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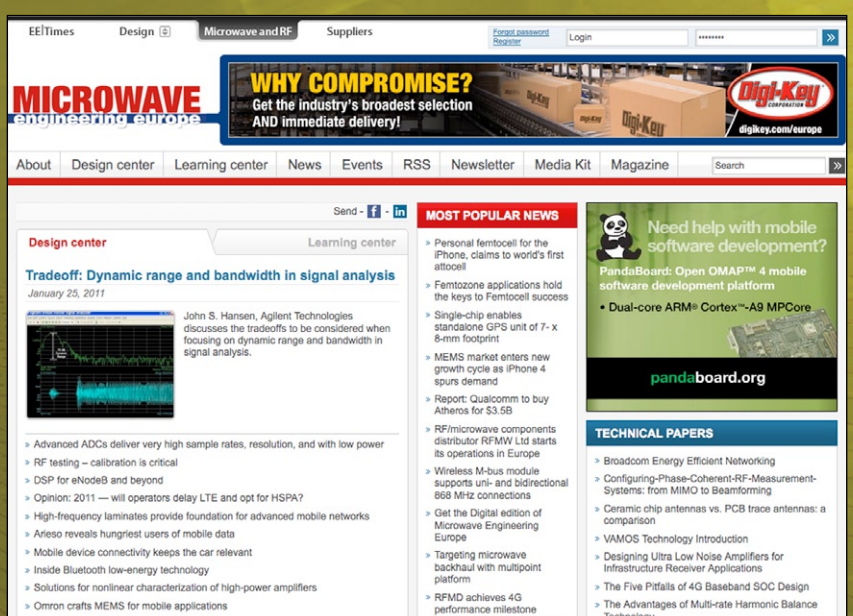

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GET CONNECTED

IN BRIEF

Google's Android tablet delay angers OEMs

Google is for an unspecified time limiting the release of Honeycomb, the tablet version of Android, a move frustrating many mobile systems makers who want to compete with the Apple iPad. Google's move highlights the difficulties of a broad open source movement like Android to compete with a vertically integrated manufacturer like Apple.

"Google refused to give out any information about Honeycomb, and the end result was no one could deviate from the reference design," said a senior engineer with a large mobile systems maker in Taiwan.

www.android.com

Amimon raises $15 million for wireless HDTV

Fabless startup Amimon Ltd., has announced it has raised $15 million in its latest round of funding. The latest round includes new and existing investors Amimon said, but the company did not list the investors. Previous rounds have included Stata Venture Partners, Argonaut Private Equity, Cedar Fund, Evergreen Venture Partners, Walden Israel and Motorola Ventures who are still listed as Amimon's main investors.

The money will be used to accelerate the development of follow-on generations of wireless high definition video chipsets. The money is also expected to help Amimon expand its position in the mobile TV and tablet markets enabling mobile- and tablet-to-TV connection.

According to Yoav Nissan-Cohen, chairman and CEO of Amimon, "We will use this round of funding to solidify Amimon's WHDI technology as the connection method of choice for all mobile devices and tablets to the TV."

The WHDI standard utilizes a 40 MHz channel in the 5 GHz unlicensed band to deliver uncompressed 1080p/60-Hz HD video.

www.amimon.com

U.K. prepares auction for 4G spectrum

Ofcom, the U.K. government's regulatory body for telecommunications, has announced plans for an auction of radio spectrum for 4G mobile services in the U.K. It has announced a consultation procedure as it decides the detailed rules for the auction which is expected to take place in the first quarter of 2012. Ofcom defines 4G to include Long-Term Evolution (LTE) and WiMax communications and the U.K. needs the technology and spectrum to provide high bandwidth, such as streaming video, for mobile users. 4G will allow mobile bandwidth to approach that of current ADSL wired connections.

The auction is due 1Q12 with a view to deployment of services in 2013. This puts the U.K. some way behind such territories as the United States and Japan, which already have some 4G networks. Ofcom is also building conditions into the auction procedure to ensure coverage of 95 percent of the population and competition in the form of ensuring there are at least four national wholesale 4G service providers.

The auction will be for two spectrum bands – 800 MHz and 2.6 GHz. The lower frequency 800 MHz band is part of the digital dividend, which is being freed-up as the UK switches from analog to digital TV. This spectrum is ideal for widespread mobile coverage. The 2.6 GHz band is at a higher frequency, and is ideal for delivering the capacity needed to deliver higher speeds. These two bands add up to 250 MHz of additional mobile spectrum.

www.ofcom.org.uk

3D antenna printing yields an order of magnitude better performance

Researchers at the University of illinois have experimented with omnidirectional printing techniques using metallic nanoparticle inks and a 3D controlled dispensing nozzle to manufacture very compact and high performance antennas.

So far, antennas produced by screen-printing, inkjet printing, and liquid metal-filled microfluidics were designed in simple motifs, such as dipoles and loops, but with limited spatial resolution and dimensionality. This yielded planar antennas that occupy a large area relative to the achieved performance.

"Omnidirectional printing of metallic nanoparticle inks offers an attractive alternative for meeting the demanding form factors of 3D electrically small antennas (ESAs)," stated Jennifer A. Lewis, the Hans Thurnauer Professor of Materials Science and Engineering and director of the Frederick Seitz Materials Research Laboratory at Illinois.

These antennas are electrically small relative to a wavelength (typically a twelfth of a wavelength or less) and exhibit performance metrics that are an order of magnitude better than those realized by monopole antenna designs, claim the researchers.

"There has been a long-standing problem of minimizing the ratio of energy stored to energy radiated, the Q of an ESA," ECE Professor Jennifer Truman Bernhard explained. "By printing directly on the hemispherical substrate, we have a highly versatile single-mode antenna with a Q that very closely approaches the fundamental limit dictated by physics (known as the Chu limit). Conformal printing allows the antenna's meander lines to be printed on the outside or inside of hemispherical substrates, adding to its flexibility.

Unlike planar substrates, the surface normal is constantly changing on curvilinear surfaces, which presents added fabrication challenges," Lewis noted. To conformally print features on hemispherical substrates, the silver ink must strongly wet the surface to facilitate patterning even when the deposition nozzle (100 µm diameter) is perpendicular to the printing surface.

To fabricate an antenna that can withstand mechanical handling, for example, the silver nanoparticle ink is printed on the interior surface of glass hemispheres. Other non-spherical ESAs can be designed and printed using a similar approach to enable integration of low Q antennas on, for example, the inside of a cell phone case or the wing of an unmanned aerial vehicle. The antenna's operating frequency is determined primarily by the printed conductor cross-section and the spacing (or pitch) between meander lines within each arm.

www.illinois.edu.

This month's cover depicts the growing importance of wireless communications. In this issue we look at the latest advances in LTE-Advanced, an emerging technology that looks beyond current 4G networks, currently in the initial phases of commercial roll-out.

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IN BRIEF

ST-Ericsson's Thor modem in T-Mobile Sidekick 4G

ST-Ericsson has announced that a thin modem from the company's Thor™ family will power network connectivity for the new T-Mobile® Sidekick® 4G by Samsung.

Expected to be available later this spring, the Sidekick 4G utilizes ST-Ericsson's Thor M5720 compact and power-efficient modem capable of delivering theoretical peak download speeds of up to 21 Mbps to connect to the Internet.

In February, T-Mobile launched the Samsung Galaxy S™ 4G, also using the Thor M5720 modem, which provides blazing-fast connectivity through T-Mobile's 4G network.

www.stericsson.com

Broadcom to pay $313 million for Provigent

Broadcom has signed a definitive agreement to acquire mixed-signal IC vendor Provigent for $313 million, a provider of mixed-signal chips for microwave backhaul systems.

Broadcom (Irvine, CA) said that the addition of Provigent's engineering expertise in microwave radio products would enable the company to expand its portfolio to more thoroughly address the $5 billion microwave backhaul equipment business.

"Provigent is a unique asset with world-class microwave backhaul technology and strong engineering talent developing innovative and highly integrated semiconductor solutions for the microwave segment," said Rajiv Ramaswami, executive vice president and general manager of Broadcom's Infrastructure and Networking Group, in a statement.

"Combining their microwave backhaul solutions with our industry leading network infrastructure and wireless solutions allows us to better serve our customers and expand our addressable market."

www.broadcom.com
www.provigent.com

Bluetooth in 467M health devices by 2016

As many as 467 million health care and personal fitness devices will ship in 2016 using Bluetooth Low Energy, according to a new report by ABI Research. But a delay releasing the spec has given competing technologies a leg up in the new markets, it said.

The Bluetooth Core Specification Version 4.0 was released in July 2010, more than six months later than anticipated, said Jonathan Collins, principal analyst at ABI Research and author of the report.

"The wait for adoption by the Bluetooth SIG has put a brake on many wireless health and sports devices' market launches," said Collins in a press release. "Where [the delay] hasn't halted product development it has fostered adoption of rival traditional Bluetooth and proprietary offerings in the market," he said.

The alternative approaches include "a host of rival protocols from 802.15.4-based offerings to low-power Wi-Fi to proprietary wireless protocols," said Sam Lucero, another ABI analyst.

Chips supporting the Bluetooth 4.0 spec are now sampling and systems using them should be available in 12 months, the report said. The chips also will be used in some smartphones, it said. About half of the wireless health and fitness systems sales by 2016 will be for medical systems in hospitals and clinics, ABI estimates. Another third will be for fitness devices.

www.abiresearch.com

Partnership develops secure NFC solutions

STMicroelectronics and Gemalto have announced a partnership to develop a range of solutions to initiate and distribute digital security services for NFC (Near Field Communications) applications. Building on the two companies' security expertise and portfolio of NFC technologies, the partnership aims to deliver solutions that will meet the strong global demand for NFC-based services.

The partners are addressing the industry's need for a secure element, such as the widely adopted SIM-based NFC solution, for trusted NFC applications. They plan to further develop a number of additional packaged offers that include the highly secure ST33 EAL5+ chipset from ST, specially designed for mobile applications, and Gemalto's secure operating system, mobile handset software, Trusted Service Management and secure personalization services.

The combined turn-key solution aims to accelerate the adoption and implementation of NFC services, including consumer applications such as contactless payment, transportation ticketing, personal data protection and device integrity.

The development incorporates leading public key cryptography, matching the latest GP 2.2, JavaCard 3.0.1 specifications as well as Common Criteria EAL4+ and EMVCo certifications.

www.st.com, or www.gemalto.com

Smart wireless microsystems to provide wearable and implanted body area networks

A European consortium lead by CSEM has launched an EC-funded WiserBAN project, with the objective of developing innovative ultra-miniature RF microsystems for wireless Body Area Networks (BAN) targeting primarily wearable and implanted devices for healthcare, C, wellness and lifestyle applications.

The WiserBAN project will address primarily the following wearable and implantable use cases: hearing instruments, cardiac implants, insulin pumps and cochlear implants. In such applications where miniaturization and unobtrusiveness are a must, only limited wireless connectivity and autonomy can be achieved using today's wireless solutions because of their excessive size and power consumption. WiserBAN will push wireless microsystem technology beyond state of the art by delivering an ultra-tiny and ultra low-energy radio that will enable WBAN capability and novel product perspectives for wearable and implanted devices for use in lifestyle and bio-medical applications.

www.csem.ch

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4G will it be enough for next generation smartphones?

According to Mobile Access in 2010, smartphones require 10x more bandwidth than typical feature phones and tablet PCs generate 100x more traffic. Further, sales for both continue to explode. Consequently, bandwidth demands have carriers upgrading TDM to Ethernet-based networking to handle the growth, with Ethernet use in base stations at 100 percent by 2014.

The growing dominance of data traffic generated from the growing use of smartphones and tablets has determined a clear direction to 4G mobile networks. The key to providing the spectral density required in such networks is effective backhaul at much higher data rates than in 3G networks.

Inherently packet based, these 4G mobile network architectures enable operators to deliver IP-based services much more efficiently and at much lower cost points than alternative backhaul options.

One company leading the charge, DragonWave, notes that 4th generation microwave systems are an order of magnitude more cost effective per bit than traditional backhaul. The company further notes that higher spectral efficiency is one of the key advantages of packet microwave systems. New techniques such as bandwidth optimization are taking capacity per channel to much higher levels.

There is a definite trend to 4G due to the inherent cost structure and efficiency of 4G network architectures as well as the benefits that end-to-end Ethernet brings to such networks. Since data by all counts is set to explode over the next few years, voice traffic will represent a very small portion of the total capacity requirement. Two alternatives exist to preserve the voice cash cow, use an older 2G or 3G network in parallel or implement VOIP within the 4G network with voice carrying an absolute packet priority to ensure QoS (Quality of Service).

The question remains, given such forecasts of tablets needing 100x more capacity and smartphones requiring 10x more, will even the 4G networks based on LTE and WiMAX be enough to meet demand? I say this because, forecasts of the data capacity generated by the first and second generation smartphones was on the low side and the actual capacity requirements caught many by surprise. I suspect that as smartphones and tablets evolve there will be many more surprises down the road.

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IN BRIEF

Cavium buys baseband chip maker

Cavium Networks Inc., has recently acquired the assets of Wavesat Inc., a wireless baseband IC provider. The company paid approximately $10.0 million in cash for the firm. Cavium just recently completed its acquisition of China-based privately held Celestial Semiconductor. Celestial provides a family of ARM-based high-performance devices with HD quality video processing, multi-source video input and multi-format video playback.

www.caviumnetworks.com

Anite's LTE test platform selected by CETECOM

CETECOM has selected Anite's LTE Conformance Toolset and SAS test solutions for Verizon Wireless device certification testing. Anite's Conformance Toolset delivers comprehensive and industry leading coverage of LTE signalling protocol test cases encompassing both GCF and PTCRB certification requirements. SAS is Anite's industry leading interoperability testing solution, enabling accelerated time to market for new mobile devices. Its intuitive user interface and advanced feature support have made SAS the preferred solution for 2G/3G and now for LTE device approval.

www.anite.com

Wireless LAN market reached record in 2010

A recently published report by Dell'Oro Group reveals that the worldwide Wireless LAN (WLAN) market achieved a record high in 2010 as revenues grew 25 percent to surpass $5 billion. The report also shows that the small office, home office (SOHO) segment surpassed $3 billion, while the Enterprise WLAN segment grew at its fastest rate since 2006 to exceed $2 billion in 2010.

www.DellOro.com

Researchers integrate silicon, III-V

Integrating gallium nitride emitters and other optical materials onto silicon substrates was recently demonstrated at the Toyohashi University of Technology. Researchers there claim to have solved the lattice mismatch problem between silicon and III-V materials, thereby enabling future integration of optics onto silicon chips.

Silicon photonics has been demonstrated for most optical functions, including waveguides, resonators and switches, but optical emitters has remained a task for III-V materials using gallium, arsenide, indium and their various nitrides.

Now, Akihiro Wakahara, the project team leader at Toyohashi Tech (Aichi, Japan) and colleagues claim to have invented a method of mitigating the lattice mismatch between silicon and III-V materials, thereby enabling optical emitters—including lasers—to be fabricated on silicon chips.

As a demonstration, Wakahara's team constructed a one-bit opto-electronic counter circuit that combines silicon field effect transistors (FETs) alongside gallium phosphide nitride (GaPN) LEDs on a single chip. The key to solving the lattice mismatch between silicon and III-V was accomplished by growing a thin gallium phosphide (GaP) layer using migration-enhanced epitaxy with III–V–N alloys. The resulting lattice matched Si/GaPN/Si hetero-structures were grown on silicon substrates using dual-chamber molecular beam epitaxy (MBE)

www.tut.ac.jp/english

AT&T continues 4G spectrum grab with T-Mobile buy

With its purchase of T-Mobile USA, AT&T appears to be continuing to use acquisitions to gain control of more of the limited supply of wireless spectrum required to compete in the market for 4G services. AT&T announced it will buy T-Mobile USA from Deutsche Telekom AG in a deal worth $39 billion.

The deal represents the second acquisition that AT&T has undertaken recently that will give it additional 4G spectrum. AT&T in December 2010 expanded its long-term evolution (LTE) downlink bandwidth by acquiring Qualcomm's defunct MediaFlo mobile TV service. The addition of T-Mobile's spectrum will allow AT&T to immediately gain network capacity and to gain a better competitive position against Sprint Nextel and Verizon Communications in the key 4G area. The 4G segment represents a fast-growing portion of the wireless market in North America. Subscriptions to 4G in North America took off in 2010, and the service has become a competitive differentiator for AT&T and competitor Sprint.

www.ihs.com

Industry's first system-on-chip two-way radio enabling cost effective digital radios

Freescale Semiconductor claims to have introduced the industry's first system-on-chip for the two-way radio market. The MC13260 consists of an integrated 32-bit ARM-9™ processor, a software defined modem, an RF transceiver and audio converters.

The single chip MC13260 offers a high level of integration, minimizing external components and slashing the required board area. As a result, it requires less than one third the total parts count and less than half the board space of existing solutions. It contains a vector digital signal modem processor optimized for communication systems, which provides a low power, high MIPS solution as compared to general purpose digital signal processors used in two-way radios today. This software-defined modem offers a single platform which can implement a wide range of communications protocols and provides the flexibility to adapt to evolving standards.

www.freescale.com/SoCRadio

Starting up – make sure you cover all bases

By Jackie Maguire, CEO, Coller IP

Qualcomm, Nokia, Apple, HTC, RIM, Motorola, Toshiba, Microsoft, and the LG Group are a few of the household names in the mobile RF arena that are actively engaged in protecting/increasing their market share using their intellectual capital (e.g. patents in this case). They are all vigorously leveraging their intellectual capital to secure their position in the smart-phone market. Incredibly, most of them were once a start-up or spin-out in the 80s or early 90s and succeeded in securing a position amongst giants. They now compete on an equal level in this market.

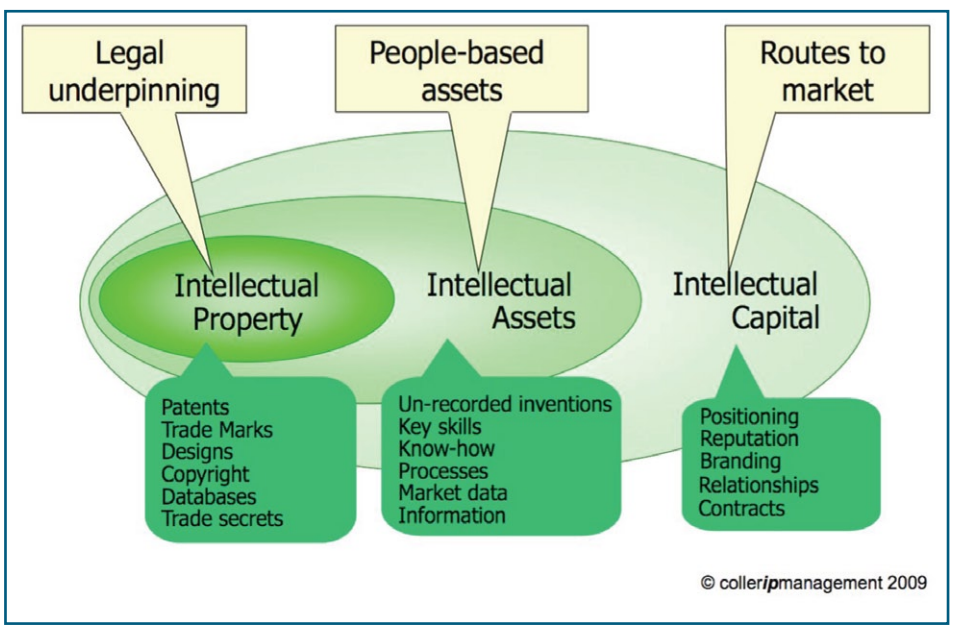
Their success is down to numerous factors: right-place right-time, focus on core strengths and products, ability to adapt quickly to change (especially in core markets), and a heavy involvement in setting standards. Although most of this could be attributed to their CEOs, it could not have been achieved without the talent and ingenuity of their engineers and designers. MOST importantly, all of these companies recognised and appreciated, at the very beginning, the value in continually creating core intellectual capital that would be needed by them, their competitors and others. They saw intellectual capital as an asset.

Starting or spinning off a new company in the RF industry with large established players such as these is tremendously exciting as well as very demanding on both the time and energy of those involved. In the excitement, one of the basic tasks, often ignored until it is too late, is an understanding by everyone involved in the company, from the CEO to the engineers, of the value in protecting and commercialising your intellectual capital.

What do we mean by intellectual capital? Most people assume that it has something to do with filing applications for patents or registering a trade mark. This is certainly part of it. But, intellectual capital goes far wider than that. The various elements which make up intellectual capital are shown in Figure 1.

Intellectual capital is not just about patents and other formal intellectual property rights (formal IP) such as trademarks, designs and copyright – which are underpinned by various statutes and laws. Formal IP is only a piece of the intellectual capital jigsaw.

Figure 1: The various elements which make up intellectual capital.



Intellectual capital also includes workforce skills, business processes, customer and business relationships, branding, reputation and the know-how of employees, importantly all your RF engineers and designers. Ideas and inventions provide a company's heart beat, while the wider intellectual capital drives growth and sustainability.

Many small companies in the communications and electronics industries have talented engineers who come up with radical inventions, yet these companies for whom they work fail – for a number of reasons - not only to protect, but also to commercialise, those designs and inventions

As a CEO or engineer in a start-up, you might think you are too small or specialised to be considered a threat by any of the giants with established intellectual capital, so they will leave you alone. You may even say, "why bother with establishing or understanding intellectual capital now? I have an accountant and other things to worry about like repaying loans, product deadlines to meet, meetings to attend…", the list is seemingly endless. But it is worth noting that most start-ups to fail within one to five years. Bear in mind, once your core product or process is marketed and after you have developed a following such that it is eventually desired (or required) by others, a lack of intellectual capital may allow them to copy it. Will this ruin the business you run or work for? And if it does, can you adapt?

The risk of your core product, process or idea being stolen, or that your company is not the first mover you thought it was, can be minimised by understanding where you, as a CEO or engineer, can contribute to the intellectual capital jigsaw and where the core products you are working on lie within the patent minefield. Importantly, are you and those in your company willing to recognise and appreciate, at the very beginning (or now), the value in continually creating core intellectual capital that would be needed by you, your competitors and others?

At the very least, CEOs and engineers in a start-up in the RF industry need to be aware of what patents their competitors hold and how these may affect core products. It is useful to ask the question, what is your core product(s) made up of? What are the key elements? In this industry core products can range from a single component (e.g. D/A convertors, an antenna, a display, or chip), or several components working in unison (e.g. antenna and transceiver chipset, or chipsets for software defined radio), to an entire consumer product (e.g. display, power

supply, internal circuitry, antenna, and casing of the product). Simply put, any of the components that make up your core product may be patentable or, at risk to the business, already patented by your competitors or suppliers.

For electronics companies, a key area to watch for is where intellectual capital, in particular formal IP such as patents, meets the standards arena. Most telcos, chipmakers, and consumer electronics manufacturers, for example, have very large patent portfolios, such as those held by Philips, Qualcomm, Samsung, Nokia and the like. As an example, the digital communications field in 2010 alone has seen a 17 percent rise in published PCT international applications (these are a "special applications" that assist in getting patents in many countries/regions around the world) Qualcomm alone had 1,677 PCT international applications published in 2010, which are most likely applicable to the LTE or LTE Advanced standards. Such large portfolios can mean lots of systems, components, and hardware related to RF technologies in this area may have been, or are in the process of being, patented.

What can they do with such a large portfolio? Typically, they can use it for cross-licensing purposes. By cross-licensing portions of their portfolios with each other they can make the latest phones, chips, and electronics that consumers want without fear of infringement issues and expensive litigation from each other. In emerging markets, such as the smart-phone market at the moment, there is a lot of patent litigation in progress focussed on the various components/aspects of smart-phones. In the end, companies may settle and cross licence.

It is evident that the electronics field, in particular in RF communications, is very crowded in terms of patents. Many small to medium sized companies in this area may not realise how vulnerable they are. Nowadays, a small company simply implementing a product that conforms to a standard can risk infringing another company's patent(s). A start-up company can inadvertently step on the toes of the "giants" due to a lack of understanding of the patent landscape within which the start-up is operating or is intending to operate. For some, this can end the dream.

Start-ups and spin-out companies need to understand that they should take advice on their freedom to operate in relation to their core product(s) and also how they can establish their intellectual capital, e.g. when should they patent their inventions? How should they go about it? To build a patent portfolio that is worth cross-licensing, there needs to be patents and/or good pending patent applications in it. What is a "good" patent or patent application? As a patent defines an invention (e.g. it may define an antenna structure in general terms), it is the scope of this definition of the invention that can prevent others from making variants of the invention (e.g. slight modifications to the antenna structure). At the very least, a "good" patent should: 1) have a broad definition of the invention; 2) cover obvious work-a-rounds or variants; 3) still be commercially applicable to the business; 4) cover the aspects of the core product that implements the invention.

In order to obtain a patent, an invention should be new (i.e. the invention has not been made available to the public before the filing date of the patent application) and inventive (i.e. not obvious over all mankind's knowledge so far). An invention is obvious if a person skilled in the art (that is, an "unimaginative" expert in the field - this is a fictitious person), whom using their common general knowledge and the documents available to them prior to the filing date of the patent application, i.e. the invention, would have found it obvious to modify or adapt these documents or knowledge to put the invention into effect.

Formal IP law can be complex, but to ensure that your particular trade mark, design or invention is properly protected, in all the relevant jurisdictions/markets, the advice of a specialist intellectual property lawyer or patent attorney is often recommended. Remember, even though the "giants" now have in-house patent departments and outsource their patenting work to specialist patent attorneys, they were once start-ups and still sought advice. This will ensure your company is starting on the right foot to build a sound and watertight foundation.

Depending on the business needs, in the telecommunications/electronics industries it is important to find a lawyer or patent attorney who is within your budget, has an excellent technical grounding in electronic engineering, computer science, and/or physics, who is not only able to understand a complex technical brief quickly, can draft a specification rapidly, but also is able to engage with engineers and the inventors and draw out alternative embodiments or examples of the invention, and alternative ways of doing something, in order to fully claim the invention. They are out there.

Intellectual capital issues should not just be treated as an add-on for a start-up or small business. Ideas are its lifeblood. New and small businesses should not take unnecessary risks, especially in the current climate. Taking all the steps required to get a company up and running and trading successfully is quite enough to worry about without the fear that someone might steal your assets or that you are accused of stealing theirs. Yet it is surprising how many companies function without taking these basic steps – even some quite large ones. Taking steps to protect your intellectual property is something that many companies think they will get round to later, but never do or it is too little too late. If done early on, it can save a great deal of heartache – and even possible insolvency.

Protecting intellectual capital is vital. However, many companies stop there. It is important not just to protect but also to understand the commercial value of the IP and ensure that you are fully exploiting it, having a clear idea of the commercial goal from the outset. Choice of business model is the key to considering whether value is realised from manufacturing, production, direct sales or licensing. For some companies with the correct experience and know-how it makes sense to manufacture a new product. For others, a license to an established manufacturer/supplier is the best way to get a return from your invention. The correct business model, product proposition and route to market need to be laid out as inputs to an IP strategy ideally from the outset, so that the best form and details of protection can be established. In addition, market issues need to be factored into the process to guide and inform the key IP decision making steps along the way.

Despite the market downturn, new opportunities to trade internationally are still being created at a rapid pace and there are opportunities for start-ups who can provide products or services that will be taken up by the marketplace. However, companies need to ensure that, in taking advantage of these new opportunities, they do not leave themselves open to exploitation.

About the author

Jackie Maguire is the CEO of Coller IP, a specialist in commercial IP management and valuation based in Wallingford, UK. Her contact details can be found at: **www.colleripmanagement.com**.

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CHANGING THE STANDARDS

EM simulation continues to transform microwave and signal integrity design

By ANSYS, Inc., www.ansys.com

HFSS developers focus on product features and new technology that delivers expanded capability with accuracy, capacity and performance. HFSS 13.0 introduces a new 3D full-wave transient field solver based on the discontinuous Galerkin method (DGTD). This finite element based time domain solution provides engineers with an additional tool for analyzing electromagnetic phenomenon, while maintaining the same gold standard for accuracy, provided by HFSS through adaptive meshing. A new solver technology, finite element boundary integral or FE-BI enables a combination of finite element and method of moment solvers to be employed for efficient simulation of large radiating or scattering problems. With FE-BI engineers can solve larger more complex problems such as antenna placement analysis on an aircraft. Finally simulation productivity is addressed through algorithm improvements and application of multiprocessing to parts of the solution and data processing. This product feature discusses in detail two of the newest technologies being introduced in HFSS 13.0, Transient and Finite Element - Boundary Integral

Table 1: Highlights of HFSS 13.0.

FEATURE	COMMENT
Transient, DGTD, full-wave solver	Accuracy for transient electromagnetic phenomenon
Finite Element – Boundary Integral technique for open boundary condition	Accuracy and capacity for radiating and scattering problems
Faster meshing via multiprocessing	Faster simulations for complex geometries
Faster solution field recovery via multiprocessing	Faster simulations for large, complex simulations with large excitation counts
Faster far field post-processing via multi-processing, algorithm improvements and data management	Significant speed up in far field post-processing
Generalized, multi-pole Debye frequency dependent material input	Ensures generation of causal s-parameter models
Automated settings for material properties	DC thickness for 3D conductors Causal material models for lossy dielectrics

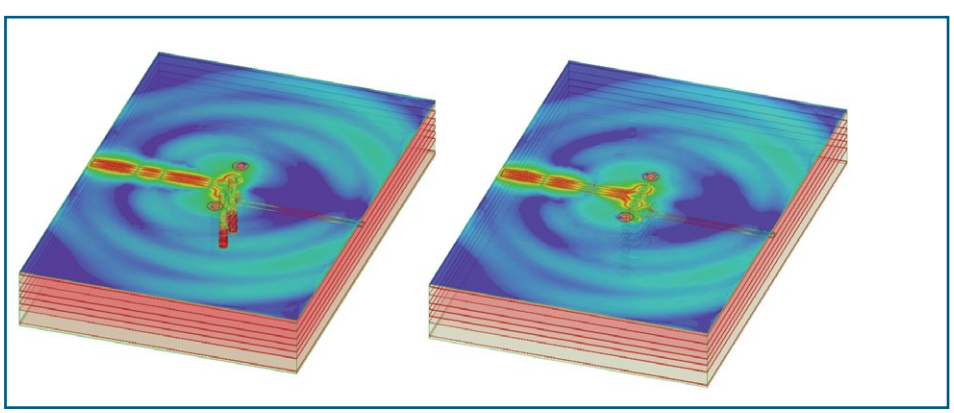


Figure 1a (left) and b (right): Electric field plot for differential via design without (a) and with (b) back drill to stripline breakout layer.

HFSS Transient

A new finite element based transient or time domain field solver provides engineers with additional insight to electromagnetic phenomenon. Most commercial time domain solvers are based on non-conformal brick mesh which has known issue for accuracy and reliability. A finite element mesh conforming to geometry and allowing for an inhomogeneously sized mesh provides accuracy and efficiency when transient electromagnetic field analysis is of interest. Key technologies implemented in HFSS Transient such as local time stepping and a hybrid implicit/explicit solving scheme provides efficient and accurate solutions. This new solver complements the existing frequency domain solver technology in HFSS, allowing an engineer to investigate transient electromagnetic phenomenon in their designs.

Time domain reflectometry

Time domain reflectometry or TDR is a standard design parameter for evaluating the performance of devices in a high speed serial channel or data link. When designing to a TDR parameter the goal is to produce a flat response as close as possible to the nominal impedance of system thereby minimizing signal reflection and loss in the system or channel.

As data rates for printed circuit board (PCB) applications have increased a common practice for improving the performance of these “higher” speed channels has been the applications of a technique referred to as via back drilling. Back drilling eliminates any open ended via stubs that may extend to the bottom layer of a PCB. Although relatively small these stubs can act as resonating structures which can absorb, reflect and/or radiate energy of a digital signal carried by the channel. Their elimination means a high speed signal can propagate more easily with less reflection through the via geometry. Although very effective back drilling can add cost to the manufacturing of a PCB and thus the designer needs to understand the impact of such a technique to the channel’s performance. Figure 3a shows the image of a differential via design in a 10 layer PCB with a stripline breakout layer at layer five which results in via stubs extending to the bottom of the PCB with lengths of ~60mils in FR4. A snap shot of the electric fields are taken in time at the moment when a pulse with a five picosecond rise time reflects at the end of these stubs. Much of this energy will undesirably reflect back to the differential microstrip input

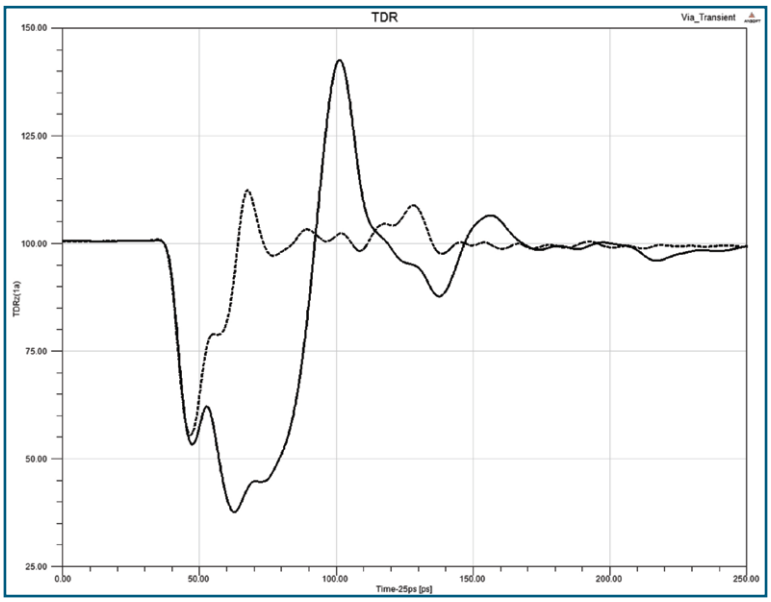


Figure 2: TDR from design in Figures 1a (solid) and b (dashed).

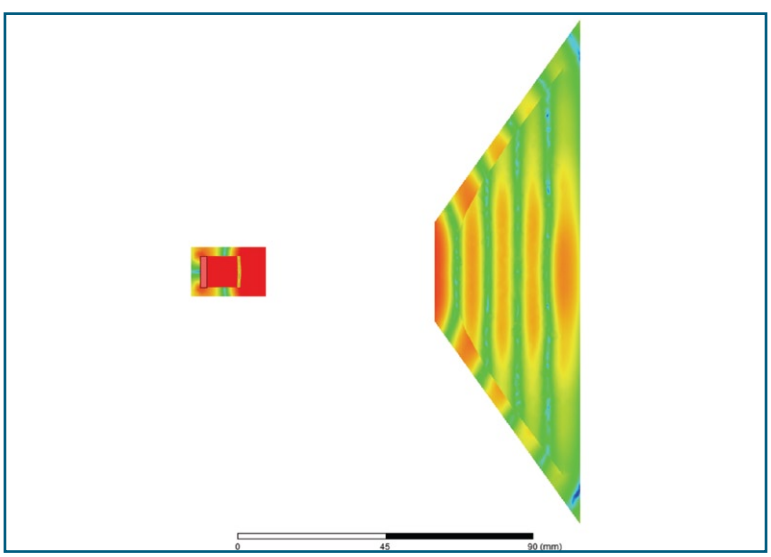


Figure 3: Dielectric lens with rectangular waveguide feed with FEBI and separate air volumes (left) and traditional PML with all surrounding air volume (right).

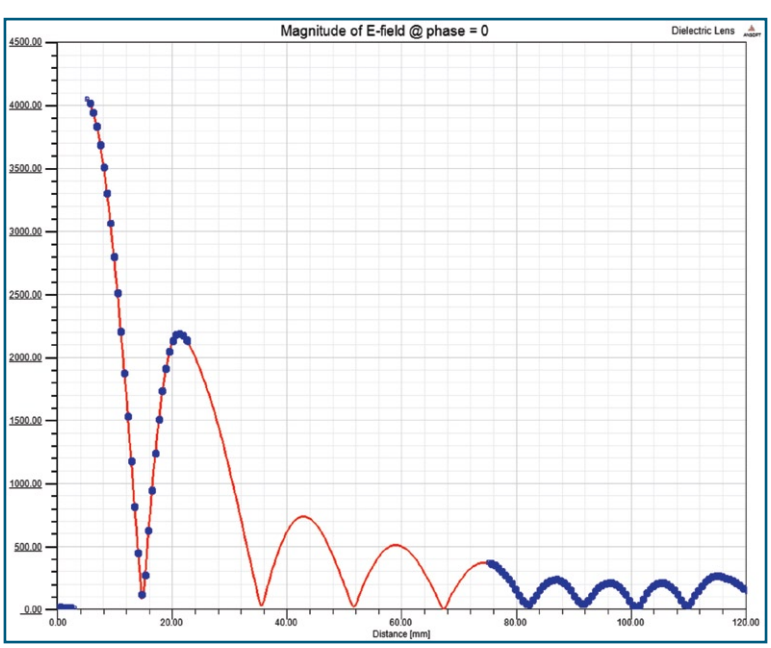


Figure 4: Field along line through center of feed antenna and lens for FEBI model (blue circles) and PML model (red line). Results are identical.

transmission line on the top layer. Figure 3b shows the same image for a similar via design where back drilling has been implemented to just short of the breakout layer. Significantly less energy has been reflected at this transition. In the lab this behavior is identified through the TDR measurement technique. Figure 4 shows the corresponding TDR plot from the analyses described in Figures 3a and b. The responses align through the microstrip transmission line until reaching the stripline breakout layer where the design without back drilling exhibits a sharp and undesirable capacitive response in the TDR.

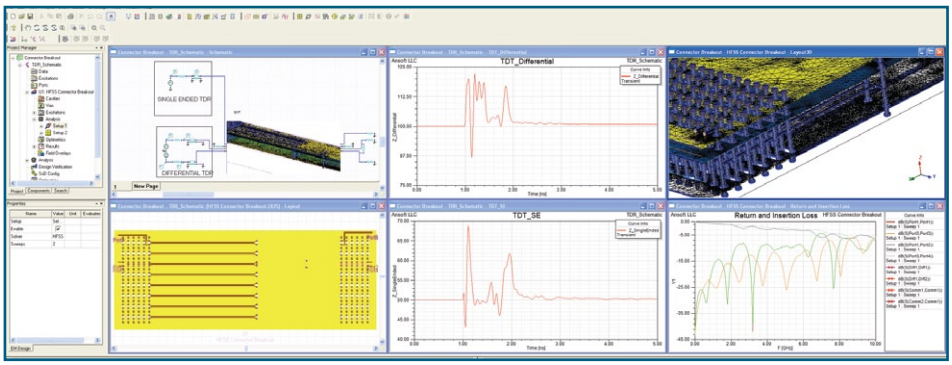
Finite element – boundary integral

Inspired by recent advancements in domain decomposition techniques a new hybrid finite element/integral equation technique is introduced in HFSS 13.0 for modeling large unbounded radiation and scattering problems. This technique, more commonly referred to in the literature as finite element-boundary integral (FEBI) [2], effectively truncates a nominally bounded finite element solution with a boundary integral. In HFSS 13.0 this new truncation is implemented as full wave integral equation, i.e. method of moments solution that satisfies the Sommerfeld radiation condition at infinity. This effectively utilizes the two simulation techniques, FEM and MoM, in their respective areas of strength; finite elements for handling complex geometries, materials and excitations and method of moments in solving directly for surface currents satisfying an open boundary problem. Engineers are able to model much larger systems such as antenna placement or radar cross section studies

Separate finite element volumes

A very interesting aspect of the FEBI technique is its ability to act as a two way “field link” between two physically separate volumes. To demonstrate, consider a snapshot of the electric fields in a cut plane between a rectangular waveguide radiator illuminating a composite dielectric microwave lens. An FEM only solution would require the simulation of the entire air volume contained between the horn and lens. For such a rectangular waveguide radiator illuminating a composite dielectric microwave lens, however, only the air volume immediately surrounding the radiating horn and lens need to be included in the FEM portion of the simulation. The equivalent surface currents capturing the coupling between these air volumes are computed via the integral equation solver.

Figure 5: Backplane in Designer layout interface solved with HFSS SoD.



Thus the overall computational domain for this system can be significantly reduced through the application of the FEBI technique. Also note that the separation between the horn and lens may be varied without affecting the computational effort since the FEM volume and IE surface area will not change with separation. A plot of the electric fields along the center connecting axis of the radiating horn and lens system yields a line that represents the fields for a full FEM solution with the entire air volume between horn and lens simulated. The data points represent the same system with the FEBI technique coupling the fields between separate air volumes.

HFSS – Solver on Demand

Ease of use and accessibility are two very critical aspects of simulation software design. Many electrical engineers are familiar with layout based design flows for chip package and board design. These designs, although 2D in the nature of their creation, are representations of 3D designs which at higher frequencies and data rates, require a rigorous full-wave 3D simulation. The HFSS Solver on Demand technology enables users to drive HFSS directly from the intuitive parametrically driven stack-up based layout interface of Ansoft Designer (Figure 5). With Solver on Demand technology the material properties, port definitions and boundary conditions are set automatically within the Ansoft Designer layout interface. Integration to Cadence Design Systems, Mentor Graphics, Altium, Zuken, Autocad, and GDSII support exists through AnsoftLinks.

Conclusions

HFSS version 13.0 introduces new solver technologies and integrated design flows to allow engineers to solver large more complex designs. HFSS Transient and the new hybrid finite element – boundary integral solvers provide additional insight and higher solution capacity for the toughest electrical design challenges. HFSS Solver on Demand in Designer provides an easy to use layout driven interface for the HFSS solver technology to enable simulation of chip, package and printed circuit board designs generated from layout.

"V3DIM" research project to lead the 3D vertical design of 40 to 100 GHz ICs

The "V3DIM" research project lays the foundations for working out the design requirements to develop innovative, highly integrated 3D System-in-Package (SiP) solutions for systems in the extremely high frequency range of 40 to 100 GHz, the so-called millimeter-wave range.

V3DIM stands for "design for vertical 3D system integration in millimeter-wave applications". Five partners from industry, science and research joined forces in the project funded by the German Federal Ministry of Education and Research (BMBF) to explore how innovative 3D integration technologies can be exploited in chip and package manufacture.

In their quest, special attention will be paid to miniaturization, performance (including power loss, signal integrity, noise and cost), energy efficiency and reliability. The five project partners are Fraunhofer Institutes in Dresden, Munich and Berlin lead-managed by the Dresden Institute for Integrated Circuits, Symeo GmbH, which produces sensor components and complete position detection and distance measurement systems for industrial applications, Siemens AG with Corporate Technology, the Institute of Technical Electronics at the University of Erlangen-Nuremberg, and the project manager Infineon Technologies AG.

The project is scheduled for completion at the end of August 2013. In the V3DIM project the five partners will devise new design methods, models and SiP technology components to meet the special challenges of vertical 3D system integration in the sphere of millimeter-wave applications. The results of the research project are to promote the optimal exploitation of present and future technologies in the millimeter-wave range for SiP applications. The development time for 3D SiP designs could thereby be cut by at least one third.

V3DIM's overall project cost amounts up to Euro 6.8 million, and approximately 40 percent of it is funded by the three industry project partners. In addition, the research project will receive BMBF support of about Euro 4.1 million over a three-year term under the "Information and Communications Technology 2020" (ICT 2020) program as part of the German Federal Government's High-Tech Strategy.

Among the objectives of the ICT 2020 program are promoting microchip design as an overarching enabling technology, opening up new, innovative applications and hence consolidating and expanding Germany's leading position in the ICT sector. The German V3DIM project collaborates closely with the European CATRENE 3DIM3v project which works on complementary aspects of vertical 3D system integration.

www.infineon.com
www.fraunhofer.de
www.symeo.com
www.siemens.com
www.uni-erlangen.org

Standardisation boosts momentum for Envelope Tracking

By Nigel Dixon, Chairman, OpenET Alliance, www.open-et.com

Envelope Tracking (ET) is the most effective wideband power reduction technology for RF Transmission. The formation of the OpenET Alliance to standardise the interfaces between the ET power supply modulator and the baseband or RF transceiver will accelerate adoption.

The new generation of data-oriented digital communications networks being rolled out in the cellular, broadcast, military and other environments carry major challenges for RF designers. In order to achieve high data rates, these new standards use advanced modulation techniques such as OFDM which significantly increase the variations in amplitude of the transmitted signal, reducing the efficiency of the RF transmission system. The frequency bands used for these new networks are allocated as a result of the "digital dividend" without consideration for the practicalities of designing a cost effective radio system, making the design job even harder.

Envelope Tracking is coming to the fore as the most effective wideband power optimisation technology to address this challenge. Not only does it offer attractive transmitter efficiency of 50% plus with high peak to average ratio signals, but it maintains this performance over a very wide bandwidth. As a result, an efficient 4G cellular handset design covering all fourteen frequency bands defined in the 3GPP for LTE and all of the operating modes (GSM, EDGE, WCDMA, HSUPA and LTE) can be implemented using just two Power Amplifiers (PAs) instead of the seven or more needed using alternative approaches. In a Base Station just a handful of PA subsystems are required to cover all the power level, frequency and modes required, instead of the more than 60 separate designs required by alternative narrow-band approaches. ET therefore enables significant cost reduction as well as power savings in cellular equipment.

Growing adoption

These considerations have led to adoption of ET in both cellular terminal and infrastructure equipment. A Tier 1 semiconductor vendor in the handset ecosystem has already adopted ET technology, and several others are looking at it closely. On the network side, Sumitomo was first to market with an ET radio head, and reference designs for ET PA platforms have been developed by RFMD, Triquint and Nujira. ET can be combined with many of the other approaches to create an 'efficiency multiplier', as has been demonstrated by both Texas Instruments and Xilinx who have integrated ET with their Digital Pre Distortion (DPD) platforms.

Xilinx is the latest semiconductor vendor to support ET, and Dave Hawke, its senior product marketing manager, wireless communications, believes the cellular network industry is motivated by both economic and environmental concerns. "Xilinx is fully committed to supporting the cellular industry in minimising the environmental impact and operating cost of the next generation of 3G and 4G infrastructure, and is adding an Envelope Tracking port to its DPD solution," he said.

David Brubaker, Product Line Manager, Wireless Infrastructure Radio Products at TI, says, "We see Texas Instruments digital predistortion technology and Envelope Tracking as key enablers for energy-efficient basestations. OEMs can now rapidly deploy these technologies to produce high-performance, power-efficient 3.5G and 4G basestation platforms that reduce operating costs for network operators worldwide."

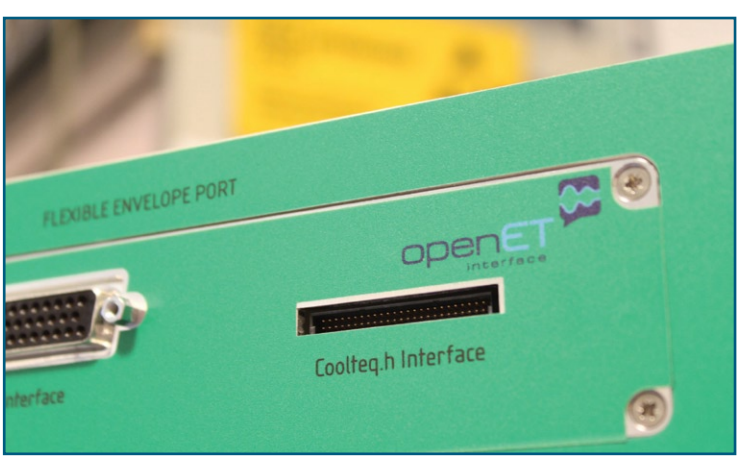


Figure 1: World's first openET interface.

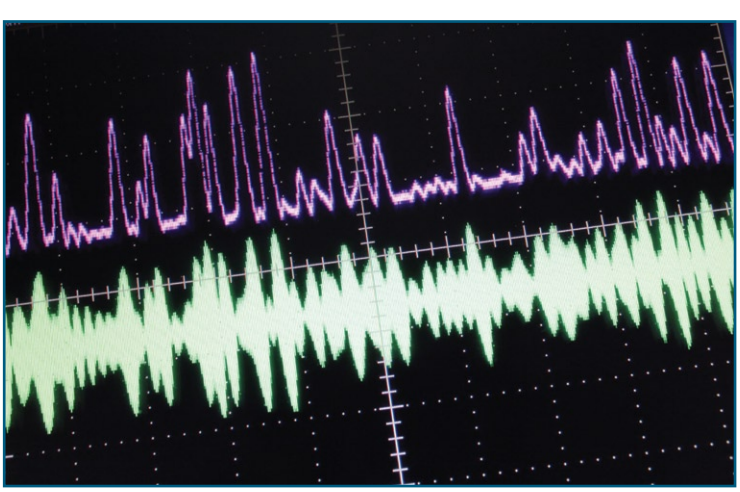


Figure 2: Envelope Trcking as seen on a scope.

ET Interface standardisation

Implementing ET requires a connection between the RF Transceiver or Baseband and the Envelope Tracking power supply modulator, allowing it to track the transmitted waveform and ensure that the optimal amount of power is available to the PA to satisfy transmission demand at any point.

To encourage faster adoption, the market leader in ET technology, Nujira, has assisted in the setting up the OpenET Alliance to develop and standardise these interface specifications to make them accessible to any manufacturer who wants to use the technology.

The OpenET Terminal Interface specification for Envelope Tracking ports enables ET capability to be added to baseband and RF Transceiver chipsets for mobile terminals, cellular base stations and other applications with minimal impact on the cost and power consumption of the chipset itself. The OpenET Alliance is a non-profit corporation that operates as an open membership organisation, and welcomes members from companies in the mobile industry, including Universities, Press and Analysts. ET is also attracting growing interest in other industries facing similar challenges such as broadcast and military communications, and the OpenET Alliance is welcoming members from these industries too. The Alliance aims to be not only a centre of excellence on Envelope Tracking technology and power optimisation of wireless transmission, but also to become the non-proprietary body that will define and develop Envelope Tracking and power reduction standards, leading to wider adoption for the benefit of all.

By acting as a focal point for promoting and developing best practice in efficient wireless transmitter design, the OpenET Alliance will not only minimise carbon emissions, but also promote the development of attractive wireless products that are cheaper, smaller, more reliable and with a longer battery life.

World's smallest MEMS microphone debuts for mobile phones and portable electronics

The world's smallest MEMS chip—a tiny 700 square micron digital microphone—was fabricated recently by Bosch Sensortec GmbH for its subsidiary Akustica Inc. The CMOS die integrates a mechanical microphone diaphragm in a sea of mixed signal CMOS circuitry that culminates in a standard PDM (pulse density modulation) output.

The MEMS microphone market topped 695 million units in 2010, up more than 57 percent from the 441 million units shipped in 2009, according to IHS iSuppli (El Segundo, CA), which predicts that shipments will rise to more than 1.7 billion units, or $471 million, by 2014. Applications for MEMS microphones include mobile phones, touchscreen tablets, PCs, laptops, netbooks, video- and audio-recorders, Bluetooth headsets and camera modules.

The first chip to come from Akustica since its 2009 acquisition by Bosch Sensortec, the design team was able to squeeze another 30 percent out of the die's area—which had already been shrunk from two- to one-millimeter square—to qualify the new digital microphone as having the world's smallest MEMS die at just 700 square microns.

"Bosch's experience in shrinking high-performance circuitry enabled us to reduce the size of the die while also maintaining its low noise and improving is sensitivity," said Akustica's CEO and general manager, Stefan Finkbeiner. "For directionality and noise cancelation, it is also thin enough that you can fit multiple mics into the bezels of any PC, laptop, netbook or even the smallest tablet computer."

Akustica also plans to downsize its current 3.8-by-4.7-by-1.3 millimeter package further for handheld devices wishing to fit high-fidelity MEMS microphones into spaces too small for conventional electret microphones, such as ultra-thin cell phones. The 840-by-840 micron die is just 380 microns thick, allowing it to comfortably fit in even the smallest industry standard packages.

www.akustica.com

Dual-platform 4G strategy rewards mobile network operators, chip, and device makers

There's no question that in the long term LTE will become the mainstay 4G network technology, although its universal use is still in the future. Until then, says ABI Research, some service providers will benefit from a dual-platform strategy based on both LTE and WiMAX.

According to research director Philip Solis, "Intel and others are pushing the idea of heterogeneous networks. This is not to deny LTE's long-term position as the leading 4G platform, but to recognize that a small part of the ecosystem will still be characterized by diversity for some time."

Who stands to benefit?

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

Multi-standard base stations now being deployed support several generations of technologies as well as both 4G standards. Alvarion, Huawei, NEC, NSN, Samsung, and ZTE are some vendors supporting both technologies in the same flexible base station.

There will also be multimode 4G chipsets in devices. Prior to its acquisition by Broadcom, Beceem was already planning such chipsets. Chipmaker Sequans recently announced a similar product initiative it calls 4Sight, with software allowing for handoffs between multiple networks if carriers choose to implement it. According to Solis, these solutions "provide the ecosystem with the flexibility it needs."

Intel already has WiMAX/Wi-Fi chipsets and in the near future it will focus designs on HSPA+/LTE. Longer term, it will likely combine those into one solution along with short-range wireless technologies.

Multi-mode chipsets also benefit mobile device manufacturers interested in reducing the number of their SKUs.

www.abiresearch.com

What's new in LTE-Advanced

By Agilent Technologies, www.agilent.com

LTE-Advanced will meet or exceed the requirements of the ITU for the 4G radio communication standard known as IMT-Advanced. LTE-Advanced is being specified initially as part of Release 10 of the 3GPP specifications and will continue to be developed in subsequent 3GPP releases. This article summarizes the 3GPP requirements for LTE-Advanced—those necessary to meet ITU expectations as well as those of 3GPP operators for advancing LTE. LTE-Advanced and IMT-Advanced are compared. The article also describes the new features introduced in Release 10—carrier aggregation, enhanced uplink multiple access, and higher order MIMO—as well as technologies that are under consideration for the future. Some of the anticipated implementation and test challenges are briefly considered.

LTE-Advanced is the next evolution of 3GPP LTE. As more and more wireless operators announce plans to deploy LTE in their next-generation networks, interest in LTE-Advanced is growing. The 3GPP partners submitted LTE-Advanced as a candidate for IMT-Advanced in October 2009[i], and the ITU announced its acceptance in October 2010[ii]. The first LTE-Advanced specifications were published as part of 3GPP Release 10 in December 2010 with a functional freeze expected in March 2011.

LTE-Advanced will support the high level requirements for IMT-Advanced:

- A high degree of common functionality worldwide while retaining the flexibility to support a wide range of local services and applications in a cost-efficient manner.
- Compatibility of services within IMT and with fixed networks.
- Capability for interworking with other radio systems.
- High quality mobile services.
- User equipment suitable for worldwide use.
- User-friendly applications, services, and equipment.
- Worldwide roaming capability.
- Enhanced peak data rates to support advanced mobile services and applications (100 Mbps for high mobility and 1 Gbps for low mobility).[iii]

3GPP notes that a major reason for aligning LTE with IMT-Advanced is that IMT-conformant systems will be candidates for any new spectrum bands identified at the WRC-07 (World Radiocommunication Conference).[iv]

While it was determined that Release 8 LTE could meet most of the IMT-Advanced requirements, further enhancements were needed to achieve the peak data rate and uplink spectral efficiency targets. These are addressed in Release 10 LTE-Advanced through the addition wider bandwidths, enabled by carrier aggregation, and higher efficiency, enabled by enhanced uplink multiple access and enhanced multiple antenna transmission (advanced MIMO techniques).

Table 1: Performance targets for LTE, LTE-Advanced, and IMT-Advanced. Note: ISD = Inter-site distance.

Item	Subcategory	LTE target	LTE-Advanced target	IMT-Advanced (4G) target
Peak spectral efficiency (b/s/Hz)	Downlink	16.3 (4x4 MIMO)	30 (up to 8x8 MIMO)	15 (4x4 MIMO)
	Uplink	4.32 (64 QAM SISO)	15 (up to 4x4 MIMO)	6.75 (2x4 MIMO)
Downlink cell spectral efficiency (b/s/Hz), 3 km/h, 500 m ISD	2x2 MIMO	169	24	
	4x2 MIMO	187	26	26
	4x4 MIMO	267	37	
Downlink cell-edge user spectral efficiency (b/s/Hz) 5 percentile, 10 users, 500 m ISD	2x2 MIMO	5	7	
	4x2 MIMO	6	9	75
	4x4 MIMO	8	12	

Additional 3GPP considerations

3GPP Technical Report (TR) 36.913, "Requirements for Further Advancements for E-UTRA (LTE-Advanced)," describes the requirements for further advancement of the LTE E-UTRA (air interface) and E-UTRAN (air interface network)[v]. These requirements are based on the IMT-Advanced targets as well as 3GPP operators' own requirements for advancing LTE. Major technical considerations for the development of LTE-Advanced include:

- Continual improvement to the LTE radio technology and architecture.
- Scenarios and performance requirements for interworking with legacy radio access technologies.
- Backward compatibility of LTE-Advanced with LTE. An LTE terminal should be able to work in an LTE-Advanced network and vice versa. Any exceptions will be considered by 3GPP.
- Account taken of recent WRC-07 decisions for new IMT spectrum as well as existing frequency bands to ensure that LTE-Advanced geographically accommodates available spectrum for channel allocations above 20 MHz. Also, requirements must recognize those parts of the world in which wideband channels are not available.

System performance requirements

The system performance requirements for LTE-Advanced will in most cases exceed those of IMT-Advanced. The 1 Gbps peak data rate required by the ITU will be achieved using 4x4 MIMO and transmission bandwidth wider than approximately 70 MHz. In terms of spectral efficiency, today's LTE (Release 8) satisfies the IMT-Advanced requirement for the downlink, but the bps/Hz must be doubled in LTE-Advanced to meet the IMT-Advanced requirement.

Table 1 compares the spectral efficiency targets for LTE, LTE-Advanced, and IMT-Advanced. Note that the peak rates for LTE-Advanced are substantially higher than the IMT-Advanced requirements, which highlights a desire to drive up peak performance in 4G LTE,

although targets for average performance are closer to ITU requirements. However, TR 36.913 states that targets for average spectral efficiency and for cell-edge user throughput efficiency should be given higher priority than targets for peak spectral efficiency and other features such as VoIP capacity[vi]. Thus LTE-Advanced work will be focused initially on the challenges of raising average and cell-edge performance.

Spectrum flexibility

In addition to the frequency bands currently defined for LTE, TR 36.913 identifies new bands at the following frequencies: 450–470 MHz, 698–862 MHz , 790–862 MHz, 2.3–2.4 GHz, 3.4–4.2 GHz, and 4.4–4.99 GHz.

Some of these bands have been formally included in the Release 10 specifications. Note that frequency bands are considered release-independent features, which means that it is acceptable to deploy an earlier release product in a band defined in a later release.

To achieve higher performance and target data rates, LTE-Advanced will operate in spectrum allocations of different sizes, including allocations wider than the 20 MHz specified in Release 8. Although it is desirable to have bandwidths greater than 20 MHz deployed in adjacent spectrum, the limited availability of spectrum means that aggregation from different bands will be necessary to meet the higher bandwidth requirements.

LTE-Advanced solution proposals

Proposed solutions for achieving LTE-Advanced performance targets are defined in 3GPP TR 36.814, "Further Advancements for E-UTRA Physical Layer Aspects." [vii] The following proposed features are supported in 3GPP Release 10:

- Carrier and spectrum aggregation — The lack of contiguous spectrum for wider transmission bandwidths (to 100 MHz) forces the use of carrier aggregation to meet peak data rate and spectrum flexibility requirements. Aggregation of contiguous and non-contiguous component carriers is allowed.
- Enhanced uplink multiple access — The addition of N-times DFT-spread OFDM (also known as "clustered SC-FDMA") will satisfy increased data rate requirements while maintaining backward-compatibility with LTE.
- Enhanced multiple antenna transmission — Up to 8x8 MIMO in the downlink and 4x4 MIMO in the uplink is used to reach peak data rates. Beamforming with spatial multiplexing is being considered to increase data rates, coverage, and capacity.

There is ongoing work in 3GPP that is complementary to LTE-Advanced but not considered essential for meeting the IMT-Advanced requirements. Features that could be implemented in Release 11 include the following:

- Coordinated multipoint (CoMP) transmission and reception — This MIMO variant is intended to improve performance for high data rates, cell-edge throughput, and system throughput. CoMP being studied for Release 11.
- Relaying — In-channel relays receive, amplify, and retransmit downlink and uplink signals to improve coverage. More advanced relaying enables the use of some subframes in a channel to carry backhaul traffic. The main use cases for relays are to improve urban or indoor throughput, to add dead zone coverage, and to extend coverage in rural areas. Although the RF parts will likely be done, security for the backhaul to the DeNB will not be completed in Release 10 and so deployment is expected with Release 11 at the earliest.

Other proposals related to LTE-Advanced address the support needs of an increasingly heterogeneous network that combines macro-, micro-, pico-, and femtocells, along with repeaters and relay nodes. Work is ongoing to develop advanced methods of radio resource management including new self-optimizing network (SON) features. The 4G LTE specifications also continue to focus on the use of femtocells and home base stations (eNBs) as a means of improving network efficiencies and reducing infrastructure costs.

Carrier aggregation

Achieving the IMT-Advanced target downlink peak data rate of 1 Gbps will require wider channel bandwidths than are currently specified in LTE Release 8. At the moment, LTE supports channel bandwidths up to 20 MHz, and it is unlikely that spectral efficiency can be improved much beyond current LTE performance targets. Therefore the only way to achieve significantly higher data rates is to increase the channel bandwidth. IMT-Advanced sets the upper limit at 100 MHz, with 40 MHz the expectation for minimum performance.

Because most spectrum is occupied and 100 MHz of contiguous spectrum is not available to most operators, the ITU has allowed the creation of wider bandwidths through the aggregation of contiguous and non-

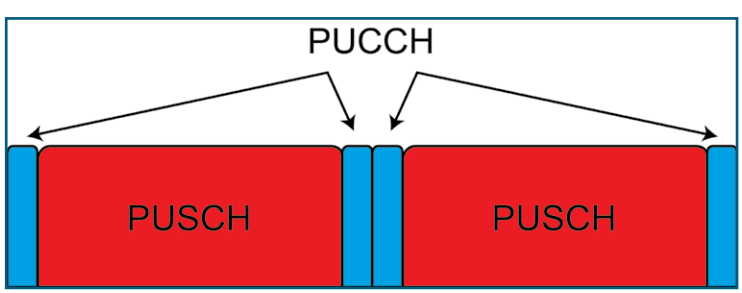


Figure 1: Contiguous aggregation of two uplink component carriers.

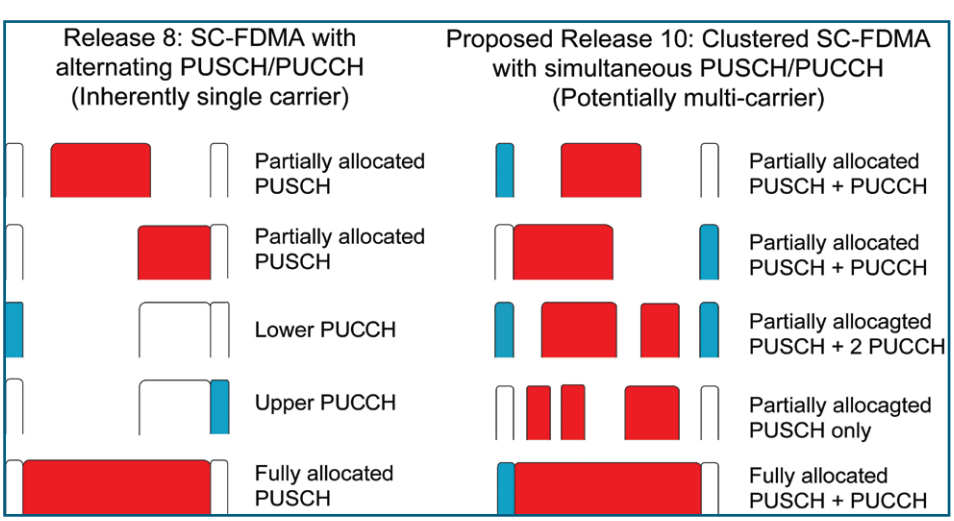


Figure 2: Comparison of Release 8 and proposed Release 10 uplink configuration.

contiguous component carriers. Thus spectrum from one band can be added to spectrum from another band in a UE that supports multiple transceivers. Figure 1 shows an example of contiguous aggregation in which two 20 MHz channels are located side by side. In this case the aggregated bandwidth covers the 40 MHz minimum requirement and could be supported with a single transceiver. However, if the channels in this example were non-contiguous — that is, not adjacent, or located in different frequency bands — then multiple transceivers in the UE would be required.

Release 10 LTE-Advanced will support three component carrier aggregation scenarios: intra-band contiguous, intra-band non-contiguous, and inter-band non-contiguous. (The term component carrier used in this context refers to any of the bandwidths defined in Release 8/9 LTE.) An LTE-Advanced UE with capabilities for receive and/or transmit carrier aggregation will be able to simultaneously receive and/or transmit on multiple component carriers. A Release 8 or 9 UE, however, can receive and transmit on a single component carrier only. Component carriers must be compatible with LTE Release 8 and 9.

In Release 10, the maximum size of a single component carrier is limited to 110 resource blocks, although for reasons of simplicity and backwards compatibility it is unlikely that anything beyond the current 100 RB will be specified. Up to 5 component carriers may be aggregated. An LTE-Advanced UE cannot be configured with more uplink component carriers than downlink component carriers, and in typical TDD deployments the number of uplink and downlink component carriers, as well as the bandwidth of each, must be the same.

For mapping at the interface of the physical layer (PHY) to medium access control (MAC) layer, there will be one transport block (in the absence of spatial multiplexing) and one hybrid-ARQ entity for each scheduled component carrier. (Hybrid ARQ is the control mechanism for retransmission.) Each transport block will be mapped to a single component carrier only. A UE may be scheduled over multiple component carriers simultaneously. The details of how the control signaling will be handled across the multiple carriers are still being developed.

Enhanced uplink multiple access

Today's LTE uplink is based on SC-FDMA, a powerful technology that combines many of the flexible aspects of OFDM with the low peak to average power ratio (PAPR) of a single carrier system. However, SC-FDMA requires carrier allocation across a contiguous block of spectrum and this prevents some of the scheduling flexibility inherent in pure OFDM.

LTE-Advanced enhances the uplink multiple access scheme by adopting clustered SC-FDMA, also known as discrete Fourier transform spread OFDM (DFT-S-OFDM). This scheme is similar to SC-FDMA but has the advantage that it allows non-contiguous (clustered) groups of subcarriers to be allocated for transmission by a single UE, thus enabling uplink frequency-selective scheduling and better link performance. Clustered SC-FDMA was chosen in preference to pure OFDM to avoid a significant increase in PAPR. It will help satisfy the requirement for increased uplink spectral efficiency while maintaining backward-compatibility with LTE.

Examples of different Release 8 and Release 10 uplink configurations are given in Figure 2. All of the Release 8 configurations are single carrier, which means that the PAPR is no greater than the underlying QPSK or 16QAM modulation format, whereas in Release 10 it is possible to transmit more than one carrier,

which makes the PAPR higher than the Release 8 cases. Note that the multiple carriers referred to here as part of clustered SC-FDMA and simultaneous PUCCH/PUSCH are contained within one component carrier and should not be confused with the multiple component carriers of carrier aggregation.

Enhanced multiple antenna transmission

Figure 3 shows the Release-8 LTE limits for antenna ports and spatial multiplexing layers. The downlink supports a maximum of four spatial layers of transmission (4x4, assuming four UE receivers) and the uplink a maximum of one per UE (1x2, assuming an eNB diversity receiver). Multiple antenna transmission is not supported in order to simplify the baseline UE, although multiple user spatial multiplexing (MU-MIMO) is supported. In the case of MU-MIMO, two UEs transmit on the same frequency and time, and the eNB has to differentiate between them based on their spatial properties. With this multi-user approach to spatial multiplexing, gains in uplink capacity are available but single user peak data rates are not improved.

To improve single user peak data rates and to meet the IMT-Advanced requirement for spectrum efficiency, LTE-Advanced specifies up to eight layers in the downlink which, with the requisite eight receivers in the UE, allows the possibility in the downlink of 8x8 spatial multiplexing. The UE will be specified to support up to four transmitters allowing the possibility of up to 4x4 transmission in the uplink when combined with four eNB receivers. See Figure 4.

In the enhanced downlink, there will be changes to the UE-specific demodulation reference signal (DMRS) patterns to support up to eight antennas. Channel state information reference signals (CSI-RS) and associated modifications to UE feedback in the CSI codebook design will be introduced. There also will be equivalent changes for downlink control signaling. Modifications to the downlink control signaling that have been agreed to include the following:

- Support of 2 orthogonal DMRS ports and 2 scrambling sequences for MU-MIMO operation.
- No additional signaling to be added for the MU-MIMO case in which one RB is scheduled to more than one UE.
- Additions to support the new 8Tx SU-MIMO mode dynamic switching between SU-MIMO and MU-MIMO.

Equivalent work is ongoing to define multiple antenna transmission for the uplink. A major issue is how uplink control information will be multiplexed between two or more PUSCH. This is also an issue for carrier aggregation. Essential agreements have been reached on resource sizes for HARQ, RI, CQI, and PMI. Agreement has been reached on mapping of the PHICH on the downlink for uplink SU-MIMO, and on the cyclic shift and orthogonal cover code (OCC) definitions for the uplink DMRS. Enhancements to the sounding reference symbols (SRS) have been proposed.

The physical layer definition for multiple antenna transmission is well advanced, although the radio performance aspects for the UE and eNB are still in the early stages of discussion with completion not expected until June 2011.

Design and test challenges

LTE is new and quite complex, with its use of multiple channel bandwidths, different downlink and uplink transmission schemes, two transmission modes (FDD and TDD), and MIMO. As an evolution of LTE, LTE-Advanced will pose similar challenges to design and test engineers. Both LTE and LTE-Advanced systems will likely have to co-exist with 2G and 3G systems for some time, so interworking necessities and the potential for interference are big issues. In a difficult radio environment, the bar for performance targets is being set very high.

New challenges are anticipated with LTE-Advanced. For example, carrier aggregation will undoubtedly pose major difficulties for the UE, which must handle multiple simultaneous transmit and receive chains. The addition of simultaneous, non-contiguous transmitters creates a highly challenging radio environment in terms of spur management and self-blocking. Simultaneous transmit or receive with mandatory MIMO support will add significantly to the challenge of antenna design. The exact impact of carrier aggregation on the specifications in terms of performance requirements depends on the reference UE architecture, which is still under discussion.

The introduction of clustered SC-FDMA in the uplink allows frequency selective scheduling within a component carrier for better link performance. Also, the PUCCH and PUSCH can be scheduled together to reduce latency. However, clustered SC-FDMA increases PAPR by a significant amount, adding to transmitter linearity issues. Simultaneous PUCCH and PUSCH also increase PAPR. Both features create multi-carrier signals within the channel bandwidth and increase the opportunity for in-channel and adjacent-channel spur generation. Test tools will need to be enhanced with capability for signal generation and analysis of in-channel multicarrier signals in LTE-Advanced power amplifiers.

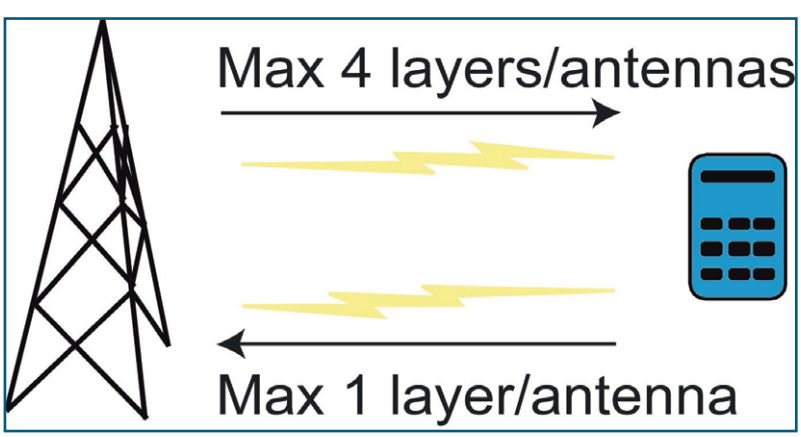


Figure 3: Release 8 LTE maximum number of antenna ports and spatial layers.

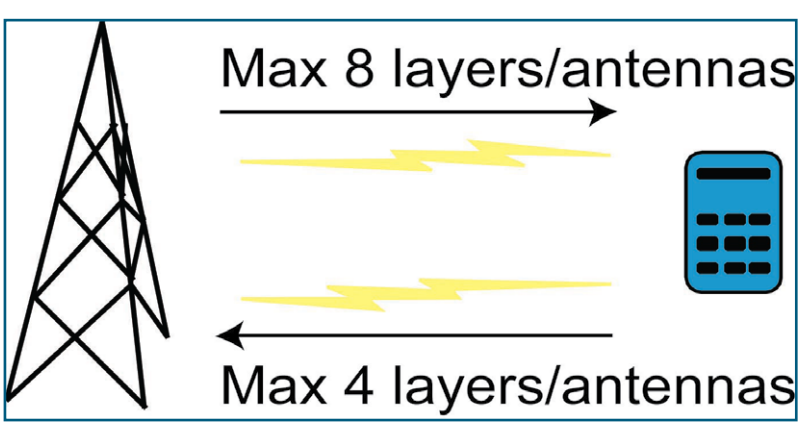


Figure 4: LTE-Advanced maximum number of antenna ports and spatial layers.

Higher order MIMO increases the need for simultaneous transceivers in a manner similar to carrier aggregation. However, MIMO has another challenge because the number of MIMO antennas will multiply and they all must be de-correlated. It will be especially difficult to design multiband, MIMO antennas with good de-correlation to operate in the small space of an LTE-Advanced UE. Conducted testing of higher order MIMO terminals will no longer be usable for predicting actual radiated performance in an operational network. A study item in Release 10 is looking at MIMO over the air (OTA) testing that could be extended to the higher order MIMO defined for LTE-Advanced.

The potential reception gains from MIMO systems are a function of the number of antennas. Although the theoretical potential of such systems can be simulated, practical considerations make commercial deployment more challenging. At the base station, compact 4x antenna systems are already in use. Increasing this to 8x to maximize the potential for spatial multiplexing and beamsteering may require the use of tower-mounted remote radio heads to avoid running 8 sets of expensive and lossy cables up the tower. The increased power consumption of MIMO systems is a factor that cannot be overlooked, as there is a tradeoff between the number of antennas per sector and the number of sectors per cell. In some cases a six-sector cell with four antennas per sector may be preferable to a three-sector cell with eight antennas per sector.

Outlook for LTE-Advanced

Industry-supported field trials are already demonstrating the viability of many of the technical concepts in LTE-Advanced. However, the timing of LTE-Advanced deployment is difficult to predict and will be dependent on industry demand and the success of today's Release 8 and 9 LTE rollouts.

From a standardization perspective LTE-Advanced is about two years behind LTE. However, the deployment of LTE-Advanced may be more than two years behind LTE for many reasons. These include the fact that LTE itself will have a slow rollout due to limited spectrum availability and the continued development and success of 2G and 3G systems. In addition, LTE-Advanced represents a big increase in system and device complexity, and it will take time for the industry to respond.

References

i) Press release, "3GPP Partners propose IMT-Advanced radio," Geneva, October 8, 2009. http://www.3gpp.org/3GPP-Partners-propose-IMT-Advanced.

ii) Press release, "ITU paves the way for next-generation 4G mobile technologies," October 21, 2010. http://www.itu.int/net/pressoffice/press_releases/2010/40.aspx.

iii) 3GPP web site, 3GPP - LTE-Advanced.

iv) 3GPP web site, 3GPP - LTE-Advanced.

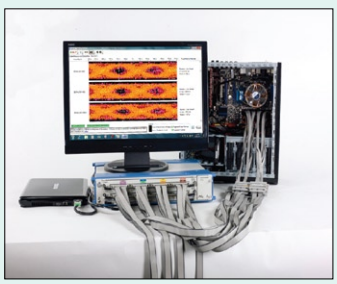
v) 3GPP TR 39.913, "Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (LTE-Advanced)." ftp://ftp.3gpp.org/Specs/html-info/36913.htm.

vi) 3GPP TR 39.913, "Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (LTE-Advanced)." ftp://ftp.3gpp.org/Specs/html-info/36913.htm.

vii 3GPP TR 36.814, "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects."www.3gpp.org/ftp/Specs/archive/36_series/36.814.

Logic analyser

data capture rates up to 4 Gb/s



Agilent Technologies claims to have introduced the industry's fastest logic analyzer. The instrument combines an industry-leading state capture speed of 4 Gb/s on 68 channels and 2.5 Gb/s on 136 channels with the ability to reliably capture data on the industry's smallest eye openings, as small as 100 ps by 100 mV.

These capabilities allow engineers to measure the increasingly fast digital signals used in emerging technologies and validate and troubleshoot their designs with confidence.

The U4154A AXIe-based logic analyzer module and associated probes and powerful analysis software provide essential capabilities for engineers working with DDR (double data rate) memory systems, high-speed application-specific integrated chips, analog-to-digital converters and field-programmable gate arrays operating at speeds up to 4 Gb/s. Timing zoom provides simultaneous state and timing measurements with 80 ps timing resolution and 256 K-sample memory depth, which gives designers more insight into problems by allowing simultaneous state and high-resolution timing measurements over a 20-µs time span.

The industry's highest trigger sequencer speed (2.5 Gb/s) gives engineers the ability to trigger reliably on sequential events on DDR memory and other high-speed signals without having to give up triggering flexibility.

www.agilent.com

High density PXI RF switches

suitable for switching signals to 1.8 GHz

Pickering Interfaces is expanding its range of PXI RF switches with the introduction of the 40-755 multiplexer modules which support up to 10 off SP4T RF switches in a single unit and are available in two different versions based on a common switch design.

The high density version occupies just one slot of a 3U PXI chassis and uses a high density multi-way connector that is suitable for switching frequencies to 500 MHz. The higher frequency version uses SMB connectors and is suited for switching signals to 1.8 GHz. The 40-755 is suitable for use in both commercial and military ATE systems. The two models use a switch design based around high quality electro-mechanical relays and in addition to being supported in any PXI compliant chassis they can be supported in Pickering Interfaces Modular LXI Chassis.

www.pickeringtest.com

ISM band wireless gateways and nodes

for industrial sensor networks

SureCross Performance wireless gateways and nodes from Banner Engineering feature a high-power radio frequency architecture with 1-W transmit power in the 900 MHz ISM band. This innovative architecture provides an increased range between devices, up to 10 km. The latest radio units deliver the same power management, deterministic network and integrated Site Survey features originally designed for the company's SureCross product line, while offering additional model enhancements.

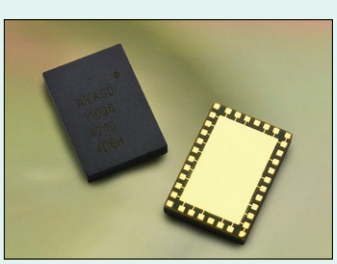
New models within this product family include universal analog inputs, providing users with increased input selection options in a single device. Operators have the ability to select either 4 to 20 mA or 0 to 10 V inputs in the field. Additional node and gateway models provide up to 12 discrete inputs or outputs.

The family also includes new temperature Node options, offering up to four factory-calibrated temperature inputs for thermocouples or RTD inputs. The radio modules and external 3rd party sensors can be powered by solar panels, battery modules or 10-30 Vdc.

www.bannerengineering.com

Fail-safe bypass low-noise amplifier modules

target cellular infrastructure applications



Avago Technologies has announced a series of fail-safe bypass low-noise amplifier (LNA) modules for tower mounted amplifiers (TMA) and base transceiver stations (BTS) applications. The ALM-11x36 LNAs deliver best-in-class noise performance and high linearity with a compact package. The modules can replace large discrete and surface-mount component counts in conventional designs, shortening design cycle time and providing board space savings.

The LNA modules have low noise and high linearity achieved through the use of the company's proprietary 0.25 µm GaAs Enhancement-mode pHEMT process. Their superior bypass isolation eliminates the possibility of oscillation issues, and the modules also feature low bypass insertion loss and high input and output return loss. In addition, the LNAs are equipped with a fail-safe bypass function, which is especially critical for TMA applications to enable the LNA bidirectional bypass path during the absence of DC power supply.

All matching components are fully integrated within the modules and the 50 ohm RF input and output pins are already internally AC-coupled.

www.avagotech.com

2.4 to 2.7 GHz WiMax and WiFi antenna

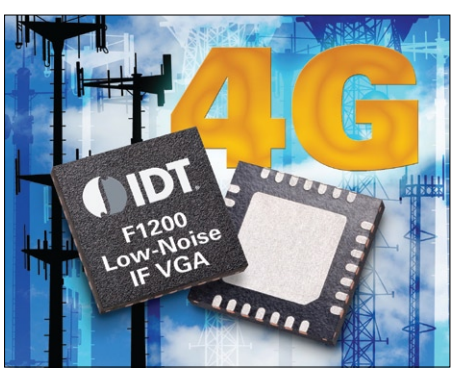
As Ofcom announces its auction plans for the wireless spectrum designated for 4G services such as high speed mobile broadband access, Low Power Radio Solutions (LPRS) is offering the ARW-2400-2700-10 directional antenna for WiMax and WiFi applications.

Operating in the 2.4 to 2.7 GHz frequency band, the ARW-2400-2700-10 antenna meets the existing requirements of wireless communications infrastructure and 3G communications operators and is also designed to meet the needs of 4G systems as they become available from 2014. The 2.4 to 2.7 GHz antenna operates in the -40 to +60 ºC temperature range, measures 140 x 120 x 20 mm and weighs a mere 600 grams.

www.lprs.co.uk

IF VGA claims lowest noise

improves QoS in base stations



Integrated Device Technology has introduced a digitally-controlled IF VGA with high SNR for improved Quality of Service (QoS) for receiver systems located in cellular base stations and other wireless infrastructure equipment. The new device expands IDT's product offerings for base station equipment in the growing 4G wireless infrastructure market, which today includes high performance timing, RapidIO solutions, and other devices from IDT's rich communications portfolio.

The IDT F1200 digitally-controlled IF VGA offers a low noise figure of less than 3.0 dB and a broad 23 dB control range with 7-bit resolution, resulting in better QoS for cellular base stations.

The low distortion provides increased spurious-free dynamic range (SFDR), making the device flexible for use in myriad applications. In addition, the excellent gain accuracy makes it easy to digitally compensate, while the 200 ohm differential input and output impedances allow the device to integrate seamlessly into the RF signal path, minimizing design effort and risk.

www.idt.com

Ultra-thin antenna

with GPS and 3G functionality

The W4150GG5000 antenna can be installed with either side facing up so only one antenna is required, whether mounting on the windshield or dashboard, to make installation simple. It receives location information from a GPS satellite and uses the cellular network to transfer this location information to a central control center or third party.

The antenna assists in vehicle and asset tracking and location, navigation, emergency call systems, fleet tracking, insurance tracking, and pay-as-you-go transport systems. The GPS/3G antenna comes in a small elliptical package measuring 100 x 50 mm with a height of only 8 mm.

It combines a Pulse Electronics GPS ceramic chip antenna, a low noise amplifier, and 3G antenna functions resulting in a thinner profile

than standard GPS and 3G band antennas while still maintaining an excellent level of performance.

The 3G antenna is suitable for global operation providing coverage at frequencies of 824-960/1710-2170 MHz with a gain of 2/4 dBi and a radiated efficiency of up to 70%. The GPS operates at 1575.42 MHz frequency with a gain of 26 dBi max. The antenna can be installed with either side facing up. It comes with RG-174 cable in a variety of lengths and SMA male connectors.

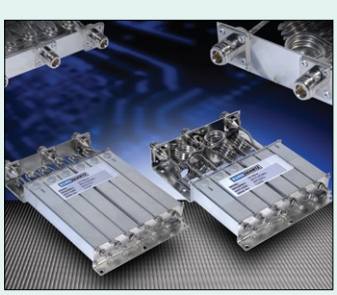
www.pulseeng.com

Duplexer range

simultaneous transmit and receive from a single antenna

Euroquartz has announced the launch of a range of duplexers that enable simultaneous transmit and receive from a single antenna. Enhancing the company's crystal filter offering, the duplexers are three-port devices comprising a combination of transmit and receive filters with a common antenna port.

Four models are available in the range. DU-462-L 66- to 88-MHz duplexers are available in 5 and 2.3-MHz split versions. Both feature 50-Ohm impedance, 50 W maximum power, standing wave ratio (SWR) of <1.5 and frequency stability of 9 ppm/°C. The connector is Pi-female and dimensions are 270- x 156- x



33-mm, with a weight of 1.4 kg. The DU-9060-G GSM and DU-7062-T Tetra duplexers feature 50-Ohm impedance, 40 W maximum power, SWR of <1.5 and frequency stability of 10 ppm/°C. The connector for these models is N-female and dimensions are 180- x 156- x 33-mm, with a weight of 0.9 kg.

www.euroquartz.co.uk

Low current GSM/GPRS modem

designed for M2M applications

The Cellgo external modem from eDevice enables power-constrained serial devices to connect to the GSM/GPRS network through a single cable grouping both data and power signals. With its internal super capacitor, Cellgo eases the installation process of M2M modems by eliminating the need for a dedicated power supply. The modem can handle power bursts required during cellular data transmission and its maximal consumption is below 400 mA under 5 V.

Cellgo is driven through easy-to-use AT# commands that trigger TCP socket data transfers, email sending, and FTP file reception for immediate transfer of data via

the Internet through the cellular network. Equipped with an internal quad-band antenna and internal SIM card holder, all in a compact and stylish form, Cellgo is a perfect fit for snap-in installations and can be used with different types of "already-in-the-field" devices equipped with serial ports.

www.edevice.com

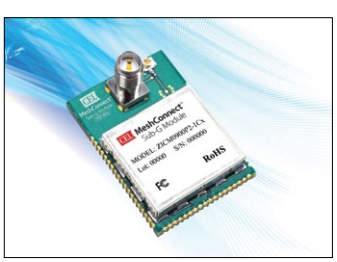
Wireless MCUs

power sub-GHz mesh network modules

Silicon Laboratories is providing the wireless microcontroller technology for a new line of sub-GHz wireless mesh networking modules from California Eastern Laboratories (CEL). Powered by the Si10xx, the MeshConnect Sub-G modules are CEL's first series in the sub-GHz ISM band targeting smart meters, home automation, security systems, remote keyless entry, irrigation control and weather stations.

The 868 MHz and 902-928 MHz frequency ranges suit non-line-of-sight applications; the modules can achieve a link budget up to 140 dB with a sensitivity of up to -121 dBm.

The modules support multiple software platforms, providing compliance with US and European operating standards, using Synapse SNAP embedded firmware, wireless



M-Bus, Silicon Labs' EZMac software and CEL's proprietary application programming interface (API). The modules also provide a 1 MB flash memory option to support over the air (OTA) programming.

CEL's wireless modules provide pre-certified hardware/software solutions, helping to reduce development time by months and eliminate the costly certification process. CEL also offers developers the MeshConnect Sub-G Development Kit.

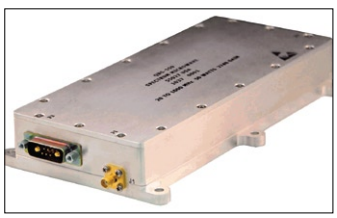
www.silabs.com
www.cel.com

Broadband 50 W amplifiers

auto-adjust for extreme load mismatch conditions

Spectrum Microwave continues adding to their line of S.M.A.R.T. power amplifiers with the addition of a 20 to 800 MHz 50 W design. With 45 dB of linear gain, this 21 to 30 VDC unit produces 50 W off of only 5.1 A at 28 V. The QBS-559 amplifier offers a unique feature by automatically adjusting the active biasing to enhance efficiency under various load mismatch conditions.

This rugged, high efficiency, push-pull design can even withstand a 10:1 load mismatch. It offers both an internal DC-DC converter as well as an integral heatsink. A



variety of fault and monitoring options are also available.

The QBS-559 amp is a high reliability broadband design ideal for both jamming, communications and laboratory applications. This power amplifier is feature rich, offers an internal heat sink and comes in a variety of customizable configurations.

www.spectrummicrowave.com

Vector signal analysis software

first to support 802.11ac

Agilent Technologies has announced that its 89600B vector signal analysis software is now able to test 802.11ac signals, adding that this is the first dedicated 802.11ac signal analysis solution on the market. Agilent is also announcing a new SystemVue 802.11ac library, the W1917EP WLAN baseband verification library, which interoperates with the 89600B VSA 802.11ac software.

The 89600B VSA 802.11ac software allows engineers to view and troubleshoot all 802.11ac modulation formats, from BPSK up to 256QAM, implemented in components and receivers. For even greater flexibility, the software supports all signal bandwidths, including 20, 40, 80 and 160 MHz, and up to 4x4 MIMO.

Using the 89600B VSA 802.11ac software, engineers gain greater insight into their next-generation 802.11ac

WLAN chips and devices, regardless of the 802.11ac format implemented.

The new W1917EP WLAN library is available for SystemVue 2011.03, which provides transmit source support for 802.11ac, as well as full transmit/receive support for legacy 802.11a signal-processing blocks.

The library interoperates with the 89600B VSA software to provide models and test benches for end-to-end system modeling and simulation of the physical layer of WLAN systems.

www.agilent.com

Small 3.75G penta-band module

for industrial and consumer applications

Telit Wireless Solutions has launched the HE910, which claims to be the smallest module available featuring 5-band HSPA+. The module can thus be used in any 3G network worldwide without the need for regional variants.

The Land-Grid-Array (LGA) form factor with a footprint of only 795 mm^2 is especially suitable for compact devices, such as e-readers or PDAs, with data-rich applications like multimedia.

In 3G mode the HE910 supports all five existing frequency bands: 850/900/1700 /1900/2100 MHz. Additionally it provides ubiquitous 2G coverage with quad band GPRS and EDGE class 33.

The universal applicability warrants business scalability and is a strong asset for vendors who want to market their solutions worldwide because these features eliminate the need for individual country versions and part numbers of the module, featuring different frequency allocations. On the other hand the HE910 provides a strong benefit for end users whose portable devices require worldwide coverage because regionally differing frequency bands are no longer an issue.

The LGA package with a size of 28.2- x 28.2- x 2.6-mm provides an ultra low profile in the integrated solution.

www.telit.com

5 GHz WiFi front end modules

for handsets, smartphones and tablets

RF Micro Devices has announced the expansion of its industry-leading 5 GHz WiFi product portfolio to include two 5 GHz high-band WiFi front end modules (FEMs) with integrated power amplifiers (PAs). The two latest 5 GHz FEMs — the RF5506, and the RF5516 — deliver high power and linearity and are optimized for the rapidly growing smartphone and tablet markets.

The global WiFi market is growing rapidly and is forecast to represent a greater than $1 billion total addressable market (TAM) by 2014. Adoption of dual-band WiFi (2.4-GHz/5-GHz) in handsets is estimated to increase from approximately 25 percent of all handsets in 2011 to approximately 50 percent of all handsets in 2012, with increasing emphasis on the 5 GHz band for use in 3G/4G smartphones. The anticipated growth in tablet devices is also forecast to support 5 GHz FEM adoption, as mobile WiFi chipsets for tablets increasingly adopt dual-band functionality.

To satisfy the growing market demand, the company has developed FEMs with high levels of integration, small package sizes, and best-in-class linearity performance. RFMD offers a broad portfolio of highly integrated FEMs that include the PA, the switch, filtering, baluns and an optional low noise amplifier (LNA) for both single-band (2.4 GHz or 5 GHz) and dual- band (2.4-GHz/5-GHz) operation. The company's WiFi product portfolio also includes discrete PAs, switches and switch/LNA products that support integrated chipset solutions.

www.rfmd.com

CALENDAR

European Wireless 2011
27th - 29th April 2011
Vienna University of Technology
Austria
www.ew2011.org

The IEEE Sarnoff Symposium
3rd - 4th May 2011
Nassau Inn
Princeton, NJ, USA
http://sarnoff-symposium.ning.com

4G World China 2011
19th - 21st May 2011
China National Convention Center
Beijing, China
www.4gworldchina.com

LTE World Summit 2011
17th - 19th May 2011
Amsterdam RAI
The Netherlands
http://ws.lteconference.com

LIDAR & RADAR 2011
26th - 29th May 2011
Hohai University
Nanjing, China
www.lidar2011.org

2011 Microwave Industry Exhibition in China
1st - 4th June 2011
Qingdao International Convention Center
Qingdao, Shandong, China
www.cnmw.cn

DAC 2011
5th - 10th June 2011
San Diego Convention Center
San Diego, CA, USA
www.dac.com

Paris Air Show 2011
20th - 26th June 2011
Paris le Bourget, Parc d'Expositions
www.paris-air-show.com

Wireless Sensor Networks and RTLS Summit Europe 2011
21st - 22nd June 2011
Holiday Inn Munich City Centre
Munich, Germany
www.idtechex.com/wireless-rtls-europe-11

International Microwave Symposium 2011 (IMS 2011)
5th - 10th June 2011
Baltimore Convention Center
Baltimore, Maryland, USA
www.ims2011.org

2011 IEEE Radio Frequency Integrated Circuits Symposium
5th - 7th June 2011
Baltimore Convention Center
Baltimore, Maryland, USA
www.rfic2011.org

EMC 2011
14th - 19th August 2011
Long Beach Convention Center
Los Angeles, CA, USA
http://emc2011.org

Wireless Technologies 2011
27th - 28th September 2011
Schwabenlandhalle
Stuttgart-Fellbach, Germany
www.mesago.de/en/wireless/0

European Microwave Week 2011
9th - 14th October 2011
Manchester Central
Manchester, UK
www.eumweek.com

4G World 2011
24th - 27th October 2011
McCormick Place
Chicago, USA
www.4gworld.com

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