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BAND-PASS FILTERS WITH SELF-FILTERING RESONATORS : A SOLUTION TO CONTROL SPURIOUS RESONANCES

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ABSTRACT :

We propose original procedures for the design of high performance filters with simultaneously controled band-pass and band-reject responses. Resonators are described as self-filtering structures and contributes to the in-band and out-of-band transfer function. The control is achieved either by specifying the resonators synchronization, or by inserting low-pass structures inside resonators

INTRODUCTION

The synthesis of microwave integrated filters is basically based upon equivalences between the ideal electrical scheme -depending on the selected mathematical transfer function- and corresponding design topologies. In this way, approximations are commonly used, so as to fit both ideal and synthetized responses around a resonant frequency (for bandpass filters), using for example the slope parameter method.

Consequently, in-band and out-of-band specifications are usually respected when implementing microstrip or coplanar bandpass filters, but parasitic responses appear, mainly at 1st, 2nd and 3rd harmonic frequencies; indeed, the basic resonant structure produces uncontrolled additional poles and zeros outside the operating bandwidth.

In many applications, low-pass filters are employed in order to reject such spurious res-

ponses, thus increasing both the size of the complete filter and transmission losses. In addition, such a technique is only efficient in suppressing the first higher order parasitic resonances, the same synthesis limitations being encountered for the low-pass filter (in terms of spurious harmonics).

In this paper, two alternative procedures are proposed to improve band-pass filter performances. The main idea lies in the possibility of designing resonators fundamentally resonant at a center frequency f_0 , including simultaneously self-filtering harmonic structures.

CONTROLLING HARMONIC RESPONSE OF INTEGRATED RESONATORS

Integrated filters are usually based upon the use of halfwavelength resonant structures. The geometry of such an element can be modified so as to improve its design flexibility, therefore leading, for example, to SIR topologies (Stepped Inverter Resonators : see figure 1) where the various parameters can be efficiently used to improve the filter specifications.

- Non conventional stepped impedance resonators -

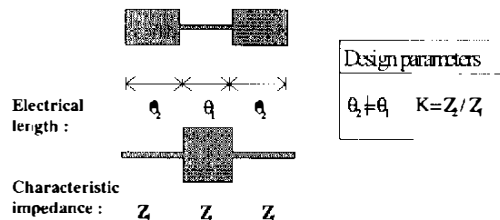


Fig. 1 :Stepped impedance resonators : description

In this way, we have previously shown [1] that such resonators can be analyzed through their input admittance, which is equal to zero at resonance.

$$Y_i = jY_2 \frac{2(K \tan \theta_1 + \tan \theta_2)(K - \tan \theta_1 \tan \theta_2)}{K(1 - \tan^2 \theta_1)(1 - \tan^2 \theta_2) - 2(1 + K^2) \tan \theta_1 \tan \theta_2} \quad (\text{Eq :1})$$

with $K = \frac{Z_2}{Z_1}$: Impedance ratio

The fundamental resonance depends on the following relation : $K - \tan \theta_1 \tan \theta_2 = 0$ while the location of the higher order resonant frequencies is determined with respect to the other poles and zero of the global equation. In this way, a high rejection level is obtained if the resonators are correctly synchronized at harmonic frequencies.

Nevertheless, the technique is quite sensitive to technological dispersion.

INCLUDING LOW-PASS FILTERS INTO RESONANT STRUCTURES

We propose a new method for improving the out-of-band rejection [2] [3] [4]. In this case, low-pass structures are directly integrated in the different resonators of a band-pass filter and can be synthesized in order to ensure a high rejection level of higher resonant frequencies.

This second solution is applied to the well-known band-pass filter based upon quarter-wavelength shunt stubs and series impedance inverters depicted on figure 3 [5]. The associated electrical response is presented on figure 2, and the numerous spurious resonances around harmonic resonant frequencies can be observed.

A low-pass filter can be basically considered as a L-C-L or C-L-C structure, and is implemented using cascaded thin and wide microstrip lines. So, we have modified the geometry of the impedance inverter of a 2nd order filter, so as to insert an equivalent low-pass structure. The electrical response of the complete filter is modified in the out-of-band region

(see figure 2) while it remains quite similar in the desired operating bandwidth.

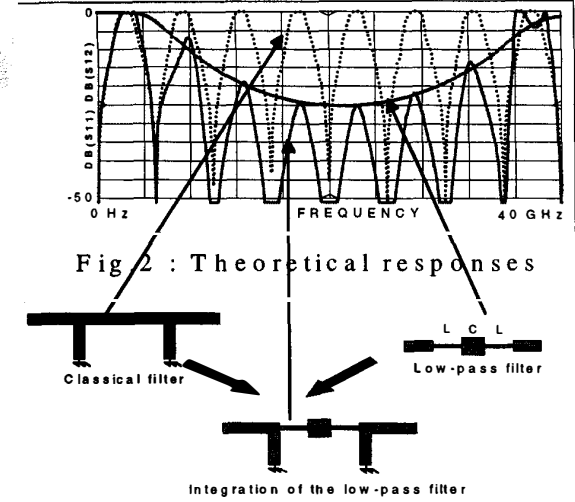


Fig.3 : The basic idea

The same procedure can be used for shunt stubs, to further improve the stop-band rejection (fig. 4).

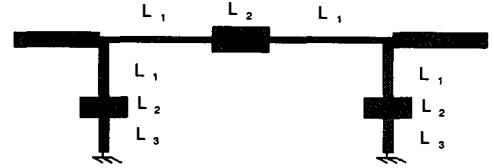


Fig.4 : The modified prototype

Equations (1) and (2) are used in order to synthesize the low-pass filter (3rd order filter) respectively around f_0 and near the first transmission zero. q can be considered as a synchronization parameter between inverters and stubs, which improve the near out-of band rejection (fig.5 and fig.6).

$$L_1 = \frac{1}{q\beta_0} \arctan \left[\frac{K \tan(q\beta_0 L_3) + K \tan(q\beta_0 L_2)}{K(K \tan(q\beta_0 L_3) \tan(q\beta_0 L_2) - 1)} \right] \quad (\text{Eq : 2})$$

with $K = \frac{Z_L}{Z_C}$ impedance ratio

Z_L : high characteristic impedance
 Z_C : low characteristic impedance

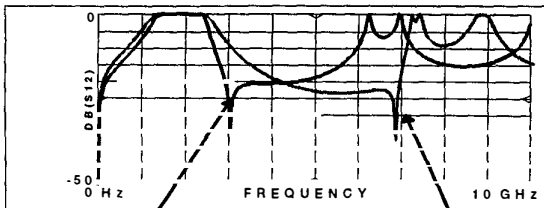


Fig. 5 : Theoretical responses

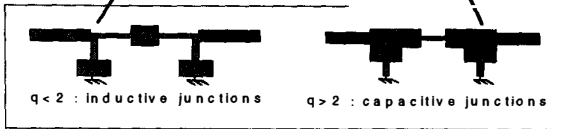


Fig. 6 : The different topologies

The K ratio determines the step discontinuity between inductive and capacitive sections of each low-pass architecture. The higher this K factor is, the better the spurious resonances attenuation will be. Nevertheless, the K values are unfortunately limited, according to technological limitations.

For this reason, we investigate on a multilayer technology, based upon thick-film technological process, in order to increase this factor [6]. As mentioned on figure 7, Various technological configurations can be expected, through different combinations of dielectric and conductive layers on an alumina substrate.

- Very low characteristic impedance levels are obtained by using a microstrip configuration on a thin dielectric layer (typically 30 μm) (Fig. 7a).
- High characteristic impedance levels are available by using multilevelled coplanar configurations with low permittivity ($\epsilon_r=4$) dielectric sheets (Fig. 7b).

Finally, very low and very high characteristic impedances may be both synthesized while minimizing the series step discontinuities.

Preliminary investigations have been performed on a semi-lumped low-pass filter (cut-off frequency : 3GHz / Order 7). The experimental response is presented on figure 8. No spurious resonance appears in the out-of-band region, between 3 GHz to 40 GHz.

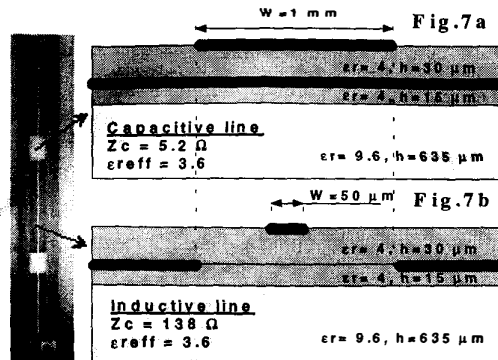


Fig. 7 : Multilayer technology

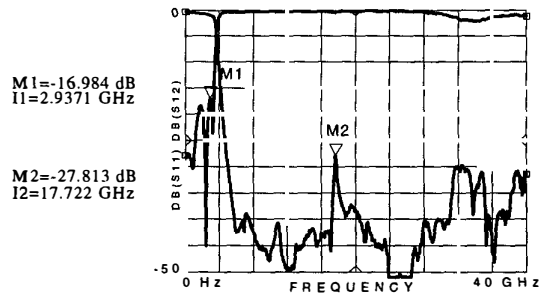


Fig. 8 : Low-pass filter

Experimental response (0 - 40 GHz)

A 2nd order band-pass filter ($f_0 = 2.1$ GHz, BW = 15%) has been designed and tested (fig.9). As shown on figures 10 and 11, good performances are achieved inside the operating bandwidth (Return losses < -24.5 dB, Insertion losses > -1.1 dB) while the first spurious resonance appears at about 24 GHz (I.L.= -10 dB), corresponding approximatively to the 12th harmonic frequency. This is quite a significant improvement with respect to classical results.

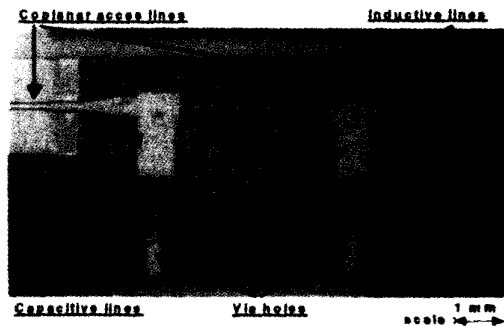


Fig. 9 : 2th order band-pass filter

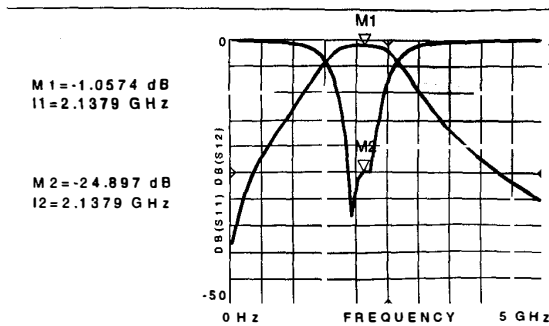


Fig.10: Experimental response (0 - 5 GHz)

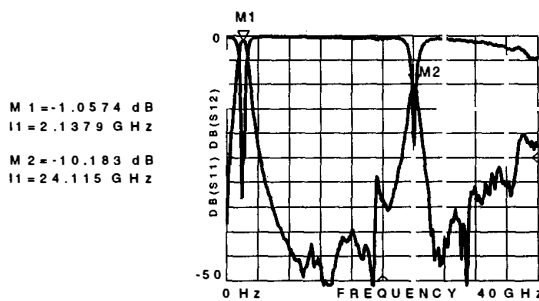


Fig.11: Experimental response (0 - 40 GHz)

CONCLUSION

Original approaches concerning the improvement of band-pass filters performances have been proposed. The insertion of low-pass filters into conventional resonant structures appears as quite a convenient solution for suppressing spurious responses in a desired rejected bandwidth, without any degradation concerning size area or transmission losses. Nevertheless, we have shown that this method leads to great constraints concerning required characteristic impedance levels on the different stubs and quarterwavelength transmission lines. This can be solved by using a multilayer multitechnology process, for which the different available topologies can be properly combined so as to converge to optimum integrated self-filtering structures.

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