Visvesvaraya Technological University, Belagavi.

PROJECT REPORT
on

Miniaturized Wilkinson Power Divider using

Compact Stub Structure

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CERTIFICATE

This is to Certify that the dissertation work **Miniaturized Wilkinson power divider using compact stub structure** carried out by Dilip Kumar .V, E. Akshaya , Harsha .A , Harshitha .H , 1CR16EC040,1CR16EC041,1CR16EC046,1CR16EC049, bonafide students of **CMRIT** in partial fulfillment for the award of **Bachelor of Engineering** in **Electronics and Communication Engineering** of the **Visvesvaraya Technological University, Belagavi,** during the academic year **2019-20**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

INTRODUCTION

With the Rapid Development in wireless/wireline communications, their functions are further enhanced, and the applications are also broadened. For industrial systems, however, circuits/devices with much more stringent requirements are suffering from the system cost, compactness, stability, reliability, and other specifications, as compared with those systems like consumer electronics. It is known that any wireless / wireline (RF) system is generally composed of passive and active circuits. Among various RF passive circuits, Wilkinson power divider is a basic and important component in application to RF power amplifiers, mixers, phased-array antennas, and many kinds of equipment.

The problem of dividing up an input signal into a number of equi-phase equi-amplitude output signals is a familiar one to RF engineers. It is often desired that the equi-phase equi-amplitude condition be obtained in a manner which is fundamentally independent of frequency, and, in addition, that a fairly high degree of isolation exist between output terminals over some specified frequency band.

A power divider divides an incoming signal into two (or more) output signals. In the ideal case, a power divider can be considered loss-less, but in practice there is always some power dissipation. Because it is a reciprocal network, a power divider can also be used as a power combiner, where two (or more) ports are used to combine input signals into a single output. Theoretically, a power divider and a power combiner can be the exact same component, but in practice there may be different requirements for combiners and dividers, such as power handling, phase matching, port match and isolation.

Power dividers are often referred to as splitters. While this is technically correct, engineers typically reserve the word “splitter” to mean an inexpensive resistive structure that splits power over very wide bandwidth, but has considerable loss and limited power handling.

The term “divider” is most often used when the incoming signal will be split evenly across all outputs. For example, if there are two output ports, each would get slightly less than half of the input signal, ideally -3 dB compared to the input signal. If there are four output ports, each port would get about one-quarter of the signal, or -6 dB compared to the input signal.

There are different types of power dividers

1. Wilkinson power divider
2. Hybrid coupler
3. Hybrid ring coupler
4. Multiple output divider

1.1 Wilkinson power divider:

The Wilkinson power divider is widely used by many researchers and is widely used in the antenna feed network due to its simple geometric shape, compact size, and reduced input loss. The Wilkinson power divider consists of two parallel *uncoupled* $\lambda/4$ transmission lines. The input is fed to both lines in parallel and the outputs are terminated with twice the system impedance bridged between them. The design can be realized in planar format but it has a more natural implementation in coax – in planar, the two lines have to be kept apart so that they do not couple but have to be brought together at their outputs so they can be terminated whereas in coax the lines can be run side-by-side relying on the coax outer conductors for screening. The Wilkinson power divider solves the matching problem of the simple T-junction: it has low VSWR at all ports and high isolation between output ports. The input and output impedances at each port are designed to be equal to the characteristic impedance of the microwave system. This is achieved by making the line impedance $\sqrt{2}$ of the system impedance.

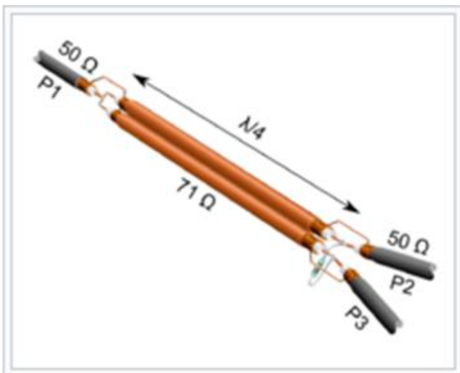

Fig 1. Wilkinson divider in coaxial format

1.2 Hybrid coupler:

Coupled line directional couplers are described above. When the coupling is designed to be 3 dB it is called a hybrid coupler. The S-matrix for an ideal, symmetric hybrid coupler reduces to;

$$\mathbf{S} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & -i & -1 & 0 \\ -i & 0 & 0 & -1 \\ -1 & 0 & 0 & -i \\ 0 & -1 & -i & 0 \end{bmatrix}$$

The two output ports have a 90° phase difference (-i to −1) and so this is a 90° hybrid

1.3 Hybrid ring coupler:

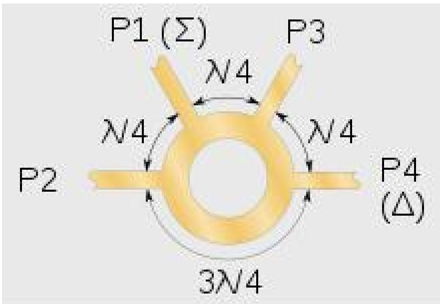

Fig 2. Hybrid ring coupler in planar format

The hybrid ring coupler, also called the rat-race coupler, is a four-port 3 dB directional coupler consisting of a 3λ/2 ring of transmission line with four lines at the intervals shown in fig 2. Power input at port 1 splits and travels both ways round the ring. At ports 2 and 3 the signal arrives in phase and adds whereas at port 4 it is out of phase and cancels. Ports 2 and 3 are in phase with each other, hence this is an example of a 0° hybrid. Fig 2 shows a planar implementation. The S-matrix for this hybrid is given by;

$$\mathbf{S} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & -i & -i & 0 \\ -i & 0 & 0 & i \\ -i & 0 & 0 & -i \\ 0 & i & -i & 0 \end{bmatrix}$$

The hybrid ring is not symmetric on its ports.

1.4 Multiple output dividers:

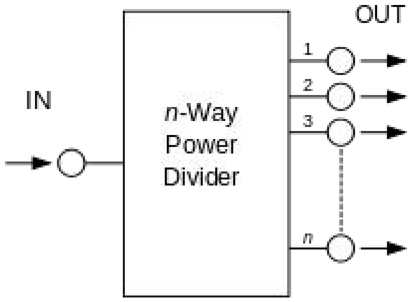

Fig 3. Power Divider

A typical power divider is shown in fig 3. Ideally, input power would be divided equally between the output ports. Dividers are made up of multiple couplers and, like couplers, may be reversed and used as multiplexers. The drawback is that for a four-channel multiplexer, the output consists of only 1/4 the power from each, and is relatively inefficient. The reason for this is that at each combiner half the input power goes to port 4 and is dissipated in the termination load. If the two inputs were coherent the phases could be so arranged that cancellation occurred at port 4 and then all the power would go to port1. However, multiplexer inputs are usually from entirely independent sources and therefore not coherent. Lossless multiplexing can only be done with filter networks

The parameters considered are:

- Coupling factor
- Loss
- Isolation
- Directivity
- S-Parameters
- Amplitude balance
- Phase balance

Wilkinson Power Divider

The Wilkinson Power Divider was introduced by Ernest J. Wilkinson in 1960.

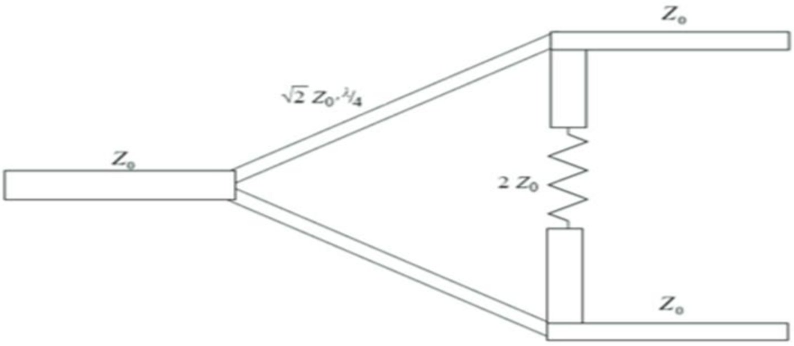

Fig 4: Wilkinson Power Divider

The purpose of the Wilkinson Power Divider is to split the power of the input equally between two output ports, ideally without loss. It can also be used in the reverse direction – as a power combiner. Other properties of the Wilkinson power divider is that all ports are matched, the two output terminals are isolated from one another, and that it is reciprocal. Reciprocity means that you get the same result if you send the signal from one port to another in either direction.

Three-port networks cannot be reciprocal and matched without being lossy. The solution to this, in the Wilkinson Power Divider, is to add a resistor between the two outputs. This resistor absorbs energy if there is a mismatch between the outputs. It also helps isolating the two outputs when the circuit functions as a power combiner.

Assuming a system impedance of 50 Ω, 50 Ω would have to appear at the input for this to be matched. With the two loads being 50 Ω each in parallel, we would achieve match if they both were transformed to 100 Ω (two 100 Ω loads in parallel equals 50 Ω). The way that this is achieved in the original Wilkinson Power Divider is by the use of quarter-wave transformers. We can see that this is possible, by looking at the equation (1) for a quarter-wavelength transmission line:

$$Z_{in} = \frac{Z_o^{\,2}}{Z_{load}} \qquad \text{-------------------- (1)}$$

By using lines with the appropriate characteristic impedance, we can theoretically transform the 50 Ω loads to any real impedance.

1.5 S-Parameters

It describes the input-output relationships between ports in an electrical system. Specifically, at high frequency it becomes essential to describe a given network in terms of waves rather than voltage or current. Thus, S- parameter matrix for a ideal Wilkinson Power Divider is shown below

$$[S] = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

The S-parameter matrix can be used to determine reflection coefficients and transmission gains from both sides of a two-port network. These concepts can further be used in determining Gain, Return loss, VSWR and Insertion Loss.

The s-parameter matrix tells us:

•That the ports are matched (S_{11}, S_{22} and S_{33} equals 0)

•That ports 2 and 3 are isolated (S_{23} and S_{32} equals 0)

•That the power present at port 1 is equally divided between ports 2 and 3 (S_{12}, S_{13}, S_{21} and S_{31} equals -3 dB with a 90 phase shift)

•That the circuit is reciprocal (S_{mn} equals S_{nm}).

One of the biggest drawbacks of the Wilkinson Power Divider is that it has a quite narrow bandwidth. This can be improved by adding a quarter-wavelength section in front of the power combiner. In this way the impedance transformation is done in two steps, thereby improving the bandwidth. The bandwidth of the power divider can also be increased by splitting the two quarter wavelength sections into multiple sections with a resistor between each section.

Conventional power dividers are quite large and there is a need to reduce the size as some of the power dividers below X-band, the quarter-wave transmission lines can be several millimetres long.

Chapter 2

LITERATURE SURVEY

Wilkinson power dividers [1] are indispensable components of microwave amplifier and antenna distribution circuits. However conventional power dividers are quite large, below X-Band where the quarter-wave transmission lines can be several millimetres long. Consequently, when they are incorporated into monolithic microwave integrated circuits (MMICs), the circuit's size depends heavily on the size of the power dividers. Therefore, techniques to reduce the size of power dividers are required for low cost and small size circuits. One of the methods used to reduce circuit size is capacitive loading to miniaturize hybrid couplers [2]. Small, lumped element Wilkinson power dividers have recently been reported [3], but these designs are very dependent on the quality factor and self-resonant frequency of the inductors. Other approaches to reduce the size of Wilkinson power dividers include the use of stepped impedances [4] and capacitive loading [5].

In the domain of microwave engineering, the Wilkinson power divider is better among all of the power divider circuits in which isolation can be attained between the output ports when all the ports of the divider are matched. The alternate use of this Wilkinson design is a power combiner since it is designed with the passive components and hence the reciprocity theorem is satisfied.

In the basic design of the Wilkinson power divider, the matching conditions to its ports is achieved by the symmetrical quarter-wavelength branches, which causes the design to be very bulky, when it is physically implemented. Thus, we can obtain compact structure of Wilkinson power divider by replacing them with other structures which maybe active or passive devices.

Wilkinson's power divider was introduced with varying power consumption ratios using loaded circuits that can restore high or low levels of blockage. In some cases, by properly designing the loading, compression of the adjoining components is achieved. There are designs which uses microstrip electromagnetic bandgap (EBG) as a structure to reduce the size of the power separator/combiner. Due to the band stop and slow wave characteristics of EBG, we can realize the Wilkinson power divider with harmonic suppressions. There is an effective reduction in occupied area of up to 60% using the EBG cells [6].

Electromagnetic band-gap (EBG) structure is a structure that creates a stopband to block electromagnetic waves of certain frequency bands by forming a fine, periodic pattern of small metal patches on dielectric substrates. EBG refers to such a stopband as well as to substances (medium to transmit electromagnetic waves) that have such a structure. Applications of the EBG structure include components of electronic devices to suppress electronic noise.

On the other hand, the EBG structure reflects little electronic waves of the frequency bands it can detect, and receives them at a high sensitivity. Moreover, its resolution (the ability to measure and discriminate electromagnetic waves) can be enhanced by placing the metal patches at a higher density. Due to these characteristics, the EBG structure is also utilized for sensors to measure electromagnetic radiation.

Active power dividers and combiners have been proposed to compensate power loss in passive circuits. Since active combiners and dividers utilize amplifier cores to obtain power gain, the additional issues such as stability, linearity, power consumption should be taken into account in the design phase Based on a bi-directional distributed amplifier (BDA) topology, it exhibits not only both dividing and combining operations, but also wide bandwidth by utilizing artificial transmission lines. In addition, the use of a SiGe BiCMOS technology provides seamless integration with common silicon-based platforms [7].

Wilkinson power divider/combiner can also be realised using active components such as a CMOS active inductor. The dividers/combiners that is designed using the CMOS technology have achieved better reduction in size because of the design does not comprise of any transmission lines and spiral inductors. The insertion loss and return loss achieved was better in this design, which was due to the Q-factor of the active inductor [8].

There are designs of Wilkinson power divider which uses differential transformers. Ultra-compact transformers that provide fully differential operation and input/output matching are connected in parallel. The parasitic components i.e., the parasitic capacitances and leakage inductances, of the impedance transformation networks that are employed by the transformers are naturally absorbed. This design was demonstrated using 130 nm SiGe BiCMOS process [9].

Wilkinson power dividers can be tuneable/adjustable, by replacing quarter-wave transmission line with a T-type structure. Using these designs,we can control the magnitude of the fed signal to the antenna array, thus helps in reducing the side loops and internal interference. The efficiency of beamforming circuit of antenna array of mobile network can be increased using these variable power separators. The design parameters of these designs is found using even and odd mode analysis, which is same as that of conventional Wilkinson power dividers [10,11].

The quarter-wave transmission lines of a Wilkinson power divider are realized through lines of reduced length. This reduction in length causes the reflections due to impedance mismatch and hence size reduction is realized through capacitive loading. This capacitive loading is realized through the use of open circuited stub(OCS). The λ/4 Wilkinson power divider with branching network using open stub as shown in Fig.5 also provides suppression of the third harmonic components without sacrificing the characteristics of the conventional Wilkinson power divider at the operating frequency.

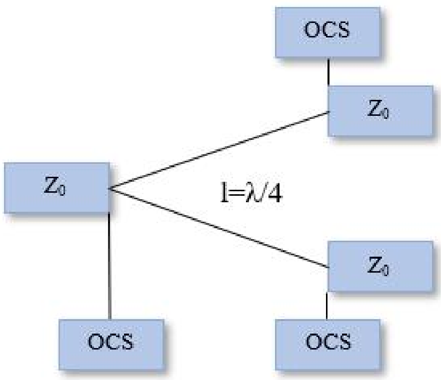

Fig 5: Wilkinson Power Divider using capacitive loading

To improve the performance of the divider a few changes have been made to the standard design. Curved corners are replaced by sharp edges of unintended radiation reduction from the feed network and also changes in the length of the matching stub are achieved [12]. The capacitive loading is realized through the use of open circuited stub and the inductive loading is realized through the closed circuited stub.

Chapter 3

METHODOLOGY

3.1 Design Procedure

In the basic design of the Wilkinson power divider, the matching conditions to its ports are achieved by the symmetrical quarter-wavelength branches, which cause the design to be very bulky, when it is physically implemented. Thus, we can obtain compact structure of Wilkinson power divider by replacing them with other structures which maybe active or passive devices.

The Advance Design System (ADS) is a software tool used to design and simulate the results for the proposed design using microstrip lines. A 2.4 GHz operating frequency is used due to the popular demand for a compact Wi-Fi system. The dielectric material used in the formulation is FR4 as it is readily available and is very popular in the industry because of its microwave composition. Other details such as height, size, etc., of the dielectric materials are described in Table I. The schematic representation of the Power Divider is shown in Fig 6.

S. N	Parameters	Units
1	Frequency (f)	2.4 GHz
2	Thickness of the Substrate (H)	1.5 mm
3	Relative dielectric constant (ε_r)	4.5
4	Dielectric loss tangent (Tan D)	0.01
5	Upper ground plane to substrate spacing (Hu)	100 mm
6	Conductor surface roughness	1.389e-3 mm

Table 1: Design Parameters

The power divider consists of two parts of the transmission line, each quarter wavelength. To achieve the equivalent power split, the characteristic impedance of the line has a 50-ohm value. Transmission line for a Wilkinson power divider, which is usually a microstrip line divided by a specific number of lines.

This asymmetrical power divider uses two section transmission microstrip line, three capacitors which is realized using the open circuit stubs (OCS). The values of the impedance line (Z_X), the capacitors (C_1 and C_2), and the resistor (R) of the given line length (s) are used to analyze using even-odd mode.

Even and odd modes are the two main modes of propagation of the signal through a coupled transmission line pair. Odd mode impedance is defined as impedance of a single transmission line when the two lines in a pair are driven differentially (with signals of the same amplitude and opposite polarity). Even mode impedance is defined as impedance of a single transmission line when the two lines in a pair are driven with a common mode signal (the same amplitude and the same polarity). The even-odd mode analysis uses two important principles:

- Superposition
- circuit symmetry

In order to achieve zero reflectance from all three ports and unlimited separation between output ports, the capacitance value of C_1 should be twice the value of the capacitance of C_2 i.e., $C_1 = 2C_2$. In addition, the Z_X and C_1 of the total transmission length (l) are given by

$$Z_X = (\sqrt{2}\, Z_0)/\sin(\beta_0 l) \qquad (2)$$

$$C_2 = \cos(\beta_0 l)/(\omega_0 Z_0 \sqrt{2}) \qquad (3)$$

$$C_1 = 2C_2 \qquad (4)$$

where Z_0 is the characteristic impedance of the transmission line, β_0 is the propagation constant at the design frequency and ω_0 is the angular frequency at the design frequency. Values of C_1, C_2 and Z_X are calculated using (2), (3) and (4). To realize the evaluated capacitance in the form of open circuited stub, the following relation is employed. With the assumption that characteristic impedance of the stub is equal to the characteristic impedance Z_0.

$$\cot \beta l = 1/(Z_0 C \omega) \qquad (5)$$

A Resistor R of about twice the value of characteristic impedance Z_0 is connected at the output port in order to achieve better isolation between the two output ports i.e., $R=2Z_0$.

The length and width of the microstrip line is changed using the approximate function found by M.V. Schneider is meant to have an accuracy of ±2% for $\varepsilon_{r\,eff}$ and an accuracy of ±1% for $\sqrt{\varepsilon_{r\,eff}}$

$$\varepsilon_{r\,eff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2} \cdot \frac{1}{\sqrt{1+10\frac{h}{W}}} \qquad \text{-----------(6)}$$

Where ε_r is the dielectric constant of the substrate,

W is the width of the microstrip,

h is the height of the substrate.

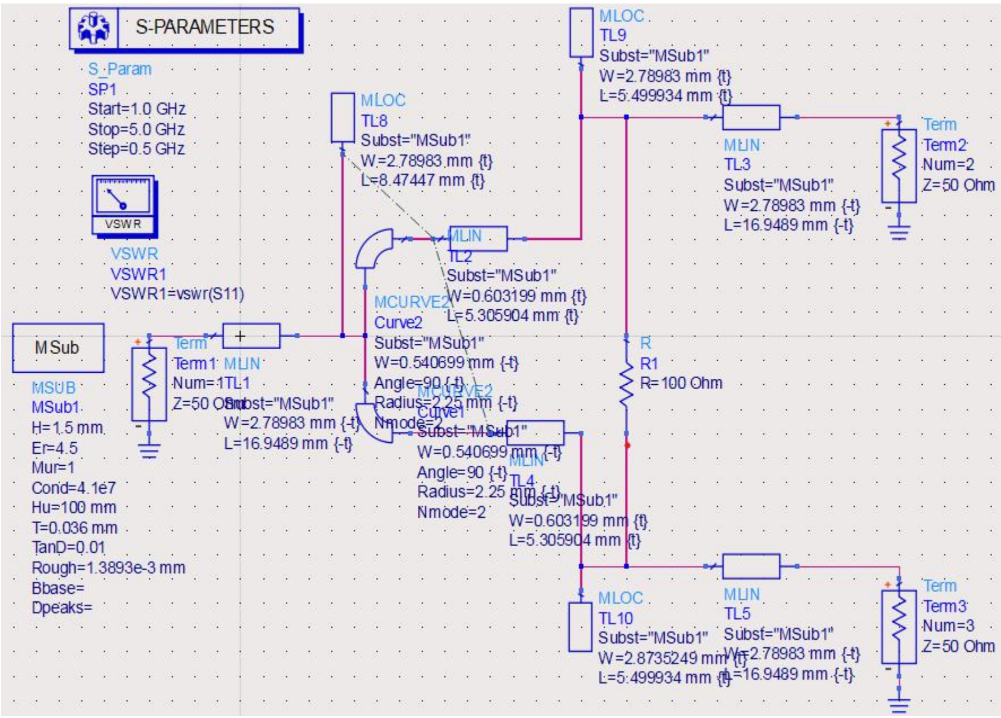

Fig. 6: Proposed schematic of power divider

3.2 Open circuit stub (OCS):

In microwave and radio-frequency engineering, a stub or resonant stub is a length of transmission line or waveguide that is connected at one end only. The free end of the stub is either left open-circuit or (always in the case of waveguides) short-circuited. Neglecting transmission line losses, the input impedance of the stub is purely reactive;

either capacitive or inductive, depending on the electrical length of the stub, and on whether it is open or short circuit. Stubs may thus function as capacitors, inductors and resonant circuits at radio frequencies.

The input impedance of a lossless open circuit stub is given by

$Z_{OC} = -jZ_0 \cot(\beta l)$ ---------(7)

It follows that depending on whether is positive or negative, the stub will be capacitive or inductive, respectively.

The length of an open circuit stub to act as an inductor *L* at an angular frequency of is:

$$l = \frac{1}{\beta}\left[(n+1)\pi - \operatorname{arccot}\left(\frac{\omega L}{Z_0}\right)\right]$$ ------(8)

The length of an open circuit stub to t as a capacitor *C* at the same frequency is:

$$l = \frac{1}{\beta}\left[n\pi + \operatorname{arccot}\left(\frac{1}{\omega C Z_0}\right)\right]$$ -------(9)

3.3 Hardware

The power divider technology has undergone a substantial change over the past decade, due to smaller size, lighter weight, potentially lower cost, high reliability, broad bandwidth capability, and function reproducibility. When selecting a suitable substrate material, factors to be considered in the designs of the microstrip power dividers are cost, availability, ease of machining, and etching. There are a whole range of mechanical, electrical, thermal, and chemical criteria to be taken into account. Most of these criteria are mechanical stability with high and low storage temperature, thermal expansion similar to that of metals, good electrical properties (homogeneity of and high electric insulation strength), chemical resistance and easy workability with low cost. There is no substrate material that simultaneously fulfills all the above requirements. The best compromise must be found for all applications.

The materials commonly used for microwave substrate have dielectric constants typically range from 2.0 to 10.0. Microstrip circuits designed to be fabricated on such dielectric materials will be most compact or pressed because of the wave-slowing action of the electric signal. Usually, this is an advantage, but such small size makes it difficult to fit any conventional discrete parts into microstrip layout.

Microstrip is a type of electrical transmission line which can be fabricated using printed circuit boarding 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. Microwave components such as antennas, couplers, filters, power dividers etc. can be formed from microstrip, with the entire device existing as the pattern of metallization on the substrate. Microstrip is thus much less expensive than traditional waveguide technology, as well as being far lighter and more compact.

Microstrip lines are also used in high-speed digital PCB designs, where signals need to be routed from one part of the assembly to another with minimal distortion, and avoiding high cross-talk and radiation. Microstrip is one of many forms of planar transmission line, others include strip line and coplanar waveguide, and it is possible to integrate all of these on the same substrate.

3.4 Different substrates used in microstrip technology:

- Bakelite
- FR4 glass epoxy
- RO4003
- Taconic TLC
- RT Duroid

3.4.1 Bakelite:

Bakelite or polyoxybenzylmethylenglycolanhydride, is an early plastic. It is a thermosetting phenol formaldehyde resin, formed from an elimination reaction of phenol with formaldehyde. It is most commonly used as an electrical insulator possessing considerable mechanical strength.

Fig 7. Bakelite

3.4.2 FR-4 or (FR4) Glass Epoxy:

FR-4 or (FR4) is a grade designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing). FR-4 glass epoxy is a popular and versatile high-pressure thermo set plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength.

Fig 8. FR4 glass epoxy

3.4.3 RO4003:

RO4003 Series High Frequency Circuit Materials are glass reinforced hydrocarbon/ceramic laminates (Not PTFE) designed for performance sensitive, high volume commercial applications. RO4000 laminates are designed to offer superior high frequency performance and low-cost circuit fabrication. The result is a low loss material which can be fabricated using standard epoxy/glass (FR4) processes offered at competitive prices.

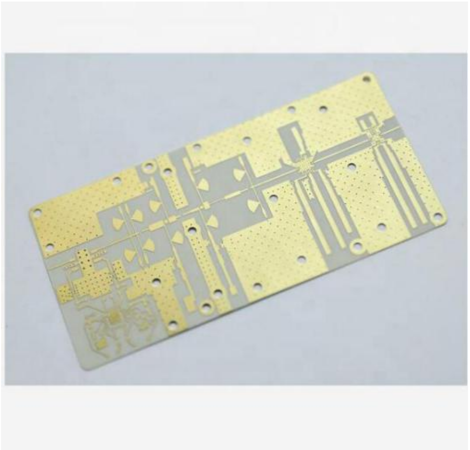

Fig 9. RO4003

3.4.4 Taconic TLC:

Taconic TLC substrates are specifically designed to meet the low cost objectives for newly emerging commercial RF/microwave applications. Both materials exhibit excellent mechanical and thermal stability and cost less than traditional PTFE substrates.

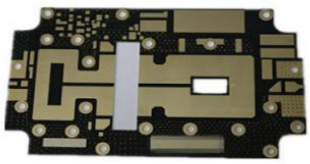

Fig 10. Taconic TLC

3.4.5 RT Duroid:

RT Duroid is Glass Microfiber Reinforced PTFE (polytetrafluoroethylene) composite produced by Roger Corporation. RT Duroid 5870 substrate has low loss tangent. They exhibit excellent chemical resistance, including solvent and reagents used in printing and plating, ease of fabrication –cutting, shearing, machining, environment friendly.

Fig 11. RT Duroid

Parameters	Bakelite	FR4 Glass Epoxy	RO4003	Taconic TLC	RT Duroid
Dielectric constant	4.78	4.36	3.4	3.2	2.2
Loss tangent	0.03045	0.013	0.002	0.002	0.0004
Water absorption	0.5-1.3%	< 0.25%	0.06%	< 0.02%	0.02%
Tensile strength	60 MPa	< 310 MPa	141 MPa	-	450 MPa
Volume resistivity	3×10^{15} Mohm.cm	8×10^{7} Mohm.cm	1700×10^{7} Mohm.cm	1×10^{7} Mohm.cm	2×10^{7} Mohm.cm
Surface resistivity	5×10^{10} Mohm	2×10^{5} Mohm	4.2×10^{9} Mohm	1×10^{7} Mohm	3×10^{7} Mohm
Breakdown voltage	20-28 kV	55 kV	-	-	> 60 kV
Peel strength	-	9 N/mm	1.05 N/mm	12 N/mm	5.5 N/mm
Density	1810kg/m^3	1850 kg/m^3	1790 kg/m^3	-	2200 kg/m^3

Table 2: Different substrates used in microstrip technology

Chapter 4

SOFTWARE

4.1 Software

Advanced Design System (ADS) is an electronic design automation software system. It provides an integrated design environment to designers of RF electronic products such as mobile phones, pagers, wireless networks, satellite communications, radar systems, and high-speed data links.

ADS support every step of the design process—schematic capture, layout, design rule checking, frequency domain and time domain circuit simulation, and electromagnetic field simulation—allowing the engineer to fully characterize and optimize an RF design without changing tools.

Advanced Design System is the world’s leading electronic design automation software for RF, microwave, and high-speed digital applications.

Fig 12. Advanced Design System tool

4.1.1 Tuning and Optimization

Advanced Design System's tuning capability enables you to change one or more design parameter values and quickly see its effect on the output without re-simulating the entire design. Multiple traces generated from various tuning trials can be overlaid in the Data

Display window. This can help you find the best results and the most sensitive components or parameters more easily.

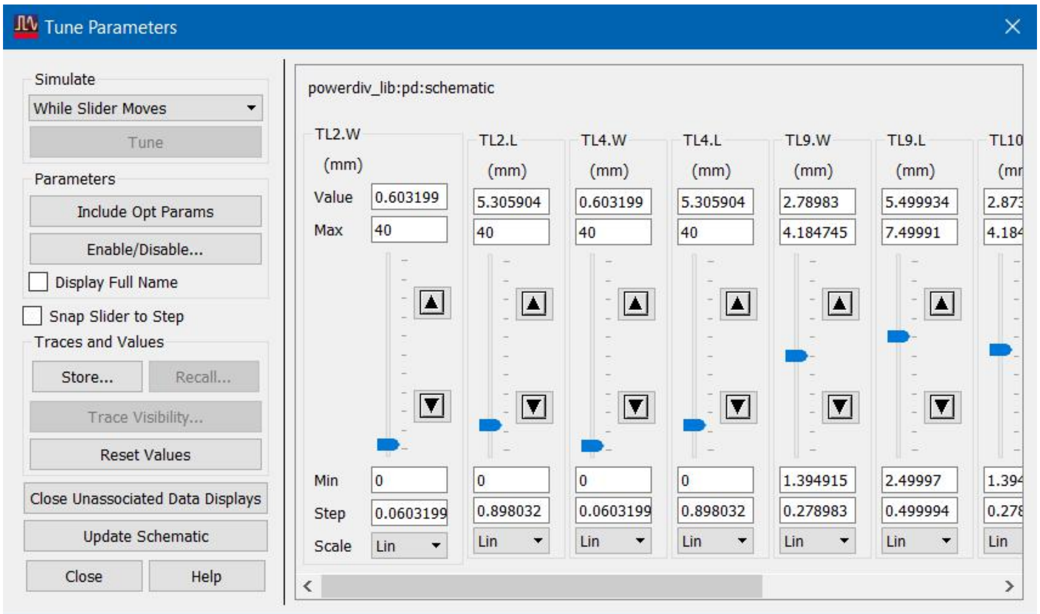

Fig 13. Tuning option in ads tool.

With the ADS tuning features, you can avoid repeating the pre-processing. Tuning performs the pre-processing once and then assumes that you are now just trying to change some of the parameter values. A new simulation will take place, but using the same network topology and list of measurements. Only the small changes regarding the new parameter values are needed. You can tune a large number of components, including those that are processed by a measurement equation component, such as VSWR.

Optimization is an automated procedure of achieving the circuit performance in which ADS can modify the circuit component values in order to meet the specific optimization goals. Please note that care should be taken while setting up the goals to be achieved and it should be practically possible else it will not be possible to meet the goals. Also, the component values which are being optimized should be within the practical limits and this needs to be decided by designers considering the practical limitations.

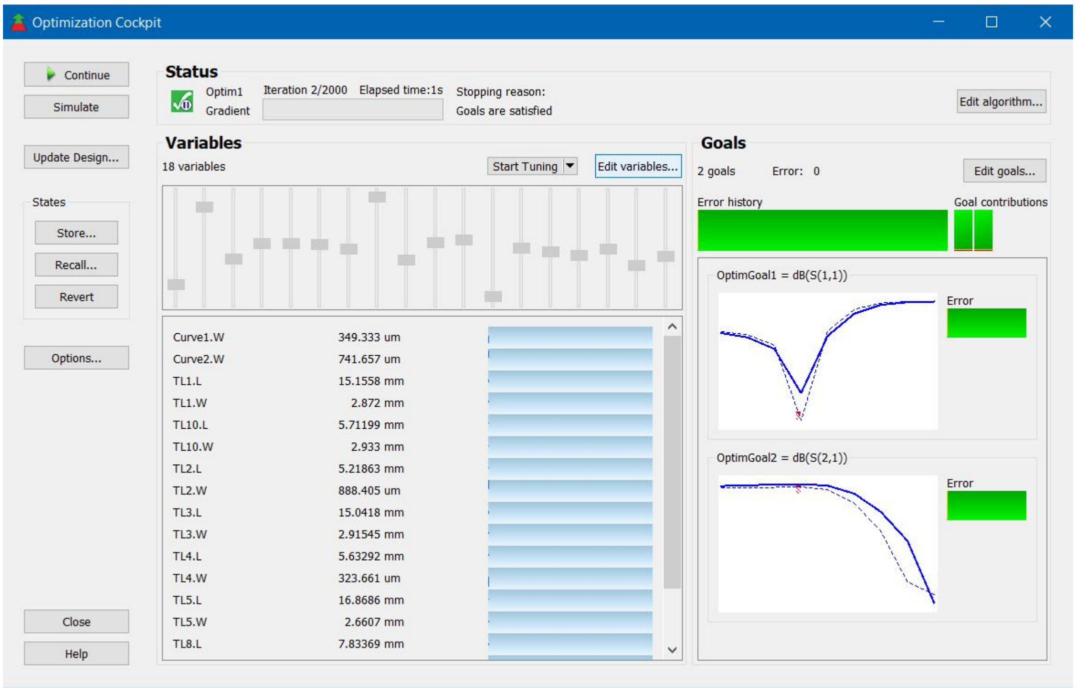

Fig 14. Optimization in ads tool.

The Optimization Cockpit is a live, graphical view of an optimization job. You see the cockpit data (error graphs, goal plots, and variable values) change in real time as the optimization progresses. In addition, you can use the cockpit to control the optimization while the optimization is running. For example, during the course of an optimization, you can increase the range of an optimization variable, modify the limit line of a goal, tune the optimization variables, and change the algorithm from Random to Gradient.

4.1.2 LineCalc

LineCalc is an analysis and synthesis program for calculating electrical and physical parameters of single and coupled transmission lines. LineCalc can communicate directly with the circuit simulators. You can send parameter data for selected circuit design elements, along with data on any associated substrates or walls, directly from the simulator to LineCalc. After the element parameter values are calculated, you can update the associated schematic or layout circuit design in the active simulator immediately with the LineCalc results. Or you can place a newly synthesized component into the Schematic window.

Using dialog boxes, you can make changes in parameter values of your transmission lines and see the results of those changes on the screen. You can use LineCalc like a spreadsheet, in the sense that a change in one value brings about a recalculation through all related values when you choose the appropriate Calculate button.

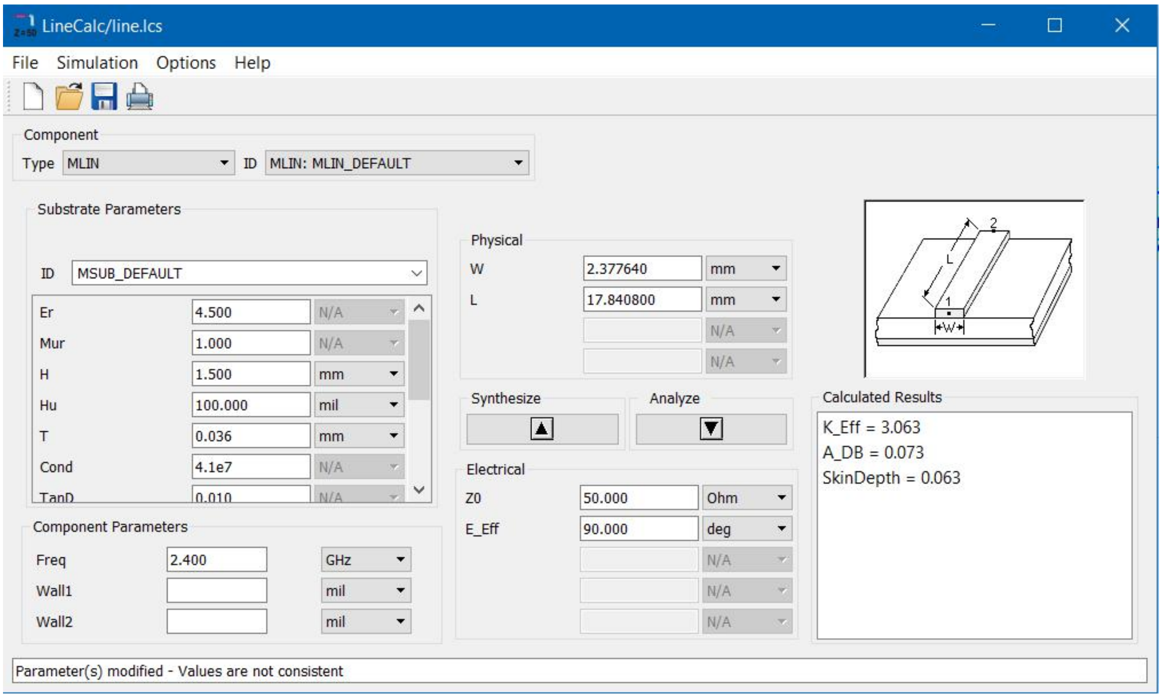

Fig 15. LineCalc

Chapter 5

RESULTS

The results of the designed Wilkinson Power Divider by ADS are used to make the comparison of various parameters like size of the circuit, percentage bandwidth utilization, SWR and insertion loss for harmonic suppression. The circuit is designed at 2.5 GHz with a FR4 substrate (ε_r=4.5 and Tan D= 0.01). The results of the proposed design are shown in Fig 14,19. Insertion loss is the loss of signal power resulting from the insertion of a device in a transmission line or optical fiber and is usually expressed in decibels (dB). The ideal value of insertion loss is 0dB.

Insertion loss (dB) = 10 log (pi/po) ------(10)

Pi: Maximum amount of power that can be transmitted before the insertion of a device in a transmission line.

Po: Maximum amount of power that can be received after the insertion of a device in a transmission.

The divider provides an insertion loss which seems to be lesser than 0.7 dB. There is also suppression of higher order harmonics achieved by the proposed divider. From Fig. 16 and Fig. 17 it is clearly seen that the power is distributed equally between the two output ports, since the value of $|S_{21}|$ and $|S_{31}|$ is nearly -3 dB i.e., -3.3 dB to be exact. The 0.3dB variation in the output parameters is negligible.

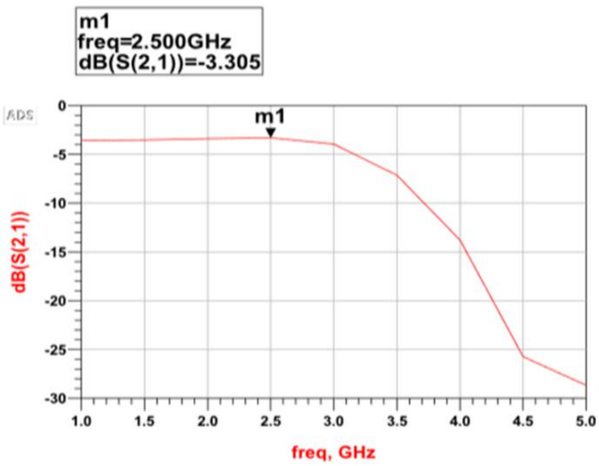

Fig 16. Simulated S_{21}

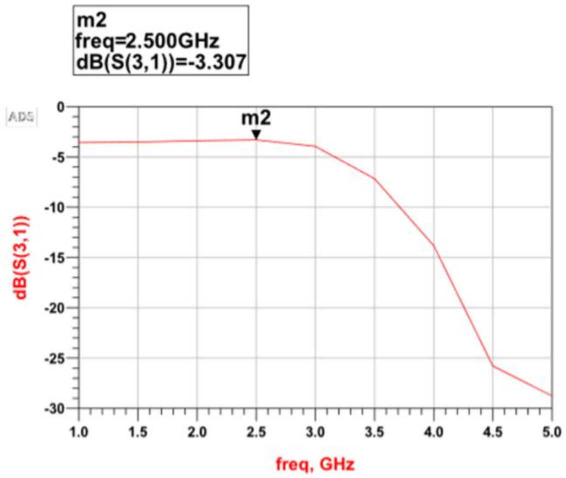

Fig 17. Simulated S_{31}

Return loss or reflection loss is the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line or optical fiber. This Discontinuity can be a mismatch with the terminating load or with a device inserted in the line. Return loss calculated in the proposed design is better than the return loss calculated in some of the other designs as well as the standard power divider design. The Return loss i.e., $|S_{11}|$ is found out to be better than -37 dB as shown in Fig. 18.

Return loss (dB) = 10 log (Pi/Pr) -----(11)

Pi: Amount of power incident on a transmission line.

Pr: Amount of power reflected back to transmission line.

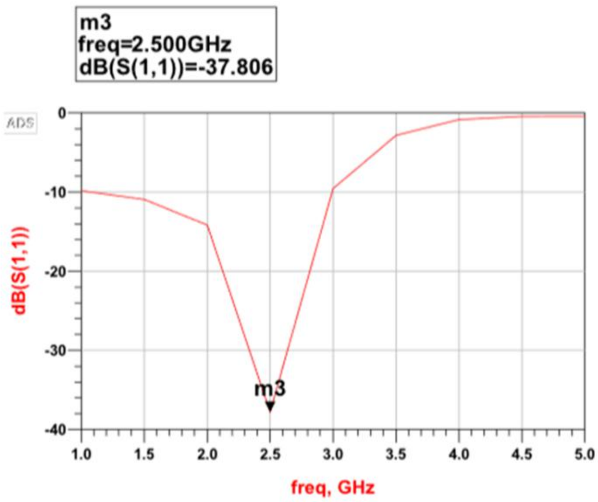

Fig 18. Simulated S_{11}.

Isolation is the insertion loss in the open path of a switch or between two ports on a passive device. It is measured between any one of the output port and input port with the condition of another port in terminating condition. Isolation between the output ports is comparatively better than the standard design. The better Isolation between the output ports is achieved due the introduction of resistance R at the output side which is standard of a Wilkinson power divider. The Isolation i.e., $|S_{32}|$ and $|S_{23}|$ is found out to be greater than -39 dB as shown in Fig. 19 and Fig. 20.

$$\text{Isolation loss (dB)} = 10 \log (Po/Pi) \quad \text{-----(12)}$$

Po: Amount of power received at output ports.

Pi: Amount of power incident on a transmission line.

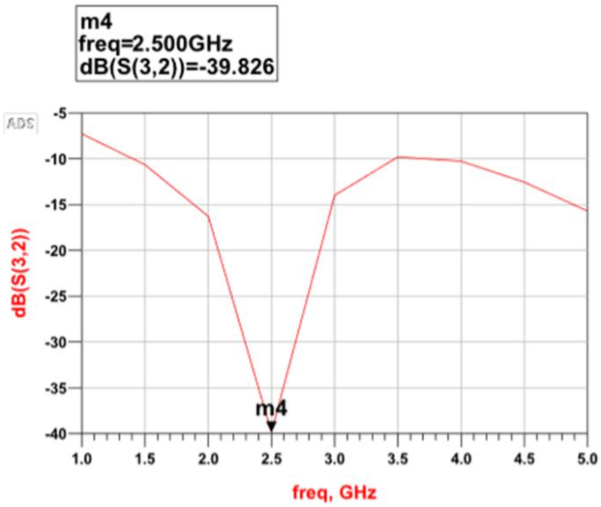

Fig 19. Simulated S_{32}.

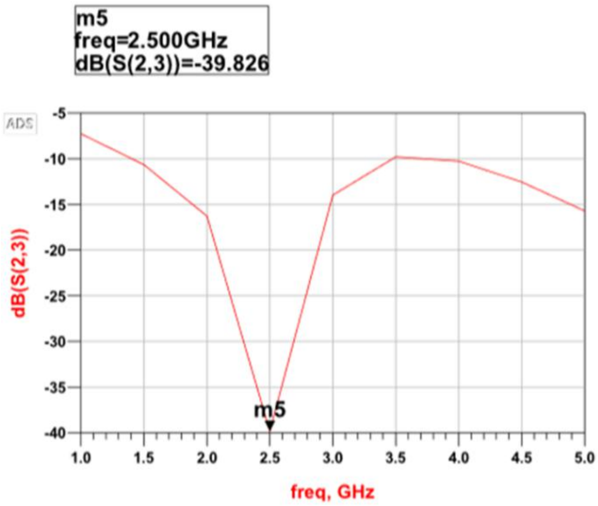

Fig 20. Simulated S_{23}

The SWR is found out to be less than 1.1, as shown in Fig. 21. The proposed Wilkinson divider showed a 40% reduction in size without any compromise in the performance. The size of the divider reduces the circuit size by 40% as expected of capacitive loading when compared to using the stepped impedances. The size reduction of the divider was achieved with better insertion loss. There was better utilization of the Bandwidth as well. It is also seen that, as the circuit is reduced, there is an increase in the frequency of the highest isolation.

Standard Wilkinson power separators are constant at all odd harmonics which is why there is a need to compress the order of maximum magnitude. They act as a low pass filter that is strongly rejected at high frequencies, thus increasing the capacitive loading (stub length) resulting in an increase in line impedance as well.

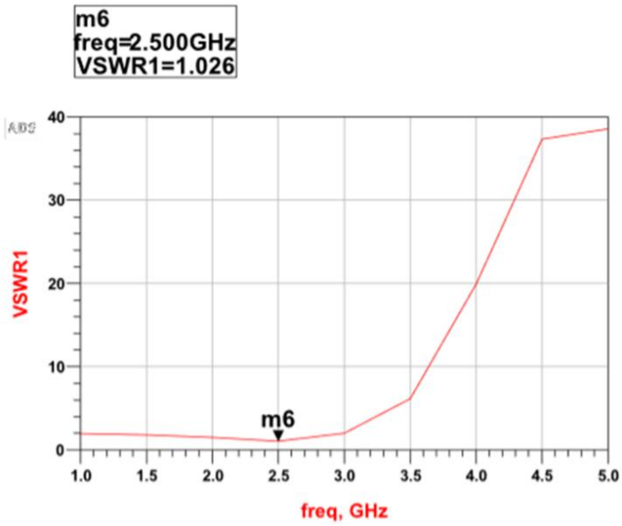

Fig 21. VSWR

Chapter 6

APPLICATIONS AND ADVANTAGES

In order to determine whether to use a Wilkinson power divider splitter, it is necessary to weigh up the advantages and disadvantages of using them.

6.1 Wilkinson divider / combiner advantages:

1. Simplicity: The Wilkinson divider / splitter / combiner is particularly simple and can easily be realized using printed components on a printed circuit board. It is also possible to use lumped inductor and capacitor elements, but this complicates the overall design.
2. Loss: If perfect components were used, the Wilkinson splitter divider would not introduce any additional loss above that arising from the division of the power between the different ports. In addition to this, the real components used for the Wilkinson splitter can be very low loss, especially when PCB transmission lines are used along with low loss PCB substrate material
3. Isolation: The Wilkinson divider / combiner provides a high degree of isolation between the "output" ports.
4. Cost: When the Wilkinson power divider is realized using printed circuit board elements, the cost is very low - possibly the only increase above that of the single resistor used results from an increase in the board area used as a result of the printed elements. However, to reduce losses, a low loss PCB substrate may need to be used and this would increase the cost.

6.2 Wilkinson divider / combiner disadvantages:

1. Frequency response: As the Wilkinson splitter is based around the use of quarter wave transmission lines, it has a limited bandwidth, although there are some Wilkinson splitters available that offer reasonably wide bandwidths.
2. Size: At lower frequencies the size of the quarter wave transmission lines means that it can be too large for many applications, and therefore the Wilkinson power divider topology is most widely used at microwave frequencies.

Power dividers can be used as combiners or splitters. Wilkinson and high isolation power dividers offer high isolation, blocking signal cross talk between output ports. Low insertion and return loss. Wilkinson power dividers offer excellent (<0.5dB) amplitude and (<3°) phase balance.

6.3 Applications

- Telecom
- Point-to-point communication, Satellite, Cellular access technologies
- Space
- Sensing/Spectroscopy, Communication, Radio astronomy
- MedTech
- Diagnostics, imaging, and treatment applications.
- Defense
- Radar, Communication
- Security
- Car avoidance radar, Traffic surveillance, Air traffic security “cameras”
- Navigation, Positioning & Measurement
- GPS
- Food
- Heating & detection of foreign bodies in food New and novel application areas are constantly being added.

Chapter 7
CONCLUSIONS AND SCOPE FOR FUTURE WORK

Wilkinson power divider with the capacitive loading through open circuited stubs (OCS) is analyzed at an operating frequency of 2.5 GHz and is simulated using ADS tool. The proposed design divides the incoming signal equally among its output ports with a gain of -3 dB at each port. As shown in the results section, the proposed divider provides return loss better than -37 dB, isolation between the output ports better than -39 dB and VSWR < 1.1. If these design values are incorporated and fabricated, there would be a reduction in size of up to 40% compared to existing designs and also better bandwidth utilization. The higher order harmonics is suppressed by the divider and thus it acts like a low pass filter. The proposed divider can be used for different electrical lengths to achieve better results.

It is used for wireless transmission (wireless LAN protocol Ex-Bluetooth) signals having higher bandwidth.They are commonly used in radar systems where radar uses microwave radiation to detect the range, distance, and other characteristics of sensing devices and mobile broadband applications. Used in radio for broadcasting and telecommunication of transmission because due to their small wavelength, highly directional waves smaller and therefore more practical than they would be at longer wavelengths (lower frequencies) before the introduction of Fiber optic transmission. Microwaves are generally used in telephone for long-distance communication

7.1 Communication

Wireless LAN protocols, such as Bluetooth and the IEEE 802.11 specifications, also use microwaves in the 2.4 GHz ISM band, although 802.11a uses ISM band and U-NII frequencies in the 5 GHz range. Licensed long-range (up to about 25 km) Wireless Internet Access services have been used for almost a decade in many countries in the 3.5–4.0 GHz range. The FCC recently carved out spectrum for carriers that wish to offer services in this range in the U.S. — with emphasis on 3.65 GHz. Dozens of service providers across the country are securing or have already received licenses from the FCC to operate in this band. The WIMAX service offerings that can be carried on the 3.65 GHz band will give business customers another option for connectivity.

Metropolitan-area networks: MAN protocols, such as WiMAX (Worldwide Interoperability for Microwave Access) based in the IEEE 802.16 specification. The IEEE 802.16 specification was designed to operate between 2 to 11 GHz. The commercial implementations are in the 2.3 GHz, 2.5 GHz, 3.5 GHz and 5.8 GHz ranges.

Some mobile phone networks, like GSM, use the low-microwave/high-UHF frequencies around 1.8 and 1.9 GHz in the Americas and elsewhere, respectively. DVB-SH and S-DMB use 1.452 to 1.492 GHz, while proprietary/incompatible satellite radio in the U.S. uses around 2.3 GHz for DARS.

7.2 Remote sensing

Radar uses microwave radiation to detect the range, speed, and other characteristics of remote objects. Development of radar was accelerated during World War II due to its great military utility. Now radar is widely used for applications such as air traffic control, weather forecasting, navigation of ships, and speed limit enforcement, Microwave imaging

Microwave imaging, photo-acoustic imaging in biomedicine.

7.3 Power

A microwave oven passes (non-ionizing) microwave radiation (at a frequency near 2.45 GHz) through food, causing dielectric heating by absorption of energy in the water, fats and sugar contained in the food. Microwave ovens became common kitchen appliances in Western countries in the late 1970s, following development of inexpensive cavity magnetrons. Microwave heating is used in industrial processes for drying and curing products.

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