Optimization for Microstrip Antenna using Complementary Split Ring Resonator

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ABSTRACT
Today's world of minituration needs more optimizations for effective utilization of patch antenna. The paper proposed technique for optimization of microstrip antenna using Complementary Split Ring Resonator Metamaterials (CSRR). The CSRR exhibits negative refractive index since it had negative permittivity at its plasma frequency. The frequency of optimization for microstrip antenna is same as that of plasma frequency of Metamaterial structure. Simulation of Unit Cell for Metamaterial gives S-parameters for the same. Parameter extraction from those S-parameters gives operating range of frequency. When patch antenna is loaded with Metamaterial structure negative permeability and negative permittivity enhances antenna parameters. This results in optimized patch dimension and similar antenna performance. The same patch simulated at 3.17 GHz with Unit Cell which results in approximately 44% reduction in patch dimensions. In both case antenna gain is 5.6 dB over an impedance band of 200 MHz. Limitation of the suggested technique is that it operates over a limited band of frequencies.

Keywords
Complementary Split Ring Resonator ,Antenna Optimization,

1. INTRODUCTION
Use of Wireless Technology in day today life had completely changed life of common man. This motivated RF researches to come up with new products not only for defense and industrial use but for common man as well. This complete cycle gave rise to miniaturization and optimization for Wireless products. The vigorous use of these products had land up with very upcoming area for researches which was optimization for microstrip antennas (MA). Low weight, low fabrication cost, circular polarizations, dual band operation, frequency agility, feed line flexibility, beam scanning are a few notable advantages of microstrip patch antenna. A few critical drawbacks which limit the applicability of microstrip patch antennas are low efficiency, low gain, narrow bandwidth, low power handling capability. There are many techniques to optimize MAs like defected ground structures [1] , parasitic elements or slots, thick substrate with low permittivity, stacked patches [2] and use of Meta-materials [3] (MTMs).The paper introduces a technique to optimize MAs using Complementary Split Ring Resonators (CSRR). CSRR exhibits negative permittivity. MA using air dielectric material has been optimized using CSRR. Structure is simulated using HFSS and results for the same are compared with and without CSRR.

2. COMPLEMENTORY SPLIT RING RESONATOR
Metamaterials which are defined as effectively homogeneous electromagnetic structure exhibiting unusual electromagnetic properties especially the backward wave and negative refraction index [4] Initially Unit Cell for CSRR has been designed 3.1 GHz which is shown in figure1 and Table -I gives dimensions for the same. Perpendicular E-field and parallel H-field excites CSRR. Plasma frequencies for CSRR may differ by few KHz. The resultant Unit Cell is simulated using HFSS. HFSS gives S-parameters for the same. Permittivity and permeability has been extracted using S-parameters [4] with the help of equations given below. The matlab program has been written for parameter extraction. The resultant parameters are tabulated in Table-II.

$$\square = nz \quad (1)$$

$$\varepsilon = \frac{n}{z} \quad (2)$$

$$n = \frac{1}{kd} cos^{-1}[\frac{1}{2S_{21}}(1 - S_{11}^2 + S_{21}^2)] \quad (3)$$

$$z = \frac{\sqrt{(1+S_{11})^2 - S_{21}^2}}{\sqrt{(1-S_{11})^2 - S_{21}^2}} \quad (4)$$

The simulated results shows over a narrow bandwidth CSRR exhibits negative permittivity. Though plasma frequency for both SRR and CSRR structure is same, simultaneous occurrence of negative permeability and permittivity has been observed over a very narrow band. Thus MTM structures are narrow band in nature

3. DESIGN FOR MICROSTRIP PATCH ANTENNA
Single MA has been designed with air substrate at 6 GHz. It is simulated. To achieve maximum antenna efficiency and good amount of gain approximate dimensions for antenna should be 25 mm which is approximately half wavelength at 6 GHz. HFSS structure is shown in figure 2 and results are tabulated in Table-III. When patch size was approximately (22*25) mm, patch resonates at 6 GHz and Impedance bandwidth is 200 MHz Obtained gain is 6 dB over a beamwidth of 75 degree.

4. PROPOSED STRUCTURE FOR MICROSTRIP ANTENNA OPTIMIZATION USING CSRR

Antenna structure explained in III, has been loaded with unit cell of CSRR which are described in II. This proposed structure is shown in figure 3. When patch antenna was loaded with single unit cell, the same antenna resonates at 3.1 GHz instead of 6 GHz. Table-IV shows that patch dimensions of proposed structure without and with MTM are same. But there is measureable decrement in resonant frequency. Also obtained impedance bandwidth and gain along with radiation pattern is same. This is because when CSRR resonates, it acts as MTM resulting in negative refractive index at their plasma frequency. As shown in figure 1, MTM structures are planar in nature. These planar structure provides enhanced permeability only in the direction normal to the plane of MTM and enhanced permittivity in the direction tangent to the plane [6]. Negative permeability lengthen the current path which results in decrease in resonant frequency for the same patch dimensions. Negative permittivity of CSRR decrease resonant frequency for the patch. Also since it is perpendicular to the plane of MTM, concentrate the radiated field in the same direction as that of radiated field of the patch without MTM structure. Thus this is not changing radiation pattern of patch. Gain and beamwidth remains same though patch dimensions are reduced. The HFSS simulated results for the same are shown in figure 4.

The decrement in resonant frequency for the same patch dimensions with CSRR MTM structure can be interpreted from equivalent circuit for CSRR. Outer and inner ring of CSRR gives offers inductance. Gap spacing of inner and outer ring offer capacitance. Thus this reduces resonant frequency of the patch.Now same structure is simulated with two unit cells of CSRR. Insertion of one more unit cell further decreases resonant frequency for patch keeping antenna parameters same. This is followed by insertion of one more unit cell. This also results in decrement in resonant frequency and rest of the antenna parameters are same. Now insertion of four CSRR unit cell decreases antenna resonant frequency. Thus cell size of MTM helps in further antenna optimization. The proposed structure is shown in figure 5 and corresponding results are compared in Table-III. As shown in figure 5 all CSRR unit cells are aligned. Some simulations are also carried out to observe effect of alignment for Unit cell. It has been observed that if CSRR-TW are not aligned, they won't work as MTM array. Due to which desired optimization is not obtained. This is because there is effect of cell size on performance of MTM. The corresponding structure is shown in figure 6 and results are compared in Table-IV.

5. CONCLUSION

The manuscript highlights Microstrip antenna optimization using Complementary Split Resonating Structure. Almost 60 % reduction in antenna dimensions was observed at the same resonant frequency. The energy stored in CSRR structure keep the gain almost same in spite reduced dimensions. Since CSRR is narrow band structure, band of the frequencies over which optimization obtained is very narrow. The paper proposed technique to optimize antenna parameters such impedance bandwidth, gain and antenna dimensions using Metamaterials. The technique utilizes CSRR MTM to optimize the antenna. Parameter extraction from CSRR concludes MTM structure are narrow band structures. Also, though plasma frequency for the SRR and CSRR structure is same, simultaneous occurrence of negative permeability and permittivity has been observed over a very narrow band of frequencies. For this very precise design for CSRR unit cell is required. The same patch simulated at 3.17 GHz with Unit Cell which results in approximately 44% reduction in patch dimensions. In both case antenna gain is 5.6 dB over an impedance band of 200 MHz Now number of Unit Cell are two instead of one. The same results are obtained at resonant frequency of 4.9 GHz. Whereas when number of Unit Cells are increased from two to Three and Four, the resonant frequency decreases to 4.7 GHz and 4.6 GHz respectively. Here also same antenna parameters obtained. Thus approximately 50 % reduction in patch dimensions is observed. Same patch is also optimized using CSRR structure. Almost more than 50% reduction in antenna dimensions had been observed. In spite of deduction in patch dimensions, its radiation pattern is almost unchanged over desired band of frequencies. Limitation of the suggested technique is that it operates over a limited band of frequencies**.**

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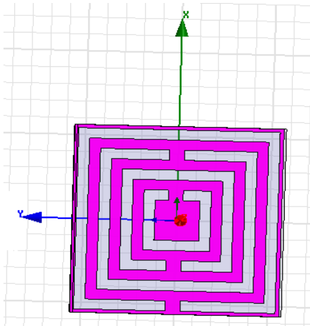


Fig 1: . Unit Cell for CSRR

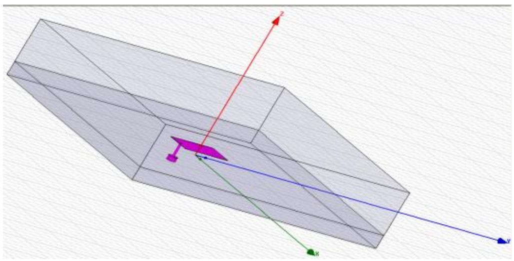


Fig 2: **Only Patch Antenna on Air Substrate**

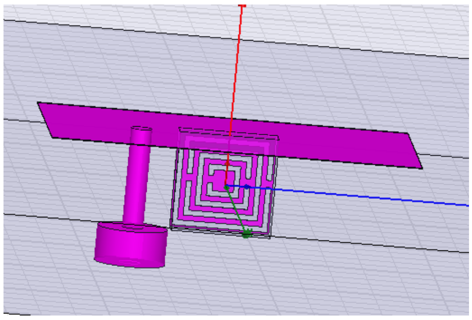
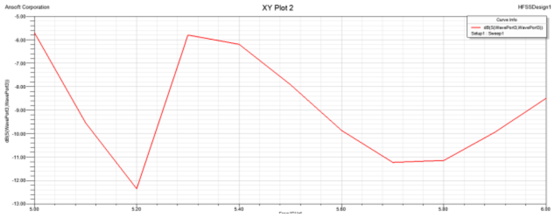
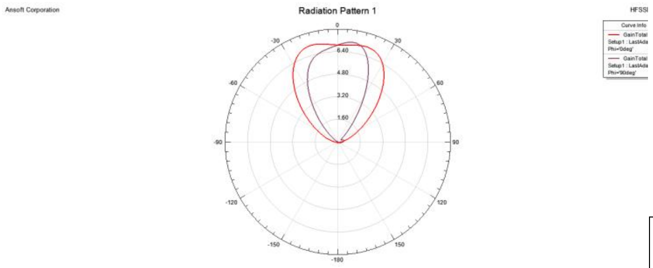


Fig 3: . Proposed CSRR Structure for Antenna Optimization



(a)



(b)

Fig 4: Simulated Results for Proposed Structure With Single Unit Cell a) Return Loss b) Radiation Pattern

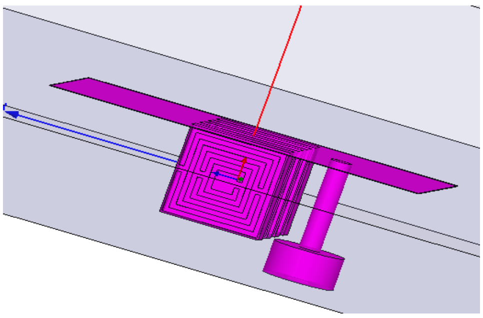


Fig 5: : Proposed Structure with Four Unit Cells

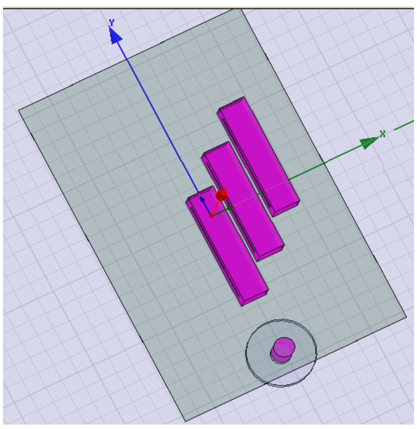


Fig 6: : Proposed Structure where Unit Cells are Not Aligned

Table 1. Dimensions for unit cell CSRR table styles

Sr No	Dimension in mm	
1	Length of outer perimeter for outer ring	5.4
2	Length of inner perimeter for outer ring	4.8
3	Gap Spacing for outer and inner ring	0.6
4	Length of outer perimeter for inner ring	3
5	Length of inner perimeter for inner ring	2.4

Table 2. Extracted Permittivity for unit cell

Sr.no	Frequency(GHz)	Permittivity
1	3.21	-7.3152 - 0.0398i
2	3.24	-5.2984 -0.0399i
3	3.3	-3.2648-0.0400i

Table 3. Comparision for antenna parameters without and with CSRR MTM

Sr No	Antenna Para-meters	Patch With-out SRR and TW	Patch With SRR and TW			
			Single SRR and TW Unit Cell	Two SRR and TW Unit Cell	Three SRR and TW Unit Cell	Four SRR and TW Unit Cell
1	Antenna Dimension in mm	22*25	14*21	14*21	14*21	14*21
2	Resonant Freq-Uency (GHz)	6	2.9	3	3.2	3.2
3	Impe-dance Band-width (MHz)	200	180	180	175	172
4	Gain (dB)	6	5.8	5.5	5.5	5.5
5	Beam-width (degree)	75	72	76	76	75

Table 4. Comparision for patch dimensions and approximate reduction in patch dimension

Sr.No	Resonant Frequency in GHz	Desired Patch Dimensions in mm	Optimized Patch Dimensions in mm	% Reduction in Antenna Dimension
1	6	22*25	22*25	-
2	5.2	28*30	14*21	42
3	4.9	31*34	14*21	61
4	4.8	30*34	14*21	61
5	4.7	32*35	14*21	66

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