Simulation and Analysis of Compact Defected Microstrip Structure (DMS) with Narrow Bandwidth Notch Characteristics

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***Abstract*—A narrowband bandstop filter using hashtag-shaped of defected microstrip structure (DMS) with band-reject characteristic and high-*Q* is presented in this paper. This paper conducted parametric analysis on the different structure of DMS that consists of different length and width in order to produce a good band-reject response at the resonant of approximately 5.2 GHz. These types of structure were designed and simulated on Roger Duroid RO4350 with a dielectric constant, ε_r of 3.48 and a thickness of 0.508 mm. The optimum topology of DMS with Hashtag-shape exhibited high selectivity, sharp response as well as high attenuation in the stopband. The simulation performance results showed good and promising results with high *Q*-factor and narrow bandwidth, and therefore they could be further examined in future works during experimental works. The structure of DMS is useful for microwave applications when the undesired signals need to be removed, such as in wideband systems.**

***Index Terms*— Microwave Filter, Defected Microstrip Structure (DMS), Band-reject, Q-factor**

I. Introduction

Microwave filters play an important role in various aspects of application in communication systems. The applications include cellular mobile radio, satellite communications, earth stations, radar, etc. However, certain applications continue to challenge the microwave filter designers with more stringent requirements, i.e. lower costs, a smaller size, lighter weight, and higher attenuation [1]. Another important application concerning filtering to improve the frequency response is the use of Defected Ground Structure (DGS) [2]-[5], Defected Microstrip Structure (DMS)[6] and photonic band-gap (PBG)[7].

The DGS is realized by etching specific patterns in the ground plane, such as the dumb-bell shape and the spiral shape. However, DGS introduces wave leakage through the ground plane. The comparison of DGS and DMS can be found in [8]-[9]. PBG has been very effectively used to improve the performance of various microwave circuits, but this structure has the disadvantage of having many design parameters and difficulty in finding its equivalent circuits.

Slot on the strip, that is the DMS makes a defect on the circuit, and it can be used in designing microwave devices, such as antennas [10], filters [11]-[13], and amplifiers [14]-[16]. This new technique is very useful in microwave because the disturbance occurs at the microstrip line. Therefore, the leakage of electromagnetic wave can be reduced by following this technique in order to produce the narrow bandstop filter. DMS can be achieved by cascading the band-reject structure into the arbitrary filter design in order to produce two responses in a single device. It can also be used to obtain a band reject at any desired frequency band. The properties of the band reject can be utilized in the suppression of unwanted signals, which is closely located to the desired signals in the spectrum. The realization of equivalent circuit modeling of transmission line of DMS has been reported in [17]. The realization model of equivalent circuit of DMS provides a single band-gap characteristic only. In addition, there is very limited research on the equivalent circuit that can prove this concept.

In this paper, several structures, which are the T-shape, M-shape, Square-shape and Hashtag-shape are compared and analzyed. The resonant frequency is controlled by adjusting the length and width of the structure. The proposed structure of Hashtag-shape provides improved *Q*-factors, that is more than 170 at 5.2 GHz with an insertion loss, S_{21} is greater than -24 dB. A double Hashtag-shape was designed to improve the selectivity and attenuation of the response. The overall structures of DMS were designed, focusing on the production of good selectivity of band reject and high *Q*-factor with narrow bandwidth.

II. Structure and Design of Defected Microstrip Structure (DMS)

In microwave filter, the transition from passband to stopband is an important factor to produce high selectivity of bandstop with high *Q*-factor. The bandstop characteristics of the filter can be used in the suppression of unwanted signals. DMS offers better performance in terms of high selectivity and narrow bandwidth with high *Q*-factor. The DMS consists of a horizontal and vertical slot in the middle of conductor line. The concept of DMS is similar to the defects ground structure (DGS), which is when the current distribution is disturbed by slot line, there is an increase in the electric length of microstrip line as well as an increase in the effective capacitance and inductance of microstrip line.

Four different structures of DMS are studied in this paper. As shown in Figure 1, the structures consist of the conventional T-shape, M-shape, Square-shape and Hashtag-shape. Figure 1 (d) shows the improved structure from the Square-shape. It shows an improvement in the return loss and a reduction of the overall size of the design. The values of the design parameters of DMS were obtained by using full EM simulator ADS 2011. The EM simulator, changes these values to make all the four designs of DMS have the same resolution frequency of approximately 5.2 GHz. Table 1 shows the parameters of the four different structures of DMS. It shows that the M-shape has a smaller size compared to the others that have an overall size of 16.1 mm x 1.5 mm.

The Hashtag-shape is an improvement from the Square-shape. While it maintains the performance, it reduces the overall size by 5%. From the simulated S-parameter in Figure 2 and Figure 3, the conventional T-shape provides a wider bandwidth with low selectivity and poor return loss comparable to the Square and Hashtag-shape. The four DMS designs were simulated using Roger Duroid RO4350 with a thickness of 0.508 mm and dielectric constant, ε_r =3.48.

A comparison of performance among these four shapes is shown in Table 2. The sharpness of the level of transition from the passband to stopband region determines the narrowband of the response f_0/f_c, where f_c and f_0 are the cut off and resonance frequencies respectively. An effective filtering is better, if the sharpness factor is smaller. The *Q*-factor for Hashtag-shape exhibits better performance than the other shapes with high selectivity and narrow bandwidth of 290 MHz. The insertion loss, S_{21} is better than -20 dB.

Table 1: Dimension structure of conventional T-shape, M-shape, Square-shape and Hashtag-shape

SHAPE	L1 (mm)	L2 (mm)	W1 (mm)	Overall Size L x W (mm)
Conventional T-shape	16.4	1.0	0.2	22.2 x 2.2
M-shape	8.9	2.0	0.1	16.1 x 1.5
Square-shape	19.6	0.6	0.2	23.15 x 1.8
Hashtag-Shape	18.7	0.6	0.2	22.2 x 2.2

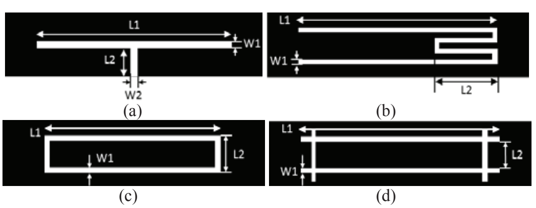


Figure 1: Structure of defected microstrip structure (a) conventional T-shape, (b) M-shape, (c) Square-shape and (d) Hashtag-shape

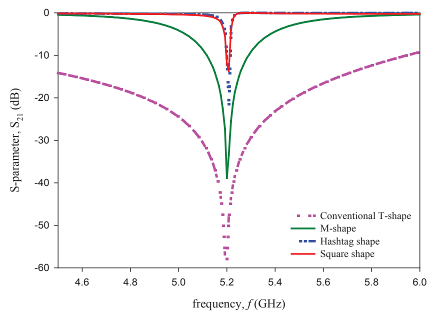


Figure 2: Comparison of Insertion Loss, S_{21} for several structure of Defected Microstrip Structure (DMS)

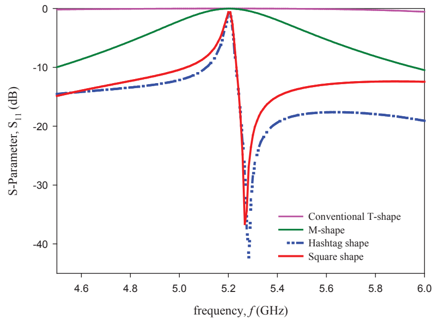


Figure 3: Comparison of Return Loss, S_{11} for several structure of Defected Microstrip Structure (DMS)

Table 2: Comparison result of conventional T-shape, M-shape, Square-shape and Hashtag-shape

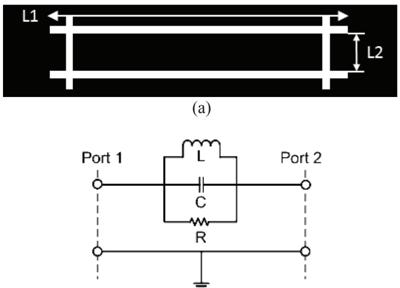
Shapes	3-dB Bandwidth (GHz)	*Q*-factor	Insertion Loss S_{21} (dB)
Conventional T-shape	3.572	1.46	-48.15
M-shape	0.514	10.12	-37.96
Square-shape	0.037	140.54	-23.72
Hashtag-Shape	0.029	179.31	-24.38

Figure 4(a) shows the proposed design of Hashtag-shape. The equivalent circuit for Hashtag-shape is shown in Figure 4 (b). The equivalent circuits of the DMS can be expressed as a parallel RLC circuit. The center frequency of the stopband for DMS is determined by the response frequencies of these defects.

$$C = f_c / 200\pi\left(f_0^2 - f_c^2\right) \quad (1)$$

$$L = 1/\left(4\pi^2 f_0^2 C\right) \quad (2)$$

where f_0 and f_c are the resonant frequency and 3-dB cutoff frequency respectively. The values of L and C for DMS are 49.66 pF and 0.0188 nH respectively. The values of this circuit are nearly equal, but the resistance in DMS due to higher density of current is greater than the other circuit in the resonant frequency.



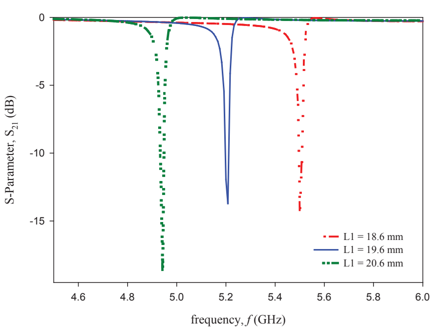
(a)

(b)

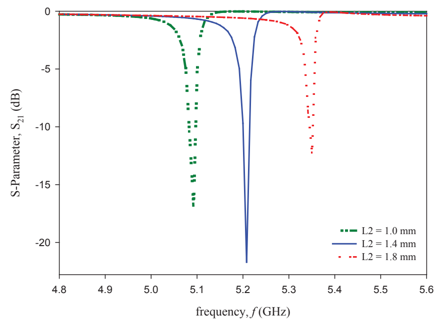
Figure 4: (a) Structure of Hashtag-shape and (b) equivalent circuit of Hashtag-shape for DMS

This proposed structure has a single resonant frequency at 5.2 GHz with narrow bandwidth and high selectivity. To investigate this new structure with the Hashtag-shape, the lengths of L_1 and L_2 were analyzed in detail. The results of S-parameter for different lengths, L_1 from 18.6 mm to 20.6 mm are shown in Figure 5 (a). Figure 5 (b) shows the effect of varying the length, L_2 from 1.0 mm to 1.8 mm. This effect can be concluded as; i) as the length of L_1 increases, the resonant frequency decreases. ii) as the length of L_2 increases, the resonant frequency increases too..

The 3D view of Hashtag-shape for DMS is shown in Figure 6. It consists of microstrip line on the top of substrate and ground plane at the bottom of the substrate. Simulated current distributions at 5.2 GHz of the Hashtag-shape for DMS are shown in Figure 7, where the red region represents the peak surface current, while the blue area represents the low surface current. The structure of Hashtag-shape is concentrated at the both ends of the microstrip line.



(a)



(b)

Figure 5: Parametric analysis (a) effect of L_1 on Hashtag-shape design and (b) effect of L_2 on Hashtag-shape design

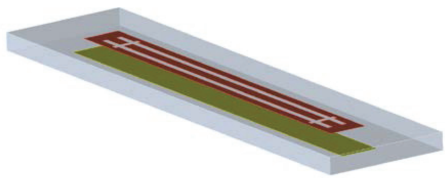
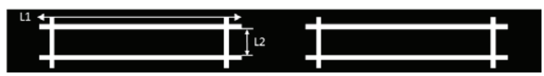


Figure 6: 3D view of Hashtag-shape for DMS

Figure 7: Current flow visualization of Hashtag-shape for DMS at 5.2 GHz

III. Cascading the Double Hastag Shape Defected Microstrip Structure (DMS)

The bandstop filter structure with double hastag-shaped DMS is shown in Figure 8(a). The same Roger Duroid substrate and the same dimension of earlier Hashtag-shape DMS were used. The equivalent circuit for the double Hashtag-shape is shown in Figure 8 (b). The comparisons of the S-parameter for single and double Hashtag-shape are shown in Figure 8 (c) and (d). It is observed that the double Hashtag-shape produced more selective and high attenuation compared to the single design. The same frequency response at 5.2 GHz is produced with high Q-factor. This double Hashtag-shape also improves the return loss S_{11} , which can be placed at anywhere in transmission line.



(a)

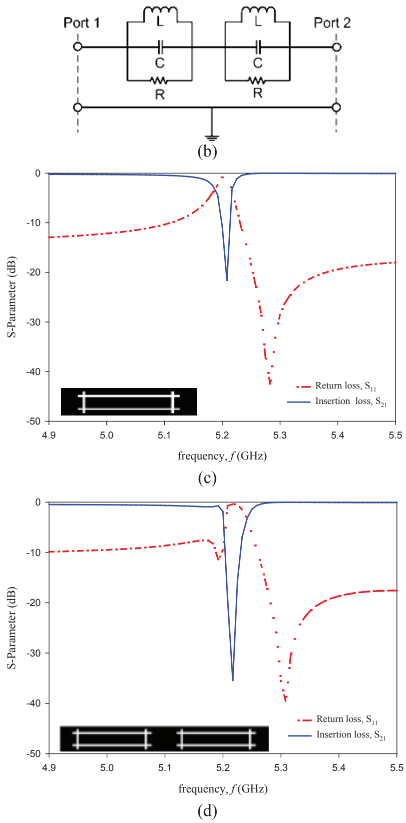


Figure 8: (a) Double Hashtag-shape structure. (b) Equivalent circuit of Hashtag-shape (c) Simulation result of single Hashtag-shape and (d) Simulated result of double Hashtag-shape

IV. Conclusion

A new design of DMS based on Hashtag-shape has been designed and simulated. Performance comparisons with the existing structures, such as the T-shape, M-shape, Square-shape and Hashtag-shape have been analyzed and conducted. The proposed design of Hashtag-shape produced better performance and has the advantages in terms of simple topology, miniature size, low loss and excellent performance. It is shown that the Hashtag-shape produced better performance of Q-factor and high selectivity in comparison to theo ther shapes. The DMS design has the benefits of reducing the overall size as well as avoiding undesired radiation. Therefore, this study can be further explored in future works by fabricating and validating the prototype and experimentally in the laboratory.

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