Planar Array of a Probe Excited Circular Ring Radiating Bidirectional Pattern

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Abstract

This paper reports the characteristics of a bidirectional antenna by using a planar array of a probe excited circular ring. The element of a bidirectional antenna is first designed to achieve the maximum directivity. The directivity can be further increased by arranging these elements to form the linear array. There are two types of linear array to be investigated i.e., on axis and off axis arrangement. On-axis linear array yields better directivity than off-axis linear array. Therefore, this orientation is further used to form the planar array. The radiation characteristics of this optimum planar array are rigorously reported. The proposed structure is very useful to extend the distance between the base station in PCT system.

1. Introduction

Nowadays, cellular mobile system becomes a vital role in daily life essence [1]. Therefore, the investigations of the mobile antenna at the base station are of interest. Conventionally, the omnidirectional antenna is employed to cover the approximated circle area. To increase the zone size for applying to the long and narrow path service area such as the highway, the tunnel, and the corridor; the bidirectional antenna is installed in place of the omnidirectional ones. The conventional bidirectional antennas are made up by combining two unidirectional antennas such as Yagi pointed in opposite directions or the omnidirectional antenna such as monopoles excited by appropriate phase [2]. The antenna constructed by this technique suffers from feeder loss and complicated structure that results in expensiveness. Thus, researches and developments on bidirectional antenna have been continuously conducted. The bidirectional narrow patch antenna (BNPA), which has narrow patches on both sides of a narrow dielectric substrate fed by a parallel stripline is easily fabricated by printing patches and feeding network on a substrate. However, BNPA has low radiation efficiency. The radiation efficiency can be improved by adding two opposing parasitic patches to a BNPA to form the so-called BNPA-P [3]. It was found that gain is higher than a collinear antenna of the same length. For a wide street about the width ranging from *30* to *60* meters, a BNPA element is developed to be a bidirectional rod antenna (BIRA) that possesses an optimum beam shape [4]. Furthermore, a bidirectional antenna using two notch antennas cut in a sheet of conductor above a ground plane was proposed to extend the coverage of a relay station in booster system inside tunnel [5]. To suppress the cross polarization in the H-plane of this notch antenna, the crank shaped antenna modified from the original notch antenna was proposed [6]. It was found that the radiation patterns of these antennas are tilted up from the mounting wall and they should be tilted downward in order to cover the service area. This was accomplished by using the crank shaped antenna with the parasitic elements for gain enhancement [7]. From these aforementioned literatures, it is evident that development of a bidirectional antenna that has suitable characteristics for a particular application is desired. Moreover, cost effective must be considered since the number of cell is very large. Therefore, a bidirectional antenna using a linear probe excited a circular ring [8] was proposed. It was pointed out that a moderate gain bidirectional antenna [9] could be easily realized with a very cost effective. Moreover, the directivity can be increased by forming an array of a probe excited circular ring.

This paper reports the directivity enhancement of a bidirectional antenna using a planar array of a probe excited circular ring. The radiation characteristics such as radiation pattern, half power beamwidth, first side lobe ratio, angle of the first side lobe, number of minor lobes and maximum directivity are substantially examined.

2. An Element of a Probe Excited Circular Ring

The structure of a bidirectional antenna using an element of a probe excited circular ring consists of a linear electric probe of length l aligned along the y axis, and this probe is surrounded by a circular ring of the radius a. At the two ends of the ring, there are circular apertures on the planes $z = -d/2$ and $z = d/2$, respectively, as shown in Fig.1.

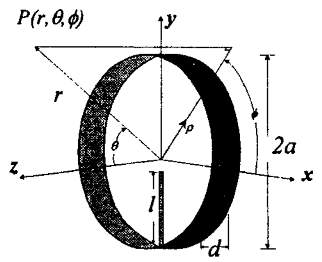
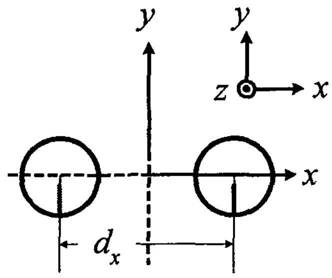


Fig.1 A bidirectional antenna using a probe excited circular ring

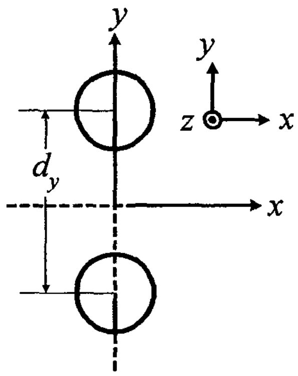
From the investigation [10], it is found that the optimum ring radius and width are 0.3019λ and 0.154λ for the operating frequency of *1.9065* GHz. These parameters are used as the design parameters for a single element of a bidirectional antenna using a probe excited circular ring. It is evident that the directivity of an element is *6.82* dBi with the half power beamwidth in E-plane and H-plane of *70.5* and *59.6* degrees, respectively. There is no side lobe in case of using single element of a probe excited circular ring.

3. A Linear Array of a Probe Excited Circular Ring

To enhance the directivity of a bidirectional antenna using a probe excited circular ring the linear array arrangement is an alternative choice to accomplish the higher directivity. There are two configurations of linear array to orient the array element i.e., on axis orientation and off axis orientation. The antenna elements are aligned on *x* axis, *y* axis and *z* axis for on-axis arrangement as shown in Fig.2. For the off-axis arrangement, the elements will be located on *xy* plane for different azimuth angle (ϕ_{xy}) as illustrated in Fig.3. Fig.4 shows the directivity comparison between on-axis and off-axis linear array. It is evident that the on axis linear array achieves higher directivity. Therefore, this arrangement is used to form the planar array configuration in the next section.



(a) *x axis*



(b) *y axis*

Fig.2 On axis linear array antenna configuration

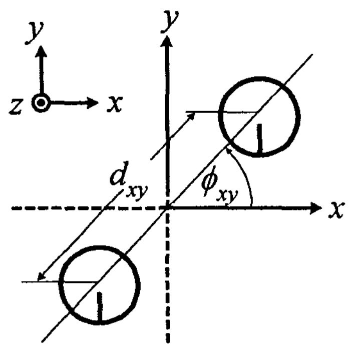


Fig.3 Off axis linear array antenna configuration

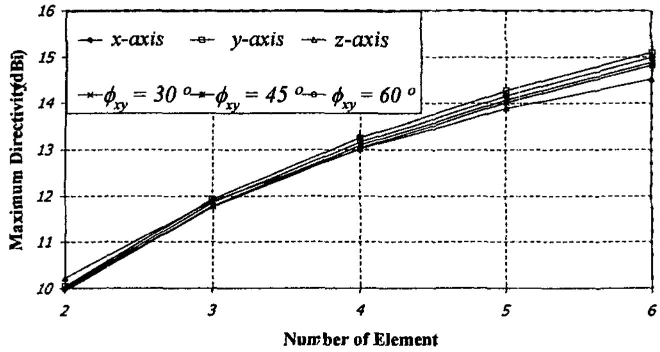


Fig.4 Directivity of linear array

4. A Planar Array of a Probe Excited Circular Ring

A planar array of a probe excited circular ring is constructed from two-dimensional linear array of on axis in x and y direction to yield the maximum directivity. The structure of the planar array is illustrated in Fig.5. It is apparent that the optimum spacing in x and y directions are 1.15λ and λ, respectively. This parameter is used as the guideline for the antenna design. The numerical results of this antenna will be reported in the next section.

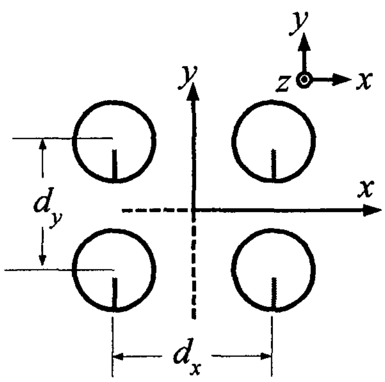


Fig.5 Planar array antenna configuration

5. Numerical Results

The numerical results of the radiation characteristics such as radiation pattern, half power beamwidth, side lobe ratio, angle of the first side lobe, number of minor lobes and maximum directivity are reported.

5.1 Radiation pattern

Fig.6 illustrates the three-dimensional radiation pattern of the optimum planar array. It can be seen that the bidirectional pattern in E-plane and H-plane is obtained. This graph confirms that the bidirectional antenna could be properly achieved from the planar array configuration. The two-dimensional radiation patterns in each plane are also shown in the same figure.

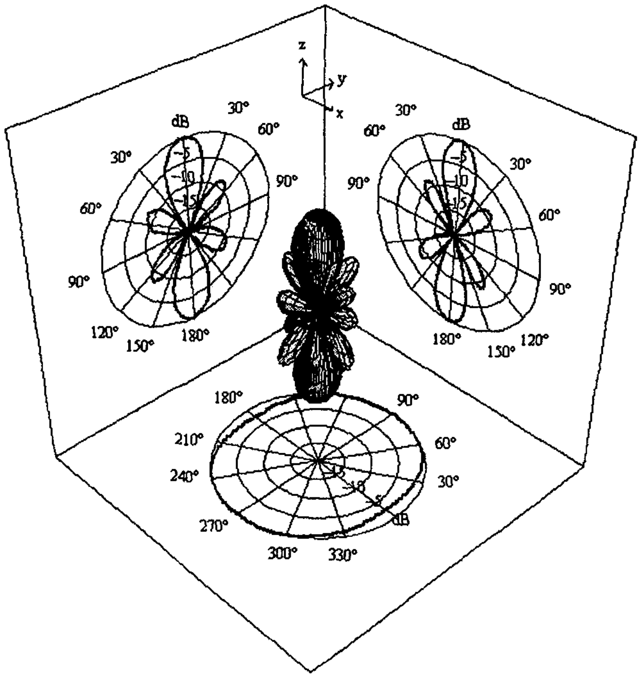


Fig.6 Three dimensional pattern

5.2 Half power beamwidth

Half power beamwidth of the antenna in E-plane and H-plane are displayed in Fig.7 and Fig.8, respectively. It is obvious that the beamwidth in E-plane and H-plane for any element have the same trends. The desired narrower beamwidth can be carried out when the number of elements is increased.

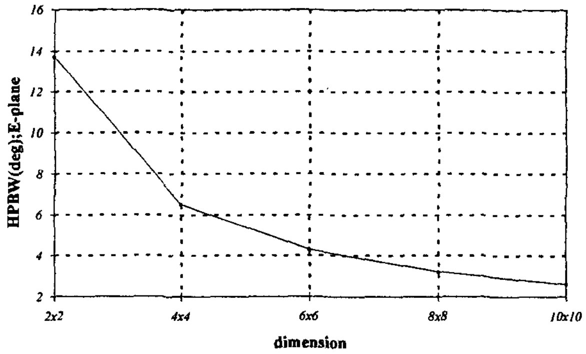


Fig.7 Half power beamwidth in E-plane

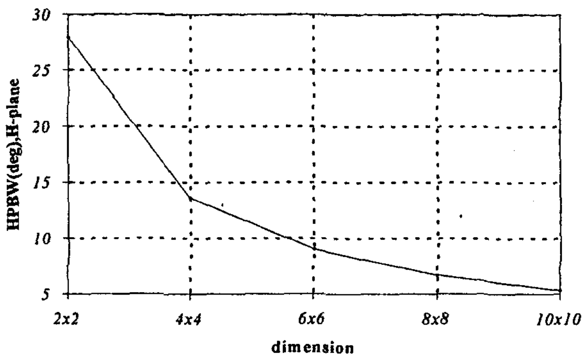


Fig.8 Half power beamwidth in H-plane

5.3 First side lobe ratio

The first side lobe ratio in E-plane and H-plane are shown in Fig.9 and Fig.10, respectively. It is seen that when the number of element is *2x2*, the very small side lobe ratio is observed. However, the better side lobe ratio is achieved for the number of element larger than *4x4* numbers of elements.

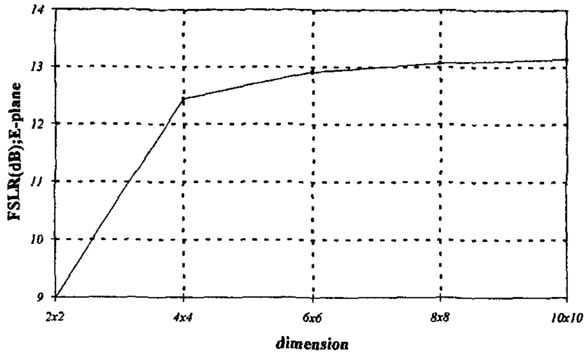


Fig.9 First side lobe ratio in E-plane

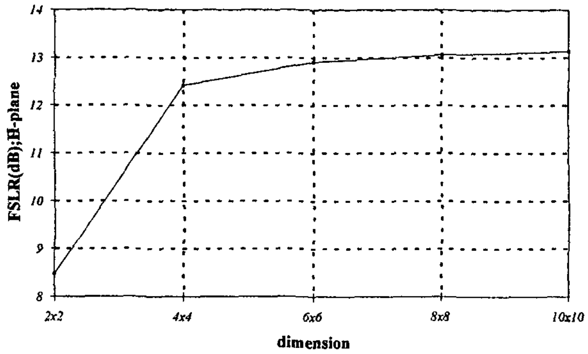


Fig.10 First side lobe ratio in H-plane

5.4 Angle of the first side lobe

The angle of the first side lobe is the characteristic that expresses the location of the first minor lobe. The parameters that influences to the angle of the first side lobe is the beamwidth and the number of minor lobes. Fig.11 and Fig.12 show the angle of the first side lobe versus the number of the elements of the planar array. It can be found that the same trend has been observed both E-plane and H-plane. The larger the number of elements the smaller the angle of the first side lobe. Accordingly, this characteristic should be prescribed in the antenna design.

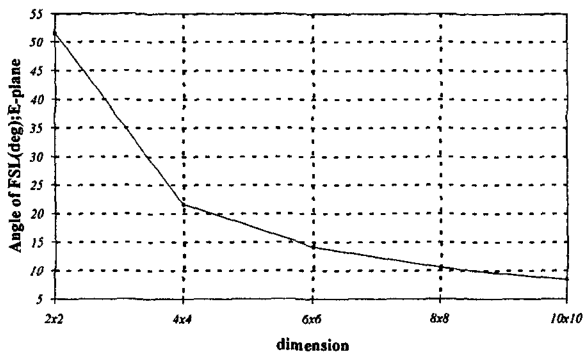


Fig.11 Angle of the first side lobe in E-plane

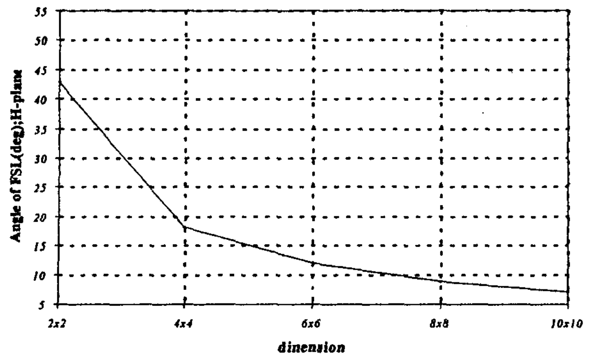


Fig.12 Angle of the first side lobe in H-plane

5.5 Number of minor lobes

In the communication, it is desirable to minimize the number of the minor lobes because the noise or interference will enter to them. However, the behavior of the antenna when the beamwidth is narrower, the number of the minor lobes will be increased. Fig. 13 and Fig. 14 depict the number of minor lobes in both E-plane and H-plane for various numbers of elements. As expected from the information of the beamwidth, the number of minor lobes will increase as the number of elements.

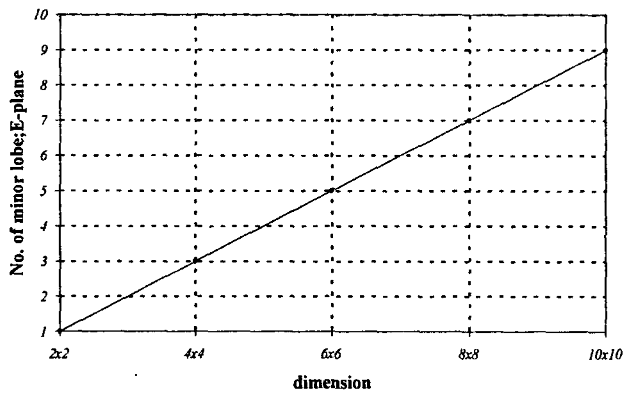


Fig.13 Number of minor lobes in E-plane

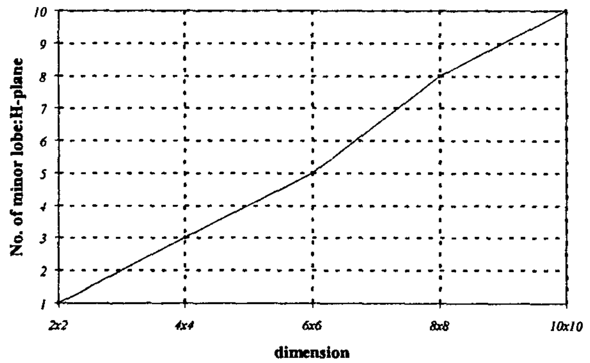


Fig.14 Number of minor lobes in H-plane

5.6 Maximum directivity

Fig.15 shows the maximum directivity as a function of the number of elements. It is summarized that the directivity can be enhanced by increasing the number of elements. The maximum directivity of *27.5* dBi is observed when the number of element is *10x10*.

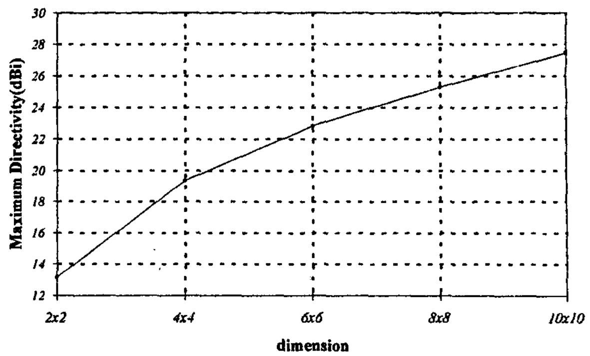


Fig.15 Maximum directivity

6. Discussions and Conclusions

Planar array of a probe excited circular ring is investigated. The optimum single element is first characterized to carry out the maximum directivity. Subsequently, various linear arrays with on axis and off axis arrangement are comparatively analyzed. It is found that the on axis arrangement are optimized chosen to perform highest directivity. The planar array is consequently constructed by using on axis arrangement. The numerical results express that when the number of elements is increased, the directivity will be higher, the number of side lobe become larger and the beamwidth is narrower.

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