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Research article

PARAMETRIC STUDY OF IMPROVED U-SHAPED SPLIT RING RESONATOR STRUCTURE ON UWB MONOPOLE ANTENNA

Shaik Mohammad Khaja[1]., Suman V.K[2]., Syed Azeemuddin[3] and MotiRam[4]

[1]Shri Venkateshwara University, Gajraula, Dist. Amroha, U.P. India
[2]IIMT, Meerut, U.P. India
[3]IIIT Hyderabad, Hyderabad, A.P. India
[4]Shri Venkateshwara University, Gajraula, Dist. Amroha, U.P. India

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A B S T R A C T

This paper discusses about the parametric study work U-shaped split ring resonator (SRR) structure effect on the ultra-wide-band (UWB) monopole. Five different stage are done, consist from Design *A* to Design *E*, with three stages are considers with parametric study – Design *B*, Design *C*, and Design *D*. Firstly, Design *A* represent the basic UWB monopole antenna without SRR structure while the last design, Design *E* shows the proposed UWB monopole antenna with modified SRR structure. The Design *E* successfully resonate at first resonant frequency of 6.272 GHz with return loss performance of – 25.91 dB while resonate at second resonant frequency at 7.82 GHz with return loss of – 26.165 dB. This antenna operates at UWB range frequency from 2.572 GHz to 10.746 GHz of with bandwidth performance of 8.174 GHz. It shows that a 0.972 GHz range of band-notch frequency bandwidth, starting with 5.028 GHz to 6.0 GHz.

INTRODUCTION

The rapid growth of wireless communication desires the need of dual-band, tri-band or multiband antenna. Many techniques are done previously to cater this needed. Besides that, the ultra wide-band (UWB) band covers the frequency between 3.1 GHz and 10.6 GHz. There are several researchers that apply his antenna design with UWB technique to create an ultra wide-band effect such as in [1-4]. Azizi had been design a staircase patch antenna technique for UWB frequency range that function for human arm model [5] while in his other works it applies complimentary patch technique to create the UWB on the nerve fiber action potential of human body [6].

Another work on UWB antenna is by Elobaid [7] that design for future wireless networks that using on flexible polymer-fabric tissue in frequency band range between 2.2 GHz and 25 GHz. In the other hands, Lu [8] had been proposed CPW-fed UWB antenna that have band notches function at 5.1-5.9 GHz for WLAN rejection. The microstrip patch antenna technology is the basic type in fabricating the antenna because of many advantages such as the lightweight, and easy to construct. This microstrip patch using FR-4 also suitable for UWB technique without using a high cost substrate such as Roger Duroid substrate.

Corresponding author:* **Shaik Mohammad Khaja
Shri Venkateshwara University, Gajraula, Dist. Amroha, U.P. India

In this work, a several parametric studies of different dimension of the split ring resonator at UWB monopole antenna had been done. The parameter such as return loss, resonant frequency and antenna gain are considered to see the best performance of antenna design.

Split Ring Resonator Design

The split ring resonator structure has been firstly presented on 1999 by Pendry [9] and 2000 by Smith [10] to create material with negative permeability. This structure sometimes called left handed material (LHM) structure or metamaterial. This SRR structure potentially to reduce the size and functioning to create tri-band antenna effect, example in [11]. In his paper, the researcher design tri-band fractal SRR structure at WLAN 2.4 GHz, WiMAX 3.5 GHz and WLAN 5.2 GHz antenna. In other paper of Rajasekhar [12], he had been proposed a triple-band monopole SRR antenna for WiMAX, WLAN and RFID applications. Yang [13] introduce the CPW-fed slot antenna with SRR structure that covers WLAN and WiMAX application with bandwidth between 1.96 GHz and 4.33 GHz while at other part between 5.05 GHz and 7.23 GHz. The others work on SRR antenna is stated in [14-17]. There is also the combination technique of UWB antenna with embedded of SRR structure to effect the wider bandwidth and miniaturize size of the antenna, such as in [18-20].

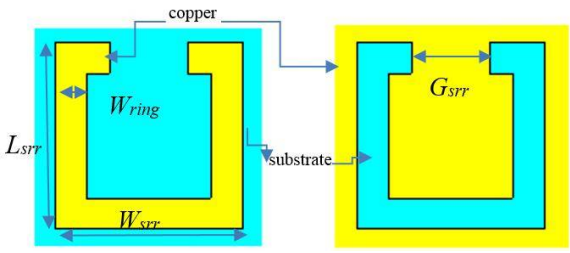

Figure 1 The schematic diagram of the SRR, (a) basic SRR, (b) complimentary SRR

The SRR consist several types such as the basic SRR or sometime called the edge couple SRR, the broadside couple SRR, spiral type of SRR and other types called open shaped SRR structure. Beside apply in the antenna, this structure is found in several applications such as microwave absorber, RF filter, oscillator and sometimes used as the structure in the frequency selective surface. Figure 1 shows the basic SRR and complimentary SRR (C-SRR). A basic SRR consist a copper ring (represent the inductor) that have a gap between ring (represent the capacitor effect). A complimentary SRR is the mirror situation of the basic SRR that contain a FR-4 substrate base ring while the outer part is copper based with thickness of 0.035 mm. Table 1 shows the dimension of the SRR

Table 1 The dimension of the SRR structure

Parameter of the antenna	Symbol	Dimension (mm)
SRR width	*Wsrr*	6.0
SRR length	*Lsrr*	6.0
SRR gap	*Gsrr*	2.5
SRR ring width	*Wring*	1.0

Antenna Design

This section describes the parametric study of different stage of UWB monopole antenna design, starting with the basic antenna of Design *A* to last antenna design in Design E. The parameter that consider in this section in the return loss with resonant frequency, the band-notch frequencies, gain and bandwidth of the antenna.

Design A – Basic UWB Monopole Antenna

This Design *A* is the starting basic design that consist a staircase patch antenna at the front side on 32.0 mm substrate width, *Ws* and 32.0 mm substrate length *Ls* while a 32.0 mm *Wg* x 16.0 mm *Lg* partial ground at ground plane. The feedline dimension is 3.6 mm *Wf* x 17.0 mm *Lf*.. Figure 2 shows the schematic diagram of basic UWB monopole antenna.

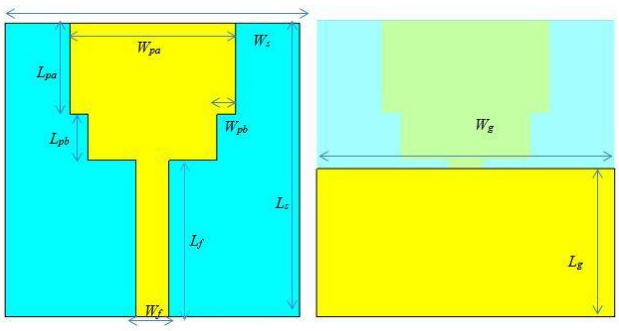

Figure 2 Schematic diagram of basic UWB monopole antenna

Figure 3 shows the return loss of basic UWB monopole antenna. From the graph, it shows that this antenna covers operate frequency starting from 2.777 GHz to 10.847 GHz of frequency and covers in 8.07 GHz of bandwidth performance. At 4.916 GHz of resonant frequency had been achieve with – 29.992 dB of return loss while at 8 GHz and 9.124 dB, it shows performance of – 25.401 dB and – 27.754 dB, respectively. The gain performance for all resonant frequency is 1.522 dB, 3.316 dB and 3.905 dB, respectively.

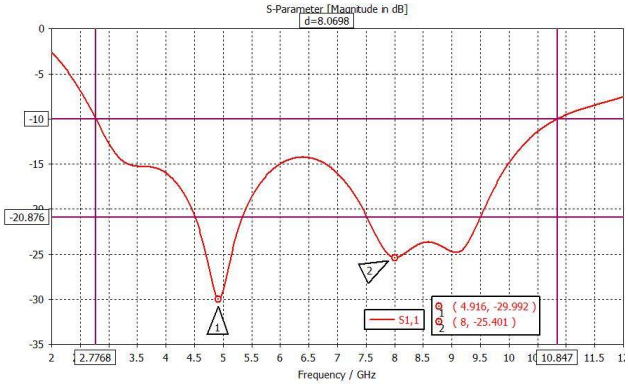

Figure 3 Return loss of basic UWB monopole antenna

Design B – UWB Monopole Antenna with Modified SRR ring gap

The second stage (Design *B*) of the design consist an addition of the basic SRR structure on the patch part UWB monopole antenna. The dimension of this UWB antenna stage is similar from the Design *A* accept the SRR part. The dimension of the SRR is 6.0 mm *Wsrr* x 6.0 mm *Lsrr* of split ring resonator with SRR gap, *Gsrr* of 2.5 mm. For the first parametric study is on the different dimension of the SRR gap, *Gsrr* starting from 0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm and 2.5 mm, with increment of 0.5 mm. Figure 4 represent the schematic diagram of UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring top width, *Gsrr*).

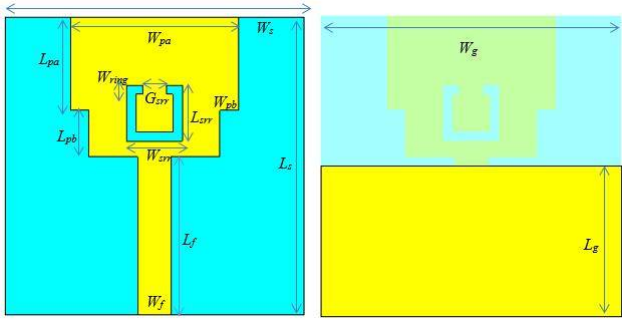

Figure 4 Schematic diagram of UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring gap, G_{srr})

Figure 5 illustrate the parametric study of return loss for UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring gap, *Gsrr*). It shows that the increment of the SRR width will effect to shifted to higher band-notch frequency. For example, the *Gsrr* = 0.5 mm have a band-notch at 4.988 GHz with - 8.222 dB of return loss, while it can be shifted to 5.732 GHz (return loss of - 6.893 dB**)** with the increment of *Gsrr* to 2.5 mm. Besides that, it had been shows the increment of the ring gap effect to increase the bandwidth performance of the UWB monopole antenna. From Table 2, it shows the increment from 239.0 MHz to 370.0 MHz for the *Gsrr* = 0.5 mm to *Gsrr* = 2.5 mm.

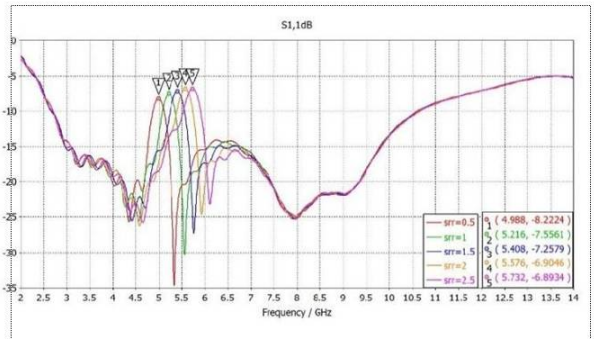

Figure 5 Parametric study of return loss for UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring gap, G_{srr})

Table 2 UWB monopole antenna with SRR with different width of SRR ring gap, G_{srr}

Gsrr	Band-notch frequency (GHz)	Return loss (dB)	Frequency range (GHz), Bandwidth
0.5	4.988	- 8.222	4.871 - 5.110 (239 MHz)
1.0	5.216	- 7.556	5.081 - 5.362 (281 MHz)
1.5	5.408	- 7.258	5.240 - 5.558 (318 MHz)
2.0	5.576	- 6.905	5.397 - 5.741 (344 MHz)
2.5	5.732	- 6.893	5.535 - 5.905 (370 MHz)

Design C – UWB Monopole Antenna with Modified SRR Ring Top Width

Design *C* is consisting the modified SRR ring top width, *Wringtop* at UWB monopole antenna. At this stage four increment in parametric study had been work with *Wringtop* = 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm. Another dimension of the SRR structure is remaining as before. Figure 6 represent the schematic diagram of UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring top width, *Wringtop*). Figure 7 shows the parametric study of return loss performance for UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring top width, *Wringtop*).

Table 3 shows the UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring top width, *Wringtop*). It shows that, the increment of the *Wringtop* will effect to shifted the band-notch frequency to lower part, from 5.76 GHz to 4.738 GHz. It also shows that the bandwidth also reduces from 373 MHz to 335 MHz.

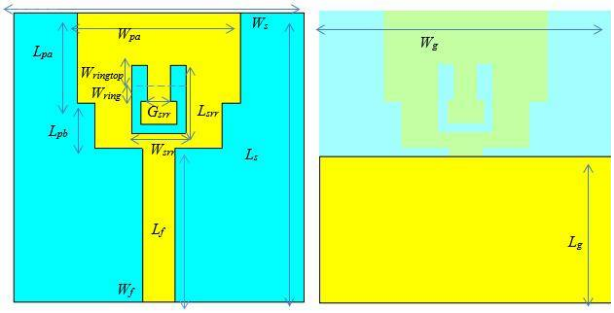

Figure 6 Schematic diagram of UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring top width, $W_{ringtop}$)

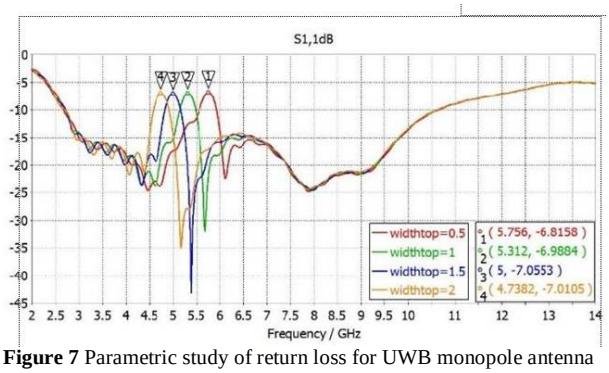

Figure 7 Parametric study of return loss for UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring top width, *Wringtop*)

Table 3 UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR ring top width, $W_{ringtop}$)

$W_{ringtop}$	Band-notch frequency (GHz)	Return loss (dB)	Frequency range (GHz), Bandwidth
0.5	5.756	- 6.816	5.532 – 5.905 (373 MHz)
1.0	5.312	- 7.988	5.125 – 5.463 (338 MHz)
1.5	5.000	- 7.055	4.816 – 5.145 (329 MHz)
2.0	4.738	- 7.011	4.569 – 4.904 (335 MHz)

Design D – UWB Monopole Antenna with Modified Side Width

Next, the work followed by Design *D*, UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR side width, *Wringside*, shown in Figure 8. In this case, four different dimensions of *Wringside* are consider, starting with 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm. Figure 9 shows the parametric study of UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR side width, *Wringside*).

From the graph, it shows that the notch-band frequency had been reduced by increase the *Wringside* dimension. In this case, *Wringside* = 0.5 mm shows the performance of the band-notch frequency at 5.216 GHz with return loss of – 5.491 dB while the *Wringside* = 2.0 mm effect to shifted the band-notch frequency to 4.724 GHz with – 3.213 dB. Table 4 shows the UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR side width, *Wringside*)

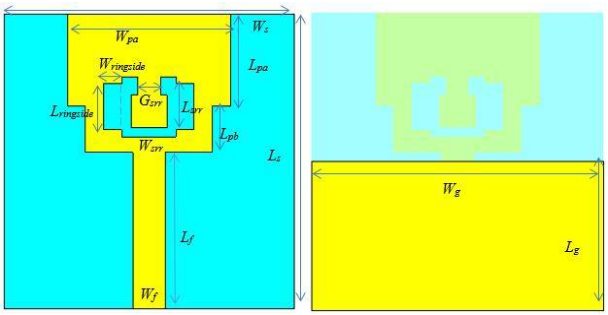

Figure 8 Parametric study of return loss for UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR side width, $W_{ringside}$)

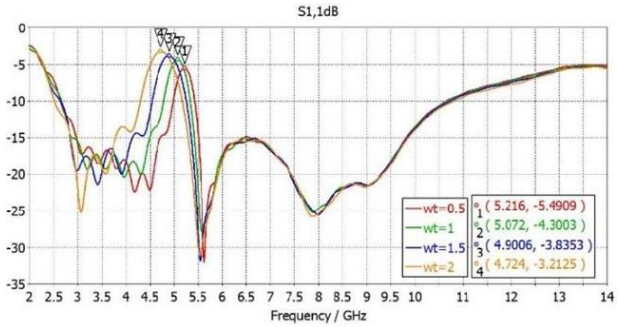

Figure 9 Parametric study of UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR side width, $W_{ringside}$)

Table 4 UWB monopole antenna with modified U-shaped SRR (with parametric study of SRR side width, $W_{ringside}$)

$W_{ringside}$	Band-notch frequency (GHz)	Return loss (dB)	Frequency range (GHz), Bandwidth
0.5	5.216	- 5.491	4.986-5.422 (436 MHz)
1.0	5.072	- 4.300	4.794-5.335 (541 MHz)
1.5	4.901	- 3.835	4.543-5.250 (707 MHz)
2.0	4.724	- 3.213	4.311-5.164 (853 MHz)

Design E – UWB Monopole Antenna with Modified U-Shaped SRR

This is the last part of the UWB monopole antenna design with the 1.75 mm width x 2.0 mm length cut-off rectangular effect at the above part of the SRR. Figure 11 shows the schematic diagram of UWB monopole antenna with modified U-shaped SRR while Figure 11 shows the return loss for of UWB monopole antenna with modified U-shaped SRR.

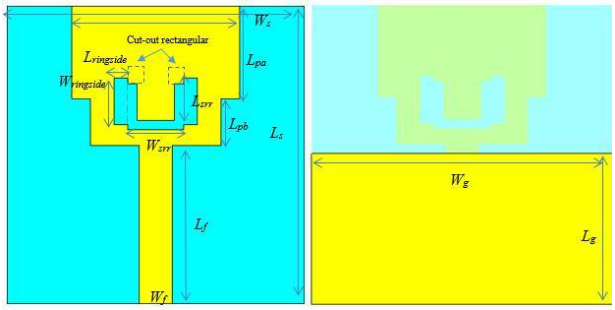

Figure 10 Schematic diagram of UWB monopole antenna with modified U-shaped SRR

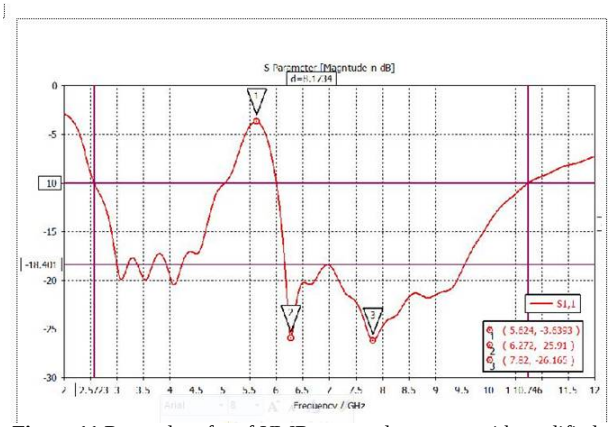

Figure 11 Return loss for of UWB monopole antenna with modified U-shaped SRR

From the graph of Figure 11, it displays the proposed antenna is covers at the UWB range frequency. It had been radiated from 2.572 GHz to 10.746 GHz with 8.174 GHz of bandwidth. It also had been creating a band-notch frequency range between 5.028 GHz and 6.0 GHz with 0.972 GHz of bandwidth. A band-notch frequency peak is shown at 5.624 GHz with return loss of – 3.639 dB. Besides that, this antenna has a two-different resonant frequency at 6.272 GHz 7.82 GHz with return loss of – 25.91 dB and – 26.165 dB, respectively.

Table 5 represent the performance of the UWB monopole antenna with modified U-shaped SRR performance (Design *E*) while Figure 12 shows the antenna gain performance result of the UWB monopole antenna with U-shaped SRR.

Table 5 Performance of UWB monopole antenna with modified U-shaped SRR performance (Design *E*)

Frequency (GHz)	Return loss (dB)	Gain (dB)
Resonant frequency, 5.624	- 3.639	0.251
Resonant frequency, 6.272	- 25.91	1.763
Band-notch frequency, 7.82	- 26.165	3.213

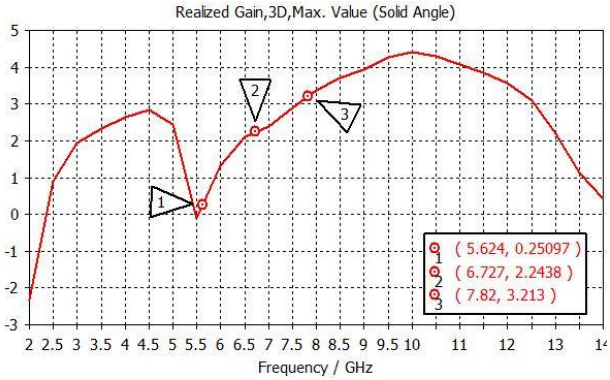

Figure 12 Antenna gain performance result of the UWB monopole antenna with U-shaped SRR

CONCLUSION

The UWB monopole antenna with U-shaped SRR design had been done with several parametric studies works at SRR structure. The UWB effect had been done by the partial ground at the back part of the antenna. The increment and the reduction the size of the SRR structure had been effect to shifted the location of the resonant frequency of the antenna. This technique also had a capability to control the size of the antenna by adjust the patch antenna after the reduction or the increment of the resonant frequency. The important thing in this work is to create the band-notch frequency of the antenna, effect from the embedded of the SRR structure at the patch antenna.

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