guide one is about $h_c = \lambda_g/4 = 0.335\ \lambda$, where λ_g is wavelength in a waveguide. In our case, $h_c = 0.4\ \lambda$, where λ denotes signal wavelength in the free space.

Exciting circuit for subarray of four radiators is shown in Figure 3. It was designed on the base of symmetric stripline. For circular polarized field exciting in each horn, orthogonal resonators $L6$ and $L7$ with phase shift of $\pi/2$ are used, such phase shift is realized by different length of resonators $L6$ and $L7$. Ellipses of circular polarization of the radiators 1–4 are rotated in space on $\pi/2$ one by one for increasing of polarization coefficient of total field of subarray. For this space rotation, different lengths in exciting circuit $L1$, $L2$ and $L3$, $L4$ are used and such difference of electric lengths $L2 - L1$ and $L4 - L3$ equals $\pi/2$.

The fabricated radiator element of single horn is shown in Figure 4. Figures 5(a) and 5(b) present the simulated and measured radiation pattern and return loss of the microstrip-fed cavity-backed 2×2 four-element horn subarray, respectively. The measured antenna gain of the subarray is 15.2 dBi at 20.5 GHz and the 15 dB return loss is about 1.85 GHz. The measured radiation pattern well matches to the expectation, but the gain is slight smaller by 1.2 dB. This loss is attributed to the loss in power combining from each element of the 2×2 subarray in the air due to the unbalance of the four-way power divider in the feeding network, the loss in the dielectric substrate, and measurement errors.

4. CONCLUSIONS

This letter has presented a microstrip-fed cavity-backed horn antenna for circular polarization. Two types of single and 2×2 subarray of four-element have been discussed for selection of a basic radiator element for phased array antenna. The designed circularly polarized horn antenna is structurally compact and exhibits good performances in bandwidth, radiation pattern, and gain. The height of the radiator is reduced as compared to using waveguide types of circular polarizer, on the other hand, the antenna gain increases when using flat microstrip antennas.

REFERENCES

1. M. Sironen, Y. Qian, and T. Itoh, A 60 GHz conical horn antenna excited with quasi-Yagi antenna, IEEE MTT-S Int Microwave Symp Dig, 1 (2001), 547–550.
2. A. Abdel Rahman, A.K. Verma, and A.S. Omr, High gain wideband compact microstrip antenna with quasi-planer surface mount horn, IEEE MTT-S Int Microwave Symp Dig 3 (2003), 1721–1724.
3. Q. Li, Z. Shen, and P.T. Teo, Microstrip-fed cavity-backed slot antennas, Microwave Opt Technol Lett 33 (2002), 229–233.
4. Y.-B. Jung, S.-Y. Eom, S.-I. Jeon, and C.-J. Kim, Novel Ka-band microstrip antenna fed circular polarized horn array antenna, IEEE MTT-S Int Microwave Symp Dig 3 (2004), 2476–2479.
5. Nasimuddin, K. Esselle, and A.K. Verma, Compact circularly polarized enhanced gain microstrip antenna on high permittivity substrate, Microwave Conf Proc Asia–Pacific Conf Proc 4 (2005), 4–7.

A NOVEL DESIGN OF A CPW-FED SQUARE SLOT ANTENNA WITH BROADBAND CIRCULAR POLARIZATION

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ABSTRACT: *A novel design of a broadband circularly polarized square slot antenna fed by a single coplanar waveguide is proposed and discussed. The circularly polarized radiation is achieved by means of using an outer rectangular ring and an inner rectangular ring at the center of a square slot. The proposed antenna has the fundamental resonant frequency of 2.44 GHz with the return loss of −40.93 dB, and it has the bandwidth of 3 dB axial ratio of 420 MHz or (17.21%). Details of the results are presented and discussed.* © 2006 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 2456–2459, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21951

Key words: *circularly polarized; square slot antenna; coplanar waveguide; axial ratio*

1. INTRODUCTION

Coplanar waveguide (CPW) was widely studied as an alternate to microstrip line for feeding square slot antenna in past few years, because they are compatible with the monolithic microwave integrated circuits (MMIC) and active device applications [1–4]. Besides, the CPW-fed slot antenna can also have relatively much wider impedance bandwidth than the conventional microstrip antenna [5, 6]. They have enough bandwidth to support modern wireless communication. Thus, the designs of the CPW-fed antennas have recently received much attention, especially for the circularly polarized (CP) CPW-fed slot antenna. In order to obtain CP radiation using a single feed, many microstrip antenna designs have been reported [7]. The obtained CP bandwidth determined by 3 dB axial ratio (AR) bandwidth is usually narrow and less than 2%. It is also noted that most of the available CP wide slot antenna designs are with a microstrip line feed. However, few studies have been done on the design with CPW feeding [8, 9]. Furthermore, it is very difficult to achieve a good impedance matching and a good AR at the same dimensions for the CPW-fed slot antenna.

In this study, we propose a novel design of a CPW-fed square slot antenna with broadband CP. The proposed antenna exhibits several advantages such as 3 dB AR profile over a wide frequency range, 3 dB AR space distribution over a wide elevation range, and broad impedance bandwidth.

2. ANTENNA CONFIGURATIONS

The geometry of the proposed CPW-fed CP slot antenna is depicted in Figure 1. We used an inexpensive FR4 dielectric substrate with a thickness of 1.6 mm, a relative permittivity of 4.4, and a loss tangent of 0.0245. In this suggested antenna, the lengths of L_1, L_2, L_3, and L_f are fixed to be 49, 29, 17, and 11 mm, respectively, and the widths of W_1, W_2, W_3, W_5, and W_6 are fixed to be 49, 23, 17, 15, and 10 mm, respectively. A 50-Ω CPW transmission line, having a protruded single strip of width $W_f = 6.3$ mm and a gap of distance $g_1 = 0.5$ mm

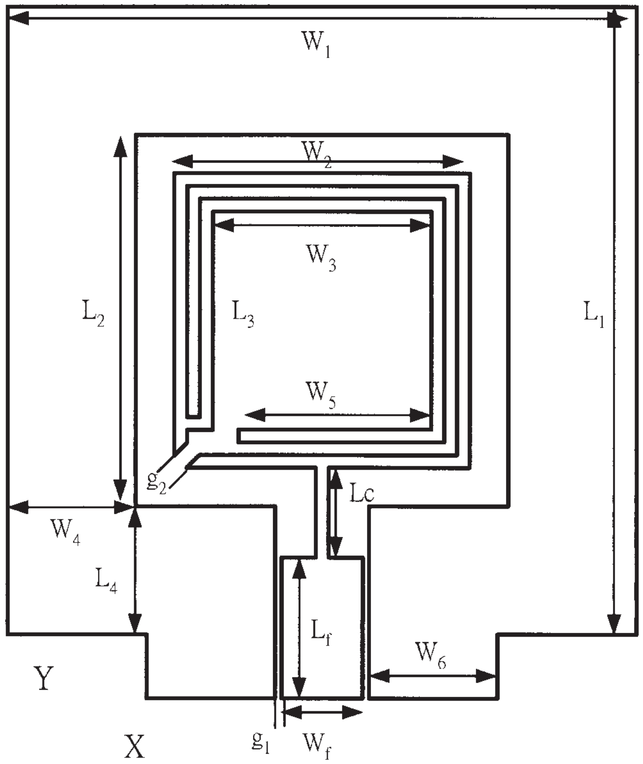


Figure 1 Geometry of the proposed CPW-fed circularly polarized slot antenna

between the signal strip and the ground plane, is used to feed the proposed antenna. By adjusting the length of the protruded strip L_C, the impedance matching of the slot antenna can be easily controlled, and its width of the protruded strip is fixed to be 1 mm. Besides, for this proposed antenna, an outer rectangular ring is printed on the center of the slot antenna, and it has a gap (g_2) to excite CP radiation. If the gap is located at the lower-left corner of the rectangular ring, the slot antenna excites a left hand circular polarization (LHCP). However, if the gap is located at the lower-right corner, the slot antenna generates a right hand circular polarization (RHCP). From the empirical experiences, the circumference of the outer rectangular ring is about 1.03 λ (λ is the wavelength of operational frequency). To improve the 3 dB AR bandwidth and the impedance bandwidth, an inner rectangular ring has been implemented. The space between inner ring and outer ring is 1 mm, and the width of both rings is 1 mm.

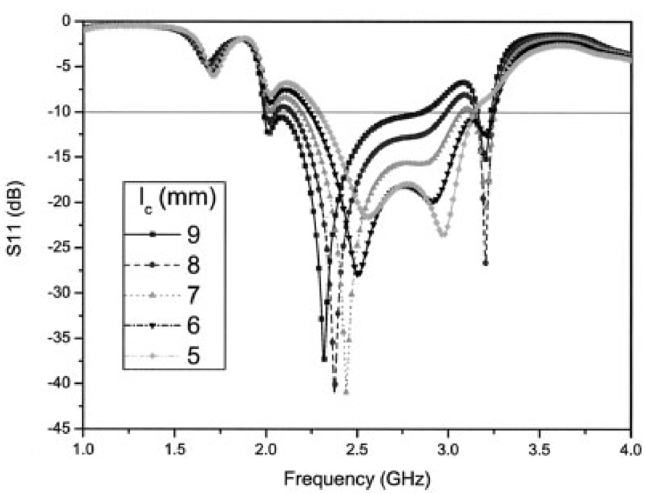


Figure 2 Return loss against frequency for the proposed antenna with different signal strip length (L_C) as the length of $L_4 = W_4 = 10$ mm and $g_2 = 1.35$ mm

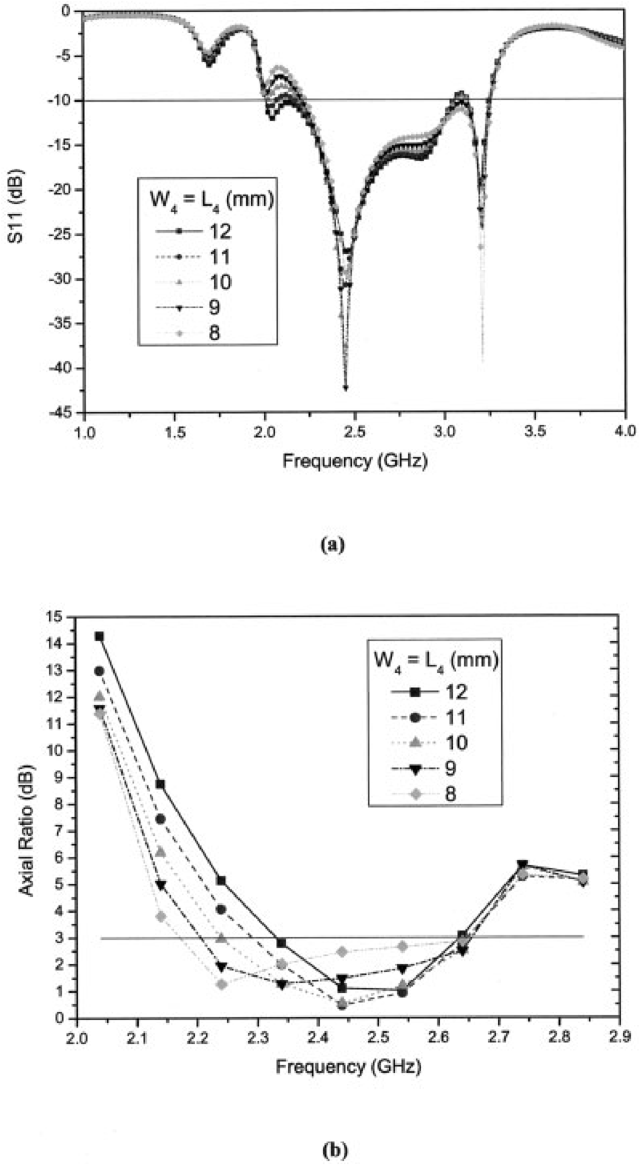
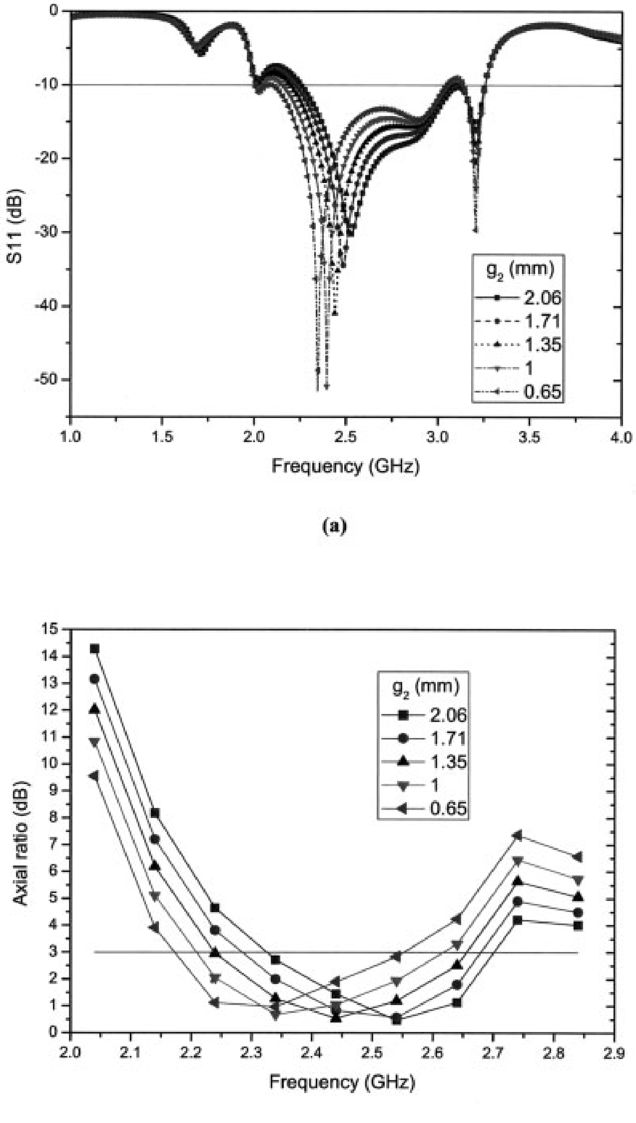


Figure 3 (a) Return loss against frequency and (b) axial ratio against frequency for the proposed antenna with different ground size ($L_4 = W_4$) as the length of $L_C = 7$ mm, and $g_2 = 1.35$ mm

3. RESULTS AND DISCUSSIONS

The length of the protruded signal strip (L_C) in the proposed antenna is varied and the influence on the impedance matching is investigated. Figure 2 shows the return loss against frequency for the proposed antenna with different signal strip length of $L_C = 9$, 8, 7, 6, and 5 mm when $g_2 = 1.35$ mm and $L_4 = W_4 = 10$ mm. It is apparent that as the length of L_C decreases, the fundamental resonant frequency increases, and the return loss decreases and then increases. The minimum value of return loss occurs as $L_C = 7$ mm. It presents a fundamental resonant frequency of 2.44 GHz with a return loss of −40.93 dB, and has the impedance bandwidth of 880 MHz or 36.07% which is from 2.19 to 3.07 GHz. Besides, from the analysis of AR against frequency with the variation of L_C,



(b)

Figure 4 (a) Return loss against frequency and (b) axial ratio against frequency for the proposed antenna with different gap space (g_2) as the length of $L_C = 7$ mm, and $L_4 = W_4 = 10$ mm

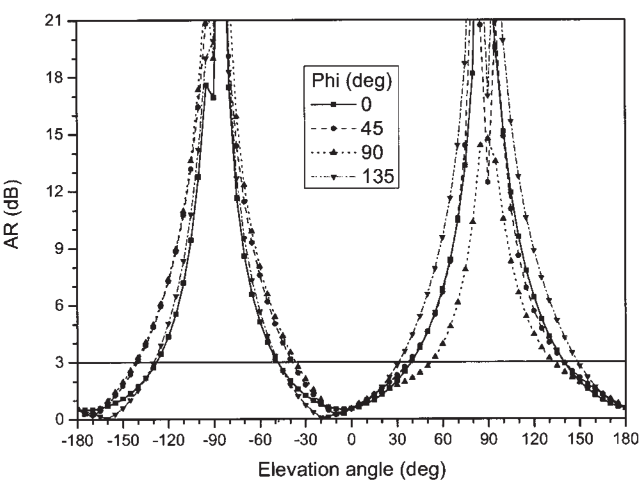
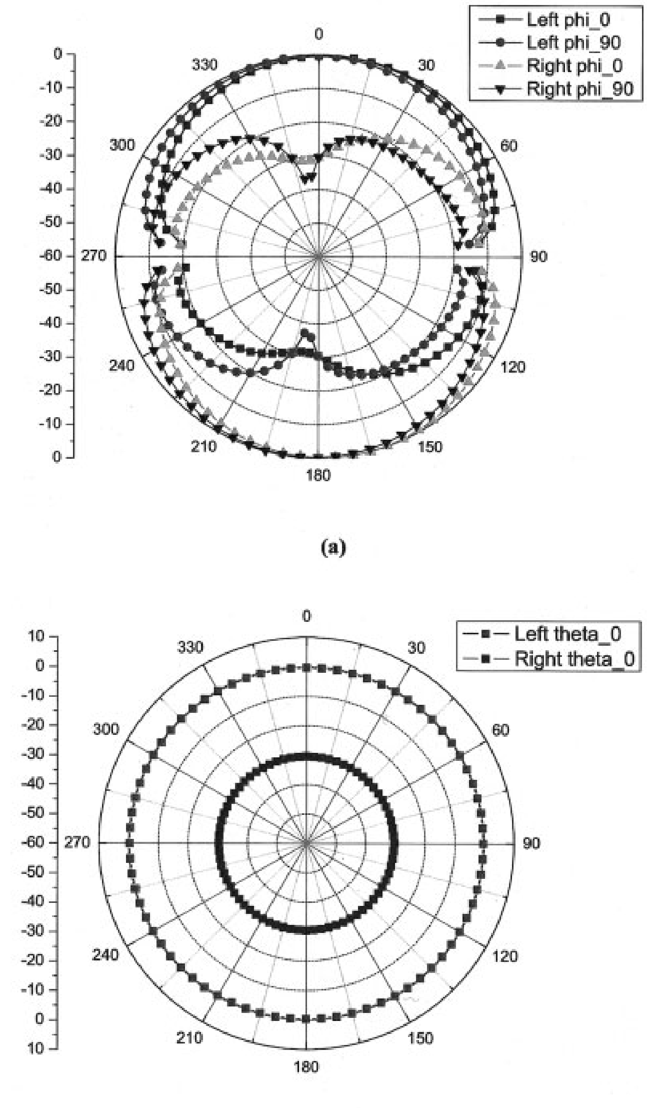


Figure 5 Axial ratio against elevation angle (θ) at the resonant frequency of 2.44 GHz for the proposed antenna with different azimuthal angle as the length of $L_C = 7$ mm, $L_4 = W_4 = 10$ mm, $g_2 = 1.35$ mm



(b)

Figure 6 Radiation patterns on the (a) elevation plane and (b) azimuthal plane at the resonant frequency of 2.44 GHz for the proposed antenna as the length of $L_C = 7$ mm, $L_4 = W_4 = 10$ mm, $g_2 = 1.35$ mm

the fundamental resonant frequency consisting the frequency of minimum AR value only occurs in the condition of $L_C = 7$ mm. The return loss against frequency and AR against frequency for the proposed antenna with different ground size (W_4, L_4) as $L_C = 7$ mm and $g_2 = 1.35$ mm are demonstrated in Figures 3(a) and 3(b), respectively. It is evident that the ground size has less influence on the fundamental resonant frequency, but has larger effect on the value of return loss. Besides, the ground size also affects the AR profile, and it is obvious that as $W_4 = L_4 = 11$, 10 mm, the minimum AR value for the proposed antenna occurs at the frequency of 2.44 GHz. However, as $W_4 = L_4 = 12$, 9, and 8 mm, the minimum AR value occurs at 2.53, 2.34, and 2.24 GHz, respectively, but they do not meet the fundamental resonant frequency. In comparison with these different ground sizes, the proposed antenna with the length of $L_4 = W_4 = 10$ mm has the 3 dB AR bandwidth of 420 MHz or 17.21% which is from 2.23 to 2.65 GHz, the minimum AR value of 0.54 dB, and the fundamental resonant frequency of 2.44 GHz.

Figures 4(a) and 4(b) present respectively the return loss against frequency and the AR against frequency with different gap (g_2) located at the lower-left corner of the outer rectangular ring as the length of $L_4 = W_4 = 10$ mm and $L_C = 7$ mm. It is apparent that as the space of g_2 decreases, both the fundamental resonant frequency and the return loss value decrease. The bandwidths of return loss and 3 dB AR bandwidth do not show significant change. As the space of $g_2 = 1.35$ mm, the proposed antenna has the minimum 3 dB AR value at 2.44 GHz.

From above discussions, the minimum return loss and minimum 3 dB AR bandwidth can be adjusted to the same frequency by modified ground size. The best dimensions for the proposed antenna are $L_C = 7$ mm, $L_4 = W_4 = 10$ mm, and $g_2 = 1.35$ mm. Figure 5 shows the AR against elevation angle (θ) for the proposed antenna with different azimuthal angles of $\varphi = 0, 45, 90$, and 135°. From Figure 5, all of the 3 dB AR bandwidth for the proposed antenna at the four azimuthal angles at least covered the range of θ from −30 to 30°, and all of the AR values at the elevation angle of 0° are below 1 dB. It is obvious that the proposed antenna demonstrates very well performance of AR space distribution.

The radiation patterns against elevation angle and against azimuthal angle are shown in Figures 6(a) and 6(b), respectively. From these figures, the proposed antenna presents good LHCP radiation, and shows omnidirectional radiation pattern for all of the azimuthal angles. These good radiation characteristics are very attractive to modern wireless communication applications.

4. CONCLUSION

A novel design of CPW-fed CP square slot antennas has been investigated and successfully implemented. The proposed antenna has several advantages at the same time which include return loss of −40.92 dB at the fundamental resonant frequency of 2.44 GHz, impedance bandwidth of 880 MHz, 3 dB AR bandwidth of 420 MHz, omnidirectional radiation pattern, and good broadside radiation at least covering the range from 30 to −30° at the elevation direction. The proposed antenna has excellent performances and is very suitable for wireless communication applications.

REFERENCES

1. K.C. Gupta, R. Garg, I. Bahl and P. Bhartia, Microstrip lines and slot lines, 2nd ed., Artech House, Norwood, MA, 1996.
2. W. Menzel and W. Grabherr, A microstrip patch antenna with coplanar feed line, IEEE Microwave Guided Wave Lett 1 (1991), 340–342.
3. R.Q. Lee and R.N. Simons, Coplanar waveguide aperture coupled microstrip patch antenna, IEEE Microwave Guided Wave Lett 2 (1992), 138–139.
4. T.J. Ellis, J.P. Raskin, G.M. Rebeiz, and L.P.B. Katehi, A wideband CPW-fed microstrip antenna at millimeter wave frequencies, In: proceedings of IEEE MTT-S international microwave symposium digest, Anaheim, CA , June 1999, Vol. 2, pp. 629–632.
5. J.Y. Sze, K.L. Wong, and C.C. Huang, Coplanar waveguide fed square slot antenna for broadband circularly polarized radiation, IEEE Trans Antennas Propag 51 (2003), 2141–2144.
6. L.T. Wang, X.C. Lin, and J.S. Sun, The broadband loop slot antenna with photonic bandgap structure, In: IEE international conference on antennas propagation (2003), pp. 470–472.
7. K.L. Wong, Compact and broadband microstrip antennas, Wiley, New York, NY, 2002, Chapter 5.
8. Jyh-Ying Chiou, Jia-Yi Sze, and Kin-Lu Wong, A broadband CPW-fed strip-loaded square slot antenna antennas and propagation, IEEE Trans 51 (2003), 719–721.
9. Jia-Yi Sze, Kin-Lu Wong, and Chieh-Chin Huang, Coplanar waveguide-fed square slot antenna for broadband circularly polarized radiation, IEEE Trans 51 (2003), 2141–2144.

WIDEBAND CIRCULAR WIRE MESH AND ANNULAR RING MONOPOLE ANTENNAS

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ABSTRACT: *Two new configurations of circular wire mesh and annular ring monopole antennas have been investigated and the results are compared with the corresponding circular disc monopole antenna. For the wire mesh monopole antenna of diameter 26 cm with peripheral metal strip, the measured bandwidth for voltage standing wave ratio ≤ 2 has been obtained from 258 to 5240 MHz, which has a bandwidth ratio of 20.3:1. For annular ring monopole with outer diameter of 26 cm and inner diameter 14 cm, the measured band width for voltage standing wave ratio ≤ 2 has been obtained from 245 to 5275 MHz leading to 21.5:1 bandwidth ratio. These new configurations have less wind loading and weight as compared to circular disc monopole antenna.* © 2006 Wiley Periodicals, Inc.
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Key words: *planar monopole antenna; circular disc monopole; wire mesh monopole; annular ring monopole*

1. INTRODUCTION

A circular disc monopole (CDM) antenna has been reported, which has very large impedance bandwidth and similar radiation pattern as that of the equivalent linear monopole antenna [1–4]. This antenna has been redesigned to cover the ultra high frequency range (300–3000 MHz). Because of the solid plate used for CDM, the weight of the antenna is more and wind-loading effect is large. To overcome these two problems, new configurations such as circular wire mesh, circular wire mesh with outer rim, and annular ring monopole antennas have been proposed. A circular wire mesh monopole antenna having same diameter as CDM is studied experimentally, which gave lesser BW than the CDM. Also, the circumference of this monopole was not binded leading to mechanically unstable configuration. To overcome this problem, a wire mesh of same radius with peripheral solid copper rim is used. This improved the BW and also the mechanical rigidity. Another new configuration of annular ring has been studied. Theoretical analysis of CDM and annular ring antennas have been carried out using IE3D software, followed by experimental verifications [5].

2. CIRCULAR DISC MONOPOLE

To cover the lower frequency of 300 MHz, the diameter 2a of the CDM was approximately calculated using formulations given in [3, 4]. The lower frequency corresponding to voltage standing wave ratio (VSWR) = 2 of the planar disc monopole antenna is given as [4]:

$$f_L = c/\lambda = 7.2/(L + r + p) \quad \text{GHz} \tag{1}$$

where, L is the length of the equivalent cylindrical monopole (which is equal to $2a$), r is the effective radius of an equivalent cylindrical monopole antenna (given by $2 \times \pi \times r \times L = \pi \times a^2$),