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Design of Stepped Impedance Microstrip Low-Pass Filter for Coexistence of TV Broadcasting and LTE Mobile System Close to 700 MHz

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***Abstract*— The evolution of mobile networks has demanded more frequency spectrum and in many countries part of UHF band previously allocated to TV broadcasting now is used to broadband mobile networks and is important avoid any interference caused by signals transmitted in adjacent bands.**

In the Brazil and in others countries the new spectrum is being assigned to Long Term Evolution (LTE) mobile networks at 700 MHz band that is close to the frequency spectrum used by TV broadcasting. In this context the paper presents a microstrip low-pass filter to be used into television and avoid interferences produced by LTE signals.

The proposed low-pass filter was designed using microstrip step-impedance method, fifth-order Chebyshev with ripple of 0.01 dB and cut-off frequency at 700 MHz. The designed low-pass filter was simulated using full wave simulator Ansoft HFSS. After simulation the low-pass filter was fabricated by photolithographic process in a FR-4 pcb. Finally, it was tested using vector network analyzer and the measured results presented a good agreement with the simulations.

***Index Terms*— filter, interference, microstrip, TV, LTE**

I. Introduction

THE fourth generation technology of mobile telecommunications, whose base is the standard 3GPP Long Term Evolution (LTE), and improvements in speed and capacity have been made available from telecom operators to customers, boosting the market to propose services and applications and they need more and more bandwidth.

This paragraph of the first footnote will contain the date on which you submitted your paper for review. It will also contain support information, including sponsor and financial support acknowledgment. For example, "This work was supported in part by the U.S. Department of Commerce under Grant BS123456".

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This requirement of bandwidth to use in mobile broadband telecommunications is feeding the debate among regulators and the according to the spectrum reforming process, currently is in progress all around the world [1] [2] [3].

As a consequence of these reforms in spectrum, the LTE is operating alongside broadcast applications (UHF TV channels) and potential coexistence issues might arise [4] [5] [6] [7].

This article proposes a low-pass filter to use in TV receiver that allow all frequencies up to 700 MHz to pass without influence on the TV signals to be received, while blocking all frequencies above 700 MHz used by LTE. The low-pass filter was designed in microstrip FR-4 pcb using step-impedance method, fifth-order Chebyshev with ripple of 0.01 dB and cut-off frequency at 700 MHz.

II. Design of Microstrip Low-Pass Filter

The microstrip filters are highly researched [8] [9] [10] and popular in design of filter at frequencies beyond of 500 MHz because of the difficult to realize filters with lumped elements that have predetermined commercial values and physical dimensions comparable with the wavelength of frequency operation of filter resulting in degrading of performance.

There are several ways to implement low-pass filters in microstrip and an easy way is use alternating sections of high and low characteristic impedance lines like inductors and capacitors and this filters are usually referred to as stepped-impedance, or hi-Z, low-Z filters [11] [12]. The Fig. 1 shows a general structure of the stepped-impedance low-pass filter in microstrip.

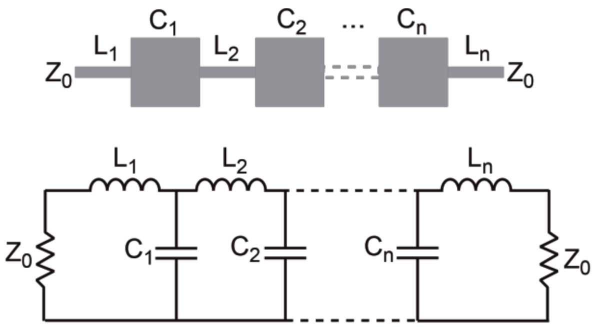

Fig. 1. Structure of the stepped-impedance low-pass filter in microstrip.

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The design of the stepped impedance low-pass microstrip filter is a well-known method [11] and basically consists to find the order of the filter, determine the filter element coefficients from the table, calculate the inductors and capacitors, and determine the values of lengths and widths of transmission lines are calculated using the effective dielectric constant.

To design the low-pass filter was chosen a low cost dielectric substrate FR-4 (ε_r = 4.2 and *tan* δ = 0.02) with a thickness of 1.6 mm was used.

Thus, the low-pass filter was designed in microstrip configuration with the following specification:

Order: 5ª
Cut off frequency, f_c = 700 MHz
Dielectric constant, ε_r = 4.2
Loss tangent, tan δ = 0.02
Pass-band ripple = 0.01 dB
Substrate thickness, *h* =1.6 mm
Approximation = Chebyshev
Input/Output impedance, Z_0 = 50 Ω

The initial dimensions were calculated and a model was made using the full wave electromagnetic (EM) simulator Ansys HFSS. In the software simulator the dimensions were parametrized and adjusted to better filter operation. The final dimensions of the low-pass filter simulated and manufactured are shown in Fig. 2.

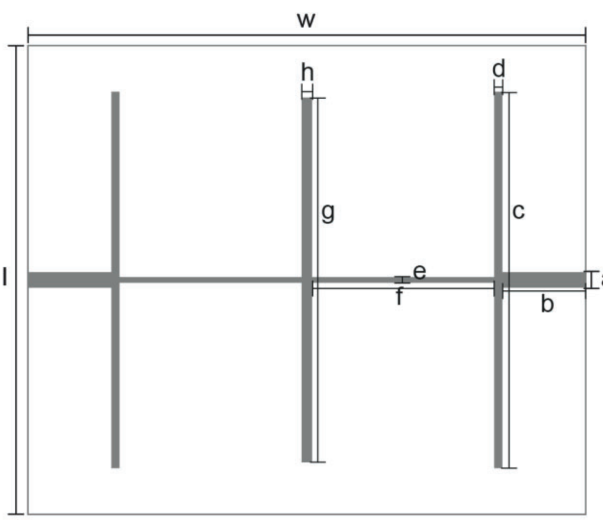

Fig. 2. Dimensions of low-pass filter: *a = 3 mm, b = 16 mm, c = 72.325 mm, d = 1.575 mm, e = 1.1 mm, f = 35 mm, g = 70.086 mm, h = 2.018 mm, l =90 mm , w = 107.168 mm.*

In order, the stepped-impedance low-pass filters have the advantage take up less space than a similar low-pass filter using stubs [11], therefore is a good choice to use in devices with limited dimensions.

The Fig. 3 shows the model built in simulator software with the magnitude of electric field.

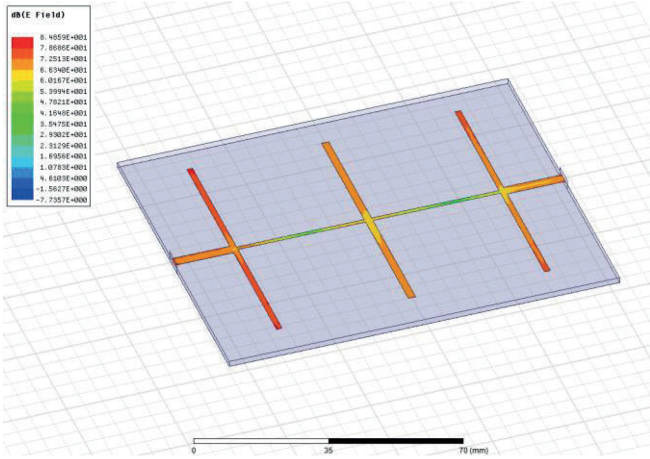

Fig. 3. 3D model of low-pass filter with magnitude of electric field.

III. Measurements and Results

Once we carried out all the simulations was manufactured a prototype using photolitography process that is standard in manufacturing printed circuit board. Fig. 4 shows the photograph of fabricated low-pass filter.

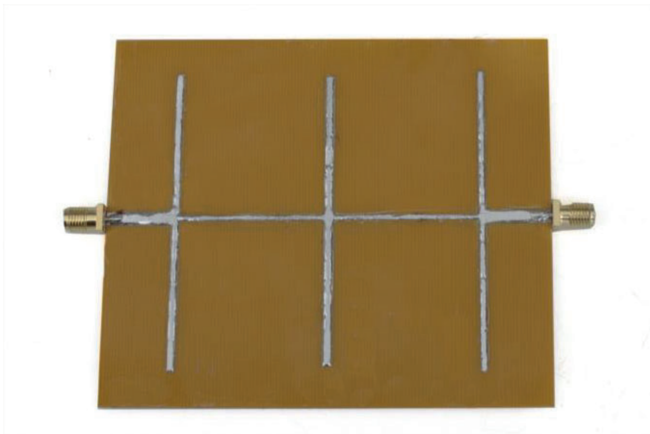

Fig. 4. Fabricated prototype of the low-pass filter.

The performance of the low-pass filter prototype was measured using vector network analyzer (VNA) to get the S-parameters as shows the Fig. 5.

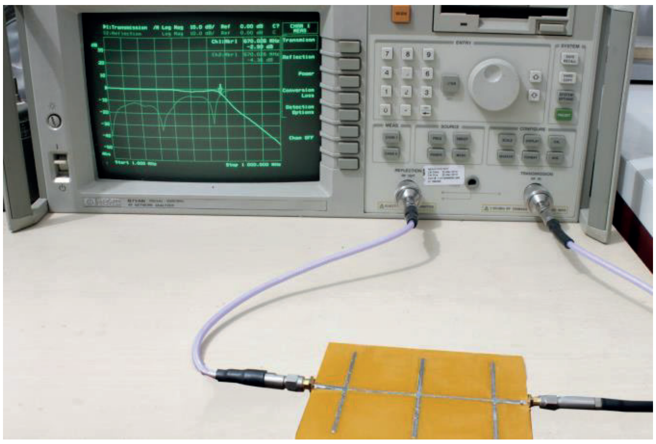

Fig. 5. Low-pass filter measurement with VNA.

Fig. 6 show low-pass filter scattering parameters (S_{11} and S_{21}) to the VNA measurements results and the EM simulation results.

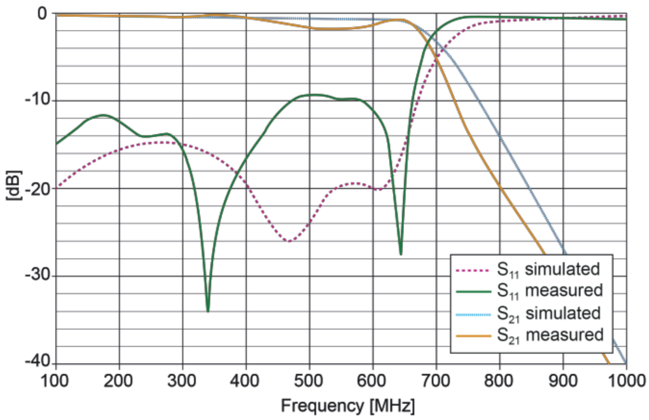

Fig. 6. Comparison of measured and simulated scattering parameters (S_{11} and S_{21}) of low-pass filter.

Measurements results show a cut-off frequency at 680 MHz, maximum insertion loss (S_{21}) of 1.7 dB at 540 MHz and stop band attenuation is better than 10 dB at 730 MHz. The offset of cut-off frequency of 700 MHz to 680 MHz can causes signal degradation of TV channels close to 700 MHz.

IV. Conclusions

A low-pass filter using microstrip on FR-4 PCB was designed using step-impedance method with fifth-order Chebyshev with ripple of 0.01 dB and cut-off frequency at 700 MHz. The proposed low-pass filter was fabricated and tested with vector network analyzer and shows good agreement with the simulations.

The low-pass filters presented a maximum insertion loss of -1.7 dB at 540 MHz that is admissible, but has impact on increasing the receiving system noise figure. The filter not has a sharp cut-off frequency and the measured results shows an offset of cut-off frequency to 680 MHz, therefore the TV channels close to 700 MHz will have an additional loss. But this offset of the cut-off frequency is due to FR-4 class material not have a specific value of ⊠, but it can be corrected by a preliminary characterization of the FR-4 used in the manufacture of the filter. Effects caused by parasitic capacitances and inductances and/or by adapters and connectors which were not considered in the simulations and may also affect the results.

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