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A Microstrip Coupled Line Bandpass filter for 6/4 GHz Transverter

M. Bhagavathi Priya[1], K. Ramprakash[2], P. Pavithra[3], D. Allin Joe[4]
[1,2,3]Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, India
[4]Associate Member IETE, Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, India

***Abstract*—** *In this paper, 4 GHz and 6 GHz bandpass filters are designed using microstrip coupled lines for 6/4 GHz Transverter applications. Transverters have a combined up converter and down converter that is used to vary the communication frequencies of a transceiver device. Simulations are done using Advanced Design System (ADS) simulator and RO4003 substrate with the thickness of 0.8 mm is used. The simulated design has low insertion loss and high return loss on the desired 6/4 GHz Transverter frequency bands.*

Keywords*— *Bandpass Filter, Coupled Line, ADS, Transverter, Return Loss, Insertion Loss.

I. INTRODUCTION

In a geostationary satellite communication system, a message signal is transmitted from an earth station via an uplink to a satellite and amplified in a transponder then retransmitted from the satellite via a downlink to another earth station. A satellite transponder receives signals over a variety of uplink frequencies generally from a satellite ground station, amplifies and re-transmits them on a different variety of downlink frequencies to receivers on earth without changing the content of the received signal. The most popular frequency band for satellite communication is 6 GHZ (c-band) for the uplink and 4 GHZ for the downlink and these frequency bands are selected because of low attenuation due to rainfall as rainfall is the primary cause of signal degradation [1]. C band is used for TV transmission with downlink range of 3,200 MHz to 4,200 MHz and uplink range of 5,925 MHz to 6,425 MHz [2].

Band pass filters are used at both the ends of up/down converter to select the specific range of frequencies. Totally, four band pass filters are used for the whole process where two filters are for 4 GHz band and the other two filters are for 6 GHz band [3]. The block diagram of an earth station transmitter and receiver is shown in Fig. 1.

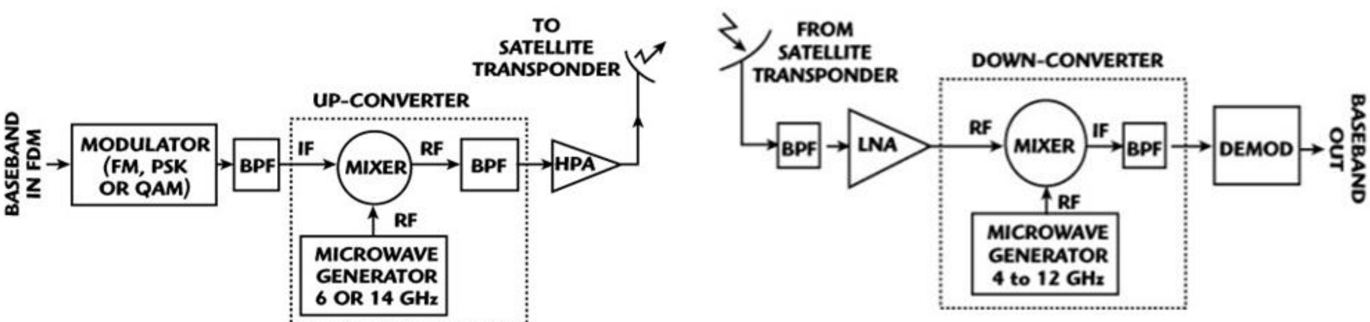

FIG. 1. BLOCK DIAGRAM OF EARTH STATION TRANSMITTER AND RECEIVER

The down converter receives an RF-signal at uplink frequency (6 GHz) and performs a frequency conversion of this signal to the selected internal IF band. Bandpass filtering is performed both sides of block and at IF block. The down converted and filtered signal is then up converted to the applicable downlink frequency (4 GHz) by the up converter.

The organization of this paper is as follows. The next section represents the Design Procedure of the bandpass filter. Section III provides the Result and Discussion of the bandpass filter using ADS. The final section summarizes the main conclusions of this paper.

II. DESIGN PROCEDURE

Advanced Design System (ADS) software is used for simulation [4]. Design procedure includes 3 steps.

Step 1: Choose the specification of the filters.

Filters are classified into Lowpass filter, Highpass filter, Bandpass filter, and Bandstop filter. The filter used for this application is Bandpass filter. Bandpass filter allows the specific range of frequencies and block remaining frequencies. The substrate used for the bandpass filter design is RO4003 [5]. The Specification of the substrate is tabulated in TABLE 1.

TABLE 1
SPECIFICATION OF SUBSTRATE

Specification	Value
Substrate Name	RO4003
Order of filter, N	3
Center Frequency for 4 GHz, f_c	4 GHz
Center Frequency for 6 GHz, f_c	6 GHz
Impedance, Z_0	50 Ω
Fractional Band Width, Δ	0.1

Step 2: Calculation of filter parameters.

Chebyshev prototype with the ripple factor of 0.5 dB and the order of 3 is selected for the filter design [6]. Microstrip line, coupled line, hairpin, comb line are some of the designs used for the manufacturing of filters and these designs are selected according to the requirement of the application. The filter in this paper is designed using Coupled lines approach. The theoretical values of the Coupled line chebyshev 3rd order filter is obtained using the following equations [7-8]. Fractional bandwidth of the filter is determined using the equations (1) to (4) and the obtained coefficients of the 3rd order filters are provided in the Table 2.

$$\omega_1 = 2\pi f_1 \tag{1}$$

$$\omega_2 = 2\pi f_2 \tag{2}$$

$$\omega_o = \sqrt{\omega_1 \omega_2} \tag{3}$$

$$\Delta = \left(\frac{\omega_1 \omega_2}{\omega_o}\right) \tag{4}$$

TABLE 2
RIPPLE FACTOR 20LOG10 $\varepsilon = 0.5$ dB

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7
1	0.6986	1.0000					
2	1.4029	0.7071	1.9841				
3	1.5963	1.0967	1.5963	1.0000			
4	1.6703	1.1926	2.3661	0.8419	1.9841		
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000	
6	1.7254	1.2479	2.6064	1.3137	2.4578	0.8696	1.9841

The fractional bandwidth is used to identify the inverter impedance. The inverter admittance J_N is calculated using the equations (5) to (7) where N represent the order of the filter.

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$$Z_oJ_1 = \sqrt{\frac{\pi\Delta}{2g_1}} \tag{5}$$

$$Z_oJ_N = \frac{\Delta\pi}{2\sqrt{g_{N-1}g_N}} \tag{6}$$

$$Z_oJ_{N+1} = \sqrt{\frac{\pi\Delta}{2g_Ng_{N+1}}} \tag{7}$$

Even mode (Z_{oe}) and Odd mode (Z_{oo}) impedances of the coupled line is calculated using the equations (8) and (9). The Calculated inverter admittance, even mode and odd mode values of 4 GHz filter and 6 GHz filter are justified in the Table III and Table IV respectively.

$$Z_{oe} = Z_o[1 + JZ_o + (JZ_o)^2] \tag{8}$$

$$Z_{oo} = Z_o[1 - JZ_o + (JZ_o)^2] \tag{9}$$

TABLE 3
INVERTER ADMITTANCE, EVEN MODE AND ODD MODE IMPEDANCE VALUES OF 4 GHZ FILTER

G_n	$Z_o J_n$	Z_{oe}	Z_{oo}
1.5963	0.2218	63.5497	41.3697
1.0967	0.0593	53.1408	47.2108
1.5963	0.0593	53.1408	47.2108
1.000	0.2218	63.5497	41.3697

TABLE 4
INVERTER ADMITTANCE, EVEN MODE AND ODD MODE IMPEDANCE VALUES OF 6 GHZ FILTER

G_n	$Z_o J_n$	Z_{oe}	Z_{oo}
1.5963	0.2429	65.0950	40.8050
1.0967	0.0356	51.8433	48.2833
1.5963	0.0356	51.8433	48.2833
1.000	0.2429	65.0950	40.8050

Step 3: Implementation of bandpass filter in ADS

LineCalc tool in the ADS software is used for the application of converting the even and odd mode impedance values into the Width, Spacing, and Length of the coupled line. The LineCalc window in ADS is shown in Fig. 2.

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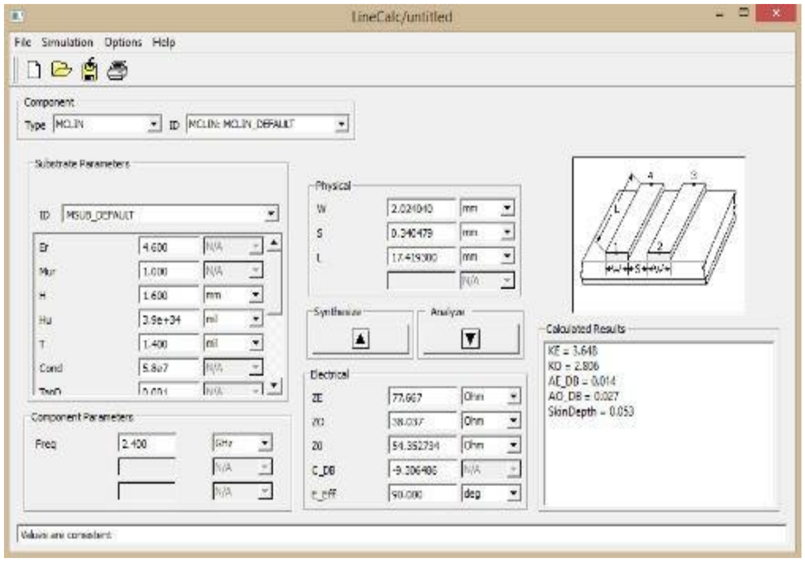

FIG. 2. LINECALC WINDOW IN ADS

Parallel-coupled lines is another popular topology for printed boards, for which open-circuit lines are the simplest to implement since the manufacturing consists of nothing more than the printed track. The design consists of a row of parallel λ/2 resonators, but coupling over only λ/4 to each of the neighbouring resonators, so forming a staggered line as shown in Fig. 3. Wider fractional bandwidths are possible with this filter than with the capacitive gap filter [9-10].

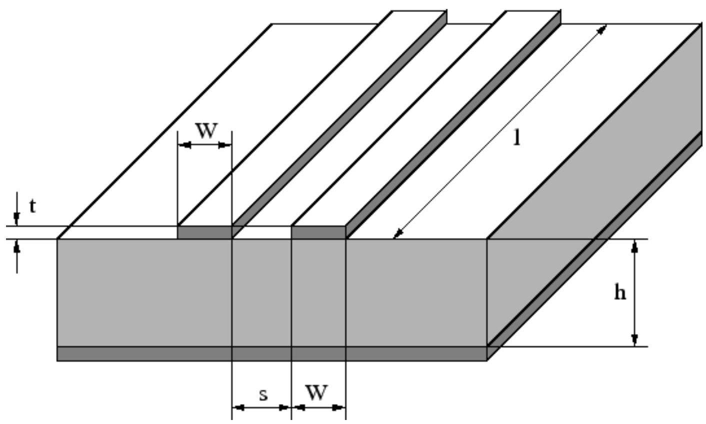

FIG. 3. STRUCTURE OF COUPLED LINE

Characteristic impedance, Z_o is the impedance between the conductors when there is no coupling to ground. Even mode impedance, Z_{oe} is the impedance between one conductor and the ground plane when both conductors are driven with same polarity signal against the ground. Odd mode impedance, Z_{oo} is the impedance between one conductor and the ground plane when the conductors are driven with opposite polarity signal against the ground. Theoretically calculated even mode impedance, odd mode impedance and characteristics impedance are substituted in Linecalc to calculate width, space and length of the coupled line.

III. RESULT AND DISCUSSION

Coupled lines are used to design filter with the configuration of perfect conductor and RO4003 substrate. The schematic and layout windows of the designed bandpass filters are shown in Fig. 4.

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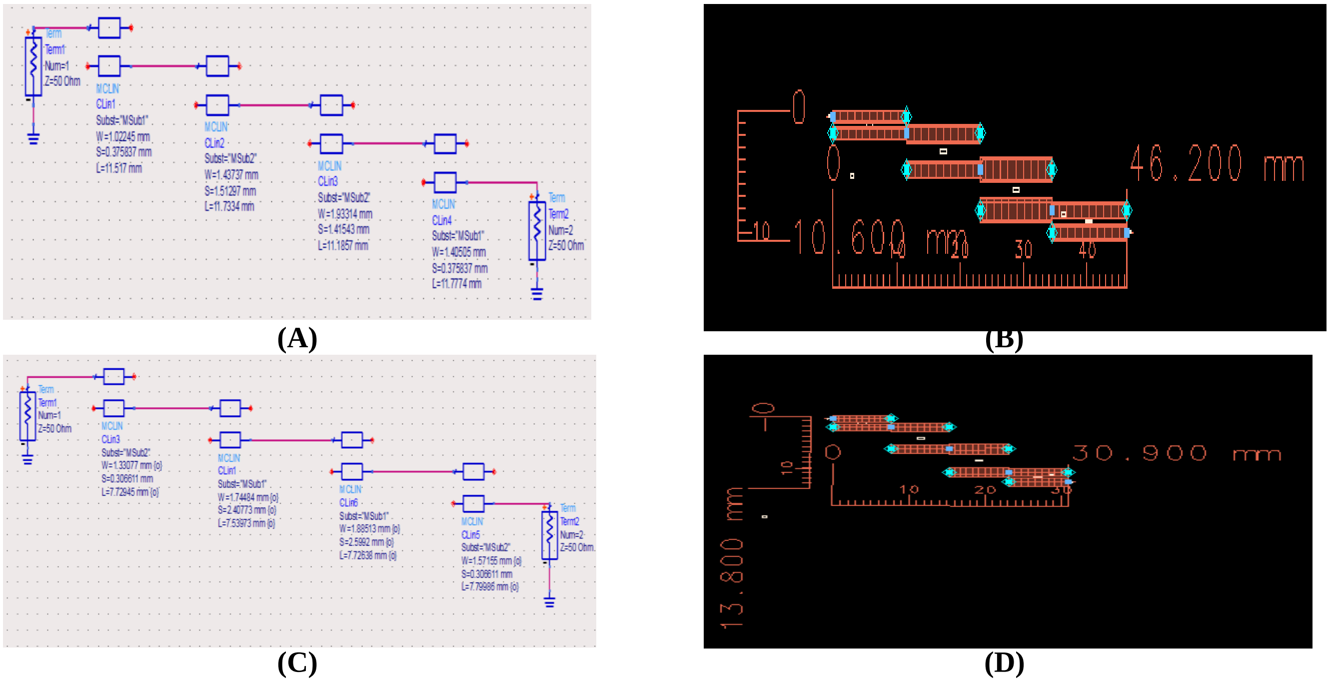

FIG. 4. (A) SCHEMATIC OF 4 GHZ BANDPASS FILTER (B) LAYOUT OF 4 GHZ BANDPASS FILTER (C) SCHEMATIC OF 6 GHZ BANDPASS FILTER (D) LAYOUT OF 6 GHZ BANDPASS FILTER

The Simulated S parameters of 4 GHz and 6 GHz bandpass filters are shown in Fig. 5.

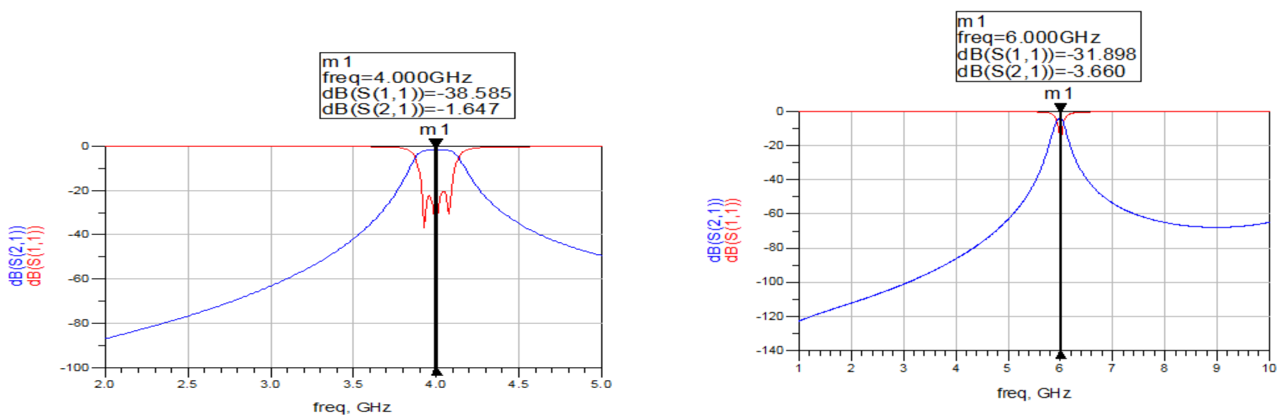

FIG. 5. SIMULATED S PARAMETERS OF 4 GHZ AND 6 GHZ BANDPASS FILTERS

The 4 GHz and 6 GHz simulation outputs provide the return loss and insertion loss values. The simulation output of filter has low insertion loss and high return loss in the desired frequencies. For 4 GHz band pass filter, S_{11}= -38.585 dB and S_{21}= -1.647 dB and for 6 GHz bandpass filter, S_{11}= -31.898dB and S_{21}= -3.660 dB. The size of the designed 4 GHz filter is length = 46.2 mm and width = 10.6 mm (46.2 mm x 10.6 mm) and the size of the designed 6 GHz filter is length = 30.9 mm and width = 13.8 mm (30.9 mm x 13.8 mm).

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IV. CONCLUSION

Microstrip Coupled line bandpass filter approach is designed using the configuration of perfect conductor and RO4003 substrate. 4 GHz and 6 GHz filters are designed separately for the application of 6/4 GHz transverter. The filter has high return loss and low insertion loss for perfect performance in the desired frequency band.

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