Chapter 7
Application of SRR Loaded in CPW FED UWB Monopole Antenna
7.1 INTRODUCTION

Ultrawideband (UWB) antennas have been an active area of research since the FCC has opened up the spectrum of 3.1 GHz-10.6 GHz for civilian use in 2003. However interference with narrowband signals like WLAN, PCS, DCS and WiFi has lead to a new area of designing UWB antennas with band notch characteristics. Several design configurations have been proposed in open literature using planar monopole antennas with modified radiator and/or ground plane to achieve this characteristic [1]-[14]. Notch characteristics with triple notched frequency bands [1]-[5], dual notched frequency bands [6]-[9] and single notch bands [10]-[14] were achieved using various design configurations on planar monopole printed antennas. Each antenna has unique design characteristics for obtaining the desired notches like multiple etched slots on the patch and split ring resonators (SRRs) coupled to the feed line [1] to achieve triple notch frequency. Similarly other designs include inserting two I-shaped notched slots and a open-ended U-shaped slot on the edge of the radiation patch [2], using three open-ended quarter-wavelength slots [3], embedding an Omega-shaped slot on the radiating patch [4] and by using a pentagonal radiating patch with two bent slots [5] yielded triple notch characteristics. Dual band-notched characteristic have been proposed by etching one quasi-complementary split-ring resonator (CSRR) in the feed line [6]. Dual-band-notched has also be achieved using a trapezoidal ground plane with a rectangular slot together with a modified complementary co-directional split ring resonator (SRR) etched on the radiating patch [7] and also by employing a U-slot defected ground structure in the ground plane on the back side and etching a split ring slot in the radiation patch on the front side [8]. Two notched frequency bands were achieved by embedding an E-slot in the radiation patch and a U-slot defected ground structure in the feeding line [9]. Similarly, antenna consisting of a patch with arc-
shaped edge and a partially modified ground plane for band notched characteristics has been proposed in [10]. The band-notch characteristic was also realized by introducing a microstrip feeder with a tuning stub [11], utilizing a mushroom-type electromagnetic-bandgap (EBG) structure is an effective way for band-notched designs [12] and also by using a coplanar waveguide with two asymmetrical ground planes [13]. An ultra-wideband (UWB) planar monopole antenna with a tunable band-notch characteristic was realized by loading an embedded resonant slot with a varactor [14].

![Fig. 7.1](image_url) Schematic of a CPW fed Printed Circular Monopole loaded with Square SRR (a) Top view with SRR loaded in the back side (b) Side View showing the printed SRR separated by $h$ from the CPW fed Printed Circular Monopole (c) Square SRR loaded on the back side of the CPW fed monopole antenna

This chapter describes a new and simple method to design a frequency notched UWB antenna by loading a pair of SRR on the opposite surface of the CPW line feeding the circular monopole antenna. These SRRs are placed symmetrically on the other side of the CPW fed planar monopole antenna and this leads to very weak radiation at the notch frequency. This can be attributed to a very strong magnetic coupling of the EM
signal with the SRR around its magnetic resonance frequency determined by the SRR's geometrical and material constitutive parameters. This phenomenon has been studied, analyzed and implemented in previous chapters. This unique property can be used to avoid the possible interference in UWB systems (3.1 GHz to 10.6 GHz). Figure 7.1 shows the schematic diagram of the proposed antenna. The circular monopole having radius $R$ is fed by a CPW consisting of ground planes having width $W_1$ and $W_2$, length $L_s$ and a strip line of width $S$ and length $L_s + \delta$. The antenna is printed on a substrate having thickness $h$, and dielectric constant $\varepsilon_r$. Two square shaped split ring resonators having dimension $a_{sr}$ which is half the dimension of the side-length of the SRR, conductor thickness $c$, separation between rings $d$ and split gaps $g_1$ and $g_2$ as shown in Fig. 7.1 (c), are printed on the other side of the substrate with their centers coinciding with the slot lines of the CPW feed. This design can be employed on any CPW planar monopole UWB antenna and does not require change in the shape of the radiator or the ground plane nor does it conflict with any other parameters of the antenna.

7.2 Antenna Design

The fabricated prototype of the SRR loaded circular monopole antenna is shown in Fig. 7.2. Table 7.1 shows the design parameters used to design the prototype. The circular monopole is fed with a coplanar waveguide (CPW) with dimensions as in Table 7.1 and the CPW line having characteristic impedance of nearly 50 ohms. The monopole, CPW and SRR are printed on a dielectric substrate having dielectric constant, $\varepsilon_r = 2.33$ and thickness, $h = 1.575$mm. The square SRR having dimensions as provided in Table 7.1 yields a magnetic resonance frequency of 6.34 GHz. This is
determined from the equivalent circuit approach which involves calculation of distributed capacitance between the rings of the SRR \( (C_{pu}) \) and total inductance of the SRR \( (L_T) \) as derived in chapter 3. The SRR geometry and the dielectric constant of the host substrate are the factors determining the magnetic resonance frequency of the SRR [15]. The SRR dimensions for the related frequencies of stop band are calculated using the magnetic resonance frequency for the square SRR derived in Chapter 3 and is given by,

\[
f_0 = \frac{1}{2\pi \sqrt{L_T C_{eq}}} = \frac{1}{2\pi L_T \left[ \left( \frac{2a_{avg} - g}{2} \right) C_{pu} + \frac{\varepsilon_r \varepsilon_0 c h}{2g} \right]}
\]

Fig. 7.2 Fabricated prototypes of the CPW fed circular monopole loaded with SRR. Parameters as in Table 7.1.

### 7.3 Experimental and Simulation Results

Two working prototypes of the CPW fed circular monopole antenna, one without SRR loading and the other with SRR loading were printed on a Taconic substrate TLY-3 having thickness \( h = 1.575 \) mm and dielectric constant, \( \varepsilon_r = 2.33 \). The prototypes were measured using a vector network analyzer (VNA Model No. Agilent E8363B) and an anechoic chamber to obtain the impedance and radiation
characteristics. Figures 7.3 and 7.4 show the measured and simulated return loss $|S_{11}|$ of the fabricated prototypes with design parameters described in Table 7.1. As can be seen from Fig 7.3, the simple circular monopole without any loading operates from

| TABLE 7.1 |
| Design parameters of the fabricated CPW fed circular monopole antenna loaded with SRR printed on a dielectric substrate having dielectric constant $\varepsilon_r = 2.33$ (Parametric Variables as shown in Fig. 7.1) |

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>All are in (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R$</td>
<td>12.5</td>
</tr>
<tr>
<td>$W$</td>
<td>50</td>
</tr>
<tr>
<td>$L$</td>
<td>50</td>
</tr>
<tr>
<td>$W_1 = W_2$</td>
<td>22</td>
</tr>
<tr>
<td>$S$</td>
<td>5</td>
</tr>
<tr>
<td>$L_S$</td>
<td>22.4</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.2</td>
</tr>
<tr>
<td>$\alpha_{er}$</td>
<td>2.5</td>
</tr>
<tr>
<td>$C$</td>
<td>0.35</td>
</tr>
<tr>
<td>$d$</td>
<td>0.6</td>
</tr>
<tr>
<td>$g_1 = g_2$</td>
<td>0.7</td>
</tr>
<tr>
<td>$h$</td>
<td>1.575</td>
</tr>
</tbody>
</table>

Fig. 7.3 Simulated and measured $S_{11}$ characteristics of the fabricated prototype without SRR loading. Parameters as given in Table 7.1
Fig. 7.4 Simulated and measured $S_{11}$ characteristics of the fabricated prototype with SRR loading. Parameters as given in Table 7.1

Fig. 7.5 Simulated VSWR characteristics of the CPW fed UWB Circular Monopole with and without SRR loading. Parameters as given in Table 7.1
2.6 GHz to 10.8 GHz considering 10 dB return loss. When loaded with SRR as shown in Fig. 7.4, the return loss shows a notch at around 6.34 GHz corresponding to the resonance frequency of the employed SRR. The SRR is excited at this frequency due to very strong magnetic coupling of the propagating signal with the SRR around its magnetic resonance frequency and yields a notch in the reflection coefficient. This frequency is determined by the geometrical parameters \( a_{cl}, c, d, \) and split gaps \( g_1 \) and \( g_2 \) of the employed SRR and constitutive parameter mainly the permittivity \( \varepsilon_r \) of substrate on which the SRR is printed. This resonance frequency of the square SRR (S-SRR) can be calculated using the design formulations proposed in Chapter 3.

Figure 7.5 compares the simulated VSWR of the CPW fed SRR loaded circular UWB monopole and the unloaded circular UWB monopole depicting very high VSWR of almost 8.5 at 6.34 GHz. Figures 7.6 (a) and (b) show the Smith chart of the proposed antenna with and without SRR loading. Figures 7.7 (a) and (b) depicts the impedance
Fig. 7.7 Impedance plot (simulated) of CPW fed UWB circular monopole antenna (a) with SRR loading, (b) without SRR loading.

The measured and simulated radiation patterns in the $x$-$y$ plane and $x$-$z$ plane of the SRR loaded circular UWB monopole and the unloaded circular UWB monopole.
Fig. 7.8 Measured and Simulated radiation patterns for x-y plane and x-z plane of the fabricated antenna, (Parameters as in Table 1) for three different frequencies (a) 3.1 GHz (b) 6 GHz (c) 10 GHz

(--- [Measured], --- [Simulated])

Fig. 7.9 Three dimensional simulated radiation pattern of the SRR loaded CPW fed Circular Monopole UWB antenna at three different frequencies (a) 4.45 GHz (b) 6.34GHz (Resonance frequency of SRR) (c) 7.72 GHz

plane for the CPW fed planar monopole with SRR loading are presented in Fig. 7.8 for 3.1 GHz, 6 GHz and 10 GHz. The radiation patterns exhibit good directivity in the x-y plane and omni directionality for the x-z plane.
The 3D radiation patterns of the SRR loaded circular UWB monopole antenna are shown in Fig. 7.9. Figure 7.9 (b) shows the 3D radiation pattern of the antenna at 6.34 GHz corresponding to the resonance frequency of the SRR when the SRR is fully excited. Figures 7.9 (a) and (c) depict the 3D radiation patterns of the antenna at two frequencies, 4.45 GHz and 7.72 GHz, on either side of the resonance frequency of the SRR. It is evident from the 3D patterns that at frequency corresponding to the resonance frequency of the SRR, the realized gain and the corresponding radiation efficiency of the antenna falls drastically compared to the gain at the other two frequencies on either side of resonance. The measured and simulated gain versus frequency of the SRR loaded prototype is illustrated in Fig. 7.10. The plot shows a reduction in gain at the notch frequency of operation as was evident in Fig. 7.9(b) whereas the gain at the rest of the frequencies remains acceptable. The measured gain is also compared with the simulated results showing good correspondence at
frequencies near SRR resonance frequency. The measured result yields higher value of directive gain at lower and upper end of the operating spectrum compared to the simulated gain.

The simulated surface current distribution at three different frequencies 6.34 GHz, 3.1 GHz and 10 GHz of operation is shown in Fig. 7.11. It is clearly visible that at the frequency of interest at 6.34 GHz shown in Fig. 7.11 (b), corresponding to the resonance frequency of the SRR, the circular monopole is not excited resulting in suppression of radiation at that frequency. However, at the two ends of the operating spectrum corresponding to 3.1 GHz and 10 GHz, the antenna characteristics remain unperturbed due to minimal excitation of the SRR.

7.4 Conclusion

A compact CPW fed UWB SRR loaded circular monopole with frequency notch characteristics is proposed in this chapter. The configuration works with precise and strategic positioning of the SRR with respect to the CPW feeding the radiator. This design does not require tampering of the radiating element or the ground plane. Since
the antenna design and SRR dimensions are independent of each other, the notch frequency can be customized to any value. Multiple SRRs of different dimensions may be employed to yield multi frequency suppression over the operational bandwidth. Prototypes have been measured and fabricated and the results are compared and validated using simulations. The measured impedance and radiation characteristics are compared with simulation showing good correlation. The theoretical analysis and the design methodology can be used to customize the rejection frequency on an UWB antenna as per the requirement of the design specifications.
REFERENCES


[16] High Frequency Simulation Software, Ansoft corp. v.11