Parallel-coupled-line microstrip band-pass filter using space mapping Technique

Rajkumar Gehlot (Assistant Professor), Nidhi Maheshwari (Assistant Professor), Suruchi Gour (Assistant Professor)

*Electronics & Communication Engg. Department, Lord Krishna College of Technology, Indore, India
**Electronics & Communication Engg. Department, Lord Krishna College of Technology, Indore, India
**Electronics & Communication Engg. Department, Mandsaur Instituted of Technology, Indore, India

Abstract

Space mapping is a powerful technique to optimize such complex models by efficiently substituting accurate but expensive electromagnetic models, fine models, with fast and approximate models, coarse models. In this paper, we apply space mapping, an explicit space mapping techniques to Design, a micro strip pass band filter. The filter structure is made of a perfect conductor on the top of a substrate (RT_DURROID_5880) with a relative dielectric constant of 2.2 and a height of 20 mil, backed with a perfect conductor ground plane The proposed passband filter 9-10 GHz is designed and simulated with Advanced Design System (ADS2009) and was implemented with good compactness and low insertion loss.

Index Terms— ADS, space mapping, microstrip, passband filter

1. INTRODUCTION

In modern wireless communication systems, the miniaturized MMIC microwave bandpass filters are required to reduce the cost and lower the efforts of RF system design, especially for single RF transceiver chip. Therefore, many studies on reducing the large size of conventional bandpass filter have been made. The lumped element approach, which uses spiral inductor and lumped capacitor, is one of the solutions to this problem. However, the design of lumped element circuits must be somewhat empirical and these circuit demonstrations have been confined to frequencies up to few GHz due to the low quality factor (Q) [1] and low resonant frequencies. The folded hairpin resonator filters, stepped-impedance resonator (SIR) filters [2]-[4] and slow wave open-loop resonator filters [5] were developed. Using these methods, a relative compact bandpass filter can be designed. However, they still take up quite a large circuit area. Another disadvantage of these traditional microstrip filters is that they can't effectively suppress the spurious passband, which may seriously degrade the attenuation level in the stopband and passband response symmetry and could restrict the applicability of the filters.

Combline filters using low temperature co-fired ceramic (LTCC) or ceramic materials with the multi-layer technology can be used as a reduced size bandpass filter [6], [7]. However, conventionally the electrical length has been recommended by 45º or less for efficient coupling [8]. Nowadays SAW filters are widely used in the mobile communication market. But they are still not compatible with standard IC technology and presently available in the frequency range up to 3GHz [9]. An active bandpass filter can be integrated in single manufacturing process. In this case, the active circuit which behaves as a negative resistance is inserted [10] and has a drawback associated with nonlinearity and poor noise figures [11].

Considering the development of computer-aided design techniques, optimization plays a vital role in modeling and design of microwave circuits. A typical design problem is to choose the design parameters to get the desired response. Space mapping (SM) approach, introduced by Bindley et al. [12], is a powerful technique to optimize complex models. It substitutes efficiently expensive electromagnetic models, fine models, with fast and approximate models, coarse models. To obtain the optimal design for the fine model, the SM establishes a mapping between parameters of the two models iteratively [12- 13]. SM techniques can be classified to original or explicit SM [14] and implicit SM (ISM) [15] methods. Both methods use an iterative approach to update the mapping and predict new design parameters. In this paper, we apply space mapping, an explicit space mapping technique to Design, a microstrip passband filter. Therefore, a passband filter can be formed. The proposed passband filter with passband 9-10 GHz is designed and simulated with Advanced Design System (ADS2009).

II. MICROSTRIP

One of the main requirements for a transmission structure to be suitable as a circuit element in microwave integrated circuits (MICs) is that the structure should be planar in configuration. A planar configuration implies that characteristics of the element can be determined by dimensions in a single plane. There are several transmission structures that satisfy the requirement of being planar. The most common of these are: i) microstrip,

ii) coplanar waveguide, iii) slot line, and iv) coplanar strips. A microstrip is the most popular of these transmission structures. The mode of propagation in a micro strip is almost transverse electromagnetic (TEM). This allows easy approximate analysis and yields wide band circuits. The microstrip line has a single upper conductor above an infinite ground plate with a dielectric substrate as carrier. Since microstrip is an open structure, devices can be easily attached to it and post fabrication adjustments can be performed

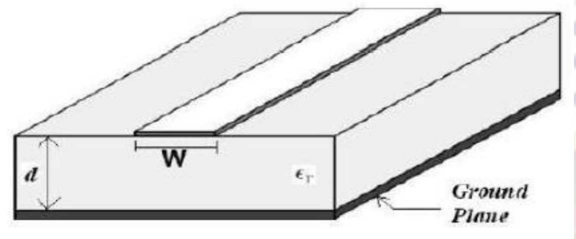

Figure 1. Microstrip geometry

There are several variations of the transmission line configuration that are also found in MICs. These include coplanar-waveguide (CPW), inverted microstrip, trapped inverted microstrip and suspended strip line.

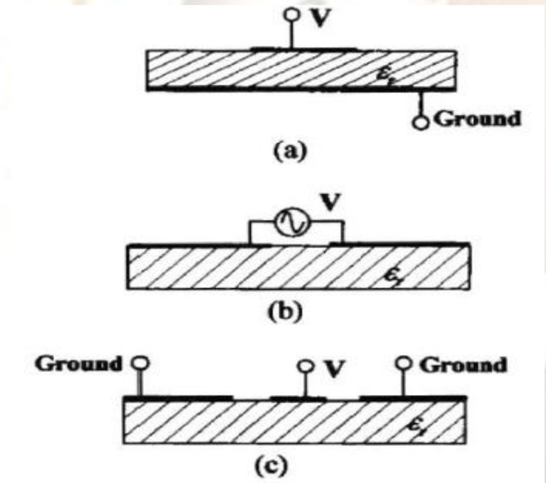

Figure2. Common quasi-TEM mode transmission lines: a) microstrip b) slot line c) coplanar waveguide [17].

The characteristic impedance range of a microstrip is typically 20 Ω to 120 Ω. The upper limit is set by technological constraints on the minimum line width that can be realized and the production tolerances, while the lower limit is essentially set by the appearance of higher order modes. The fabrication of microstrip circuits is relatively simple and done with low-cost technology. The dimensions of microstrip on standard substrates are relatively large, so that the demand for highly precise photolithography is not stringent. Some of the particularly useful characteristics of microstrip include the following [16].

- DC as well as AC signals may be transmitted.
- Active devices, diodes and transistors may be readily incorporated.
- Shunt connections can be made quite easily.
- In-circuit characterization of devices is relatively straight forward to implement.
- Line wave length is reduced considerably (typically one-third) from its free space value, because of the substrate dielectric constant.
- The structure is quite rugged and can with stand moderately high voltage and power levels.

III. THE SPACE MAPPING CONCEPT

Space Mapping (SM) is a novel concept for circuit design and optimization that combines the computational efficiency of coarse models with the accuracy of fine models. The coarse models are typically empirical equivalent circuit engineering models, which are computationally very efficient but often have a limited validity range for their parameters, beyond which the simulation results may become inaccurate. On the other hand, detailed or “fine” models can be provided by an electromagnetic (EM) simulator, or even by direct measurements: they are very accurate but CPU intensive. The SM technique establishes a mathematical link between the coarse and the fine models, and directs the bulk of CPU intensive evaluations to the coarse model, while preserving the accuracy and confidence offered by the fine model. The modeling procedure starts with optimization of the coarse model to obtain the reference point of the region of interest. According to star distribution, shown in Figure 1, an n dimensional interval centered at the reference point is created. Then, the input and output’s mapping parameters are calibrated such that multiple sets of responses of the SM-based surrogate model match those of the fine model, simultaneously. To check the validity of the resulting model, it is tested with some test points in the region of interest. If the test results are not satisfactory, more data should be provided. The SM-based surrogate model’s response is generated in specific points over a range of frequencies because the size of output mapping matrices is fixed. To generate the SM-based surrogate model’s response over all points of the frequency range, optimized output mapping matrices should be interpolated using linear frequency interpolation techniques [18]. Then, the resulting model, provided for any frequency sweep, is optimized to determine optimal design parameters satisfying design specifications.

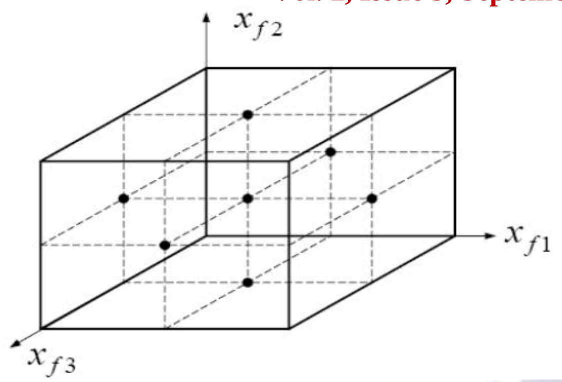

Figure 3. Three-dimentional star set for the base points

IV. DESIGN AND SIMULATION OF MICROSTRIP FILTER WITH ADS

The structure of the parallel-coupled-line microstrip filter is illustrated in Figure 4.

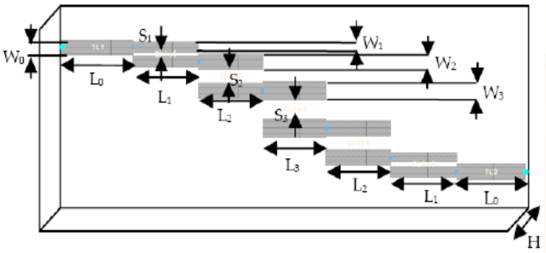

Figure 4. Parallel-coupled-line microstrip band-pass filter.

The filter structure is made of a perfect conductor on the top of a substrate (RT_DURROID_5880) with a relative dielectric constant of 2.2 and a height of 20 mil, backed with a perfect conductor ground plane. To simplify the modeling and design procedure by reducing the number of design parameters, the following parameters (all in mm) are assumed to be constant.

w0=□ 0.59, w1=0.42, w2=0.52, w3=0.48
L0=□ 3, L1=6, L2=5.8, L3=5.7
s1=0.21, s2=0.42, s3=0.51

A. Ideal Transmition line

We simulated design in ADS using the above lengths and widths for the microstrip dimensions. We then used the optimization tool using our design goal as the goal for optimization. The final circuit schematic (coarse model) passband filter shown in Figure 5 and Simulated results of the passband shown in Figure 6.

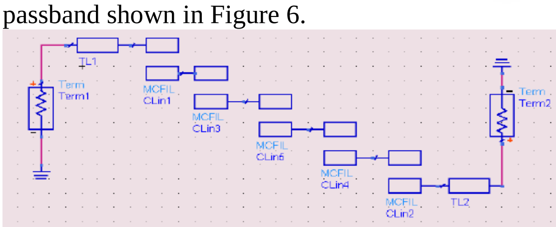

Figure 5. final circuit schematic of the passband filter by ideal transmision line

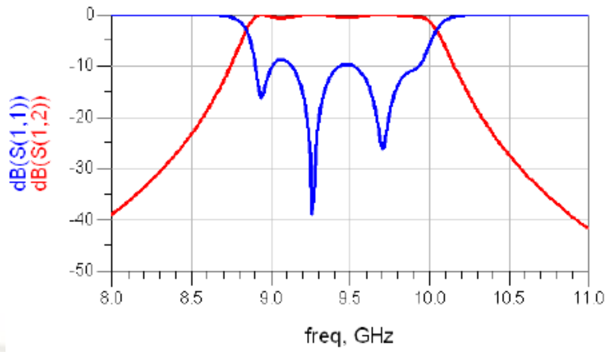

Figure 6. Simulated results of the passband filter by ideal transmission line

B. Layout and Momentum Simulation

After the schematic circuit has been modified, we created Layout. Figure 7 shows Microstrip Layout of the passband filter and Figures 8, 9 shows S21, S11 of the passband filter by Momentum Simulation.

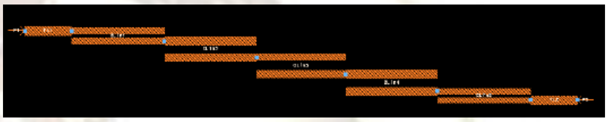

Figure 7. Microstrip Layout of the passband filter

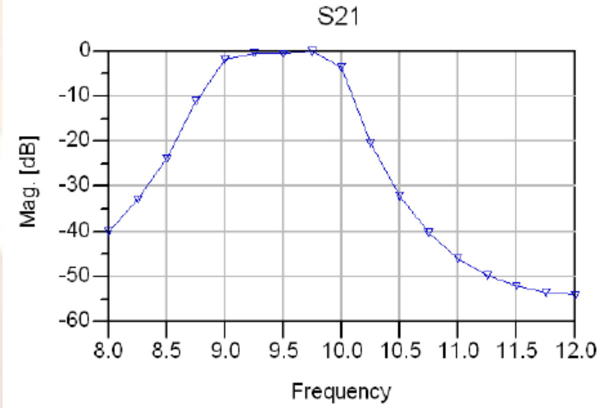

Figure 8. S21 of the passband filter by Momentum Simulation

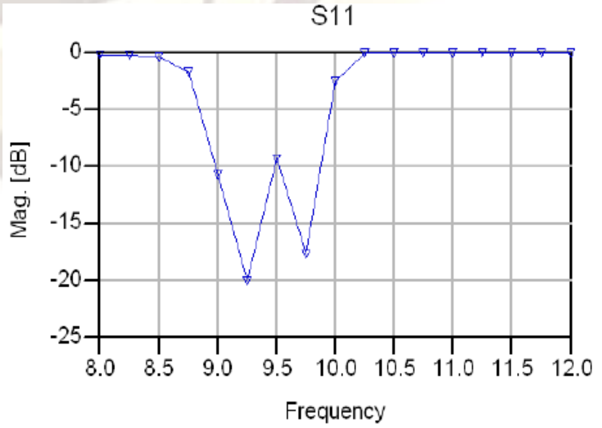

Figure 9. S11 of the passband filter by Momentum Simulation

V. CONCLUSIONS

This paper aimed to model a parallel-coupled-line microstrip passband filter simulation and design parameters. Using explicit space mapping modeling approach, a surrogate model was used instead of fine one to simplify the design procedure. To get satisfactory results, the accuracy of coarse models should be good enough. The proposed passband filter 9-10 GHz is designed and simulated with Advanced Design System (ADS2009) and was implemented with good compactness and low insertion loss.

REFERENCES

[1] B. Piernas, K. Nishikawa, T. Nakagawa and K. Araki, "Improved Three-Dimensional GaAs Inductors," IEEE MTT-S Int. Microwave Symp. Dig., pp. 189-192, May 2001.

[2] M. Sagawa, K. Takahashi, and M. Kakimoto, "Miniaturized hairpin resonator filters and their application to receiver front-end MICs," IEEE Trans. Microwave Theory Tech., vol. 37, pp. 1991-1997, 1989.

[3] M. Makimoto and S. Yamashita, "Bandpass filters using parallel coupled strip-line stepped impedance resonators," IEEE Trans. Microwave Theory Tech., vol. MTT-28, no. 12, pp. 1413–1417, Dec 1980.

[4] A. Djaiz and T. A. Denidni, "A new compact microstrip two-layer bandpass filter using apertured-coupled SIR-hairpin resonators with transmission zeros," IEEE Trans. Microwave Theory Tech., vol. 54, no. 5, pp. 1929-1936, May 2006.

[5] J. S. Hong and M. J. Lancaster, "Theory and experiment of novel microstrip slow-wave open- loop resonator filters," IEEE Trans. Microwave Theory Tech., vol. 45, pp. 2358-2365, 1997.

[6] C. W. Tang, Y. C. Lin and C. Y. Chang, "Realization of transmission zeros in combline filters using an auxiliary inductively coupled ground plane," IEEE Trans. Microwave Theory Tech., vol. 51, no. 10, pp. 2112-2118, Oct 2003.

[7] A. Kundu and N. Mellen, "Miniaturized Multilayer Bandpass Filter with multiple Transmission Line Zeros", IEEE MTT-S Int. Microwave Symp. Dig., pp. 760-763, June 2006.

[8] G. Matthaei, L. Young, E. M. T. Jones, Microwave Filters, Impedance-Matching networks, and Coupling Structures. Artech House, pp. 500, 1980.

[9] A. Hussain, Advanced RF Engineering for Wireless systems and Network, Wiley, pp. 262, 2005.

[10] C. Tzuang, H. Wu, H. Wu and J. Chen, "A CMOS Miniaturized C-Band Active Band pass Filter," IEEE MTT-S Int. Microwave Symp. Dig., pp. 772-775, June 2006.

[11] Jia-Sheng Hong and M.J. Lancaster, "Microstrip Filters for RF/Microwave Applications," Advanced Materials and Technologies, pp. 217-219, 2001.

[12] J. W. Bandler, R. M. Biernacki, S. H. Chen, P. A. Grobelny, and R. H. Hemmers, "Space Mapping Technique for Electromagnetic Optimization", IEEE Transactions on. Microwave Theory an Technology, vol. 42, pp. 2536–2544, 1994.

[13] J. W. Bandler, Q. S. Cheng, S. A. Dakroury, A. S. Mohamed, M. H. Bakr, K. Madsen, and J. Søndergaard, "Space Mapping: the Sstate of the Art", IEEE Transactions on. Microwave Theory and Technology, vol. 52, pp. 337–361, 2004.

[14] J. W. Bandler, Q. S. Cheng, N. K. Nikolova, and M. A. Ismail, "Implicit Space Mapping Optimization Exploiting Preassigned Parameters", IEEE Transactions on. Microwave Theory and Technology, vol. 52, pp. 378–385, 2004.

[15] S. Koziel, Q. S. Cheng, and J. W. Bandler, "Space Mapping", IEEE Microwave Magazine, pp.105-122, Dec. 2008

[16] Terry Edwards, Foundations for microstrip circuit design. New York: Wiley-Interscience, 1991.

[17] R. K. Mongia, I. J. Bahl, P. Bhartia and J. Hong, RF and microwave coupled-line circuits. Norwood, MA: Artech House, 2007.

[18] J. W.Bandler, Q. S. Cheng, S. Koziel, "Simplified Space Mapping Approach to Enhancement of Microwave Device Models". International Journal of RF and Microwave Computer- Aided Engineering 2006; 16(5):518–535.