COMPACT MICROSTRIP BANDPASS FILTER WITH MIXED ELECTROMAGNETIC COUPLING MULTILAYERED STRUCTURE

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ABSTARCT

In this paper, a new and compact microstrip narrow-band bandpass filter using multilayer technology is proposed for WiMAX Applications. The new filter structure consists of four spiral resonators placed on two stacked layers where the metallic ground plane is deposited onto the bottom surface of the dielectric. Compared to conventional microstrip filters, the proposed multilayer structure provides a significant size reduction by halving about 50% the whole filter size. It was designed, simulated, fabricated and tested. There are good agreements observed between the simulated and measured results. The proposed multilayer filter is aimed to simply integrate into and perform better within any circuit design of microwave application as present communication systems always demand at lower cost.

Keywords: bandpass filter, multilayer structure, compact, spiral resonator.

INTRODUCTION

Contemporary speedy advancement in technology has massively extended the heavy human reliance on microwave or radio frequency devices and gadgets in countless daily activities around the globe. Devices like microwave filters, antenna, amplifiers, switches, etc. have become crucial inevitability in either the civilians' life or furthermore for defence purposes in military. Recent progress witnesses stronger demand from communications engineering industry to innovatively create more compact microwave devices which are capable to outperform earlier technology. Among the most demanded in the microwave devices list is microwave filter which is used most in wireless communication technology to provide more efficient telecommunication beyond classic expectation. Bandpass filters are among important components utilized in the RF/Microwave and wireless communication systems, which are usually found in both transmitters and receivers. They are used to select or reject RF/Microwave signals within particular assigned spectral limits. Accordingly, the key of bandpass filters performance is definitely its quality.

Among nowadays domineering demands are being economical, compact size and excellent performance to acclimatize within the rapid advancement of wireless communications systems industry. In order to meet these demands, several types of planar microstrip filters, such as open-loop resonator filters, hairpin resonator filters, coupled-line filters, multilayer coupled resonator filters, fractal-shaped defected ground structure (DGS) filters, and coupled stepped-impedance resonator filters have been proposed in [1-6]. However, the real challenge goes to planar microstrip filters, which typically are larger in size if it is implemented on a single microstrip layer. There is effort overcoming it by using low temperature co-fired ceramic (LTCC) technology [7, 8]. It turned popular due to its low loss, high performance, high precision substrate that allows higher number of passive components to be integrated in a smaller area, and high reliability. Unfortunately, the technique is a three-dimensional development process, so, it is inevitably costlier than other filter design techniques, in addition to its design complexity.

The shift is seen in overcoming those problems by merging it with multilayer technology in bandpass filters designs [9, 10]. The technology also offers design flexibility as it is easier to be integrated into other microwave components, circuits, and subsystems. Lately [11] had presented a cross-coupled multilayer bandpass filter with an embedded-resonator topology. It used different types of inter-resonator and feed line-resonator couplings in a three metallic-layer configuration, which demonstrates a significant size reduction compared with classical microstrip filters. Another very compact filter was designed by associating open-loop resonators and floating metallic patches to enhance the coupling between resonators located on different layers found in [12]. Yet, there is a long way ahead to go for these techniques to reach its ripe maturity.

Meanwhile in [13], a multilayer dual-mode filter is improved based on the substrate integrated waveguide circular cavity for X-band applications. The filter comprises two circular cavities and each cavity supports two degeneration modes where the coupling aperture and slot located between layers can generate and control. Another dual-mode filter design is a multilayer substrate integrated waveguide (SIW) with four transmission zeros due to its high-selectivity application [14]. The filter generates mixed coupling between source and load in to order to flexibly control the transmission zeros. Advantageously, it exhibits better frequency selectivity although occupies similar area with single-layer technique compared to conventional dual-cavity dual mode SIW filters. Apart from dual-mode techniques, there are multilayer SIW bandpass filters with higher-order mode suppression created for instance in [15]. This filter distinctively demonstrates better out-of-band rejection and a reduced size. Nonetheless, in spite of the benefits, the

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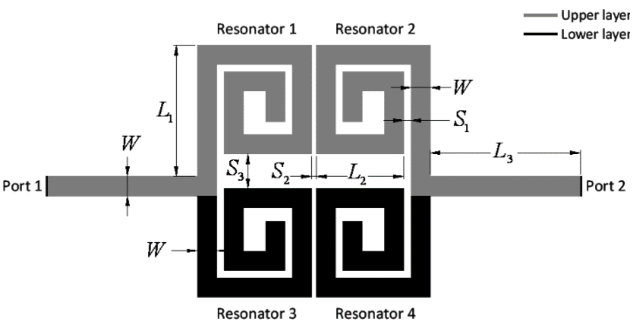
SIW approach complexifies the designing process which, is worsened if traditional photolithography process is applied.

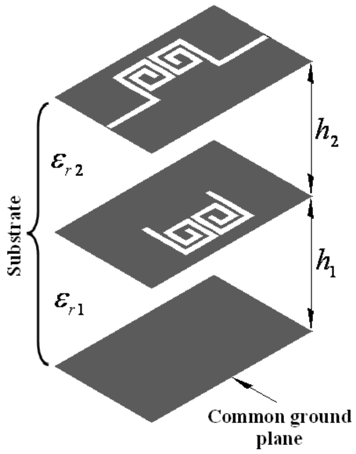
Thus, through skimming we are inspired to bring about this work of a new design of four-pole narrow-band bandpass filter using multilayer topology, which, the resonators can be implemented onto both different layers. The proposed filter is designed using coupling coefficients, where the couplings between the resonators on the upper layer and those on the lower layer are obtained by overlapping these resonators to produce the desired coupling through the substrates. The resonators are spiral type, which applies similar design method as reported in [16]. The design was later simulated, fabricated and tested. Briefly, the goal is to fulfil the demanded characteristics of undeterred better performance by smaller size, lower cost, lower losses, simpler design, as well as more efficiently applicable for wireless communication system applications.

CONFIGURATION OF THE PROPOSED MULTILAYER BPF

Figure-1 shows the exploded view of the proposed spiral resonator filter based on multilayer structure. This topology is composed of two layers where the metallic ground plane is deposited onto the bottom surface of the dielectric. In separate two layers, the resonators are located at exact calculated spaced distance to produce the desired coupling between resonators which is crucial for this design. Meanwhile, overlapping the resonators between two layers ignite mixed couplings between upper and lower resonators. The filter uses half-wavelength spiral microstrip resonators which makes the structure of the filter more compact. The width of microstrip is determined by setting its characteristics impedance to 50 Ω. For our demonstration, Table-1 exhibits the specifications of the proposed multilayer filter.



(a)



(b)

Figure-1. Structure of the proposed BPF in a multilayer configuration (a) top view (b) perspective view.

Table-1. Specifications of the designed filter.

Parameter	Value
Center frequency (f_0)	2.3 GHz
Order of the filter (n)	4
Bandwidth (at -3 dB)	120 MHz
Passband ripple (L_{Ar})	0.05 dB
Lower layer substrate thickness (h_1)	0.508 mm
Upper layer substrate thickness (h_2)	0.508 mm
Lower layer dielectric constant (ε_{r1})	2.2
Upper layer dielectric constant (ε_{r2})	2.2

Bandpass filters can be designed by measuring or computing the coupling coefficients between the resonators and the external quality factors of the resonators at the input and output [17-19]. This method is applicable to all types of coupled resonator filters no matter whether materialized in microstrip or in any type of mediums. Initially, we evaluate the lumped element values of the lowpass prototype filter so as to determine the physical length of the coupled resonators. Finally, the coupling coefficient M_{ij} and external quality factors Q_{ex} can be calculated by using the equations 1-3 [20].

$$Q_{ex1} = \frac{g_0 g_1}{FBW} \tag{1}$$

$$Q_{exn} = \frac{g_n g_{n+1}}{FBW} \tag{2}$$

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}}\ , \quad \text{for } i = 1 \text{ to } n-1 \tag{3}$$

where Q_{ex1} and Q_{exn} are the external quality factors of the resonators at the input and output, g_i's are the element values of Chebyshev lowpass prototype filter,

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FBW is the fractional bandwidth of the bandpass filter, and *n* is the order of the filter.

In order to design the multilayer filter with the required specifications, it is necessary to calculate the coupling coefficients (M_{ij}) between two adjacent resonators. Figure-2 shows the coupling coefficients curve as a function of distance, *S* for the coupling between resonators 1 and 2 and resonators 3 and 4, which are also identical. Figure-3 presents the mixed coupling, with resonators on different layers. The proposed multilayer filter is designed and verified by simulation. After a few repetitions in the optimization process, the structural parameters for this prototype bandpass filter (BPF) circuit are shown in Table-2.

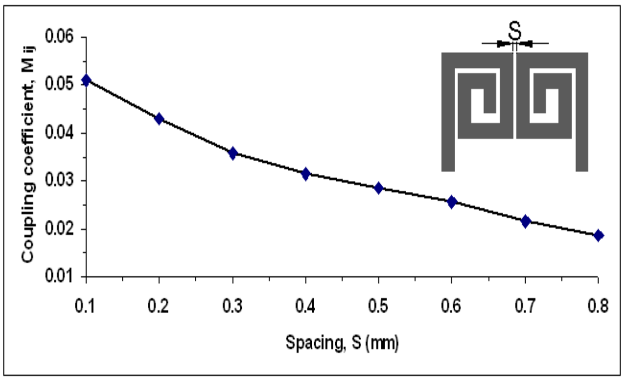

Figure-2. Coupling coefficients between adjacent resonators (resonators 1 with 2 and resonators 3 with 4).

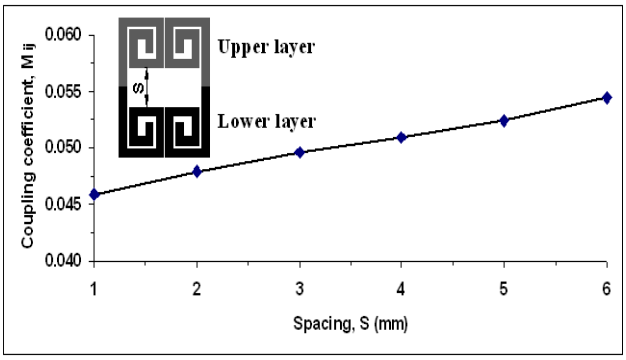

Figure-3. Mixed coupling with resonators on different opposite layers (resonators 1 with 3 and resonators 2 with 4).

Table-2. Dimensions of the proposed multilayer BPF.

Parameter	*W*	L_1	L_2	L_3	S_1	S_2	S_3
Dimension (mm)	1.54	10.56	7.02	12.10	0.6	0.4	2.8

RESULTS AND DISCUSSIONS

To confirm the simulation results, the proposed multilayer filter was fabricated on R/T Duroid 5880, using the same substrate characteristics that were specified in the simulation. Experimental measurements are carried out using an Agilent N5230A Network Analyzer. Measured filter responses are presented and compared with simulations. Figure-4 shows the simulated and measured results of S-parameters magnitude. It can be observed that the simulated and measured results exhibits small frequency shift by 0.17 GHz due to fabrication unavoidable flaws, in addition of input/output connectors and epoxy glue between the layers.

The measured minimum passband insertion loss is 3.6 dB. This loss is mainly identified to be contributed by conductor loss of copper, mismatch at connectors and the presence of epoxy glue in between the two layers. The measured return loss is no more than -17 dB in the passband. Nevertheless, observations on the results show a good agreement between the simulated and experimental results achieved in terms of the passband shape. The overall filter size is 380 mm^2, which is approximately 10% smaller as compared to the multilayer filter reported in [10], and reduced more than 25% compared to the single-layer microstrip filter presented in [16, 21]. Figure-5 shows a photograph of the fabricated multilayer BPF, where only two microstrip spiral resonators on the top layer are visible.

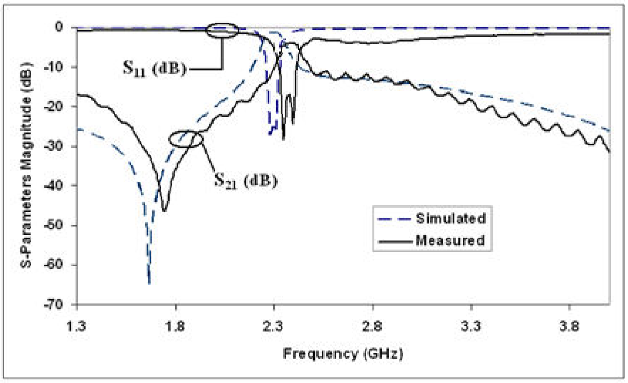

Figure-4. Simulated and measured frequency responses of the proposed multilayer BPF.

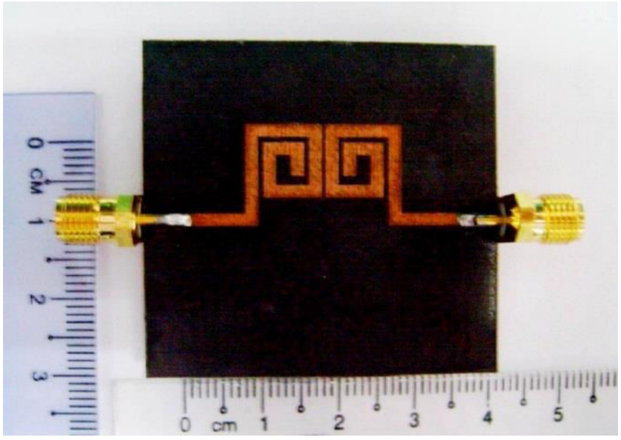

Figure-5. Photograph of the fabricated multilayer BPF (showing only top layer).

Finally, simple and efficient design method for microstrip BPFs with single and multilayer structures is presented in this research. The obtained results have shown excellent performances of the proposed filters. In addition, good agreement has been achieved between experimental and simulated results. With these features, the proposed filters in this study are suitable for current compact microwave system. Therefore, the overall design results proved that this design is capable to fulfill the present engineering demanded requirements.

In this work, microstrip BPF design using coupled spiral resonator is presented for wilress communication systemsspecifically in WiMAX applications. This design then rearranged using dissimilar coupled resonators with embedded-resonators in order to make it more compact; yet it has high quality performance. Finally, multilayer technology is used to reduce the size of the filters more compared to the microstrip filters using single-layer structure.

CONCLUSIONS

The presented concept in this study mainly based on basic single-layer structure of spiral resonators, which are venturesomely twisted into a multilayer four-pole narrow band filter. The proposed design was systematically configured by implementing coupling coefficient extracted through and verified by a 3-D electromagnetic simulation. In spite of the slightly increased insertion loss measurement of (3.6 dB) due to epoxy glue loss; its potential can be further advanced through modern high standard manufacturing practices where the use of epoxy glue can be substituted. The simulation and measured results from mentioned specifications demonstrated good agreement. It is substantially compact, low cost, surprisingly high performance although follows simple methods to fabricate the attractive design and applicable for current wireless communication systems such as WiMAX applications.

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