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Design of 2.4 GHz Microwave Bandpass Filter

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This paper presents in detail the design of highly selective microstrip bandpass filters that consist of microstrip open-loop resonators with a cross coupling that exhibit a single pair of attenuation poles at finite frequencies. The design approach enables one to use advanced full-wave EM simulators to complete the filter design, namely, to determine the physical dimensions of the filter. The results acquired through research & development process are simulated, analyzed and verified by using parallel-coupled lines filter topology, which are later, enhanced by various value-aided software tools such as MATLAB-7.0, CorelDraw-12, Microwave Office-2012.

Keywords: microwave bandpass filter, design.

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Конструкция 2,4 ГГц полосового микроволнового фильтра

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В этой статье подробно представлен дизайн микрополосковых резонаторов с разомкнутым контуром с перекрестным соединением, которые демонстрируют одну пару полюсов ослабления на конечных частотах. Подход к проектированию позволяет использовать

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симулятор полноволновой ЭМ для завершения проектирования фильтра. Результаты, полученные в процессе исследований и разработок, моделируются, анализируются и проверяются с использованием топологии параллельных фильтров, которые в дальнейшем улучшаются с помощью различных программных инструментов с высокой стоимостью, таких как MATLAB-7.0, CorelDraw-12, Microwave Office-2012.

Ключевые слова: микроволновый полосовой фильтр, дизайн.

1. Introduction

Rapid development of wireless communications present extraordinary demand for narrow-band RF/microwave bandpass filters with high selectivity and low insertion loss. One filter with these attractive characteristics is that of quasi-elliptic function response filters with a pair of attenuation poles at finite frequencies. The capability of placing attenuation poles near the cutoff frequencies of the pass band improves the selectivity using fewer resonators. This type of filter is usually realized using waveguide cavities or dielectric-resonator-loaded cavities. However, with the advent of high-temperature superconducting (HTS) and micromachined circuit technologies, there is an increasing interest in microstrip filter structures. Two technical approaches are normally used to realize this type of filter. The first is to extract poles from both ends of a filter prototype by using shunt resonators. The size of the microstrip filter resulting from this approach may, however, be large. The second approach is to introduce a cross coupling between a pair of nonadjacent resonators. The filter employing the cross coupling generally results in a compact topology. This is obviously more attractive for those systems where size is important. It has been known that the cross coupling is more difficult to be arranged and controlled in a microstrip filter owing to its semiopen structure. It is obvious, however, that a higher degree is required for a more selective filter. Several works on this topic can be found in literatures [1-4].

2. Design procedure

2.1. Basics

2.1.1. The Microstrip

The microstrip shown in Fig. 1 belongs to the group of parallel-plate transmission lines and consists of a single ground plane and an open strip conductor separated by a dielectric substrate. Microstrip lines are the most commonly used form of transmission lines for microwave integrated circuits. Also, microstrips are used as circuit components for filters, phase shifters, couplers, resonators and antennas.

The electromagnetic field in the microstrip line is not confined only to the dielectric and because of the fringing; the effective relative permittivity ϵ_{eff} is less than the relative permittivity ϵ_r of the substrate. The electromagnetic waves in microstrip propagate in transverse electric magnetic (TEM) mode, which is characterized by electric and magnetic fields that exist only in the plane perpendicular to the axis of the wave propagation.

2.1.2. Parallel couple microstrip lines

As in the case of a single microstrip line, a parallel-coupled microstrip arrangement is also a TEM-mode system. The relative polarities of the voltages on the coupled microstrip lines at any

specific plane along the structure and at any specific time will be the same or opposite resulting in two different modes of field distribution, namely the even-mode and the odd mode. These modes are illustrated in Fig. 2.

The two field distributions result in even-mode and odd-mode characteristic impedances denoted by Z_{0e} and Z_{0o} . These characteristic impedances are major parameters in design procedures. The complete behavior of the parallel-coupled microstrip structure can be obtained by superposition of the effects due to these two modes.

2.1.3. The filter

A filter is a device or substance that passes electric currents at certain frequencies or frequency ranges while preventing the passage of others. Based on the frequencies they pass, the filters are classified as low pass filters (LPF), high pass filters (HPF), bandpass filters (BPF) and bandreject filters (BRF). These filter types are best explained based on the characteristics of a normalized low pass filter because characteristics of other filter types can be related to the low pass filter characteristics. The ideal low pass filter is characterized by zero loss and zero ripples in the passband, an infinite attenuation slope at cutoff frequency and infinite attenuation in the stopband.

2.2. Methodology

Basic design specifications for a bandpass filter are considered which are center frequency and bandwidth. For this research, a center frequency of 2.4 GHz, which corresponds to the free-space wavelength of 12.5 cm, is chosen for hand-based dimensions fabrication. With using formula related

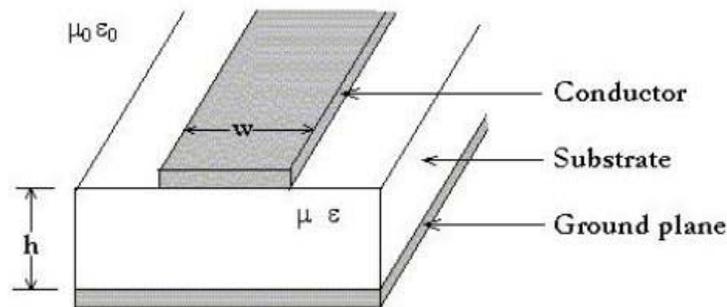


Fig. 1. Diagram of a microstrip transmission line

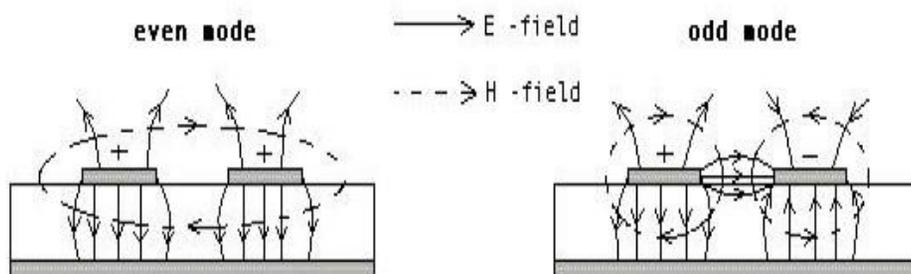


Fig. 2. Even and odd modes for for the microstrip line

to calculate dimension of parallel couple filter, then L (length), W (width), and S (spice) are obtained. The filter designed is fabricated with the aid of Correl Draw 12 and CAD tools to print exact dimension on printed circuit board (PCB) for simulation purpose. The filter characteristics are measured. As the results of literature review recommendations, $\pm 10\%$ bandwidth, which corresponds to 240 MHz at 2.4 GHz center frequencies, is chosen for further research and development process. The choice of the parallel-coupled lines filter has been explained analytically with the help of Microwave Office 2004 to aid design process for the evaluation of calculated result and simulation frequency response.

2.3. Design of microstrip filter

In this section, a sample ultra-wideband microstrip filter design and development are presented. Filter details including circuit model, simulations, optimizations, layout creation, manufacturing, testing and troubleshooting are explained. The essential design in this study is given in the flow chart in Fig. 3.

After determining the prototype and specifications for the filter, the circuit simulation optimizations are done by using AWR Microwave Office. EM Simulation is followed the circuit simulation. Sonnet EM Simulation and CST EM Simulation Tools are used for the EM Simulation to have accurate results with a good comparison performance. A tolerance analysis is also done using the simulation tools. Then filter layout is generated and fabricated using the circuit milling machine. Filter response is measured using a vector network analyzer (VNA). Once it is observed that the filter basically is functioning near the specifications, a minor troubleshooting is applied to tune the filter. The filter design in this study starts with an ideal model composed of quarter wavelength shorted stubs separated with half wavelength inverters. This topology has been adopted for its simple structure. In this paper, design and manufacturing of an ultra-wideband microstrip line filter covering the 2.4 Ghz strip are considered. The ideal electrical model for the filter is based on half wavelength separated shorted stub resonators using distributed microstrip lines. The design specifications for this filter as follows:

-30 dB rejection at 2.1 GHz.

Return loss better than -10 dB within the band.

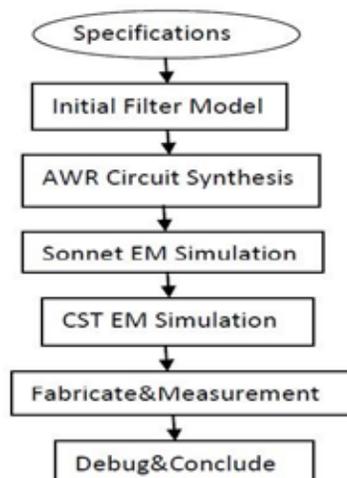


Fig. 3. Flow chart for the implementation of the filter

2.3.1. Design model

The structure of couple line band pass filter microstrip (N= 3) is in Fig. 4.

The dimensions for the above microstrips are calculated using the TX line feature on AWR 2012 as shown in Fig. 5.

The filter schematic as designed on AWR Design Environment is as shown in Fig. 6. The dimensions of the various sections are obtained from Fig. 5.

The complete filter after fabrication is as shown in Fig. 7.

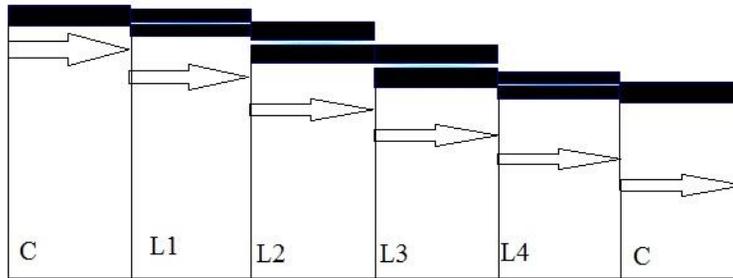


Fig. 4. Structure of couple line band pass filter microstrip.(N= 3)

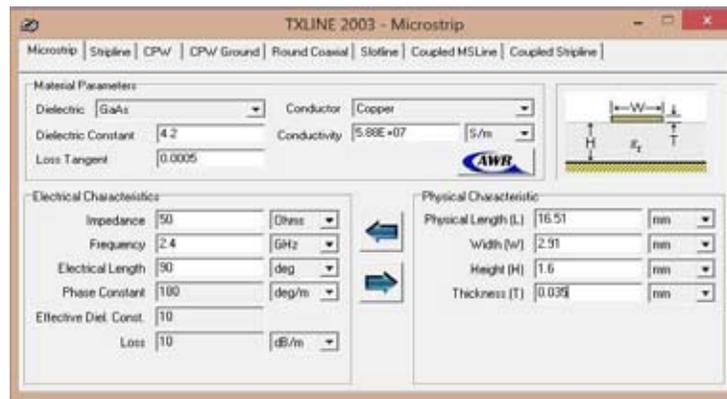


Fig. 5. Screen capture of a microstrip line analyzer

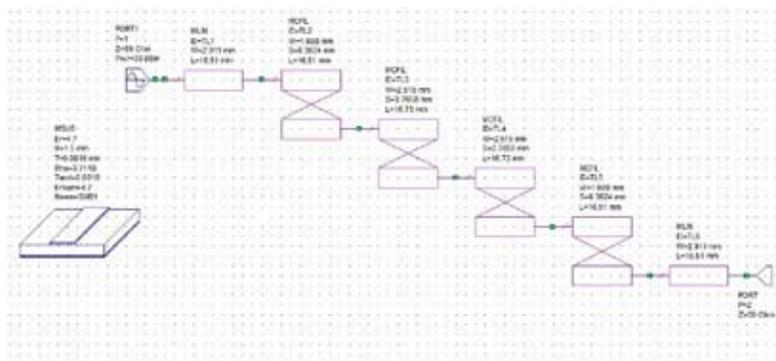


Fig. 6. Design of the 2.4GHz bandpass filter on AWR Design Environment



Fig. 7. Fabrication of bandpass filter

3. Results

Fig. 8 shows the attenuation and return loss of the filter, while, Fig. 9 shows the attenuation and power.

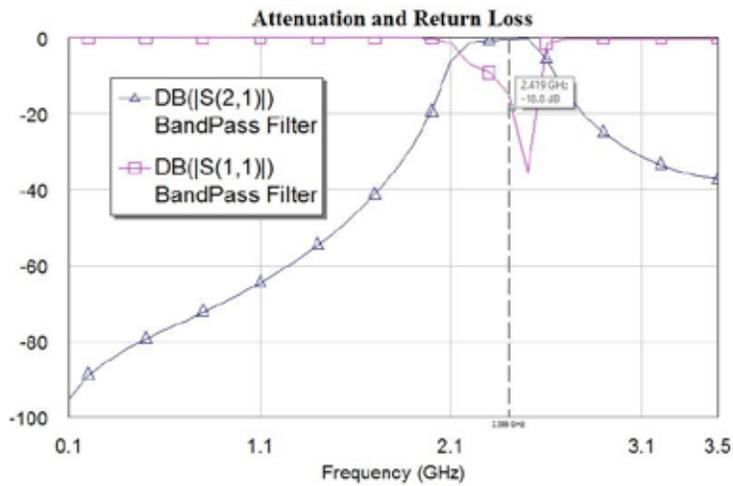


Fig. 8. Attenuation and return loss

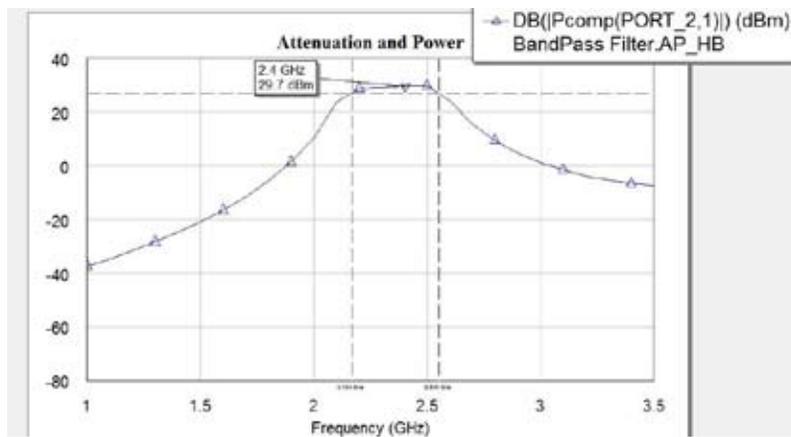


Fig. 9. Attenuation and power

4. Conclusion

This paper dealt with the designing of bandpass filter with Butterworth approach in combination with concentrated components, i.e. inductors and capacitors and its computational verification in form of parallel-coupled microstrip lines with the program AWR Design Environment give very good filter characteristics at the center frequency 2.4 GHz with frequency bandwidth of about 240 MHz as required at the specification stage. At the center frequency the insertion loss and reflection factor has the values about -2 dB and better than -15 dB, respectively. The measurement gives also very good filter characteristics at the frequency of 2.4 GHz, however with larger insertion loss of about -7.5 dB and smaller bandwidth of about 50 MHz This larger loss originates likely from losses of the coaxial connectors and their poor contacts to the microstrip line.

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