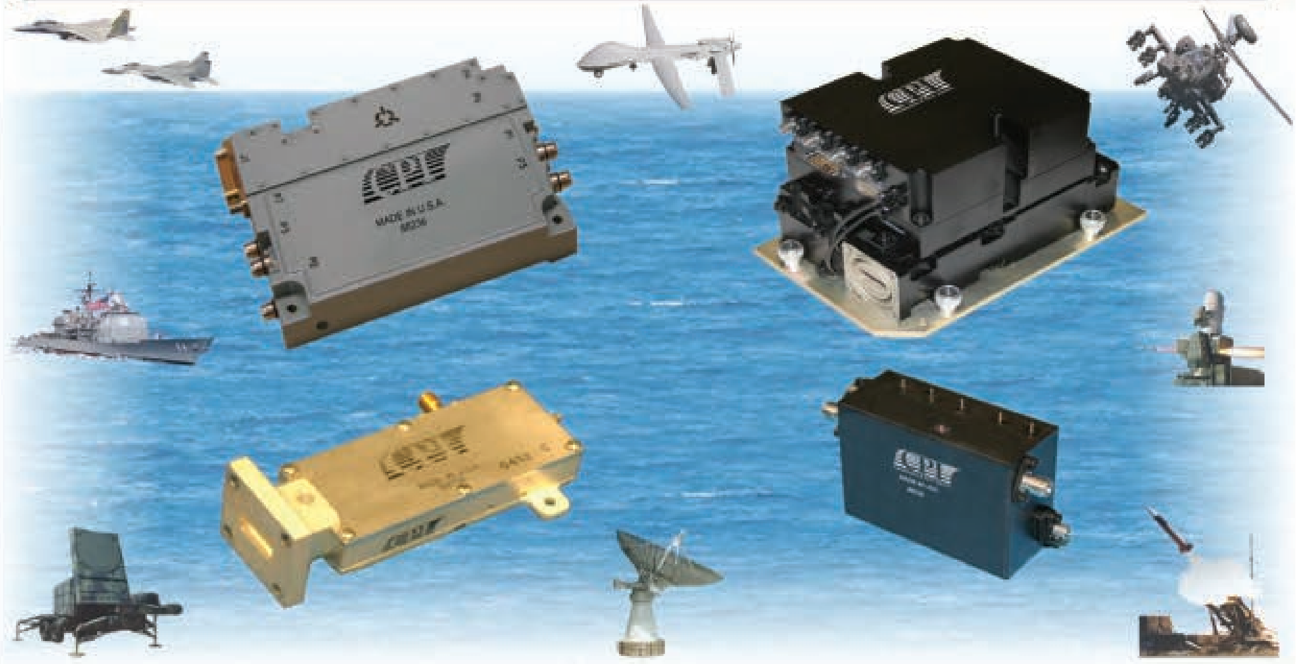

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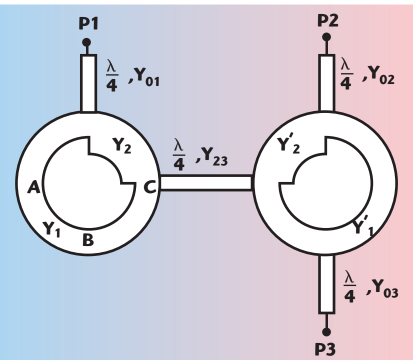
DUAL RING BALUN-BPF WITH IMPROVED BALANCED PORT CHARACTERISTICS

A dual ring structure for the Balun-bandpass filter (Balun-BPF) to improve balanced-port characteristics is presented. The conventional Balun-BPF has limitations in output symmetry and skirt steepness. A dual ring structure is introduced and a suitable coupling point between the two ring resonators is obtained to solve these problems. An interdigital coupled-line inverter and the cross-coupling effect between the resonators are also discussed. The fabricated dual ring Balun-BPF, with a center frequency of 2.45 GHz and a 90 MHz bandwidth, shows excellent characteristics as a Balun-BPF without the conventional limitations.

Most modern microwave communication systems require balanced components as well as unbalanced structures. In some wireless applications, such as dipole antennas, balanced LNAs, mixers, power amplifiers and so on, a balun frequently connects a bandpass filter with balanced components.[1,2] Recently, simple balun-BPFs and their design equations have been proposed and found useful to reduce the cost and size of the functional blocks in some microwave systems.[1,3] However, a conventional Balun-BPF shows unequal skirt responses between the two balanced outputs because one output has two notches near the passband, but the other does not have any, which also limits the skirt steepness of the Balun-BPF characteristics.



▲ *Fig. 1 Schematic of the proposed dual ring Balun-BPF.*

In order to eliminate the restrictions of the conventional Balun-BPF, two substantially identical ring resonators are combined. The arrangement of the combining points of the two ring resonators is essential to obtain symmetrical output responses. An interdigital-type inverter structure and the cross-coupling effect between two ring resonators are also investigated.

ANALYSIS OF THE DUAL RING BALUN-BPF

Figure 1 shows the circuit schematic of the proposed dual ring Balun-BPF; ***Figure 2*** shows the simulated frequency responses for the three possible dual ring structures that show the possibility of balun characteristics. The first ring can be coupled to the unbalanced port of a conventional Balun-BPF in three different positions (A, B, or C). Only the arrangement with position C shows the Balun-BPF characteristics with symmetrical notch responses at the balanced two output ports (port 2 and port

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3). The other structures show Balun-BPF characteristics with asymmetric skirt response as the conventional one or a broken passband with asymmetric response.

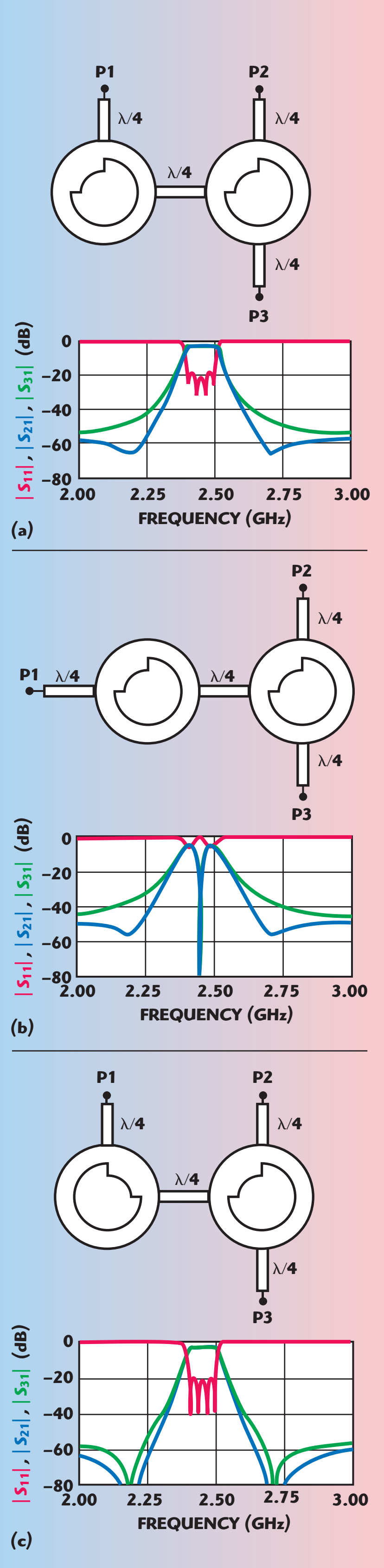
The BPF equivalent circuit is shown in ***Figure 3***. The admittance slope parameters (b_i, b_i') and inverter values (J_{ij}) of the two ring resonators are as follows[3]

$$b_1 = \frac{\pi}{4}(3Y_1 + Y_2),\ b_2 = b_1 \qquad (1a)$$

$$b_1' = \frac{\pi}{4}(3Y_1' + Y_2'),$$

$$b_2' = \frac{\pi}{4}\left(3Y_1' + Y_2' - 2\frac{Y_{in}^2}{Y_1'}\right) \qquad (1b)$$

where $Y_{in} = Y_{03}^2/Y_0$, and



▲ *Fig. 2 Simulated frequency response for three different coupling positions.*

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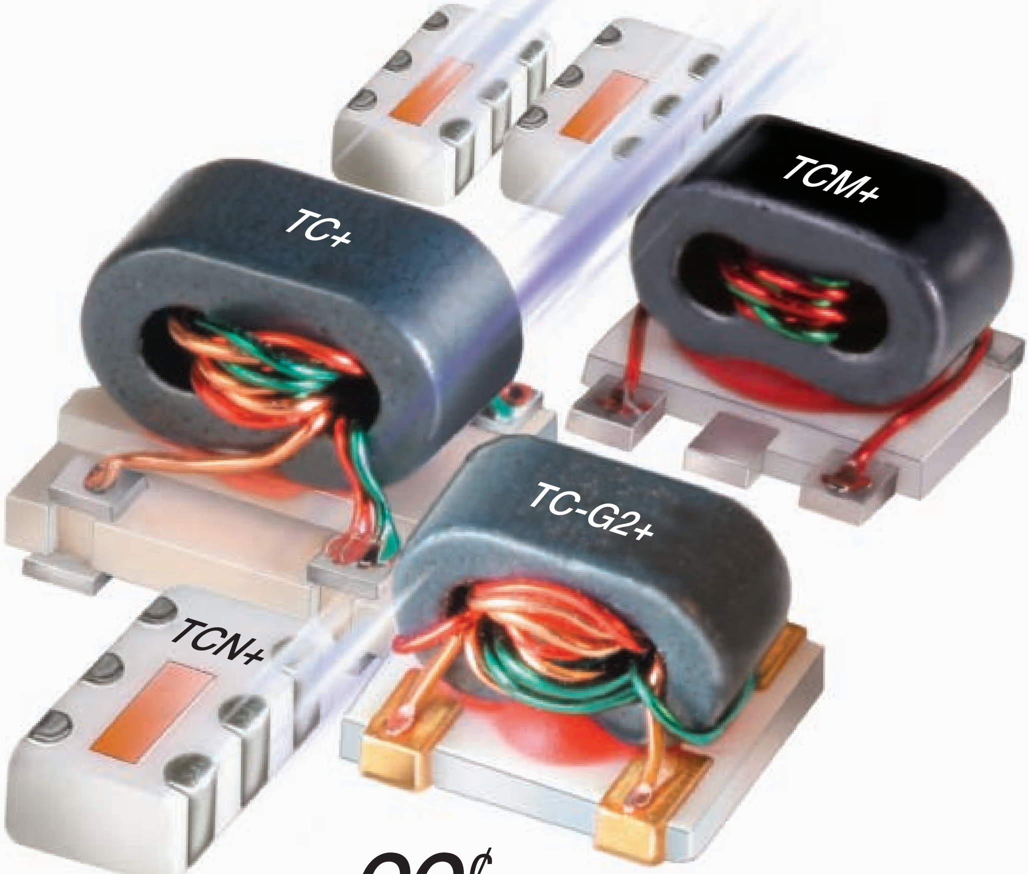

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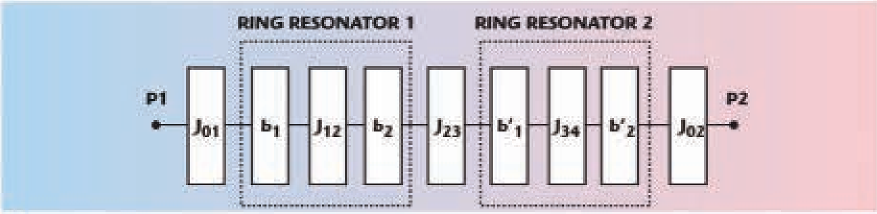


▲ *Fig. 3 Equivalent circuit of the proposed dual ring Balun-BPF.*

$$J_{12}\big|_{\omega=\omega_0} = \left|Y_1 - Y_2\right| \qquad (2a)$$

$$J_{34}\big|_{\omega=\omega_0} = \left|Y_1' - Y_2'\right| \qquad (2b)$$

The Balun-BPF can now be designed with Equation 3, using the standard design method for a band-pass filter with J-inverters. Here, J_{02} was divided by √2 because there are two filter sections in a balun filter.[3,4]

TABLE I

PARAMETER VALUES FOR THE DUAL RING BALUN-BPF OF FIGURE 1

Y_1, Y_3	Y_2	Y_1', Y_3'	Y_2'	
0.0500	0.0563	0.0500	0.0563	
J_{01}	J_{12}	J_{23}	J_{34}	J_{02}, J_{03}
0.0123	0.0063	0.0048	0.0063	0.0087

$$J_{01} = \sqrt{\frac{\overline{w}b_1Y_0}{g_0g_1}},\ J_{02} = \sqrt{\frac{\overline{w}b_2'Y_0}{2g_4g_5}} \qquad (3)$$

$$J_{i,i+1} = \overline{w}\sqrt{\frac{b_ib_{i+1}}{g_ig_{i+1}}}\Bigg|_{i=1,2,3}$$

As an example, the design specifications are chosen as f_0 = 2.45 GHz, BW = 100 MHz and ripple = 0.03 dB. The calculated parameter values, using the above design procedure, are listed in ***Table 1***.

The value of J_{23} is too small to be fabricated using a λ/4 microstrip line. Hence, an interdigital type inverter structure is proposed for the inverter, as shown in ***Figure 4***, which has an additional advantage in size compared to a λ/4 transmission line inverter. The Y-matrix of inverters is well-known as

$$Y_{inverter} = \begin{bmatrix} 0 & \pm jY_{23} \\ \pm jY_{23} & 0 \end{bmatrix} \qquad (4)$$

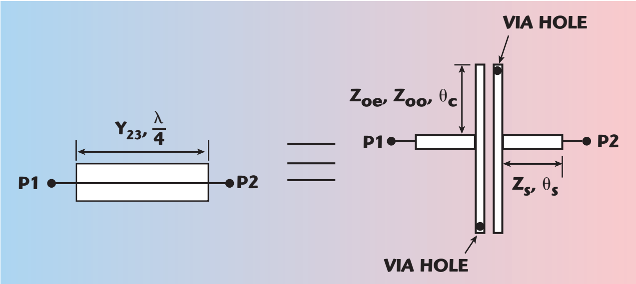
The value of the proposed inverter elements can be obtained by equating the Y-matrix of the proposed structure according to Equation 4 at the center frequency, using a commercial circuit simulator. ***Figure 5*** shows the simulated J and θ_s values for each coupling coefficient, C, when Z_{eo} = 169.6 Ω, physical length l_s = 2, 3, 4 mm for θ_s and Z_s = 111.062 Ω are used. The coupling coefficient is defined by Equation 5.[5]

$$C = \frac{Z_{oe} - Z_{00}}{Z_{oe} - Z_{00}} \qquad (5)$$

The design parameters of the interdigital inverter for J_{23} = 0.0048 and l_s = 3.00 mm are listed in ***Table 2***.

The cross-coupling effect from

the proximity of the two ring resonators is also considered when the dual ring Balun-BPF is simulated. ***Figure 6*** shows the schematic for the cross-coupling effect used with ADS™. The cross-coupling part of the two rings

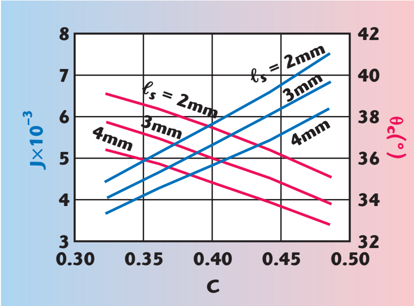


▲ *Fig. 4 Equivalent circuit for a λ/4 transmission line using an interdigital inverter.*

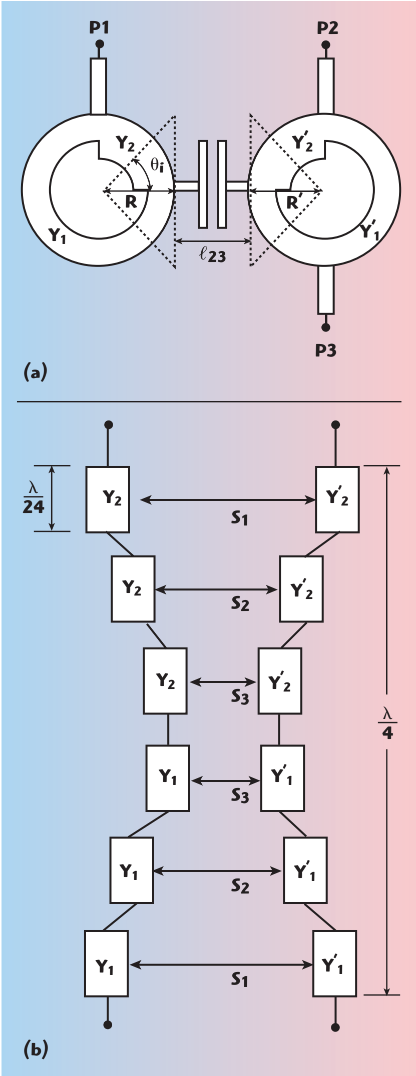
TABLE II

PARAMETER VALUES FOR THE INTERDIGITAL INVERTER

Z_{oe}	Z_{00}	θ_C	Z_S	L_S
169.60 Ω	77.22 Ω	37.00°	111.06 Ω	3 mm



▲ *Fig. 5 J and θc values for the coupling coefficient C and length ls of the interdigital inverter.*



▲ *Fig. 6 (a) Schematic for circuit simulation of the proposed Balun-BPF; (b) approximation using six coupled lines for the dotted line parts.*

was approximated by dividing it into 6-coupled lines. Then each gap of the coupled lines S_i is calculated with Equation 6, where $Y_1 = Y_1'$, $Y_2 \approx Y_2'$ and $R_1 \approx R_1'$ are used and u_i = 37.5°, 22.5°, 7.5°, and i = 1, 2, 3.

$$S_i = 2R(1 - \cos\theta_i) + l_{23} \qquad (6)$$

The result of the changes in the notch frequencies due to the cross-coupling effect is shown in ***Figure 7***.

SIMULATION AND MEASUREMENT RESULTS

The simulations and measurements were performed using the commercial circuit simulator ADS, and vector network analyzer, Anritsu 37397C. The substrate used is WINUS IS640 with a thickness of 0.762 mm, a relative dielectric constant of 3.38 and a loss tangent of 0.0042.

Figure 8 shows the fabricated dual ring Balun-BPF with two small tuning stubs. The 1 by 3 mm stubs, inside the rings, are used to finely adjust the slope parameters of the dual ring resonator. ***Figure 9*** shows the simulated and measured frequency responses. The measured

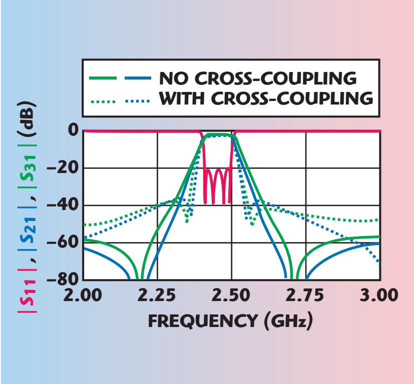


Fig. 7 Frequency responses of the Balun-BPF with and without cross-coupling.

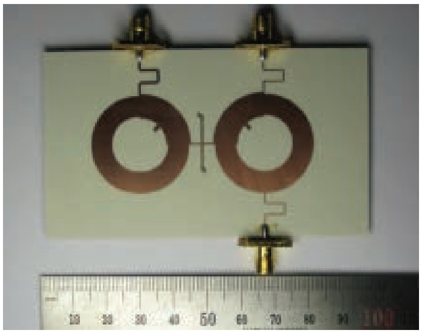


Fig. 8 Fabricated Balun-BPF.

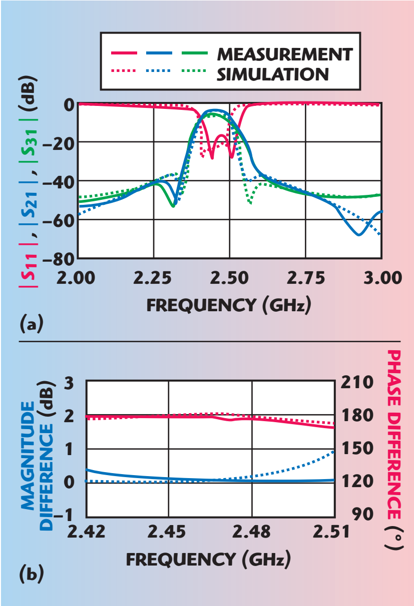


Fig. 9 Simulated and measured results: (a) S-parameters and (b) magnitude and phase differences.

response shows the equal amplitude and balanced phase characteristics between the two balanced output ports as well as the symmetrical passband response and the intended sharp skirt responses of this excellent Balun-BPF.

CONCLUSION

The proposed dual ring arrangement shows excellent improvement in the symmetry and the skirt response of the two balanced outputs of a Balun-BPF. An interdigital type inverter structure for inter-ring coupling and the effect of cross-coupling between two rings are also discussed. The proposed concept of the dual ring Balun-BPF could be even more useful by applying the multilayer, LTCC or MMIC technologies for miniaturization. ■

References

1. E.Y. Jung and H.Y. Hwang, "A Balun-BPF Using a Dual Mode Ring Resonator," *IEEE Microwave and Wireless Components Letters*, Vol. 17, No. 9, September 2007, pp. 652-654.
2. D.R. Huang and H.R. Chuang, "A 40 to 900 MHz CMOS Broadband Differential LNA for a DTV RF Tuner," *Microwave Journal*, Vol. 50, No. 2, February 2007, pp. 128-136.
3. S.J. Kang, U.H. Park, H.Y. Hwang, "An Analysis of Three Port Ring Resonator for the Balun-BPF Characteristics," *Journal of the Korean Electromagnetic Engineering Society*, Vol. 19, No. 4, April 2008, pp. 436-441.
4. G.L. Matthaei, L. Young and E.M.T. Jones, *Microwave Filters, Impedance Matching Networks and Coupling Structures*, Artech House Inc., Norwood, MA, 1980.
5. D.M. Pozar, *Microwave Engineering*, Second Edition, John Wiley & Sons Inc., Hoboken, NJ, 1998.

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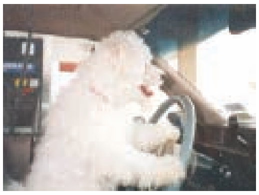

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MICROSTRIP BANDPASS FILTER WITH SLOTTED HEXAGONAL RESONATORS AND CAPACITIVE LOADING

A compact microstrip elliptic-function bandpass filter (BPF) is introduced in this article. The techniques, etching slot and adding open stubs with capacitive loading, are applied to enhance the self-inductance and self-capacitance of the hexagonal open-loop resonators, which increases the electrical length of the resonator. At the same time, the capacitive coupling between two hexagonal resonators is enhanced. Size reduction and improved insertion-loss performances are obtained. Compared to the conventional design, the center frequency and insertion loss of the proposed filters are reduced by 28 percent and 3.1 dB, respectively. The measurements show that the proposed filter, called Type II, has a fractional bandwidth of 23 percent at the center frequency of 1.84 GHz and its insertion loss in the passband is less than 1.5 dB. The BPF occupies only 12 × 21.2 mm.

Modern mobile systems impose strict requirements for bandpass filters, such as small size, high selectivity, wide upper stopband, low insertion loss and cost. A planar microstrip elliptic-function BPF is a good choice for this purpose. BPF advances on the base of circular, square and triangular patch/ring resonators have been reported widely. For example, Hong proposed an elliptic-function BPF using meander square resonators for size reduction,[1] while Zhang presented another elliptic-function BPF with capacitive loading for compactness and sharp rejection performances.[2]

Recently, there has been a growing interest in planar hexagonal resonators/filters because of their small size and high electric coupling. For instance, a compact BPF using hexagonal resonators was presented by Zhu.[3] By adopting a skew-symmetric feed structure, an additional transmission zero occurs within the upper stopband of this filter, which generates a wide bandstop performance. In 2002, Chang provided a high-selectivity quasi-elliptic BPF with five hexagonal resonators,[4] which proved that some frequency responses can be achieved by

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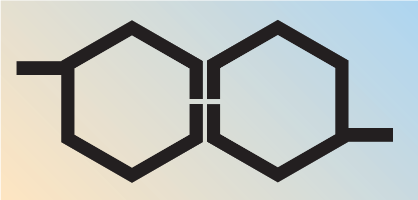


Fig. 1 Conventional hexagonal filter.

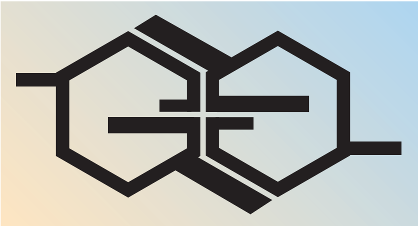


Fig. 2 Type I hexagonal filter.

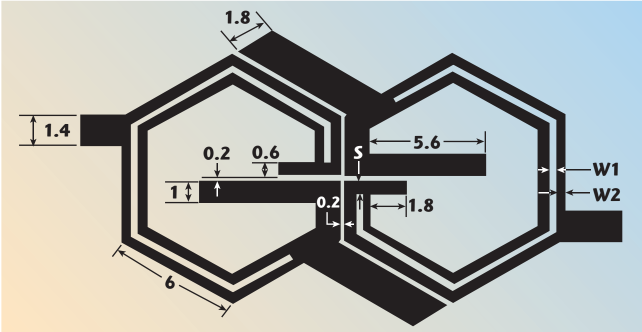


Fig. 3 Type II hexagonal filter (dimensions in mm).

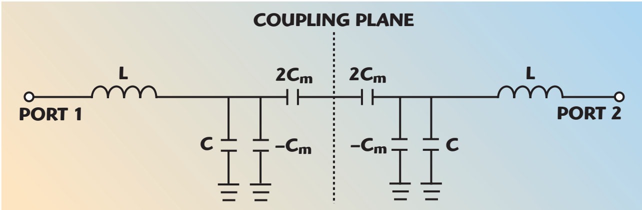


Fig. 4 Circuit model of the conventional hexagonal filter.

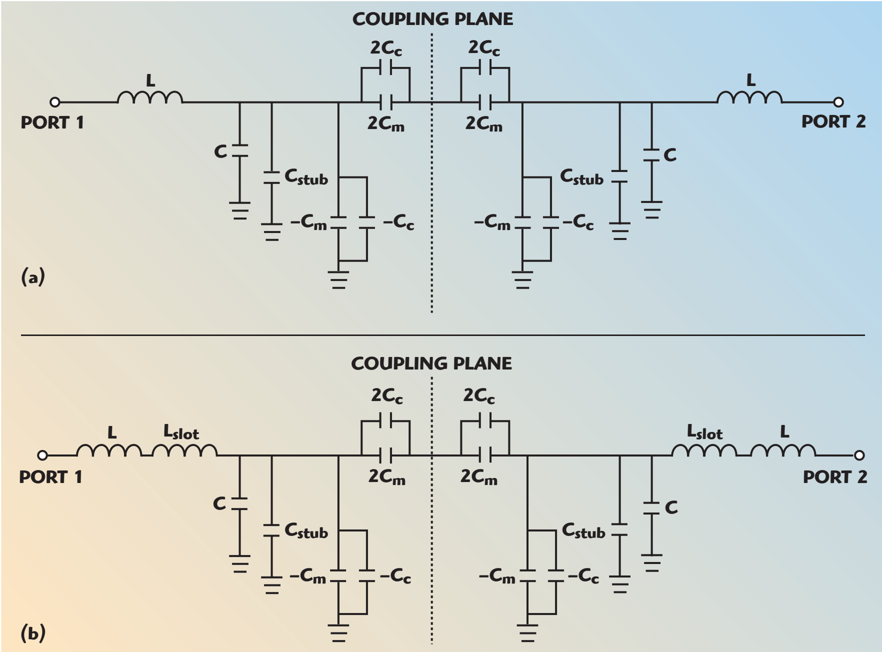
a fewer number of hexagonal resonators than with square resonators. Also, Mao described a dual-mode BPF using hexagonal resonators in 2006.[5] The filter is easy to fabricate and possesses enhanced power-handling capability. However, the circuit sizes are large and occupy at least 0.83λg × 0.71λg, where λg is the guided wavelength at the center frequency of the passband. To make the circuit size compact and enhance the coupling between resonators, Ni reported a hexagonal filter with a source-load coupling structure.[6] The filter requires a size amounting to 0.32λg × 0.21λg.

In this article, a novel and small elliptic-function hexagonal BPF is proposed. The design techniques, etching slot and adding open stubs are analyzed and verified by simulations and measurements. Also, an asymmetrical 50 Ω feed structure is used. Compared to the reported hexagonal filters in the literature, the proposed filter exhibits size reduction and excellent transmission performances.

HEXAGONAL FILTER DESIGN AND CIRCUIT MODELING

A conventional BPF design, using λ/2 hexagonal open-loop resonators, is shown in ***Figure 1***. The filter electric coupling structure is chosen and elliptical frequency responses are achieved by using two skew-symmetric transmission line feeding structures.[7,8] Based on the conventional filter, two pairs of inner open stubs and a pair of outer open stubs are added to produce the Type I filter shown in ***Figure 2***. The inner open stubs increase the resonator's self-capacitance, while the outer open stubs enhance the electric coupling between resonators. Based on the Type I filter, slots are etched in the resonator and the Type II is produced, as shown in ***Figure 3***, where the dimensions are in mm. After etching one slot on each resonator, extra transmission zeros may occur. Additionally, the extra transmission zero can be adjusted by changing the slot's length which leads to a wider stopband than before.[9] Without occupying extra size, the proposed filter, with reduced center frequency and low insertion loss performances in the passband, may be realized.

According to the equivalent circuit model described by Hong,[7] the circuits' modeling of the hexagonal filters are implemented. Similar to the circuit model of the square open-loop resonator, the circuit model of the conventional hexagonal filter is set up and shown in ***Figure 4***. L and C are the self-inductance and self-capacitance of the hexagonal open-loop resonator and Cm denotes the mutual capacitance. Correspondingly, the circuit models of the Type I and Type II hexagonal filters are given in ***Figure***

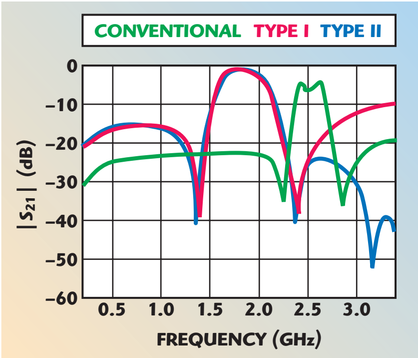


▲ *Fig. 5 Circuit models of the Type I (a) and Type II (b) hexagonal filters.*

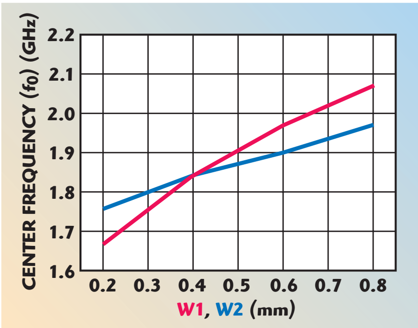
5. The effects of the capacitive coupling from the inner open stubs and the outer open stubs are represented by Cc and Cstub, respectively. Furthermore, the self-inductance of the hexagonal open-loop resonator is improved by etching the slot. The increment is described by Lslot.

RESULTS AND DISCUSSION

To demonstrate the proposed topology usefulness, the filters were simulated with Ansoft HFSS 8.0; their insertion loss performance is presented in ***Figure 6***. The substrate used for simulation and measurements is FR-4, 0.8 mm thick with a dielectric constant ε_r = 4.5. The input and output lines are 50 Ω microstrip lines. The physical dimensions of the filters have been given previously. From the comparison between the insertion loss of the conventional and proposed filters, it is found that the center frequency in the passband is decreased from 2.5 GHz to 1.8 Hz and the insertion loss in passband reduced from 4.2 to 1.1 dB. The center frequency and insertion loss are reduced by 28 percent and 3.1 dB, respectively. It shows that the outer open stubs increase the capacitive coupling between the resonators so that the insertion loss decreases. On the other hand, the total capacitive effect from the inner and outer open stubs increases so that the resonant frequency of the hexagonal resonator is reduced. Notice that there is an additional transmission zero in the upper stopband, which is located at 3.1 GHz for Type II. That is to say an improved wide stopband performance is obtained.



▲ *Fig. 6 Insertion loss performance of the hexagonal filters.*

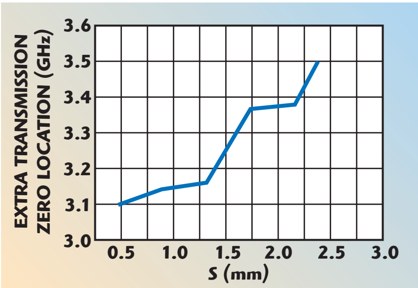


▲ *Fig. 7 Center frequency of the proposed filter vs. W1 and W2 dimensions.*

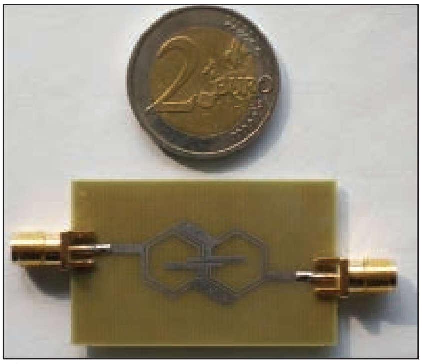
The relationship between the physical parameters, W1 and W2, and the center frequency is described in ***Figure 7***. It is clear that the center frequency decreases when W1 (W2) becomes

smaller. Also, the design parameter S is affecting the extra transmission zero location, as shown in ***Figure 8***.

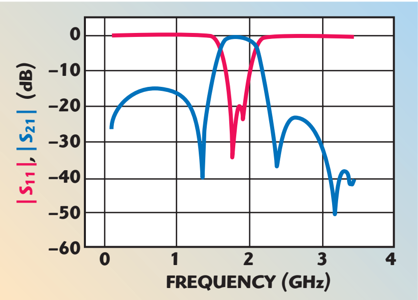
The proposed Type II filter was fabricated and its photograph is shown in ***Figure 9***. Its physical parameters are the same as shown previously, with W1 = 0.4 mm, W2 = 0.4 mm and S = 0.6 mm. The measured results are given in ***Figure 10***. The measurements verify that the proposed filter has a fractional bandwidth of 23 percent with a center frequency of 1.84 GHz. The filter has a return loss greater than 15 dB from 1.71 to 1.98 GHz. The insertion loss in the passband is less than 1.5 dB. There are two transmission zeros on both sides of the passband. They are -41 and -38 dB at 1.35 and 2.37 GHz, respectively. Another transmission zero is -51 dB at 3.20 GHz. There is a good agreement between simulated and measured results. The circuit size is 21.2 × 12 mm. A comparative study of the sizes of the reported hexagonal BPFs[6] (0.32λg × 0.21λg) and the proposed filter (0.24λg × 0.14λg) shows that the latter is more compact and its size is reduced by approximately 50 percent. The measurements were carried out on an Agilent 8722 vector network analyzer.



▲ *Fig. 8 Location of the extra zero vs. S.*



▲ *Fig. 9 Proposed filter photograph.*



▲ *Fig. 10 Measured data for proposed filter.*

CONCLUSION

A novel design of a hexagonal BPF is introduced in this article. The techniques, etching slot and adding open stubs are applied to enhance the self-inductance and self-capacitance of the hexagonal open-loop resonators so that a compact filter with low insertion loss is achieved. Also, an extra transmission zero occurs, which leads to a wide upper rejection performance. Finally, this filter was designed, fabricated and measured. This compact BPF, with good transmission performance, has a potential for compact microwave circuit applications.

ACKNOWLEDGMENTS

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References

1. J.S. Hong and M.J. Lancaster, "Compact Microwave Elliptic Function Filter Using Novel Microstrip Meander Open-loop Resonators," *Electronics Letters*, Vol. 32, No. 6, 14 March 1996, pp. 563-564.
2. X.Y. Zhang, J.X. Chen and Q. Xue, "Compact Bandpass Filter Using Open-loop Resonators with Capacitive Loading," *Microwave and Optical Technology Letters*, Vol. 49, No. 1, January 2007, pp. 83-84.
3. Y.Z. Zhu and Y.J. Xie, "New λ/2 Microstrip Bandpass Filters Using Skew-symmetric Feed Structure," *Microwave and Optical.Technology Letters*, Vol. 50, No. 2, February 2008, pp. 440-442.
4. K.F. Chang, K.W. Tam, W.W. Choi and R.P. Martins, "Novel Quasi-elliptic Microstrip Filter Configuration Using Hexagonal Open-loop Resonators," *2002 IEEE International Symposium on Circuits and Systems Digest*, Vol. 3, pp. 863-866.
5. R.J. Mao and X.H. Tang, "Novel Dual-mode Bandpass Filters Using Hexagonal Loop Resonators," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, No. 9, September 2006, pp. 3526-3533.
6. D. Ni, Y. Zhu and Y. Xie, "Design of Hexagonal Filter with Source-load," *Electronics Letters*, Vol. 42, No. 23, 9 November 2006, pp. 1355-1357.
7. J.S. Hong and M.J. Lancaster, "Couplings of Microstrip Square Open-loop Resonators for Cross-coupled Planar Microwave Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 44, No. 11, November 1996, pp. 2099-2109.
8. C.M. Tsai, S.Y. Lee and C.C. Tsai, "Performance of a Planar Filter Using a 0° Feed Structure," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 50, No. 10, October 2002, pp. 2362-2367.
9. C.F. Chen, T.Y. Huang and R.B. Wu, "Miniaturized Microstrip Quasi-elliptical Bandpass Filters Using Slotted Resonator," *2006 IEEE MTT-S International Microwave Symposium Digest*, pp. 1185-1188.

DESIGN OF A UWB BANDPASS FILTER WITH A NOTCHED BAND AND WIDE STOPBAND

A novel ultra-wideband (UWB) bandpass filter (BPF) is proposed and implemented in this article. The proposed UWB BPF has a highly rejected notched band and improved out-of-band performances. It is composed of two cascaded interdigital hairpin resonator units and four semicircle defected ground structures (S-DGS). The interdigital hairpin resonator unit and S-DGS with different dimensions are theoretically analyzed. The equivalent circuit of S-DGS is also presented. The working frequency band of the proposed UWB BPF is 3.1 to 10.6 GHz and the notched band is 7.5 to 7.6 GHz. Good insertion and return losses and high out-of-band rejections are achieved as demonstrated in both simulation and experiment.

Research into ultra-wideband technology has risen dramatically since the US Federal Communications Commission (FCC) authorized the frequency band of 3.1 to 10.6 GHz for commercial purposes.[1] A bandpass filter is a key component of a UWB wireless communication system. Many BPFs have been developed based on various kinds of methodologies, such as non-periodical shunt-stub loading,[2] composite low pass/high pass topology,[3] cascaded broadside-coupling,[4] circular resonator[5] and multiple-mode resonator (MMR).[6-9] Most of these BPFs have good in-band frequency performance, but the out-of-band performance is poor. Due to the existing radio signals such as wireless local-area network (WLAN) signals, which may interfere with the UWB users, a small BPF with a notched band is needed to reject these interfering signals. A UWB BPF with a notched band was realized using an embedded open-circuited stub,[10] which is an effective way to reject any undesired radio signal. However, this structure has poor out-of-band performances.

In this article, a novel UWB BPF is proposed and implemented. It exhibits good frequency performances and a highly rejected notched band in the passband and achieves a wide stopband. The designed UWB BPF consists of two cascaded interdigital hairpin resonator units and four semicircle defected ground structures (S-DGS) along with the microstrip line. This structure is simple and flexible for the purpose of blocking any unwanted existing radio signals that may appear in the UWB band. S-DGSs are used to improve out-of-band performances. Measured results agree well with the simulated results.

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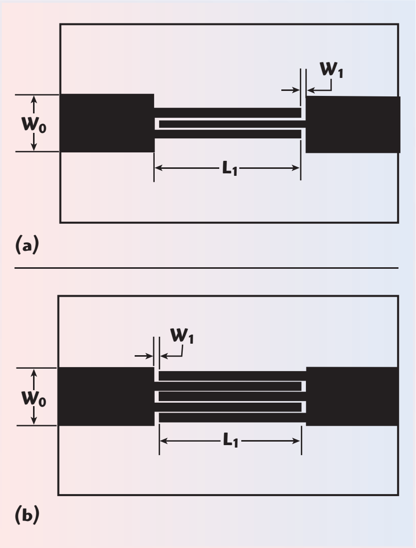
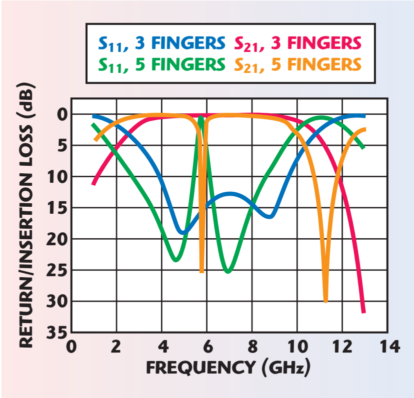
ANALYSIS AND DESIGN

Interdigital Hairpin Resonator

Figure 1 shows the geometry of a conventional interdigital hairpin resonator unit with three identical fingers within a 50 Ω microstrip line. The width of the finger is W_2 and the distance between the adjacent coupling fingers is W_3. The microstrip interdigital hairpin resonator proposed in this article, with five identical fingers, is also shown. The coupling-finger length (L_1) is first chosen to be one-quarter wavelength at the center frequency of this UWB passband, which is 6.85 GHz. The frequency characteristics of these two interdigital hairpin resonators are simulated by HFSS V.10.0. The simulation results show that a notched band is introduced by adding two fingers, as shown in ***Figure 2***, where W_0 = 3.0 mm, W_1 = 0.15 mm, W_2 = 0.4 mm, W_3 = 0.15 mm, L_1 = 9.4 mm, substrate ε_r = 2.2 and the substrate thickness is 1.0 mm. Different notched bands can be achieved by changing W_2 and W_3. However, it can be seen that the proposed interdigital hairpin resonator unit has a gradual cut-off frequency response and poor out-of-band performance.



▲ *Fig. 1 Geometry of interdigital hairpin resonators: (a) 3 fingers and (b) 5 fingers.*



▲ *Fig. 2 Simulated S-parameters of the hairpin resonator unit.*

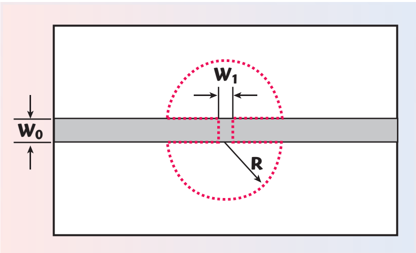
Semicircle Defected Ground Structure

A defected ground structure (DGS) for a microstrip line is a periodic defect etched in the ground plane, which can provide a good band-rejection property. The conventional dumbbell DGS consists of two rectangular defected areas and one connecting slot on the backside metallic ground plane. The configuration of the proposed S-DGS, fed by a 50 Ω microstrip line, is shown in ***Figure 3***. It consists of two semicircle defected areas and one narrow connecting slot on the ground plane of the microstrip line. The new S-DGS has better stopband characteristics.

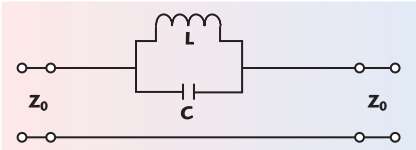
The frequency characteristic of the S-DGS unit can be modeled by a series-connected parallel LC resonance circuit in the transmission line, as shown in ***Figure 4***. The equivalent capacitance and inductance of the circuit can be extracted by using the circuit analysis theory as follows:

$$C = \frac{\omega_C}{2Z_0(\omega_0^2 - \omega_c^2)} \quad (1)$$

$$L = \frac{1}{4\pi^2 f_0^2 C} \quad (2)$$



▲ *Fig. 3 Geometry of the proposed S-DGS unit.*



▲ *Fig. 4 Equivalent circuit of the proposed S-DGS unit.*

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IKE Micro owner Scott MacKenzie discusses his latest fashion choices.

MWJ: I guess the first obvious question is, why the outfit?

SM: I promised to dress up like a woman if we beat our productivity goal in 2008. We did, so here I am in all my glory!

MWJ: How does IKE Micro produce at such a high level?

SM: We have a veteran, low-turnover workforce, and a good balance of automated and manual assembly capability. Because of our 100% focus on build-to-print manufacturing, design and market issues don t get in the way of the delivery schedule.

MWJ: Are your company's assembly capabilities comprehensive?

SM: Yes, from DC to 100GHz. Our capabilities include surface mount, epoxy and solder board mount, feedthru installation, die attach, wire/ribbon bond, coil and beam lead bonding, and all the crazy RF soldering and bonding needed so our units make it through test with minimal tuning.

MWJ: What types of customers take advantage of IKE's experience and capabilities?

SM: It s a good mix. It includes the big systems companies and many of the small to mid-sized module suppliers. Many of these companies advertise with you. We do complex modules and pretty basic subassemblies. Our domestic and international customer mix is 65% defense and 35% commercial.

MWJ: What are your goals for 2009?

SM: I want to continue to produce at high levels and exceed customer expectations. More importantly, I plan to steer clear of the EE design guys, some of those guys freak me out, especially when I m wearing this dress.

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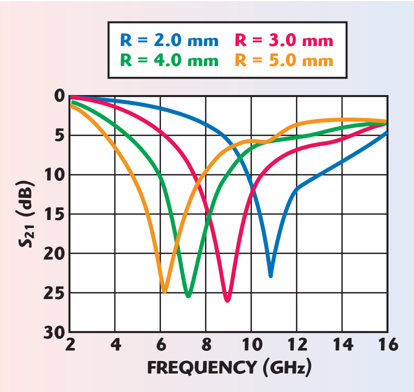
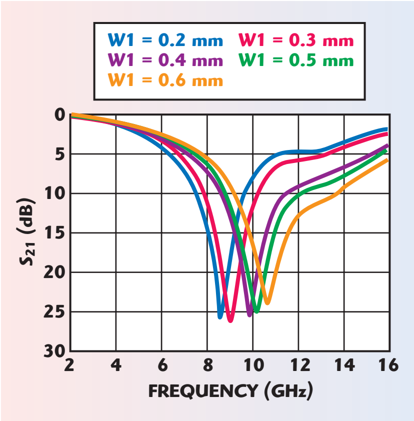


▲ *Fig. 5 Simulated S_{21} of the proposed S-DGS unit for various semicircular radius.*

where f_c is the 3 dB cut-off frequency and f_0 is the resonant frequency of the stopband.

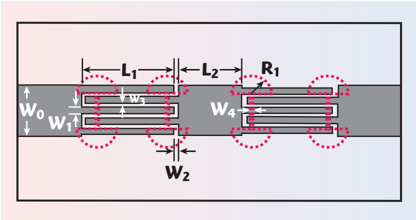
Furthermore, the effects of the proposed S-DGS parameters on the frequency characteristics have been investigated. ***Figure 5*** shows the transfer characteristics of the S-DGS with a different radius with W_0 = 3.0 mm and W_1 = 0.4 mm. The simulation results show that the cut-off frequency is dependent on the radius of the semicircle. As the radius is increased, the cut-off frequency decreases. ***Figure 6*** shows the frequency response of the S-DGS for various gap distances with W_0 = 3.0 mm and R = 4.0 mm. It can be seen that the resonance frequency is proportional to the gap distance.



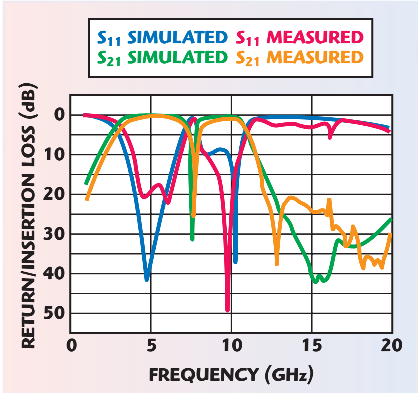
▲ *Fig. 6 Simulated S_{21} of the proposed S-DGS unit for various gap distances.*

UWB BPF

For the design of a UWB BPF with a highly rejected notched band and good frequency characteristics in passband and stopband, two interdigital hairpin resonator units and four S-DGSs are cascaded along with the microstrip line. S-DGSs are on the backside metallic ground plane under the microstrip line. The configuration of the proposed UWB BPF is shown in ***Figure 7***. Different notched bands can be obtained by changing W_2 and W_3. The BPF simulation is performed by using HFSS V.10.0. The substrate is RT/Duroid 5880 with a thickness of 1.0 mm and a dielectric constant of 2.2. All the dimensions are determined as follows: W_0 = 3.0 mm, W_1 = 0.4 mm, W_2 = 0.4 mm, W_3 = 0.15 mm, W_4 = 0.1 mm, L_1 = 7.2 mm, L_2 = 5.0 mm and R_1 = 1.0 mm.



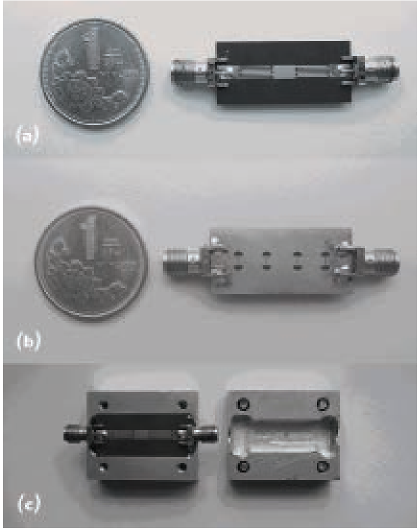
▲ *Fig. 7 Geometry of the proposed UWB BPF.*



▲ *Fig. 8 Simulated and measured S-parameters of the designed UWB BPF.*

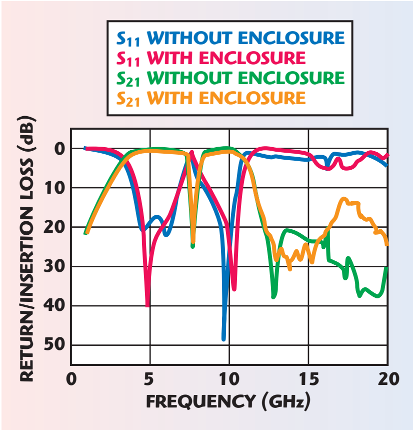
RESULTS AND DISCUSSIONS

Finally, the designed UWB BPF is measured with an Agilent N5230A vector network analyzer. The comparison between the simulated and measured results is shown in ***Figure 8***. It is found that the working frequency of the proposed UWB BPF is 3.1 to 10.6 GHz and the notched band is 7.5 to 7.6 GHz. The insertion loss is less than 1.0 dB and the return loss is better than 10 dB in most part of the passband. The measured rejection loss is more than 25 dB at the mid-band frequency of the notched



▲ *Fig. 9 Photographs of the fabricated UWB BPF: (a) top view, (b) bottom view and (c) with opened metallic enclosure.*

band and the upper-stopband with 20 dB attenuation is up to 20 GHz. It is found that the measured lower corner frequency is shifted to a higher frequency, which could be attributed to the fabrication tolerance. ***Figure 9*** shows photographs of the fabricated UWB BPF. The volume of the UWB BPF with the metallic enclosure is 36 × 29 × 22 mm. In consideration to the application, the influence of a metallic enclosure on the S-parameters of the proposed UWB BPF has also been analyzed, as shown in ***Figure 10***. By observing the figure, one can find that the influence is weak and the insertion loss at the upper-stopband is slightly increased but still is less than 10 dB, which can be neglected when the proposed BPF is applied to a UWB system.



▲ *Fig. 10 Measured S-parameters of the UWB BPF with and without metallic enclosure.*

CONCLUSION

In this article, a compact UWB BPF with a highly rejected notched band and improved out-of-band performance has been proposed, designed and implemented. By using two cascaded interdigital hairpin resonator units and introducing four S-DGSs, the proposed UWB BPF can have a wide stopband and in the meantime effectively introduce a narrow notched band. The measured results are in good agreement with the simulated results. ■

References

1. Federal Communications Commission, "Revision of Part 15 of the Commission's Rules Regarding Ultra-wideband Transmission Systems," *Cover Report ET-Docket 98–153, FCC02–48*, April 2002.
2. J.S. Hong and H. Shaman, "An Optimum Ultra-wideband Microstrip Filter," *Microwave and Optical Technology Letters*, Vol. 47, No. 3, March 2005, pp. 230-233.
3. W. Menzel, M.S.R. Tito and L. Zhu, "Low-loss Ultra-wideband (UWB) Filters Using Suspended Stripline," *2005 Asia-Pacific Microwave Conference Proceedings*, pp. 2148-2151.
4. K. Li, D. Kurita and T. Matsui, "An Ultra-wideband Bandpass Filter Using Broadside-coupled Microstrip-coplanar Waveguide Structure," *2005 IEEE International Microwave Symposium Digest*, pp. 675-678.
5. J.K. Xiao and Y. Li, "Novel Compact Microstrip Square Ring Bandpass Filters," *Journal of Electromagnetic Waves and Applications*, Vol. 20, No. 13, 2006, pp. 1817-1826.
6. L. Zhu, W. Menzel, K. Wu and F. Boegelsack, "Theoretical Characterization and Experimental Verification of a Novel Compact Broadband Microstrip Bandpass Filter," *2001 Asia-Pacific Microwave Conference Proceedings*, pp. 625-628.
7. L. Zhu, S. Sun and W. Menzel, "Ultra-wideband (UWB) Bandpass Filters Using Multiple-mode Resonator," *IEEE Microwave Wireless and Components Letters*, Vol. 15, No. 11, November 2005, pp. 796-798.
8. L. Zhu and H. Wang, "Ultra-wideband Bandpass Filter on Aperture-backed Microstrip Line," *Electronics Letters*, Vol. 41, No. 18, September 1, 2005, pp. 1015-1016.
9. H. Wang, L. Zhu and W. Menzel, "Ultra-wideband (UWB) Bandpass Filters with Hybrid Microstrip/CPW Structure," *IEEE Microwave Wireless and Components Letters*, Vol. 15, No. 12, December 2005, pp. 844-846.
10. H. Shaman and J.S. Hong, "Ultra-wideband (UWB) Bandpass Filter with Embedded Band Notch Structures," *IEEE Microwave and Wireless Components Letters*, Vol. 17, No. 3, March 2007, pp. 193-195.

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RF AND MICROWAVES IN ASIA: CHALLENGING TIMES

Over the last decade Asia has seen unprecedented economic, industrial and commercial growth. However, with the economic downturn impacting globally, and consumers, manufacturers and investors having to face harsh realities, will the region continue to prosper? This report highlights the prevailing indicators, examines the region's RF and microwave market, and gauges the current market.

When this annual report was published a year ago, the reality of a global economic downturn had just begun to loom large. The banking and financial services sectors were the first to take a hit, but all industries, including the RF and microwave sector, were bracing themselves for the full impact of a global financial crisis and recession. The threat has been heightened by the two things that are most difficult to combat and legislate for—uncertainty and unpredictability.

Surely though, if there was one geographical region in a position to ride the economic storm, it would be the Asia-Pacific. In recent years the region has been the Utopia of development and expansion, the focus of internal activity and outside investment, and a hub of technological innovation. The established countries have been innovators and models for commercial development, while emerging nations offer competition through low cost, large scale mass production.

Market growth has been stimulated by consumer demand both from booming home markets in developing and emerging countries, eager to embrace the latest technology and innovation, and from industrialized countries across the globe that have exhibited an insatiable appetite for low price products.

After a period of growth and development, Asia is facing challenges that were largely unforeseen. One of the first opportunities to gauge how it is faring will come at the 2009 Asia-Pacific Microwave Conference (APMC 2009), which will be held in Singapore from 7 to 10 December. The event is a platform for the region's technological research and development, a forum for networking and will provide an opportunity to gauge the current climate.

This article provides an insight into the prevailing market conditions and the development and implementation of technology. It does not purport to be a comprehensive market overview, but offers a snapshot of the current status of industrial development and identifies the main trends influencing it. It also provides a commercial perspective as executives from a small cross-section of companies actively participating in the Asian RF and microwave industry contribute to the 'company survey'.

ASIAN PERSPECTIVE

In the past year statistical forecasts have been amended, rewritten and even abandoned, so the emphasis in this article is on the technology rather than the numbers. Telecommunications is a major area of RF and microwave activity, with the semiconductor and electronics industries also being significant.

RICHARD MUMFORD
Microwave Journal *International Editor*

Telecommunications

The Asia-Pacific region has been the fastest growing telecommunications market in the world. The complete developmental spectrum is represented from the established markets of Japan, Singapore, South Korea, Taiwan and Hong Kong to the potentially vast markets of China and India.

In the mature markets there is near saturation of mobile subscriptions. The latest handsets are readily available, the range of services offered is comprehensive and operators are looking to technology to provide differentiation, be it speed, accessibility, longer battery life, etc.

Mobile revenues in Japan, Hong Kong and South Korea are not achieved through subscriber growth but by data usage and network expansion. All three countries are at the forefront when it comes to rolling out new networks and adopting new technologies. Japan, in particular, is renowned for using cutting-edge technologies. South Korea, on the other hand, leads in adopting new business models and innovation and has become a leader in CDMA technology.

Over recent years mobile subscriptions have risen steadily towards saturation in Malaysia and Singapore, while the likes of Cambodia, Laos and Vietnam are yet to reach such figures. In these countries growth is primarily driven by expansion into rural areas as networks extend beyond the major urban conurbations.

Although it is yet to have extensive penetration, 3G technology has been gaining in popularity as a number of operators in countries such as Vietnam and Thailand have begun to deploy 3G networks in order to supplement their non-voice revenues and profit from the wider range of service that faster network speeds facilitate.

Even in the current economic climate it is India and China where there is significant activity. India, in particular, has put long-term initiatives in place, which it continues to invest in. The Indian Telecom sector has developed dramatically, with the share of the private sector increasing to more than 66 percent and the contribution of mobile telephony going up to 80 percent, according to India's department of Telecommunications (DoT). The country has the third largest telecom network and the second largest wireless network in the world, and the DoT has set a target of 500 million telephones and broadband connectivity to 20 million subscribers by the end of 2010.

In India the demand for the masses to 'get connected' has seen the growth of wireless telephony, which is affordable, accessible and has the capacity to service rural and remote communities. There are ongoing efforts to expand the country's infrastructure to cover all of the districts and states in India where there is no existing fixed wireless or mobile coverage. A second phase is then proposed that will see the erection of additional towers to provide mobile services to cover the remaining remote areas. These activities are being supported through the Universal Service Obligation Fund (USOF), which was set up by the Indian government in order to provide people in rural and remote areas access to telecommunication services at affordable and reasonable prices.

The country is also set to enter the 3G arena with the DoT setting a deadline for the nation's 3G auctions in early December 2009 with WiMAX and EVDO auctions commencing just a few days later. However, at the time of going to press, there is speculation that the December deadline will not be met and will be shifted into 2010. Having set floor prices of 35 billion rupees (approximately $725 M) for the 3G auction and 17.50 billion rupees (approximately $365 M) for the WiMAX auction, when the auctions do take place the government expects to reap at least 250 billion rupees (approximately $5.2 B).

China is also in transition from 2G to 3G with the government awarding 3G licenses for CDMA 2000, WCDMA and TD-SCDMA to China Telecom, China Unicom and China Mobile, respectively. The Chinese government and the three operators are supporting LTE, with each operator's implementation strategy being dictated by their present positions in the market and their currently adopted 3G technologies.

In terms of technology, WiMAX faces challenges, particularly from LTE, but at the current time the Asia-Pacific region represents good prospects for the technology in terms of subscriber uptake and the number of network deployments. There is particular potential in emerging markets as they try to bridge the digital divide.

Wi-Fi development in China is interesting and growing in three sectors. First, there is industrial implementation driven by the information-based nature of Chinese business. Secondly, the delays in awarding and implementing 3G licenses have seen Wi-Fi being adopted for home usage.

Third, and most significant, is the deployment of Wi-Fi City in many cities throughout China. As the name suggests, Wi-Fi City differs from Wi-Fi hotspots as it aims to provide seamless Wi-Fi connectivity citywide, rather than in limited areas. It has been popular as it is often free to access. This was the case in many areas up to and including the Beijing Olympics in 2008, but whether that is a realistic business model that can be sustained indefinitely remains to be seen.

Worldwide there have been moves to increase the broadband connectivity. Asia is no exception and broadband Internet has become one of the fastest growing market segments in the region. As is to be expected, broadband has been led by the region's developed economies such as South Korea, Japan, Taiwan, Singapore and Hong Kong. In developing countries dial-up narrowband access has been prevalent, but that is changing. ■

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MCA1-24	7	300-2400	6.1	40	5.95
MCA1-42	7	1000-4200	6.1	35	6.95
MCA1-60	7	1600-6000	6.2	30	7.95
MCA1-85	7	2800-8500	5.6	38	8.95
MCA1-12G	7	3800-12000	6.2	38	10.95
MCA1-24LH	10	300-2400	6.5	40	6.45
MCA1-42LH	10	1000-4200	6.0	38	7.45
MCA1-60LH	10	1700-6000	6.3	30	8.45
MCA1-80LH	10	2800-8000	5.9	35	9.95
MCA1-24MH	13	300-2400	6.1	40	6.95
MCA1-42MH	13	1000-4200	6.2	35	7.95
MCA1-60MH	13	1600-6000	6.4	27	8.95
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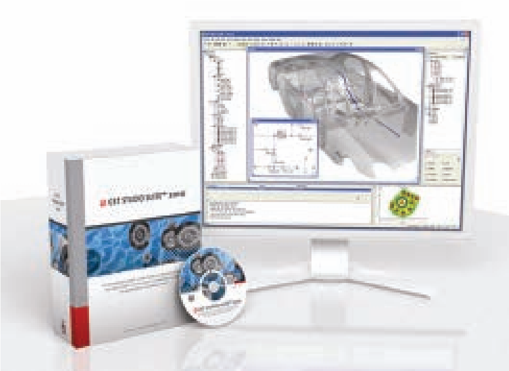


DESIGN SOFTWARE TOOL WITH COMPLETE TECHNOLOGY

Some years ago CST introduced a frequency domain solver into CST MICROWAVE STUDIO® (CST MWS) in addition to its time domain solver. The company recognized that an ever increasing array of microwave/RF and high speed data applications required alternate solver technology in order to optimize speed and memory usage. While such technology was available from various vendors, CST's approach placed the solvers within the same user friendly front-end that many engineers were already familiar with.

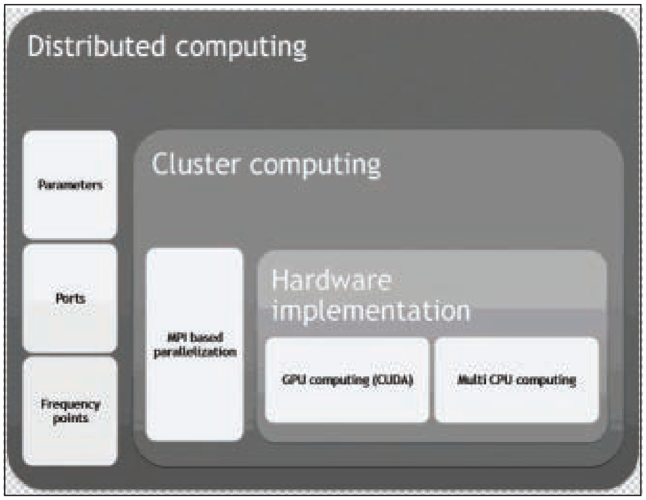
The company has continually expanded the range of technology available and increased the vast number of RF, microwave and high speed applications that can be solved quickly and accurately. Non-EM physics has also been introduced with circuit, thermal and mechanical simulation all available and closely coupled either directly or through CST DESIGN STUDIO™ (CST DS).

In the new CST STUDIO SUITE 2010 the circuit and system simulator CST DS, including optimization and layout, is a standard feature of all licenses. Full system simulation with CST tools is now emerging as a mainstream task for the design engineer—a breakthrough in a world of compact, high frequency devices with multi materials, antennas and circuits all within the same housing.

With such complete technology, CST can offer ideal solutions. For example, the data networking company may appreciate just the time domain solver for its broadband capabilities and memory efficiency for complex devices, but the defense contractor may additionally need the frequency domain solver for phased-array antennas and the asymptotic solver for electrically large aircraft.

While advancing the solving technology, CST has recognized that engineers often have large software toolboxes comprising mechanical CAD, layout, circuit simulation, legacy EM and more. A stand alone or 'point tool' EM simulator is no longer sufficient; it has to fit into existing workflows. This article reviews the latest 3D EM technology in CST STUDIO

CST - COMPUTER SIMULATION TECHNOLOGY
Framingham, MA



▲ *Fig. 1 CST Studio Suite HPC options.*

SUITE 2010 and how it has become a vital component in so many design workflows and system simulations.

ADDITIONS TO CORE SOLVERS

While the core solvers remain time-domain (T) and frequency-domain (F), these are constantly being enhanced, driven both by new algorithm research and high performance hardware. New in the F solver for version 2010 is sensitivity and yield analysis where S-parameter ranges for tolerant parameters can be calculated efficiently without numerical recalculation.

Also for the F solver, third-order elements and mixed elements are allowed. This combination is ideal for applications requiring frequency domain simulation that are electrically large but that also have critical small features. For the T solver, Nth order material fitting is new and allows accurate broadband modeling of critical material properties. Improved handling of port losses at broadband ports increases accuracy for certain applications.

The acquisition of the EM division of Flomerics has brought an additional approach to time-domain via the transmission line matrix method (TLM). This approach to 3D EM has strengths in EMC/EMI applications and installed antenna performance. One of its key benefits is its 'compact model' library, whereby geometrically complex components, such as vents and seams (including curved models for version 2010) that are difficult to mesh, are replaced by accurate circuit representations. Its 'octree meshing' approach is very efficient for structures with large differences in detail.

For version 2010, CST MICROSTRIPES™ (CST MS) is further integrated into CST STUDIO SUITE allowing easy model exchange and, key in this release, integration with CST DS. As with CST MWS, this allows CST MS blocks to be placed in the system simulator with circuit components or cascaded. CST MS also now benefits from the import of broadband sources from CST PCB STUDIO™ (CST PCBS) or CST CABLE STUDIO™ (CST CS).

This allows the results of PCB or cable harness simulations to be placed inside an enclosure and then simulated with CST MS to give the complete radiated emissions response. This decoupled approach leverages the strengths of both tools, allowing systems with components on vastly different scales to be simulated in a reasonable time. This approach is also available between other members of CST STUDIO SUITE via the 'field source' monitor.

ACCELERATING THE SIMULATION

In recent versions, techniques for ensuring that available hardware can be fully exploited to speed up simulations have been introduced. High performance computing (HPC) platforms can be used to achieve dramatic speedups.

To consolidate the many acceleration features now available through hardware and HPC, CST has introduced 'acceleration tokens.' One token will enable access to all acceleration features, but on limited hardware. More tokens will allow greater hardware utilization.

Examples of acceleration features include GPU cards (graphics card technology), MPI (using a computing cluster) and port/frequency point/parameter distribution (sending directly parallel tasks to multiple machines). For version 2010 the multi-CPU option becomes a standard feature where utilization of up to 16 threads is allowed on one main board. ***Figure 1*** shows HPC features available.

NEW SOLVER TECHNOLOGY

Despite recent advances in hardware capability, certain applications are still too demanding for the core general-purpose solvers. Particularly challenging problems range from complex multi-layer PCBs to large aircraft or ships. In either case, the complexity or size of the required solution mesh means that alternative techniques must be sought to achieve reasonable simulation times.

There are also physical consequences of driving high frequency currents or fields through devices, in particular heating and mechanical stress. To fully realize complete system simulation, these effects need to be considered in the system design.

ASYMPTOTIC SOLVER

In recent versions an integral equation solver (I) was introduced making use of the method of moments (MoM) and multi-level fast multipole method (MLFMM). This has proved successful for large antennas and aircraft. ***Figure 2*** shows installed performance simulation of an antenna radiating at around 9.5 GHz. This corresponds to an electrical length of the helicopter of ca. 600 wavelengths. However, the simulation of electrically huge (thousands of wavelengths) operational aircraft and ships at radar frequencies requires other approaches.

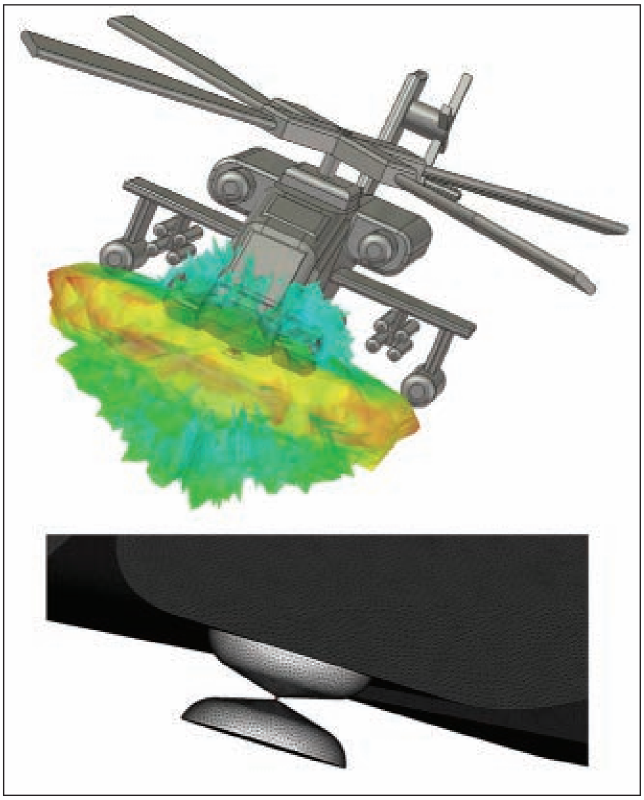
CST's new asymptotic solver uses the recently developed shooting bouncing ray (SBR) method, an extension to physical optics (PO). The technique employs a second-order curved surface mesh that avoids mesh singularities. Very high accuracy and correlation to full wave solver results (within full solver limits) is being observed for a wide range of examples.

SI/PI SOLVER

CST PCBS was introduced in CST STUDIO SUITE 2009. With a very easy to use 'layout' type interface familiar to PCB designers, the software is able to import and quickly calculate S-parameters of nets in PCBs up to four or so layers. CST PCBS links to CST DS for larger overall

system simulation. In version 2010 a technique able to solve much more complex PCBs and obtain output power delivery network (PDN) input impedances is introduced.

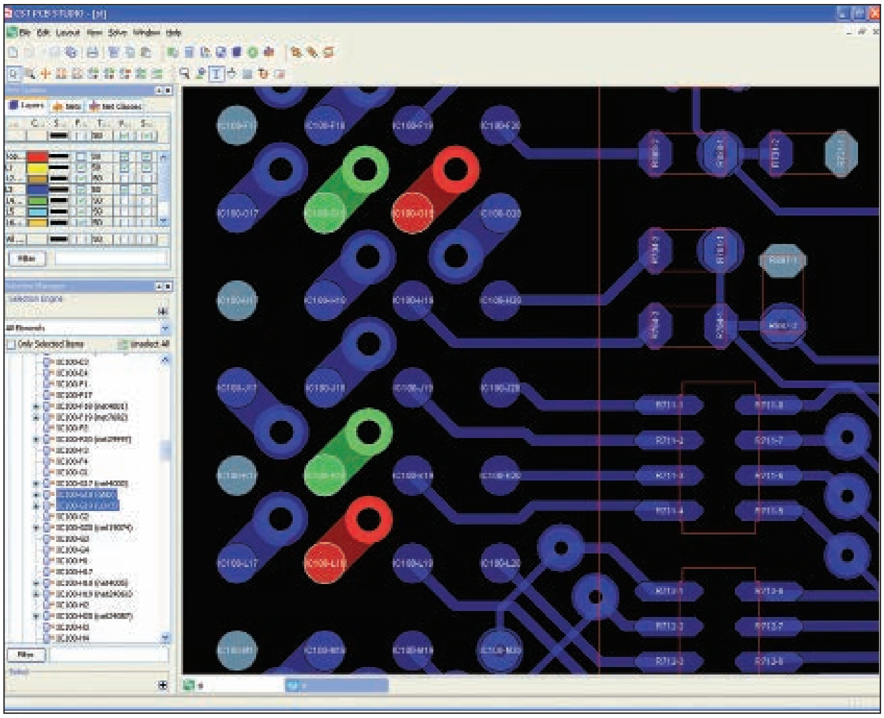
This is a 3D FEM frequency domain-based method that is able to identify dominant EM effects from the PCB structure. Complexity is reduced by applying selective EM models in critical parts and replicating these through the structure. The 3D (FE FD) solver is based on the frequency-domain finite-element method, combined with a domain-decomposition approach. Problem-adapted basis functions are used to improve simulation performance by exploiting the structural characteristics of the PCB. ***Figure 3*** shows a screen shot of CST PCBS.



▲ *Fig. 2 Antenna installed beneath an Apache helicopter. Inset shows the meshed biconical antenna.*

CABLE MODELING

Also in version 2009, CST CS was introduced, allowing full cable harness simulation inside and outside chassis structures. Fully integrated with CST DS, it is a major piece of the system



▲ *Fig. 3 Imported PCB for power integrity analysis.*

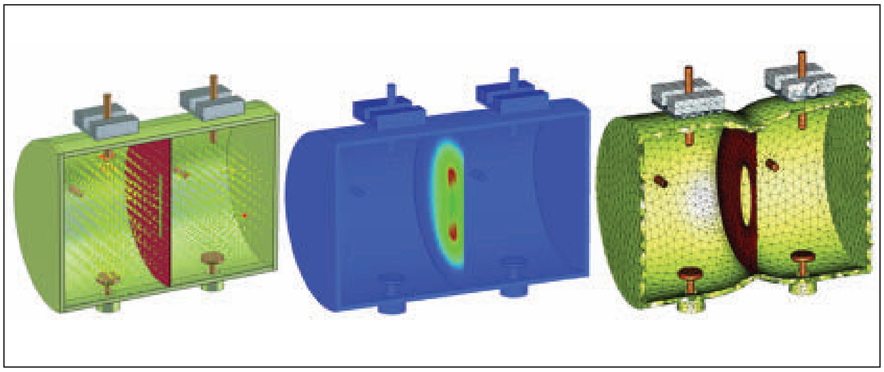


Fig. 4 *The multi-physics analysis of a cavity filter (courtesy of Spinner GmbH).*

simulation puzzle allowing cable radiation (or irradiation) to be taken into account. For 2010, a number of enhancements are introduced including a direct link to the 3D modeler. The illustration at the beginning of this article shows a vehicle and cable harness simulation in CST CS.

MULTI-PHYSICS SIMULATION

CST MPHYSICS STUDIO™ incorporates the existing thermal solver with a new mechanical stress solver. This combination allows currents generated from an EM simulation to be used as a heat source, which in turn can be used for mechanical stress analysis. To complete the loop, the deformation arising from the mechanical stress can be fed back for sensitivity analysis. ***Figure 4*** shows progressive field, thermal and mechanical simulations for a cavity filter.

PRE- AND POST-PROCESSING

Advanced modeling capabilities such as bending sheets to create conformal layers and interactive transformations have been successfully used in applications such as smart phone and RFID simulation since being introduced at the end of 2008. In version 2010, some key features enhancing usability for the most complex of structures are added. This includes full hierarchical component assemblies maintained from CAD assembly imports, a continuity (connectivity) checker for the hexahedral mesh. The continuity checker is ideal for verifying that EDA trace imports are electrically connected. It can also be used to check for unintended short circuits.

Layout and mechanical imports have further been extended in version 2010 so that virtually all commercial and interchange formats are covered. In addition to existing Mentor, Zuken and ODB++, direct import of Cadence .brd and .mcm files is now possible through an advanced import filter. With a look and feel familiar to layout engineers, this filter allows interactive selection of areas and traces, stack-up editing and component placement, all before the 3D model is created. An 'EDA token' can now be purchased to access all aforementioned imports.

On the post-processing side, sensitivity analysis is introduced as described earlier. Farfield processing has also been consolidated and improved. For visualization of fields and current on the largest structures a new plotting engine is incorporated, which gives significantly improved graphic performance.

CONCLUSION

Building even further on the complete technology theme, CST STUDIO SUITE 2010 enhances existing solvers and introduces completely new ones for the most demanding of applications. It leverages high performance computing to offer excellent solution turnaround times. With new coupled physics solvers, greater integration of all modules and greater interoperability, the software will allow engineers to consider full system simulation before entering the test lab.

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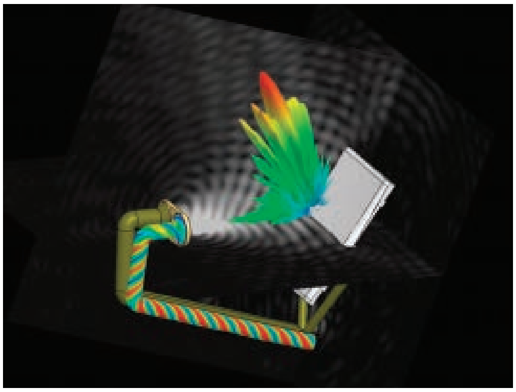

HFSS™ 12.0: High Performance Computing

The High Frequency Structure Simulator (HFSS™) is a software tool for 3D full-wave electromagnetic field simulation. HFSS provides E- and H-fields, currents, S-parameters, and near and far radiated field results. Intrinsic to this engineering design tool is an automated solution process where users are only required to specify geometry, material properties and the desired output. HFSS automatically generates an appropriate, efficient and accurate mesh for solving the problem using the proven finite element method (FEM).

HFSS includes many Ansoft-pioneered research and development innovations. These breakthroughs have made HFSS a widely used software product for solving 3D full-wave electromagnetic field simulations. The invention of tangential vector basis functions enabled the highly accurate finite element method for electromagnetic field solution. The transfinite element method, another Ansoft invention, allows the 3D finite element solution to couple to port solutions for fast and accurate multimode S-parameter extractions. Finally, the development of automatic mesh generation and adaptive refinement was a key innovation for reliable, repeatable and efficient results.

NEW IN HFSS 12.0

HFSS 12.0 is a major step forward for three-dimensional full-wave electromagnetic field simulation with new innovations for engineering simulation and design. The software includes key updates in mesh generation, solver technologies, and enhancements to the user interface and the modeler. The most significant solver technology enhancement is domain decomposition, a technique that allows the tool to exploit high-performance computing (HPC) capabilities to solve electromagnetic field problems of unprecedented size and scope. With domain decomposition, a single HFSS job can be divided into smaller pieces and then distributed across a network of computers. The use of all of the memory across a network allows for truly giant simulations with the rigor, accuracy and reliability of HFSS.

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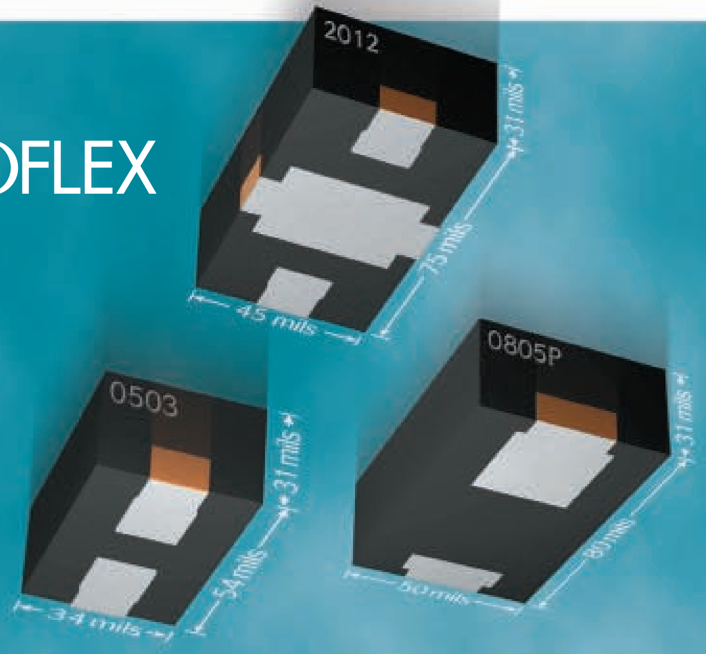

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Part Number	Rated Power Max	Freq Max	Insertion Loss Typical		Isolation Typical		Package*
			1 GHz	2.7 GHz	1 GHz	2.7 GHz	
MSWSE-050-10	50	1	0.15	–	10	–	0805P (SE)
MSWSE-044-10	40	2	0.20	0.25	15	8	0805P (SE)
MSWSHB-020-30	40	10	0.10	0.20	38	40	2012 (SH)
MSWSS-020-40	20	6	0.15	0.30	63	50	2012 (SS)
MEST²G-020-15	20	6	0.20	0.20	25	18	2012 (SE)
MEST²G-010-20	10	10	0.40	0.40	31	23	2012 (SE)
MSWSE-010-15	10	2	0.25	0.25	18	9	0503 (SE)
MSWSE-005-15	5	6	0.30	0.60	24	17	0503 (SE)

*Configurations: series (SE), shunt (SH), and series shunt (SS)

High Dynamic Range Shunt Attenuator Diodes

Part Number	Polarity	Insertion Loss dB Typ	Attenuation Value, dB typ.					Package
			10 uA	100 uA	1 mA	10 mA	100 mA	
MSAT-N25	NIP	0.3	0.4	0.8	5	17	27	2012
MSAT-P25	PIN	0.3	0.4	0.8	5	17	27	2012

- Low distortion vs. forward current, harmonic distortion at 85 dBc typical.
- Broadband performance beyond 10 GHz.

GaAs and Silicon Schottky Mixer/Detector Diodes

Part Number	Type	Freq	Vbr Min V	Ct Typ pF	Vf		Rs Max Ω	Package
					Min mV	Max mV		
SMGS11	Detector	>26.5	5	0.10	620	760	7	0503
SMGS21	Mixer	>26.5	–	0.15	620	760	7	0503
SMS201	Detector	>26.5	1	0.08	60	120	80	0503
SMS202	Detector	<18	1	0.18	60	120	80	0503

- GaAs Schottky diode SMGS11 is ideal for temperature compensated detector.
- GaAs Schottky diode SMGS21 is an anti-parallel pair, ideal for a doubler and harmonic mixer.
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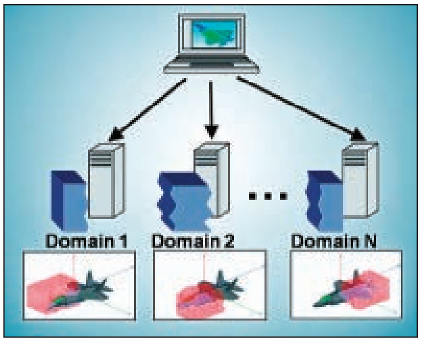


▲ *Fig. 1 Domain decomposition divides mesh across network to solve large problems.*

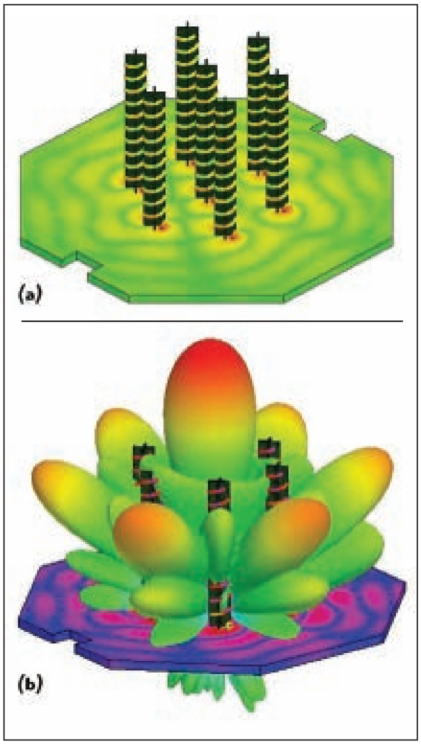
especially those imported from external 3D CAD tools. Other important enhancements include mixed element orders, curvilinear elements and adjoint derivative computation. Ease of use and automation in the user interface has been improved and include additional modeler capabilities such as sheet wrapping and imprinting. Advanced integration with load-sharing utilities and an Ansoft-developed Remote Solve Manager (RSM) provide integration within popular computing environments. These advances in HFSS 12.0 enable electrical engineers to expand their solution capability, exploit HPC hardware and fully integrate electromagnetics analysis into their design processes.

HFSS HPC OPTION

The HPC Option in HFSS 12.0 enables new solver technology using Ansoft's breakthrough implementation of the domain decomposition method. With the HPC option, large-scale simulations can be solved across a network of machines using all of their available memory.

HFSS 12.0 has seamless, out-of-the-box integration with industry standard schedulers (computer queuing systems) to allow engineering organizations to combine the power of HFSS with Load Sharing Facility (LSF), from Platform, Windows HPC Scheduler, from Microsoft, Portable Batch System (PBS) from Altair, and Sun Grid Engine (SGE).

These enhancements allow engineers to simulate and design at a scale and speed never before possible. Users of this latest version of HFSS software can achieve a dramatic reduction in development time and costs while at the same time realizing increased reliability and design optimization.



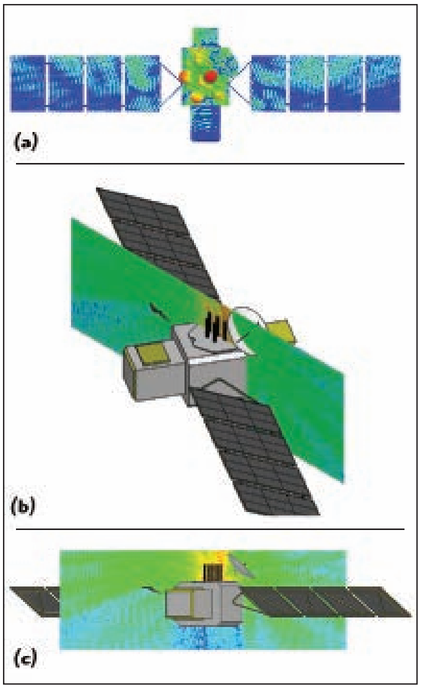
▲ *Fig. 2 Seven-element helix array (a) showing uniform excitation at S-band with mutual coupling and ground plane edge effects (b).*

HIGH-PERFORMANCE COMPUTING (HPC) TECHNOLOGIES

The HFSS High-Performance Computing (HPC) options enable intra- and inter-machine parallel solving and processing that distribute and speed the solution.

Domain Decomposition Method (DDM)

DDM enables the simulation of very large models by accessing the memory of a network of machines. ***Figure 1*** shows how DDM splits the finite-element mesh of the geometry automatically into a number of smaller mesh sub-domains. HFSS determines the optimum number of domains, depending on the mesh size and the number of computers and processors available. The domains are analyzed separately on a single machine or on a network of machines, after which an iterative procedure on the domain interfaces reconstructs the full solution. This network memory access allows the simulation of very large models for which one machine might not have enough memory. It also reduces simulation time and overall memory



▲ *Fig. 3 Ansoft HPC with domain decomposition solved the helix array on a spacecraft with other antennas nearby (1.3 M tetrahedra, 25 M unknowns, 35 computer cores).*

load, offering in some cases better than linear speed improvements with each additional processor.

Figure 2 shows a seven-element phased array of helix elements simulated in HFSS 12.0 across the 3 to 4 GHz S-band. The array is excited uniformly to provide broadside radiation. Mutual coupling among the elements and edge effects of the finite-sized ground plane are included because the array was simulated with all the elements and ground plane present. Such a model is useful for understanding these effects and for preliminary design. Of course antennas are ultimately installed on some larger system. ***Figure 3*** shows the helix array placed on a satellite. Real estate is precious on a satellite platform and other services must share space on the spacecraft. Another high-gain antenna is also mounted on the spacecraft with the potential of disrupting radiation from the helix array. HFSS 12.0 with domain decomposition was used to simulate both antennas and the spacecraft in a single simulation. As can be seen in the figure, field interaction is significant when the array beam is steered 10° off bore-sight. The radiation of the array interacts with the back side of the high-gain reflector antenna.

90° SPLITTERS

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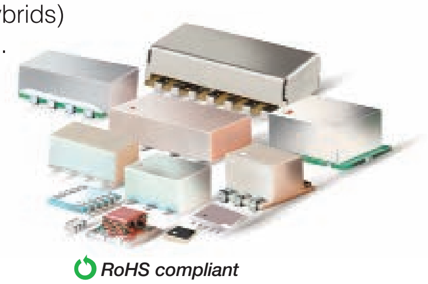
At Mini-Circuits, we understand that two-way 90° power splitters (hybrids) are critical building blocks in a wide array of RF design solutions. That's why we offer them in extra-tight phase and amplitude balance to ensure your expected high-performance design results. Plus, our robust, rugged units deliver repeatable performance and are available in over 91 different models, in the widest range of frequencies in the industry (from 5 MHz to 7.2 GHz), and in package sizes as small as 0.08" x 0.05".



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463 Rev.A

The size and scope of this simulation is unique in full-wave simulators.

Multiprocessing (MP)

The multiprocessing option is used for solving models on a single machine with multiple processors or multiple cores that share RAM. Operations during the solution process are parallelized across the available cores on a machine thus significantly reducing the simulation time.

Distributed Solve Option (DSO)

The DSO option allows users to distribute parametric sweeps to explore variations in geometry, materials, boundaries and excitations. Additionally, users can distribute frequency sweeps to generate responses over a broad frequency band of interest. This time-saving capability splits multiple pre-defined parametric design variations and/or frequency points, solves each simulation instance on a separate machine and then reassembles the data. This dramatically accelerates parametric studies and design optimization.

VOLUMETRIC MESHING

A new highly robust volumetric meshing technique results in even more efficient and higher-quality meshes that reduce memory and simulation time. The new technique meshes the 3D volume with uniformly distributed tetrahedra, followed by boundary refinement and surface meshing. By following this procedure, HFSS can reliably mesh geometries imported from other CAD tools while creating an even higher quality mesh for finite element simulation.

NEW ELEMENT TECHNOLOGIES

Curvilinear elements and mixed element orders allow for higher accuracy and more efficient distribution of computational resources. Curvilinear elements model the fields exactly on curved surfaces and in these cases provide higher accuracy even with a coarser mesh discretization. Mixed element orders allow for an automated and judicious localized application of element order based on geometry and electromagnetic requirements. Smaller features are solved more efficiently by lower-order elements while large homogenous regions benefit from higher-order elements, all element orders being automatically and appropriately "mixed" in one mesh. Mesh refinement is now performed on both the size and order of the elements.

ADJOINT DERIVATIVES

Adjoint derivative computation provides a highly efficient and accurate procedure to evaluate the derivatives of S-parameters with respect to geometric and material model parameters. This technique provides sensitivity information for use in device tuning, tolerance evaluation and optimization. These derivatives are employed to speed up the sequential nonlinear programming (SNLP) optimizer included with the Optimetrics™ add-on program.

CONCLUSION

HFSS has been used the world over to design electronic and microwave products from smart phones to high-speed computer backplanes to high-performance antenna systems. The HPC options in HFSS allow engineers to solve giant electromagnetic simulations on a network of computers using all of the available memory. A new meshing engine provides even more reliable and high-quality FEM meshes that simulate even faster. New element technologies enable true curved surface simulation representing the fields along those surfaces perfectly without approximation. Mixed element orders provide numerical efficiency and accuracy from very concentrated regions of the problem to very open regions. Adjoint derivatives provide engineers data on the local sensitivity of their designs with respect to project variables like material properties, geometry and boundary conditions.

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RS No. 304

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Strength, ruggedness, and reliability…*supercharged!* That's what you get when you choose Mini-Circuits ultra-flexible precision test cables. Engineered to be a workhorse for your day-to-day test operations, these triple shielded cable assemblies are qualified to at least 20,000 bends, employ an advanced strain relief system, and are equipped with passivated stainless steel connectors, *so you can rely on them to* ***flex, connect and disconnect over and over and over again!*** They're so rugged, each test cable is backed by our 6 month guarantee*! With low insertion loss and very good return loss, you can also rely on getting good performance over the wide DC-18 GHz band. Visit our website to choose and view comprehensive performance curves, data sheets, and environmental specifications.

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New! ***Tough Armored Cables*** *are steel triple shielded and qualified to at least 25,000 bends. They're so rugged they can even pass a crush test of a 600lb. nitrogen tank over the cable 1000 times, without any change in electrical performance.*

RoHS compliant

Frequency Range: DC-18 GHz, Impedance: 50 ohms

Models	Connector Type	Length (Ft.)	Inser. Loss (dB) Midband Typ.	Return Loss (dB) Midband Typ.	Price $ ea. Qty.(1-9)
FLEX TEST CABLES		Male to Male			
CBL-1.5FT-SMSM+	SMA	1.5	0.7	27	68.95
CBL-2FT-SMSM+	SMA	2	1.1	27	69.95
CBL-3FT-SMSM+	SMA	3	1.5	27	72.95
CBL-4FT-SMSM+	SMA	4	1.6	27	75.95
CBL-5FT-SMSM+	SMA	5	2.5	27	77.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-10FT-SMSM+	SMA	10	4.8	27	87.95
CBL-12FT-SMSM+	SMA	12	5.9	27	91.95
CBL-15FT-SMSM+	SMA	15	7.3	27	100.95
CBL-25FT-SMSM+	SMA	25	11.7	27	139.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-10FT-NMNM+	N-Type	10	4.7	27	156.95
CBL-15FT-NMNM+	N-Type	15	7.3	27	164.95
CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
CBL-25FT-NMNM+	N-Type	25	11.7	27	199.95
		Female to Male			
CBL-3FT-SFSM+	SMA-F to SMA-M	3	1.5	27	93.95
CBL-2FT-SFNM+	SMA-F to N-M	2	1.1	27	119.95
CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95
ARMORED CABLES		Male to Male			
APC-6FT-NM-NM+	N-Type	6	3.0	27	181.95
APC-10FT-NM-NM+	N-Type	10	4.8	27	208.95
APC-15FT-NM-NM+	N-Type	15	7.3	27	243.95

Metric Sizes Available On Our Website

6 mo. GUARANTEE **Mini-Circuits will repair or replace your test cable at its option if the connector attachment fails within* ***six*** *months of shipment. This guarantee excludes cable or connector interface damage from misuse or abuse.*

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DC to 18 GHz ATTENUATORS

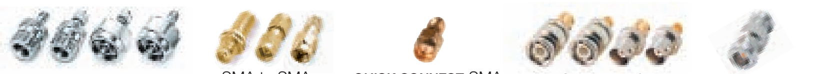
from **$29.95** ea. (1-49)

Rugged Stainless Steel Construction, High Repeatability, Miniature Size, Low Cost, and Off-The-Shelf Availability are some of the features that make Mini-Circuits "BW" family of precision fixed attenuators stand above the crowd! This extremely broad band DC to 18 GHz series is available in 5 watt Type-N and 2&5 watt SMA coaxial designs, each containing 15 models with nominal attenuation values from 1 to 40 dB. Built tough to handle 125 watts maximum peak power, these high performance attenuators exhibit excellent temperature stability, 1.15:1 VSWR typical, and cover a wealth of applications. So contact Mini-Circuits today, and capture this next generation of performance and value! *Mini-Circuits...Your partners for success since 1969*

MODELS (Add Prefix BW-)

2 W SMA	5 W SMA	5 W Type-N	Attenuation (dB)	
$29.95	$44.95	$54.95	Nominal	Accuracy*
S1W2	S1W5	N1W5	1	±0.40
S2W2	S2W5	N2W5	2	±0.40
S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	-0.4, +0.9
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	-0.4, +0.8
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60

***Now Available!* Adapters** (Prices: qty. 1-49)



Type-N to SMA **DC-18 GHz** $22.95 ea.
SMA to SMA / ***QUICK CONNECT*** SMA **DC-18 GHz** from $4.95 ea.
SMA to BNC **DC-2 GHz** $3.95 ea.
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To order Attenuators as RoHS, add + to base model No. *Example: BW-S1W2+*
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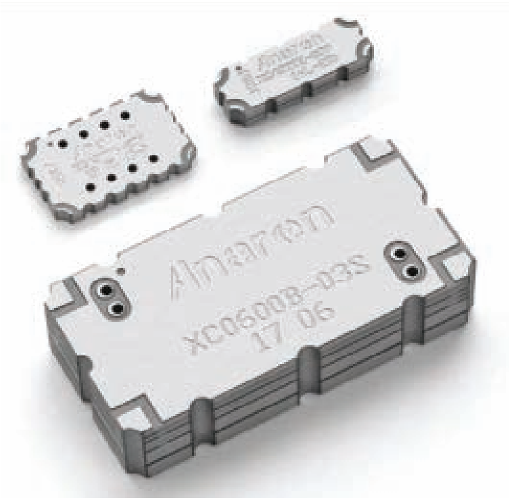

NEW SURFACE-MOUNT COUPLERS DESIGNED FOR DEFENSE APPLICATIONS

EXECUTIVE INTERVIEW SERIES

MWJ SPEAKS WITH DAVID WHITAKER, PASSIVE PRODUCT LINE MANAGER, SPACE & DEFENSE GROUP, ANAREN INC.

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It goes without saying that components and sub-assemblies supporting today's defense equipment, such as military radio receivers and counter-IED solutions, must be rugged, light and reliable. Increasingly critical, however, are a host of beyond-requisite demands that reflect today's new military procurement and combat realities. One example is the dictum that communications technologies must operate over wider and more numerous frequency bands in support of the equally wide variety of electronics being deployed at the warfighter level and across all branches of the military. Then there is the intense downward pressure on procurement costs and bills of materials, ironically paired with intense upward pressure to pack ever-more functionality into the ever-smaller gear being deployed to today's multi-mission armed service members.

Anaren has recently introduced a new family of couplers designed specifically for both these traditional and emerging requirements. Leveraging its original innovation and subsequent track record in multilayer, stripline components in the commercial wireless infrastructure sector, the company has expanded its popular Xinger®-brand packaging approach to the military side with three new couplers specifically designed to cover the wide range of frequencies utilized by military equipment OEMs, while reducing both cost and component footprints.

ANAREN INC.
East Syracuse, NY

What's NEW at DLI DIELECTRIC LABORATORIES

A DOVER COMPANY

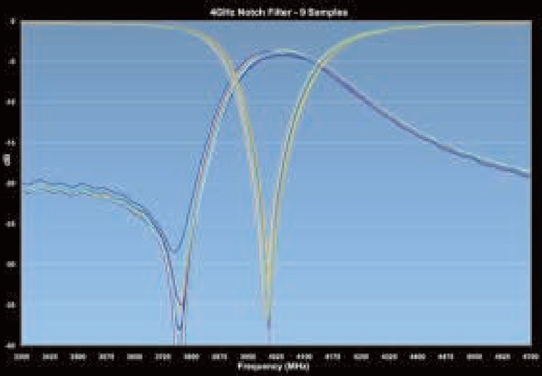
CMP

Certified AS9100B

In an effort to be at the forefront of the aerospace market, Dielectric Laboratories, Inc. (DLI) has been certified to the AS9100B standard. DLI was informed in March 2009 that the Quality Management System in place was found to be in compliance with the standard and was officially certified to ISO 9001-2000 & AS9100B.

Custom Microstrip Filters

DLI has expanded its filter capability beyond microstrip bandpass designs. Notch filters, lowpass and highpass filters, ceramic cavity filters, and various other filter types are now available. All filters employ DLI's high-K ceramics which allow for great size reduction, and unbelievable temperature stability compared to alumina and PWB materials. Solder surface mount and chip and wire filters are all possible.



Typical Notch Filter

- Greater than 20dB attenuation typical Notch frequency
- Low loss in passband regions [better than 1.5dB]
- Typical size: .25 x .196 x .02 inches
- Chip and Wire or SMT mounting schemes possible
- Designs possible from S to Ku Band

Typical Lowpass Filter

- Low loss in passband [better than 1.0dB]
- Greater than 40dB attenuation in stopband
- Typical size: .4 x .25 x .015 inches
- Chip and Wire or SMT mounting schemes possible
- Designs possible from S to Ku band

Typical Highpass Filter

- Low loss in passband region [better than 2.0dB]
- Greater than 35dB attenuation in stopband
- Typical size: .3 x .2 x .015 inches
- Chip and Wire or SMT mounting schemes possible
- Designs possible from 1GHz to 67GHz

L1/L2 GPS Notch Filters

- Greater than 20dB attenuation typical
- Low loss in passband regions [better than 1.5dB]
- Typical size: .25 x .25 x .075 inches
- Includes integral cover
- Chip and Wire or SMT mounting schemes possible

SLC on tape and reel

DLI is pleased to offer tape and reel packaging solutions for a variety of our Single-layer capacitor case sizes. Utilizing the latest technology and equipment to provide our customers the highest quality products, our standard SMD tape and reel packaging meets or exceeds EIA standards.

"NA" material temperature compensating capacitors

DLI is now offering our proprietary NA dielectric formulation in a variety of MLC case sizes. With its negative temperature coefficient of capacitance (N30+/-15ppm/˚C), this high-Q porcelain dielectric is ideal for temperature compensating situations. NA is offered as a drop-in replacement for most AH/CF part numbers.

Extreme leach resistant terminations

When design engineers told us they'd like a termination that would allow them the freedom to use harsh solder profiles and multiple reworks, we listened! DLI has qualified enhanced versions of its RoHS compliant terminations designed to handle both the rigors of the test bench and the production floor with ease. The enhanced terminations are available in both standard (term code: E) and non-magnetic (term code: H) finishes. Please contact our Sales Representatives for more details.

High Voltage 1111 case size

DLI is pleased to introduce the new C18 series of enhanced voltage high-Q porcelain capacitors. With voltage ratings up to 2000V, the C18 is designed to be the most robust "1111" high-Q capacitor available today. The C18 is available in both our ultra stable (0±15ppm/˚C) CF and temperature compensating (+90ppm/˚C) AH dielectrics, and is form-factor compatible with our existing line of C17 "1111" capacitors.

Tuning Rod Kits

DLI designed tuning rods to utilize our C11 or C17 capacitors of a specified value attached to High-Q insulating holder to find the optimum capacitor for a particular circuit or application without soldering capacitors.

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Pushing the frequency of operation up to 6 GHz, Anaren's new wideband couplers are available in three formats—the smallest measuring only 0.20 × 0.56 × 0.089 inches—and, like their commercial-grade counterparts, are 100 percent RF tested and fully compatible with high-volume, automated pick and place equipment. They are the first in a family of such military components the company intends to put in its pipeline over time.

SOLID AND HIGHLY REPEATABLE PERFORMANCE

The new Anaren couplers feature low insertion loss, excellent phase balance, less amplitude imbalance and high isolation. The new parts are also much less frequency sensitive and feature considerably more power handling capability, as well as a higher maximum operating temperature. In addition, they are available in a lead free version.

The XC0600B-03P 3 dB hybrid coupler operates from 225 to 1000 MHz and features an insertion loss of 0.70 dB maximum, a phase balance of 90° ± 5.0° maximum, an amplitude balance of ± 0.6 dB maximum, a maximum VSWR of 1.33:1 and 17 dB of minimum isolation. The coupler is rated to handle power levels up to 75 W CW. The package dimensions are 0.5 × 1.0 × 0.22 inches.

The XC4300-E-03P is also a 3 dB hybrid coupler that operates over the 2500 to 6000 MHz frequency range. This device features a low insertion loss of 0.25 dB maximum, a phase balance of 90° ± 4.0° maximum, an amplitude balance of ±0.75 dB maximum, a maximum VSWR of 1.3:1 and 21 dB of minimum isolation. The coupler is rated to handle power levels up to 100 W CW. The package dimensions are 0.20 × 0.56 × 0.089 inches.

The third device in the new family is the XC4300-A-20P. This 20 dB directional coupler also operates over the 2500 to 6000 MHz frequency range with a low insertion loss of 0.2 dB maximum, a mean coupling of ±1.0 dB maximum, a maximum VSWR of 1.3:1 and 18 dB of minimum directivity. The coupler is rated to handle power levels up to 100 W CW.

These three new Anaren Xinger-brand packaged couplers bring high performance and reliability to military broadband applications reducing the cost, parts count and foot print for many demanding applications.

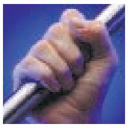
Anaren Inc.,
East Syracuse, NY
(315) 432-8909,
www.anaren.com.

RS No. 305

0.5 to 2000 MHz MIXERS

$1.69

(ea. qty. 1000)



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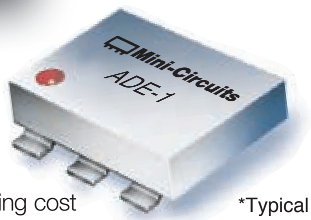
Recession Busters!



In today's tough economic times there is no choice, reducing cost while improving value is a must. Mini-Circuits has the solution… pay less and get more for your purchases with our patented frequency mixers ADE-1, ADE-2, and ADE-11X. Total solutions for high performance, reliability, and value…and they cost only $1.69 each (quantity 1000), with prices even lower at higher quantities!
Right from the start, we've embedded premium advantages into these level 7 mixers such as broad bandwidths, low conversion loss, excellent L-R isolation, and IP3 as high as +20 dBm. These units also feature our low profile surface mount package with open cover to allow high reliability water wash, tin plated leads for excellent solderability and RoHs compliance, and all-welded connections which reduce parasitic inductance and improve reliability. In fact, these units are so reliable that they are backed by our exclusive ***2 year guarantee***.

actual size

Mini-Circuits...Your partners for success since 1969

*Typical Specifications:	ADE-1	ADE-2	ADE-11X
Frequency LO/RF (MHz)	0.5-500	5-1000	10-2000
Frequency LO/IF (MHz)	DC-500	DC-1000	5-1000
LO Level (dBm)	7	7	7
IP3 (dBm)	15	20	9
Conv. Loss (dB)	5.0	6.67	7.1
L-R Isolation (dB)	55	47	36
L-I Isolation (dB)	40	45	37
Dimensions: L.310"xW.220"xH	.162"	.112"	.112"
*Specified midband unless otherwise noted.			
Price $ea. (Qty. 25)	*2.49*	*2.49*	*2.49*

Protected by U.S. patent 6133525.

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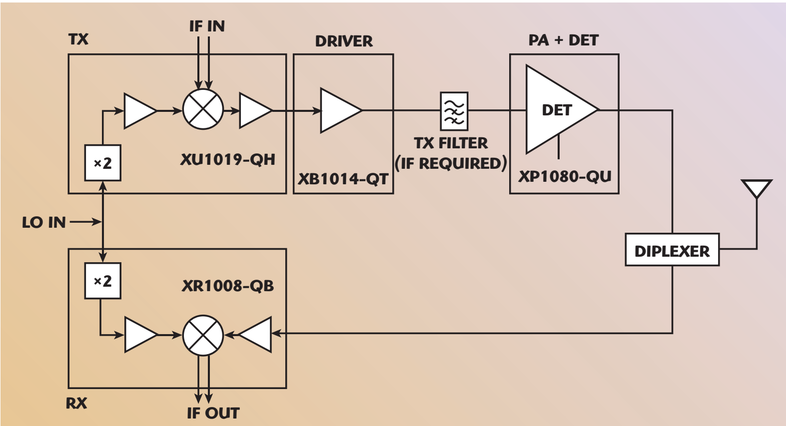
348 Rev C

NEW SMT 38 GHZ CHIPSET MEETS MARKET NEEDS

Sustained growth in wireless communications and greater demands for bandwidth place tremendous pressure on component manufacturers to provide high performance, surface-mount technology (SMT) packaged products. The market is seeking low-cost, SMT components for high volume printed circuit board (PCB) assembly flow, particularly for applications such as point-to-point (PTP) digital radio at microwave and millimeter-wave frequencies. The drivers for industry growth in the PTP market are next generation data services and the rapid expansion of cellular usage in developing nations such as China and India. In order to meet the performance, cost and time to market requirements of these systems, OEMs are turning to complete SMT chipset solutions.



▲ *Fig. 1 Mimix SmartSet: 38 GHz transceiver.*

Mimix Broadband's new 38 GHz Mimix SmartSet products are high performance, highly integrated devices that are offered in SMT packages and include a receiver, up-converter, driver amplifier and power amplifier. The Mimix SmartSets offer industry leading performance and are consistent with typical requirements for high performance PTP ETSI 38 GHz Radios. The SMT packages offer a number of advantages, including low cost, ease of handling and assembly, and suitability for mass production.

Figure 1 shows the functional schematic for a transceiver using the 38 GHz Mimix

MIMIX BROADBAND INC.
Houston, TX

18–40 GHz POWER DIVIDERS

Features

- Wide Frequency Range . . . 18–40 GHz
- High Isolation . . . . >17 dB
- Low Insertion Loss . . . . . 1.6-3.4 dB typ.
- Amplitude Balance . . . . . ±0.4 dB typ.
- Phase Unbalance . . . . . . ±2° typ.
- Input/Output VSWR . . . . . 1.7:1 typ.

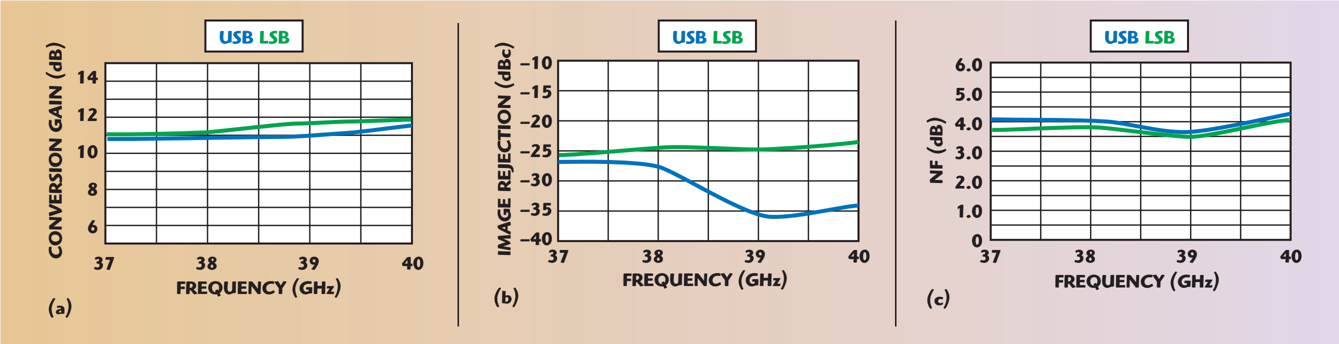
3 YEAR WARRANTY

RF INPUT PARAMETERS	UNITS	MINIMUM	MAXIMUM
2 Way Power Divider - Model D0289			
RF frequency range	GHz	18	40
Insertion loss	dB		1.5
Isolation	dB	17	
Input VSWR	Ratio		1.8
Output VSWR	Ratio		1.7
Phase unbalance	Degrees		±5.0
Amplitude balance	dB		±0.5
4 Way Power Divider - Model D0489			
RF frequency range	GHz	18	40
Insertion loss	dB		2.5
Isolation	dB	17	
Input VSWR	Ratio		1.8
Output VSWR	Ratio		1.7
Phase unbalance	Degrees		±5.0
Amplitude balance	dB		±0.5
8 Way Power Divider - Model D0889			
RF frequency range	GHz	18	40
Insertion loss	dB		3.5
Isolation	dB	17	
Input VSWR	Ratio		1.8
Output VSWR	Ratio		1.7
Phase unbalance	Degrees		±5.0
Amplitude balance	dB		±0.5

For additional information or technical support, please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com

MITEQ®

100 Davids Drive, Hauppauge, NY 11788
Tel: 631-436-7400 • Fax: 631-436-7430
www.miteq.com



▲ *Fig. 2 Conversion gain (a), image rejection (b) and noise figure (c) of the XR1008-QB.*

SmartSet. On the transmit (TX) side, the IF1 and IF2 inputs are applied through a 90 degree hybrid for image rejection. The XU1019-QH upconverter is balanced, so the complimentary outputs IF1* and IF2* are also brought out, and normally terminated to 50 ohms. The 2xLO leakage can be minimized by tuning the DC bias on the main and complimentary IF signals. If further 2xLO rejection is required, the signal is filtered after the output of the transmitter through a bandpass filter (BPF). Gain is provided by the linear driver amplifier XB1014-QT, and the power amplification and detector functions are implemented in the XP1080-QU. Linear gain control of the Tx lineup can be achieved through drain current control of the XU1019-QH, XB1014-QT and XP1080-QU. The received signal is coupled into the XR1008-QB receiver, which integrates a low noise amplifier and image reject mixer.

XR1008-QB PACKAGED 38 GHZ RECEIVER

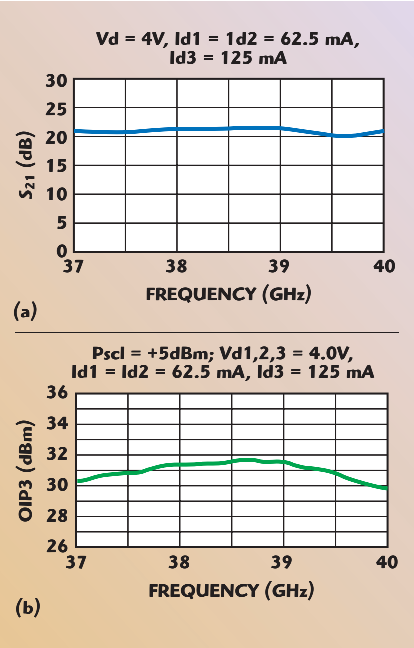
A receiver chain is traditionally designed using up to four MMICs: an LNA that provides the optimum noise figure; an image reject mixer with high linearity performance; an LO driver amplifier; and often, a frequency doubler for the LO input. In this device, all of these functions are combined into a single SMT chip.

The XR1008-QB offers 12 dB conversion gain, 20 dB image rejection and 4 dB noise figure (see ***Figure 2***). The device is offered in a 7 × 7 mm surface-mount package that can be installed onto radio boards using standard SMT manufacturing lines.

XB1014-QT PACKAGED 38 GHZ LINEAR DRIVER AMPLIFIER

This small, low cost, three-stage 37 to 40 GHz GaAs MMIC driver ampli-


Mini-Circuits
LAVI



▲ *Fig. 3 Small-signal gain (a) and OIP3 (b) of the XB1014-QT.*

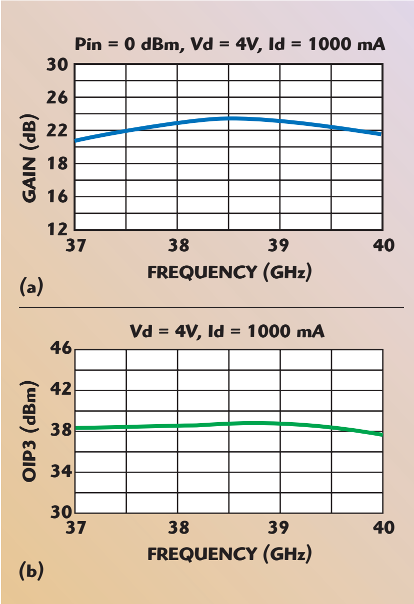
fier has a small-signal gain of 21 dB with an OIP3 of 30.5 dBm. The device delivers 22 dBm of saturated power, and P1dB of 19.5 dBm.

Typical 38 GHz Tx paths require some level of ATPC, and the XB1014-QT gain turn-down while maintaining linear performance is easily achieved by control of the drain currents. The device is offered in a low cost 3 × 3 mm plastic QFN package. Typical gain and OIP3 performance curves are shown in ***Figure 3***.

XP1080-QU PACKAGED 38 GHZ LINEAR POWER AMPLIFIER

Mimix Broadband's four-stage 37 to 40 GHz GaAs MMIC power amplifier has a small-signal gain of 22 dB with an OIP3 of 38 dBm. An on-chip temperature compensated power detector has a useable dynamic range of greater than 25 dB.

This device is a highly compact, low-cost amplifier ideally suited for the digital microwave radio market. The amplifier comes in a 7 × 7 mm QFN-style package, giving the user an easy-to-install 38 GHz power amplifier product with excellent linear performance. Typical gain and OIP3 performance curves are shown in ***Figure 4***.



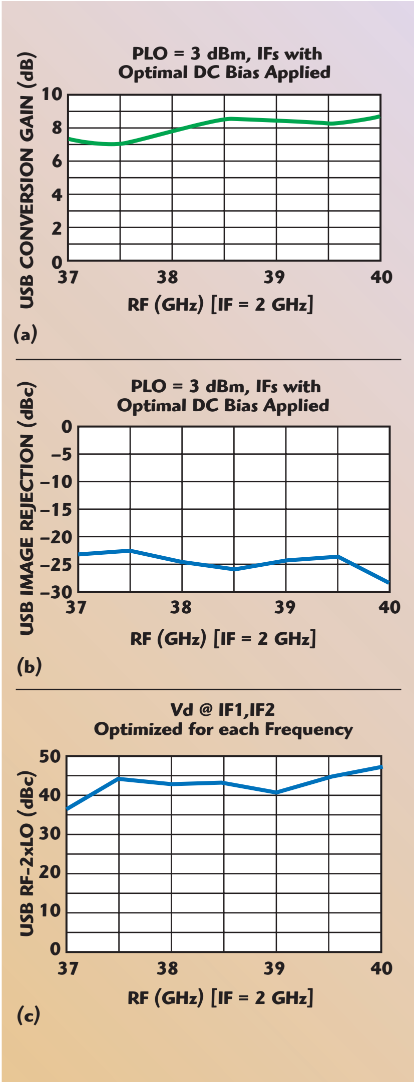
▲ *Fig. 4 Small-signal gain (a) and OIP3 (b) of the XP1080-QU.*

XU1019-QH PACKAGED 38 GHZ UP-CONVERTER

Mimix Broadband's 38 GHz up-converter integrates a mixer, RF buffer, LO buffers and LO doubler. The

balanced mixer uses an image rejection configuration, offering good nominal 2×LO leakage into the RF port. This performance can be enhanced by applying appropriate DC bias to the four IF lines coming out of the package (IF1, IF1*, IF2, IF2*). The bias is applied through simple bias tees in line with the IF ports and can be tuned to various levels of complexity (over frequency, over temperature), depending on the level of 2×LO leakage the user has allowed. The addition of image rejection in the up-converter results in minimal or no Tx filtering required, depending on power detector accuracy requirements.

The up-converter achieves 7 to 9 dB gain across the 38 GHz band, 20 dBc image rejection and tuned RF 2×LO isolation of greater than 17 dB, as shown in ***Figure 5***. The device comes in a 4 × 4 mm QFN package.



▲ *Fig. 5 USB conversion gain (a), image rejection (b) and 2×LO isolation (c) of the XU1019-QH.*

"MIMIX SMARTSET SOLUTIONS"

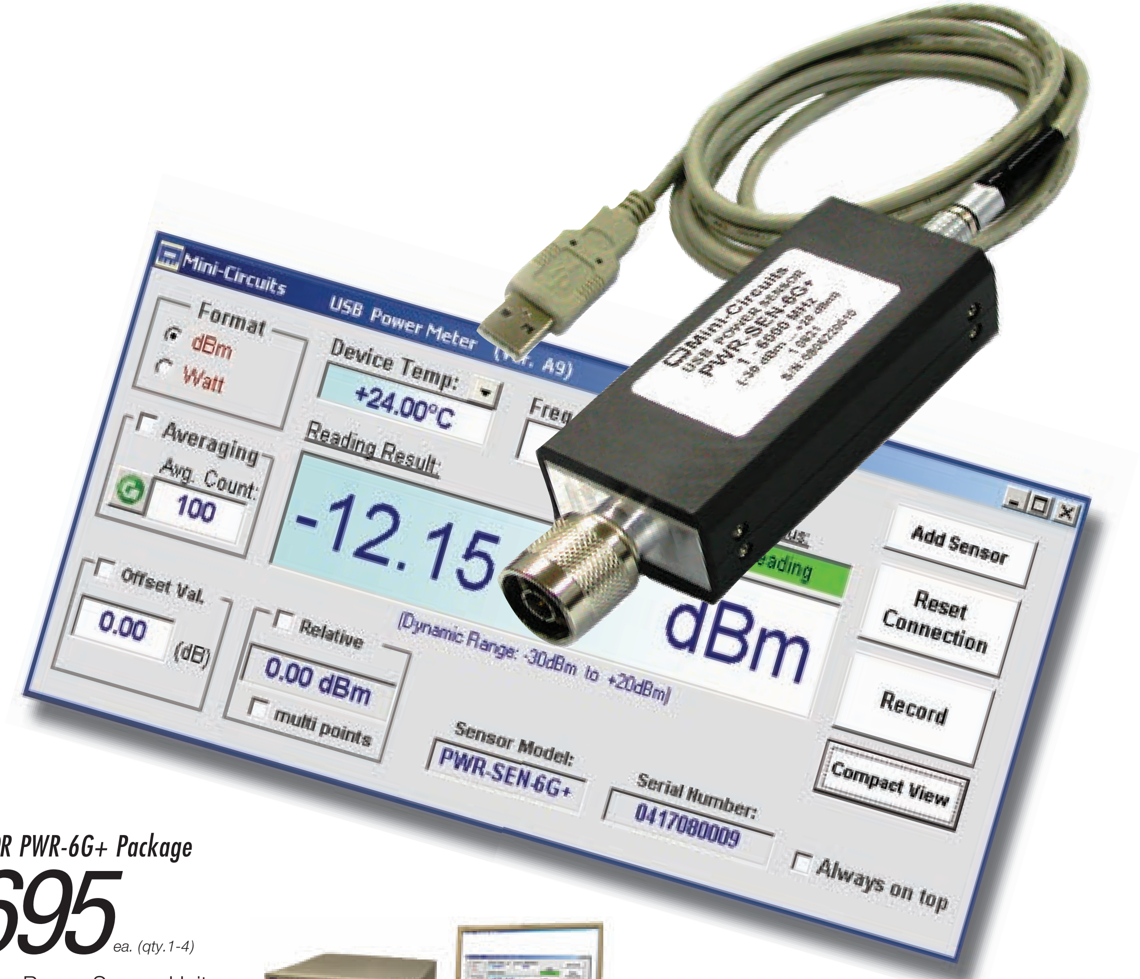
The concept of Mimix SmartSet Solutions has been applied not only to 38 GHz, but to all the major PTP bands, providing the industry with highly integrated devices that are offered in SMT packages and include a receiver, up-converter, driver amplifier and power amplifier. The SMT packages offer a number of advantages, including low cost, ease of handling and assembly, and suitability for mass production.

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

RS No. 303

USB POWER SENSOR

-30 to +20 dBm 1 to 6000 MHz



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- *Averaging of measurements*
- *Interface with test software*
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- *Compatible with LabVIEW™, Delphi, C++ and Visual Basic software*

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Now, Mini-Circuits offers a USB Power Sensor and software together with your laptop that will ***reduce your equipment costs*** and provide new application features that will simplify your power measurements. Having a measurement range of -30 to +20 dBm at frequencies from 1 to 6000 MHz. The PWR-6G+ is supplied with easy-to-use, Windows-compatible measurement software to speed and simplify your power measurements, allowing you to set as many as 999 averages and to record results for further analysis. The PWR-6G+ USB Power Sensor provides 0.01-dB measurement resolution and impressive accuracy over temperature.
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IF/RF MICROWAVE COMPONENTS

457 rev G

Visit http://mwj.hotims.com/23292-80 or use RS# 80 at www.mwjournal.com/info

LINC2 FILTER PRO SOFTWARE RELEASE

ACS has recently released a new version of its LINC2 filter synthesis software. LINC2 Filter Pro version 1.18 adds new capabilities for exporting design and analysis data to other programs. This new version can send filter analysis data, including frequency response data, to Excel and other programs for creating user designed charts and custom documentation of filter performance. CSV files can be automatically created that capture the filter's S-parameters or other performance data (such as group delay and attenuation characteristics). Distributed filters implemented in microstrip and stripline can automatically be rendered in both schematic and layout windows. The wizard-like GUI quickly and effortlessly guides the user through the process of entering the specifications for the automatic synthesis of a wide variety of filters.

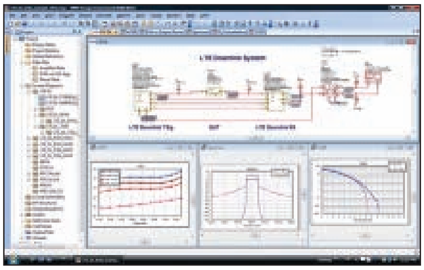
Applied Computational Sciences LLC, Escondido, CA (760) 612-6988, www.appliedmicrowave.com.
RS No. 310

SOFTWARE FOR COMPLIANT TESTING

VENDORVIEW

AR's SW1006 software is a standalone program that combines conducted immunity test software, radiated susceptibility test software and pre-compliance conducted and radiated emissions test software into one user-friendly package suitable for corporate to professional test lab users. The software automatically performs both calibration and immunity testing in full compliance with IEC 61000-4-3, 4-6; MIL STD 461/462 RS103, CS114 and RTCA/DO160 Section 20 specifications. In addition, the program supplies the user with selectable test parameters and a "thresholding" mode for pre-compliance investigation of equipment susceptibility.

AR RF/Microwave Instrumentation, Souderton, PA (215) 723-8181, www.ar-worldwide.com.
RS No. 311



VISUAL SYSTEM SIMULATOR

VENDORVIEW

AWR announced Version 2009 of its Visual System Simulator (VSS) software for the end-to-end design and optimization of communications systems. The versatile simulation tool now supports AWR Connected™ for Rohde & Schwarz that adds real-world test signals from the company's R&S WinIQSIM2 instrument software to the simulation to produce much greater accuracy than generic waveforms. VSS Version 2009 also features a new LTE communication library, many new RF component models and measurement enhancements that let users gain greater insight into performance of their designs throughout the design cycle. The pre-release of Visual System Simulator software Version 2009 is available now to qualified customers.

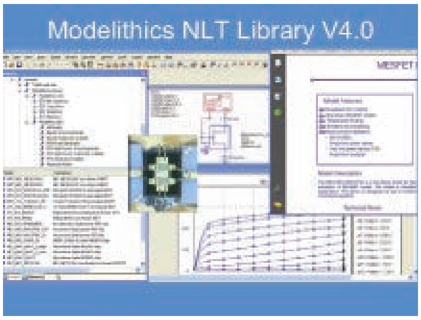
AWR, El Segundo, CA (310) 726-3000, www.awrcorp.com.
RS No. 314

PLL PHASE NOISE SOFTWARE

VENDORVIEW

The widely popular PLL Phase Noise Calculator tool on Hittite's website was specifically designed to help synthesizer designers select the best Hittite divider, phase frequency detector and VCO for their PLL circuit needs. The interrelation of these building blocks is critical to achieving optimal PLL phase noise, and each component in the PLL circuit will impact overall performance. A graphical interface guides the user through the component selection process, and the calculator uploads the key performance attributes for each Hittite component selected. The PLL Phase Noise Calculator quickly provides the phase noise contribution of each PLL element, as well as the total for the entire loop.

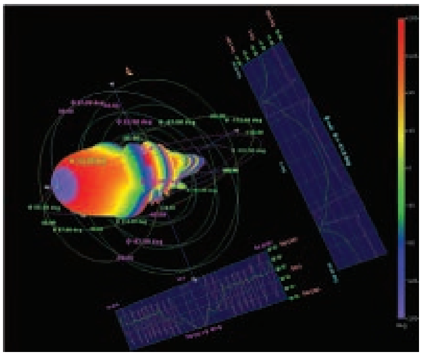
Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.
RS No. 312



NON-LINEAR TRANSISTOR LIBRARY

Modelithics Inc. has announced the release of an enhanced version of the Non-Linear Transistor Model Library for AWR Microwave office. This latest release features new models for TriQuint GaAs HFET, NEC LDMOS FET and Excelics HEMT devices. The Modelithics® NLT Library addresses accurate predictions of noise, substrate-scalability, temperature dependence, broad-bandwidth, non-linearities and high power, among other stringent requirements of state-of-the-art RF and microwave design. This upgrade will be forwarded, free of charge to all customers currently under a Modelithics Platinum Maintenance contract for the NLT Library or The Modelithics Library Complete for Microwave Office. See release notes at www.modelithics.com/products.asp for details.

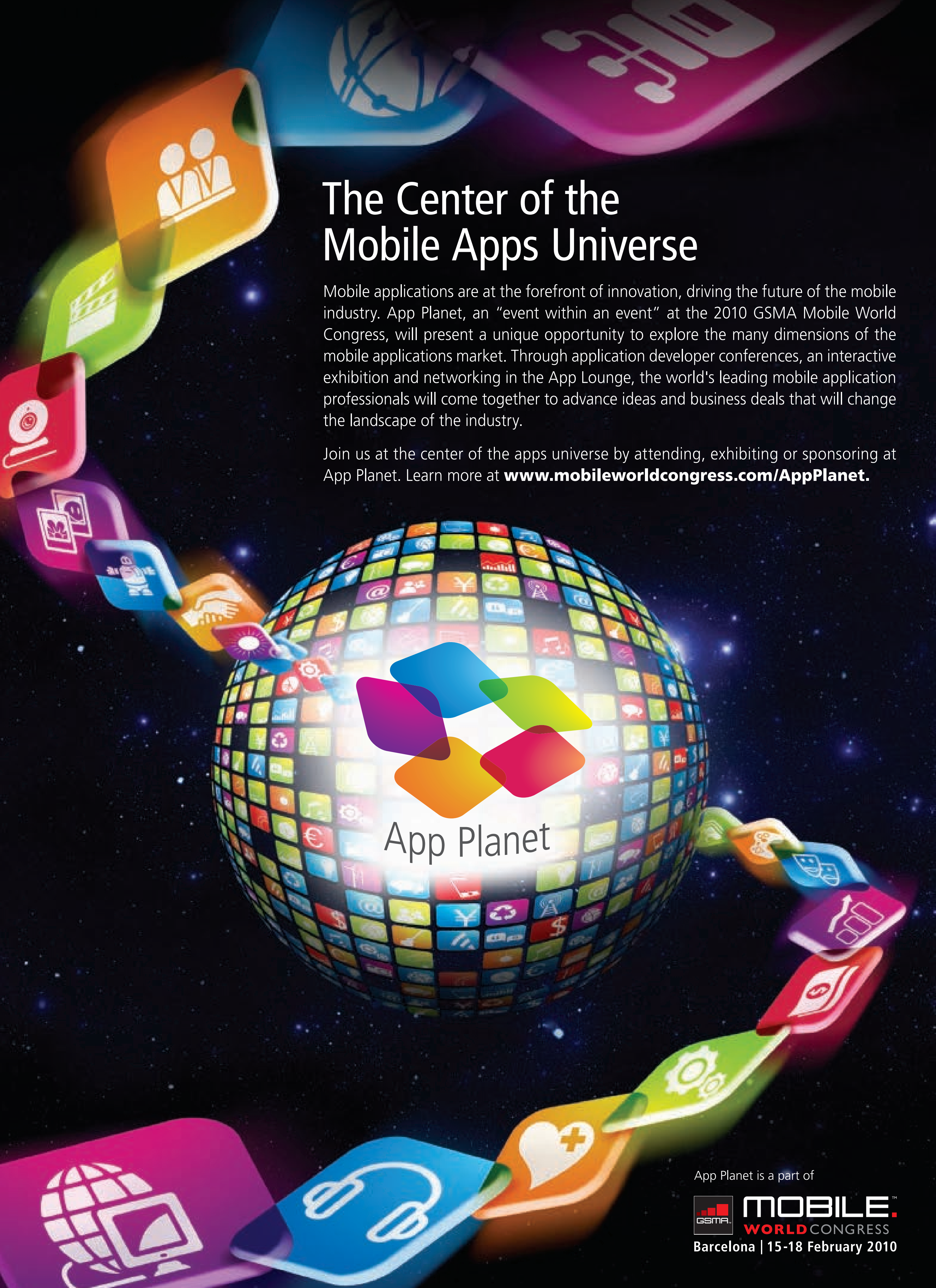
Modelithics Inc., Tampa, FL (888) 359-6359, www.modelithics.com.
RS No. 315



NSI 2000 ANTENNA MEASUREMENT SOFTWARE

The NSI 2000 antenna measurement software is an integrated software package that contains far-field, planar, cylindrical and spherical near-field test capabilities. The software consists of an acquisition module, a data display and processing module, and an optional scripting module that allows for full customization of all processes. This software represents the most advanced antenna measurement software available in industry today allowing for fully automated high-speed data acquisition controlling all axes of motion, test range RF instrumentation and antenna control electronics. Data is displayed in 3D format as shown above and the user has full control of coordinate systems, amplitude or phase modulation.

Nearfield Systems Inc., Torrance, CA (310) 525-7000, www.nearfield.com.
RS No. 313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Power Divider

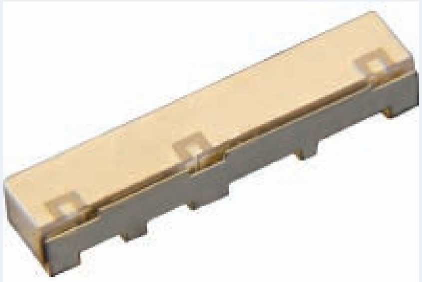
Model PD0218-S2 is a two-way Wilkinson power divider that was just released and covers most military and EW bands from 2 to 18 GHz. These power dividers are available in octave and multi-octave bandwidths and are available from Aeroflex/Inmet stock. The designs are based on an industry standard footprint, and achieve excellent isolation, loss and phase characteristics while offering an economic solution for various market applications.

Aeroflex-Inmet,
Ann Arbor, MI (734) 426-5553,
www.aeroflex.com.

RS No. 216

Ceramic Duplexer

VENDORVIEW

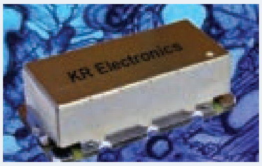


The model AM1880-1960D268 is a surface-mount monoblock ceramic duplexer designed for use in base station transceivers serving wireless communication applications operating in the 1850 to 1960 MHz band. The transmit-to-receive response of the duplexer includes insertion loss from 1850 to 1910 MHz of 3.4 dB or less and return loss of at least 11 dB. Attenuation ranges from 45 dB from DC to 1000 MHz to 38 dB from 2040 to 2100 MHz. Antenna-to-receiver response includes insertion loss of 3.7 dB or less from 1930 to 1990 MHz and attenuation ranging from 51 dB from 1850 to 1910 MHz to 30 dB from 2150 to 2210 MHz. Rejection in the transmit band is at least 54 dB and 49 dB in the receive band. The 50 ohm duplexer will handle RF input power of 2 W and measures 4.6 × 23 × 6.5 mm.

Anatech Electronics,
Garfield, NJ (201) 772-4242,
www.anatechelectronics.com.

RS No. 217

Elliptic Type Low Pass Filter



KR Electronics introduces part number 2927, a surface-mount 440 MHz elliptic type low pass filter. The filter has < 3 dB attenuation at 440 MHz and > 50 dB at 520 MHz. The filter is supplied in a surface-mount package measuring 1.0" × 0.5" × 0.3" and can also be supplied connectorized. The filter can be customized for other center frequencies and bandwidths.

KR Electronics Inc.,
Avenel, NJ (732) 636-1900,
www.krfilters.com.

RS No. 218

Directional Coupler

The model 101004006 is a directional coupler that operates in a frequency range from 1 to 4 GHz. This model offers coupling (with respect to output) of 6 ± 0.5 dB and frequency sensitivity of ± 0.5 dB. The directional coupler features directivity of > 20 dB, maximum VSWR (any port) of 1.2, insertion loss of < 1.3 dB, maximum power rating (Input) of 20 W Average, 3 kW Peak. This model offers SMA female standard connectors and operates in a temperature range from -54° to +85°C. Delivery: Stock to 30 days.

Krytar,
Sunnyvale, CA (877) 734-5999,
www.krytar.com.

RS No. 219

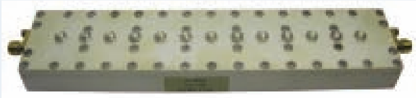
Power Dividers

Microlab/FXR announced an important wideband addition to its already wide range of $ Saver power splitters/dividers. The new low cost, two-, three-, four- and eight-way power dividers, Dx-63FF series, cover from 1700 to 4200 MHz to not only include the PCS and UMTS bands but the new 2.5 to 2.7 MHz WiMAX/LTE expansion band up, and 3.5 GHz WiMAX bands. Microlab/FXR Model Dx-63FF series of Wilkinson style power dividers has been designed for low power applications where output isolation is preferable over lowest possible loss. The wide frequency range of this design allows use with multi-band antennas and leaky cable systems. Lower loss dividers that enhance receive sensitivity and preserve transmitted power over the same wideband are also available from Microlab/FXR in the Dx-82FN and Dx-86FN series.

Microlab/FXR,
Parsippany, NJ (973) 386-9696,
www.microlab.fxr.com.

RS No. 220

Temperature-compensated Cavity Filters



NIC's new temperature compensated cavity filters have a percentage bandwidth as narrow as 0.5 percent. This design offers an economic solution to meet the temperature performance, but avoids using expensive cavity housing material such as Invar. The design is also optimized with maximum resonator quality factor, which ensures low insertion loss operation of the filter. Features include: stable operation over temperature; narrow bandwidth; high selectivity and low insertion loss; custom designs available; and stability as low as ± 2 ppm.

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

RS No. 221

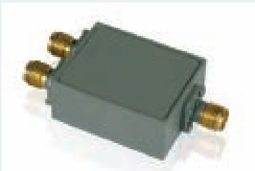
Directional Couplers

The CHP series of high power directional couplers offer accurate coupling, low insertion loss and high directivity in a compact package. The standard units are optimized for 2 octave bandwidths and are available with a choice of coupling values. These units are ideal for sampling forward and reflected power with a negligible effect on the transmission line and very low intermodulation products.

RLC Electronics,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

RS No. 222

Compact Lumped Element Diplexer



Trilithic has released a new series of compact lumped element diplexers designed specifically for the 802.11, 5 GHz WiMAX bands. These diplexers feature high isolation and low insertion loss in a 1.25" × 1.25" × 0.5" package. This diplexer combines the full 2.4 to 2.5 GHz and 4.9 to 5.9 GHz bands with a maximum insertion loss of 1.5 dB in either band, a maximum passband VSWR of 1.5:1 and a minimum of 45 dB isolation between bands. It can accommodate up to 5 W in each band simultaneously. Both connectorized and PCB mount versions are available. Other band combinations are available.

Trilithic Inc.,
Indianapolis, IN (317) 895-3600,
www.trilithic.com.

RS No. 223

Components

Eight-way Active Splitter

CAP introduces the MCA2016 dual eight-way active splitter. This high linearity multi-coupler is suitable for satellite IF signal distribution and supports all analog and digital standards, from 950 to 1450 MHz. Featuring extremely flat gain and phase linearity response, it also offers LNB bias capability on its feeds, complete DC power supply redundancy without diode OR-ring, all in a one EIA rack unit (1.75") height 19" rack mount chassis.

CAP Wireless,
Newbury Park, CA (805) 499-1166,
www.capwireless.com.

RS No. 224

Cable Assemblies

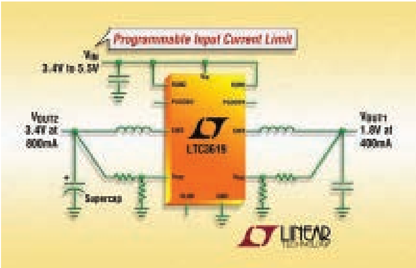
VENDORVIEW

EAM announced the availability of dozens of quick turn RG cable assemblies. These 50 and 75 ohm RG cable assemblies can be supplied with a wide range of coaxial connector types, including 7/16, BNC, Type N, MCX, MHV, SHV, TNC, UHF, MMCX and MIL-qualified connectors for harsh environments. EAM's RG cable assemblies are available in a variety of constructions using a wide range of dielectric materials, jacket materials and shield materials depending on performance requirements. Cable sizes include outside diameters of 0.098", 0.195" and 0.390", and assemblies can be manufactured to meet a host of mechanical and electrical requirements.

Electronic Assembly Manufacturing Inc.,
Methuen, MA (978) 374-6840,
www.eamcableassemblies.com.

RS No. 225

Step-down DC/DC Converter



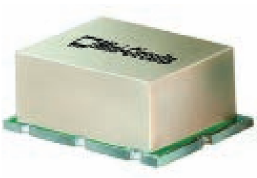
The LTC3619 is a dual output, high efficiency, 2.25 MHz, synchronous buck regulator with programmable average input current limit. It can deliver up to 800 mA of continuous output current from one channel and 400 mA from the other with efficiencies as high as 96 percent. Using a constant frequency and current mode architecture, the LTC3619 operates from an input voltage range of 2.5 to 5.5 V, making it ideal for single-cell Li-Ion and USB applications. It can generate two independent output voltages as low as 0.6 V, enabling it to power the latest generation of low voltage DSPs and microcontrollers. The LTC3619 uses a switching frequency of 2.25 MHz, which allows for the utilization of tiny, low cost ceramic capacitors and inductors less than 1 mm in height.

Linear Technology,
Milpitas, CA (408) 432-1900,
www.linear.com.

RS No. 226

Frequency Mixer

VENDORVIEW



Model SYM-63LH+ is an ultra broadband double balanced mixer utilizing core and wire transformers and a diode quad in a ring configuration. The transformers are designed to provide ultra wide bandwidth using simulation software together with Mini-Circuits proprietary transformer technology. These mixers provide an IF response from DC to 1000 MHz and are especially useful in wideband system applications such as IED. Price: $12.95 (QTY 10 to 49).

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

RS No. 227

Integrated Switch Solutions

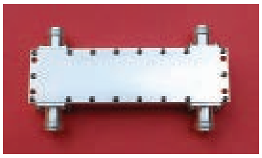
Renaissance Electronics has developed integrated switch solutions that covers diverse market sectors such as consumer electronics, military, aerospace, automotive, communications, semiconductor and medical. The ability to integrate state-of-the-art RF components like MEMS, hermetic switches and 10 million life cycle coaxial switches in custom specified configurations has yielded highly reliable solutions with unsurpassed MTBF. Designs are available in standard configuration of reciprocal or non-reciprocal and/or blocking or non-blocking formats. Renaissance can design and integrate other RF components like LNAs, mixers, amplifiers, filters, attenuators, couplers, dividers/combiners and detectors, to build custom RF/microwave switch matrices that meet cost and performance goals.

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

RS No. 228

High Power Hybrid

VENDORVIEW



Response Microwave announced the availability of its new application specific 3 dB, 90° quadrature hybrid for use in high-power telecom distribution applications. The new unit operates between 800 to 2400 MHz. Electrical performance offers typical insertion loss of 0.3 dB, isolation of 23 dB minimum, VSWR of 1.22:1 maximum and coupling of 3 ± 0.5 dB. Average power handling is 200 W. Unit is available with type N female connectors standard and alternate interfaces available upon request. The package size is 5.6" × 1.54" × 1.02", plus connectors. Units accommodate environmental extremes from -35° to +80°C. Delivery is from stock.

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

RS No. 229

Digital Frequency Discriminator

Sage Laboratories introduces its newest addition to the IFM/DFD family of products. The FDFD7409-4 is a broadband (2 to 18 GHz) digital frequency discriminator incorporating a pulse detector/processor. Processing pulse widths as narrow as 80 ns up to CW, the DFD provides fast and accurate identification of threats. With ultra-low power consumption and small, lightweight packaging, this cost-effective model continues to build the Sage legacy of high-capability Instantaneous Frequency Measurement Receivers. This model is available with an optional VME interface as well as 50 ns pulse capability.

Sage Laboratories, Hudson, NH (603) 459-1600, www.sagelabs.com.

RS No. 230

Amplifiers

Hybrid Power Amplifier Modules

VENDORVIEW

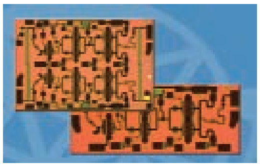
AR's new line of wideband, hybrid power amplifier modules (HPM) cover the 6 to 18 GHz frequency range, and are the result of combining Microelectronic technology with the latest developments in thin film substrates. These hybrid modules require a single DC voltage source and are 50 ohm cascadable building blocks with output powers up to 37 dBm. AR offers in-house capabilities to create custom HPM design solutions with frequencies from DC to 40 GHz. Bring AR your requirements and they will work with you to create a solution.

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

RS No. 231

MMIC Power Amplifiers

VENDORVIEW



These two new GaAs PHEMT, ½ and 1 W power amplifiers are ideal for high linearity transmit chains in Point-to-Point/Point-to-Multi-Point microwave radio, military & space, VSAT, and test applications from 16 to 24 GHz. The HMC756 and the HMC757 are GaAs PHEMT, ½ and 1 W power amplifier dies that are rated from 16 to 24 GHz, and provide up to 23 dB of small-signal gain across the band. These three-stage, balanced power amplifiers are also capable of providing +33 dBm of saturated output power at 28 percent PAE and +30 dBm of saturated output power at 30 percent PAE, respectively, from a +7 V supply. The HMC756 and the HMC757 Power Amplifiers also feature output IP3 of up to +41 dBm, P1dB output power up to +32 dBm, and require no external matching components.

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

RS No. 232

High Power Pallet Amplifier

VENDORVIEW

MITEQ introduces a new addition to its family of broadband high power amplifiers. Model AMF-8B-18002650-70-37P is a plate mounted high power amplifier, covering 18 to 26.5 GHz and delivering a minimum of 5 W of saturated power. The SMA connectorized module has a base of 5" wide, 5.24" long and 2" high including fins on top. Housing is EMI and environmentally shielded, and can operate in baseplate temperatures up to 60°C. The power

amplifier includes over temperature protection in addition to full internal regulation. A 20 dB output coupled port is optional.

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

RS No. 233

RF Amplifier

VendorView

OPHIR RF solution for your 2 to 6 GHz, 50 W RF power requirement of EN 61000-4-3:2006 is now available. The 5193 is a 50 W multi-octave broadband 2 to 6 GHz amplifier system. This 5.25" compact and lightweight amplifier utilizes Class A/AB linear power devices that provide an excellent third order intercept point, high gain, and a wide dynamic range. Optional digital controller is available to display the amplifier operating status and remote interface with Ethernet, IEEE488 and RS232. In stock.

OPHIR RF,
Los Angeles, CA (310) 306-5556,
www.ophirrf.com.

RS No. 234

High Power Pallet Amplifier

The PP88-108-800 is a high power Class AB Pallet Amplifier providing 800 W CW power output in an extremely small footprint. Featuring the latest generation LDMOS transistors, the PP88-108-800 provides the highest power density of any FM pallet in the world today. Thermal tracking bias allows the PP88-108-800 to operate Class AB while providing 800 W CW with a typical efficiency of 80 percent.

Power Module Technology Inc.,
Carson City, NV (775) 883-1122,
www.pmtrf.com.

RS No. 235

Broadband Amplifiers

The R&S BBA100 is the most flexible and advanced broadband amplifier system on the market. Its modular design allows users to select frequency range and output power to suit their requirements. The built-in expansion capability protects capital investment. Individual amplifier modules can be replaced quickly and easily, making downtime a thing of the past. The R&S BBA100 is ideal for EMC applications in test houses and the electronics and automotive industry. The high quality and reliability of the amplifiers will also benefit research institutes, development labs and government agencies, as well as radiocommunications applications. The amplifier will have three frequency bands that cover the range from 9 kHz to 1 GHz and provide power up to 500 W. The base unit includes comprehensive control functions.

Rohde & Schwarz GmbH & Co. KG,
Munich, Germany +4989/4129-0,
www.rohde-schwarz.com.

RS No. 236

Antennas

High Power, Crossed Notch Antenna

Model 94800568 is a dual-linear, high-power, crossed notch antenna that operates over the 2 to 18 GHz frequency range. The antenna VSWR is 2.5:1 maximum and < 2.0:1 over 90 percent of the frequency range. Antenna gain ranges between 5 and 10 dB, and is +8 dB nominal. The port-to-port isolation is more than 20 dB and RF power is 500 W CW at each port simultaneously. Model 94800568 is suitable for high-power ECM applications; it is also suitable for feeding reflector antennas, wide-band antenna arrays and other broadband applications.

Cobham Sensor Systems -
Sensor Electronics,
Baltimore, MD (410) 542-1700,
www.cobham.com.

RS No. 237

Broadband Conical Monopole Antenna

The low-loss antenna BCM40 supports a monopole antenna characteristic and an ultra broad frequency band (1.2 to 40 GHz). This antenna covers all major frequency bands, ideal for surveillance applications with a very robust casing and design. The BCM40 antenna is manufactured precisely, offers good matching and an antenna gain of ca. 0 dBi. The robust casing allows for indoor and outdoor use even in moist conditions.

Heuermann HF-Technik GmbH,
Stolberg, Germany +49 2402/9749764,
www.hhft.de.

RS No. 238

Integrated Circuit

MMICs

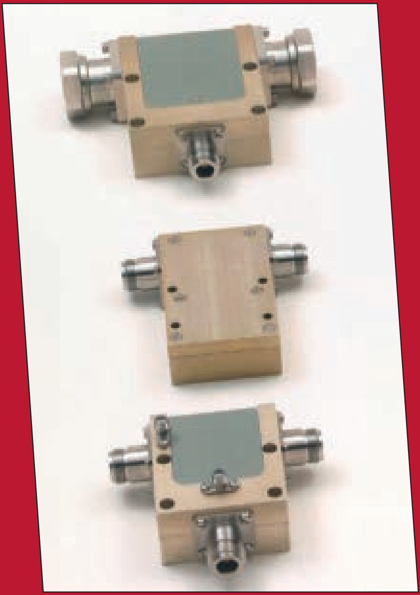
Endwave Corp. has announced the release of an extensive product line of microwave and millimeter-wave integrated circuits (MMIC) for use in microwave radios and other high frequency systems. The product line consists of a wide variety of circuit types including amplifiers, voltage-controlled oscillators, up and down converters, variable gain amplifiers, voltage variable attenuators, fixed attenuators and filters. Both bare die and QFN packaged devices are available. Devices are available over the full microwave radio frequency range of 7 to 38 GHz and the product line also includes devices for the new E-band (71 to 76 GHz and 81 to 86 GHz) frequency range. The product line has been derived from Endwave's extensive design library created while providing custom microwave and millimeter-wave RF modules to radio systems OEMs.

Endwave Corp.,
San Jose, CA (408) 522-3100,
www.endwave.com.

RS No. 239

HIGH POWER

Isolators / Circulators For Military / Radar Applications.

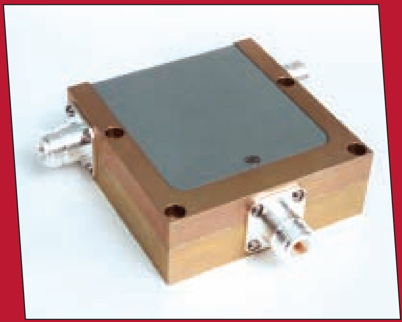


Communications

Drop-in Model CT-3885-S

Military and Radar

100 MHz to 20 GHz



Telecom

Scientific – Medical

Our **"POWER-LINE"** capability serves major markets...
Military and Commercial

UTE Microwave is one of the leading suppliers of ferrite components in the industry. We offer innovative engineering, reliability, custom design, standards...many off-the-shelf...plus superior service and over 35 years of know-how.

For Military and Radar applications our Drop-in Model CT-3885-S is designed to operate at 2.5 KW Peak and 250 Watts average power in the 3 GHz radar bands. Bandwidth is up to 12%. Typical specs are 20 dB Isolation. 0.3 dB max Insertion loss and 1.25 max VSWR. The 1-5/8 x 1-5/8 x 7/8 package provides for optimum RF grounding and heat transfer. Other stripline interface HIGH POWER units are available from VHF thru C band.

A broad line of low loss HIGH POWER coaxial and stripline mounting circulators are available. Typical coax units handle 3 KW CW, 10 KW peak at 120 MHz and 1 KW CW, 3 KW peak in the 400-800 MHz TV bands. 250 Watt stripline drop-in units are also available. In the 800-3.5 GHz spectrum, 0.15 dB loss stripline drop-in units operate at 200 Watts CW, 2 KW peak power levels.

FEATURES:

- **Power levels to 5 KW CW, 75 KW Pk.**
- **Low Intermod Units**
- **Low Loss Options**
- **Extended Octave Bandwidths**
- **Power Monitors and DC Blocks**
- **Iso Filter-Monitor Assemblies**

The following models are examples of our High Power units

Model No.	Power	Connectors	Freq. Range
CT-1542-D	10 Kw Pk 1 Kw Av	DIN 7/16	420–470 MHz
CT-2608-S	3 Kw Pk 300 W Av	"Drop-in"	1.2–1.4 GHz
CT-3877-S	2.5 Kw Pk 250 W Av	"Drop-in"	2.7–3.1 GHz
CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
CT-1645-N	250 W Satcom	N Conn.	240–320 MHz
CT-1739-D	20 Kw Pk 1 Kw Av	DIN 7/16	128 MHz Medical

Visit http://mwj.hotims.com/23292-123 or use RS# 123 at www.mwjournal.com/info

Broadband Units • Common Band Devices • High Isolation Units • Multiport Devices • Drop-In Devices • Wireless/PCN Devices • High-Power Industrial/Medical Iso Adaptors Waveguide Junctions • High-Power TV Units • VHF and UHF Devices sales@utemicrowave.com

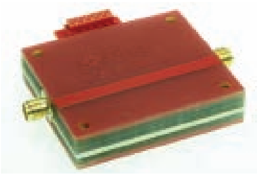
UTE MICROWAVE INC.

3500 Sunset Ave., Asbury Park, NJ 07712
Tel: 732-922-1009 Fax: 732-922-1848
E-mail: info@utemicrowave.com

Contact us for more information on our extensive product line and current catalog. We accept Visa, MC, Amex

Materials

Patented RF Packages



Patents have been awarded to RF packages for the company's components, which includes attenuators, power dividers/combiners and switches. This cost-effective, special high frequency plastic patented package is entirely built from printed circuit material. The frames, the internal isolation and cover parts are achieved by printed circuit layers. The individual parts are pressed and soldered in the soldering machine together with the connectors, producing a very mechanically robust RF module. The RF shielding is made by connecting through the single printed circuit layers and is in accordance with standard full metal housings.

eubus GmbH,
Munich, Germany +49 (0) 89 540 32 733,
www.eubus.net.

RS No. 240

6.15 DK Laminates

VENDORVIEW

Rogers Corp. has introduced RO4360™ laminates, developed for the special requirements of high-frequency amplifier designers. RO4360 laminates feature a dielectric constant of 6.15 and loss of 0.003 at 2.5 GHz. The laminates are based on a ceramic-filled, thermoset resin system reinforced by glass fiber for excellent mechanical stability compared to PTFE woven glass. RO4360 laminates provide the performance and reliability designers need in a lower total PCB cost solution. The new product features low dissipation factor, generous power-handling capability, and improved thermal conductivity. Environmentally friendly RO4360 laminate materials are RoHS compliant and compatible with standard printed circuit board processing methods.

Rogers Corp.,
Chandler, AZ (480) 961-1382,
www.rogerscorp.com.

RS No. 241

Capacitor

Multilayer Capacitors

ATC announced the introduction of non-magnetic (non-nickel) barrier layer capacitor products. They are manufactured in 600L, S and F (0402, 0603, 0805) EIA case sizes as well as 800 A and B (0.055" × 0.055" and 0.11" × 0.11") signature case sizes, and 800R NPO Ceramic, High RF Power Lowest ESR MLCs (0.070" × 0.090"). ATC's new non-magnetic MLCs are designed and manufactured to provide the same superior performance as the current nickel barrier versions. These products are suitable for use in MRI and other medical electronics applications. They also may be used in applications where there is a concern regarding passive intermodulation distortion in wireless communications systems.

American Technical Ceramics,
Huntington Station, NY (631) 622-4700,
www.atceramics.com.

RS No. 242

Software

3D Planar EM Analysis Software

VENDORVIEW

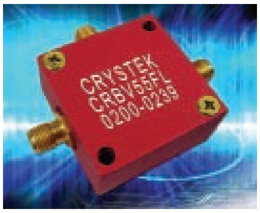
AWR announced significant performance enhancements to its AXIEM 3D planar electromagnetic (EM) analysis software that greatly increase the software's speed, accuracy and capacity. AXIEMs proprietary solver and meshing algorithms have made it possible for the first time to migrate EM analysis from a back-end, post-verification tool to an upfront design diagnostic solution. With nearly linear scaling achieved through its novel method-of-moments (MoM) engine, AXIEM even in its first year of commercial availability, outperforms competing 3D planar solutions that have been on the market for more than a decade.

AWR,
El Segundo, CA (310) 726-3000,
www.awrcorp.com.

RS No. 243

Sources

Voltage-controlled Oscillator



Crystek's CRBV55FL-0200-0239 RedBox voltage-controlled oscillator (VCO) operates from 200 to 239 MHz with a control voltage range of 0.5 to 4.5 V. This VCO features a typical phase noise of -123 dBc/Hz at 10 kHz offset and has excellent linearity. Output power is typically +9 dBm. Crystek's RedBox line comprises VCOs enclosed in a robust aluminum enclosure (1.25" × 1.25" × 0.58") with SMA connectors, enhancing the VCO's durability and making integration of a VCO into any application an easy, plug-and-play option.

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

RS No. 244

Reference Oscillators

The PLXO Series phase-locked crystal oscillator can be designed to operate at select custom frequencies from 200 to 350 MHz as a reference oscillator in military and other electronic systems. The PLXO units feature excellent phase

UNITED STATES POSTAL SERVICE

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☐ Has Not Changed During Preceding 12 Months
☐ Has Changed During Preceding 12 Months *(Publisher must submit explanation of change with this statement)*

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	(2) Free or Nominal Rate In-Country Copies Included on PS Form 3541	0	0
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	(4) Free or Nominal Rate Distribution Outside the Mail *(Carriers or other means)*	1866	4146
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f. Total Distribution *(Sum of 15c and 15e)*	▶	39,457	41,067
g. Copies not Distributed *(See Instructions to Publishers #4 (page #3))*	▶	167	77
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17. Signature and Title of Editor, Publisher, Business Manager, or Owner
Carl S. Sheffres, Publisher
Date: September 23, 2009

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

PS Form **3526**, September 2007 *(Page 2 of 3)*

noise (<-119 dBc/Hz at 1 kHz) and low power consumption (+12 V at 155 mA). The PLXO units are housed in a rugged, connectorized package (1.50" × 1.50" × 0.6") to withstand harsh environments. The PLXO-250 units also feature no sub-harmonics and a wide operating temperature range (-30° to +70°C).

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

RS No. 245

Voltage-controlled Oscillator

The model CRO3400C-LF is a RoHS compliant voltage-controlled oscillator (VCO) in S-band. The CRO3400C-LF operates at 3400 MHz with a tuning voltage range of 0.5 to 4.5 VDC. This VCO features a typical phase noise of -112 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 5 MHz/V. The CRO3400C-LF is designed to deliver a typical output power of 3 dBm at 5 VDC supply while drawing 24 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -20 dBc and comes in Z-Comm's standard MINI-16-SM package measuring 0.5" x 0.5" x 0.22".

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

RS No. 246

Test Equipment

Vector Network Analyzer

VENDORVIEW

Anritsu Co. announces it has extended the low-end frequency of its MN469xB VectorStar 4-port test sets, making the instruments the first microwave multiport Vector Network Analyzer (VNA) solutions to measure down to 70 kHz. The MN469xB series now combines DC coverage and the wide dynamic range time domain capability of a VNA, making the test sets ideal for digital engineers who need to conduct signal integrity measurements on passive high-speed balanced transmission lines and connections in order to optimize their Gbit designs. Two models are available in the MN469xB series. The MN4694B covers up to 40 GHz, while the MN4697B has a frequency range up to 70 GHz. Both include bias tees for active measurement applications.

Anritsu Co.,
Morgan Hill, CA (408) 778-2000,
www.us.anritsu.com.

RS No. 247

Spherical Near-field Arch Roll Scanner

The NSI-700S-300 Spherical Near-Field Arch Roll Scanner is designed for precision testing of stationary Antennas Under Test (AUT). An innovative probe motion design delivers spherical measurement accuracies for antennas rivaling those currently obtained only with planar scanning techniques. The scanner's arch provides accurate probe motion over an extended hemispherical scan area, and its software supports multi-beam, multi-frequency control of the RF subsystem and includes an 'on-the-fly' probe position correction subsystem to maintain probe position accuracy on the order of 0.0025" (63 microns).

Nearfield Systems Inc.,
Torrance, CA (310) 525-7000,
www.nearfield.com.

RS No. 248

2010 INTERNATIONAL MICROWAVE SYMPOSIUM

IEEE MTT-S • MAY 23-28, 2010 • ANAHEIM, CALIFORNIA

THE GOLDEN STATE OF MICROWAVES

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The IEEE Microwave Theory & Techniques Society (MTT-S) International Microwave Symposium for 2010 (IMS2010) will be held in Anaheim, California, as the centerpiece of Microwave Week 2010, scheduled from Sunday, May 23 through Friday, May 28, 2010. IMS2010 offers technical paper sessions, workshops/tutorials, poster sessions (called open forum), applications seminars (called MicroApps), plenary and panel sessions, industrial exhibits, historical exhibits, and a host of other activities including a guest program for the spouses and accompanying family members. The Microwave Week comprises still other activities, including the RFIC Symposium, and the ARFTG conference collocated with IMS2010.

REQUEST Authors are invited to submit technical papers describing original research, development, and application work on radio-frequency and microwave theory and techniques, in the various areas within this field; the following list of areas is only suggestive and not intended to exclude other areas:

Microwave Field and Circuit Techniques

1. Field Analysis and Guided Waves
2. Frequency-Domain EM Analysis Techniques
3. Time-Domain EM Analysis Techniques
4. CAD Algorithms and Techniques
5. Linear Device Modeling
6. Nonlinear Device Modeling
7. Nonlinear Circuit and System Simulation

Passive RF and Microwave Components

8. Transmission Line Elements
9. Passive Circuit Elements
10. Planar Passive Filters and Multiplexers
11. Non-planar Passive Filters and Multiplexers
12. Active, Tunable, and Integrated Filters
13. Ferroelectric, Ferrite, and Acoustic Wave Components
14. MEMS Components and Technologies

Active RF and Microwave Components

15. Semiconductor Devices and Monolithic ICs
16. Signal Generation
17. Frequency Conversion and Control
18. HF/VHF/UHF Technologies and Applications
19. Power Amplifier Devices and Circuits
20. High-Power Amplifiers
21. Low-Noise Components and Receivers
22. mm-Wave and THz Components and Technologies

RF and Microwave Systems and Applications

23. Microwave Photonics
24. Signal Processing Circuits and GHz speeds
25. Packaging, Interconnects, MCMs and Integration
26. Instrumentation and Measurement Techniques
27. Biological Effects and Medical Applications
28. RF Arrays as Antennas and Power Combiners
29. Radar and Broadband Communication Systems
30. Wireless and Cellular Communication Systems
31. Sensors and Sensor Systems
32. Emerging Technologies

PAPER SUBMISSION INSTRUCTIONS Technical papers to be considered for presentation at IMS2010 must be submitted electronically, in pdf format, via the symposium webportal, www.ims2010.org. This website provides complete information on submission procedure, registration, and related items. Paper or printed copies of submissions cannot be accepted. Symposium proceedings are published as a CD ROM by IEEE, and posted in their digital library. Authors of high-quality papers will be invited to submit an extended version of their paper for the Special IMS2010 issue of IEEE Trans. Microwave Theory & Techniques.

PROPOSAL INVITATION The Technical Program Committee (TPC) of the Symposium also invites proposals for:

- Workshops (ranging from expert-level to tutorials and short courses), and
- Special Sessions (including focused, honorary, and panel/rump sessions).

Details regarding the types of workshops sought, information requested along with the proposal, and the proposal evaluation criteria, are available on the Symposium website www.ims2010.org. Special sessions on topics that are currently being intensely pursued, contentious, or relevant to the theme of the Symposium or to the microwave community in Southern California, may be proposed for consideration by the Technical Program Committee of the Symposium. For full consideration, all proposals should be received by August 28, 2009.

SUBMISSION DEADLINES

Workshop and Special Session Proposals	Posted at www.2010.org	
Technical Paper Electronic Submission	Monday	November 30, 2009
Notification of Acceptance	Monday	January 18, 2010
Final Manuscript for Accepted Papers	Thursday	March 4, 2010
Final Manuscript of Workshop Notes	Thursday	March 11, 2010

MTT-S®
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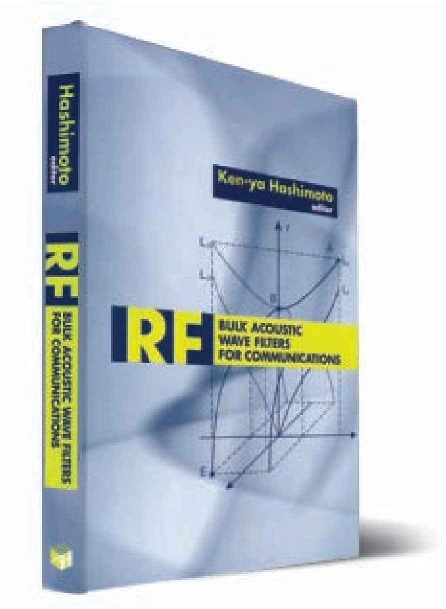
Celebrating 125 Years of Engineering the Future

RF Bulk Acoustic Wave Filters for Communications

Ken-ya Hashimoto, *Editor*

RF-BAW devices employing a piezoelectric thin membrane were proposed in 1980. Although their excellent performance was well recognized, the majority of engineers believed that their applicability was limited due to extremely tight requirements given to device fabrication. However, RF-BAW devices have progressed surprisingly in the last decade and are now mass produced. They are currently attempting to take over the current RF-SAW filter market. The devices also receive much attention from Si-IC industries for their use as a core element in sophisticated RF front-end and/or one-chip radio modules based on the system-on-chip (SoC) or system-in-package (SiP) integration with active circuitry.



This book deals with key technologies and information necessary for the realization of high-performance RF-BAW resonators and filters. All the authors are prominent professionals in this field, and they attempt to transfer their knowledge to the younger generation as various chapters are written by different experts in the field.

The first several chapters review BAW's background, history, topologies, fabrication and device basics to provide the foundation to understand the more detailed information in the later chapters. The book then covers FBAR resonators and filters with a comparison to SAW devices. The book then segues into thin film deposition of BAW devices and characterization. Finally, the last couple of chapters review practical applications of the devices through monolithic and SiP integration.

The editor notes that the term film bulk acoustic wave resonator (FBAR) might be more familiar to many readers, although he states that its use is often limited to the category of a free-standing membrane fabricated by the surface or bulk micromachining technology. Namely, the solidly mounted BAW resonator (SMR) employing the multilayered reflector(s) is excluded from this category. For this reason, the RF-BAW resonator categorization is used as the whole set of these two categories throughout the book.

This book is invaluable for young engineers and students who wish to acquire this exotic technology and covers the subject thoroughly. In addition, it is for more advanced engineers who wish to further extend their knowledge, as experts in various areas have written each chapter. The last two chapters are very useful as they review actual designs and integration techniques that would be utilized in actual applications.

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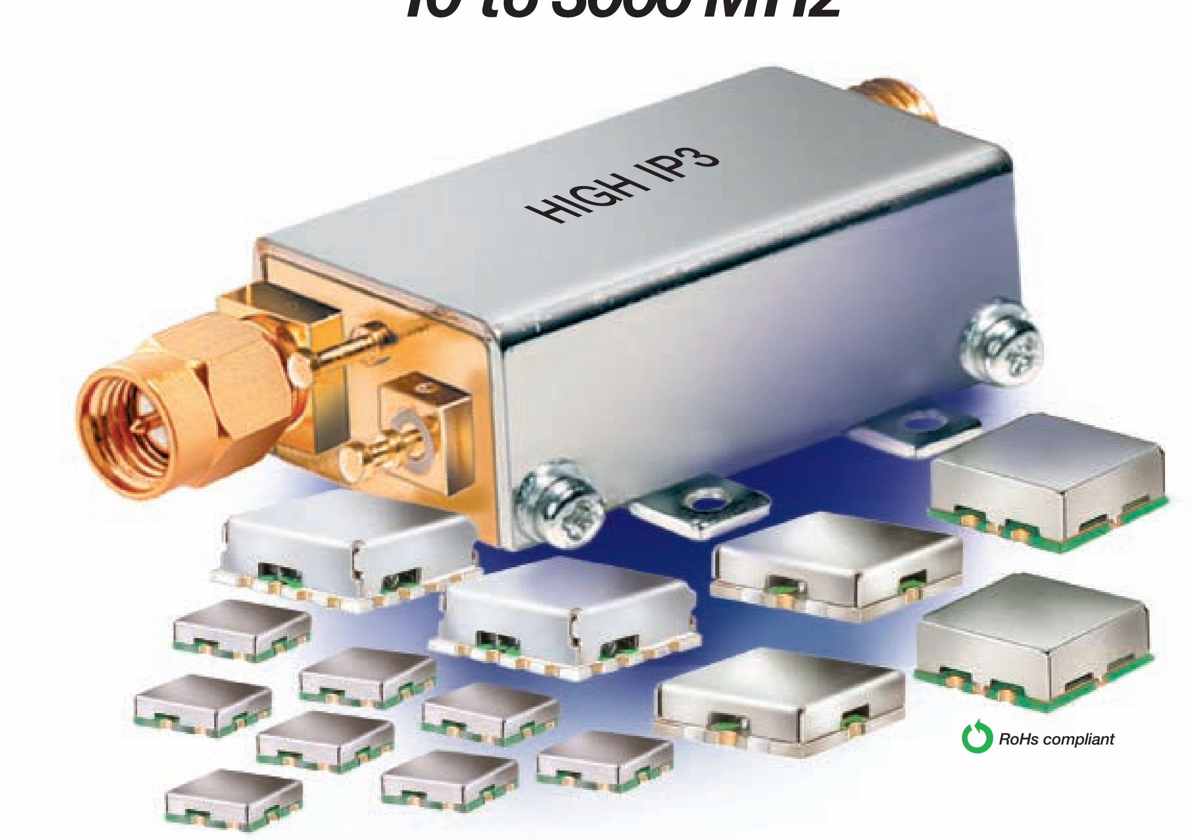

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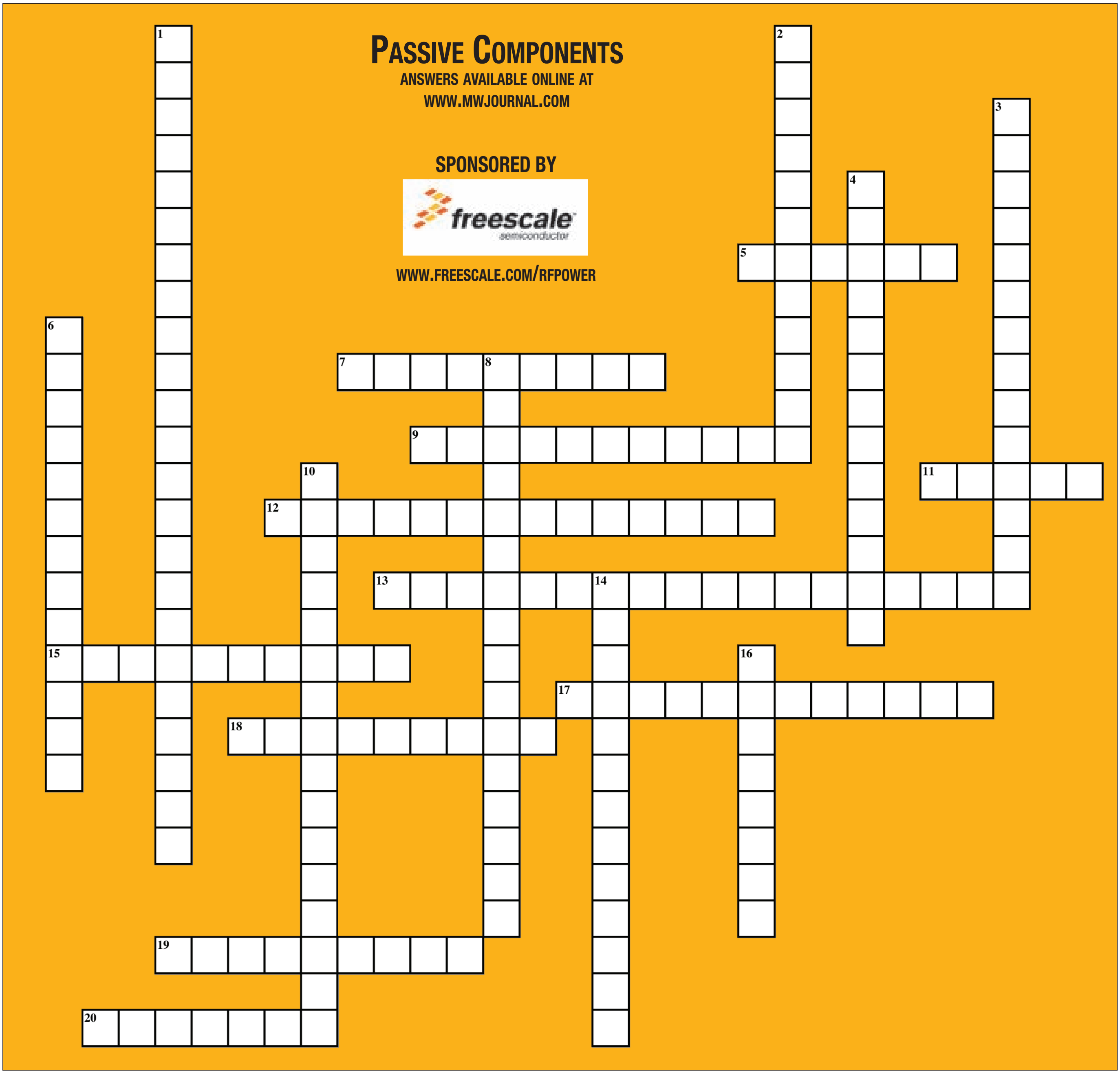

ACROSS

5 A circuit that is designed to propagate signals of a desired frequency or frequency interval and to reject all other signals

7 Frequency-dependent impedance that is capable of storing but not dissipating energy

9 A component that transfers electric energy by magnetic induction from one circuit to another, usually with a change in voltage or current

11 A transformer circuit that couples a balanced transmission line to an unbalanced transmission line

12 A filter that only allows frequencies above a cut-off frequency to pass (3 words)

13 Resonator consisting of free-space rings of metal with a gap that prevents them from being a complete ring (3 words)

15 The property of a circuit or component that tends to oppose changes in current due to the magnetic field that is a result of the current itself

17 A measure of how much better a material is as a path for magnetic flux as compared to free space

18 The difference in power, expressed in dB, between the input level and output level when a unit is in high loss condition

19 The vector ratio of voltage to current, the reciprocal of admittance

20 A class of multiport components that directs the majority of an incident signal to the output port and the remainder of the signal to other ports

DOWN

1 Arbitrary shaped structure etched into the ground plane which disturbs the shield current distribution (3 words)

2 A circuit that splits the power of an input signal into two or more locations without producing impedance mismatch (2 words)

3 A reactive circuit that rejects signals whose frequencies are outside of its passband 3 dB point frequencies and propagates signals whose frequencies are within the 3 dB point frequencies (3 words)

4 Technology for transmitting information spread over a large bandwidth, typically >500 MHz (3 words)

6 Artificial materials engineered to provide properties that may not be readily available in nature typically with negative index properties

8 Frequency where signal transmission between input and output is stopped (2 words)

10 A transmission line structure that splits an input signal into two or more equal phase output signals (2 words)

14 The ratio between the amplitude of the output signal of a device or circuit compared to the amplitude of its input signal (2 words)

16 The frequency interval that is propagated through a filter with minimum insertion loss

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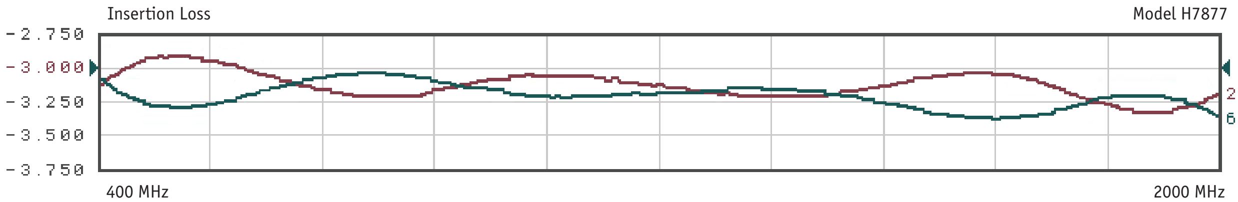

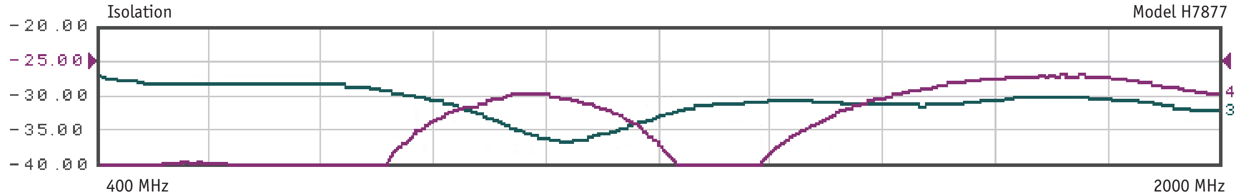

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H6751	20-512	50	0.8	1.40:1	25	4 X 1.6 X 0.8
H7450	100-500	200	1.0	1.35:1	20	6 X 5 X 2.25
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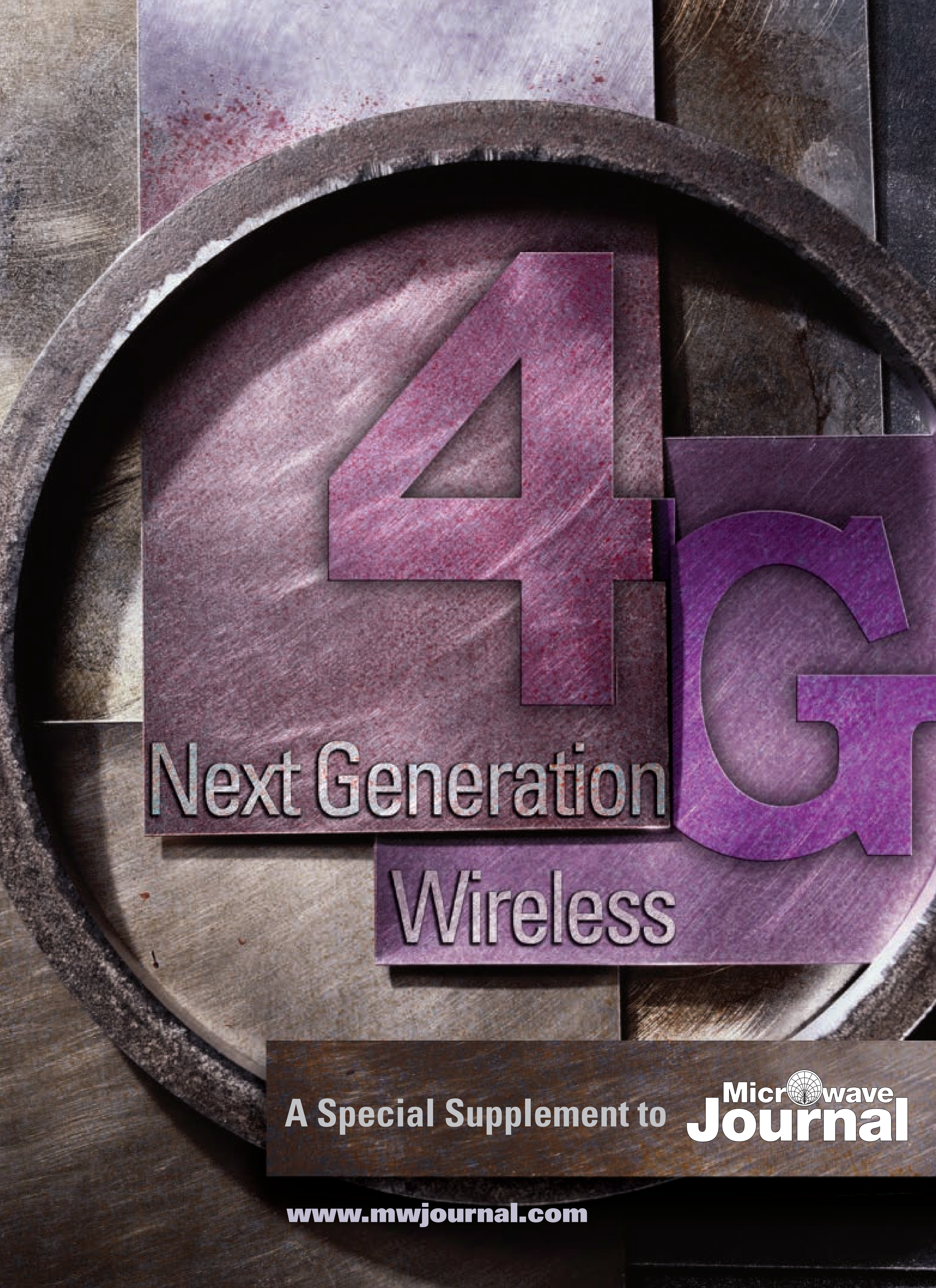
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Next Generation Wireless

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Using Base Station and MIMO Channel Emulators to Characterize Performance of a Mobile WiMAX Device

This article describes how a channel emulator can be used to characterize the performance of a MIMO receiver. The testing was done in stages of increasing complexity, namely testing under AWGN conditions, MIMO testing with known static channels, and finally testing with channels chosen to represent "real world" behavior. The article seeks to demonstrate how testing at each of these stages can help give engineers confidence in their design as well as potentially expose issues that may be difficult to isolate with the more complex "real world" testing.

The IEEE 802.16 working group is focused on developing standards for Broadband Wireless Access. As a part of this work, a physical layer specification has been written for mobile devices,[1] which uses Orthogonal Frequency Division Multiple Access (OFDMA) in combination with advanced techniques such as Adaptive Modulation and Coding (AMC) and multiple input, multiple output (MIMO). The overall performance gain for a network that uses techniques such as AMC and MIMO is strongly influenced by the receiver characteristics of client devices within that network. For example, a good receiver will allow the network to more readily use complex modulation schemes and hence achieve greater throughputs. This article uses the combination of a base station emulator and a MIMO channel emulator to characterize the receiver performance of a commercially available Mobile WiMAX device.

MEASUREMENT SET-UP

Figures 1 and ***2*** show a schematic representation and a photograph of the equipment used for the testing. The E6651A is a fully functional base station emulator designed for testing mobile WiMAX devices. It supports a number of different use models, including RF testing, functional emulation of protocol features, end-to-end application testing and protocol conformance testing. In this case, the equipment was used to perform a downlink "ping test", with a variety of different modulation and coding formats both with and without MIMO.

The E6651A has two RF ports that can be configured to provide transmitter outputs for MIMO testing. Each downlink signal was fed into a signal analyzer (MXA) that down-converted the RF signal to a differential baseband digital signal that served as an input to the PXB.

The N5106A PXB MIMO Receiver Tester is a baseband channel emulator that allows the user to emulate a variety of single channel and MIMO fading conditions. In addition to channel characteristics, such as Doppler spread and delay spread, the PXB is able to emulate antenna characteristics, including antenna spacing, polarization, antenna lobe patterns and angular spread. The PXB can be used in a baseband configuration, where it is connected to a signal source (MXG) and used to test receiver perfor-

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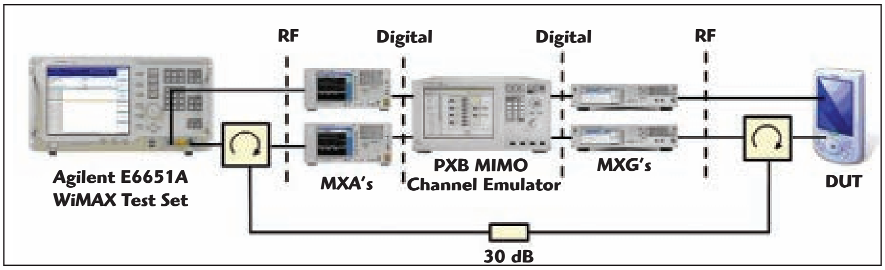


Fig. 1 Equipment set-up for measuring receiver performance.

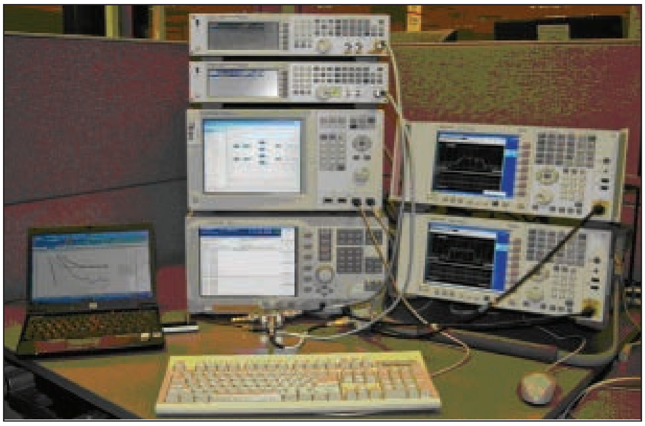


Fig. 2 Photograph of the measurement set-up used for receiver testing.

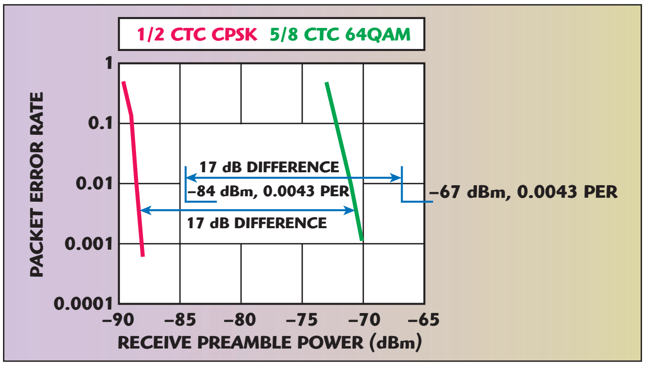


Fig. 3 Packet error rate under AWGN conditions.

mance for a variety of different wireless formats.

In this test set-up the digital outputs from the PXB were up-converted to RF using a signal source and then connected with the device under test (DUT). In order to support a fully functional radio, the cabling set-up uses isolators to provide an un-faded uplink signal to the RF1 port of the E6651A.

THERMAL NOISE PERFORMANCE

Figure 3 shows the sensitivity measurements for the device under test under thermal noise conditions. The figure is also annotated to show the test limits as defined by the WiMAX Forum in its Radio Conformance Test (RCT) specification.[2]

These results demonstrate that the receiver is meeting the required sensitivity limits under additive white Gaussian noise (AWGN) conditions. The WiMAX Forum test limits are set by calculating the theoretical thermal noise power and then assuming degradation due to the noise figure of the receiver and an implementation loss. Passing this test provides a level of confidence about both the device and the measurement set-up.

MIMO PERFORMANCE UNDER STATIC FADING CONDITIONS

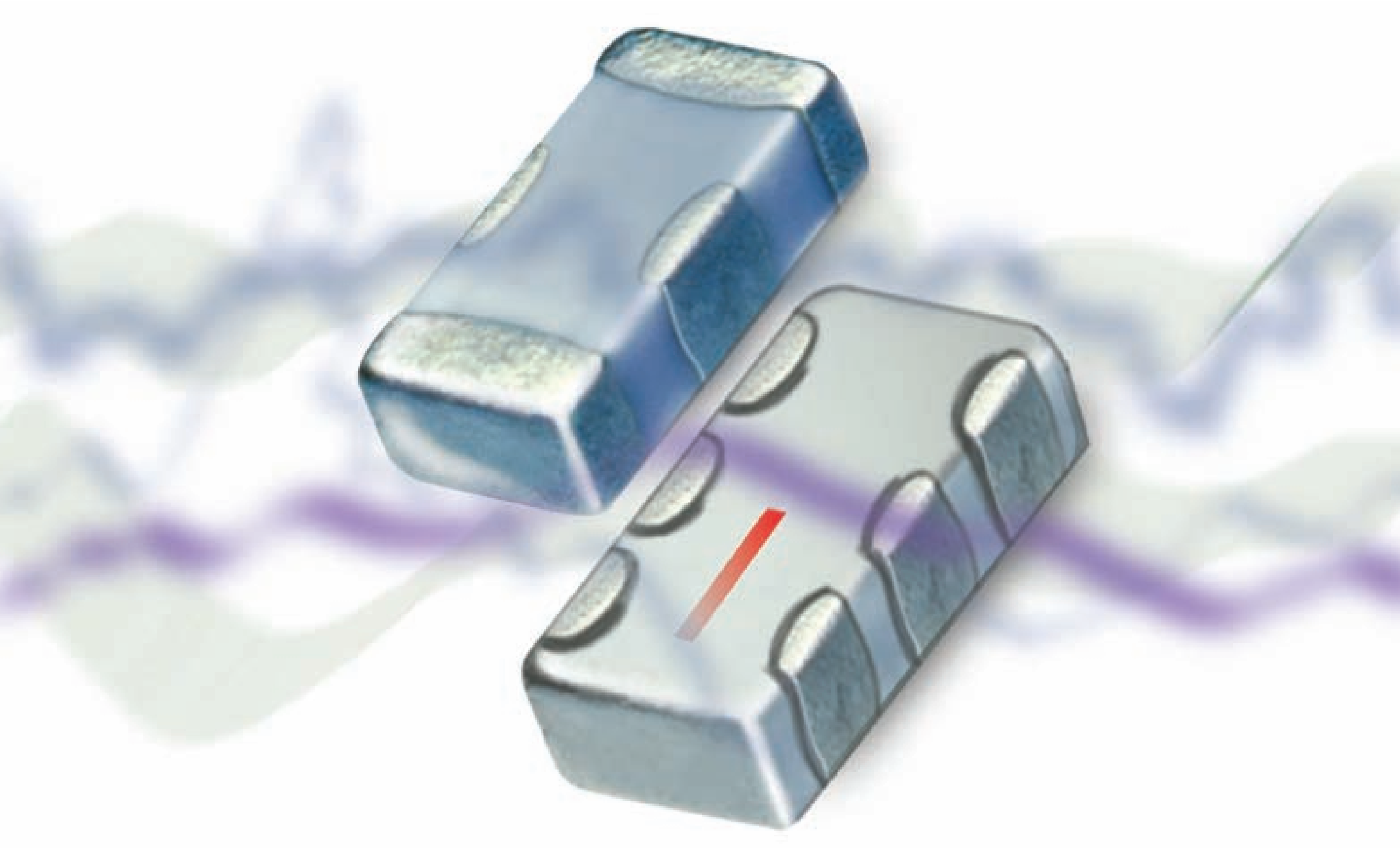
MIMO techniques exploit the multipath characteristics of radio channels and allow the link to either benefit from higher orders of diversity or to create separate spatial streams, which can support the transmission with increased data throughput. The use of spatial streams for increasing data throughput is an exciting development which, given the right conditions, provides the possibility of achieving data rates that exceed the Shannon Capacity limit.

Given that MIMO is exploiting the characteristics of a multipath channel, it is not possible to characterize the performance using a simple AWGN channel. However, prior to testing the performance in channels that are intended to emulate "real world" environments, it is helpful to test the MIMO performance in simple static channels, where the expected behavior is known.

One way of characterizing whether or not a "channel" is well suited to providing multiple spatial streams is to calculate the condition number.[3] The condition number is a measure of how sensitive the eigenvalues of a given matrix are to small perturbations of the values in that matrix. If the condition number is low then the eigenvalues will not be sensitive to small perturbations (or noise) and the channel will be well suited to supporting two MIMO streams. A high condition number indicates that the channel matrix is very sensitive to noise and the system requires a significant increase in the required signal to noise ratio in order to support multiple spatial streams.

Figure 4 shows a schematic representation of a 2 × 2 MIMO channel. Each of the Tx-Rx pairs has their own channel, which in the general case can be represented by a complex time varying impulse response. For the simplified static channels h00, h01, h10 and h11 can each be represented by a constant complex number within a single matrix. The matrix (1,0,0,1) has a condition number of 0 dB and reflects a theoretically perfect MIMO channel with two spatial streams, which are orthogonal. The packet error rate curves in ***Figure 5*** show a shift in the required SNR for a single input, single output (SISO) link vs. an ideal MIMO link with two transmitters and two receivers (condition number = 0 dB). The figure also shows curves for packet error rates for a variety of channels with varying levels of condition number.

Cain[3] has plotted graphs to show the empirical relationship between the condition number and the additional carrier to noise required to maintain a given error vector magnitude (EVM). ***Figure 6*** shows an example where the blue line corresponds to the additional CNR required to sustain an EVM of 32 percent. Placed on this graph are three data points (shown as a yellow circle, square and triangle), which overlay the measurements presented in this article. This shows a good correlation between the SNR required for a given EVM vs. those related to specific bit error rate curves. The figure also shows that, for a practical receiver implementation at high condition numbers, MIMO techniques fail to provide a useable benefit



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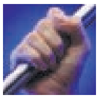

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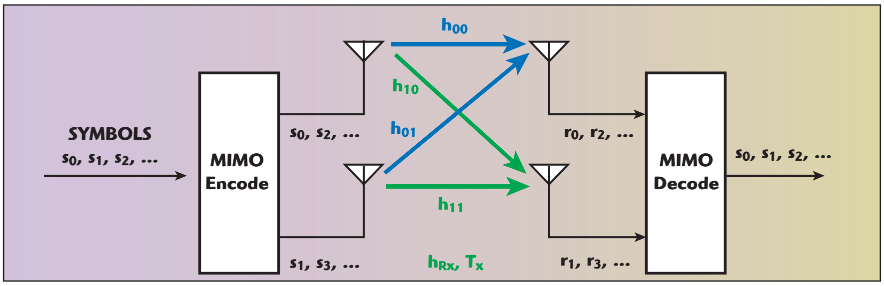


Fig. 4 2 × 2 MIMO channel.

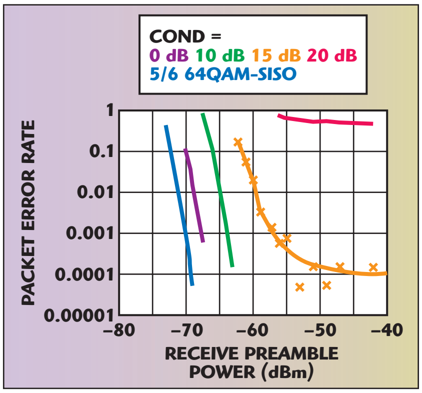
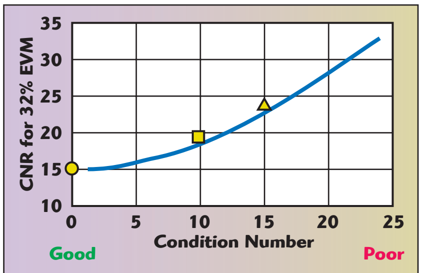


Fig. 5 MIMO performance in static channels with varying condition numbers.



Condition Number	Delta CINR
0 dB	0 dB ○
10 dB	4.5 dB □
15 dB	9 dB △
25 dB	Irreducible

Modulation & Coding: 5/6 Rate 64QAM, Per 10%

Fig. 6 Increased SNR requirements vs. condition number.

as the system suffers from irreducible error rates (see curve for condition number = 25 dB).

RECEIVER PERFORMANCE IN AN ITU-PEDB CHANNEL

Testing with static channels is instructive as it allows comparison between measured results and the theory of MIMO operation. However, in order to assess the expected performance of a given system, it is necessary to emulate time varying "real world" channels. In this article, an ITU pedestrian profile B (mobile speed of 3 km/h) was used as one example of a real world channel.

Figure 7 shows the SISO receiver performance for both ½ rate QPSK and $^5/_6$ rate 64QAM under both AWGN and pedestrian B channel conditions. For the $^1/_2$ rate QPSK, the sensitivity is degraded by approximately 8 dB, using the pedestrian B channel at the 1 percent PER level. For $^5/_6$ rate 64QAM, the receiver suffers from an irreducible error rate when measured under pedestrian B channel conditions. To verify this result the measurement was repeated on a different DUT and similar results were found.

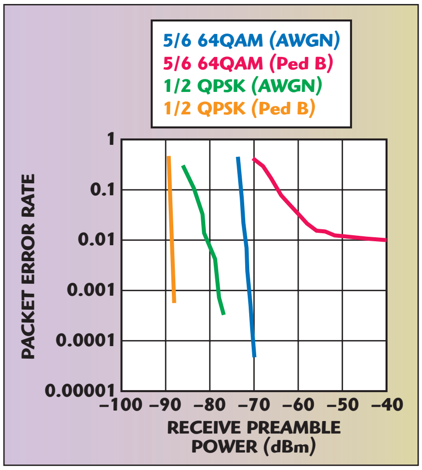


Fig. 7 QPSK vs. 64QAM under noise and pedestrian B conditions.

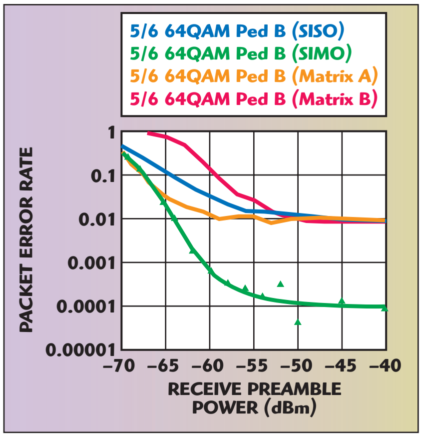


Fig. 8 WiMAX MIMO receiver performance.

Figure 8 shows the $^5/_6$ rate 64QAM performance with a variety of SISO/MIMO configurations. The green line for SIMO shows the benefit of Rx diversity with the irreducible PER reduced to only 0.1 percent. This is expected theoretically if the errors on each of the channels can be considered to be mutually exclusive random variables (that is 0.01 × 0.01 = 0.0001). Interestingly, if Matrix A MIMO is employed (that is transmit diversity), the irreducible error rate is 1 percent and not 0.01 percent achieved with Rx diversity. This could be explained by quantization issues during deep fades as, for Tx diversity, each Rx has to extract the two Tx signals from one sampled waveform, which is not required in simple Rx diversity. Matrix A MIMO does, however, demonstrate a diversity gain versus the blue SISO curve. Given that WiMAX networks seek to optimize approximately a 10 percent PER, the Matrix A performance gain will be valuable to the system. Finally, Matrix B MIMO demonstrates that even under these Ped B channel conditions, it is possible to double the data throughput. There is, however, a penalty in terms of the required signal to noise.

CONCLUSION

This article has shown how a base station emulator can be used in conjunction with a channel emulator to characterize the performance of a MIMO capable receiver. Measured results were compared with theory for both AWGN and static MIMO channel conditions. Finally, this article presents MIMO receiver performance results using the ITU pedestrian B profile. This work shows how the ITU pedestrian B profile does stress the receiver (witnessed by the presence of an irreducible error rate), but that it is still possible to exploit the benefits of both receive diversity and MIMO in this radio environment. ■

ACKNOWLEDGMENT

The authors would like to acknowledge their colleague Hong Wei Kong for his insightful analysis of this work.

References

1. 802.16e-2005 IEEE Standard for Local and Metropolitan Area Networks: Part 16 Air Interface for Fixed and Mobile Broadband Wireless Access Systems; Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1.
2. WiMAX Forum™ Mobile Radio Conformance Tests mRCT Release 1.0 Approved Specification Revision 2.0.0.
3. P. Cain, "What You Should Know About MIMO Operation and Measurement," http:www.mwjournal.com/BGDownload/MWJ1012AgilentInsertOct.pdf.
4. M. Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications," *IEEE Journal of Selected Areas of Communication*, Vol. 16, No. 8, October 1998, pp. 1451-1458.

Deployment and Link Planning of Adaptive Coding and Modulation Radio Networks

This article covers how Adaptive Coding and Modulation (ACM) systems operate and can be deployed, illustrates their significant advantages, and recommends a new planning methodology. It shows that significant increases in data throughput can be obtained without compromising Quality of Service (QoS) requirements—even if the maximum modulation scheme was planned in the first place. In ACM systems it is essential to understand the difference between link availability (i.e., uptime) and link performance (i.e., signal quality while the system is operational) as detailed in the International Telecommunications Union (ITU) standards. High frequency links (>13 GHz) are affected by rain attenuation and should be designed to meet the link availability objectives in a different manner from that of low frequency links, where multipath fading predominates, affecting performance but not availability.

Operators are faced with the challenge of providing enough transmission capacity for the almost exponential demand in bandwidth from new data services, while constrained by a relatively modest increase in revenue from those services (see ***Figure 1***). This additional bandwidth demand is not an issue for fiber optic transmission systems, which have virtually limitless capacity. However, radio systems are constrained in capacity by available radio frequency (RF) bandwidth and can suffer quality degradations during atmospheric irregularities.

Conversely, fiber is not readily available in the access portion of the network and is too time consuming and costly to provide in a ubiquitous manner. Therefore, microwave radio will continue to be the technology of choice for next-generation access networks, compelling a solution to the problem of constrained bandwidth.

User data throughput can be increased in a fixed RF bandwidth through the use of more complex modulation schemes, improving the bits/Hz efficiency. However, historically, this came at the cost of all the traffic being more susceptible to noise and interference. Thus, there was a trade-off between quality and capacity. This was a one-off decision that had to be made at the design phase, where the choice was either to deploy radios with a low modulation scheme, which could achieve higher availability and performance for a given size of antenna, or have much higher capacity in the same RF bandwidth, but with a lower level of

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Trevor Manning
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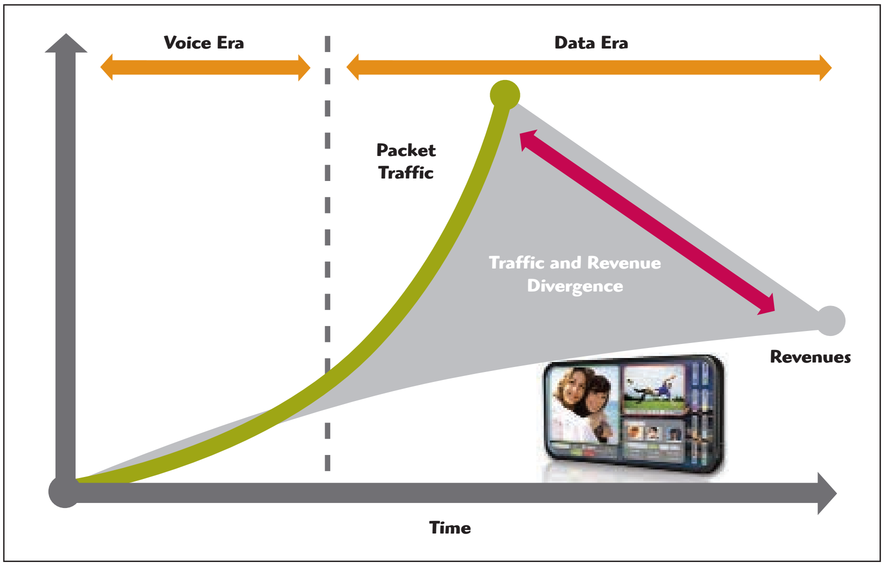
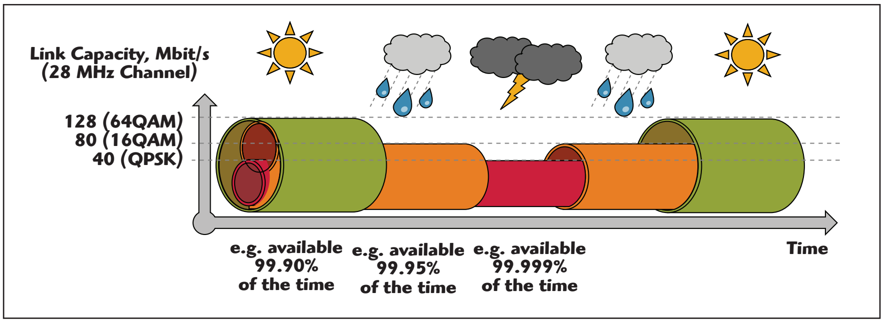


▲ *Fig. 1 The end of the 'Voice Era' and the increase in demand for data traffic is creating a widening Revenue Gap .*



▲ *Fig. 2 Adaptive Coding and Modulation (ACM) takes advantage of good propagation conditions to boost link capacity.*

quality for all traffic. Alternatively, to achieve the same Quality of Service (QoS) metrics, extra expense had to be incurred by deploying larger antennas on the radio hops.

ACM UNLOCKS ADDITIONAL CAPACITY

Microwave radio systems have now evolved that can provide significantly more capacity in a fixed RF bandwidth—at the equivalent level of service to fiber. The key technology enabler for this is Adaptive Coding and Modulation (ACM).

ACM radio systems are able to monitor path conditions and switch to lower modulation schemes, creating more available fade margin, when necessary, to extend the primary traffic and critical radio control services by enhancing the availability and performance of the link. ACM systems can thus offer significantly more throughput most of the time, the only trade-off being that additional traffic being carried cannot achieve the same availability and performance as the core traffic.

Transmission networks now have a mix of traditional TDM and Ethernet traffic. Ethernet is becoming more popular in transmission networks, largely due to the efficiencies and scalability for carrying data traffic, which includes voice in the case of VoIP. Using various prioritization methods, Ethernet traffic is easily differentiated to achieve different QoS levels and thus ACM becomes a very attractive solution for reducing the overall transmission bottleneck.

WHAT IS ACM?

ACM is a new technology available in radio equipment that allows the coding and modulation schemes to be changed according to path conditions. ACM equipment is designed to ensure these changes do not exceed either transmitter or receiver spectrum regulatory masks. Changes in modulation and thus throughput of data and link uptime can be improved under adverse path conditions. Traffic shaping is done at the radio input to match the offered traffic with available channel capacity. This ensures that prioritized traffic is transmitted at its peak level in order to meet availability and performance requirements. As shown in ***Figure 2***, additional traffic can be carried over the link during non-fading periods, significantly increasing the overall average throughput of the link.

ACM increases the average throughput of data, but at the cost of blocking access to some traffic to the radio path for small periods of time. It is particularly useful when:

- Maximum throughput is more important than reliability;
- Different levels of priority traffic can be identified;
- Licensing conditions insist on high spectrum efficiency modulation schemes, yet extra performance is desired for some critical traffic;
- Licensing conditions allow a simple modulation scheme to operate on the link, but maximum return on the investment in the spectrum allocated is desired;
- Existing links are required to be upgraded to a higher capacity using the same path and antenna sizes.

The term "adaptive" is somewhat misleading, as it creates the impression the links are constantly changing as weather conditions change. Digital radio links operate on a threshold basis, where they are not affected by changing weather conditions until a critical receiver threshold value is exceeded. Any fading activity is thus not seen by users until it breaches this critical threshold. Lower modulation schemes allow this threshold to be breached for less time, thus increasing availability and performance.

However, this margin is not needed most of the time, and the links can operate at this higher throughput with no degradation in quality. The radio monitors the hop conditions, and it only changes the modulation scheme when it is possible that these critical thresholds could be breached. In practice, this happens very seldom, despite the fact that modulation switching is done on a predictive basis, pre-emptively deciding to switch prior to any potential failure event.

Adaptive modulation should not be considered as a dynamic optimization technique.

DEFINING QUALITY OF SERVICE

With the emergence of high speed mobile data, the IP and telecom worlds are converging. The IP world is very familiar with using statistical gains in multiplexing data into asynchronous packets to achieve maximum data throughput. More recently, work has been done to define a specific QoS for "carrier grade" service, which typically refers to technologies that can achieve network availability of 99.999 percent with re-convergence times of 50 ms or less. In the telecom world the focus has traditionally been on providing a dedicated channel, and associated fixed bandwidth and throughput, with clear methodologies to calculate any expected outages or quality impairments on the radio hop.

In a radio-based ACM network, instantaneous throughput can change as link conditions demand. Traffic can be shaped at the radio channel input such that different streams can experience different levels of service. What is important to note is that the background error rate of the traffic itself is unaffected.

QoS allows quality metrics to be defined as part of a customer's Service Level Agreement (SLA). A top-down design methodology is needed, where the network has to be designed to a specific QoS, which in turn dictates QoS objectives for radio links and individual radio hops.

QUALITY IN A RADIO NETWORK

In radio networks, weather irregularities cause additional impairment to background noise in the equipment. Rain outages affect the availability of the link, whereas multipath fading affects the quality of the link, during the period when the link is available.

The ITU standards clearly differentiate between availability standards (defined in ITU-T G.827 and ITU-R F.1703) and performance standards (defined in ITU-T G.821, 826 and 828 and ITU-R F.1668). This is complex to apply to real radio networks, so for short radio links it has been a common industry practice to combine availability and performance in a per hop reliability target of between 99.99 percent to 99.999 percent.

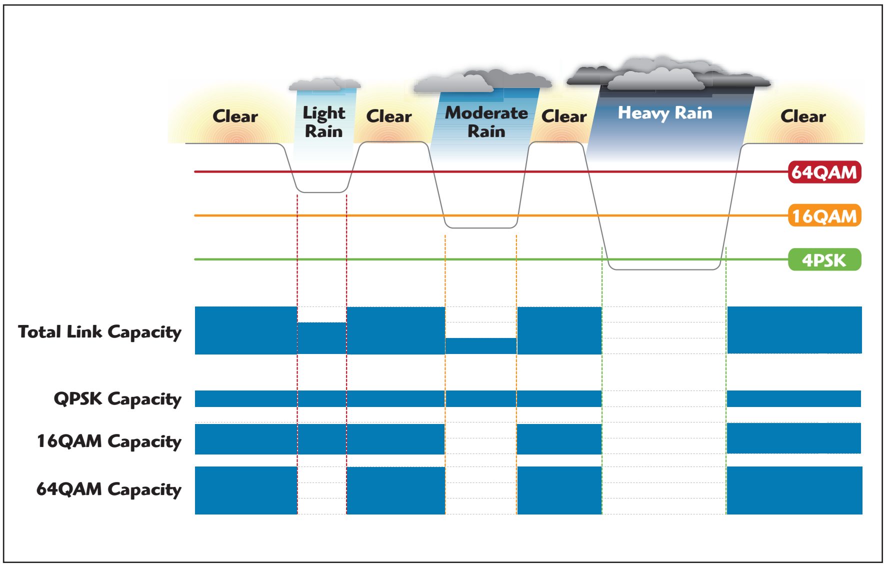


Fig. 3 In ACM systems, each modulation will support a different level of uptime.

While this has been a useful design simplification for access links, it gets the "right answer" using the "wrong method." With ACM systems, which can have variable throughput and have different traffic streams experiencing differentiated availability and quality levels, it becomes essential to separate these two aspects again. Otherwise operators will become very confused as to the true performance of the link, and system planners could make incorrect hop design decisions. Availability is the amount of "uptime" of the radio link, and during this period, performance is measured, which affects throughput and transmission quality.

AVAILABILITY (RAIN OUTAGE)

For links greater than 13 GHz, rain is the primary reason for any outage. When the hop fade margin is exceeded by rain of a particular intensity, an outage will occur for the duration of that rain fading event. This could be many minutes and thus affects availability. It can be treated equivalent to a fiber cut, so the fade margin should be chosen to ensure it is a rare event. These outages can be easily quantified if the rain intensity statistics are known or can be estimated.

In ACM links, where each modulation scheme has a different fade margin, the available time for each traffic stream has to be considered separately, as shown in ***Figure 3***. Each differentiated traffic stream will thus have a different level of "uptime," which is a function of the system gain figure for each modulation scheme.

PERFORMANCE (MULTIPATH OUTAGE WITH THROUGHPUT IMPACT)

For links less than 10 GHz, multipath fading—where multiple radio signals with differential delays arrive at the antenna simultaneously—is the primary reason for any "outage." The atmospheric conditions that cause multipath outages are typically limited to a fading season of some months and occur at specific times of the day (usually several hours at sunrise and sunset).

While unusual for multipath outages to exceed 10 seconds, which, strictly speaking, is not an unavailability outage (i.e., "downtime"), error bursts that often result would mean short blocks of time where quality is so impaired that the service quality is not "acceptable." This can result in a short break in transmission (i.e., severely errored seconds, loss of frame), which is considered a performance outage. Until the fading depth equals the fade margin, no errors will occur.

Multipath fading that does not cause errors to priority traffic on lower modulation schemes would cause errors to traffic on higher modulation schemes due to the lower fade margin. When the performance levels of the lower- or non-priority traffic is calculated, if the number of fading events is considered too high, the fade margin can be increased with bigger antennas

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or, better still, space diversity should be used to reduce the outages. Route diversity should not be used to improve performance because multipath fading is a fast event and requires hitless protection switching as provided per space or frequency diversity. The improvement with ACM against multipath fading can be seen in ***Figure 4***.

INTERFERENCE

Interference is any unwanted signal that has sufficient signal energy within the pass-band of the wanted receiver to affect the demodulated signal quality. For the demodulator to correctly demodulate a wanted signal error-free, the unwanted signal has to be below a minimum signal to noise (SNR) level. The higher the SNR value is, the more complex the modulation scheme. Since the radio hop is required to carry operational traffic all the way down to the threshold of the receiver, interference signals must be considered under faded and unfaded conditions.

In ACM systems, when the modulation scheme changes from a lower order to a higher order, the receiver threshold degrades and the minimum SNR figure required by the demodulator increases. In Europe, where ETSI standards apply, the transmitter power also needs to be backed off to achieve the required linearity using the higher modulation scheme.

Measured from the 256QAM threshold point, the maximum interference level is roughly the same, regardless of modulation scheme. This is because at a lower modulation scheme, although the minimum SNR is relaxed, the reference point is its receiver threshold point, which is much lower than at a higher modulation scheme.

This is significant, as it means that once a frequency is allocated, the maximum interference level allowed will be below the minimum SNR for any modulation scheme. For example, an interfering signal below an unfaded receiver would not cause problems for a 4PSK link, but it would seriously degrade the threshold of a 256QAM radio. However, an interfering signal that high would not be allowed in the first place because it would exceed the SNR requirements of a faded 4PSK hop.

It could be argued that the 4PSK radio would still be more resilient to

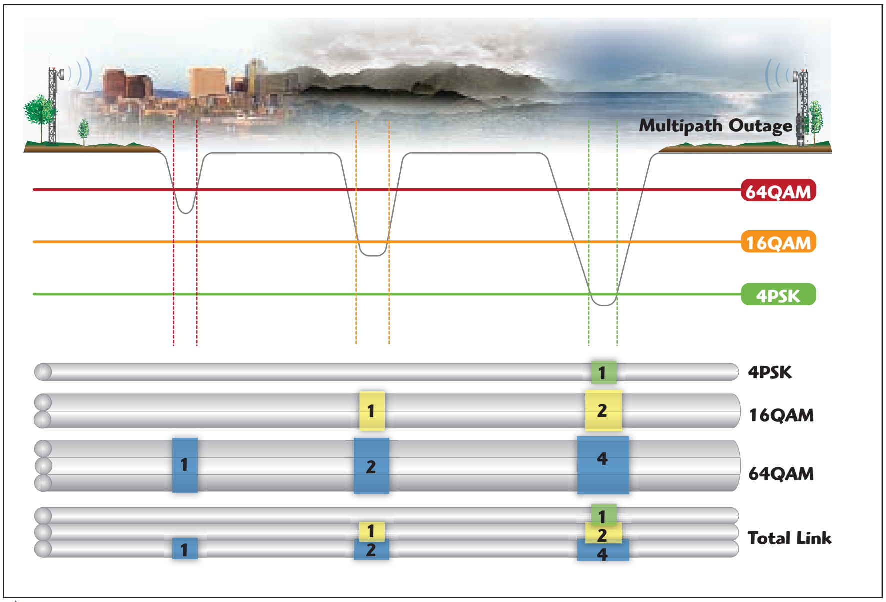

Fig. 4 ACM performance in the presence of multipath or selective fading.

"rogue" interferers, generated outside of the frequency planning process. However, that negates the benefits of having a licensed frequency. Higher level interferers that exist on a temporary basis under adverse conditions are also addressed by frequency planning and the fact that lower modulation schemes are more robust under this condition—part of the benefit of using ACM in the first place.

While it may appear that a new link could be allowed by the regulator for a radio with a lower modulation scheme, this could breach the SNR requirements of the existing high modulation scheme radio, inhibiting its return to the higher modulation scheme after a fade has occurred. In practice this could not happen.

TRAFFIC PRIORITIZATION

Key to achieving maximum benefit with ACM is the ability to prioritize customer traffic. In traditional TDM networks, traffic multiplexed into a PDH-aggregated stream could not be identified with different priority levels because the information would have been bit-interleaved into the aggregate stream. In SDH, each virtual container (VC) could be directed through the network and its performance characteristics measured through the header bytes allocated to the VC. In ATM networks, QoS was an embedded design goal in the standard.

Prioritization of different IP traffic types with differentiated QoS for different types of services was taken into account from the start to allow the router to select a route based on minimum delay, maximum throughput, maximum reliability or lowest cost.

Routing of traffic types can be prioritized by inspecting the packet headers in the switches or routers. It is also possible to define each port of a device with a different priority level. In radio equipment, TDM traffic can be queued according to priority so that both TDM and Ethernet traffic can be differentiated.

ACM HOP AND LINK DESIGN

ACM requires a change in thinking to traditional radio hop design. Current practices often ignore practical considerations, are not cost optimized and focus on high levels of availability per hop with no consideration of optimizing the throughput in the RF channel. All traffic is treated as being equal despite the fact that the types of traffic have different real QoS requirements and revenue profiles.

In the past, link capacity was fixed and thus the only variables were the fading conditions. To design a radio hop, the availability and performance of the traffic must be calculated. This defines the hardware set-up (i.e., antennas, equipment type, configuration) and software settings (e.g., maximum transmitter power). In the case of ACM, not all traffic experiences the same QoS metrics because some

traffic is restricted during anticipated heavy fading to enable changing the modulation scheme and reducing the outage time for the remaining traffic. Radio link design must therefore take into account the improvements made using ACM.

TRADITIONAL METHODOLOGY

Historically, the approach with radio link design has been to set a 'hop' objective and then increase antenna size until the fade margin meets the hop objective. On long hops this often meant that the largest antennas in the manufacturer's line were used, which puts huge stresses on towers. ACM can be used to provide extra system gain instead of increasing antenna size, with no infrastructure implications.

ACM DESIGN METHODOLOGY

Radio hop design should be designed in a pragmatic way taking into account where the hop is in the network, what type of traffic is carried, the overall network topology and practical considerations of radio and antenna spares, antenna space on the tower and maintenance constraints.

The customer experiences the effects of the holistic design considerations and not just the per-hop fade margin. The ACM design can be accomplished assuming that the traffic outages can be calculated for each prioritized queue, linked to the various modulation schemes deployed, or "virtual pipes." In the case of a non-prioritized aggregate input, the average outage figure can be computed.

ACM LINK DESIGN

In order to design an ACM link, it is important to consider in which of two modes ACM is being used:

Equal priority traffic mode: In this mode the link is designed using the highest modulation scheme and an improvement factor can be calculated for running the link with ACM. This improvement may not result in smaller antennas, but does improve customer experience. The average availability and throughput are improved.

Prioritized traffic mode: In this mode, the link is designed to meet the QoS metrics of the core traffic using the lowest modulation scheme. The performance and availability of the other "virtual pipes" for additional non-priority traffic can be calculated separately. In other words, QoS can be calculated for each priority queue, treating the radio as having n virtual links where n is the number of modulation schemes deployed. Thus, smaller antennas can be used rather than if the whole path had been designed for the maximum modulation scheme.

In either case, the basic QoS figures for the "core" or "all traffic" are tabulated using the conventional outage calculations for availability and performance. The end-to-end outage is calculated using the traditional approach of cascaded hops making up a radio link.

KEY RECOMMENDATIONS FOR DEPLOYING ACM LINKS

A more holistic approach to radio design is needed, where the nature of the traffic in terms of importance (e.g., revenue, cost of failure) and type (e.g., delay sensitive, bandwidth sensitive) should drive design. A top-down design methodology should be assumed, where the radio hop design is a subset of network topology decisions.

In summary, the following are some particular guidelines that should be followed:

- Design to network and link objectives that include system architecture and traffic management considerations, with less emphasis on radio hop design to fixed design limits.
- Ensure the link meets the overall QoS objective, taking network topology into account, and do not iterate antenna sizes until a per hop threshold value is reached.
- Focus less on flat fade margin and large antennas to achieve availability and performance goals.
- Treat availability and performance separately.
- Compare rain outage with annual availability (uptime) objectives for each virtual ACM pipe. The overall average uptime can be calculated for the system.
- Radio link design should be done treating each capacity stream linked to a modulation scheme as a virtual pipe. The radio system gain parameters should be used for the ACM radio that has the built-in ACM coding gains.
- If core traffic can be differentiated, the link should be designed to meet the lowest modulation scheme outage.
- If all traffic is treated equally, the link should be designed for the highest modulation scheme deployed. The improvement in average uptime can be specified.

CONCLUSION

ACM is a technology available to operators at relatively little additional CAPEX that can significantly optimize the transmission available bandwidth and therefore user throughput of data. The usual tradeoff in quality vs. RF bandwidth efficiency is removed by segmenting and prioritizing the input traffic, so that the highest level of availability and performance can be achieved for priority traffic, while achieving the throughput expected using spectrally efficient systems.

ACM provides benefits, but is particularly useful where input traffic can be prioritized with different QoSs. Even where no traffic prioritization is performed, the average availability and performance improves compared to non-ACM, high-modulation systems.

The coding gains through ACM are an excellent alternative to increased gain provided by large antennas, which can enable significant savings in installation and tower costs. In order to design ACM links, QoS must be considered where availability is the uptime period, which is maximized through redundant equipment and network topology, and performance is considered during uptime periods and is optimized to achieve the maximum throughput of data.

Operators are struggling with the threat of insufficient backhaul capacity for new bandwidth hungry data services. Modern ACM-equipped microwave radio systems are now available that provide an ideal solution. Adaptive modulation will be a key technology feature sought by mobile operators who are planning to evolve their transmission networks to all-IP to support next-generation broadband services, enabling them to smoothly and cost effectively introduce high speed Carrier Ethernet transport, with minimal CAPEX demands. ■

The Missing Link in Ethernet Cellular Backhaul: IEEE 1588-2008, Precision Time Protocol

From its beginning, one of the challenges of mobile cellular communications systems has been delivering a very stable and accurate (as little as 16 parts per billion, ppb) long-term frequency reference at each base transceiver station (BTS) to maintain accurate radio transmit and receive frequencies needed for reliable inter-cell call handoff and interference control. An even bigger challenge comes with some existing and emerging cellular architectures that require a precision (as stable as ± 1 µs) time reference to support time division duplex (TDD) operational modes. By 'time,' a common (relative) sense of time across the network is meant, but not necessarily absolute time of day (such as 9:35 AM PST, 12 Dec 09). Be aware that some writers' use of 'time' refers to relative time, while others mean absolute time of day.

Historically, syntonization means two or more oscillators having the same frequency while synchronization means two or more clocks indicating the same time. Syntonization is often confusingly referred to as synchronization. The syntonization reference was provided by the T1 (1.544 Mbps) or E1 (2.048 Mbps) backhaul lines that connect the Time Division Multiplexed (TDM) data to the wired network. The time reference required installing a Global Positioning System (GPS) downlink to each base station (see ***Figure 1***).

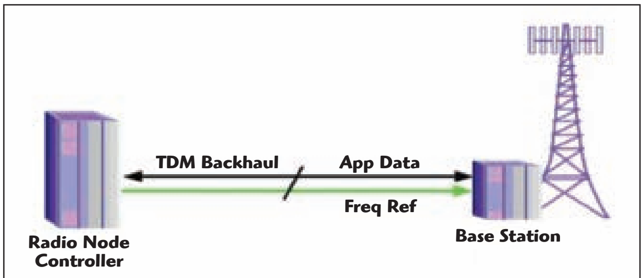

Fig. 1 Cellular network syntonization via TDM backhaul.

Exploding demand for data capacity for new cellular services like mobile Web browsing, music and video downloads, in combination with intense cost pressure to support mass service demand, have led cellular network equipment manufacturers and cellular service providers to look for alternate approaches to backhaul traffic. A promising approach is to use carrier-class Ethernet equipment to provide additional data capacity at approximately one-sixth the cost per bit, while preserving service quality. Unfortunately, using Ethernet to eliminate the expensive T1 or E1 connections breaks the frequency reference provided by the TDM link, forcing operators again to install a GPS downlink at each station (see ***Figure 2***). Thus, the Ethernet cellular backhaul solution has a missing link in providing cellular backhaul references.

ENTER IEEE 1588, PRECISION TIME PROTOCOL

In 2002, the IEEE 1588-2002 Precision Time Protocol (PTP) standard was created to provide precision timing across Local Area Networks (LAN) for test and measurement

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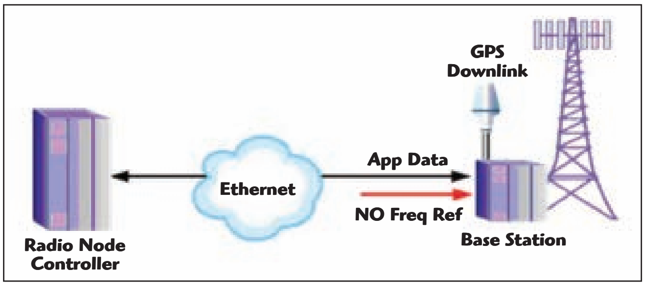
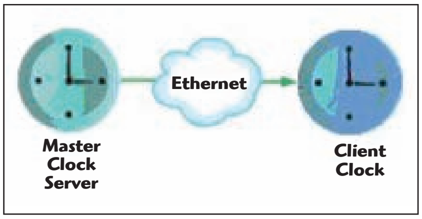
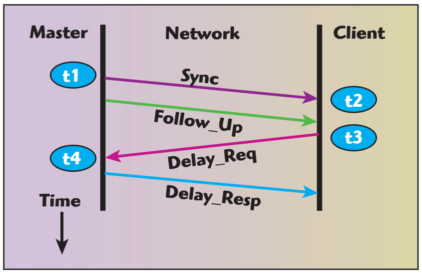


▲ *Fig. 2 Ethernet backhaul with GPS reference.*



▲ *Fig. 3 PTP master clock server and client Ethernet work.*



▲ *Fig. 4 Timestamp packet exchange.*

and industrial control applications. Segments of these industries need to provide widely distributed sensors and actuators a common sense of time for coordinated measurement and control. For example, what is the distribution of stress in aircraft wings under dynamic vibration conditions? (Are the wings going to fall off?) And, how do we ensure that newsprint paper fed into a 100 meter long printing press at 30 meters per second also comes out at 30 meters per second? (Will it rip or end up in a pile on the floor?)

PTP is a time transfer protocol that allows precision time at one (Master Clock) location to be accurately transferred to another (Client Clock, also called a Slave Clock in the literature) location through an asynchronous packet network using an exchange of carefully produced timestamps of packet arrival and departure times as measured by the local clock (see ***Figures 3*** and ***4***), some assumptions and some arithmetic.

If the network is constrained to use identical forward and reverse network paths, it is a good assumption that the forward and reverse packet propagation delays are equal. The offset of the two clocks is then simply:

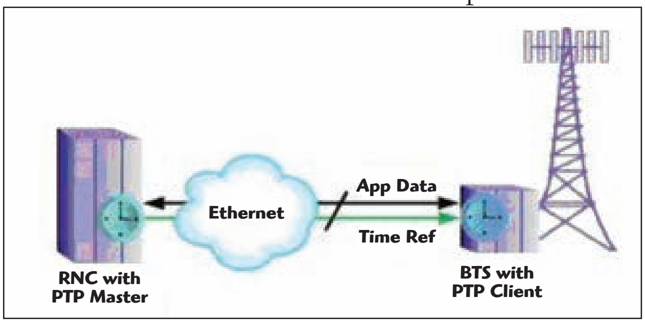
DeltaTime = (t2-t1) - PathDelay

where PathDelay = ½[(t2-t1)+(t4-t3)]

After the Delay_Resp message, the client can calculate DeltaTime, reset itself to the master clock's time and thus transfer the time from master to client. As the two clocks naturally drift relative to each other and propagation delay changes, new timestamps are exchanged and the process repeats, keeping the two clocks the same, or synchronized.

THE TELECOM INDUSTRY SEES AN OPPORTUNITY

The original PTP standard conceptually solved the Ethernet base station reference problem, shown in ***Figure 5***, except for the not insignificant need for greatly improved frequency and time stability (to have accurate time, one must have accurate frequency), the ability to apply it beyond the LAN environment to reach cellular base stations and carrier-class reliability. With the otherwise stellar potential of carrier-class Ethernet for cellular backhaul, the telecom industry teamed with their test and measurement and industrial control partners to take on PTP for telecom timing, including base station backhaul. The result of this effort is a much-improved standard for telecom applications: IEEE 1588-2008, Precision Time Protocol, commonly called PTPv2. PTPv2 defines a significant number of improvements that support the stringent needs of base station frequency and time references.



▲ *Fig. 5 Conceptual PTP solution for Ethernet cellular backhaul timing.*

Higher Message Rates

To ensure stability requirements can be met with inexpensive client clock oscillators, the client clock time must be updated more frequently. The revised PTP standard allows timestamp exchange (sync, follow_up, delay_request and delay_response message) rates over 128 per second, from the original maximum value of once per second. Though not explicitly required by the standard, more frequent timestamp updates do little good without accurate timestamps to exchange. Hardware timestamping, on both the master and client sides, delivers the sub-microsecond accuracy needed for base station references, as compared to software timestamping, which has jitter associated with typical software processes.

Shorter Message Formats

To keep the network bandwidth consumed by timestamp exchanges to a minimum, the original 165 octet (eight bit) message format was shortened to 44 octet sync messages by placing information about clock source and quality into a separate Announce message that need not be sent as frequently.

Unicast

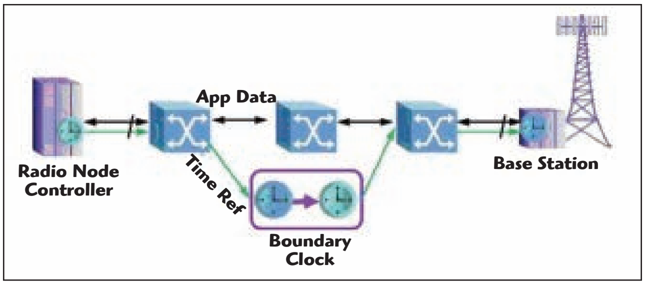
The original PTP standard only supported multicast message exchanges between clock masters and clients. PTPv2 adds support for the unicast messaging needed in a telecom environment. Unicast messaging allows each client clock to only listen to messages from its master. This reduces the processing power and cost of the many client clocks typically found in a network, compared to what would be required using multicast. Also, unicast messaging allows clients of different capabilities and in different locations in the network to have different sync messaging rates. Multicast messaging requires the master to send messages to all clients at the highest rate required by any client in the network, potentially wasting network bandwidth.

Beyond LANs

Two significant innovations enable PTP to apply beyond the original LAN limitation: ITU-T Recommendation G.8261/Y.1361 and Boundary/Transparent Clocks. LANs typically consist of physical layer (OSI model Layer 1) network elements (hubs, repeaters and extenders), which have very stable propagation delays, keeping packet jitter or Packet Delay Variation (PDV; the variation in propagation delay that packets experience as they traverse the network) low, even through multiple devices (hops). On the other hand, Wide Area Networks (WAN) contain network elements (switches and routers) that operate at the link and network layers (OSI Layers 2 and 3) and make more complex packet path decisions and therefore often induce more PDV due to data control techniques and computational processing time variation.

The International Telecommunications Union (ITU) has studied the timing performance needed from packet networks to support stringent telecom industry requirements at the TDM interfaces. ITU-T Recommendation G.8261/Y.1361 identifies methods to evaluate packet network behaviors that impact time transfer performance, including Packet Delay Variation. This recommendation, in conjunction with other ITU recommendations, provides a mechanism to determine the ability of PTP masters, clients and networks to support specific telecom applications. Forthcoming ITU recommendations are expected to establish specific PTP network performance limits for selected telecom applications.

The other innovation is that of synchronization-friendly packet network elements. If messages need to traverse multiple switches and routers from the master clock to the client clock at the base station, Boundary Clocks or Transparent Clocks can be used to mitigate the total PDV through a cascade of network elements. The job of the Boundary Clock is to transfer precise time from one network domain (on the master side) to another network domain (on the client side). The Boundary Clock acts like both a client clock to an 'upstream' master clock and like a master clock to a 'downstream' client clock. Precise time of day is passed within the Boundary Clock from internal client to internal master through a high quality local oscillator, as shown in ***Figure 6***. Thus, a Boundary Clock can be connected across a switch or router to eliminate its PDV contribution. The Transparent Clock similarly reduces the PDV contribution in multi-hop paths, but through the use of a trick. With accurate knowledge of its own contribution to the path delay, a Transparent Clock updates the timestamp values as they pass through the device, thereby compensating for its path delay.



▲ *Fig. 6 Using a boundary clock to improve PDV over multi-hop networks.*

Another method to improve PDV over a multi-hop path is by adding a Grand Master Clock closer to the client clocks, effectively shortening the number of hops between master and client. A Grand Master Clock (GMC) is a master clock that can provide a precise time reference independent of other master clocks.

Service Reliability

Carrier class service means very few minutes of outage per year. The enormity and complexity of typical telecom packet networks makes it likely some paths will have occasional failures. TCP/IP networking takes care of re-routing data around failed paths, but re-routing paths can create a massive path delay transient (and therefore frequency and time transient) until timestamp messages are exchanged and new PathDelay calculations are made for the new path. The PTP standard specifies that client clocks use the 'Best Master Clock' algorithm to scan the network for the best possible backup master clock in case of path failure and to minimize a re-routing transient.

THE CLOCK OF GIBRALTAR

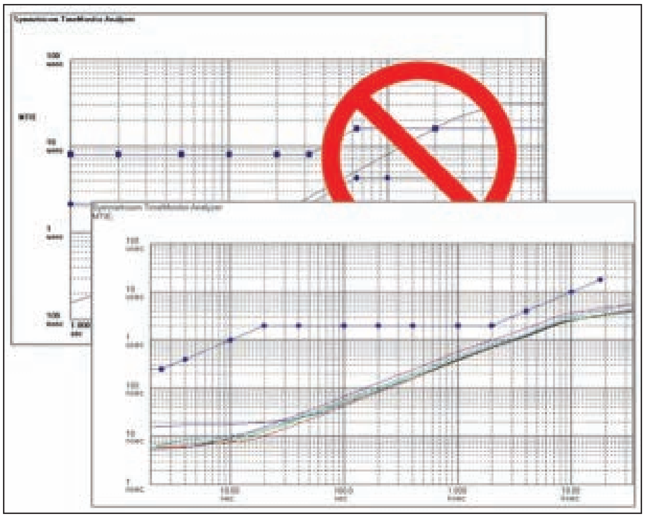
A carrier-class frequency and time reference solution is only as good as its component parts. The origin of the frequency and time references in PTP is the GMC. This is where PTP time originates and propagates through the network to the PTP client clocks, so the quality and reliability of the GMC is key.

Carrier-class GMCs start with a good quality oscillator, either an Oven-Controlled Crystal Oscillator (OCXO) or better-yet, a Rubidium atomic oscillator (RbO), to maintain the required time accuracy even if the time or frequency reference used by the GMC (such as GPS or T1 or E1) should fail for an extended period of time, a function called 'holdover.' A good OCXO-based GMC should be able to maintain sufficient accuracy in holdover for eight hours or more. A good RbO-based GMC should have ten times the holdover performance.

The GMC must have hardware timestamping, which, as was already mentioned, is required to precisely transfer clock time accuracy to the timestamps. Since the GMC is serving timestamps to a great many PTP slaves, the serving capacity of the GMC is also important. For example, a network with 125 client clocks within the network topology, and the client oscillator quality require an average of 16 sync and delay messages each, plus two announce messages per second to maintain the required frequency and time reference stability. The resulting GMC serving capacity needed is:

125 clients × [(16 × 2) + 2] messages/second/client = 4250 messages/second server capacity.

To deliver carrier-class reliability, one must eliminate single points of potential failure. A quality GMC will have redundant power supplies and redundant clocks with built-in hardware and network protection, which keeps the GMC operating even if one power supply or clock oscillator should fail. Wide deployment of PTP technology requires that GMCs have the ability to be remotely monitored, managed, and upgraded with new firmware to deliver new capabilities as they are developed. Because of its central role in the cellular backhaul system, it is essential that GMC sup-



▲ *Fig. 7 PTP client clock performance examples.*

pliers stand behind their products with both hardware and software warranties, as well as providing a 24 × 7 support wherever they are deployed throughout the world.

Carrier-class GMCs are available in both a 'blade' type form-factor for installation in Sync Supply Units (SSU) in Mobile Switching Centers (MSC), and in a small, 1 rack unit (RU) integrated form-factor, well-suited for MSCs without SSUs and Base Station Controller/Radio Node Controller (BSC/RNC) locations.

THE CLIENT MAKES ALL THE DIFFERENCE

While the Grand Master Clock is central to the synchronization solution and therefore must be extremely accurate, stable and reliable, the PTP Client has the toughest job. It lives on the other side of the network 'cloud' from the GMC and must contend with whatever is happening in the cloud (such as traffic levels, failures, re-routes) and locally to the client (such as temperature changes, power supply failures) to do its job.

The fundamental choice for PTP clients is around oscillator quality, cost and form-factor. The better the client local oscillator, the better it can handle whatever is thrown its way. However, better oscillators cost more money and reducing cost is the ultimate goal with the cellular backhaul packet upgrade. To get great results with low cost oscillators, the best PTP clients support message rates up to 128 per second and use hardware timestamping to minimize induced jitter. Just as important to getting frequent low-jitter timestamps is the design of the oscillator servo, the circuit inside the PTP client that directs the oscillator to speed up or slow down after a new message is received. This can have profound effects on how well the client behaves in a challenging network environment. ***Figure 7*** shows some sample clients' servo performance compared to application performance requirements masks. With good design around these factors, the best PTP clients can support cellular backhaul frequency and time reference requirements with low-cost OCXOs.

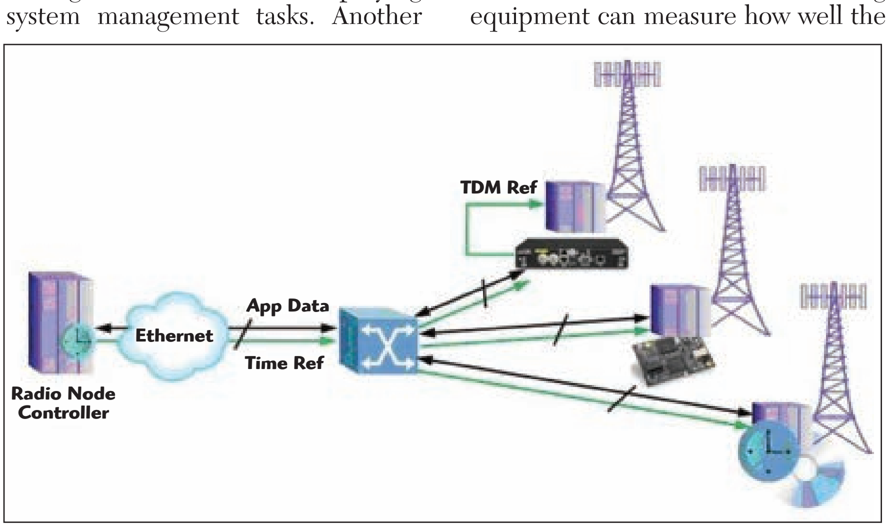
Earlier, the 'Best Master Clock' algorithm to reduce timing transients during path re-routes and unicast support to allow message rates to be tuned for best performance was discussed. The best PTP clients support these. Also, many network operators like to manually assign PTP clients to primary GMCs, as well as backup GMCs to ensure they know exactly which clients will be affected during various network outage scenarios. The best PTP clients will allow this GMC assignment approach, as well as enabling remote management through centralized GMCs and PTP Network Management Software, simplifying system management tasks. Another valuable capability is the ability of clients to report back their performance status to their GMC, enabling operators to conveniently monitor timing quality of service.

PTP clients are available as small half-rack 'translators' with traditional TDM outputs to enable packet timing to support existing TDM equipment. Also, leading network equipment manufacturers (NEM) are integrating PTP clients into their products. Some have chosen to use commercially available small integrated module solutions that speed and simplify integration of PTP clients into their solutions, while others are developing PTP client technology themselves or getting a hand with performance optimization by using commercially available 'soft clients' consisting of microprocessor and FPGA source code and licenses, as shown in ***Figure 8***.

GO FOR A TEST DRIVE

Some great news about PTP solutions is that you can now test them out to ensure they will work. Most vendors can share test data to demonstrate how their GMCs and/or PTP clients work under various network conditions—with different network elements from the various NEMs, through multiple hops across networks, with varying traffic dynamics—to better understand the performance of the end-to-end packet timing solution.

Also, legacy and newly available test equipment allows one to test the performance. With a GMC, packet network and PTP client TDM translator to test, traditional TDM timing equipment can measure how well the



▲ *Fig. 8 Stand-alone PTP translator, embedded module and embedded code solutions.*

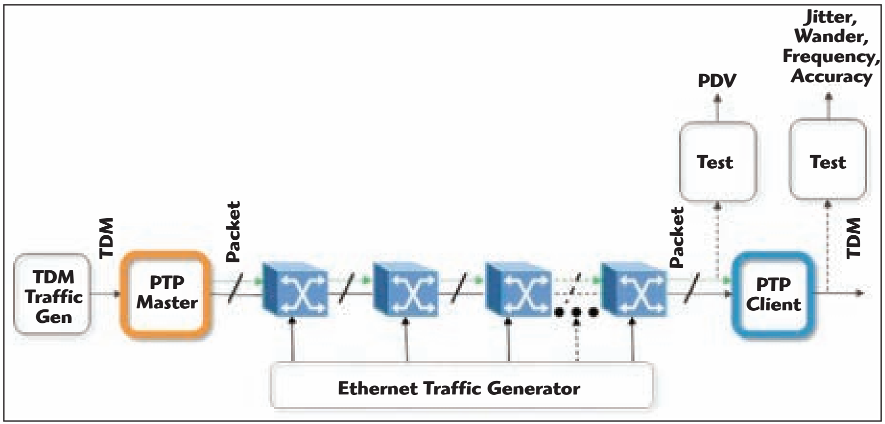


Fig. 9 Timing network measurement at TDM packet interfaces.

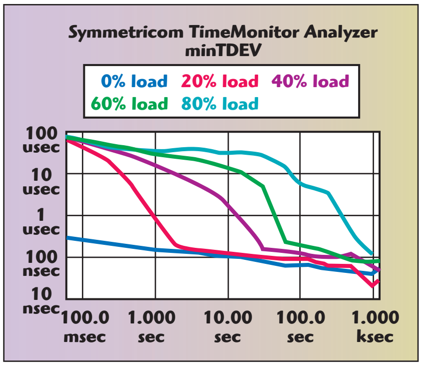


Fig. 10 Packet delay variation (PDV) measurements.

client meets TDM performance requirements over whatever network conditions are created. Recently introduced test equipment allows moving to the packet side of the PTP client and directly measuring Packet Delay Variation (PDV) as in ITU-T Recommendation G.8261/Y.1361, as shown in ***Figures 9*** and ***10***. Another handy tool for PTP solution evaluation is a network emulator, which can conveniently create various network packet delay, jitter and loss conditions. An added bonus with some network emulators is their ability to 'playback' delay, jitter, and loss behavior recorded on real networks to allow convenient and accurate network simulation in a lab environment. Some PTP solution vendors have consulting and evaluation services available to assist with testing PTP solutions under particular conditions of interest.

PUTTING IT ALL TOGETHER

Simple deployment guidelines help ensure the best results in Ethernet cellular backhaul timing applications. Selecting a carrier-class 'Clock of Gibraltar' Grand Master Clock server—with the best possible performance and reliability, plus adequate capacity for the number of clients expected now and in the future in the network—forms the foundation of a solid solution. Everything flows from there, so do not scrimp on the GMC. Then, if the base station equipment already supports PTP, the client side is covered. If not, selecting a good quality PTP client 'translator' will support the reference needs of legacy TDM cellular base station equipment.

Deciding where to place GMCs throughout the network requires consideration of both GMC capacity and PDV seen by each PTP client. Cost considerations encourage fewer GMCs and more hops, while robustness during severe network conditions balances the solution back toward more GMCs and fewer hops. Measurements of a variety of network element cascades under various traffic conditions have led to excellent results with PTP networks up to ten hops. Sufficient GMC capacity can be checked by summing the message rate load for each client served by the GMC. If the demand exceeds the capacity of the GMC, an additional GMC can be added to divide the load. This has the added benefit of reducing the number of hops and lowering the PDV seen by some of the PTP clients. Finally, each PTP client needs to have access to a backup GMC with available capacity in the case of network failure.

The GMC may have capacity to support the desired quantity of clients, but the multi-hop network may have excessive PDV to meet the timing performance required. There are five choices under these conditions: get a better GMC, get a better PTP client, add a closer GMC, add a boundary clock, or add a transparent clock. Assuming you have already got the best GMC and PTP clients available, adding a GMC, boundary clock, or transparent clock appear to be the remaining options. As of this writing, lack of commercially availability boundary clocks and transparent clocks for telecom applications leaves adding a GMC as the practical solution to controlling PDV over wide area networks, and it has the added benefit of flattening the overall timing network.

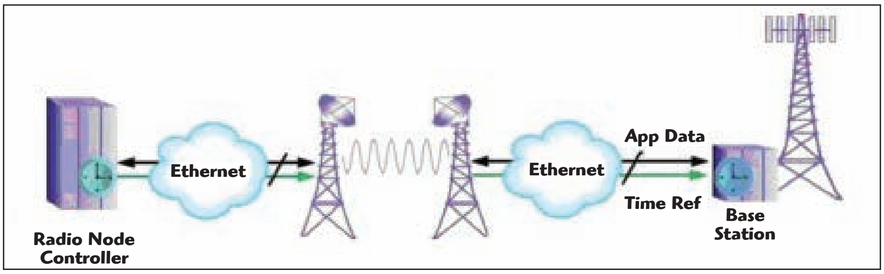


Fig. 11 Cellular backhual via Ethernet over microwave with PTP timing.

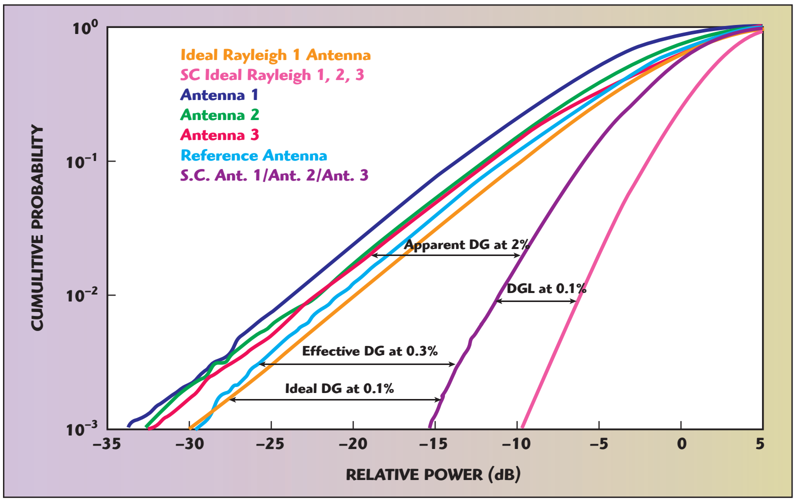
CONCLUSION

Ethernet is an enabling technology for improving capacity and cost of cellular network backhauling. The missing link in this approach has been providing the precise frequency and time references to base stations. IEEE 1588-2008, Precision Time Protocol can now be used to complete this link. Best results require a carrier-class PTP Grand Master Clock, performance-optimized PTP clients, and following some basic network design guidelines. GMCs are available in both 'blade' form factor for Sync Supply Units (SSU) installations and small standalone form factor for remote Base Station Controller/Radio Network Controller (BSC/RNC) sites. PTP clients are available as small 'translator' boxes to support legacy TDM equipment, as well as modular and firmware/license packages ready for integration. Measurement tools are available to evaluate the robustness of PTP solutions. PTP GMC/client combinations are available that simplify management and monitoring of PTP timing networks. ■

The MIMO Analyzer: MIMO Measurements Made Simple

With the recent inclusion of MIMO into both WiMAX and LTE standards, MIMO technology is booming. In an unusual multidisciplinary approach, multi-mode multi-cavity microwave applicator, signal-processing, aperture-iris coupling and RF antenna engineering techniques are being jointly applied to provide realistic and repeatable emulation of MIMO. As a result, EMITE Ing has developed the E300 MIMO Analyzer, which measures 0.82 × 1.425 × 1.95 m. With nine wideband antennas, different DUT-holder stirring positions, polarization stirring, two mechanical stirrers, 18 iris-coupling aperture stirring and variable frequency stirring, it avoids the use of a rotating platform, and therefore the need to make MIMO measurements using switched-mode or virtual array techniques.

Unlike conventional reverberation chambers, the MIMO Analyzer operates in both reverberating and non-reverberating modes, avoiding polarization imbalance, and is able to emulate a wide variety of Rayleigh, Rician, isotropic and non-isotropic environments from 690 MHz to 12 GHz.



▲ *Fig. 1 Measured diversity gain using the E300 MIMO Analyzer.*

EMULATING CAPABILITIES

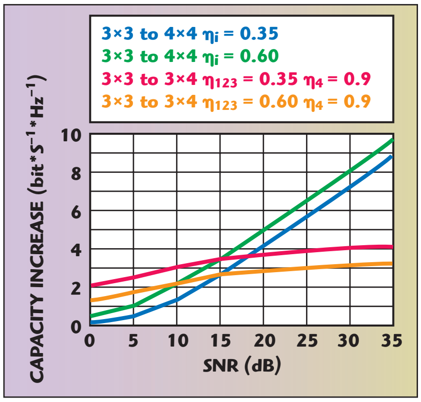
The 8 × 8 MIMO Analyzer provides both non-physical—correlation, mutual coupling, effective, ideal and apparent implemented diversity gain, efficiency (η), diversity gain loss (DGL) due to efficiency/user, MIMO capacity (C_{MIMO}), capacity loss (CL_{MIMO}) due to efficiency/user, mean effective gain (MEG) and effective mean effective gain (EMEG)—and physical parameters—angle of arrival (AoA), angular spread (AS), number of scatters (NS), number of multipath components (MPC)—to the MIMO engineer. The E300 Series also provides for active parameters like Total Radiated Power (TRP) and Total Isotropic Sensitivity (TIS) for 3GPP/CTIA compliance testing. The physical effect of the user on the above parameters can also be measured by an agreement with Schmid and Partner Engineering AG (SPEAG), whereby the SAM v4.5BS head and SHO v2RBLB hand phantoms are employed in conjunction with the MIMO Analyzer.

Some of the different definitions of diversity gain measured with the E300 are illustrated in ***Figure 1***. Similarly, MIMO capacity is measured using the measured channel samples between each of the MIMO receiving antennas (R) and each one of the transmitting ones (T). The recently defined efficiency-or-user related parameters of DGL and CL_{MIMO} can also be measured using the new MIMO Analyzer.

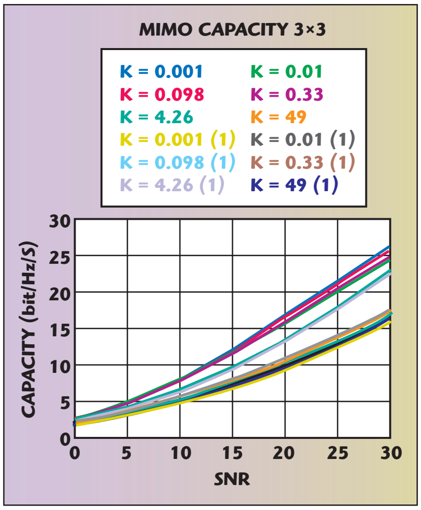
Since it is highly unlikely that all receiving antennas have the same efficiency, these two parameters help identify the MIMO design optimum β=T/R for a specific fading environment and angular spread, as depicted in ***Figure 2***, or even for a variety of fading conditions through automatic multiple tests in the MIMO Analyzer.

In addition, the instrument is able to emu-

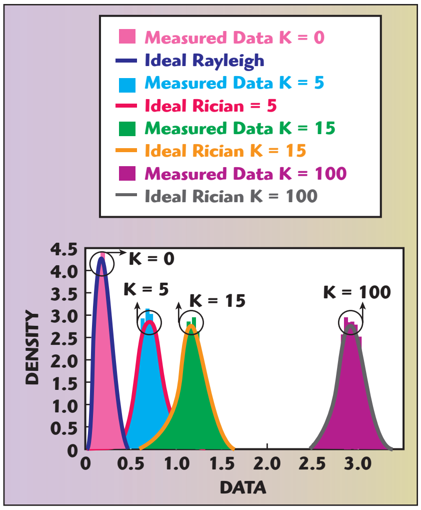
EMITE ING
Murcia, Spain



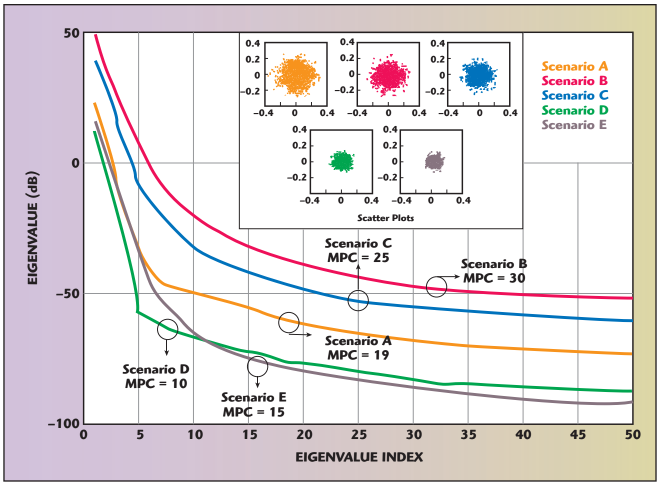
▲ *Fig. 2 Measured capacity increase using the E300 MIMO Analyzer.*



▲ *Fig. 3 Rician benchmarking for the E300 MIMO Analyzer.*



▲ *Fig. 4 Some measured Rician distributions at the E300 MIMO Analyzer.*



▲ *Fig. 5 Eigenvalues for some scenarios at the E300 MIMO Analyzer.*

late Rician-fading environments. To do this, a combination of smart-stirrers movement, variable iris-coupling, holder position and sample-selection by genetic algorithms is used. The MIMO Analyzer can specify the contribution of each sample to final fading environment emulation, providing for an accurate way of determining Rician-fading environments (patent protected). Rician benchmarking is shown in ***Figure 3***, while different K-factors obtained from measured data analyses and their data distribution is shown in ***Figure 4***.

The E300 can also repeatably emulate both isotropic and non-isotropic fading scenarios, providing for MPC and AoA histograms of measured data, along with the measured values of angular spread and number of scatters. In ***Figure 5***, the measured eigenvalues of the data matrix for some emulated scenarios are depicted.

Two techniques for emulating non-isotropic scenarios are available on the MIMO Analyzer: A decrease in the main cavity Q-factor and the combined use of a wide coupling aperture and a relatively-large T-R separation with a non-reverberating mode with the door open (patent protected).

Figure 6 shows the measured angle of arrival for some emulated scenarios. Angular spreads ranging from 36 to 85 have successfully been emulated by EMITE Ing and incorporated onto the MIMO Analyzer firmware. In some emulated scenarios a high degree of non-isotropicity is observed, with up to 50 dB power differences for diverse angles.

Finally, the E300 is also able to measure TRP and TIS for compliance testing purposes, serving the pre-compliance design and testing stages with a final certification of performance. ***Figure 7*** shows a comparison of TRP measured with the E300 MIMO Analyzer, the SATIMO SG24 and EMS-CAN LabExpress. This feature was not included in the E300 predecessors, the E200 and E100 Series, which can be acquired at a lower cost.

APPLICATIONS

The E300 is ideally suited for MIMO applications that simply cannot be simulated, such as the use of metamaterial antennas for wireless terminals. The radiating element length in a mobile phone can be reduced between 1/15th and 1/20th of the wavelength using metamaterials. A four-element 2.4 GHz MIMO antenna, for example, will fit in a volume of only 48 × 8 × 0.8 mm, without sacrificing efficiency. It is also an excellent tool for identifying the maximum allowable Shannon capacity of the RF antenna front-end, which poses a limit to the baseband MIMO algorithm and places its performance into context.

Another key deployment where the new MIMO Analyzer can be helpful is that of femtocells, where interference is an issue. Trials have shown that in some situations, particularly buildings with thick concrete floors, coverage may not penetrate the entire desired area, and then the RF interface acquires great importance. The ideal femtocell will support multiple standards simultaneously, and with significant levels of voice and data performance, MIMO technologies will be exploited.

Now that the IEEE 802.11n WiFi standard is a reality, WiFi systems with pre-N products based on draft versions of the standard can be tested by the MIMO Analyzer and certified for the recently approved standard. The pre-N products have been able to multiply existing peak data rates of IEEE 802.11g by 5 to 20 Mbps. Speed can go up to 150 Mbps raw symbol rate when combined with 40 MHz channels, and 600 Mbps are said to be achievable with four spatial streams.

Another application is that of fixed wireless access (FWA) in WiMAX (IEEE 801.16) or mobile WiMAX/

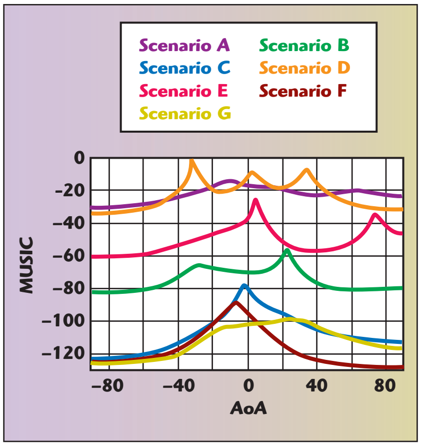


Fig. 6 Some AoA histograms at the E300 MIMO Analyzer.

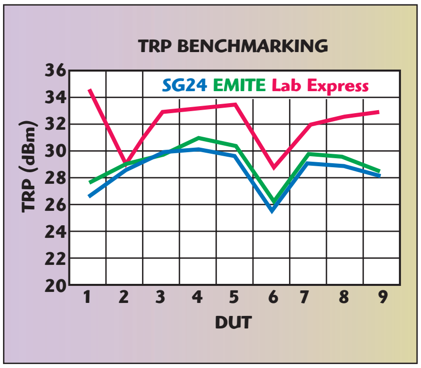


Fig. 7 TRP benchmarking for GSM900.

WiBRO (IEEE 802.16e). Time-division duplex (TDD) WiMAX includes several types of MIMO. In the predicted downlink schemes for mobile WiMAX, the criterion to switch between Matrix-A (STBC) and Matrix-B is based upon the scheme that gives the highest spectral efficiency. It is here where the MIMO Analyzer can be helpful in identifying such selection for specific MIMO array prototypes in diverse emulated scenarios.

Also, in the mobile WiMAX evolution, MIMO is also being added to frequency-division duplex (FDD) mobile WiMAX. Both the IEEE 802.16 Working Group and the WiMAX Forum aim to get twice the spectral efficiency of mobile WiMAX release 1.0 in several metrics at both the downlink and uplink using MIMO. The same is true for IEEE 802.16m (WiMAX 2 II/Wave 2) and pre-LTE transition standards like HSPA evolution (HSPA+). The foreseen MIMO technologies embedded into LTE have to be carefully tested and validated against realistic fading environments using the MIMO Analyzer.

Furthermore, wireless is rapidly moving beyond the handset and even the PC and becoming included in every new device or media platform. One niche application is that of embedded in-car wireless systems for vehicle-to-vehicle (VtV), vehicle-to-infrastructure (VtI) or inter-vehicle communication (IVC). These systems include MIMO techniques in order to achieve fast data rates in harsh communications environments. DSRC/WAVE (IEEE 802.11p) systems fill a niche in the wireless infrastructure by facilitating low latency, geographically local, high data rate and high mobility communications.

Some applications envisioned using DSRC include applications such as local danger warning, vehicle collision avoidance, traffic control and remote toll collection, emergency warning systems for vehicles, cooperative adaptive cruise control, cooperative forward collision warning, and intersection collision avoidance. In addition, a plethora of more demanding applications, such as high-speed networking, video streaming and mobile commerce, are envisioned.

An in-vehicle infotainment/safety system fully integrated to the phone could also certainly make use of MIMO to solve the large variability of link conditions, particularly the non-stationary nature of the fading behavior with temporary high path loss and a strong shadowing influence. MIMO, which is already being tested by car makers worldwide, could be the answer.

MIMO techniques for VtV communication could be used either to obtain large capacities or to reduce interference effects through spatial filtering. Here, channel modeling is critical and MIMO measurements are essential to identify prototype performance in an environment with a widely changing K factor. The E300, which is able to emulate diverse K factors and nonisotropicity, could simplify MIMO test and measurement for these prototypes.

Similarly, the UWB air interface (IEEE 802.15.3a) is expected to enable peak download data rates of 288 Mbps in a 20 MHz bandwidth. It uses OFDMA with sophisticated control and signaling mechanisms, radio resource management (RRM), adaptive reverse link (RL) interference management, and, of course, MIMO.

Throughput gains of between 20 to 40 percent using MIMO relative to SIMO have already been observed in drive tests. Since UWB supports both single user and multiuser MIMO, it is also a good candidate to be tested using the versatility of the MIMO Analyzer. Some other mm-wave standards that may include MIMO techniques are WirelessHD (WiHD), IEEE 802.15.3c or IEEE 802.11 VHT60, among others.

CONCLUSION

The E300 MIMO Analyzer has an emulating performance well beyond conventional reverberation chambers, which are limited to Rayleigh-fading and isotropic behavior. Standardization is also on the way following the recent Vodafone proposal to 3GPP to use the reverberation chamber technique as an alterative to OTA systems for MIMO measurements. The MIMO Analyzer delivers accurate, fast and repeatable MIMO measurements, all united in a single and intuitive interface, and can drastically reduce research, production and compliance testing costs and time to market. These capabilities also provide a basis for comparing test results as system hardware/software is changed, or alternate devices are tested, or even when new materials are employed. Automated testing improves time to market, test coverage, repeatability as well as the collection and archiving of the results.

Increased broadband speeds are driving the development of new categories of devices such as smartphones, mobile Internet devices, ultra mobile PCs and netbooks, where MIMO has to be fully integrated. Consequently, the new MIMO Analyzer is of interest to both 3.5/4G cellular handset and non-handset wireless device manufacturers, including the chipsets, cellular phones, smartphones, wireless LAN access points, 4G base station antennas, HSPA+ routers, compact handheld mobile computers, PCMCIA cards, PDAs, netbooks, etc. The low-cost E300 is an important new tool for evaluating final product performances as well as MIMO conformance tests and compliance testing in an efficient, fast and accurate way.

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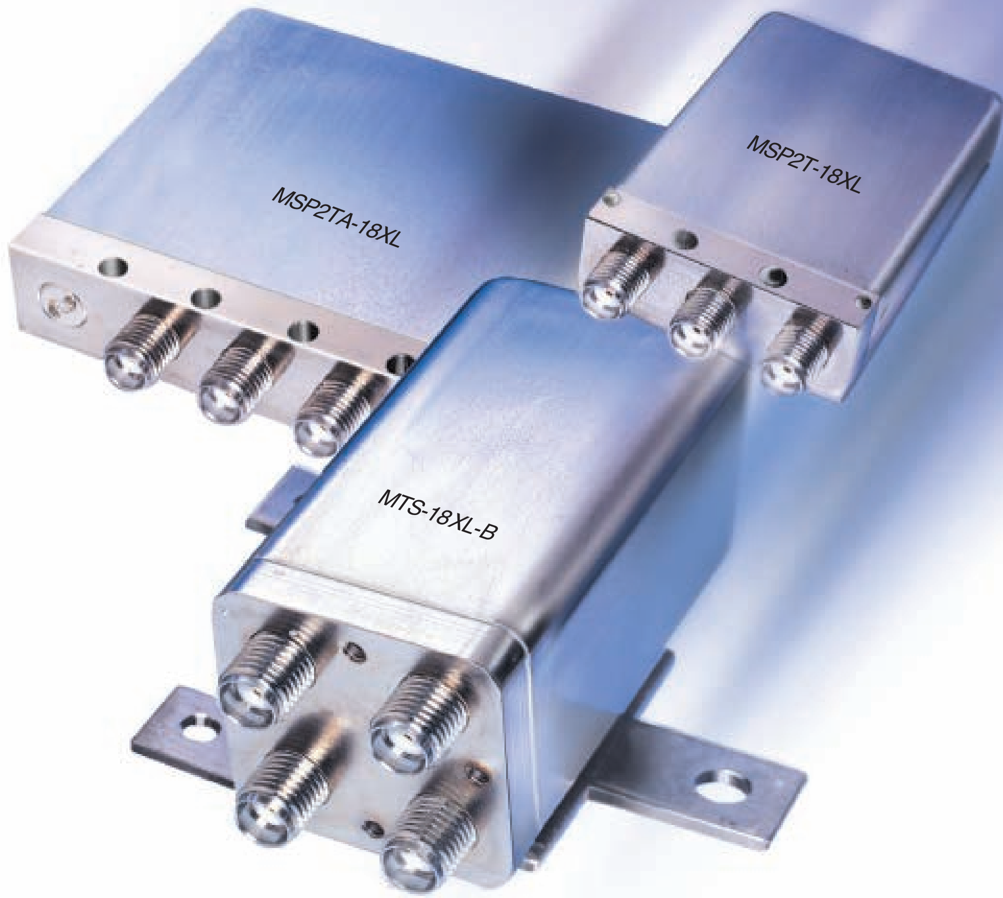

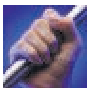

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Digital Step Attenuator Protects 4G Infrastructure

Because of the unique characteristics of the specification, LTE mobile infrastructure will require components with high linearity and low loss in very small form factors; they must also operate with low power consumption. Manufactured using UltraCMOS, the Peregrine PE43204 digital step attenuator (DSA) meets these complex demands. It is best suited for use in the signal chain to adjust power levels and is specifically designed for LTE infrastructure applications such as base stations and remote radio heads.

Offering exceptional attenuation accuracy, +61 dBm linearity, and low phase error over temperature and frequency, the PE43204 is a high-performance DSA that provides flexible attenuation options across an 18 dB attenuation range in 6 and 12 dB steps. Each 6 dB step in attenuation, for example, results in a 50 percent reduction in the incoming signal.

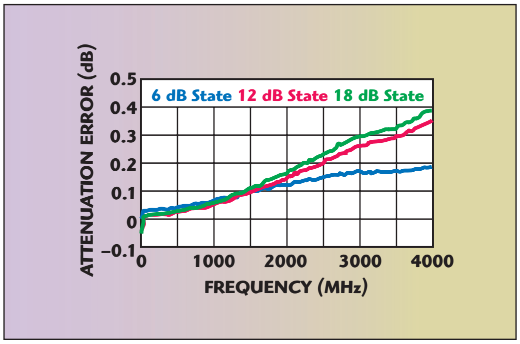

Fig. 1 PE43204 attenuation error vs. frequency (25°C).

Typically used in the receive path for gain control, the PE43204 DSA features a fast switching speed, which allows attenuation to be added quickly to protect the receiver and prevent over-driving the analog-to-digital converter. The new DSA takes advantage of the company's proprietary HaRP™ technology that dramatically improves linearity and eliminates gate lag or phase drift, which results in a very fast settling time.

Specifically, the PE43204 features a typical switching time of 26 ns with a typical attenuation accuracy of +0.2 dB across a wide operating range of 50 MHz to 3 GHz (see ***Figure 1***). In comparison, many GaAs DSAs dem-

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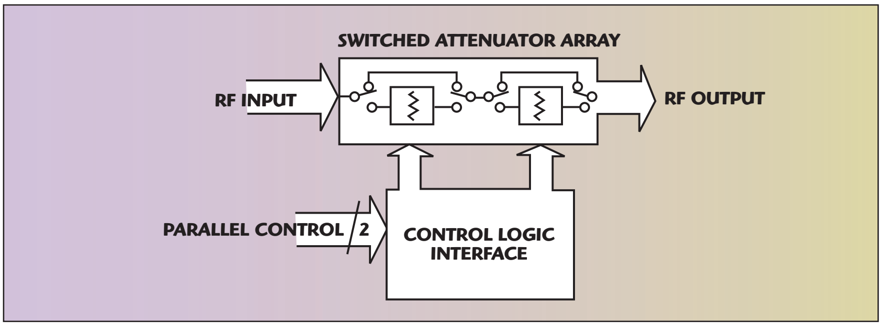
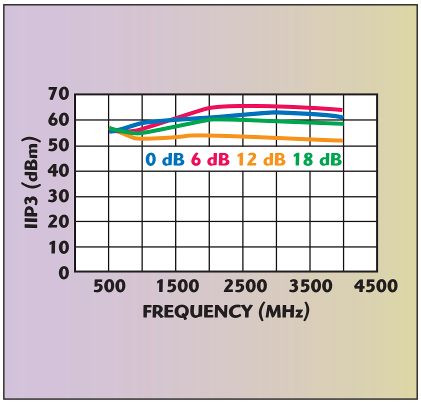
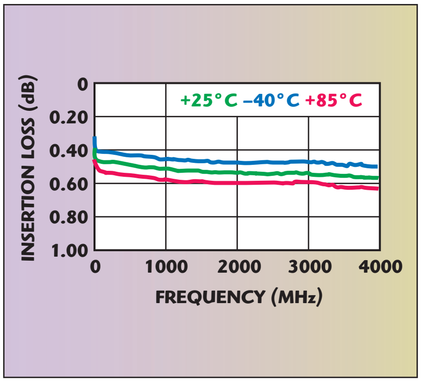


▲ *Fig. 2 Functional block diagram for PE43204 DSA including on chip integrated control logic.*



▲ *Fig. 3 PE43204 input IP3 vs. attenuation setting (25°C).*



▲ *Fig. 4 PE43204 insertion loss vs. temperature.*

onstrate a typical switching speed of 130 nS, which is more than 4x slower than the UltraCMOS DSA.

In some receiver architectures fast switching speed is imperative to protect the receive path from damage when strong blocking signals are present, and it is also key for gain control on the base station. As throw counts increase for LTE, this specification becomes even more important. Faster switching speeds and shorter settling times lead to more reliable and more accurate performance, and UltraCMOS inherently offers these advantages.

If multiple-input and multiple output, or MIMO, antenna technology is implemented this increase in functionality and signal paths increases the need for smaller form factors (and higher integration in order to control component count). For instance, in a 2 × 2 configuration there will be a DSA in each transmit and receive path. The cost of deploying new LTE services will also keep pressure on minimizing the bill of materials and design complexity. Clearly, the need for higher integration as well as smaller sizes and higher performance is critical.

Recognizing this need, designers at Peregrine took advantage of the ability to realize logic in CMOS and integrated a parallel control interface programming logic in the PE43204, all while housing it in an ultra-compact 12-lead 3 × 3 × 0.85 mm QFN package (see ***Figure 2***).

The challenges of LTE design do not stop with switching speed and board real estate. Specifically, on the downlink, LTE implementation of orthogonal frequency division multiplexing (OFDM) uses several closely spaced orthogonal subcarriers make up a resource block (RB). The number of RBs will vary depending upon the system's bandwidth, but generally, 1RB is equivalent to twelve 15 kHz subcarriers. The use of RBs complicates receiver design, especially in terms of adjacent channel selectivity because the LTE specification notes that a very large in-band interferer is located only 1RB away. To be successful, devices with high linearity and isolation will be required to meet this challenge.

While maintaining a best-in-class typical input third order intercept point (IIP3) of +61 dBm, the PE43204 DSA demonstrates typical insertion loss of 0.6 dB and electrostatic discharge (ESD) of 2 kV (see ***Figures 3*** and ***4***). High data rate systems, like LTE, benefit from higher linearity and low loss like the specifications demonstrated by the PE43204 DSA. In addition, components with high ESD ratings are highly desired in the manufacturing process to reduce the likelihood of ESD damage during assembly.

Despite their need for higher performance and more circuitry packed into an IC, designers of LTE systems also need to limit or reduce overall system power consumption, and many want to move towards 'greener' semiconductor processing choices. RF CMOS technology's advantages of low power are well known. UltraCMOS technology is a CMOS process where a 50 to 100 nm silicon film is formed directly on a sapphire substrate. This provides for fully-depleted devices with little or no body charge under the gate. As a result, UltraCMOS processing delivers faster devices with reduced power consumption (as compared to GaAs) as well as excellent linearity and high isolation. Also, UltraCMOS does not use Arsenic. The PE43204 DSA, for instance, is biased from a 3 V supply with power supply current of 8 µA typical. These advantages make UltraCMOS devices in general (and the PE43204 DSA in particular) an excellent match for the rigorous demands of next-generation communications systems and LTE.

Peregrine Semiconductor,
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Next Generation Wireless

Literature Showcase

LTE Poster

VENDORVIEW

Agilent's LTE poster is a vital tool for engineers working with this exciting technology. It has recently been updated to include technical detail on FDD and TDD frame structures, including down and uplink physical mapping, downlink configurations and TDD 5-ms switch periodicity mapping. Get your free copy today. For more information, visit www.agilent.com/find/ltetest.

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Understanding Cable and Antenna Analysis

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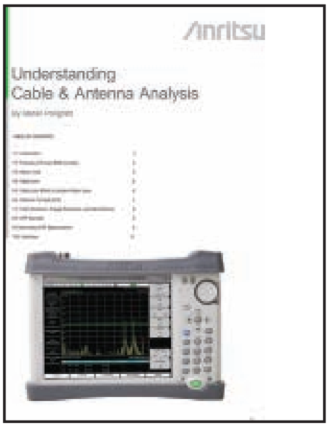

Visit Anritsu's New Masters of the Wireless web site and download its free White Paper, *Understanding Cable and Antenna Analysis*. Field technicians today rely on portable cable and antenna analyzers to analyze, troubleshoot, characterize and maintain the system. The purpose of this white paper is to cover the fundamentals of the key measurements of cable and antenna analysis, return loss, cable loss and distance-to-fault (DTF). Learn more now.

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LTE Solutions Guide

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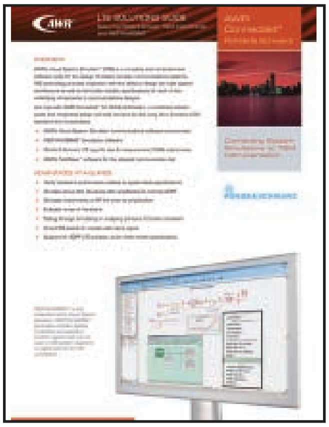

AWR® Connected™ for Rohde & Schwarz now offers an LTE Solutions Guide that highlights how to combine design and test domains for the Long Term Evolution (LTE) standard. The contents of it demonstrate how to use AWR's Visual System Simulator (VSS) v2009 software, incorporating R&S® WinIQSIM2™ simulation software, along side R&S LTE, specific test and measurement instruments for designing communication systems in support of the LTE standard. Download the guide at www.awrcorp.com/vss.

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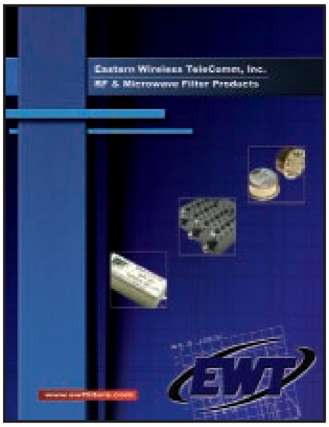
Filter Catalog



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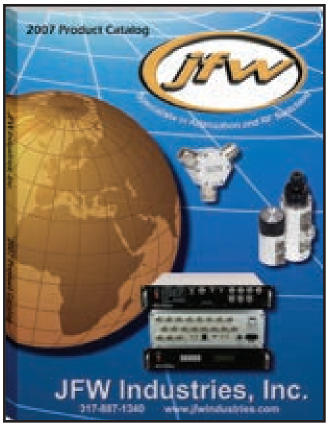

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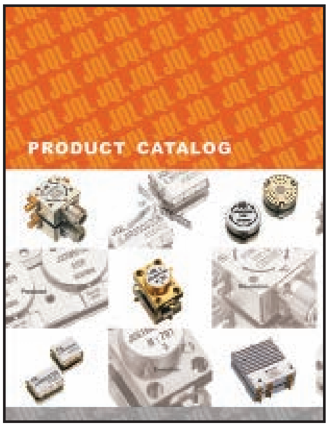

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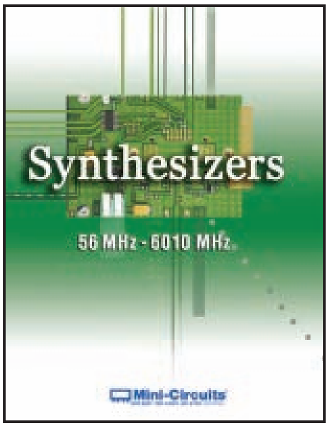

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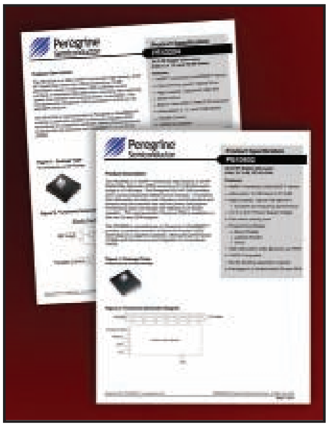

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