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Miniature dual-band filters using integrated bandpass and bandstop filters for wide bandwidths

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Abstract: This paper presents a novel microstrip dual-band filter in which a shunt-stub bandpass filter and an open-stub bandstop filter are integrated into a single structure of short length. The bandstop filter is centered within the passband of the bandpass filter, resulting in a filter having dual passbands. Good return loss is obtained using an optimization routine. This method is suitable for designing dual-band filters having wide bandwidths. Good agreement between theory and measurements in respect of low insertion loss and high isolation is demonstrated.

Keywords: dual-band filter; open-stub bandstop filter; shunt-stub bandpass filter; wide bandwidth
Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Recently, with the challenging demand of personal communications, multi-mode or multi-band systems that can access or treat two or more systems simultaneously with good isolation between bands are becoming important. Dual-band filters are key components in these systems. Various configurations have been proposed to realize dual-band filters. Thus [1] combined two passband filters with a proper output circuit to achieve the dual-band response. In [2] and [3] the second resonating mode of quarter- or half-wave resonators was designed to resonate at the second passband of the dual-band filter. In [4] a dual-band filter achieves its two bands with the aid of three open-circuited stubs for band separation. Commonly these design techniques are limited to relatively narrow bandwidths.

In [5] a direct cascade circuit of the bandpass and bandstop filters is described. It presents a solution for the case of broad bandwidths, but obviously has greater length than the integrated structure reported in this paper.

2 Design Technique For the Integrated Dual-band Filter

The circuit topology for the proposed dual-band filter is shown in Fig. 1. The overall bandpass filter portion consists of shorted shunt stubs spaced by 1/4 wavelength lines as described in [6], and is shown mounted below the main through line. In the case depicted there are five shunt stubs spaced 1/4 wavelength along the main through line. Above the mainline are open stubs loaded on the midpoints of the 1/4 wavelength lines to realize the bandstop filter having four resonators.

We can regard each open-stub loaded $1/4\lambda$ main line section as a modified admittance inverter. Near the center frequency each open circuited stub has an input reactance of zero, which means the midpoint of the $1/4\lambda$ sections is short-circuited and will give high rejection near this frequency. Outside this stopband region the open stub does not affect the $1/4\lambda$ section nearly as much, and a good approximation of an admittance inverter may be obtained. It should be noted also that one can place the open stubs on the same side of the shunt stubs giving a smaller width, but possibly introducing more interactions between neighboring stubs.

The bandwidth of the bandpass filter is designed to be sufficiently wide to accomodate the two passbands, while the frequency separation between these dual passbands is determined by the bandwidth of the bandstop filter. Since the two filters both utilize the same center mainline they will interact, causing mismatches. The design technique is to construct a circuit model, followed by optimization of the dimensions.

3 Experiment results and discussion

A dual-band filter with two bands of 700-1000 MHz and 1920-2170 MHz was designed. The lower passband covers the frequency ranges of GSM and CDMA2000, while the higher passband is allocated for WCDMA. Ansoft Serenade 8.7 was used to carry out circuit simulation and optimization of the

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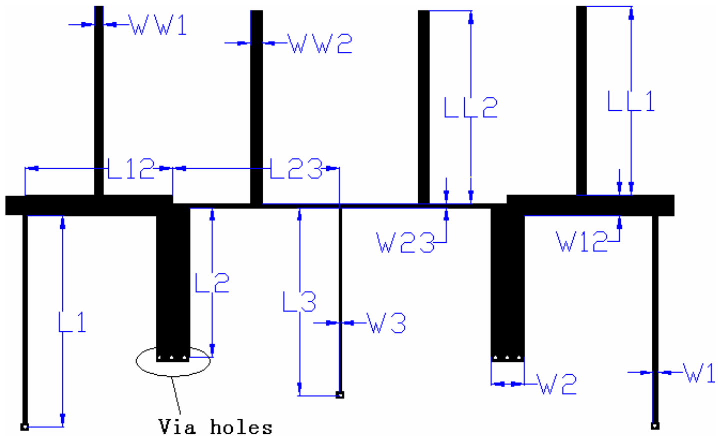

Fig. 1. Configuration for the dual-band filter

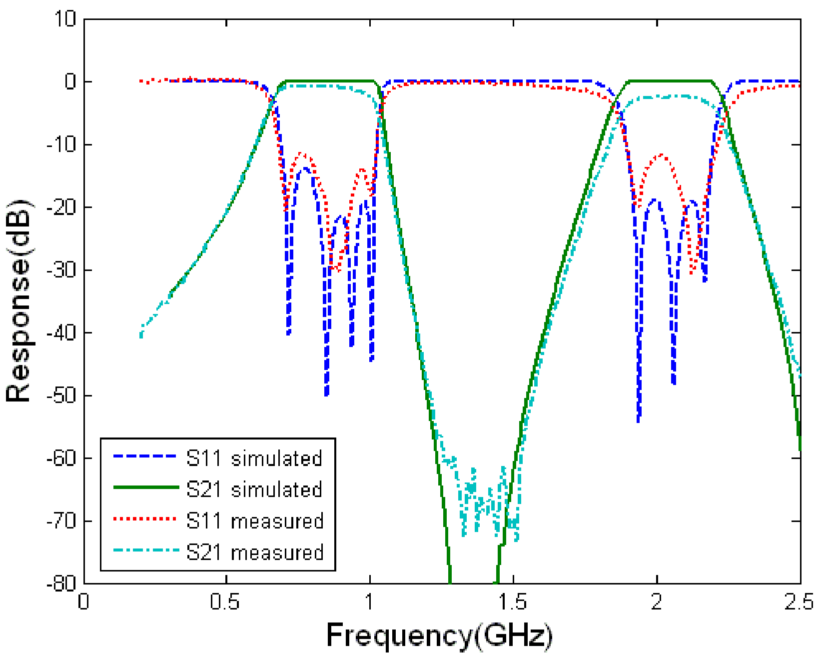

Fig. 2. Simulated and measured filter response.

dual-band filter, followed by an EM simulation for verification. The prototype filter was fabricated on a substrate with a thickness of 1.6 mm and an effective dielectric constant $\varepsilon_r$of 4.6. Referring to Fig. 1, the dimensions (in mm.) for the designed filter are as follows:

$L1 = 33.4$, $W1 = 0.73$, $L2 = 23.7$, $W2 = 5.3$, $L3 = 29.7$, $W3 = 0.3$, $L12 = 23.5$, $W12 = 3.3$, $L23 = 26.5$, $W23 = 0.69$, $LL1 = 29.8$, $WW1 = 1.39$, $LL2 = 30.45$, $WW2 = 1.82$.

The measured results compared with the circuit simulation are shown in Fig. 3, demonstrating good agreement except for the somewhat degraded return loss, caused probably by dimensional tolerances and by not having tuning screws. However the performance is acceptable for the system requirements. The measured highest insertion losses for the lower and higher bands are 1.9 dB and 3 dB respectively, due to conductor, dielectric, and radiation losses, plus some loss due to the mismatch. A high isolation of more

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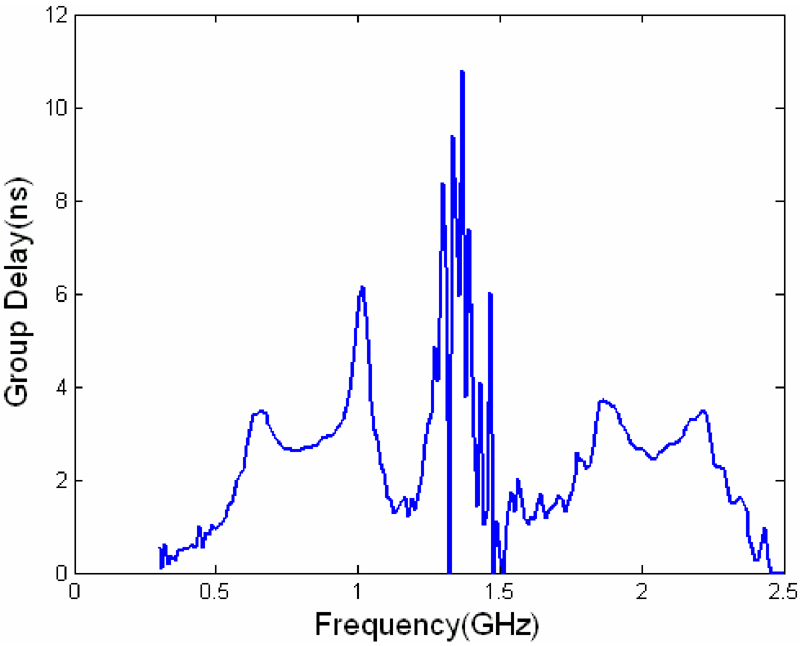

Fig. 3. Measured group delay of S21.

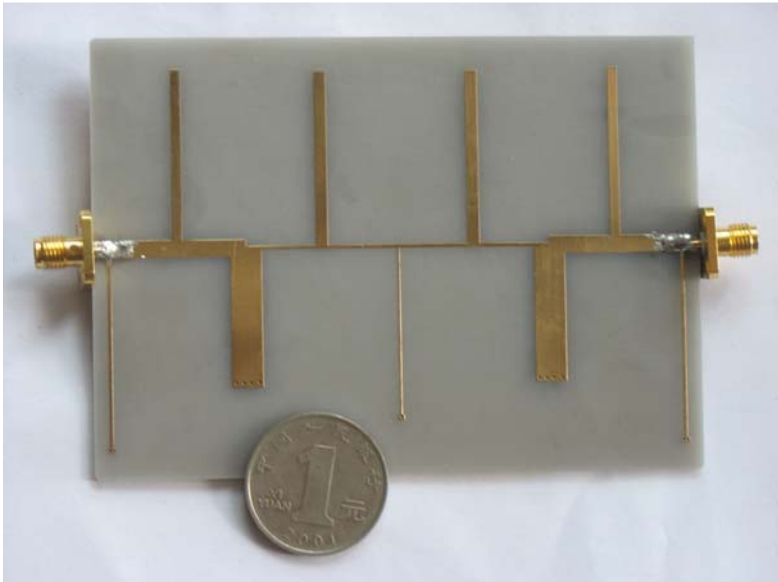

Fig. 4. Photograph of the fabricated filter

than 65 dB is achieved between the two passbands.

The group delay of the filter is shown in Fig. 3.

The wide bandwidths are difficult to achieve by many other forms of dual-band filters, such as stepped-impedance–resonator (SIR) dual-band filters. Compared with [5] that describes cascaded bandpass and bandstop filters, the method reduces the length dimension to by about half by embedding the bandstop filter within the bandpass filter without increasing the total length.

A photograph of the fabricated circuit is shown in Fig. 4.

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4 Conclusion

In this paper we present a novel dual-band filter designed by integrating a bandpass short-circuited shunt-stub filter with a bandstop open-circuited stub filter. It is compact in size compared to the cascaded bandpass-bandstop solution. It is also much more suitable for realizing dual-band filters for wide bandwidths compared to previously reported techniques, except for the lengthier version described in Ref. [5]. Experiment results show acceptably low insertion loss and high isolation between the two passbands.

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