Design of Non-uniform Aperture Illumination RLSA and Its Applications in mm-Waves

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***Abstract*—This paper discusses a design of Radial Line Slot Antenna (RLSA) having non-uniform aperture illumination for specific applications. We control the slot couplings to produce a linear taper amplitude distribution that can be applied into two cases: RLSAs having lossy dielectric waveguides and RLSAs for short-range communications. At 60GHz, several prototypes were designed and fabricated, and their measured taper amplitudes give better performances than the uniform designs, from the system point of view.**

***Keywords*—Radial line slot antennas; slot couplings; aperture illumination; lossy dielectrics WG; short-range communications.**

I. INTRODUCTION

Radial Line Slot Antenna (RLSA) is a well-known planar slot array antenna that provides high gain, high efficiency, low profile, and compact structure [1]. Different from other transmission lines, RLSA utilizes a simple over-sized parallel plate waveguide (PPW) as its feeding network, and that result in a very low conductor loss. In the past, RLSA was designed and optimized to have uniform aperture illumination, which maximizes the antenna directivity and efficiency, considering a very low dielectric loss. However, this "uniform" design policy does not always give us desired antenna characteristics, from the communication system point of view.

Recently, we have encountered with two specific designs in which a non-uniform aperture illumination RLSA is more desirable than the uniform one.

1. The design of RLSA having lossy dielectric waveguides. A proper taper amplitude distribution should be applied to balance the amount of radiated power from slots and dissipated power due to lossy dielectric materials.
2. The design of RLSA to create a uniform receiving zone in short-range. A taper amplitude design is employed to reduce the contribution of the radiation from edge, which causes errors in short-range communications.

The first design is recommended for Hayabusa 2 satellite [2], in which the use of light-weight and high-loss material was indispensable. The second design is now being investigated for a Gigabit Access Transponder Equipment (GATE) [3], and its image is illustrated in Fig. 1.

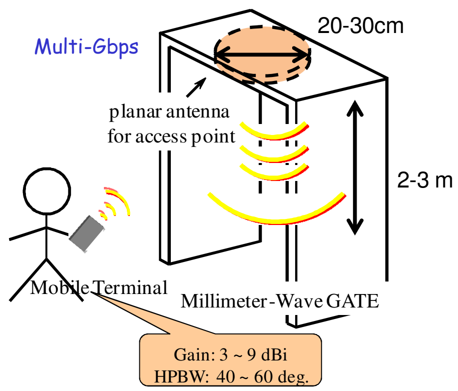


Fig.1. Image of RLSA as Gigabit Access Transponder Equipment (GATE)

II. RLSA WITH TAPER APERTURE ILLUMINATION

In RLSA operation, slot coupling is the key factor to control the aperture illumination. By arranging the slot with proper length/ coupling factor at a particular position (ρ, ϕ) on the aperture, we can achieve uniformity illumination even on a rotational asymmetrical aperture [4]. On the other hand, by introducing a loss factor α_l of the radial transmission line, a desired amplitude taper can be created, and it serves our two purposes mentioned in the introduction. Formulation of the slot coupling distribution $\alpha_r(\rho)$ for taper amplitude was derived from an energy conservation model in Fig. 2, and its mathematical details were reported in [5].

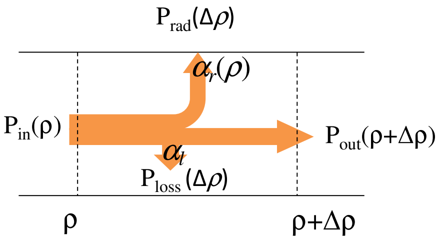


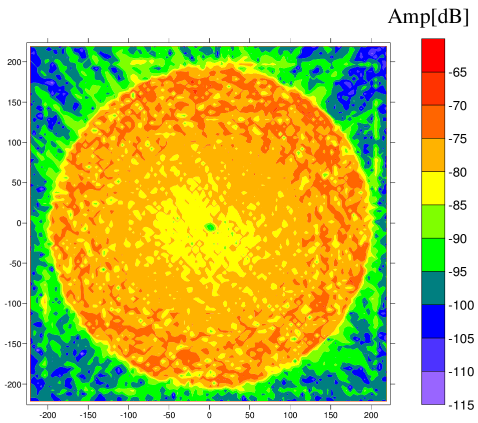
Fig.2. Energy conservation model

III. MEASUREMENT RESULTS

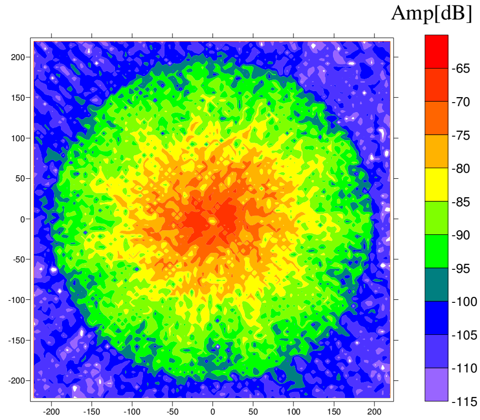
To verify our amplitude taper design and its effect on the antenna and system performances, we fabricated several prototypes at 60GHz. There measurement results will be reported hereafter to demonstrate the effectiveness of non-uniform aperture illumination RLSAs for particular cases.

A. *RLSA Having Lossy Dielectric Waveguides*

At 60GHz, a very lossy dielectric material Roger4003C (RO4003C^{TM}) was used to fill the over-sized PPW. The loss factor α_l = 0.1dB/mm and antenna diameter ϕ = 400mm were chosen for the design. Fig. 3 shows the aperture illumination of the uniform and non-uniform design RLSAs measured at peak frequencies. A clear taper toward the antenna rim can be seen from Fig. 3(b). Frequency characteristics of those two are presented in Fig. 4. Regardless the frequency shift due to etching errors and a possible misestimation of the material permittivity, it is observed that with the amplitude taper design, we can achieve a 3.2dBi gain enhancement compared to the uniform design.This non-uniform design should be applied on the Hayabusa 2' antenna, in which a lossy NoMEX® material (α_l = 0.018dB/mm) was used to construct the waveguide structure.



(a) Uniform aperture illumination



(b) Non-uniform aperture illumination

Fig.3. Measured amplitude distributions on 400mm apertures

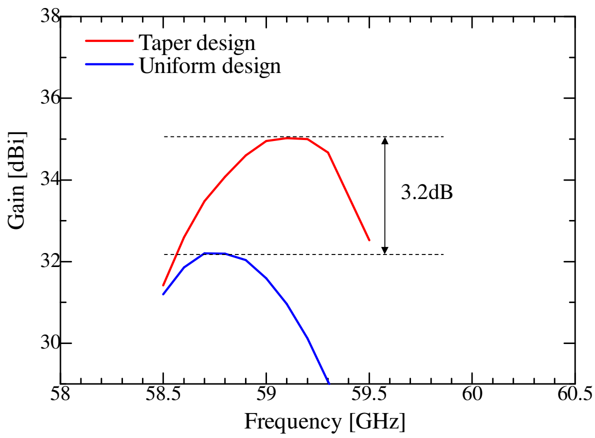


Fig.4. Measured frequency characteristics of two 400mm RLSAs

B. *RLSA for Short-range Communications*

In short range communications, high gain antennas are desired because they can create constant field in confined areas, where error free transmissions can be achieved. Nevertheless, signals coming from the center and the edge of the antenna aperture interfere with each others and create a ripple field pattern in propagation z-direction as indicated by the blue line in Fig. 5. We apply an amplitude taper to suppress the contribution of the edge element, and ripple level is reduced as shown by the black line in Fig. 5.

At 60GHz, a 200mm RLSA was designed considering the amplitude taper; and their measured aperture illumination is presented in Fig. 6. We also measure the field-intensity in propagation z-direction, and plot it in Fig. 7. From Fig. 6, a taper aperture illumination is confirmed. More importantly, a constant field area with 200mm wide and up to 1m length suggests the possibility of using taper RLSA for the GATE.

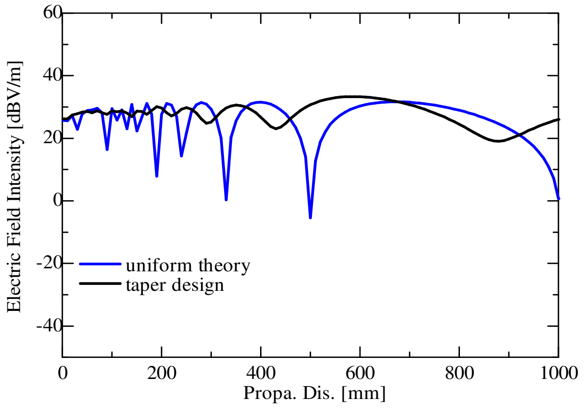


Fig.5. Field intensity along propagation z-direction (predicted at 60GHz)

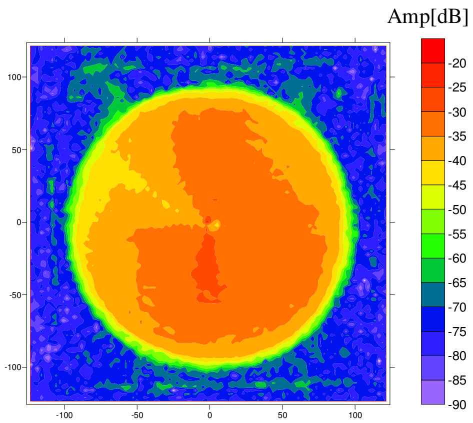


Fig.6. Measured amplitude distributions on 200mm aperture

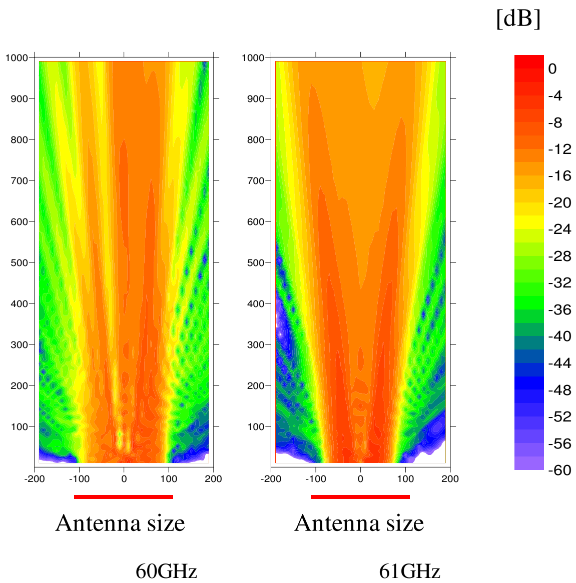


Fig.7. Measured field intensity in propagation z-direction

IV. Conclusions & Future Works

In this paper, we have introduced non-uniform aperture illumination RLSA in order to meet with the requirement of specific applications. Two cases in which non-uniform designs give us better performances than the uniform ones were orderly presented. In case the uses of high loss dielectric materials are indispensable, a proper non-uniform design would produce maximum antenna gain. And in short-range communications, an amplitude taper design is recommended in order to reduce the contribution of the edge's elements, which degrades the transmission quality. These theories were predicted and confirm by experiments. We are now conducting further system evaluations (SNR, BER, ISI, SAR, etc…) to estimate the feasibility of employing RLSA for the GATE.

Acknowledgment

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