Analysis of Triple Band Split Ring Resonator Based Microstrip Bandpass Filter

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Abstract: This paper presents the design, simulation and implementation of microstrip bandpass filter having SRR structures on radiating side which resonates at tri-frequencies (2.4, 4.5 and 5.2 GHz) which are used for WLAN applications. Filter parameters like return loss, insertion loss, group delay, phase delay and bandwidth are improved by the implementation of SRR structures on the center of the transmission line. To optimize the dimension of the SRR unit cell and filter parametric analysis are performed with ANSYS HFSS. The proposed filter with 3 SRR unit cell having the minimum transmission coefficient of -0.7dB, -1.27dB, and -2.1dB across 2.4, 4.5 and 5.2GHz, reflection coefficient of -22.7dB, -23dB, and -16.5dB across 2.4, 4.5 and 5.2GHz, group delay value of 1.52ns, 1.38ns and 0.58ns across 2.4, 4.5 and 5.2GHz with minimum nonlinear phase response and the quality factor value of 14.1, 18.7, 13.7 across 2.4, 4.5 and 5.2GHz. The proposed filter was designed with the order of 5 using Chebyshev type 1 approximation technique having a ripple factor value of 0.01dB. Surface current distributions of the proposed filter are also evaluated. Fabricated microstrip bandpass filter results are measured and validated using ANRITSU-MS2037C combinational analyser.

Key words: SRR structure, Filter and WLAN.

1. Introduction

Now a days in communication system to meet the requirement of narrow bandwidth, high return loss, compact size, high selectivity and low insertion loss microstrip bandpass filters are implementing [1]. The fetching feature of the multi-mode filter is its compactness, as the addition of resonators needed for a given degree of the filter is decrease by half. Moreover, the multimode filter exhibits quasi elliptical or elliptical frequency response which results in high selectivity [2]. Mostly mu lti mode micro strip structure consists of defected ground structure, cross slotted and right cross slotted [3] and loaded crossed slots in the square patch. SRR are used to reduce the circuit size [4] in the literature. In 1994 metamaterial structure such as SRR are first reported. These structures are used for enhancing the microwave and millimeter wave devices which improve the performance and reduce the radiation losses. Various types of artificial resonator [5] are placed in the antenna or filter to improve their performance by varying the with, gap distance, split width,
number of rings of the SRR and SRR [6]. Split ring resonators are mainly used for the improvement of reflection and insertion losses in low cost, light weight and compact filter. A work has been reported with the integration of parallel step impedance resonator and MTM structure to attain triple passband filter in addition in TZs. A compact triple band bandpass filter has been proposed using Koch fractal shape transmission line and complementary split ring resonator. By the design and implementation of the multi-mode resonator electromagnetic characteristics of multiband filter are enhanced. In a triple-band BPF to improve passband and filter performance two identical square open loop resonator has been designed. Design compliance are required for triple bandpass filter to offer different pass bands with different bandwidths in communication system.

In this paper narrow bandpass microstrip filter with 3 SRR unit cells which operation in S and C band is proposed. The proposed band pass filter was designed using FR-4 as the substrate which having the thickness of 1.6mm. The proposed bandpass filter showing the minimum insertion loss and high reflection coefficient by using Chebyshev type -1 analog approximation technique with the stopband attenuation of -40dB having the ripple factor value of 0.01dB. The proposed filter having the high-quality factor value with minimum group delay and linear phase repose.

2. Design of Microstrip band pass filter with integration of SRR structure

2.1 Design of Microstrip band pass filter

In this paper a compact metamaterial inspired band pass filter are proposed and characterized using ANSYS electronic desktop. The dimension of the filter along with SRR unit cells have been optimized and placed in figure 3. The band pass filter having the impedance value of 50ohm using fr-4 as substrate with the dielectric constant of 4.3 and having the thickness of 1.6mm. The order and LC equivalent model of the proposed band pass filter along with its iterations have been designed using Chebyshev type 1 approximation with the ripple factor value of 0.01dB.

The length and width of the Microstrip bandpass filter was optimized by considering parametric analysis in the ANSYS HFSS software.
From figure 1 it was observed that as the length and width of the microstrip bandpass filter with etched slot from 19.5mm to 22.5mm and 16.5mm to 13.5mm as its return loss value increases and insertion value decreases with a value of -22dB and -1.12dB at a frequency of 2 GHz, -23.1dB and 1.45dB at a frequency of 4.1 GHz and -15.1dB and -2.1dB at a frequency of 5.2GHz. Due to etched slot triple bands are occurs in bandpass filter.

2.2 Design of Metamaterial structure

The length and width of the SRR structure was optimized by considering parametric analysis in the ANSYS HFSS software which was stated in figure 5.

![Figure 2: Optimization cure of first, second and third rectangle cell in SRR structure Width optimization and Length optimization](image)

Form figure 2 a,b it was observed that as the length and width of the first rectangle cell increases from 1.7mm to 2mm and 2.7mm to 3mm as its return loss value increases and insertion value decreases with a value of -25dB and -2.12dB at a frequency of 2.4 GHz. Form figure c,d it was observed that as the length and width of the second rectangle cell increases from 0.7mm to 1mm and 0.9mm to 1.2mm as its return loss value increases and insertion value decreases with a value of -23dB and -1.4dB at a frequency of 4.5 GHz. Form figure 2 e,f it was observed that as the length and width of the second rectangle cell increases from 0.32mm to 0.35mm and 0.1mm to 0.4mm as its return loss value increases and insertion value decreases with a value of -12dB and -4dB at a frequency of 4.5 GHz.
2.3 Metamaterial properties

Figure 3: Optimized dimensions of Microstrip bandpass filter and SRR unit cell

Figure 4: Permeability value of SRR unit cell (a) 2.4GHz, (b) 4.5GHz and (c) 5.2GHz

Figure 5: Permittivity value of SRR unit cell (a) 2.4GHz, (b) 4.5GHz and (c) 5.2GHz

Figure 6: Refractive index value of SRR unit cell (a) 2.4GHz, (b) 4.5GHz and (c) 5.2GHz
From figure 4, 5, and 6 it was observed that by the implementation of SRR structure the mechanical properties like permittivity, permeability, and refractive index of the structure showing negative values which ranges from -0.6 to -0.8 which improve the performance of any system by integrating these SRR unit cell in the middle of the transmission line.

3. Results and Discussion

3.1 Filter parameters

Figure 7 stating the return loss and insertion loss, group delay and phase response of the proposed filter. From the figure 7 (a) it was observed that the microstrip bandpass filter with slotted center with three SRR unit cell performing at three different modes of frequency like 2.4, 4.5 and 5.2 GHz with return loss and insertion loss value of -22 dB & -2.12 dB, -23 dB & 1.9 dB and -14.2 dB & -3 dB. Similarly, figure 7 (b) stating the group delay value of 1.52 ns, 1.38 ns and 0.58 ns across 2.4, 4.5 and 5.2 GHz which are very low. Finally, figure 7 (c) stating the phase response of the proposed filter which was linear.

![Figure 7: Filter parameters](image)

3.2 Bandwidth and Quality factor

Proposed microstrip band pass filter with three SRR having the bandwidth value of 170, 240 and 390 at 2.4, 4.5 and 5.2 GHz. Minimum the bandwidth occurs due to narrow band in the pass band filter and Proposed microstrip band pass filter with three SRR having the quality factor value of 14.1, 19.5 and 13.6 at 2.4, 4.5 and 5.2 GHz.

3.3 Surface currents

Surface current distribution represent the intensity of current in the device. Higher the current distribution values at operating frequency higher the performance value in term of its scattering parameters (i.e.) return loss, insertion loss. The surface current of the proposed band pass filter is 124 A/m.

4. Conclusion

The proposed filter with 3 SRR unit cell having the minimum insertion loss of -0.7 dB, -1.27 dB, and -2.1 dB across 2.4, 4.5 and 5.2 GHz, reflection coefficient of -22.7 dB, -23 dB, and -16.5 dB across 2.4, 4.5 and 5.2 GHz, group delay value of 1.52 ns, 1.38 ns and 0.58 ns across 2.4, 4.5 and 5.2 GHz with minimum nonlinear phase response and the quality factor value of 14.1, 18.7, 13.7 across 2.4, 4.5 and 5.2 GHz. The proposed filter was
designed with the order of 5 using Chebyshev type 1 approximation technique having a ripple factor value of 0.01 dB. Surface current distributions of the proposed filter are also evaluated. Fabricated microstrip bandpass filter results are measured and validated using ANRITSU-MS2037C combinatorial analyzer. Simulated results and measured results are of good agreement.

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