A Novel 60 GHz Short Range Gigabit Wireless Access System using a Large Array Antenna

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***Abstract-* A novel concept of short range wireless access system is proposed for multi-Gb/s data transfer in the 60 GHz band. An extremely large array antenna (64x64 elements) generates a quasi-plane wave and forms communication zone proportional to the antenna size. The key is that the stable signal coverage up to 10 m with uniform illumination still stays in the Fresnel region of the array antenna. The link budget based upon Friis Transmission Equation is not applicable in this short range communication system. The mobile user standing everywhere in the coverage, receives a constant signal almost free of multipath. For demonstrations, the circularly-polarized waveguide slot arrays are designed and fabricated first. They are installed in the prototype of a short range Gigabit wireless access system as the transmitting antenna. The system performances of not only the RF receiving level but also the bit error rate et al. will be evaluated to verify our proposal.**

I. INTRODUCTION

The high-performance mobile wireless terminals such as tablet PC, smartphone et al. are fast becoming widespread in recent years. In addition, a cloud computing system is widely expected to realize a free high-capacity data transfer with the server. However, the present mobile communication systems are facing the spectrum congestion worldwide, and their traffics are exploding and facing their limitation as the weak points. The "wireless-fiber project" to realize millimeter-wave wireless communication systems has been developed by the authors for years [1]. One of the two outputs from this project is a 60 GHz short range file transfer system with a maximum throughput of 3.5 Gb/s [2]. It has the potential of speed-up to 6.3 Gb/s [3], and a burst type download of high capacity files becomes possible. The other output is a 38 GHz-band 1Gbps FWA (Fixed Wireless Access) system for the outdoor backhauls [4]. These indoor and outdoor millimeter wave technologies open up the utilization of radio frequency resources and solve the frequency congestion in lower frequencies.

This paper presents a new concept of "short range communication" as the high-speed multi-Gb/s short range wireless access system in millimeter-wave band. The GATE (Gigabit Access Transponder Equipment) will provide the mobile terminals with an access to the cloud service. An extremely large array antenna with a high gain of 45dBi is realized in 60GHz band. It will be installed in the GATE as

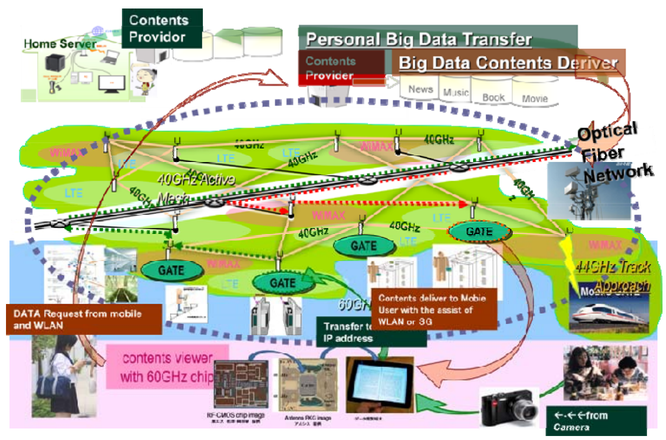

Figure 1. Image of a millimeter-wave Gigabit Network for realizing the mobile cloud service.

the wireless access point antenna, and will provide a stable and large signal-reception zone, which has an area proportional to the antenna aperture and a communication distance up to 10 m. In addition, the peak electric field density is favorably suppressed by introducing the large aperture antenna instead of the small one, and it is safe in terms of SAR (Specific Absorption Rate) for human body [5]

II. THE MMW GIGABIT NETWORK AND 60 GHZ GATE

Fig.1 gives the image of the millimeter-wave Gigabit network to realize the mobile cloud service. The key is to make full use of the two outputs from our "wireless-fiber project". That is the mobile terminals are connected with GATE by 60 GHz compact range communication while GATEs are the access points to the mesh network consisting of the 40 GHz FWA systems. Fig. 2 illustrates the 60 GHz GATE to be equipped in stations and other public areas. It provides the Gigabit access to the mobile users when they are staying in the coverage area of GATE.

The communication distance between the mobile wireless terminal and the GATE is relative short from tens of centimeters to several meters. It is necessary to specify the reception zone first which is different from the conventional far-field wireless systems in terms of user-friendliness and access performance. Those far-field evaluation indices as represented by Friis Transmission Equation as well as the antenna gain and HPBW cannot be easily applied as before. For example, the design of link budget based upon Friis Transmission Equation is not applicable for the GATE.

III. Communication Zone Formation by Applying Large Aperture Antenna

In this paper, we propose a new concept of "Compact range communication" where the user standing in the clearly defined coverage is illuminated as if it was receiving the plane wave. To realize this ultimate radio environment, the GATE antenna must have the antenna aperture large enough so that the user antenna may be well in the near-field or Fresnel region. The communication zone with uniform signal intensity has been investigated by varying the aperture sizes of the GATE antennas [5]. Our findings are briefly summarized as follows:

1) For the large aperture antenna (251 mm square, 45 dBi), the electric field intensity keeps almost unchanged in a short range up to 10 m. A larger reception area for the wireless terminal can be achieved by adopting a large aperture antenna in the access point compared with the small one as illustrated in Fig. 3;

2) In terms of safety issue for the human body, the peak electric field density associated with the large aperture (high gain) antenna is much weaker than those of the standard small antennas, which is also demonstrated in Fig. 3.

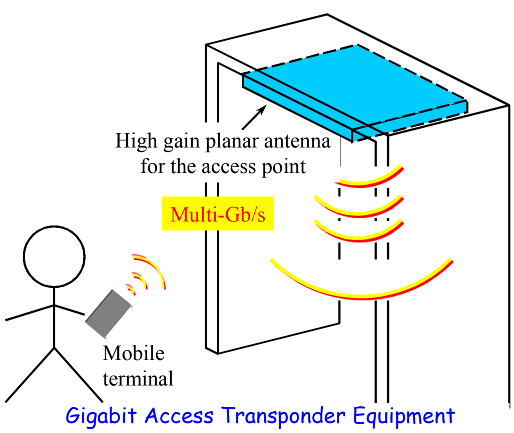

Figure 2. The concept of GATE for short range high-speed data transfer.

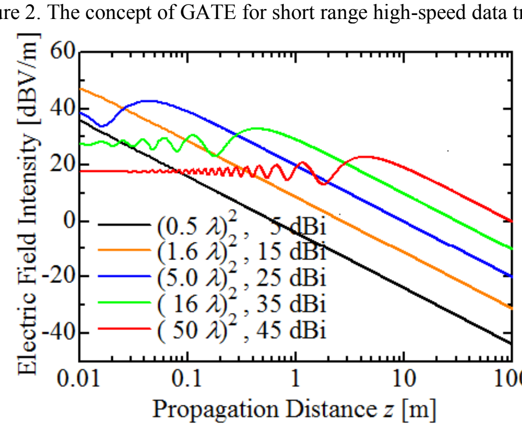

Figure 3. Propagation distance dependence of the electric field intensity generated by the antennas with various aperture sizes

3) Reflection from walls and obstacles outside of the coverage is negligible since the field strength is rapidly decreasing away from the coverage, and multipath radio environment may be neglected in principle.

IV. System Evaluation Including BB and RF Circuits

To verify our proposal of applying an extremely large aperture antenna to form the clearly defined communication zone for GATE, the circularly-polarized waveguide slot arrays [6] with different numbers of elements are designed. Fig. 4 shows the photograph of the 2×2, 4×4, 8×8, 16×16, 32×32 and 64×64 elements antennas fabricated by diffusion bonding of thin copper plates. The antenna characteristics of reflection, aperture illumination and antenna gain in far field region are evaluated first. The aperture efficiencies of more than 70% are achieved for all antennas and are acceptable to be applied in the system evaluation.

At first, the electric field intensity is simply evaluated by connecting a RF circuit on the backside of antennas. The 16×16, 32×32 and 64×64-element arrays are used as the transmission antenna, while a V-band waveguide probe is used as the receiving antenna. A continuous wave without modulation at 60 GHz is adopted. The receiving signal intensity is measured when changing the communication distance between the Tx and Rx antennas. As illustrated in Fig. 5, relatively good agreement between predicted and measured result is observed.

Secondly, the prototype of a short range Gigabit wireless access system including a BB module [2] and RF front end is established. This system only uses the second channel of 60 GHz band WPAN system [7], covering the frequency range of 59.40 ~ 61.56 GHz. A maximum throughput of 3.5 Gb/s is expected by adopting the modulation of QPSK. The longitudinal distance between the Tx and Rx terminals is fixed at 10 m. The position of the Rx terminal is shifted transversely within the range of ± 20 cm. The bit error rate (BER) as summarized in Fig. 6 is measured to evaluate the system performances. By adopting a rate-14/15 low-density parity-check (LDPC) code, a communication zone with a BER below 1e-11 proportional to the array size is realized as expected.

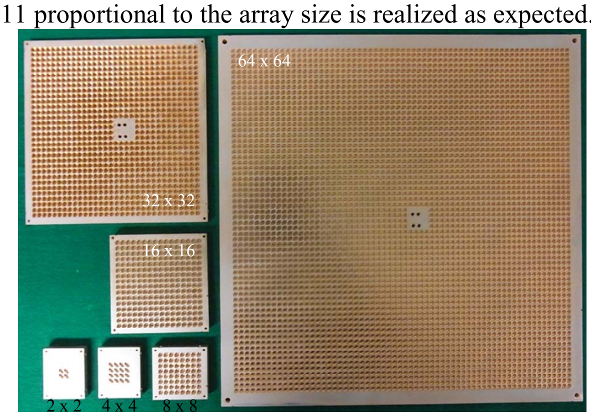

Figure 4. Circularly-polarized waveguide slot arrays fabricated by diffusion bonding of copper plates in the 60 GHz band.

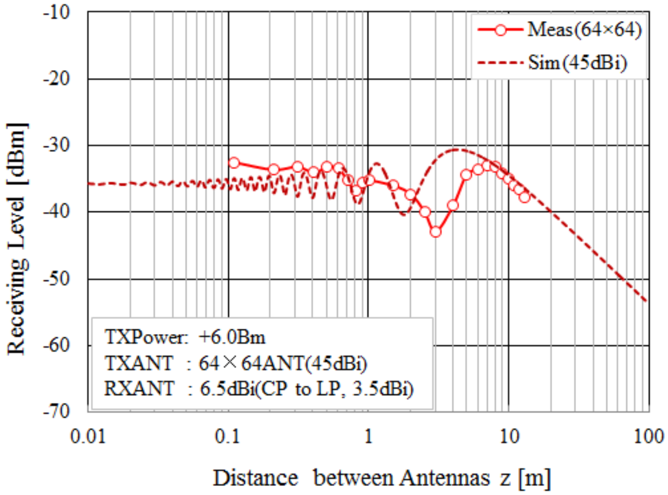

Figure 5. Measured receiving level as the function of distance between the transmitting and receiving antenna.

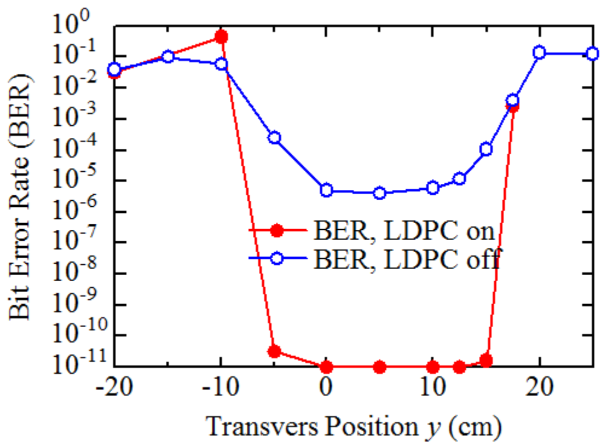

Figure 6. Measured bit error rate as the function of transverse position of receiving antenna.

V. CONCLUSION

A new concept of 60GHz Gigabit Access Transponder Equipment (GATE) for short range and short-time file transfer is proposed. A larger reception area in short range can be achieved by using the large aperture antenna compared with the small one, even though the high gain antenna has narrower HPBW in the far-field. In addition, the large aperture antenna provides wide and stable reception area regardless of the reflected waves. The circularly-polarized corporate-fed waveguide slot array antennas with 2×2, 4×4, 8×8, 16×16, 32×32 and 64×64 elements are designed and fabricated in the 60 GHz band. The system evaluation including the BB module and RF front end has been conducted. Relatively good agreement between predicted and measured receiving level as the function of antennas distance is observed. An error-free communication zone proportional to the array size is also realized as expected.

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