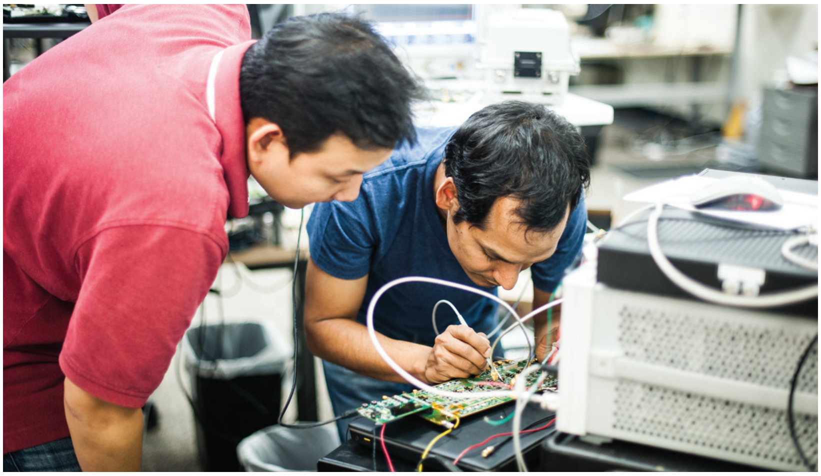
News

FULL-DUPLEX WIFI RADIO
Utilizes Hybrid Analog-Digital Cancellation

Full-duplex radio technology has the potential to double bandwidth, which would obviously have huge implications for wireless-network designs—potentially halving the spectrum needs of cellular networks. A startup out of Stanford University has come up with a design that makes the full-duplex radio an actual possibility by achieving total cancellation of self-interference. The in-band, full-duplex WiFi radio can simultaneously transmit and receive on the same channel using standard IEEE 802.11ac technology and a single antenna. Novel analog and digital cancellation techniques are used to cancel the self-interference to the receiver noise floor, thereby ensuring no degradation to received signals.

In a paper titled "Full Duplex Radios," Kumu Networks' Dinesh Bharadia, Emily McMilin, and Sachin Katti describe the design and implementation of a full-duplex WiFi radio that provides 110 dB of self-interference cancellation for standard WiFi signals. The wideband radio works with the widest bandwidths (80 MHz) and data rates used by the latest IEEE 802.11ac physical-layer (PHY) standard in the 2.4-GHz spectrum. The team also experimentally demonstrated a complete, full-duplex communications link, whereby they nearly achieved the theoretically expected double throughput *(see photo)*.



Two of the founders of Kumu Networks, Jung-Il Choi (left) and Mayank Jain (right), are shown working on the circuit.

According to the researchers, "Since WiFi signals are transmitted at 20 dBm (100 mW) average power, and the noise floor is around –90 dBm, the transmit self-interference has to be canceled by 20 dBm – (–90 dBm) = 119 dB to reduce it to the same level as the noise floor and render it negligible. If self-interference is not completely canceled, any residual self-interference acts as noise to the received signal and reduces SNR and consequently throughput."

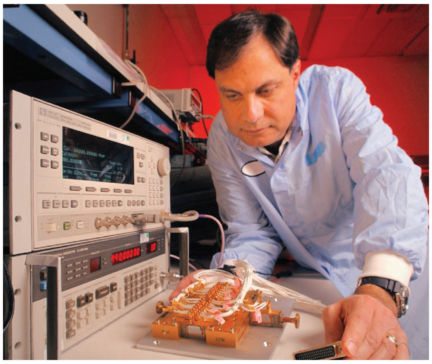
At best, previous full-duplex designs provided 85 dB of cancellation, which leaves about 25 dB of residual self-interference. This reduces the signal-to-noise ratio (SNR) in each direction of the full-duplex link by 25 dB. Prior designs also utilized two antennas, which actually weakens the argument for full duplex approaches. After all, the same doubling of capacity could be obtained by using the two antennas in a multiple-input multiple-output (MIMO) approach to spatially multiplex two independent packets in half-duplex mode instead of using them for full duplex.

The paper goes on to describe the design and implementation of a key part of the design: the use of both analog and digital cancellation. "We design a novel programmable analog cancellation circuit using off-the-shelf components that allows us to…dynamically cancel the self-interference. Such analog cancellation prevents receiver saturation from strong self-interference and allows us to use commodity radios. However, the analog cancellation does not completely cancel the self-interference. We complement it with a novel digital cancellation algorithm and implementation that cancels any remaining self-interference. Our digital cancellation algorithm differs from all prior work because it not only models the linear distortions, but also nonlinear effects and other special effects, such as oscillator noise. Thus, overall we use a hybrid analog-digital design that successfully models all linear and nonlinear distortions as well as transmitter noise."

The system was deployed in an indoor, noisy office environment in the 2.4-GHz Industrial, Scientific, and Medical (ISM) band. The WiFi PHY was used over 80 MHz on RS radios and over 20 MHz using WARP radios. In practice, it delivered a median throughput gain of 87%, which is close to the theoretically expected 2×. In terms of cancellation, the design consistently delivered the required 110 dB needed for linear self-interference cancellation. The researchers note that their architecture is not novel, as similar ones have been proposed before. But their design of cancellation circuits and algorithms is the only one to achieve the necessary amount of cancellation at these performance levels.

Future research will help flush out related problems, such as the size of the circuit and adapting the design to work with Long-Term-Evolution (LTE) technology. The current prototype board measures a cumbersome 10 × 10 cm, which is far too large to implement on phones or other portable devices. If full-duplex technology is ever to be realized on these devices, significantly smaller boards need to be designed through the use of delay lines like LC ladders. Because LTE uses smaller channels than WiFi, different cancellation numbers also are necessary. LTE's 20-MHz channel does simplify the cancellation problem, however. ■

ASICS HELP TO Raise Capacity And Slash Size In AEHF Payloads



The customized ASICs will decrease the size of AEHF payloads while increasing capacity. (Photo courtesy of Northrop Grumman)

ADVANCED EXTREMELY HIGH FREQUENCY (AEHF) satellites have been heralded for providing improved global, survivable, highly secure, jam-proof communications for strategic command and tactical warfighters. Thanks in part to customized semiconductors, AEHF payloads are now half the size and weight of previously used MILSTAR payloads. What they lack in size, however, they make up for in capacity—providing up to 10 times more capacity than previous-generation satellites.

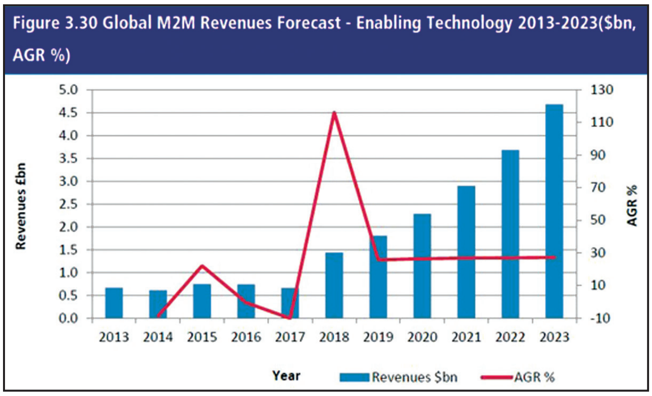
More than 800 application-specific integrated circuits (ASICs) were delivered by Honeywell Aerospace and BAE Systems to Northrop Grumman for the Air Force's fifth and sixth AEHF satellites *(see photo)*. To deliver on-demand, flexible connectivity, the AEHF payloads blend on-board digital-signal-processing (DSP) hardware, firmware, and software. Each customized component reinforces the electronic units, providing AEHF-specific functions. These include on-board signal processing and a suite of 14 antennas, which provides users with upwards of millions of options for countering adversaries' electronic, cyber, and physical threats.

Each payload has constellation interconnects provided through satellite crosslinks. They form a global, protected network without requiring vulnerable overseas ground gateways or stations. To meet more than 3000 other specific requirements, every AEHF payload includes almost one million lines of software code; 25 computers; nearly 800 ASICs; almost 18000 monolithic-microwave integrated circuits (ICs) of 70 unique designs; and more than 13000 integrated microwave assemblies, as well as hybrids of 50 unique designs. ■

IoT ADVANCES WILL Expand Wireless M2M Market

AS THE NUMBER of connected devices increases, technology is being leveraged in new ways across a growing number of industries. For the machine-to-machine (M2M) industry, interconnected wireless networks for communications have helped to increase production and efficiency while decreasing costs. As a result, global wireless M2M revenues are expected to reach $50.1 billion in 2013 *(see figure)*.

Within the consumer market, devices like tablets and e-readers are being heavily adopted



Global wireless M2M revenues are expected to rise through 2023. (Graph courtesy of Visiongain)

on a global scale. Those devices—in addition to the ones that are used in homes and businesses—are currently being transformed for use in M2M applications. In the Visiongain report, "The Machine to Machine (M2M) Market 2013-2023: Smart Devices & the Internet of Things (IoT)," researchers determine that there will be significant growth in the market through 2023. Companies are currently addressing consumer demands for full-time connectivity while governments continue to support initiatives for greater mobile connectivity.

A catalyst for M2M-connected devices has been the uptake of LTE services. The report covers problems, requirements, opportunities, and impact as the market steadily switches from GSM to LTE. Opportunities include public and personal health applications, the smart grid, connected appliances, and connected-home devices.

The eight leading M2M market segments—in terms of connectivity—are discussed in terms of predicted growth rates and emerging trends. These segments are utilities, automotive, security, retail, healthcare, government, financial services, and industrial. Major network concerns are discussed as well. They include solving deployment issues, security concerns, and analysis of barriers to entry, among others. Leading companies within the industry, such as AT&T, are discussed in addition to those with the greatest potential for gain.

The report includes forecasts through 2023 at global, submarket, and national levels. The researchers also assess technologies, competitive forces, and expected product developments. ■

MEADS RADAR PERFORMS 360-Deg. Rotation For Missile Tracking

TO PROVIDE SYSTEM capabilities that are not being met by current air and missile defense systems, the Medium Extended Air Defense System (MEADS) is being developed to meet International Common Operational Requirements. To enable coverage with no blind spots, this next-generation system incorporates netted and distributed battle management, easily transportable launchers, a PAC-3 missile, and 360-deg. radar capability. As part of a recent demonstration, the MEADS Multifunction Fire Control Radar (MFCR) acquired and tracked a live tactical ballistic missile (TBM) for the first time. The system also was tested for its ability to intercept and destroy two simultaneous targets attacking from opposite directions.

The MFCR is an X-band, solid-state, phased array radar using element-level transmit/receive modules. (Photo courtesy of Meads-amd.com)

Both presentations were completed at the White Sands Missile Range in New Mexico. The first demonstration showcased the radar positively detecting the missile shortly after launch. It maintained dedicated track mode until shortly before ground impact. The MEADS MFCR is a 360-deg., X-band, solid-state, active electronically steered array (AESA) radar *(see photo)*. It can provide tracking capabilities against highly maneuverable, low-signature threats. These include short- and medium-range ballistic and cruise missiles, in addition to other air-breathing threats.

The second test put all MEADS system elements to work including the surveillance radar, a networked MEADS battle manager, two lightweight launchers firing the missiles, and the MFCR. A QF-4 air-breathing target approached from the south as a Lance missile attacked from the north. The surveillance radar successfully acquired both targets and provided cues to the MEADS battle manager, which generated cue commands for the MFCR. The MFCR then tracked both targets and guided missiles from launchers in the Italian and German configurations to intercept them.

To provide enhanced operational flexibility, MEADS' netted-distributed architecture utilizes distributed sensors, launches, and tactical operations centers (TOCs). Its "plug-and-fight" capability enables all of the sensors, shooters, and other TOCs to act as nodes within the MEADS network. From there, a commander can dynamically add or subtract elements without shutting the entire system down. That flexibility—in conjunction with the radar's 360-deg. tracking—reportedly allows MEADS to defend up to eight times the coverage area with far fewer system assets compared to previous approaches. ■