An Original Topology of Dual-Band Filter with Transmission Zeros.

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***Abstract* — This paper reports on a new topology of high-performance dual-band filters. This topology is derived from Dual Behavior Resonator (DBR) filter. The resulting resonator is directly dual-band. It allows the control of two bandpasses separated by a transmission zero to ensure a high rejection level between them. Moreover, two other transmission zeros are located on either side of the two bandpasses. The possibilities offered by this structure are, first, discussed, then measurements are presented to validate the method.**

I. INTRODUCTION

The continual evolution of telecommunication systems leads to increase the number of frequency bands they use. In this way, each constitutive element (antennas, filters, amplifiers) of such a system needs to be designed in order to present a multiband behavior.

For filter applications, the publications that deal with this subject can be divided into two classes according to the chosen solution. The first one consists in using a wide band Zolotarev filter [1] [2], but getting a good rejection between the two bandpasses when they are very close is difficult. In the second solution, two different filters are set in parallel [3], but in this case, the global size must be reduced.

This paper proposes an original topology derived from Dual Behavior Resonator (DBR) filter [4][5]. This approach allows the direct design of dual-band resonator. In fact, DBR is based on the parallel association of two bandstop structures. The electrical response of the resulting structure is composed of one bandpass between the two transmission zeros associated to their bandstop structures. In this way, as shown in Fig. 1, a simple solution to create two bandpasses consists in adding another bandstop structure to the basic DBR.

So, the equivalent impedance of this structure can be described as follows by relation (1):

$$Z = \frac{Z_{S1}Z_{S2}Z_{S3}}{Z_{S1}Z_{S2} + Z_{S2}Z_{S3} + Z_{S1}Z_{S3}} \qquad (1)$$

where Z_{S1}, Z_{S2} et Z_{S3} are the input impedance of each element.

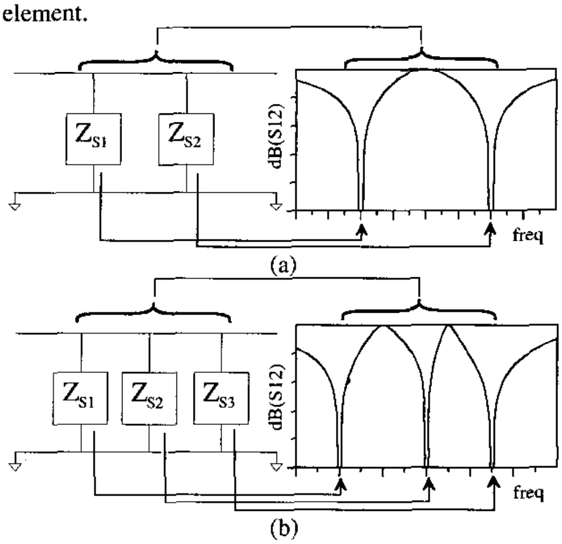

Fig. 1. Basic structure. (a) classical Dual Behavior Resonator. (b) Dual-band resonator.

Like in DBR case, this procedure has no effect on the transmission-zero frequencies induced by each bandstop structure when $Z_{S1} = 0$ or $Z_{S2} = 0$ or $Z_{S3} = 0$, $Z = 0$. Nevertheless, once the stubs have been properly connected under constructive recombination criteria, this original association can be transparent within two given frequencies.

II. SYNTHESIS OF A SINGLE RESONATOR

The stopband structure we have chosen is the open-ended shunt stub (Fig. 2).

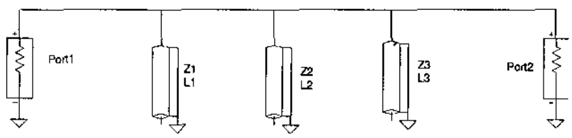

Fig. 2. Basic dual-band resonator composed of three open-ended shunt stubs.

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The transmission-zero frequencies should be first fixed in order to determine the length of each stub:

$$L_i = \frac{c_0}{4F_{Zi}} \qquad (2)$$

for i = 1..3
where L_i are the lengths of stubs,
F_{Zi} are the frequencies of transmission zeros,
C_0 is the speed of light in vacuum.

Then, the condition of constructive recombination has to be simultaneously recovered at two central frequencies, F_{c1} and F_{c2}:

$$Z_{S1}Z_{S2} + Z_{S2}Z_{S3} + Z_{S1}Z_{S3} = 0 \qquad (3)$$

So, equations related to the central frequency of each band may be found for Z_1 and Z_2 as follows:

$$Z_1 = -\frac{Z_2 Z_3 \tan(\beta_1 L_1)}{Z_2 \tan(\beta_1 L_3) + Z_3 \tan(\beta_1 L_2)} \qquad (4)$$

$$Z_2 = Z_3 \frac{A}{B} \qquad (5)$$

Where

$$A = \tan(\beta_1 L_2)\tan(\beta_2 L_1) - \tan(\beta_1 L_1)\tan(\beta_2 L_2) \qquad (6)$$

$$B = \tan(\beta_1 L_1)\tan(\beta_2 L_3) - \tan(\beta_2 L_1)\tan(\beta_1 L_3) \qquad (7)$$

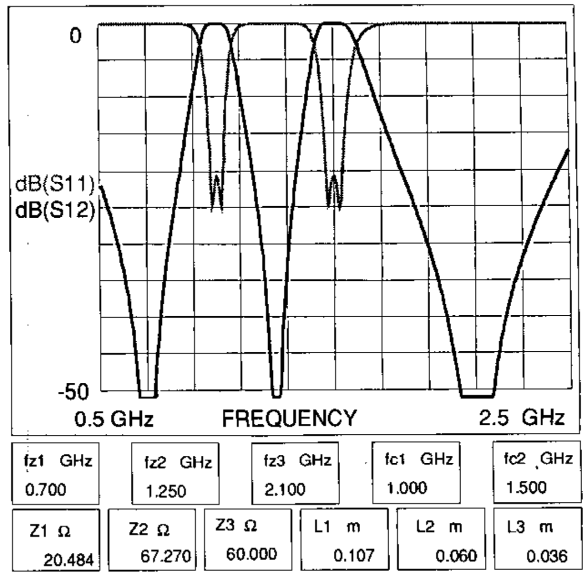
$$\beta_i = \frac{2\pi F_{ci}}{c_0} \qquad (8)$$

for i=1..2
Where F_{ci} are the central frequencies of bandpass.

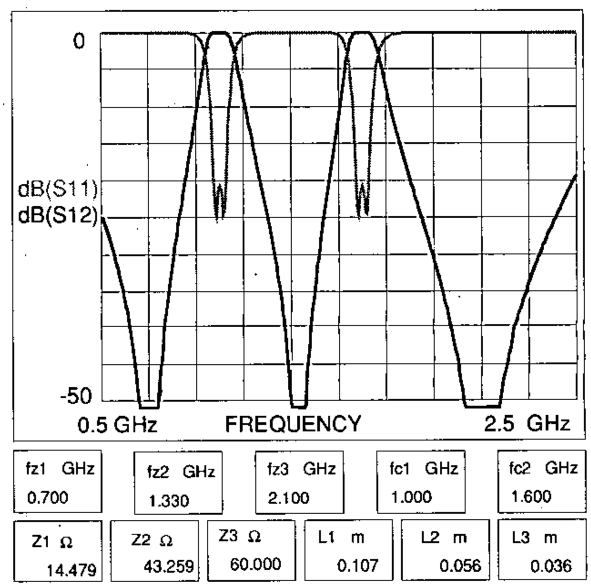
Once the central frequencies have been defined, the third characteristic impedance (Z_3) allows bandwidths control.

II. Some among the possible structures

By using the above equations, the performances of such a structure are quickly and effectively estimated through simulations. Figures 3a-3d illustrate some among the possibilities allowed by this structure. They show four different electrical responses of a second-order dual-band filter



(a)



(b)

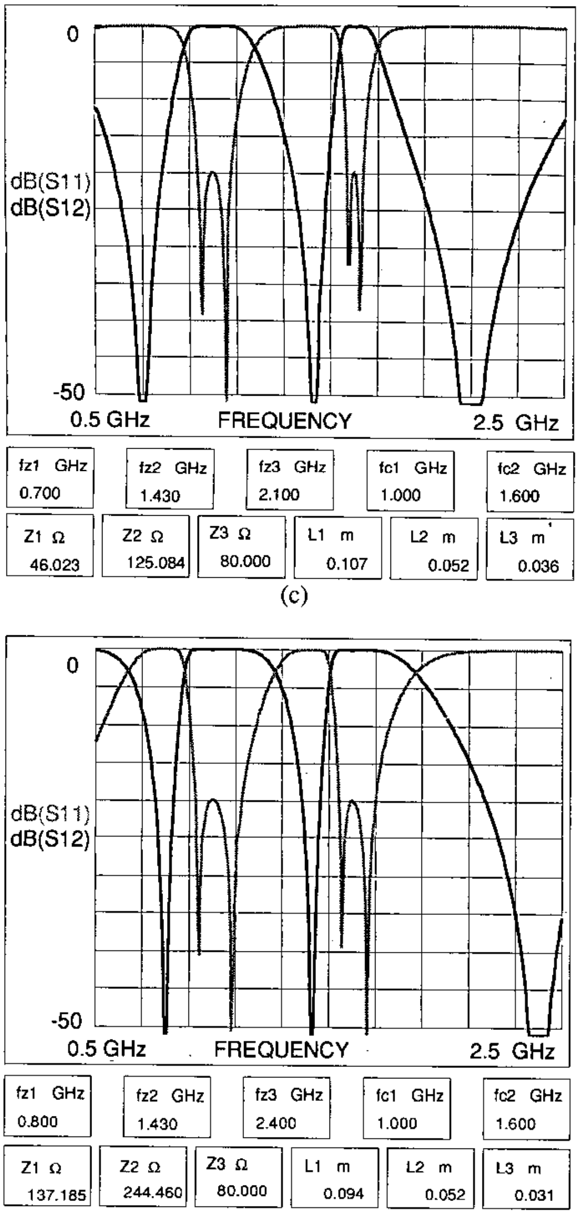


Fig. 3. Electrical responses and physical parameters of various second-order dual-band filter.

The main electrical parameters of these simulations are presented in Figure 4.

Characteristics Figure	central Frequency 1	Fractional Bandwidth 1	central Frequency 2	Fractional Bandwidth 2
Figure 3a	1 GHz	4%	1,5 GHz	4%
Figure 3b	1 GHz	4%	1,6 GHz	3%
Figure 3c	1 GHz	16%	1,6 GHz	3%
Figure 3d	1 GHz	20%	1,6 GHz	10%

Fig. 4. Central frequencies and fractional bandwidths for each bandpass.

One should note that the admittance inverter used in this simulation is ideal to free from frequency dependence. Here, impedance value was fixed to 45.5 Ohms. In the third part (experimental results), we will, however, show clearly that it can be easily corrected.

III. EXPERIMENTAL RESULTS

A second-order dual-band filter was designed to validate our method. It was implemented in microstrip technology (substrate: $\varepsilon_r = 10$; $h = 635\ \mu m$). Central frequencies were set to 1.5 and 2 GHz, and fractional bandwidths to about 5 and 4%, respectively. The chosen technique for achieving admittance inverters is, in first approximation, the middle quarter-wavelength between 1.5 and 2 GHz.

$$L_I = \frac{c_0}{2(F_{C1} + F_{C2})} \tag{10}$$

Figure 5 depicts the filter layout.

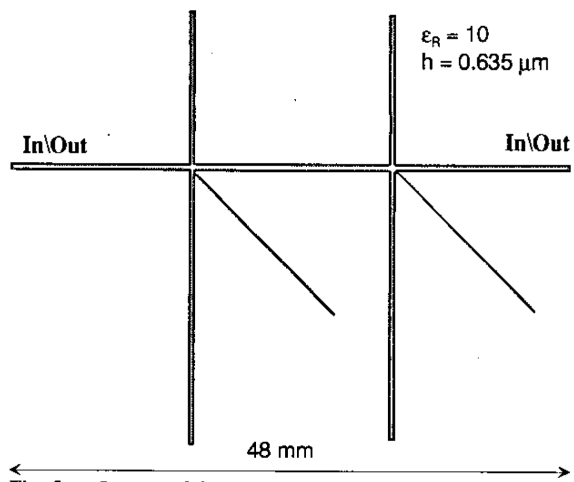


Fig. 5. Layout of the second-order dual-band filter.

At first, the layout was defined through a circuit simulator analysis by using classical microstrip lines and open-end discontinuity models. As no circuit model is available for the five-branch discontinuities, approximation has to be made. So, few electromagnetic simulations were performed in order to finalize the layout. This correction process was done with the commercial software (Momentum ©), but may be time-consuming. Thus, this point is a very strong limitation to optimize this kind of filter. The time spent for design may be reduced by using specific methods.

Figures 6 and 7 show the good agreement between electromagnetic simulation and measurement results. Losses are, indeed, about 1 and 4 dB for the first and second bandpasses, respectively, and matching level is about 17 dB for the two bandpasses. However, one should note a frequency shift of the electrical response that can be explained by considering the dispersion characteristics of the employed substrate.

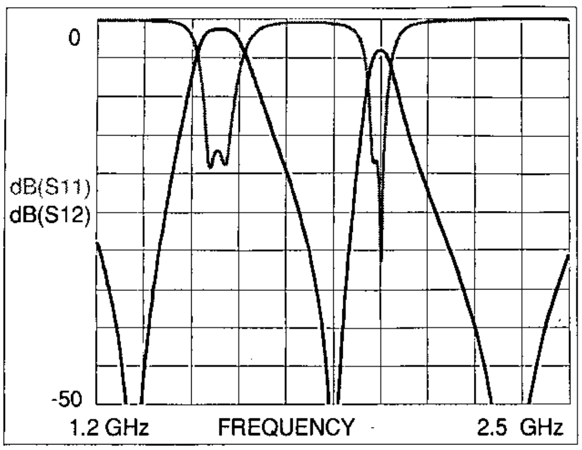


Fig. 6. Electromagnetic simulation of second-order dual-band filter.

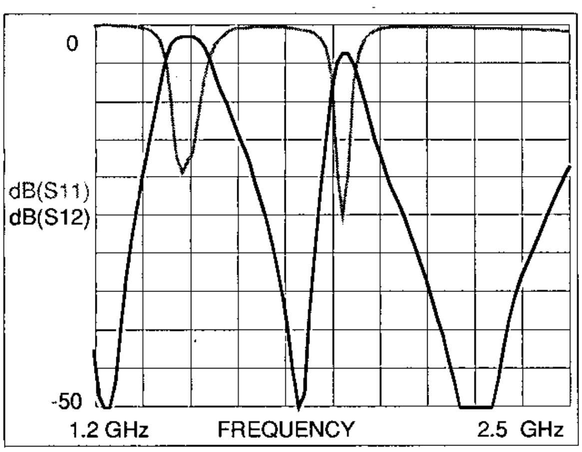


Fig. 7. Measured electrical response of the second-order dual-band filter.

V. Conclusion

The original topology of dual-band filters reported in this paper is based on a general concept of resonators that present various behaviors. Some possibilities were introduced and a second-order dual-band filter was achieved in microstrip technology to validate the concept.

So, this original topology of dual-band filter seems to be quite convenient for multistandard applications. It, however, needs thorough study to evaluate performances in term of losses and achievable filters by considering a classical substrate. Moreover, equations should be worked again to get a complete analytical synthesis. The correction process on electromagnetic simulator can be also improved by using an experimental statistical analysis (DOE: Design Of Experiment [6]) [7].

In a more general case, this concept can be applied to realize multi-band filters through stub addition. However, the increasing complexity of the junctions discontinuities requires specific investigations.

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