# Generation of High-performance, Ultra-low-power, Short-range Wireless Mobile Information System

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## I. Wireless Mobile Information System

"Ubiquitous" means an interface or an environment which exists anytime, anywhere, and for anyone without being noticed. In these days, the part "anytime, anywhere, for anyone" is often emphasized however originally "without being noticed" was with more emphasis.

"Ubiquitous" was first used in this meaning in Mark Weiser's paper, "The Computer for the 21st Century" in Scientific American 1991 [1]. The subtitle is "Specialized element of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence." The key point is more clarified in the beginning of the paper: "The most profound technologies are those that disappear. They weave themselves into the fabric of every day life until they are indistinguishable from it."

In order to "weave" information-processing technology into the "fabric" of our life, downsizing and wireless connectivity are the most important. Computers have been downsized by advance in LSI technology. Energy and cost per bit calculation have also been significantly reduced. In the near future, numerous numbers of tiny and inexpensive computers will be distributed and embedded into our life space. These computers will be interconnected wirelessly and they create networks. Once the network is connected to high performance server computer through the broadband internet, information-processing devices will disappears from our life. In 2025, we will be using 1,000 computers with 1,000 wireless connections.

However, the problem is increase in energy dissipation required for communication. Computation is digital processing in a virtual space so that the energy dissipation can be reduced by the downsizing. Communication, on the other hand, is analog processing in a real space. The energy dissipation can not be reduced as in the computation. For weaving the devices into our life, it is desired that the devices can operate permanently under a small battery without any annoying power lines. It is more desired if the devices could operate only with environmental energy such as electromagnetic wave, light, heat, or vibration. Even though energy charging is needed to the devices, by delivering the energy wirelessly, the system can acquire mobility. As a result, an advanced information-processing space woven in a daily life can be realized where the devices can think, speak, and move itself, so called wireless mobile information system (Fig.1).

From above-mentioned background, a research project "Generation of High-performance, Ultra-low-power, Short-range Wireless Mobile Information System" was launched in 2005 under support from Core Research for Evolutional Science and Technology (CREST), Japan Science and Technology Agency (JST). In this research, 100x higher-speed and 1/1,000 lower-energy short-range wireless communication and energy delivery were studied where following 4 research programs were conducted:

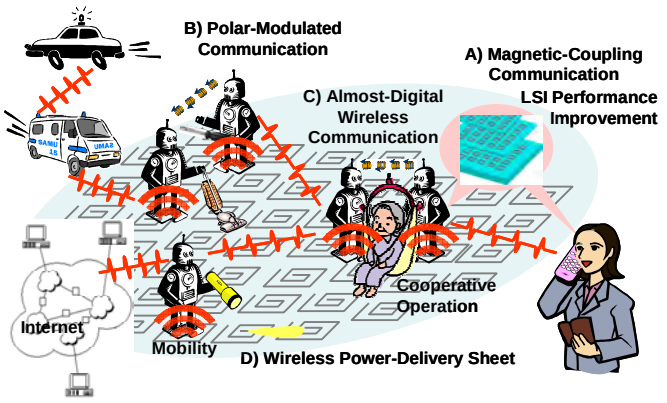



Fig.1 Conceptual sketch on wireless mobile information system.

A) <1mm-range inter-chip magnetic-coupling communication
B) <1m-range inter-device polar-modulated communication
C) <10m-range almost-digital wireless communication
D) <10mm-range wireless power-delivery sheet

## II. Research Achievements

### A. *Inter-Chip Magnetic-Coupling Communication*

Three-dimensional (3D) chip stacking is one of the promising approaches to realize high-performance and low-energy computing systems. A wireless interface utilizing magnetic coupling between on-chip coils delivers data between 3D-stacked chips (Fig.2). In this research project for 5 years, several energy-efficient circuit techniques [2-7] have been developed and achieved energy reduction to 1/1,000 (Fig.3).

### B. *Inter-Device Polar-Modulated Communication*

In this research project, millimeter-wave (60GHz-band) wireless transceiver circuit was studied. By utilizing wideband radio frequencies available around 60GHz, high-speed data communication can be achieved. In this project, a novel millimeter-wave high-speed switching transmitter and pulse receiver have been developed for energy reduction. As a result, a 10Gb/s mm-Wave wireless transceiver [8] was developed with the lowest energy dissipation ever reported (Fig.4).

### C. *Almost-Digital Wireless Communication*

By exploiting transistor's performance improvement in the downsizing, operation speed and energy efficiency of digital circuits are significantly improved. The key concept of the

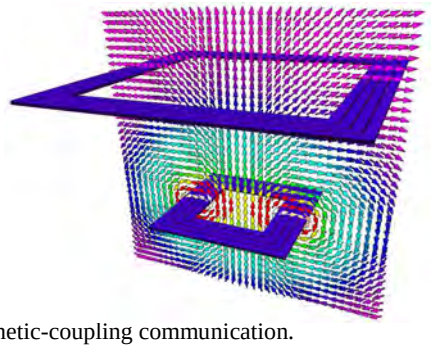


Fig.2 Magnetic-coupling communication.

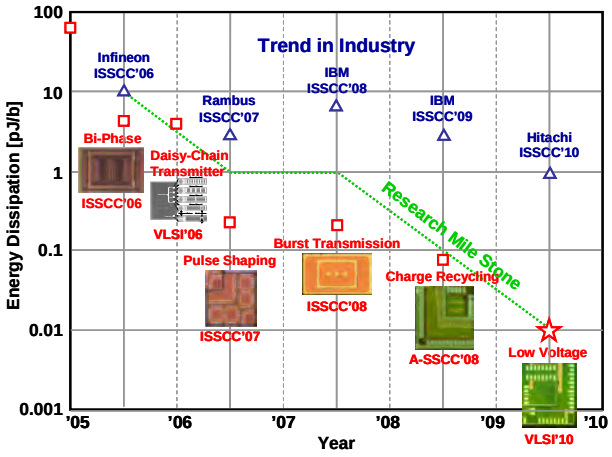



Fig.3 Energy dissipation of magnetic-coupling communication.

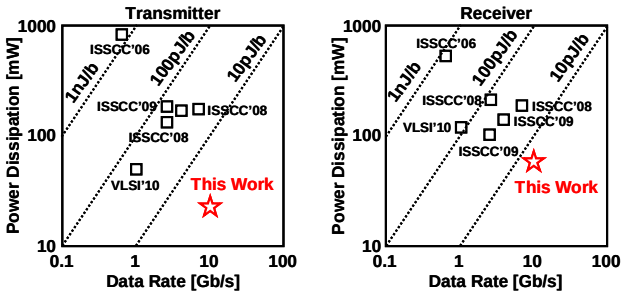



Fig.4 Power dissipation in millimeter-wave transceiver.

almost-digital wireless is to consist most of the building blocks in the wireless transceiver by digital circuits. In this research project, a digital pulse shaping technique for the transmitter and a digital sampling-based correlation technique for the receiver have been developed and the energy dissipation was reduced down to 10pJ/b [9] (Fig.5).

### *D. Wireless Power-Delivery Sheet*

In this research project, an 80%-efficiency 40W wireless power-delivery sheet [10] has been developed (Fig.6). It detects a position of power-receiving device and dynamically activates power-delivery coil close to the device. A plastic MEMS switch and high-efficient organic field-effect transistor were developed to improve the energy efficiency.

## III. FUTURE VISION

Based on the achievements from this research project, what can we create? It may be possible to carry a 100PFLOPS computer in a suitcase and set up a data center anywhere in the world. The energy dissipation can be reduced to 1/27,000 of conventional. Other applications such as distributed processing

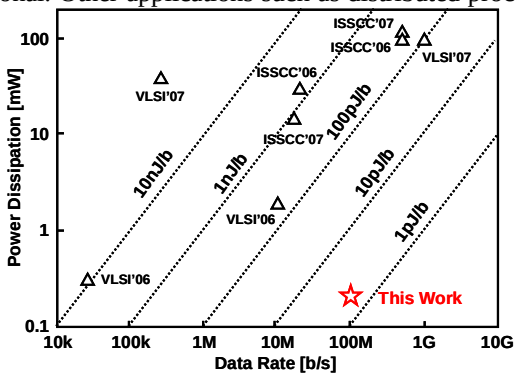
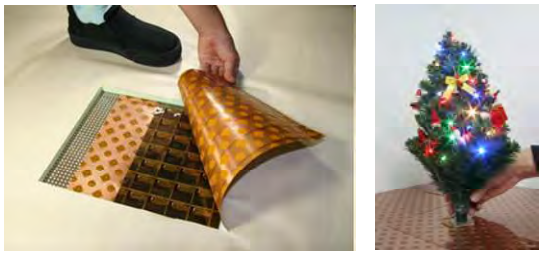



Fig.5 Power dissipation of almost-digital wireless transceiver.



OFET Performance Improvement

| | Supply Voltage | Mobility | Channel Length | Energy Efficiency |
|---|---|---|---|---|
| 2005 | 40V | 0.5cm²/Vs | 20μm | 1 |
| 2010 | 2V | 2cm²/Vs | 1μm | 1/1600 |

Fig.6 Wireless power-delivery sheet.

in a vehicle, home ad-hoc network using mobile phone, piping inspection in a nuclear plant, or medical application for plaque inspection in blood vessel are possible. High-speed and low-power short-range wireless technology would be a fundamental technology in advanced ubiquitous information society.

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