Medical info-communications signals an era of body area networking

While advances in implantable RF transceiver chips is facilitating in-body medical communications, rapid developments in ultralow-power wireless body sensors is resulting in on-body communications. Thus, creating a platform for body area network or BAN to wirelessly connect in/on-body medical sensors with monitoring tools and provide patient health data in real time.

By Ashok Bindra

Combining broadband mobile electronics with ultralow-power consumption and miniaturization in implantable semiconductor radio transceiver chips and sensors, healthcare and wellness is rapidly changing across the world. Consequently, new services and applications are emerging that will enable real-time medical sensing and treatment from a distance. Thus, taking ubiquitous medical care to a new level.

Last year, in a keynote speech at the International Microwave Symposium in Honolulu, Prof. Ryuji Kohno of Yokohama National University and director of the University's Medical Information Communications Technology Institute signaled a new direction for advanced wireless communications and introduced medical info-communication technology (ICT) projects and activities in Japan. According to Kohno, under a five-year plan (FY2006-FY2010), called "u-Japan Plan, the Japanese government is aiming to establish a ubiquitous ad-hoc network for medical services that is safe and reliable.

To implement such a medical healthcare service, advanced ICT will exploit technologies like RFIDs, network robots, sensor networks, and mobile communication systems based on advances in ultrawideband (UWB), software-defined radio (SDR), and multiple-input, multiple-output (MIMO) technologies. Consequently, he added, further R&D is needed in areas such as ultralow-power amplifiers and LNAs, software-reconfigurable RF, antennas on implanted chips and cognitive sensor robots. In addition, packaging technology is critical to wearable and implanted devices.

Furthermore, Kohno said that improvements in implanted devices for humans, in combination with implantable radio chips is facilitating in-body communications for supporting new monitoring, diagnostic and therapeutic applications. Toward that end, Kohno described a wireless capsule endoscope developed by Olympus that enables monitoring of the small intestine in a non-invasive manner.

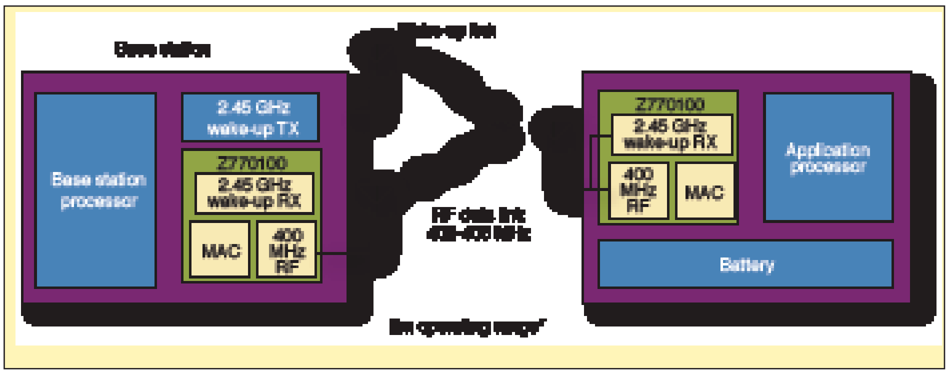

Figure 1. Based on ZL70101 implantable transceiver, Zarlink has readied a development kit that enables design and development of wireless telemetry linking implantable devices with monitoring equipment.

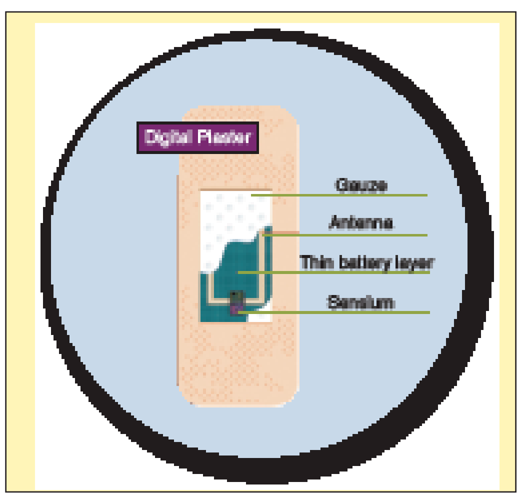

Figure 2. Sensium enabled digital plaster is used to monitor key physiological parameters on the body.

Implantable devices

Speaking of implantable semiconductor chips and in-body communications, Zarlink Semiconductor continues to improve its implantable ultalow-power transceiver ZL70101 (See, "Implantable ultralow-power radio chip facilitates in-body communications," *RF Design*, June 2007, p. 20.) for medical telemetry systems linking implanted medical devices and monitoring equipment. In fact, according to Zarlink, Given Imaging has implemented this device in a pill camera for diagnostics. Using CMOS imaging, this camera takes pictures and transmits to a recorder at four frames/s with a data rate of 2.7 Mbps. It consumes about 5.2 mW when transmitting and is designed to operate for more than eight hours. FDA approved, some 600,000 patients have swallowed this pill, said Peter Putnam, director of marketing for Zarlink's medical communications group.

Plus, it has been combined with a pacemaker that is in production, noted Putnam. However, the company would not identify the OEM producer in this case. Other such devices targeted include neurostimulators, drug pumps, implantable cardioverter defibrillators (ICDs) and other physiological monitors.

Meanwhile, based on the ZL70101 implantable transceiver, Zarlink has readied a development kit that enables faster design and evaluation of wireless telemetry systems linking implanted medical devices with monitoring and programming equipment.

The ZLE70101 application development kit (ADK) demonstrates the high data rate, ultralow-power and reliable communication link supported by the transceiver. This highly integrated RF chip delivers data rates up to 800 kbps and operates in the medical implant communication service (MICS) 402-405 MHz band.The chip currently consumes 5 mA of supply current in full operation, while incorporating a unique “wake-up” receiver that allows the device to operate in an extremely low current 250 nA in sleep mode.

A commonly used microcontroller is used for the implant and base station platforms to enable rapid integration into a customer’s specific system design. The graphical user interface (GUI), running on Windows, interfaces to the MICS RF boards via a USB2.0 interface. The kit also includes an applications development platform (ADP100) board that interfaces with the PC through a USB2.0 interface to the implant or base station mezzanine boards. The application implant mezzanine (AIM100) board performs all MICS-related implant communications. This board includes the ZL70101 transceiver, discrete circuits including matching networks for normal data transmission and wake-up operation, an application microcontroller connected to the ZL70101 over an industry-standard SPI bus, and an SMA connector interface to a PCB-based loop antenna (Figure 1).

Additionally, the base station mezzanine (BSM100) board performs all MICS-related base station/monitoring equipment communications processing. The board includes the same features as the AIM100, with the addition of a wake-up transmitter subsystem and a received-signal-strength indicator (RSSI) filter for performing clear-channel assessment (CCA). The BSM100 also includes a dual-band antenna optimized for performance in the MICS band and supporting wake-up signaling. To minimize development time, the ADP100, AIM100 and BSM100 are fully supported by embedded firmware with thoroughly commented source code to help developers quickly understand the programming requirements of the chip while allowing for firmware reuse.

Concurrently, Zarlink is working with the European consortium Healthy Aims based in the UK. Researchers are developing medical technologies, including implantable devices that integrate wireless capabilities. One application is functional electrical stimulation (FES) that uses signals from implants to stimulate muscles to allow limb movement. Zarlink is also developing in-body antenna for this application.

Combining the skills of its healthcare and wireless divisions, Cambridge Consultants has developed a control and communications architecture for in-body medical diagnostics and therapeutic applications, called SubQore. Designed to be compatible with the MICS band, it offers a range of 2 m when implanted under the skin, according to Cambridge Consultants manager for surgical and interventional products Manasas added, “It is a customizable architecture which a client could turn into a custom ASIC. I'm not sure about the simulation status, but the design incorporates a range of pre-developed low-power silicon blocks that have been proven in previous designs."

Meanwhile, Zarlink continues to drive down the power consumption of the implantable transceiver chip. Toward that goal, it is readying 70102 that will exploit 0.18 µm RF CMOS process with new radio architecture and modulation techniques. It is expected to be unwrapped in the second half of this year.

On-body communications

While Canada’s Zarlink and Cambridge Consultants have focused on in-body communications for body networking, UK’s Toumaz Technology Ltd. is developing solutions for on-body communications to improve healthcare and lifestyle management. Toward that goal, Toumaz has readied an ultralow-power wireless body monitoring system-on-chip called Sensium. Using Sensium, it has developed a body-worn sensor that is labeled digital plaster. When worn by the patient, this digital plaster (Figure 2) can continuously monitor multiple health signs, such as heart rate, body temperature, pulse rate and respiration and transfer that data to a base station where a medical record is kept.

In short, the Sensium is an ultralow-power-sensor interface and transceiver platform that includes a reconfigurable sensor interface, a digital block with 8051 processor and an RF transceiver block, along with a temperature sensor on-chip. In addition, on-chip program and data memory permits local processing of signals. One or more Sensium-enabled digital plasters continuously monitor key physiological parameters on the body and report to a base station Sensium plugged into a PDA or a smartphone. The data can be further filtered and processed by application software. According to the developer, a single Sensium can operate for a year on a single 30 mAhr battery.

In such an application, the system architecture can be split into three units: target station, base station and web server/central database. The wearable sensor nodes (target stations) support a range of sensors generating data at rates up to 50 kbps. Very low-level analog signals from the sensors are pre-processed by the chip before being transmitted as an RF signal to the base station. The base station can be linked to up to eight target stations, each monitoring multiple physiological signals on the body (Figure 3).

Based on its patented advanced mixed-signal (AMx) technology, this highly integrated medical chip, labeled TZ1030, was taped-out on Infineon’s advanced 130 nm RF CMOS process. In fact, this chip leverages advances made at Imperial College London in ultralow-power RF circuits and signal processing. It has met all the targeted accuracy and performance parameters in initial functional testing, stated Toumaz’s COO and co-founder Keith Errey. This ultralow-power 1 V SoC is now ready for mass production, noted Errey.

Concurrently, the developer has also inked a strategic development

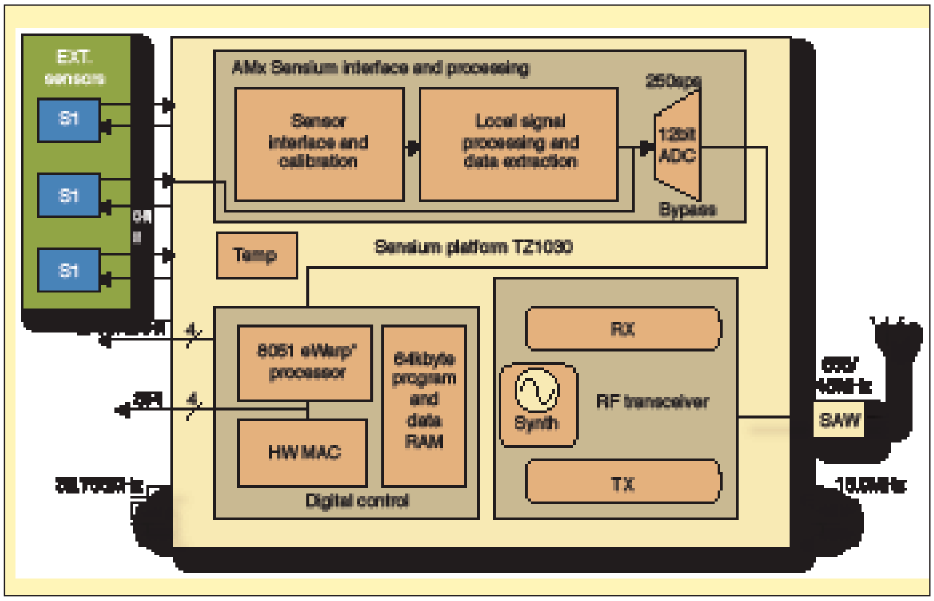

Figure 3. System architecture using ultralow-power wireless sensor interface and transceiver platform TZ1030.

and distribution deal with a major U.S. healthcare service provider. Although its OEM partner was not identified, Toumaz said that the U.S. partner will help in gaining regulatory approvals, manufacturing, marketing and distribution.

Presently, the chip consumes about 3 mA at 1 V. The developer is looking to cut that power consumption significantly in the future. For that, it is exploring new radio architectures and other modulation techniques. Currently, the chip is using frequency-shift keying (FSK) with a carrier frequency of 868/915 MHz and is encased in an 80-pin BGA package. In addition, efforts are under way to increase the data rate from 50 kbps to more than 150 kbps without sacrificing power.

Meanwhile, the supplier continues to improve its digital plaster, which is still under development, according to Errey. Issues being addressed include flexible materials that are bio-compatible and water and air permeable, as well as low-cost manufacturing.

Body area networking

Spurred by advances in ultralow-power implantable and on-body RF devices and sensors, body area networking (BAN) is emerging as a high-speed, short-range wireless technology to wirelessly connect implanted medical devices and on-body sensors with monitoring tools to provide patient health data in real time. In fact, toward that goal, IEEE 802 in December 2007 approved the formation of a working task group 6 (TG6) for IEEE 802.15. Arthur W.Astrin was named the chairman of this task group. Astrin is also CEO of Astrin Radio in palo Alto, Calif.

This group will further define a standard for short-range, wireless communication in the vicinity of, or inside the human body, and will use the frequency bands approved by national medical and regulatory authorities. In fact, in a paper presented by Astrin at last year's second International Symposium on Medical Information and Communications Technology (ISMICT 07) in Oulu, Finland, he showed the following bands as candidates for the application.

- MICS band: 402-405 MHz: USA, EU, Korea, Japan (FCC 47 CFR 95.601-95.673 subpart E);
- 10 channels of 300 kHz;
- adaptive frequency agility;
- 25 µW EIRP;
- medical radio FCC proposed band: 401-402 MHz and 405-406 MHz;
- wireless medical telemetry service (WMTS) band: 608-614 MHz (TV ch. 37), 1395-1400 MHz, 1427-1432 MHz;
- idustrial, scientific and medical (ISM) band: 868/915 MHz, 2.4 GHz, 5.8 GHz;
- UWB band;
- RFID links: 135 kHz, 6.78 MHz, 13.56 MHz (ERC Rec. 70-03);
- inductive link band: 9 kHz-315 kHz (ECC Report 12); and
- capacitive carrierless baseband transmission.

The paper also presented a draft of initial requirements for BAN. As per the table, the distance coverage for BAN is 2 to 5 m with a power consumption of about 1 mW/Mbps at a distance of 1 m. For powering BAN nodes, Astrin's paper identified rechargeable Lithium, inductive recharging and energy scavenging as power sources for in-body devices. Likewise, for on-body sensors, power technologies to be considered include temperature difference, non-rechargeable (Zinc-air, Lithium and silver-oxide) and Lithium-ion rechargable.

To get the process moving, IEEE 802.15.6 task group had its first meeting in January in Taipei, Taiwan. In essence, with a coverage of 2-5 m, 802.15.6 is being targeted at three major markets: medical healthcare service, assistance to people with disabilities, and body interaction and entertainment. However, there is no official timeline for ironing out the standard.

Meanwhile, researchers Marco Hernandez and Ryuji Kohno of Medical Information and Communications Technology Group, National Institute of Communications and Information Technologies, Kanagawa, Japan have developed a novel physical layer (PHY) for BAN and have proposed it to the IEEE standardization working group 802.11.6.

As BANs require very low power consumption, the researchers have developed a theory of signaling in the very low-power regime from an information theory perspective. For a practical implementation, Hernandez and Kohno have worked out a lower bound on the energy consumed by a practical system, including power consumption at transmitter and receiver. As transceivers operate close to the human body, and, in some cases, implemented onto a human body, the level of radiation absorbed by human tissues is a special concern, stated Hernandez. Keeping those factors in mind, the researchers have proposed a simple, energy efficient and low-risk tissue-heating UWB signal design for BAN. For that, they have developed energy-efficiency metrics that include the effect of practical transceivers and information theoretic results as the starting point for low-power system design. Also, a safety metric based on the SAR in the near and far fields of dipole antennas is also estimated.

In essence, based on the results achieved, Marco and Kohno have proposed on-off signaling with non-coherent detection, which employs a truncated-triangular-modulated sine function as pulse waveform for PHY. To demonstrate its feasibility, the researchers have implemented the low-power UWB transceiver design in CMOS. The results of this research were presented at ISMICT07 in a paper titled, "Ultralow-power UWB signal design for body area networks." RFD