BROADBAND IMPEDANCE MATCHING TECHNIQUES FOR MICROWAVE AMPLIFIERS

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CERTIFICATE

This is to certify that the work entitled, “Broadband Impedance Matching Techniques for Microwave Amplifier” submitted by Shweta Rabra, Pallavi Singh and Richa Saxena in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and communication of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Prof. Tapas Chakravarty

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(PALLAVI SINGH) (SHWETA RABRA) (RICHA SAXENA)

Singh Rabra Richa

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LIST OF ABBREVATIONS

A:ABCD matrix for amplifier
D: Determinant
E_{eff}: Effective dielectric constant
F: Noise figure
G: Gain
Gt: Transducer power gain
K: Stability factor
L1: Length of microstrip line at the source end
L2: Length of microstrip line at the load end
MSG: Maximum stability gain
R: Resultant ABCD matrix
R1: Source resistance
R2: load resistance
T_0: Standard temperature (290 K)
VSWR IN:
VSWR OUT:
W: wavelength
X: ABCD matrix for microstrip line 1
Y: ABCD matrix for microstrip line 2
Z_L: ABCD matrix for load impedance
Z_S: ABCD matrix for source impedance

ABSTRACT

In this project report we present a new technique of impedance matching of a microwave amplifier over a wide frequency range conventional matching techniques use open circuited shunt stubs, which are frequency dependent. In this configuration two microstrip lines are connected both at the source and the load terminal. By altering the characteristic impedance and electrical length of the lines a broadband operation is achieved, the analysis is done using transmission matrices and the results show good return loss figures over a wider frequency range.

CHAPTER-I

DESIGN OF RF AMPLIFIER:

S-parameters:

S-parameters refer to the scattering matrix ("S" in *S-parameters* refers to *scattering*). The scattering matrix is a mathematical construct that quantifies how RF energy propagates through a multi-port network. The S-matrix is what allows us to accurately describe the properties of incredibly complicated networks as simple "black boxes". For an RF signal incident on one port, some fraction of the signal bounces back out of that port, some of it *scatters* and exits other ports (and is perhaps even amplified), and some of it disappears as heat or even electromagnetic radiation. The S-matrix for an N-port contains N2 coefficients (S-parameters), each one representing a possible input-output path. S-parameters are complex (magnitude and angle) because the network changes both the magnitude and phase of the input signal. S-parameters are defined for given frequency and system impedance, and vary as a function of frequency for any non-ideal network. S-parameters refer to RF "voltage out versus voltage in" in the most basic sense. S-parameters come in a matrix, with the number of rows and columns equal to the number of ports. For the S-parameter subscripts "i j", j is the port that is excited (the input port), and "i" is the output port. Thus S_{11}refers to the ratio of signal that reflects from port one for a signal incident on port one. Parameters along the diagonal of the S-matrix are referred to as reflection coefficients because they only refer to what happens at a single port, while off-diagonal S-parameters are referred to as transmission coefficients, because they refer to what happens from one port to another. Here are the S-matrices for one, two and three-port networks:

$$(S_{11}) \quad (one-port)$$

$$\begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \quad (two-port)$$

$$\begin{pmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{pmatrix} \quad (three-port)$$

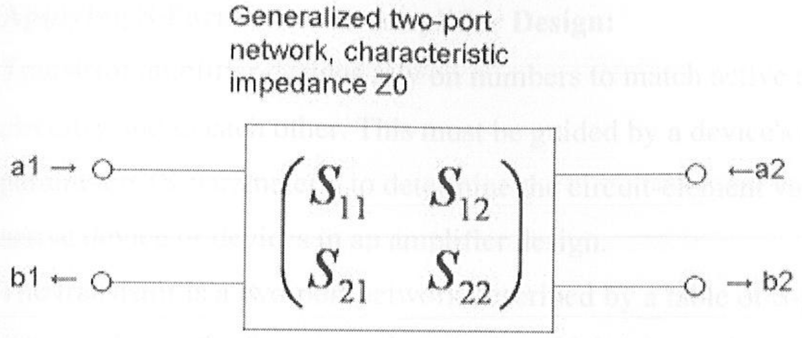
$$Etc.$$

Note that each S-parameter is a vector, so if actual data were presented in matrix format, a magnitude and phase angle would be presented for each Sij.

Definition of S-parameters:

S-parameters describe the response of an N-port network to voltage signals at each port. The first number in the subscript refers to the responding port, while the second number refers to the incident port. Thus S21 means the response at port 2 due to a signal at port 1. The most common "N-port" in microwaves are one-ports and two-ports, three-port network S-parameters are easy to model with software such as Agilent ADS, but the three-port S-parameter measurements are extremely difficult to perform with accuracy. Let's examine a two-port network. S-parameters are based upon the concept of *incident* (a_i) and *exiting* (b_i) waves. Customarily the b_i waves are called *reflected* waves. By using a and b waves, a linear network can be characterized by a set of simultaneous equations describing the exiting waves from each port in terms of the incident waves at all of the ports.

The incident voltage at each port is denoted by "a", while the voltage leaving a port is denoted by "b".



Now we can define the four S-parameters of the 2-port as:

$$S_{11} = b1/a1$$

$$S_{12} = b1/a2$$

$$S_{21} = b2/a1$$

$$S_{22} = b2/a2$$

Here's the matrix algebraic representation of 2-port S-parameters:

$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \times \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

If we want to measure S_{11}, we inject a signal at port one and measure its reflected signal. In this case, no signal is injected into port 2, so a2=0; during all laboratory S-parameter measurements, we only inject one signal at a time. If we want to measure S_{21}, we inject a signal at port 1, and measure the resulting signal exiting port 2. For S_{12} we inject a signal into port 2, and measure the signal leaving port 1, and for S_{22} we inject a signal at port 2 and measure its reflected signal.

S-parameter magnitudes are presented in one of two ways, linear magnitude or decibels (dB). Because S-parameters are a voltage ratio, the formula for decibels in this case is

S_{ij} (dB) =20 log [S_{ij} (magnitude)]

The angle of a vector S-parameter is almost always presented in degrees course.

Applying S-Parameters to Amplifier Design:

Transistor amplifier designs rely on numbers to match active devices to surrounding circuitry and to each other. This must be guided by a device's measured scattering parameters (S-parameters) to determine the circuit-element values needed to surround an active device or devices in an amplifier design.

The transistor is a two-port network described by a table of S-parameters that have been measured over the frequency domain for which it has gain. After the bias and heat sinking needs of the transistor have been satisfied, the RF design proceeds using these S-parameters.

For a two-port network, the b wave leaving Port 1 (b_1) is the phasor sum of a wave reflected from the input port ($S_{11}a_1$) plus a wave that passed through the two-port from Port 2 ($S_{12}a_2$). That is,

$b_1 = S_{11}a_1 + S_{12}a_2$;

$b_2 = S_{21}a_1 + S_{22}a_2$;

Where

$a_i = v_{i1}/\sqrt{(z_{0i})} = I_{i1} * \sqrt{(z_{0i})}$;

$b_i = v_{ir}/\sqrt{(z_{0i})} = I_{ir} * \sqrt{(z_{0i})}$;

And the voltage at port 1, for example, is the sum of an incident voltage and a reflected voltage ($V_1 = V_{1I} + V_{1R}$). Similarly, the current at port 1 is the sum of an incident current and a reflected current ($I_1 = I_{1I} + I_{1R}$). The normalized incident (a_i) and reflected (b_i) waves can be measured with the aid of directional couplers with matched source and loads presented to the two-port terminals. This measurement simplicity underlies the advantage of the *S* parameters, but it introduces a complication. Whereas the alternate Z, Y, and ABCD parameters depend only upon the network being measured, the *S-parameter values depend both upon the network and the characteristic impedances of the source and load used to measure it*

When the source and load impedances are the same as those used to determine the S-parameters, the magnitude of S_{21} is the ratio of the outgoing wave, b_2, to the incoming wave, a_1. Hence, it is equivalent to the voltage or current gain of the amplifier. Similarly, the magnitude of the square of S_{21} is equal to the power gain.

CHAPTER 2

MICROWAVE AMPLIFIER DESIGN ASPECTS

An amplifier has four main aspects related to it – stability, impedance matching, maximum gain and noise figure. They are discussed below in brief.

Amplifier stability:

Even if we are satisfied with the performance obtained by installing a transistor in the same impedances in which it was measured, we have treated the transistor as if it were a unilateral device. In other words, it is assumed that signals pass from the input to the output, but not in the reverse direction. Making the unilateral assumption is equivalent to assuming that S_{12} is zero. The S_{12} parameter provides the feedback term by which power from the output circuit (which is relatively high due to the transistor's amplification) can feed back to the input. When it does so, it may combine with reflections already present at the input to produce an effective S_{11} whose magnitude exceeds unity. This corresponds to reflection gain, and a transistor amplifier that can experience this gain, is termed conditionally unstable, the condition being certain combination(s) of load impedance, S_{12} and S_{11}, that could produce self-oscillation (instability).

The transistor is potentially unstable when the K Factor is less than one. In such cases a stable amplifier can still be designed but only for restricted values of source and load impedances. Further more, it will not be possible to use conjugate impedance matching at both input and output. The conditions for amplifier stability are established by requiring that the reflected power from the amplifier ports be smaller than the incident power. This means that reflection coefficient looking into the amplifier ports must have a magnitude less than one for all passive sources and load impedances.

K factor:

We define stability factor as K as

$K = (1 - |S_{11}|^2 - |S_{22}|^2 + |D|^2) \ / \ (2|S_{12} S_{21}|)$

$|D|^2 = |S_{11}S_{22} - S_{12}S_{21}|^2$

The amplifier is unconditionally stable provided that

$K>1$ and $|D|^2<1$

The amplifier is unconditionally stable if $k>1$ and $B_1>0$

Where $B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |D|^2 > 0$

Impedance matching:

The connection of an additional impedance to an existing one in order to accomplish a specific effect such as to balance a circuit or to reduce reflection in a transmission line.

Impedance matching is done for the following purposes:

1) Maximization of power transfer from source to loads.
2) Losses minimization in transmission lines.
3) Signal to noise ratio minimization in input stage of receivers.
4) Minimization of signal distortion in transmission lines, avoiding wave front reflections and pulse superposition.
5) Voltage amplification or attenuation.
6) Current amplification or attenuation.

There are many ways to do impedance matching including:

1) Computer Simulations:

Complex to use as simulators are dedicated to differing design functions and not to impedance matching. Designers have to be familiar with the multiple data inputs that need to be entered and the correct formats. They also need the expertise to find the useful data among the tons of results coming out. In addition, circuit simulation software is not pre-installed on computers, unless they are dedicated to such an application.

2) Manual Computations:

Tedious due to the length ("kilometric") of the equations and the complex nature of the numbers to be manipulated.

3) Instinct:

This can be acquired only after one has devoted many years to the RF industry. In short, this is for the super specialist.

4) Smith Chart:

A smith chart is a circular plot with a lot of interlaced circles on it. When used correctly, matching impedances, with apparent complicated structures, can be made without any computation. The only effort required is the reading and following of values along the circles.

The smith chart is a polar plot of the complex reflection coefficient (also called gamma). Or, it is defined mathematically as the 1-port scattering parameter S_{11}. It is developed by examining the load where the impedance must be matched. Instead of considering its impedance directly, its reflection coefficient L is expressed, which is used to characterize a load.

Amplifier Gain:

Gain of an amplifier is another important parameter. The maximum stable gain should be high enough in order for the amplifier to work more efficiently. There are several definition used for the gain of an amplifier:

Power gain Gp= power delivered to the load /input power to amplifier

Transducer gain G=power delivered to load/available input power from source

Available power gain Ga=available load power/available input power from source

If the device is unconditionally stable, then conjugate impedance matching can be used both at the input and output. if this is done then

Gp=G=Ga=maximum gain

For a device that is only conditionally stable, conjugate impedance matching at both the input and output cannot be used. When the stability parameter $k<1$,the power gain achieved in this case is Gp.

In terms of the parameter k, the power gain for an absolutely stable device, using conjugate impedance matching is given by:

$Gp=G=Gmax= |S_{21}/S_{12}|(k-\sqrt{(k^2 - 1)})$

The parameter $|S_{21}/S_{12}|$ is called "Figure of merit" for the transistor.

When k=1,it gives Maximum stable gain Gmsg= $|S_{21}/S_{12}|$

Noise figure:

One important quality factor of an amplifier is a measure of how much noise it adds to the signal while it amplifies it. The noise figure F is a convenient measure of how the amplifier affects the total output noise. It is a measure of the total output noise after it leaves the amplifier divided by the input noise power entering the amplifier and amplified by an ideal noise less gain Gt. It is defined as

F=signal to noise ratio at input/signal to noise ratio at output.
The output noise is the amplified thermal noise from the source resistance plus the noise produced by the amplifier. F requires source to be conjugate impedance matched to the network, that is Zs= Zin and source resistance Rs to be at standard temperature To=290K. The standard 290 K noise temperature approximates the actual

F=(actual noise output power at To / available noise input power)*(1/Gt)
=Ntout / kToGtSf

Where Gt is transducer power gain.

Resistive loading:

Apart from all this, an important point that needs attention is the concept of resistive loading and how it can be used to achieve stability. The S_{12} parameter provides the feedback term by which power from the output circuit can feedback to the input. When it does so it may combine with the reflections already present at the input to produce an effective S_{11} whose magnitude exceeds unity. This corresponds to reflection gain and an amplifier which experiences this gain is termed conditionally unstable, the condition being certain combinations of load impedance, S_{12} and S_{11}, that could produce self-oscillations (instability). To solve such a problem of instability, resistive loading can be used. For example if low impedance at the input causes instability then a resistance placed in series with the base lead can reduce the gain. At low frequencies, where usually the devise instability is at its peak, a resistor can be shunted with a capacitor to minimize its effects. Similarly when high output load impedance causes instability, a shunt resistance can be added at the output.

CHAPTER 3

MICROSTRIP LINE:

The microstrip line is transmission line geometry with a single conductor trace on one side of a dielectric substrate and a single ground plane on the opposite side. Since it has an open structure, microstrip line has a major fabrication advantage over strip line .It also features ease of interconnections and adjustments.

It consists of a conductive strip of width "W" and thickness "t" and a wider ground plane, separated by a dielectric layer. It is by far the most popular microwave transmission line, especially for microwave integrated circuits. The major advantage of microstrip over stripline is that all active components can be mounted on top of the board.

In a micro strip line, the wavelength (W) is given by

$$W = W_o / (E_{eff})^{1/2}$$

Where Eeff is the effective dielectric constant, which depends on the dielectric constant of the substrate material and the physical dimension of the microstrip line and Wo is the free space wavelength.

In a microstrip line, the electromagnetic field exists partly in the air above the dielectric substrate and partly within the substrate itself. Intuitively, the effective dielectric constant of the line is expected to be greater than the dielectric constant of air and less than that of the dielectric substrate.

CHAPTER 4

PROPOSED METHOD:

We propose a method of simultaneous stabilization and impedance matching of a microwave amplifier using series transmission line. The concept is to connect two microstrips to an amplifier, one on each side. Source and load impedance is also considered.

The ABCD matrix of this cascaded arrangement is calculated by multiplying ABCD matrices of the individual components, which are in the following order – source impedance; microstrip line; amplifier; microstrip line; load impedance.

The resultant ABCD matrix is converted into scattering matrix. The stability factor, s parameters, reflection coefficient for source and reflection coefficient for load can now be calculated at different combinations of impedances of the two microstrip lines.

Why ABCD matrix?

ABCD matrix is defined only for two port networks. The main advantage of taking ABCD matrix for calculation is that ABCD matrices can be multiplied together by using simple matrix multiplication to form an overall matrix of a cascade of circuits. This is because the outputs of the network have the same direction as the inputs of the network.

Conditions for stability and impedance matching:

For an amplifier to be unconditionally stable, the following must be true.

Stability factor $K>1$

Determinant $D<1$

S parameters $S_{11}<1$; $S_{22}<1$; $S_{12}<<1$

Load reflection coefficient $10 \log |\Gamma_L|^2 < -10$ dB

Source reflection coefficient $10 \log |\Gamma_s|^2 < -10$ dB

CHAPTER 5

CONFIGURATION:

Amplifier circuit with resistance in shunt and series:

Two different circuits were used to check the unconditionally stable zone for the amplifier MITSUBISHI MGFC4419G with the use of microstrip line and resistances applied in series and parallel.

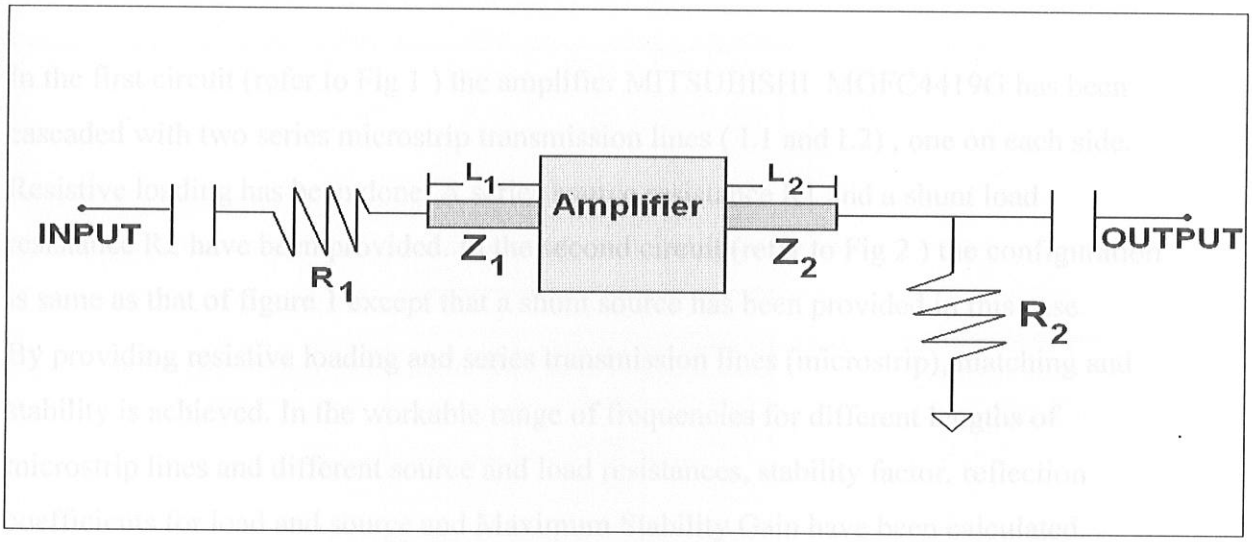


fig1

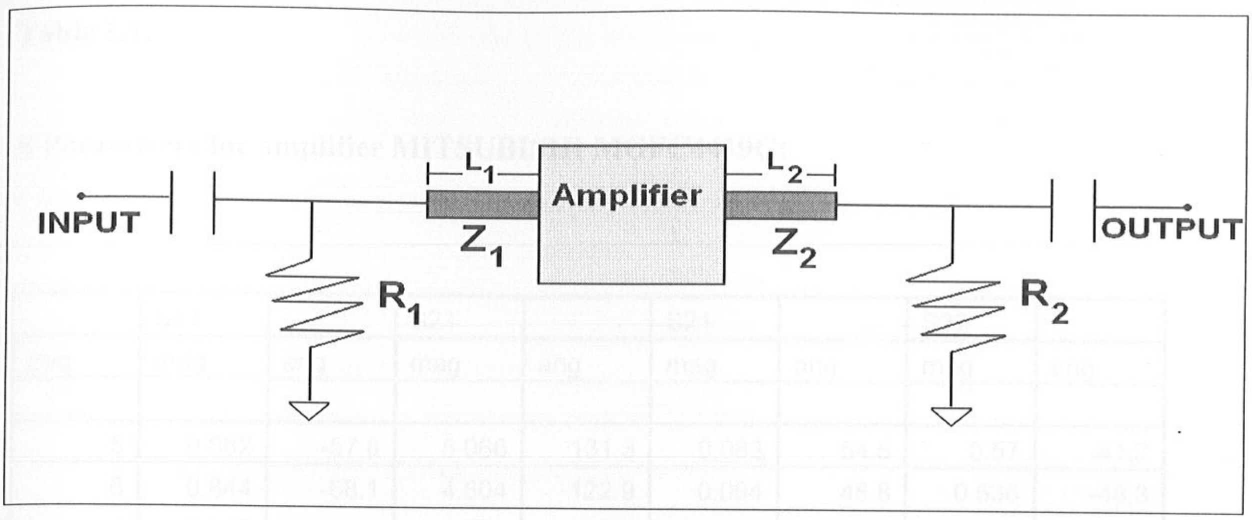


Fig 2

- In the first circuit (refer to Fig 1) the amplifier MITSUBISHI MGFC4419G has been cascaded with two series microstrip transmission lines (L1 and L2) , one on each side. Resistive loading has been done. A series source resistance R1 and a shunt load resistance R2 have been provided. In the second circuit (refer to Fig 2) the configuration is same as that of figure 1 except that a shunt source has been provided in this case. By providing resistive loading and series transmission lines (microstrip), matching and stability is achieved. In the workable range of frequencies for different lengths of microstrip lines and different source and load resistances, stability factor, reflection coefficients for load and source and Maximum Stability Gain have been calculated.

Table 1.1:

S Parameters for amplifier MITSUBISHI MGFC4419G:

	S11		S21		S21		S22	
freq	mag	ang	mag	ang	mag	ang	mag	ang
5	0.882	-57.8	5.066	131.3	0.083	54.5	0.57	-41.2
6	0.844	-68.1	4.804	122.9	0.094	48.8	0.536	-48.3
7	0.808	-77.9	4.542	114.9	0.103	43.5	0.502	-55.1
8	0.773	-87.2	4.286	107.4	0.111	38.8	0.469	-61.6
9	0.742	-96.2	4.043	100.4	0.117	34.5	0.438	-67.7
10	0.713	-104.7	3.813	93.7	0.123	30.6	0.408	-73.7
11	0.688	-112.9	3.599	87.4	0.127	27	0.38	-79.6
12	0.667	-120.7	3.401	81.3	0.13	23.8	0.355	-85.5
13	0.649	-128.2	3.218	75.6	0.133	20.9	0.332	-91.3
14	0.634	-135.4	3.049	70	0.135	18.2	0.311	-97.3
15	0.623	-142.4	2.893	64.7	0.137	15.8	0.293	-103.4
16	0.614	-149	2.75	59.5	0.139	13.5	0.277	-109.6

Table 1.2 : Stability factor and gain

Freq	K	G
5	0.26	17.9
6	0.31	17.1
7	0.36	16.4
8	0.41	15.9
9	0.46	15.4
10	0.51	14.9
11	0.56	14.5
12	0.61	14.2
13	0.66	13.8
14	0.71	13.5
15	0.75	13.2
16	0.8	13

The matrix multiplication is performed using the formula below:

$$[R] = [Zs] . [X] . [A] . [Y] . [ZL]$$

Where R=>resultant ABCD matrix

Zs => ABCD matrix for source impedance

X => ABCD matrix for microstrip line 1

A => ABCD matrix for amplifier

Y => ABCD matrix for microstrip line 2

Z_L => ABCD matrix for load impedance

This resultant matrix is then converted to scattering matrix.

CHAPTER 6

ANALYSIS OF THE CIRCUITS

Analysis of fig 1

In figure 1 source resistance R1 is applied in series and two microstrip lines are attached to amplifier both at source end and load end in series. Length of microstrip line is calculated using different software to achieve the condition of best matching and maximum gain. values of source resistance and load resistance is also varied to check the condition of best stability and matching.

The following Table indicates the values of S-parameters, Stability factor and reflection coefficients for the optimum values of:

Length of microstrip line: 11mm

Width of microstrip line: 1 mm

Height of microstrip line: 0.538 mm

Source resistance: 50 ohms

Load resistance: 70 ohms

Resistance of L_1:20 ohms

Resistance of L_2: 100 ohms

Table 2.1:S-Parameters for fig 1

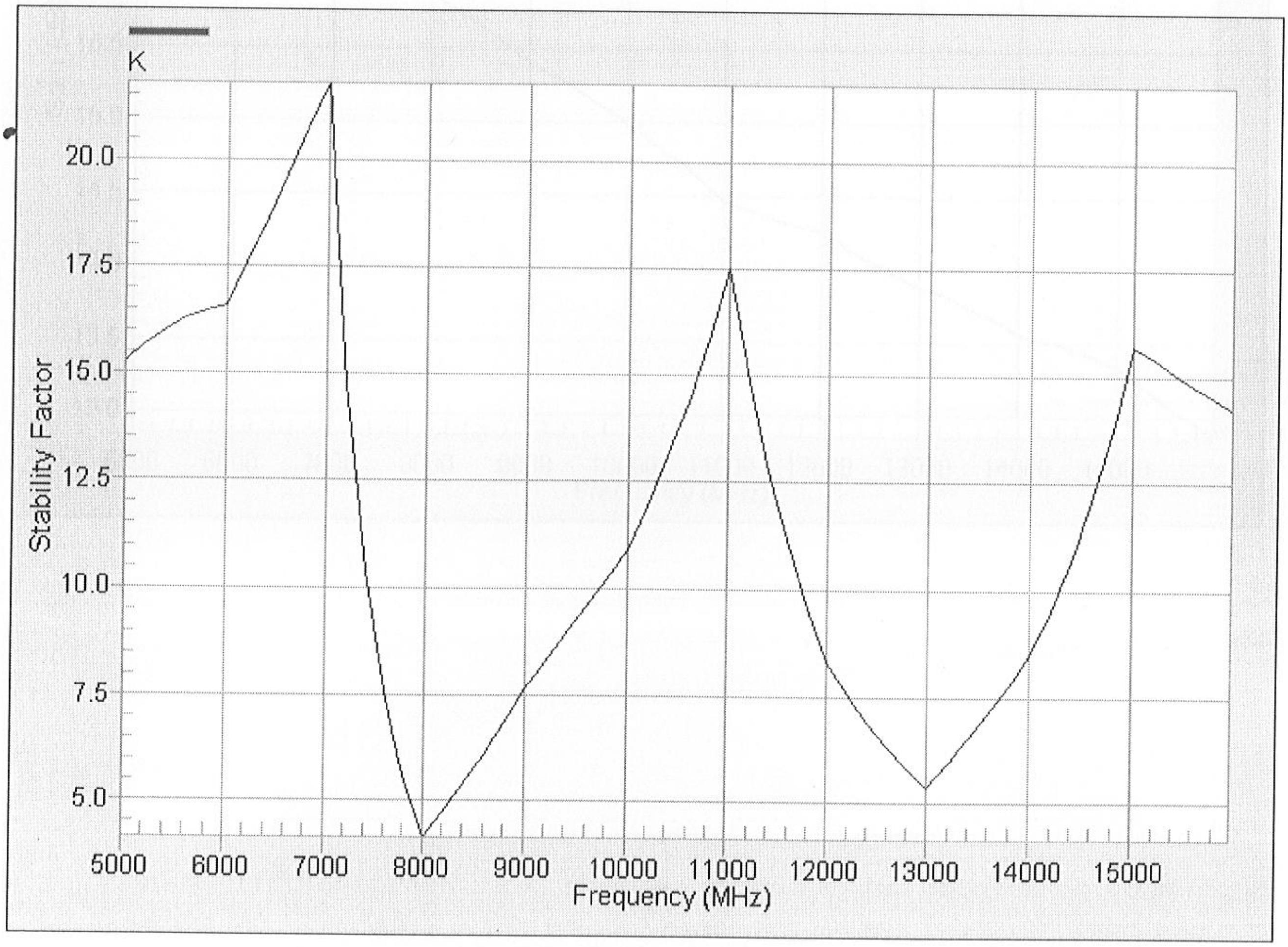
Freq	S11		S21		S12		S22	
	M	ang	mag	ang	mag	ang	mag	ang
5	0.225	-80.53	1.366	71.38	0.022	-15.89	0.185	-135.4
6	0.026	35.53	1.167	-4.08	0.023	-75.91	0.333	166.4
7	0.15	56.41	0.98	-88.88	0.022	-160.3	0.191	81.27
8	0.498	30.11	1.817	-160.3	0.047	131.5	0.216	-51.58
9	0.248	-71.92	1.424	62.21	0.041	-3.699	0.219	-152.6
10	0.053	24.62	1.133	-11.72	0.036	-81.4	0.333	163.4
11	0.138	33.8	0.866	-98.83	0.031	-159.2	0.205	76.5
12	0.317	27.77	1.172	-164.4	0.044	137.7	0.205	-46.97
13	0.264	-54.08	1.393	72.28	0.057	17.17	0.285	-155.5
14	0.081	24.03	1.09	-16.02	0.048	-68.19	0.329	165.3
15	0.155	11.96	0.796	-105.9	0.037	-154.7	0.223	78.63
16	0.214	18.26	0.791	-170.7	0.041	143.9	0.179	-39.55

Table 2.1: Stability factor, gain and reflection coefficients for fig 1

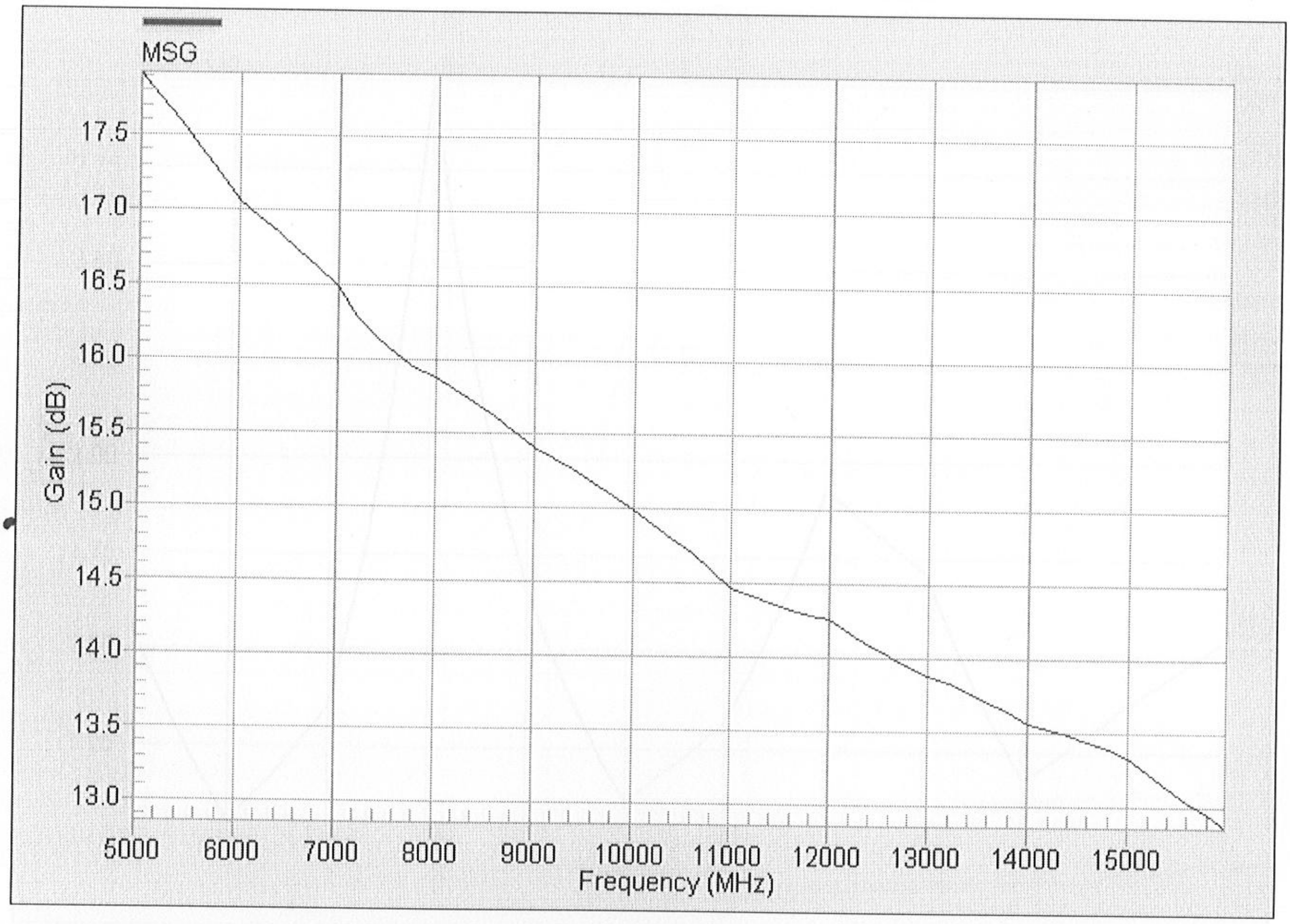
Freq	k	D	TL	TS
5	15.12	0.055	-14.69	-12.99
6	16.753	0.023	-9.54	-29.91
7	21.557	0.014	-14.22	-16.25
8	4.15	0.026	-11.20	-5.633
9	7.644	0.07	-12.99	-11.96
10	10.809	0.039	-9.505	-24.47
11	17.716	0.004	-13.59	-16.83
12	8.229	0.015	-12.98	-9.645
13	5.35	0.078	-10.49	-11.08
14	8.459	0.058	-9.628	-21.42
15	15.535	0.006	-12.85	-15.82
16	14.375	0.007	-14.57	-13.15

As can be seen from the table above, Stability factor is greater than 1 and Determinant is less than one making the amplifier unconditionally stable for the workable range of frequencies. The reflection coefficients are less than -10 dB for most cases implying a matched circuit.(refer to fig 1)

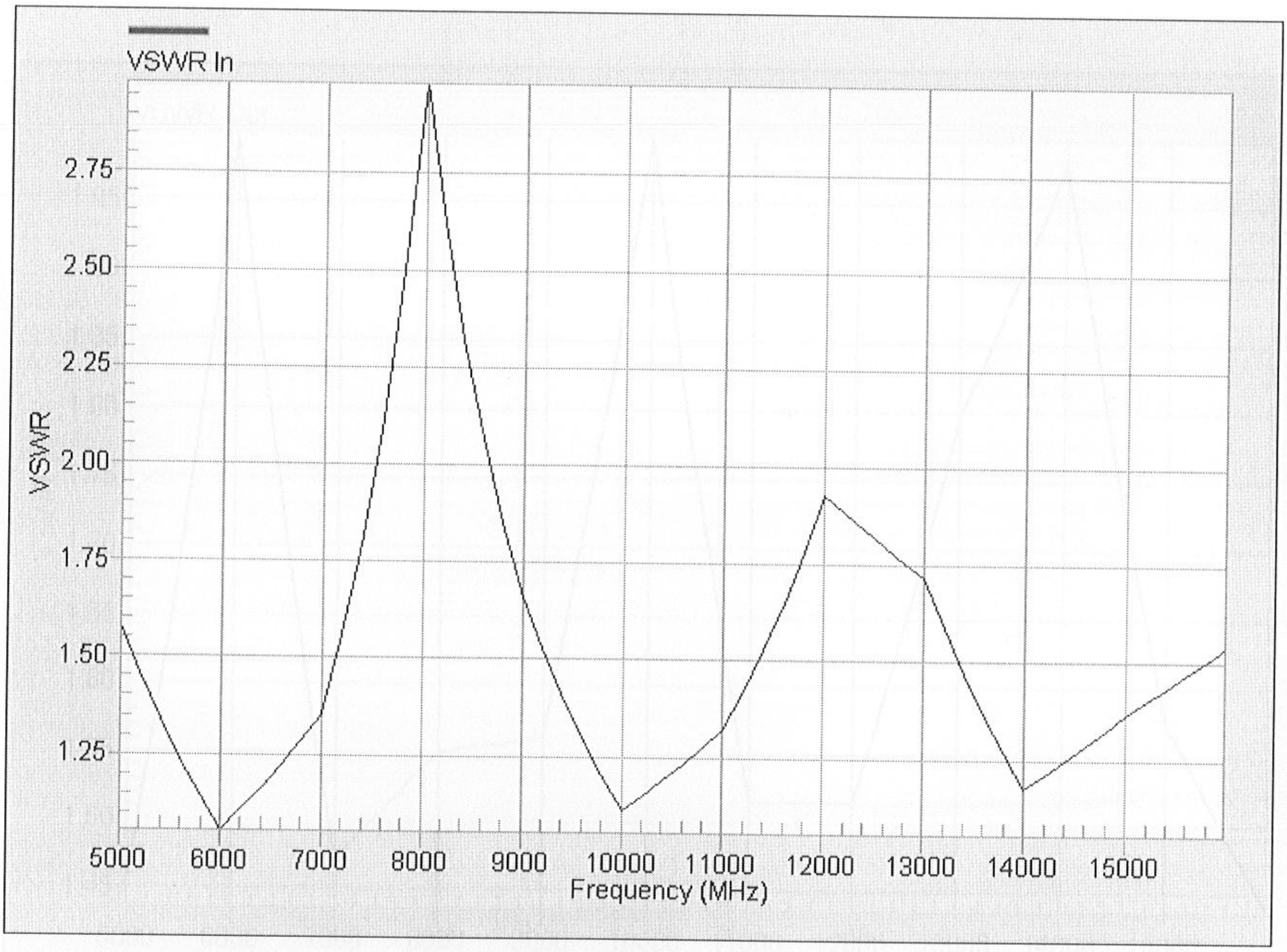
Graph for stability factor (refer to fig 1) :



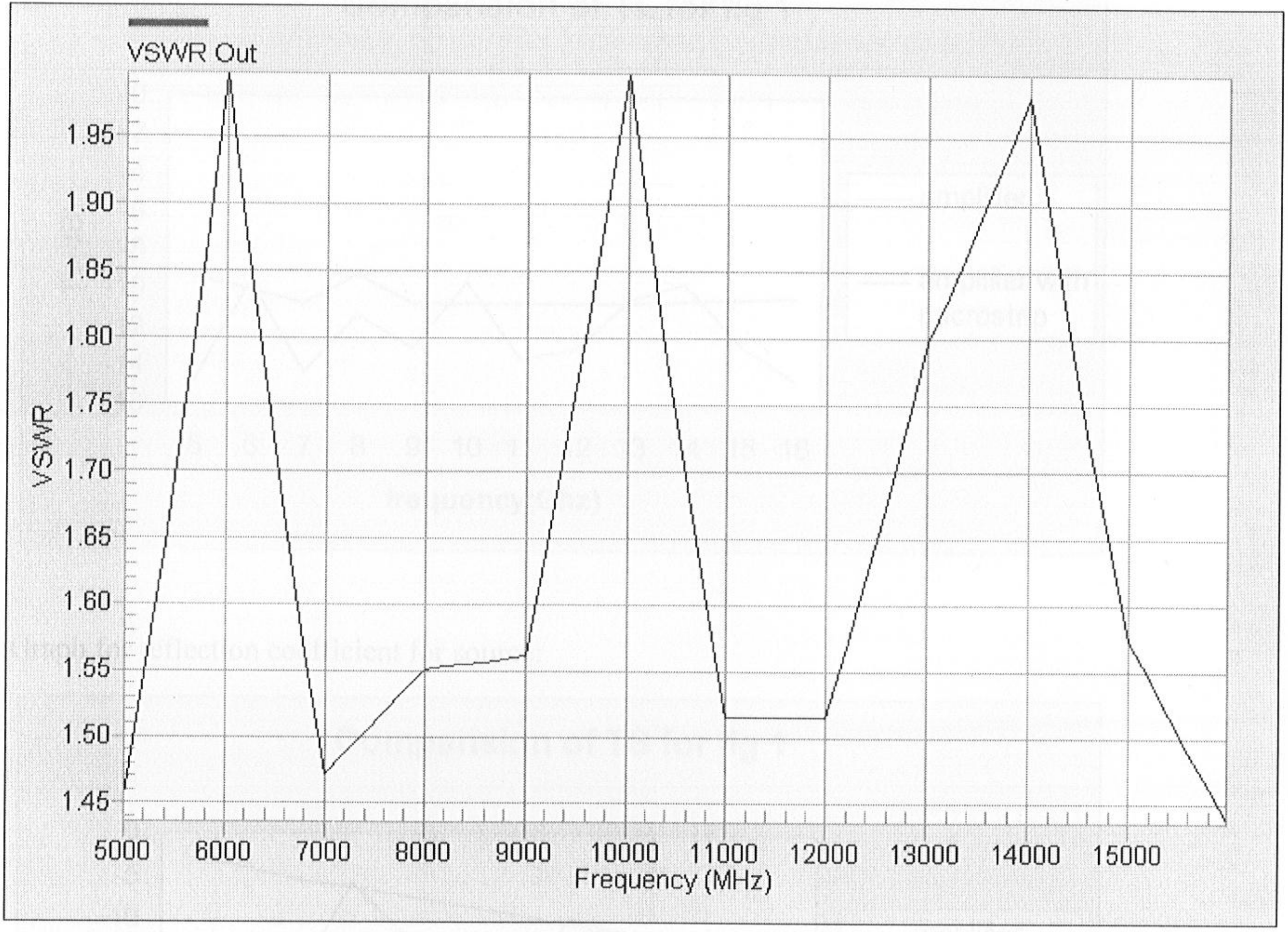
Graph for MSG:(refer to fig 1)



Graphs for VSWR in (refer to fig 1) :



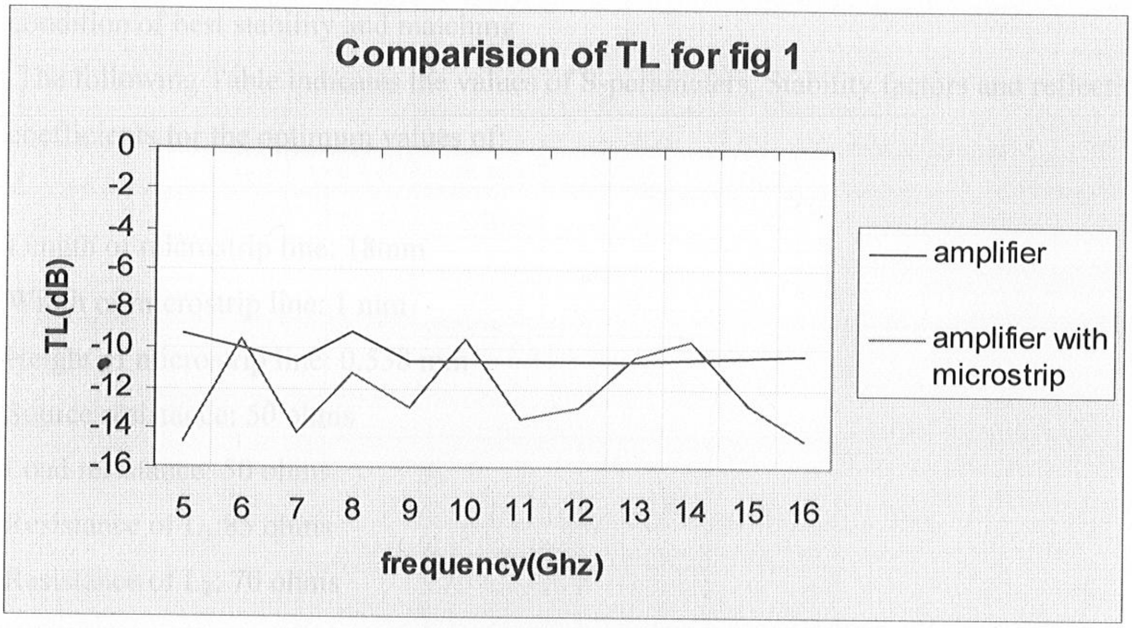
Graph for VSWR out (refer to fig 1) :



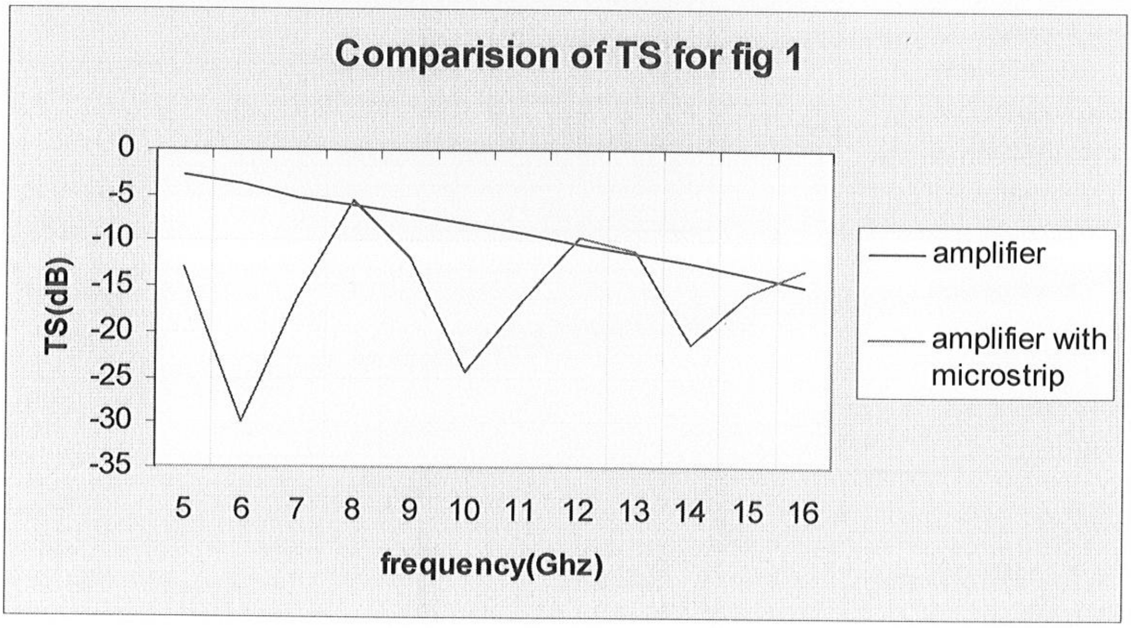
Comparison between reflection coefficients:

A comparison between the reflection coefficients for the amplifier without microstrip line and the amplifier with microstrip line has been shown in the graphs below to indicate that matching is achieved when we apply microstrip lines on either side of the amplifier.

Graph for reflection coefficient for load:



Graph for reflection coefficient for source:



Analysis of fig 2

In figure 2 source resistance R1 is applied in shunt and two microstrip lines are attached to amplifier both at source end and load end in series. Length of microstrip line is calculated using different software to achieve the condition of best matching and maximum gain. values of source resistance and load resistance is also varied to check the condition of best stability and matching

The following Table indicates the values of S-parameters, Stability factors and reflection coefficients for the optimum values of:

Length of microstrip line: 18mm
Width of microstrip line: 1 mm
Height of microstrip line: 0.538 mm
Source resistance: 50 ohms
Load resistance: 50 ohms
Resistance of L_1:85 ohms
Resistance of L_2: 70 ohms

Table 3.1: S-Parameters for fig 2

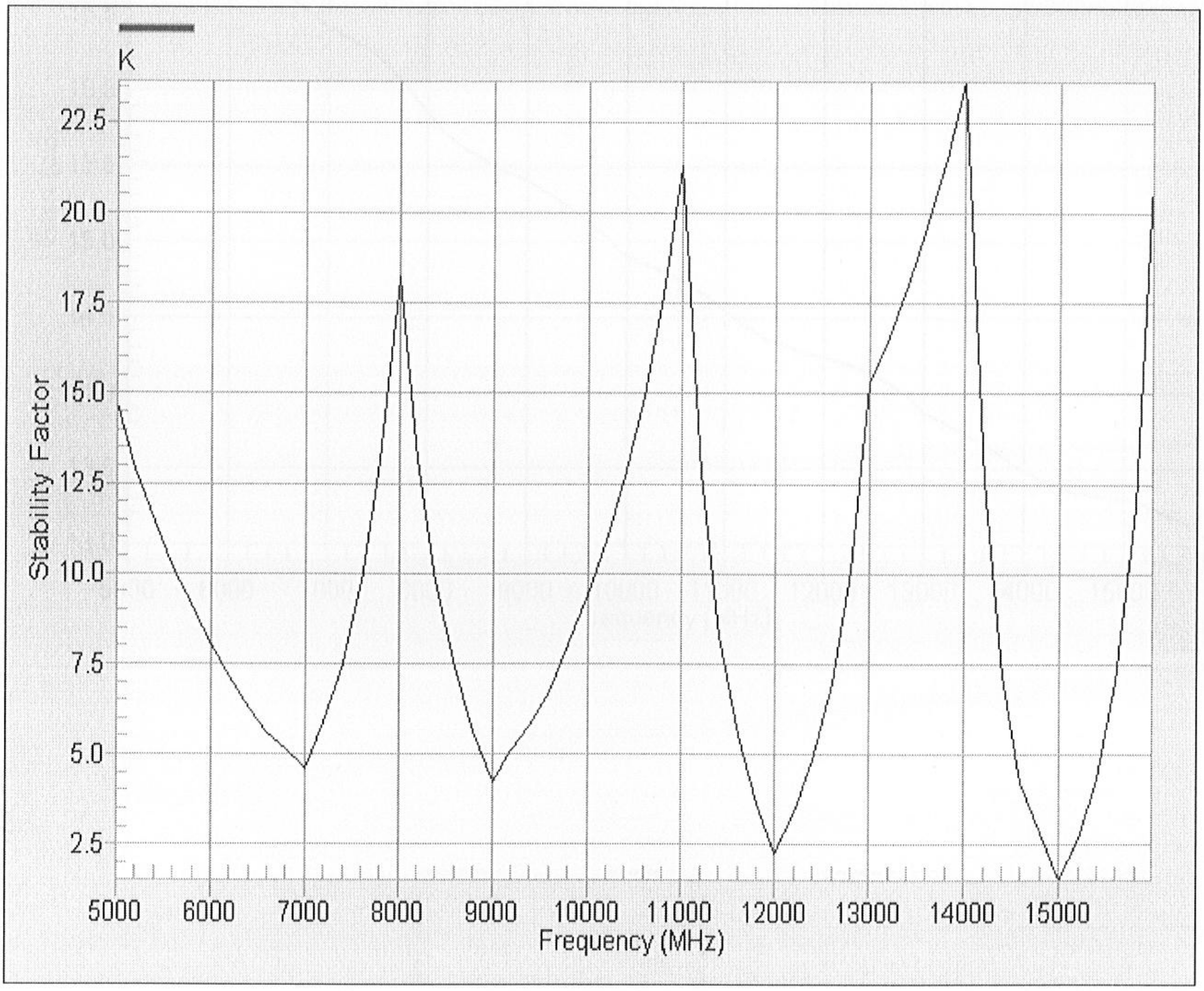
Frequency	S11		S21		S12		S22	
	mag	ang	mag	ang	mag	ang	mag	ang
5	0.091	142.125	1.389	-141.33	0.023	142.125	0.231	160.54
6	0.292	-112.60	1.67	140.053	0.033	66.571	0.195	-134.17
7	0.352	116.856	1.97	-59.99	0.045	-131.42	0.291	150.35
8	0.073	-172.37	1.002	-153.43	0.026	138.17	0.209	168.153
9	0.447	-126.18	1.737	117.5	0.05	51.519	0.284	-135.71
10	0.241	116.56	1.206	-75.157	0.039	-138.12	0.256	156.74
11	0.096	-146.64	0.797	-164.06	0.028	135	0.2	175.117
12	0.596	-142.23	1.778	92.38	0.067	35.34	0.376	-143.55
13	0.186	118.217	0.854	-87.65	0.035	-143.13	0.24	159.52
14	0.124	-134.34	0.669	-174.17	0.03	135	0.195	-178.65
15	0.707	-1660.1	1.728	65.37	0.081	16.429	0.452	-154.73
16	0.151	120.311	0.642	-99.594	0.033	-144.87	0.228	160.53

Table 3.2:Stability factor and reflection coefficient for fig 2

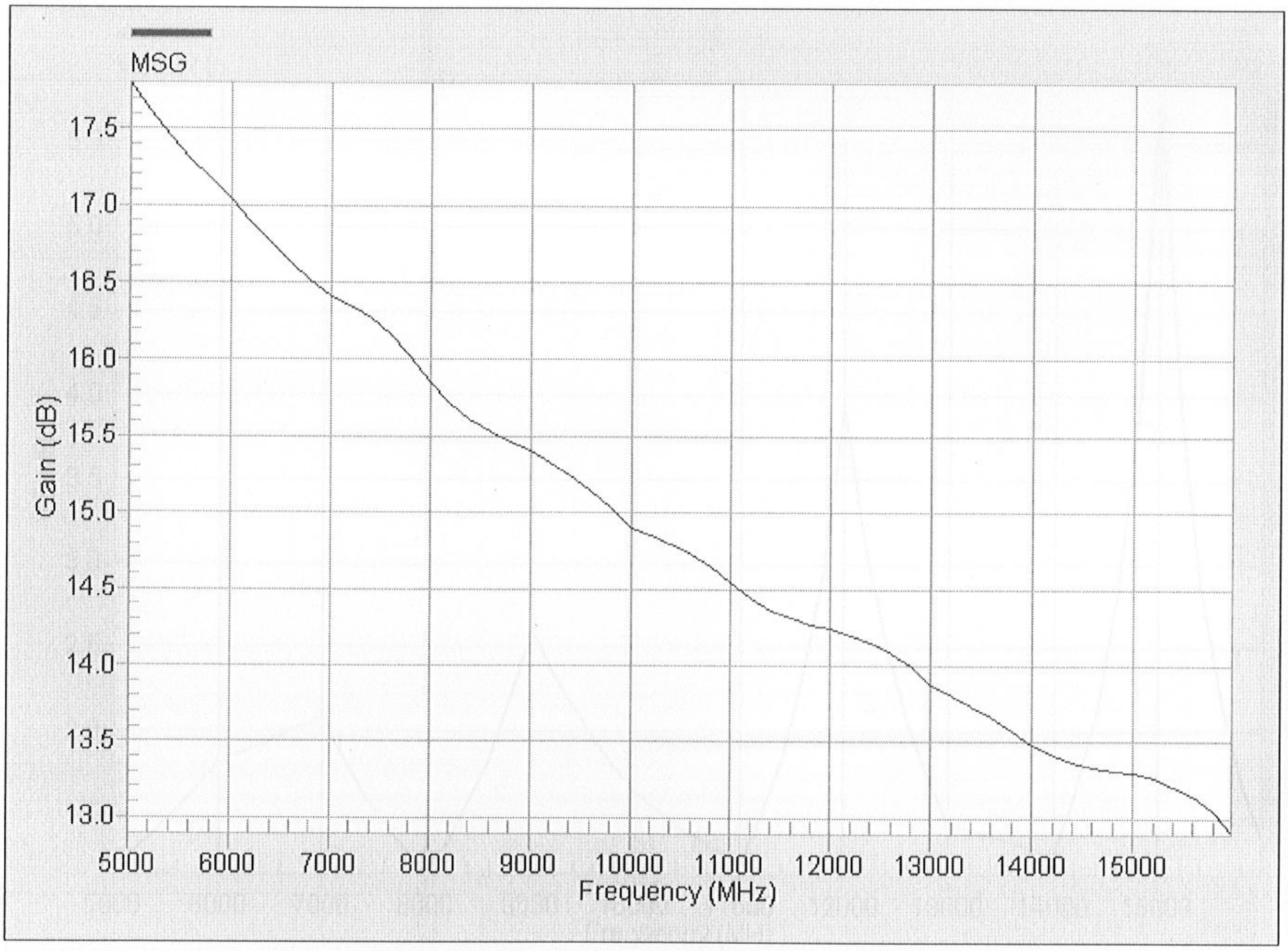
Frequency	K	TL	TS
5	14.949	-12.667	-20.366
6	14.888	-10.652	-31.644
7	16.286	-10.826	-16.165
8	18.369	-13.501	-22.07
9	4.228	-10.264	-6.707
10	9.525	-12.062	-12.596
11	21.208	-14.037	-20.153
12	2.232	-6.521	-3.73
13	15.174	-12.557	-14.914
14	23.942	-14.172	-18.099
15	1.23	-2.574	-1.416
16	21.93	-12.947	-16.735

As can be seen from the table above, Stability factor is greater than 1 and Determinant is less than one making the amplifier unconditionally stable for the workable range of frequencies. The reflection coefficients are less than -10 dB for most cases implying a matched circuit.(refer to fig 2)

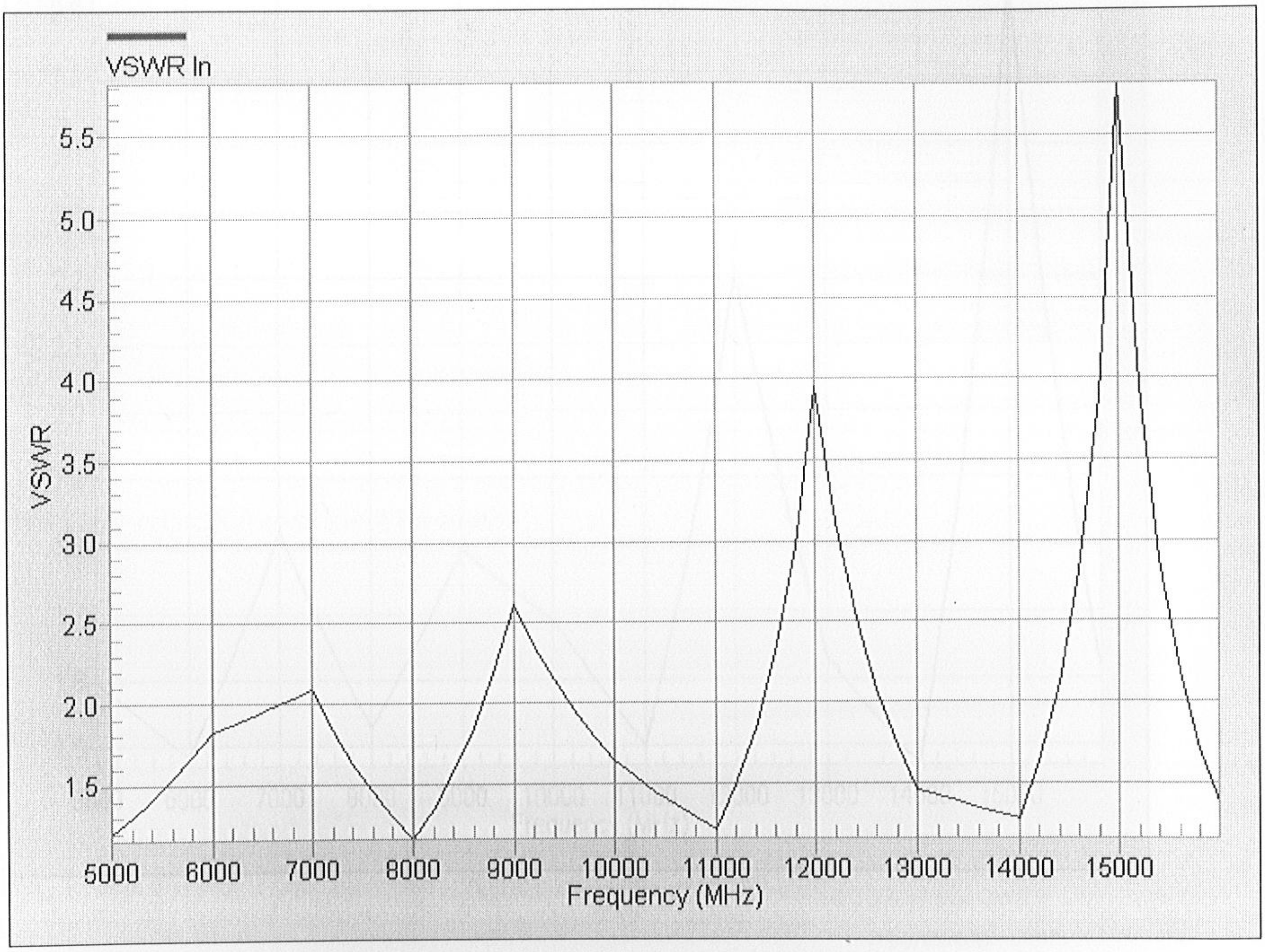
Graph for stability factor (refer to fig 2):



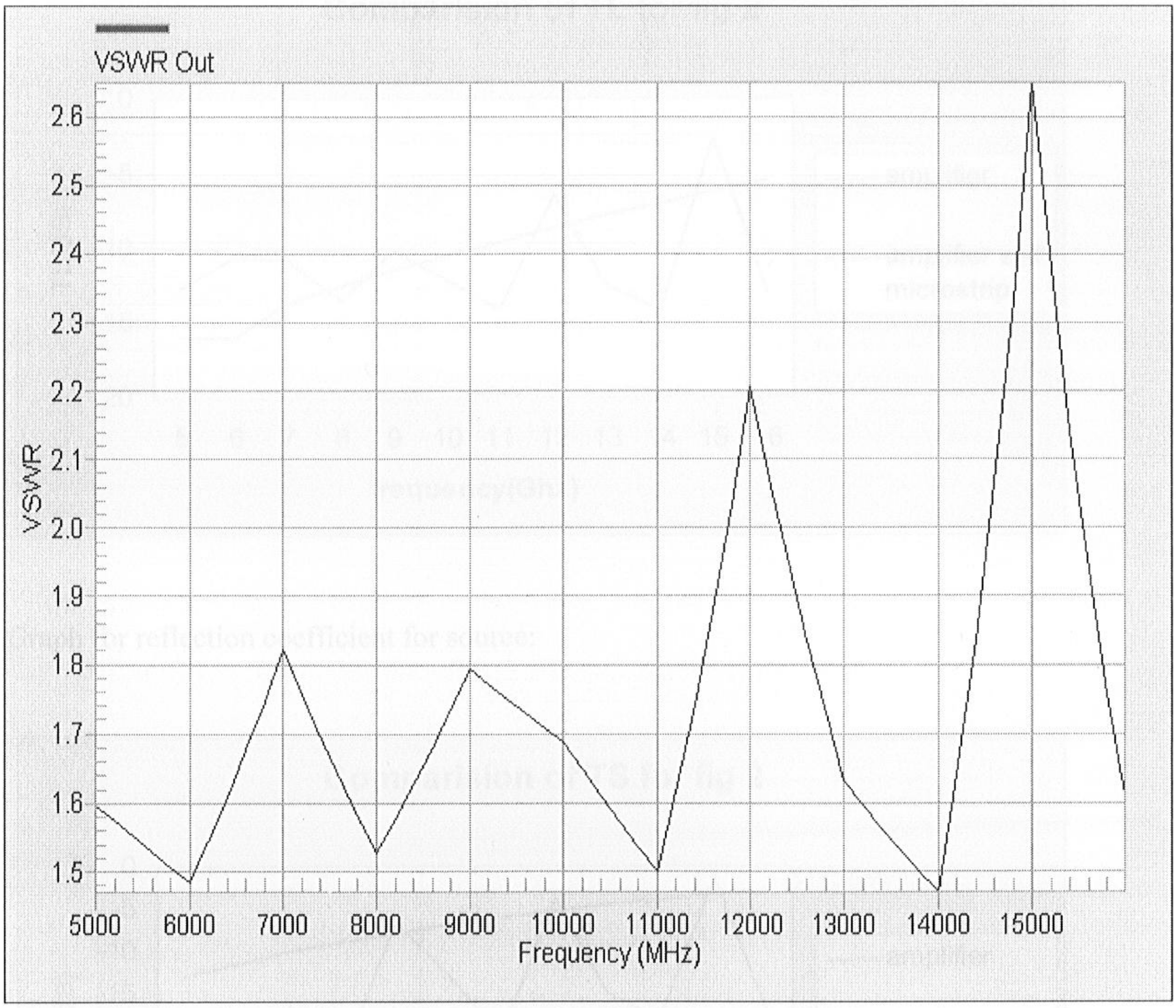
Graph for MSG (refer to fig 2):



Graph for VSWR in (refer to fig 2):

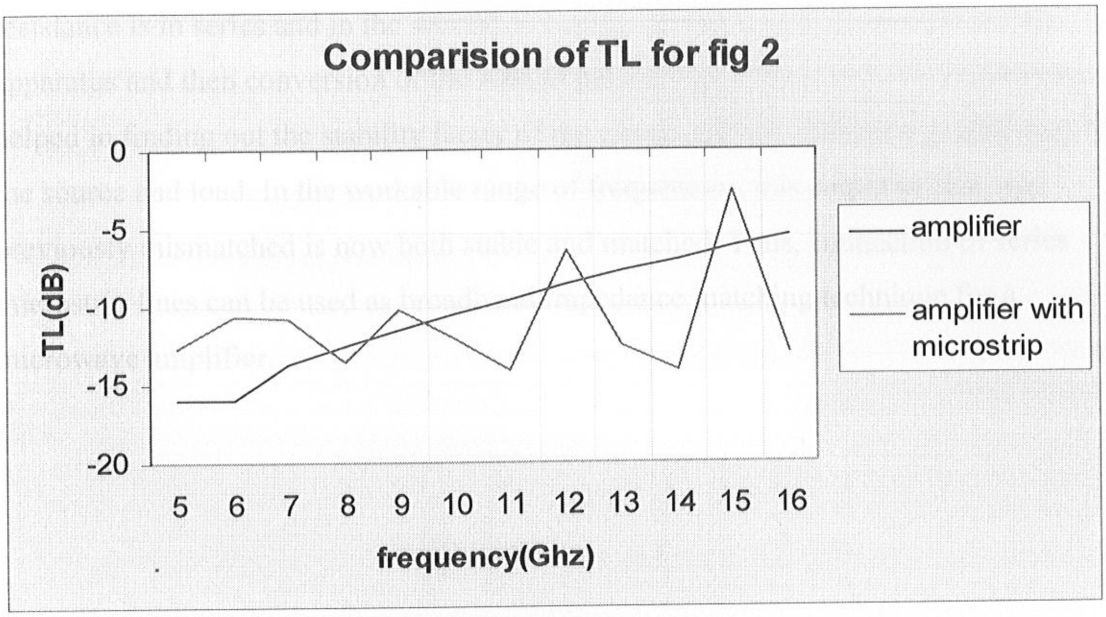


Graph for VSWR out (refer to fig 2):

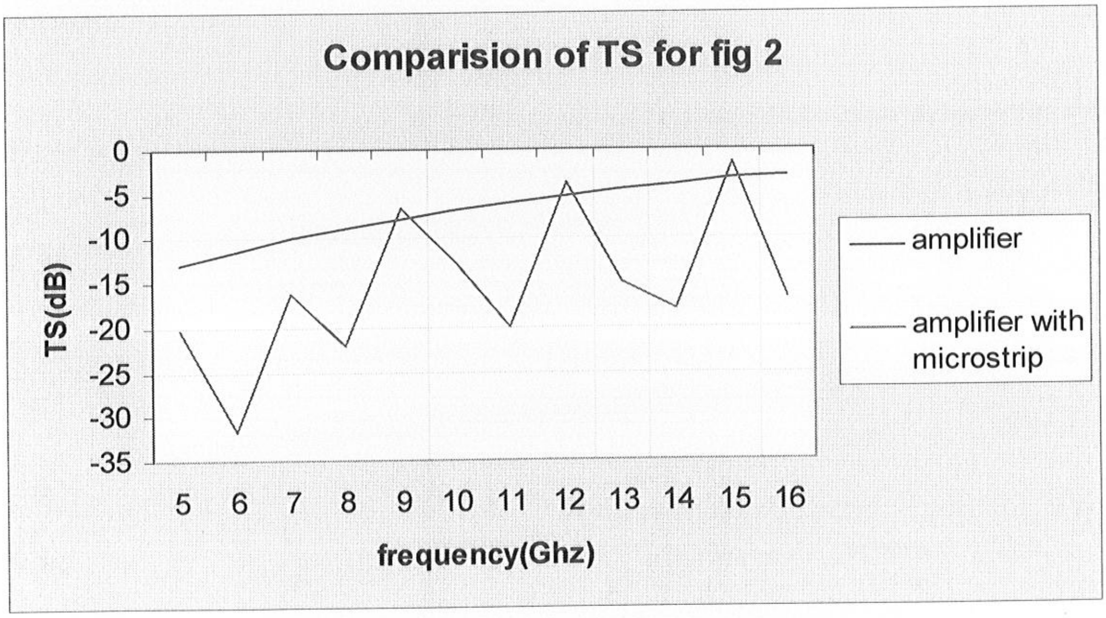


Comparison between reflection coefficients:

Graph for reflection coefficient for load:



Graph for reflection coefficient for source:



CONCLUSION:

The detailed analysis of Fig 1 and Fig 2 has been carried out. The difference between the two circuits is only the position of the source resistance. In the first circuit the source resistance is in series and in the second, it is place in shunt. ABCD analysis of the apparatus and then conversion of the ABCD parameters of the circuit to S parameters helped in finding out the stability factor of the circuit and the reflection coefficients for the source and load. In the workable range of frequencies, this amplifier that was previously mismatched is now both stable and matched. Thus, connection of series microstrip lines can be used as broadband impedance matching technique for a microwave amplifier.

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