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Significance of Split Ring Resonator to Design Multiband Operation by Coupling with Monopole

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Abstract

The metamaterials (MTMs) are broadly defined as artificial effectively homogeneous electromagnetic structures with unusual properties not readily available in nature. Metamaterials provide engineerable permittivity, permeability, and refractive index, which led to utilization of metamaterials in electromagnetic applications from microwave to optical domain. This paper presents the application of SRR to gives multiband antenna operation which can be used for various applications in wireless communication. As per measured results the fabricated antenna gives four frequency bands which are 3.086GHz, 4.68GHz, 6.51GHz and 8.501GHz. Here the effect of SRR on monopole is observed using simulation and optimized design is fabricated on FR4 and tested using VNA. SRR in combination with monopole is used to give multiband antenna operation. Tolerable agreement between measured and simulated results is observed and is presented in terms of S11(return loss)

Keywords: Electromagnetic metamaterials, Multiband antennas, Monopole antenna, Split Ring Resonator

INTRODUCTION

Metamaterials are artificially fabricated structures and composite materials which gives new physically realizable response functions which do not readily available in nature.[1][2][3][4] In general metamaterials are generated by creating modifications in fabricated structures of host medium and properties of such metamaterials can be predicted. [4][5][6] Metamaterials have ability to concoct the electromagnetic and optical properties of materials for variety applications. By using the properties of matamaterials it is possible to minimize the size and weight of antenna and microwave devices.[4][5][6] Use of matamaterials can intensify the performance and electromagnetics properties of the devices like antenna.

Presently metamaterial based antennas are proposed which uses metamaterial like resonator in the vicinity of radiating structure.[7][8][9] This radiating element is perceptive to the presence of resonator due to coupling. Using resonating element like Split Ring resonator parameters of monopole antenna can be engineered to obtain Metamaterial multiband antenna operating in wireless communication frequencies for various wireless applications.[7][8][9] In this paper printed monopole antenna is designed using FR4 substrate at 3GHz. Then SRRs are placed in the vicinity of monopole antenna to obtain multiband operation. Gap between SRR and monopole antenna, SRR dimensions are changed to optimize required results. This research is carried out by taking the reference [9]

Concept of Monopole Antenna

A general purpose dipole antenna [8] (long thin wire antenna) with height $l_1 = l_2 = L/2$, where L is the total length of the antenna is shown in Figure 1(a)[10]

Two thin linear elements are used to construct dipole antenna. Two thin linear symmetrical elements of dipole antenna are fed at the center by a balanced two wire transmission line. The antennas may be of any length, but it is assumed that the current distribution is sinusoidal. Current-distribution measurements indicate that this is a good assumption provided that the antenna is thin; That is, when the conductor diameter is less than λ/100.

The current of the centre fed antenna of length L at any point z on the antenna is

$$I(z) = I_0 sin\left[\frac{2\pi}{\lambda}\left(\frac{L}{2} - |z|\right)\right] \quad (1)$$

From dipole antenna concept monopole antenna is designed. For monopole antenna single ended sources can be used without baluns [9]. λ/4 monopole antenna display the same radiation pattern in the region above the ground as a half-wave dipole in free space as shown in Figure. 1(b). Monopole radiates only half as much power as the dipole.

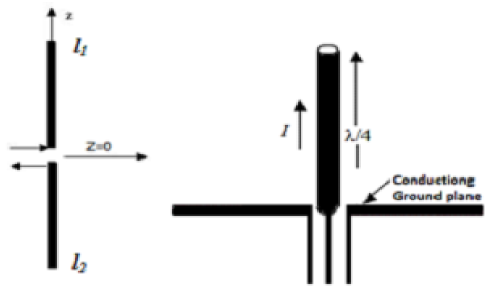

Figure 1 (a) Dipole antenna total length of h1+h2. (b) λ/4 monopole antenna

Based on the same concept, in this paper printed monopole antenna is designed and fabricated on FR4. For design FR4 substrate of thickness 1.6mm, dielectric constant of 4.4 and loss tangent of 0.02 is used.

Printed Monopole Antenna

Monopole antenna is simulated in electromagnetic simulator is as shown in Figure 2(a). Figure 2(b) shows measured and simulated results of monopole antenna. Results show good agreement between the measured and simulated values of S11. The dimensions of the ground plane are 70.8mm by 4.5mm. The dimensions of monopole antenna are 2.98mm by 19.5mm. Comparative results are as shown in Table 1. Simulated radiation pattern for printed monopole antenna is as in Figure 2 (c)

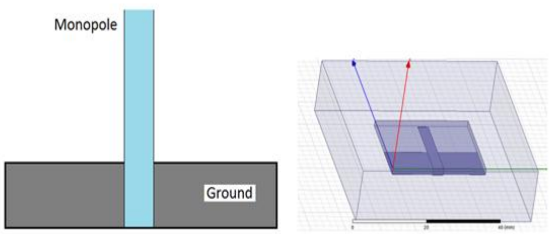

Figure 2(a) Simulated monopole antenna structure

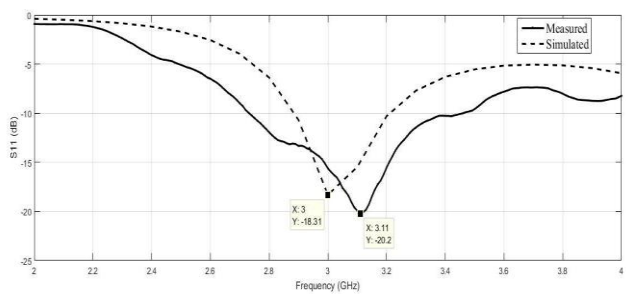

Figure 2 (b) Measured and Simulated S11 in dB for printed monopole antenna

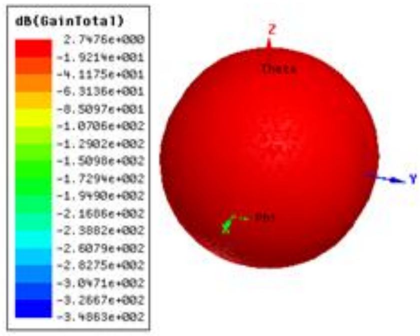

Figure 2 (c). Simulated radiation pattern for printed monopole antenna

Table 1 Comparison between Simulated and measured results

	Frequency	Return Loss(dB)	VSWR	Band width	Impedance
Measured Result	3.11 GHz	-20	1.24	640MHz	47Ω
Simulated Result	3.0 GHZ	-18.31	1.27	300MHz	56 Ω

Printed Monopole Antenna Coupled With SRR on Right Hand Side

By introducing double split ring resonator to the right side of SRR gives multiband operation. The layout of antenna and SRR is as shown in Figure 3.

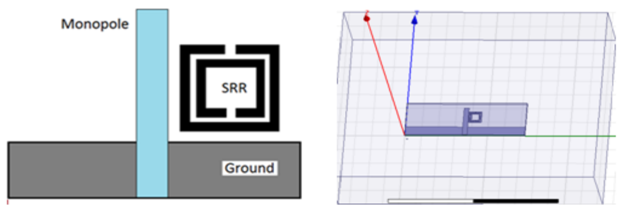

Figure 3 Monopole Antenna with SRR on right side

The outer side (SRR) split ring resonator is 7.7mm and the thickness is 0.7mm. The inner side of (SRR) split ring resonator is 5.7mm and the thickness is 0.7mm.The gap between the two SRRs is 0.3mm.

This antenna design is simulated using electromagnetic simulator. The design is verified for different gaps between the monopole and the Split Ring Resonator. If the gap between monopole and SRR is adjusted 4mm it gives better response compared to 0.2mm, 0.3mm and 0.5mm in terms of S11, VSWR, Bandwidth, Impedance and radiation. Hence the antenna fabricated with gap of 0.4mm and tested using vector Network analyzer. Simulated and measured results are matching as per the graph shown in Figure 4.

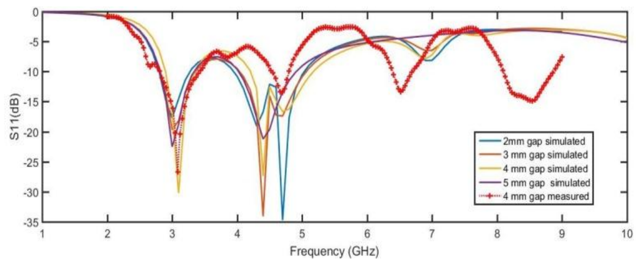

Figure 4. Measured and Simulated S11 of Monopole with SRR on right hand side for different gaps.

Comparison of simulated (for 0.2mm, 0.3mm 0.4mm and 0.5mm gaps) and measured (0.4mm gap) results is as shown in table 2. Simulated radiation pattern for different gaps is as shown in Figure 5.

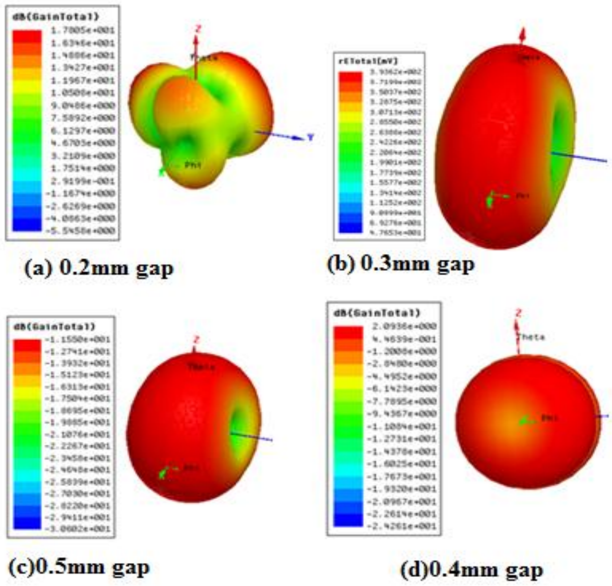

Figure 5 Radiation patterns for different gaps between monopole and SRR

Measured and simulated S11(dB) of monopole antenna and double SRR of gap 4mm is as in Figure 6.

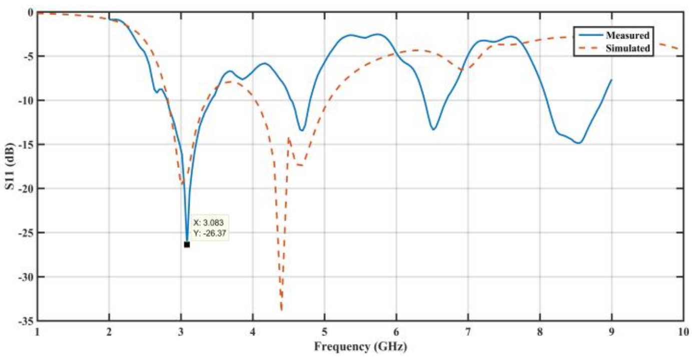

Figure 6 Comparative S11 for 4 mm gap between monopole and SRR

Printed Monopole Antenna Coupled with SRR on Bothside

Monopole antenna is now coupled with the same SRR on left side with gap between monopole and SRR as 0.4mm as shown in Figure 7. The gap of SRR slit is changed from 0.3mm to 0.5mm. After simulation from the results it is observed that return loss is improved and Simulated S11 is as in Figure 8. The fabricated antennas are as shown in figure 9

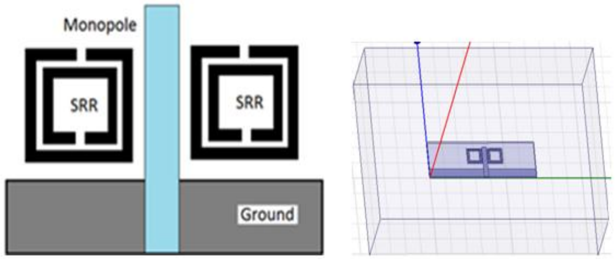

Figure 7. Monopole with SRR on both Side.

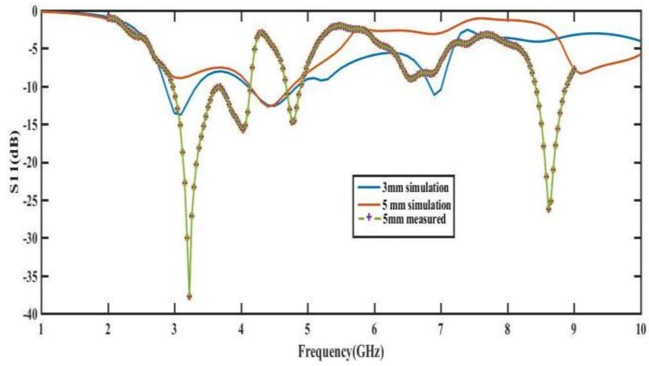

Figure. 8 Return loss for slit gap of 0.5mm and 0.3mm

Table 2. Return Loss for different gaps and comparison of simulated and measured results

Simulated results					
Marker position		**M1**	**M2**	**M3**	**M4**
0.2mm gap	frequency (GHz)	3	4.3	4.7	7
	S11(dB)	-17.75	-19.06	-34.72	-8.13
	VSWR	1.29	1.25	1.03	2.29
	Impedance(Ω)	64.84	60.96	48.39	26
	Bandwidth (MHz)	470	600	400	---
0.3mm gap	frequency (GHz)	3	4.4	----	7
	S11(dB)	-19.68	-34.07	-----	-6.5
	VSWR	1.2	1.3	----	2.8
	Impedance(Ω)	58.83	58.81	--	14
	Bandwidth (MHz)	546	892	---	---
0.5mm gap	frequency (GHz)	3	4.4	-----	----
	S11(dB)	-22.52	-21.23	-----	-----
	VSWR	1.16	1.19	-----	----
	Impedance(Ω)	58.83	58.81	--	14
	Bandwidth (MHz)	546	892	---	---

0.4 mm gap	frequency (GHz)	3.1	4.7	6.9	----
	S11(dB)	-30.19	-16.85	-7.88	-----
	VSWR	1.06	1.3	2.35	----
	Impedance(Ω)	50.40	65	28	----
	Bandwidth (MHz)	470	949	---	---
	Measured Result				
0.4mm gap	frequency (GHz)	3.086	4.68	6.51	8.501
	S11(dB)	-26.14	-13.33	-13.33	-14.93
	VSWR	1.104	1.55	1.55	1.44
	Impedance(Ω)	54	70	77	71

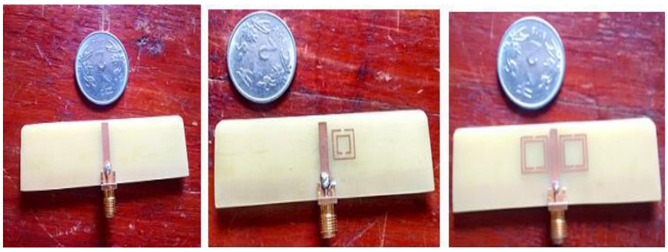

Figure 9. Fabricated antennas.

RESULTS AND DISCUSSION

This paper presents the application of SRR to gives multiband antenna operation which can be used for various applications in wireless communication. Figure 1 shows the basic to design monopole antenna. Based on the same concept of monopole antenna design simple printed monopole antenna is designed and size of antenna is optimized with 70.8mmX23mm. Figure 2(b) shows good agreement between simulated and measured results for said antenna. Figure 2(c) shows radiation pattern for monopole antenna. Multiband operation is achieved by placing double split ring resonators on right side of monopole antenna. Bands will be tuned by changing the gap between the monopole and split ring resonator. Gap between the SRR and monopole is optimized to 4mm, which is clear from the Figure 4. Radiation pattern for the said antenna with gap of 4mm is as shown in Figure 5. In order to improve the S11 same double split ring resonator is added on left hand side of monopole as shown in Figure 7. By adding the split ring resonators on both side it is observed that return loss is improved in simulated results but improvement is not significant in measured results as well as radiation pattern is also disturbed. Hence placing split ring resonators on both sides is not advisable. Radiation pattern for antennas are shown in figure 2(c), figure 5. Simulated and measured results are compared in Table 1 and in Table 2. Fabricated antennas are shown in Figure 9.

CONCLUSION

Now days metamaterials and its application as antenna is growing field in the area of research. This paper presents the application of SRR to generate multiband antenna which can be used for various applications such as WiFi, LTE, LAN, Bluetooth etc. In this paper frequency bands of 3GHz, 4.6GHz, 6.5GHz and 8.5 GHz are observed, which finds applications in maritime radiolocation, aeronautical radiolocation, fixed mobile,etc. Here the effect of SRR on monopole is observed using simulation and optimized design is fabricated and tested using VNA. Tolerable agreement between measured and simulated results is observed and is presented in terms of S11.

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