A Unidirectional Beam Antenna using a Probe Excited Circular Ring near the Reflector

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Abstract

This paper proposes a unidirectional beam antenna using a probe excited circular ring near the reflector. The antenna structure is simple. The radiation characteristics of the antenna for various spacing between a probe excited circular ring and the reflector are analyzed. These characteristics are also compared with the conventional single aperture near the reflector. It is found that the proposed structure yields better characteristics than the conventional structure. The numerical results of the radiation pattern, elevational beam peak, beamwidth, and maximum directivity are investigated. The result of the analysis is very useful to design the antenna of the high directivity with unidirectional beam.

1. Introduction

The point to point communications have extensively and continuously received an attention for several decades. The antenna that can useful for the point to point communication is the antenna radiating unidirectional beam pattern. There have been the developments of these antenna types in literature [1]. The unidirectional beam antenna can be achieved by using some types of antenna structures such as microstrip antenna operating at fundamental mode [2], horn antenna [3], reflector antenna [4] and many others. In addition, the unidirectional beam can be obtained by using some specific antenna that is arranged to form the array configuration [5]-[6]. One alternative way is carried out by placing the antenna near the reflector or the ground plane [7]. However, each antenna belongs to its own advantage and disadvantage. This paper proposes to accomplish the unidirectional beam by using the probe excited circular ring near the reflector. The structure is simple and easy to fabricate. In addition, since there is no dielectric component, it has low loss. The antenna can be made using low cost material that is easy to find in the market. This structure expects to possess cost effective [8]. The radiation characteristics of this proposed structure are compared with the conventional single aperture near the reflector. It is evident that the probe excited circular ring near the reflector yields the better characteristics. The radiation characteristics such as the radiation pattern, elevational beam peak, beamwidth, and maximum directivity are examined. The optimum spacing between the probe excited circular ring and the reflector that provides the maximum directivity is clarified. The result of the analysis is very useful for designing the high directivity unidirectional beam antenna.

2. A Unidirectional Beam Antenna using a Circular Aperture near the Reflector

The structure of a circular aperture near the reflector is made up from the single aperture of which a part of circular waveguide. The electromagnetic fields radiated from this aperture are derived from the Fourier transform of the fields propagated inside the circular waveguide. The radius of the ring is reasonably chosen to perform the dominant mode propagation inside the circular waveguide. The radiation pattern of this antenna is appeared to be the unidirectional beam. It is found that the radiation characteristics of this single aperture without the reflector of the radius 0.3019λ are that the HPBW in E-plane and H-plane are $116°$ and $76°$ respectively. The maximum directivity is 6.89 dBi. Furthermore, the directivity can be further increased by placing this structure near the reflector. Fig.1 shows the antenna geometry. The single aperture of the radius a placing near the reflector of the radius r_g at the spacing of h. The spacing between the single aperture and the reflector should be optimized. The direction of the unidirectional beam is toward the z axis. The radiation characteristics of this structure will be described in section 4.

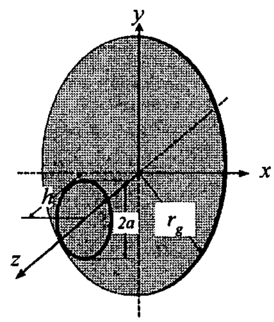

Fig.1 A unidirectional beam antenna using a circular aperture near the reflector

3. A Unidirectional Beam Antenna using a Probe Excited Circular Ring near the Reflector

For a unidirectional beam antenna using a probe excited circular ring near the reflector, the geometry is composed of the probe of the length l aligned in y direction and it is protruded inside the circular ring of the radius a and the width d. The optimum value of the probe length, ring radius and ring width are 0.25λ, 0.3019λ and 0.154λ, respectively, This structure radiates the bidirectional beam with the HPBW in E-plane and H-plane of *70.5* and *59.6* degrees, respectively. The maximum directivity is *6.82* dBi. In the similar fashion, the unidirectional beam can be made up by placing the probe excited circular ring near the reflector at the spacing of h as shown in Fig.2. The comparison between the characteristics of the single aperture near the reflector and the probe excited circular ring (two apertures) near the reflector are given the next section.

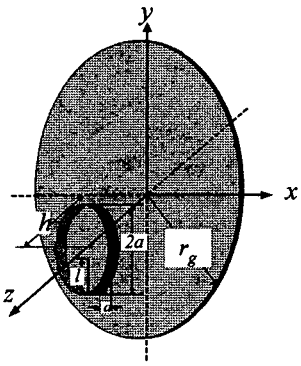

Fig.2 A unidirectional beam antenna using a probe excited circular ring near the reflector

4. Radiation Characteristics

The radiation characteristics such as radiation pattern, elevational beam peak, beamwidth and maximum directivity are illustrated in this section.

4.1 Radiation pattern

Radiation pattern of single aperture near the reflector and a probe excited circular ring near the reflector (two apertures) in both E-plane and H-plane is revealed in this section.

4.1.1 Single aperture near the reflector

Fig.3 and Fig.4 show the radiation pattern of single aperture near the reflector for various spacing h in E-plane and H-plane, respectively. It is found that the unidirectional beam is obtained when the spacing is not greater than 0.3λ. The Unidirectional beam with the side lobes is realiged at the spacing of 0.7λ. The smaller the spacing the narrower the beamwidth. The beam is split when the spacing is larger than 0.3λ. The radiation characteristics for other spacing are disclosed in the subsequent section.

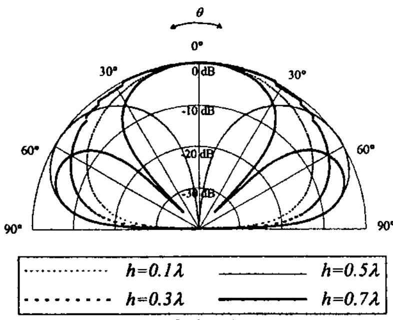

Fig.3 Radiation pattern of single aperture near reflector (E-plane)

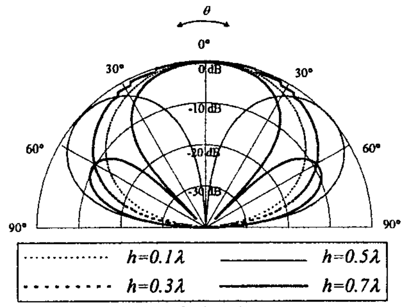

Fig.4 Radiation pattern of single aperture near reflector (H-plane)

4.1.2 Two apertures near the reflector

The radiation pattern for different spacing of two apertures near the reflector in E-plane and H-plane are depicted in Fig.5 and Fig.6, respectively. It is obvious that the unidirectional beam can be realized when the spacing is not larger than 0.3λ and equal to 0.7λ. The beam is also split for the spacing larger than 0.3λ except for 0.7λ.

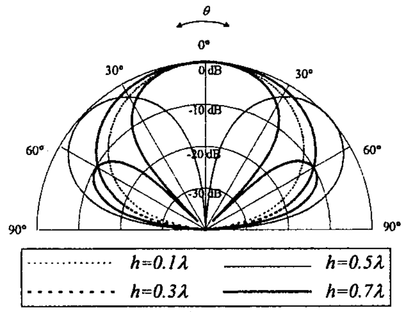

Fig.5 Radiation pattern of two apertures near reflector (E-plane)

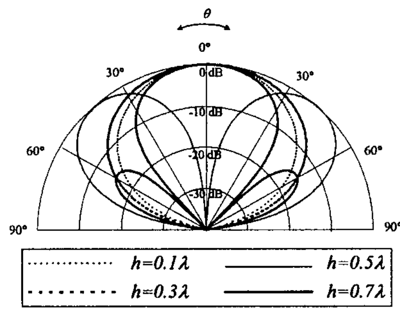

Fig.6 Radiation pattern of two apertures near reflector (H-plane)

4.2 Elevational beam peak

The unidirectional beam in boresight axis occurs when the elevational beam peak is $0°$. So, the elevational beam peak greater than $0°$ is not the unidirectional beam. Fig.7 and Fig.8 show the elevational beam peak of single aperture near the reflector and two apertures near the reflector as a function of the spacing. Notified that the unidirectional beam can be realized when the elevational beam peak both E-plane and H-plane directs toward z-axis. It is found that the unidirectional beam is achieved only some specific spacing. The two apertures near the reflector can provide the unidirectional beam when the spacing is 0.1λ to 0.3λ and 0.6λ to 0.8λ. However, the single aperture near the reflector will give the unidirectional beam only for $0.1 \leq h \leq 0.3$ and $h = 0.7\lambda$. The result of this investigation is very important in the further antenna design.

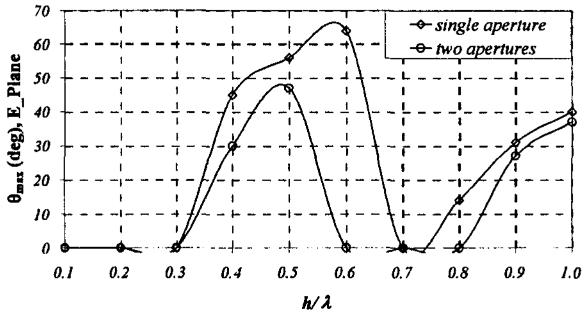

Fig.7 Elevational beam peak (E-plane)

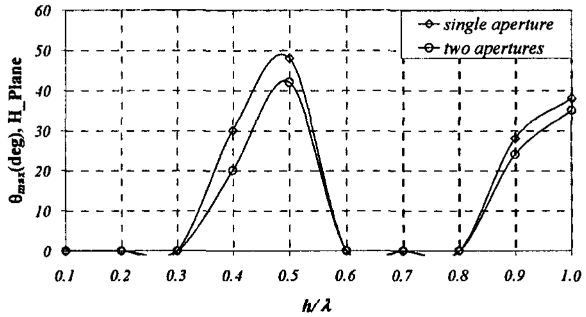

Fig.8 Elevational beam peak (H-plane)

4.3 Beamwidth

4.3.1 Half power beamwidth

Half power beamwidth is an important parameter to evaluate the merit of the antenna [9]. It is desirable for the antenna to posses the narrow beamwidth. Fig.9 and Fig.10 illustrate the half power beamwidth of the antenna against the spacing in E-plane and H-plane. It is evident that the two apertures near the reflector have narrower beamwidth than the single aperture near the reflector. However, the same trends of the variation of half power beamwidth can be inspected for both structures viz., the antenna beam will be wider as the increment of the spacing until maximum at the spacing of 0.4λ. Then, the beamwidth will be smaller when the spacing is increased from 0.4λ to 0.5λ. Subsequently, the beamwidth will be increased until maximum at h equal 0.8λ or 0.9λ and decreased again. From the comparison, the single aperture near the reflector exhibits wider beamwidth in both E-plane and H-plane than the two apertures near the reflector. These results should be taken into account for the design aspects.

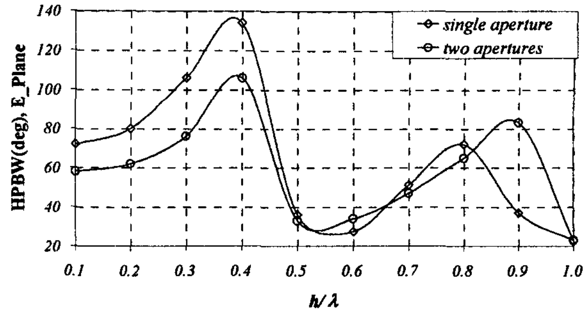

Fig.9 Half power beamwidth (E-plane)

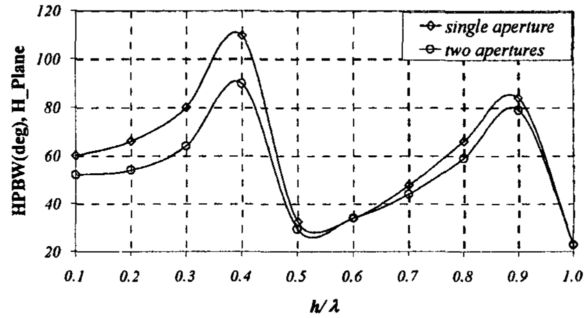

Fig.10 Half power beamwidth (H-plane)

4.3.2 First null beamwidth

Fig.11 and Fig.12 illustrate the first null beamwidth in E-plane and H-plane, respectively. The first null beamwidth will not be changed as the spacing for the spacing less than 0.3λ. For the spacing greater than 0.3λ, the first null beamwidth has the same trend as the half power beamwidth. We found that both single aperture and two apertures near the reflector have almost identical first null beamwidth. In the viewpoint of the first null beamwidth, there is no distinction between the single aperture near the reflector and the two apertures near the reflector.

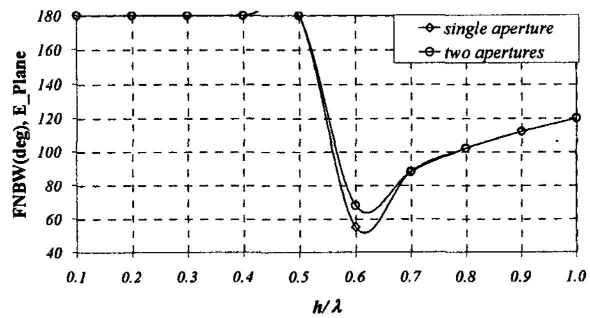

Fig.11 First null beamwidth (E-plane)

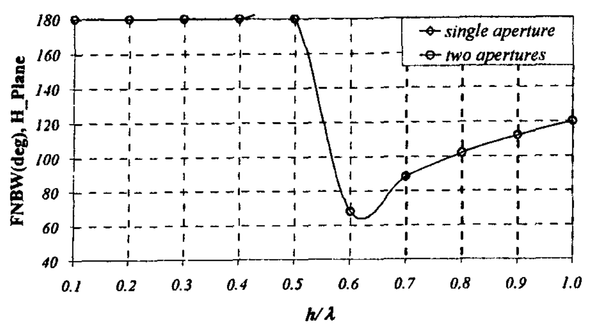

Fig.12 First null beamwidth (H-plane)

4.4 Directivity

Ultimately, the directivity of the antenna is shown in Fig.13. It is apparent that the directivity of the two apertures near the reflector is higher than the single aperture near the reflector about *1-3* dB for any spacing. The maximum directivity is achieved when the spacing is 0.7λ. At that spacing, the single aperture near the reflector provides *9.9* dBi whereas the two apertures near the reflector gives *12.8* dBi directivity. Accordingly, we can summarize that the optimum spacing of both single aperture and two apertures near the reflector is 0.7λ because the unidirectional beam with the maximum directivity is obtained.

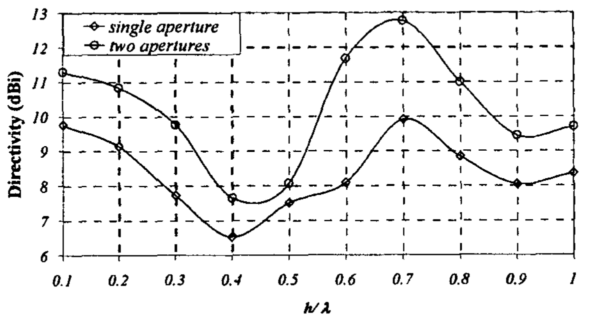

Fig.13 Directivity

5. Discussions and Conclusions

A unidirectional beam antenna using a probe excited circular ring near the reflector is proposed in this paper. The radiation characteristics are comparatively studied with the conventional single aperture near the reflector. It is found that the probe excited circular ring near the reflector provides higher directivity about 1-3 dB than the single aperture near the reflector for any spacing between the antenna and the reflector. The optimum spacing that accomplish the maximum directivity for both antennas are 0.7λ. The result of the analysis is very useful for the design of the high directivity unidirectional beam antenna.

References

[1]R.C.Johnson and H.Jasik, *Antenna Engineering Handbook*, McGraw-Hill, New York, 1984.

[2]J.R.James and P.S.Hall, *Handbook of Microstrip Antennas*, vol.1-3, Peter Peregrinus, 1989.

[3]C.A.Balanis, "Horn Antennas," Chapter 8 in *Antenna Handbook: Theory, Applications and Design* (Y.T.Lo and S.W.Lee, eds.), Van Nostrand Reinhold Co., New York, 1988.

[4]A.W.Love (ed.), *Reflector Antennas*, IEEE Press, New York, 1978.

[5]W.H.Kummer, "Basic Array Theory," *Proc.IEEE*, vol.80, no.1, pp.127-140, Jan.1992.

[6]R.Tang and R.W.Burns, "Array Technology," *Proc.IEEE*, vol.80, no.1, pp.173-182, Jan.1992.

[7]C.A.Balanis, "Analysis of an Array of Line Sources above a Finite Size Ground Plane," *IEEE Trans.Antennas Propagat.*, vol.19, no.2, pp.181-185, Mar. 1981.

[8] S.Kosulvit, M.Krairiksh, C.Phongcharoenpanich, and T.Wakabayashi, "A Simple and Cost-Effective Bidirectional Antenna Using a Probe Excited Circular Ring," *IEICE Trans. Electronics*: vol. E84-C, no.4, pp.443-450, Apr. 2001.

[9]C.A. Balanis, "Antenna Theory Analysis and Design," *John Wiley & Sons*, 1997.