DGS Based Micro strip Band pass Filter for Wireless Devices

Pranita P. Padhye, Mrs J. H. Patil

***Abstract*— Bandpass filters play a significant role in wireless communication systems. Transmitted and received signals have to be filtered at a certain center frequency with a specific bandwidth. This paper proposes an efficient technique to design a destructive ground structure (DGS) based microstrip bandpass filter. A dumbbell shaped DGS is used to design a microstrip bandpass filter. Here, a chebyshev type of bandpass filter is designed first and then by DGS the losses occurred in the gain will be minimized resulting in the miniaturizing the structure of bandpass filter. Furthermore, the extraction method of equivalent circuit parameters has also been derived. Demonstrating several simulations and comparisons on DGS circuits shows the validity of the proposed equivalent circuit model and modeling method. Also, by employing the proposed equivalent circuit of DGS, a harmonic rejection band pass filter is optimized. Simulation results for an optimized DGS based band pass filter for pass band from 5 GHz to 7 GHz are demonstrated. The simulation results agree with the theoretical ones.**

***Index Terms*— Wireless communication, WiMAX, bandpass filter, parallel-coupled microstrip, computational electromagnetics, destructive ground structure.**

I. INTRODUCTION

The advances of telecommunication technology arising hand in hand with the market demands and governmental regulations push the invention and development of new applications in wireless communication. These new applications offer certain features in telecommunication services that in turn offer three important items to the customers. The first is the coverage, meaning each customer must be supported with a minimal signal level of electromagnetic waves, the second is capacity that means the customer must have sufficient data rate for uploading and downloading of data, and the last is the quality of services (QoS) which guarantee the quality of the transmission of data from the transmitter to the receiver with no error. In order to provide additional transmission capacity, a strategy would be to open certain frequency regions for new applications or systems. WiMAX (Worldwide interoperability Microwave Access) which is believed as a key application for solving many actual problems today is an example [1]. In realization of such a system like WiMAX we need a complete new transmitter and receiver. A bandpass filter is an important component must be found in the transmitter or receiver. Bandpass filter is a passive component which is able to select signals inside a specific bandwidth at a certain center frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere the information signals. In designing the bandpass filter, we are faced the questions, what is the maximal loss inside the pass region, and the minimal attenuation in the reject/stop regions, and how the filter characteristics must look like in transition regions [2]. In the process to fulfill these requirements there are several strategies taken in realization of the filters, for example, the choice of waveguide technology for the filter is preferred in respect to the minimal transmission loss (insertion loss). This strategy is still used in satellite applications. The effort to fabricate waveguide filters prevents its application in huge amounts. As alternative, microstrip filter based on printed circuit board (PCB) offers the advantages easy and cheap in mass production with the disadvantages of higher insertion losses and wider transition region. In this work we would like to give a way to conceive, design and fabricate bandpass filter for the WiMAX application at the frequency 5.2 GHz with parallel-coupled microstrips as opposed to the [3] which has designed the filter for wireless local area network 5.75 GHz, and [4] which uses the composite resonators and stepped impedance resonators for filter realization.

Filters designed with Butterworth approach show the maximal flat characteristics in the pass region. The Butterworth approach is expected to have the attenuation factor as high as possible. In practical implementation, the specification for losses in pass region can normally be higher than zero. Chebyshev approach exploits this not so strictly given specification values. It can be 0.01 dB, or 0.1 dB, or even higher values. The Chebyshev approach thereby shows certain ripples in the pass region, this can lead to better (higher) slope in the stop region.

Recently, there has been an increasing interest in studying the microstrip line with various periodic structures including photonic band gap (PBG) and defected ground structure (DGS) [1]-[8]. Each periodic structure has its own properties and advantages. DGS, which is realized by etching only a few defects on the ground plane under the microstrip line, is also a kind of periodic structures [4]. Most of PBG applications are limited for providing deep and wide stopband performance for circuits [1]-[2]. Meanwhile, DGS has prominent advantage in extension its applicability to other microwave circuits such as filters, dividers, couplers, amplifiers, and so on [3]-[8]. The PBG has been also used in filter designs to improve stopband performance by rejecting the higher order passbands, due to its inherent stopband behavior. Specially, both PBGs and DGS have been very effectively used to terminate the harmonics for power amplifiers. However, it is very difficult for implementing the PBG or DGS based circuits for the purposed of the harmonic termination to

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satisfy simultaneously the excellent passband and stopband characteristics [3]..

II. Basic Element of DGS

DGS is realized by etching a defect in the ground plane of planar circuits, which disturbs the shield current distribution in the ground plane and change the characteristics of a transmission line such as line capacitance and inductance. The DGS applied to microstrip line creates a resonance in the circuit with the resonant frequency controllable by changing the shape and the size of the slot. The combination of DGS elements and microstrip line yields sharp resonances at microwave frequencies which can be controlled by changing shape and size of DGS circuitry [9].

To fulfill the different requirements, a variety of DGS shapes have evolve over times including dumbbell, periodic, fractal, circular, spiral, L and H shaped structures [10], [11]. The basic element of DGS is shown in Fig. 1 which is a resonant gap or slot in the ground surface placed directly under the transmission line and aligned for efficient coupling to the line. Consequently DGS is able to provide a wide band-stop characteristics in some frequency bands with only one or small number of unit cells. Defected Ground Structures as the name implies, refers to some compact geometries commonly known as a "unit cell" etched out as a single defect or in periodic configuration with small period number on the ground plane of a microwave printed circuit board (M-PCB) to attribute a feature of stopping wave propagation through the substrate over a frequency range.

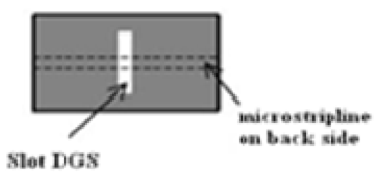


Fig. 1: Basic element of DGS.

The DGS slots are resonant in nature. They have different shapes and sizes with different frequency responses and equivalent circuit parameters. The presence of a DGS under a printed transmission line actually perturbs the current distribution in the ground plane and thus modifies the equivalent line parameters over the defected region. Thus, it influences the guided wave characteristics and is found to exhibit (i) Band-gap properties as revealed due to electromagnetic band-gap (EBG) structures and (ii) a slow wave effect, which helps in miniaturizing the printed circuits. The DGS geometries reported so far include shapes such as rectangular dumbbell, circular dumbbell, spiral, "U", "V", "H", cross, concentric rings etc. Also different complex structures like split ring resonators or fractals have been examined. Some simple and complex type unit cell DGSs are shown in Fig. 2.

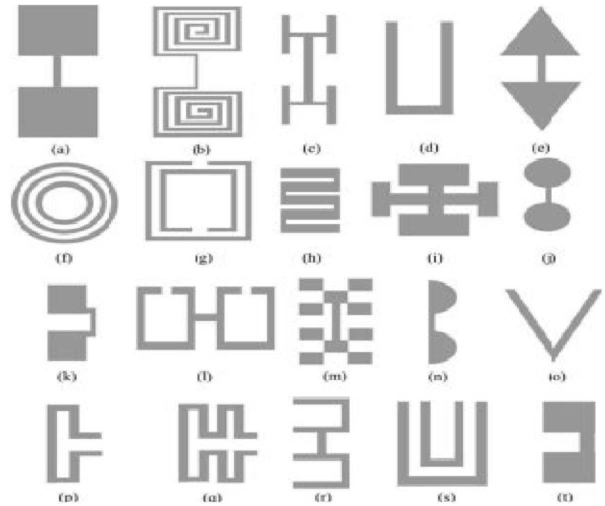
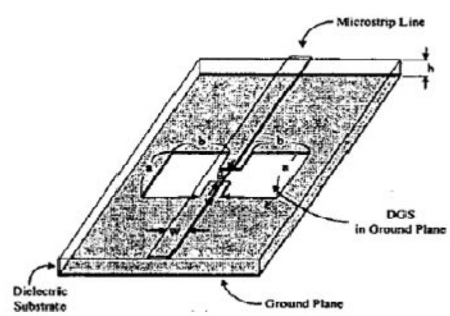
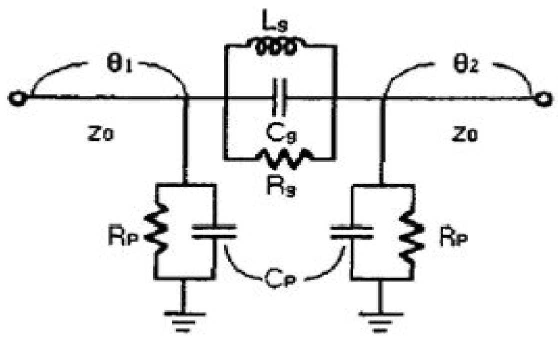


Fig. 2: Different DGS geometries:(a) dumbbell-shaped (b) spiralshaped (c) H-shaped (d) U-shape (e) arrow head dumbbell (f) concentric ring shaped (g) split-ring resonators (h) interdigital (i) cross-shaped (j) circular head dumbbell (k) square heads connected with U slots l) open loop dumbbell (m) fractal (n) halfcircle (o) V-shaped (p) L-shaped (q) meander lines (r) U-head dumbbell (s) double equilateral U (t) square slots connected with narrow slot at edge.

If a spiral and a dumbbell shaped DGS both occupying same surface areas are etched on identical substrates, it is observed that the attenuation pole for spiral shaped DGS occurs at a much lower frequency than that due to the dumbbell shaped DGS. This means that a spiral DGS needs a much smaller space for a given frequency response. It also gives comparatively steeper rejection characteristics. Fig. 3 (a) shows the DGS microstrip with unit defect, which is etched off on ground plane and Fig. 3 (b) shows its equivalent circuit.



(a)

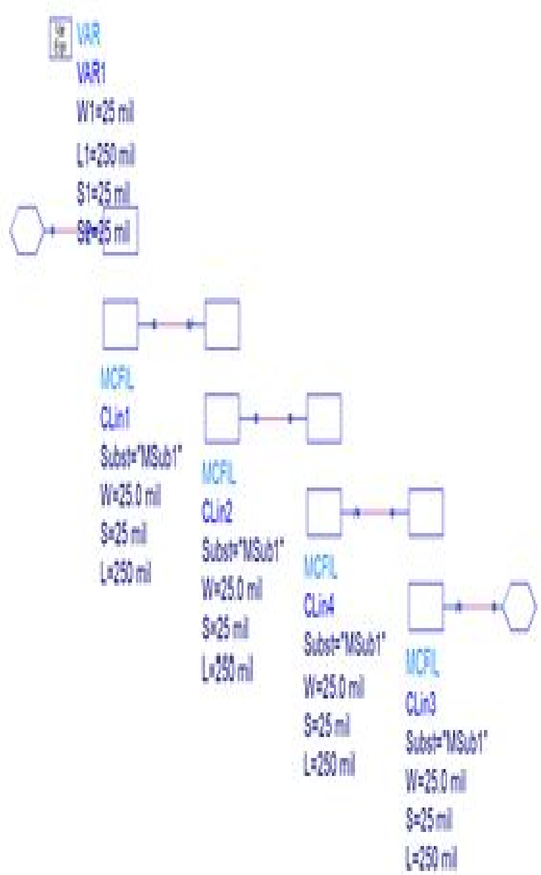


(b)

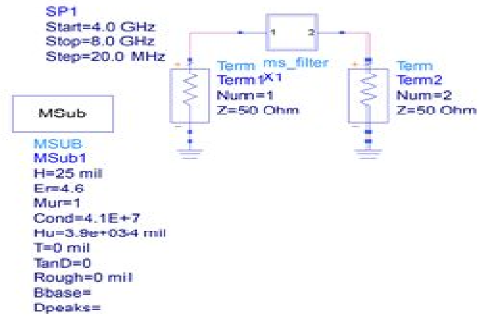
Fig. 3: (a) 3-Dimensional view of the DGS unit section (b) Its equivalent circuit

III. Proposed DGS Based Bandpass Filter

The proposed DGS based bandpass filter may be used in wireless communication applications. This section gives a way to design and fabricate DGS based bandpass filter for the WiMAX application for the frequency range from 5 GHz to 7 GHz with parallel-coupled micro strips which uses the composite resonators and stepped impedance resonators for filter realization. The schematic of the chebyshev type of bandpass filter is shown in Fig. 4.



(a)



(b)

Fig. 4: The schematic of the chebyshev type of bandpass filter

The schematic also shows all the specifications of the filter design. The layout of the designed filter is shown in the Fig. 5.

Fig. 5: Layout of bandpass filter given in Fig. 4.

Filters designed with Butterworth approach show the maximal flat characteristics in the pass region. The Butterworth approach is expected to have the attenuation factor as high as possible. In practical implementation, the specification for losses in pass region can normally be higher than zero. Chebyshev approach exploits this not so strictly given specification values. It can be 0.01 dB, or 0.1 dB, or even higher values. The Chebyshev approach thereby shows certain ripples in the pass region, this can lead to better (higher) slope in the stop region. So, it is required to have better slope as in case of chebyshev type of filters and as flat characteristics in the pass region as possible as in case of Butterworth filter.

To achieve this, a Chebyshev type of filter is designed first and later this bandpass filter with dumbbell shape DGS is proposed to remove the ripples in pass band region. Thus, a maximal flat characteristic in the pass region can be achieved. The two dumbbell shape DGS are placed near the feed point as shown in the layout of Fig. 6.

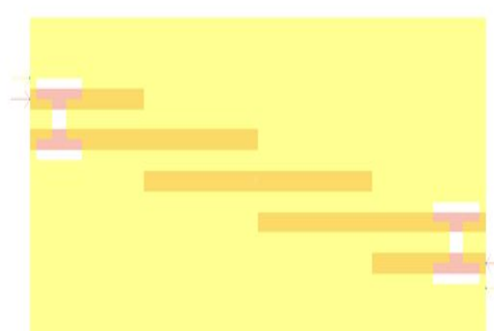


Fig. 6: band pass filter with DGS at feed point

Furthermore the number of dumbbell shape DGSs is increased to get the maximal flat characteristic in pass band. The schematic of this proposed filter is as shown in Fig. 7.

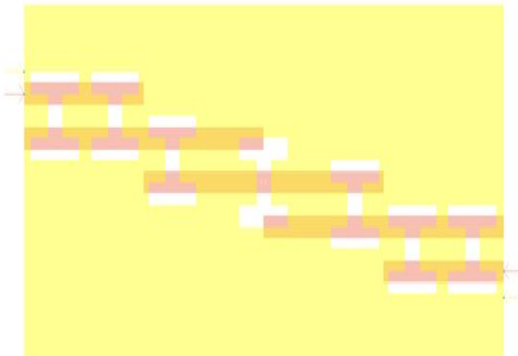
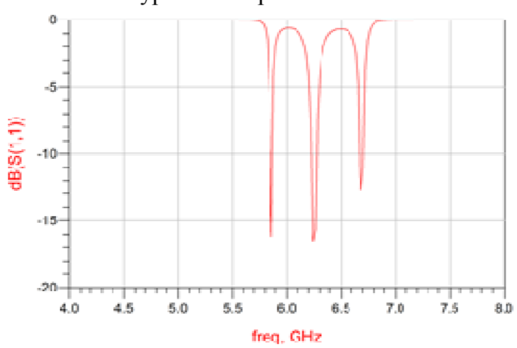


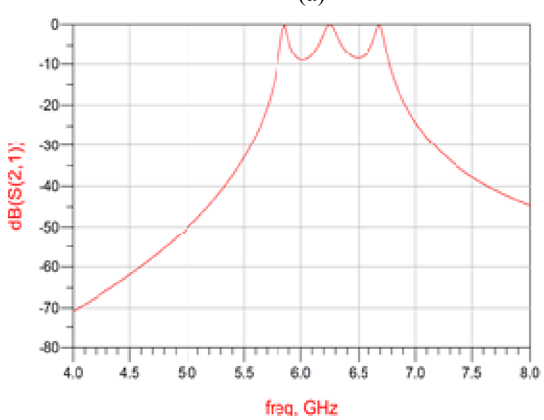
Fig. 7: Bandpass filter with dumbbell shape DGS

IV. Results and Discussion

The bandpass filter given in Fig. 5 is simulated on Agilent's ADS2011.05. The simulation result of the filter is shown in Fig. 8. The proposed DGS based bandpass filter with two dumbbell shape DGS shown in Fig. 6 is simulated for the frequency range from 4 GHz to 8 GHz and the simulation results are as shown in Fig. 9. The proposed bandpass filter with increase in DGSs shown in Fig. 7 is simulated and the simulation results are shown in Fig. 10. From the result shown in Fig. 10 (b), one can see that the characteristic is maximally flat in pass band. As the flat characteristic has been derived by inserting DGS in Chebyshev type of bandpass structure, the size of the structure will be small compared to that of Butterworth type of bandpass structure.

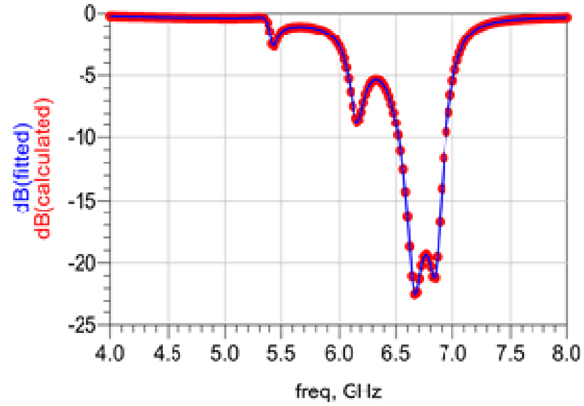


(a)



(b)

Fig. 8: Simulation results a) parameter s11 b) parameter s21 for designed band pass filter shown in Fig. 5.



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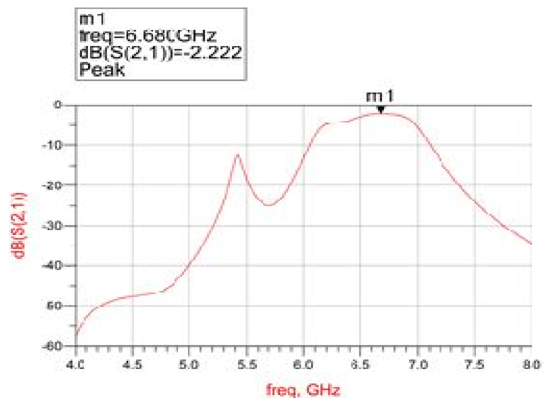

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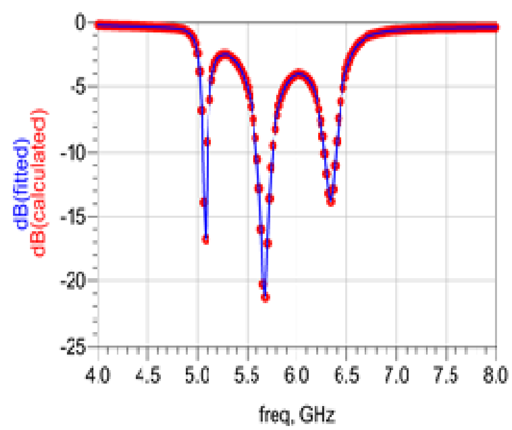
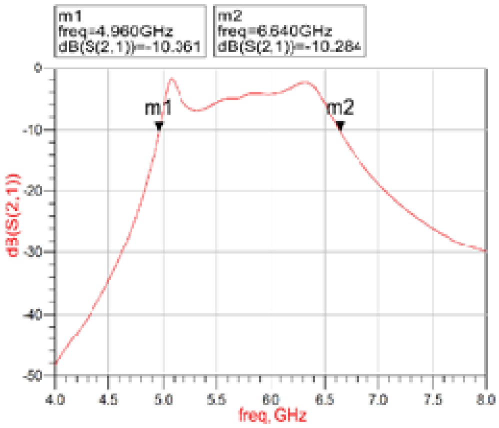
Fig. 9: Simulation results a) s parameter s11 b) s parameter s11 for designed band pass filter shown in Fig. 6.



(a)



(b)

Fig. 10: Simulation results a) parameter s11 b) parameter s21 for designed band pass filter shown in Fig. 7.

CONCLUSION

An efficient technique to design a destructive ground structure (DGS) based microstrip bandpass filter is proposed. A dumbbell shaped DGS is used to design a microstrip bandpass filter. Due to the use of Chebyshev type of bandpass filter and DGS, the losses occurred in the gain are minimized resulting in the miniaturizing the structure of bandpass filter. Demonstrating several simulations and comparisons on DGS circuits shows the validity of the proposed equivalent circuit model and modeling method. Also, by employing the proposed equivalent circuit of DGS, a harmonic rejection bandpass filter is optimized. Simulation results for an optimized DGS based band pass filter for pass band from 5 GHz to 7 GHz are demonstrated. At the center frequency the insertion loss and reflection factor has the values about -2 dB and better than -15 dB, respectively. The simulation results are in best agreement with the theoretical ones.

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