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**Antennas**

**Power Amplifiers**

The European journal for the microwave  
and wireless design engineer



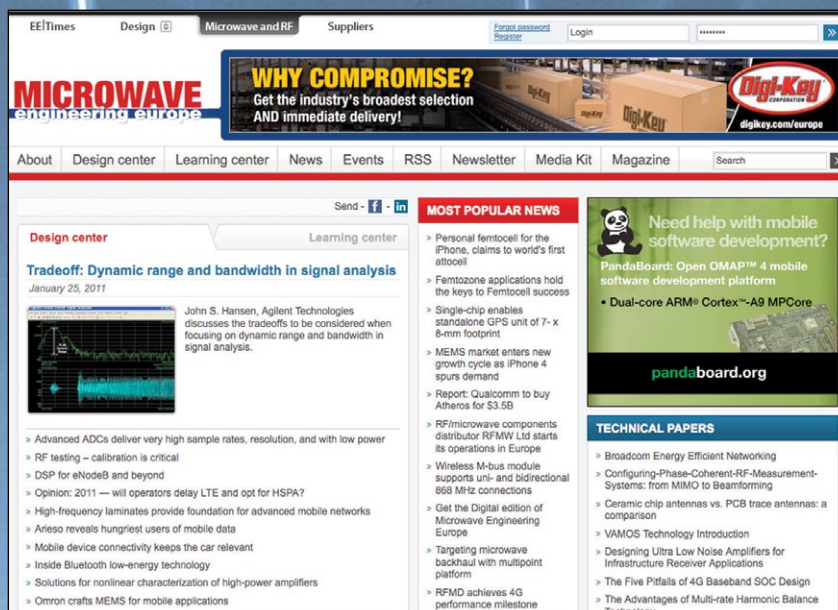
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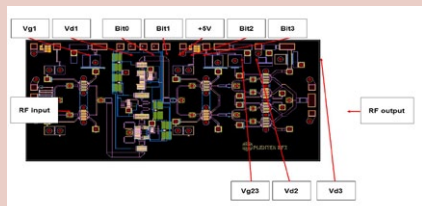
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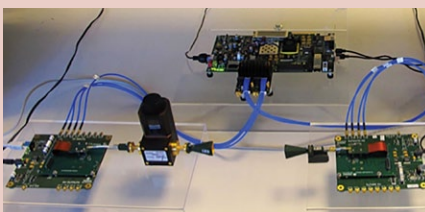
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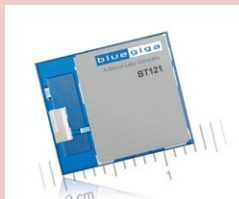


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## Solid state RF to revolutionize cooking and catering

One hears a lot about microwave ovens being useful for warming things up rather than cooking food. In fact, even the traditional TV dinner either ends up with a cold centre or overcooked at the edges. Now imagine a microwave oven that can cook a whole meal heating the different parts at different rates and intensities so that vegetables, meat and pasta and rice are cooked exactly right — but leaving the ice-cream ice cold!

Not only that, such an oven could be connected to the Internet or IoT, or read a smart RFID tag on a prepared dinner and know exactly how to cook the meal in a minimal amount of time.

Freescall Semiconductor recently introduced its vision for a radically innovative appliance concept that leverages solid-state radio frequency technology to revolutionize cooking. Developed in partnership with global product strategy and design firm frog, this breakthrough proof of concept will help enable fresh, chef-quality meals available at home with virtually no effort or prep time.

With the convenience of a microwave and quality of a traditional oven, this smart, connected RF cooking concept can control where, when and how much heating energy is directed into food — enabling more precise cooking for dramatically improved consistency, taste and nutrition. This fine-tuned heating capability helps prevent overcooking, which can destroy nutritional content, reduce moisture and waste energy. Solid state RF cooking technology can also enable appliance OEMs to create products capable of cooking multiple dishes and items at the same time within the same

appliance, significantly simplifying meal preparation.

By precisely controlling the location, cycles, and levels of cooking energy, the appliance will bring food from a raw or frozen state to a cooked temperature rapidly and without intervention. With the addition of convection heating to enable browning and crisping, the oven concept can also support a wide array of cooking types and qualities, from searing to browning to baking to poaching.

“Consumers worldwide are strapped for time but still want nutrient-rich, high quality meals at home,” said Paul Hart, senior vice president and general manager for Freescale’s RF business. “They will no longer need to choose between quality and convenience. Imagine not only having ready-to-cook, gourmet meals delivered to your door, but achieving restaurant-quality results in mere minutes.”

With the emerging IoT, the era of the smart homes and smart cooking is beginning to take shape. This breakthrough paves the way for a host of new business models and opportunities, including internet-driven home delivery of freshly prepared meals from a variety of sources — including restaurants, grocery stores and farm-to-table cooperatives — all quickly and easily cooked in the appliance. The concept also holds the broader potential of improving food supply chain efficiency by collecting and transmitting Big Data sets which can contribute to more efficient food distribution, targeted services and enhanced products.

Further, the concept appliance’s solid state RF power technology keeps form factors small, allowing for stylish, modern countertop designs. Manufacturers are free to imagine and create highly differentiated design

geometries, features, and functions.



**Freescall’s breakthrough cooking appliance concept will enable fresh, chef-quality meals at home with virtually no effort or prep time. (Photo: Business Wire)**



## Business models of mobile devices damaging the environment

Researchers from the University of Surrey have analysed studies on the lifespan of mobile devices, from manufacture, use and disposal to see what impact each stage had on the environment, and have concluded that the current mobile business model, driven by frequent upgrades, is costing both the manufacturer and the environment. The research has been published in the International Journal of Life Cycle Assessment.

The study argues that where frequent upgrades are encouraged and recycling schemes not actively pursued, valuable materials integral to phone manufacture are lost, causing damage to the environment by additional waste to landfill as well as from the impact of extracting additional finite resources.

"There are an estimated 85 million unused phones in the UK," said lead author Dr James Suckling from the University of Surrey. "Each of these phones has been manufactured using precious metals such as gold, copper and silver

which are costly to extract, both in cash-terms and environmental impact. These unused phones contain approximately 4 tonnes of gold, lost resource that would cost £110million and an equivalent of 84,000 tonnes of CO<sub>2</sub> released into the atmosphere to replace."

As an alternative, the researchers propose a 'cloud-based product service system', where the heavy processing and memory storage of mobile devices are moved to a remote server, over the internet. Without the need for complex processing, mobile devices could become less complex, designed to last longer and requiring less precious resources to make. Together with a "take-back" clause in the mobile service contract, researchers believe that consumers would be encouraged not only retain their device for longer, but to return it to the manufacturer at the end of the service contract. This would be instrumental in ensuring that the resources tied up in mobile phones are retained and not lost to landfill.

## NPS-400 EZchip selected for ZTE carrier routers

EZchip Semiconductor Ltd., has announced that ZTE Corporation has selected EZchip's NPS-400 network processor for its next-generation carrier router line cards.

The ZTE routers that will utilize the NPS-400 will benefit from its high throughput, advanced functions and greater flexibility. The NPS-400 will allow ZTE to offer customers higher port densities at lower power, as well as the ability to deliver new high-value services and features, with time to market advantages.

The NPS is architected to address the next generation of smart high-performance carrier and data-center networks. It provides packet processing simplicity and flexibility through C-based programming, a standard toolset, support of the Linux® operating system, large code space, and a run-to-completion or pipeline programming style. A comprehensive library provides source code for a variety of applications to speed customer's design cycle.

[www.ezchip.com](http://www.ezchip.com)  
[www.zte.com.cn](http://www.zte.com.cn)

## Making hackers obsolete

Cybersecurity is a big and growing problem for smartphones, tablets and the emerging IoT. Data breaches end up costing businesses, government agencies and individuals billions of dollars in damages and destroying trust and reputations.

Global Data Sentinel (GDS) claims to have the answer to this pertinent

problem with its ability to provide retroactive security to remove access to email and files even after they have left a company's network; prevent ransomware, a malicious code that locks up computer files until ransom is paid; and work across multi-devices, including PCs, Macs, smartphones and other mobile devices, such as medical equipment, printers/scanners, and other peripherals.

According to Steven Fadem, Chairman of Global Data Sentinel, "It is clear that hackers will not be stopped until the information that they obtain is rendered

useless to them because they can't access or store it. GDS encrypts data to ensure that it is inaccessible to the hacker even after it has left a company server or has been downloaded to a computer."

GDS provides encryption of all data whether it is at rest, in transit or in storage. It allows for storage of files and databases that can be integrated with existing appli-



cations. In addition, GDS has proprietary hardware that integrates with its software to provide secure data streaming to and from any device. It is highly functional, detailed and intuitive for non-technical personnel to use easily. GDS clients

are able to track file access, user access, adoption rates, and task management workflow with completely tamperproof auditing. It provides proprietary apps that maintain encrypted data containers on all Window, iOS and Android platforms.

[www.globaldatasentinel.com](http://www.globaldatasentinel.com)

## RF MEMS tuner designed into LTE phones

Cavendish Kinetics says its RF MEMS switch is gaining design wins as a tuning element for antennas in multiband LTE smartphones. The switch, designated SmarTune is shipping in 5 or more models where it can help phones address both the 2 GHz band required in China and the 700/800MHz bands required by European and North American operators.

These RF MEMS tuners outperform traditional SOI-based antenna tuners by 2 to 3 dB which results in data rates that are twice as high and improved battery life. Optimising the MIMO performance in smartphones further improves user data rates and network efficiency.

The SmarTune RF MEMS switch has been designed into the Nubia Z9 smartphone from ZTE for dual antenna optimization, Cavendish said. This was necessary because the screen extends to the edge of the device leaving little room for antenna. The RF MEMS switch can be used to shift the resonant frequency of multiple narrow-band antennas.

[www.cavendish-kinetics.com](http://www.cavendish-kinetics.com)



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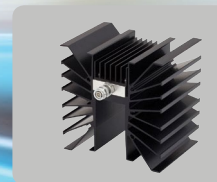
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## Researchers call for reform of safety standards for millimeter-wave devices

Recently NYU researchers — NYU Polytechnic School of Engineering doctoral student Ting Wu, NYU WIRELESS Director Theodore “Ted” Rappaport, and Christopher Collins, a professor of radiology at the NYU Langone School of Medicine — published “The Human Body and Millimeter-Wave Wireless Communication Systems: Interactions and Implications,” detailing their study, which used four models representing different body parts (both clothed and unclothed) to evaluate the thermal effects of mmWave radiation on humans.

Their simulation showed the steady state temperature increases — even of clothed parts with less blood flow such as the forehead of a person wearing a hat — are negligible compared with the environmental temperature variations when the exposure intensity is similar to that likely to be used in a next-generation cellphone. This is not the same as ionizing radiation such as gamma and X-rays, which cause genetic mutations. However, their paper called for temper-

ature changes in the tissues of the body to be used as a safety metric for mobile devices operating at mmWave frequencies, rather than power density, now the standard.

“Because future devices will operate on a spectrum with different properties than today’s communications devices, FCC rules and regulations on safety must be reviewed and adjusted accordingly,” says Rappaport, who is the founder and director of NYU WIRELESS, the first university center to combine wireless engineering, computing, and medical applications research and home to pioneering experimentation with the mmWave spectrum. “Additionally, current safety rules regarding radio frequency exposure don’t specify limits above 100 GHz, but because spectrum use will inevitably move to these bands over time, safety metrics must also be codified at these frequencies.”

<http://nyuwireless.com>  
<http://engineering.nyu.edu>

## GreenTouch improves energy efficiency in wireless networks by more than 10,000 times

GreenTouch™, the global consortium dedicated to dramatically improving the energy efficiency of data communications networks, has announced its final results and unveiled new tools, technologies and architectures to improve the energy efficiencies of communications networks in years to come.

During a celebratory event in New York, GreenTouch revealed that its new approaches can improve energy efficiencies of mobile-access networks by more than 10,000X — an achievement far exceeding the original goals of the working group.

The consortium also announced research that will enable significant improvements in other areas of communications networks, including core networks and fixed (wired) residential and enterprise networks. With these energy-efficiency improvements, the net energy consumption of communication networks

could be reduced by 98% from 2010 to 2020 while accounting for significant traffic growth. This savings is equivalent to the greenhouse gas emissions of 5.8 million cars.



Thierry Van Lan-degem, chairman, GreenTouch commented, “With the public release of tools and technologies that industry and academia can use now to design and deploy more energy-efficient

communications networks today and in the future. Our work will not only enable a more productive and sustainable future, but will also help many more people to connect with one another.”

GreenTouch was formed in 2010, driven by the vision and leadership of Bell Labs, the industrial research arm of Alcatel-Lucent.

[www.greentouch.org](http://www.greentouch.org)

## Startup to develop neural network front-end for wireless sensor systems

Analog Computing Solutions is developing a neural network IC that monitors sensor data for key events and thereby allows microcontrollers to stay in sleep mode until required. The company is aiming at improving battery life in wireless sensor applications by reducing the communication and data storage requirements. The chip architecture allows detection and identification of randomly distributed events.

ACS was awarded an STTR Phase I grant in July 2014 for the development of a configurable analog circuit for use with myoelectric prosthetics. A portion of the effort will be done in collaboration with Indiana University Purdue University Indianapolis Biomedical Engineering Department. Such an analog network can help save power in applications from neural spike detection in prosthetic devices to heart arrhythmia detection to engine misfire detection and on to gesture recognition and multi-sensor signature detection.

[www.analogcomputingsolutions.com](http://www.analogcomputingsolutions.com)

## LTE subscriber base to hit 1.4 billion by year-end

Market research firm ABI Research estimates that there will be nearly 1.37 billion 4G LTE subscribers worldwide by year-end 2015, up from nearly 650 million in 2014. The firm forecasts that the LTE subscriber base will exceed 3.5 billion by 2020, demonstrating a 5 year CAGR of 20.8%. The exponential rise in LTE points-of-presence covered justifies the need for sustained investment in LTE infrastructure, which is expected to grow nearly 10% year-on-year.

Major carriers in the United States are still investing heavily in LTE technology to consolidate their networks. Verizon Wireless is partnering with Ericsson to deploy small cells or micro-basestations to densify its network capabilities, with nearly US\$500 million allocated for small cells deployment.

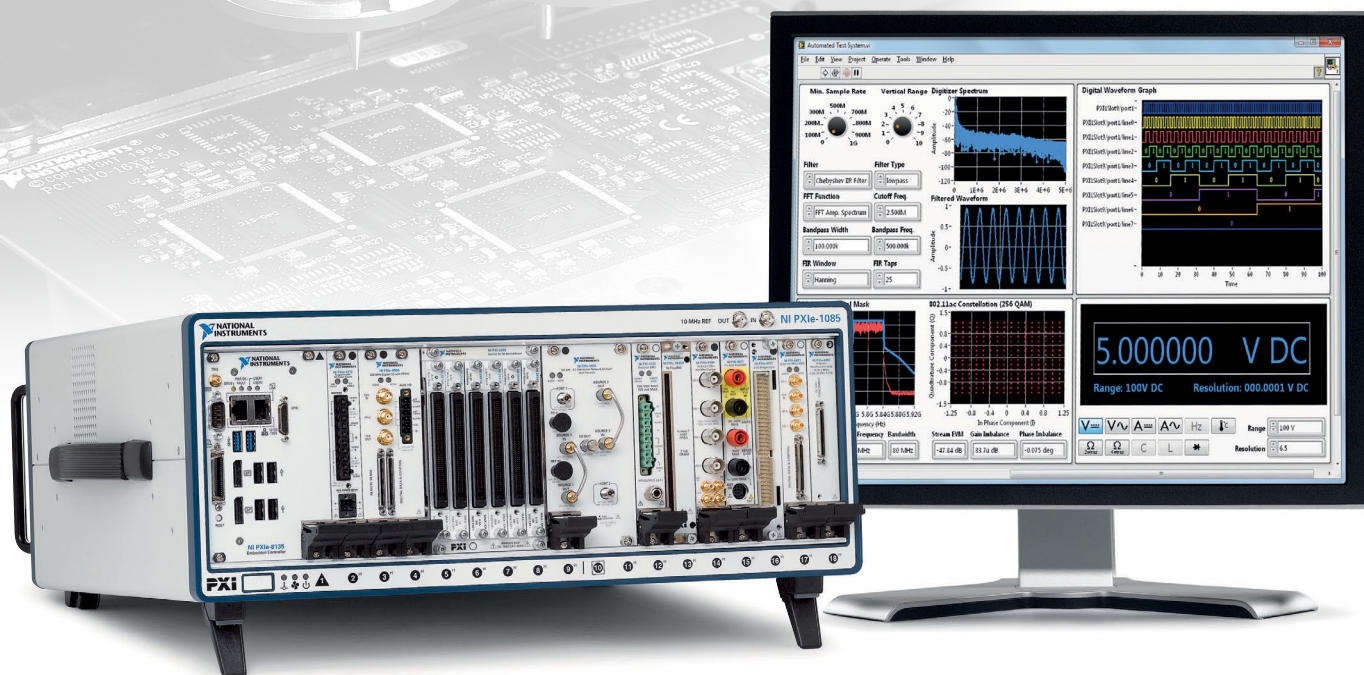
Similarly, T-Mobile US is also partnering with Nokia Networks to explore small cell deployments that operate using LTE-Unlicensed technology.

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## Wasted energy can keep smartphone running 30 percent longer

The Ohio State University has found a way to make smartphone batteries last up to 30 percent longer on a single charge, by capturing wasted RF energy and feeding it back to battery.

The patented circuitry converts some of the radio signals emanating from a phone into direct current (DC) power, which then charges the phone's battery. This technology can be built into a smartphone case, without adding more than a trivial amount of bulk and weight.

Some of the inventors, all engineering researchers at Ohio State, are working with a spin-off company to further develop the technology and will launch a Kickstarter campaign in June for market validation and fund development.

"When we communicate with a cell tower or Wi-Fi router, so much energy goes to waste," explained Chi-Chih Chen, research associate professor of electrical and computer engineering. "We recycle some of that wasted energy back into the battery."

There are some products newly on the market that harvest stray radio signals to charge tiny wireless devices such as temperature sensors. But the Ohio State invention is many times more powerful and efficient, said Robert Lee, professor of electrical and computer engineering.

"These other devices are trying to harvest little bits of energy from the air," Lee said. "Our technology is based on harvesting energy directly from the source. They can capture microwatts or even nanowatts (millionths or billionths of a watt), but cell phones need milliwatts (thousandths of a watt) or higher."

By Lee's reckoning, nearly 97 percent of cell phone signals never reach a destination and are simply lost. Not all of it can be recaptured, but some can.

"No one can charge a cell phone from the air, but we can reduce power consumption by retrieving some of those lost milliwatts. Think of it as a battery extender rather than a charger," Lee said.

[www.osu.edu](http://www.osu.edu)

## Toshiba and Microsoft to deliver sensor-data-driven IoT applications

Toshiba and Microsoft have signed a memorandum of understanding (MOU) to jointly develop systems for the Internet of Things (IoT). Leveraging Toshiba's innovative IoT devices with Microsoft's Azure IoT Cloud infrastructure, Toshiba will deliver state of the art sensor-data-driven applications in various market segments starting in calendar year 2015.

In this partnership, Toshiba will provide XaaS (X as a Service) making use of its extensive in-house technologies such as ApP Lite™ (Application Processor Lite), in-vehicle driving recorders, sensors and cloud storage services and Microsoft will provide IaaS (Infrastructure as a Service), private line services (Azure ExpressRoute) and advanced analytics (Azure Machine Learning) as part of Microsoft Azure (collectively, "Azure").

Together the companies will offer innovative IoT enterprise systems, starting with the transportation and logistics market.

<http://toshiba.semicon-storage.com>

## WiFi can be used to count people in a designated space

Researchers in UC Santa Barbara professor Yasamin Mostofi's lab have demonstrated that a WiFi signal can be used to count the number of people in a given space, leading to diverse applications, from energy efficiency to search-and-rescue.

"Our approach can estimate the number of people walking in an area, based on only the received power measurements of a WiFi link," said Mostofi, a professor of electrical and computer engineering. This approach does not require people to carry WiFi-enabled telecommunications devices for them to be counted, Mostofi emphasized.

To accomplish this feat of people-counting, the researchers put two WiFi cards at opposite ends of a target area, a roughly 70-square-meter space. Using only the received power measurements

of the link between the two cards, their approach can estimate the number of people walking in that area.

This people-counting method relies in large part on the changes of the received



wireless signal, according to the researchers. The presence of people attenuates the signal in the direct line of sight between the WiFi cards if a person crosses the line of sight, and human bodies also scatter the signal — resulting in a phenomenon called multi-path fading — when

they are not in the direct line of sight path. By developing a probabilistic mathematical framework based on these two key phenomena, the researchers have then proposed a way of estimating the number of people walking in the space.

[www.ece.ucsb.edu/~ymostofi/HeadCountingWithWiFi.html](http://www.ece.ucsb.edu/~ymostofi/HeadCountingWithWiFi.html)

## Avago, Broadcom merger to produce third largest semi supplier

Merger activity in the semiconductor industry moved to a new level with the announcement of the agreement for Avago Technologies to acquire Broadcom, according to market research firm IHS. The deal, which is valued at \$37 billion in cash and stock, will create a new company valued at \$77 billion.

"This is the latest and, by far the largest, merger in the semiconductor industry, as major players continue to move in an aggressive way to establish position and profitability in key segments of the industry," said Dale Ford, vice president and chief analyst for IHS Technology.

The combined revenues of the two companies in 2014 exceeds \$14 billion, making the newly merged semiconductor company the sixth-largest globally, according to final annual semiconductor market shares. More significantly, the combination of the two companies creates the third-largest semiconductor supplier, if memory IC revenues are excluded.

[www.ihs.com](http://www.ihs.com)



## A 28 GHz, 4-channel phase adjustable power amplifier IC for 5G front-ends

By Stuart Glynn and Liam Devlin, Plextek RF Integration, [www.plextekRFI.com](http://www.plextekRFI.com)

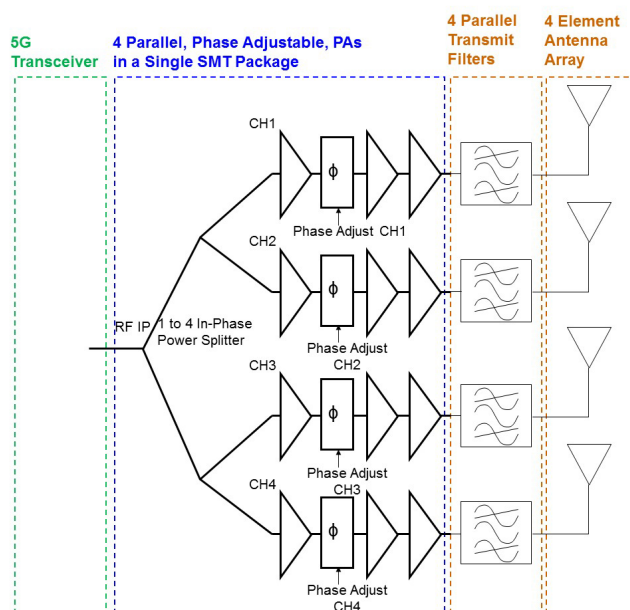
**5G** communications promises to offer the user the perception of near infinite capacity. This will require a step change in data rates, which will be facilitated by including the use of higher transmission frequencies where wider bandwidths are more readily available. New innovative components will be required to allow the design of suitable hardware, such as the 4-channel 28 GHz (27 – 29.5 GHz) phase adjustable power amplifier (PA) IC described here. Each channel of the IC includes a PA with an integral 4-bit, digitally controlled phase shifter. The 4-channel IC thus offers a compact means of implementing beam steering as an integral part of the PA. The output power capability of each channel is +30 dBm (at 1 dB compression) with an IP3 of +38 dBm. The phase shifters include TTL compatible control and have an RMS phase error of 2.3°.

### INTRODUCTION

A huge amount of research effort is currently being devoted to developing 5G technology with the aim of roll out by the year 2020. The details of the 5G standard have yet to be defined, but a common vision is that as well as providing much higher data rates this new standard must also allow for extremely low latency (less than one millisecond) and uniform coverage over a wide area. In addition to providing improved performance for existing applications, for example allowing the download of several HD movies in a second, the technology will enable and encourage the development of new markets, technologies and applications.

Although there is still much debate about the precise form that 5G will take, there is a degree of consensus that the standard will frequently require large chunks of contiguous spectrum. This can only be found by utilizing much higher frequencies than those used for current cellular systems operating below 3 GHz. It is therefore envisaged that, as well as making use of current cellular frequencies, a key component

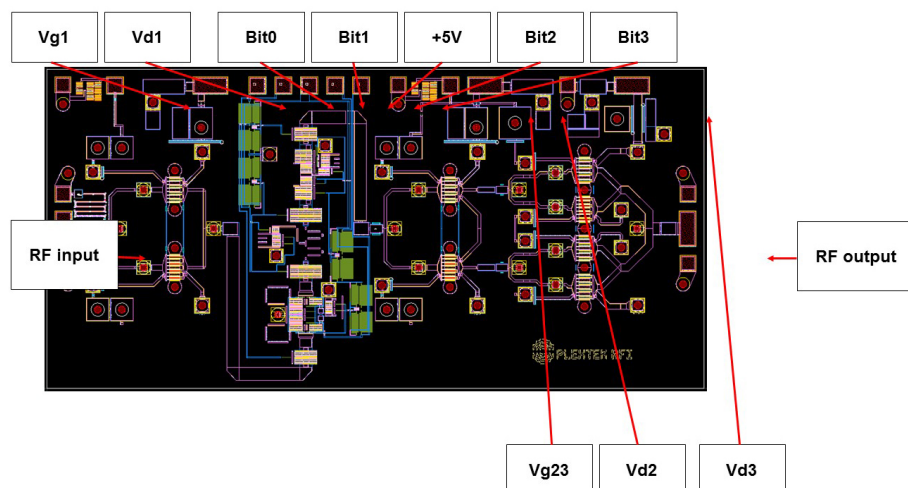
**Figure 1:**  
**Architecture**  
**of the 4-channel**  
**transmitter IC.**



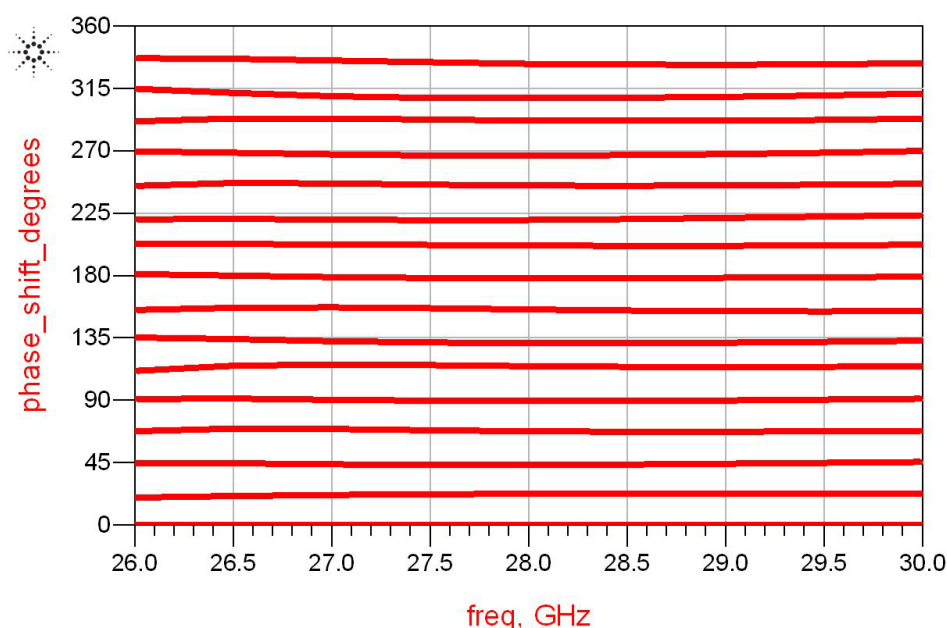
of the new 5G radio interface will be the use of mm-wave frequencies where there is greater spectral availability.

Until recently the use of mm-waves for mobile applications has been viewed as a rather inappropriate choice due to their unfavourable propagation characteristics. However a number of research programmes into the implementation

of 5G systems have recently reported the results of extensive mm-wave propagation measurements. These were conducted around metropolitan areas in both the United States [1] and South Korea and have shown that the issues can be addressed and overcome. Such research included the investigation of more sophisticated antenna schemes



**Figure 2:** **Layout plot of one channel of the transmitter IC.**



**Figure 3: Phase shift versus frequency for a single channel.**

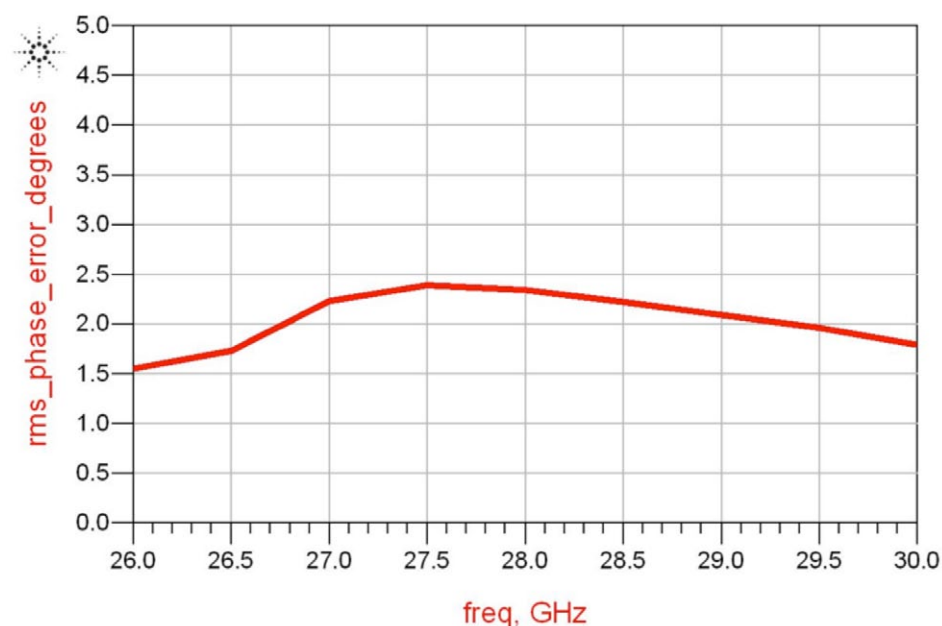
employing phased arrays of antennas to optimise the transmitted and received beams at both the mobile device and the base-station. The fact that wavelengths are small at mm-wave frequencies allows such arrays to be incorporated into a small mobile form factor. It also allows the implementation of compact base-stations which will facilitate regular deployment around metropolitan areas.

Bands in the range 27 – 29.5 GHz are strong candidates for the new 5G radio interface and much of the research undertaken to date has been conducted at around 28 GHz [2]. This paper de-

scribes the design of a 4-channel transmitter IC with each channel containing a PA with integral 4-bit phase shifter. The IC is designed using a commercially available 0.15 $\mu$ m GaAs pHEMT process and is intended to be housed in a low cost SMT package suitable for volume production.

## 28 GHZ 5G TRANSMIT RF FRONT END ARCHITECTURE

The architecture of a typical RF Front-End (RFFE) using the 28 GHz transmit IC is depicted in Figure 1. It shows a 4-element antenna array, with each element being driven by one of the



**Figure 4: RMS phase shift error versus frequency for a single channel.**

four parallel phase adjustable power amplifiers. It is likely that some degree of filtering would be implemented immediately after each power amplifier for harmonic rejection and suppression of receive band noise and unwanted spurious outputs. A common RF input signal drives each of the 4 channels via an in-phase 4-way splitter at the input of the IC.

The IC itself is a 4-channel device but if a particular architecture was developed that required a higher number of elements in the antenna array, say 16, then multiple ICs could simply be used in parallel.

Figure 2 shows a layout plot of one channel of the transmitter IC; this is a stand-alone test-chip – the transmitter IC itself comprises 4 separate channels with an in-phase splitter at the input. The test chip measures 3.8-x 1.84-mm.

The PA output (to the right of the layout image) comprises 4 power combined transistors, driven from a pair of power-combined transistors of the same size. The 4-bit phase shifter is positioned before this with an input stage of amplification that is a modified version of the 2 transistor driver stage. Vd1, Vd2 and Vd3 are the drain supplies for the power amplifier and they are nominally set to +6V. Vg1 sets the quiescent bias current in the first stage and Vg23 in the second and third stages.

The phase state of each bit of the integrated phase shifter is controlled by a single-ended TTL compatible control line. All of the control logic required to shift the levels to those needed for the phase shifter bits is included on-chip.

## SINGLE CHANNEL PERFORMANCE

The performance plots presented below are at room temperature, nominal bias across the frequency range 26 – 30 GHz.

The 4-bit phase shifter is based on a switched high-pass/low-pass filter topology [3]; it allows the insertion phase of each channel to be independently set with 22.5° resolution. The most significant bit of the phase shifter (180°) uses two Single Pole Double Throw (SPDT) switches to route the RF signal through either a high pass or a low pass filter. The phase through the high pass filter is advanced compared to the low pass filter with the phase difference being relatively constant over a reasonable bandwidth. Optimisation of the component values is required to obtain the desired phase difference with an accept-



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Parameter	Min	Max	Units
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RMS Amplitude Error		0.53	dB
Gain	18.5	21.5	dB
Min Output Return Loss	14.9		dB
Min Input Return Loss	13.4		dB
P1dB at 0°	28.5	30.5	dBm
PAE at P1dB at 0°	18.5	24.5	%
OIP3 at 0°	38.1	39.5	dBm

**Table 1: Performance summary of each channel of the 4-channel phase adjustable PA.**

able amplitude difference. The lower order bits make use of re-configurable phase shifter bits, in which individual filter components are selectively bypassed with switching elements rather than switching between two different filter networks. This configuration offers the benefit of lower insertion loss.

A plot of the simulated phase shift versus frequency for each of the 16 states of a single channel, including the PA, is shown in Figure 3; the desired flat phase shift versus frequency response is clearly evident.

With all digitally controlled phase shifters there is always a (hopefully) small phase difference between the phase shift produced by a certain

the 4-way in-phase splitter). Gain variation across all 16 phase states is less than  $\pm 0.6$  dB at 28 GHz. The total gain variation with both frequency (over 26 – 30 GHz) and all phase states is  $\pm 1.5$  dB.

An ideal phase shifter would have an amplitude response that did not change with phase state. In reality there will always be some change in amplitude associated with a change in phase state. At 28 GHz the RMS amplitude error of each channel of this IC is just 0.2 dB.

As the phase state of a multi-bit, digitally controlled phase shifter changes the reflected waves from each bit experience different phase shifts as they travel back towards the input. Sometimes the reflected waves add constructively

phase setting and the ideal phase shift that would be produced if each bit were perfect. The RMS phase error is a statistical measure of this deviation, used to quantify the accuracy of the phase setting, and is plotted against frequency in Figure 4 showing a worst case of  $2.38^\circ$  occurring at around 27.5 GHz.

The gain of each channel of the transmitter IC is just over 20 dB (excluding the splitting losses of

at the input, so degrading return loss, sometimes they add destructively, so improving return loss. All multi-bit phase shifters exhibit significant variation in return loss with phase state [3]; the input and output return losses versus frequency for a single channel of this design are plotted in Figure 5 for all phase states. Although significant variation in return loss with phase state is evident, the worst case return loss is still good. The worst case return loss across the 26 – 30 GHz range occurs at 26 GHz for both input and output. At the input the worst case return loss is 13.4 dB and at the output it is slightly higher at 14.9 dB.

The quiescent bias current of the complete 3-stage PA is 626mA from +6V. Each PA can provide an RF output power at 1 dB gain compression (P-1-dB) of 30 dBm at 28 GHz. Across the 26 to 30 GHz band the P-1-dB is nominally +29.5 dBm with a variation of  $< \pm 1$  dB.

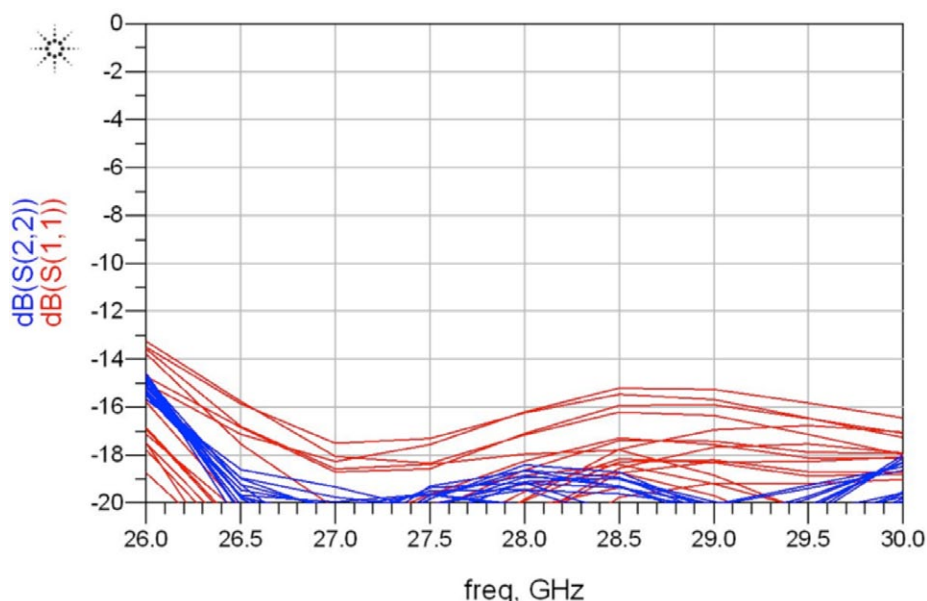
The corresponding Power Added Efficiency (PAE) for one PA channel operating at 1 dB gain compression is 24% at 28 GHz, whilst across the full 26 – 30 GHz simulated range it is nominally 21.5% with a variation of  $\pm 3\%$  across the band. 5G systems will operate with modulation schemes that have high peak to average power levels. It is therefore likely that the PA will be operated at an average output power level that is backed off from P1-dB to preserve modulation fidelity.

The traditional linearity metric for microwave amplifiers is the output referred third order intercept point (OIP3). With the total average input power set to 0 dBm i.e. the power in each input tone is set to -3 dBm, the nominal power in each output tone is around +17 dBm. The simulated OIP3 for each channel in this case is +38.8 dBm  $\pm 0.7$  dB across the band.

Table 1 presents a summary of the simulated performance of each channel of the phase adjustable PA.

## SIMULATIONS OF A FOUR CHANNEL ARRAY

Simulations were undertaken to show the antenna pattern that could be produced by a linear array of 4 omnidirectional (0 dB gain) antennas spaced by a half wavelength ( $\lambda/2$ ) at 28 GHz when driven by the 4-channels of the phase adjustable PA MMIC. With all channels set to the reference ( $0^\circ$ ) phase state, the maximum gain is on bore-sight. The absolute gain of the 4 element array of 0 dB gain elements would be 6 dB ( $10 \cdot \log_{10}(N)$ , where N is the number of ele-



**Figure 5: Input and output match versus frequency for a single channel, all phase states.**



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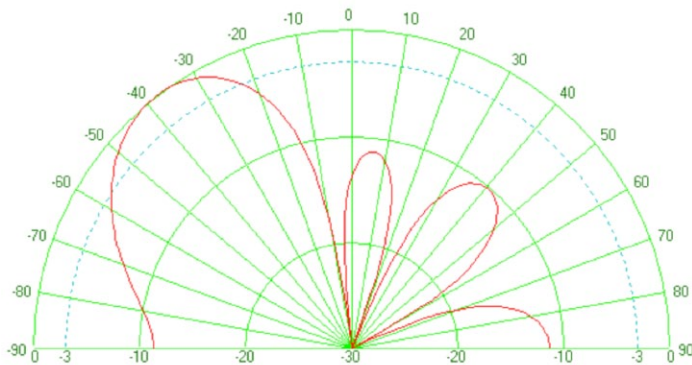


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**Figure 6: Beam pattern produced with phase states of the 4 channels set to steer the beam to  $-38^\circ$ .**

ments). In practise the individual elements would have some level of gain and the bore-sight gain of the array would be augmented by this.

By adjusting the insertion phase of the channels it is possible to electrically steer the antenna beam. The polar plot of Figure 6 shows the simulated antenna pattern when the beam is steered to  $-38.68^\circ$ . This is achieved by applying an incremental phase shift of  $-112.5^\circ$  across the elements of the array. The amplitude response of the plot is normalised in dB and the azimuth angle is in degrees. The ability to electronically steer the antenna beam is one of the benefits of using a phased array approach. The plot includes the effects of the systematic gain and phase errors in each channel.

### CONCLUSION

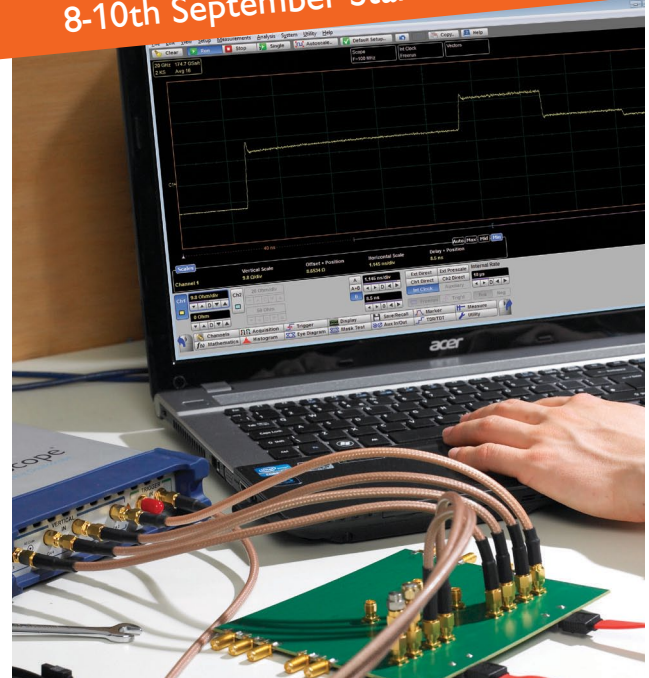
This article has described the design of a 4-channel 28 GHz (27 – 29.5 GHz), transmitter IC. Each channel of the IC includes a power amplifier with an integral, independently controllable 4-bit digital phase shifter. The IC is intended for use in the transmit chain of an RF Front-End (RFFE) module in either a 5G mobile device or base-station. It has been designed using a commercially available  $0.15\mu\text{m}$  GaAs pHEMT process and is suitable for assembly in to a single SMT package.

Details of the layout of a test chip for evaluating the performance of a single channel were presented along with simulations of key performance parameters including RMS phase error, RMS amplitude error and OIP3. Antenna pattern simulations for the four channels of the IC driving a four element linear array were also produced to show its potential for beam steering.

It should be noted that although this article has focused on a four element array, the solution can be extended to arrays containing a larger number of antenna elements. For example if the desired number of elements in the antenna array was 16 then this would require four of the 4-channel phase adjustable power amplifiers operated in parallel.

### REFERENCES

- [1] Theodore S. Rappaport, NYU Wireless, "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!", IEEE Access 30th May 2013
- [2] Wonbin Hong, Samsung Electronics, "Design and Analysis of a Low-Profile 28 GHz Beam Steering Antenna Solution for Future 5G Cellular Applications", IEEE MTT-S International, June 2014
- [3] Liam Devlin, "The Design of Integrated Switches and Phase Shifters", Proceedings of the IEE Tutorial Colloquium on "Design of RFICs and MMICs", Wednesday 24th November 1999, pp 2/1-14



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## Coherency and synchronisation in MIMO systems – more than just a phase

By Jeremy Twaits, Senior RF Marketing Engineer, National Instruments, Northern Europe

In modern communications systems, we're always looking for more: more data; more bandwidth; more coverage. Beyond using more processing power, more spectrum and more base stations, one option helping to provide greater capability is more antennas. Since the n revision of IEEE 802.11 was published in 2009, multiple-input multiple-output (MIMO) systems have become commonplace. As we look towards future wireless and cellular standards, however, MIMO will play an even more important role.

### APPLICATIONS OF MIMO

Multi-antenna technology is important in a variety of microwave and communications applications. Direction finding relies on multiple inputs from a single transmitter, calculating the unique phase delay to each receiver to triangulate the location of the source of transmission. Beamforming uses multiple transmitters to output signals that will interfere constructively or destructively depending on the angle it is observed from, a technique used in active radar, jamming or focusing radiation in communications systems. Passive radar uses multiple receivers but no dedicated transmitter, instead relying on third-party transmitters in the environment and measuring the time of arrival difference between the signal arriving directly from the transmitter and arriving via reflection from the object. Finally, in cellular or connectivity systems, both multiple transmitters and multiple receivers are used to improve link quality and data rates.

### THE THEORY OF OPERATION

In MIMO systems, the effective signal-to-noise (SNR) ratio can be increased by transmitting unique bit streams with multiple transmit antennae in the same physical channel, known as spatial multiplexing. This technique takes a single data stream and multiplexes it into individual data streams, which differs from the traditional approach of growing data rates by simply using more spectrum. Prior to MIMO systems, a physical

channel could be characterised by the amplitude, phase and frequency of the signal being transmitted. However, with multiple transmitters utilising the same portion of spectrum, the same models do not apply. For MIMO systems, multiple transmitters interfere with one another, causing the receiver to observe a signal that is a product of all transmitted signals. To make meaningful use of the signal, signal processing is used to reconstruct each of the transmitted streams and decode them individually. For this to be possible, the receiver must perform channel estimation, a technique that predicts characteristics of the transmitter and physical channel, including gain, phase and multipath effects.

### MIMO TEST CHALLENGES

Accurately testing MIMO transceivers brings challenges beyond those faced for single channel systems. In a multichannel system, there are many sources of channel-to-channel phase variation, including uncorrelated ADC sample clock phase noise, uncorrelated LO phase noise, SNR and ADC quantisation noise.

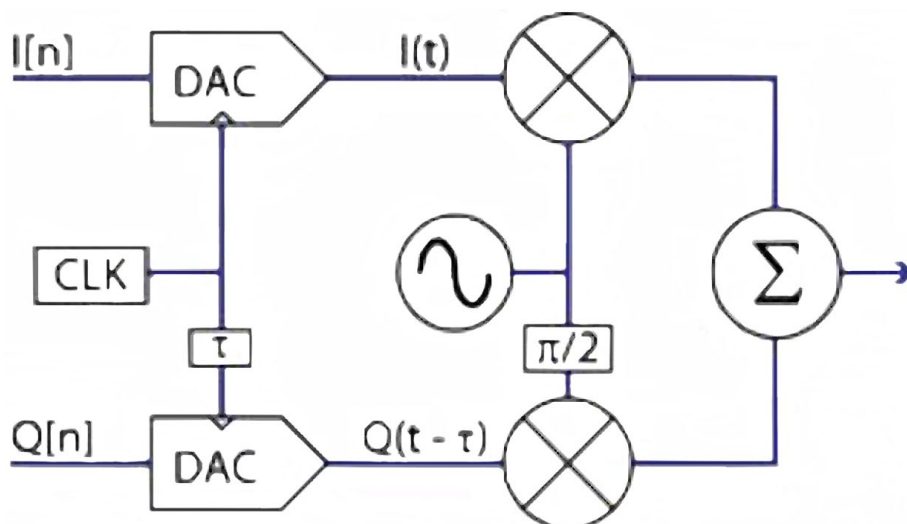
The first area to consider is baseband synchronisation. The data being

transmitting begins life as a digital representation of the required signal, represented by in-phase and quadrature-phase information, I and Q. These two digital bit streams are typically passed into arbitrary waveform generators, which utilise a digital-to-analogue converter (DAC) to convert it into an analogue signal that can be mixed with a local oscillator (LO).

Ideally, the two ADCs should share one clock source, allowing them to be synchronised, but naturally there is a distribution delay in propagating the clock signal. This  $\tau$ , the propagation delay, causes a phase skew between I and Q, which becomes a quadrature skew on the RF signal, leading to an increase in error vector magnitude (EVM). To reduce this, signal generators built on the PXI modular platform can share a 10 MHz system clock, which can help reduce instrument-to-instrument skew to the order of 100 ps.

### THE IMPORTANCE OF PHASE COHERENCE

Once appropriate measures have been taken to synchronise baseband I and Q, just as important is the synchronisation of the multiple channels that are in use. In this case, even sharing the



*Upconversion of I and Q, showing clock propagation delay,  $\tau$ , between the two ADC sample clocks.*



10 MHz reference clock is not sufficient. In order to reduce channel-to-channel phase skew, local oscillators should be shared between multiple channels. With many instruments this is not necessarily straightforward, since the LO is not always exposed for sharing with other instruments, plus their size dictates the use of fairly long cable lengths, leading to longer propagation delays. Modular instrumentation has the advantage of being able to daisy-chain LOs from instrument to instrument, thus significantly reducing phase skew.

Comparing the same two sets of PXI modular instruments, firstly sharing 10 MHz reference clocks, then sharing local oscillators, it is clear that the phase coherency is significantly improved in the case of shared LOs.

Hittite Microwave Corporation use this approach when testing RF integrated circuits and multichip modules. As these components evolve to provide greater capability, they also become more complex and expensive to test, since they contain multiple transmit and receive paths with differential I/Q baseband I/O, plus multiple internal filters, modulators, amplifiers, DACs, ADCs and more. Hittite stated that, “Fully testing these modules with traditional rack and stack test instruments in a multiple-input, multiple-output (MIMO) configuration would be cumbersome and expensive, and would require complex cabling and fixturing. By contrast, the NI vector signal transceiver easily expands to support MIMO test applications in a single PXI Express chassis.”

## WHY SIGNAL-TO-NOISE RATIO MATTERS

Synchronising both the baseband and RF signals will remove much of the phase skew, but another source of phase errors is in the Gaussian noise occurring naturally in over-the-air transmissions. This noise causes an increase in EVM, which corresponds to errors in I and Q, and hence errors in signal amplitude and phase. By increasing the signal amplitude and improving the SNR, the symbol moves away from the origin on the IQ plot, hence reducing the impact of the EVM on the angular error on the plot and reducing phase error.

## MIMO IN FUTURE COMMUNICATIONS SYSTEMS

The next generation of cellular communications networks are tasked with improving across a number of areas



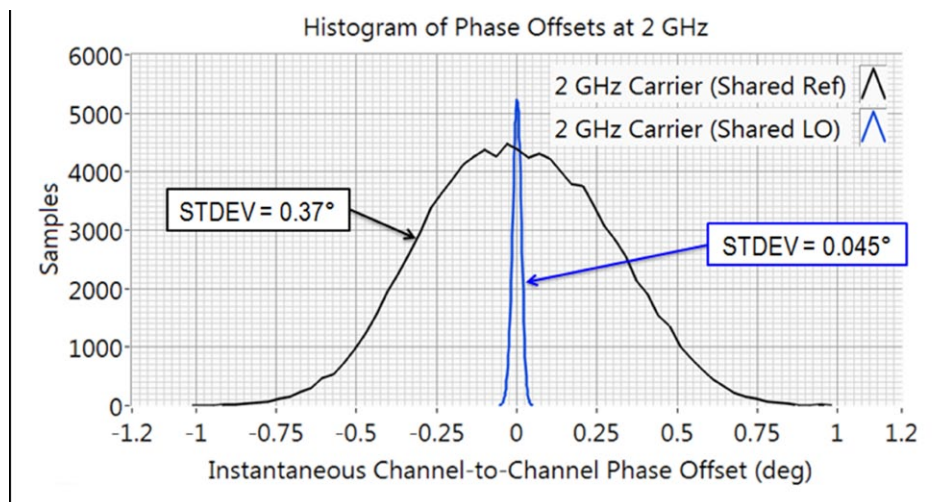
**PXI Express modular vector signal analysers and generators, with LOs daisy-chained from module to module.**

– coverage, energy efficiency, latency, reliability and, of course, data rates. So far, we’ve discussed relatively low numbers of antennas, but in order to substantially improve data rates and reliability, even more antennas can be used. Today’s base transceiver stations (BTS) use up to eight directional antennas in a sectorised topology, allowing them to serve several cells from the same location by using directional antennas or beamforming. A candidate for 5G technology extends this further. Known as ‘Massive MIMO’, this approach uses more than 64 antennas at the BTS, allowing energy to be focused to targeted mobile users using beamforming techniques like precoding. This means that the overall power radiated is reduced, making the network more energy-efficient, and interference to other users is decreased, allowing more users to be accommodated in a more reliable fashion.

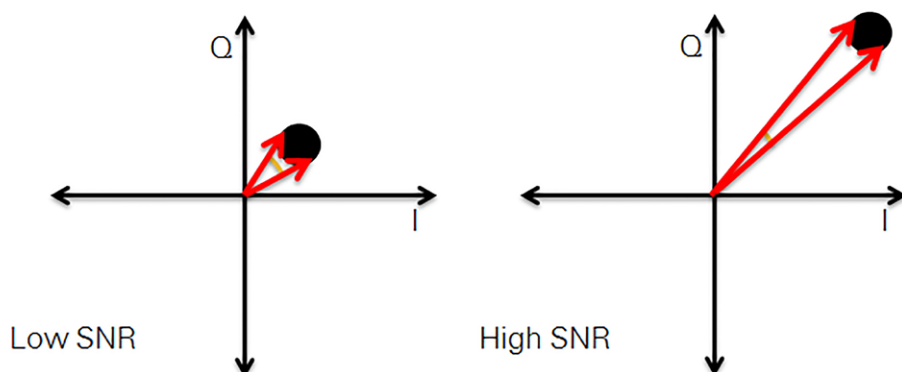
The sheer volume of antennas adds system challenges beyond those

encountered in today’s networks. Today’s networks based on LTE or LTE-Advanced require pilot overhead proportional to the number of antennas. By comparison, massive MIMO networks manage this overhead using time division duplexing (TDD) between uplink (UL) and downlink (DL), providing channel reciprocity. This allows UL channel knowledge to be taken from DL measurements and vice versa, reducing the need for additional feedback through pilot data. In addition to this, further considerations include how to manage the large amounts of data and how to synchronise the large numbers of transceivers.

These timing, processing and data collection challenges make prototyping vital. For researchers to validate theory, this means progressing from theoretical work to testbeds. Using real-world waveforms in real-world scenarios, researchers can develop prototypes to determine the feasibility and commercial viability of massive MIMO.



**Comparison of phase offset on channels synchronised by sharing 10 MHz reference clocks (in black), and sharing local oscillators (in blue).**



**Low SNR brings the symbol closer to the IQ plot origin, meaning that Gaussian noise has a larger impact (ie a wider angle) on phase uncertainty. Higher SNR moves the symbol further from the origin, reducing the impact on phase noise.**

As with any new wireless standard or technology, the transition from concept to prototype impacts the time to actual deployment and commercialisation. And the faster researchers can build prototypes, the sooner society can benefit from the innovations.

An example of this comes from Lund University, in Sweden, where Professors Ove Edfors and Fredrik Tufvesson

worked with NI to develop the world's largest MIMO system. Their system uses 50 USRP RIO software-defined radios (SDRs) to create a 100-antenna configuration for the massive MIMO BTS.

Just like other cellular communications systems, Massive MIMO systems consist of BTS and user equipment (UE) or mobile users. It differs, however,

from the traditional approach by assigning a large number of BTS antennas to communicate with multiple UEs simultaneously. In the system that NI and Lund University developed, the BTS uses a system design factor of 10 base station antenna elements per UE, providing 10 users with simultaneous, full-bandwidth access to the 100-antenna base station. This design factor of 10 base station antennas per UE has been shown to allow for most theoretical gains to be harvested.

In a massive MIMO system, a set of UEs concurrently transmits an orthogonal pilot set to the BTS. These known uplink pilots can then be used to perform channel estimation. In the

downlink time slot, this channel estimate is used to compute a precoder for the downlink signals. Ideally, this results in each mobile user receiving an interference-free channel with the message intended for them. Precoder design is an open area of research and can be tailored to various system design objectives. For instance, precoders can be designed to null interference at other users, minimise total radiated power, or reduce the peak-to-average power ratio of transmitted RF signals. Although many configurations are possible with this architecture, the Massive MIMO Application Framework from NI supports up to 20 MHz of instantaneous real-time bandwidth that scales from 64 to 128 antennas and can be used with multiple independent UEs.

Just like in test and measurement, clock synchronisation remains a serious concern in prototyping communications systems. In Lund University's massive MIMO, they used an Ettus Research OctoClock 8-channel clock distribution module. This uses matched-length traces to distribute a signal from either an internal GPS-disciplined oscillator (GPSDO) or an amplified externally-supplied reference clock. In order to provide an accurate and stable reference, Lund opted to use multiple OctoClock modules, with a common clock generated from an NI PXIe-6674T timing and synchronisation module, which uses an oven-controlled crystal oscillator (OCXO) capable of 50 ppb accuracy. The BTS system shares this common 10 MHz reference clock, as well as a master digital trigger to start generation or analysis on each radio, ensuring synchronisation across the entire system.

## MASSIVE MIMO, MASSIVE DATA

Beyond the topic of synchronisation, a further consideration with massive MIMO is how to cope with the increased volume of data. Naturally, more transceivers means more data being sent, received and digitised, so adequate platforms for data aggregation and processing must be considered. Firstly, the bus that transports data from the radios to the system controller cannot be a bottleneck – it must be capable of streaming with sufficient throughput to cope with the large data rates from multiple radios. Commonly used buses like GPIB or USB will struggle to provide the required throughput, so instead a bus like MXI-Express should be used. MXI-Express provides a cabled PCI Express Generation 2 link



**The massive MIMO testbed at Lund University in Sweden is based on USRP RIO with a custom cross-polarized patch antenna array.**



to allow data streaming back to a host PXI system at up to 3.2 GB/s.

Once the data has been transferred to the host, the burden is on the processor to run decoding and processing algorithms to make sense of the received signals. To help meet this demand, NI offers the PXIe-8880 controller, which features an Intel Xeon 2.3 GHz eight-core processor. Additionally, by including FPGA-based processing nodes like FlexRIO, data can be processed inline and in real-time with up to 3 GB/s throughput and less than 5 microseconds of latency from radio to processing node.

Whether in the communications systems deployed today or those we're developing for tomorrow, MIMO plays a huge part in enhancing the capability of our networks. Whilst the consumer will experience a more reliable network with higher data rates, it's engineers who will need to face the challenges of testing today's and designing tomorrow's MIMO communications systems. MIMO will continue to drive the need for measurement and prototyping platforms to offer high degrees of synchronisation and coherency. MIMO is truly not just a phase.

## Mobile data traffic growth in Q1 mainly from emerging markets

As a slow-down in traffic growth takes place in developed markets, Strategy Analytics reports that mobile data traffic growth surged 77 percent in Q1 as emerging market momentum builds.

According to the marketing research firm micro-bundles for data, device and data plan combinations, and affordable smartphones have a role to play in any cost-conscious customer segment, irrespective of location. Consequently, mobile operators in developed markets experiencing a slow-down in traffic growth may want to look to emerging markets for ideas on unlocking growth in more cost-conscious segments.

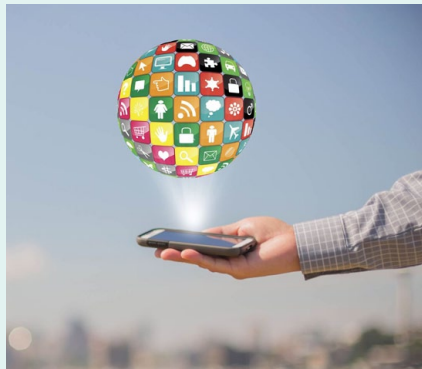
Phil Kendall, Executive Director, Wireless Operator Strategies, said "Developing countries are behind the current boost to traffic growth rates. Some of this is down to emerging 4G opportunities, most notably in China, though it is mainly due to the growth in affordable 3G smartphones. Traffic stimulation strategies in these developing markets should not be overlooked by developed market operators trying to push 4G growth further into the mass market."

The top operators in terms of traffic growth in Q1 2015 were AIS Thailand (192%), Geocell Georgia (176%), Play Poland (163%), Indosat Indonesia (159%) and China Mobile (158%).

Another key finding is that 2G is not

dead. In India, 2G traffic growth is still strong, where low-cost smartphone models remain in use. 2G accounted for 44% of total data traffic at Idea Cellular in Q1 2015 and recorded 68% annual growth, compared to the 135% growth seen on the company's 3G network.

In developed markets 4G is king. 4G is dominant in markets such as the US, where Verizon Wireless saw 86% of



its traffic on the LTE network, and South Korea, where operators carried 96% of their data traffic on 4G. Advanced 4G markets reported slower traffic growth, for example in Singapore (25%) and Hong Kong (34%). These results are in line with the 26% growth

in US mobile data traffic recently reported by the CTIA for 2014.

Susan Welsh de Grimaldo, Director, Wireless Operator Strategies, commented "The positives in the traffic figures have not translated into faster revenue growth from non-SMS data services for operators, with data revenue growth falling below 20% globally for the first time. With monetization strategies built on upselling more data, operators will need to work harder to encourage users to consume more chargeable 3G and 4G data on more devices."

[www.StrategyAnalytics.com](http://www.StrategyAnalytics.com)

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## 60G millimeter-wave backhaul link is poised to boost cellular capacity

**A complete 60-GHz two-way data communication scheme based on Xilinx's Zynq SoC offers the performance and flexibility to serve the small-cell backhaul market.**

By John Kilpatrick, Consulting Engineer, Analog Devices , John.Kilpatrick@analog.com  
Robbie Shergill, Strategic Applications Manager, Analog Devices Robbie.Shergill@analog.com  
Manish Sinha, Product Marketing Manager, Xilinx, Inc. manish.sinha@xilinx.com

**T**he ever-increasing demand for data on the world's cellular networks has operators searching for ways to increase the capacity 5,000-fold by 2030 [1]. Getting there will require a 5x increase in channel performance, a 20x increase in allocated spectrum and a 50x increase in the number of cell sites.

Many of these new cells will be placed indoors, where the majority of traffic originates, and fiber is the top choice to funnel the traffic back into the networks. But there are many outdoor locations where fiber is not available or is too expensive to connect, and for these situations wireless backhaul is the most viable alternative.

Unlicensed spectrum at 5 GHz is available and does not require a line-of-sight path. However, the bandwidth is limited and interference from other users of this spectrum is almost guaranteed due to heavy traffic and wide antenna patterns.

Communication links of 60 GHz are emerging as a leading contender to provide these backhaul links for the many thousands of outdoor cells that will be required to meet the capacity demands. This spectrum is also unlicensed, but unlike frequencies below 6 GHz, it contains up to 9 GHz of available bandwidth. Moreover, the high frequency allows for very narrow and focused antenna patterns that are somewhat immune to interference.

A complete 60-GHz two-way data communication link developed by Xilinx and Hittite Microwave (now part of Analog Devices) demonstrates superior performance and the flexibility to meet the requirements of the small-cell backhaul market (Figure 1). Xilinx developed the digital modem portion of the platform and Analog Devices, the millimeter-wave radio portion.

As depicted in Figure 1, two nodes are required to create this link. Each node contains a transmitter (with a modulator) with its associated analog Tx chain and a receiver (with a demodulator) with its associated analog Rx chain.

The modem card is integrated with analog and discrete devices. It contains oscillators (DPLL module) to ensure the accuracy of frequency synthesis, and all the digital functions are executed in an FPGA or SoC. This single-carrier modem core supports modulations from QPSK to 256QAM in channel bandwidths up to 500 MHz, and achieves data rates as high as 3.5 Gbps. The modem also supports both frequency-division duplex (FDD) and time-division duplex (TDD) transmission schemes. Robust modem design techniques reduce the phase noise implications of the local oscillators and powerful LDPC coding is included for improved performance and link budget.

### MILLIMETER-WAVE MODEM

The Xilinx millimeter-wave modem solution enables infrastructure vendors

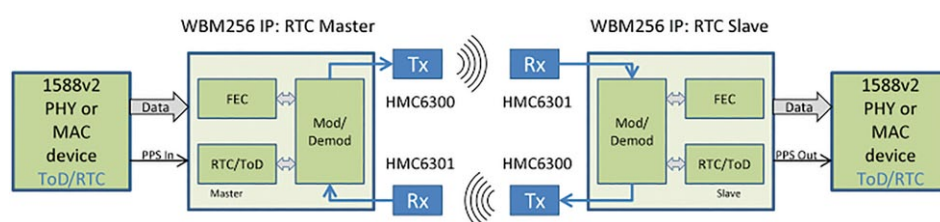
to develop flexible, cost-optimized and customizable links for their wire-less backhaul networks. This solution is targeted at the Xilinx® Zynq®-7000 All Programmable SoC or Kintex®-7 FPGA devices, which are part of Xilinx's "generation-ahead" 28-nanometer product family.

Xilinx's solution is fully adaptive, is low in power and small in footprint, and can be used to deploy indoor and full outdoor point-to-point links as well as point-to-multipoint microwave links. Just as with its silicon, Xilinx's road map for its millimeter-wave modem solution is very aggressive, and presents operators with the unique ability to deploy scalable and field-upgradable systems.

Figure 2 further details the digital modem as implemented on the Zynq SoC platform. Alongside the programmable logic (PL), the platform's scalable processing system (PS) contains dual ARM® Cortex™-A9 cores with integrated memory controllers and multi-standard I/Os for peripherals.

This system-on-chip (SoC) platform is highly flexible. Here, it is used to perform various data and control functions and to enable hardware acceleration. An integrated millimeter-wave modem solution complete with PHY, controller, system interfaces and packet processor is shown in Figure 2. However, based on the required architecture, you could insert, update or remove different modules. For instance, you might choose to implement an XPIC combiner so that you could use the modem in cross-polarization mode with another modem. The solution is implemented in the PL, where serdes and I/Os are used for various data path interfaces such as those between the modem and packet processor, the packet processor and memory, inter-modem or DAC/ADC.

Some of the other important features of the Xilinx modem IP include



**Figure 1 – High-level block diagram of the complete two-way communication link.**

automatic hitless and errorless state switching through adaptive coding and modulation (ACM) to keep the link operational; adaptive digital closed-loop predistortion (DPD) to improve RF power amplifier efficiency and linearity; synchronous Ethernet (SyncE) to maintain clock synchronization; and Reed-Solomon or low-density parity check (LDPC) forward error correction (FEC). The FEC choice is based on the design requirements. LDPC FEC is the default choice for wireless backhaul applications, whereas Reed-Solomon FEC is preferred for low-latency applications such as front-haul.

LDPC implementation is highly optimized and exploits FPGA parallelism for the computations done by the encoders and decoders. The result is noticeable SNR gains. You can apply different levels of parallelism by varying the number of iterations of the LDPC core, thereby optimizing the size and power of the decoder. You can also model the solution based on channel bandwidth and throughput constraints.

The Xilinx modem solution also comes with a powerful graphical user interface (GUI) for both display and debug, and is capable of high-level functions such as channel bandwidth or modulation selection as well as low-level ones such as setting of hardware registers. To achieve 3.5-Gbps throughput for the solution shown in Figure 1, the modem IP runs at a 440-MHz clock rate. It uses five gigabit transceivers (GTs) for connectivity interfaces to support ADCs and DACs, and a few more GTs for 10GbE payloads or CPRI interfaces.

## MILLIMETER-WAVE TRANSCEIVER CHIP SET

In late 2014, Analog Devices released its second-generation silicon germanium (SiGe) 60-GHz chip set, significantly enhanced and optimized for the small-cell backhaul application. The HMC6300 transmitter chip is a complete analog baseband-to-millimeter-wave upconverter. An improved frequency synthesizer covers 57 to 66 GHz in 250-MHz steps with low phase noise and can support modulations up to at least 64QAM. Output power has increased to roughly 16-dBm linear power, while an integrated power detector monitors the output power so as not to exceed the regulatory limits.

The transmitter chip offers either analog or digital control of the IF and RF gains. Analog gain control is

sometimes needed when using higher-order modulations, since discrete gain changes can be mistaken for amplitude modulation, leading to bit errors. Digital gain control is supported using the built-in SPI interface.

For applications requiring even higher-order modulation in narrow

channels, an external PLL/VCO with even lower phase noise can be injected into the transmitter, bypassing the internal synthesizer. Figure 3 shows a block diagram of the HMC6300.

The transmitter supports up to 1.8 GHz of bandwidth. An MSK modulator option enables low-cost data

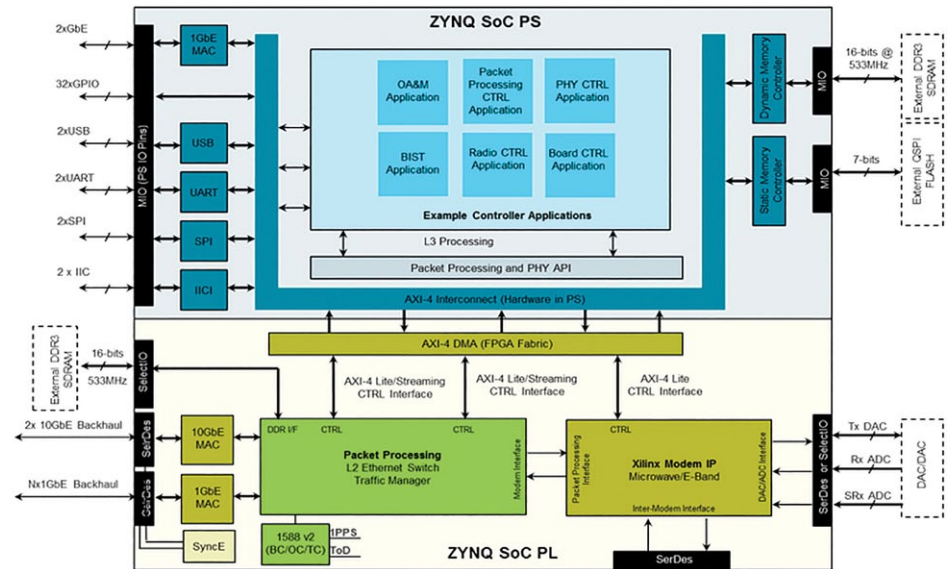


Figure 2 – All Programmable SoC for wireless modem applications.

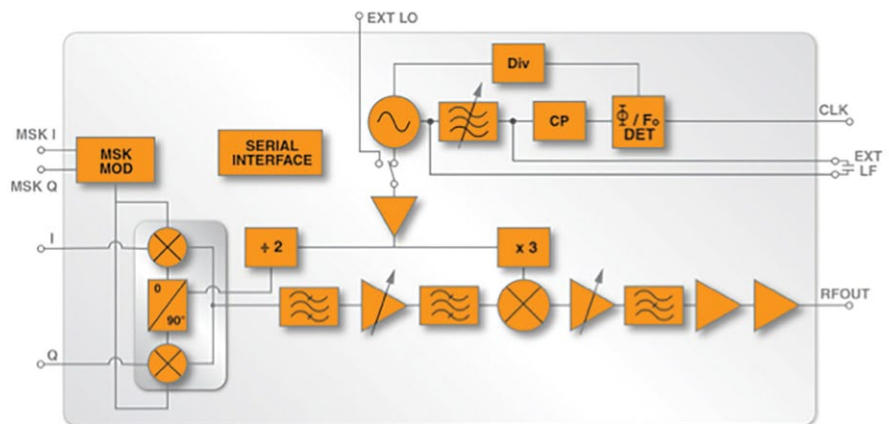


Figure 3 – HMC6300 60-GHz transmitter IC block diagram.

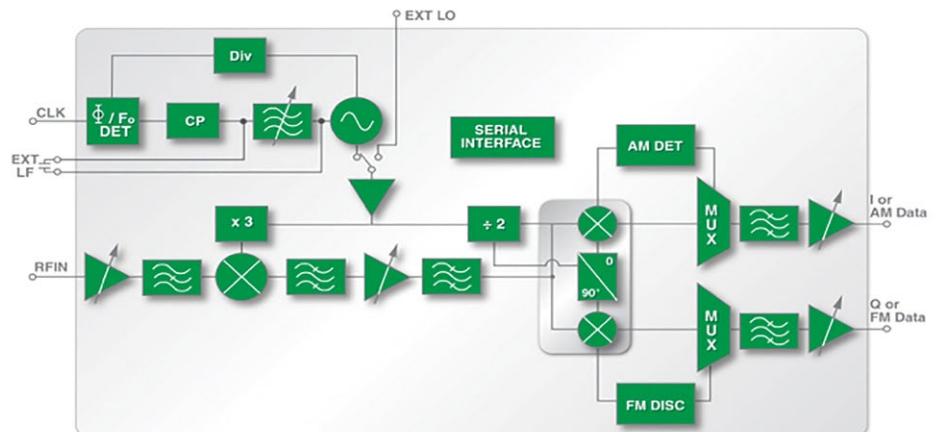
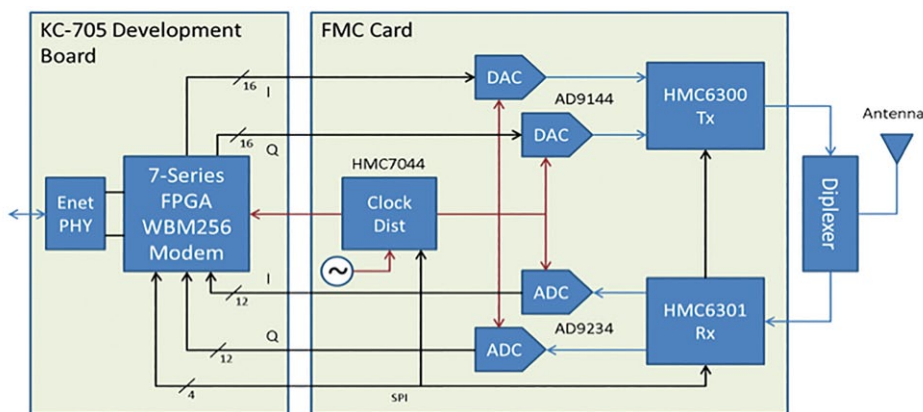


Figure 4 – HMC6301 60-GHz receiver IC block diagram.



**Figure 5 – Example reference design using Xilinx and Analog Devices ICs.**

transmissions up to 1.8 Gbps without the need for expensive and power-hungry DACs.

Complementing this device is the HMC6301 receiver chip, likewise optimized to meet the demanding requirements of small-cell backhaul. The receiver features a significant increase in the input P1dB to -20 dBm and IIP3 to -9 dBm to handle short-range links where the high gain of the dish antennas lead to high signal levels at the receiver input.

Other features include a low, 6-dB noise figure at the maximum gain settings; adjustable low-pass and high-pass baseband filters; the same new synthesizers as found in the transmitter chip to support 64QAM modulation over the 57- to 66-GHz band; and either analog or digital control of the IF and RF gains.

A block diagram of the HMC6301 receiver chip is shown in Figure 4. Note that the receiver also contains an AM detector to demodulate amplitude modulations such as on/off keying (OOK). Also, an FM discriminator demodulates simple FM or MSK modulations. This is in addition to the IQ demodulator that is used to recover the quadrature baseband outputs for QPSK and more-complex QAM modulations.

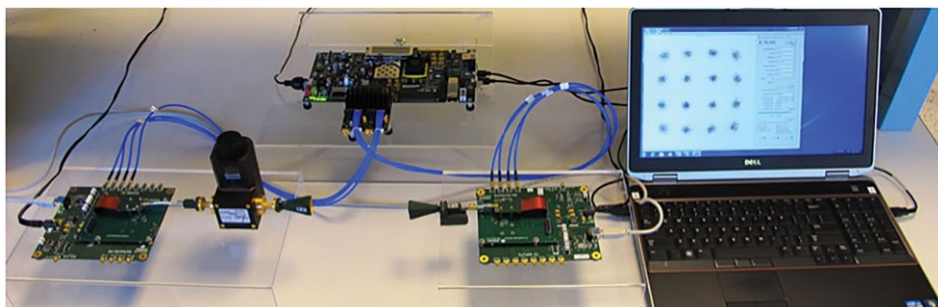
Both the HMC6300 transmitter and HMC6301 receiver will be available

in a 4 x 6-mm BGA-style wafer-level package. They will be designated the HMC6300BG46 and HMC6301BG46 and are scheduled for sampling in early 2015. These surface-mount parts will enable the low-cost manufacturing of the radio boards.

A block diagram of an example millimeter-wave modem and radio system is shown in Figure 5. In addition to the FPGA, modem software and millimeter-wave chip set, the design also contains a number of other components. They include the AD9234 dual-channel 12-bit, 1-Gsample/second ADC; the AD9144 quad-channel 16-bit, up to 2.8-GSPS TxDAC; and the HMC7044 ultralow-jitter clock synthesizer with support for the JESD204B serial data interface that is employed on both the ADC and the DAC ICs.

## DEMONSTRATION PLATFORM

Xilinx and Analog Devices have jointly created a demonstration platform implementation featuring the FPGA-based modem on the Xilinx KC705 development board, an industry-standard FMC board containing ADCs, DACs and clock chip, and two radio module evaluation boards (Figure 6). The demo platform includes a laptop for modem control and visual display, and a variable RF attenuator to replicate the path loss of a typical millimeter-wave link.



**Figure 6 – The demonstration platform in action.**

The Xilinx KC705 development board features the Kintex-7 XC7K325T-2FF-G900C FPGA executing the WBM256 modem firmware IP. An industry-standard FMC mezzanine connector on the development board is used to connect to the baseband and millimeter-wave radio boards.

The millimeter-wave modules snap onto the baseband board. The modules have MMPX connectors for the 60-GHz interfaces as well as SMA connectors for optional use of an external local oscillator. This platform contains all the hardware and software needed to demonstrate point-to-point backhaul connections of up to 1.1 Gbps in 250-MHz channels for each direction of a frequency-division duplex connection.

## MODULAR AND CUSTOMIZABLE

FPGAs are increasingly being used in various wireless backhaul solutions, since the platforms based on them can be highly modular and customizable, thereby reducing the total cost of ownership for the OEMs. Owing to significant power improvements in its 7 series FPGA/SoC families and high-performing wideband IP cores, Xilinx expects its millimeter-wave modem solution to be a front-runner for the small-cell backhaul application. Xilinx FPGAs and SoCs are suitable for high-speed and power-efficient designs, and its high-speed GTs can be used effectively for wideband communications and switching functions. Xilinx's solution can be scaled to support multiple product variations, from lower-end small-cell backhaul products operating at a few hundred megabits per second to 3.5 Gbps on the same hardware platform.

For the radio portion, the transceivers have now been integrated into silicon-based ICs and packaged into surface-mount parts, allowing for low-cost manufacturing. Analog Devices' millimeter-wave chip set meets the wireless backhaul needs of the small-cell deployments and provides market-leading performance in power, size, flexibility and functionality. Analog Devices also provides industry-best data converters and clock-management ICs that are critical components of this complete solution. Together, the two companies intend to drive the industry adoption of this exciting technology.

## REFERENCE

1. "Evolutionary and Disruptive Visions Towards Ultra High Capacity Networks," IWPC, April 2014



## TM500 WCDMA network test system expanded to 24 cells

Cobham Wireless has announced the latest version of the industry-standard TM500 WCDMA network test system, with expanded capability to emulate four cells and hundreds of mobile terminals from a single benchtop unit.



Combining six TM500 units into a rack-mount cabinet enables the network operator or infrastructure vendor to validate real data applications usage on a WCDMA network of 24 cells — supporting thousands of terminals — in a controlled laboratory environment.

Supporting 3GPP Release 99 CS/PS, HSDPA, HSUPA, HSPA+ and Release 8 DC-HSDPA operation, the TM500 WCDMA network test system shares the same hardware platform as the TM500 LTE-A test system, allowing the same unit to be used for both 3G and 4G network validation.

The TM500 family is a scalable test system for validating network performance as experienced by end users, across multiple cells and different radio access technologies.

[www.cobham.com/wireless](http://www.cobham.com/wireless)

## Variable attenuators cover 1.45 to 5.0 GHz

Skyworks has introduced a series of voltage-controlled variable attenuators (VVs), which are designed to have excellent third order input intercept point and superb dynamic range.

The devices cover operation from 1.45 to 5.0 GHz, and have control voltages ranging from 0 to 5.0 V. The SKY12232-21, SKY12233-11, SKY12235-11 and SKY12236-11 are optimized for use as low distortion, analog attenuators — centered at 1.95, 2.60, 3.15, and 3.8 GHz.

These VVs are ideal for automatic power leveling/gain control circuits in 3G/4G LTE and WCDMA cellular base stations, IF chains, radar, and Satcom systems. They are also designed for broad

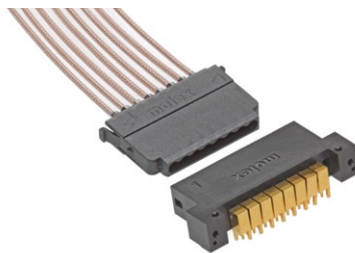
market wireless systems including military communication transceivers, S-Band radar, and VSAT. Each is provided in a MCM 8-pin 4.9 x 3.2 x 1.0 mm package.

[www.skyworksinc.com](http://www.skyworksinc.com)

## Multi-port RF coaxial cable-to-board connector

Featuring a rugged single housing design with dual latches to support the weight of the coaxial cables, the MPRF system ensures a secure multi-port RF I/O connection. The compact connectors also meet space demands for shrinking electronic devices in a variety of industries including telecommunications and networking; data communications and computing; medical; and aerospace and defense.

With a 3.75-mm-pitch, the connectors accept 2.10-mm cable diameters (RG-316) for PCB space savings. The robust outer shell can withstand a minimum of 500



mating cycles, while the 1.00-mm contact wipe ensures proper engagement under extreme conditions. The 4-, 6- and 8-port configurations deliver greater design flexibility and the DC to 6 GHz frequency range supports a broad range of potential applications. The non-magnetic versions provide relative permittivity close to 1.0 and high signal-to-noise ratio (SNR) for imaging systems in medical and aerospace applications.

[www.molex.com](http://www.molex.com)

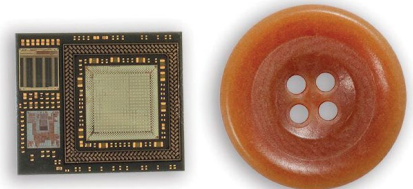
## IoT platform comes in a tiny single chip module

Freemove Semiconductor claims to offer the smallest available single chip module (SCM) for the Internet of Things (IoT).

As the IoT requires more processing horsepower to be packed into ever smaller spaces, the SCM line of products can integrate hundreds of components including

processors, memory, power management and RF parts, which would otherwise be deployed on a six-inch board, into a tiny 17-mm X 14-mm X 1.7-mm package — the size of a U.S. dime.

At the Freescale Technology Forum (FTF) in Austin, Texas, Freescale unveiled



the first product in its SCM portfolio. Designed to function as a computer on a chip, the i.MX 6Dual SCM is enabled for DDR memory and combines the performance of the company's i.MX 6Dual applications processor together with a power management integrated circuit (PMIC), flash memory, embedded software/firmware, and system-level security technology including random number generation, cryptographic cipher engines and tamper prevention.

SCM products are engineered to dramatically reduce time-to-market, allowing an estimated 25 percent reduction in hardware development time — as well as greater than 50 percent reduction in size versus current discrete solutions.

[www.freescale.com](http://www.freescale.com)

## Precision VNA cable assemblies to 65 GHz

Response Microwave, Inc., has announced a series of durable and phase stable VNA cable assemblies for use in precision test applications.

The vCBLZ series operates over DC to 65 GHz and offers interface combinations in 1.85-mm, 3.5-mm, 2.92-mm, 2.4-mm,



N18 and all NMD combinations of the same series. Phase stability ranges from  $< \pm 2^\circ$  to  $< \pm 6^\circ$  depending upon frequency range. Typical electrical performance of 1.5 dB insertion loss and 1.25:1 VSWR.

Compression resistance is  $> 920 \text{ kgf/cm}$ . Units are operational over the 0 to

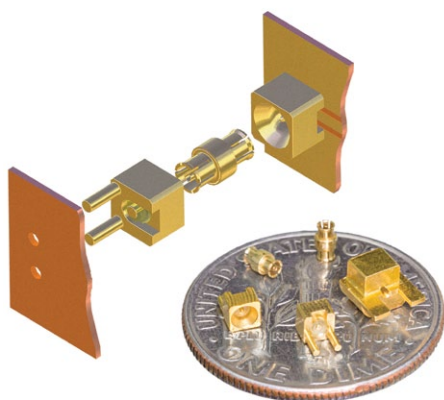
+40 °C range and all connector bodies are SUS303F stainless with gold plated BeCu center contacts. Standard length is 24-inches and custom lengths are available on request.

[www.responsemicrowave.com](http://www.responsemicrowave.com)

## SuperMini board-to-board DC to 67 GHz connectors

Southwest Microwave, Inc., has introduced a line of SuperMini board-to-board DC to 67 GHz connectors for RF and millimeter wave applications. These blind-mate connectors optimize interconnect performance for board-to-board stacking.

Based on the company's superior coax platform, SuperMini board-to-board connectors maximize electrical



performance of the transmission path between connector and circuit while accommodating axial misalignment of up to 0.010-inches and radial misalignment of  $\pm 5^\circ$  via unique bullet and PCB receptacle (jack) designs. With an array of available bullets that enable board-to-board spacing as close as 3 mm, this ensures RF and millimeter wave transmission line dependability for tightly stacked PCBs.

Designed to optimize match to circuit for surface and thru-hole PCB mounting applications, SuperMini connectors are available in smooth bore or detent style Vertical and End Launch jack configurations for microstrip and grounded co-planar circuit launch transitions. Additionally, smooth bore and detent style 4-hole flange SuperMini board-to-board jack to 2.92 mm (K) jack adapters are available.

[www.southwestmicrowave.com](http://www.southwestmicrowave.com)

## High linearity gain blocks boast leading linearity and saturated output power



Guerrilla RF has introduced a line of gain blocks that feature industry-leading linearity and outstanding saturated output power along with low noise.

These cost-effective and internally matched devices enable a number of general-market designs including small cells, cellular repeaters, LTE/WCDMA linear driver amplifiers, high power saturated power amplifier (PA) drivers and other wireless infrastructure applications over a wide range of frequencies.

The GRF2013 (2.7- to 8.0-V) and GRF3013 (industry-standard SOT-89 at 5.0 V) are broadband gain blocks with low broadband noise figure, industry-leading linearity and saturated output power. They exhibit outstanding return losses over 50 to 3,800 MHz. Configured as driver amplifiers or cascaded gain blocks, these devices offer potential for high levels of reuse within a design and across platforms.

Internally matched to 50 ohms, they only need external direct current blocks and a bias choke on the output. Custom tuning/evaluation board data and device s-parameters are available.

<http://guerrilla-rf.com>

## Low power PCIe clock generators

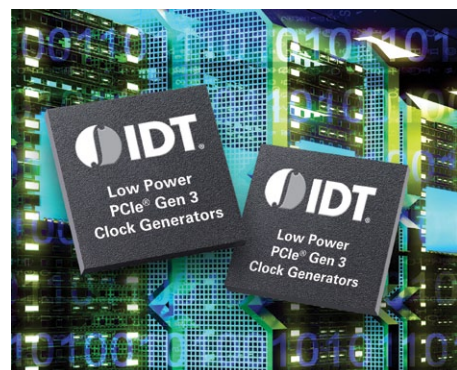
*anticipate upcoming PCIe Gen4 specification*

The 3.3 V family of devices joins the existing 1.5 V and 1.8 V families. The latest products operate at approximately 100 mW, claiming to be the lowest power 3.3 V PCIe clock generators on the market. By operating at roughly one-fifth the power of traditional PCIe clock

devices, the IDT 3.3 V devices effectively eliminate thermal concerns.

With their integrated terminations, the 9FGL06 and 9FGL08 devices' ultra-compact 5x5- and 6x6-millimeter packages can deliver up to a 90 percent reduction in board area. Factory programmable versions provide quick turn device optimizations to meet exact customer requirements. The SoC-friendly devices greatly exceed the phase jitter requirements of the PCIe Gen3 specification in anticipation of the upcoming PCIe Gen4 specification, and are also suitable for applications needing less than 3ps rms 12k-20M phase jitter, such as gigabit Ethernet and other high-performance applications.

The 9FGL PCIe clock generator family includes devices with 2, 4, 6, or 8 outputs. The clock generators support both the PCIe Common Clock architecture



with or without spread spectrum, and the PCIe Independent Reference (IR) clock architecture (non-spreading). The devices also provide a copy of the reference clock, saving a crystal in the design.

The 6-output 9FGL06xx and 8-output 9FGL08xx PCIe clock generators are available now. The 2-output 9FGL02 and 4-output 9FGL04 clock generators will be available in Q3, 2015.

[www.IDT.com](http://www.IDT.com)

## High precision arbitrary waveform generators

Spectrum has released three M4i series arbitrary waveform generators (AWGs) that set new standards in speed and precision.

The latest models of the M4i.66xx series offer one, two and four channels with each channel capable of outputting electronic signals at rates of up to 625 MSamples/s with 16 bit vertical resolution. The combination makes these arbitrary waveform generators ideal for generating high frequency signals up to



200 MHz with the best possible accuracy and fidelity.



The frequency range and dynamic performance of these instruments makes them ideal for communications, radio, radar, semiconductors, nano-technology, media testing, automation, ultrasound, optics, medical and biological science.

Based on the company's proven M4i series PCI Express (PCIe) platform the products are much smaller than conventional instruments and can be used in most modern PCs. Simply install the AWG cards into a vacant PCIe x8 or x16 slot, install the driver, load Spectrum's software and start generating waveforms. The AWGs are fully program-

mable and work with the company's own SBench 6 control software as well as third party software tools such as LabVIEW, LabWindows and MATLAB.

[www.spectrum-instrumentation.com](http://www.spectrum-instrumentation.com)

## Web-based RF cable assembly designer

Pasternack Enterprises has just released their latest engineering resource called the Cable Assembly Designer which allows the user to design and customize RF cable assemblies with an easy-to-use online web application.

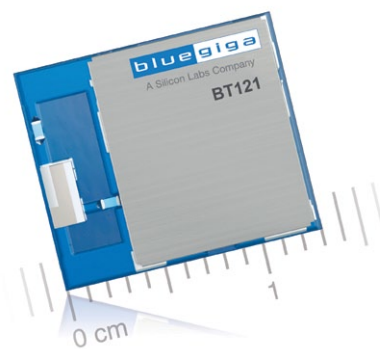
The custom cable designer enables engineers and buyers to create customized RF cable assemblies that meet their specifications from any combination of compatible connectors and cables offered by the company. Pasternack stocks and builds a comprehensive selection of RF cable assemblies, with over 250,000 possible combinations, all available to ship the same day they are ordered. Whether the requirements are for a common off-the-shelf cable or something unique, the web tool enable customers to build their own custom cable assembly from over 1,300

connector types and 115 different coaxial cables (including Twinax).

[www.pasternack.com](http://www.pasternack.com)

## Flexible dual mode Bluetooth module

Silicon Labs has unveiled a dual-mode Bluetooth® Smart Ready module that gives embedded developers unparalleled flexibility to integrate both Bluetooth Smart and Bluetooth Basic Rate/Enhanced Data Rate (BR/EDR) wireless technologies while minimizing design time, cost and complexity.



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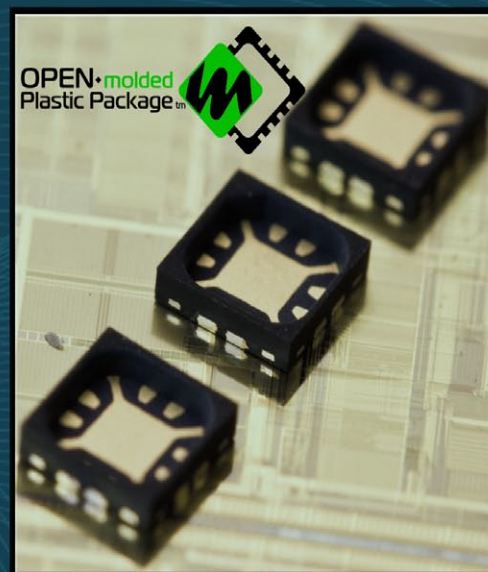
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## Quik-Pak's Air Cavity QFN Packages are Ideal for MW and RF Applications

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The Bluetooth Smart Ready BT121 module from Bluegiga, a Silicon Labs company, provides a pre-certified, fully integrated, high-performance solution that includes the Bluetooth radio, micro-controller (MCU) and on-board Bluetooth software stack supported by Silicon Labs' complimentary Bluetooth Smart Ready software development kit (SDK) and easy-to-use BGScript™ scripting language.

The BT121 module provides a "best of both worlds" for both ultra-low-power and high-data-rate Bluetooth connectivity applications. The module can connect to legacy devices that only support Bluetooth SPP or Apple® iAP2 profiles, for example, as well as to devices that support Bluetooth Smart. The easy-to-use BT121 module integrates a high-performance Bluetooth radio with an extended range of up to 400 meters, a low-power ARM® MCU, and a fully certified Bluetooth Smart Ready protocol stack in a compact 11 mm x 14 mm surface-mount package, making this one of the smallest Bluetooth Smart Ready modules in the market.

[www.silabs.com/bluegiga](http://www.silabs.com/bluegiga)

## Nordic Semiconductor redefines Bluetooth chips by adding NFC

Nordic Semiconductor says its ARM-based, nRF52 Series of devices "redefines single-chip Bluetooth Smart", by combining performance and power efficiency with on-chip NFC for Touch-to-Pair and with active management of functional blocks for minimum power drain.



The nRF52832 is the first of Nordic Semiconductor's nRF52 Series Systems-on-Chip, with a 64 MHz ARM Cortex-M4F processor (the first time this core has been used in this type of chip, Nordic asserts), a high performance, low power 2.4 GHz multi-protocol radio, and fully automatic power optimisation. Achieving a CoreMark

score of 215 the nRF52832 delivers up to 60% more generic processing power than competing solutions, Nordic says. With hardware floating point (the 'F' in Cortex-M4F) the chip claims 10x floating point and twice the DSP performance of comparable products. At 90 CoreMark/mA the SoC is up to twice as power efficient as competing offerings, Nordic adds.

Nordic has given the single-chip Bluetooth Smart device the added function of integrated NFC tag capability that will allow Touch-to-Pair operation of end-user devices.

[www.nordicsemi.com](http://www.nordicsemi.com)

## Portable test amplifier covers 1 to 18 GHz

Designed to meet a demand among RF and microwave test engineers, a portable test amplifier from AtlanTecRF is convenient-to-use, versatile and covers the full 1 to 18 GHz frequency range. The rugged housing is suited to the busy laboratory environment.



Built within a cast aluminium housing, 129 x 84 x 67 mm, the 1-18 GHz amplifier delivers 35 dB gain and +20 dBm P1 output power and comes complete with a manual on-off locking toggle switch for quick application and removal of the amplified signal. A green LED indicates an active unit.

The 12 V, 525 mA DC input is applied via a sturdy XLR socket while there is a choice of SMA, Type N or TNC RF connectors in stainless steel with IP rating of IP66/67.

Additional RF specifications include 2.0:1 VSWR, ±2 dB gain flatness and saturated power output of +21 dBm. The operating temperature range is -10 to +60°C, making it suitable for uses not only in ambient laboratory conditions but also within temperature test chambers and on outdoor field trials.

[www.atlantecrf.com](http://www.atlantecrf.com)

## Low power Bluetooth 4.1 controller supports any microprocessor

The latest version of the EM9301 ultra-low power Bluetooth Smart controller from EM Microelectronic now supports Bluetooth 4.1, and is ideal for



implementing Bluetooth Smart with any microcontroller, ASIC or electronic system. Optimized for different ultra-low power modes, the chip consumes only 9 µA in BLE idle state, and <0.5 µA in OFF mode.

Ideally suited for ultra-low power wireless sensing, remote control and monitoring applications, the EM9301 operates on as little as 0.8 V. It can be powered by a wide range of common single-cell batteries or energy harvesters such as solar cells, piezo-electric or electro-magnetic elements. EM9301 supports both BLE MASTER and SLAVE roles as defined in Bluetooth specification V4.1, and combines the Physical Layer, Link Layer and Host Controller Interface (HCI) layer in one low cost chip. When paired with a low-power host controller, it enables cost/performance/size-optimized systems for most Bluetooth Smart applications.

The EM9301 offers users a flexible, modular and low-cost way to add Bluetooth 4.1 connectivity to their products, allowing them to preserve their legacy microcontroller choice and leverage their software investment while adding wireless connectivity.

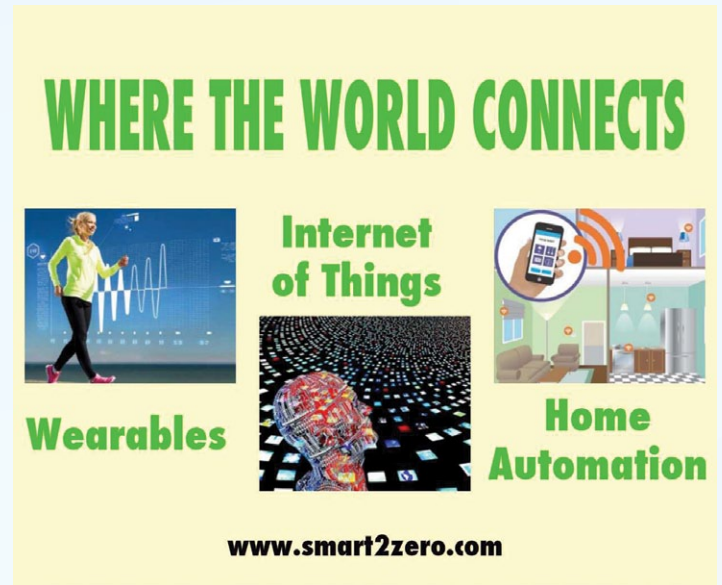
The EM9301 is in production and is available in both die format and in a ROHS-compliant MLF-24 package. EM9301 device purchase includes a license-free Bluetooth Smart stack for 8051 or ARM® Cortex™ M0/M3 cores. Development kits for numerous micro-controllers are available.

[www.emdeveloper.com](http://www.emdeveloper.com)

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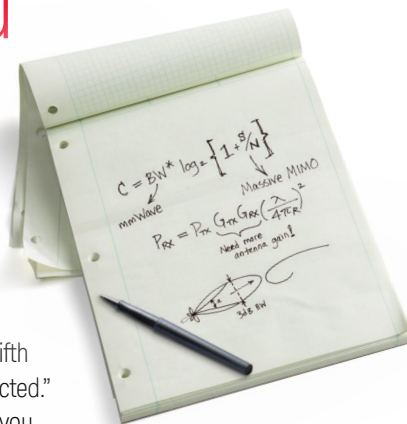
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