Design of Square Split Ring Resonator Meta Material Antenna for Novel Planar Microwave Using X-Band

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Abstract :- **Planar Meta Materials and Many antennas are designed by means of periodic structures having lattice constants smaller than the wavelength at their resonating frequency. The basic building blocks of Meta Materials are synthetically fabricated structures of Split Ring Resonators (SRRs). A magnetic response is attained with this resonator and negative magnetic permeability values can be achieved which is generally unity for naturally occurring materials. This paper emphasizes on simulation of a SRR structure of a metal on a substrate inside a waveguide with Finite Element Method based software 'High Frequency Structure Simulator'. The magnetic resonance of Split Ring Resonators has been investigated with variation in geometrical parameters of SRRs. The results reveal that resonant frequency of Meta Materials can be controlled by the design of resonators and hence in achieving the bulk Meta Materials with negative permeability.**

Keywords:– **Left-handed Meta Materials (LHM), Meta Materials (MTM), Negative Index Materials (NIMs), Split Ring Resonators (SRRs), Refraction Index.**

I. INTRODUCTION

There has been unprecedented escalation in study of Metamaterials (MMs) with unusual properties not occurring naturally, in the last decade. The man behind the discovery of the concept of Metamaterials was Victor Veselago permeability in 1968 [1-3]. These materials are artificially designed material that gains effective properties from its structures rather than inheriting them directly from its constituents [4]. i.e. the direction of propagation is reversed with respect to the direction of energy flow. The edifice building blocks of MTM are synthetically fabricated periodic structures having lattice constants smaller than the wavelength of the incident radiation. The building blocks of Metamaterials are Thin wires (TW), Split Ring Resonators (SRRs) and combination of both Thin Wires and Split Ring Resonators. So Metamaterial properties can be controlled by the design of their building blocks in 1998 and 1999 and then extensively studied by several groups. In year 2000, Smith et al experimentally confirmed that the use of thin wire arrays in addition to SRR (Split Ring Resonator) arrays provide negative effective permittivity,(εeff) along with negative effective permeability (μeff) simultaneously over a common frequency band [6-7]. The conventional split-ring resonator unit cell was composed of two circular coplanar metallic rings each with a split displaced by 180 degrees. These rings were patterned on a low-loss dielectric substrate having the same center and alienated from each other by a short gap distance. SRRs can be of any shape rectangular, square, triangular etc. These resonators permit control and manipulation of light on sub wavelength length scales for incorporating Optics into Micro and Nanotechnology. These resonators have a wide range of applications such as absorbers, frequency selective surfaces, sensors, antenna structures, high frequency modulators and composite materials. The SRRs have undergone numerous miniaturized refinements since its inception in order to optimize the resonances supported in the structure as these resonances hold the solution in tailoring the effective permeability and permittivity of the MMs [8-10].

In this paper, the magnetic resonance of Square SRRs structure of copper is numerically investigated to analyze the dependence of the resonance frequency on their parameter designs. Square SRR structure on a substrate is investigated with Finite Element Method (FEM) based software 'High Frequency Structure Simulator (HFSS)'. a square SRR formed with Metallicstrips of width, *c*, and the distance of the outer boundary of the inner and outer rings are denoted as *ao* and *a^*, respectively, measured from the centre of the structure.

II. EQUIVALENT CIRCUIT OF SRR

SRRs consist of two metallic rings of metal with a split (gap) introduced in its structure. When a current circulates in a coil, it produces a magnetic dipole moment. The generated dipole moment vector is at right angles to the plane of the coil an increased dipole moment at its resonance the ring introduces a parallel plate capacitor (C) can be derived as follows:

Magnetic resonance frequency $\omega_m = 1/\sqrt{(LC)}$ ----------(1)
Capacitance, $C = (\varepsilon_o \varepsilon_r A) / d = (\varepsilon_o \varepsilon_r w t / d)$ --------(2)
Inductance (L) = μ_o coil area / length (with a single turn in the coil) --------(3)
Where,

A is area and d the distance between the plates. ε_r is relative permittivity of Dielectric present between the plates.Presence of dielectric effects the resonance frequency of SRR which is inversely proportional to the size of SRR. If there is no split in SRR, then the capacitance will become infinity as d=0 and there will not be a resonance. So it is imperative to introduce the split in the ring to have a capacitive effect which can lead to the negative value of magnetic permeability (μ). There are several parameters that necessitates to be tuned including width and height of the SRRs, spacing between the rings, size of the Split, Material properties of the rings, thickness of substrate and surrounding medium in order to get the desired negative permeability property at certain frequency range.The Value of Permeability (μ) can be retrieved from Nicolson-Ross-Weir (NRW) approach. This method is used to attain the permeability from Reflection Coefficient (S11) and Transmission Coefficient (S21).

V1=S21+S11 -----------------------(4)

V2=S21-S11 ------------------------(5)

k=w$\sqrt{(\varepsilon r \mu r)}/c$ =$k_0\sqrt{(\varepsilon r \mu r)}$------(6)

Where,

ω=2πf, and k0= ω/c,
μr is relative permeability,
εr is relative permittivity,
c is speed of light=3*108m/s
$\mu r \approx 2/(jkod)(1-V2)/(1+V2)$----------(7)
d is thickness of substrate.

III. GEOMETRICAL PARAMETERS OF SRR MODEL IN WAVEGUIDE

SRR shown in Fig.1 are considered to be made of Copper.The gap of SRR is taken as 0.2mm.The spacing between outer ring and inner ring is 0.2mm. The SRR is patterned on a Rogers RT Duroid 5880 tm substrate with dielectric constant of 2.2 with Loss tangent 0.0009.

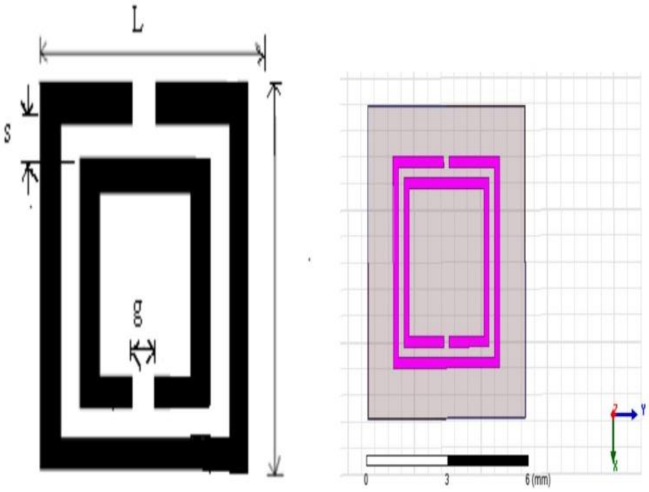

Fig 1: Square Split Ring Resonator

IV. SIMULATION OF MATERIAL UNIT CELL TO DETERMINE VALUE OF PERMEABILITY

In order to obtain the Metamaterial structure that exhibit the left-handed Metamaterial properties in the desired working frequency region, SRR unit cell with different dimensions is simulated inside a waveguide and the effect of the geometrical parameters on the resonating frequency region and the Metamaterial properties is observed. For simulation, the Perfect Electric Conductor (PEC) boundary conditions were employed on the z-faces of the unit cell. The Perfect Magnetic Conductor (PMC) boundary conditions were used on the y-faces of the unit cell so that the negative permeability behavior of SRR would be excited. The two waveports 1 and 2 are assigned along each of the substrate line on the x-faces. Besides the effect the variation in dimensions of SRR, spacing and gap, parametric studies on influence of substrate thickness and the thickness of the SRR are also done.

V.RESULTS AND DISCUSSIONS

NRW method is commonly used technique to determine the value of permeability strength of the total resonance. frequency and depicted in Fig. 3. The magnitude and phase of S11 and S21 are shown in Fig. 4 and Fig. 5. The phase reversal of S21 and S11 confirms the Metamaterial behaviour of SRR. 6 and Fig. 7. S21 and S11 values are exported in MATLAB to calculate effective negative permeabilityregion.

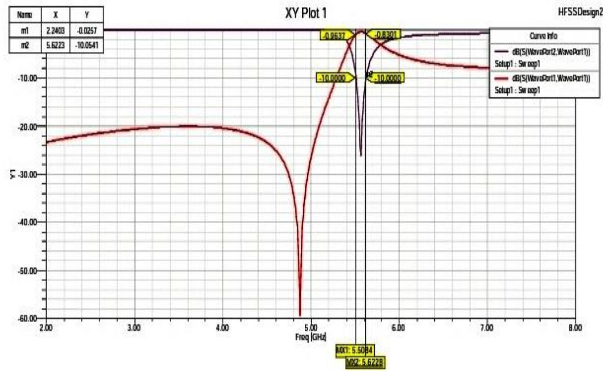

Fig 2:Transmission Coefficient (S21) and Reflection Coefficient (S11)

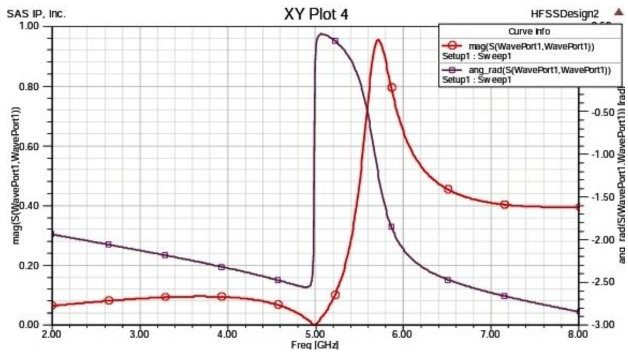

Fig 3: Magnitude and Phase of Reflection CoefficientS_{11}

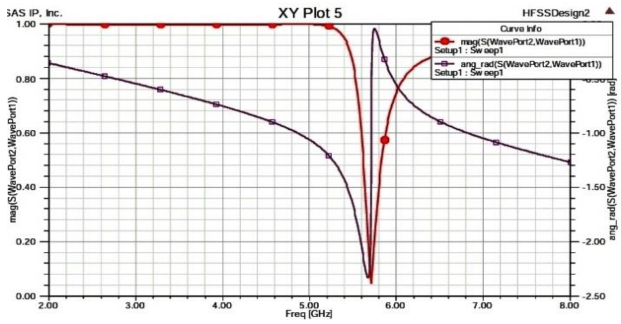

Fig 4: Magnitude and Phase of Transmission CoefficientS_{21}

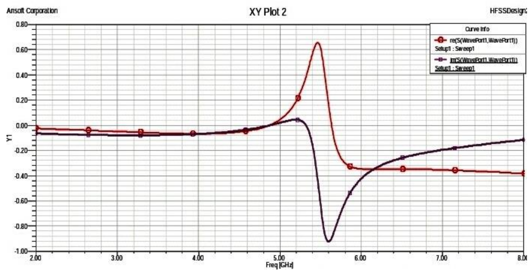

Fig 5: Real and Imaginary Part of Reflection Coefficient S_{11}

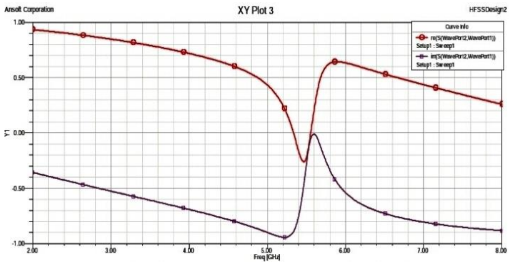

Fig 6: Real and Imaginary Part of Reflection Coefficient S_{21}

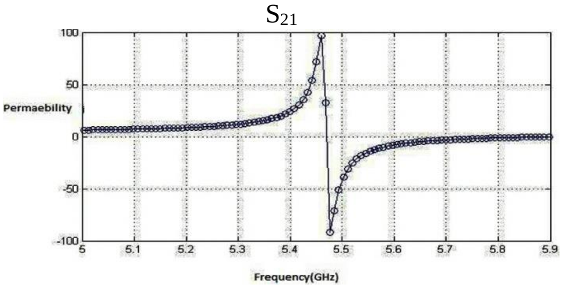

Fig 7: Extracted Real Part of Permeability(μr)

VI. Conclusion

It can be summarized that for a small gap and spacing, the resonance will split or spacing. This behavior is accredited to a decrease in capacitance for larger gap widths and spacing, resulting in increase in the resonance frequency. Increase in length of SRR legs leads to an increase in SRR inductance and hence resonant frequency get decreased. Increase in thickness of SRR will shift the resonating frequency and negative permeability region to lower frequency. With the reduction of thickness of the substrate, the strength of the magnetic resonance will enhance to make transition from conventional material to Metamaterial behaviour.

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