Jurnal
Teknologi

Full Paper

COMPACT MICROSTRIP BAND-PASS FILTER FOR EMI REDUCTION

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Article history
Received
15 April 2015
Received in revised form
29 September 2015
Accepted
12 November 2015

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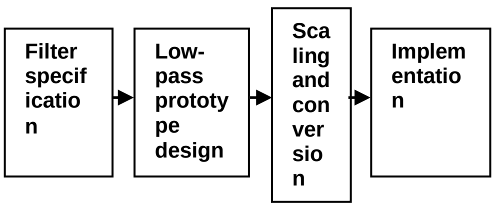
Graphical abstract



Abstract

Compact microstrip band-pass filter design using parallel coupled lines is presented in this paper. The microstrip lines are calculated and constructed using CST studio with two input and output ports of the filter structure are printed over Defected Ground Structure (DGS).The proposed symmetrical structure offers a simple and compact design while exhibiting an improved stop-band characteristics in comparison to conventional coupled microstrip line filter structure. The simulation and measurements of 2GHz prototype band pass filter are presented. The measured result agrees well with the simulation data. Compared with conventional parallel coupled line band pass filter, the second, third and fourth spurious responses are suppressed; in addition, the size of the prototype filter circuit is reduced up to 20.8%.

Keywords: Band-pass filter, compact, EMI reduction, Defected Ground Structure (DGS), delay filters, delay-lines, power amplifiers

1.0 INTRODUCTION

The increasing development of wireless applications introduces new requirements for transceiver architectures that feature excellent microwave performances (linearity, spurious rejection, noise figure and bandwidth) and enhanced integration density that is achieved through miniaturization of modules as well as the introduction of multi standard functionalities. All these requirements translate to the need for miniature filters with low pass-band insertion loss and high stop-band rejection [1]. In today's fast-growing wireless and RF industry, time to market is critical. Smaller and less expensive units are becoming the norm and the use of CAD tools to quickly and accurately simulate the behaviour of wireless components becomes more important as designs become more complex and prototyping cycles become shorter.

Widespread use of electric and electronic systems for household, industrial, communications and other applications makes it necessary for circuits to operate on close proximity of each other. Often these circuits affect the performance of other nearby circuits adversely via inadvertent coupling of their signals through near and far region, propagating Electro Magnetic fields [2] and [3]. This interference is thus called Electro Magnetic Interference (EMI) and is emerging to be a major problem for Communication systems.

In addition, the use of integrated circuits has reduced the size of electronic equipment and more circuits are being put in less space, thereby increasing the problem of interference. The rapid growth in the use of personal communication systems such as cellular, radios and pagers, and the very large user base for networked systems such as the Internet have further increased the possibilities of EMI leading to malfunctions.

A Ground Defected Structure is considered, in which the wave propagation level through the exploitation of defected ground structure's properties. The DGS, realized by etching patterns in the ground plane, enables higher order modes suppression through the introduction of a wide stop-band in the frequency response of the filter, and on the other hand introduces slow wave effect which translates into a reduction of the electrical length and hence the overall filter dimensions [4]and [6].

2.0 DGS CONFIGURATION AND EQUIVALENT CIRCUIT

A parallel LC circuit represents the equivalent circuit of the proposed DGS section. From a practical point of view, the DGS section can serve as replacements for a parallel LC resonator circuit. To apply the DGS section to a practical circuit design, it is essential to extract the equivalent circuit parameters. A dumbbell DGS shape and its equivalent circuit of the proposed DGS is shown in Figure 1 and 2:

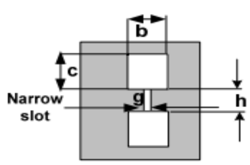


Figure 1 dumbbell shape

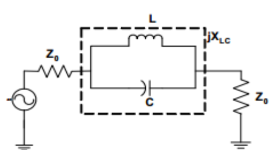


Figure 2 DGS Equivalent circuit

There are two different DGS shape which were used in this paper. The dumbbell shape DGS as shown Figure 1 which is the common type of normal DGS which is used most of the coupled lines. But the slanted shape as shown Figure 3 is only used in the middle. This DGS was chosen with respect to the structure of the parallel coupled line filter since a normal dumb-bell shaped DGS may not be able to apply to a parallel coupled line filter properly and it can overlap the adjacent resonators, thereby causing failure during the line filter's operation.

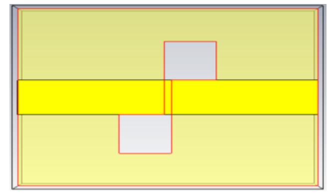


Figure 3 Slanted dumbbell DGS

The DGS acts as stop-band which is the aimed used in this paper is to eliminate the EMI and reduce the size as the same time. Figure 4 shows the s-parameter of DGS.

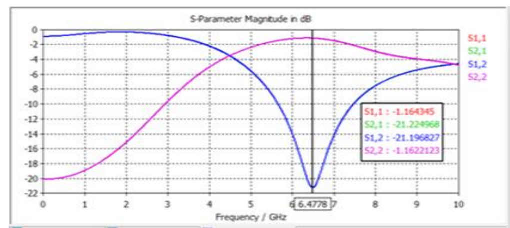


Figure 4 Response graph of DGS

As mentioned earlier any design of DGS can be converted to its equivalent circuit, LC parallel circuit with its parameters using the equations found in [2-3].

3.0 BPF DESIGN PROCETURE

The technique begins with the design of a low-pass filter prototype that is normalized in terms of impedance and cut-off frequency as shown in Figure 5.

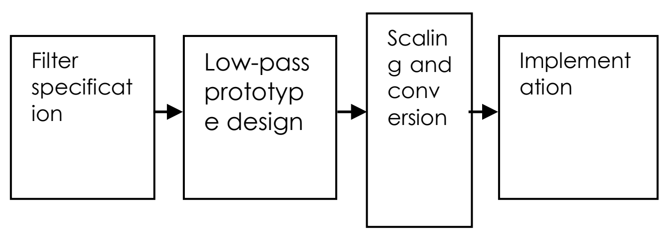


Figure 5 Design process of BPF

Filter specification means type of filter response and the number of order (N), as well as the center frequency. In this paper it is proposed a maximally flat type filter and an order N=3 at 2GHz operating frequency. Following the design procedure it is used ADS for conversion, after the low-pass prototype element values have been scaled as j-inverter using the equations found in [4-6]. Then calculated as odd and even impedance using the equations found [4-6] and the values are shown in Table 1.

Table 1 Characteristic impedance of odd and even modes

n	1	2	3	4
gn	1.0000	2.0000	1.0000	1.0000
jnZ0	0.3963	0.1111	0.1111	0.3963
Zoe	77.6600	56.1700	56.1700	77.6600
Zoo	38.0370	45.0600	45.0600	38.0370

With the aid of computer design ADS (advanced Design System) we can calculate the dimensions of each resonator using the odd and even mode values.

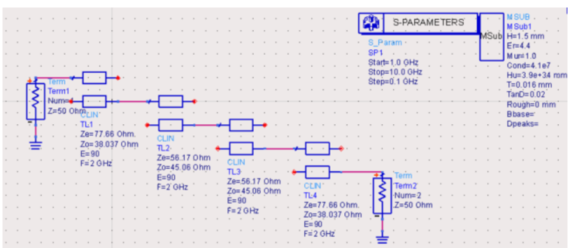


Figure 6 Schematic design of BPF using ADS software

Using these dimensions above we can use CST software to simulate it. And the design will look like as Figure 7.

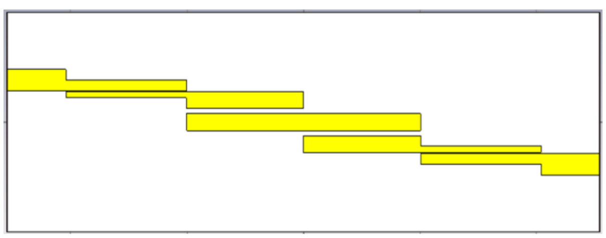


Figure 7 Parallel coupled line BPF

Figure 7 shows the conventional parallel coupled line filter with a substrate of dielectric constant of 4.3 and with thickness of 1.6 mm. The simulation result of this conventional design is shown in Figure 8.

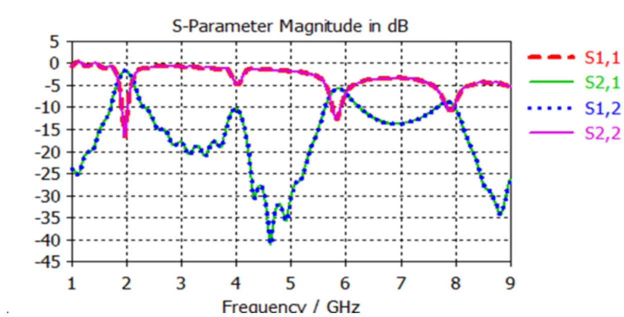


Figure 8 S11 and S21 of conventional design BPF response

It can be seen from Figure 8 that the center frequency is 2GHz. This is the required operating frequency of the proposed design. But it does also show other harmonic effects at 5.8GHz and 7.8GHz. To suppress these harmonics or these unwanted signals it requires additional technique to be employed. The conventional BPF has another setback which is a larger size. To make the size compact and at the same time suppress the harmonics a DGS dumbbell shape and slated dumbbell shape is introduced as shown in Figure 9.

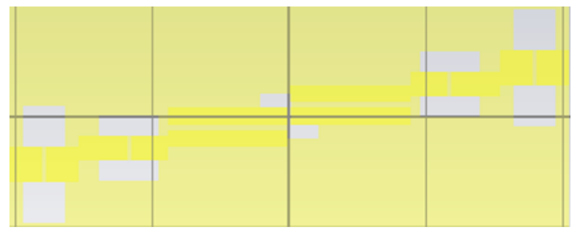


Figure 9 Applied DGS to a reduced size BPF

Simulated S-parameter S11 and S21 of the compact size band-pass filter is shown in the Figure 10.

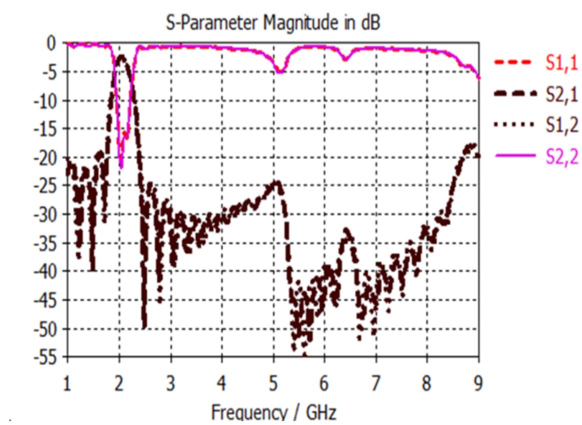


Figure 10 S11 and S21 of a compact design BPF response

Figure 10 shows the response graph of S21 which is free from all the unwanted harmonics generated in the conventional BPF design. There is only one operating frequency 2GHz which is the desired frequency of the design. Similar to S11 which has only one operating frequency too.

4.0 FABRICATION AND MEASUREMENT

The DGS not only suppress the harmonics, it is also used to reduce the size of the conventional design. The designed band pass filter in CST studio with FR4 material was fabricated in BCP board and measured using network analyzer. Both fabricated conventional and compact designs are shown in Figures 11 and 12.

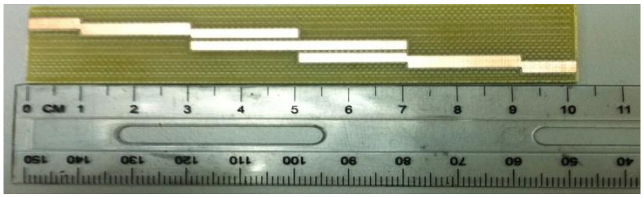


Figure 11 A 101 mm length of conventional BPF

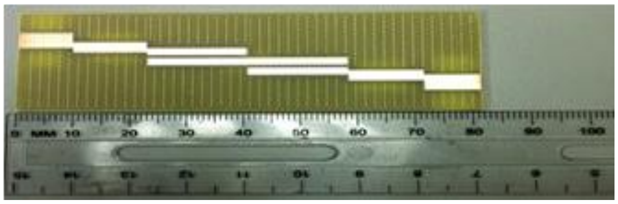


Figure 12 An 80 mm length of conventional BPF

A comparison study was carried out by comparing the CST studio Simulation results with practical measurement of microstrip parallel coupled line band-pass filter. Figures 13 and 14 shows the scattering parameters of S11 return loss and S21 transmission loss for simulation and measured results consequently.

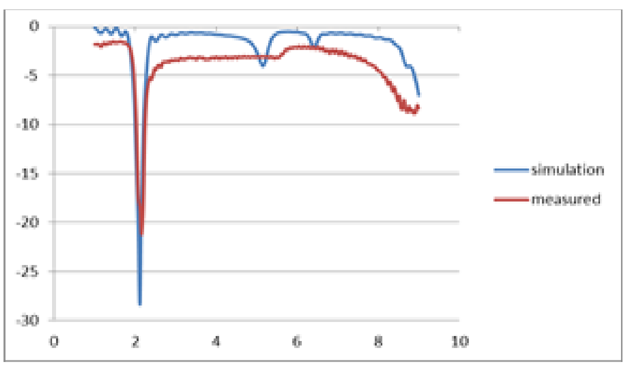


Figure 13 Comparison between simulation and measured S11 results

Both simulation and measured results show a good agreement and conform the proposed Band-pass filter configuration possesses better performance in terms of wide rejection band levels. This new filter's characteristics in size minimization and spurious-response suppression until indeed extend the classical parallel coupled-line band-pass filter design flexibility.

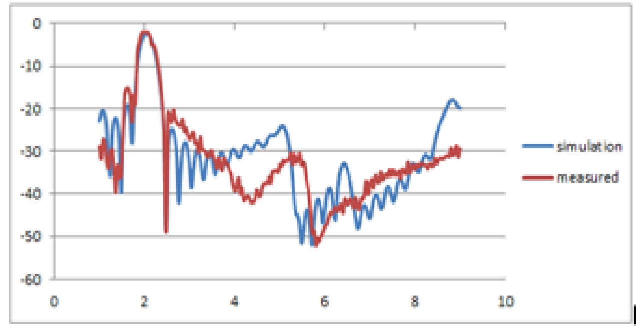


Figure 14 Comparison between simulation and measured S21 results

5.0 CONCLUSION

A novel parallel coupled-line has been proposed and analyzed. The compact parallel coupled-line filter having harmonic suppression or EMI reduction has been presented. Due to the increased slow wave factor and electrical length of the microstrip line with dumb-bell shaped DGS, the size of the original parallel coupled-line filter has been reduced successfully without any critical deviation in center frequency and bandwidth. By the simulation and experimental results of 500 MHz with a 20.8% size minimization and a rejection level of greater than -30 dB until 5f0 stop-band was achieved.

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