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Optimization for Microstrip Antenna using Split Ring Resonator and Thin Wire Metamaterial

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Abstract— Extensive use of Microstrip antenna motivates researchers for its optimization. May techniques are there for antenna optimization which results up to 30% reduction in patch dimensions. Today's world of minituration needs more optimizations for effective utilization of patch antenna. The paper proposed technique for optimization of microstrip antenna using Split Ring Resonator and Thin Wire Metamaterials. This Metamaterial structure gives negative refractive index at their 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. Approximately 44 % reduction at frequency 5.2 GHz and 4.7 GHz had been observed. The proposed technique results in almost 6 dB of gain over a impedance band over 200 MHz at frequency 5.2 GHz and 4.7 GHz. Limitation of the suggested technique is that it operates over a limited band of frequencies.

Index Terms— Split Ring Resonator, thin wire, antenna optimization, metamaterial, permeababilty, permittivity, microstrip antenna.

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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 defence 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 , parasitic elements or slots, thick substrate with low permittivity, stacked patches and use of Meta-materials (MTMs).

The paper introduces a technique to optimize MAs using Split Ring Resonators (SRR) and Thin Wire (TW). SRR exhibits negative permeability whereas TW has negative permittivity. MA using air dielectric material has been optimized using SRR and TW. Structure is simulated using HFSS and results for the same are compared with and without SRR and TW.

2 Split Ring Resonator and Thin Wire

Metamaterials are defined as effectively homogeneous electromagnetic structure exhibiting unusual electromagnetic properties especially the backward wave and negative refraction index.

Perpendicular E-field and parallel H-field excites SRR. Plasma frequencies for SRR and TW 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 with the help of equations given below. The matlab program has been written for parameter extraction. The resultant parameters are tabulated in Table 1.

$$\mu = nz \qquad (1)$$

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

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

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

The simulated results show over a narrow bandwidth SRR and TW exhibits negative permeability and permittivity respectively. Though plasma frequency for both structures 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.

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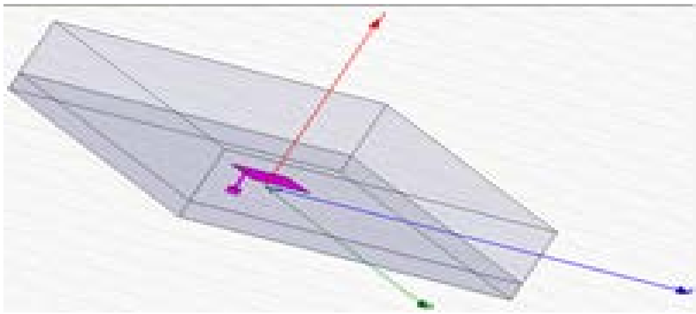


Fig. 1 Patch Antenna on Air Substrate

TABLE 1.

DIMENSIONS FOR UNIT CELL SRR AND TW TABLE STYLES

Sr No	Dimension in mm	
1	Length of outer perimeter for outer ring	5.2
2	Length of inner perimeter for outer ring	4.4
3	Gap Spacing for outer and inner ring	1.5
4	Length of outer perimeter for inner ring	3.8
5	Length of inner perimeter for inner ring	3

TABLE 2.

EXTRACTED PERMITIVITY AND PERMEABILITY

Sr no	*Frequency in GHz*	*Permittivity*	*Permeability*
1	5.28	4.3152 - 0.0398i	-0.2147 + 0.0606i
2	5.30	4.2984 - 0.0399i	-0.2643 + 0.0608i
3	5.35	4.2648 - 0.0400i	-2.5225 + 0.0684i
4	5.40	-1.2780 + 0.0466i	-2.6483 - 0.0687i
5	5.45	-1.2625 + 0.0466i	-0.2643 + 0.0608i
6	5.50	-0.8478 + 0.0466i	-0.1320 + 0.0602i

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. 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 SRR AND TW

Antenna structure has been loaded with unit cell of SRR and TW.But there is measureable decrement in resonant frequency. Also obtained impedance bandwidth and gain along with radiation pattern is same. This is because when SRR and TW resonates, they act 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. Negative permeability lengthen the current path which results in decrease in resonant frequency for the same patch dimensions. Negative permittivity of TW decrease resonant frequency for the patch. Also since it is perpendicular to the plane of MTM i.e. TW, 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 decrement in resonant frequency for the same patch dimensions with SRR and TW MTM structure can be interpreted from equivalent circuit for SRR and TW. Outer and inner ring of SRR 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 SRR and TW. 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 SRR and TW unit cell decreases antenna resonant frequency. Thus cell size of MTM helps in further antenna optimization.

All SRR-TW unit cells are aligned. Some simulations are also carried out to observe effect of alignment for Unit cell. It has been observed that if SRR-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.

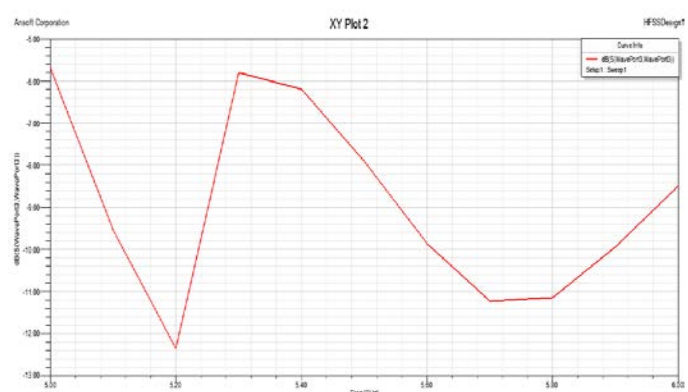
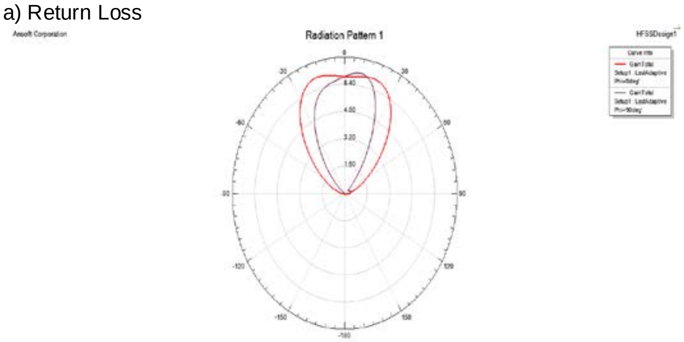


Fig. 2 Simulated Results for Proposed Structure with Single Unit Cell

a) Return Loss



b) Radiation Pattern

CONCLUSION

Various techniques are there to optimize microstrip patch antenna. The paper proposed technique to optimize antenna parameters such impedance bandwidth, gain and antenna dimensions using Metamaterials. The technique utilizes SRR and TW MTM to optimize the antenna. Parameter extraction from SRR and TW concludes MTM structures are narrow band structures. Also, though plasma frequency for both structures 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 SRR and TW unit cell is required. Insertion of MTM Unit cell decrease size of patch antenna approximately by 44% at 6 GHz, 5.2 GHz and 4.7 GHz. The proposed technique results in almost 6 dB of gain over impedance band over 200 MHz at frequency 5.2 GHz and 4.7 GHz. 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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