A Novel Design of Waveguide Dual Beam Antenna

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***Abstract*—This paper presents new type of waveguide antenna which has a dual beam (rabbit-ear-shaped beam) characteristic. The antenna design is based on the interpretation that guided wave in rectangular waveguide cans be thought of as a superposition of two plane waves bouncing obliquely. The proposed antenna is designed and fabricated at 60 GHz as an example. Measurement results show a wideband matching characteristic as well as good agreements with calculations (or simulations) in angle between two beams, gain and radiation patterns, etc.**

***Index Terms*— Waveguide antenna, Dual beam antenna, Array structure**

I. Introduction

There is a situation where a transmitter transmits its power to two receivers separated in space with angle θ as shown in fig. 1. We can generally choose one of the two choices in this case. The first way is to make the antenna that has a wide beam width to cover two receivers. In this case, however, the power, S/N characteristics get much worse since the beam does not focus on the direction we want. Another way is to make a dual beam by using a power divider and two antennas that is of small beam width and of high gain. Because we have to use two antennas in this time, the system gets more complex and bulky. To make up for the both cases mentioned above, we propose the structure of a waveguide antenna which has a rabbit-ear-shaped pattern. A better communication efficiency can be achieved in the triangular communication environment by using the proposed antenna that has two beams to go to the directions we want. Also it can make the system more compact, since only one antenna is used for system implementation. In this paper we, using two apertures and the properties of guided waves in rectangular waveguide, proposed the novel structure of waveguide dual beam (rabbit-ear-shaped beam) horn antenna. We could obtain stable dual beam radiation patterns by dividing the guided wave in rectangular waveguide into two plane wave components, and by making each wave radiated through two apertures. Simple fabrication was possible because any array structure wasn't used for dual beam.

II. Basic Theory And Design Procedure

It is well known that the dominant guide wave (TE_{10} mode) in the rectangular waveguide is consisted of two plane waves. It is polarized so that the electric vector is vertical, and bouncing between the two side walls of the waveguide at such an angle with the sides that the total electrical field is vanished along the two sides [1]. Two uniform plane wave components of the guided wave are indicated in fig. 1. When the width d is $\lambda/2$, the waves travel exactly back and forth across the guide with no component of propagation in the axial direction.

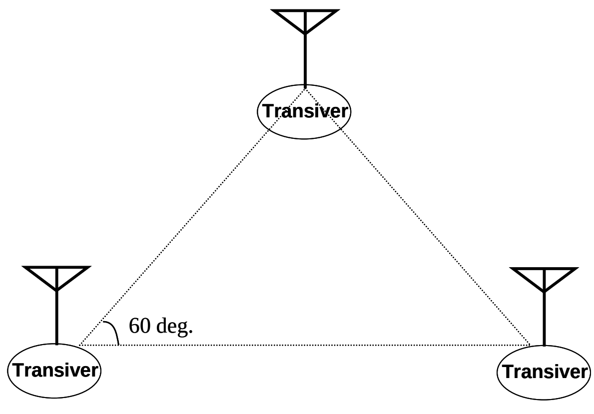


Fig. 1 The situation where the rabbit-ear-shaped beam antenna is useful.

At slightly larger width *d*, there is a small angle θ such that $d = \lambda / 2\cos\theta$, and there is a small propagation in the axial direction. As the width *d* approaches infinity, θ approaches 90 degrees, so that the wave travels down the guide practically as a plane wave in space propagating in the axial direction.

$$\beta d \cos\theta = \pm m\pi$$

$$d = \pm\frac{m\pi}{\beta\cos\theta} = \pm\frac{m\lambda}{2\cos\theta} \quad (\text{m} = 1, 2, 3\ldots) \qquad (1)$$

$$d = \frac{\lambda}{2\cos\theta} \qquad (2)$$

(For dominant mode in rectangular waveguide)

By changing the width of the rectangular waveguide, at fixed frequency, we can control bouncing angle θ of each wave from the equations shown in (1) and (2).

And also, we can obtain the angle φ between two waves bouncing obliquely using bouncing angle as follows.

$$\varphi = 180° - 2\theta$$

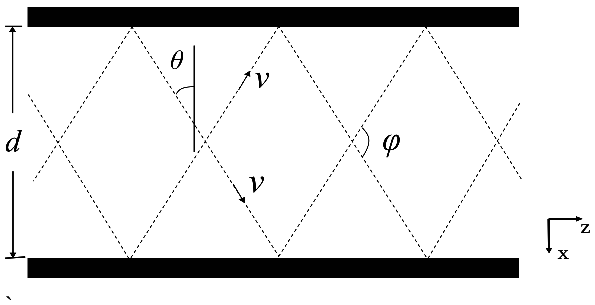


Fig.2 Path of uniform plane-wave component in rectangular waveguide

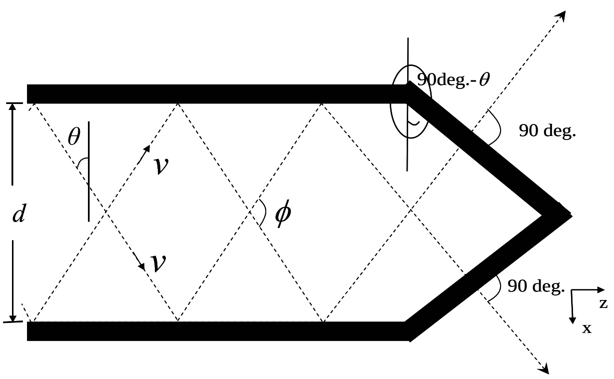


Fig. 3 Rectangular waveguide with aperture

With such a guided characteristic of rectangular waveguide, dual beam characteristic of waveguide antenna could be obtained.

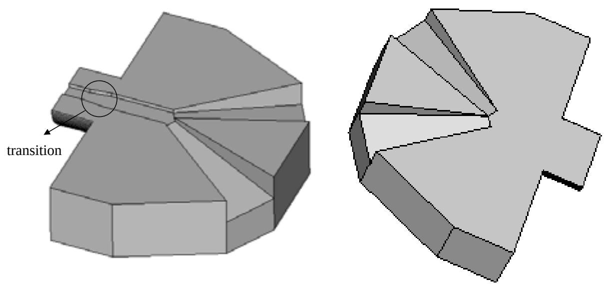
First of all, for obtaining dual beam, make two apertures at the end of waveguide as shown in fig. 2. Then, the guided wave is divided into two waves with the proper angle, which radiates through the two apertures respectively. Here, when the aperture is parallel to the wavefront of each plane wave, we can achieve the optimum gain and matching characteristic of antenna.

The proper angle of the apertures can be calculated through bouncing angle.

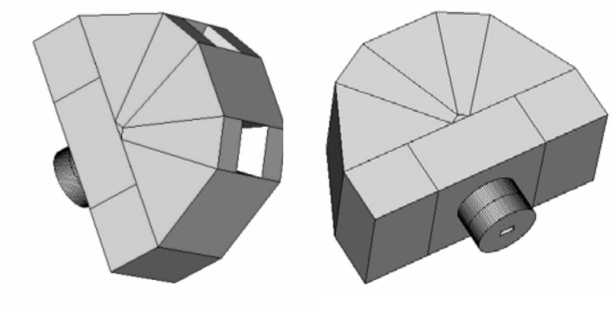
$$(\text{ Slop angle of apertures }) = 90° - \theta$$

III. Fabrications

As an example, we fabricated the waveguide dual beam antenna at 60 GHz, which feed through WR15 and has the angle φ of 60 degrees between two beams. Since the angle between two waves bouncing obliquely is not 60 degrees but about 52 degrees at WR-15, we used a taper transition that has wider width than that of WR15.



(a)



(b)

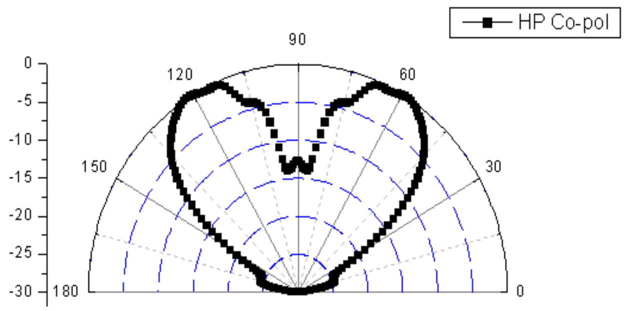
Fig.4 The structure of dual beam waveguide antenna
(a) Parallel slice model of antenna with tapered transition
(b) The fabricated waveguide dual beam antenna

To evaluate the insertion loss by transition part, we used the commercial field simulator MWS (MicroWave Studio). With a minor tuning, final dimension of transition part could be obtained easily. In the simulation, reflections due to transition were very low over wide frequency range. Through the taper transition of the proper angle, we could obtain the wanted angle between two waves bouncing obliquely without insertion loss. The width of the rectangular waveguide after taper transition is 5 mm. Fig. 3 shows the fabricated antenna.

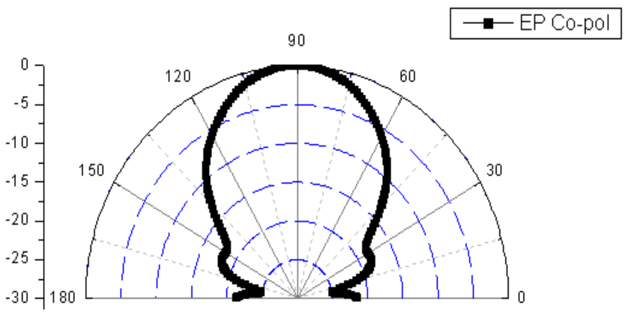
And, when the aperture is inclined at 30 degrees, it becomes parallel to the wavefront of each divided plane wave and we can obtain the optimum gain and matching characteristic of the antenna.

IV. MEASUREMENT

Performances of the proposed waveguide dual beam antenna were confirmed through the simulation and the measurement results. To see the relation between the slope angle of aperture and traveling direction of wave, we measured the antenna, which has the angle of 60 degrees between two beams at 60 GHz, at slightly different frequencies of 58 GHz, 60 GHz and 62 GHz. Fig. 5 and 6 show the radiation patterns at 58 GHz, 60 GHz and 62 GHz



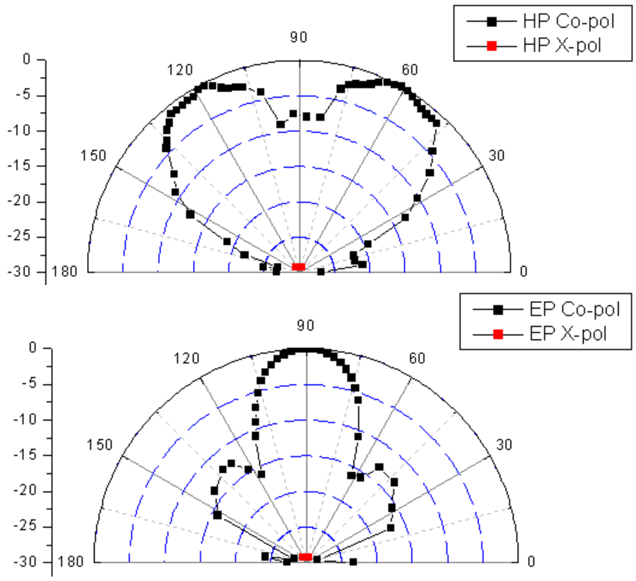
(a)



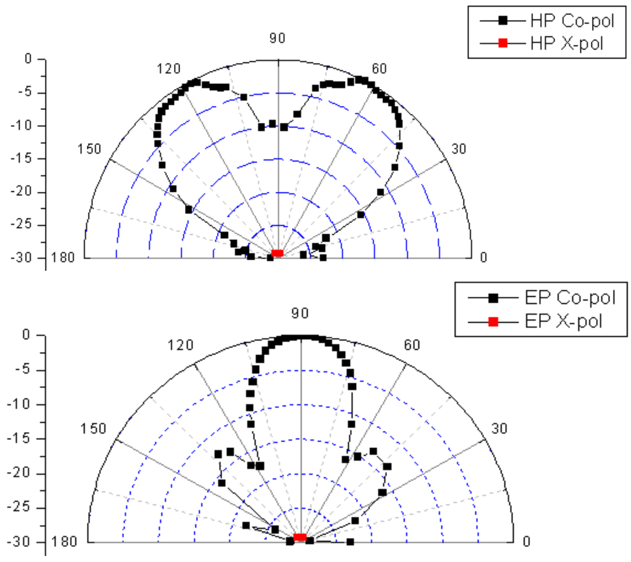
(b)

Fig.5. Simulated characteristics of the antenna at 60 GHz
(a) *H*-plane (b) *E*-plane

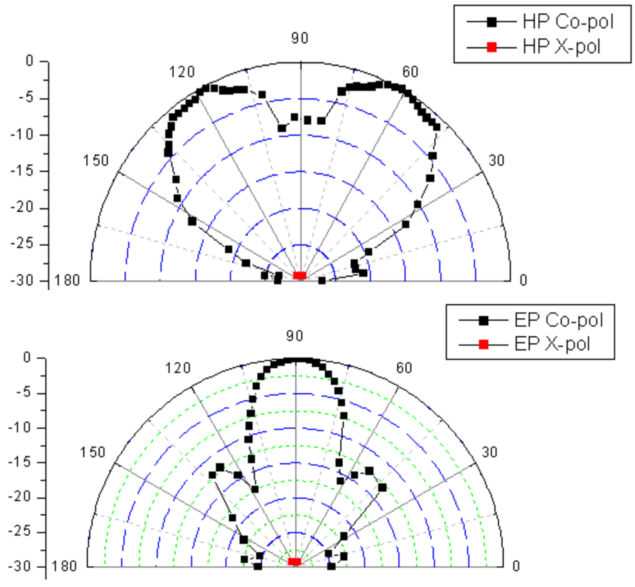
respectively. Measured gains at 58 GHz, 60 GHz and 62 GHz are 13.5 dBi, 15 dBi, and 13.3 dBi, respectively and radiation patterns shows dual beam with 60 degrees in *H*-plane, as expected. 3 dB beam widths of each beam in *H*-plane at 58 GHz, 60 GHz, and 62 GHz are about 30 degrees, 28degrees and 27degrees, respectively. And side lope level between two beams is 7.8 dB at 58 GHz, 9.7 dB at 60 GHz and 10.5 dB at 62 GHz. As shown in results, we can obtain the maximum gain of the antenna at 60 GHz, where the aperture is exactly parallel to the wavefront of each plane wave.



(a)



(b)



(C)

Fig. 6. Measured radiation pattern of the antenna
(a) 58 GHz (Gain: 13.5 dBi) (b) 60 GHz (Gain: 15 dBi)
(c) 62 GHz (Gain: 13.3 dBi)

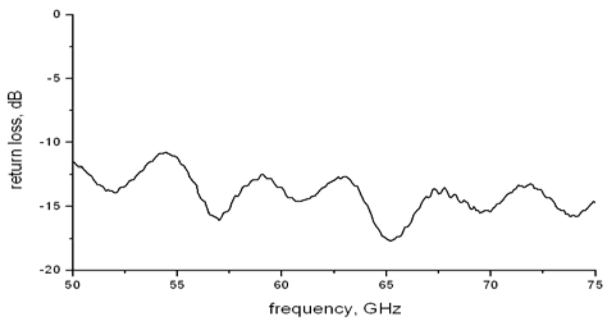


Fig. 7. Measured matching characteristic at 60 GHz.

Furthermore, by flaring properly the aperture like the pyramidal horn aperture, we could control the gain of the proposed antenna. In this paper, a gain of about 15 dB is achieved. Fig. 7 shows the good matching characteristic of proposed antenna compared to the conventional waveguide horn antenna [2].

V. CONCLUSION

A novel structure of waveguide antenna with dual beam has been introduced. The proposed waveguide dual beam antenna could be fabricated simply because any array structures don't be used to make dual beam. By changing the width of the feeding waveguide through a taper transition and the angle of the aperture, we could control the angle between two beams. And also, the area of the aperture could control a gain of the antenna. Measurement results of fabricated waveguide dual beam antenna show the validity of the basic theory and design procedure of our proposed antenna.

ACKNOWLEDGMENT

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