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MODIFIED MULTIBAND MULTIPLE RING MONOPOLE ANTENNA

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Abstract—In this paper, a modified version of the multi-band multiple ring monopole antenna is proposed. The height of the new design which consists of multiple half rings is half of the original one. The modified design is more attractive for low profile applications due to its lower height. The antenna is simulated and measured. It is shown that the simulation and measurement results are in good agreement. The performance of the modified version of the antenna is compared with the original design in terms of input characteristic and far field radiation patterns. It is shown that the multiband behaviour of the modified design is similar to the original one. However, there is a frequency shift between the operating bands of the new and the original antennas. The radiation patterns of the both antennas are similar to the conventional monopole antenna in lower operating frequency bands. However, degradation in radiation patterns of the both antennas is observed as frequency increases.

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1. INTRODUCTION

Emerging new wireless communication services demands more frequency bands. Proper design of the antenna, as one of the key components of the whole system, plays an important role to make the system efficient in terms of its performance, lightness and compactness. The multiband antennas are good candidates for using in modern wireless links which operate at several frequency bands [1–4]. Among multiband antennas the monopole structures have attracted a great deal of attention. Many structures and geometries such as the multiband Sierpinski gasket monopole antenna [5, 6] have been investigated in the literature. The multi-band multiple ring monopole antenna was introduced by Song et al as an alternative to the Sierpinski gasket monopole antenna [7, 8]. In comparison to the wideband circular disk [9, 10], the multiple ring monopole antenna shows improved radiation pattern control at higher operating bands due to its discrete structure. Also, the bandwidth in each band is larger than the fractal Sierpinski gasket antenna. The effect of changing the ellipticity ratio on the multiple ring monopole antenna was investigated in [11]. The influence of the thickness of the rings and height from the ground plane on the input characteristic of the multiple ring monopole antenna was presented in [12]. The planar version of the antenna was proposed in [13] where the antenna was fed by a microstrip transmission line.

In this paper, a modified design of the antenna, which has half the height of the original design, is proposed. The new design consists of half multiple rings. The simulation and measurement results are presented. The simulations have been carried out by CST Microwave Studio. The new design is compared with the original one and it is demonstrated that both designs show a similar multiband behaviour. However, the new antenna is more suitable for low profile applications because its height is half of the original design.

2. MODIFIED MULTIPLE RING MONOPOLE ANTENNA

To explain the modified design of the multiple ring structure, first a brief illustration of the original design will be given. The multiple ring monopole antenna consisting of a set of self similar circular rings is shown in Fig. 1, where the dimensions of the antenna are also given [8]. The antenna shown in Fig. 1 consists of four rings and a disk. Each ring is half of the former ring. This antenna operates at five bands and the highest operating band shows a wideband behaviour which is believed to be due to the presence of the circular disk [8]. In

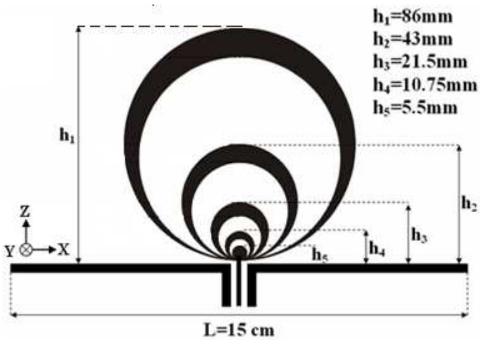


Figure 1. Multiple ring monopole antenna [8].

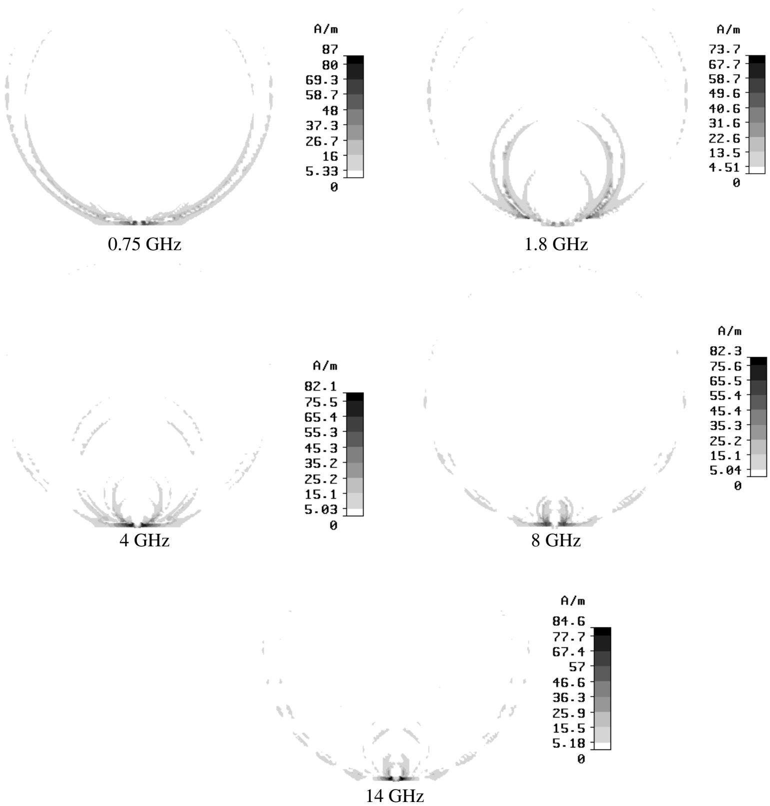


Figure 2. Simulated current distribution on the multiple ring monopole antenna shown in Fig. 1.

Figure 3. Modified multiple ring monopole antenna consisting of half rings.

order to have a better understanding of the antenna performance, the current distributions of the antenna at the operating frequency bands are obtained and shown in Fig. 2. The antenna was simulated in CST Microwave studio environment. It can be observed that the current distribution on the top half of the rings is much less than the bottom half of the rings. It suggests that the characteristics of the antenna are mainly controlled by the current distribution on the bottom half. Therefore we expect that if the rings are cut and the bottom half of them are retained, the modified antenna will show similar behavior. Based on this reasoning a modified version of the antenna was designed, simulated and measured. Fig. 3 shows the new configuration. As it can be observed the new antenna consists of four half rings and a half disk. The return loss and the far field radiation patterns of the antenna will be given next. Also the characteristics of the modified antenna will be compared with its counterpart, i.e., the original multiband multiple ring antenna which consists of four rings and a disk.

3. SIMULATION AND MEASUREMENT RESULTS

The return loss of this antenna was simulated and measured. The simulations were done by CST Microwave studio. The modified antenna was fabricated using the conventional printing techniques on a 0.8 mm thick FR4 substrate ($\varepsilon_r = 4.4$) and are mounted perpendicularly over a metallic ground plane of 15 cm × 15 cm. A 50 Ω SMA connector is used to feed the antennas at the centre of the ground plane. Fig. 4 shows the simulated and measured return loss of the antenna. As can be seen the simulation and measurement results agree well except at frequencies between 10.5 GHz to 12.2 GHz. This discrepancy is believed to be due to the fabrication issues like the soldering of the SMA connector to the bottom of the antenna. In fact, the soldering could slightly change the input impedance of the antenna at high frequencies where the small dimension of the half disk makes it sensitive to any changes such as soldering. The return loss of the modified antenna, similar to the original design, shows five operating bands and the highest band is wideband. It should be noted that the number of the bands, the same as the original design, is equal to the number of the half rings and the half disk. These bands are shown in Fig. 4. Based on the −10 dB crossing point of the measured return loss the frequencies at the beginning and ending of the second, third and the fourth bands are: 1.65 GHz and 2.35 GHz, 3.5 GHz and 5 GHz, 6.5 GHz and 10.1 GHz respectively. The fifth band shows a wideband behaviour whose initial −10 dB crossing point is 12.4 GHz. The matching of the second band can be improved by slightly changing the height of the antenna from the ground plane. In fact, that part of the inner conductor of the SMA connector which is between the ground plane and the bottom of the antenna acts as a reactive element. Changing the height of the antenna will change the length of that part of the SMA inner conductor which varies the input reactance of the antenna leading to improvement of the matching characteristics of the antenna [12]. Also it is worth to mention that the antenna is not well matched at the first band like the original design which is an inherent of such multiband monopole antennas [8].

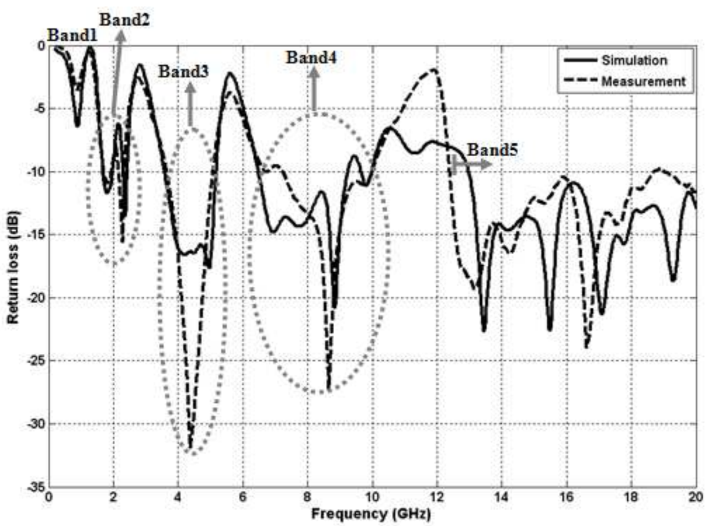


Figure 4. The simulated and measured return loss of the modified multiple ring monopole antenna.

To compare the modified design with the original antenna the return loss and the radiation patterns of both antennas are presented

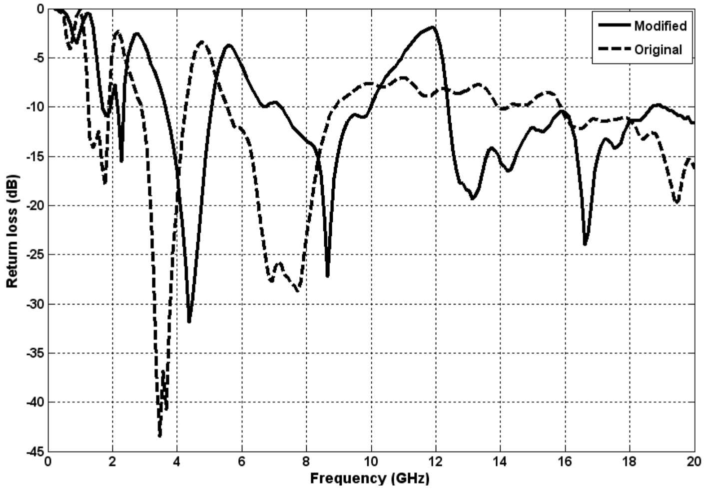


Figure 5. The measured return loss of the modified and original multiple ring monopole antennas.

Table 1. The beginning frequency (F_1), the ending frequency (F_2) and the centre frequency (CF) of each band for modified and original design of multiple ring antenna.

	Modified			Original		
	F_1 (GHz)	F_2 (GHz)	CF (GHz)	F_1 (GHz)	F_2 (GHz)	CF (GHz)
Band 1	-	-	0.89	-	-	0.67
Band 2	1.65	2.35	2	1.2	1.88	1.55
Band 3	3.5	5	4.25	2.88	4.24	3.56
Band 4	6.5	10.1	8.3	5.69	9	7.32
Band 5	12.4	-	-	14	-	-

and compared with each other. It is worth to mention that the ground plane and the substrate of the both antennas were the same. Both antennas were fabricated on a 0.8 mm thick FR4 substrate with the permittivity of 4.4. Fig. 5 shows the measured return loss of the both antennas. Based on the -10 dB crossing point, Table 1 gives the beginning, ending and the centre frequencies of the operating bands of the antennas. It can be observed that the both antennas show a multiband behavior and the fifth band of both antennas is wideband. However, there is a frequency shift between two antennas. The current distribution on the original multiple ring antenna, shown in Fig. 2, explains this frequency shift. As can be observed although the most of the current distribution is concentrated on the bottom half of the antenna, leakage currents exist on the top half of the antenna at all frequency bands. Cutting out the top half of the original antenna eliminates the leakage currents. So the modified antenna has slightly smaller electrical length compared to the original one which results in a frequency shift toward the higher frequencies.

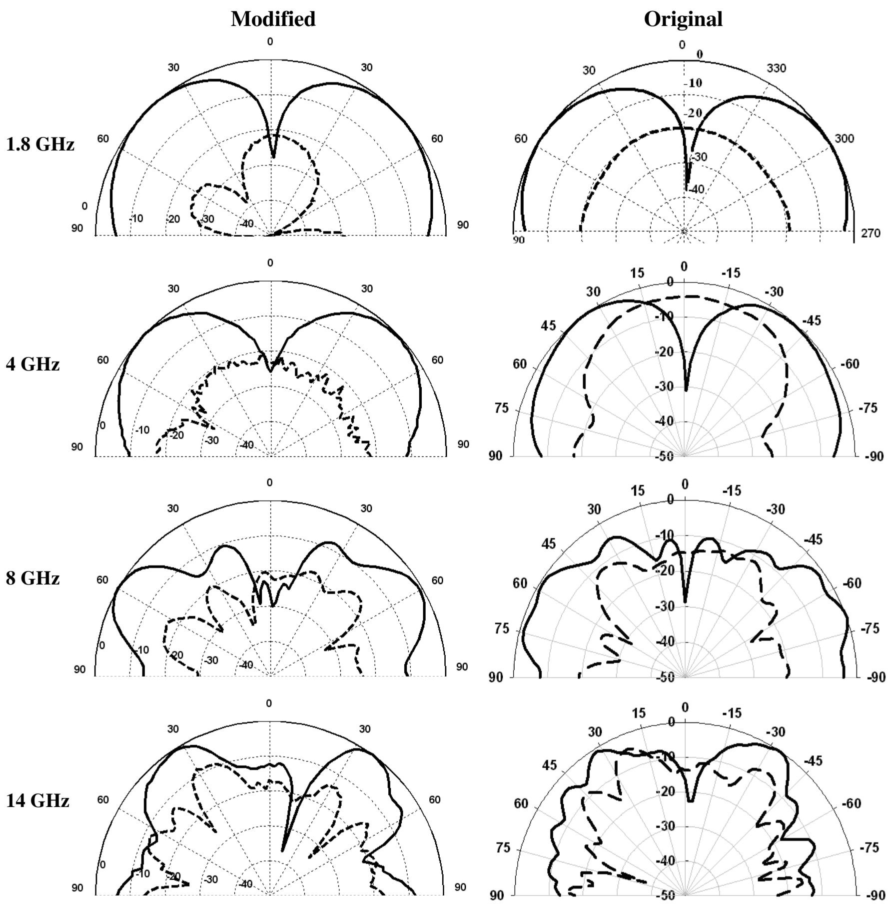
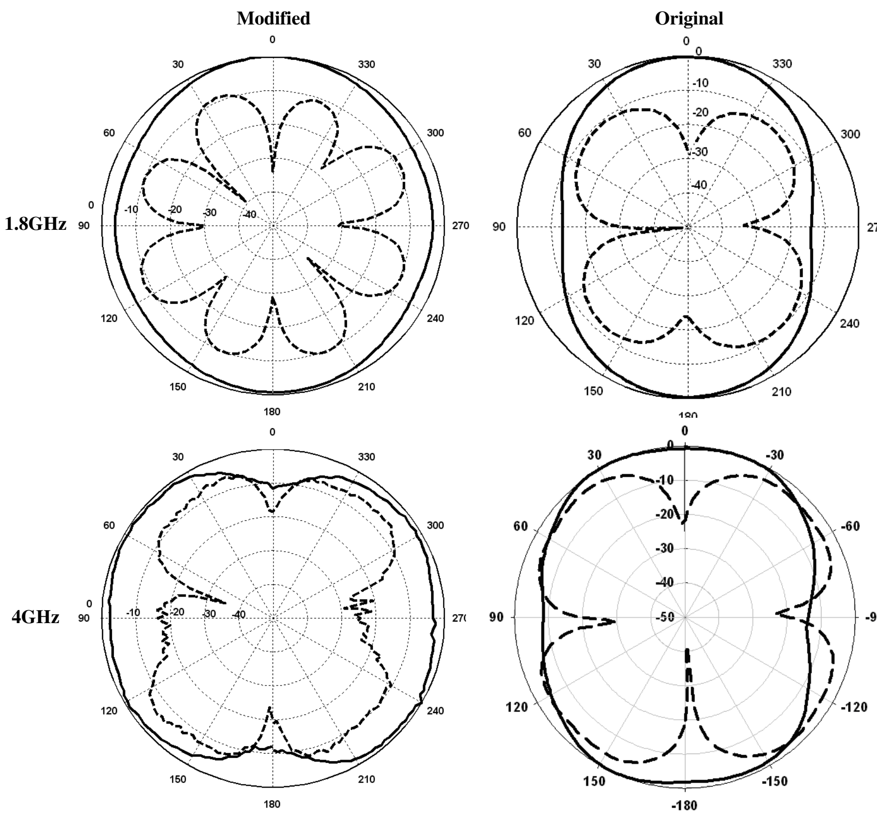


Figure 6. Measured radiation patterns of the modified and original multiple ring antennas in the E-plane. Solid line is co and dashed line is cross polarization. (E plane is $\varphi = 90°$, θ is variable in plots; see inset Fig. 1).

The radiation patterns of the original and the modified designs at the operating frequency bands in the E- and H-planes were measured in an anechoic chamber. Fig. 6 shows the measured radiation patterns of the antennas in the E-plane and Fig. 7 in the H-plane. The radiation patterns of the both antennas at the first band are good monopolar mode patterns and are not shown here. The radiation patterns of the both antennas at the second and the third bands in the E-plane are two lobes with a deep null along the normal direction to the ground plane. This is similar to the radiation pattern of the conventional monopole antenna. It should be noted that the level of the radiated cross polarization of the modified design is less than the original one in the second and the third band. As frequency increases the radiation patterns of the both antennas in the E-plane degrade and multi-lobe pattern begin to form. This effect is more severe at the fifth band. This could be due to the excitation of the higher order mode currents on the larger rings and half rings when frequency increases. As can be observed in Fig. 7, the H-plane radiation pattern of the modified antenna at the second band is more omnidirectional than the original



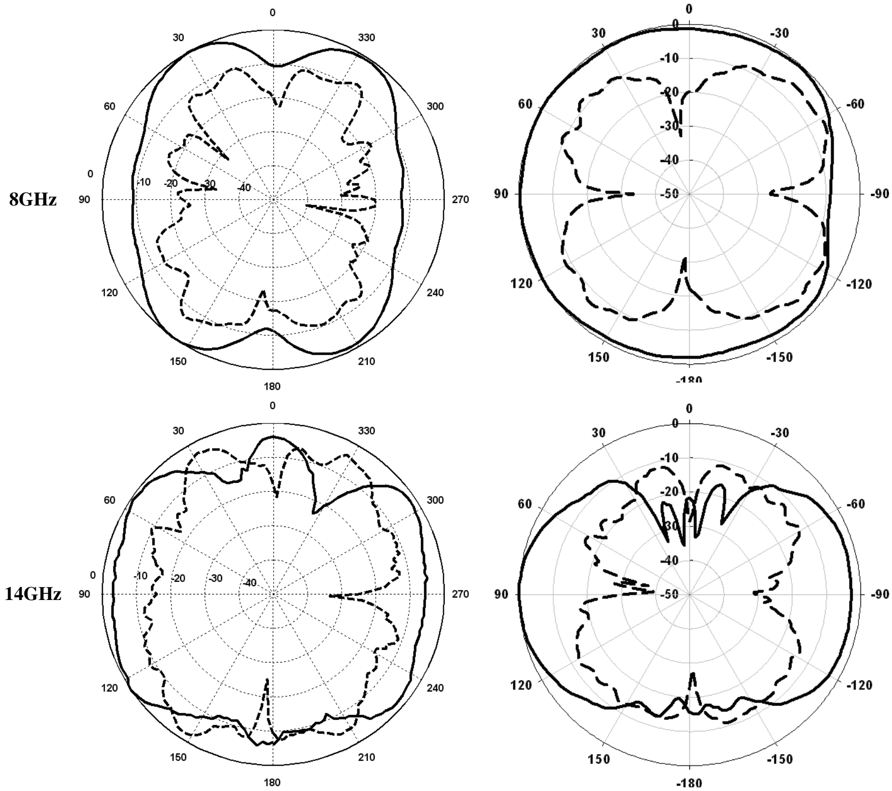


Figure 7. Measured radiation patterns of the modified and original multiple ring antennas in the H-plane. Solid line is co and dashed line is cross polarization. (H plane is $\theta = 90°$, φ is variable in plots; see inset Fig. 1).

one. In the third band the H-plane radiation patterns of the both antennas slightly deviate from the omindirectional form, although the level of the radiated cross polarization of the modified design is less than the original antenna. At the fourth band, the H-plane radiation pattern of the original design shows a better performance than the modified design. However, the H-plane patterns of the both antennas degrade as frequency increases. It can be seen at the fifth band where the excitation of the higher order mode currents on the larger elements causes this adverse effect. The simulated peak gain of the modified antenna at frequency bands is given in Table 2.

Table 2. The simulated peak gain of the modified multiple ring antenna.

Frequency (GHz)	0.8	1.8	4	8	14
Gain (dB)	1.9	4.8	4.3	6.2	7.1

4. CONCLUSION

A modification on the multi-band multiple ring monopole antenna is investigated in this paper. The new design consists of multiple half rings and a half disk. The antenna is simulated and measured. The Performance of the antenna is studied by comparing its return loss and radiation patterns with the original design. The return loss of the new antenna, similar to the original design, shows a multiband behaviour and the number of the bands is equal to the number of the elements of the antenna. There is a frequency shift between the operating bands of the antennas. The radiation patterns of the both antennas are similar to the conventional monopole antenna at lower frequency bands. However, nulls begin to form in the radiation patterns of both antennas in E- and H-planes as frequency increases. Overall height of the modified antenna is half of the original one, thus is more attractive for low profile applications.

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