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Band-notch Effect of U-shaped Split Ring Resonator Structure at Ultra Wide-band Monopole Antenna

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Abstract

This work focuses on the development of the design the ultra-wide-band (UWB) monopole antenna with U-shaped split ring resonator (SRR) structure. This SRR structure successfully to create a band-notch at several frequencies. These works are offer in four dissimilar designs starting with Design *A1* and finished by the proposed Design *A4*. It started with a basic rectangular patch antenna of Design *A1* while it followed with the second stage of rectangular patch with partial ground plane for Design *A2*. Then, a truncated staircase-shaped technique had been done for Design *A3*. Lastly, a U-shaped of split ring resonator had been effect to give a better performance of Design *A4*. The performance of proposed antenna of Design *A4* at two different resonant frequency at 6.272 GHz with – 25.91 dB and 7.82 GHz with – 26.165 dB. It also covers at UWB range frequency between 2.572 GHz and 10.746 GHz of with bandwidth of 8.174 GHz. A 972 MHz range of band-notch rejecting frequency bandwidth, covers from 5.028 GHz and 6.0 GHz.

Keywords: band-notch frequency, split ring resonator, ultra-wide-band, monopole antenna, slot

INTRODUCTION

In the year 2002, the Federal Communication Commission's (FCC) allocate of the UWB frequency band between 3.1 GHz and 10.6 GHz. Several researcher had been used this technology to use as many application that only used single patch antenna design. Several techniques exist this UWB effect such as the parasitic patch, stacking, and partial ground. Sometimes, in UWB system it will cause the interference to the existing wireless communication systems from the other unwanted frequency. Various techniques have been invented to eliminate this interference in the UWB such as loading rejection function designs of different types or using different numbers at different spaces. However, this two technique effect need the larger size to the design. Besides that, the researcher used such as slotted elements at the patch whiles other paper using the split ring resonator structure in their design.

The microstrip patch antenna using FR-4 substrate is among the popular types compares other. These antennas are used because of the lightweight, low cost and easy to fabricate. However, sometime the unwanted noises that interference the several ranges among the UWB range

Ahmed [1] in his paper proposed a staircase UWB patch antenna with band-notch effect using U-shaped slot resonator at WLAN frequency range. This antenna covers UWB between 2.84 GHz and 13.9 GHz (fractional bandwidth of over 135%) with rejection band range at 5 GHz for WLAN application. In other paper by Bao [2], he used coupled H-shaped slotted element at extra slotted plate of groundside for band-notch rejection frequency at printed rectangular monopole antenna. This antenna operates in the range between 2.80 GHz and 12.60 GHz (bandwidth of 9.8 GHz) with band rejection range between 5.15 GHz and 5.825 GHz. Dayanandan [3] proposed X-band notch between 7.96 GHz and 9.01 GHz using inverted C-shaped and T-shape conductor for ultra-wideband circular patch antenna. This X-band is allocated for satellite and military applications. Waheed [4] proposed symmetrical staircase design coplanar waveguide (CPW)-fed between 2.00 GHz and ll.00 GHz of UWB band with WiMAX-WLAN dual band-notch frequency at 3.5 GHz and 5.0 GHz. Another UWB antenna with band-notch design with several techniqu are [5-10]

Split ring resonator (SRR) is one of the techniques to produce a band-notch rejecting band to the antenna design. Besides that, this structure also have capability to control the resonant frequency location [11] and effect of the size reduction of the antenna design [12-13]. Xiao [14] in his paper had been proposed a band-notches effect for UWB MIMO antenna. This antenna operates at 3.1 to 10.6 GHz region frequency with band region between 5.2 GHz and 5.9 GHz, effect by four slot-type split ring resonators structure that located surrounded on radiation patch and ground of the antenna. Li [15] in his paper

investigate the effect of modified SRR on UWB planar monopole antenna. The results shows there are two band-notch regions at different frequencies: 3.4 GHz and 5.2 GHz. Sarkar [16] used the parasitic rectangular SRR on the antipodal Vivaldi antenna to create the band-notch at 5 GHz until 6 GHz between the UWB range. Another UWB antenna with band-notch using SRR structure design is [17-20]. In this paperwork, a UWB monopole antenna with notch band effect using U-shaped SRR is offered.

METHODOLOGY

Figure 1 represents the development flow of UWB monopole antenna with U-shaped SRR (Design *A1* to Design *A4*). This antenna are design using simulation software of CST Microwave Studio using FR-4 substrate with dielectric contast of 4.4, substrate thickness of 1.6 mm and 0.035 mm thickness of copper.

The initial design stating with the Design *A1* (shown in Figure 1(a)) that consist only the basic rectangular patch antenna with length x width was 32.2 mm x 32.0 mm with FR-4 and copper thickness of 1.6 mm and 0.035 mm, respectively. This patch antenna is connected by 17.0 mm length x 3.6 mm width of feedline. At the below end of the feedline is the 50 ohm SMA connector port.

The next stage is the Design *A2* (shown in Figure 1(b)), consists of the basic monopole antenna with 32 mm width x 16 mm length partial ground effect. This partial ground technique basically functioning to create the wider bandwidth to the antenna. The patch antenna dimension is remained as the Design *A1*.

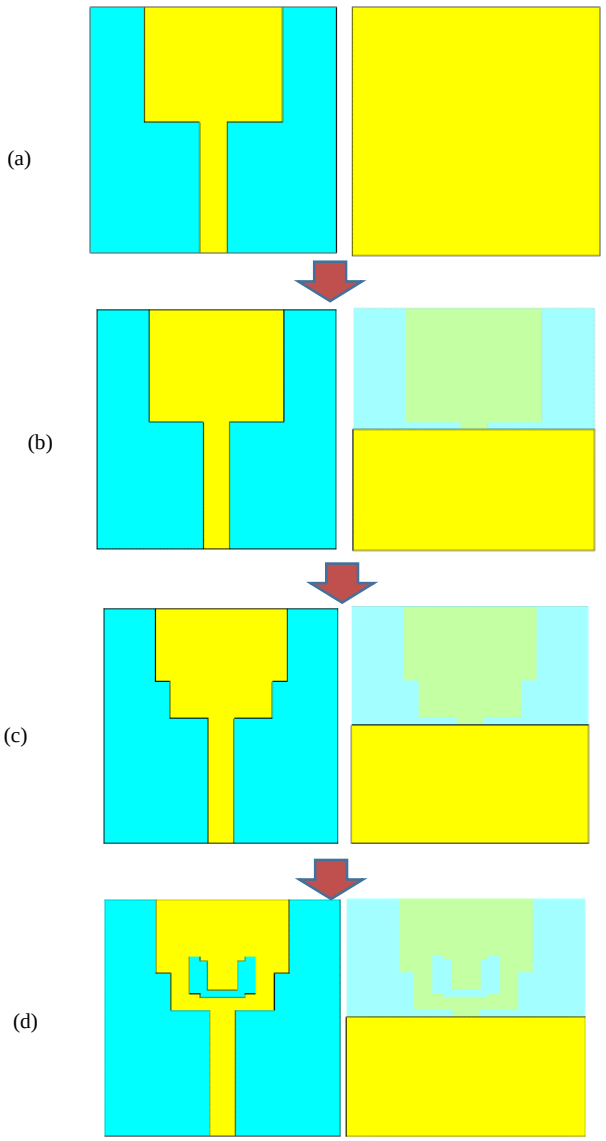


Figure 1. The development flow of UWB monopole antenna with U-shaped SRR (a) Design *A1*, (b) Design *A2*, (c) Design *A3*, (d) Design *A4*

Then, the designed is followed by the third development stage of Design *A3*, shown in Figure 1(c). In this case, basic UWB monopole antenna with the partial ground are had been cut-off by a 3 mm width x 5 mm length staircase shaped at the bottom part of the antenna. It had been expand more bandwidth performance for UWB antenna with 10.0 mm of patch length *a*, L_{pa} and 5.0 mm patch length b, L_{pb}.

Figure 2 shows the schematic diagram of the ultra-wide-band (UWB) monopole antenna with U-shaped split ring resonator (SRR) structure of Design *A4*. A 1.75 mm width x 2.0 mm length had of square been cut-out to control the location of the resonant frequency range for UWB. This SRR functioning to create a band-notch at several frequency range, depends on the size and the location at the patch. At this work, the width of SRR, W_{srr} = 6.0 mm and the width of the ringside of the SRR, $W_{ringside}$ = 5 mm.

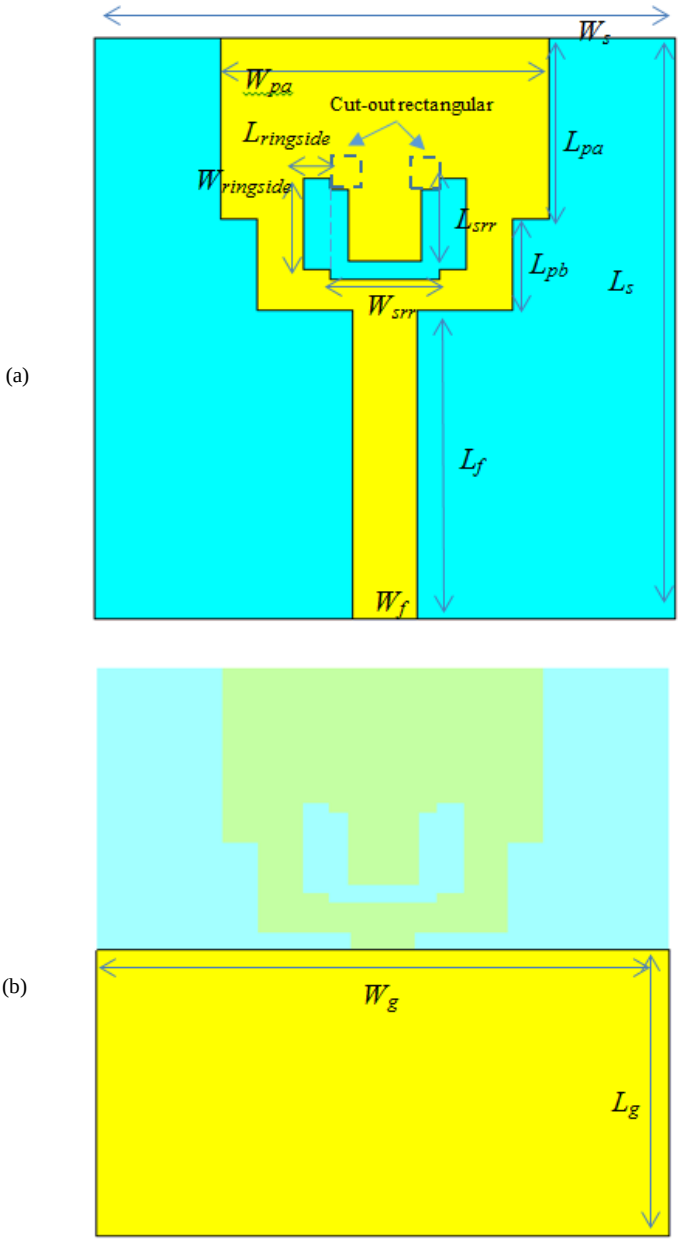


Figure 2. The schematic diagram of the ultra-wide-band (UWB) monopole antenna with U-shaped split ring resonator (SRR) structure of Design *A4* (a) front view, (b) back view

Figure 3 shows the fabricated version of the UWB monopole antenna with modified U-shaped SRR (Design *A4*). The dimension of this antenna stage follows as in the simulation design. This feedline antenna connected relates to the SMA connector. Table 1 shows the dimension for all design of the antenna.

(a)

(b)

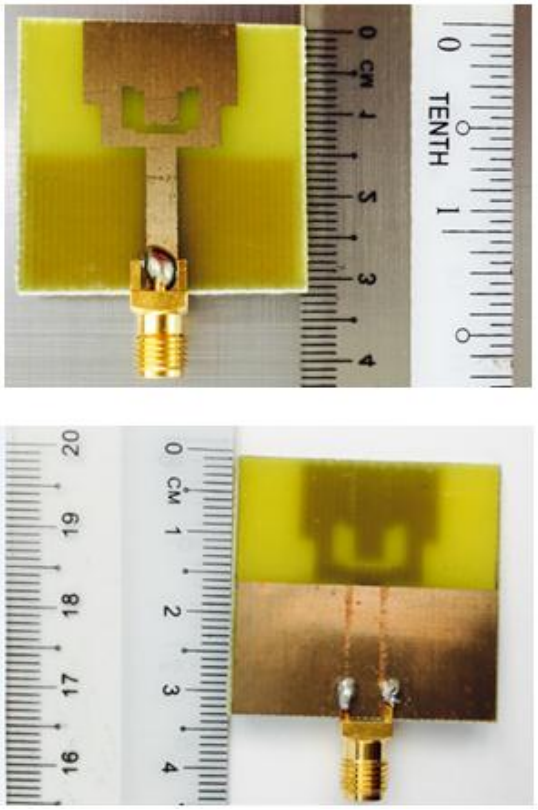


Figure 3. Fabricated design of the UWB monopole antenna with U-shaped SRR, (a) front view, (b) back view

Table 1. UWB monopole antenna dimension for Design *A1* to Design *A4*

Parameter of the antenna	**Symbol**	**Dimension (mm) for each antenna design**			
		A1	***A2***	***A3***	***A4***
Substrate width	W_s	32.0	32.0	32.0	32.0
Substrate length	L_s	32.0	32.0	32.0	32.0
Patch width a	W_{pa}	-	-	18.0	18.0
Patch length a	L_{pa}	-	-	10.0	10.0
Patch width b	W_{pa}	-	-	2.0	2.0
Patch length b	L_{pa}	-	-	5.0	5.0
Feedline width	W_f	3.6	3.6	3.6	3.6
Feedline length	L_f	17.0	17.0	17.0	17.0
Ground width	W_g	32.0	32.0	32.0	32.0
Ground length	L_g	32.0	16.0	16.0	16.0
SRR width	W_{srr}	-	-	-	6.0
SRR length	L_{srr}	-	-	-	6.0
SRR side width	$W_{ringside}$	-	-	-	2.0
SRR side length	$L_{ringside}$	-	-	-	5.0
Thickness of copper	T_c	0.035	0.035	0.035	0.035
Thickness of substrate	T_s	1.6	1.6	1.6	1.6

RESULT AND DISCUSSION

In this paperwork, some significant performance outcomes considered for this proposed monopole antenna. These performance outcomes are resonant frequency (in GHz), return loss (in dB), antenna gain (in dB), 2D radiation pattern, voltage standing wave ratio (VSWR), and bandwidth (in MHz).

Figure 4 compared the return loss performance of all stage of the antenna design – Design *A1* to Design *A4*. At the first stage, the antenna operates at single narrowband of 12.5 GHz of resonant frequency with return loss performance of -19.862 dB. It has the bandwidth of only 771 MHz between between 12.155 GHz and 12.926 GHz. The gain of this antenna at this stage is only 0.277 dB.

For Design *A2*, it effect more wider range of the operation frequency because of the partial ground technique. From the graph, it shows that this antenna covers the range between 2.896 GHz and 7.320 GHz of frequency with 4.424 GHz of bandwidth. The best point of this antenna located at 5.876 GHz with -16.849 db. For WLAN application point at 5.2 GHz, it achieves - 16.452 dB while at 6.0 GHz, the return loss performance is – 16.795 dB.

Based on the graph, it shows that the performance of the Design *A3* had been improved by cut-off effect by the staircase technique with bandwidth of 8.069 GHz, covers from 12.777 GHz to 10.846 dB. It creates three different resonant frequency at 4.916 db, 8.024 GHz, 9.172 GHz with – 29.992 dB, - 25.397 dB, and - 24.582 dB.

For the last part of the antenna design of Design *A4* radiates at the UWB range between 2.572 GHz and 10.746 GHz of frequency with improve of the bandwidth to 8.174 GHz. This stage radiates at two different resonant frequency at 6.272 GHz with – 25.91 dB and 7.82 GHz with – 26.165 dB

However, the U-shaped SRR had been create a 972 MHz range of band-notch rejecting frequency bandwidth, covers from 5.028 GHz and 6.0 GHz. The peak of notch frequency is at 5.624 GHz with return loss of – 3.639 dB.

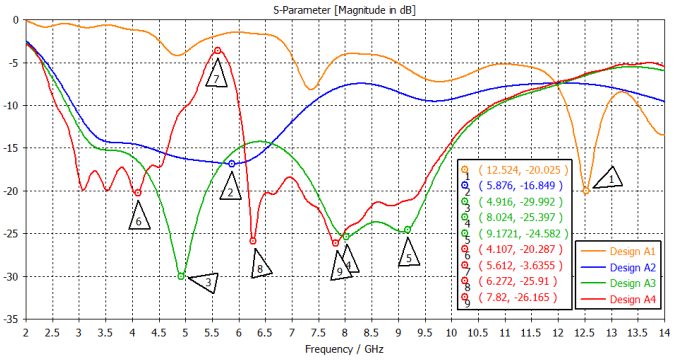


Figure 4. Return loss of the UWB monopole antenna with U-shaped SRR for Design *A1*, *A2*, *A3* and *A4*.

Figure 5 compares both return loss results of simulated and measured for basic UWB monopole antenna with U-shaped SRR (Design *A4*). Compare with the simulation result, it shows that the resonant frequency of measurement result had been shifted. It had been shifted from 6.272 GHz with – 25.91 dB of return loss for simulation to 6.56 GHz with – 38.1 dB of return loss for measured. For notch-band frequency, it had been shifted from 5.84 GHz with – 3.42 dB to 5.612 GHz with – 3.636 dB.

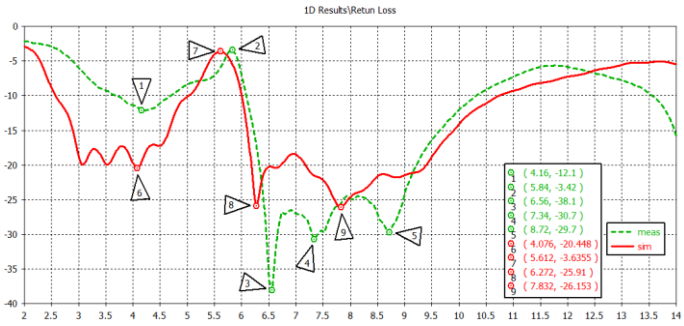


Figure 5. Simulated and measured return loss comparison result of the UWB monopole antenna with U-shaped SRR (Design *A4*)

Figure 6 shows the antenna gain performance result of the UWB monopole antenna with U-shaped SRR (Design A4) while Table 2 shows the comparison performance of simulation and measurement for UWB monopole antenna Design *A4*. From the Compared result between the simulation and measured antenna gain, the measured result had been reduced. It shows that at the first resonant frequency, the gain reduced from 1.763 dB to 1.557 dB. This situation also had been seen at the second resonant frequency. The gain had been decrees from 3.213 dB to 3.025 dB. For measurement result, the third resonant frequency shown at 8.72 GHz with – 29.70 dB and gain of 2.124 dB. It represents that the gain of the antenna at 6.272 GHz and 7.82 GHz are 1.763 dB and 3.213 dB. It also illustrates that the lower performance of the gain antenna displays at 5.5 GHz with – 0.108 dB.

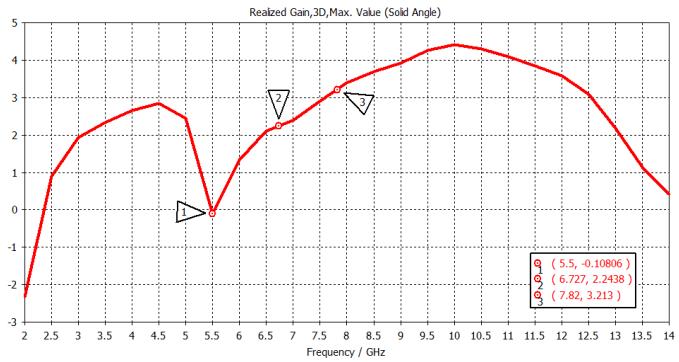
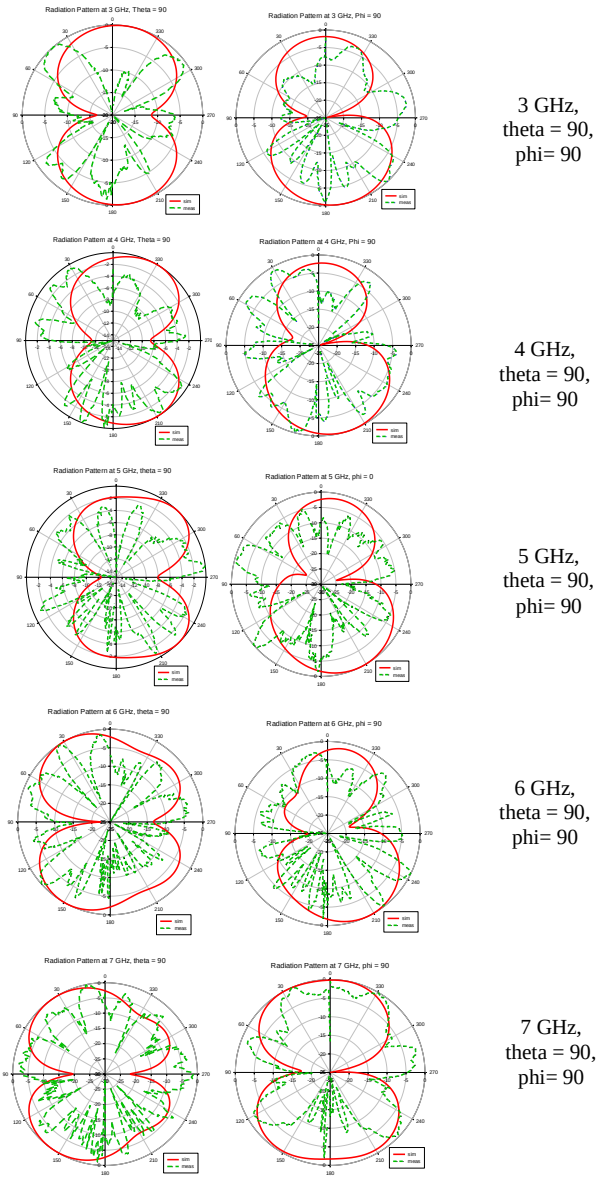


Figure 6. Antenna gain performance result of the UWB monopole antenna with U-shaped SRR (Design *A4*)

Table 2. Comparison performance of simulation and measurement for UWB monopole antenna Design *A4*

Design Antenna *G*	**Resonant frequency, f_r (GHz)**	**Return loss (dB)**	**Gain (dB)**
simulation	6.272	- 25.910	1.763
	7.820	- 26.165	3.213
measurement	6.560	- 38.100	1.557
	7.340	- 30.700	3.025
	8.720	- 29.700	2.124

Figure 7 illustrate the radiation pattern of UWB monopole antenna with modified U-shaped SRR (Design *A4*) with theta = 0 and phi = 90 for numerous range of frequencies of 3.0 GHz to 9.0 GHz. Dissimilar frequencies effect to determine the different shaped of radiation pattern.



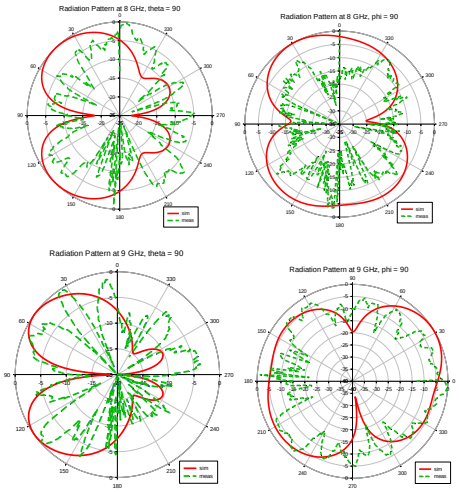


Figure 7. Radiation pattern (simulation in red and measurement in green) comparison result of the UWB monopole antenna with U-shaped SRR (Design *A4*) from 3 GHz to 9 GHz (theta = 90 and phi = 90)

Figure 8 displays the VSWR of UWB monopole antenna with modified U-shaped SRR (Design A4) between simulation and measurement. From the graph, it displays that the band-notch point at 5.612 GHz with VSWR = 4.848 for simulation. It had been shifted to 5.78 GHz of with VSWR = 5.2 for measured result.

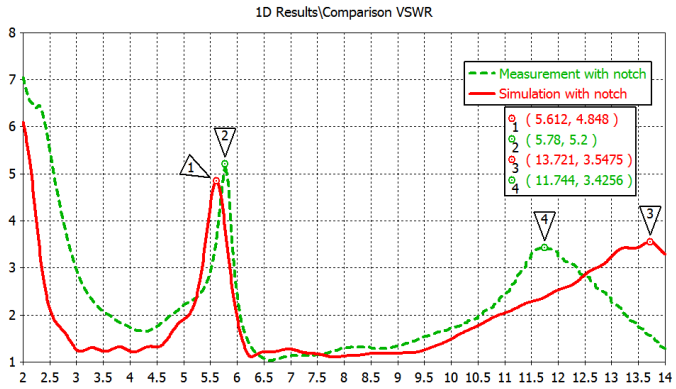


Figure 8. VSWR performance result of the UWB monopole antenna with U-shaped SRR (Design *A4*) between simulation and measurement.

CONCLUSION

After simulated and measured work of UWB monopole antenna with U-shaped SRR had been done, it shows that the U-shaped SRR structure had the capability to rejected the several range at nearly 5.5 GHz the UWB band range between 2.572 GHz and 10.746 GHz of frequency.

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