Design and Realization of Different Microstrip Low Pass Filter Topologies by aid of AWR Microwave Office iFilter Wizard

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Abstract

In this work; 7th order Butterworth, Chebyshev, Cauer (elliptic), Bessel, Legendre and Gaussian low pass filters designed, simulated, realized and measured with aid of iFilter tool of AWR Microwave Office. First, all the filters were designed with lumped L-C elements. Secondly, all lumped components were converted to the microstrip lines as series lines and shunt stubs. All microstrip line widths and lengths were optimized with AWR simulation tool. Comparisons in terms od insertion loss between simulation results of designed lumped filters and measurement results of realized distributed (microstrip) filters show that, distributed filters can be easily optimized by changing widths and lengths of lines without any performance degradation.

1. Introduction

Ladder filters are actually one of the oldest types of filters. A circuit designer can achieve a sharper frequency roll off with ladder filters than RC or RL circuits [1]. There are 6 basic type of ladder filter type. These are Butterworth, Chebyshev, Bessel, Legendre, Elliptic and Gaussian [2]. In a number of studies designed filter with different microwave programs [3],[4].

In this paper, these basic 7th order analog low-pass ladder filters were designed, simulated iFilter tool of AWR Microwave Office, realized and compared with each other. With iFilter wizard of AWR Microwave Office, 7th order Butterworth, Chebyshev, Elliptic, Bessel, Legendre and Gaussian filters were designed by using lumped L and C components. After that, lumped L and C components converted to distributed elements: microstrip lines.

2. Basic Ladder Filter Topologies

The Butterworth filter is a type of signal processing filter designed to have as flat a frequency response as possible in the passband. It is also referred to as a maximally flat magnitude filter [1].

Chebyshev filters are analog or digital filters having a steeper roll-off and more passband ripple (type I) or stopband ripple (type II) than Butterworth filters. Chebyshev filters have the property that they minimize the error between the idealized and the actual filter characteristic over the range of the filter, but with ripples in the passband [2].

An elliptic filter is a signal processing filter with equalized ripple behavior in both the passband and the stopband. The amount of ripple in each band is independently adjustable, and no other filter of equal order can have a faster transition in gain between the passband and the stopband, for the given values of ripple [5]. Alternatively, one may give up the ability to independently adjust the passband and stopband ripple, and instead design a filter which is maximally insensitive to component variations [1].

In electronics and signal processing, a Bessel filter is a type of linear filter with a maximally flat group delay (maximally linear phase response). Bessel filters are often used in audio crossover systems [6]. Analog Bessel filters are characterized by almost constant group delay across the entire passband, thus preserving the wave shape of filtered signals in the passband [1].

The Legendre filter is a monotonic all-pole filter: the passband slope is always zero or downward, never upward. The response is optimized for the greatest slope at the passband edge. Legendre filters are useful in applications which require a steep cutoff at the passband edge without passband ripple; or in cases where a Chebyshev I filter produces too much group delay at the passband edge [2].

In electronics and signal processing, a Gaussian filter is a filter whose impulse response is a Gaussian function or an approximation to it. Gaussian filters have the properties of having no overshoot to a step function input while minimizing the rise and fall time. This behavior is closely connected to the fact that the Gaussian filter has the minimum possible group delay. It is considered the ideal time domain filter, just as the sinc is the ideal frequency domain filter. These properties are important in areas such as oscilloscopes and digital telecommunication systems [5].

3. Simulations and Measurements

In the design phase of all ladder filters mentioned above, first the filters must be designed with lumped elements. AWR Microwave Office has iFilter Wizard tool and this tool is capable of design any filter type with any degree, instantly. Simulations of insertion loss parameter of simulated lumped filters are shown in Fig. 1.

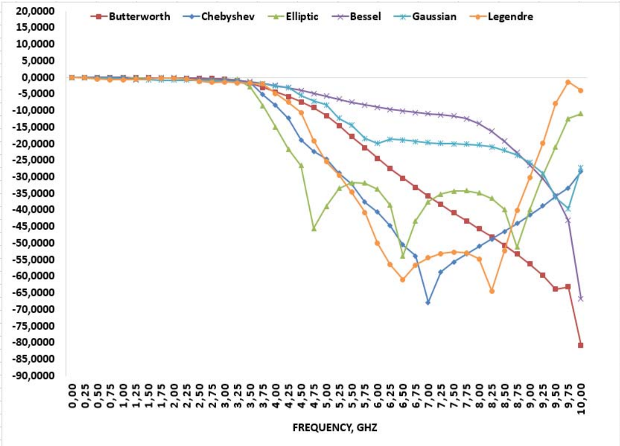

Fig. 1. Simulation results of S_{21} parameter of designed 7^{th} order lumped filters

Of course, it is impossible to get non-standard and high-Q elements to realize the filter circuits with these lumped elements. To easily optimize and increase the total quality factor of the circuits, lumped elements must be converted to microstrip lines.

In this step, lumped inductors were converted to series lines and lumped capacitors were converted to shunt stubs. Rogers RT5880 was chosen as the substrate. Its relative permittivity and thickness are 2.2 and 10 mil, respectively. Furthermore, center frequency was chosen as f_c=3000 MHz. The distributed element values of series lumped inductors were computed as given in (1),

$$X_L = \omega_c L = Z_0 \sin\theta \qquad (1)$$

Also, the parameters of the distributed open stubs are calculated by (2),

$$X_C = \frac{1}{\omega_c C} = Z_0 \cot\theta \qquad (2)$$

Schematics of converted filters are shown in Fig. - Fig. 7. Input and outpu impedances are both 50 Ohm.

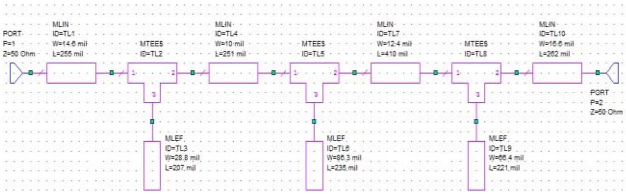

Fig. 2. Schematic representation of the designed 7^{th} order Butterworth low-pass filter

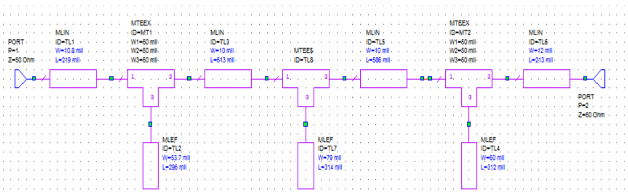

Fig. 3. Schematic representation of the designed 7^{th} order Chebyshev low-pass filter

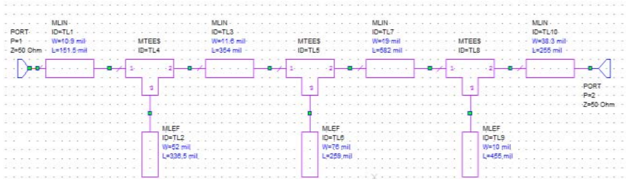

Fig. 4. Schematic representation of the designed 7^{th} order Elliptic low-pass filter

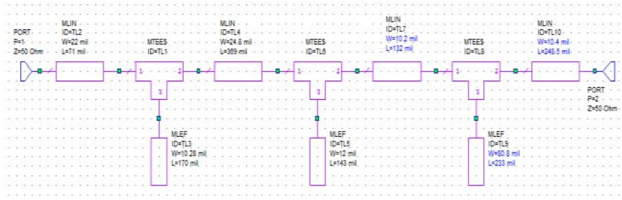

Fig. 5. Schematic representation of the designed 7^{th} order Bessel low-pass filter

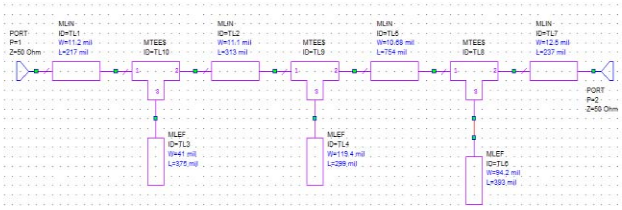

Fig. 6. Schematic representation of the designed 7^{th} order Legendre low-pass filter

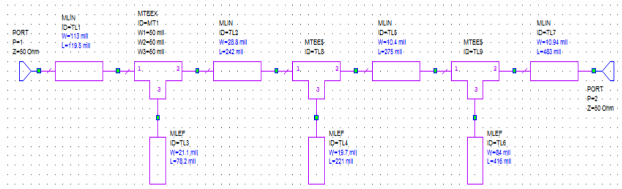

Fig. 7. Schematic representation of the designed 7^{th} order Gaussian low-pass filter

Designed microstrip filters can be realized easily with PCB tools. In Fig. 8- Fig 13, realized filter prototypes are shown.

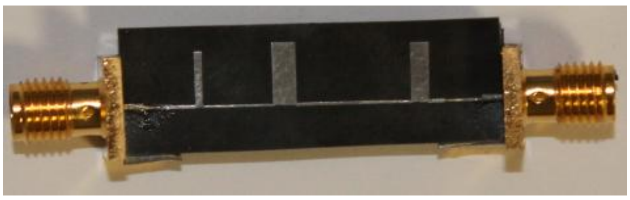

Fig. 8. Prototype board of the 7^{th} order Butterworth low-pass filter

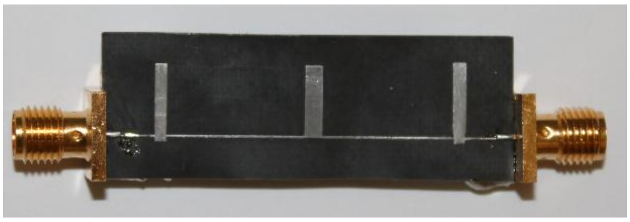

Fig. 9. Prototype board of the 7^{th} order Chebyshev low-pass filter

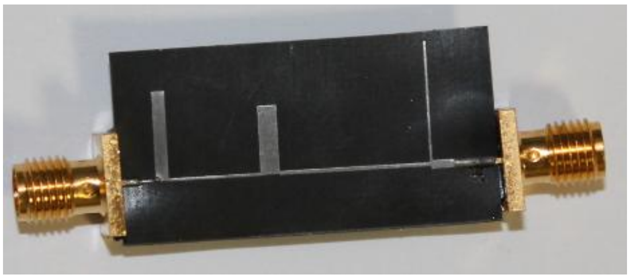

Fig. 10. Prototype board of the 7^{th} order Elliptic low-pass filter

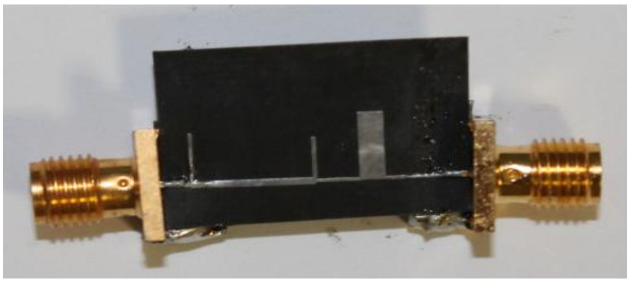

Fig. 11. Prototype board of the 7^{th} order Bessel low-pass filter

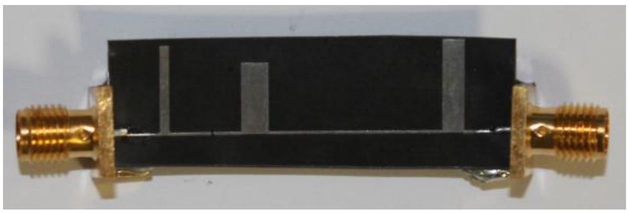

Fig. 12. Prototype board of the 7^{th} order Legendre low-pass filter

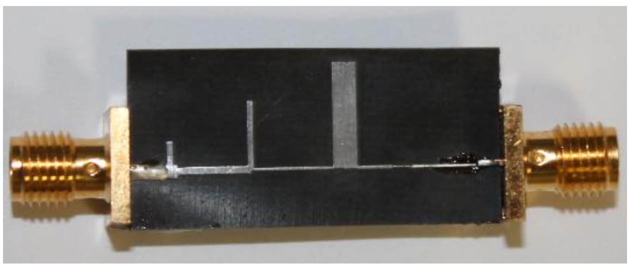

Fig. 13. Prototype board of the 7^{th} order Gaussian low-pass filter

Measurement results of insertion loss parameter of fabricated 7^{th} order filters are shown in Fig 14. As it can be seen easily, the insertion loss performance of all filters are better than their lumped equivalents.

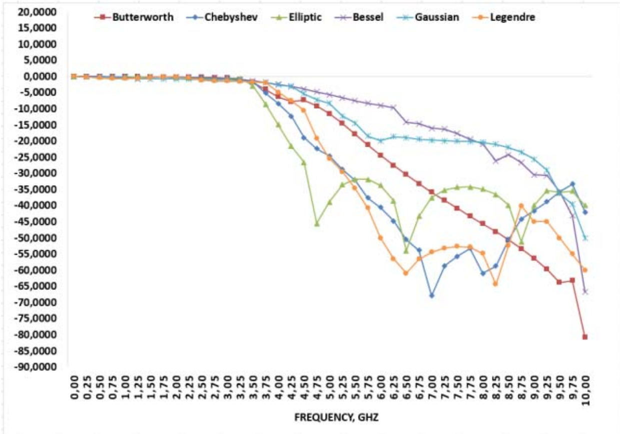

Fig. 14. Measurement results of S_{21} parameter of designed distributed 7^{th} order filters

4. Conclusions

The simulation and measurement results show that, the passive lumped element filters can be realized with distributed elements and the performance of the microstrip filters is as satisfactory as filters that combined with lumped elements.

5. References

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