The effect of the PIN diodes on antenna gain was studied via comparison with a device terminated by a copper line. The copper line-terminated device achieves an antenna gain of approximately 5.9 dBi, compared to 5.7 dBi in the PIN diode-terminated device, thus confirming that the use of PIN diodes has no appreciable effect on antenna gain. The radiation efficiency was about 85.5% in both cases. The measured radiation pattern at 5.94 GHz for RHCP radiation ($P_{s1} = \lambda_g/2$) shows that the XPD is comparatively low (at ±40°), whereas that in Figure 8 is greater than 20 dB in the same region. Miniaturization of the feed circuit will suppress the diffracted wave by increasing the separation of the feed line from the edge of the substrate, thus resulting in high XPD.

4. CONCLUSION

A feed circuit that allows switching of CP between RHCP and LHCP has been presented and analyzed. It was confirmed that CP can be switched using a patch antenna with diagonal truncated corners holding the XPD at more than 25 dB. The effect of the feed circuit on the XPD and the expansion of bandwidth will be addressed in future research, and the possible use of varactor diodes or field-effect transistors (FETs) to lower the bias current will be considered.

ACKNOWLEDGMENT

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REFERENCES

1. F. Yang and Y. Rahmat-Samii, A reconfigurable patch antenna using switchable slots for circular polarization diversity, IEEE Microwave Wireless Compon Lett 12 (2002), 96–98.
2. D.K. Jung, T. Fukusako, N. Kitamura, N. Mita, and C.S. Ha, Polarization-switchable microstrip antenna using PIN diodes, IEICE Trans Commun E87-B (2004), 152–157.
3. H.R. Chuang and L.C. Kuo, 3D FDTD design analysis of a 2.4-GHz polarization diversity printed dipole antenna with integrated balun and polarization switching circuit for WLAN and wireless communication applications, IEEE Trans Microwave Theory Tech 51 (2003), 374–381.
4. T. Fukusako, A. Imahase, and N. Mita, Polarization characteristics of patch antenna using in-plane and weakly biased ferrite substrate, IEEE Trans Antennas Propagat 52 (2004), 325–327.
5. P.E. Matick, Transmission lines for digital and communication networks, McGraw-Hill, New York, 1969, pp. 321–322.
6. P.L. Sullivan and D.H. Schaubert, Analysis of an aperture coupled microstrip antenna, IEEE Trans Antennas Propagat 34 (1986), 977–984.

ELLIPTICAL MULTIPLE-RING MONOPOLE ANTENNAS

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ABSTRACT: *The effect of ellipticity ratio on elliptical multiple-ring monopole antennas is presented. Several elliptical multiple-ring monopole antennas with different ellipticity ratios are designed, fabricated, and measured. The results show that the resonance bandwidths can be controlled by the ellipticity ratio.* © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 4–8, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21247

Key words: *multiband antennas; elliptical multiple-ring monopole antenna*

1. INTRODUCTION

Multiband and wideband monopole antennas have attracted a great deal of attention for modern wireless-communication systems. Among these are disk and multiple-ring monopole antennas. In [1], the circular-disk monopole antenna with a very large impedance bandwidth was introduced and in [2] this antenna was further studied and the effect of changing the circular disk to an elliptical disk was investigated. Multiple-ring monopole antennas were introduced in [3, 4], although the effect of changing the ellipticity ratio on the antenna characteristics was not investigated. Several elliptical multiple-ring antennas with different ellipticity ratios have been designed, fabricated, and measured. The results show that to design a multiband antenna based on multiple rings, the ellipticity ratio plays an important role; thus, by changing this parameter, different bandwidths for each resonance band can be obtained. The effect of the elliptical shape on the radiation pattern is also investigated. The results show that the radiation patterns are similar to the conventional monopole antenna, although some nulls occur at higher frequencies.

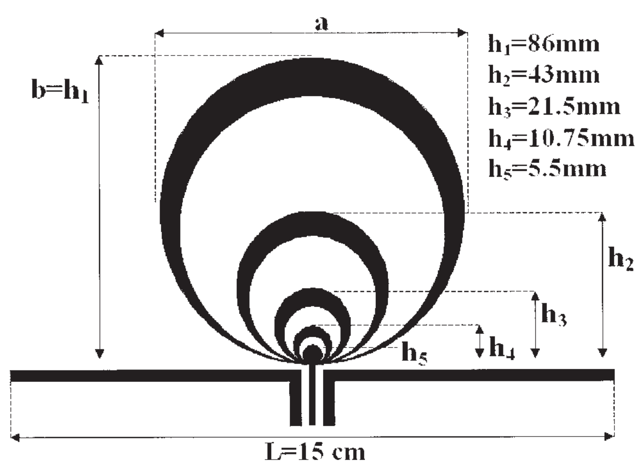

Figure 1 Circular multiple-ring monopole antenna

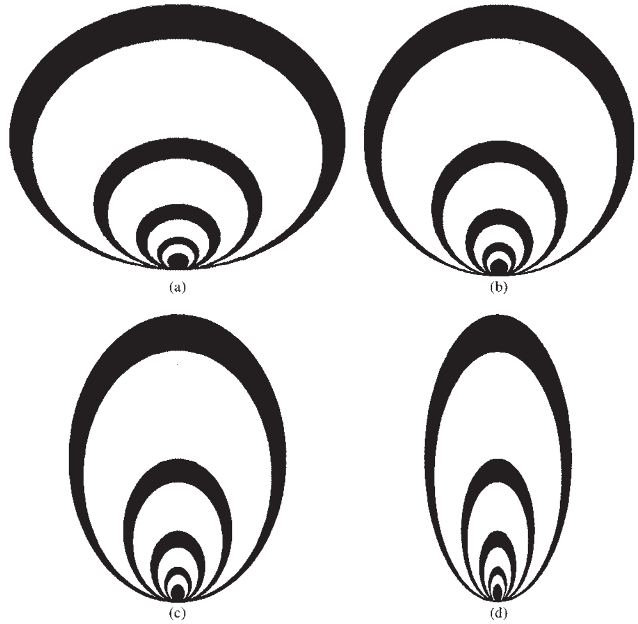

Figure 2 Elliptical multiple ring with different ellipticity ratios: (a) 1.25; (b) 1; (c) 0.75; (d) 0.5

2. MEASUREMENT RESULTS

Four different elliptical multiple-ring monopole antennas with different ellipticity ratios of $(a/b) = 1.25$, 1, 0.75, and 0.5 were chosen, where a and b are defined as shown in Figure 1.

Each ring height for all of the monopoles discussed here is similar to the circular multiple-ring monopole antenna in [3, 4], as shown in Fig. 1, with an overall height of 86 mm and smaller ring heights of 43, 21.5, 10.75, and 5.5 mm. The monopoles with different ellipticity ratios are shown in Figure 2. The antennas were fabricated using conventional printing techniques on a 0.5-mm-thick FR4 substrate ($\varepsilon_r = 4.4$) and mounted perpendicularly over a metallic ground plane of 15 × 15 cm. A 50Ω SMA connector was used to feed the antennas at the centre of the ground plane. The height of antennas from the ground plane was 1 mm.

2.1. Return Loss

Figure 3 shows the return loss of these antennas. The centre frequency, bandwidth, and the beginning and ending frequencies of each band are shown in Table 1. The results show that the centre frequencies shift to higher frequencies and the bandwidths are widened when the ellipticity ratio is decreased. For example, the centre frequencies of the third bands are 3.28, 3.56, 3.85, and 4 GHz for the ratios of 1.25, 1, 0.75, and 0.5, respectively, and their respective bandwidths are 29.3%, 38.2%, 50.6%, and 62%. The increase of the bandwidths is believed to be due to the mutual coupling between the rings. When the ellipticity ratio is small, the coupling between adjacent rings is increased, thus leading to wider bandwidth. In addition, the beginning

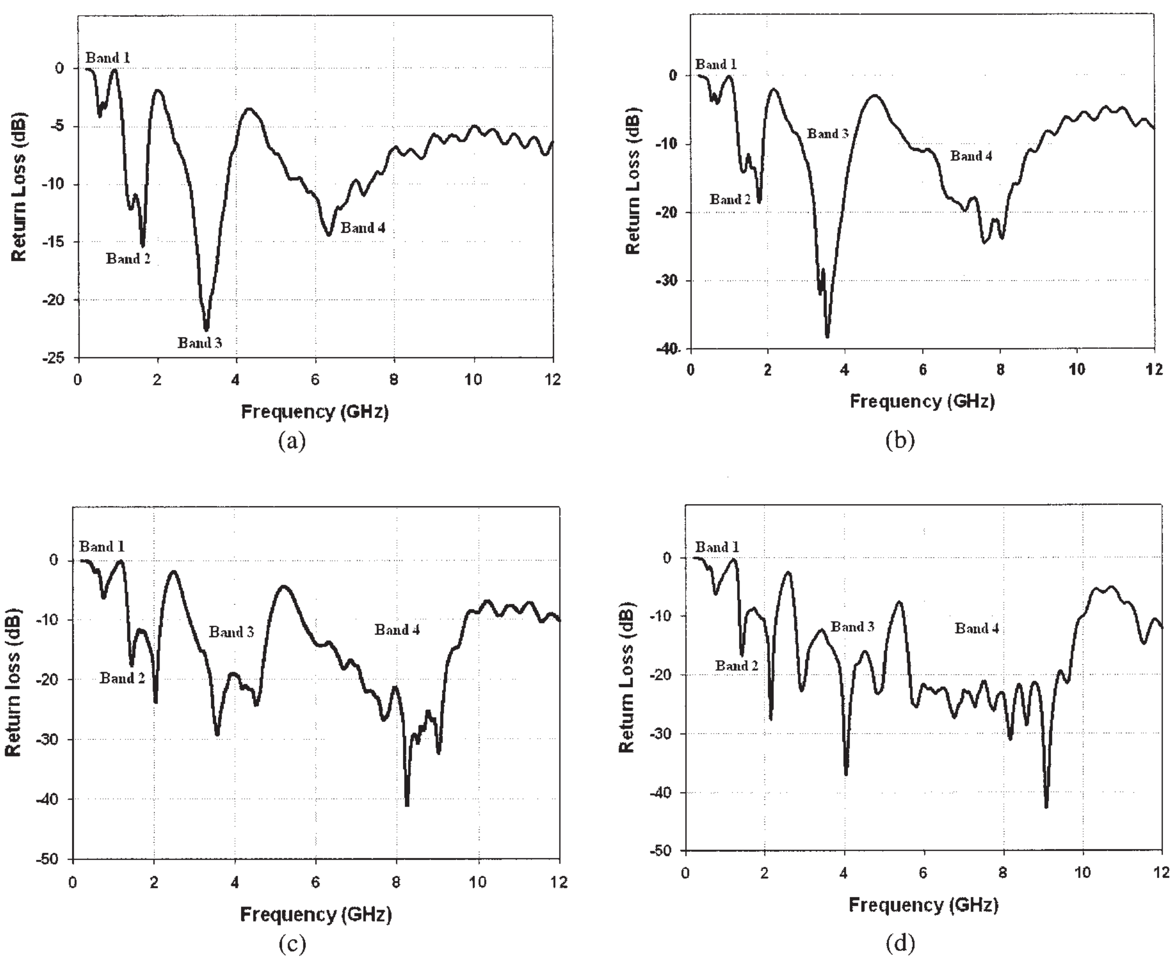

Figure 3 Measured input return loss of the elliptical multiple-ring monopole antennas with ellipticity ratios of (a) 1.25, (b) 1, (c) 0.75, and (d) 0.5

TABLE 1 Centre Frequency (CF), Bandwidth (BW), and Beginning and Ending Frequencies (F_1 and F_2) of Each Band for Elliptical Multiple-Ring Monopole Antennas

	Ellipticity = 1.25				Ellipticity = 1.0			
	CF [GHz]	BW [%]	F_1 [GHz]	F_2 [GHz]	CF [GHz]	BW [%]	F_1 [GHz]	F_2 [GHz]
Band 1	0.55	—	—	—	0.67	—	—	—
Band 2	1.45	34.5	1.2	1.7	1.55	42	1.2	1.88
Band 3	3.28	29.3	2.8	3.76	3.56	38.2	2.88	4.24
Band 4	6.32	19.7	5.7	6.95	7.32	45.7	5.65	9
	Ellipticity = 0.75				Ellipticity = 0.5			
	CF [GHz]	BW [%]	F_1 [GHz]	F_2 [GHz]	CF [GHz]	BW [%]	F_1 [GHz]	F_2 [GHz]
Band 1	0.73	—	—	—	0.73	—	—	—
Band 2	1.76	46	1.35	2.17	1.82	51	1.35	2.3
Band 3	3.85	50	2.88	4.83	4	62	2.76	5.24
Band 4	7.65	52	5.65	9.66	7.72	58	5.48	10

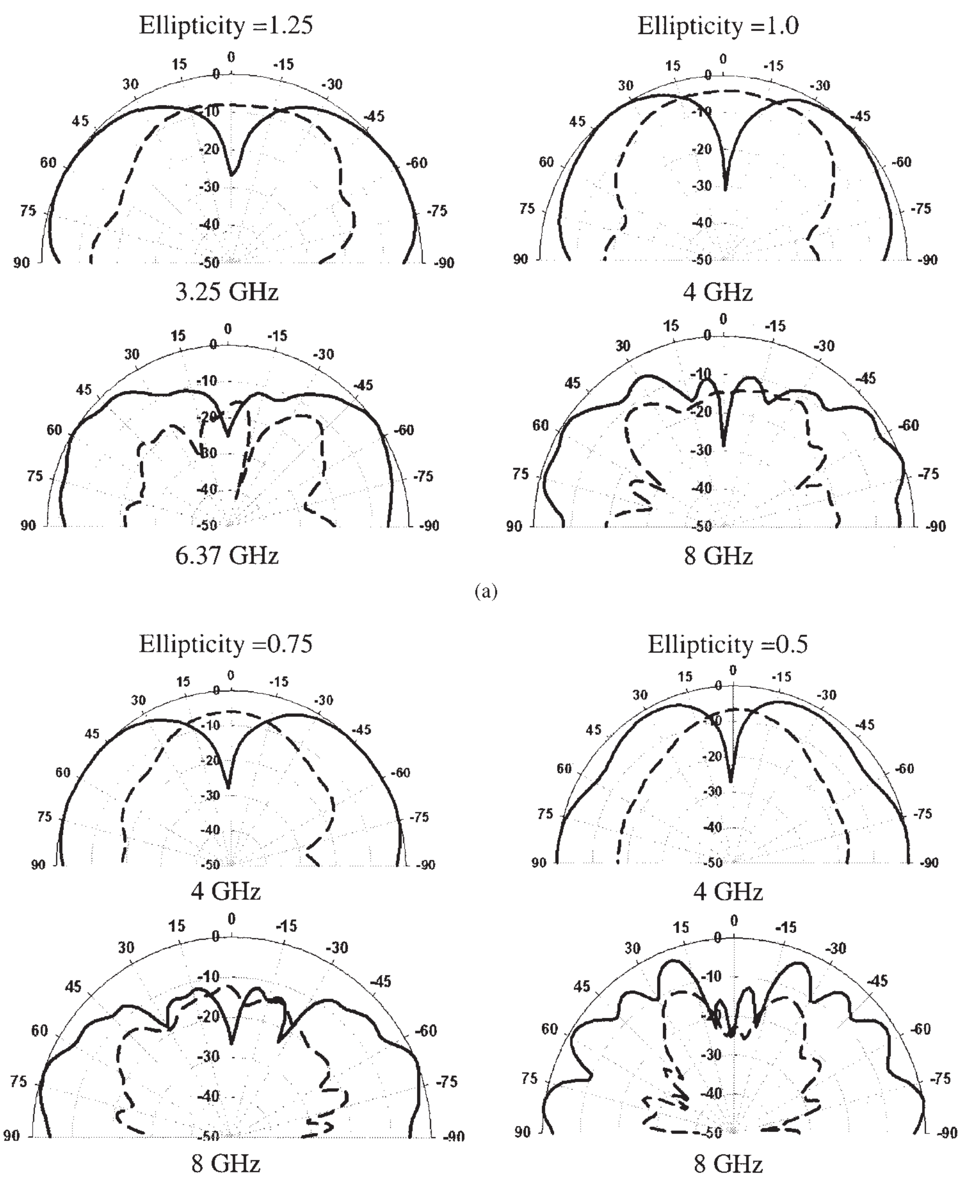

Figure 4 Measured radiation patterns of the elliptical multiple-ring monopole antennas in the E-plane (— co-polarization, – – – cross-polarization)

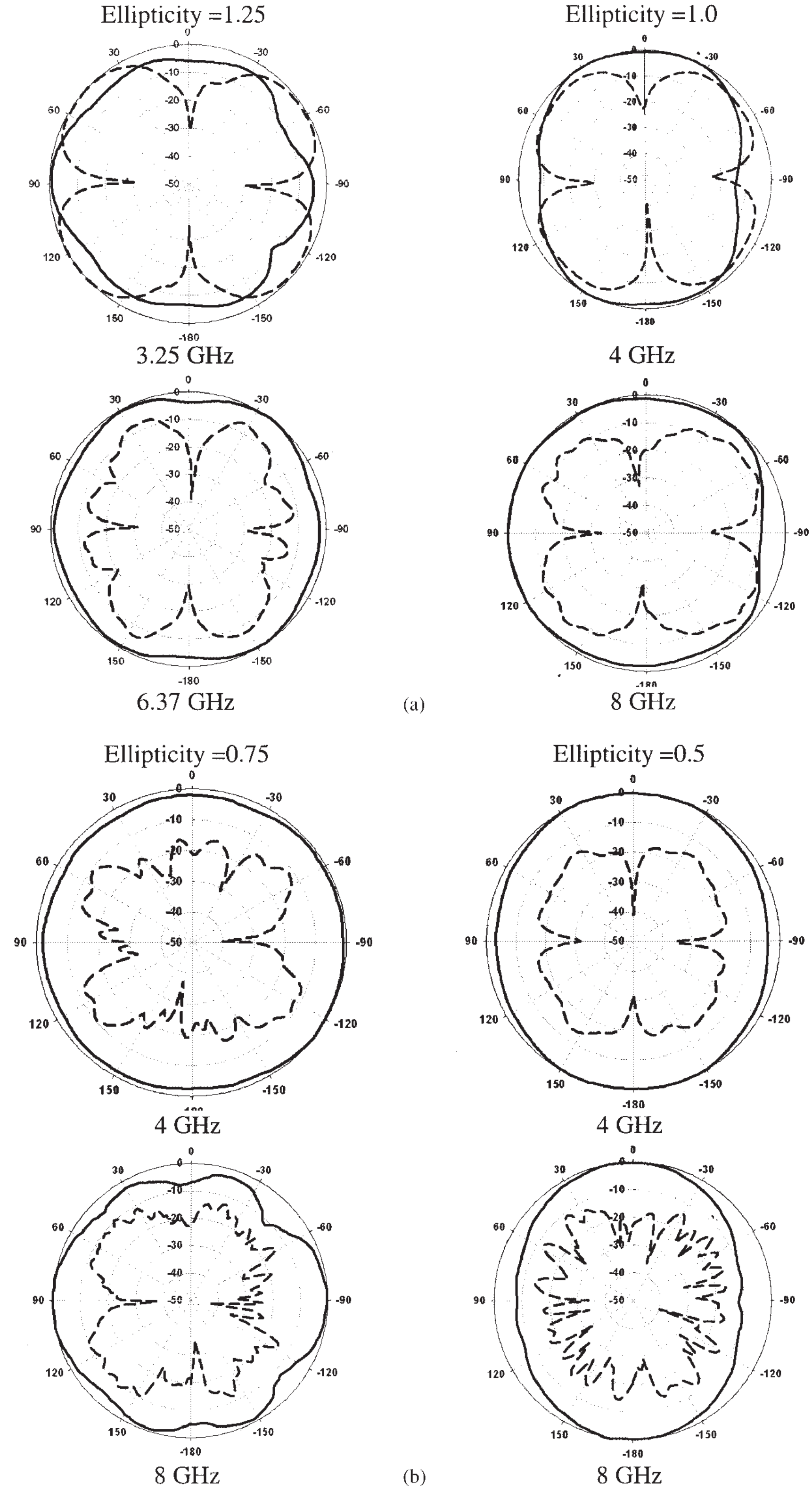

Figure 5 Measured radiation patterns of the elliptical multiple-ring monopole antennas in the H-plane (— co-polarization, – – – cross-polarization)

frequencies at the low ends of the bands are not changed as much as the frequencies at the top ends of the bands. For example, the beginning frequencies of the third bands are 2.8, 2.88, 2.88, and 2.76 GHz for the antennas with ellipticity ratios of 1.25, 1, 0.75, and 0.5, respectively, while the frequencies at the top ends of these bands are 3.76, 4.24, 4.83, and 5.24 GHz.

2.2. Radiation Pattern

The far-field radiation patterns of the antennas at the resonance bands were measured. The radiation patterns at the lower frequencies are similar to the conventional monopole antenna but at higher frequencies some nulls occur. The radiation patterns of the antennas in the E-plane and the H-plane at the third and the fourth bands are shown in Figures 4 and 5, respectively. The radiation patterns are similar to those of the conventional monopole antenna, although at the fourth band some nulls can be observed and these nulls are deeper for the antenna with ellipticity of 0.5 in the E-plane. In spite of this degradation, the radiation patterns at the fourth band are similar to those of the conventional monopole antenna.

3. CONCLUSION

Several elliptical multiple-ring monopole antennas with different ellipticity ratios have been fabricated and measured. The results show that the widths of the resonance bands with regard to return loss can be controlled by the ellipticity ratio and wider bandwidth can be obtained by decreasing the ellipticity ratio. The radiation patterns were found to be similar to those of the conventional monopole antenna, although at higher frequencies some nulls did occur.

REFERENCES

1. S. Honda, M. Ito, H. Seki, and Y. Jingo, A disk monopole antenna with 1:8 impedance bandwidth and omnidirectional radiation pattern, Proc Int Symp Antennas Propagat, Sapporo, Japan, 1992, pp. 1145–1148.
2. N. Prasad Agrawall, G. Kumar, and K.P. Ray, Wideband planar monopole antennas, IEEE Trans Antennas Propagat 46 (1998), 294–295.
3. C.T.P. Song, P.S. Hall, H. Ghafouri-Shiraz, and D. Wake, Multicircular loop monopole antenna, IEE Electron Lett 36 (2000), 391–393.
4. C.T.P. Song, P.S. Hall, and H. Ghafouri-Shiraz, Multiband multiple-ring monopole antennas, IEEE Trans Antennas Propagat 51 (2003), 722–729.

COMBINATION OF ELECTRIC AND MAGNETIC DIPOLES WITH SINGLE-ELEMENT FEEDING FOR BROADBAND APPLICATIONS

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ABSTRACT: *This work presents four types of broadband compound antennas. The antennas are a combination of an electric dipole and small square or circular loops. The feeding of the electric dipole only is realized. The input impedance, reflection coefficient, and gain of the antennas with different geometries are analyzed numerically using the method of moments (MoM). It is shown that for the level of the reflection coefficient* $|\Gamma| < -10$ *dB, 80% to 90% bandwidth can theoretically be achieved for the proposed antennas.* © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 8–12, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21248

Key words: *electric and magnetic dipoles; broadband antennas; combined antennas*

1. INTRODUCTION

General fundamental limits about the performance of antennas were investigated for the first time by Wheeler [1] and Chu [2]. They showed in particular that an antenna possesses the minimum radiation factor if and only if this antenna radiates the fundamental TM_{10} and TE_{10} modes with an equal amount of energy. These modes are radiated by infinitesimal electric and magnetic dipoles, respectively [3]. More recent works that confirm this conclusion can be found in [4, 5]. Note that the radiation factor is inversely proportional to the bandwidth of the antenna.

The results of this general theory suggest combining electric and magnetic dipoles to increase the bandwidth. Investigations on the mutual interaction between an electrical dipole and a magnetic dipole (small loop) for different relative orientations of their dipole moments were presented in [6, 7]. The authors of [7] adjusted the magnitudes of the currents of the dipoles with the purpose to obtain TE and TM modes of equal power. They noted a significant absorption of energy by one of the active dipoles when the dipole moments were orthogonal.

In [8], a combination of one electric dipole and two magnetic dipoles with sinusoidal distribution of the electric and magnetic currents along the dipoles was used. The authors of the paper obtained broadband characteristics by adjusting the positions of the elements and magnitudes and the phases of the sources' currents. However, the realization of this antenna is not simple because the theory supposes the ideal magnetic dipole, and the optimal magnitudes and phases of the sources depend on frequency.

The main idea of this paper is to use several coupled radiating elements and to vary their mutual positions in order to enlarge the bandwidth of the combined antenna. In contrast to [8], all of the antennas presented here are combinations of orthogonal electric and magnetic dipoles (in fact, circular or square loops) with

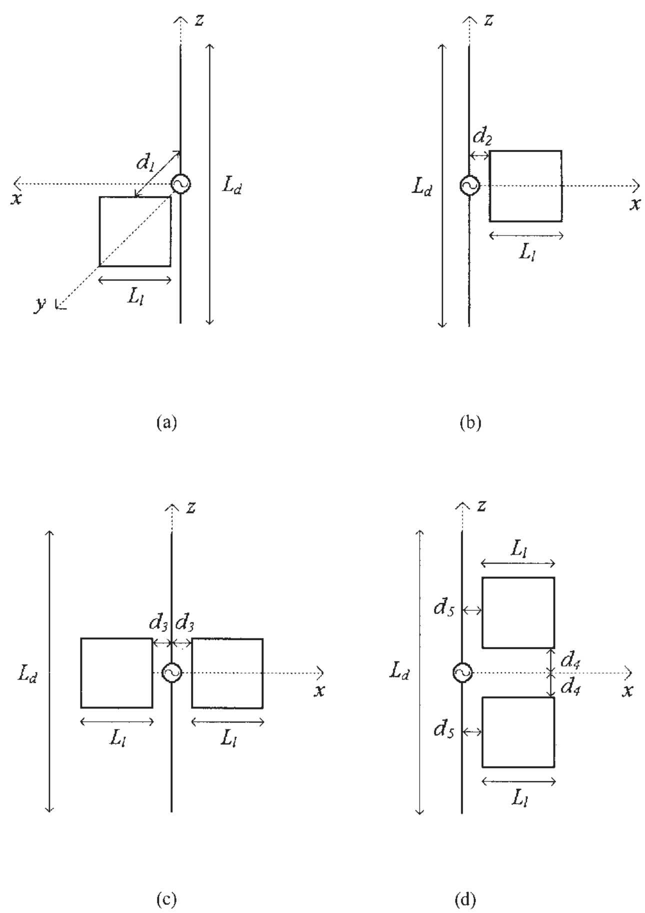

Figure 1 The four types of antennas analyzed: (a) case 1; (b) case 2; (c) case 3; (d) case 4