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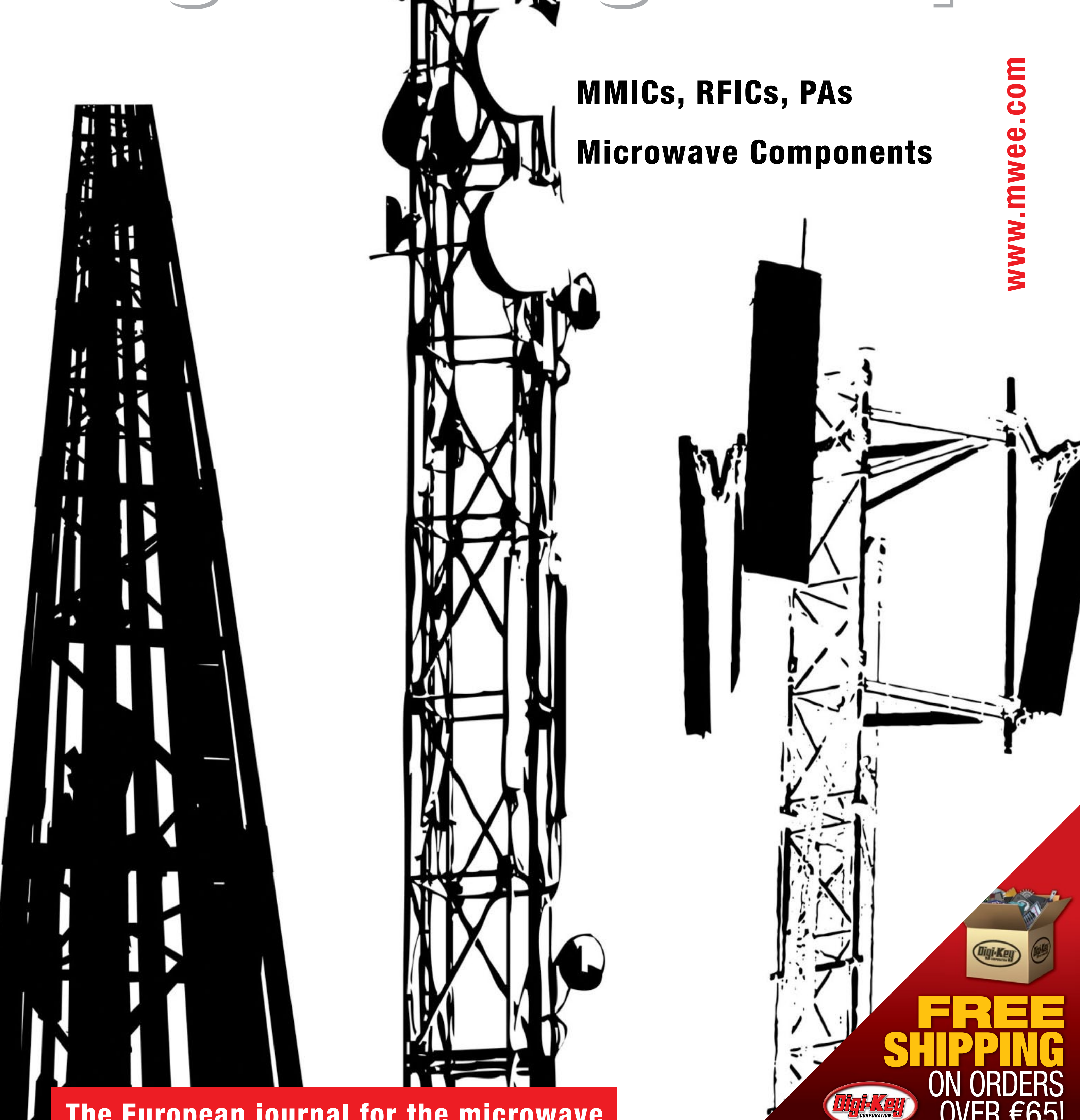

MMICs, RFICs, PAs

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The European journal for the microwave and wireless design engineer


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Internet of Things is great technology but it will need to appeal to the consumer

There has been a lot of hype over the Internet of Things (IoT) especially in predictions of the number of devices that will be connected to this new communications fabric. In reality, we are only seeing the first steps in the building of the IoT.

Industrial companies have started to embrace connecting all sorts of sensors and systems to an open standards communications network as it enables easier monitoring and control. The Smarthome is also looking at the concept of the IoT. In fact, I would go as far as saying that for the Smarthome to become a commercial reality, it will need the IoT. Homes don't change quickly and for the general public to embrace Smarthomes a cheap open communications fabric will need to readily available — such as the IoT promises to be.

Further, the Smarthome will move beyond monitoring consumption, to control and interaction of systems in the house, which will notably include enertainment and health. In other words the Smarthome will have to look after its inhabitants to be of use to the general public, and it will need to be affordable.

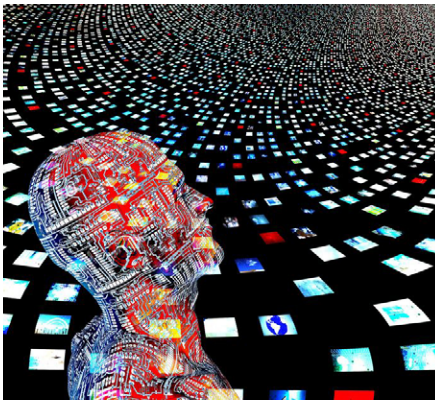
IoT will embrace many communications protocols and leverage the smartphone as this is the most effective way of providing the raw computing power to the user. Bluetooth, ZigBee and WiFi are set to dominate the short-range communications within the house.

According to ABI Reasearch the emergence of standardized ultra-low power wireless technologies is one of the main enablers of the Internet of Everything (IoE) with semiconductor vendors and standards bodies at the forefront of the market push, helping to bring the IoE into reality. 2013 is seen by many as the year of the IoE, but it will be many years until it reaches its full potential. The next 5 years will be pivotal in its growth and establishment as a tangible concept to the consumer.

In essence the smartphone as far as the consumer is concerned will hold all the apps needed to run the Smarthome, including entertainment systems, health monitoring systems, security and any other devices that need looking after. Intelligent fridges that update your shopping list on your smartphone are nice but it is really entertainment, health and security that will drive conumers to make the investment in IoT.

For business and industry, the IoT will improve communications and optimise consumption and costs. Business see such technology as a way of reducing running costs and when it becomes available, it will be readily adopted.

To see this in action, ARM is currently transforming its headquarters into a hub for its partners' Internet of Things (IoT) technologies. ARM and its partners won £800,000 in a competitive funding call



from the Technology Strategy Board, the UK's innovation agency, to deploy network technology and over 600 connected sensors across its premises in Cambridge.

All of these connected sensors are controlled by smart ARM-technology based chips. The project will provide information and finer grained control of the site and its 75 car park lights, 40 meeting rooms, heating and water management systems. The company believes that making connected assets across the ARM campus work together will demonstrate tangible business benefits and help it achieve a reduction in energy use.

By Jean-Pierre Joosting
Editor: Microwave Engineering Europe

Entrust and Radio IP Integration secures connection across wired and wireless IP networks

Entrust and Radio IP are partnering to integrate industry-leading mobile VPN and user authentication solutions to provide secure, seamless mobile connectivity for police, fire, EMS, transport services and more.

A persistent network connection — while moving around cities, states and the country — is critical to the safety and success of mobile workers. The solution is designed to enable organizations to optimize worker productivity, protect critical assets and help ensure compliance.

"Regardless of industry or global location, more organizations require complete solutions to support dispersed work-forces," said Entrust President and CEO Bill Conner. "These security-conscious organizations, and their mobile employees, rely upon flexible mobile networking capabilities that deliver data and voice connectivity — whenever and wherever needed — while adhering to corporate security policies."

The integration between the Entrust IdentityGuard software authentication platform and Radio IP's mobile VPN solutions helps provide continuous, authenticated connectivity by automatically and seamlessly reconnecting clients to the network when signal interruptions occur — all without any loss of data.

Leveraging Radio IP's mobile VPN, authenticated corporate users may move freely between secure and non-secure networks without losing their connection and without jeopardizing security policies.

www.entrust.com, www.radio-ip.com

Building the Internet of Things requires Bluetooth

ABI Research estimates that the installed base of Bluetooth-enabled devices alone reached 3.5 billion in 2012 and is forecast to grow to almost 10 billion by 2018. This doesn't take into account many other technologies such as Wi-Fi, ZigBee, and cellular.

The emergence of standardized ultra-low power wireless technologies is one of the main enablers of the Internet of Everything (IoE) with semiconductor vendors and standards bodies at the forefront of the market push, helping to bring the IoE into reality. 2013 is seen by many as the year of the IoE, but it will be many years until it reaches its full potential. The next 5 years will be pivotal in its growth and establishment as a tangible concept to the consumer.

"There has been (and still is) a lot of hype about IoE with some protagonists predicting 10s of billions of IoE devices populating the planet over the next 5 to 10 years," said Peter Cooney, practice director. "In reality the market is already huge, and Bluetooth will continue to be one of the key technologies that enable IoE market growth."

Bluetooth Smart Ready devices shipments are growing rapidly and this is creating a large number of "hub" devices that Bluetooth Smart "node" devices can connect to. Initial growth has been strong in the health and fitness market, but the massive Bluetooth eco-system is also driving growth in many other markets including keyboards, remote controls, watches, toys, door locks, and many more.

"The smartphone will continue to be the primary market for Bluetooth and the catalyst for growth of the emerging Bluetooth v4.0 ecosystem, but strong adoption is also occurring in the PC, mobile consumer, and connected home segments," added Cooney.

www.abiresearch.com

Bristol-based startup gets funding for 60 GHz wireless IP

Bristol-based 60 GHz wireless startup Blu Wireless has closed a $3.1 million (£2m) funding round to customize and productize its IP.

This will allow the company to drive further growth, doubling in size to 30 staff, and complete the development of its HYDRA programmable baseband IP that supports both 802.11ad next generation WiFi (WiGig CERTIFIED) and 4G mobile network backhaul applications.

The funding round was led by Qi3 Accelerator, who represented a syndicate of over $1.5m (£1m) of London Business Angels private investors, including Wren Capital. A further $0.9 million (£0.6m) was invested by the Angel Co-Fund, several additional investors made up the remainder.

Blu Wireless's baseband technology uses a programmable parallel processing architecture to efficiently support the complex modulation schemes required for emerging multi-gigabit wireless communication standards. The IP is currently optimised for chipsets used in both advanced WiFi and 4G small cell deployments, and can be simply scaled to support the anticipated future standards as they move to 20 Gbps and beyond.

The firm is already working with several of the world's leading semiconductor and system companies in these markets, says CEO Henry Nurser with the same customers using the IP for both 802.11ad and for wireless backhaul. The IP will be sold under license agreement to chipset manufacturers that compete in, or want to enter, markets that exploit the unlicensed 60 GHz frequency band.

The WiGig standard offers data rates of up to 7 Gbit/s and hence outperforms existing WiFi technology by 10x and the LDPC-based forward error correction is an integral part of the WiGig baseband technology.

www.bluwirelesstechnology.com

Mobile phone uses FPC fingerprint technology

The Fujitsu F-07E Android smartphone was recently launched in NTT DoCoMo stores all over Japan. This is a Disney-branded phone, containing Fingerprint Cards' (FPC's) swipe sensor technology.

"Finger sensors in smart devices have become an increasingly essential way to ensure that these devices are secure and at the same time they add convenience for the users. Finger sensors in smartphones have become something of a trademark for Fujitsu and by adding 1080 swipe sensor technology from Fingerprint Cards, we are taking the next step in helping smartphone users to increase the convenience of their experience through effortless fingerprint security ," says Katsumi Takada, head of Mobile Phone Group of Fujitsu.

Fingerprint Cards AB (FPC) markets, develops and produces biometric components and technologies that through the analysis and matching of an individual's unique fingerprint verify the person's identity. The technology consists of biometric sensors, processors, algorithms and modules that can be used separately or in combination with each other.

www.fingerprints.com

First 100 GHz real-time scope demonstrated

Teledyne LeCroy has demonstrated the first 100 GHz real-time oscilloscope by successfully acquiring and displaying live signals at 100 GHz bandwidth. This demonstrated performance dramatically exceeds currently available capabilities.

The demonstration was conducted at the research facilities of Teledyne Scientific Company in Thousand Oaks, CA. Teledyne LeCroy and Teledyne Scientific also announced today they have completed the design of a jointly developed next-generation indium phosphide (InP) chip and have released the design for fabrication at Teledyne Scientific's InP foundry. The jointly developed chip is the first device in an expansive chip set planned for future generations of high speed oscilloscopes. InP is an advanced semiconductor process that promises higher speed devices than can be designed in other known processes.

www.teledynelecroy.com

Alcatel-Lucent, Qualcomm plan ultra-broadband small cells

Alcatel-Lucent and Qualcomm Technologies have announced a plan to collaborate to develop small cell base stations that enhance 3G, 4G and WiFi networks to improve wireless connectivity in residential and enterprise environments. These next-generation small cells would combine Alcatel-Lucent's proven expertise and innovation in developing small cell solutions with Qualcomm Technologies' industry-leading mobile and networking technologies, to enable ultra-broadband wireless communications.

With the growing popularity of smartphones, tablets and other mobile devices using high-bandwidth video and gaming applications, wireless network operators and service providers are looking to small cells to cost-effectively meet the rapidly expanding demand for mobile data capacity and network coverage. By working together, Alcatel-Lucent and Qualcomm Technologies intend to accelerate the adoption of small cells and alleviate the impact of mobile data on wireless networks.

To facilitate this acceleration, the two companies plan to jointly invest in a strategic R&D program to develop the next generation of Alcatel-Lucent lightRadio™ Small Cell products featuring Qualcomm Technologies' FSM9900 family of Small Cell chipsets.

www.qualcomm.com
www.alcatel-lucent.com

Agilent and Gradient Design Automation expand relationship

Agilent Technologies has announced a new agreement that expands its business relationship with Gradient Design Automation, a leading provider of electrothermal simulation technology used to identify hazards and improve performance in integrated circuits that will be subject to temperature variations during operation.

As part of the agreement, Agilent has increased its financial commitment in exchange for increased access to Gradient's technology. In 2012, Agilent introduced a version of Gradient's technology integrated within its Advanced Design System software as part of a comprehensive multi-technology solution for RFIC and MMIC development.

www.agilent.com/find/eesof-ads

Innovative single antenna technology for cellular handsets

Smart Antenna Technologies (SAT) has launched its innovative single-antenna technology that will enable smartphone and tablet device manufacturers to replace several antennae with a single multi-band antenna, the performance of which will match that of the separate antennae at their specified frequencies.

Currently mobile devices require a separate antenna to support each communication technology such as Bluetooth, WiFi, GPS, GSM and 3G/4G. 4G phones are expected to have up to six narrow band antennae operating on individual band segments. This is highly inefficient in terms of cost and space occupied in the device.

SAT's technology has emerged from research by Professor Peter Hall, one of the leading experts in radio antenna technology, and his team at The University of Birmingham. The patented solution uses a novel foil or printable antenna and control chip to produce a compact multi-frequency antenna.

SAT's single antenna solution is expected to ultimately cost a few dollars per handset compared to US $20 per handset for existing antennas. Additionally, SAT uses software re-configurable hardware enabling manufacturers to produce one device for all territories, reduce costs and streamline manufacturing & logistics. SAT's technology has already generated interest from its target customers, including include cellular handset and chipset manufacturers.

This technology delivers major benefits on every critical constraint for handset manufacturers, including cost, design flexibility, space, single product for multiple territories and extended battery life. It is also fully complementary to existing RF solutions being used by the mobile phone industry and emerging products such as Qualcomm's RF360 technology.

Having won both the Cambridge Wireless 'Discovering Start-ups' competition in 2012 and the Enterprising Birmingham Innovation Competition 2013 the SAT team has been working with Venture Capital company, Mercia Fund Management (MFM), to secure its first investment, a Seed Enterprise Investment Scheme round, and will be shortly completing a further syndicated round. Funding will be used to produce the first product and customer deployment.

www.smartantennatech.com

Marki Microwave uses Microwave Office for innovative mixer design

AWR Corporation has announced that its customer, Marki Microwave has leveraged its high-frequency design software platform to develop a revolutionary design and manufacturing flow for successful mixer design.

The innovative mixer design flow combines AWR's Microwave Office® circuit design software and Marki's patent-pending Microlithic™ mixer manufacturing process, resulting in a 14x reduction in the size of Marki's mixers and a 5x reduction in design time with the same industry-leading quality and performance as the former handcrafted devices. As a result of the intimate coupling between modeling and fabrication, these mixers are also provided by Marki in the form of accurate, realistic, and fully multi-dimensional electrical models that can be readily integrated within the AWR Microwave Office ecosystem.

Mixer devices are available today from Marki Microwave. Models ML1-0113 and ML1-0220 cover frequencies up to 20 GHz are available for purchase, with several models covering up to 50 GHz currently in pre-production.

www.awrcorp.com
www.markimicrowave.com

Hughes exceeds 1-Gbps throughput on JUPITER satellite

Hughes Network Systems has achieved carrier data rates exceeding 1 Gbps on its JUPITER System. The company believes this achievement to be a technology first for High Throughput Satellite (HTS) systems, resulting in more subscribers per satellite and greater capacity per subscriber.

"With this development, we are extending our JUPITER technology to maximize data throughput and achieve the industry's fastest VSAT," said Adrian Morris, executive vice president of Engineering and CTO, Hughes. "This capability positions us to continue to lead the market in delivering the most bandwidth-hungry applications that demand the highest speeds."

JUPITER high-throughput technology is the cornerstone of the highly successful HughesNet® Gen4 service that was launched in October of 2012, which has accelerated growth of the total HughesNet subscriber base in the U.S. to approximately 700,000 subscribers, the world's largest satellite Internet service. HughesNet Gen4 customers enjoy high speeds, from 10 to 15 Mbps, and a richer Internet experience, including the recently announced VoIP calling option.

"This breakthrough demonstrates the enormous potential of our JUPITER technology," said Arunas Slekys, vice president of Corporate Marketing, Hughes. "Not only has it proven rock-solid in powering the fastest growth of satellite Internet service experienced anywhere, it means we can further expand the addressable market for satellite-based services — whether for consumers, enterprises or governments — and beyond North America, as we are poised to bring JUPITER Systems to International markets soon."

www.hughes.com

Cree RF technology stars in Hollywood aerial action sequence

Cree's GaN RF technology played a critical behind-the-scenes role in the upcoming action film, "Escape Plan," starring Sylvester Stallone and Arnold Schwarzenegger. The film features aerial stunt sequences captured using a low-latency HD camera and transmitter and Array Wireless' S-Band linear power amplifier, which employs Cree's world-class GaN HEMT semiconductors to meet the stringent linearity requirements for wide bandwidth HD digital transmission.

Mounted in the nose ball turret of a filming helicopter to capture near-in, high action shots of another helicopter while both aircraft were in free flight, the powerful combination of Cree and Array technology was essential for providing the director with low distortion, low latency, high definition video in addition to real-time viewing, editing, and staging capabilities from more remote distances than were previously possible. As such, the director had greater freedom to pursue more exciting action footage of the aerial stunt sequences that were occurring far from his location.

Cree's leading-edge GaN HEMT devices enable a broader transmission range, higher efficiency performance, improved reliability, and smaller, lighter product packages than are possible using traditional gallium arsenide (GaA) or silicon (Si) RF technology. Consequently, they are a critical component of Array Wireless' patent-pending linearization technology, which minimizes distortion and provides superior signal quality for complex multi-carrier modulations while also minimizing DC power consumption, heat, and weight. Further, the combination of Cree and Array technology also results in greater link range without distortion when operating in multi-path environments, such as canyons and cities.

http://escapeplanmovie.com
www.cree.com/rf

Cypress to integrate BLE radio with PSoC

Cypress Semiconductor has qualified a Bluetooth Low Energy (BLE) radio to integrate with the company's programmable platforms.

Cypress will develop single-chip solutions combining the radio with its PSoC programmable system-on-chip, industry-leading CapSense capacitive sensing and TrueTouch touchscreen technologies. The combinations will enable Cypress to quickly address emerging Bluetooth Smart applications such as PC peripherals, remote controls, wearable electronics and portable medical devices.

Cypress has qualified the BLE radio in its S8 130-nanometer flash-based SONOS (Silicon Oxide Nitride Oxide Silicon) process technology, which is the primary manufacturing technology for PSoC, CapSense and TrueTouch products. SONOS is compatible with standard CMOS technologies and offers numerous advantages, including high endurance, low power, and radiation hardness. The technology enables Cypress's BLE radio to operate in the industrial temperature range of -40 to +85 °C.

Cypress plans to sample its first integrated BLE device in the first quarter of 2014.

www.cypress.com

Bluetooth to surpass ZigBee in home automation in 2015

ABI research expects annual home automation device shipments to exceed 351 million, growing at a CAGR of 78%. ZigBee dominated IEEE 802.15.4 and claimed the top share of node shipments at 4.5 million, narrowly beating out proprietary protocol offerings.

Smart devices that use the Bluetooth Low Energy (BLE) protocol part of Bluetooth v4.0 single-mode specification will experience the highest growth in the category, reaching over 133 million units by 2018. Practice director Dan Shey explains, "Consumer electronics (CE), including smartphones, tablets, and laptops equipped with Bluetooth are a major contributor to Bluetooth growth in home automation."

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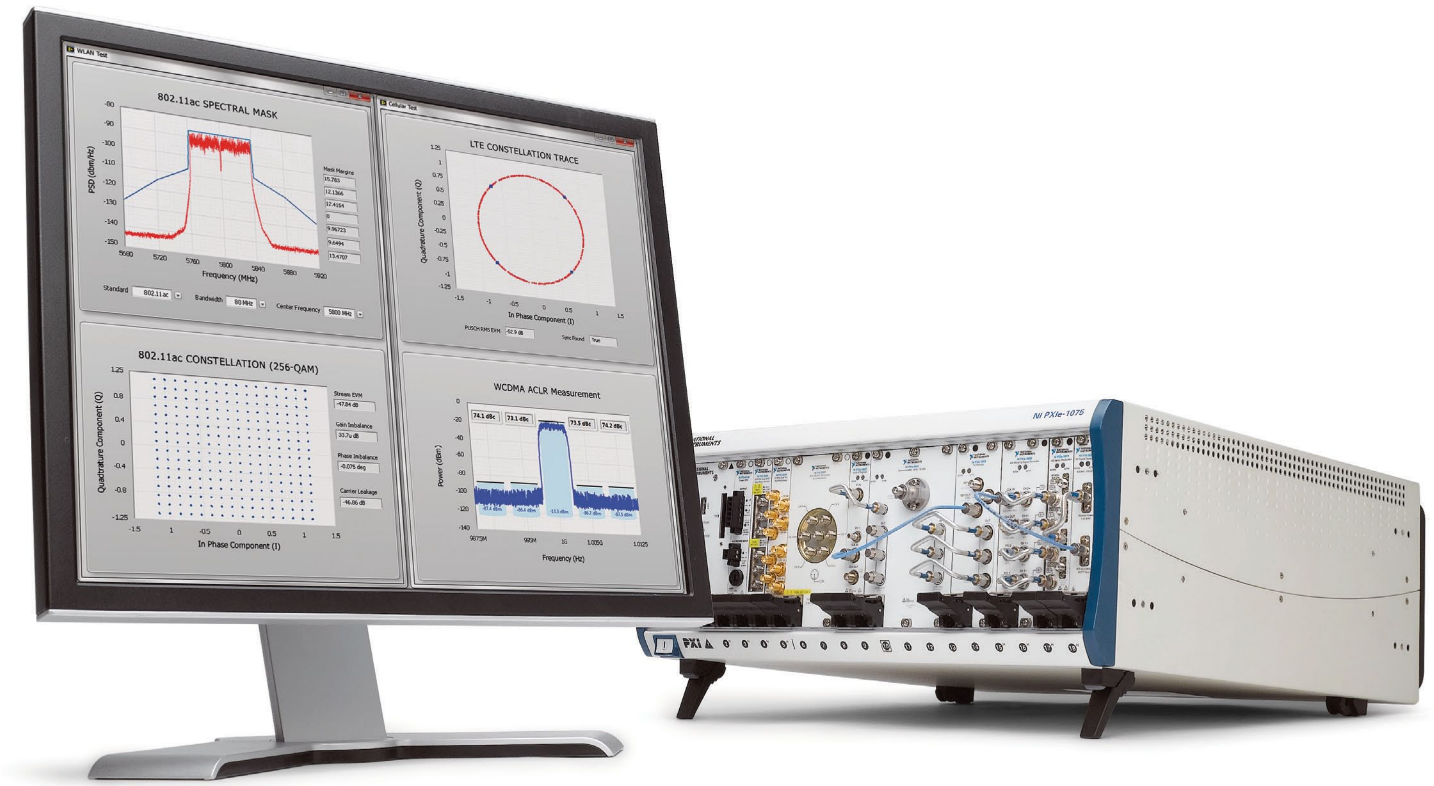

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NATIONAL INSTRUMENTS™

UMTS base station receiver fits in half-inch square

By Douglas Stuetzle and Todd Nelson, Linear Technology Corporation

How much integration is possible while still meeting macrocell base station performance requirements? Process technology dictates that certain key functions are produced in specific processes: GaAs and SiGe in the RF realm, fine-line CMOS for high speed ADCs, and high-Q filters cannot be implemented well in semiconductor materials. Yet the market continues to demand higher integration.

With that in mind, Linear Technology has applied system-in-package (SiP) technology to build a receiver occupying about one-half square inch (just over 3 cm^2). The boundaries of the receiver are the 50 Ω RF input, the 50 Ω LO input, the ADC clock input and the digital ADC output. This leaves the low noise amplifier (LNA) and RF filtering to be added for the input, LO and clock generation, and digital processing of the digital output. Within the 15 mm × 22 mm package is a signal chain utilizing SiGe high frequency components, discrete passive filtering and fine-line CMOS ADCs.

This article presents a design analysis for the LTM9004 μModule receiver implementing a direct conversion receiver.

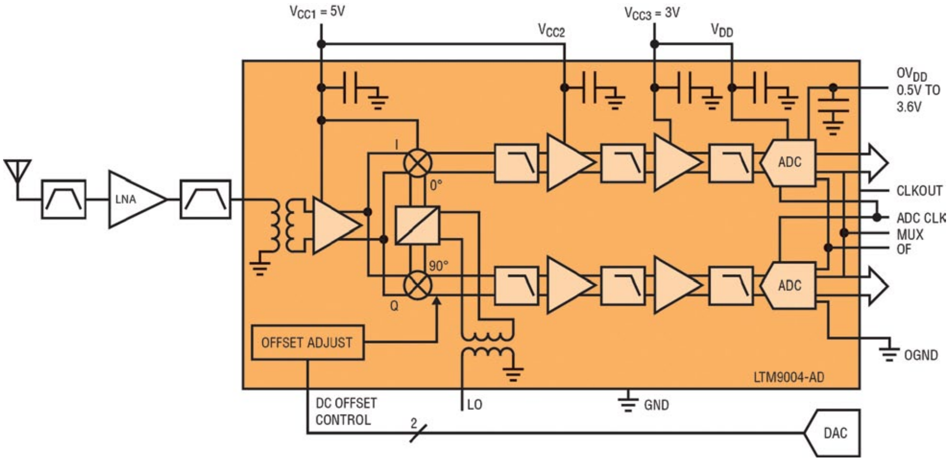

Figure 1: Direct conversion architecture implemented in the LTM9004 μModule receiver.

Design targets

The design target is a Universal Mobile Telecommunications System (UMTS) uplink Frequency Division Duplex (FDD) system, specifically the Medium Area Base Station in Operating Band I as detailed in the 3GPP TS25.104 V7.4.0 specification. Sensitivity is a primary consideration for the receiver; the requirement is ≤ –111 dBm, for an input SNR of –19.8 dB/5MHz. That means the effective noise floor at the receiver input must be ≤ –158.2 dBm/Hz.

Design analysis: zero-IF or direct conversion receiver

The LTM9004 is a direct conversion receiver utilizing an I/Q demodulator, baseband amplifiers and a dual 14-bit, 125 Msps ADC, as shown in Figure 1. The LTM9004-AC lowpass filter has a 0.2 dB corner at 9.42 MHz, allowing four WCDMA carriers. The LTM9004 can be used with an RF front end to build a complete UMTS band uplink receiver. An RF front end consists of a diplexer, along with one or more low noise amplifiers (LNAs) and ceramic bandpass filters. To minimize gain and phase imbalance, the baseband chain implements a fixed gain topology, so an RF VGA is required preceding the LTM9004. Here is an example of typical performance for such a front end:

- Rx frequency range: 1920 MHz to 1980 MHz;
- RF gain: 15 dB maximum;
- AGC range: 20 dB;
- Noise figure: 1.6 dB;
- IIP2: +50 dBm;
- IIP3: 0 dBm;
- P1dB: –9.5 dBm;
- Rejection at 20 MHz: 2 dB;
- Rejection at Tx band: 96 dB.

Given the effective noise contribution of the RF front end, the maximum allowable noise due to the LTM9004 must then be –142.2 dBm/Hz. Typical input noise for the LTM9004 is –148.3 dBm/Hz, which translates to a calculated system sensitivity of –116.7 dBm.

Typically, such a receiver enjoys the benefits of some DSP filtering of the digitized signal after the ADC. In this case, assume the DSP filter is a 64-tap RRC lowpass with alpha equal to 0.22. To operate in the presence of co-channel interfering signals, the receiver must have sufficient dynamic range at maximum sensitivity. The UMTS specification calls for a maximum co-channel interferer of –73 dBm. Note the input level for –1 dBFS within the IF passband of the LTM9004 is –15.1 dBm for a modulated signal with a 10 dB crest factor. At the LTM9004 input this amounts to –53 dBm, or a digitized signal level of –2.6 dBFS.

With the RF automatic gain control (AGC) set for minimum gain, the receiver must be able to demodulate the largest anticipated desired signal from the handset. This requirement ultimately sets the maximum signal the LTM9004 must accommodate at or below –1 dBFS. The minimum path loss called out in the specification is 53 dB, and assumes a handset average power of +28 dBm. The maximum signal level is then –25 dBm at the receiver input. This is equivalent to –14.6 dBFS peak.

There are several blocker signals detailed in the UMTS system specification. Only a specified amount of desensitization is allowed in the presence of these signals—the sensitivity specification is –115 dBm. The first of these is an adjacent channel 5 MHz away, at a level of –42 dBm. The level of the digitized signal is –11.6 dBFS peak. The DSP post-processing adds 51 dB rejection, so this signal is equivalent to an interferer at –93 dBm at the input of the receiver. The resulting sensitivity is –112.8 dBm.

The receiver must also contend with a –35 dBm interfering channel ≥10 MHz away. The IF rejection of the μModule receiver will attenuate it to an equivalent digitized signal level of –6.6 dBFS peak. With the DSP post-processing, it amounts to –89.5 dBm at the receiver input and the resulting sensitivity is –109.2 dBm.

Out-of-band blockers must also be accommodated, but these are at the same level as the in-band blockers which have already been addressed.

In all of these cases, the typical input level for –1 dBFS of the LTM9004 is well above the maximum anticipated signal levels. Note that the crest factor for the modulated channels will be on the order of 10 dB to 12 dB, so the largest of these will reach a peak power of approximately –6.5 dBFS at the LTM9004 output.

The largest blocking signal is the –15 dBm CW tone ≥ 20MHz beyond the receive band edges. The RF front end will offer 37 dB rejection of this tone, so it will appear at the input of the LTM9004 at –32 dBm. Here again, a signal at this level must not desensitize the baseband μModule receiver. The equivalent digitized level is only –41.6 dBFS peak, so there is no effect on sensitivity.

Another source of undesired signal power is leakage from the transmitter. Since this is an FDD application, the receiver described here will be coupled with a transmitter operating simultaneously. The transmitter output level is assumed to be ≤ +38 dBm, with a transmit to receive isolation of 95 dB. Leakage appearing at the LTM9004 input is then –31.5 dBm, offset from the receive signal by at least 130 MHz. The equivalent digitized level is only –76.6 dBFS peak, so there is no desensitization.

One challenge of direct conversion architectures is 2nd order linearity. Insufficient 2nd order linearity allows any signal, wanted or unwanted, to create DC offset or pseudo-random noise at baseband. The blocking signals detailed above will then degrade sensitivity if this pseudo-random noise approaches the noise level of the receiver. The system specification allows for sensitivity degradation in the presence of these blockers in each case. Per the system specification, the –35 dBm blocking channel may degrade sensitivity to –105 dBm. As we have seen above, this blocker constitutes an interferer at –15 dBm at the receiver input. The 2nd order distortion produced by the LTM9004 input is about 16 dB below the thermal noise, and the resulting predicted sensitivity is –116.6 dBm.

The –15 dBm CW blocker also gives rise to a 2nd order product; in this case the product is a DC offset. DC offset is undesirable, as it reduces the maximum signal the A/D converter can process. The one sure way to alleviate the effects of DC offset is to ensure the 2nd order linearity of the baseband μModule receiver is high enough. The predicted DC offset due to this signal is <1 mV at the input of the ADC.

Note that the transmitter leakage is not included in the system specification, so the sensitivity degradation due to this signal must be held to a minimum. The transmitter output level is assumed to be ≤ +38 dBm, with a transmit to receive isolation of 95 dB. The 2nd order distortion generated in the LTM9004 is such that the loss of sensitivity is < 0.1 dB.

There is only one requirement for 3rd order linearity in the specification. In the presence of two interferers, the sensitivity must not degrade below –115 dBm. The interferers are a CW tone and a WCDMA channel at –48 dBm each. These appear at the LTM9004 input at –28 dBm each. Their frequencies are such that they are 10 MHz and 20 MHz away from the desired channel, so the 3rd order intermodulation product falls at baseband. Here again, this product appears as pseudo-random noise and thus reduces the signal-to-noise ratio. The 3rd order distortion produced in the LTM9004 is about 20 dB below the thermal noise floor, and the predicted sensitivity degradation is < 0.1 dB.

Measured performance

Using the evaluation boards shown in Figure 2, the LTM9004-AC achieved excellent results as shown in Figures 3 and 4. The test set-up consisted of two Rohde & Schwarz SMA 100A signal generators for RF and LO, a Rohde & Schwarz SMY 01 generator for the ADC clock and TTE in-line filters.

The LTM9004-AC consumes a total of 1.83 W from 5 V and 3 V supplies. AC performance includes SNR of 72-dB/9.42-MHz and SFDR of 66 dB.

Conclusion

The LTM9004 exhibits the high performance necessary for UMTS base station applications, yet offers the small size and integration necessary for very compact designs. By utilizing SiP technology, the μModule receiver utilizes components made on optimum processes (SiGe, CMOS) and passive filter elements.

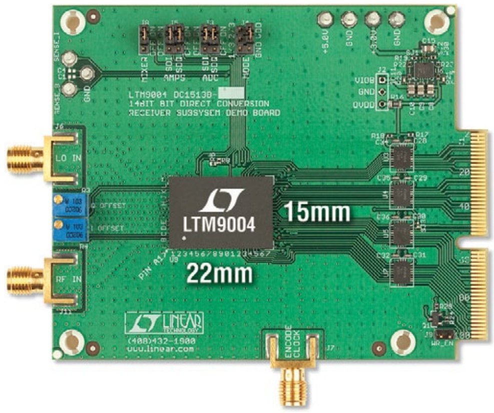

Figure 2: Minimal external required circuitry is required to build a complete receiver

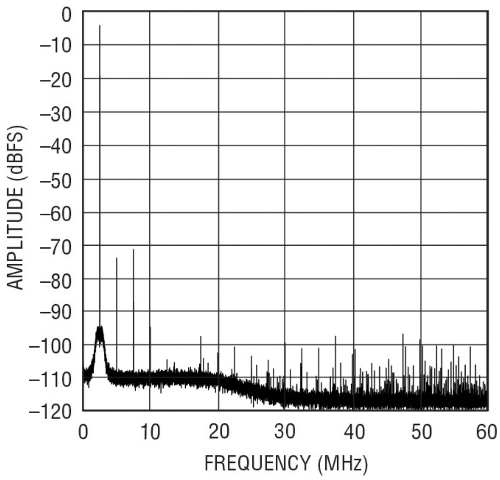

Figure 3: Single tone FFT

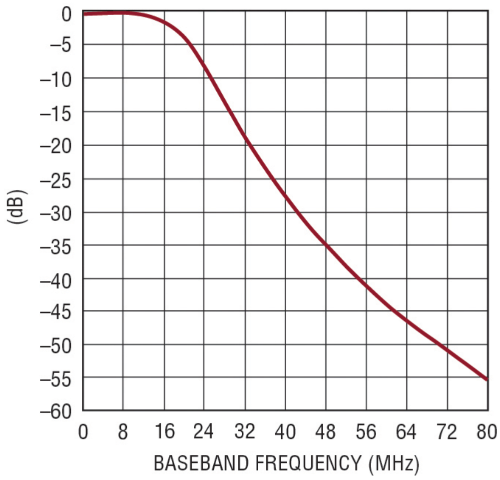

Figure 4: Baseband frequency response.

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Less is More: The New Mobile RF Front-End

By Steve Brown and Peter Carson, Qualcomm

The printed circuit board area inside of a smartphone has become the second most precious—and contested—real estate in the mobile landscape, right behind radio spectrum. Ironically, the proliferation of newly-added radio spectrum bands—aimed at alleviating bandwidth scarcity—is what has intensified the pressure on PCB space in smartphones. More bands demand more discrete RF front-end components such as power amplifiers, multiband switches, duplexers and filters, along with matching components. Add the demands for bigger screens, quad-core application processors, connectivity, batteries and add-ons, all wrapped up in thin sleek form factors, and it is clear there is no room to expand the space devoted to RF front-ends, even to accommodate the doubling or tripling of bands needed for global LTE roaming in a single-SKU design (see Figure 1).

The Qualcomm® RF360 RF front-end solution from Qualcomm Technologies Inc., (QTI) has been designed to address this issue, and others, with a highly integrated RF front-end combining essentially all the components between the modem and the antenna: an RF power amplifier integrated with the antenna switch, the transceiver, an antenna matching tuner and an envelope power tracker. This is a "360-degree" approach to simplifying and addressing multiple complex challenges to the cellular RF front-end, starting with band proliferation and extending across multiple performance and size enhancements so product appeal—as well as the significant production scale advantages of reducing unique SKU designs—can be maximized. Announced in February for OEM products anticipated to ship later in 2013, the front-end has been designed from the ground up as a full system solution that also works interactively with the device's modem, transceivers and sensors to deliver unique new performance gains.

Design approach

At the broadest technological level, the design primarily addresses the RF band fragmentation that comes with the expansion of 4G LTE (FDD and TDD) on top of continuing 2G and 3G coverage worldwide, and the need to support all the associated bands in a single device, or at least fewer SKUs and to do that without increasing the demand for space or compromising performance.

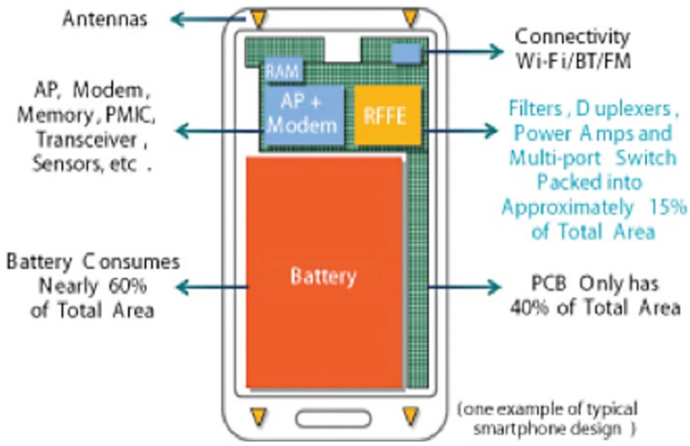

Figure 1: Limited PCB space in a typical smartphone.

At an economic level, it is also designed to enable production scale—and its dramatic cost benefits—for cellular device manufacturers. Instead of needing up to ten different designs to competitively support the required LTE band combinations around the world, an OEM may only need three, or even fewer, and the differences across those can be addressed without a change in board layout, or an increase in board space.

RF band proliferation with no increase in PCB space

The central RF challenge today is the proliferation of cellular bands worldwide—already 40 and counting—required to address exploding service demands and network capacity. This is compounded by the need to simultaneously launch multiple handsets to meet OEMs' desire to maximize their returns on product investments. This has pushed mobile device makers to develop multiple versions of each device model, each with smaller production unit potential, using legacy RF solutions that handle only a subset of bands or require multiple chipsets in a single device for greater regional coverage.

The Qualcomm solution addresses this RF band proliferation challenge with a single board-level SKU designed to work across any combination of modes and bands (all major cellular modes from GSM onwards and bands currently fully specified in 3GPP) that enables global roaming, particularly for 4G LTE. How is this possible, when no single RF solution can yet address all bands worldwide, without resorting to a brute force approach using a large number of discrete parts? It actually requires a combination of key technologies, all of which are integrated into the Qualcomm solution and optimized as an end-to-end system.

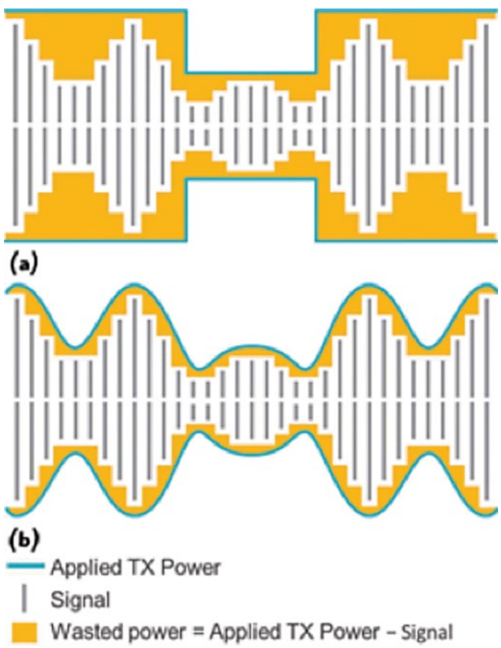

Figure 2: Power wasted with average power tracking (a) compared to power saved with power envelope tracking (b).

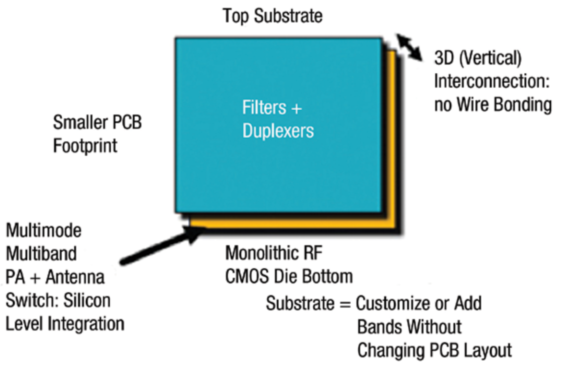

Figure 3: RF POP 3D design CMOS front-end.

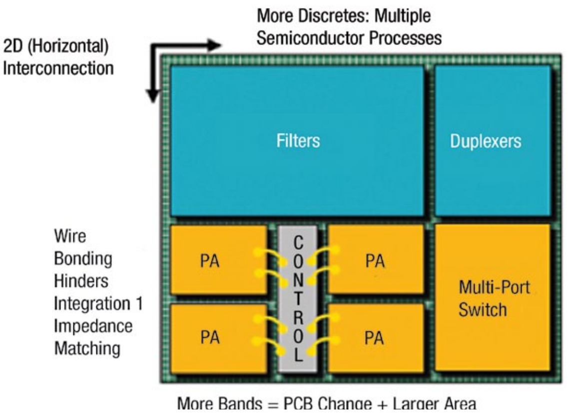

Figure 4: Side-by-side conventional RF front-end discrete design.

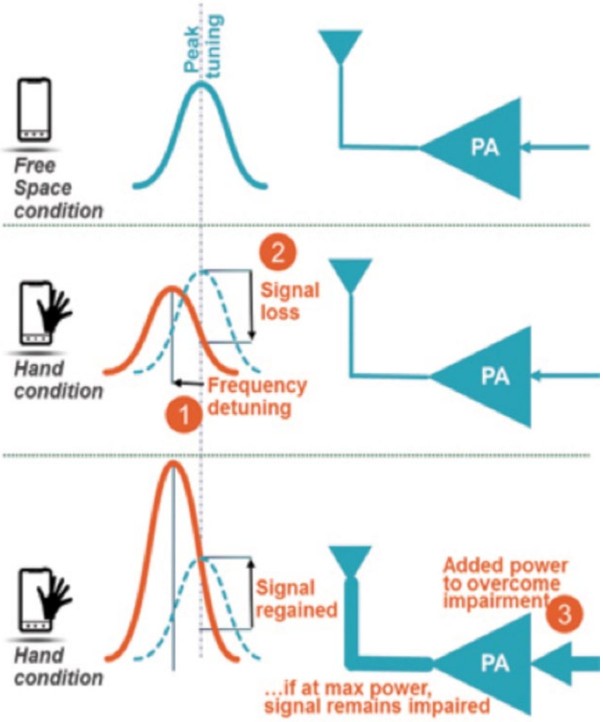

Figure 5 Conventional RF front-end de-tuning causes power increase or call drop.

Power envelope tracking

The first key technology is power envelope tracking (ET) that tailors the PA power supply to the instantaneous needs of the signal content being transmitted. It is an advancement over conventional average power tracking (APT), that adjusts the PA power supply on power level groupings instead of on the instantaneous signal need. The unused energy with APT not only wastes battery power, but also generates waste heat, creating added demands for space for dissipation of the heat (see Figure 2a). With envelope tracking, the transmission power supplied is tailored to the instantaneous needs of the signal content being transmitted (see Figure 2b).

Working interactively with the device's modem, the envelope power tracker adjusts transmission power to match instantaneous requirements of the content being transmitted, rather than adjusting after long intervals of constant power. This modem-assisted envelope tracking, the first in the industry for 3G/4G LTE, reduces power consumption by up to 20 per cent, and heat generation by almost 30 per cent (based on QTI testing and analysis). This extends battery life and reduces the thermal footprint inside the thin cavity of a smartphone.

Envelope tracking works with the modem to sense instantaneous power needs, and manages the PA. With CMOS-based PAs, the level of integration can be substantially increased, and points toward the idea of a fully integrated RF front-end system-on-chip. A system-on-chip means advanced 3D packaging techniques have now become possible for the RF front-end.

RF POP

The second key technology in the Qualcomm front-end solution is the industry's first stacked, 3D RF packaging, or RF POPTM solution, using advanced 3D packaging that integrates the single-chip multimode power amplifier and antenna switch (AS) into a base package, integrates the filters and duplexers onto a single substrate and then stacks the substrate on top of the base package into a single "3D" chipset combination, reducing overall complexity and eliminating the need for the wire bonding commonly used in today's RF front-end modules. The package containing the integrated PA and AS form the base substrate layer, and have a common footprint for all devices. The package containing the filters and duplexers is configurable for global and/or multi-regional band combinations and goes on top of the PA/AS base, much like a customizable "roof" over a universal foundation. The combination is one millimetre thick and uses half the board area of previous Qualcomm RF front-end solutions. Importantly, customizing devices for different regions does not require changes to the board layout since the base PA/AS layer can remain constant (see Figure 3).

This design is based on an architecture capable of supporting 700 MHz to 2.7 GHz LTE bands worldwide, along with legacy 2G/3G bands, and reduces local RF band customization to simplified variations in the "roof." With the RF POP approach, two to three PCB designs can now replace what would take a dozen or more designs otherwise to cover an OEM's worldwide needs, since multiple frequency configurations can use the same board layout. This creates the potential to drive LTE economies of production scale in much the same way that quad-band did for GSM and penta-band did for 3G.

In contrast, conventional PCB module-based solutions mix and match different technologies such as GaAs- and CMOS-based components device-by-device for an optimum solution within a single device's operating environment. Accommodating a broader array of environments is more complex, resulting in some cases in multiple solutions residing side-by-side within a single device. These side-by-side solutions require multiple PAs, depending on the band combinations being designed for, with more discrete chips and the associated wire bonding, which hinders integration due to introducing radiated interference and added impedance matching requirements. If more bands are needed, a board change is required, including the

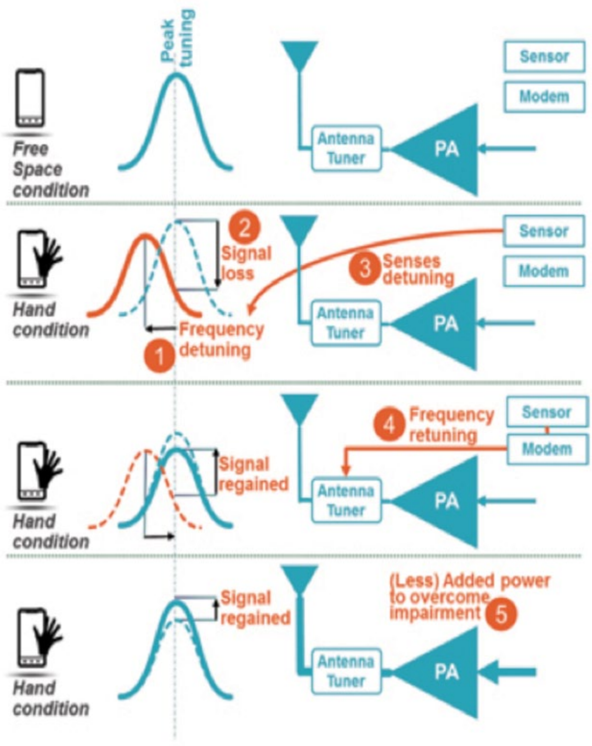

Figure 6: Qualcomm RF 360 de-tuning provokes re-tuning.

possibility of a size increase, and reducing the volume potential of each unique design (see Figure 4).

Adaptive antenna tuning

The third key technology is adaptive antenna tuning. One RF problem that has been exacerbated by thinner, sleeker device designs is that the much closer physical proximity of users' hands and head to the antenna causes the antenna to de-tune from the targeted frequency, losing signal with the base station beyond the signal attenuation caused by the physical impediment of the hand and/or head. The base station responds by instructing the device to increase transmission power to compensate for the lost signal. If more device transmission power is available, battery drain is increased. If the device is already at maximum transmission power, the call is compromised or dropped (see Figure 5).

In contrast, the Qualcomm system works with the device's sensors, which detect the antenna de-tuning and gain loss, and the modem directs the antenna matching tuner to re-tune to the correct frequency. This eliminates the need to increase power to compensate for off-frequency transmission, reducing the power increase to only that needed to compensate for the attenuation caused by the physical impediment (see Figure 6).

Power amplifier performance

The Qualcomm RF360 solution utilizes a comprehensive system design to enable an all-CMOS RF front-end, which historically has been judged inadequate to meet cellular power performance requirements, when compared to the module-based, GaAs/CMOS mixed technology approach. However, testing by QTI has demonstrated that—utilizing only the current generation power envelope tracking enabled by the CMOS integration—transmission power performance (power consumption for TX power produced) of the Qualcomm solution closely matches the profile of conventional power amplifiers using today's average power tracking across the broad range of transmission power levels (see Figure 7).

The Qualcomm solution with envelope tracking and the conventional average power tracking solution have small differences at different power levels. The system has been optimized for performance efficiency to deliver best in class talk time and data transmission across power ranges most used in real world experience (see Figure 8), based on QTI field data collected across commercial networks in rural California from 8 AM to 8 PM over seven days in 2013 and urban Los Angeles from 6 AM to 7 PM over one day in 2011, and closely matches the profile of conventional power amplifiers even outside of these most used ranges of transmission power.

When power performance is weighted based on real-world usage distribution patterns across high and low bands, the total power consumption using the Qualcomm RF360 solution is virtually identical to conventional PAs for rural settings and slightly better for urban settings (see Figure 9).

It is worth noting that these performance comparisons do not factor in improvements from the use of precision analogue circuitry to optimize PA and ET operation, for example, through the addition of multiple programmable gain states. Antenna tuning gains have also not

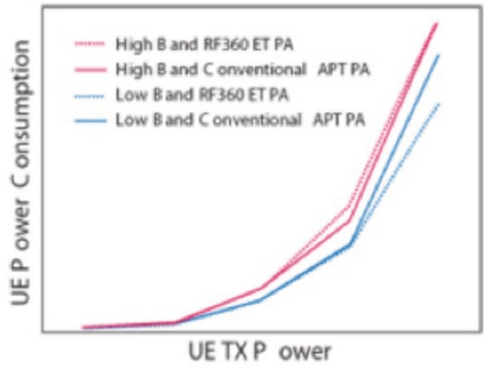

Figure 7: PA performance comparisons.

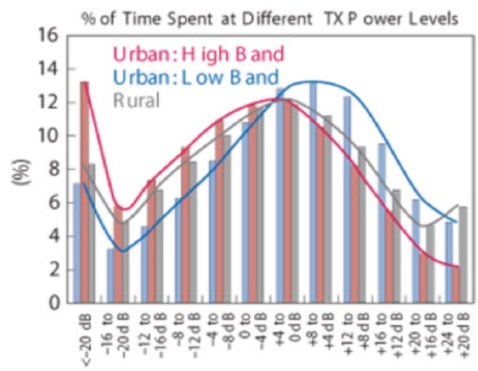

Figure 8: TX power usage patterns.

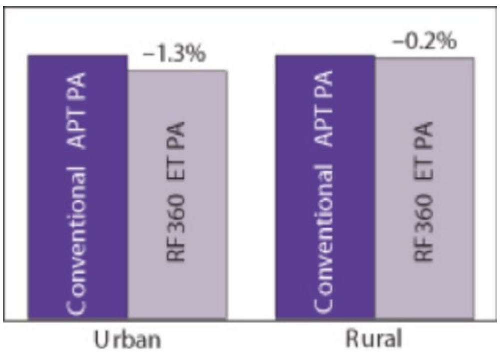

Figure 9: Usage-based total power consumption comparisons.

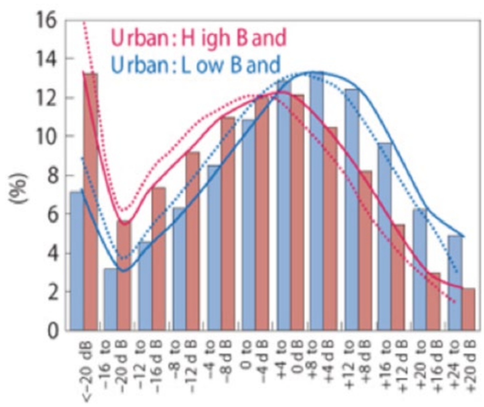

Figure 10: Shift in TX power usage patterns with antenna tuning.

been factored into the comparison. QTI Testing has shown a 2 dB gain contribution from antenna tuning, which would shift the frequency of TX power usage curves "left" by –2 dB in the usage patterns (see Figure 10).

Applying these shifted TX power usage frequency distribution patterns to the performance analysis would indicate additional improvements in total power consumption. So even without PA optimizations and antenna tuning gains, overall system performance meets today's requirements and is comparable in efficiency to existing front-end solutions, accomplished with a much smaller PCB space requirement and much greater RF band scalability.

Conclusion

The Qualcomm front-end is a collection of innovations:

- The first fully integrated monolithic die multimode, multi-band CMOS power amplifier with an integrated antenna switch
- The first stacked RF POP solution (3D packaging) that reduces the RF front-end footprint while enabling common board layout and simplified RF band customization or expansion
- The first CMOS power amplifier for LTE
- The first CMOS power amplifier with envelope tracking
- The first dynamic reconfigurable LTE multimode antenna tuner
- In total, the first fully integrated CMOS-based RF front-end, including everything between the modem and the antenna

The solution is focused on addressing the fact that worldwide LTE band proliferation has created a direct challenge to producing mobile devices at economic scale, and doing it within an extremely limited PCB space. The RF POP approach enables a common global board-level design, with simplified RF band expansion or customization, to help regain device design and production scale. Smaller RF front-end footprint, heat dissipation and size, along with longer battery life, help enable sleek, thin, powerful and efficient device designs. Plus, the solution is sampling now in order to meet the immediate challenges of establishing LTE economies of scale and global roaming.

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Reconfigurable antenna systems come to life with smarter handset designs

ByTero Ranta and Jill Olson, Peregrine Semiconductor Corporation

The concept of a reconfigurable antenna has a long history. In the days when HF radio carried important international traffic, and especially in the case of amateur radio operators "working" a wide range of HF bands, segmenting long radiating elements was an efficient way of using wire – and space. Reconnect a few plugs or change a feed point and you could cover an octave or more with, basically, one hardware installation. In principle, the challenge faced by some of today's systems is not very different.

The ultimate in reconfigurable antennas might be a software-defined antenna, in much the same way that software-defined radio allows configurable hardware to radiate and receive on a wide range of frequencies, and with a choice of modulation schemes. Such concepts have been proposed, and experimental systems designed with, for example, pixelated metallisation connected and shaped to operate as different modes of patch antennas. They are, for the time being at least, in the realm of advanced research and bear little resemblance to the very practical solutions to current RF challenges that are discussed here.

Why reconfigure an antenna? There are many possible scenarios, and different applications might require control of operating frequency, or radiation pattern, or other factors such as polarisation. The multi-element array of a phased-array radar can be considered a reconfigurable antenna in which altering the phase of the signal feeds to the different antenna radiators alters the beam direction. Take for example the mobile handset antenna. In this case the objective is to have the antenna maintain the same performance, or as close to it as possible, in terms of electrical match to the transceiver, and in its radiation pattern and radiation efficiency, with the key variable being its ability to operate at diverse frequencies.

Perhaps the greatest challenge is the addition of yet more bands to the RF spectrum, as designs progress from 3G to LTE and LTE-Advanced standards. Specifically, in the USA, the addition of the "low" spectrum at around 700 MHz has presented a further challenge to a development process that has already seen the applications of a considerable amount of ingenuity. Handset antennas have been in constant evolution. Fashion and what has become conventional design now dictates that only an internal antenna is acceptable, while external stub antennas lie in the past, and whip or wire antennas are ancient history.

As is well-known, almost every handset now hosts a variety of radios, to provide not only the communication function of the phone but also services such as wireless LAN (WiFi), Bluetooth, NFC, GPS and broadcast FM radio, although that band is often received using the earphone cable as an antenna. To accompany those radios, it is not uncommon to find as many as five antennas in a high-end handset.

With the highest band in use until recently being in the region of 2 GHz – full-wavelength 15 cm – it is immediately apparent that any form of traditional antenna with dimensions comparable to, say, a half-wave dipole are completely infeasible. The reason for re-stating that obvious fact is to emphasise that the cellular handset antenna has many man-years of experimentation and design embodied in it, with folded and shaped radiating elements and clever use of dielectrics. The antennas in today's phone will be capable of presenting a reasonable match to the transmitter output stage, and the receiver's input, over the existing bands, but without changes are likely not able to extend that performance to the 700 MHz band.

In seeking to increase the band coverage, an element of minimum-necessary-change applies. A further separate antenna would require more space, and the addition of a further path through the transmit/receive antenna switch. Since these highly-capable devices already offer up to 10-way switching (SP10T, and other configurations) any further complication is clearly best avoided if at all possible.

Further adding to pressures on handset designers is the move to MIMO (multiple-input/multiple output) configurations, which implies that diversity, with

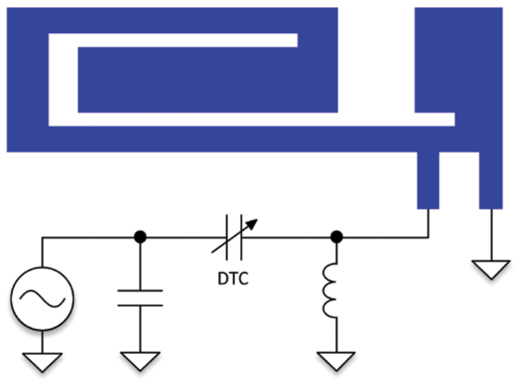

Figure 1: Smartphone antennas must operate with VSWR (voltage standing-wave ratio) figures of 2 – 3 (or worse); mismatches can be minimised by an Impedance Matching network.

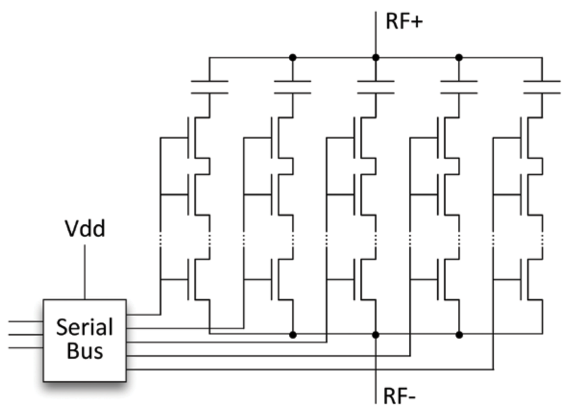

Figure 2: Digitally-tuned capacitors are implemented as a switched capacitor bank. The FET switches fabricated in the CMOS-on-insulator process have close to ideal low on-resistance, high off-state isolation and excellent linearity. The DTC can readily be fabricated to handle the signal peaks that will occur with high VSWR to the antenna.

duplication of front-end circuitry and antenna elements, has to be accommodated within the already-limited space available. Emerging designs for 4G/LTE-A envisage 4-way MIMO in the handset; the multiplicative consequences are readily apparent. LTE-A will also require carrier aggregation, concatenating the bandwidth of two channels to enable the system to deliver the advertised download speeds to consumers.

It is helpful to the design process for such a system if an individual antenna can serve as many as possible of the 41 distinct bands that next-generation systems will use, so that the total number of antennas needed in a handset can be kept from proliferating any more than is necessary. Reconfiguring the antenna(s) in this case therefore means antenna tuning, and there are two distinct aspects to the tuning function. The first is to match at any given operating frequency the transmitter output/receiver input impedance as closely as possible to the antenna itself. This can be achieved with an LC network that includes a variable component, as in Figure 1. An ideal candidate for this function is the Digitally Tunable Capacitor (DTC, Figure 2) fabricated using UltraCMOS® process. UltraCMOS technology is an advanced silicon-on-insulator process developed to produce a range of RF functional blocks that demonstrate desirable characteristics such as broad frequency range, silicon switches (pass transistors) with very low impedances in their on-state and high levels of isolation when off; and with excellent linearity leading to very low intermodulation products. The technology, which was described in more detail in a recent paper in this journal [1] lends itself to functions such as low-loss multi-way antenna switches, switched capacitor banks and others. DTCs are implemented using switched capacitor banks, offering fine-resolution capacitor value steps under logic control. Further, DTCs incorporate DuNE™ design methodologies to deliver high power handling and tuning excellence.

The performance of the switches largely defines that of the DTC. A useful metric is the product of the switch's channel resistance in its on-state, and the off-state capacitance, which is an aggregate of capacitance associated with the FET channel and parasitic capacitances. For the value $R_{on}.C_{off}$, therefore, smaller is better. The metric is a constant for a given process node in the chosen technology. As a resistance-capacitance product, the term has the units of time, and in the latest UltraCMOS process, values of 176 fsec are realised, which leads to very low losses right across the frequency bands used in today's mobile radio networks.

The DTC comprises an array of capacitors connected in parallel, with each path in the array being switched into circuit (or not) by a series-connected FET. Transistor on-state resistance determines the Q factor: reducing C_{off} increases Ron (because the product is a fixed value) and if that happens, the max-to-min tuning ratio diminishes. Therefore, in the DTC, tuning ratio is inversely proportional to Q. As is ever the case with RF impedance matching, the value of Q (current-generation SoS DTCs can achieve Q of 50 at 1900 MHz) has a direct bearing on how well the load impedance (in this case, the antenna) can be matched to the radio front-end's source impedance, and to the insertion loss achievable. Balancing these factors against the maximum tuning ratio, which will determine the spectrum covered by any single physical antenna, is just one of the compromises and trade-offs that must be considered by the radio system designer. A lower value of that key parameter R_{on}.C_{off} directly assists the designer. As the Smith-charts in Figure 3 reveal, a lower value substantially increases the range of impedances and frequencies over which a low-loss match can be realised.

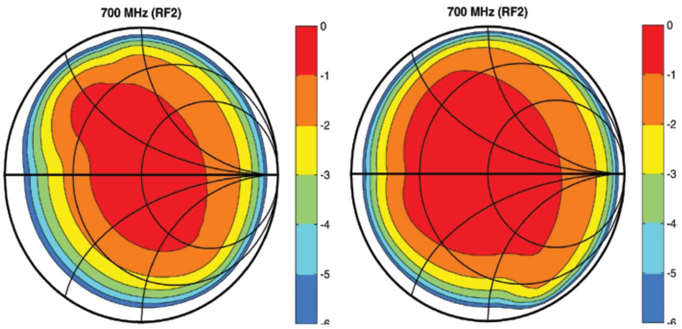

Figure 3: With UltraCMOS technology, fabrication in smaller process geometry leads directly to an improved R_{ON}.C_{OFF} metric, which in turn greatly increases the low-loss matching range, as denoted by the expanded red region on the chart.

Returning to the two basic techniques that are available to broaden the response of an antenna, the second (Figure 4) is that of altering the resonant frequency of the antenna itself; this is aperture tuning or band-switching. Altering the physical length of the radiating element is clearly impractical, so the technique focuses on adjusting the electrical length of the antenna by applying either a digitally tuned capacitor to load the antenna at a selected point, or a shorting switch. Here, too, the characteristics of semiconductor switches fabricated using UltraCMOS technology are an excellent fit to the application. In both variants, the added components must be low-loss in order not to degrade the radiation efficiency of the antenna, in either its loaded or original operating mode; results are potentially better than those of impedance matching, as the loaded antenna itself is tuned to the wanted frequency. The additional connection to the antenna is made away from the feed point, often at the maximum of the current pattern that flows within the radiating element. As that connection is into a low-impedance context, the on-resistance of the switch assumes a much greater importance in determining insertion loss than it does in a 50-Ω path.

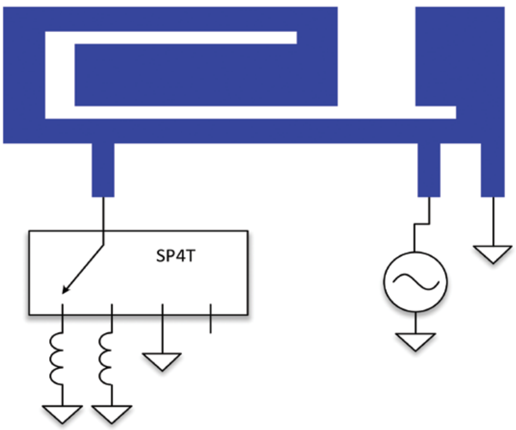

Figure 4: As the physical parameters of the antenna are fixed, in Aperture Tuning the electrical length of the antenna is adjusted to shift its resonance to match the operating band.

This has been demonstrated by modelling an inverted-F antenna (a configuration commonly used in cellular radio systems), loaded by a shorting connection to be resonant at 800 MHz. As might be anticipated, the lower the value of R_{on} in the shorting switch, not only does the radiated efficiency rise but the resonant peak of the entire antenna becomes broader, effectively increasing the useful coverage (Figure 5).

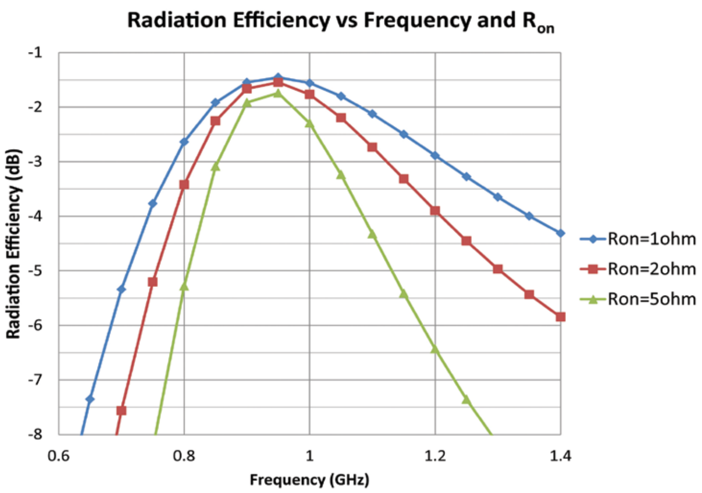

Figure 5: These simulation results depict an antenna adjusted by a shorting connection to operate at 800 MHz. The performance of the shorting switch (its on-resistance) directly affects the effective bandwidth around the resonant frequency.

What does this mean in practice? An established relationship (Wheeler's equation) links the physical volume needed for efficient operation of an antenna to frequency and channel bandwidth. To serve the 2-, 3-, and 4G bands in a typical handset needs around 43 cm^3. The equation contains an arbitrary constant that is characteristic of a particular antenna type and construction but in general, higher bandwidth at lower frequencies demands higher antenna volumes. This is exactly the situation imposed by opening a band at 700 MHz for 4G traffic. Calculations indicate that an untuned, non-reconfigurable, antenna using a realistic value for the arbitrary constant in the equation would require a volume that approaches that of an entire modern handset. The spectral efficiency of successive standards increases, but as the carrier frequency drops, that is more than offset by the larger physical dimensions required. The relationship of the terms in the equation indicates that a smaller antenna will handle a wider frequency range if its resonant frequency is made tunable. The antenna delivers superior performance within a narrower instan-

Antenna Type	F_{MIN} (MHz)	F_{MAX} (MHz)	BW (MHz)	Vol (cm^3)
Passive 3G	824	960	136	58
Passive 3G/4G	698	960	262	112
Tunable 3G/4G	698...834	834...970	136	58

Table 1: Antenna volume and bandwidth vs. antenna type, demonstrating that application of antenna tuning can allow handset designers to hold volume constant as they move to more advanced standards.

Process	$R_{ON}C_{OFF}$ [fs]
0.5 µm CMOS-on-Sapphire	768
0.35 µm CMOS-on-Sapphire	253
0.25 µm CMOS-on-Sapphire	176

Table 2: Values of $R_{on}.C_{off}$ achieved with fabrication in successively more advanced CMOS-on-insulator technologies suited to implementation of DTCs.

taneous bandwidth and the peak of that bandwidth is shifted as required by the tuning components.

Table 1 gives an indication of what may be achieved. These figures were derived by calculation from Wheeler's equation. Moving from a passive antenna that handles only 3G signals, in the established low-band frequency span of 136 MHz centred on 892 MHz, to a 3g+4G-capable design spanning an extra 126 MHz down to just under 700 MHz, doubles the volume. Moving to a tunable design delivers the needed performance while maintaining the status quo in terms of antenna volume. Radiation efficiency is better with the active versus the passive solution, by several percentage points over almost all of the RF spectrum of interest.

DTCs and SoS FETs continue to advance

Current state-of-the-art DTCs exhibit improved RF performance relative to early commercial versions. These performance improvements are primarily due to improved design techniques. Specifically, current DTCs exhibit improved Q, tuning ratio and CMIN. Additionally, redesigned bias circuitry in current DTCs eliminates the need for a regulated VDD and enables connection directly to the battery. Table 2 is based upon measured data and summarises the improvements found in current-generation DTCs.

The examples in this article have centred around the specific case of the multi-band smartphone. However, "smart" RF devices will proliferate in consumer, industrial, automotive and defence systems, to a far greater extent than we have experienced until now. To mention just one example, systems that accurately locate people and objects by RF means are forecast to see explosive growth. That implies beam-forming and beam-steering systems, and the close-to-ideal semiconductor switches described here are an excellent match to the task of configuring and feeding phased signal to multi-element antennas. Dramatic as the potential gains are, the tuning and band switching being designed into next-generation phones is likely only to be the start of what we will see in agile and reconfigurable antenna systems.

Reference:

Reference 1. "Tuning components enable better wireless performance", Richard Whatley and Duncan Pilgrim, Peregrine Semiconductor; Microwave Engineering Europe, www.microwave-eetimes.com/en/tuning-components-enable-better-wireless-performance.html?cmp_id=71&news_id=222902986

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Measuring E band microwave connections

By Dr. Wolfgang Wendler, Rohde & Schwarz

The growing volume of data traffic, due to the use of wireless devices, calls for high bandwidths for connecting base stations to the network. Two 5 GHz frequency bands between 71 GHz and 86 GHz are available in the E band for point-to-point connections. The high frequencies are a challenge for T&M equipment; not only when developing transmit and receive modules, but also when measuring transmission systems.

E band: extra bandwidth for more data

Over 30 years ago at the World Radiocommunication Conference WARC-79 in Geneva [1], the International Telecommunication Union (ITU) passed the decision to dedicate the E band frequencies from 71 GHz to 76 GHz and from 81 GHz to 86 GHz for transmission applications. It took more than 20 years before commercial interest in these applications emerged and led the US Federal Communications Commission (FCC) and European authorities to issue licenses for these bands and to specify the technical requirements for their use. The reason why interest finally evolved was that, by then, it had become possible to commercially manufacture components for this frequency range. At the same time the demand for increasing transmission rates made it necessary to use new frequency bands. Transmission links with data rates of several Gbit/s are no problem in the E band. The two frequency bands, each with a continuous range of 5 GHz, make transmission bandwidths of several 100 MHz possible. Combined with a simple modulation method such as BPSK, high data rates can be achieved. Consequently, it is possible to implement simple and reliable transmit and receive modules for these millimeter-wave connections. It goes without saying that more complex types of modulation may be used as this technology evolves. The achievable range in these frequency bands is only insignificantly shorter than for example in the 38 GHz band. This was proven with open field tests done in normal weather conditions with an attenuation of 0.5 dB/km [2].

The high frequencies pose new T&M challenges. Although licensing protects against interference from other microwave sources, the power and spectrum of the transmitters must be measured to ensure disturbance-free coexistence of licensed communications. The requirements for transmitters in this frequency range, especially for the radiated power (EIRP) spectrum density mask, are described in ETSI TS 102 524 V1.1 [3].

Spectrum measurements in the E band – harmonic mixers are essential

Spectrum analyzers are the most suitable instruments for these sophisticated measurements. However, commercially available spectrum analyzers have a continuous frequency range of up to 67 GHz only. To carry out spectrum measurements in the E band, they must be used together with external harmonic mixers. The mixers multiply the spectrum analyzer's local oscillator output signal and use a suitable harmonic to downconvert the millimeter-wave signal to be measured to the analyzer's intermediate frequency. However, the large number of harmonics created in the mixer and the input signal's harmonics produce a multitude of signals in the spectrum. The image frequency is not suppressed because there is no preselection.

This will not create any problems as long as only CW signals are present at the mixer's input. With this type of signal, the spectrum analyzer can tell the difference between real signals and unwanted mixing products and their image-frequency signals that are present at the mixer output. To enable this distinction, the analyzer conducts a reference measurement prior to the actual measurement. During the reference measurement, the local oscillator frequency is increased to a value that is twice the intermediate frequency. Only signals that are detected in the reference measurement and in the actual measurement are real signals and are displayed in the spectrum.

If modulated signals are present at the mixer input, the task is more complicated. The real signal and the signal received on the analyzer's image frequency may overlap each other, especially in the case of very wideband signals, so that it is no longer possible to tell them apart.

Figure 1 shows a spectrum measurement performed with a high-end signal and spectrum analyzer, which no longer belongs to the newest generation and has an intermediate frequency of 404 MHz. The frequency difference between the input signal and the image-frequency signal is 808 MHz. With this 500 MHz bandwidth input signal, it is just still possible to test if it complies with the EIRP spectrum density mask according to ETSI TS 102 524 V1.1, by subtracting the reference measurement spectrum from that of the actual measurement. If the input signal had a bandwidth of 1 GHz, that would

Spectrum measurement

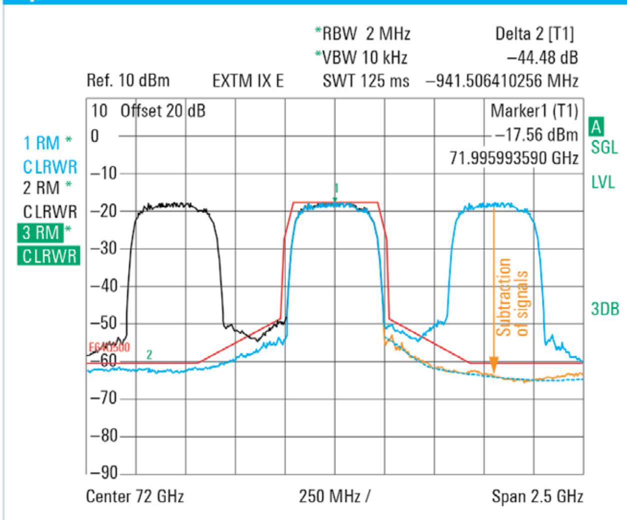


Figure 1: Measuring a 500 MHz bandwidth E band input signal with the R&S FSQ signal and spectrum analyzer. The blue curve shows the results of the actual measurement, the black curve represents the reference measurement. It is apparent that the image signal, which has a frequency positioned above that of the input signal, can still be subtracted (orange curve). This would not be possible with 1 GHz bandwidth input signals.

no longer be possible because the input signal and image-frequency signal would superimpose on each other. The influence of the image-frequency signal would strongly distort time domain analysis of the signal (I/Q data), where correction using a reference measurement is not possible.

Spectrum analysis: able to handle wideband-modulated signals

Modern signal and spectrum analyzers such as the R&S FSW equipped optional LO/IF connectors for external mixers have a major advantage compared to conventional instruments. With an intermediate frequency of 1.3 GHz, the analyzers have an image-free frequency range of 2.6 GHz. This makes it easy to measure the EIRP spectrum density mask of wideband-modulated signals, even if their bandwidth reaches into the GHz range. Together with the harmonic mixers from Rohde & Schwarz, e.g. the R&S FS-Z90 (60 GHz to 90 GHz), the achievable dynamic range is truly unique. The mixer has a typical conversion loss of 23 dB at 80 GHz, resulting in a displayed average noise level (DANL) of approximately –150 dBm/Hz for the complete test setup, including the R&S FSW. A 1 dB compression point of nominally –3 dBm results in a dynamic range sufficient for measuring the spectrum mask. The ETSI technical specification defines a value of 50 dB. The R&S FS-Z90 harmonic mixer is also equipped with an isolator at the input, which makes a VSWR of typically 1.4:1 possible. Power measurement errors due to reflections at the input resulting from mismatch are typically reduced by a factor of 5 compared to mixers without isolators.

Figure 2 shows the measurement of the same signal of an E band microwave connection as Figure 1. The 500 MHz bandwidth input signal and the image signal are 2.6 GHz apart, and it is possible to measure if the spectrum is within the prescribed mask (red line). The required dynamic range of at least 50 dB is also easily achieved with this setup.

The R&S FSW can measure the spectrum as well as the modulation quality. Its optional high analysis bandwidth of up to 320 MHz makes it possible to capture wideband signals, demodulate them with the vector signal analysis option and to analyze the modulation quality.

Figure 3 shows the analysis of a 300 MHz bandwidth QPSK signal.

The error vector magnitude (EVM) as a measure of the modulation quality, as well as the frequency error, the symbol rate error and many more parameters can be measured. The R&S FSW signal and spectrum analyzer displays the results in tables or graphs. For example, the phase and amplitude are displayed in a constellation diagram, which delivers a visual impression of the modulation quality.

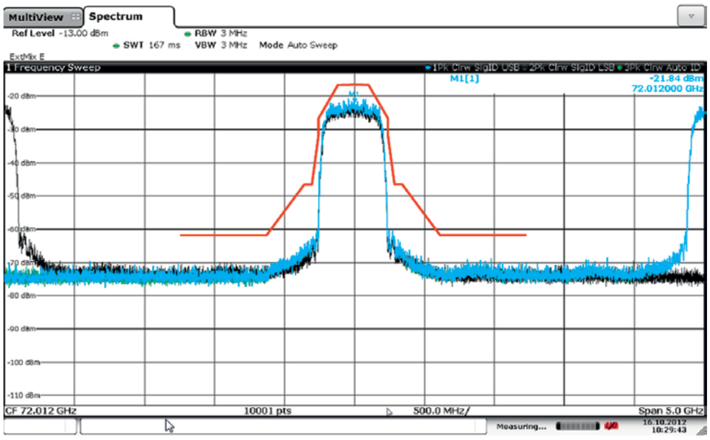


Figure 2: Measurement of the same signal as in Figure 1 with the R&S FSW signal and spectrum analyzer. The input and image-frequency signal are 2.6 GHz apart. Measuring the spectrum mask or analyzing the modulation quality of significantly wider signals is possible without any difficulty.

Figure 3: Modulation analysis of a 300 MHz bandwidth QPSK signal. Besides graphic displays, e.g. the constellation diagram or input signal versus time, values displayed in tabular form offer information about the modulation quality at a glance.

Summary

E band microwave connections are becoming more and more popular due to the constantly growing demand for higher data volumes to be transmitted. This range offers the highest achievable data rates of all available wireless transmission technologies. A spectrum analyzer with an external harmonic mixer is required to measure the spectrum. The R&S FSW signal and spectrum analyzer's high intermediate frequency offers a wide image-free range. The low conversion loss of the Rohde & Schwarz harmonic mixers provides a high dynamic range, and the good matching results in high power measurement accuracy. This makes the R&S FSW together with the R&S FS-Z90 harmonic mixer a peerless solution for spectrum measurements in the E band.

References

[1] Radiofrequency Use and Management, Impacts from the World Administrative Radio Conference of 1979, WARC-79, chapter 4, overview, actions and impacts, page 77.

[2] ITU-R P.676-6, Attenuation by atmospheric gases, 2005.

[3] ETSI TS 102 524 V1.1. Technical Specification: Fixed radio systems; point-to-point equipment; radio equipment and antennas for use in point-to-point millimeter-wave applications in the fixed services (mmw FS) frequency bands 71 GHz to 76 GHz and 81 GHz to 86 GHz.

The Rohde & Schwarz FSW signal and spectrum analyzer.

Outdoor redundant line amplifiers

ensure continuous operation of satcom systemss points

Designers of satellite communication systems can help to prevent disruption to signal transmissions by using a range of redundant line amplifiers now available from Link Microtek.

Manufactured by US company MITEQ, the robustly constructed RL-W series of amplifier systems are built for outdoor use and provide redundancy in a choice of 1:1, dual 1:1 or 1:2 configurations.

In the event of a fault condition or when initiated by an operator-generated command, the system automatically switches the standby amplifier into the satcom link while removing the original amplifier from the signal path, thereby ensuring continuous operation.

The RL-W systems can be specified with 17 different satcom bands covering frequencies from 950 MHz to 33 GHz. Performance figures for the standard units are a 30 dB minimum gain and a +10 dBm minimum power output (at 1 dB compression), and these can be optionally uprated to 40-dB/50-dB and +15-dBm/+20-dBm if required.

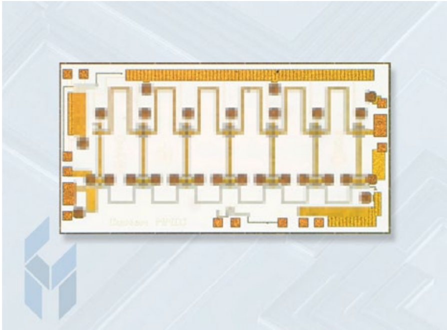
Remote control is provided as standard via a user-selectable RS485/RS422 interface, while contact-closure, RS232 and 10/100Base-T Ethernet interfaces are also available as options.

www.linkmicrotek.com

Positive gain slope amplifier

operates from DC to 20 GHz

Custom MMIC has added the CMD192 to their growing MMIC library of standard products. The CMD192 is a wideband DC to 20 GHz GaAs MMIC distributed amplifier available in die form. This amplifier



delivers greater than 20 dB of gain with a corresponding output 1 dB compression point of + 22 dBm and a noise figure of 2.8 dB at 18 GHz.

Unlike most distributed amplifiers, the CMD192 has a positive gain slope with increasing frequency, thus compensating for the higher frequency losses typical of other components in a system. In addition, the use of on-chip tracking circuits ensure consistent performance over temperature and process variation. The device is a 50 Ohm matched design that requires minimal off-chip components to complete the bias network, which is typical of this amplifier topology.

The CMD192 is suitable for microwave radio and VSAT, telecom infrastructure, test instrumentation, and military and space applications.

www.CustomMMIC.com

Ultra wideband antenna

dual polar, sinuous spiral

The SSA0218RL/2044 sinuous, spiral antenna is particularly suitable for security, surveillance and EW applications. Its rugged, machined housing makes it ideal for harsh environments. Ultra wideband, frequency covers 2 to 18 GHz.

All development engineering and manufacture has been carried out in the UK which means that the product is not subject to ITAR.

Directional, the beamwidth is 65° to 95° in azimuth and elevation, with a maximum Beam Squint of only ±4 degrees to -3 dB points across the band.

Dual circular (Right and Left Hand) polarisation over the entire band means that there is no likelihood of any frequency being missed at any polarisation.

The very good, consistent, monotonic radiation patterns enable Direction Find (DF) systems to provide accurate Angle of Arrival data when using amplitude comparison techniques. Amplitude-matched sets of antennas can be provided.

Phase-matched sets of antennas can be provided, with support radiation pattern data, to allow high resolution DF.

The antenna measures 84mm (3.3-inches) by 67mm (2.6-inches) diameter, weight 250 grams (8.8 ounces).

www.cobham.com

Variable attenuators

for distributed antenna systems, available in high volumes

Trilithic now stocks high volume quantities of variable step attenuators with a frequency range of DC to 3 GHz, and 50 dB of attenuation in 1 dB steps, that enable DAS RF power levels to be appropriately adjusted for the DAS head-end equipment.

These ruggedized infrastructure attenuators deliver attenuation accuracy: ±0.25 dB over DC to 1 GHz, ±0.35 dB over 1 to 2 GHz and ±0.5 dB over 2 to 3 GHz. Insertion loss is: 0.6 dB over DC to 1 GHz, 1.0 dB over 1 to 2 GHz and 1.5 dB over 2 to 3 GHz.

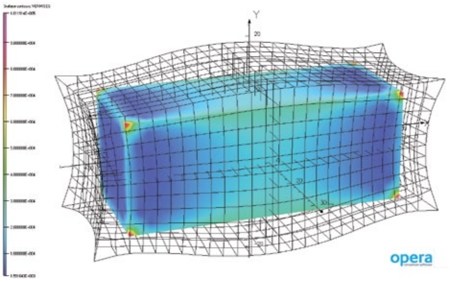
VSWR is: 1.3:1 maximum over DC to 1 GHz, 1.4:1 maximum over 1 to 2 GHz, and 1.5:1 maximum over 2 to 3 GHz.

Other features include average power of 2 W to 25° C ambient temperature and 1 kW peak power (5 µs pulse width; 0.5% duty cycle), RoHS compliance, and SMA female connectors.

http://rfmicrowave.trilithic.com

EM design software

leverages parallel processing to boost multiphysics analysis



Cobham Technical Services has released a new version of its Opera electromagnetics and multiphysics design software that enables design engineers to considerably accelerate analysis time. By harnessing the parallel processing capabilities of multi-core processors, computational time can be significantly reduced using Opera-3d version 16.

Designed for use on standard office-grade PCs, Opera-3d version 16 contains numerous enhancements to take advantage of the multi-core processor architecture offered by many of today's computers. One of the advanced features in Opera-3d is the extremely accurate method it uses to represent coils. This feature is widely used by scientists and engineers to model complex devices with up to several hundred coils, which can be computationally intensive. The run-time of such complex simulations can be much faster with the latest Opera version; for instance, four-times faster using a PC with a quad-core processor has been achieved.

Opera version 16 further extends the multiphysics capabilities of Opera-3d. Electromagnetic, thermal and stress analysis simulation now operate seamlessly, enabling results from one type of simulation to automatically pass to other simulation types. Users can set up a chain of analyses of the same model and solve them sequentially. Shape deformation caused by forces acting on a model can be employed across different types of simulation; the deformed mesh from stress analysis can be nominated for use in subsequent electromagnetic or thermal analyses.

www.OperaFEA.com

Low-loss flexible microwave coaxial cable assemblies

Delivering up to 88% velocity-of-propagation, Temp-Flex air-dielectric ultra-low-loss flexible microwave coaxial cables exceed stringent aerospace and defence specifications. Molex has launched a line of microwave cable assemblies that uses its Temp-Flex flexible microwave coaxial cables featuring a patented dual monofilament air-enhanced design and a helically wrapped shield. The Temp-Flex coaxial cables achieve 85 to 88 percent velocity of propagation (VOP) for increased signal speed.

Molex coax cables provide stable electrical performance with minimal impedance and insertion loss variation in dynamic applications. A consistent manufacturing processes ensures the smallest mechanical tolerances in 0.047-, 0.086-, and 0.141-inch shield OD constructions. The flexible microwave coaxial cables offer 100 dB or greater shielding effectiveness and protect signals from internal and external interference. The reliable return-loss performance of the Temp-Flex coaxial cables optimises VSWR characteristics for the complete end-to-end interconnect.

www.molex.com/link/tempflex/microwavecoax.html

Digital radio test set

features a low phase noise RF signal generator

Aeroflex Incorporated has announced the introduction of the 3920B digital radio test set for Analog AM and FM, Digital P25, P25 Phase II, DMR, NXDN™, dPMR, TETRA and TEDS technologies.

The 3920B features a new low phase noise RF signal generator in addition to the already advanced functionality available on the Aeroflex 3900 Series radio test sets. The 3920B is the direct replacement for all versions of the Aeroflex 3900 Series, including the 3901, the 3902, and the 3920.

The low phase noise RF signal generator provides enhanced spectral purity with SSB phase noise specified at -110 dBc/Hz at 10 kHz offset. This level of performance is achieved at an offset from the carrier that is significantly less than the industry standard for this type of specification, which is typically 20 kHz The ability of the 3920B to achieve such low phase noise specifications close to the carrier, makes the 3920B an ideal test solution for today's digital narrowband or analog receiver testing where narrowband phase noise is critical.

www.aeroflex.com

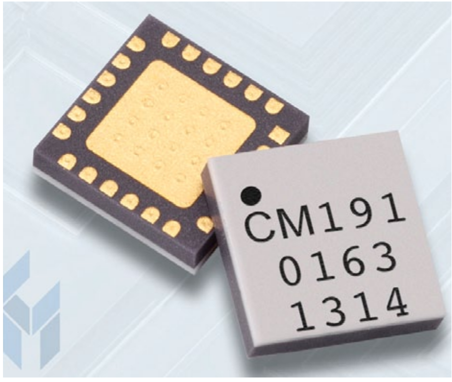
4-10 GHz driver amplifier

delivers high output power

Custom MMIC announces the addition of the CMD191C4 to their growing MMIC library of standard products.

The CMD191C4 is a GaAs MMIC driver amplifier housed in a leadless, RoHs compliant, 4x4 mm surface mount package. It offers high output power and low current consumption.

Ideally suited for complex communications systems where small size and high linearity are needed, the device operates from 4 to 10 GHz and delivers 20 dB



of gain with a corresponding output 1 dB compression point of greater than +21 dBm. It is a 50 ohm matched design, which eliminates the need for external DC blocks and RF port matching.

The CMD191C4 is biased with a single 5.0 V positive drain supply. RF power can be applied at any time.

Suitable applications include WiLAN, C and X Band communications systems, and military end-use.

www.CustomMMIC.com

Antenna grade laminates

offer improved performance

Rogers Corporation Advanced Circuit Materials Division recently introduced improved high frequency materials to address several market needs.

The improved RO4700JXR™ Series antenna grade laminates were designed for use in base station, RFID and other antenna designs and combine low-loss dielectric with low-profile copper foil for reduced passive intermodulation (PIM) and low insertion loss. The specially formulated RO4700JXR thermoset resin system incorporates a hollow microsphere filler resulting in a light weight, low density laminate, which is approximately 30% lighter weight than woven-glass PTFE materials. In addition, RO4725JXR™ (2.55Dk) and RO4730JXR™ (3.0 DK) laminates provide a lower cost solution for high frequency circuit boards used in base station and other antennas.

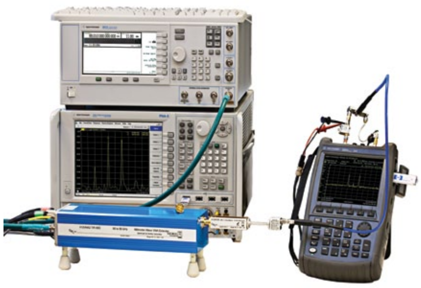
RO4700JXR laminates feature a low Z-axis coefficient of thermal expansion (CTE of <30 ppm/ºC) for design flexibility. With a TCDk <40 ppm/ºC, the laminates provide consistent circuit performance regardless of short term temperature variations. They feature the same high glass transition temperature (Tg) as the company's other high-performance RO4000® laminates, greater than 280ºC, making them lead-free and automated assembly compatible.

RO4700JXR series RoHS-compliant laminates are compatible with standard PCB fabrication techniques and plated-through-hole (PTH) processing. Designed for base station and other RFID antennas, the proprietary, halogen-free laminates support longer drill tool lifetimes than other filled materials, reducing fabrication costs.

www.rogerscorp.com

Millimeter wave IMD measurements

with single connection workflow



OML introduces millimeter wave intermodulation distortion (IMD) measurements to target emerging gigabit applications such as WirelessHD, WiGig, 802.11ad and E-band point-to-point radios.

In these applications, the linearity of amplifiers and transceivers can adversely affect bit error rate, especially those involving higher order modulation. Due to waveguide constraints, IMD has been nearly non-existent on the millimeter wave (mm-wave) frontier until now. For the first time, OML can thoroughly characterize mm-wave devices for S-parameters, gain compression and IMD.

IMD is an industry standard technique that reveals the linearity of an amplifier using a two-tone approach. With optional IMD, the standard VNA module adds a source module and coupler for handling the two-tone prerequisite. The main tone functions to characterize S-parameters and gain compression while the new second tone is easily available for IMD measurements. The twotones and their IMD products reveal the linearity of the device: smaller products correspond to better linearity. Engineers can also calculate the third order intercept (TOI) for third, fifth, seventh and ninth order products.

Adoption of emerging amplifiers depends on cost. By combining measurement capabilities, OML addresses emerging requirements for single connection workflow (e.g., on-wafer) that can also reduce manufacturing cost.

www.omlinc.com/find/imd

Surface mount OCXO

holds tight stabilities down to 5 ppb

Fox Electronics offers the FTM series of surface mount OCXOs that is ideally suited as the timing reference for network synchronization.

The SMD OCXO offers specifications suitable for communication equipment, including base stations, radio network controllers, wireless backhaul equipment and routers as well as gateways, PON (Passive Optical Network), DSLAM (Digital Subscriber Line Access Multiplexer), multi-service switching platform and transmission equipment.

The oscillator provides a standard stability of ±10 ppb across a set of standard frequencies in the 5 MHz to 40 MHz range with temperatures from -40°C to +85°C and stabilities as tight as ±5 ppb available, depending upon operating conditions. The FTM also has a frequency control pin that allows a minimum of ±0.7 ppm of frequency adjustment.

The SMD oscillator comes with a 3.3 Vdc supply voltage, with 5 Vdc as an option, and operates at a maximum of 1.2 W at 25°C. Output load is typically 15 pF and long term aging over 10 years is only 0.4 ppm for all effects.

www.foxonline.com

EMI test receiver

for standard-compliant EMC testing up to 26.5 GHz

Rohde & Schwarz has expanded its successful ESR family by adding a model for up to 26.5 GHz. This means that high measurement speeds and comprehensive diagnostic tools are now also available for EMC certification testing in line with the FCC standard and measurements in line with military standards.

The ESR26 EMI test receiver covers the frequency range from 10 Hz to 26.5 GHz. It performs conducted or radiated certification measurements in line with commercial standards such as EN, CISPR and FCC as well as military standards. The North American FCC standard and the CISPR standard both specify EMI measurements up to 18 GHz.

Thanks to its broadband architecture, the ESR26 performs standard-compliant disturbance measurements up to 6000 times faster than other testers. EMI measurements that took hours in the past can now be completed in just seconds, saving users valuable time on the way to obtaining desired results.

In addition, the instrument offers comprehensive diagnostic tools to support design engineers. The persistence mode allows users to clearly differentiate between pulse and continuous disturbances. It displays the probability of amplitudes occurring at specific frequencies using different colors, making it possible to detect disturbances that are hidden by broadband signals. The frequency mask trigger responds to specific events within a disturbance spectrum. If the mask is violated, a trigger is activated. The measurement is stopped, and the user can analyze the disturbance and its effect.

www.rohde-schwarz.com

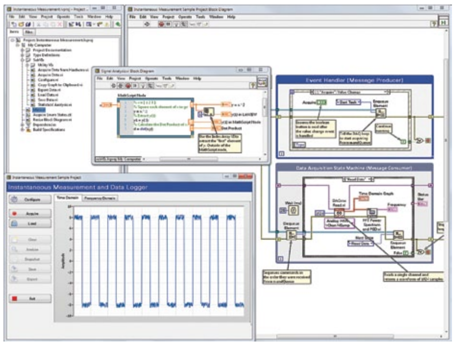
LabVIEW 2013

focuses on innovation rather than infrastructure

National Instruments has introduced LabVIEW 2013, the latest version of its industry-leading design platform. Users can take advantage of the most advanced technologies without rewriting their applications or learning new tools. LabVIEW 2013 also offers overhauled sample projects and an expanded training library that serve as a strong foundation for any undertaking.

"LabVIEW 2013 utilises the most current and powerful technologies, making it a necessity for any developer," said Ray Almgren, Vice President of Marketing at National Instruments. "Not only does it support the NI Linux Real-Time OS, giving developers access to dynamic, community-sourced libraries, it's the foundation of the new cRIO-9068 software-designed controller."

Making designing complex, web-based systems more intuitive, LabVIEW 2013 allows users to more easily create, debug, and publish LabVIEW Web services.



LabVIEW 2013 includes simplified block diagram comment navigation and organisation. It also provides access to the LabVIEW Tools Network, an expansive network of third-party add-ons.

www.ni.com/labview

UltraCMOS antenna switches

boost performance in 4G LTE-Advanced mobile applications

Peregrine Semiconductor has announced that it is expanding its family of MultiSwitch™ STeP8 dual single-pole, seven throw (SP7T/SP7T) UltraCMOS® antenna switches optimized to solve the significant carrier aggregation challenges of 4G mobile wireless applications as adopted by leading RF front-end module suppliers such as Murata Manufacturing.

The PE42128x devices support simultaneous multi-band operation of up to 14 frequency bands while delivering exceptional linearity, insertion loss performance and small size.

The LTE-A protocol calls for carrier aggregation – or the simultaneous reception of multiple frequency bands – which improves data delivery speed to dramatically improve consumer experience. The

PE42128x antenna switches are designed specifically to solve the challenges of carrier aggregation. Each of the latest MultiSwitch devices features an innovative combination of two SP7T switches in a single IC to support 14 different frequency bands including simultaneous multiband operation.

With HaRP™ technology enhancements, the PE42128x devices deliver high linearity with an IIP3 of +75 dBm, as well as extremely low insertion loss (0.35 dB at 900 MHz; and 0.45 at 1900 MHz) and high isolation (38 dB at 698-2170 MHz; and 33 dB at 2500-2690 MHz).

The switches also feature industry-leading 2fo and 3fo for LTE of less than -80 dBm at 700 MHz. High linearity and isolation performance are critical in LTE-Advanced Smartphones to ensure that radio signals don't spill into other bands during multi-band operation.

www.psemi.com

Ultra-broadband 2-way power dividers

up to 50 GHz

Pasternack Enterprises has introduced a line of ultra-broadband power dividers capable of 50 GHz. These millimeter wave power dividers (also referred to as RF power splitters) are ideal for use in radar systems, electronic warfare equipment, fiber optic systems, 10G Ethernet and any application that requires high frequency, multi-octave performance.

The company is offering three configurations of broadband power dividers including two with 2.92 mm connectors, one of which is a low VSWR version. Both 2.92 mm power dividers are capable of frequencies ranging from 10 GHz to 40 GHz and are rated to 10 W maximum input power. The third option is a 2.4 mm power divider capable of 10 GHz to 50 GHz and also has a power rating of 10 W. All three high frequency power dividers are Wilkinson 2-way designs utilizing a compact package that offers low insertion loss and phase stability across their broad operating range.

The 40 GHz and 50 GHz power dividers have a maximum insertion loss of 1.5 dB and VSWR of 1.6. These ultra-broadband power dividers have a typical phase balance of 6 degrees and carry a maximum isolation rating of 15 dB. These 2-way RF power dividers are RoHS compliant.

www.pasternack.com

Compact high power GaN SSPAs

Diamond Microwave has announced ultra-compact high power solid state power amplifiers in the X-Band and Ku-Band, which are ideal for use in demanding defence, aerospace and communications applications.

These solid-state power amplifiers are based on GaN devices, and offer state-of-the-art pulsed power performance coupled with a power-to-volume ratio that the company believes to be among the highest in the industry for such products.

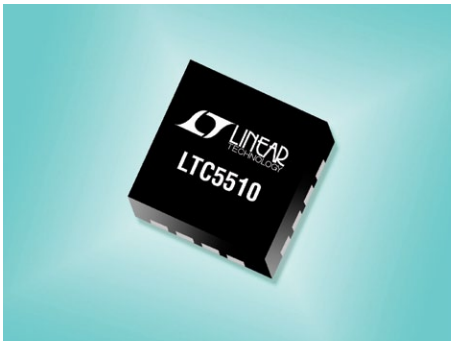
Pulsed power output levels of up to 150 W have been achieved. The designs are flexible in layout and architecture, and are fully customisable to meet individual specifications for electrical, mechanical and environmental parameters. Amplifiers with pulsed power outputs in excess of 1 kW, and with multi-octave bandwidths, are also under development.

An example of a Ku-band amplifier was displayed on the company's booth at the International Microwave Symposium (IMS 2013), having a peak pulsed output power of 125 W at 16.5 GHz and a 1 dB bandwidth of 1.5 GHz in a space outline that is similar in size to a smartphone.

www.diamondmw.com

Wideband mixer offers high linearity

with 50 Ohm matched input from 30 MHz to 6 GHz



The LTC5510 form Linear Technology is a high performance mixer with very wide frequency range, extending to 6 GHz. It provides a continuous 50-Ohm matched input from 30 MHz to 6 GHz, while delivering outstanding linearity and gain flatness. These features enable applications to work over a wider frequency span without needing to rematch the input for different frequency bands, thereby reducing cost and simplifying design.

Additionally, the LTC5510's output can reach up to 4.5 GHz, allowing the device to be used either as an upconversion or downconversion mixer, making it highly versatile. The mixer has excellent linearity performance of 27.8 dBm OIP3 as an upconverting mixer, and 24.9 dBm IIP3 as a downconverting mixer at 2 GHz. Moreover, its conversion gain of 1.1 dB and noise figure of 11.6 dB produce outstanding dynamic range performance for robust radios.

The LTC5510 employs an active mixer core with an on-chip LO buffer. Its LO input requires only 0 dBm drive levels. Additionally, the device has excellent input and output isolation. For example, in downconverting mixer applications, the LO signal leakage to the RF input is only -70 dBm. This low level leakage minimizes or eliminates external filters.

www.linear.com

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Don't miss Europe's premier microwave conference event. The 2013 week consists of three conferences and associated workshops:

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- **European Radar Conference (EuRAD): 9th - 11th October 2013**
- **Workshops and Short Courses from 6th October 2013**

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Please see the Conference Registration Rates table on the back page for complete pricing information.
All payments must be in Euros – cards will be debited in Euros.

Online registration is open now, up to and during the event until 11th October 2013

DELEGATES

Registering for the Conference

- Register online at www.eumweek.com
- Receive a confirmation email receipt with barcode
- Bring your email, barcode and photo ID with you to the event
- Go to the Fast Track Check In Desk and print out your delegate badge
- Alternatively, you can register onsite at the self service terminals during the registration opening times below:
  - Saturday 5th October (16.00 – 19.00)
  - Sunday 6th October (07.30 – 17.00)
  - Monday 7th October (07.30 – 17.00)
  - Tuesday 8th October (07.30 – 17.00)
  - Wednesday 9th October (07.30 – 17.00)
  - Thursday 10th November (07.30 – 17.00)
  - Friday 11th November (07.30 - 10.00)

Once you have collected your badge, you can collect the conference proceedings on USB stick and delegate bag for the conferences from the specified delegate bag area by scanning your badge.

CONFERENCE REGISTRATION INFORMATION

EUROPEAN MICROWAVE WEEK 2013, 6th - 11th October, Nuremberg, Germany

Register Online at www.eumweek.com

ONLINE registration is open from 1st June 2013 up to and during the event until 11th October 2013.
ONSITE registration is open from 16:00h on 5th October 2013.
ADVANCE DISCOUNTED RATE (until 6th September) STANDARD RATE (from 7th September & Onsite)

Reduced rates are offered if you have society membership to any of the following: Eu*M*A, GAAS, VDE, IET or IEEE.

Eu*M*A membership costs: Professional € 25/year, Student € 15/year.

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students less than 30 years of age and Seniors 65 or older as of 11th October 2013).

ADVANCE REGISTRATION CONFERENCE FEES (UNTIL 6 SEPT)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 420	€ 100	€ 550	€ 130
EuMIC	€ 325	€ 90	€ 430	€ 120
EuRAD	€ 280	€ 80	€ 370	€ 110
2 Conferences				
EuMC + EuMIC	€ 600	€ 190	€ 790	€ 250
EuMC + EuRAD	€ 570	€ 180	€ 740	€ 240
EuMIC + EuRAD	€ 490	€ 170	€ 650	€ 230
3 Conferences				
EuMC + EuMIC +EuRAD	€ 730	€ 270	€ 960	€ 360

STANDARD REGISTRATION CONFERENCE FEES (FROM 7 SEPT AND ONSITE)

CONFERENCE FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 550	€ 130	€ 720	€ 170
EuMIC	€ 430	€ 120	€ 560	€ 160
EuRAD	€ 370	€ 110	€ 490	€ 150
2 Conferences				
EuMC + EuMIC	€ 790	€ 250	€ 1030	€ 330
EuMC + EuRAD	€ 740	€ 240	€ 980	€ 320
EuMIC + EuRAD	€ 650	€ 230	€ 850	€ 310
3 Conferences				
EuMC + EuMIC + EuRAD	€ 960	€ 360	€ 1260	€ 480

WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
	Standard	Student/Sr.	Standard	Student/Sr.
1/2 day WITH Conference registration	€ 80	€ 60	€ 110	€ 80
1/2 day WITHOUT Conference registration	€ 110	€ 80	€ 150	€ 110
Full day WITH Conference registration	€ 120	€ 90	€ 160	€ 110
Full day WITHOUT Conference registration	€ 160	€ 120	€ 210	€ 150

Proceedings on USB Stick

All papers published for presentation at each conference will be on a USB stick, given out FREE with the delegate bags to those attending conferences. For additional USB sticks the cost is € 50.

DVD Archive EuMC

DVD Archive EuMC 1969-2003	FREE
DVD Archive EuMC 2004-2008	€ 10

Partner Programme and Social Events

Full Details and contacts for the Partner Programme and other Social Events can be obtained via the EuMW website www.eumweek.com.

SPECIAL FORUMS & SESSIONS					
Date	**Time**	**Title**	**Location**	**No. of Days**	**Cost**
Tues 8th & Weds 9th October	Tues: 13:50h - 17:40h Weds: 08:30h - 17:40h	The Defence & Security Forum	Room St. Petersburg	2	FREE
Mon 7th & Tues 8th October	08:30h - 17:40h	European Microwave Student School	Room Oslo	2	€ 40
Thurs 10th & Fri 11th October	08:30h - 17:40h	European Microwave Doctoral School	Room Oslo	2	€ 80