Transmission zeros origin and behaviour in a Microwave Transversal Filter based on Planar Technology

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***Abstract*- This paper uses a simple configuration to implement a bandpass transversal filter based on microstrip technology. The structure is of second order and implements two transmission zeros and two reflection zeros in the frequency response of the filter. The basic configuration consists of input and output ports coupled in a shunt configuration to two printed resonators of different lengths. In this paper we obtain a method that consists of several simple steps that guide us to achieve the filter at the desired central frequency. Measured results confirm theoretical predictions, and validate the structure for high selective applications.**

I. INTRODUCCIÓN

The Radioelectric Spectrum is a limited natural resource and universally utilized by the different systems of radioelectric communications in all the country, require of a management and a reasonable administration.

Nowadays, there is an increasing demand of this spectrum for the new wireless services.

Communications system requirements and efficient spectrum utilization imposes the development of frequency selective components, exhibiting sharp cut-off slopes. This need of rejecting certain unwanted frequencies led to the development of microwave filters whose insertion loss response exhibits transmission zeros at finite frequencies. The method traditionally used for the implementation of transmission zeros at precise frequencies is the introduction of cross-couplings between nonadjacent resonators. An example composed of a square open-loop resonators is presented in [2].

A study about transmission zeros implementation on determined frequencies and how control them can be observed in [1].

In the figure below we can see the coupling scheme:

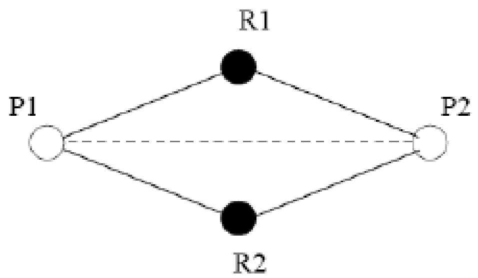

Fig.1: Coupling scheme

Input port (P1) and output port (P2) (non-resonant nodes), and resonant nodes R1 and R2 are shown in this scheme. Continues lines represent the port-resonator coupling, and dashed line represents direct coupling between ports.

This configuration corresponds to a second order coupling (Modifies Doublet (MD)) that allows a combination of two transmission zeros and reflection zeros in the filter frequency response. Physically, the presence of this transmission zero can be explained as due to a phase cancellation between the signals in both resonators. The input signal is split into two paths (see Fig. 1). The signal in the two paths suffers different phase change, due to the different resonant frequencies of the resonators (non zero diagonal entries in the coupling matrix). When the phase difference equals 180º, a cancellation occurs, thus producing the transmission zero.

The additional coupling between non-resonant nodes introduces a new transmission zero in the filter insertion losses response. Therefore, two transmission zeros can be obtained for maximum selectivity both above and below the passband.

[2] explains the influence that the transmission zeros localization has in the filter response, specially concerning to group delay.

The analysed structure will be used in the development of this paper. It consists in input and output lines in shunted configuration, which are coupled to two open loop resonators. These resonators have different lengths and a capacitive coupling between non-resonant nodes.

II. THEORY

As we have seen before the input signal is split into two paths (see Fig. 1). The signal in the two paths suffers different phase change, due to the different resonant frequencies of the resonators (non zero diagonal entries in the coupling matrix). When the phase difference equals 180º, a cancellation occurs, thus producing the transmission zero.

In this kind of technology the wavelength is a very important parameter and it will help us to control the filter behaviour regarding to its physical dimensions.

The wavelength in microstrip lines is given by the expression below:

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}} = \frac{c}{f\sqrt{\varepsilon_{eff}}}$$

c: light speed, $3 \cdot 10^8$ m/s, f: Centre frequency, Hz, ε_{eff}: Substrate effective permittivity.

Also the electric length given by the bends must be considered. It can be obtained with the next equation.

$$\phi = \beta \cdot l = \frac{2\pi}{\lambda_g} \cdot l$$

ϕ: Phase, rad., β: Phase constant., l: Equivalent electric length.

III. IMPLEMENTATION

The studied structure is displayed in the figure below:

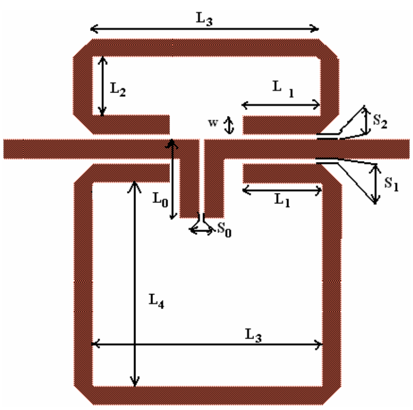

Fig.2: Structure

It consists in input and output lines coupled to two open-loop resonators of different lengths. Also cross coupling between non-adjacent resonators become visible, and it produces a second transmission zero that can be used to obtain a high selectivity at both sides of the passband. Furthermore, a capacitive coupling between non-resonant nodes can be obtained by bending the input and output lines as shown in figure 2.

The input signal is divided in two paths. The signal in the two paths suffers different phase change, due to the different resonant frequencies of the resonators.

The interaction between signals in both paths produces the energy cancelation required in a determined frequency, obtaining the transmission zero required.

Thus the most important dimensional parameters in this structure are the resonators lengths, which approximated values are λg and λg/2 long at the centre frequency. Tuning these lengths, the energy cancellation and, therefore, the transmission zero, occur near the central frequency, achieving an abrupt difference between transition and pass bands.

On the other hand the coupling lengths will determine the filter centre frequency, being the correct one λg/12. In this way we can obtain a method that consists of several simple steps that guide us to achieve the filter at the desired central frequency.

1. Choose of the central frequency.
2. Get the effective dielectric permittivity.
3. Calculation of the microstrip wavelength:
$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}} = \frac{c}{f\sqrt{\varepsilon_{eff}}}$$
4. The total lengths are obtained in relation with wavelength.
   R1= λg/2
   R2= λg
   L1= λg/12
5. The equations that define the filter dimensions are:
   R1=2·L1+2·L2+L3+4·Lbend
   R2=2·L1+2·L4+L3+4·Lbend
   L3=2·L1+Laux1+Laux2+2·w+So
6. Calculation of the electrical length produce by bends:
$$\phi = \beta \cdot l = \frac{2\pi}{\lambda_g} \cdot l$$
7. Tune w (line width) in order to maintain the impedance 50Ω.
8. Define an auxiliary lengths and gaps so, s1 and s2.

9. Obtain L3, L2 and L4.
10. Simulating these values and tuning auxiliary lengths and gaps in order to obtain the desired response.

IV. RESULTS

The central frequency chosen is 1.5 GHz. Following the described method the filter features are:

w= 0.9mm; so= 0.6mm; s1= 0.2mm; s2= 0.1mm; Laux1= 1mm; Laux2= 3mm; Lo= 1.5mm; L1= 8.3mm; L2= 2.6mm; L4= 26.6mm; L3= 23mm.

We found that the frequency range in which de filter works properly is between 1 and 3 GHz. With frequencies less than 1 GHz the physical dimensions are too big, and with frequencies higher than 3 GHz these dimensions are too small.

The filter shown has been manufactured and tested. The substrate selected for manufacturing is a TACONIC RF-60A-0250-CH/CH, with relative permittivity ξr=6.15 and thickness 0.635mm. In the simulations, losses are included in both dielectric substrate ($\tan(\delta)=0.0019$) and in the printed metallic areas ($\sigma=4\cdot10^{-7}\Omega^{-1}$). The circuit has been simulated with MicroWave Office, and measurements are taken with an Agilent N3383A vector network analyzer.

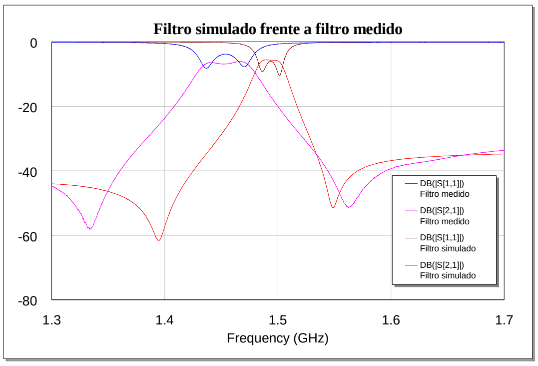

Fig.3: Measured versus simulated

We can observe a good agreement between measured results and predictions, considering that:

- Measures of lines and lengths are not exact, as we verified with the microscope.
- The soldiering between connectors and lines are not perfect.
- The wires used add losses.

The final aspect of the manufactured hardware is the shown:

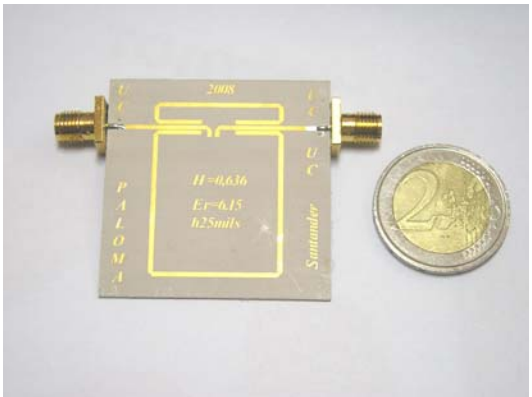

Fig.4: Manufactured filter

V. CONCLUSIONS

This paper has proposed a method based on simple and mechanic steps that will provide us a filter centred on the desire central wavelength. The scheme is based on a transversal filter, where coupling between non-resonant nodes is introduced. This coupling produces a new transmission zero, which can be used to synthesize quasi-elliptic responses for maximum selectivity on both sides of the passband. The good agreement between measured results and predictions is good feature for the manufactured filter, and validates the structure for practical applications.

VI. REFERENCES

[1] David Cañete Rebenaque, José L. Gómez Tornero, Fernando D. Quesada Pereira, Juan Pascual García y Alejandro Álvarez Melcón, “Implementaciones sencillas de filtros planares con múltiples acoplos”.

[2] David Cañete Rebenaque, Mónica Martínez Mendoza, José Luis Gómez Tornero, Fernando Quesada Pereira y Alejandro Álvarez Melcón, “Investigación sobre ecualización de fase en filtros transversales en tecnología planar”.