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Modelling and Validation of Microwave LPF Using Modified Rectangular Split Ring Resonators (SRR) and Defected Structures

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***Abstract*— We propose a design of lowpass filter (LPF) using modified rectangular split ring resonator (SRR) that acts as a unit cell of metamaterials. Initially, a conventional LPF of 4.5 GHz is designed and the low impedance line is replaced to produce a sharp cut-off with a modified SRR structure. A brief parametric study is done to establish a relationship between the inner perimeter of the SRR to the cut-off frequency of the proposed LPF. Same study is also done for the outer perimeter. Using this relationship, another LPF of 2.4-GHz cut-off frequency is obtained. Defected ground structures (DGS) and microstrip structures (DMS) are incorporated with the 2.4-GHz LPF structure for the removal of harmonics and better pass-band characteristics. The IE3D simulation results and the circuit simulation results are in good agreement with the measured results. The obtained structure can thus be used for several useful applications such as in Bluetooth, Wi-Fi, cordless phones, computers, and other wireless communication devices.**

Keywords—LPF; Metamaterials; Modified SRR; DGS; DMS;

1. INTRODUCTION

In recent research, the microstrip-based lowpass filters (LPF) are used to suppress spurious signals as well as play a vital role in microwave communication owing to their enormous advantages. As an important front-end component, the compact-sized, planar configuration, sharp cut-off, and good performance of LPF was thoroughly investigated [1–2]. Designing of a conventional LPF includes two-steps, including the selection of an appropriate lowpass prototype [3] and finding a microstrip realization. However, such structures provide a gradual decline at -3dB cut-off when designed at low order. Hence, rather than increasing the order of the filter, the low impedance line of the existing filter can be replaced by a modified split ring resonator (SRR) structure. Several papers have explained the conventional and non-conventional SRR structures [4–7]. SRR is used as an element of metamaterials (MTMs) [8] and also as single negative MTMs (SNG-MTM). In this paper, the proposed SRR has a modified structure. The inner and outer rings of the dual-ring SRR structure were shortened. The MTMs [9–10] are defined as the artificial materials that consist of periodic and macroscopic structures. An important property of MTM is the NRI [11–12] that is obtained by incorporating thin-wire structures and SRR structures. In the SRR, the magnetic dipole due to split rings lags the magnetic field by 180^0 which results in negative permeability. It has been observed that the modified SRR structure also exhibits NRI as well as negative permeability over the desired frequency range. The parametric extraction [13–17] of the modified SRR structure is obtained from the S-parameters.

In this paper, initially, an LPF of 4.5 GHz cut-off frequency was designed using lumped components. Later, it was transformed into a microstrip conventional structure. Due to the gradual decline in the conventional structure and the requirement of a compact size, a modified SRR structure was introduced instead of the low impedance line in the existing structure. Then, a parametric study considering the relationship between the cut-off frequencies and the perimeter of the rectangular SRR was performed. From this, a polynomial equation was derived to reveal the above relation. Using this equation, another LPF structure with 2.4 GHz cut-off frequency was derived. The observation was performed for implementing any LPF value of <4.5 GHz cut-off. It was noticed that, although sharp roll-off was achieved, harmonics occurred periodically in the response graph of 2.4 GHz LPF. It had a severe impact on stopband. Therefore, to remove these harmonics without disturbing the passband, defected ground structures (DGS) [18–20] and defected microstrip structures (DMS) [21] were introduced. It was noted that, with the combination of DGS and DMS, the structure provided excellent result. To verify this notion, the designed 2.4 GHz LPF was fabricated and then measured. The measured results provided good agreement with the simulated ones. The performance improvement was compared with previously designed LPFs [22–24]. The filters were fabricated by using FR4 substrate with a dielectric constant of $\in_r = 4.4$, substrate height (h) of 1.59 mm, thickness of microstrip conductor (t) of 0.02 mm, and tanδ of 0.02. Lastly, an equivalent circuit for the proposed microstrip structure of 2.4 GHz cut-off frequency was obtained, and responses were compared.

2. ANALYSIS OF CONVENTIONAL AND MODIFIED SRRS

The SRR structure was employed for performance enhancement of the LPF rather than increasing the order of the filter. The modified SRR structure offers much better frequency response and smaller size than the conventional SRR structure. It was