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MICROSTRIP BANDPASS FILTER AT S BAND USING CAPACITIVE COUPLED RESONATOR

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Abstract—A microstrip bandpass filter with a new type of capacitive coupled resonator is presented. The filter is designed to be smaller compared to the same type of parallel-coupled bandpass filter. The filter is designed for a centre frequency of 2.5 GHz that lies in the S-band frequency range. The insertion loss at f_o is 2.4 dB and the measured 3 dB bandwidth is 8.6%. The agreement between the predicted and measured results is excellent, and even the circuit simulator gives a very good prediction for the filter characteristics.

1. INTRODUCTION

The microstrip resonator has been widely used to measure the dispersion, phase velocity, and effective dielectric constant in microstrip structures cause Because of its high Q-factor and structural simplicity, it also finds broad applications in microwave and millimeter-wave circuits such as filters; duplexers, oscillators, mixers, couplers, and antennas [1]. Printed bandpass filters are widely used elements in various microwave subsystems due to their repeatability, reliability and low price. Practically, their only "cost" is the occupied area on a printed board. Because of that many recent papers discuss various printed filter configurations having size reduction as one of the most important design goals [2]. A bandpass filter using microstrip ring resonators with 25% size reduction compared to the conventional microstrip filter with coupled half-wavelength resonators was proposed in [1]. The papers [3–6] analyses various types of resonators filter design. Most of these filters have wider stopbands that contain deep zeros in proximity to the passband region. The most efficient way in order to obtain a filter with maximum size reduction is by using the microstrip technique in which each filter's lumped component is realized as microstrip transmission line [7–9]. Further optimization and tuning of the microstrip circuit would produce an equivalent microstrip circuit with certain percentage of size reduction relatively compared to the parallel-coupled filters [10–12]. The center frequency is designed to be at 2.5 GHz, which describes the operation of the filter with a maximum gain.

2. CONCEPT

Figure 1 shows a basic electric scheme of the proposed filter that consists of four identical resonators (Q1–Q4) electrically coupled by capacitors C_r [2]. Table 1 shows the values of corresponding lumped components in Figure 1.Although the scheme has only four variables, C_p, C_r, L_1, and L_2, by varying their values it is possible to obtain filters with different bandwidths. The overall filter is square-shaped in order to minimise the space occupied [2]. The inductance L_1 and L_2 behaves as narrow microstrip transmission lines. For the loaded (input and output) resonators those microstrip transmission lines are divided into two unequal parts by input and output 50Ω microstrip lines in order to achieve the 0° feed structure [6]. The microstrip line within the resonator is altered for minimisation of the resonator and

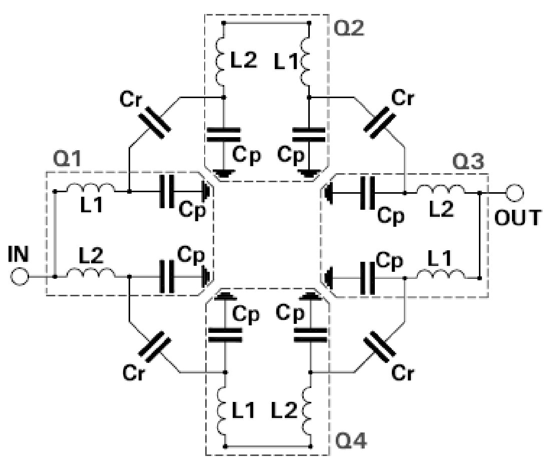

Figure 1. Basic electric scheme of proposed filter.

Table 1. Values of corresponding lumped components in Figure 1.

Description	*Component*	*Value*
Pair of capacitances in each resonator	C_p	1.15pF
First inductance in each resonator	L1	2.15nH
Second inductance in each resonator	L2	4.25nH
Coupling capacitance	C_r	0.075pF
Capacitance within the resonator	C_m	0.024pF

overall filter size, and terminated on both ends with wide microstrip patches that form required capacitances to ground (C_p). The coupling capacitances C_r are formed between adjacent pairs of patches belonging to the neighbouring resonators [2].

3. DESIGN AND RESULTS

The scheme from Figure 2 was used in a circuit simulator for the optimisation of the filter layout, mainly to optimise the width and the lengths of the microstrip transmission lines and to estimate the influence of the capacitance C_m, which tends to lower the filter's centre frequency and to broaden the passband, as well as to take into account the components' losses [2]. The lengths and widths of each microstrip transmission line are tuned and optimized in order to obtain center frequency at 2.5 GHz and lower and upper 3 dB cut-off frequencies at approximately 2.4 GHz and 2.6 GHz accordingly. Both capacitances and inductances are realized as microstrip transmission lines with impedance $Z_O = 50$ ohm. The substrate used for simulation purposes and further implementation purposes is Rogers RO3010 ($\varepsilon = 10.2$, $h = 0.635$ mm). By using a higher ε and thinner substrate, a smaller filter size could be achieved. Since the main goal or objective of the design is achieving a small filter size, the substrate RO3010 is suitable for optimum performance. Figure 3 shows a photograph of the realized filter. The filter is squared-shaped with dimension 8.5 mm $\times$ 8.5 mm (72 mm^2) while filter from [2] occupies 27 mm^2. The further center frequency increasing would lead to impractically small filter size. Because of that a filters layout at these frequencies has to be adjusted so that parasitic capacitance of transmission lines within the filters'

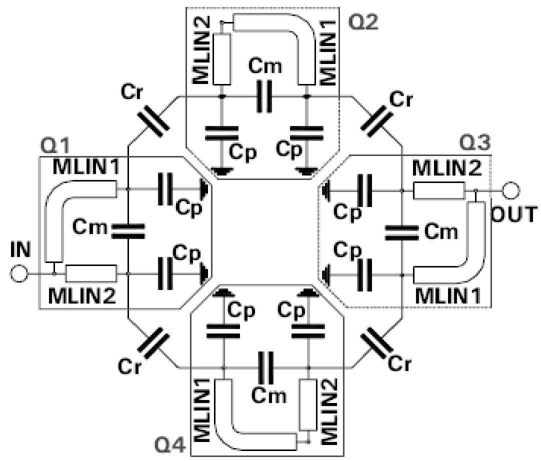

Figure 2. Circuit simulator scheme.

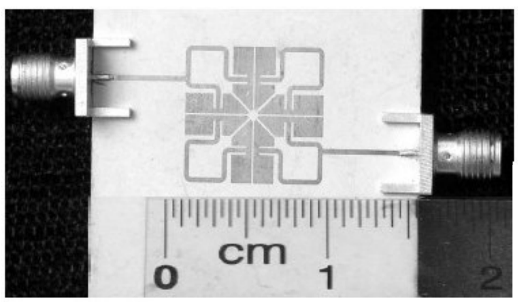

Figure 3. Photograph of the realised filter.

resonators are used to provide required ultra-small capacitances to ground (C_p). The design filter dimension is smaller compared to the conventional filter referenced in [3] that occupies 256 mm^2. As a result the proposed filter has a significant size reduction of 72% compared to the conventional microstrip filter in [3]. This size makes it suitable for integration within various microwave subsystems.

Figure 4 shows simulated and measured S_{11} and S_{21} frequency response of the filter. The agreement between the measured results and the results from Advanced Design System (ADS) analysis is excellent. The realized filter has pass-band at central frequency of 2.45 GHz, which differs from the designed value for less than 2%. This difference is caused by tolerances during filter's fabrication. The

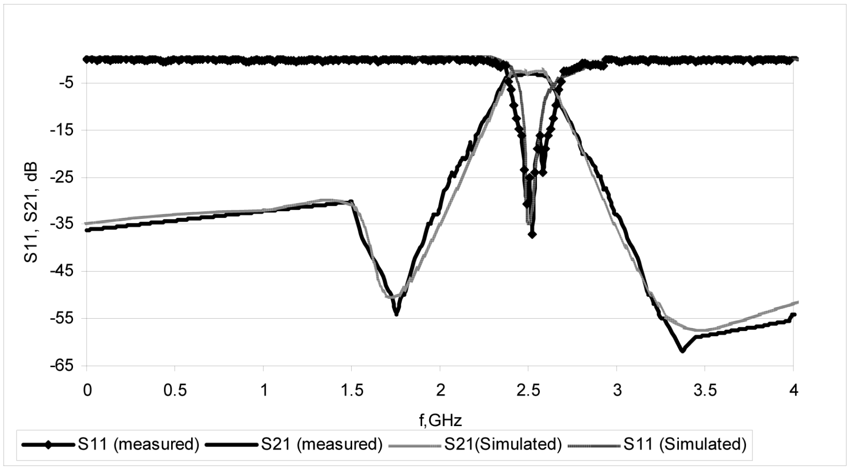

Figure 4. Simulated and measured S_{11} and S_{21} parameters of the filter.

biggest influence has the width of microstrip transmission lines within the filter's resonators. The insertion loss at the central frequency is 2.4 dB. The measured 3 dB bandwidth is 8.6%, while 1 dB bandwidth is 6.5% with return loss in the same frequency range better than 15 dB. The attenuation in the lower stop-band is around −54 dB and around −62 dB in the upper stop-band.

4. CONCLUSIONS

A new type of capacitive coupling of identical resonators to form a symmetrical microstrip bandpass filter is designed. The symmetrical approach tends to produce a more compact filter with less coupling effect in its realization. Its compact nature minimizes required space for realization and is suitable for integration within RF and microwave subsystems. The agreement between the measured and simulated results is excellent.

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