A DISSERTATION ON

DESIGN OF SUB-MILLIMETER DIPLEXER USING MICROSTRIP LINES

Submitted towards the Partial Fulfilment of the Requirement for the

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CERTIFICATE

This is to certify that the dissertation title ***“Design of Sub-millimeter diplexer using microstrip lines”***is the authentic work of **Mr. Anuj Kakkar** under my guidance and supervision in the partial fulfillment of requirement towards the degree of Master of Technology in ***Microwave and Optical Communication***, jointly run by the Department of Electronics and Communication Engineering and Department of Applied Physics at ***Delhi Technological University, New Delhi.*** To thebestofmyknowledge,thematterembodiedinthethesishasnotbeensubmittedto any other University/Institutefor the award ofanyother degree.

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DECLARATION

I hereby declare that all the information in these documents has been obtained and presented in accordance with academic rules and ethical conduct. It is being submitted for the degree of Master of Technology in Microwave and Optical Communication at Delhi Technological University. It has not been submitted before for any degree or examination in any other university.

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With all praises to the almighty and by His blessings I have finally completed this thesis.

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ABSTRACT

As we know that, instrumentation in millimetre and sub-millimetre astrophysics requires high value of spectral resolution. This problem can be overcome by means of multi-frequency detector array. In this project, sub-millimetre diplexer is designed using microstrip lines since microstrip lines can be printed directly onto a circuit board and have low cost and are easily fabricated. A diplexer, is an essential component in multi-service and multi-band communication systems, is a three terminal device that separates the input signals to two output ports. Diplexing is used to prevent inter modulation and keep reflected power (VSWR) to a minimum for each input transmitter and frequency. While diplexers can combine a relatively wide bandwidth, the major limitation comes with the antenna itself, which must be sufficiently wideband to accept all of the signals being passed through it, and transfer them to the air efficiently. We designed a sub-millimetre diplexer using microstrip lines which operates at frequency 150 GHz & 220 GHz. With the help of S parameters, we can see that theour diplexer gives good transmission at 150 GHz and 220 GHz, and also it provides good attenuation at non-required frequencies.

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INTRODUCTION

1.1 Brief Technical Overview

For Cosmic Microwave Background (CMB) studies, we generally requires high spectral resolution. A classical solution to this requirement consists in defining photometric bands with an appropriate optical filtering scheme, but it presents the disadvantage of higher surface consuming of the available focal plane. This problem can be overcome by means of multi-frequency detector array, using antenna-coupled bolometers and thus allowing to separate the pixel design from the detector itself. Diplexers are also used at medium wave broadcasting stations. However their use is not that common in this frequency range because the corresponding wavelength varies much more across the medium wave band than across the FM band and so it is more practicable to use a separate antenna for each frequency: medium wave transmission sites usually broadcast only on one to four frequencies, while FM-broadcasting sites often uses four and more frequencies.

1.2 Report Organization

The thesis report is divided into five chapters

Chapter 1: presents introduction to the brief technical overview and how the report is organized.
Chapter 2: presents the literature review of this project.
Chapter 3: describes the component used in diplexer design. It contains detail information of component used and their mathematical formulation.
Chapter 4: presents the simulation analysis and summarizes detailed results of simulation.
The Final chapter of the thesis (Chapter 5) presents the conclusions and future aspects of this project. The significance and contribution of present work is summarized.

CHAPTER-2

LITERATURE REVIEW

In this Chapter, we review several basic but important concepts that are necessary to understand the concepts of this report. Several previous works are discussed here which are necessary to understand the goal of this report. Also, it gives the importance of the work done here.

2.1 Literature Review

Modern wireless communication systems demand RF devices operating in multiple frequency bands. A diplexer, is an essential component in multi-service and multi-band communication systems, is a three terminal device that separates the input signals to two output ports. A well designed diplexer should have low cost and high performance. Now-a-days, Instrumentation in millimeter and sub-millimeter astrophysics, in particular for Cosmic Microwave Background (CMB) studies, requires increasing spectral resolution[1].
The design of a diplexer, coupled to a planar bowtie antenna for two-band Cosmic Microwave Background detection is proposed, using both HFSS and ADS softwares.

The two photometric bands are centered on 150 GHz and 220 GHz respectively. The diplexer is composed of two three-element distributed filtering circuits, taking into account the complex impedance of the antenna and the impedance of the two resistive loading bolometers. The distributed elements are transmission lines Coplanar Strip Lines (CPS) and Broadside Coupled Lines (BCL). Their balanced geometry matches to the differential signal delivered by the bow-tie antenna, avoiding the addition of abalun circuit. The envisaged technology for strips and antenna is superconducting niobium at a few 100mK on Si substrate. The overall size of the antenna/diplexer structure is around 2 mm^2, allowing to consider it as a pixel suitable for integration in a bolometer array.
SAMBA uses antenna coupled bolometers and microstrip filters. The concept allows for a much more compact, multiband imager compared to a comparable feed horn-coupled

bolometric system. SAMBA incorporates an array of slot antennas, superconducting transmission lines, a wide band multiplexer and superconducting transition edge bolometers. The transition-edge film measures the millimeter-wave power deposited in the resistor that terminates the transmission line[2].

Several methods have been originated for the fabrication of array. In the array fabrication process [6], the antenna is entirely deposited on a thin silicon substrate covered by a 1μm silicon nitride. In order to avoid some power loss due to surface waves in the substrates, we have to use a substrate thinner than λ/ε1/2 for the shortest wavelength. The high dielectric constant of the silicon substrates (ε=11.9) requires to use a thickness less than 80 μm. In reference [7], microstrip lines with niobium on silicon dioxide dielectric have revealed very low-loss behavior up to 700 GHz.

CHAPTER-3

DESCRIPTION OF COMPONENTS

3.1 MICROSTRIP LINES

Microstrip is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave-frequency signals. It consists of a conducting strip separated from a ground plane by a dielectric layer known as the substrate.

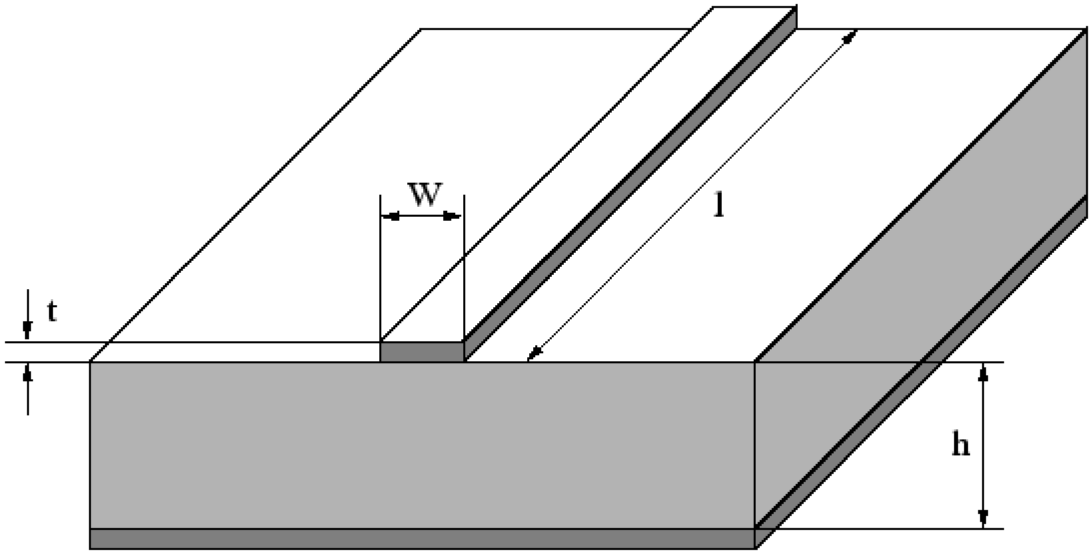


Figure 3.1 : Layout of Microstrip Line

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated.

Consider the microstrip antenna shown in Figure above, fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length *l*, width *W*, and sitting on top of a substrate (some dielectric circuit board) of thickness *h*. The thickness of the ground plane or of the microstrip is not critically important. Typically the height *h* is much smaller than the wavelength of operation, but not much smaller than 0.05 of a wavelength.

The frequency of operation of the patch antenna of Figure is determined by the length *L*.

$$f = \frac{c}{2l\sqrt{\in}}$$

3.1.1 Characteristic Impedance

The characteristic impedance Z_0 of microstrip is a function of the ratio of the height to the width (and the ratio of width to height) of the transmission line, and also has separate solutions depending on the value of W/H

When $(\frac{W}{\mathrm{H}}) \leq 1$

$$\mathrm{Z} = \frac{60}{\varepsilon} \ln\left(8\frac{\mathrm{W}}{\mathrm{H}} + 0.25\frac{\mathrm{W}}{\mathrm{H}}\right)$$

3.1.2 Feeding

Feeding techniques are important in designing the antenna to make antenna structure so that it can operate at full power of transmission. Designing the feeding techniques for high frequency, need more difficult process. This is because the input loss of feeding increases depending on frequency and finally give huge effect on overall design.

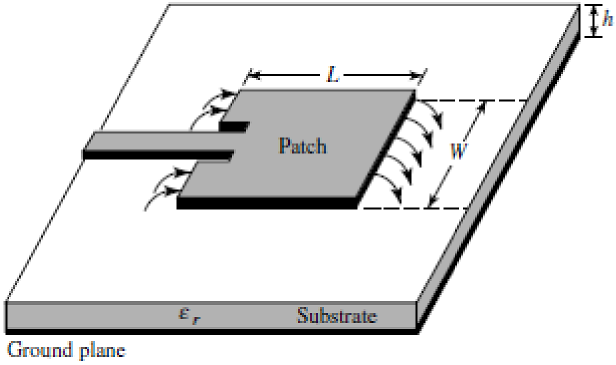


Figure 3.2: Microstrip Line Feeding

It has more substrate thickness i.e. directly proportional to the surface wave. Radiation bandwidth limit is 2-5%.It is easy to fabricate and model. Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.

3.2 POWER DIVIDERS

Power dividers (also power splitters and, when used in reverse, power combiners) and directional couplers are passive devices used in the field of radio technology. They couple a defined amount of the electromagnetic power in a transmission line to a port enabling the signal to be used in another circuit. An essential feature of directional couplers is that they only couple power flowing in one direction. Power entering the output port is coupled to the isolated port but not to the coupled port.

Directional couplers are most frequently constructed from two coupled transmission lines set close enough together such that energy passing through one is coupled to the other. This technique is favoured at the microwave frequencies the devices are commonly employed with. However, lumped component devices are also possible at lower frequencies. Also at microwave frequencies, particularly the higher bands, waveguide designs can be used. Many of these waveguide couplers correspond to one of the conducting transmission line designs, but there are also types that are unique to waveguide.

Directional couplers and power dividers have many applications, these include; providing a signal sample for measurement or monitoring, feedback, combining feeds to and from antennae, antenna beam forming, providing taps for cable distributed systems such as cable TV, and separating transmitted and received signals on telephone lines.

The most common form of directional coupler is a pair of coupled transmission lines. They can be realised in a number of technologies including coaxial and the planar technologies (stripline and microstrip). An implementation in stripline is shown in figure 4 of a quarter-wavelength (λ/4) directional coupler. The power on the coupled line flows in the opposite direction to the power on the main line, hence the port arrangement is not the same as shown in figure 1, but the numbering remains the same. For this reason it is sometimes called a backward coupler.

The term main line refers to the section between ports 1 and 2 and coupled line to the section between ports 3 and 4. Since the directional coupler is a linear device, the notations on figure 1 are arbitrary. Any port can be the input, (an example is seen in figure 20) which will result in the directly connected port being the transmitted port, the adjacent port being the coupled port, and the diagonal port being the isolated port. On some directional couplers, the main line is designed for high power operation (large connectors), while the coupled port may use a small connector, such as an SMA connector. The internal load power rating may also limit operation on the coupled line.

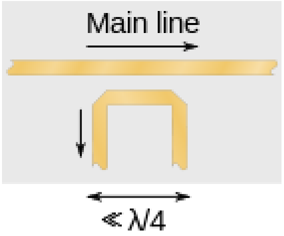


Figure 3.3: Short section directional coupler

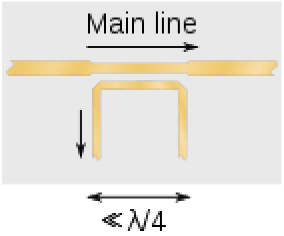


Figure 3,4: Short section directional coupler with 50 Ω main line and 100 Ω coupled line

Accuracy of coupling factor depends on the dimensional tolerances for the spacing of the two coupled lines. For planar printed technologies this comes down to the resolution of the printing process which determines the minimum track width that can be produced and also puts a limit on how close the lines can be placed to each other. This becomes a problem when very tight coupling is required and 3 dB couplers often use a different design. However, tightly coupled lines can be produced in air stripline which also permits manufacture by printed planar technology. In this design the two lines are printed on opposite sides of the dielectric rather than side by side. The coupling of the two lines across their width is much greater than the coupling when they are edge-on to each other.

The λ/4 coupled line design is good for coaxial and stripline implementations but does not work so well in the now popular microstrip format, although designs do exist. The reason for this is that microstrip is not a homogeneous medium – there are two different mediums above and below the transmission strip. This leads to transmission modes other than the usual TEM mode found in conductive circuits. The propagation velocities of even and odd modes are different leading to signal dispersion. A better solution for microstrip is a coupled line much shorter than λ/4, shown in figure 5, but this has the disadvantage of a coupling factor which rises noticeably with frequency. A variation of this design sometimes encountered has the coupled line a higher impedance than the main line such as shown in figure 6. This design is advantageous where the coupler is being fed to a detector for power monitoring. The higher impedance line results in a higher RF voltage for a given main line power making the work of the detector diode easier.

The frequency range specified by manufacturers is that of the coupled line. The main line response is much wider: for instance a coupler specified as 2–4 GHz might have a main line which could operate at 1–5 GHz. As with all distributed element circuits, the coupled response is periodic with frequency. For example, a λ/4 coupled line coupler will have responses at nλ/4 where n is an odd integer.

A single λ/4 coupled section is good for bandwidths of less than an octave. To achieve greater bandwidths multiple λ/4 coupling sections are used. The design of such couplers proceeds in much the same way as the design of distributed element filters. The sections of the coupler are treated as being sections of a filter, and by adjusting the coupling factor of each section the coupled port can be made to have any of the classic filter responses such as maximally flat (Butterworth filter), equal-ripple (Cauer filter), or a specified-ripple Chebychev filter response. Ripple in this context refers to the maximum variation in output of the coupled port in its passband, usually quoted as plus or minus a value in dB from the nominal coupling factor.

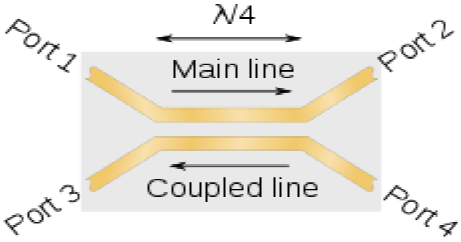


Figure 3.5 : Single Section λ/4 directional coupler

3.3 DIPLEXER

A diplexer is a passive device that implements frequency domain multiplexing. It's a three-port network that splits incoming signals from a common port into two paths (sometimes called "channels"), dependent on frequency. A diplexer is the simplest form of a multiplexer, which can split signals from one common port into many different paths. The incoming signals must be offset in frequency by an appreciable percentage so that filters can do their job sorting them out. Diplexers can use low-pass, high-pass or band-pass filters to achieve the desired result. Two ports (e.g., L and H) are multiplexed onto a third port (e.g., S). The signals on ports L and H occupy disjoint frequency bands. Consequently, the signals on L and H can coexist on port S without interfering with each other.

Typically, the signal on port L will occupy a single low frequency band and the signal on port H will occupy a higher frequency band. In that situation, the diplexer consists of a lowpass filter connecting ports L and S and high pass filter connecting ports H and S. Ideally, all the signal power on port L is transferred to the S port and vice versa. All the signal power on port H is transferred to port S and vice versa. Ideally, the separation of the signals is complete. None of the low band signal is transferred from the S port to the H port. In the real world, some power will be lost, and some signal power will leak to the wrong port. It's a three-port network that splits incoming signals from a common port into two paths (sometimes called "channels"), dependent on frequency. A diplexer is the simplest form of a multiplexer, which can split signals from one common port into many different paths. The incoming signals must be offset in frequency by an appreciable percentage so that filters can do their job sorting them out.

The chief advantage of a diplexer is that it allows two different devices to share a common communications channel. Typically the shared channel is a long piece of coaxial cable. Rather than run two separate cables, a single cable with diplexers at each end is used. The plan is economical if the diplexers cost less than running the second cable.

A diplexer is a device designed to take two signals from two different cables and intelligently put them on the same cable. A diplexer is the right thing to use when trying to add an antenna signal to an existing cable. There are many different kinds of diplexers.

Passive diplexers are little more than combiners. They take two signals that won't interfere with each other and put them on the same cable. Active diplexers add power to the line to limit the amount of loss that happens when signals move through a system. Active diplexers can also shift frequencies so that they work together. When a diplexer does this, the diplexer would also be a modulator.

There are a number of ways of implementing RF diplexers. They all involve the use of filters. In this way the paths for the different transmitters and receivers can be separated according to the frequency they use. The simplest way to implement a diplexer is to use a low pass and a high pass filter although band-pass filters may be used. In this way the diplexer routes all signals at frequencies below the cut-off frequency of the low pass filter to one port, and all signals above the cut-off frequency of the high pass filter to the other port. Also here is no path from between the two remote connections of the filters. All signals that can pass through the low pass filter in the diplexer will not be able to pass through the high pass filter and vice versa.

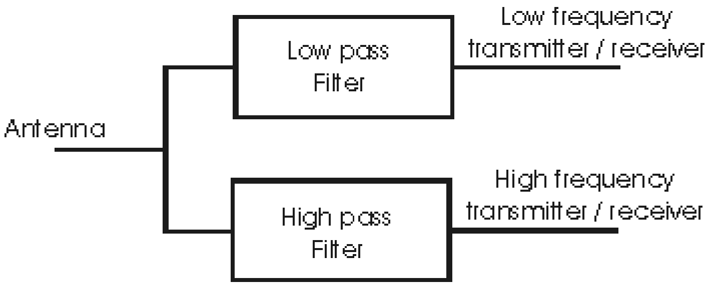


Figure 3.6 Basic concept of a high/low pass diplexer

A further feature of an RF diplexer is than it enables the impedance seen by the receiver or transmitter to remain constant despite the load connected to the other port. If the filters were not present and the three ports wired in parallel, neither the antenna nor the two transmitter / receiver ports would see the correct impedance.

Diplexers might be used to connect two receivers inside a building to two antennas that are some distance away using a single cable. Alternatively, two transmitters might connect to two antennas.

A diplexer may be used as a form of duplexer, which is a device to enable bi-directional (duplex) communication over a single path. In this usage the high and low frequency signals are travelling in opposite directions at the shared port of the diplexer.

Diplexing is used to prevent intermodulation and keep reflected power (VSWR) to a minimum for each input transmitter and frequency. While diplexers can combine a relatively wide bandwidth, the major limitation comes with the antenna itself, which must be sufficiently wideband to accept all of the signals being passed through it, and transfer them to the air efficiently.

One of the most massive diplexers in use is atop the Empire State Building in New York, where over a dozen FM radio stations transmit through one four-panel antenna. Another such setup is on a tower in Miami Gardens, serving the Miami and Fort Lauderdale media market.

Many other large UHF-/VHF-transmitters use diplexers. The number of transmitters which can share an antenna is restricted by the spacing of their frequency bands. Transmitters whose frequencies are too close together cannot be combined successfully by a diplexer.

Diplexers are also used at medium wave broadcasting stations. However their use is not that common in this frequency range because the corresponding wavelength varies much more across the medium wave band than across the FM band and so it is more practicable to use a separate antenna for each frequency: medium wave transmission sites usually broadcast only on one to four frequencies, while FM-broadcasting sites often uses four and more frequencies.

Diplexers may be used as a back-up device. An example is maintenance work at one antenna of a medium wave transmission site that has two antennas transmitting on two frequencies. Then the other antenna can be used for broadcasting both channels. If it is not possible to build a second antenna for the second transmitter due to space constraints, then the diplexer is used permanently.

At long wave broadcasting sites diplexers are normally not used since these stations usually broadcast on only one frequency. A realization of diplexers for long wave broadcasting stations may be difficult, as the ratio of bandwidth (9 kHz) to transmission frequency is high.

Diplexers are not used at VLF transmitters. In this frequency range their realization is very difficult because of the very high voltages that occur in the huge tuned loading coils that are used in the antenna feed.

Diplexers are also used for non-broadcast applications such as amateur radio.

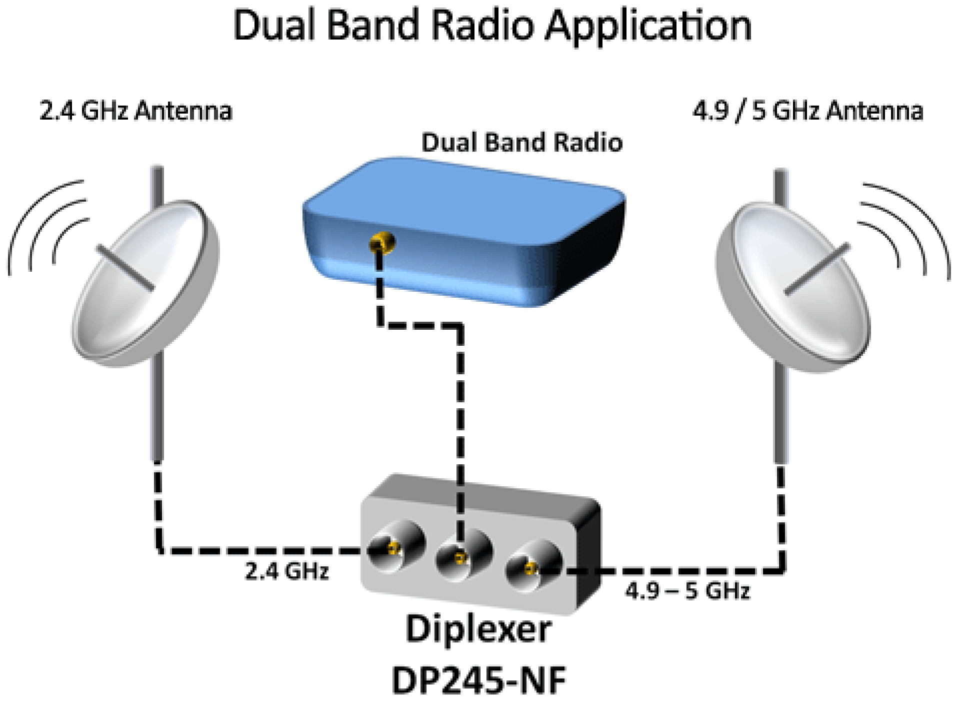


Figure 3.7 Dual band Radio Application

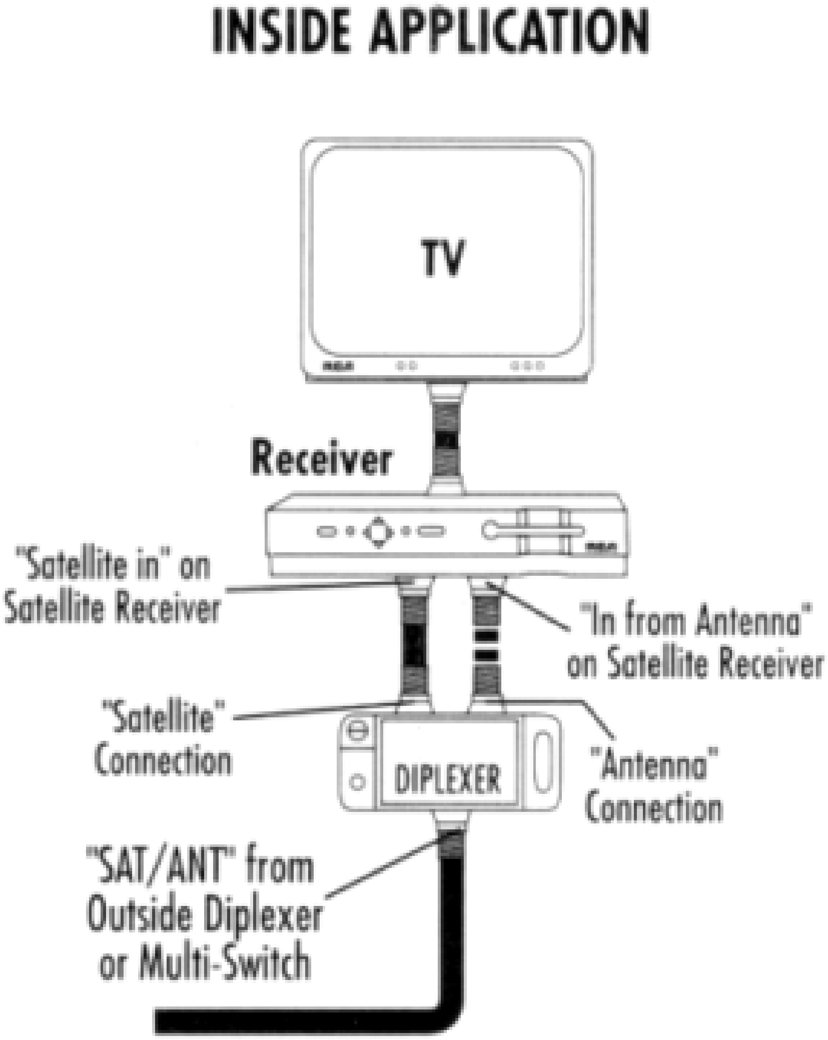


Figure 3.8: Inside application of diplexer

Diplexers are also used in the home to allow a direct broadcast satellite TV dish antenna and a terrestrial TV antenna (local broadcast channels) to share one coaxial cable. The dish antenna occupies the high frequencies (typically 950 to 1450 MHz), and the TV antenna uses lower television channel frequencies (typically 50 to 870 MHz). In addition, the satellite also gets a DC to low frequency band to power the dish's block converter and select the dish antenna polarization (e.g., voltage signaling or DiSEqC). The diplexer is useful in homes that are already wired with one cable, because it eliminates the need to install a second cable. For the diplexer to work, the existing cable must be able to pass the satellite frequencies with little loss. Older TV installations may use a solid dielectric RG-59 cable, and that cable may be inadequate. RG-6 cable is typically used for satellite feed lines.

In this application, there would be a diplexer on the roof that joins the satellite dish feed and the TV antenna together into a single coaxial cable. That cable would then run from the roof into the house. At a convenient point, a second diplexer would split the two signals apart; one signal would go to the TV set and the other to the IRD of the DBS set-top box. These usually have an antenna input and a diplexer, so that the antenna signal is also distributed along with the satellite.

More modern installations confront several issues. There are often multiple satellite dishes that need to feed several receivers or even multichannel receivers. See, for example, single cable distribution.

Diplexers were also used to combine UHF TV and VHF TV and FM signals onto one downlead, which can then be split back into its component parts as required.

3.4 INFINITELY BOW TIE ANTENNA

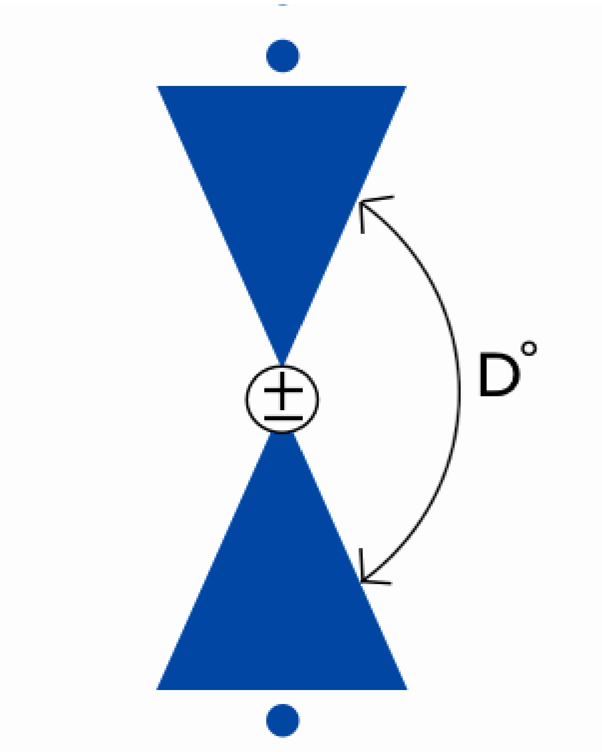


Figure 3.9: Infinitely Bow Tie Antenna

In Figure 3.4 , we have an antenna that is specified solely by the angle between the two metal pieces, *D*. The antenna feed (where the radio positive and negative terminals connect to the antenna) is at the center of the antenna. Our antenna here is infinitely long in both directions, so that wavelength never comes into the equation. As a result, this antenna would theoretically have an infinite bandwidth, because if it works at one frequency (any frequency), it must work at *ALL* frequencies, because the antenna looks the same at all wavelengths.

A bow-tie antenna has much better bandwidth than a thin-wire dipole antenna. In general, antennas with more volume have wider bandwidth. More radiation modes can fit on the structure when the current is less constrained. This antenna is easy to construct, it is very popular for this reason.

3.5 TRANSMISSION LINE MODEL

Transmission Line is a closed system in which power is transmitted from a source to a destination as shown in figure . Coaxial cable, waveguide, or other system of conductors that transfers electrical signals from one location to another, are examples of transmission line.

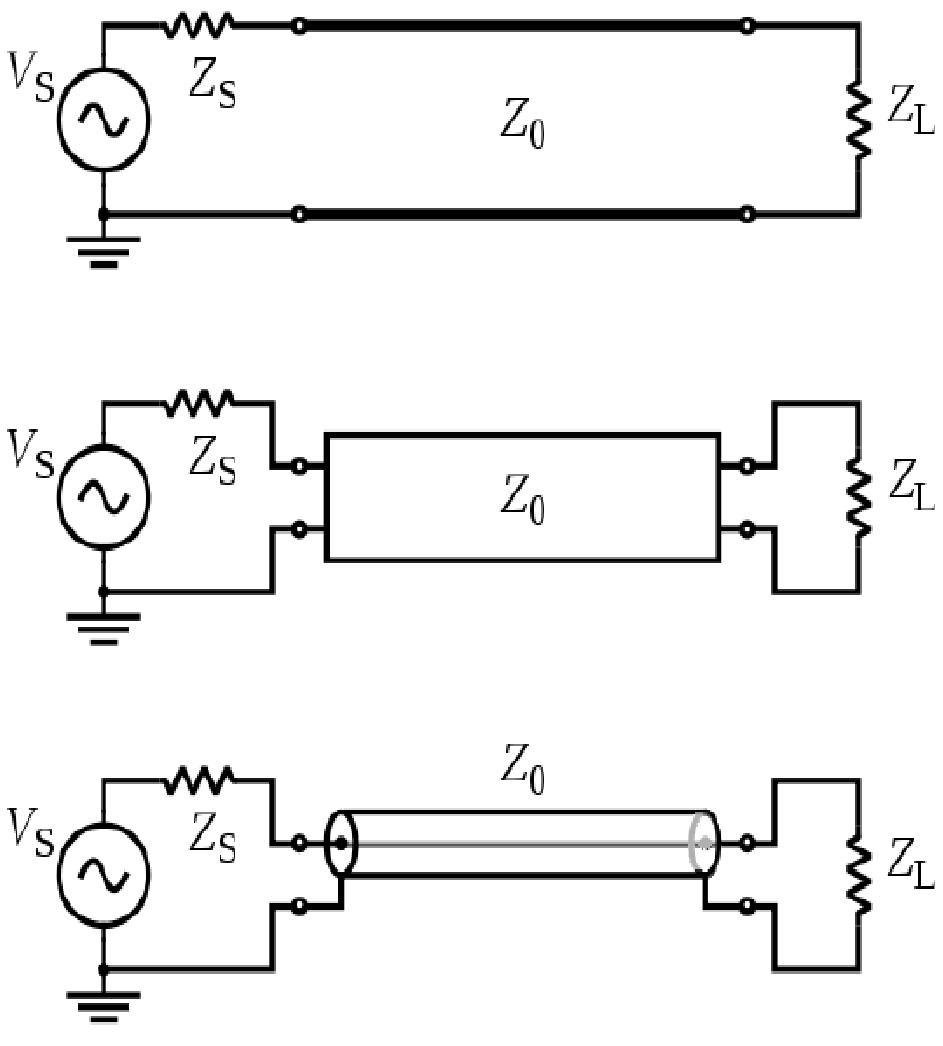


Figure 3.10: Transmission Line's elementary components

For the purposes of analysis, an electrical transmission line can be modelled as a two-port network (also called a quadrupole network), as follows:

Fig 3.11: Transmission Line

In the simplest case, the network is assumed to be linear (i.e. the complex voltage across either port is proportional to the complex current flowing into it when there are no reflections), and the two ports are assumed to be interchangeable. If the transmission line is uniform along its length, then its behaviour is largely described by a single parameter called the characteristic impedance, symbol Z_0. This is the ratio of the complex voltage of a given wave to the complex current of the same wave at any point on the line. Typical values of Z_0 are 50 or 75 ohms for a coaxial cable, about 100 ohms for a twisted pair of wires, and about 300 ohms for a common type of untwisted pair used in radio transmission.

When sending power down a transmission line, it is usually desirable that as much power as possible will be absorbed by the load and as little as possible will be reflected back to the source. This can be ensured by making the load impedance equal to Z_0, in which case the transmission line is said to be matched.

The Voltage and current phasors on the line are related by the characteristic impedance as:

$$\frac{V^+}{I^+} = Z_0 = -\frac{V^-}{I^-}$$

Some of the power that is fed into a transmission line is lost because of its resistance. This effect is called ohmic or resistive loss (see ohmic heating). At high frequencies, another effect called dielectric loss becomes significant, adding to the losses caused by resistance. Dielectric loss is caused when the insulating material inside the transmission line absorbs energy from the alternating electric field and converts it to heat (see dielectric heating). The transmission line is modeled with a resistance (R) and inductance (L) in series with a capacitance (C) and conductance (G) in parallel. The resistance and conductance contribute to the loss in a transmission line. The total loss of power in a transmission line is often specified in decibels per metre (dB/m), and usually depends on the frequency of the signal. The manufacturer often supplies a chart showing the loss in dB/m at a range of frequencies. A loss of 3 dB corresponds approximately to a halving of the power.

3.6 TELEGRAPHER'S EQUATIONS

The telegrapher's equations (or just telegraph equations) are a pair of coupled, linear differential equations that describe the voltage and current on an electrical transmission line with distance and time. The equations come from Oliver Heaviside who in the 1880s developed the transmission line model. The model demonstrates that the electromagnetic waves can be reflected on the wire, and that wave patterns can appear along the line. The theory applies to transmission lines of all frequencies including high-frequency transmission lines (such as telegraph wires and radio frequency conductors), audio frequency (such as telephone lines), low frequency (such as power lines) and direct current.

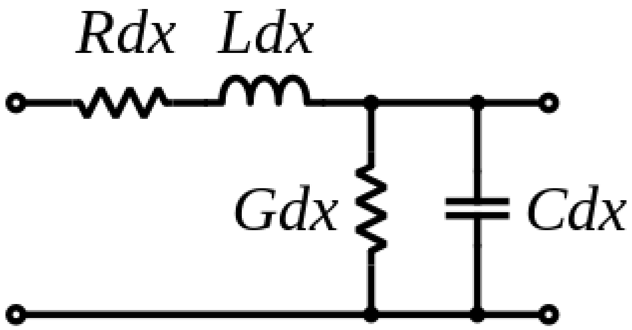


Figure 3.12: Schematic representation of elementary components of a transmission line

The telegrapher's equations, like all other equations describing electrical phenomena, result from Maxwell's equations. In a more practical approach, one assumes that the conductors are composed of an infinite series of two-port elementary components, each representing an infinitesimally short segment of the transmission line:

- The distributed resistance R of the conductors is represented by a series resistor (expressed in ohms per unit length).

- The distributed inductance L (due to the magnetic field around the wires, self-inductance, etc.) is represented by a series inductor (henries per unit length).
- The capacitance C between the two conductors is represented by a shunt capacitor C (farads per unit length).
- The conductance G of the dielectric material separating the two conductors is represented by a shunt resistor between the signal wire and the return wire (siemens per unit length).

The model consists of an infinite series of the infinitesimal elements shown in the figure, and that the values of the components are specified per unit length so the picture of the component can be misleading. These quantities can also be known as the primary line constants to distinguish from the secondary line constants derived from them, these being the characteristic impedance, the propagation constant, attenuation constant and phase constant. All these constants are constant with respect to time, voltage and current.

The line voltage V(x) and the current I(x) can be expressed in the frequency domain as

$$\frac{\partial V(x)}{\partial x} = -(R+j\omega L)I(x)$$

$$\frac{\partial I(X)}{\partial x} = -(G + j\omega C)V(x)$$

When the elements R and G are negligibly small the transmission line is considered as a lossless structure. In this hypothetical case, the model depends only on the Land C which greatly simplifies the analysis. For a lossless transmission line, the second order steady-state Telegrapher's equations are:

$$\frac{\partial^2 V(x)}{\partial x^2} + \omega^2 LC.V(x) = 0$$

$$\frac{\partial^2 I(x)}{\partial x^2} + \omega^2 LC.I(x) = 0$$

These are wave equations which have plane waves with equal propagation speed in the forward and reverse directions as solutions. The physical significance of this is that electromagnetic waves propagate down transmission lines and in general, there is a reflected component that interferes with the original signal. These equations are fundamental to transmission line theory.

If R and G are not neglected , the Telegrapher's equations become:

$$\frac{\partial^2 V(x)}{\partial x^2} = \gamma^2 V(x)$$

$$\frac{\partial^2 I(x)}{\partial x^2} = \gamma^2 I(x)$$

Where

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

And the characteristic impedance is:

$$Z_0 = \sqrt{\frac{(R+j\omega L}{(G+j\omega C)}}$$

The Solutions for V(x) and I(x) are:

$$\mathrm{V(x)} = V^+e^{-\gamma x} + V^-e^{+\gamma x}$$

$$I(x) = \frac{1}{Z}(V^+e^{-\gamma x} - V^-e^{+\gamma x})$$

3.7 LC CIRCUITS

LC circuits use inductors and capacitors (through always there is some extra resistance in circuit which affects the operation). These components are connected in series or parallel with each other; the resulting circuits are called series resonant and parallel resonant circuits, respectively.

The word resonant is used because these circuits respond to particular frequencies, much like the strings on a violin or guitar .For the reason; they are also often called as tuned circuits.

3.7.1 QUALITY FACTOR

Q is defined in terms of the ratio of the energy stored in the resonator to the energy supplied by a generator, per cycle, to keep signal amplitude constant, at a frequency (the resonant frequency), f_r, where the stored energy is constant with time:

$Q = 2\pi$. Energy stored/Energy dissipated per cycle

The factor 2π makes Q expressible in simpler terms, involving only the coefficients of the second-order differential equation describing most resonant systems, electrical or mechanical. In electrical systems, the stored energy is the sum of energies stored in lossless inductors and capacitors; the lost energy is the sum of the energies dissipated in resistors per cycle. In mechanical systems, the stored energy is the maximum possible stored energy, or the total energy, i.e. the sum of the potential and kinetic energies at some point in time; the lost energy is the work done by an external conservative force, per cycle, to maintain amplitude.

3.7.2 PARALLEL RESONANCE

Circuit diagram and frequency response of parallel resonant are shown below.

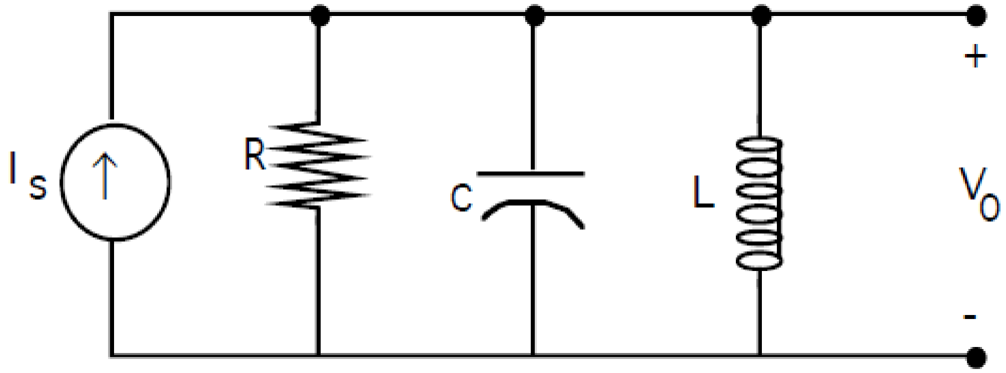


Figure 3.13: Parallel Resonance Circuit

$$w = \frac{1}{\sqrt{LC}}$$

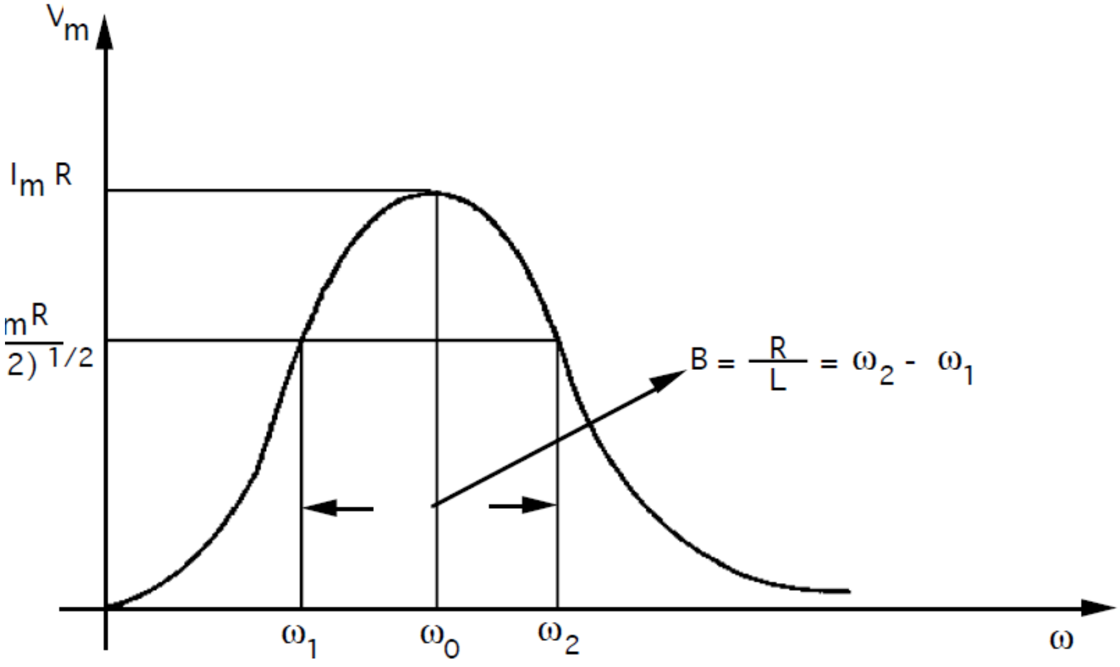


Figure 3.7.3: Diagram of parallel Resonance circuit

3.7.3 SERIES RESONANCE

Circuit diagram and frequency response of series resonant are shown below

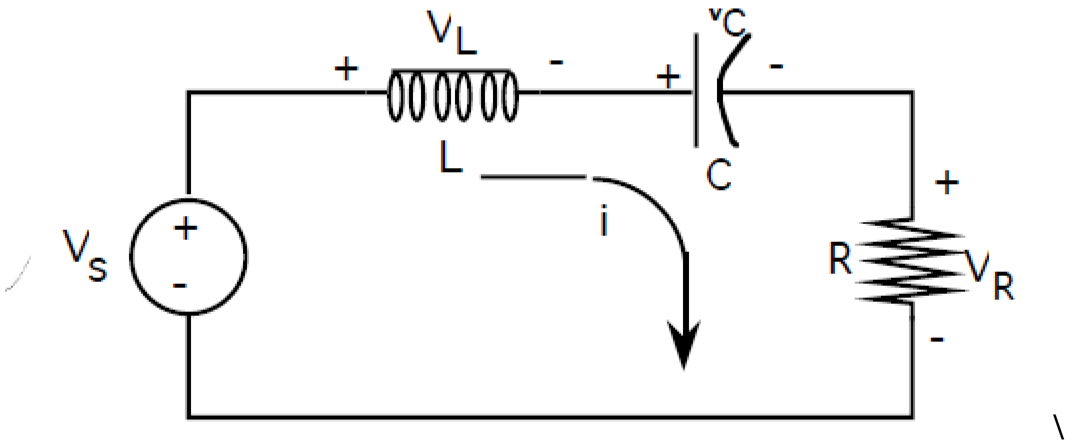


Figure 3.15: Series Resonance circuit

Resonance frequency, $\omega = \frac{1}{\sqrt{LC}}$

The bandwidth of the series circuit is defined as the range of frequencies in which the amplitude of the current is equal to or greater than $(1/\sqrt{2} = \sqrt{2}/2)$ times its maximum amplitude

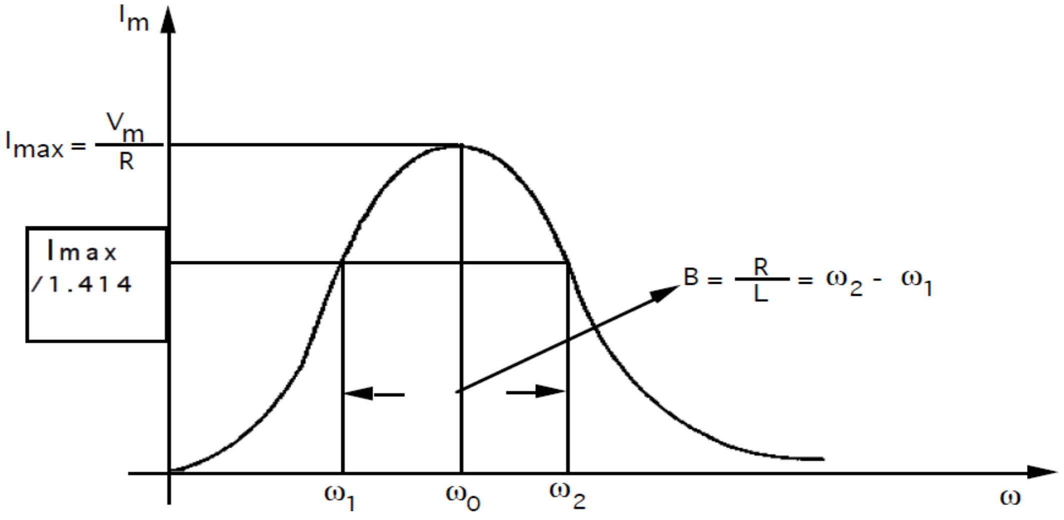


Figure 3.16: Diagram of series resonance circuit

3.8 S PARAMETERS

Scattering Parameters also known as S-Parameters, are the reflection and transmission descriptors between the incident and reflection waves, which for a two port system is given by:

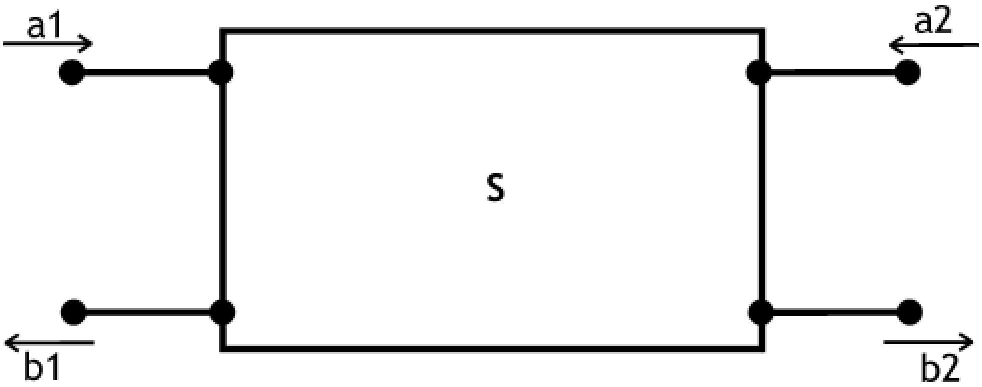


Figure 3.17: S parameters

S_{11}: reflection coefficient on the input with 50W terminated output. a1 and b1 represents electric fields. The ratio between these two electric fields results in a reflection coefficient.

$$S_{11} = \frac{b_1}{a_1}, a_2 = 0$$

S_{21}: forward transmission coefficient of 50W terminated output.

$$S_{21} = \frac{b_2}{a_1}, a_2 = 0$$

S_{12}: reverse transmission coefficient of 50W terminated input.

$$S_{12} = \frac{b_1}{a_2}, a_1 = 0$$

S_{22}: reflection coefficient on the output with 50W terminated input.

$$\mathrm{S}_{22} = \frac{\mathrm{b}_2}{\mathrm{a}_2}, \mathrm{a}_1 = 0$$

To measure S11 we inject a signal at port 1 with port two terminated with an impedance matched to the characteristic impedance of the transmission line (a2=0), and measure its reflected signal. No signal was injected into port 2 so we consider a2 = 0.

To measure S21 we inject a signal at port 1, terminate port 2 and measure the resulting signal exiting on port 2.

To measure S12 we inject a signal at port 2, terminate port 1 and measure the resulting signal on port 1.

To measure S22 we inject a signal at port 2, terminate port 1 and measure its reflected signal.

All the S-Parameter measurements are made with only one signal injected in one port at atime, the other port being terminated with a matched impedance.

CHAPTER-4

DESIGN, SIMULATION & RESULTS

4.1 INTRODUCTION

The following chapter illustrates the ADS simulation of Sub-millimeter diplexer design using Microstrip Line.

4.2 DESIGN

Microstrip Substate properties:

Substrate thickness= 15 mil

Relative dielectric constant=2.2

Microstrip Line properties:

MLIN1 length = 0.717 mil

MLIN1 width = 0.267 mil

MLIN2 length = 0.721 mil

MLIN2 width = 5.452 mil

MLIN4 length = 0.335 mil

MLIN4 width = 0.538 mil

MLIN5 length = 0.493 mil

MLIN5 width = 2.797 mil

MLSC8 width = 1.119 mil

MLSC8 length = 0.310 mil

MLSC3 width = 0.300 mil

MLSC3 length = 0.185 mil

MLSC6 width = 0.968 mil

MLSC6 length = 0.254 mil

MLSC7 width = 1.571 mil

MLSC 7 length = 0.255 mil

4.3 SCHEMATIC

The schematic of the proposed design is shown below:

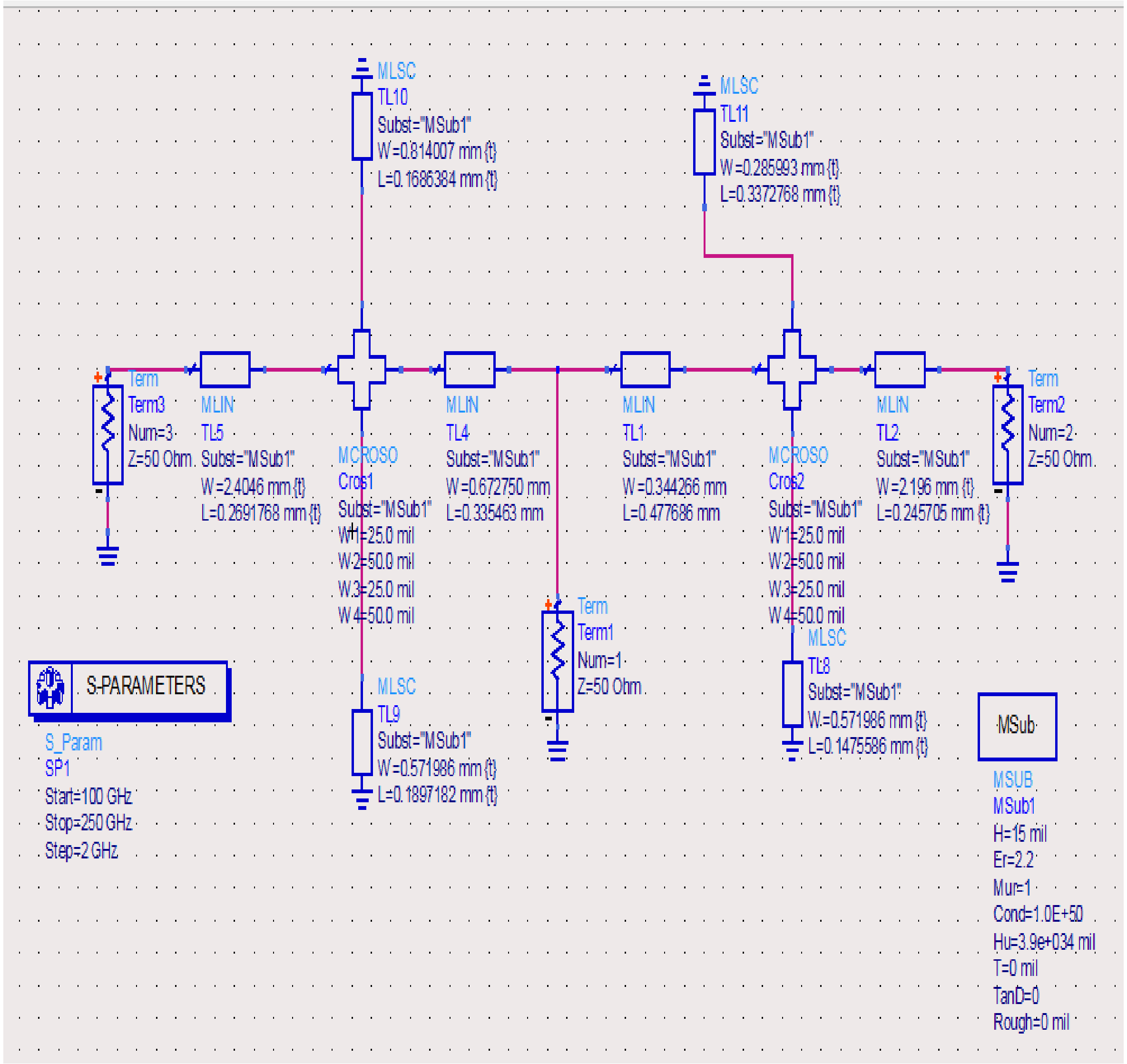


Figure 4.1: Schematic of the proposed design

Schematic contains components like MCROSO which are used to connect four microstrip components at a time. Its other use is that it reduces overlapping of several close components in the fabrication step.

4.4 RESULT ANALYSIS:

4.4.1 OBSERVATION OF S_{21} PARAMETER:

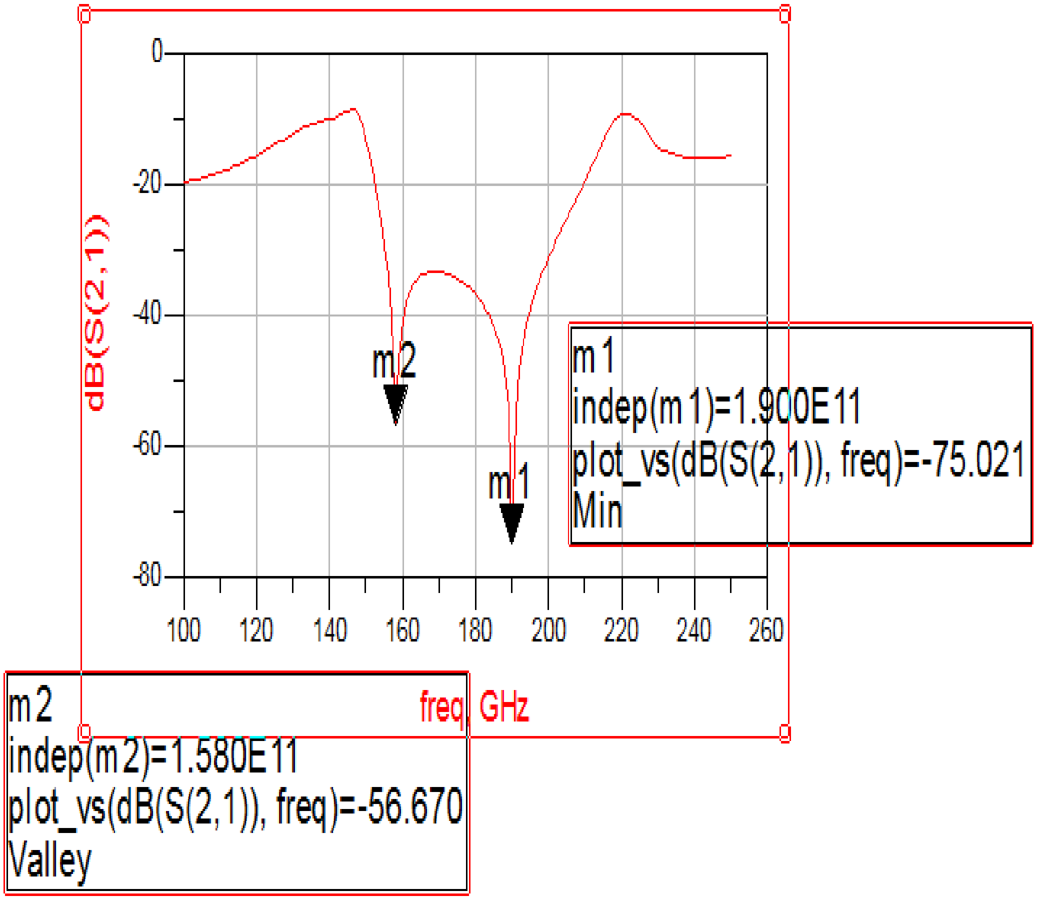


Figure 4.2: S_{21} Parameter Graph

The S_{21} parameter is used to find the transmitted power from port1 to port2, the above diagram illustrates the S_{21} behavior of the input. It shows that it allows frequency close to 150GHz and refuse to transmit the frequency close to 220 GHz, which is required.

The below figure shows the variation of the S_{21} parameter :

freq	S(2,1)
100.0 GHz	0.145 / -3.023
101.0 GHz	0.148 / -4.668
102.0 GHz	0.150 / -6.326
103.0 GHz	0.153 / -7.999
104.0 GHz	0.156 / -9.690
105.0 GHz	0.159 / -11.401
106.0 GHz	0.162 / -13.133
107.0 GHz	0.166 / -14.891
108.0 GHz	0.170 / -16.676
109.0 GHz	0.174 / -18.492
110.0 GHz	0.179 / -20.342
111.0 GHz	0.184 / -22.230
112.0 GHz	0.189 / -24.161
113.0 GHz	0.195 / -26.138
114.0 GHz	0.201 / -28.168
115.0 GHz	0.207 / -30.256
116.0 GHz	0.214 / -32.407
117.0 GHz	0.222 / -34.630
118.0 GHz	0.230 / -36.931
119.0 GHz	0.240 / -39.320
120.0 GHz	0.249 / -41.806
121.0 GHz	0.260 / -44.400
122.0 GHz	0.272 / -47.115
123.0 GHz	0.284 / -49.962
124.0 GHz	0.298 / -52.959
125.0 GHz	0.313 / -56.119
126.0 GHz	0.329 / -59.463
127.0 GHz	0.347 / -63.008
128.0 GHz	0.366 / -66.776
129.0 GHz	0.387 / -70.788

4.4.2 OBSERVATION OF S_{31} PARAMETER:

The S_{31} parameter is used to find the transmitted power from port1 to port3, the below diagram illustrates the S_{31} behavior of the input. It shows that it allows frequency close to 220 GHz, which is required.

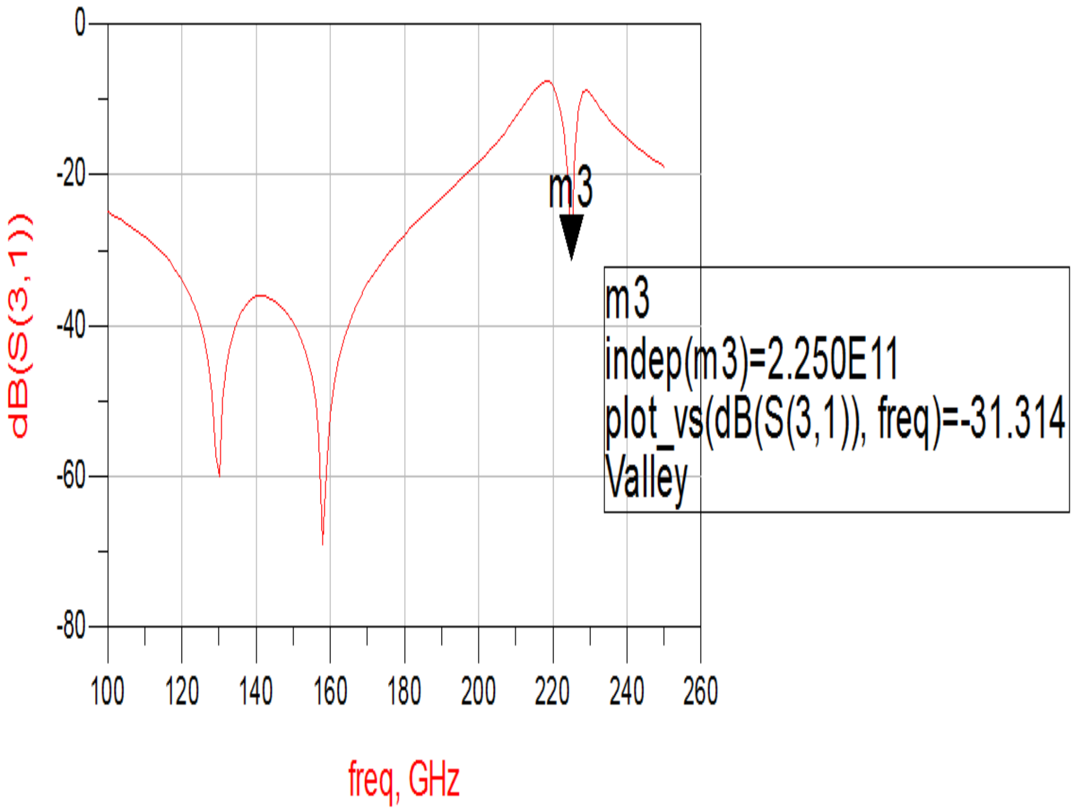
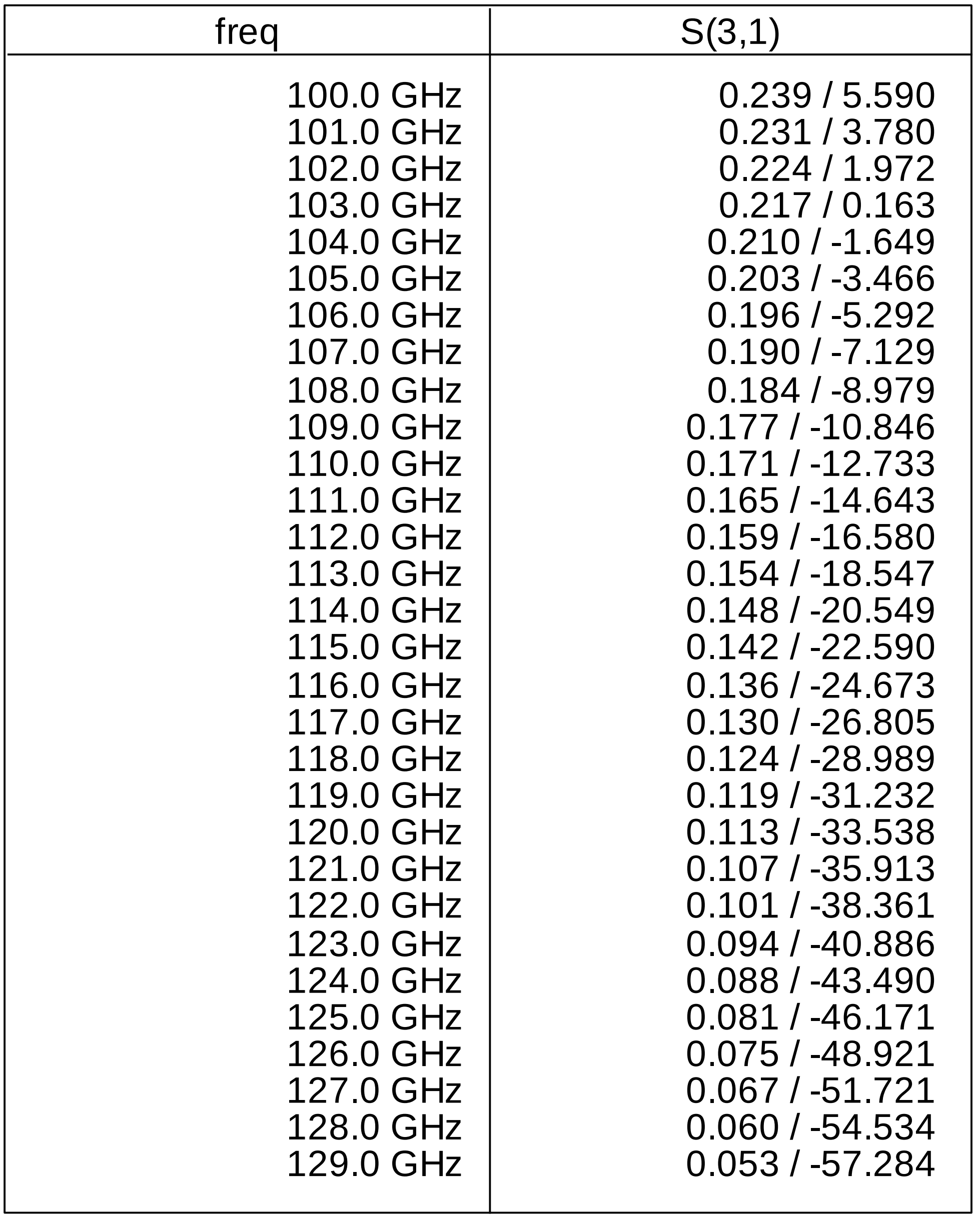


Figure 4.3: S_{31} Parameter Graph

The below figure shows the variation of the S_{31} parameter



freq	S(3,1)
100.0 GHz	0.239 / 5.590
101.0 GHz	0.231 / 3.780
102.0 GHz	0.224 / 1.972
103.0 GHz	0.217 / 0.163
104.0 GHz	0.210 / -1.649
105.0 GHz	0.203 / -3.466
106.0 GHz	0.196 / -5.292
107.0 GHz	0.190 / -7.129
108.0 GHz	0.184 / -8.979
109.0 GHz	0.177 / -10.846
110.0 GHz	0.171 / -12.733
111.0 GHz	0.165 / -14.643
112.0 GHz	0.159 / -16.580
113.0 GHz	0.154 / -18.547
114.0 GHz	0.148 / -20.549
115.0 GHz	0.142 / -22.590
116.0 GHz	0.136 / -24.673
117.0 GHz	0.130 / -26.805
118.0 GHz	0.124 / -28.989
119.0 GHz	0.119 / -31.232
120.0 GHz	0.113 / -33.538
121.0 GHz	0.107 / -35.913
122.0 GHz	0.101 / -38.361
123.0 GHz	0.094 / -40.886
124.0 GHz	0.088 / -43.490
125.0 GHz	0.081 / -46.171
126.0 GHz	0.075 / -48.921
127.0 GHz	0.067 / -51.721
128.0 GHz	0.060 / -54.534
129.0 GHz	0.053 / -57.284

4.4.3 OBSERVATION OF S_{11}(RETURN LOSS PARAMETER):

As we can show in the below figure that at frequencies 150GHz and 220 GHz, there is minimum return loss. So, we can infer that at these two frequencies signal will be transmitted and all other frequencies will be blocked

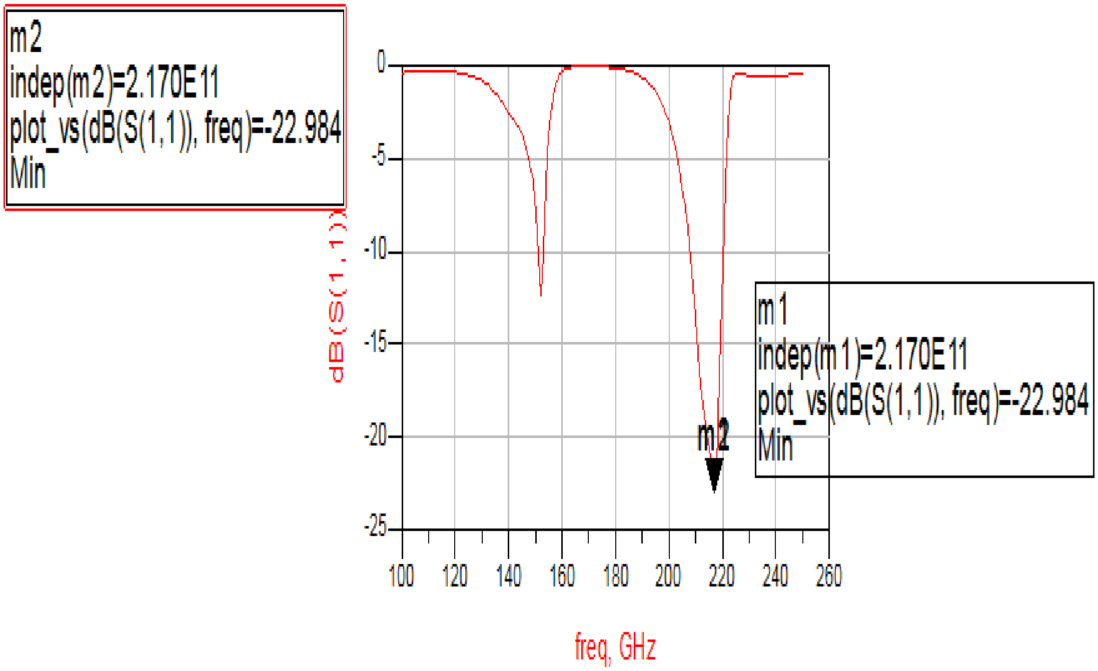
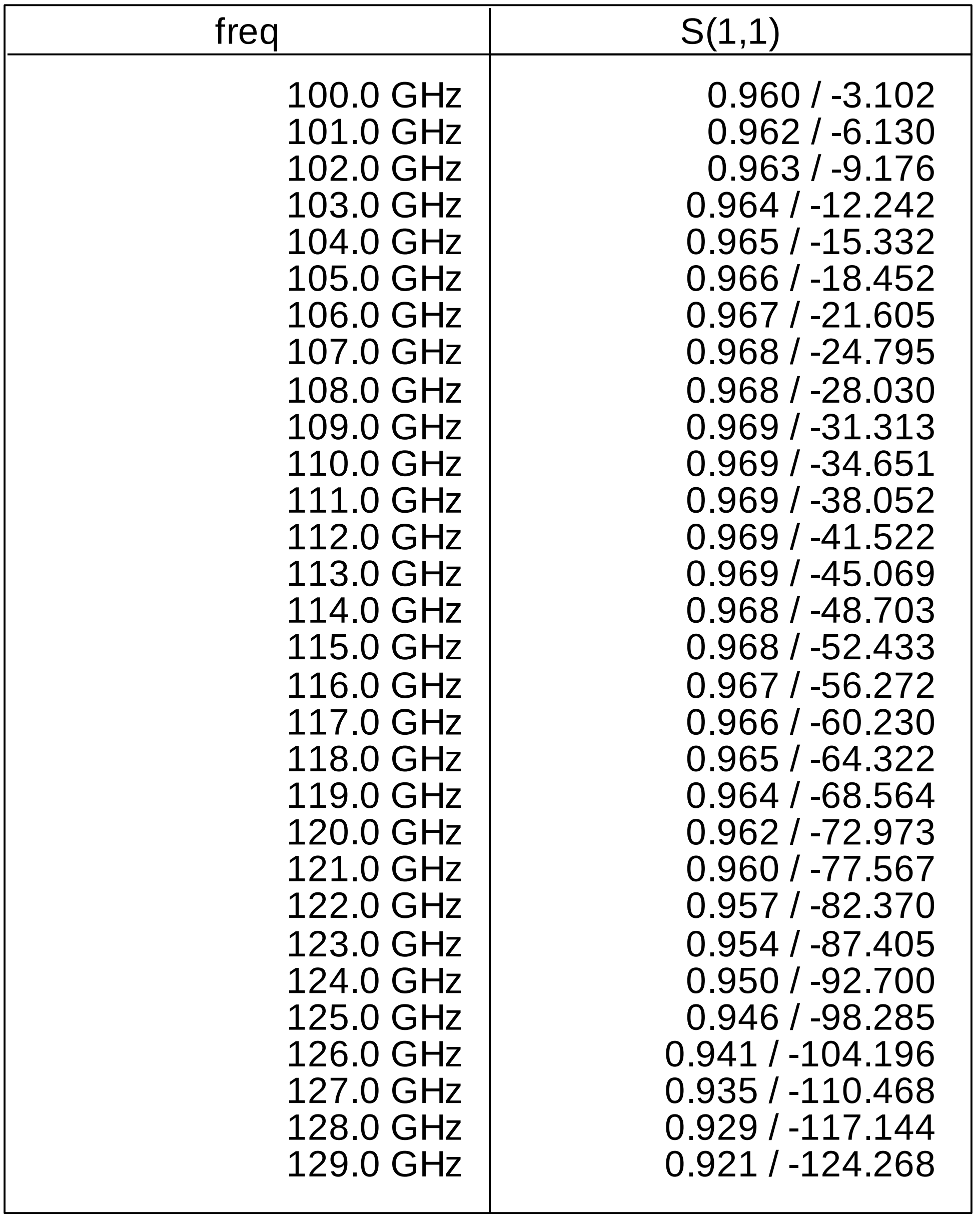


Figure 4.4: S_{11} Parameter Graph

The below figure shows the variation of the S_{11} parameter



freq	S(1,1)
100.0 GHz	0.960 / -3.102
101.0 GHz	0.962 / -6.130
102.0 GHz	0.963 / -9.176
103.0 GHz	0.964 / -12.242
104.0 GHz	0.965 / -15.332
105.0 GHz	0.966 / -18.452
106.0 GHz	0.967 / -21.605
107.0 GHz	0.968 / -24.795
108.0 GHz	0.968 / -28.030
109.0 GHz	0.969 / -31.313
110.0 GHz	0.969 / -34.651
111.0 GHz	0.969 / -38.052
112.0 GHz	0.969 / -41.522
113.0 GHz	0.969 / -45.069
114.0 GHz	0.968 / -48.703
115.0 GHz	0.968 / -52.433
116.0 GHz	0.967 / -56.272
117.0 GHz	0.966 / -60.230
118.0 GHz	0.965 / -64.322
119.0 GHz	0.964 / -68.564
120.0 GHz	0.962 / -72.973
121.0 GHz	0.960 / -77.567
122.0 GHz	0.957 / -82.370
123.0 GHz	0.954 / -87.405
124.0 GHz	0.950 / -92.700
125.0 GHz	0.946 / -98.285
126.0 GHz	0.941 / -104.196
127.0 GHz	0.935 / -110.468
128.0 GHz	0.929 / -117.144
129.0 GHz	0.921 / -124.268

4.4 LAYOUT:

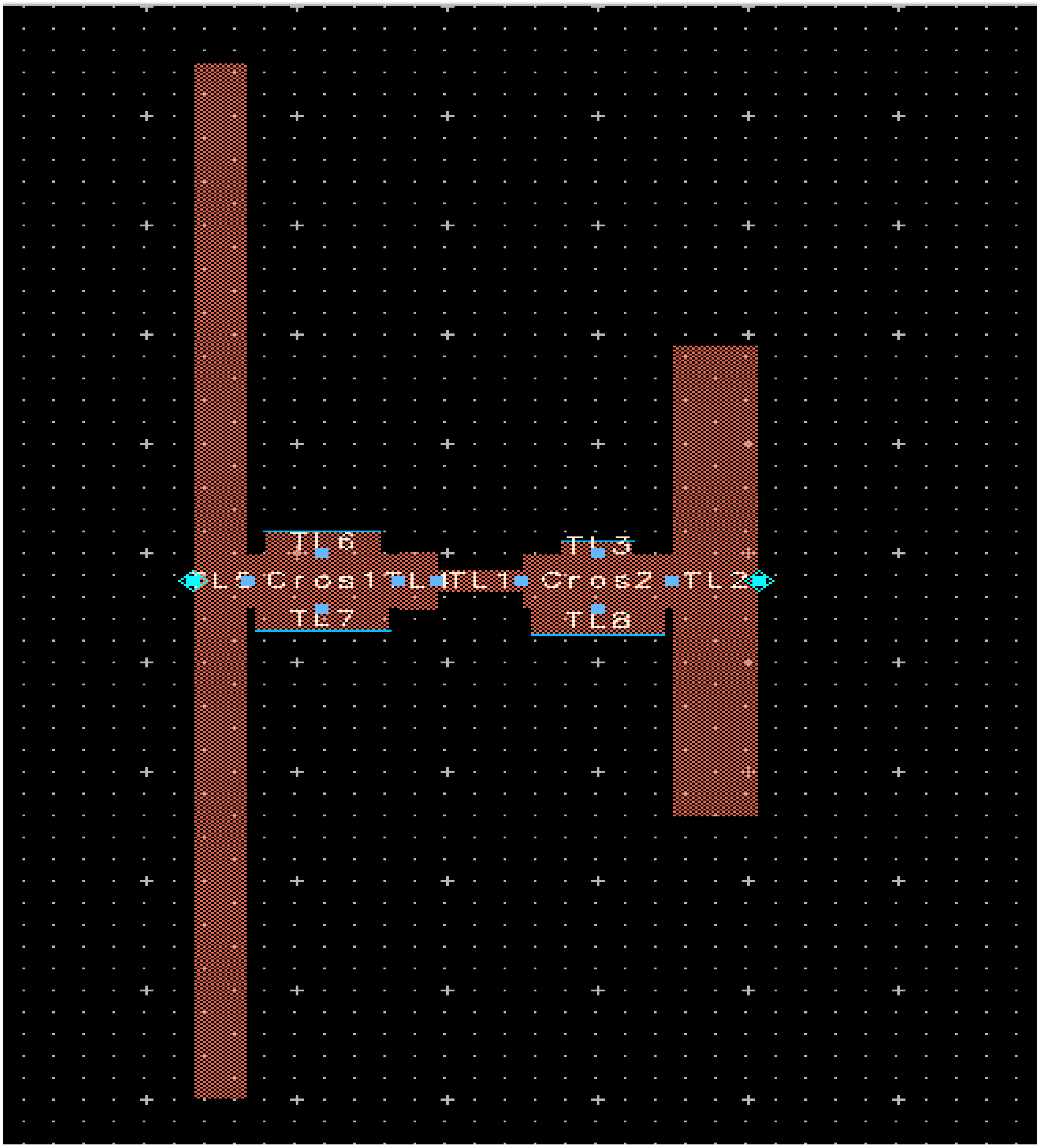


Figure 4.5: Layout

The above diagram shows the layout of our Diplexer design and we can see that there is no overlapping and it is quite feasible to fabricate

CHAPTER-5

CONCLUSION & FUTURE WORK

5. 1 CONCLUSION

This study demonstrates the feasibility of simple low-size diplexing structure, designed to separate two key-bands in astrophysics, with interesting expected performances. We can also conclude the following points:

1. It demonstrates the feasibility of simple low size diplexing structure , designed to separate two key-bands in astrophysics, with good performances.
2. The proposed device after fabrication will be around 2mm and could easily be inserted in a array.
3. Parameter S_{11} i.e Return Loss is around -22.984 dB at frequeny 150 GHz and -12.353 dB at frequency 220 GHz ,which indicates minimum return loss at these two frequencies at port1.
4. S_{31} parameter values are -31.34 dB near 220 GHz which shows that it will allow transmission of 220 GHz signal from port 1 to port 3 with minimum attenuation(i.e maximum transmission)
5. S_{21} parameter shows -56.67 dB at frequency near 150 GHz which shows that it will allow transmission of 150 GHz signal from port 1 to port 2 with maximum transmission.

5.2 FUTURE WORK

The proposed design was simulated in ADS tool and it’s layout was also generated with feasible dimensions, so it’s performance can be improved by using ADS simulation tool. Its size is very small so this can be easily inserted in antenna array, which can drastically enhance their effectiveness. Also, this study deals with the separation of two frequencies but in future, we can make a device which can separate more than two frequencies at a time

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