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A Knight Helm Shaped Ultra-Wideband (UWB) Microstrip Patch Antenna Loaded with Metamaterial

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Abstract

The paper proposes a ultra-wideband patch antenna that consists of Metamaterial layer underneath the patch. The Metamaterial layer consists of four modified complementary split-ring resonator cells (CSRR). It can be observed that by introducing Metamaterial layer there is an increase in bandwidth coverage and gain enhancement. In CSRR design the TM10 mode is combined with TM01 mode that results in wide bandwidth and unique radiation pattern. In this paper the modified complementary split-ring resonator is compared with conventional complementary split-ring resonator (CSRR). It can be seen that the modified CSRR layer covers a wider band and provides better gain as compared to conventional CSRR layer. The total area occupied by the antenna is 32mm × 30mm.

Keywords

CSRR, Wideband, modified CSRR, metamaterial

I. Introduction

There is an upsurge for the requirement of ultra wideband systems that cover maximum frequency bands. In February 2002, the unlicensed band 3.1-10.6 GHz was assigned by Federal Communication Commission (FCC) as Ultra Wide Band (UWB) [1]. The Ultra Wide Band systems have many applications in different fields such as radiolocations, information communication, localization etc [1]. The antennas supporting UWB systems can be used in transmission devices such as DVD, camera, HDTVs etc. Microstrip patch antenna has a low profile structure and can be considered for UWB systems [2].

The microstrip patch antenna has a major limitation of narrow bandwidth and hence cannot be used for UWB systems [3]. However different techniques have been proposed in the recent past to increase the bandwidth of the antenna including increasing the height of the antenna, using slots on the patch and ground plane, using parasitic elements etc [4]. A recent technique called metamaterial has been proposed that increases the bandwidth of the antenna and also provides a low system cost [5].

The metamaterials are composite structures having properties that are not found in natural materials [6]. They are also recognized as double negative materials as they possess negative permittivity and permeability. The concept of metamaterial first came into lime light in 1968 by a Russian physicist Victor Veselago [7]. The unique properties of Metamaterial have developed many novel antennas. The antennas based on metamaterials have compact size and are highly directive [8]. These structures interact with free-space propagating electromagnetic waves and hence provide desired permittivity and permeability. One of the major advantages of using this technique is that it improves the bandwidth and efficiency of the antenna. These antennas find their applications in different fields such as communication links, navigation systems and surveillance [9].

In this paper, a compact and low profile patch antenna using modified CSRR layer has been proposed. The proposed antenna is composed of a metamaterial layer on the finite ground plane. The designed antenna provides high gain with wideband coverage. Furthermore the antenna has also been compared with conventional CSRR layer. The results shows that the modified CSRR patch antenna shows better results in terms of gain and bandwidth coverage as compared to conventional CSRR patch antenna. Section II presents the design of the antenna. Various results are discussed in Section III. A comparison table between the two antennas is also included. The simulations were carried out in Ansoft's High Frequency Structure Simulator (HFSS) software.

II. Antenna Design

In order to design a compact and wideband antenna, a modified complementary split-ring resonator unit has been implemented on the radiating patch of the antenna.

Figure 1 shows the detailed dimensions of the proposed antenna & figure 2 shows geometry of proposed antenna. The antenna is designed on Roger Duroid 5880 substrate. The thickness of the substrate is 0.8mm and relative dielectric constant of 2.2. The total dimensions of the substrate are 32mm × 30mm. Hence the total volume occupied by the antenna is 32mm × 30mm × 0.8mm. The antenna consists of a modified complementary split-ring resonator (CSRR) layer on the patch of the antenna. The antenna is fed through microstrip feed line with dimensions 12mm × 2.2mm.

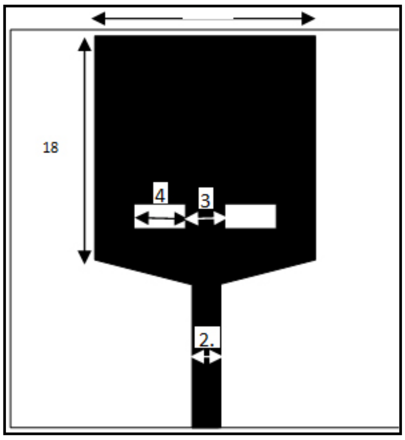

Fig. 1 : Detailed Dimension of Top Patch (mm)

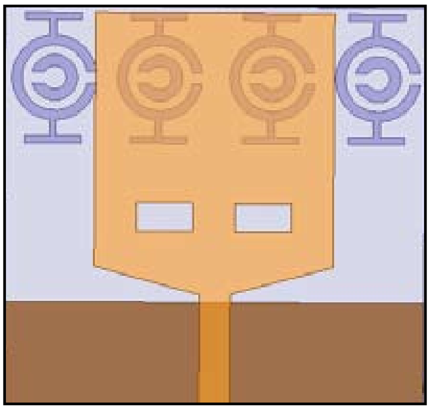
Fig. 2 : Proposed Design with Modified CSRR

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Figure 3 shows the geometry of the antenna with conventional CSRR layer. The dimensions of both the antennas are similar i.e., 32mm × 30mm × 0.8mm. The antennas are fed through microstrip feed line.

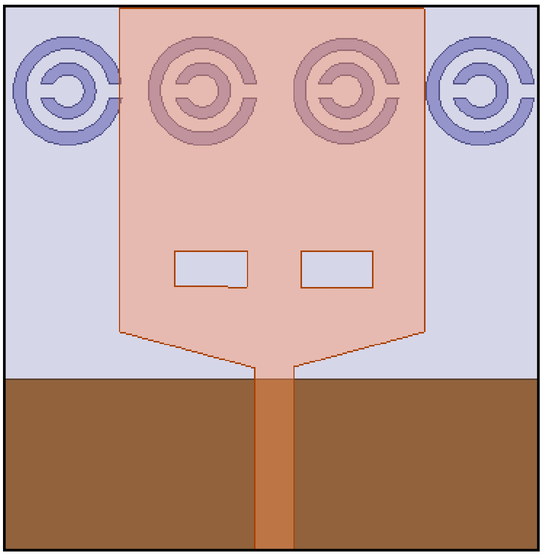

Fig. 3 : Antenna Design with conventional CSRR

III. Results And Discussions

In this section, simulation and experimental results of the proposed antenna are discussed. The antenna is designed and simulated using ANSOFT HFSS.

Figure 4 shows the simulated return loss of the proposed antenna with CSRR layer. According to the results, the proposed antenna covers a wide bandwidth of 10.81 GHz with resonant frequencies at 3.21 GHz, 6.02 GHz, 6.49 GHz, 7.19 GHz, 8.78 GHz & 14.17 GHz and return loss -8.24, -21.85, -31.41, -26.03, -16.20 & -16.29 respectively.

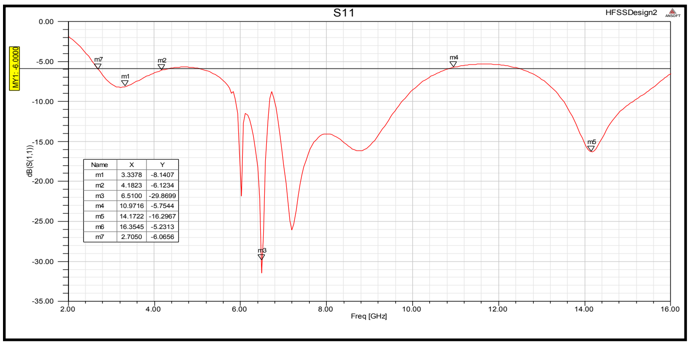

Fig. 4 : Simulated Return Loss parameter of proposed design with CSRR

Figure5 shows the simulated return loss of the proposed antenna with modified CSRR layer. According to the results, the proposed antenna covers a wide bandwidth of 12.91 GHz with resonant frequencies at 3.33 GHz, 5.74 GHz, 7.23 GHz, 8.78 GHz, 13.37 GHz & 14.82 GHz and return loss -8.55, -16.39, -23.40, -8.84, -12.31 & -11.93 respectively.

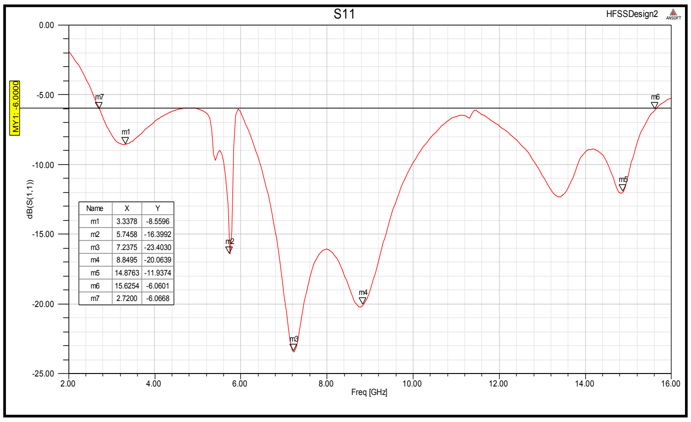

Fig. 5 : Simulated Return Loss parameter of proposed design with Modified CSRR

Figure 6 shows Voltage Standing Wave Ratio (VSWR) of the proposed antenna design with Modified CSRR. The value VSWR should be either 3:1 or less than 3 at the resonating frequencies. VSWR at various frequencies 7.23 GHz, 8.80 GHz and 5.47 GHz is 1.1, 1.7 and 2.6 respectively.

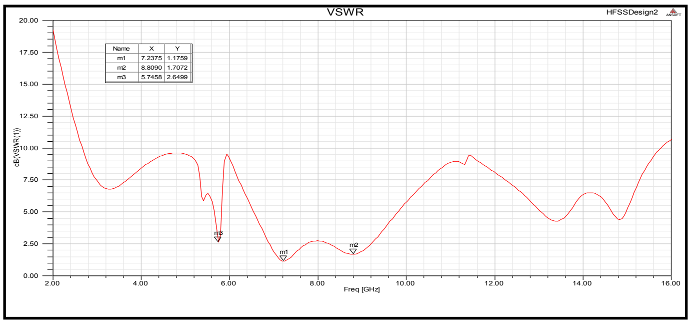

Fig. 6 : Simulated VSWR of the proposed antenna with modified CSRR

Figure 7 shows Voltage Standing Wave Ratio (VSWR) of the proposed antenna design with CSRR layer. VSWR at various frequencies 6.49 GHz, 7.2 GHz and 6.02 GHz is 0.46, 0.49 and 1.40 respectively.

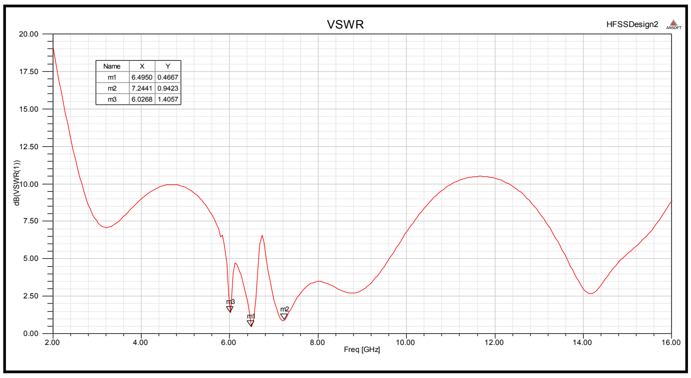

Fig. 7 : Simulated VSWR of the proposed antenna with modified CSRR

The simulated peak gain with modified CSRR layer across the impedance bandwidth of the total field is shown in figure7. As depicted from the results, the total peak gain of 9.41 dB can be observed. Hence the proposed antenna shows good gain performance. Figure 8 shows the simulated gain of the proposed antenna with modified CSRR layer.

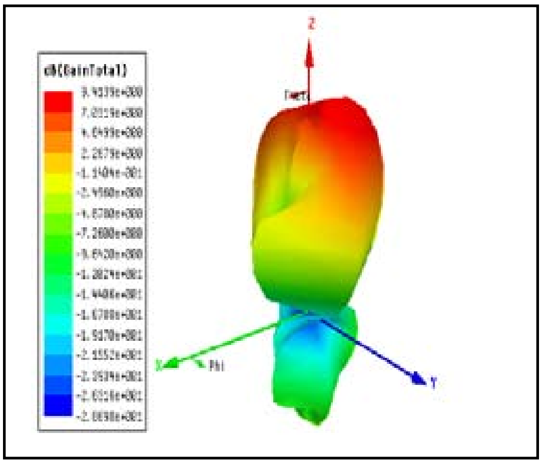

Fig. 8 : Simulated 3D Gain of the proposed antenna with modified CSRR

Figure 9 shows the simulated gain pattern with CSRR layer. A peak gain of 9.19 dB can be observed from the results.

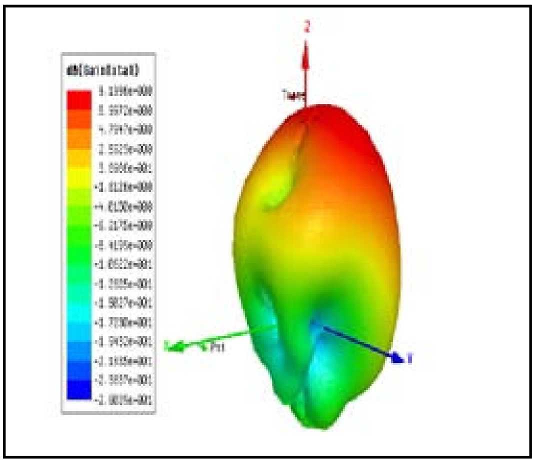

Fig. 9 : Simulated 3D Gain of the proposed antenna with CSRR

A comparison table between the two designed antennas is shown in Table 1. From the results it is concluded that the modified CSRR shows better results in terms of bandwidth coverage and gain.

Table 1 : Comparison between Conventional CSRR & Modified CSRR Design

Parameters	Design With CSRR	Proposed Antenna with Modified CSRR
Resonating frequency	3.21 GHz, 6.02 GHz, 6.49 GHz, 7.19 GHz, 8.78 GHz & 14.17 GHz	3.33 GHz, 5.74 GHz, 7.23 GHz, 8.78 GHz, 13.37 GHz & 14.82 GHz
Return loss (dB)	-8.24, -21.85, -31.41, -26.03, -16.20 & -16.29	-8.55, -16.39, -23.40, -8.84, -12.31 & -11.93
Overall Bandwidth Coverage	10.81 GHz	**12.91 GHz**
Gain	9.19 dB	**9.41 dB**

IV. Conclusion

In this paper a comparison has been performed between a conventional CSRR layer and a modified CSRR layer implemented on the radiating patch of the antenna. From the results it is concluded that by keeping the same dimensions i.e., 11mm × 30mm × 0.8mm the modified CSRR layers shows better performance in terms of gain and bandwidth. The modified CSRR layer covers a bandwidth of 12.91 GHz whereas the conventional CSRR layer covers a bandwidth of 9.41 GHz. A total gain of 9.41 dB was obtained by modified CSRR and 9.19 dB from conventional CSRR.

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