Development of Entrance Link using Millimeter-wave Digital Radio-on-Radio for Small Cell Mobile Access

Kazuo KUMAMOTO[*1], and Katsutoshi TSUKAMOTO*[2]

[1]Faculty of Engineering, Osaka Institute of Technology, Japan
kumamoto@elc.oit.ac.jp
[2]Faculty of Information Science and Technology, Osaka Institute of Technology, Japan
tukamoto@is.oit.ac.jp

Abstract

The paper proposes a cascaded Radio on Fiber and digital millimeter-wave Radio on Radio entrance link for small cell mobile access. By utilizing wideband property of millimeter-wave, RF signals such as cellular, WiFi, or WiMAX can be digitalized and transferred to remote base station over digital RoR link. This paper will show the system configuration, and theoretical evaluations of the link design, and a basic experiment shows some results of EVM measurements for WiMAX signals. The influence of the sampling rate and quantization level at ADC will be discussed.

1. Introduction

Mobile traffic is rapidly increasing to access variety cloud services, and the access methods diversify in various types of radio air interfaces, 3.5G, 3.9G, and 4G and beyond 4G, or commercial / private WLAN. This trend requires the more and more efficient use of radio frequency, and the size reduction of radio cell offering heterogeneous wireless access services. Then the distribution of a huge number of radio base stations (RBSs) and the provision of more efficient and universal mobile backhaul networks will be needed in a wide area. For such universal mobile backhaul networks, the application of RoF (Radio over Fiber) technology is effective. The transparency of the backhaul networks can be also realized by RoR (Radio on Radio) networks [1-4], which can provide a free space for heterogeneous wireless services in millimeter-wave radio.

This paper proposes Digital Radio-on-Radio (DRoR) link cascaded with RoF, and show some results of link design based on SNR considering a quantization noise at ADC in DRoR. Some experimental results of EVM measurement are also presented for WiMAX signals.

2. Cascaded RoF and Digital MMW RoR Entrance Link

Figure 1 illustrates the configuration of the proposed cascaded RoF and Digital MMW RoR entrance link for small cells. In future mobile access, larger throughput per user will be required to accommodated mobile traffic explosion. An effective solution will be small cell architecture, however, entrance networks for a large number of small cells become important in their cost, construction easiness, universality for various types of air interfaces. RoF and RoR are effective to realize such entrance links. While RoF is superior in signal transmission quality, there are some disadvantages in fiber constructions and distribution for many cells. On the other hand, RoR using broadband millimeter-wave has a potential broadband to transport microwave signals keeping their signal formats and a distributing ability to some small cells. However, MMW RoR has peculiar obstructions in signal transmission like absorption loss, rain attenuations and so on. To combat against them, we employ digital MMW RoR link cascaded with RoF to expect FEC effect. In Fig. 1, point-to-point MMW RoR is shown, but RoR can be easily extended to P-MP system.

As shown in Fig. 1, after the transmission over RoF link from CS (Center Station), wireless access signals for a small cell are digitalized at ADC (Analog to Digital Converter), and then transmitted to remote BS via digital MMW RoR link. At a remote BS, digital data is directly converted into a RF signal by using DAC and band pass filter, and the RF signal is transmitted to a cell. Because RF signals are sampled and quantized, the evaluation of the sampling rate and the quantized bit number are important. In next section, some basic evaluations are presented.

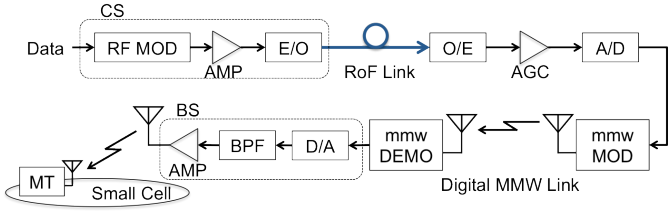

Fig 1: Block Diagram of cascaded RoF and digital MMW RoR entrance link for small cells.

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3. Link Design and Experiment

Figure 2 shows the relationship between required bit rate and quantized bit number for different types of wireless access signals. It is found from the figure that assuming 10bit quantization bit number, 1ch of LTEa or a few channel of WiFi and WiMAX can be transmitted over 1Gbps digital MMW link.

We theoretically derive the output SNR (Signal to Noise Ratio) of the proposed entrance link considering quantization bit number of ADC. Numerical results are shown in Fig.3 (a) and (b). Fig.3 (a) shows the output SNR versus input RF power at CS for the input SNR of 70dB, which is determined the NF of an amplifier at the input stage of E/O at the CS. For down link, the quantization noise causes some penalty in the output SNR, but controlling the input RF power can minimize its value. Fig. 3(b) shows the output SNR for input SNR of 30dB, which corresponds for up link. It is seen from Fig.3 (b) that the tolerable quantization bit number is 10 bits for the wide range of input RF power of uplink because the output SNR is dominated by the input SNR value of 30dB.

To confirm theoretical link design, we have performed EVM measurement in digital transmission of WiMAX (802.16e) signal with its bandwidth of 10MHz. Figure 4 shows the experimental setup. In the experiment, the off line data storing in PC emulates digital RoR. As ADC and DAC, we used USRP [5] units with its quantization bit number of 14bits. Figure 5 shows the measured EVM versus sampling speed for with / without RoF link. It is found that for more than 10 Msample per sec (Msps), EVM of about 25dB was obtained. The EVM value corresponds output SNR of 48dB. It is seen that both curves are almost identical. The penalty caused from the RoF transmission was not observed.

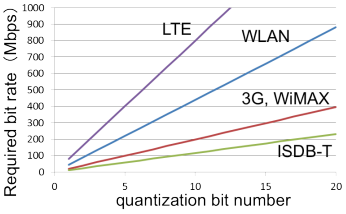
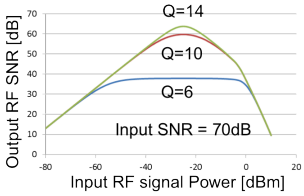
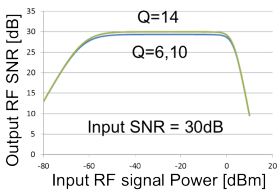


Fig. 2: Relationship between required bit rate and quantized bit number



(a) Down Link



(b) Up Link

Fig. 3: output SNR versus input RF power

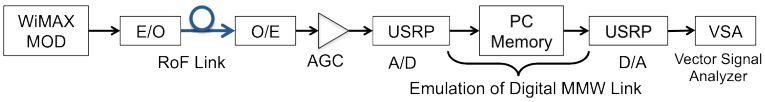


Fig. 4: Experimental setup

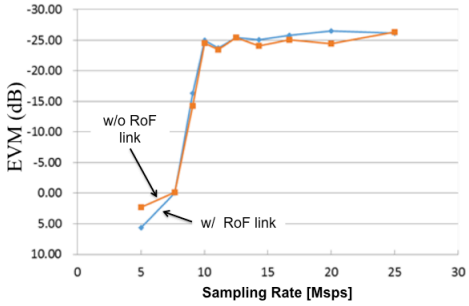


Fig. 5: measured EVM versus sampling speed

4. Conclusion

The paper proposed a cascaded Radio on Fiber and digital millimeter-wave Radio on Radio entrance link for small cell mobile access and the theoretical and experimental evaluations have been shown.

5. Acknowledgments

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