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A Circularly Polarized Unidirectional Antenna Using a Bent Probe Excited Circular Ring above Cylindrical Reflector

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1. Introduction

For modern wireless communications, the antenna plays a vital role as the key devices for transmitting and receiving the signal between communication sides. Generally, it is desirable for the antenna to possess the high gain, low side lobe level and narrow beamwidth. Thus, many researches about developments of these antennas are published in literature [1]. The unidirectional beam is obtained by using microstrip antenna with fundamental mode [2], horn antenna [3], reflector antenna [4] and many others. Moreover, the unidirectional antenna is obtained by using some specific antenna that is arranged to form the array configuration [5]-[6]. In addition, the unidirectional beam antenna that provides the circular polarization is interesting to improve the signal quality from polarization change. The circular ring antenna with the unidirectional beam and circular polarization is of interest. Previously, the probe excited circular ring is designed to radiate the bidirectional pattern [7]. To realize the unidirectional pattern with linear polarization, the reflector should be placed near one side of the ring aperture [8]-[9]. Moreover, to improve the directivity and reduce the back lobe this paper proposed a circularly polarized unidirectional antenna using a bent probe excited circular ring above cylindrical reflector. The inner circular ring uses the stub for impedance matching and the probe is also shielded by dielectric rod. At the end of probe, it was bent for identical magnitude with quadrature phase excitation for circularly polarized radiation. This antenna also provides the high gain, low side lobe and narrow beamwidth.

2. Principle of Antenna

The structure of circular ring antenna excited by a probe above the cylindrical reflector consists of a linear electric probe of the length *l* aligned along the *y* axis as shown in Fig.1. At the end of probe, it was bent with the length *g* aligned along the *x* axis. The distance between the probe and the reflector is *h*. The probe is surrounded by the circular ring of an inner radius *a* and length *t*. The radius and length of the cylindrical reflector is *b* and *d*, respectively. It is noted that the probe is shielded by dielectric rod of the height *e*. The stub of the length *s* is aligned along the *x* axis. The antenna structures both model and prototype are depicted in Fig.1.

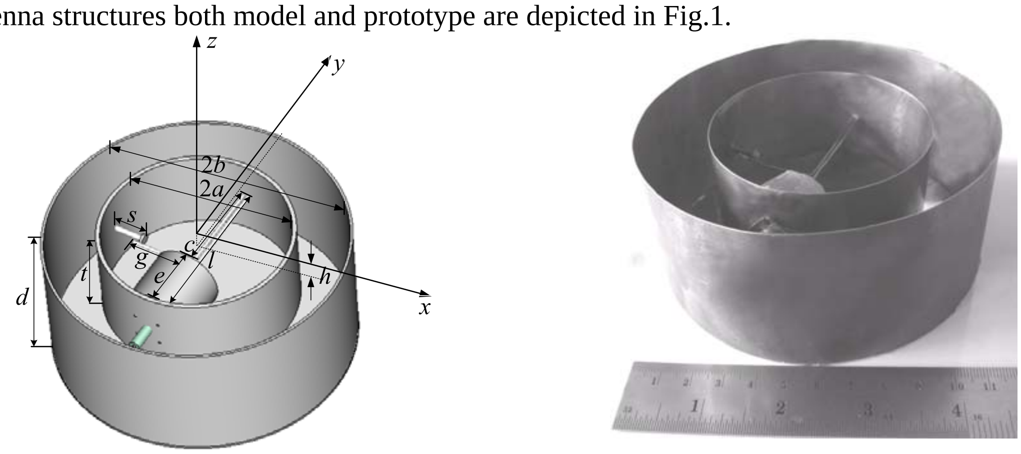


Fig.1 Antenna Structure

In order to design the antenna, the inner ring radius is first chosen to operate at the desired frequency. In this paper, the desired operating frequency is 2.45 GHz. The inner ring radius is 0.29λ or 36 mm. The other initial parameters used in this paper are tabulated in Table 1.

Table 1 Antenna Parameters

Parameters	Electrical Size	Physical Size (mm)
a	0.29λ	36
b	0.45λ	56
l	0.69λ	85
c	0.33λ	41
g	0.21λ	26
h	0.27λ	34.
t	0.28λ	35
d	0.40λ	49
e	0.13λ	17
s	0.10λ	13
ε_r	10	10
Probe Location	$\rho = a$, $\phi = 90°$, $z = 0$	

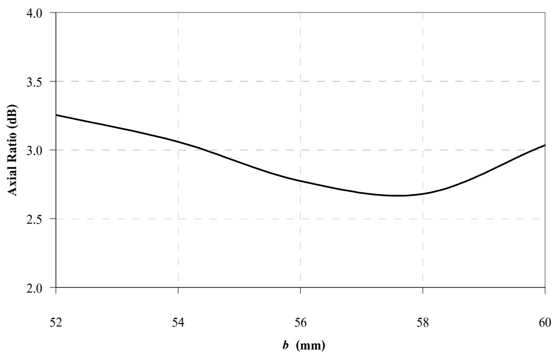


Fig.2 Axial ratio versus radius of cylindrical reflector

3. Antenna Characteristics

In order to accomplish the circular polarization, the antenna parameters are varied to minimize the axial ratio. The varied parameters are the radius of cylindrical reflector (*b*), the length of cylindrical reflector (*d*), distance between the probe and the reflector (*h*), probe length (*g*) and stub length (*s*). From the result in Fig.2, it is obvious that *b* = 58 mm is suitable for cylindrical reflector radius because the axial ratio is equal to 2.68 dB that is better than acceptable level of 3 dB.

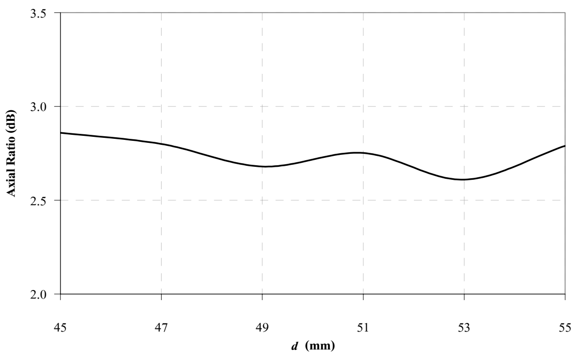


Fig.3 Axial ratio versus length of cylindrical reflector

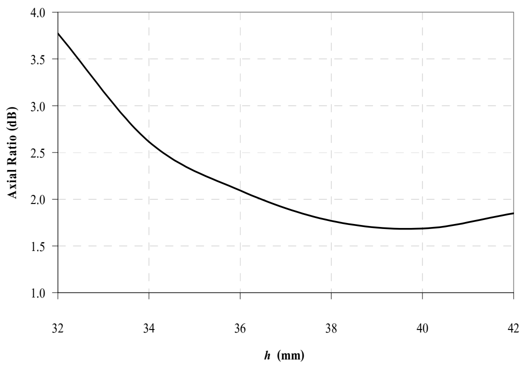


Fig.4 Axial ratio versus distance between probe and reflector

Fig.3 shows the axial ratio for various cylindrical reflector lengths. It is found the length of cylindrical reflector length (*d*) of 53 mm is appropriate because the axial ratio is reduced to 2.61 dB. The axial ratio can be further improved by varying the distance between the probe and the reflector (*h*) as shown in Fig.4. The chosen distance between the probe and the reflector is 40 mm to yield the axial ratio of 1.68 dB.

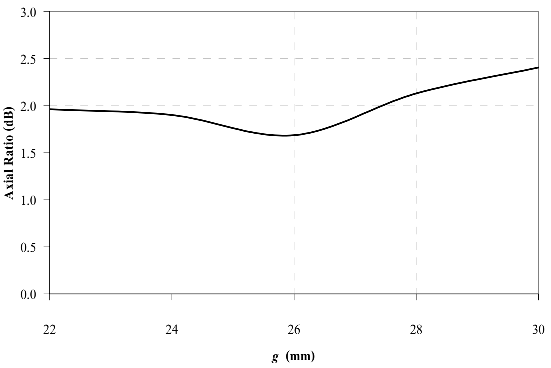


Fig.5 Axial ratio versus probe length

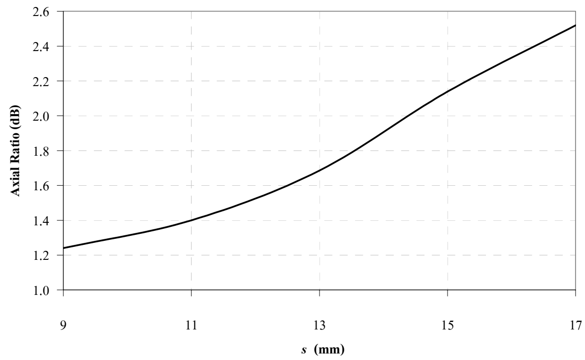
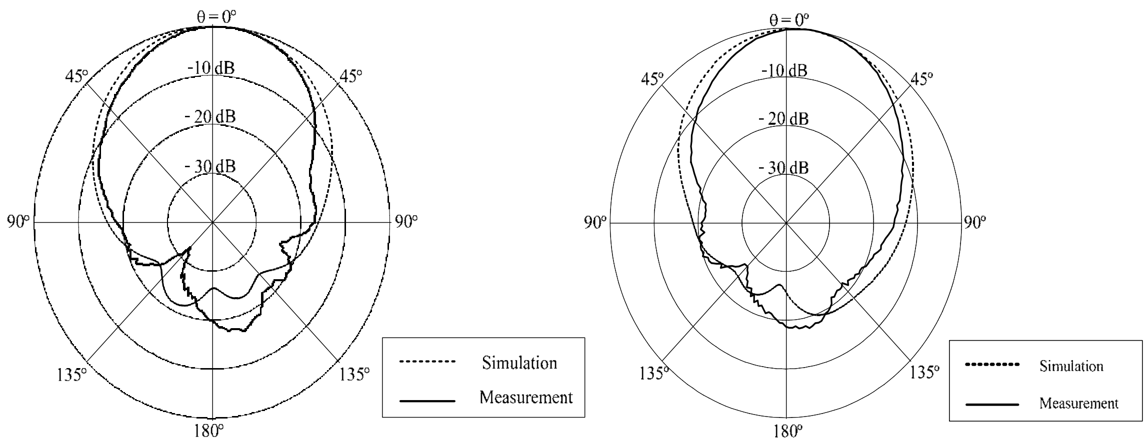


Fig.6 Axial ratio versus stub length

The probe length and stub length are also varied as shown in Fig.5 and Fig.6. However, the axial ratio cannot be further reduced. The probe length and stub length affected the impedance matching. Finally, the probe length (*g*) is 0.21λ or 26 mm, and stub length (*s*) is 0.10λ or 13 mm are used to achieve the optimum matching condition.

4. Simulated and Measured Results

The experiment is performed to confirm the theoretical principle. The prototype antenna was fabricated from the selected parameters in the previous section. These parameters are as follows: radius of cylindrical reflector (*b*) of 58 mm, length of cylindrical reflector (*d*) of 53 mm, distance between the probe and the reflector (*h*) of 40 mm, probe length (*g*) of 26 mm and stub length (*s*) of 13 mm, respectively. This structure radiates the unidirectional beam with the circular polarization as shown in Fig.7. The half-power beamwidths (HPBW) in E-plane and H-plane are 65.7° and 65.5°, respectively. The front-to-back ratio (F/B) in both planes is better than 20 dB.



(a) E-plane (b) H-plane

Fig.7 The simulated and measured patterns

The maximum gain and return loss for various frequencies are shown in Fig.8 and Fig.9, respectively. The maximum gain is 8.88 dBi at the frequency 2.45 GHz. The average gain and maximum gain are 8.18 dBi and 9.11 dBi, respectively. The impedance bandwidth (return loss < -10 dB) of 8.5% is observed. The frequency range covers 2.365-2.575 GHz.

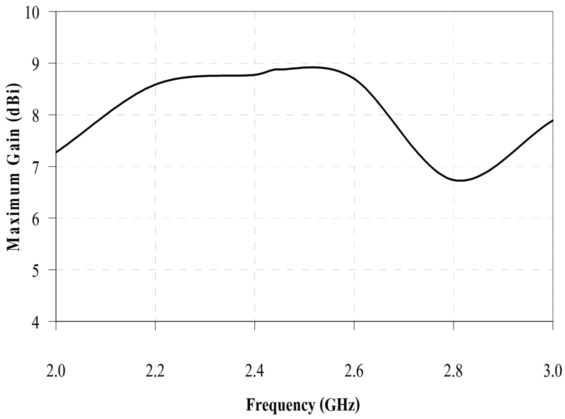


Fig.8 Maximum gain versus frequency

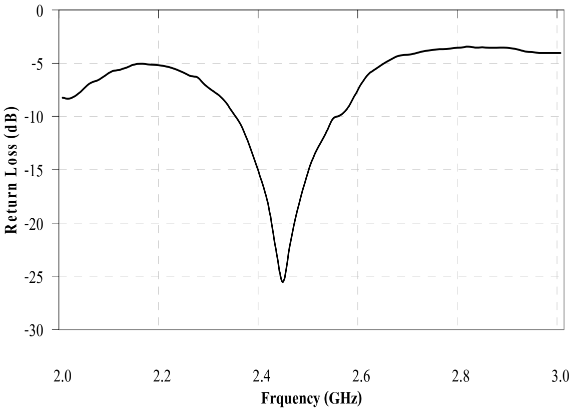


Fig.9 Return loss versus frequency

5. Discussions and Conclusions

We proposed a circular ring antenna excited by a bent probe above the cylindrical reflector. The optimum parameters that provide the maximum gain, low side lobe level is obtained from the simulation. The cylindrical reflector dimensions are varied to achieve the minimum axial ratio. The minimum axial ratio is 1.68 dB. The probe length and stub length are also adjusted. Ultimately, the probe length (*g*) of 0.21λ and stub length is 0.10λ are used to achieve the optimum matching condition. This antenna possesses a gain of 8.18 dBi over the bandwidth of 8.5% for the centre frequency of 2.45 GHz. The front-to-back ratio (F/B) in both E-plane and H-plane is better than 20 dB. This antenna has a unidirectional beam radiation with the circular polarization. The results of the investigations are very useful for the design of the high gain unidirectional beam antenna. Therefore, this antenna is suitable for the access point of the Wireless Local Area Network (WLAN) communication system.

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