A New Design of a Miniature Microstrip Bandpass Filter for DCS Applications

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Abstract. This paper presents a new miniature Microstrip Bandpass Filter optimized and validated for DCS (Digital Cellular System) Band. The proposed filter is based on a Microstrip resonator. Each port has a step impedance feed line that can be used to adapt the filter's input impedance to the characteristic impedance Z0. The suggested filter is installed on a low-cost FR-4 substrate with a dielectric constant of 4.4, a thickness of 1.6 mm, a loss tangent tan (δ) = 0.025, and a metal thickness of t = 0.035 mm. It has a bandwidth of 1.68GHz to 2.05GHz. Two electromagnetic solvers are used to optimize and validate this filter. The whole dimensions of the final circuit are 33.6x40 mm^2.
This filter is suitable for mobile communication.

Keywords: Microstrip Bandpass Filter, Microstrip resonator, DCS.

1 Introduction

A filter is a component or function that selects and eliminates one or more frequency bands from the electromagnetic spectrum.

They are devices that filter, eliminate, or separate signals in distinct frequency ranges. They can be passive or active. Planar filters are made up of metallized lines that act as resonators and have a length proportional to the wavelength of the operating frequency [1-3].

In recent years, resonators have been widely used in the design of filters. To improve performance or reduce size, filters based on resonators, quarter-wave and quasi-quarter-wave have been proposed. [4-6].

One of the most significant components in microwave circuits is the bandpass filter. Planar BPF have recently sparked increased interest due to their ease of fabrication. [7-9].

To achieve miniature planar filters, we can use Dual-mode resonators. As shown in Figure 1, Microstrip dual-mode resonator has a two-dimensional (2-D) symmetry:

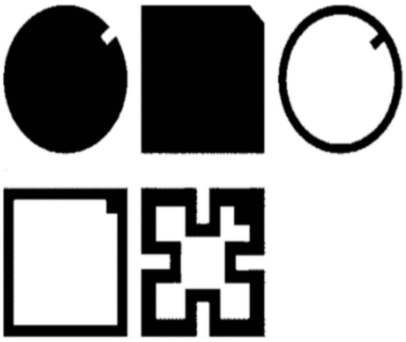

Fig. 1. Microstrip dual-mode resonators.

The number of resonators required for an n-degree filter is cut in half by using a dual-mode resonator as a double tuned resonant circuit [10-11].
This filter operates as the shunt-resonator with the design is described by the following equations [10-14]:

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2}\left(\frac{FBW}{g_0 g_1}\right)} \tag{1}$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2\sqrt{g_j g_{j+1}}} \qquad j=1 \text{ to } n-1 \tag{2}$$

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi}{2}\left(\frac{FBW}{g_n g_{n+1}}\right)} \tag{3}$$

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Where g_0, g_1 . . . g_n are the element of a ladder-type Lowpass Prototype with a normalized cutoff $\Omega_c = 1$, The $J_{j,j+1}$ are the characteristic admittances of J-inverters and Y_0 is the characteristic admittance of the Microstrip line and FBW is the fractional bandwidth [2].

2 Design procedure

The proposed BPF's configuration is illustrated in Figure 2. The design strategy begins with the construction of a double resonator Microstrip Bandpass Filter connected with two resonators that contain slots, as shown in Figure 2. A passband of 1.68 GHz to 2.05 GHz is shown in the proposed BPF. The suggested BPF has a dimension of 33.6 x 40 mm^2, which is miniature in contrast to typical Microstrip filters. Two electromagnetic solvers, one based on the Moments approach and the other on the Finite Integration methodology, were used to model the suggested filter. A low-cost FR-4 substrate is used to print the suggested filter.

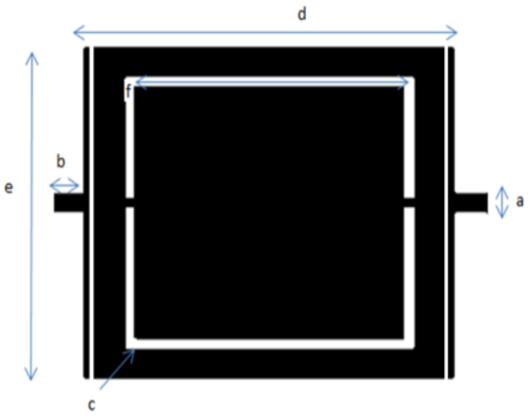


Fig. 2. The proposed structure of the Microstrip Bandpass filter

The influence of the slot width on the proposed Filter in terms of electrical characteristics has been retrieved from a parametric analysis on the effect of critical side length 'c'. After this parametric study we have conducted many series of optimization based on random method in order to obtain the fixed goal.

Table 1. The different values of the parameter 'c'

Parameter	Value (mm)
c_1	5
c_2	4
c_3	3

Figure 3 shows the varied transmission coefficient S21 filter responses as a function of different 'c' values. We can see that lowering the 'c' value allows us to alter the bandwidth at the DCS Band, which corresponds to c = 3 mm.

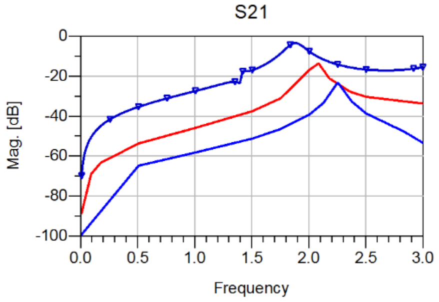


Fig. 3. Simulated result S21 of proposed BPF versus the value of 'c.

To have more precision we carried out another parametric study by decreasing the parameter 'c'.

Table 2. The different values of the parameter c.

Parameter	Value (mm)
c_1	3
c_2	2
c_3	1

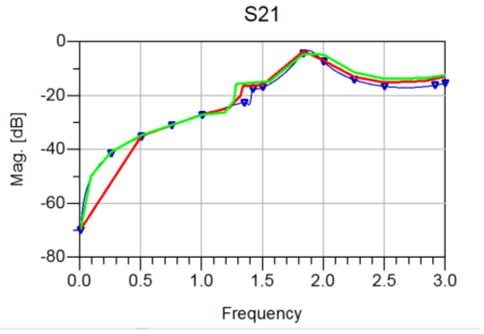


Fig. 4. Simulated result S21 of proposed BPF as a function of (c) versus the value of 'c'

At c = 1 mm, the optimal value of 'c' for generating a good frequency response may be seen. The optimum size of the parameters of the proposed Bandpass filter are shown in Table 3.

Table 3. The dimensions of the proposed Bandpass Filter

Parameter	Value (mm)
a	2
b	3
c	1
d	33.6
e	33.6
f	25.6

3 Results and discussion

Figure 5 displays the proposed filter's final response in terms of (S11) and (S21), with a bandwidth of roughly 370 Mhz.

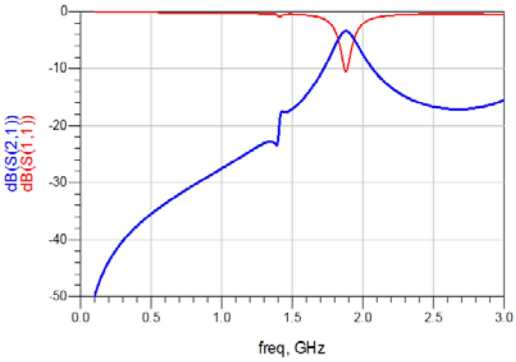


Fig. 5. S-parameters of the Bandpass Filter versus frequency.

In order to verify the simulation findings obtained using the Moments technique, we conducted the same inquiry using another electromagnetic solution utilizing Finite Integration Technique.

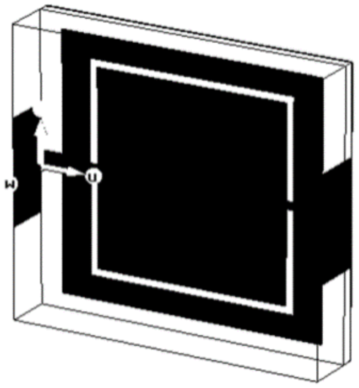


Fig. 6. Three-dimensional view of the proposed filter

Figure 7 shows that the two electromagnetic solvers have a good agreement, with just a minor difference due to the different numerical methods used in both electromagnetic solvers.

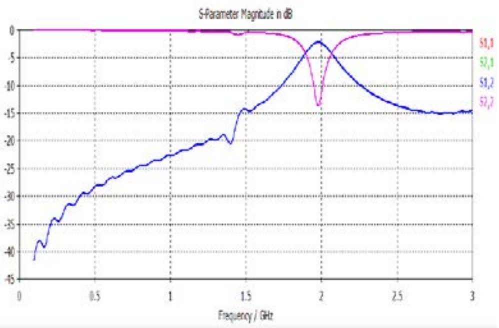


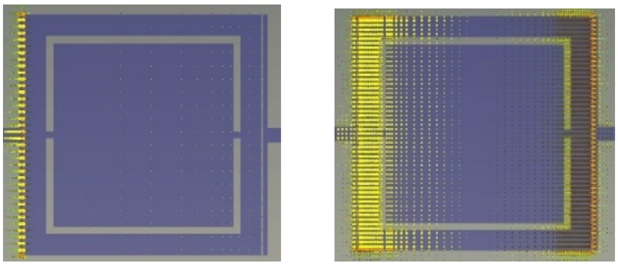
Fig.7. S parameters of the proposed Bandpass Filter obtained using Finite Integration Method.

Previous works in the literature are compared to the suggested Bandpass Filter. Table 4 demonstrates that the proposed circuit has a fractional bandwidth of 20.55% and outstanding electrical performance bandwidth. Compared to other works included in the table below, the proposed Bandpass Filter is miniature and compact.

Table 4. Performance comparison with published studies

Parameters /Ref	**Pass Band (GHz)**	**FBW**	**Size mm^2**
[13]	[1.8-2.1]	15%	1000
[14]	[1.8-2.2]	20%	1400
This Work	[1.68-2.05]	20.55%	1344

The surface current distributions at frequencies of 1 GHz and 1.8 GHz are presented in Fig.8 to further explain the behavior of the proposed BPF. It's evident that the surface current distributions at these two frequencies aren't the same. When the first resonance frequency is 1 GHz, the majority of the surface current is focused in the supply line's left half Fig.8-(a). At 1.8 GHz, the surface current distribution becomes more concentrated along the filter, as shown in Fig.8-(b).



(a) **(b)**

Fig. 8. Current distributions of the BPF (a) at 1 GHz and (b) at 1.8 GHz

Conclusion

A new Microstrip Bandpass Filter based on resonators with compact size and good electrical performance is proposed for DCS applications. The originality of this circuit is there dimensions which are miniature in comparison with standard Bandpass Filter configurations and in the same time the final proposed circuit presents good performances in terms of insertion loss and return loss. The proposed circuit's frequency response was investigated using two separate electromagnetic simulators. This final circuit is suitable for DCS applications and can be reconfigurable in term of frequency by association with varactors diodes.

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