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Short Communication

Metamaterials in microwave applications: A selective survey

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Recently, metamaterial has grabbed prime focus of research fraternity working in the field of antennas, microwave filters and components design. Many different structures of split ring resonators (SRR) for their respective applications have been reported till date. In all of these findings in some way or other, using metamaterial, drastic reduction in size of the component has been achieved. Thus, the metamaterial can be viewed as a powerful miniaturization tool in the field of radio frequency (RF) and microwave. Since its inception in 1999, many variants of SRR have come up leading to more efficient designs with better RF properties. This review paper presents an application based review of such variants and will be useful for new researchers exploring its use in their research problems.

Key words: Metamaterial, antenna miniaturization, negative refractive index metamaterial (NRIM),split ring resonators (SRR).

INTRODUCTION

In a pioneering paper, written in 1968, Prof. V.G. Vaselego coined a term Metamaterial, a hypothetical material having negative value of electrical and magnetic permeabilities and theoretically he derived the properties (Vaselego, 1968). For almost thirty years after its inception, there was hardly any substantial work reported this field. In 1999, Pendry et al. first realized negative permeability by introducing periodic array of nonmagnetic conducting units. They demonstrated that periodic array of nonmagnetic conductor split rings show negative effective permeability at high frequency side of resonance (Pendry et al., 1999). It was first time in year 2000, when Smith et al. came up with physical realization of simultaneously negative values of effective magnetic permeability and electrical permittivity and thus a negative value of refractive index (NRIM) in microwave regime (Smith et al., 2000). The structure they called left handed medium comprised of periodic array of interspaced conducting nonmagnetic split ring resonators and continuous wires. The array conducting wire provided electric field resonance and thus negative value of electrical permittivity. Since then many variants of split ring structure have been reported by researchers for different engineering applications. But complete potential of metamaterial is yet to be explored. The main objective of this review paper is to discuss different variants of metamaterial structure and their applicability in microwave engineering problems.

METAMATERIALS IN MICROWAVE APPLICATIONS

Metamaterial in the form of various structures has been extensively used by the microwave researchers to design

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miniaturized microwave components, filters and antennas. Sabah et al. (2010) presented a method of mechanical tuning of metamaterial resonant frequency by varying substrate thickness. In the paper, a metamaterial structures whose unit cell has triangular split ring resonator (TSRR) and wire strip (WS) have been analyzed for S- and C- microwave bands. Retrieval method has been used for calculation of effective material parameters. Simulation results show that the new metamaterials exhibits double negative properties in the frequency region of interest and their resonant frequency can be tuned by varying substrate thickness. In Sulaiman et al. (2010), the authors proposed two types of metamaterial composed of patch antennas, one antenna using metamaterial as substrate and the other one using metamaterial as cover. Perfectly electric conductor in omega shape on RT 5880 substrate has been used as metamaterial unit. When metamaterial unit is used as substrate of patch antenna, there exist drastic reduction in size of the patch, and becomes comparable to the metamaterial unit. The reduction in size is also accompanied by improvement in return loss. The price paid is the bandwidth. This antenna is found suitable for narrow band applications. When planar array slab consisting of metamaterial units is used as a cover of conventional patch antenna, significant improvement in directivity was also observed.

In Ziolkowski et al. (2009), the authors present design, fabrication and simulation of electrically small, coaxially fed metamaterial inspired Z antennas having ability to change resonant frequency by changing value of lumped element inductor. The structure consists of a coaxially fed monopole printed on one side of RT5880 substrate, while Z element printed on the other side. The Z element is composed by joining two “J” elements connected by a lumped element inductor. The authors have tested the design for two Z-antennas one at 570 MHz and another at 300 MHz. The results show that by changing value of lumped element inductor joining the two “J” elements, the resonant frequency of the antenna can be successfully changed.

Further, Palandoken et al. (2009) also presented a novel application of metamaterial for antenna miniaturization. Metamaterial is composed of unit cells having spiral rings connected to metal strips on both sides of FR4 substrate, arranged in 2×3 planar array form. The antenna comprises of a printed dipole directly connected to three of six unit cells. Rectangular slot in truncated ground plane allows better impedance matching. It has been shown that loaded dipole gives broad bandwidth about 63% with drastic reduction in size.

Ziolkowski et al. (2009) also explored the metamaterial property to design antenna at 300 MHz. This paper demonstrates electrically small, metamaterial inspired 3D magnetic EZ antenna, consisting of extruded capacitively loaded loop (CLL) driven by coaxially fed semi loop antenna. Resonant frequency of the antenna is found tunable by amount of Quartz filled capacitive gap of CLL) element. The antenna is found to be nearly matched without any external circuit and shows more than 95% efficiency with a fractional bandwidth of 1.66%. Sharma et al. (2011) introduced elliptical split ring resonator (ESRR structure to get metamaterial property. The structure is dual fed in offset and shows negative value refractive index at multiple frequencies. When tested for radiation properties the ESRR gives highly directional radiation pattern. In the design of metamaterial antennas some researchers also addressed the issue of optimization in design. Vidyalakshmi et al. (2009) proposed a hybrid of genetic algorithm (GA) and artificial neural network (ANN) called GA ANN for optimization of metamaterial split ring resonator to achieve given resonant frequency. Size of outer square ring, conductor width, dielectric spacing between outer and inner rings are inputs to the optimization program and error between desired resonant frequency and calculated resonant frequency has been taken as cost function to be minimized. ANN has been used to obtain fitness of chromosomes. Performance GA ANN when compared with stand alone GA and stand alone ANN, GA ANN converges more fast and gives higher accuracy. Sumanta et al. (2012) introduced a new structure, N-sided Regular Polygon Split Ring Resonator (NRPSRR). They have also nicely presented the mathematical analysis and derivation of the structure. Further my increasing the limit of N to infinity, they have obtained resonant frequency for cicular SRR. Genetic Algorithm has been successfully used to obtain simulation model of the structure.

Conclusion

The paper presents a selective review of findings reported by various researchers in the field of metamaterial research and its application in microwave structures. Various microwave structures using metamaterial for miniaturization, have been discussed. Mathematical modelling of metamaterial is a new dimension; the research fraternity is focussing now. Less research has been reported in this particular field till date. The aspect has been addressed in this survey. This paper will go a long way for the new scientists interested to use metamaterial in microwave application and miniaturization problems.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Palandoken M, Grede A, Heino H (2009). Broadband Microstrip Antenna With Left-Handed Metamaterials”, IEEE Trans. Ant. Prop. 57(2):331-338.

Pendry JB, Holden AJ, Robbins DJ, Stewart WJ (1999). Magnetism from conductors and enhanced nonlinear phenomena. IEEE Trans. Microwave Theory Technique, 47:2075–2084.

Sabah C (2010). Tunable Metamaterial Design Composed of Triangular Split Ring Resonator and Wire Strip for S- and C- Microwave bands", PIER B 22:341-357.

Smith DR Padilla Willie J, Vier DC, Nemat-Nasser SC, Schultz S (2000). Composite Medium with Simultaneously Negative Permeability and Permittivity, Phys. Rev. Lett. 84(18):4184-4187.

Sulaiman AA, Othman A, Jusoh MH, Baba NH, Awang RA, Ain MF (2010). Small Patch Antenna on Omega Structure Metamaterial. Europ. J. Sci. Res. 43(4):527-537.

Sumanta Bose M. Ramaraj Dr. S (2012). Raghavan, Swadhyaya Kumar, Mathematical Modeling, Equivalent Circuit Analysis and Genetic Algorithm Optimization of an N-sided Regular Polygon Split Ring Resonator (NRPSRR), 2nd International Conference on Communication, Computing. Security [ICCCS], Procedia Technology 6:763-770.

Vidyalakshmi MR, Raghavan S (2010). Comparison of Optimization Techniques for Square Split Ring Resonator, Int. J. Microwave. Optical Technol. 5(5):280-286.

Ziolkowski RW, Jin P, Nielsen JA, Tanielian MH, Holloway CL (2009). Experimental Verification of Z Antennas at UHF Frequencies", IEEE Antenna and Wireless Propagation Lett. 8:1329-1333.

Ziolkowski RW, Lin CC, Nielson ja, Tanielian MH, Holloway CL (2009). Design and Experimentation Verification of a 3D Magnetic EZ Antenna at 300 MHz", IEEE Ant Wireless Prop Letters. P. 8.