Design and Fabrication of Microstrip to Slotline Transition Bandpass Filter

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***Abstract*— This paper presents the modeling, Simulation and fabrication of microwave bandpass filter using microstrip-to-slotline transition. The proposed EM-Simulation offers a simple and compact structure with low insertion loss. A new type of Micrstrip-to-Slotline transition band-pass filter is presented with a centre frequency operation at 2.4 GHz, which lies in the S-band frequency range. The filter is designed to be much smaller & simple compared to other microstrip bandpass filter. The simulation results are excellent and filter is suitable for integration within various microwave subsystems. For practical applications, filter were designed and fabricated on FR4 substrates. The filter transition were simulated on commercially available EM software SONNET™ and HFSS™. The methodology is applied to a planar transmission line filter modeling and more accurate results are achieved for designing a filter using microstrip-to-slotline transitions. It is these assumptions, like model accuracy, valid frequencies range etc that differentiate one work from another. The work is of practical relevance of Microwave designers.**

Keywords*— *Microstrip-to-Slotline transition, Bandpass Filter, Scattering Characteristics, EM-Simulation and Microwave Filter Modeling.

I. INTRODUCTION

Microstrip transmission lines in combination with slotlines plays a very important role in the design of Microwave Integrated Circuitry. An important component in microstrip-to-slotline circuitry is the well matched microstrip-to-slotline transition with low insertion loss. Many authors have dealt with the problem of developing a microwave device from microstrip-to-slotline transition [1]–[2]. The simplest of wide band transition seems to be the one proposed by Schüpert based on the 90^0 crossing. Schiek and Köhler presented wide band transitions [3].

Bandpass filters are designed mathematically to respond to design frequencies while rejecting all other out of band frequencies [4]. The main aim of the design is printed filter size reduction compared to conventional printed parallel-coupled band pass filters. The centre frequency is designed to be at 2.4 GHz which describes the operation of the filter with a maximum gain. High quality microwave filters play extremely important role in communication systems. In this paper, the design and implementation of bandpass filters from microstrip-to-slotline transition is introduced

Microstrip is a very attractive and essential part of microwave integrated circuit, from which modern microwave components are made. It consists of dielectric substrate of height h, dielectric constant ε_r, metal or conducting material on its back side. On top of the substrate a metallic strip of width w and metallization thickness t is the waveguide design. An open microstrip line structure is shown in Fig. 1. The mode of propagation in a microstrip is almost TEM and mainly it is an open structure, so microstrip line has easy of fabrication and also features ease of interconnections and adjustments. Practical Microstrip line is shown in Fig. 2. Electric and magnetic fields at microstrip lines are shown in Fig. 3. At lower frequencies microstrip support pure TEM mode, and can be described in terms of static capacitance and inductances only. At higher frequencies mode of propagation is not pure TEM mode due to dielectric interface and little components of both electric and magnetic fields exits. Fullwave analysis is carried out to study time-varying electric and magnetic fields in terms of S-parameters in a microstrip lines at higher frequencies [1], [2].The slotline structure was first proposed by S. Cohn in 1969. Cohn pointed out that the guide mode in this case has a region of elliptical polarization that makes it particularly suitable for applications where the substrate if ferrite. Important microwave components like circulators & isolators have therefore been realized using slotline[5]. Electric & Magnetic field lines distribution in slotline is shown in Fig. 4.

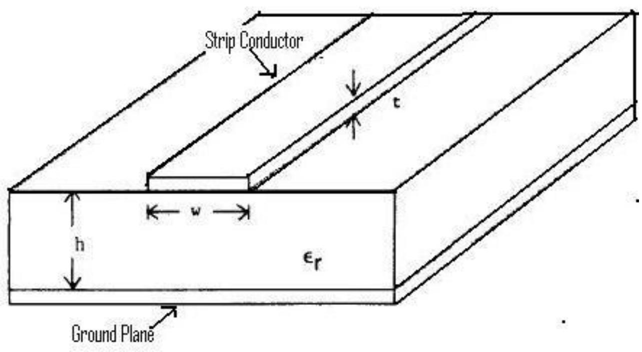

Fig. 1. Cross sectional view of Microstrip line

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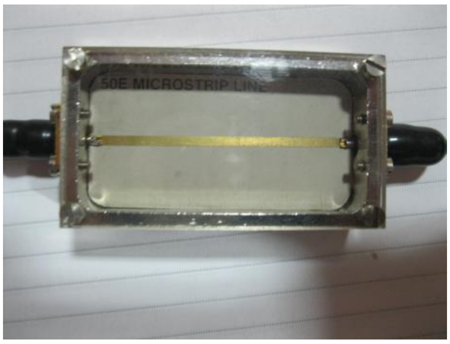

Fig. 2. Physical & Constructional view of Microstrip lines

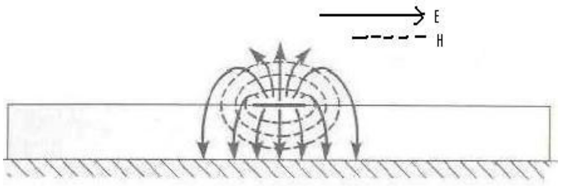

Fig. 3. Electric and Magnetic fields at Microstrip Transmission Line

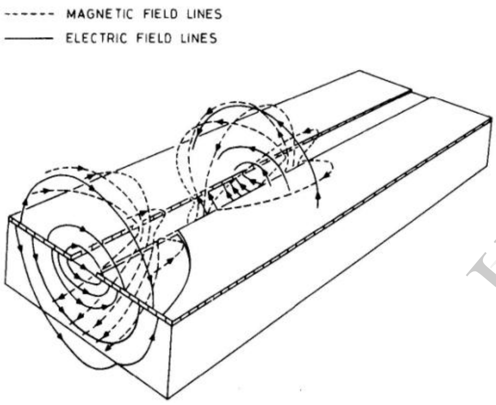

Fig. 4. Slotline Configurations

II. EM SIMULATIONS OF TRANSITIONS

A standard method for the design of a microstrip-to-slotline transition is shown in Fig. 5. The fabrication of the microstrip-to-slotline transition can easily be include in the MIC fabrication routine when an arrangement is made for etching the substrates on both sides. The slotline, which etched on one side of the substrate, is crossed at right angle by a microstrip conductor on the opposite side. The microstrip extends about one quarter of a wavelength beyond the slot. The transition can be fabricated using the usual photo etching process and is thus easily reproducible. Also, as the microstrip part of the circuit can be placed on one side of the substrate and the slotline part on the other side, this transition makes two-level circuit design possible. Coupling between the slotline and microstrip line occurs by means of the magnetic field [7].

Sonnet EM software is a 3D planar EM software, introduced in 1989, commercially successful high frequency EM analysis tool. The Sonnet EM analysis is based on a method-of-moments technique. The circuit metal is first meshed into small subsections. The EM coupling between each possible pair of subsections is calculated and this fills a big matrix. The matrix is inverted yielding all currents everywhere in the circuit metal. This, in turn, determines things like S-parameters, which can be used in other analysis programs [8]. The layout design methodology is represented in flowchart of Fig. 6. The layout design consists of circuit schematic, dimensions of planar transmission lines, post layout design, layout design in a simulator and finally analysis and optimization of a model.

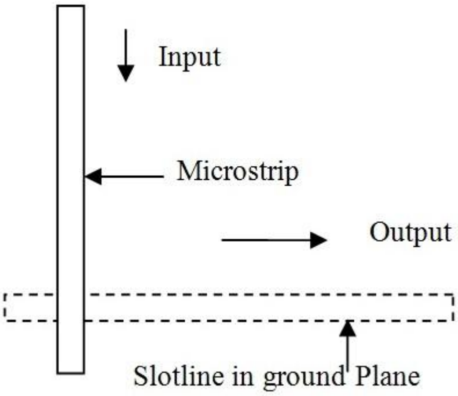

Fig. 5. Microstrip-to-slotline Transitions

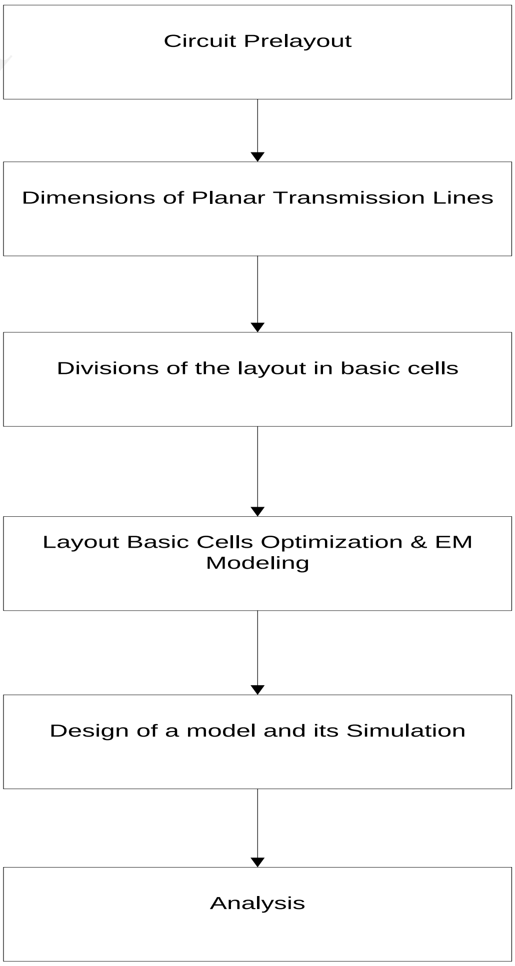

Fig. 6. Flowchart for designing EM Simulation Model

III. FILTER DESIGN AND ANALYSIS

FR4 materials are being used in numerous PCB applications. They are well proven, relative low cost and their performance is well understood. The 2D view of microstrip-to-slotline transition bandpass filters are shown in Fig. 7. The S-parameter values i.e. insertion loss S_{21}(dB) and return loss S_{11}(dB) of mirostrip-to-slotline transition bandpass filter based on FR4 (ε_r=4.4, tanδ = 0.02 and h=1.6mm) substrate is shown in Fig. 8. From figure it is cleared that at 2.4 GHz, the S_{11}(dB) and S_{21}(dB) from simulation software based on MoMs is satisfactory. The microstrip surface current and slotline edge current is also maximum at 2.4GHz which is shown in Fig. 9. FR4 laminates microstrip-to-slotline transition bandpass filter is also simulated and analyzed using HFSS™ software which is based on FEM. For a microstrip-to-slotline transition bandpass filter the simulation results using FEM software is better i.e. S_{11}(dB) and S_{21}(dB) is acceptable and its values are -1.4563 dB and -22.1982 dB respectively as shown in Fig. 10. The microstrip-to-slotline transition bandpass filter is also fabricated using FR4 substrate since FR4 based PCBs are readily available and it is an affordable substrates. The front and rear view of fabricated filter is shown in Fig. 11. The S-parameters values of microstrip-to-slotline transition bandpass filter is measured using Rohde & Schwarz, ZNB 8, Vector Network Analyzer, 9 KHz… 8.5 GHz, and is shown in Fig. 12. The FR4 based fabricated microstrip-to-slotline transition filter had a centre frequency of 2.4 GHz with an insertion loss of less than -3.2dB and the 3dB bandwidth is nearly 320 MHz.

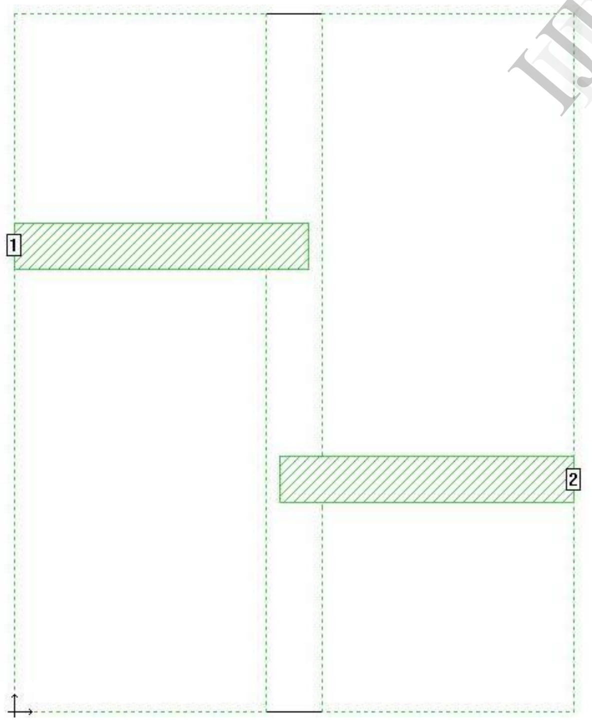

Fig. 7. Two Dimensional Microstrip-to-Slotline Transition bandpass filters

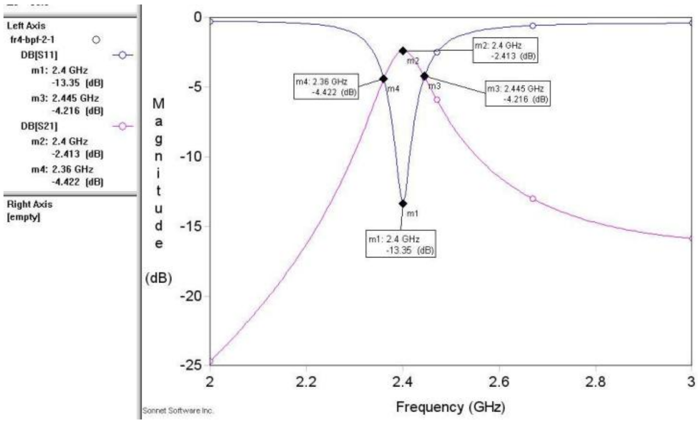

Fig. 8. Simulated frequency response S_{11}(dB) and S_{21}(dB) for Microstrip-to-Slotline Transitions bandpass filter at 2.4 GHz on FR4

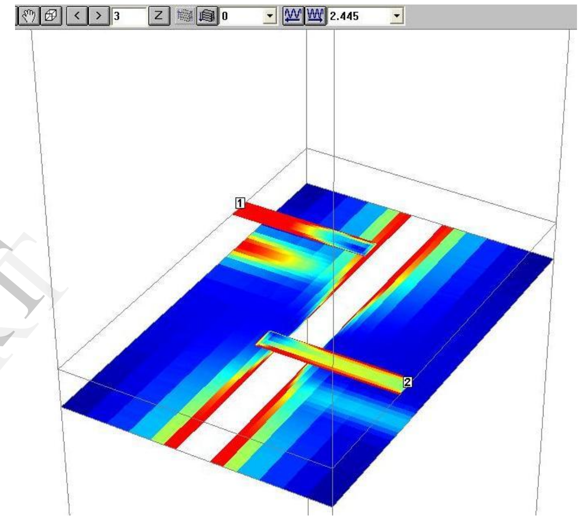

Fig. 9. Three Dimensional current of Microstrip-to-Slotline Transitions bandpass filter at 2.4 GHz for FR4

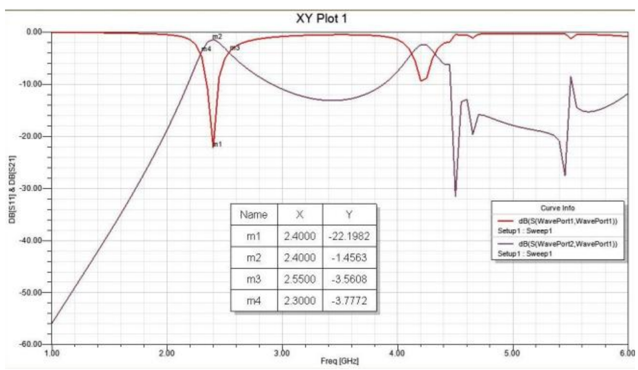

Fig. 10. Simulated frequency response S11(dB) and S21(dB) for Microstrip-to-Slotline Transitions bandpass filter at 2.4 GHz in HFSS™

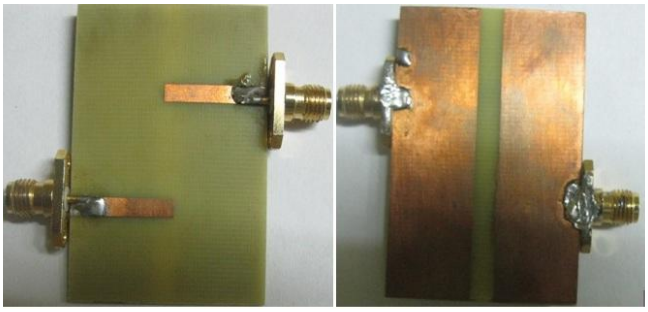

Fig. 11. Fabricated view of Microstrip-to-Slotline Transition bandpass filter

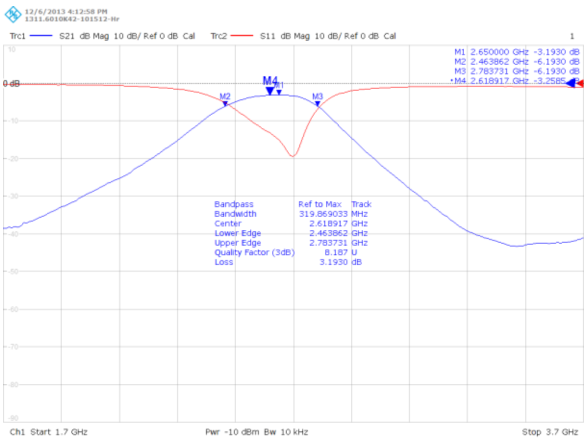

Fig. 12. Measured frequency response S11(dB) and S21(dB) (file view) of fabricated Microstrip-to-Slotline Transitions bandpass filter at 2.4 GHz for FR4

IV. CONCLUSIONS

The micostrip-to-slotline transition bandpass filters has found its applications not only in microwave region but also in millimeter wave region. The micostrip-to-slotline transition bandpass filters were designed, simulated and fabricated by using SONNET and HFSS Software. A technique that exploits a circuits based on the micorstrip-to-slotline transition has been used to optimize compact bandpass microwave filters. Efficient modeling technique have been presented and applied to microwave filters modeling & design. The proposed methodology has been applied to planar transmission line filter modeling.

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