Direct digital RF transceiver technology for millimeter-wave DBF systems

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There is an increasing demand of digital beam forming (DBF) antenna for millimeter-wave (MMW) applications such as DBF antenna for next generation high throughput satellite and fully digital massive MIMO for beyond 5G system. In such systems, several ten/hundred element antennas will be used and each element antenna requires an independent transceiver. Since the distance between the element antennas is less than 1cm in MMW frequency range, the architecture and integration technology of compact transceiver becomes a key issue. The estimated size of unit transceiver module for 28GHz-band DBF antenna is described in Fig.1.

Digital RF transceiver architecture would be one of the solutions. The original digital RF transceiver architecture was proposed for software defined radio in which the RF transmit/receive signals are generated / sampled and quantized by the DAC / ADC [1]. Since the IC die consumptive RF/analog circuits can be replaced by the digital circuits, the transceiver size can be shrunk dramatically by using fine pitch CMOS process. But, there is an operational RF frequency limit exist which comes from Nyquist frequency of the DAC / ADC. Therefore, it has been difficult to apply this architecture to MMW transceivers.

In this paper, direct digital RF technology is introduced to break this Nyquist limit. This technology utilizes the higher-order Nyquist Zones (beyond the Nyquist frequency range) and MMW frequency signal can be handled directly [2] as shown in Fig.2. A 1-bit bandpass delta-sigma (ΔΣ) modulator is introduced for transmitter which generates a 26GHz-band RF signal directly from 8Gbps 1-bit digital DATA stream. In order to enhance the image signal level and SNR, RZ signaling and Manchester coding techniques are examined. Since this transmitter's input is 1-bit digital DATA stream, it is suitable for OOK optical fiber link structure as shown in Fig.1. Higher order direct RF undersampling architecture is introduced for receiver and the measured results of 28GHz-band receiver with fabricated CMOS sample and hold (S/H)-IC using 1GHz sampling clock are shown. This direct digital RF technology brings compact/digital rich MMW transceivers in future CMOS era and will realize large scale DBF antennas for various MMW applications.

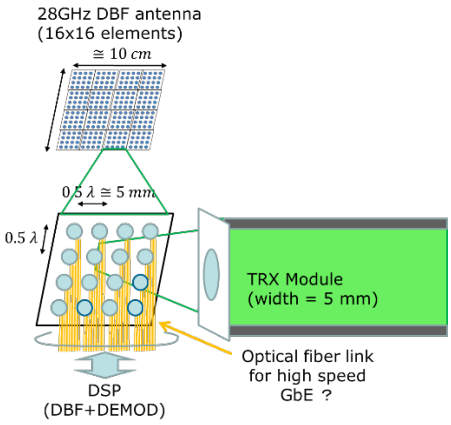

Fig.1 Sizes of 28GHz-band DBF antenna.

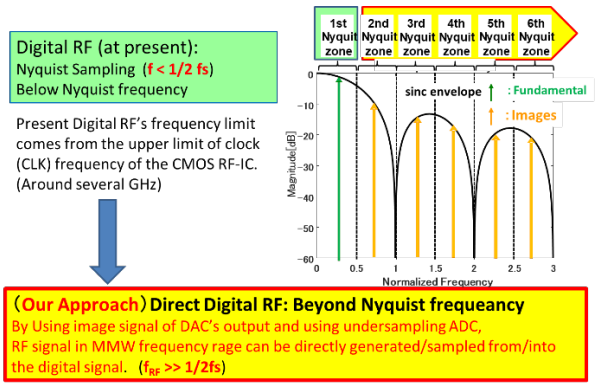

Fig.2 Concept of direct digital RF technology.

References

1. J. Mitola et al., " The Software Radio Architecture ," IEEE Com. Mag., vol.33, no.5, pp26-38, 1995.
2. N. Suematsu, et al., "Direct RF Undersampling Receiver for High-SHF Band Digital Beam Forming," 2015 IEEE IMaRC, pp.133-135, 2015..