STUDY OF METAMATERIAL APPLICATIONS IN MICROSTRIP FILTERS

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ABSTRACT

In this work, a review has been presented on filter designsbased on microstrip technology with the implementation of metamaterials. With the development of metamaterials in recent years, more and more interests have been attracted in the potential applications of these novelmaterials.It briefly describes the properties of various typrs of resonators that behave as Left handed materials. Some of the implications of SRRs, CRRs and other structures in filter design have also been discussed.

***Keywords*: Conventional Filter, Metamaterial, Microstrip, Q- factor**

I. INTRODUCTION

With fast pace developments and vivid research in the field of metamaterials, they have gained much attention in the field of microwave engineering in recent years. The metamaterials or artificial electromagnetic materials are those materials that do not have any natural occuttence in nature. They are synthesized artificially through man-made processes. Metamaterials refer to artificial structures that consist of a periodic array of metal pieces or the like. Technologies called “left-handed Metamaterials” in particular can even produce phenomena that are not available in natural substances and thus it is expected that this will enable the fabrication of electronic devices with functions heretofore unimaginable. This paper first provides an overview of what left-handed metamaterials are and then introduces technologies that are nearing practical use, focusing on such applications as telecommunication devices, we will also mention the future evolution of such technologies, and the trend of research papers on metamaterials. Metamaterials are usually composed of periodic sub-wavelength units, which can produce electric or magnetic response under the excitation of external incident waves. Since the characteristic dimensions of the composing units are far smaller than the working wavelength, effective medium theory can be utilized to describe the electromagnetic properties of the periodic structures. A number of applications have been verified by experiments like invisible cloaks, microwave lens and tunnelling structures [1-3].

II. METAMATERIALS

Periodically arranged at intervals shorter than the specified wavelength of an electromagnetic wave, small pieces of metal and the like can constitute an artificial medium that has characteristics not found in nature (Figure 1). Such a medium is called metamaterial. Metamaterials can also be made of dielectrics, magnetic substances, semiconductors, and the like, and even electric circuits instead of metal pieces.

The word "meta" derives from the Greek word that means "beyond". While conventional materials provide their intended physics properties in terms of design on the atomic or molecular level, metamaterials realize their specified physical properties through the design of an artificial structure that can be regarded as a quasi-uniform medium in a macroscopic view.

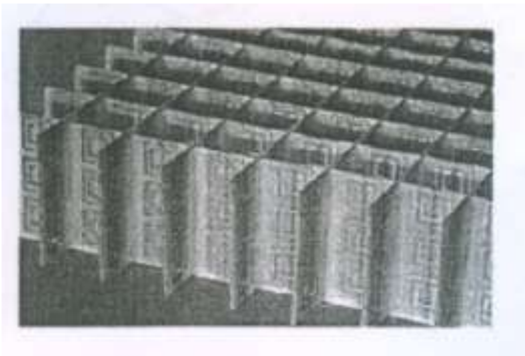

Fig. 1: Metamaterial Proposed by D.R. Smit

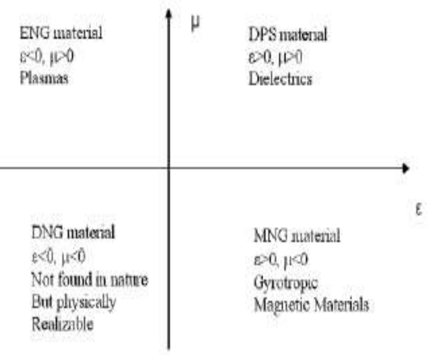

Fig. 2: Classification of Materials by Permittivity ε and Permeability μ

III. DIFFERENCES BETWEEN LEFT-HANDED METAMATERIALS AND CONVENTIONAL METAMATERIALS

Russian scientist V.G.Veslago published about 40 years ago that examined the effects of a "left-handed" material with the simultaneously negative-permittivity and permeability along with a negative refractive index. Having originated from a purely theoretical interest, the study predicted some new phenomena that had never been conceived of. Left-handed materials were supposed to have a negative refractive index and optical applications of their characteristics attracted interest. Since there was no actual material to validate the theory at that time, no further attention was given to left-handed materials. In 2000, US physicists D.R.Smith et al. Realized a left-handed material by an artificial structure called Metamaterial. A number of discussions and examples of experiments have been reported ever since. The electromagnetic characteristics of electronic material are primarily determined by the basic parameters, i.e. the permittivity, the permeability and the conductivity.

In contrast to such ordinary electronic materials, ones with this simultaneously negative- permittivity and permeability, if any are referred to as left-handed materials since the vectors correspond in direction to the thumb and two figures of the left hand (the third quadrant in Figure 2). There exist no left-handed materials in nature, however. Left-handed materials produce peculiar phenomena among which “negative refractive index” and the generation of a “backward wave” are the properties of particular significance.

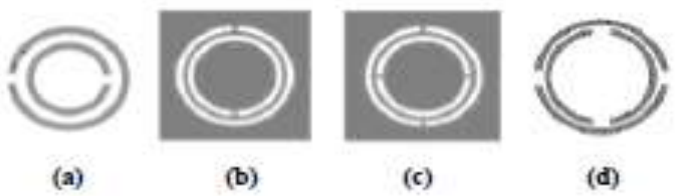

Fig. 3: Schematic layout of (a) SRR, (b) CSRR, and (c) DS-CSRR (metal regions are in dark gray) (d) DS-SRR

IV. CATEGORIES OF LEFT-HANDED METAMATERIALS

The D. R. Smith’s paper of a Metamaterial i.e. a left-handed material consisting of an artificial structure in 200 sparked research into “left-handed metamaterials” for practical use.

A left-handed metamaterials is an artificial structure in which small pieces of metal or the like are periodically arranged at an interval shorter than the wavelength of the intended electromagnetic wave. Each individual portion of the periodical structure is called “a unit cell”. The left-handed Metamaterial is fabricated by optimizing the shape and arrangement of the unit cells so that the artificial structure has the aimed characteristics. Among the characteristics produced from these artificially-structured metamaterials, left-handed metamaterials are regarded as a technique to make positive use of “dispersion characteristics” that change with frequency. In other words, left-handed metamaterials inevitably have frequency dependencies and show left-handed characteristics in a certain frequency band. It follows that left-handed metamaterials may also show right-handed characteristics or rejection characteristics as well in other frequency bands. In the field of information and communications, many left-handed metamaterials are used in many applications as a combination of left handed and right handed elements, rather than as sole left-handed elements and the former applications are the more dominant in practice. Such metamaterials are some times referred to as CRLH (Composite Right/Left-Handed) metamaterials, where they are categorized as also left handed materials since they include left-handed elements.

V. APPLICATIONS OF METAMATERIALS

A large amount of research works have been done by many research groups around the globe to understand the novel properties of electromagnetic materials and their potential applications in various fields like wireless and mobile communication, medical application, right from the microwave to the optical frequency range especially in designing of filters. Metamaterials are a new class of artificial materials whose microstructure is engineered to exhibit unique electromagnetic properties either rarely, if not, encountered in nature or previously believed to be physically inconceivable.

In 2004, Ricardo Marques, Juan Domingo Baena presented a new planar left-handed propagating medium consisting on a microstrip line with complementary split ring resonators etched on the ground plane that produces a negative dielectric permittivity whereas the negative magnetic permeability is achieved by capacitive gaps periodically spaced along the strip conductor. Using EM duality theorem, it is shown that a complementary split ring resonator produces an equivalent response to that of a negative dielectric permittivity. In this way, the complete structure permits negative wave propagation in a narrow frequency band. Since negative μ and ε coexist only in the vicinity of the resonant frequency of the rings, signal propagation in the structure is limited to a narrow frequency band. The proposed structure can be interest for the fabrication of high selectivity band pass filters based on left handedness [5].

In 2005, Christophe Caloz and Tatsuo Itoh demonstrate the fundamental aspects of LH/CRLH metamaterials , described some of their applications, discussed potential future devices and structures and has anticipated some of the challenges toward a brilliant future. It is believing that Metamaterial have a huge potential and may represent one of the leading edges of tomorrow technology in high frequency electronics [6].

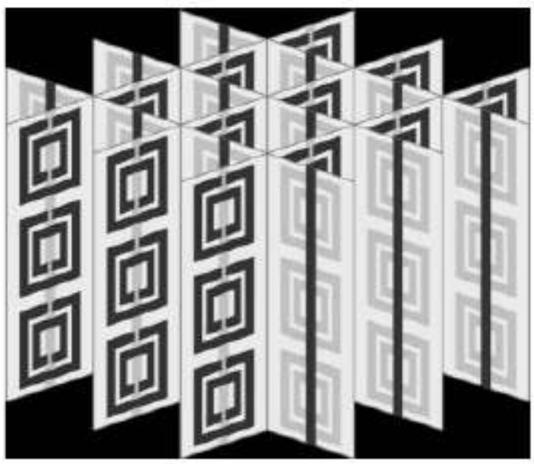

Fig.4 a) Symmetric split ring resonator b) metamaterial substrate constructed by combining dielectric strips with SSRRs.

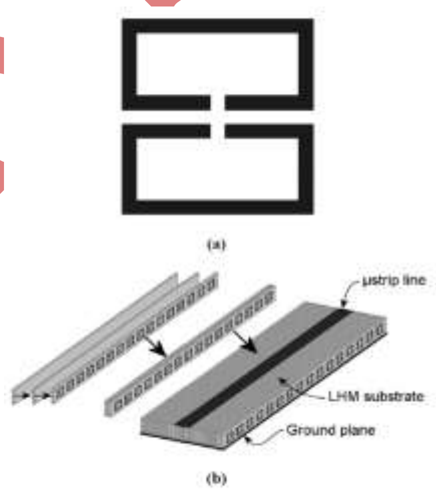

Fig.5 The Spilt Ring Resonator and Wire Medium

In 2005, J.D.Baena, et.al. proposed a new approach for the development of planar metamaterial structures. The analyzed structures are based on the coupling of SRRs & CSRRs to conventional planar lines. They are fully planar i.e. they neither incorporate vias, nor other non planar inserts nor can be implemented in both CPW and microstrip technology. By properly coupling SRRs or CSRRs to a host planar transmission line, planar structures with effective negative constituent parameters can be obtained. These structures are fully planar (i.e. without vias or other no-planar objects) and can be easily fabricated by using standard photo-etching technique.The main purpose of this paper is to provide simple and analytical techniques for the design of these structures. These techniques are based on lumped-element circuit models, able to describe the elements and their coupling to the host transmission lines, as well as on analytical formulas to determine the main circuit parameters for these models [7].

In 2006, J. Bonache, I. Gil, J. Garcia-Garcia, and F. Martin proposed a new design approach, based on theuse of CSRRs for the synthesis of compact microstrip filters. This was the first time that planar filters with controllable bandwidth based on CSRRs were achieved. Under this design method, the basic filter cell was designed such as to consist of an arrangement of grounded stubs, CSRRs and series capacitive gaps. The introduction of shunt stubs potentially provided capability to synthesize frequency responses with compact dimensions and controllable bandwidth. A equivalent circuit model for the basic filter cell has shunt stubs and series gaps have been represented by inductor (lumped) and capacitors respectively and the CSRRs have been modelled by parallel resonant structure. The structure is composed of periodic structure and behaves as a LH-TL with controllable BW [10].

In 2011,Vipul Sharma et.al, introduce conventional SRR which shows negative permeability at a narrow magnetic frequency resonant band and to obtain LHM, an additional metallic rod is to be incorporated with the SRR for electrical resonance(negative permittivity) while the ESRR structure gives LHM response without using any additional metallic rod. This type of ESRR can be easily incorporate with microstrip antennas to get highly directional beam pattern because of NRIM properties of ESRR. These types of planar microstrip structures are very useful for applications where space of equipment is a constraint. Here structure is inspired by SRR it does not incorporate additional metallic rod for electrical resonance as used with conventional SRR. The rings are elliptical in shape and coaxial dual feeding has been used that are offset in phase.

In 2013, Hichqm Lalj, Hafid Griguer, M'hamed Drissi, proposed a design where two techniques are used for the metamaterial miniaturization, to optimize the physical and electrical size of the CSRR. The band stop filter is produced by an array of miniaturized loaded CSRRs etched on the centre line of a microstrip. The size of the proposed filter is as small as 0.58 cm^2 and its electrical length is very small with only 0.08 λ compared to the conventional band stop filter, a miniaturization of a factor five while the performance is maintained [11].

In 2013, Lakhan Singh and P.K.Singhal, discuss two microstrip band pass filters. One is cascade trisection filter without split ring resonator and other is with split ring resonator and after simulation compared their results. The simulated result shows that by using rectangular split ring resonator inside the split ring resonator the fractional bandwidth is increases and the return loss in the pass band is also increase and the rejection in the lower side of the pass band is also increases. The filter without SRR is resonating at frequency 1.4 GHz with return loss -20dB where as the filter with SRR is resonating at frequency 2.05 GHz with return loss -31 dB in the passs band. The filter with SRR giving fractional band width of 10% as compared to filter without SRR having fractional band width is 8.5% [12].

VI. CONCLUSION

The microstrip filters based on resonant type left handed and composite right/left-handed metamaterialtransmission lines have been revised in this work. Moreover, it has been demonstrated that a Metamaterial structure behaves as an effective (continuous) medium with left handed wave propagation in the pass band. Due to the small electrical length of the resonators employed, the presented approaches become very attractive for the design of compact planar microstrip filters using metamaterials. If practical applications to exploit the advantageous properties of left-handed metamaterials for the market requirements are proposed by industry without being blinded by the linear model of research and development and if academic societies work cooperatively with the proposals, there will be then technical advances promoting its practical use and even another step forward. With the globalization of research activities and worldwide competition, the speed of development has grown intense.

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