論文 / 著書情報
Article / Book Information

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Title(English)	A Study on Transceivers with Simultaneous Wireless Information and Power Transfer for Millimeter-Wave Relay
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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

In recent years, the amount of network traffic has increased dramatically, and there is a growing demand for high-speed wireless communications in the millimeter-wave band to support high-capacity networks. However, coverage holes can easily occur due to obstacles on the link, so relay devices that can be flexibly deployed anywhere are needed. In this paper, we focus on simultaneous wireless information and power transfer (SWIPT) and propose a wirelessly powered relay that does not require a power connection. To confirm the feasibility of the relay system, we designed a beamformer IC including an RF/IF circuit and estimated the system performance based on the measurement results. In addition, to achieve faster communication and higher power transmission, we also evaluated prototypes of a D-band relay and a discrete semiconductor relay.

To realize a wirelessly powered relay, rectifiers and backscatters are important circuit technologies. The rectifier is required to function as an RF-DC converter and as a self-heterodyne mixer using the WPT signal as the LO signal. Conventional rectifiers require high input power to achieve maximum efficiency, which makes long-distance transmission difficult at millimeter-wave frequencies. In addition, when using a power combiner to increase the input power, there is the problem of fixed beam direction. To address these technical issues, we have proposed a CMOS-type phased-array rectifier that can control the receiving beam angle by adjusting phase shifters while supporting long-distance transmission. We have also proposed discrete semiconductor-type stub-loaded rectifiers and LPF-loaded rectifiers to achieve higher power generation and faster communication speed.

On the other hand, backscatterers are required to have the function of beamforming transmission with low power consumption. Conventional backscatterers can only support low-order modulation schemes such as BPSK and QPSK, and have low transmission data rates. In addition, IF backscatterers that can support QAM modulation do not have a phase shift function, so beamforming transmission is not possible. To overcome these technical problems, we propose a vector summing backscatter. It not only mixes the received WPT signal and IF signal and reflects an RF signal, but also achieves phase shifting with vector summation by inputting IF band I/Q signals to two binary weighted backscatters.

The evaluation results of the prototype CMOS integrated transceiver include three types: a 5G phased array, a 5G retroreflective array, and a D-band reflective array. The 5G phased array consists of a phased-array rectifier, which achieves both long-range transmission and beam steering in WPT, and a vector summing backscatter, which achieves both high data rate transmission and phase shifting. The prototype phased array module can generate power in a range of ±30° by beam steering for WPT, and beamforming transmission of 5G NR standard signals is achieved with low power consumption of 0.03mW/path by vector summing backscatter. On the other hand, the 5G retroreflective array can steer the beam in two dimensions in WPT, and supports full-duplex relay with bidirectional LC-loaded rectifiers. The rotationally symmetric antenna pair can cover a wide angle in two dimensions, and when combined with a 90° phase shifter, it can cover a range of ±60°, while the 16:1 power combining can achieve long-range WPT. Finally, the D-band reflective array is composed of an LPF load rectifier, and it can support transmission and reception with a bandwidth of 8 GHz or higher, which was not possible due to the narrow bandwidth characteristics of conventional LC loaded rectifiers. Since there is no phase shifter, the communication signal and the WPT signal are received from the same direction, and the communication signal is transmitted in the reflection direction. It can realize a higher data rate than 5G transceivers, and 48Gbps was achieved in the probe measurement. The main advantage of CMOS integrated transceivers is their multiple functionality in a compact size.

On the other hand, the prototype evaluation results for discrete semiconductor-type transceivers is a bidirectional phased array for 5G. For the relay system, the SNR within the relay and the transmit EIRP are important factors to establish communication, and the transmit EIRP is especially

dominant in the wirelessly powered relay. Therefore, the IF amplifier needs to output higher power, and it is important to increase the power generation from the WPT. The 5G bidirectional phased array is composed of a stub-loaded rectifier with GaAs diode and 180° phase shifters, and has achieved a conversion efficiency of 54%, which is higher than the conventional CMOS rectifier. When all 256 elements are used, the maximum power generated can be more than 1W. The biggest advantage of a discrete semiconductor is the high power generation in WPT, and the generous power budget leads to the use of high-power IF amplifiers, which effectively extends the relay distance.

By further improving power generation and communication speed, it is expected that these technologies will enable the deployment of critical infrastructure such as power and networks anywhere in the world, and also make it possible to realize alternative communication and power lines during disasters and HAPS (High Altitude Platform Station). We believe that SWIPT technology will contribute to a society where people can connect to the network anywhere and do not have to worry about the battery life of their devices.