GA OPTIMIZED SRR CALCULATOR

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Abstract – **Negative magnetic permeability media (NMPM) can be built up by using small resonant metallic particles like Split ring resonator (SRR) which has very high magnetic polarisability. A group of these particles shows a negative permeability region near and above the resonant frequency. The continuous medium parameters describing the SRR array can be predicted from their individual electromagnetic behavior near the resonances. The paper presents an optimizing software using Genetic Algorithm (GA) to design an edge coupled two ring SRR for a particular frequency.**

Index Terms – **Genetic Algorithm, Negative magnetic permeability, Split ring resonator**

1. INTRODUCTION

Traditional optimization techniques search for the best solutions, using gradients and/or random guesses. Gradient methods have the disadvantages of getting stuck in local minima, requiring gradient calculations, working on only continuous parameters, and being limited to optimizing a few parameters. Random search methods do not require gradient calculations, but tend to be slow, and are also susceptible to getting stuck in local minima.

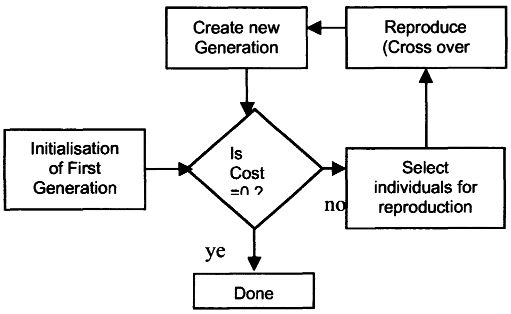

Fig.1. Genetic Algorithm flowchart

On the other hand, Genetic Algorithms (GA) are global numerical optimization methods, patterned after the natural processes of genetic recombination and evolution. They encode each parameter into binary sequences called genes, a set of genes forming a chromosome. These chromosomes undergo natural selection, mating and mutation to arrive at the final optimal solution. The GA search starts from a population of points and not a single point, following probabilistic transition rules and not deterministic rules [1]. A simple flowchart of the process is shown in Fig. 1.

In electromagnetism, a metamaterial is an object that gains its (electromagnetic) material properties from its structure rather than inheriting them directly from the materials it is composed of. Two important parameters, electric permittivity and magnetic permeability determine the response of the materials to the electromagnetic propagation. Negative magnetic permeability media(NMPM) can be built up by using small resonant metallic particles like Split ring resonator (SRR) which has very high magnetic polarisability. A group of these particles shows a negative permeability region near and above the resonant frequency. The continuous medium parameters describing the aforementioned SRR arrays can be predicted from their individual electromagnetic behavior near the resonances. Edge Coupled Two ring SRR was selected as object of study in this paper. The structure shown in Fig.2. is used to find the SRR resonances and to study the current distribution at these resonances. Genetic Algorithm method is efficiently employed for prediction of SRR parameters for a particular resonant frequency.

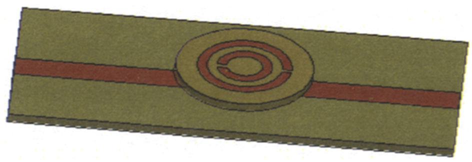

Fig.2. SRR coupled to Microstrip transmission line

II. NEGATIVE PERMEABILITY

The permeability of the SRR structure is evaluated using the cavity perturbation method.

$\mu= 1+[(f0-fs)/fs][vc/vs]K$ --------------(1)

where f_0 is the mode frequency without pertuburation, f_s is the shifted frequency, v_c and v_s are volume of empty cavity and SRR substrate respectively & K is a constant. From equation1, it is evident that μ will be negative if $f_s>f_0$.The negative permeability is validated experimentally as illustrated in Fig.3.

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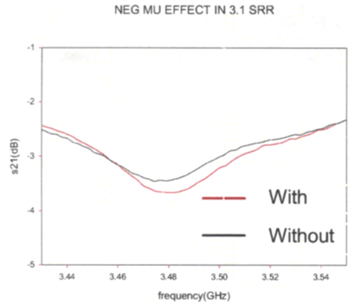

Fig.3. Results of the cavity perturbation method

III. PARAMETRIC STUDY & DESIGN EQUATION OF THE 2 RING SRR

Split ring resonator along with its parameters are shown in fig.4

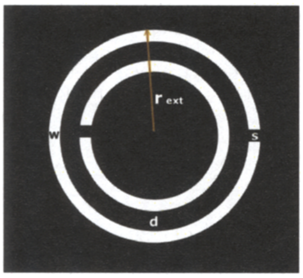

Fig.4. Two Ring SRR with variables
External radius (R_{ext}), Width of ring(w), Gap between rings(d), Height of substrate (h), Relative permittivity of substrate (ε_r), Width of slit in ring(s). Reference dimension chosen is R_{ext}=6mm; w=0.3mm; d=0.3mm; s=0.3mm; h=1.6mm; and ε_r =4.4

From exhaustive experimental and simulation studies conducted on SRR, it is observed that the resonant frequency of an SRR is directly proportional to width of ring (w), gap between rings (d) and the height of substrate (h) (up to height of 1.4mm after which the effect saturate). Resonant frequency is also inversely proportional to the radius of SRR (R_{ext}) and the dielectric constant of the substrate [2].

The resonant frequency of the SRR is found to be

$$F = \frac{1}{2\pi\sqrt{LC}} \qquad \text{(2) for } \mathbf{r} > 5.2$$

$$F = \frac{1}{2\pi\sqrt{LC}} + \frac{5.2 - r}{2} \qquad \text{(3) for } \mathbf{r} < 5.2$$

Where $L = 2.57 e^{-\frac{w_3}{\sqrt{2}}} (\pi r - 2.2 d_1 - \frac{\pi}{2})$ ..... (4)

$$C = 0.217 + [(0.059(2r + e_r - 5)) + (0.437 w1 - 0.317 w_2^2 + 0.07 w_2^3)(3.3367 e^{-3.2 d_1} - 0.1955 e^{-0.47h})] + (0.05 e_r - 0.218) + (\frac{0.599h}{0.0248 + h} - 0.599) \qquad (5)$$

where, w_1=w; w_2=w; w_3=w; for d<1; &

w_1=w/3; w_2=1.414w; w_3=w/1.414; for d>1

d_1=d; for d<1;& d_1= 1.414d; for d>1

The validity of this relation is confirmed through experiment and simulation. The comparison of resonant frequency obtained through equation and simulation are shown graphically in figure.5(a)-(e).The equation was found to hold well within 10% error and verified for frequencies from 1to 8GHz.

IV.GA OPTIMISER FOR RESONANT FREQUENCY OF THE 2 RING SRR

The parameters used for developing the optimizer are: the external radius of SRR (R_{ext}), width of rings(w) and gap between rings (d). All dimensions are specified in millimeters.The substrate properties like thickness of material(h) and dielectric constant (ε_r)are treated as input parameters to be provided by the end-user. The split in the ring (s) equals 0.3mm A chromosome consists of three genes namely, R_{ext} ,w and d. 4 bits are used for 'w' and 'd' and 6 bits are used for external radius (R_{ext}).

$0.2 \leq$(w,d)$\leq$ 1.7; where 1.7=(0.2+ (15x0.1)).
$3 \leq R_{ext} \leq 9.3$; where9.3= (3+ (63x0.1)) ;
for F < 4GHz
$1.7 \leq R_{ext} \leq 8.0$; where 8=(1.7+ (63x0.1)).
for F > 4GHz

The minimum inner radius of the inner ring is limited to 0.3mm. 20 is chosen as strength of population. Cost function is the difference between desired frequency and obtained frequency. Iterations are continued till cost attains a minimum. Validation of the optimizer is done for different desired frequencies. The results obtained are verified experimentally and through simulation using ANSOFT HFSS [Fig.5(a-e)].

V.CONCLUSION

In this paper exhaustive experimental and simulation studies are conducted on SRR to clearly understand its inherent properties and the external factors affecting it. It is observed that the width of ring (w), gap between rings (d), radius of SRR (R_{ext}), the the height of substrate (h) and its dielectric constant have a profound effect upon the resonant frequency. The resonant frequency is found to be independent of excitation, but its polarisability strongly depends on the external fields impinging on the SRR [3]. The negative permeability effect is experimentally proved by the cavity perturbation method. Validation of the design equation is done through experiment and simulation. A satisfactory result is obtained with error less than 10% for frequencies in the range 1-8 GHz. Dedicated software is also developed using Genetic algorithm for obtaining dimensions of SRR for the desired frequency.

ACKNOWLEDGEMENT

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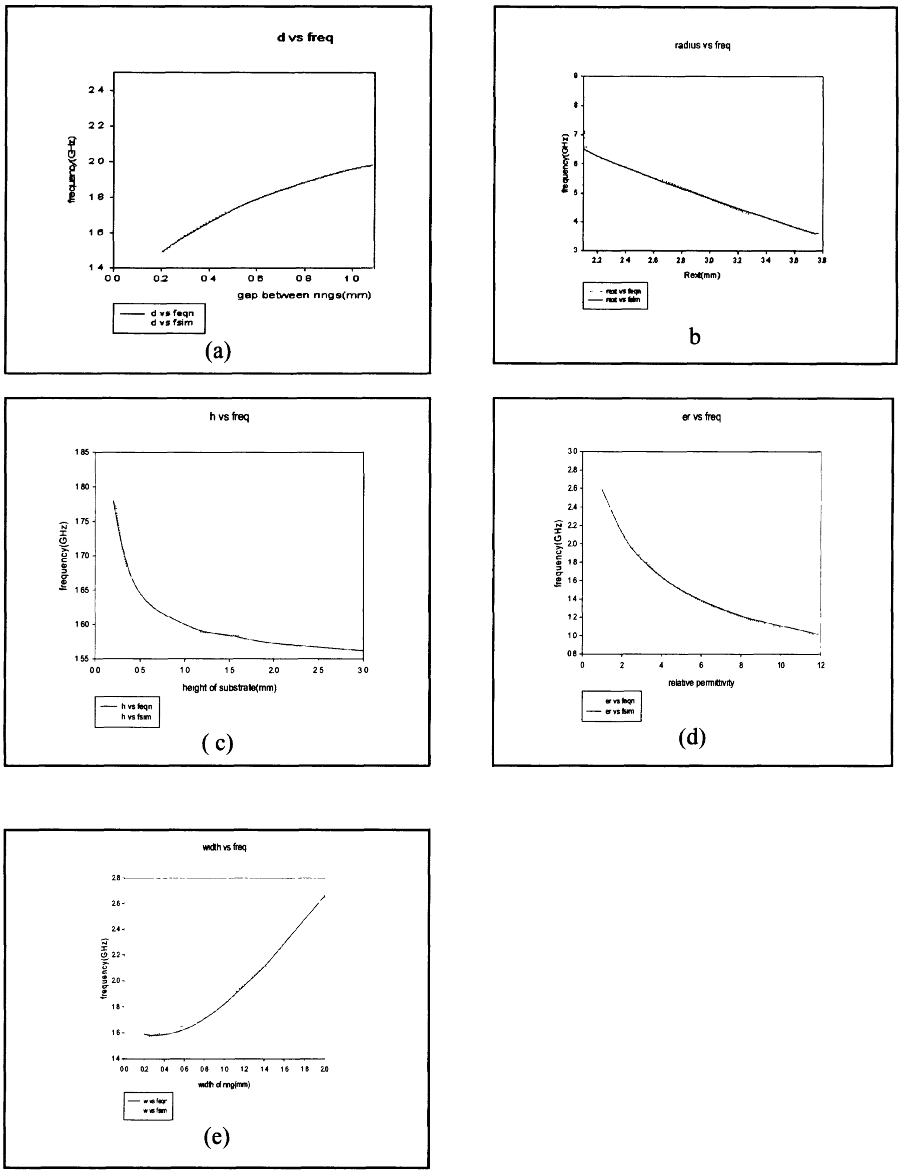

Fig:5(a-e). Validation of equation and optimizer through simulation and experiment