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Application of Metamaterial to Improve Isolation Between Two Microstrip Antennas

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Abstract- **Antenna miniaturization is very important in today's modern wireless communication systems. To achieve this we place the two antennas very close to each other. This introduces mutual coupling between the two antennas and thus reduces the efficiency and disturbs the radiation pattern of an antenna. To avoid these effects, isolation between the two antennas should be increased. We can realize this by using Metamaterials. The metamaterials(MTMs) are artificial composite structures that exhibit a homogeneous effective permittivity ∈ and permeability μ. Frequency range over which they exhibits negative ∈ or negative μ, is called plasma frequency at which the direction of propagation is reversed. It acts as insulator which is used to suppress surface waves and near field radiations. This feature is used to help isolation. Metamaterial enabled the excellent performance of Microstrip Antenna Array. Metamaterials acts as an insulator to eliminate substrate surface waves. In this paper we discuss metamaterial application to improve isolation between two Microstrip patch antennas with Split Ring Resonators(SRR) exhibiting negative permeability. The proposed antenna structure is composed of two Microstrip antennas and an array of split ring resonators. The isolation of more than -25dB was achieved with SRR array loaded between the two patches. The results show that port isolation can be improved with SRR structure between two antennas.**

Keywords- Meta-material, SRR, isolation improvement, negative permeability.

I. INTRODUCTION

Telecommunication system has developed from voice service to multimedia service such as text transmission, MP3, camera/camcorder etc. the recent increase in demand for these high quality services in wireless communication has induced the development of multi-antenna systems[1]. However, the mutual coupling between antenna reduces their efficiencies as part of the power that would generally be radiated by the other antenna. This coupling may also cause unwanted interferences between them. Therefore, the isolation improvement technique between antennas becomes one of the most important topics. A standard method of improving isolation is to limit radiation from propagating direction and to increase distance between antennas. However, this method is not highly efficient because it increases the size and area of the system[5]. Thus, various studies of improving isolation have researched. This paper presents a new method to improve isolation between two microstrip antennas with SRR array exhibiting negative permeability. The metamaterials(MTMs) are artificial composite structures that exhibit a homogeneous effective permittivity ∈ and permeability μ, which become negative over an operating frequency range[2]. Due to the unique characteristics of the MTMs and their integration, a number of the potential MTM applications have been researched. Metamaterial technology has the advantage of reducing the circuit size while providing equivalent or better performance in both antenna and passive circuits applications[4]. One of the earliest approaches uses split ring resonators(SRRs) and thin wires. A thin wire is a well known epsilon negative (ENG) material through plasma phenomenon, and a SRR is a well known mu-negative(MNG) material when a time varying magnetic field is applied to patch. In the design of the proposed antenna with the SRR structure, the 3D-field simulation tool, HFSS was used. Firstly we found that why there is need for isolation in Microstrip antenna and what are the measures to improve it. Then we introduced the Metamaterial structures in between two Microstrip patches for isolation enhancement and we achieved the desired results.

II. VARIOUS AVAILABLE METAMATERIAL STRUCTURES

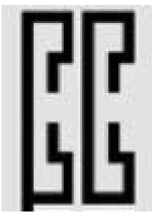
Electromagnetic metamaterials divide into different classes, as follows:

a)Negative index: In ***negative index metamaterials*** (NIM), both permittivity and permeability are negative resulting in a negative index of refraction. These also known as Double Negative Metamaterials or double negative materials (DNG).

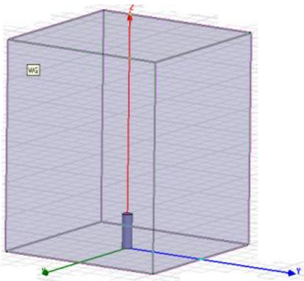
b)Single negative: Single negative (SNG) metamaterials have either negative relative permittivity (εr) or negative relative permeability (µr), but not both. Epsilon negative media (ENG) display a negative εr while µr is positive. Mu-negative media (MNG) display a positive εr while µr is negative.

MTM can be realized using various periodic structures such as ***Thin Wire*** (TW)(results into negative ε at specific frequency),***Split Ring Resonator*** (SRR)(results into negative µ at specific frequency) ,***SRR and TW*** (results into negative ε and negative µ at specific frequency),***Omega*** (results into negative ε and negative µ at specific frequency).

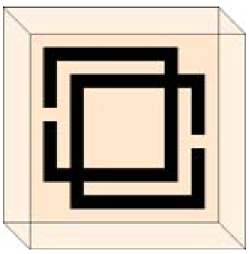
Mainly thin wire and SRR structures are used for isolation improvement in Microstrip antennas. Also mushroom shaped, fishnet, labbynet structure metamaterials are used for improving antenna performance. Following are the metamaterial structures used for isolation improvement.



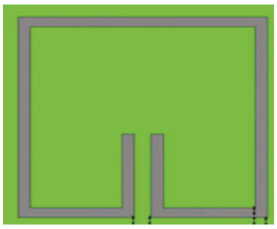
a)SRR structure



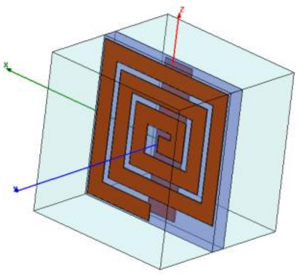
b) Thin wire structure



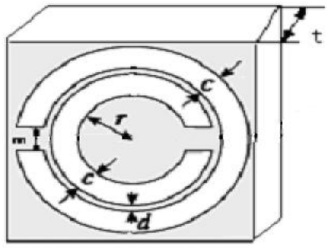
c) Modified SRR used to construct metamaterials



d) Absorber cell

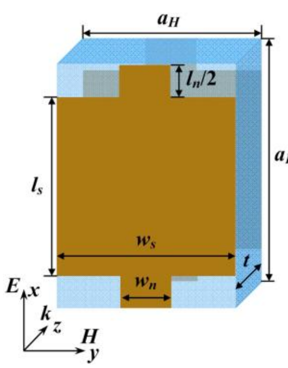


e) Spiral loop resonator



f) SRR unit cell structure

g) Labyrinth structure



h) Fishnet structure

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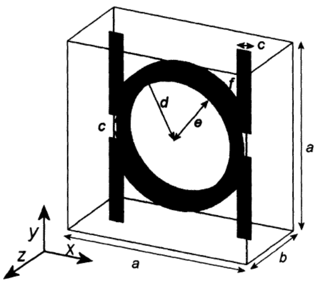
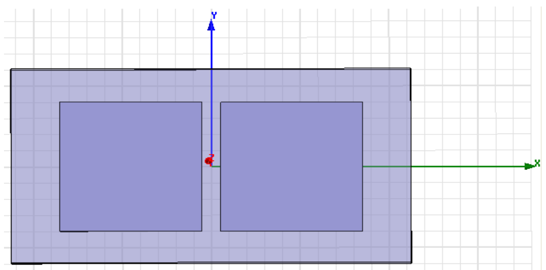


i) Omega structure

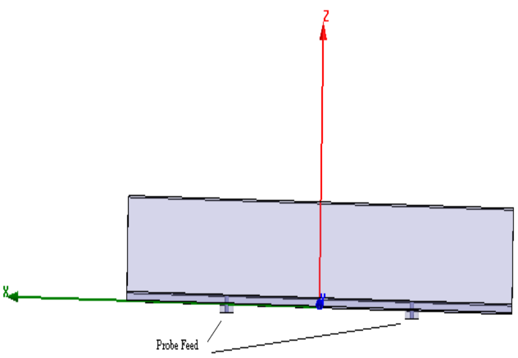
Figure 1. Various Metamaterial Structures used for isolation improvement in Microstrip antennas.

III. PROPOSED ANTENNA

The geometry of the proposed antenna is shown in fig.2. It is designed on Roger's RT duroid dielectric substrate(relative permittivity=2.2, thickness=1.6mm). What we observed here is that efficiency of antenna reduces due to the mutual coupling produced in two antennas. Radiation pattern of one antenna hampers the radiation pattern of another. Thus antenna performance degrades. To avoid these effects, it is necessary to reduce mutual coupling between two antennas that is we have to increase isolation between them electrically. For this purpose we are inserting metamaterials cells The proposed antenna now consists of two microstrip patch antennas and the SRR array in between the two patches shown in fig.3. SRR structure ia also designed on Roger's RT duroid substrate. These SRR structures will act as insulator and avoid the radiations from one antenna on other and vice-versa. This will improve the radiation pattern of both the antennas.



(a) Top view



(b) Side view

Figure 2. Geometry of the proposed antenna.

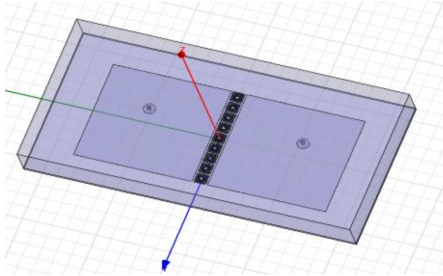


Figure 3. Proposed antenna with SRR array

IV. RESULTS

According to the variation of inter-element spacing edge to edge "d",the simulated scattering parameters for the proposed antenna is shown in table 1. Scattering parameters for proposed antenna is plotted in fig.4. and radiation pattern is shown in fig.5.

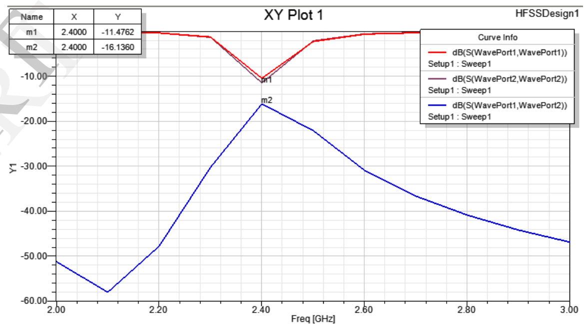


Figure 4. Scattering parameters of the proposed antenna without SRR cell.

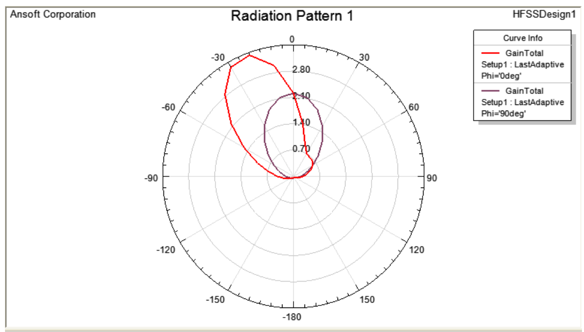


Figure 5.Radiation pattern of proposed antenna without SRR cell.

Due to the space limitation we are choosing the physical separation between two patches as $\lambda/24$. So to enhance the isolation between two patches and gain we inserted metamaterial (SRR) structure in between them. Scattering parameter plot is shown in fig.6. and table 1 shows the comparison results without the SRR cells and with SRR cells. Gain remains the same.

Maximum isolation of -25.66dB was obtained between two antennas at 2.4GHz. The results show that port isolation can be improved with SRR cells between two antennas.

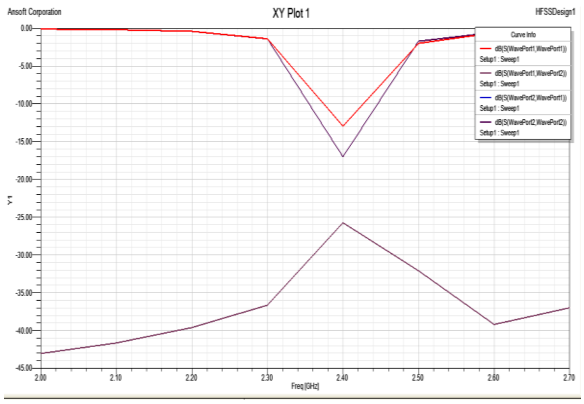


Figure 6. Scattering parameters of proposed antenna with SRR cells.

V. CONCLUSION

This paper presents a new method to improve isolation between two microstrip patch antennas with SRR cells which exhibits negative permeability. By placing the SRR cells in the middle of the antennas less than -25dB isolation values were achieved within the operation frequency bands. Almost 9db improvement in isolation has been observed using SRR cells. Thus the results show that port isolation between antennas can be improved with MTM SRR cells.

TABLE1.SIMULATION RESULTS FOR VARIOUS PHYSICAL SEPARATION BETWEEN TWO ANTENNA PATCH ELEMENTS

Antenna Parameters	Single Patch	For Two Patch Elements		
		Physical Separation in terms of wavelength		
		λ/8	λ/16	λ/24
Resonant Frequency(GHz)	**2.4**	**2.38**	**2.38**	**2.4**
Return Loss (S_{11} in dB)	**15**	**15**	**14**	**-11.47**
Impedance Bandwidth(MHz)	**400**	**360**	**370**	**-**
Gain(dB)	**5**	**3.5**	**3.2**	**1.68**
Beamwidth(deg)	**80**	**60**	**60**	**--**
Isolation(S_{21}in dB)	**----**	**25**	**22**	**-16.13**
Isolation(S_{12}in dB)	**----**	**25**	**22**	**-16.13**

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TABLE2. SIMULATED RESULTS FOR CLOSELY SPACED MICROSTRIP PATCH ANTENNA USING SRR MTM

Antenna parameters	patch elements separated by distance of λ/24 without SRR Structure	patch elements separated by distance of λ/24 with SRR Structure
Resonant Frequency(GHz)	2.4	2.4
Return Loss (S_{11} indB) (S_{22} in dB)	-10.84 -10.84	-12.92 -16.92
Impedance Bandwidth(MHz)	190	100
Gain(dB)	3.3	3.4
Beamwidth(deg)	--	62
Isolation(S_{21}in dB)	-17.9	-25.66
Isolation(S_{12}in dB)	-17.9	-25.66