Design of a 60GHz RLSA for Compact Range Applications

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***Abstract* – The design of a 60GHz Radial Line Slot Antenna (RLSA) for compact range communications is discussed in this paper. A taper window was investigated and applied for a uniformly illuminated circular aperture in order to create a uniform field in a specified receiving zone. Predicted results show a good uniformity up to a few meters in the propagation distance, and on a receiving horizontal plane as large as the antenna aperture. A 20cm diameter RLSA prototype was fabricated based on the proposed taper design, and its measured results partly support our predictions.**

***Index Terms* — radial line slot antenna, mm-wave, compact range applications, taper aperture illumination.**

I. Introduction

Recently, demands for high speed wireless communications are increasing more than ever since the rapid developments of high technology mobile devices such as smart-phone or tablet PC. Furthermore, to deal with the spectrum congestion problem, authors have been trying to develop the wireless systems operating at high frequencies such as millimeter wave band [1]. At the moment, we are also working on a "compact range communication" for high speed data transfer, whose details were reported in a recent publication [2]. Theoretically, this compact range can provide a data transfer speed as high as 3.5-6Gbps for a single-user at the time of connection, owing to the extremely high gain aperture antennas stationed at some convenient public places, as illustrated in Fig. 1. We named these antennas the Gigabit Access Transponder Equipments (GATE) [2]. As the trial step, a 25cmx25cm rectangular slotted array antenna has been designed and tested for the GATE, and some promising results were reported [2]. In this paper, we investigate the possibility of applying the well-known RLSA [3] for the GATE.

II. Radial Line Slot Antenna for GATE

RLSA is well-known for its high gain characteristic, for example, at 60GHz, a 20cm diameter RLSA with uniform illuminated aperture offers more than 40dBi gain, which is almost comparable with the rectangular aperture having the same geometrical area. Additionally, other advantages of RLSA such as lightweight, compactness, and low fabrication cost would make it a candidate for GATE antenna in compact range wireless systems.

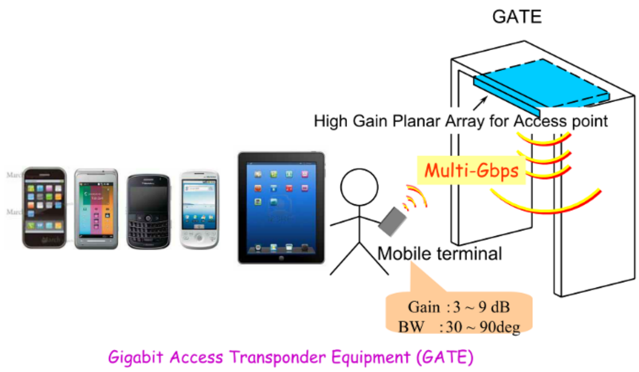

Fig. 1. Concept of a GATE for compact range communication system

Different from the long distance communication, where an antenna is always designed to have a maximum gain and efficiency, in compact range communication, constant field strength in a specified receiving zone is desired. This constant field would assure a multipath free radio environment and therefore better the quality of the link between the access point and the mobile terminals.

To test the possibility of using RLSA as GATE, we first compare the field distributions in a compact range given by the uniformly illuminated circular apertures with different sizes. Fig. 2 shows the electrical field intensity varied upon the propagation z-distance for several aperture sizes (ϕ = 30cm, 20cm, 5cm). Here, two observations can be drawn from this figure:

- Larger aperture gives lower field strength, which is advantageous in terms of SAR for human body [4].
- Ripples occur even at the close range (less than 100mm) and high fluctuations are observed in the Fresnel region.

Latter observation suggests that a non-uniform aperture illumination has to be applied for RLSA in order to reduce the diffraction effect at the edge of the circular aperture, and therefore enhance the uniformity of the near field.

According to our recent research on a lossy design of RLSA [5], a non-uniform aperture illumination can be achieved by simply controlling the slot coupling factors. This technique is applied and a taper aperture illumination is realized. The field strengths corresponding to uniform and taper aperture distributions are calculated along the center line of the aperture and are plotted in Fig. 3. Also, the 2-dim field distributions calculated on a plane perpendicular to the aperture are presented in Fig. 4. These figures clearly show

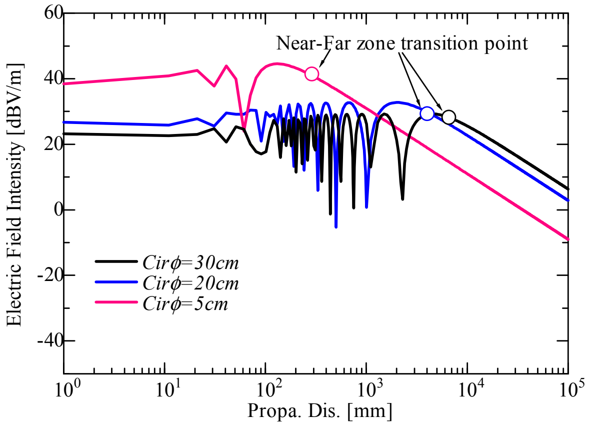

Fig. 2. Field distributions of uniform circular aperture with different sizes

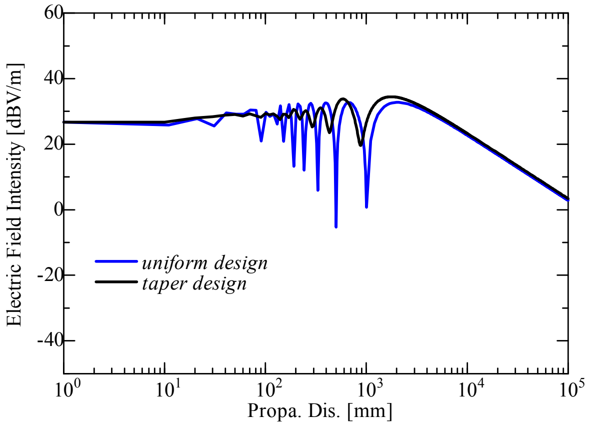

Fig. 3. 1-dim field distributions for a 20cm RLSA: calculated for uniform and taper aperture illuminations

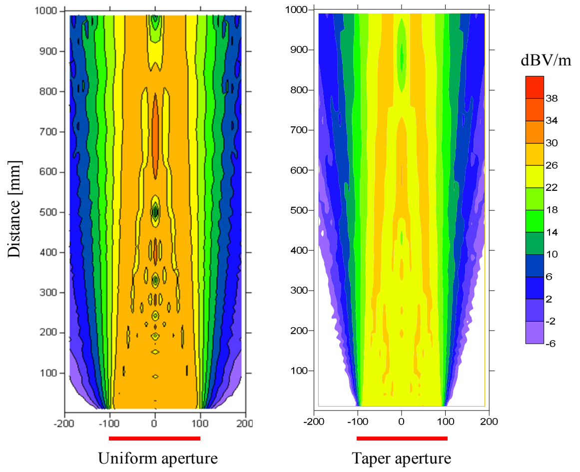

Fig. 4. 2-dim field distributions for a 20cm RLSA: calculated for uniform and taper aperture illuminations

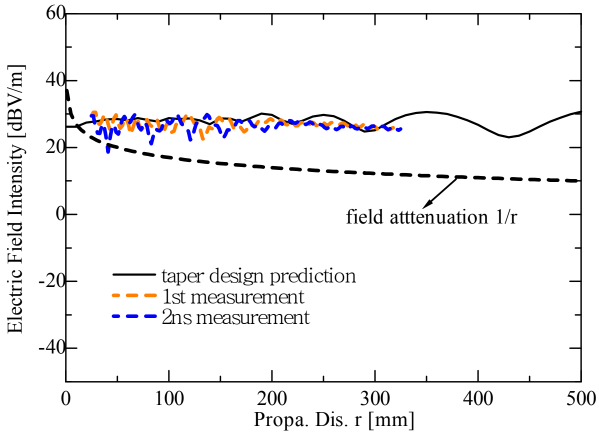

Fig. 5. 1-dim field distributions measured for a 20cm RLSA prototype

that by applying a taper design, a better uniform field in short range is achieved from a circular aperture. In a receiving zone 20cmx20cmx100cm, a ripple level in no more than 8dB.

III. Measurement Results

A 20cm RLSA having taper aperture distribution was designed, fabricated, and characterized in the near field. The measured distance is from 25mm ($5\lambda_0$) to 325mm ($75\lambda_0$), and the scan step is 2.5mm ($0.5\ \lambda_0$). The measured electrical field intensity reported in Fig.5 shows a good uniformity in the propagation direction and agrees well with our prediction The field intensity attenuates in far zone by 1/r is also included for reference, in which r is the propagation distance.

IV. Conclusion

In this paper, we proposed a RLSA with taper design for the compact range communication. By properly control the slot couplings, a taper aperture illumination was realized and a receiving zone with constant field strength was created. We are now conducting more experiments and analysis regarding the system quality evaluation (bandwidth, BER, SAR, etc…).

Acknowledgment

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References

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

[2] M. Ando et al., "A 60GHz Gigabit Access Transponder Equipment for Short Range and Short-time File Transfer," Proc. of URSI Commission B International Symposium on Electromagnetic Theory (EMTS), paper no.: 21PM1E-06, pp.215-217, Hiroshima, Japan, May 20-24, 2013.

[3] M. Ando et al., "Characteristics of a Radial Line Slot Antenna for 12GHz Band Satellite Reception," IEEE Trans. Antennas Propag., vol.34, No.10, pp.1269-1272, Oct. 1986.

[4] 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, Session: 454.6, Chicago, IL, USA, July 8-14, 2012.

[5] Tung Nguyen et al., "Gain Optimization in RLSAs with Lossy Substrates by the Slot Coupling Control," 8th European Conference on Antennas and Propagation (EuCAP), Session: A11A.5, pp.1769-1773, The Hague, The Netherlands, April 2014.