Miniature Microstrip Stepped Impedance Resonator Bandpass Filters and Diplexers For Mobile Communications

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Abstract

Miniature microstrip stepped impedance resonator bandpass filters and diplexers for satellite mobile communications have been developed. A very high dielectric constant substrate (ε_r=89 and h=2mm) is used. Experimental results show that an unloaded half wave resonator quality factor as high as 400 at 1.5 GHz, with such substrate, may be possible. The merit of this circuit lies in the simplicity of design procedure, the possibility of developing this filter with quite a variety of high dielectric constant substrate materials and the simplicity of simulation with most commercial software packages. A four resonator bandpass filter with 35 MHz bandwidth at 1.55 GHz was designed and implemented with this substrate. Based on this filter, a diplexer which meets satellite mobile communications performance has been developed. Experimental results are in good agreement with theoretical predictions

Introduction

Miniature bandpass, low cost, low loss filters are very important in mobile communications. Ceramic block versions with a high dielectric constant of coaxial line filters, in interdigital or combline form are commonly used for such applications [1]. Some other types may also be used : a dielectric filled coaxial resonators [2] in stepped impedance form has been used to design a band-pass filter based on the capacitive-coupled-resonator structure[3]; quarter-wavelength coaxial resonators made of high-Q dielectric ceramic [4] have been also used. Resonator tuning of such filters was necessary after design.

From the cost point of view, planar versions are mostly preferable for these applications. A semi-lumped filter structure [5] is one of the possible choices for this technology for its compactness when realized with a high dielectric constant substrates. Unfortunately, this structure requires sophisticated characterization of different discontinuities needed to develop it as well as resonator grounding. This procedure is leading to higher production costs.

The use of microstrip technology with a very high dielectric constant is associated with the following constraints :

- Low loss filter needed a sufficient line width. This limit is associated with the necessity of using low value characteristic impedance lines.
- High sensitivity to small variations in physical dimensions.
- Excitation of higher order modes in the low microwave frequencies.
- Difficulty in the realization of high characteristic impedance lines and in particularly a 50 Ω line.

To overcome some of these constraints, the hairpin-line filter was developed [6]. It offers an important trade-off between size, performance and production cost. However, the design procedure was based on a series of experimental results at the filter center frequency. This procedure led to some difficulties when some filters are associated, as in the multiplexer design.

In this paper, we introduce the filter structure based on the stepped impedance resonator (figure 1). This structure was developed in coaxial line form [7] and in stripline technology [8,9]. The main advantages of this structure are :

- The possibility of controlling spurious responses and insertion losses.
- The design procedure is independent of the values of the characteristic impedance of the resonators. So, the optimum line dimensions for the maximum unloaded quality factor can be chosen.

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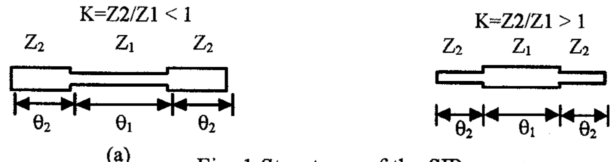

Fig. 1 Structures of the SIR

Filter design procedure

The filter design procedure herein is based on the filter synthesis techniques outlined in [8]. The spurious resonance frequency of the three first resonances of this type of resonator is shown in figure 2. Figure 3 presents the experimental results of the characteristic impedance and unloaded quality factor of a half wave resonator at 1.5 GHz using microstrip technology with a very high dielectric constant (ε_r =89 and h = 2 mm). The filter under consideration has been designed to meet the following specifications :
f_o= 1575 MHz Δf=45 MHz (3% relative bandwidth).
Filter response : Chebyshev, 0.01 dB ripple factor.

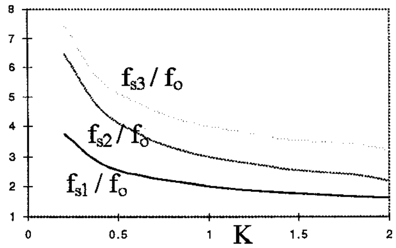

Fig. 2 Resonance condition of the SIR

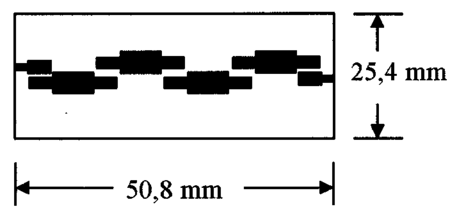

Fig. 4 Filter layout SIR filter designed with a very high dielectric constant substrate (εr = 89 et h = 2 mm)

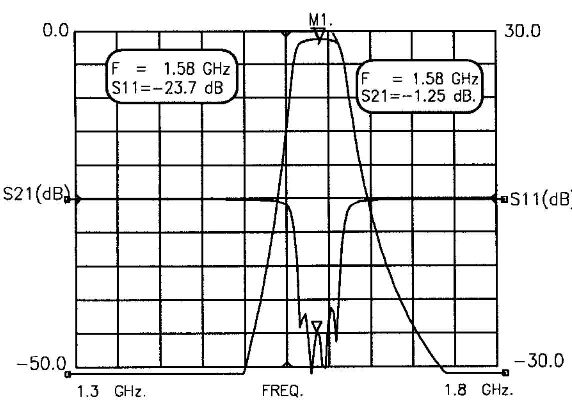

Fig. 5 Simulated results of the filter

The selection of the impedance ratio k, is chosen to minimize the losses and to shift the spurious resonance response. To minimize the losses, the resonator form in figure 1b is used. For k = 1.4, the first and second spurious responses are at 1.8 f_o and 2.6 f_o respectively (fig. 2). For the maximum unloaded Q factor, the center line width is chosen to be 3 mm. This value corresponds to line characteristic impedance Z_2 in the order of 14 Ω (figure 3). The characteristic impedance of the second section Z_1 is 20 Ω, which corresponds to a line width of 1.5 mm. The filter topology is shown in figure 4. The filter is simulated using a commercial software package HP MDS6 [10]. Simulation and experimental results are shown in figures 5, 6, and 7 respectively. The measured bandwidth is 35 MHz (w =2.2%), which is slightly lower than the designed value. The midband insertion losses are 2dB. This value corresponds to an unloaded quality factor in the order of 394. The bandpass response is shifted in the lower band by 30 MHz. The measured rejection of the second harmonic ($2f_o$) was 65 dB, while 17 dB of rejection was observed at the third harmonic. This is due to the excitation of higher order modes at 4 GHz.

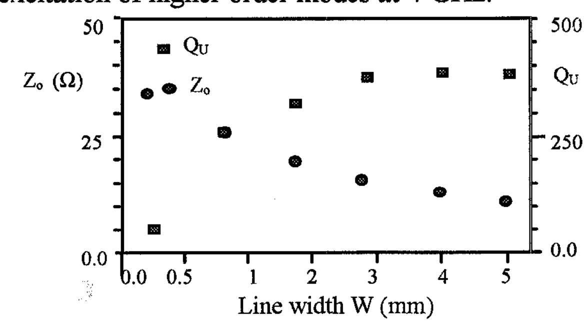

Fig. 3 Experimental results of unloaded quality factor and impedance characteristic of a microstrip technology with a very high dielectric constant (ε_r=89 and h=2 mm)

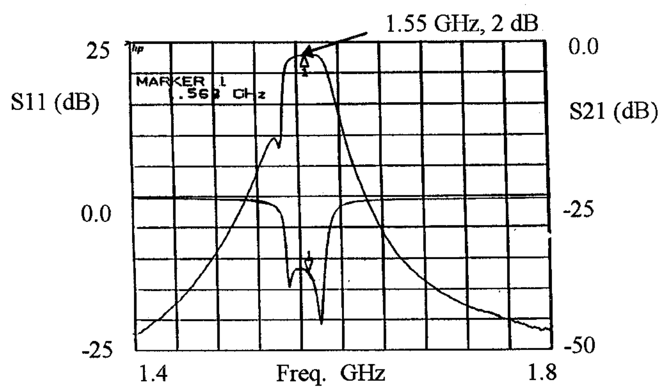

Fig. 6 Measured frequency response of the filter

Diplexer design

The diplexer designed here is based on the SIR filter explained above. In this case, the design procedure begins by the design of two filters independently, one of them meeting the desired performance in the lower band and the other meeting the performance of the upper band. Each filter must be matched to introduce an open circuit at the middle band of the other. So, the two filters can be combined using a T junction as shown in figure 8. The diplexer is simulated and lightly optimized with HP MDS6 [10]. The simulation results are shown in figure 9. The experimental results are shown in figure 10. The insertion losses at the mid band of the lower and upper frequency are about 2.3 dB. The bandwidth of the upper band is 35 MHz and 25 MHz for the lower band. The measured rejection of the diplexer is 40 dB.

Conclusion

Small-size, low insertion-losses filters and diplexers are introduced with a very high dielectric constant substrate. These circuits can be mass-produced very easily which leads to significant cost reduction. One of the important features of this structure is the controlling of the spurious response. These properties make these circuits suitable for mobile communications.

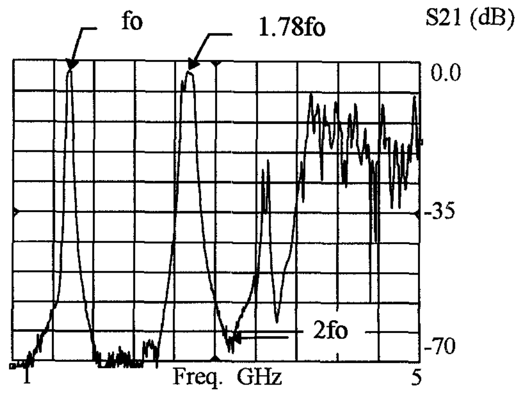

Fig. 7 Measured spurious response of the filter

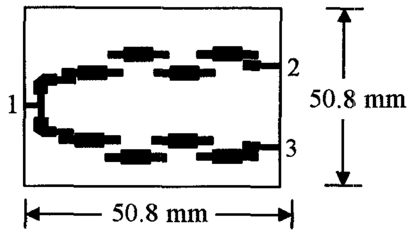

Fig. 8 Diplexer layout designed with a very high dielectric substrate

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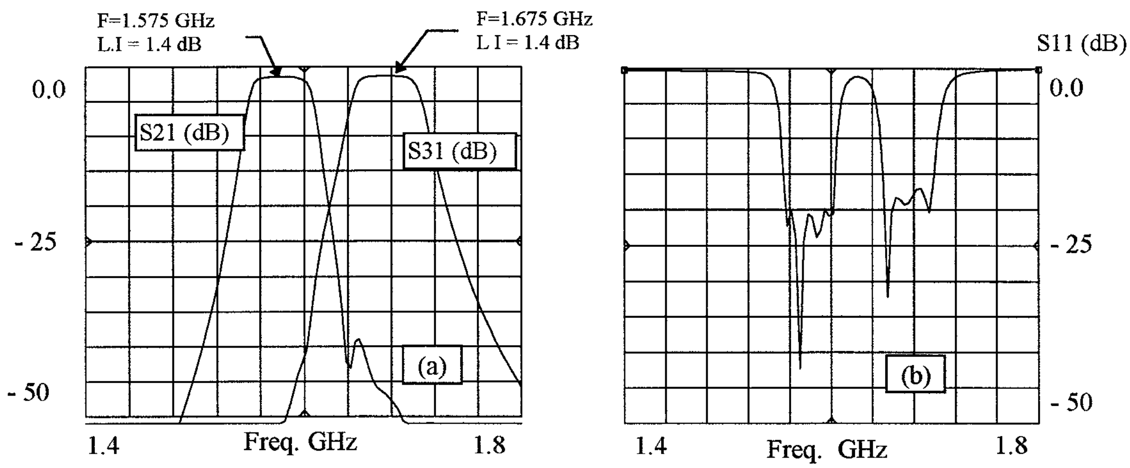

Fig. 9 Simulated response of the diplexer designed
with a very high dielectric constant substrate

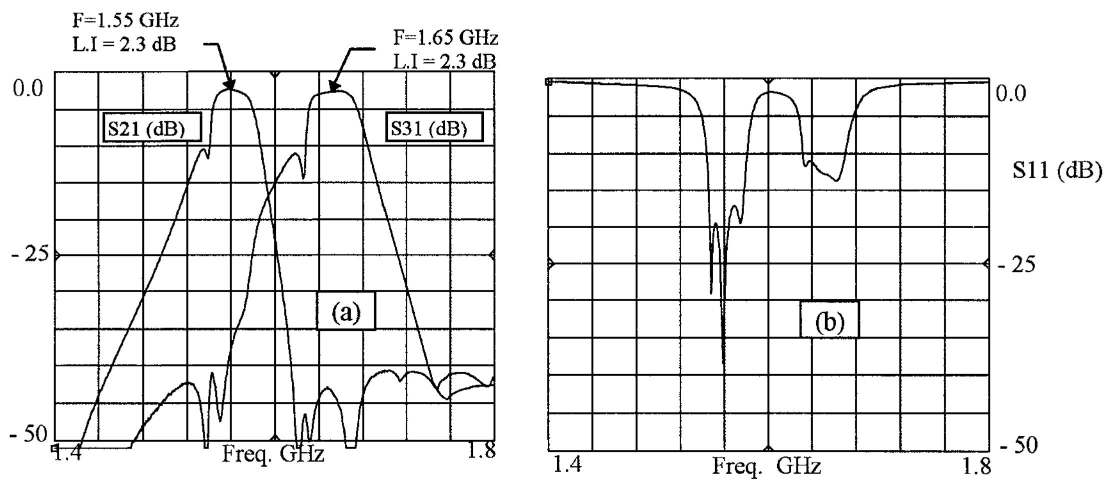

Fig. 10 Measured response of the diplexer developed
with a very high dielectric constant substrate

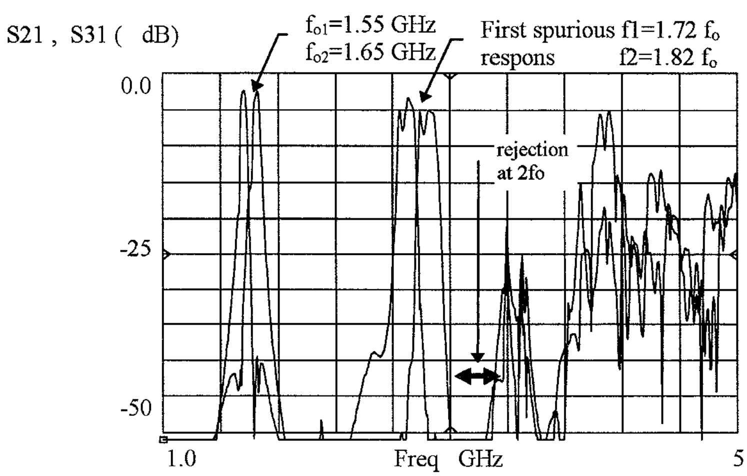

Fig. 11 Measured spurious response of the diplexer developed
with a very high dielectric constant substrate