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Size Reduction of Bluetooth Antenna: CSRR based Patch Concept

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ABSTRACT

A microstrip Bluetooth patch antenna with a planar metamaterial unit cell is proposed. A complementary split-ring resonator (CSRR) and a rectangular slot in combination gives the metamaterial property to antenna. Also an analysis of the CSRR variation to overall performance of the antenna is also taken under study by considering two different CSRR designs. The substrate material is FR4-epoxy with dielectric constant ε_r=4.4. The electrical size of the antenna is: 0.16λ_0 ×0.177 λ_0 ×0.013λ_0. A 65% size reduction could be achieved with the proposed model. The model proved to be practically viable as the experimental results tally with the simulated ones.

Keywords- Metamaterials, patch antennas, substrate, wideband, CSRR, negative index.

1. INTRODUCTION

The field of Electromagnetics had a tremendous opening with the introduction of artificial negative index medium (metamaterials) and its feasibility in microstrip patch antenna structures .The base of all these researches arouse from the metamaterial property coined by Victor Veselago in 1968.Size miniaturization of antennas have become so essential in the current scenario of communication devices. In patch antennas; size miniaturization has been accomplished through various methods. The use of substrates with high dielectric constant can reduce the size of patch antennas but it exhibits narrow bandwidth, high loss and poor efficiency due to surface wave excitation. Another common technique involves the use of shorting posts/pins/mushroom structures and reactive impedance surfaces. Folding of patches to multilayer structure reduces patch dimension by 50% but at the cost of increased thickness.Capacitive loading by using chip capacitors can also reduce antenna size, butsoldering effects should be taken into account also. Factors like radiation efficiency and poor impedance matching are to be considered in these contexts.

2. BASIC CONCEPT

A new design methodology for producing highly miniaturized patch antennas is the use of artificially created structures called metamaterials. Metamaterials are artificial composite, not a new material, which acquires their electromagnetic properties from metallic structures and its designs. The metamaterial structures that are used for patch antenna miniaturization are Split Ring Resonators (SRR) or the Complimentary split ring resonator (CSRR). Metamaterials when applied on a patch antenna can provide miniaturization; in the sense the resonant frequency at which the patch resonates is reduced. The miniaturization factor is greater in this method when compared to others forms as they are geometrically flexible and scalable to any frequencies. Metamaterials also exhibits focusing properties, when considered in the Left handed (μ, ε negative) domain.

The size of a patch antenna reduces with increment in its resonant frequency. So miniaturization, in a broader concept, can be acquired by making a high frequency antenna to radiate at a lower frequency. This is achieved by loading the patch cavity using Complementary SRRs. In this communication, a small wideband microstrip patch antenna loaded with a planar CSRR is presented, such that it shall operate in the Bluetooth frequency.

3. ANTENNA DESIGN

A slotted patch antenna with a metamaterial (CSRR rings on ground plane) is designed.A basic rectangular patch antenna at 2.45GHz operation will have the following dimensions for radiating patch: (L×W×h= $0.304\lambda_0 \times 0.235\lambda_0 \times 0.013\lambda_0$) and FR4 substrate with: (L×W×h= $0.533\lambda_0 \times 1.03\ \lambda_0 \times 0.013\lambda_0$) as per standard design equations The same antenna can be replaced by an antenna with dimensions: 26×45×1.6mm ($0.21\lambda_0 \times 0.36\lambda_0 \times 0.013\lambda_0$) and patch of size: 20.4×21.7mm. The miniaturization is enabled by the combined effect of slot and CSRR rings. The rectangular slot in the patch develops a capacitance C, whereas the CSRR on the bottom gives a mixture of capacitance(C) inductance (L) and their resultant effect helps in reduction of resonant frequency by the relation (eqn1):

$$f \propto 1/\sqrt{LC} \tag{1}$$

Fig.1(a) below shows the model of the proposed Bluetooth antenna, having two CSRR rings. By changing the metamaterial structure, the extend of coupling can be altered. The selection of CSRR is done by simulating it independently and analyzing its properties. For this, the above CSRR model was modified with three rings Fig2(b). The above implementations are approximated to the center of the patch structure so that the net inductive and capacitive effects can be obtained effectively and hence achieve good level of coupling.

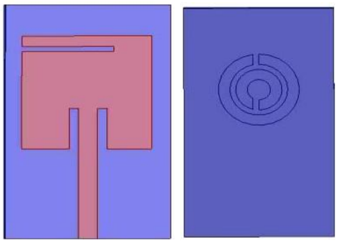

Fig1:(a) *Substrate dimension: 26×45×1.6mm.Patch dimension:20.4×21.7mm.Feed: 25.06×3mm. Slot: 13.6×1mm.* (b)*CSRR dimensions:7×1mm and 4×1mm rings. (HFSSv14.0)*

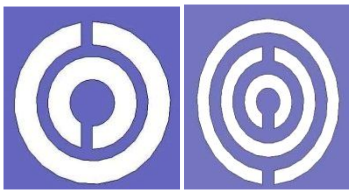

Fig2(a): *Ring:7&4mm(width=2mm).Slot width:1mm* (b): *Ring:6, 4&2mm(width=1mm).Slot width:1mm (HFSSv14.0)*

4. EXPERIMENT RESULTS

The structures were simulated in HFSSv14.0, ANSYS Inc. Based on Finite Element Method simulations in HFSS and actual antenna measurements, the return loss characteristics are obtained as in the figure below(Fig 3& 4). The fabricated structure is attached with an SMA connector -R426(Fig:5) and is then tested in an anechoic chamber using Rhode&Schawz®ZVB:20GHz network analyzer.

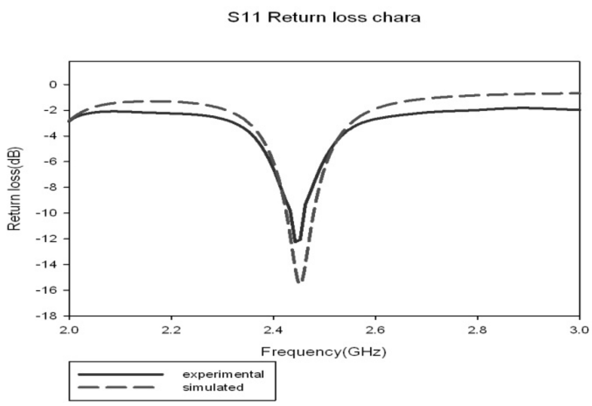

Fig3:*Return loss chara with CSRR in Fig2(a), f_R = 2.45GHz(Sigma plot™)*

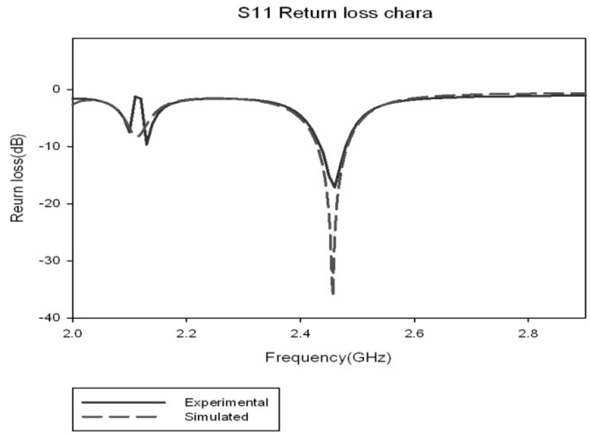

Fig4:*Return loss chara with CSRR in Fig2(b), f_R = 2.45GHz(Sigma plot™)*

Table 1: *Experimental result conclusions*

No.	Output Results		
	Property	Fig2(a) model	Fig2(b) model
1	Resonant frequency(GHz)	2.45	2.45
2	Return loss(dB)	-15.55	-36.22
3	Bandwidth(MHz)	640	510

Return loss value in the above chara suites for the antenna to function as transmitter device. Since the value below -10dB is quite good for the design models in Fig:2, both are good for use, with design Fig:2(b) holding a better rank as its matching is good.The fabricated models are as shown in the figure below.

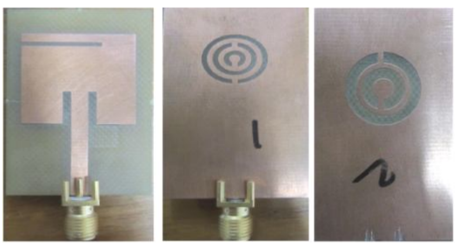

Fig5: *Fabricated antenna models*

The 2D and 3D radiation patterns of this model is shown in Fig6 & 7.

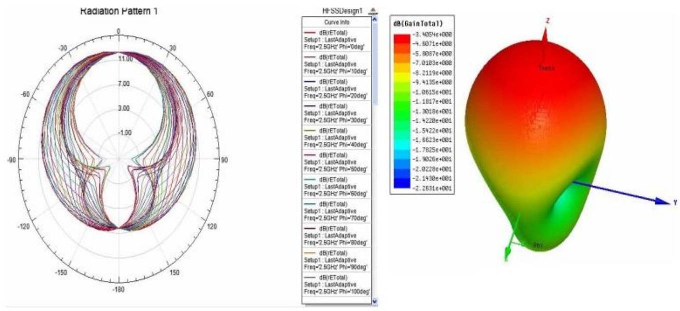

Fig6: *2D & 3D simulated radiation patterns(for all angles) of model in Fig2(b)*

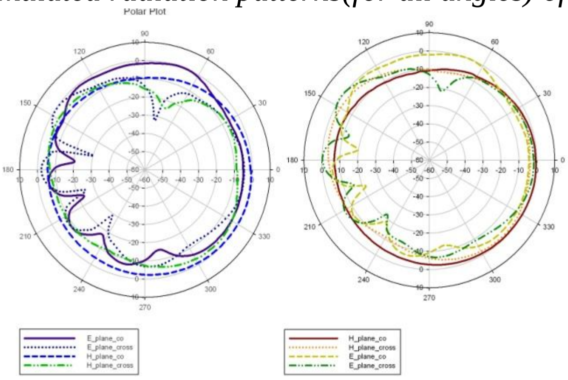

Fig7: *Radiation patterns of E and H planes co and cross polarized components* (a) *antenna with 2 CSRR rings,* (b) *antenna with 3 CSRR rings(experimental)*

6. CONCLUSIONS

The proposed antenna was found to resonate at 2.45GHz, the Bluetooth frequency with sufficient amount of impedance matching. This gives an indication that most of the input power is successfully radiated from the patch. The electrical size of the patch antenna is: $0.16\lambda_0 \times 0.177\lambda_0 \times 0.013\lambda_0$. The miniaturized antenna has about 65% reduction in size, with respect to the standard model.

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