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# A 60GHz Gigabit Access Transponder Equipment for Short Range and Short-time File Transfer

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***Abstract*—A novel concept of short range communication is proposed for millimetre-wave high speed file transfer. A very high gain antenna generates a quasi-plane wave and synthesises a coverage up to 10m with uniform illumination in near field region of the aperture, in analogy to a compact range. Apart from conventional short range communication systems with the level diagram still following Friis's equation for the far field, a mobile user, in line of sight (LOS) everywhere in the coverage, receives the constant field almost free of multipath. In terms of the safety issue for the human body, the peak field strength from the large aperture with high gain is much lower than that from the point source-type small antenna with low gain. In this paper, the concept as well as the feasibility study is introduced.**

## I. INTRODUCTION

The high-performance mobile wireless terminals such as tablet PC, Smartphone et al. are becoming widespread in recent years. Furthermore, cloud-types of services is widely expected which needs the high capacity network as the background. As the weak point of these, wireless access systems are facing the spectrum congestion. Authors have been developing millimeter wave wireless systems named as "wireless-fiber project" [1, 2]. One of two outputs from this project is 60GHz short range file transfer system with 3.5 Gbps QPSK. It has the potential up to 64QAM [3] and a burst type download of the large file is proposed. Another output is a 40GHz 1Gbps compact FWA system for the outdoor backhauls [4]. These millimeter wave technologies open up the utilization of radio frequency resources and solve the frequency congestion in lower frequencies. This paper introduces a new concept of "compact range communication" as the high-speed multi-Gbps short range wireless access system in millimeter-wave band which provides distance independent LOS and almost multipath free radio environment resulting in a ideal special domain frequency reuse. Gigabit access transponder equipment, named as GATE hereafter, works with the mobile terminal as the interface to the network. An extremely high gain aperture with more than 45dBi is realized by 25cmx25cm arrays in 60GHz band which has the peak field strength much lower than that of small antenna and is safe in terms of SAR for human body [5].

## II. MILLIMETRE-WAVE GIGABIT NETWORK

Fig.1 gives the image of the millimeter-wave Gigabit network for realizing mobile cloud services. Full use of millimeter-wave technology is illustrated where mobile terminals are connected with GATE by 60GHz compact range communication while GATES are the access points to the mesh network consisting of 40GHz FWA systems.

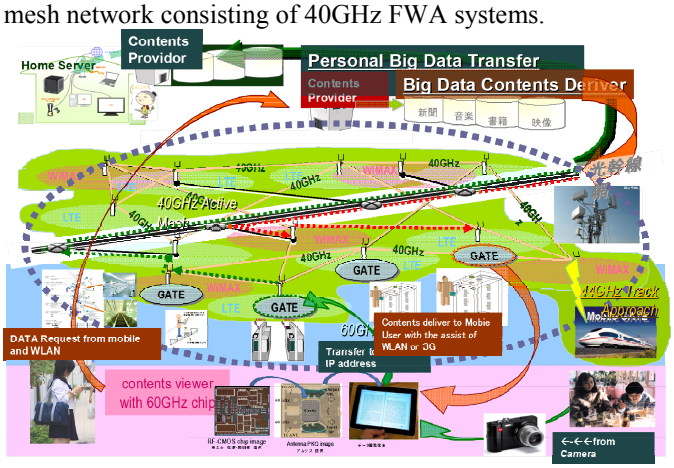


Fig.1 Image of a millimeter-wave Gigabit Network consisting of 60GHz compact range access systems and 40GHz backhaul networks.

Fig. 2 illustrates the 60GHz GATE to be equipped in stations and other public areas. This provides the Gigabit access to the mobile users which are staying in the coverage area of GATE. Fig. 3 summarizes the download time for the big file via variety of wireless systems. In principle, short range and limited area link assures the high speed of 3.5Gbps-6Gbps occupied by a single-user at a time and download is completed in quite short-time (burst-type); a visual DVD of 6GB may be downloaded in less than 10 seconds for example.

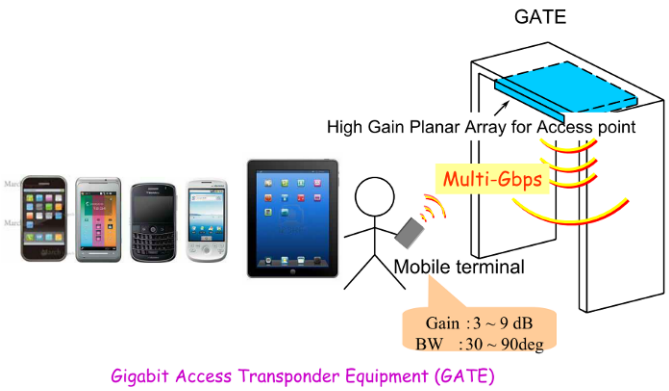


Fig.2 Conception of a GATE for compact range access.

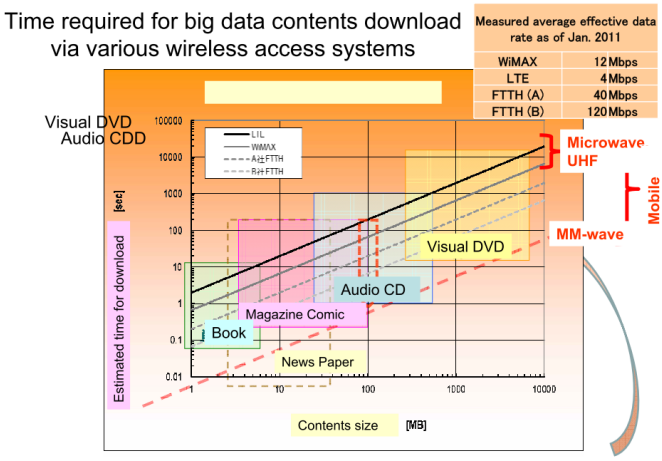


Fig.3 Time required for big data contents download via various wireless access.

GATE antenna has a large aperture which could clearly define the coverage of service area with uniform field strength and multipath free radio environment while the mobile terminal antenna may have various radiation characteristics depending upon types of mobile terminals. Relatively low gain of about 6 dBi with the HPBW (Half Power Beam Width) around 60 degrees was designed in our previous report, though it may be revised for this specific GATE model.

## III. Gigabit Access Transponder Equipment

### A. Compact Range Communication

In contrast with the conventional design of short range communication with link budget based upon Frii's equation for the far field, we propose a new concept of "Compact range communication" where the user 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 aperture large enough so that the user antenna may be well in the near-field or Fresnel region ($d<0.62\sqrt{D^3/\lambda}<<2D/\lambda^2$); ideally the aperture size corresponds to the coverage. If these apertures are characterized in terms of far field gain, it may have the gain more than 50dBi suggesting interfering to other systems, but it does not make sense since the indoor LOS coverage will not reach more than 100m and the mm-wave will be blocked and attenuated by shadowing and absorbing. The advantages of this concept in terms of high speed and large data communication are as follows.

1) Frequency is specially reused since the coverage is small and clearly defined by large aperture in high frequency.
2) Reflection from walls and obstacles outside of the coverage is negligible since the field strength is rapidly decreasing away from the coverage. Multipath may be neglected in principle. Fig.4 shows some of the field distribution in the compact range for antennas with various aperture size or Gain in far field. The fields with and without the conducting walls outside the coverage are also compared to show the disturbances due to reflected waves. For high gain antennas, the field uniformity remains unchanged while the standing waves with rapid amplitude variation are observed for the low gain antennas; the latter is multipath environment. .
3) The field strength is almost uniform in the coverage area, especially along the direction away from the antenna. Fig. 5 presents the comparison of fields from high gain and low gain antennas which would be observed in the GATE coverage.
4) According to 2) and 3), the wide-band communication requiring flatness of pass-band may be easily realized by a simple equalization technique.
5) In terms of safety issue for the human body, the peak strength of the field associated with the large aperture (high gain antenna) is much weaker than that of the standard small antennas, which is also demonstrated in Fig. 5.

Possible disadvantages are,

6) The mobile user should recognize the direction of arrival of the wave, while the GATE should recognize the target passenger. In other words, GATE or its antenna should be recognized by the mobile user during the download and the GATE should sense the passenger for switching on the mm-wave system.

Fig.6 presents photos of escalator as the analogous equipment, which has the sensor of passengers for saving the energy consumption.

### B. Feasibility of MM-wave Arrays for Compact Range Communication

To demonstrate the feasibility of the planar array as the GATE antenna for realizing the compact range communication, an circularly-polarized waveguide slot array with 64×64-element arrays was fabricated by diffusion bonding of thin copper plates [6][7]. The antenna size is as large as 290×290 $mm^2$. Fig.7 demonstrates the feasibility of GATE antenna with afore mentioned advantages.

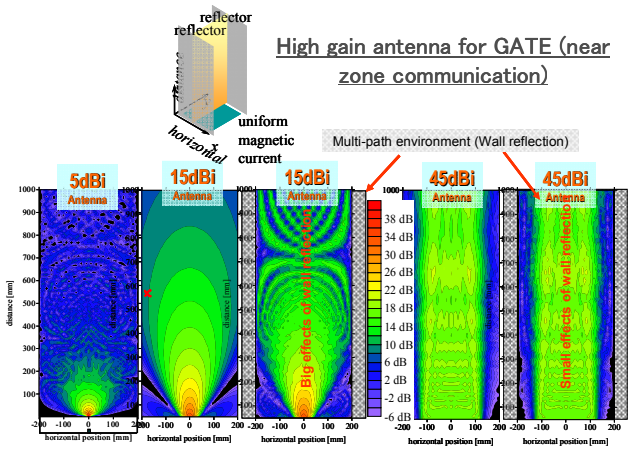


Fig. 4 Field strength in front of the GATE with various gain of the antennas with and without the wall reflection.

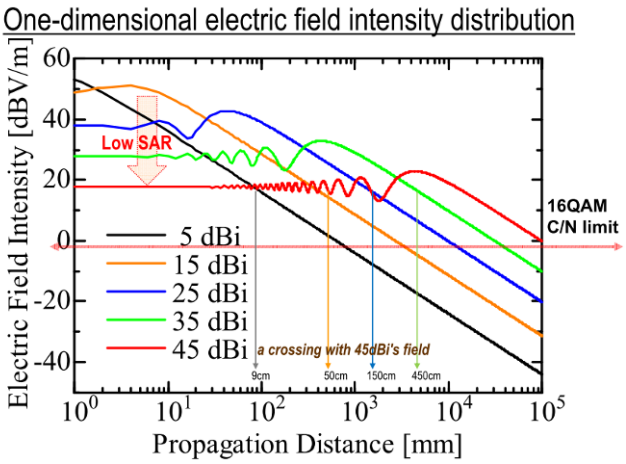


Fig.5 Distance dependence of Field strength from antennas with various gain.

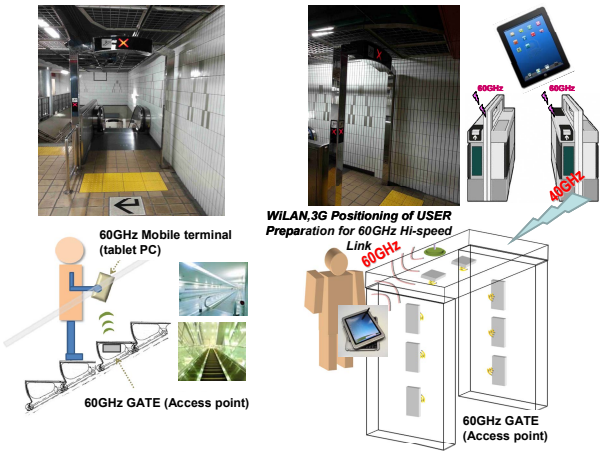


Fig. 6 Image of a Gigabit access transponder equipment at the escalator.

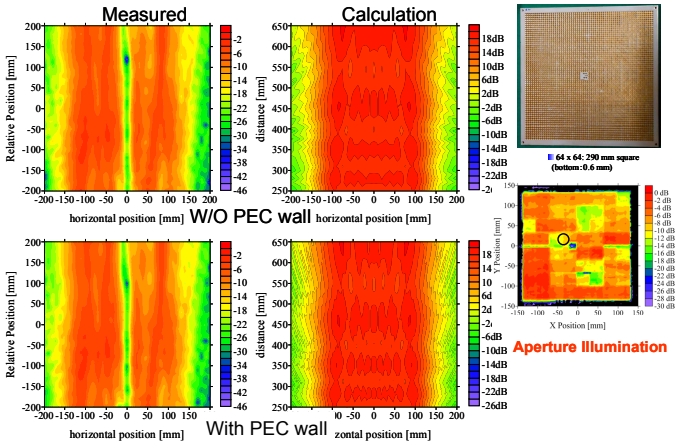


Fig.7 Feasibility of 64x64 test antenna for GATE and the field distribution –measurement and theory.

## IV. Conclusion

A new concept of 60GHz Gigabit Access Transponder Equipment (GATE) for short range and short-time file transfer is proposed. Advantages of GATE uniquely realized only by millimetre-wave are explained; a high gain planar array is tested. Electromagnetic field discussion developed here should be reinforced quantitatively with baseband performances to validate the feasibility of the system.

## Acknowledgment

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## References

[1] Makoto Ando, "Planar Waveguide Arrays for Millimeter Wave Systems," IEICE Trans. Commun., Vol.E93-B, No.10, pp.2504-2513, Oct. 2010.

[2] M. Ando, "Tokyo Tech Wireless-Fiber Project for Millimeter Wave Systems", The International Workshop on Millimeter Wave Wireless Technology and Applications -Tokyo Institute of Tech., pp.8-13, December 6, 2010

[3] Kenichi Okada et. Al., "A Full 4-Channel 6.3Gb/s 60GHz Direct-Conversion Transceiver with Low-Power Analog and Digital Baseband Circuitry," IEEE International Solid-State Circuits Conference (ISSCC), pp.218-219, San Francisco, CA, Feb. 2012.

[4] J. Sato et. Al., "A 38 GHz-band 1 Gbps TDD FWA System Using Co-polarization Dual Antenna with High Spatial Isolation" IEEE Radio & Wireless Sym., Jan., 2012.

[5] M. Zhang et. Al., "Receptionable Area Enlargement in MMW Short Range Communication Using Waveguide Slot Antennas with Large Number of Elements," IEEE AP-S International Symposium (USNC/URSI National Radio Science Meeting), Session: 454.6, Chicago, IL, USA, July 8-14, 2012

[6] Y. Miura et. Al., "A high-efficiency circularly-polarized aperture array antenna with a corporate-feed circuit in the 60 GHz band," IEICE Trans. Electron., vol.E94-C, no.10, pp.1618-1625, Oct. 2011.

[7] M. Zhang, et. Al., "Fabrication of a slotted waveguide array at 94GHz by diffusion bonding of laminated thin plates," IEICE Trans. Commun., Vol.E93-B, No.10, pp. 2538-2544, Oct. 2010.