

# Conductor Backed Co-Planar Waveguide Inspired S-Band Filter Using Multi-Ring Resonators

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**Abstract**—A conductor backed CPW-based S-band filter using Multiple Ring Resonators (MRR) is presented. The resonator is coupled with the feed line through inter-digital coupling. Square resonator structure joined with inter-digital coupling on both sides on conductor plane and multiple ring resonators implemented with equal spacing at the ground plane forms a conductor backed CPW filter model. Adjusting the size and gap factor of MRR, the wide tuning ranges of desired frequencies are achieved. The filter has an outstanding bandwidth range from (2–4) GHz which fits for Satellite S-Band applications. The S-band has low insertion loss ( $-0.95$  dB), lower return loss ( $-35$  dB), and wide bandwidth (fractional bandwidth 66.6%) at the center frequency 3 GHz. The filter performance characteristics are investigated and compared with measured results. The size of the filter is  $(39 \times 7.2 \times 1.6)$  mm. The measured values of  $S_{11}$  and  $S_{21}$  are about  $-25$  dB and  $-1.92$  dB, respectively.

## 1. INTRODUCTION

In recent years, there has been significant growth in the branch of radio technology and satellite communication in order to fulfill high demand of the consumers. Certainly, wireless communication and satellite technology will become matured in the coming years since the inevitability of wireless receivers are rapidly growing every day. Mobile radio communication is the major part of wireless technology in which it has the widespread choice of services such as text, data, images, and motion images. The core objective of the wireless system is to offer outstanding quality of service with restricted power within the allocated spectrum. The major challenges in the design of communication satellite hardware are high power, compactness, and low cost. Moreover, a well-organized design and manufacturing mechanism should be adopted to obtain economical products. The 3-D simulation tools and computer-controlled milling (CCM) machines contributions are remarkable in production of high quality products in reduced time. In order to attain more productivity, the devices should be economic, have short design time, and low manufacturing tolerances [1–3].

The S-band filters are developed by employing Co-Planar Waveguide (CPW) technology because of easy integration with both active and lumped elements. A novel band pass filter using a ring resonator has been realized and described. Discontinuities are obtained by optimizing stub width. Stub dimensions are the essential elements in filter design for tuning and to achieve the desired S-band frequency [4–6]. Sharp selectivity and low loss characteristics are obtained by multiple stubs.

In order to make the filter perform well in the desired frequency band, conductor backed CPW is adopted [5–8]. This planar structure offers some benefits such as wide bandwidth, handles less power, less delay than existing filter designs in the literature, and reduced circuit geometry. The CPW feed offers lower loss and low radiation leakage [9]. Even though several structures and manufacturing technologies can be used in the design of the filters, the hybrid MS-CPW technology is the best candidate for the

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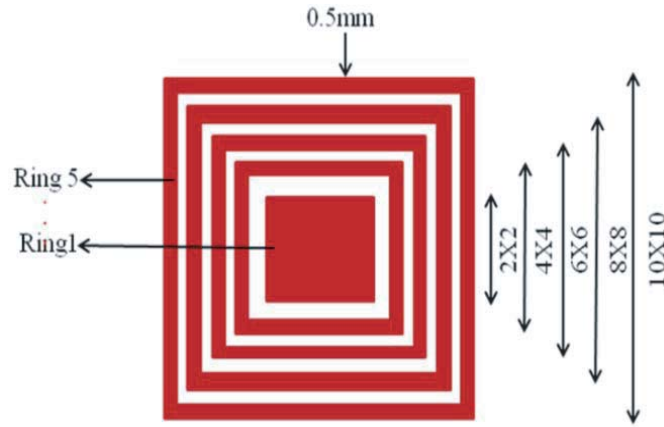
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design of S-band filters. The characteristics of the proposed S-band filter topology are analyzed and compared with the requirements of the satellite S-band communications [10–12].

The proposed S-band filter is designed by means of a simple square resonator, and the tuning of bandwidth is achieved by multiple ring resonators at the bottom of the plane. The proposed S-band filter is unique in design with compact geometry and limited filter parameters compared with prevailing filters in the literature.

## 2. ANALYSIS AND DESIGN OF RING RESONATOR

The concentric closed ring resonator concept is a form of communication link restricted to a loop. The topology of the filter consists of input/output feed lines with robust impedance matching with central resonator structure [13, 14]. Figure 1 depicts a model of a concentric closed ring shaped resonator circuit. The resonant frequency of multiple ring resonators will vary as the gap between feed lines and resonator increases.



**Figure 1.** Ring resonator structure.

The resonant frequency is expressed as

$$f_r = \frac{mc}{2\pi x \sqrt{\epsilon_{reff}}} \quad (1)$$

where  $x$  — mean side of the resonator,  $m$  — number of mode,  $f_r$  — resonant frequency,  $c$  — light speed in free space,  $\epsilon_{reff}$  — effective dielectric constant. The geometry of the square resonator is treated as a circular loop whose radius is given by

$$x = \frac{f}{\sqrt{\left\{ 1 + \frac{2h}{\pi \epsilon_r f} \left[ \ln \left( \frac{\pi f}{2h} \right) + 1.7726 \right] \right\}}} \quad (2)$$

And the effective radius is given by

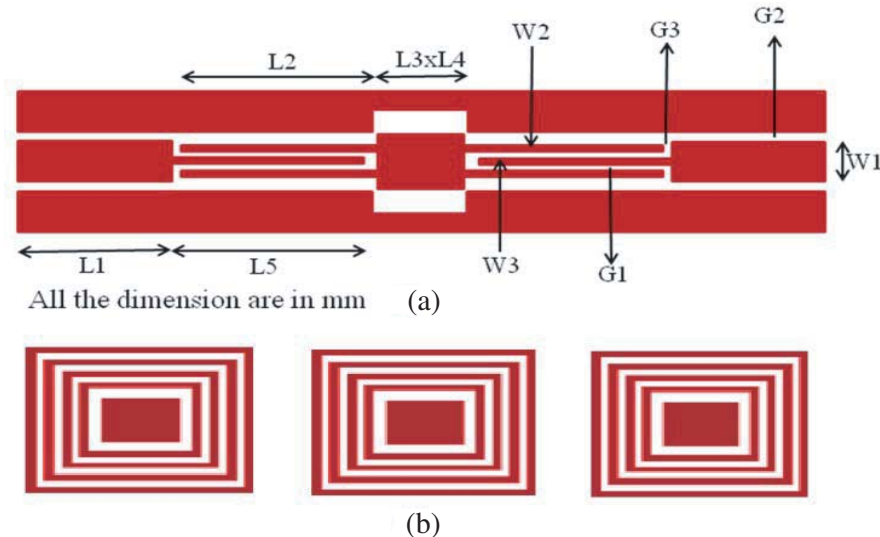
$$X_e = x \sqrt{\left\{ 1 + \frac{2h}{\pi \epsilon_r x} \left[ \ln \left( \frac{\pi x}{2h} \right) + 1.7726 \right] \right\}} \quad (3)$$

Resonant frequency for dominant mode is given by

$$f_r = \frac{1.8412c}{2\pi X_e \sqrt{\epsilon_r}} \quad (4)$$

### 3. DESIGN OF S-BAND FILTER

The geometry of proposed CPW based S-band band-pass filter is shown in Figure 2. A S-band filter primarily consists of a compact square resonator linked with a ring resonator at the substrate's  $z$ -plane. The filter is designed using an FR4-substrate material with dielectric thickness 1.6 mm and relative permittivity 4.4. The typical geometric values of S-band filter are:  $L1 = 8$ ,  $W1 = 3.2$ ,  $L2 = 8.3$ ,  $G1 = 0.3$ ,  $W2 = 0.5$ ,  $L3 = 6$ ,  $G2 = 0.5$ ,  $L4 = 5$ ,  $L5 = 8.2$ ,  $W3 = 0.3$ ,  $G3 = 0.4$ . (All the dimensions are in mm).



**Figure 2.** Compact CPW-BPF geometry.

The proposed S-band filter topology produces better results with a less complex design than existing filter designs in the literature. The multiple square-ring resonators are implemented in the form of waveguide structures. CPW structure is considered in this design for bandwidth tuning. The filter geometry is optimized for satellite S-band frequency. S-band filter and its feed lines are designed to match 50 ohm impedance. Both the input and output ports are connected to these feed lines. The interdigital line linked with square MMR on top plane which offers wide bandwidth range of (1.75–4.5) GHz. The tuning of the band is done by multiple ring resonators at the bottom plane which reject certain bands. The thickness and length of the stubs determine the desired band.

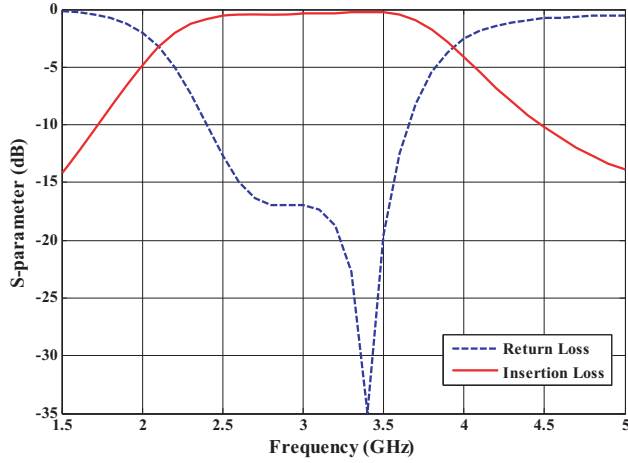
### 4. RESULTS AND DISCUSSION

The S-band filter characteristics are investigated, and the effects of fine-tuning the various filter attributes are analyzed. This filter is optimized for various elements like strip width, length, and thickness. The simulated scattering parameters and phase response of S-band filter are observed using an EM simulation tool HFSS.

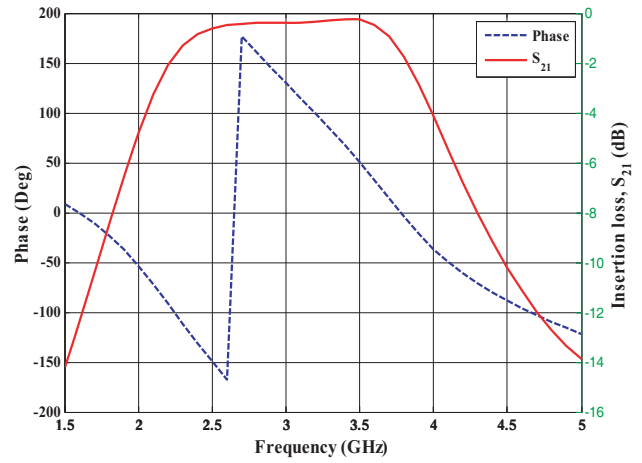
The proposed S-band filter has excellent IL of  $-0.52$  dB and RL of  $-35$  dB as shown in Figure 3. The proposed BPF produces outstanding bandwidth measured from (1.75–4.5) GHz at  $-10$  dB bandwidth line which covers S-band. The fractional bandwidth is manipulated from the response as 88.7%.

The response of phase variation of the S-band filter is represented in Figure 4. It is very clear that S-band filter has outstanding in-phase characteristic in passband. Phase is a significant function of the filter, and it should be linear in passband. Hence, the phase of the S-band filter is appreciably linear so that the filter is best suited for satellite S-band services. The prototype realization of the S-band filter is presented.  $S_{21}$  and  $S_{11}$  of the fabricated filter are measured using Network analyzer Model HP8757D as shown in Figures 5 and 6, respectively.

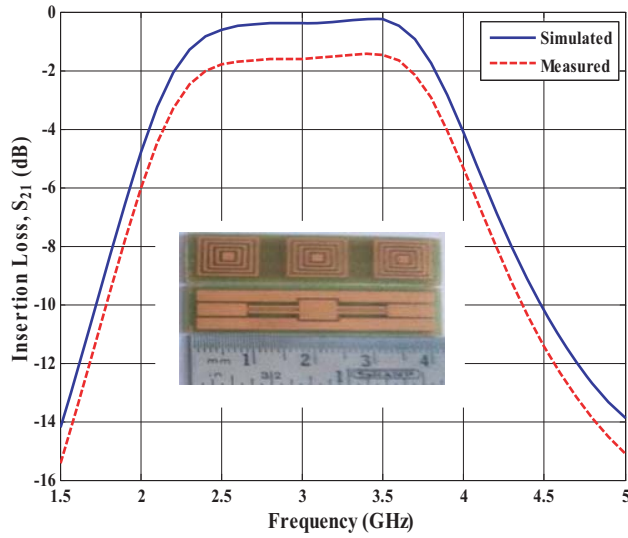
There is some discrepancy between simulated insertion loss and measured ones due to the effects of fabrication inaccuracy and calibration errors of SMA connectors.



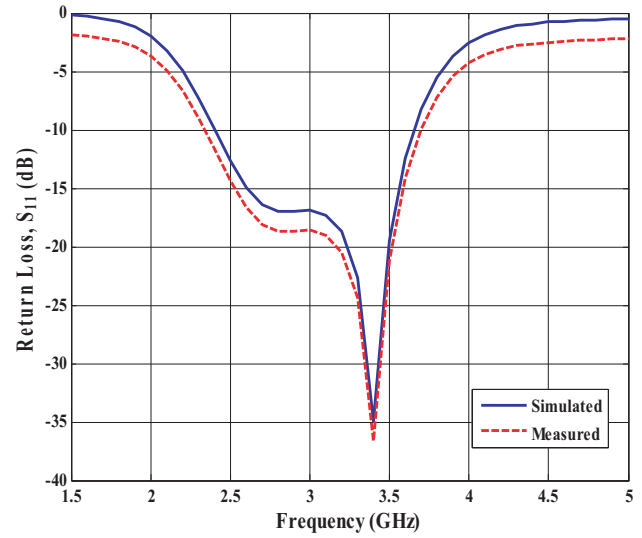
**Figure 3.**  $S$ -parameters of compact CPW-BPF.



**Figure 4.** Phase response of compact CPW-BPF.



**Figure 5.** Insertion loss of compact CPW-BPF.



**Figure 6.** Return loss of compact CPW-BPF.

Table 1 lists the comparison of simulated and measured results of compact coplanar BPF performance attributes like IL, RL, passband frequency, bandwidth, and phase. Table 2 lists the comparison report on filter performance of the proposed compact coplanar BPF with other existing

**Table 1.** Comparison of simulated and measured results.

Parameters	Simulated Values of Compact CPW-BPF	Measured Values of Compact CPW-BPF
Insertion Loss $S_{21}$ in dB	-0.52 dB	-1.5 dB
Return Loss $S_{11}$ in dB	-35 dB	-35.8 dB
Pass Band	(1.75–4.5) GHz	(1.8–4.4) GHz
Bandwidth	2.75 GHz	2.6 GHz
3-5 Phase at Pass Band	Linear	Linear

**Table 2.** Comparison of proposed and existing CPW-BPF results.

Ref. No.	$S_{11}$ in (dB)	$S_{21}$ in (dB)	Pass Band (GHz)	BW (GHz)	Size (mm) <sup>3</sup>
Jian <i>et al.</i> [15]	-20	-2	(2-4)	2	638.4
V. Gholipur <i>et al.</i> [16]	-40	-1	(2.2-3.5)	1.3	757.9
Hussein <i>et al.</i> [17]	-11	-1	(2-4)	2	210
Pratik <i>et al.</i> [18]	-22	-1.07	(1.7-4)	2.3	1800
<b>Proposed CPW-BPF</b>	-35	-0.52	(2-4)	2.75	449.2

filters. It is obvious from Table 2 that the proposed filter performs well in terms of high cut-off frequency with reduced size. The  $S$ -parameter values are also good compared with the other S-band filters listed in the reference.

## 5. CONCLUSION

Multi-ring resonators based on a compact conductor backed CPW for satellite S-band application are presented. The multi-ring resonators have a passband from 1.75 to 4.5 GHz. The dimensions of ring resonators and inter digital couplings can be varied easily for the desired band. On the other hand, the size of the open loaded stubs is responsible for the elimination of certain bands in the passband. The design, simulation, and performance of the S-band filter are clearly discussed. The filter achieves flat and constant widespread bandwidth range from 1.75 to 4.5 GHz. The size is around  $(39 \times 7.2 \times 1.6)$  mm<sup>3</sup>. This filter also has outstanding performance in terms of roll-on and roll-off characteristics. Considering all the structural and performance characteristics, the FBW is obtained as 88.7% with RL and IL of -35 dB and -0.52 dB, respectively. Thus, the  $S$ -parameter, phase, and wide operating band behavior of S-band filter convey better performance, so it is optimally suitable for satellite S-band system applications.

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