DESIGN AND SIMULATION OF DIPLEXER FOR RECEIVE TERMINAL OF RANGING TRANSPONDER

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ABSTRACT

Now a day's , Diplexers are used in various applications like, Cellular Handsets, GPS Receivers, Cordless Phones, Wireless LANs, Wireless Data, and satellite communications etc. But diplexers is operate at different frequency band for different application. I will design diplexers for two frequency band, one at 3.4GHz frequency and other at 6.7GHz frequency for Receive terminal of Ranging Transponder of IRNSS system. The diplexer is one of the major components in a Receiver front-end. Design of diplexers is done by using Advance Design System (ADS). First I will design two filter at two different frequency band. Once filter match with it's specification I will combine two filter using power divider. This paper describe a step-by-step of the design, simulation and measurement of coupled line bandpass filter at 3.4 Ghz and 6.7 Ghz. This two frequency band are used in IRNSS application. Advanced Design System (ADS 2011_10) simulation tool is used to simulate a prototype of band pass filter using distributed component for both the frequency band. FR-4 type substrate has the relative permittivity of 4.6 and tangent loss of 0.023 is used in designing the parallel coupled bandpass filter for IRNSS application. Using chebyshev approach for filter design, it provide good filter characteristics at both frequency 3.4 GHz and 6.7 GHz. At both frequencies insertion loss is less than -0.5 dB and return loss is better than 20 dB. Once filter is designed it will combine using power divider and it will provide insertion loss less than 1 dB and isolation between two point is better than 100 dB.

Keyword: *Coupled line bandpass filter, IRNSS, Power divider, Ranging transponder*

1. INTRODUCTION TO IRNSS

IRNSS Refers to Indian Regional Navigation Satellite System.IRNSS is an independent Navigation Satellite System providing services in the Indian Region.

IRNSS is being implemented by the Indian Space Research Organization.The project is being managed by the lead centre viz., ISRO Satellite Centre, Bangalore with support from the other work centres viz., Space Application Centre, Ahmedabad, ISTRAC, Bangalore, MCF, Hassan, VSSC, Thiruvananthapuram.IRNSS provides fairly good accuracy and the whole constellation is seen all the time.

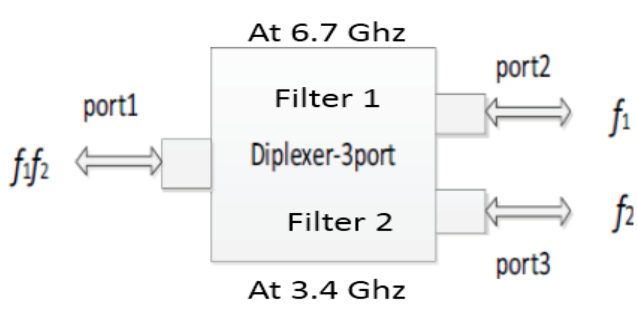

Fig- 1: Schematic of Diplexer

Diplexer used in IRNSS (Indian Regional Navigational Satellite System) and within short period of time it will replace the GPS (Global Positing System).
There are two types of transponder is used in IRNSS:
(i) Navigation transponder
(ii) Ranging transponder.
Diplexer used at receive terminal of ranging transponder.

2. INTRODUCTION TO COUPLED LINE FILTER

Band pass filter could either be realized using lumped components or distributed components. Lumped components consists of discrete elements like inductors, capacitors etc. Distributed elements consist of transmission line sections which simulate various inductance and capacitance values.
Microstrip transmission line is the most used planar transmission line in Radio frequency (RF) applications. As other transmission line in RF applications, microstrip can also be exploited for designing certain components, like filter, coupler, transformer or power divider.

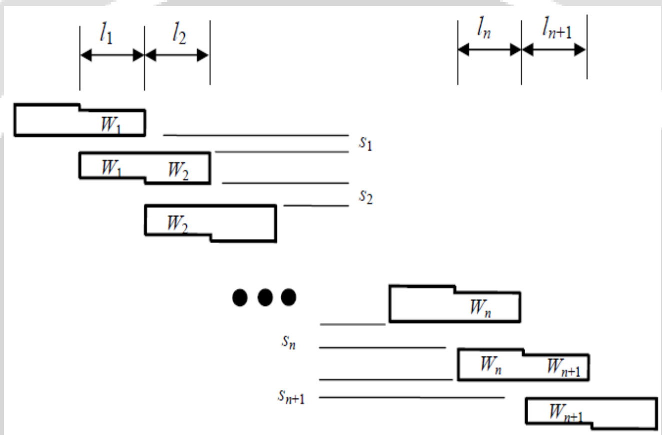

Fig- 2: Parallel Coupled Bandpass Filter

3. FILTER REALIZATION WITH MICROSTRIP TECHNOLOGY

Microstrip transmission line is used for transport of wave with relative low frequency; the wave type propagating in this transmission line is a quasi-TEM wave. This is the fundamental mode in the microstrip transmission line. It has two propagation factors, even mode and odd mode. Fig.2 shows the filter structure observed in this work. This filter type is known as parallel-coupled filter. The strips are arranged parallel close to each other, so that they are coupled with certain coupling factors. We use the following equations for designing the parallel-coupled filter

For first coupling

$$Z_0 J_1 = \sqrt{\frac{\pi\Delta}{2g_1}} \qquad \text{.......................... (1)}$$

For intermediate coupling

$$Z_0 J_n = \frac{\pi\Delta}{2\sqrt{g_{n-1} g_n}} \qquad \text{.......................... (2)}$$

For final coupling

$$Z_0 J_{n+1} = \sqrt{\frac{\Delta\pi}{2g_n g_{n+1}}} \qquad \text{.......................... (3)}$$

g0, g1, .., gn can be taken be taken from above, Δ is the relative bandwidth, Jn, Jn+1 is the characteristic admittance of J inverter and Z0 is the characteristic impedance of the connecting transmission line.

With the data of characteristic admittance of the inverter, we can calculate the characteristic impedances of even-mode and odd-mode of the parallel-coupled microstrip transmission line. The characteristic impedance of these coupled lines can be specified in terms of even (Z0e) and odd (Z0o) impedances.Even impedance is defined as the characteristic impedance of one line to ground when equal currents are flowing in the two lines. Odd impedance is defined as the characteristic impedance of one line to ground when equal and opposite currents is flowing in the two lines. The odd and even impedances are calculated by the following equations

$$Z_{Oe} = Z_0[Z_0 + JZ_0 + (JZ_0)^2] \quad \text{.............. (4)}$$

$$Z_{Oo} = Z_0[Z_0 - JZ_0 + (JZ_0)^2] \quad \text{............... (5)}$$

4. FILTER DESIGN AT 3.4 GHZ

Even and odd impedances has been calculated for five stages given in below table.

Table-1: Calculated value J, Even mode and Odd mode Impedance

Stage	Even Impedance(Ω)	Odd Impedance(Ω)
1	92.62	36.82
2	77.39	41.61
3	69.89	45.33
4	62.50	45.33
5	66.066	41.61
6	91.71	37.58

Now from above data, the design of bandpass filter in ADS software is given below.

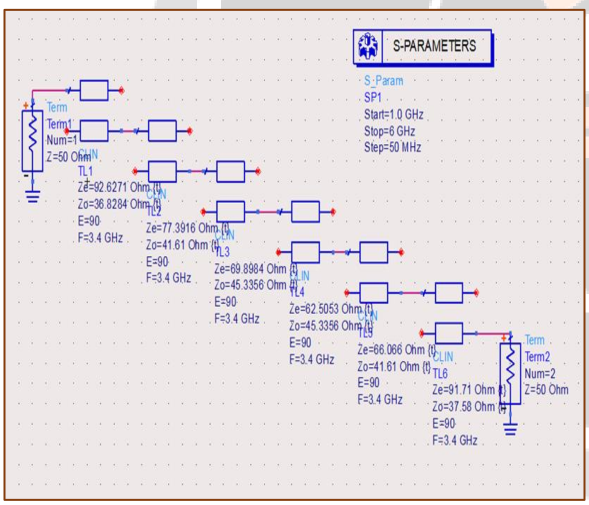

Fig-3: Bandpass filter at 3.4 GHz in ADS

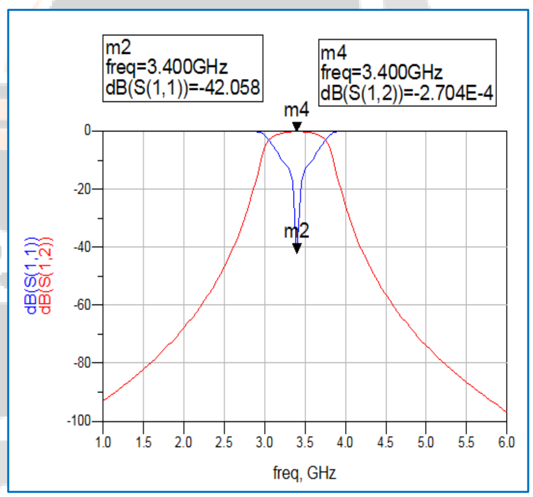

Fig-4: Output of filter at 3.4 GHz

The output of bandpass filter at 3.4 Ghz is given below.

From above graph, we obtain insertation loss aroun -2.704E^{-4} dB and return loss is -42.058 dB.

The length of each stage is chosen to be ʎ g (ʎ g is the guided wavelength), which corresponds to an electric length (Eeff) of 900.Using Line Calc tool in ADS, the dimension of the microstrip line viz. length (L), width (W) and gap(S) between each other are calculated for the given odd and even impedances. The width, gap and length of each stage of the MCLIN (Microstrip Coupled-Line Filter Section) are derived, as illustrated in Table.

Table-2: Calculaed Dimension of transmission line Section

Stage	W(mm)	S(mm)	L(mm)
1	1.18	0.20	12.02
2	1.98	0.46	12.09
3	2.53	0.96	12.07
4	1.80	1.45	12.06
5	3.56	0.08	11.94
6	1.51	0.17	12.58

From the data given in above table, the design in ADS is given below.

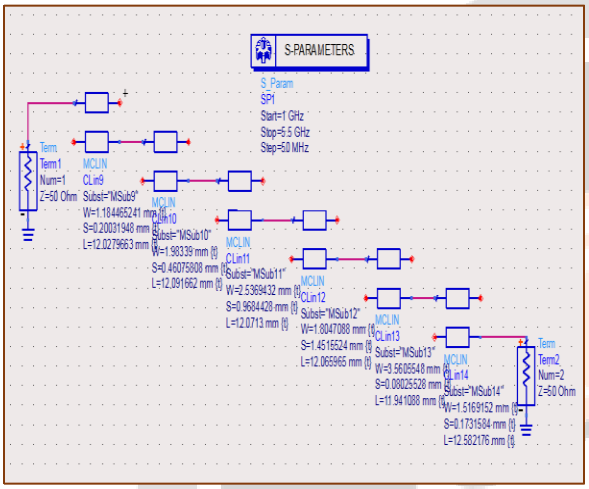

Fig-5: Bandpass filter at 3.4 GHz after

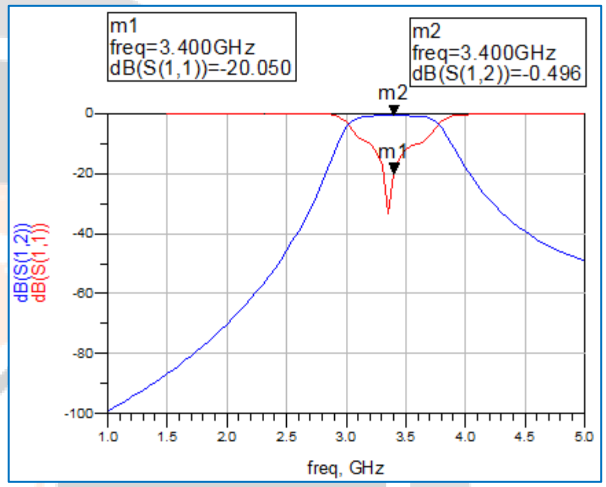

Fig-6: Output of filter at 3.4 GHz after Optimization

From above graph, we obtain insertion loss aroun -0.496 dB and return loss is -20.050 dB.

5. FILTER DESIGN AT 6.7 GHZ

Even and odd impedances has been calculated for five stages given in below table.

Table-3: Calculated value of J, Evan and Odd Impedance

Stage	Even Impedance(Ω)	Odd Impedance(Ω)
1	93.77	33.42
2	74.10	33.16
3	65.34	36.28
4	64.89	36.83
5	64.89	36.83
6	63.30	39.87
7	66.50	33.16
8	103.78	40.18

Now from above data, the design of bandpass filter in ADS software is given below.

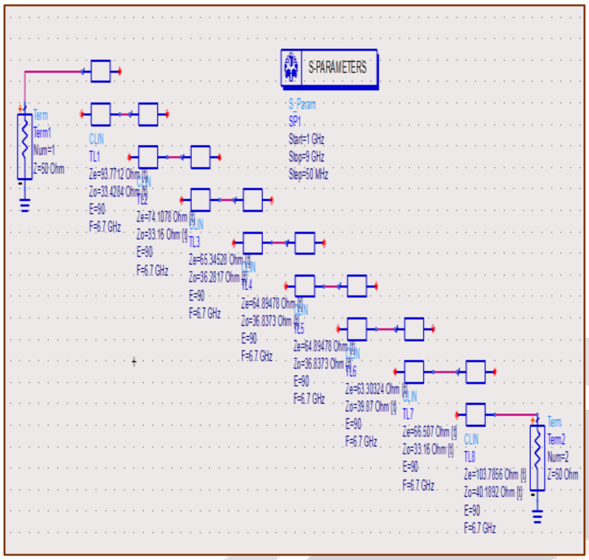

Fig-7: Bandpass filter at 6.7 GHz

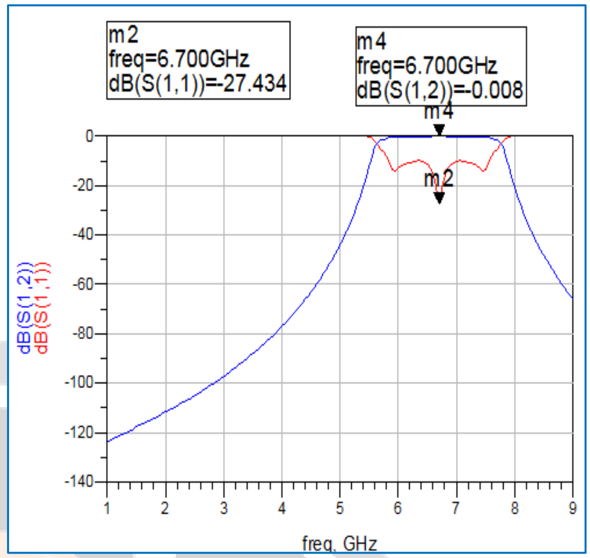

Fig-8: Output of filter at 6.7 GHz

From above graph, we obtain insertation loss around -0.008 dB and return loss is -27.434 dB.

The length of each stage is chosen to be ʎ g (ʎ g is the guided wavelength), which corresponds to an electric length (Eeff) of 900.Using Line Calc tool in ADS, the dimension of the microstrip line viz. length (L), width (W) and gap(S) between each other are calculated for the given odd and even impedances. The width, gap and length of each stage of the MCLIN (Microstrip Coupled-Line Filter Section) are derived, as illustrated in Table.

Table-4: Calculated Dimension of Transmission Line Section

Stage	W(mm)	S(mm)	L(mm)
1	1.66	0.14	5.86
2	2.34	0.22	6.14
3	2.73	0.48	6.02
4	2.74	0.53	6.01
5	2.74	0.53	6.01
6	2.74	0.82	5.98
7	2.73	0.30	6.06
8	1.31	0.24	5.70

From the data given in above table, the design in ADS is given below.

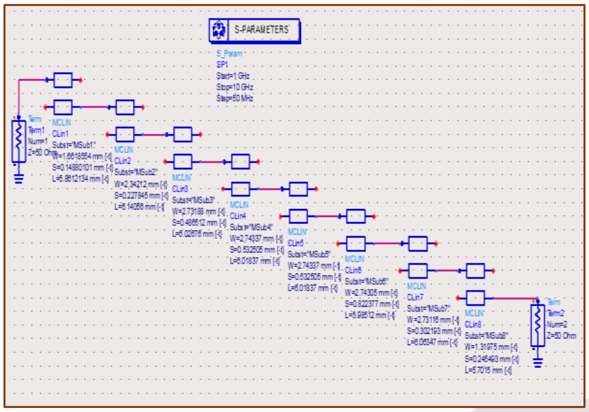

Fig-9: Bandpass filter at 6.7 GHz after Optimization

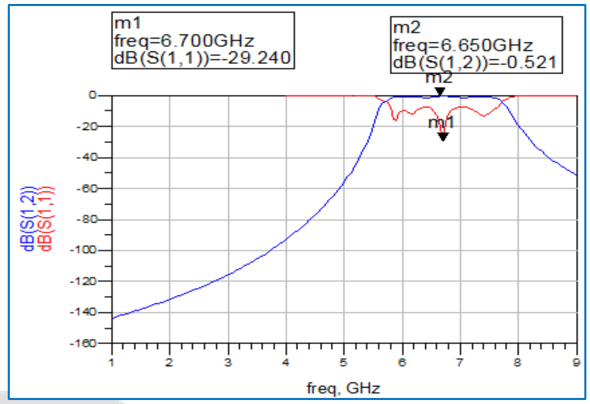

Fig-10: Output of filter at 6.7 GHz after Optimization

From above graph, we obtain insertation loss around -0.521 dB and return loss is -29.24 dB.

6. COMBINATION OF TWO BANDPASS FILTER (DIPLEXER DESIGN)

There are many option to combine the filters in diplexer like power divider, coupler and T-junction. I will combine my two filters using power divider because using power divider it is easy to combine two filters and it provide good results in simulation.
In ADS software power divider module is available using this module I will combine my filters.

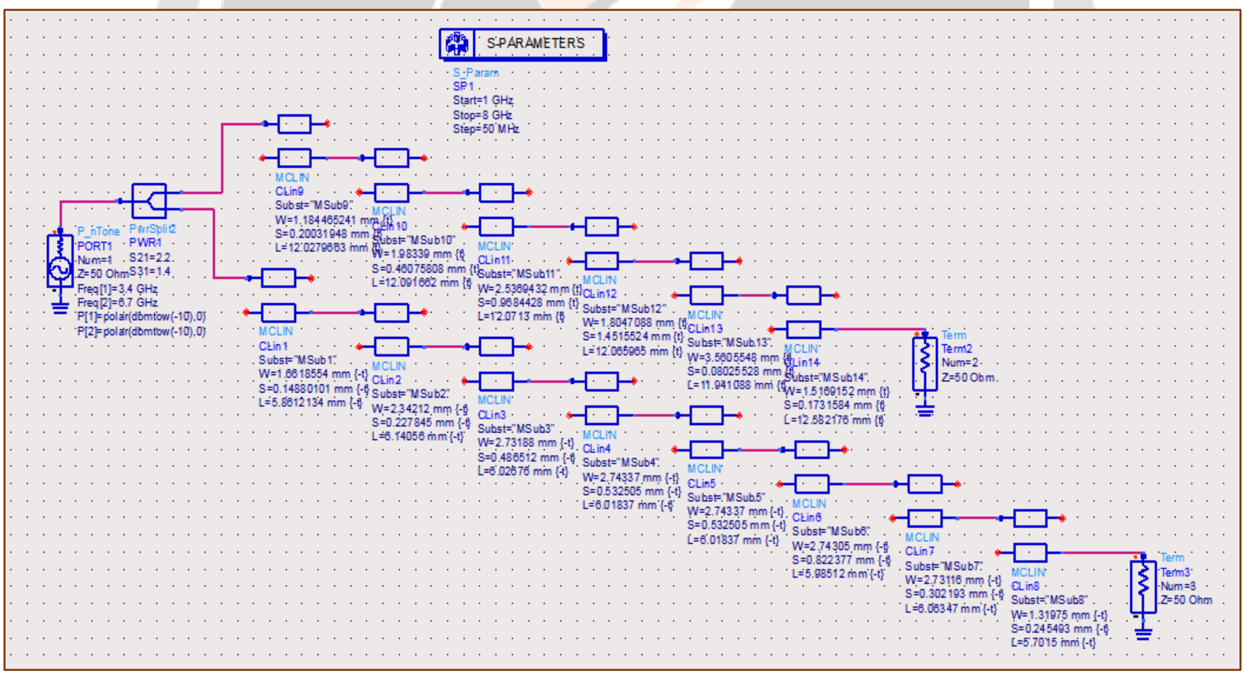

Fig-11: Diplexer Design

After combination of filter output of diplexer that is insertion loss and isolation is given below.

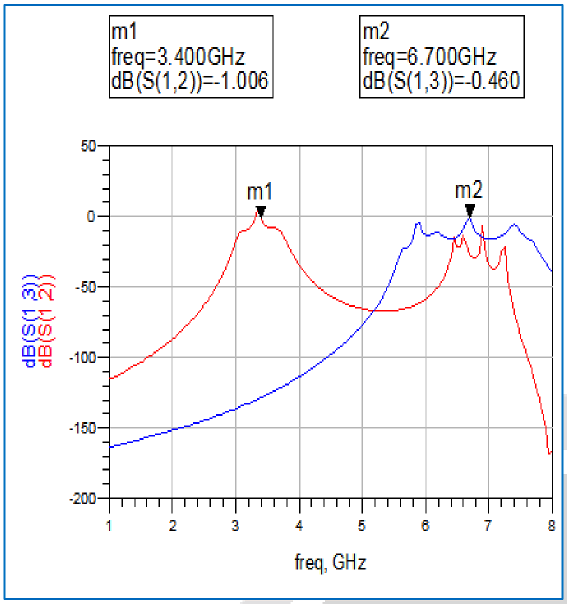

Fig-12: Insertion loss of Diplexer

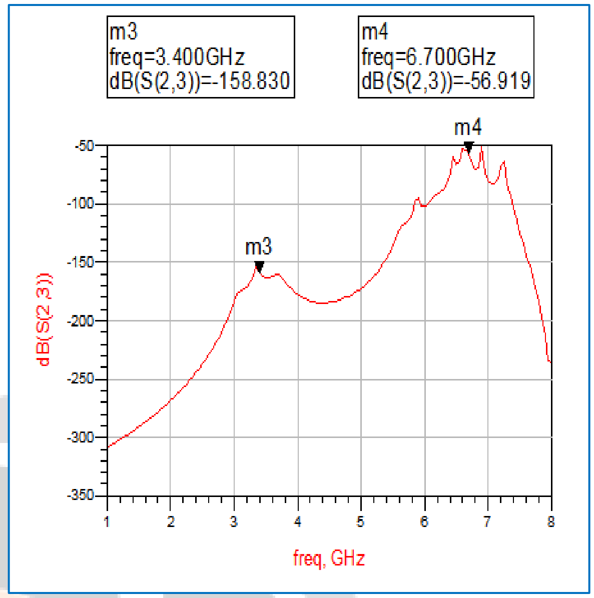

Fig-13: Return loss of Diplexer

7. CONCLUSION

By using chebyshev approach, designing of bandpass filter using distributed component i.e. microstrip coupled line (MCLIN) using Advance Design software provide very good filter characteristics at the center frequency 3.4 GHz and 6.7 GHz.At the both the center frequency input return loss S_{11} and output return loss S_{22} are greater than -18 dB and insretion loss S_{12} for both frequency band is less than -0.5 dB. In both filter design, outputs are matched with my targeted specification. Once filters are designed than I have combined my filter using power divider. After combining filter using power divider, we get insertion loss -1.006 and -0.460 at the center frequency of 3.4 GHz and 6.7 GHz respectively and isolation is around -100 dB.

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