Optimization of Microstrip Patch Antenna using Metamaterial

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***Abstract*-Optimization means to obtain the antenna parameters such as frequency , bandwidth, beamwidth and gain to design the antenna hence ,due to miniaturization of antenna here we resonate the patch antenna at the same resonant frequency, so we can optimize antenna dimensions to obtain the gain .There are various techniques used for optimization of microstrip antenna, such as Particle Swarm Optimization (PSO) with curve fitting, Central Force Optimization, Differential evolution, Ant Colony Optimization, Genetic Algorithm etc. Here we proposed the method of optimization of microstrip antenna using Metamaterial such as SRR and Thin Wire. To achieve above parameters Metamaterials are used to reduce the patch antenna dimensions. Metamateial technology has the advantage of reducing the circuit size . Therefore, the circuit size is independent of the operational frequency and can be reduced to fit in a small area .The bandwidth of more than 160MHz was achieved with SRR loaded on air substrate .**

Keywords - Metamaterial, SRR, bandwidth improvement and negative permeability

I INTRODUCTION

Optimization means to obtain the antenna parameters such as frequency, bandwidth, beamwidth and gain to design the antenna..

Various techniques of optimization are in detailed.

1) *Particle Swarm Optimization (PSO)* –This method is effectively obtains the geometric parameters for efficient antenna parameters. It is a robust stochastic evolutionary computation technique based on the movement and intelligence of swarm. The PSO algorithm searches for the global minimum of the cost function .Particles within the swarm move influenced by its current position , its memory and by the co-operation or social knowledge of the swarm.
2) *Central Force Optimization (CFO)* –It is an optimization algorithm analogizing gravitational kinematics. The proposed algorithm is used to calculate accurately the resonant frequency and feed point position of rectangular microstrip patch antenna elements with various dimensions and various substrate thicknesses .
3) *Differential Evolution* –One of the latest evolutionary computational technique apart from the PSO ,is the Differential Evolution Algorithm in which, some individuals are randomly extracted from the solution population and geometrically manipulated avoiding the destructive mutation of GA. The most prominent advantages of DE is its low computation time compared to that of GA, particularly in large antenna arrays
4) *Ant Colony Optimization* – It is one of the optimization technique based on approximation. This is most suitable technique for optimize meander line path. It takes inspiration from the foraging behavior of some real ant species. It is mostly used for path optimization problem.
5) *Genetic Algorithm* –The genetic algorithm generates individuals (amplitude excitations and phase perturbations of the antenna elements). The individuals are encoded in a vector of real numbers, that represents the amplitude, and a vector of real numbers restrained on the range(0,2Л), that represents the phase perturbations of the antenna elements. Each individual generates an array factor of certain characteristics of the side lobe level and the directivity. One drawback is their lack of memory which limits the search and convergence ability of the algorithm.

About Metamaterial-

Metamaterials (MTMs) are artificial composite structures that exhibit a homogeneous effective permittivity ϵ and permeability μ, which become negative over an operating frequency range[2]. Metamaterial technology has the advantage of reducing the circuit size while providing equivalent or better performance in both antenna and passive circuits applications[4]. Some designs of the antennas can meet impedance bandwidth requirements, but the gains or sizes are not very good. In this a SRR mu-negative and thin wire well known as epsilon negative is inserted to obtain a ultra wideband microstrip antenna with higher gain and wider bandwidth is proposed.

II THEORY

Metamaterial Absorbing Structure such as Thin Wires negative permittivity and SRR negative permeability were described .The metamaterial used to build the antennas for this work is based on the embedded circuits metamaterial such as thin wires can be as artificial dielectrics for microwave applications[7]. The structure with $\epsilon<0$ consists of a square matrix of infinitely long parallel thin metal wires embedded in dielectric medium. In the situation the medium is air and the radius of a single wire is very thinner than the distance between two wires. The effective dielectric permittivity is negative. The basic building block of SRR(Split Ring Resonator) is a highly conductive structure in which the capacitance between the two rings balances its inductance. A time varying magnetic field is applied perpendicular to the rings surface induces current which in dependence on the resonant properties of the structure, produce a magnetic field that may either oppose the incident field, thus resulting in positive or negative effective µ[2][8]. The unit cell was modeled and simulated in the finite difference time domain using HFSS so as to resonate at 2.49GHz.These unit cells are then stacked together to form a 3D structure .the resulting structure would thus have the embedded circuits distributed uniformly throughout the entire substrate. The unit cell structure is shown in below fig 1.The unit cell was designed on a Rogers RT / duroid with $\epsilon r = 2.2$.

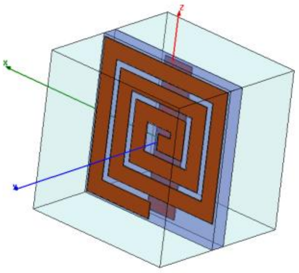

Fig.1 Unit cll structure

III ANTENNA DESIGN

A rectangular microstrip patch antenna is usually mounted on a substrate and backed by a conducting ground plane[2]. In the present paper a planar metamaterial pattern on the rectangular patch antenna mounted on the air substrate is designed to enhance its horizontal radiation as well as broaden its working bandwidth via its coupling with the conducting ground backed to the substrate. The geometry of the proposed compact metamaterial antenna is shown in fig.2 which is printed on a Rogers RT /duroid substrate of thickness 1.6mm, and permittivity 2.2. The proposed antenna structure is composed of rectangular microstrip patch antenna and array of SRR. It is seen from the structure as by inserting the metamaterial in form of SRR the bandwidth and gain increases. The gain of the antenna is one of the important characteristics .The higher the gain of the antenna, the more energy the antenna send in a specific direction[4][5].The efficiency ,another antenna performance parameter, is a measure of how much energy the antenna radiates in comparison to the energy that it receives. Metamaterials has been used to minimize surface waves arising from microstrip patch antennas. Here our objective is to increase the gain and bandwidth of the microstrip patch antenna while maintaining its low attractive profile feature at the same resonant frequency 2.49GHz.

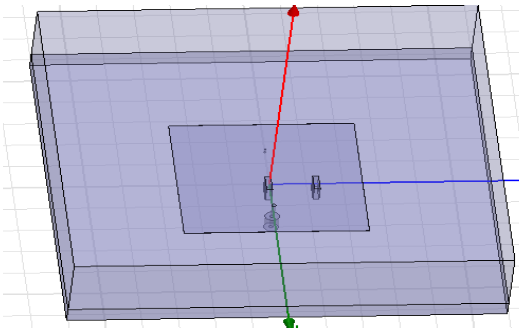

Fig 2 Proposed Structure

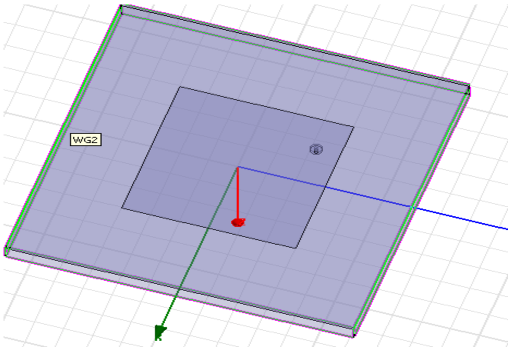

Fig 3 Patch antenna without srr

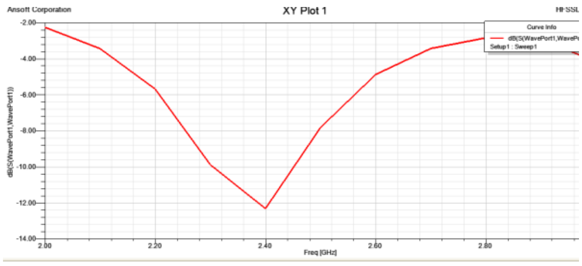

Fig 4 Frequency 2.4GHz

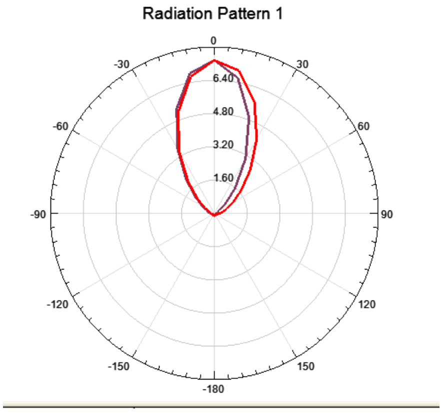

Fig 5 & 6 Simulated Radiation Pattern
Without SRR

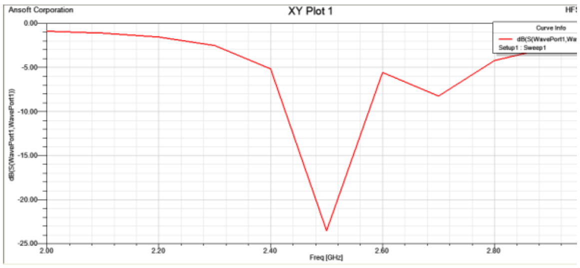

Fig 7 Frequency 2.49(GHz)

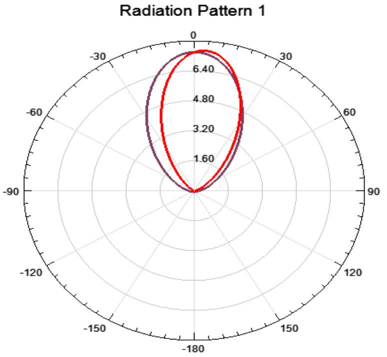

Fig 8 & 9 Simulated Radiation Pattern with SRR

IV RESULTS

A comparison of the simulated radiation patterns for the proposed antennas with or without cells at the frequency of 2.49GHz are shown in fig. 5 and fig. 8 . A comparison of the simulated results for the proposed antenna are listed in table 1.The bandwidth ,gain and efficiency was computed. Hence due to optimization of the patch antenna the band width increases.

V . CONCLUSION

In this paper the optimization of rectangular microstrip patch antenna using SRR(Split Ring Resonator) and Thin Wire acts as metamaterial with ultra wide band and high gain is successfully designed. The dimensions of the improved antenna is reduced slightly , but the frequency bandwidth of the patch antenna significantly broadened 160MHz. Moreover the average gain is 7.5db at 2.49 GHz. The unique radiation characteristics make this antenna would be a good choice for UWB Wireless Communication in the future

Simulated Results for single patch antenna

Antenna parameters	Without srr Structure	with srr Structure
Resonant Frequency(GHz)	2.4	2.49
Return Loss (S_{11} in dB)	-12.32	-24
Impedance Bandwidth(MHz)	150	160
Gain(dB)	7.4	7.53
Beamwidth(deg)	52.44	61.62

Table1. simulated results with and without SRR structure

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