COMPACT AND HIGH PERFORMANCE FILTERS FOR MOBILE COMMUNICATION

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Abstract: In the marketplace, where price and performance requirements are challenging to meet, size has become an extremely important factor for cellular base stations. In current mobile communications bands, air-filled filters, which tend to be bulky, are used in base stations. In this contribution, the alternative use of a dielectric loaded combline filter is proposed in order to reduce the size of filters, and enhance their performance. An eighth-order canonical combline filter is designed with this in mind, for which measured results show improved performance.

Key words: Bandpass filters, combline elliptic filters, dielectric filters

1. INTRODUCTION

The requirements of microwave bandpass filters employed in base stations for mobile communication are becoming more and more demanding. High selectivity and low insertion loss filters are in demand in order to conserve valuable frequency spectrum and enhance performance of the systems [1-2]. Furthermore, these filters are desired to have small size and low cost in order to be accepted by the market. The strict requirements on these filters make them difficult to be realised. Resonators with very high-unloaded Q-factor and elliptic function response filters have to be used to satisfy the loss, high selectivity and high rejection requirements. Resonators with good spurious free performance are needed to meet the out-of-band requirements.

A microwave bandpass filter can achieve a higher selectivity by increasing the degree of poles, namely the number of resonators. However, because the quality factor of the resonators is finite, the passband insertion loss of the filter increases as the number of resonators is increased. Therefore, there is always a trade-off between the selectivity and the passband insertion loss. On the other hand, for a specified filter selectivity, certain type of filter characteristics that not only meets the selectivity requirement, but also results in a minimum pass band insertion loss for a given quality factor of resonators are required. One such filter with these attractive characteristics is the elliptic function response filter.

Tremendous progress has been achieved on improving the size, in-band and out-of-band performance of the filters in the recent past. Multi-mode filters have been used to greatly reduce the size and mass of the filters and open a way of realisation of elliptic function response [3]. Dielectric loaded filters have been designed to improve the in-band performance and the thermal stability of the filters, but the suffer from poor spurious performance. To obtain very good spurious performance, lower price and compact size, the combline filter is very attractive.

This paper is concerned with designing miniaturised microwave bandpass filters to meet these demands of the mobile communication systems using the combline filter. The design of the eight-order elliptic function canonical combline filter is explained and its theoretical and measured responses are presented.

2. FILTER DESIGN AND RESULTS

In order to illustrate the design procedure, the coupling matrices and the terminal resistances of an eighth-order elliptic function filters will be calculated. The filters are to be realised as a narrow bandpass filter with eight multiple-coupled synchronously tuned cavities. The filters are designed to meet the following specifications:

(i) Centre frequency (f_0) = 1.747 GHz
(ii) Bandwidth (BW) = 75 MHz
(iii) Maximum loss in the passband = 0.05 dB
(iv) Minimum loss in the stopband = 85 dB
(v) Selectivity = 0.65

Using the above specifications and the computer program

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was developed to obtain the low-pass voltage transfer function in the form shown in equation (1) [3].

$$\left|S_{21}(s)\right|^2 = \frac{1}{1+\varepsilon^2 R_n^2(s)} \qquad (1)$$

Where $R_s(s)$ is the rational function expressed as the ratio of two polynomials. $s = j\omega$ is used for low-pass prototype filters.

Since the filter is eighth-order, the stop-band attenuation is not infinite when the frequency approaches infinity. Also theoretically, because it is even order, this filter cannot be equally terminated. To meet the conditions of realisability and equal termination, frequency transformations has been applied to move the poles and zeros to appropriate locations. The frequency transformation is in the form shown in equation (2) [4].

$$\omega^2 = \frac{\omega_{p1}^2 - \omega_p^2}{\omega_p^2 - \omega_{01}^2}\,\omega_p^2\,\frac{\omega^2 - \omega_{01}^2}{\omega_{p1}^2 - \omega^2} \qquad (2)$$

Where: ω_{01} and ω_{p1} are the first zero and pole of $R_n(\omega)$ and ω_p is the passband edge.

This would lead to an eighth-order filter with six transmission zeros at finite frequencies and seven reflection zeros. For the filter specified, the couplings between resonators were calculated using the technique in [5] which is based on matrix rotation [6]. The resulting normalised input/output resistances and the even mode coupling matrix are shown in equation (3) below.

$R_{in} = R_{out} = 1.0403\Omega$

$$M_e = \begin{bmatrix} -0.001 & 0.824 & 0.000 & 0.000 \\ 0.824 & 0.017 & 0.596 & 0.000 \\ 0.000 & 0.596 & -0.168 & 0.519 \\ 0.000 & 0.000 & 0.519 & 0.692 \end{bmatrix} \qquad (3)$$

To realise the filter, all the positive and negative coupling have been achieved using apertures between resonators. The coupling coefficient k data was determined by the TLM method from equation (4) below to two identical resonator coupled through the slot in the common wall as shown in fig 1. The size of each aperture is determined from the coupling data shown in fig 2.

$$k = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \qquad (4)$$

Where f_e and f_m correspond, respectively, to the odd and even mode resonant frequencies of the coupled resonators [7].

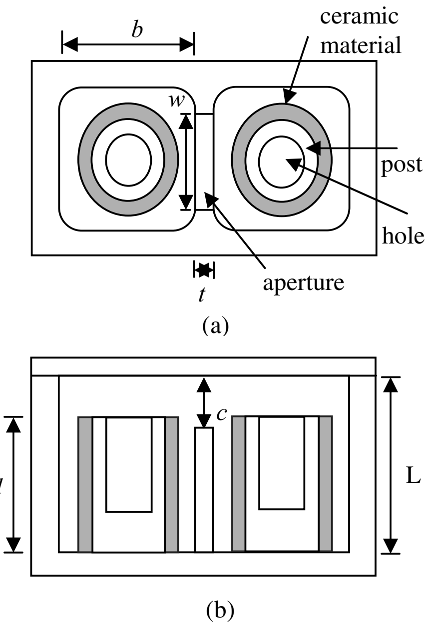

Fig. 1: Configuration of two coupled identical dielectric loaded combline resonators (a) plan view and (b) front view

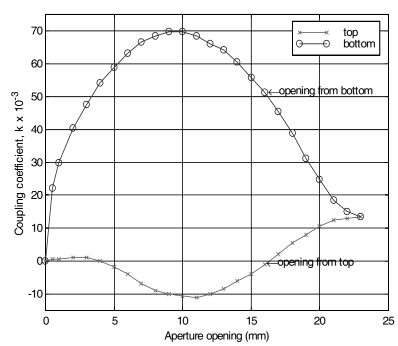

Fig. 2: Slot coupling of two dielectric loaded identical combline cavaties

The schematic layout of the canonical configuration that describes the above matrix is shown in fig. 3. The theoretical frequency response of the filter is shown in fig. 4. The measured frequency response of the filter is shown in fig. 5. The measured results were obtained using the Hewlett Packard 8753D network analyser. By comparing these two frequency responses, it can be seen that the bandwidth and the centre frequency have been correctly achieved. The return loss of the filter is 15 dB. The insertion loss of the filter is 1.50 dB. The insertion loss is high due to a combination of losses of resonators and apertures. For a silver plated filter, the insertion loss is expected to dramatically improve. Three finite transmission zeros have been obtained as opposed to six. The difficulty in realising smaller cross couplings like M_{18} and M_{27} have led to three instead of six finite transmissions zeros being achieved. This has also contributed to the poor return and insertion losses of the filter. The second problem noticeable from figs. 5 and 6 is the out-of-band rejection of the filter, which is about 40 dB. This is due to the close proximity of the input and output ports. The input and output resonators are coupled and this deteriorates the isolation. The measured isolation between the input and output is 56 dB. Therefore out-of-band rejection of the filter cannot exceed this figure. Fig. 6 shows the wide band response of the filter. It can be seen that about 2 GHz spurious free performance has been achieved.

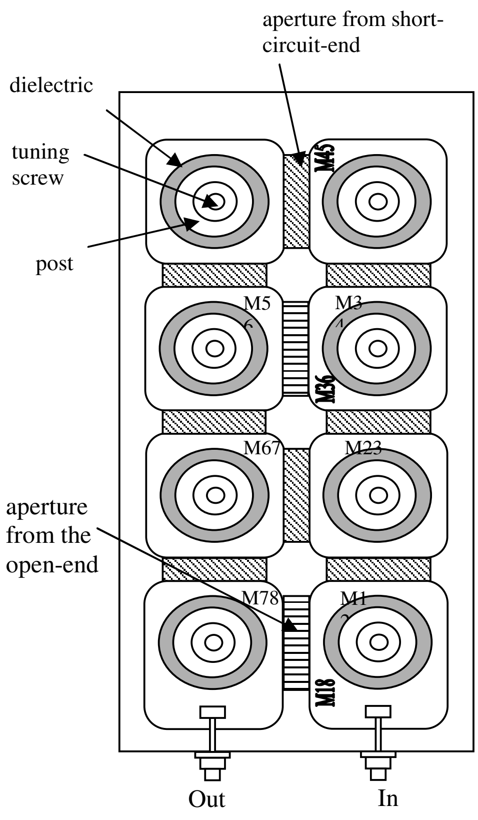

Fig. 3: The schematic diagram (plan-view) of the eight-order dielectric loaded elliptic function canonical filter

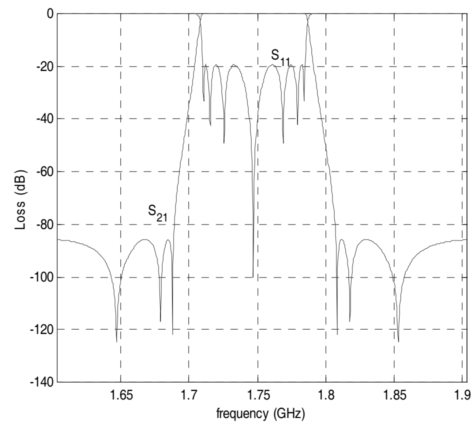

Fig. 4: The theoretical frequency response of the 8-pole elliptic function canonical filter

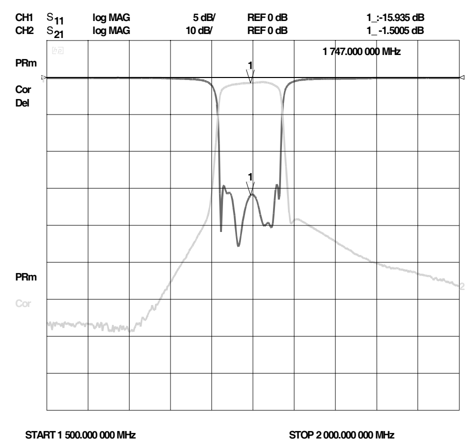

Fig. 5: The measured frequency response of the 8-pole elliptic function canonical filter

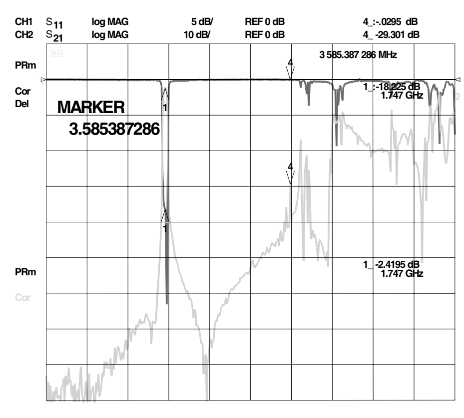

Fig. 6: The wide band response of the eight-order dielectric loaded elliptic function filter

3. CONCLUSION

An experimental eighth-order elliptic function dielectric loaded combline filter has been designed, built and tested. The insertion loss and out-of-band rejection of the filter did not meet the theoretical predictions due to he reasons outlined above. The measured response of the filter shows that the filter has a very good spurious free performance.

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