PROJECT REPORT

1999-2000

"TEST AUTOMATION SYSTEM"

Submitted in partial fulfillment of

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BACHELOR OF ENGINEERING

in

TELECOMMUNICATION

by the Bangalore University, Bangalore.

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CERTIFICATE

This is to certify that the project work entitled

" TEST AUTOMATION SYSTEM "

has been successfully carried out by

HAMSA B.S	**SOWMYA.S**
SHUBHASHINI.S	**VEENA L.P**

in partial fulfillment of the requirement for the award of bachelor of Engineering Degree inTelecommunication by the Bangalore University, Bangalore during the academic year 1999 – 2000.

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August 10, 2000

Certificate

This is to certify that the project work titled

"Test Automation System"

has been successfully completed by

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Students of the final year,
Bachelor of Engineering (Telecommunication),
R.V. College of Engineering, Bangalore
under the guidance of *Mr. K. Ramesh & Mr. R. Ganesan*

This project is in partial fulfillment of the requirement for the award of Bachelor's Degree in Telecommunication Engineering during the academic year 1999-2000.

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CONTENTS

PROJECT SYNOPSIS

Routine Measurement of various parameters of Spectrometers in the 10.4m Telescope is a time-consuming manual process. To automate the measurement of these parameters, we can follow a GPIB based approach with network capability to collect data in a remote machine. Various parameters that are to be measured are the frequency resolution, dynamic range, and band pass characteristics and noise performance of the Spectrometers.

A PC running LINUX will have a GPIB card. A frequency synthesizer will be generating the required CW signal to measure various parameters of the spectrometer. This synthesizer will be controlled via GPIB. This PC will have a network connection, through which remote commands could be sent. The code for network communication has to be developed. A spectrum analyzer will also be required to characterize analog sections of spectrometer. This instrument will be controlled using GPIB.

As part of construction activities, a 5 MHz reference signal distribution unit and a harmonic signal generating circuit will be built. The harmonic generator will produce CW signals at harmonic intervals that could be used for frequency resolution characterization of spectrometers. The 5 MHz reference signal, derived from a Rubidium based atomic clock, will be used to lock all synthesizers to the atomic standard.

The Project work involves -

- Selection of components, building and testing RF circuits
- Develop GPIB code using C on LINUX.
- Develop network code using C on LINUX.

INTRODUCTION

1.1 SPECTRAL LINE MEASUREMENT

Spectral line in radio astronomy began its study in 1921 with the detection of neutral hydrogen from interstellar space at a wavelength of 21cm. Spectral line measurements have the following important requirements.

1. The telescope used for spectral line measurements should have a good printing accuracy.
2. Stability of the gain are excellent.
3. Local oscillators have good frequency stability.

Spectral line work needs an extremely low noise receiver. The limiting noise fluctuation of a receiving system is given by

$$\Delta Trms = a\ Tsys / \sqrt{(bt)}$$

where

$\Delta Trms$: root mean square noise fluctuations present in the observation.

Tsys : system temperature

b : receiver bandwidth

t : time interval over which observations are made

For a spectral line receiver the sensitivity can be improved only by reducing system temperature or increasing the observation time. In spectral line measurements, some form of switching or differencing is invariably used to obtain adequate gain stability and an appropriate flat base line.

1.2 SINGLE ANTENNA OBSERVATIONS

The reasons that single dishes are useful for both in-line search and line work is as follows.

1. To observe lines that are widely distributed in angle in the galaxy, as well as for observing dust clouds, we use single dish which is the simplest one.
2. With a single dish, only one front end, a costly item is required for each frequency range. Change from one frequency to another is relatively easy, and operation at several frequencies simultaneously is readily achieved.
3. The versatility of the single dish is especially apparent in the recent surge towards observations of centimeter and millimeter wavelength molecular lines which were all discovered with single – dish measurements of modest size but having very accurate surfaces.

1.3 EMISSION AND ABSORPTION SPECTRA

Emission of radiation by atoms , molecules and nuclei

An atom, molecule or nucleus may be excited to a state of energy greater than the ground state. Excitation can be produced by several means. One method is by inelastic collisions in which a fast particle collides with an atom or a nucleus. In either case, the fast projectile transfers part of its kinetic energy to the target. The excited atoms, molecules and nuclei release their excess energy in the form of electromagnetic radiation. The excited atoms emit the radiation as they return to their ground state. The radiation emitted by each substance is composed of well-defined frequencies f1,f2,f3,.... which are characteristic of the substance. The frequencies composed in emission spectra appear as separate lines in a spectroscope and hence called as line spectra.

Absorption of electromagnetic radiation by atoms, molecules and nuclei

When an EM wave interacts with a system of charges such as an atom, a molecule or a nucleus, the electric and magnetic fields of the wave disturb the motion of charges. Wave impresses a forced oscillation on the natural motion of charges resulting in absorption of energy by the system of charges.

The atoms, molecules, nuclei, in general, any assembly of charge particles have a series of resonating frequencies at which the absorption of electromagnetic radiation is appreciable. At all other frequencies absorption is negligible. The resonating frequencies constitute the absorption spectrum of the substance. The frequencies observed in the absorption of a spectrum of a system of charges are also observed in emission spectrum of the system.

1.4 RADIO FREQUENCY SPECTROMETERS

Spectrometers currently used in radio astronomy fall into three categories -

1. Multi - channel filter banks
2. Autocorrelators
3. Acousto - optic spectrometers

Filter receivers are older, more common and easy to understand. However, with the rapid development of digital electronics in early 1960's it became possible to exploit the precision and stability of digital techniques for spectral analysis.

Correlation systems have some advantages and some disadvantages in comparison with filter system. Correlators tend to be more versatile (i.e., they have a variety of spectral window width and resolution choices) and more tractable if a large ratio of window width to resolution (large number of channels) is needed. The filter receivers are characterized by channels (samples) in frequency space, while correlators are characterized by channels in lag space but a continuous function in frequency space. Auto – correlation spectrometers have been demonstrated to have superior stability for long integration. By locking the IF conversion oscillators and the digital clock system to an atomic standard, the frequency calibration of the spectrum can also have atomic accuracy, whereas in a filter –typed spectrometer expensive crystal filters are needed to guarantee freedom from frequency drifts. However, one bit correlators have poorer noise performance, for the same observing mode, and usually require the use of an electronic digital computer, at least to perform the Fourier Transform.

Acousto-optic spectrometers are usually employed for wideband spectral observations, as in millimeter and sub millimeter wave observations. These instruments operate on the principle of Diffraction. Even though wide band observations are possible, the instruments need very skilled labour and can often be plaqued by instabilities and microphonics.

A Spectrometer's frequency resolution translated is to velocity resolution, where an astronomical observation is made. If there is a relative motion between an observer and an object, then the radiation emitted by the object suffers Doppler shift. This can be quantified as-

$$\Delta V / V = \Delta f / f$$

where,

ΔV : change in velocity.

V : velocity of light (speed of electromagnetic radiation is that of light).

Δf : frequency resolution of spectrometer.

f : frequency of observation.

Hence reducing observational frequency means the spectrometer should have narrower frequency resolution[Fig1.4(a), Fig1.4(b)].

TELESCOPE BLOCK DIAGRAM

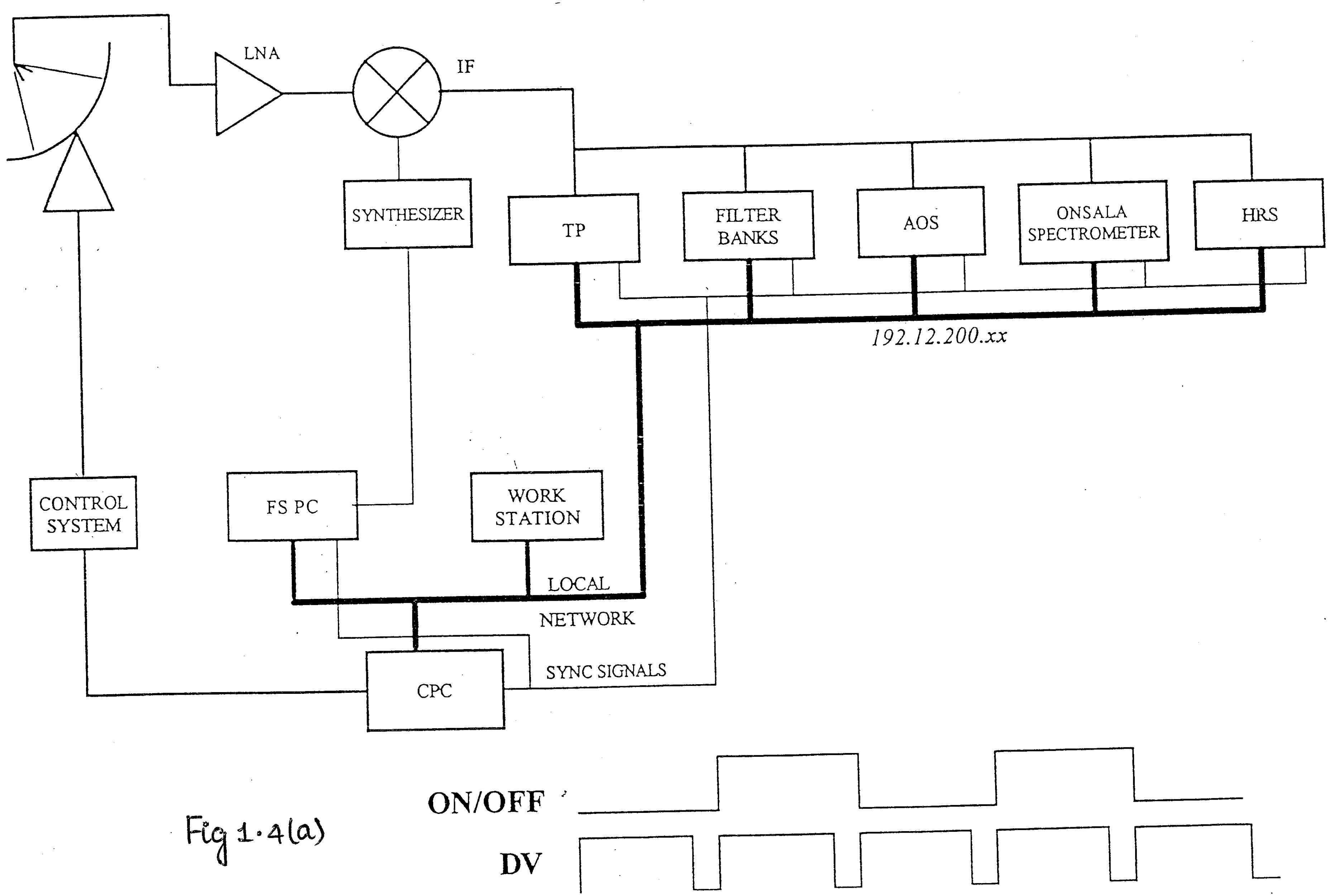


Fig 1.4(a)

SPECTROMETER	FREQUENCY RESOLUTION (in KHz)	VELOCITY RESOLUTION AT 6.7 GHz (in km/s)	VELOCITY RESOLUTION AT 100 GHz (in km/s)
FB 50	50	2.23	0.15
FB 250	250	11.2	0.75
FB 1000	1000	44.77	3.0
AOS 48	81	3.62	0.243
AOS 120	204	9.13	0.612
AOS 450	767	34.34	2.3
AOS 500	852	38.14	2.55
ACR 12.5	12.5	0.55	0.0375
ACR 25	25	1.12	0.075
ACR 50	50	2.24	0.15
ACR 100	100	4.48	0.3
ACR 200	200	8.96	0.6

Fig 1.4(b)

1.5 RADIO TELESCOPE at Raman Reasearch Institute

Raman Research Institute , Bangalore can stake its claim to being one of the finest research institute in the whole country. It boasts of its research facility in several areas including a fully equipped radio astronomy laboratory complete with a millimeter wave radio telescope. A radio telescope operates in the radio band of the electromagnetic spectrum thus making it suitable for observing the radio-sky.

Following are some of the specifications of the above mentioned Telescope:

TELESCOPE	:	alt azimuth mount parabolic dish
SIZE	:	10.4m diameter, made of 84 hexagonal panels
SURFACE ACCURACY	:	250 microns(rms)
FREQUENCY OF OPERATION	:	85 to 115 Ghz in mm band 1.4Ghz and 6.7Ghz in cm band
TRACKING ACCURACY	:	7 arc second
HP BEAM WIDTH	:	18min @ 67GHz 90arc min @ 100GHz
APERTURE EFFICIENCY	:	60% @ 6.7GHz 28% @ 86GHz
TYPE OF OBSERVATIONS	:	Line observations like Methonol maser line observation @6.7GHz 21 cm neutral hydrogen emission lines Si0 maser lines @86GHz 12co observations @115GHz
BACK-ENDS AVAILABLE	:	Multi – channel filter banks Autocorrelation Spectrometers

Acousto–Optic Spectrometers

SITE SPECIFICATIONS :

Altitude – 930m above MSL

Longitude – 13degrees North

Latitude – 77.5degrees East

1.6 PROJECT OVERVIEW :

A 10.4m parabolic reflector antenna is used to receive radiations emitted from a region of space. The frequencies of these signals are in two bands – cm band and mm band . Depending on the band of observation various spectrometers like Filter Banks, Autocorrelation spectrometer and Acousto-Optic spectrometer are used.

Before any instrument is used for a purpose it needs to be characterized for various parameters. Accordingly for a spectrometer the parameters are bandpass characteristics, frequency resolution, dynamic range and noise performance. Autocorrelation spectrometers have much narrower resolutions in some modes of operation. To characterize these instruments, a frequency synthesizer is used so that the CW signal can be stepped in frequency and amplitude as required. To characterize some analog sections of the spectrometer a spectrum analyzer is used.

A lot of time is spent in coming to the physical location of the instruments (such as spectrum analyzer and frequency synthesizer) every time some parameter needs to be changed. In addition to it operating on the instrument manually consumes some time thus making the process cumbersome. To make the job simpler, the entire process is automated i.e., the instruments are controlled by a computer – usually a PC.

The synthesizers and the spectrum analyzers are controlled by a computer via General Purpose Interface Bus (GPIB). This is a parallel bus which carries data bi-directionally providing a communication between the instrument and the PC. A generalized program (applicable to any instrument) is written using ' C ' language on LINUX platform making use of standard GPIB functions. This program has the capability of changing parameters like frequency , amplitude , span , etc., and also read data from these instruments.

The time spent on operating on the instrument manually is overcome by this automation process. But still time is spent in coming to location of the PC and instrument. To overcome this problem, network codes are developed using network communication techniques such as Client-Server model and UNIX networking features like Berkeley Sockets.

Spectrometers are used to measure line spectra in the observatory. Spectral lines have distinct frequency-spread and amplitude [Fig(1.6)]. The height of the line gives intensity or concentration of molecules at the region of interest. The line width gives the spread and local rotational velocities. The center frequency gives the radial velocity of the region. Hence the frequency resolution of the spectrometer is intimately related to the velocities. This needs to be characterized before the spectrometer is employed for observations. One variety of the spectrometer at the observatory is the filter bank. These instruments have a center frequency of 150MHz. The frequencies corresponding to different channels in the filter bank spectrometer needs to be checked. To check individual frequencies the signal generator needs to be set at different frequencies, the response acquired, analyzed and interpreted each time. This is a very tedious process. Instead a Harmonic Generator is built centered around 150MHz to characterize the frequency resolution of these spectrometers.

The frequency synthesizer is used to generate a CW signal. Internally it has a PLL. It requires a reference to generate the signal. A Rubidium Atomic Clock generally serves as the standard reference . But different synthesizers require different power reference. So a distribution unit is built with different power outputs. The input to the distribution unit is from the Atomic clock. Thus by making use of a distribution unit many synthesizers can be provided with a reference .

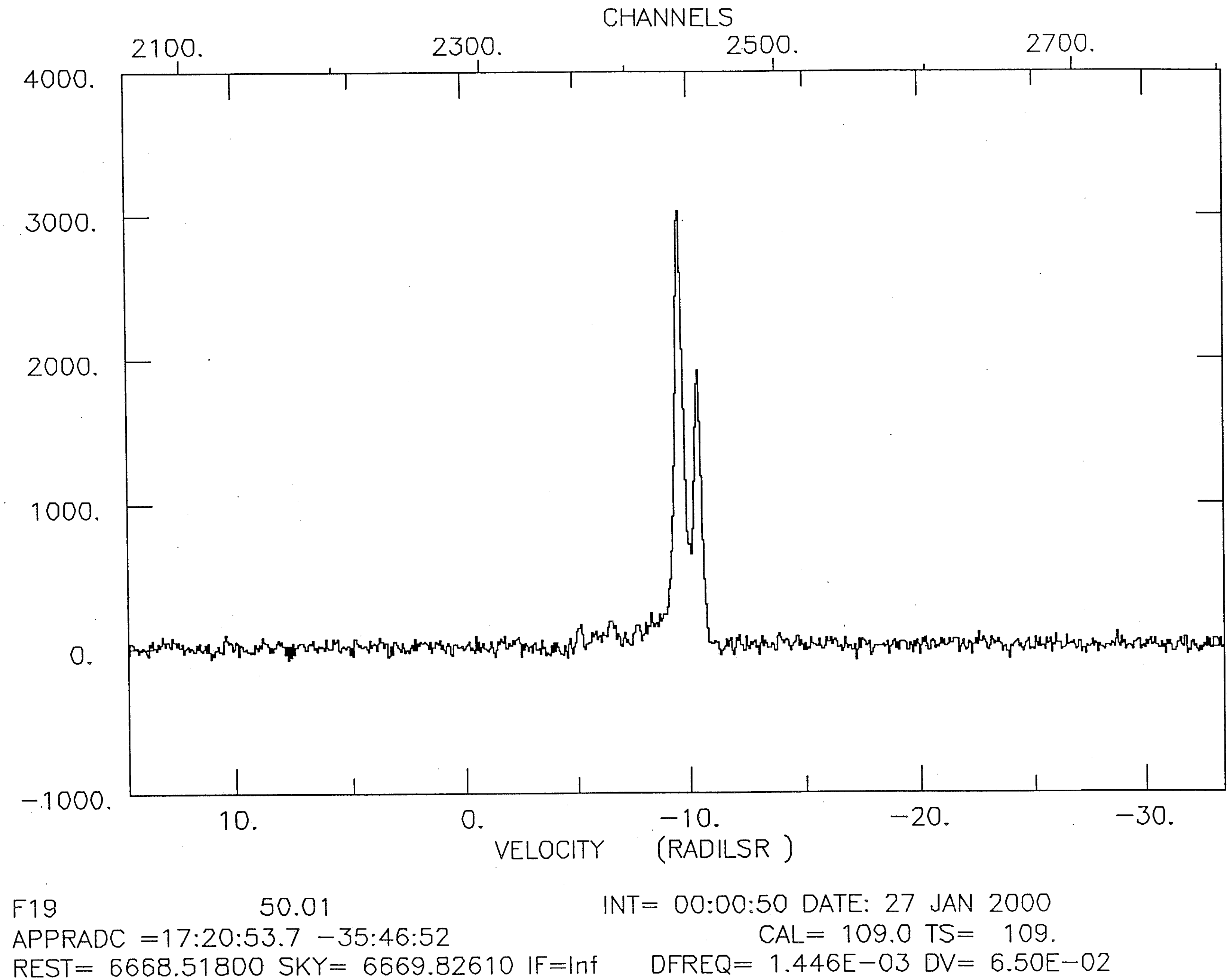

CHANNELS
2100.
2300.
2500.
2700.
4000.
3000.
2000.
1000.
0.
-1000.
10.
0.
-10.
-20.
-30.
VELOCITY (RADILSR)
F19 50.01
APPRADC =17:20:53.7 -35:46:52
REST= 6668.51800 SKY= 6669.82610 IF=Inf
INT= 00:00:50 DATE: 27 JAN 2000
CAL= 109.0 TS= 109.
DFREQ= 1.446E-03 DV= 6.50E-02

Fig 1.6.

HARDWARE SECTION

2.1 DISTRIBUTION UNITS

Necessity for distribution units:

Frequency synthesizers are used to generate the CW signal to characterize the parameters of Spectrometer. These synthesizers have PLL internally. It requires a reference to generate the signal. The Rubidium Atomic standard provides standard references of 1,5 and 10 MHz outputs, at a particular power level. But different synthesizers require different power levels as reference. So a distribution unit is built to provide different power outputs. The input to the distribution unit is from the Atomic clock at +8.7 dBm, 5MHz. Thus by making use of a distribution unit many synthesizers can be provided with the standard reference.

Design :

Two distribution unit modules with different power outputs were built.

Module 1: two outputs each of +14dBm and four outputs each of +7dBm .
Module 2: two outputs each of +14dBm.

MODULE 1:

The output of the Rubidium Atomic Frequency Standard, including cable loss is +7.78dBm which forms the input to the module1.Two different power outputs i.e.,14dBm and +7dBm are required. So, the input power is divided initially by making use of a two way power divider. Since we require two outputs each of +14dBm and four outputs each of +7dBm, we make use of a two way power divider and a four way power divider respectively. The input to the four way power divider is +13dBm as the attenuation of the power divider is +6dB. The power available after initial division is +4dBm. Since the required power is greater than the available power an amplifier with gain of 9dB is used. The input to the two way power divider is 17dBm as the attenuation of the power divider is 3dB. The power available after initial division is +4dBm. Since the required power is greater than the available power an amplifier with gain of 13dB is used[Fig 2.1(a)].

MODULE 2:

The output of the Rubidium Atomic Standard is +8.7dBm (approx. 9dBm) which forms the input to the module2. We require two outputs each of +14dBm. So, we make use of a two way power divider. The input to the power divider is +17dBm as the attenuation of the power divider is 3dB. The available input power is +9dBm . Since the required power is greater than the available power an amplifier must be made use of. The available amplifiers provide a gain of 9dB or 13dB. If the input signal is fed to the amplifiers the output will be greater than the required power of +17dBm. Initially the input signal is attenuated by 5dB and fed to the amplifier of gain 13dB to get the required output of +17dBm[Fig 2.1(b)].

MODULE - 1

Two outputs of +14dBm each and four outputs of +7dBm each

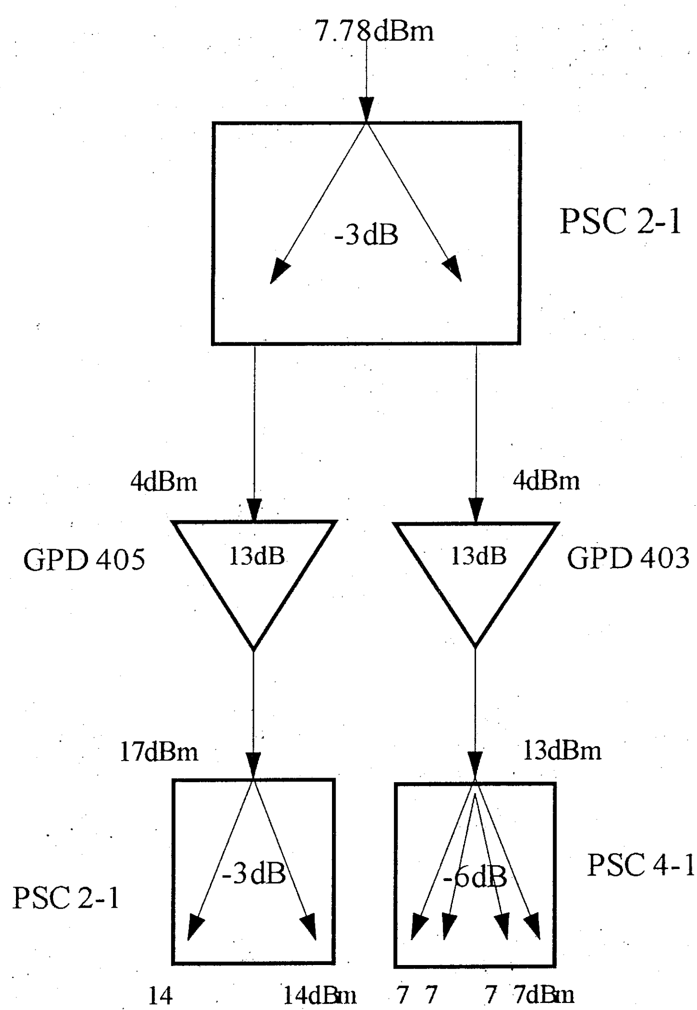
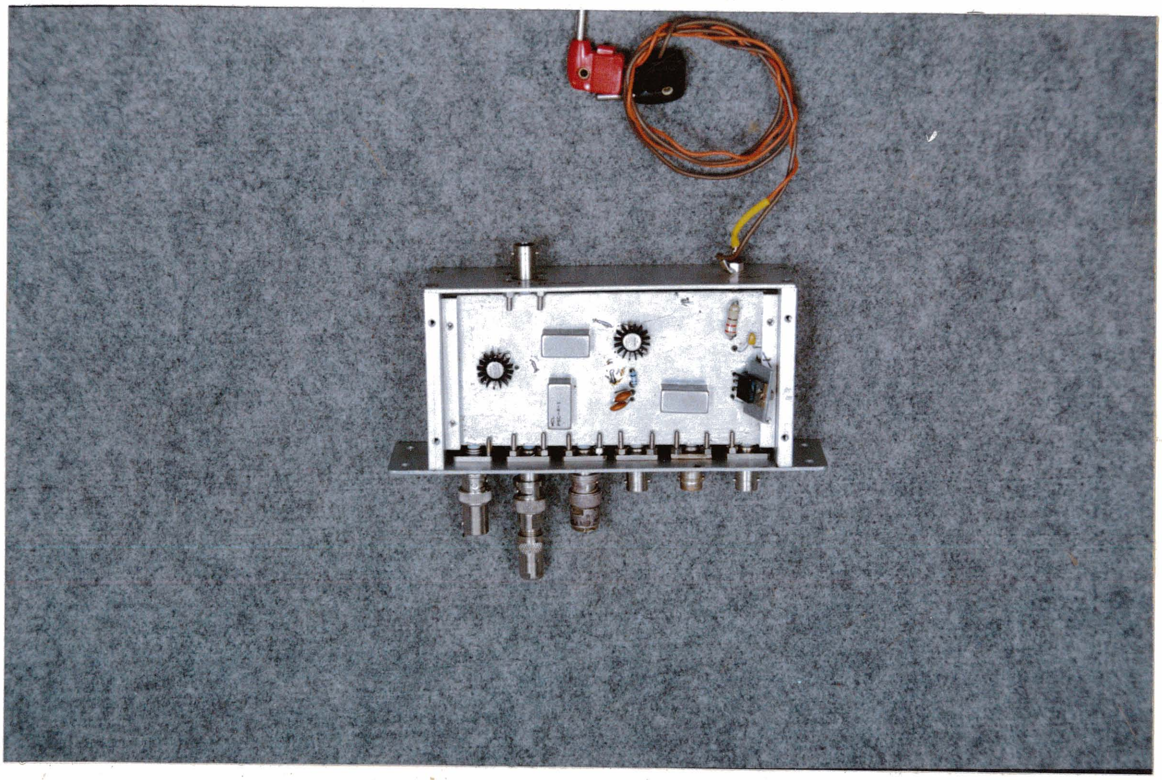
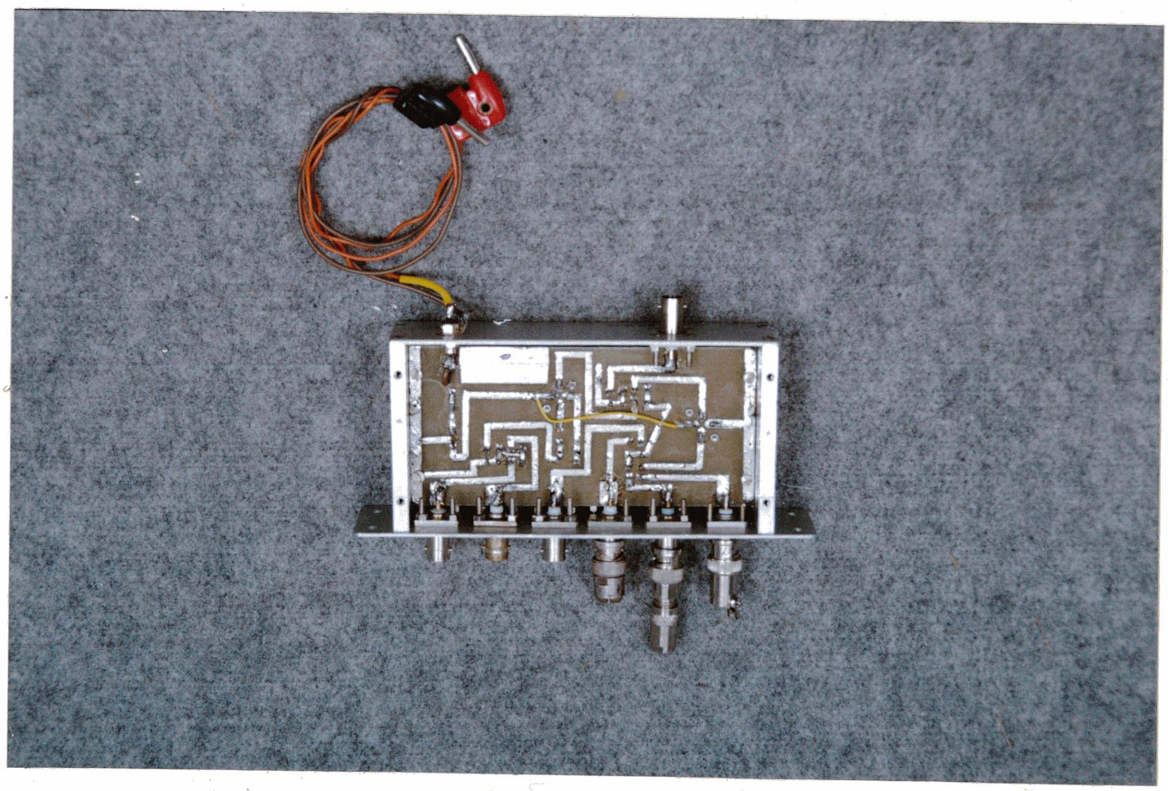


Fig 2.1 (a)



a)



MODULE - 2

Two outputs of +14dBm each

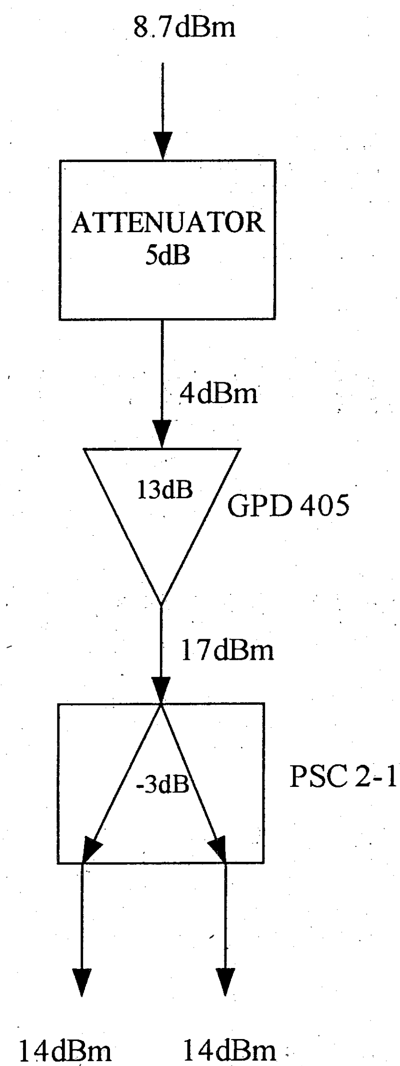
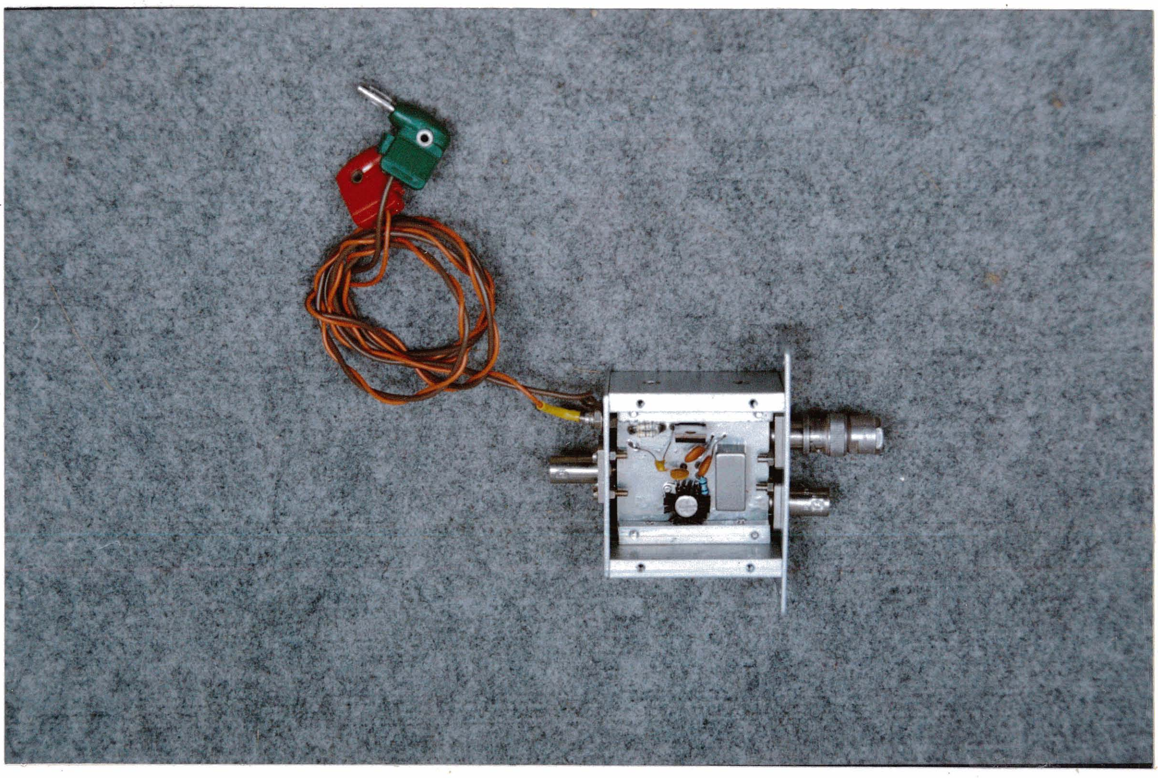
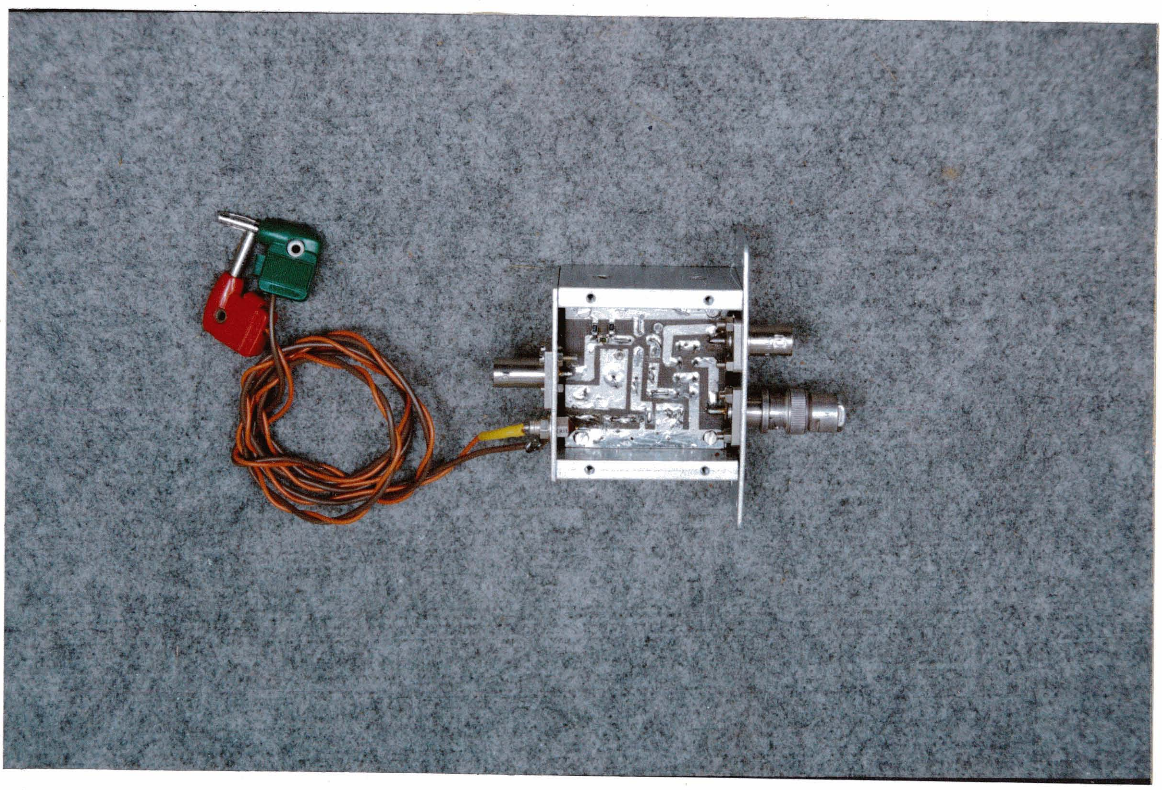


Fig 2.1(b)





SELECTION OF THE COMPONENTS:

The distribution units were built using amplifiers, power dividers and voltage regulators.

AMPLIFIER

When an amplifier is selected for an application, three important parameters to be considered are:

1. Frequency range :

   Choose an amplifier whose frequency response satisfies the required frequency of operation.

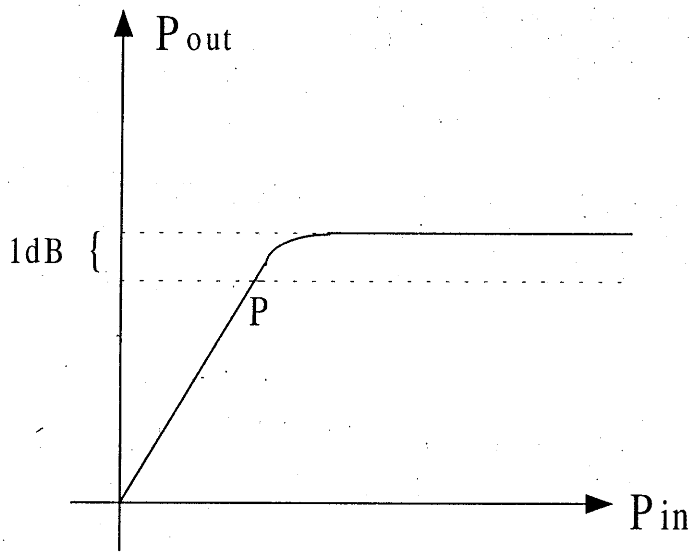
2. Gain :

   The amplifier should have adequate gain at required frequency of operation.

3. 1dB compression point :

Amplifier is a linear device. The transfer characteristics are linear. The output varies with input linearly. Once the device enters non linear region, it saturates. The output no longer follow input linearly. Spurious components will be introduced. Hence while choosing an amplifier 1dB compression point plays an important role.

1dB compression point is 1dB below the saturation level[Fig 2.1(c)]. The input is constant, hence choose a device such that output doesn't cross the 1dB compression point. i.e., the amplifier should remain in the linear region to avoid saturation.



P → 1dB compression point

Fig 2.1(c)

Based on the design, specifications and availability GPD-405 and GPD-403 were chosen. GPD is the abbreviation of GENERAL PURPOSE DEVICES. [For pin diagrams and data sheet specifications refer APPENDIX] [Ref:2]

The frequency of operation in this case is 5MHz. The GPD 405 has a frequency range of 10MHz to 400MHz. The amplifier does not have required gain at 5MHz due to an input bypass capacitor. Therefore matching sections have to be incorporated at the input and output sections to overcome the mismatches. Inductive reactance has to be suitably designed to tune out the capacitive reactance. This inductive reactance is designed using S-parameter matching technique. [sec 2.2].

POWER DIVIDER

Power divider is a passive device used to divide or combine RF power. They basically consist of resistor divider networks They are available as hermetically sealed packages from Mini circuits[Ref:3].

A N-way power divider is shown in Fig 2.1(d).

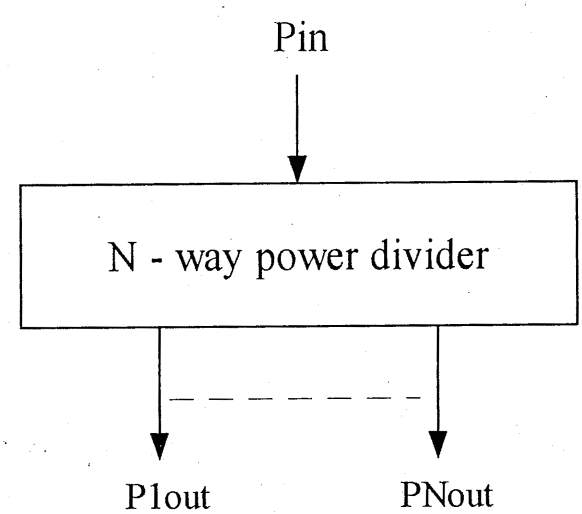


Fig 2.1(d)

Pout = Pin – 10 log N

[Pout] = [Pin] – [N]

Before selecting a power divider two parameters are to be considered.

1. Frequency range.
2. Number of outputs.

According to the design, specifications and availability we have selected PSC – 2-1 and PSC -4-1.[For pin diagrams and data sheet specifications refer APPENDIX]

VOLTAGE REGULATOR

The available D.C. supply is 23v. The bias required for the amplifiers is 15v. Hence an onboard voltage regulator is used to provide the required bias.

The voltage regulator requires an input of 18v to give a regulated 15v output. Since the available D.C. is 23v/22v, the additional voltage is dropped across a resistor based on the current specifications of the amplifiers. [For pin diagrams and data sheet specifications of voltage regulators refer APPENDIX][Ref:4]

DESIGN:

MODULE 1

Current specifications of GPD 405 is 60mA and for GPD 403 is 65mA.

Total current : 150mA { accounting for the safety factor)

Voltage to be dropped : 4V

The resistor required : **R=V / I**

=4 / 150 mA

= 27 ohms

Wattage (power dissipated in the resistor) : **P = V * I**

= 4 * 150 mA

=0.6 watts.

A resistor of 22 ohms ,1 wattage was selected.

MODULE 2

Current specifications of GPD 405 is 60ma .

Voltage to be dropped : 4V

The resistor required : **R = V / I**
= 4 / 60 mA
= 67ohms

Wattage (power dissipated in the resistor) : **P = V * I**
= 4 * 60mA
= 0.2 watts

A resistor of 82 ohms, 0.5 wattage was selected.

FABRICATION:

A glass-epoxy plate with a dielectric constant of 4.5 with a double sided copper clad was provided to make the PCB. Based on the requirement and design considerations the layout was laid and the PCB was made. The track width is 3mm, for the copper laminate. This is required to maintain an impedance of 50ohms, as all RF devices are matched for 50ohms impedance only. One side of the PCB was totally grounded for shielding purposes. Isolated holes were drilled to insert the components. Connections were provided by means of BNC connectors.

RESULTS:

MODULE 1

PARTICULARS	PORT NUMBER	EXPECTED	MEASURED
0/P POWER	1	7dBm	6.8dBm
0/P POWER	2	7dBm	6.8dBm
0/P POWER	3	7dBm	6.8dBm
0/P POWER	4	7dBm	6.8dBm
0/P POWER	5	14dBm	13.9dBm
0/P POWER	6	14dBm	13.9dBm

MODULE 2

PARTICULARS	PORT NUMBER	EXPECTED	MEASURED
O/P POWER	1	14dBm	14.5dBm
O/P POWER	2	14dBm	14.5dBm

2.2 S-PARAMETERS

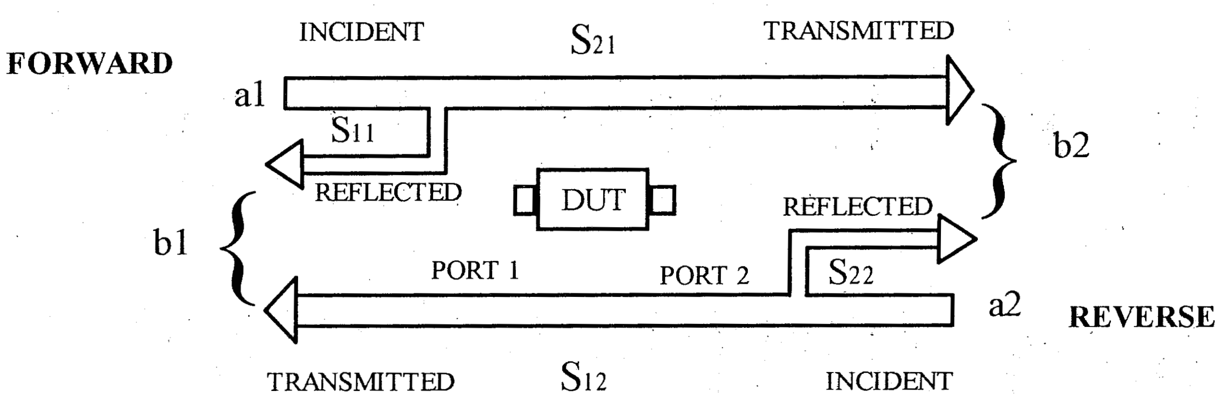
Why use S-parameters ?

- In other methods like H, Y, and Z parameters short or open conditions are required. At high frequencies 'open' or 'short' is not ideal. At high frequencies 'open' has associated capacitance and 'short' has associated inductance.
- It is difficult to measure total current or voltage at higher frequencies. Hence S-parameters are used.
- To measure S-parameters, DUT must be terminated by 50ohm resistance (characteristic impedance of RF circuits). This termination stabilizes the devices, which otherwise tend to oscillate.
- They are relatively easy to measure.
- The measured S-parameters of multiple devices can be cascaded to predict overall system performance.
- S-parameters are readily used in both linear and nonlinear CAE circuit simulation tools.
- H, Y and Z parameters can be derived from S-parameters when necessary.

Definition of S- parameters:

Scattering parameter measurements is a technique to characterize high frequency performance of devices. They are derived from power ratios and consequently provide a convenient method of measuring circuit losses. They provide a physical basis to understand the working of the device, without understanding the physics of the device. They are based on reflection characteristics rather than short and open circuit parameters[Ref:5].

S-parameters of a two port network are shown below [Fig 2.2(a)].



$$b1 = S11a1 + S12a2$$
$$b2 = S21a1 + S22a2$$

$$\begin{bmatrix} b1 \\ b2 \end{bmatrix} = \begin{bmatrix} s11 & s12 \\ s21 & s22 \end{bmatrix} \begin{bmatrix} a1 \\ a2 \end{bmatrix}$$

Fig 2.2(a)

S11 --> input complex reflection co-efficient or impedance of DUT

S21 --> forward complex transmission co-efficient

S22 --> output complex reflection co-efficient or output impedance of DUT

S12 --> reverse complex transmission co-efficient

Forward S-parameters are determined by measuring the magnitude and phase of the incident, reflected and transmitted signals when the output is terminated by a load equal to the characteristic impedance of the test system. By placing the source at the output port of the DUT and terminating the input port in a perfect load, it is possible to measure the other two (reverse) S-parameters.

FORWARD S-parameters:

S11= (reflected) / (incident)

= b1 / a1 @ (a2 = 0)

S21 = (transmitted) / (incident)

= b2 / a1 @ (a2 = 0)

REVERSE S-parameters:

S22 = (reflected) / (incident)

= b2 / a2 @ (a1 = 0)

S21 = (reflected) / (incident)

= b1 / a2 @ (a1 = 0)

Reflection co-efficient is the ratio of the reflected signal voltage level to the incident signal voltage level [Fig 2.2(b)] .

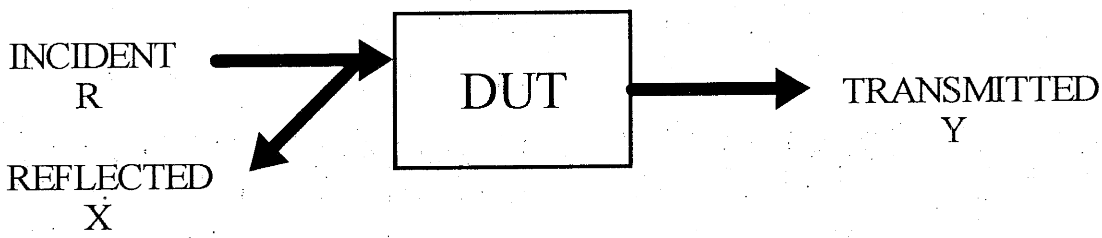


Fig 2.2 (b)

$$\text{Reflection co-efficient } (\Gamma) = (\text{reflected voltage}) / (\text{incident voltage})$$

$$= X / R$$

Return loss is a way to express the reflection co-efficient in logarithmic terms(decibels).Return loss is the number of decibels that the reflected signal is below the incident signal.

$$\text{Return loss} = 20 \log | 1 / \Gamma |$$

Transmission co-efficient is defined as the ratio of transmitted voltage to incident voltage. If the absolute value of transmitted voltage is greater than the incident voltage, a DUT is said to have gain. If the absolute value of the transmitted voltage is less than the incident voltage, a DUT is said to have attenuation or insertion loss.

$$\text{Transmission co-efficient } (T) = (\text{transmitted voltage}) / (\text{incident voltage})$$

$$\text{Insertion loss (dB)} = 20 \log | (\text{transmitted voltage}) / (\text{incident voltage})$$

$$\text{Gain (dB)} = 20 \log | T |$$

SCALAR ANALYSER

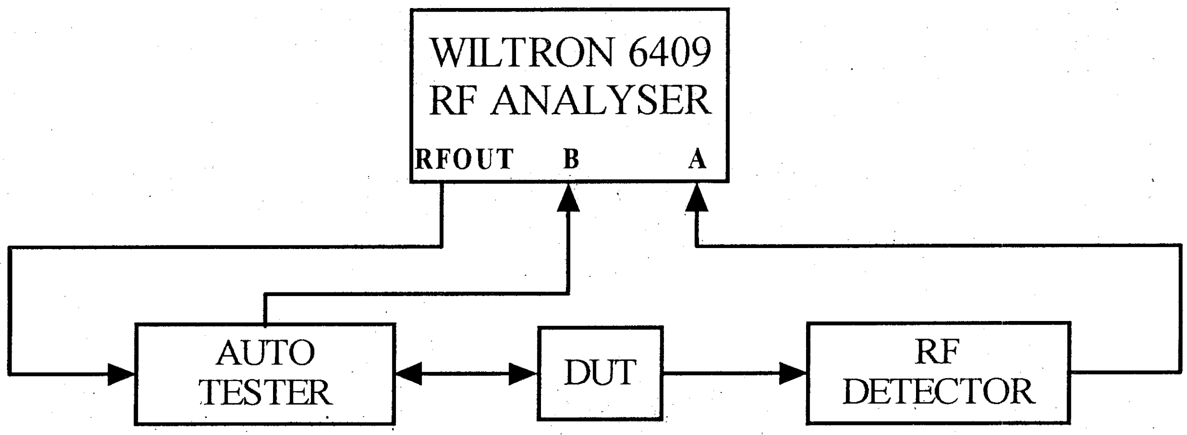


Fig 2.2(c)

Input signal is given through Auto tester (Reflectometer). The reflected signal from the DUT is detected and sent to channel B. the transmitted signal is detected and sent to channel A as shown in Fig 2.2(c).

Observations : (before matching)

GAIN : 11 dB

INPUT RETURN LOSS : -20dB

OUTPUT RETURN LOSS : -3.4dB

The observations indicate that only one hundredth of the incident power was getting reflected back to the source, while at the output nearly half the power is getting reflected. As a result gain is reduced by 2dB. Hence to design the matching section, impedance has to be measured using a Vector voltmeter.

Importance of Vector measurements:

Measuring both magnitude and phase of components is important as they are required to characterize a linear network and ensure distortion free transmission. Also to design efficient matching network, complex impedance must be measured.

S-parameter measuring set-up:

The input is given to a two way power divider so that equal outputs are obtained . One of the outputs is fed to channel A of the Vector voltmeter which serve as the reference [Fig 2.2(d)]. The other output is fed to the amplifier under test via a directional coupler . But the entire signal is not coupled to the amplifier. Some amount of power is reflected through the other port of directional coupler which is fed to the Channel B of the Vector voltmeter. Now with reference to signal at channel A , the signal at channel B is compared and the S- parameters are measured .Using these values the input and output matching sections were designed.

VECTOR MEASUREMENT SETUP

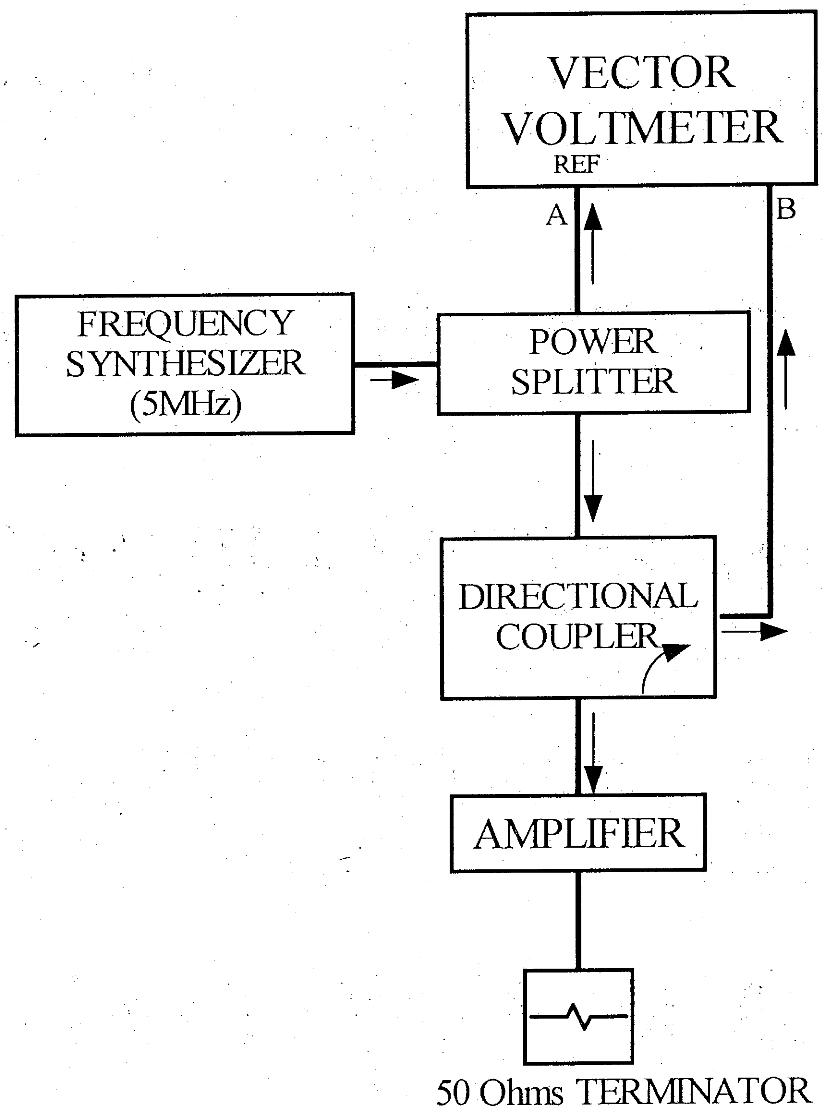


Fig 2.2(d)

S11= 0.36 $\angle$-84°

S22 = 0.71 $\angle$ 142.3° (vector measurement)

Observations :

Input impedance : 43ohms of resistance with a capacitance of 1nF

Output impedance : 10ohms of resistance with an inductance of 0.5uH

The output impedance has to be matched to 50ohms without adding any resistance (lossy component). Hence a LC matching section was designed using a Smith chart to tune out the mismatches to 50ohms.

Design of matching section using Smith chart :

The amount of reflection that occurs when characterizing a device depends on the impedances that the incident signal " sees ". Since any impedance can be represented with real and imaginary parts (R+jX, G+jB), they can be plotted on a Smith chart.

On the Smith chart, loci of constant resistance appear as circles, while loci of constant reactance appear as arcs. Impedance on the Smith chart are always normalized to the characteristic impedance of the component or system of interest, 50ohms for RF circuits.

Using the Smith chart, the output matching section was designed [input impedance is closer to the characteristic impedance and hence requires no matching section]

NAME	TITLE S-PARAMETERS MATCHING TECHNIQUE	DWG. NO.
		DATE

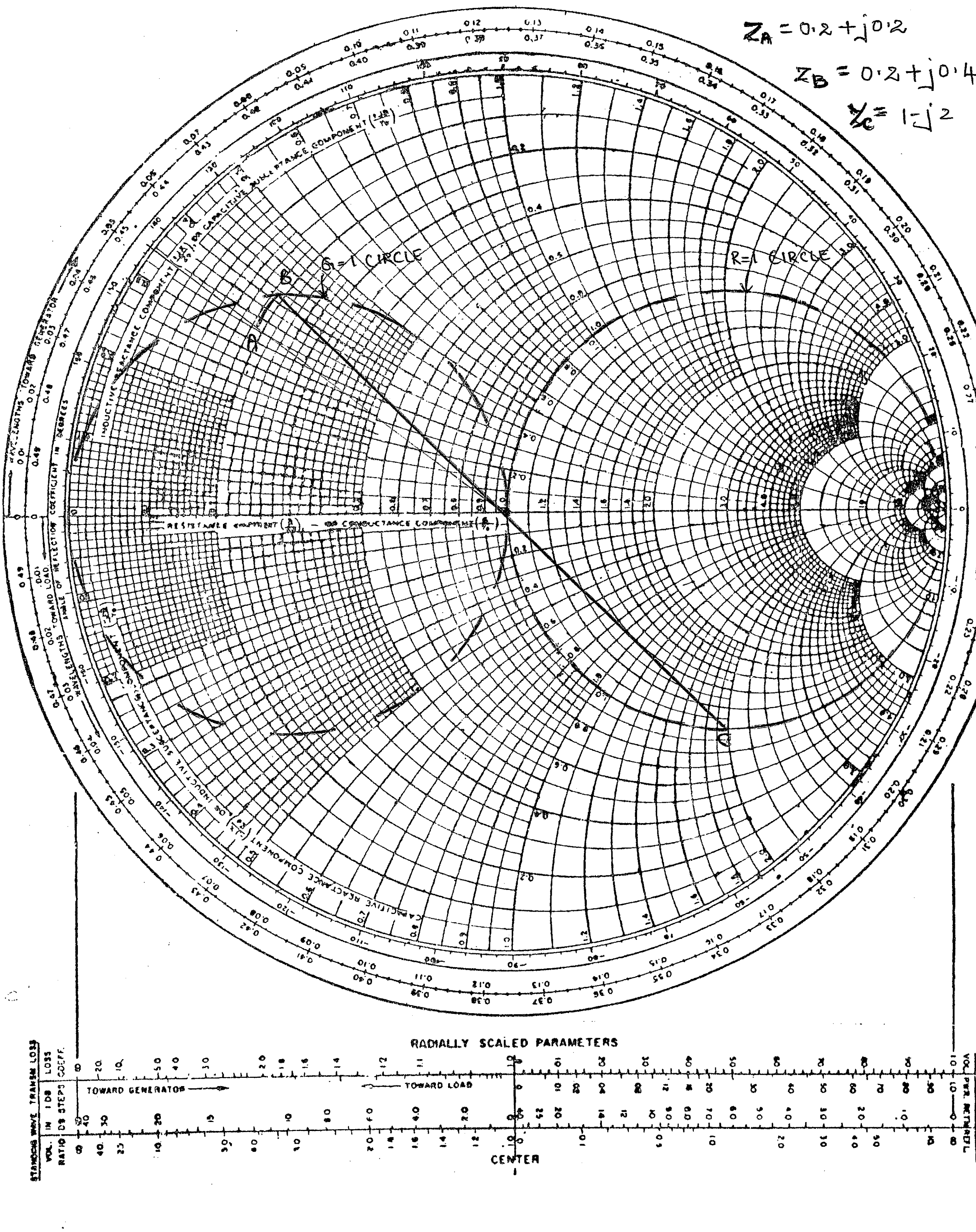
IMPEDANCE OR ADMITTANCE COORDINATES

S_{22} : 0.91 ∠142.3°

$Z_A = 0.2 + j0.2$

$Z_B = 0.2 + j0.4$

$Y_C = 1 - j2$



The measured value of S22 is plotted on Smith chart. This is extended along the constant resistance circle till it reaches a point on constant conductance circle (G=1). The difference indicates an inductance to tune out the resistance and then cross over to the other half of the Smith chart (crossing R=1 pt.) till it reaches a point on constant resistance circle (R=1). Once it is crossed over, it is an admittance chart. This point 1-j2, indicates an inductance. Hence a capacitance of suitable value is chosen to nullify this inductance. Thus the matching section was designed [Fig 2.2(e)].

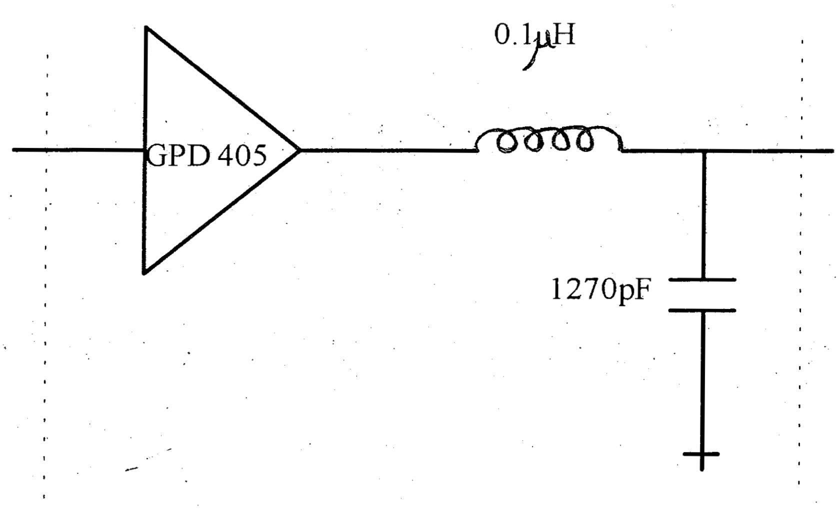
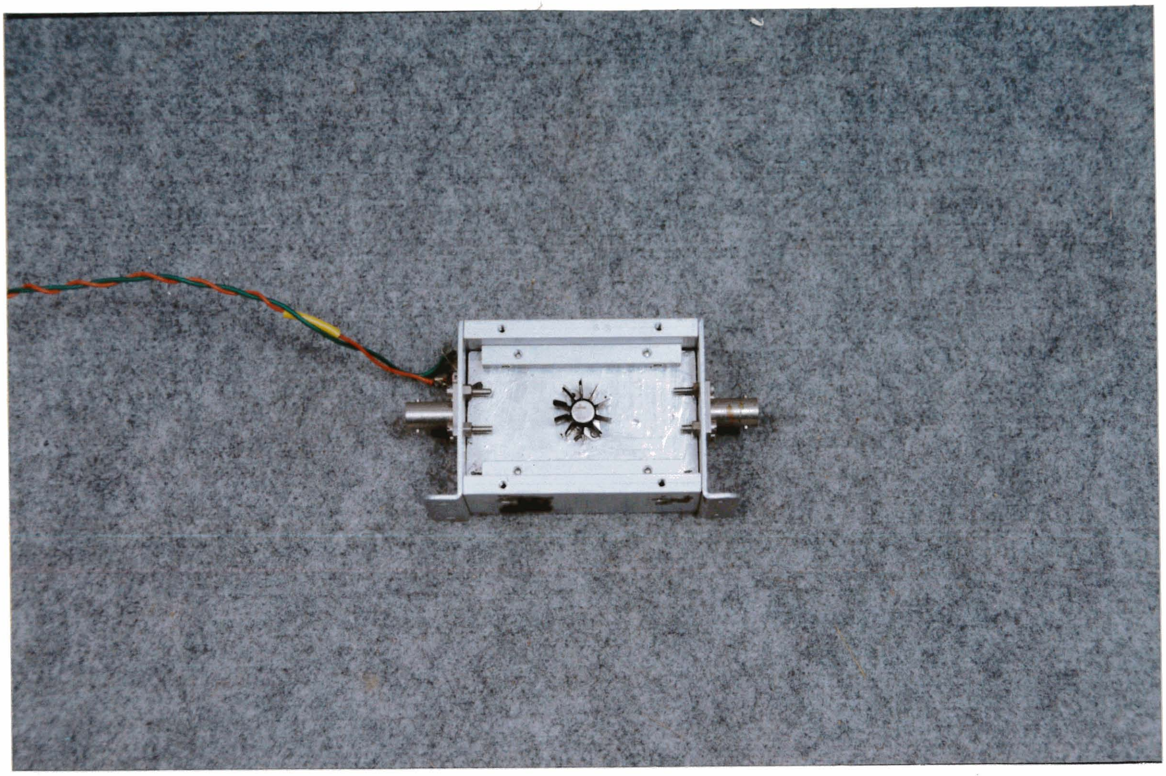
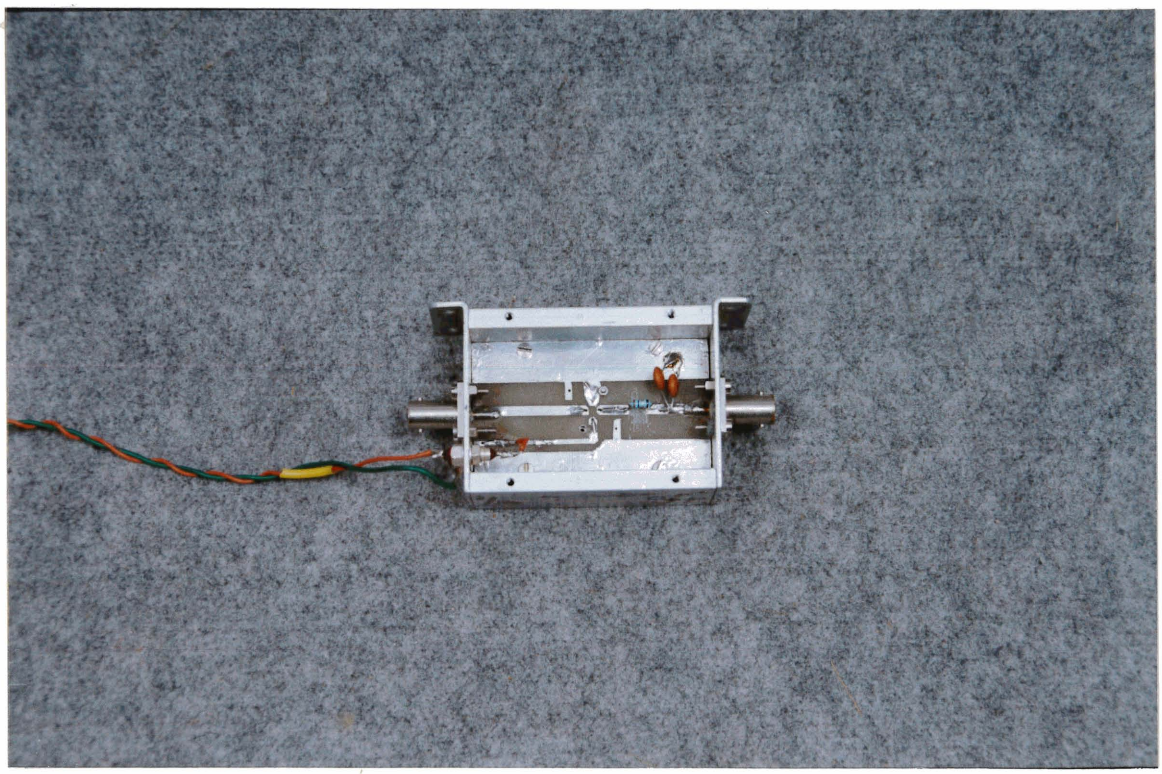


Fig 2.2(e)





The matching section was incorporated at the output of GPD-405 and was tested. The results are as follows.

Observations: (after including matching section)

GAIN : 13dB (expected)

OUTPUT RETURN LOSS : -30dB

The above observations indicate that one thousandth of the input power is reflected back. This is a good match to avoid reflections.

The matching section was incorporated at the output of the amplifier.

2.3 HARMONIC GENERATOR

Necessity of Harmonic Generator:

Filter Bank Spectrometers are older, more common and easy to understand. Filter Bank Spectrometers are characterized by channels. Channel frequencies need to be checked from time to time. To check individual frequencies the signal generator needs to be set at different frequencies, the response is acquired, analyzed and interpreted each time. This is a very tedious process. Instead a Harmonic Generator is built .

Introduction:

Harmonic generation can be achieved using a highly non-linear devices such as step recovery diodes. A harmonic generator uses step recovery diode with appropriate circuitry to generate a narrow pulse of voltage from each cycle of an incident sine wave. In the frequency domain this repeated narrow pulse is seen as the harmonics of the input frequency. This comb of frequencies is useful for testing circuits over a range of frequencies. Since the power output is divided among so many frequencies, the power level in each harmonic is quite low. In applications where more power is needed at selected harmonics, an expensive microwave amplifier is added to the harmonic generator. However, the required increase in power may often be obtained by adding an inexpensive band pass filter. The increased power comes from the active element, the step recovery diode. The wanted frequencies are reflected from the filter to the diode where they multiply and mix with each other to produce more power at the desired frequencies[Ref:8].

The block diagram representation of the harmonic generator is shown in Fig 2.3 (a)

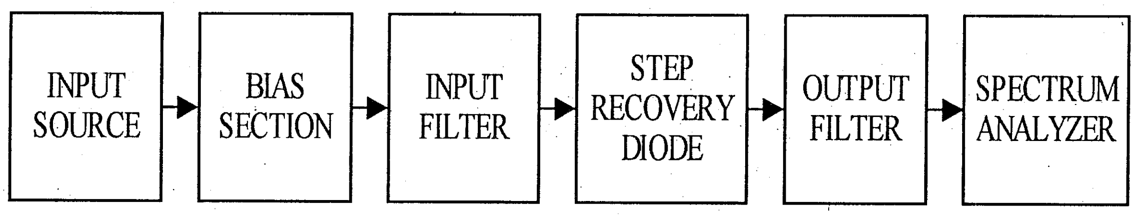


Fig 2.3 (a)

Step Recovery Diode:

The step recovery diode is specially doped silicon PIN junction diode with a dynamic performance that depends on minority carrier lifetime and junction retarding field. The important mechanism for harmonic generation is the behaviour of the diode during intermittent stages of forward conduction, reverse conduction and abrupt transition of reverse conduction.

During forward conduction, charge is stored in the diode by minority carriers. The amount of charge stored is determined by the minority carrier lifetime of the diode.

During reverse conduction, charge flows out of the diode as reverse current. During the initial phase of reverse recovery the conductivity of the diode will remain essentially the same as its forward conduction value and the impedance of the diode therefore remains low during this interval.

The reverse current ceases to flow when the stored minority carriers have been depleted by the flow of reverse current and by minority carrier recombination. This causes an abrupt transition or step in the recovery waveform as indicated in the Fig 2.3 (b). The "step" is produced for every cycle of incident sine wave, which is

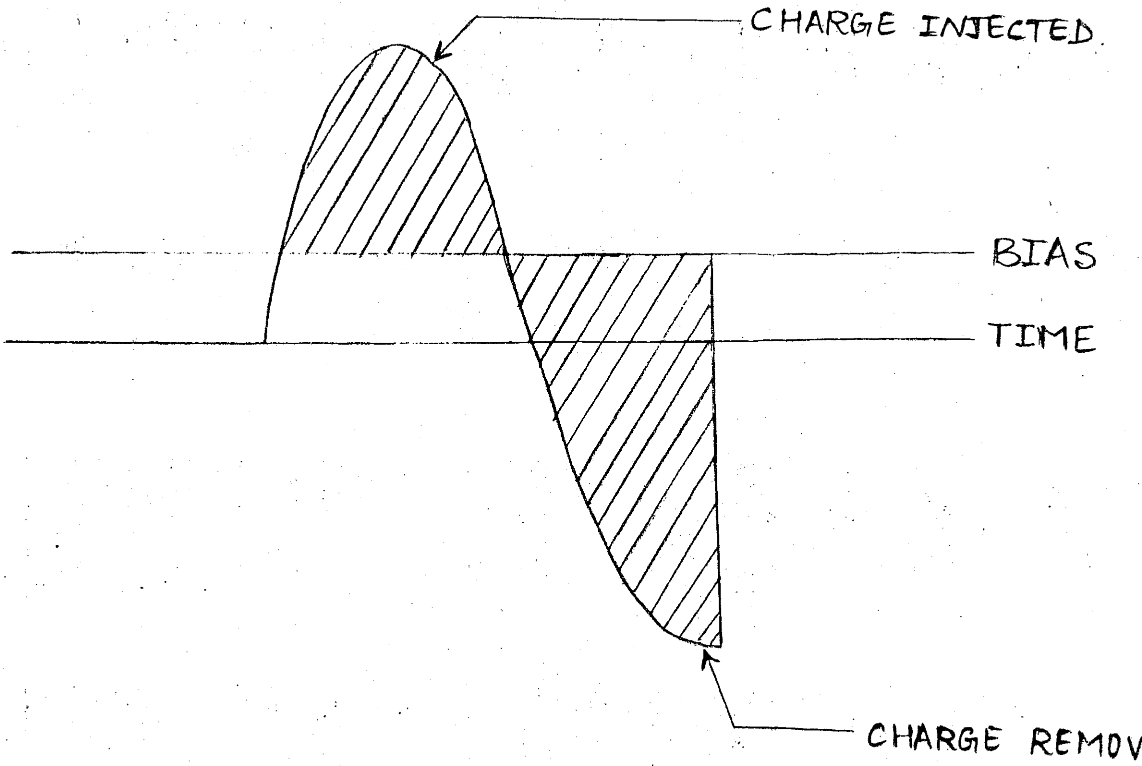


Fig 2·3(b)

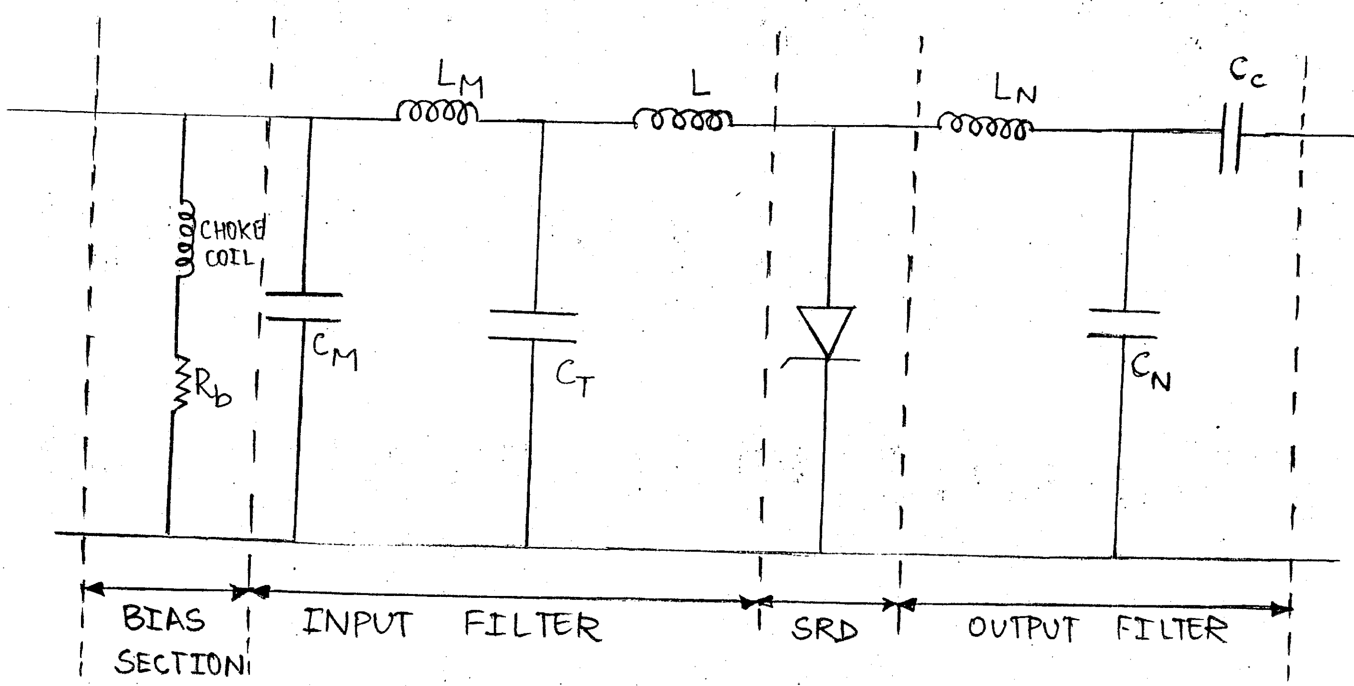


Fig 2·3(c)

seen as harmonics of input frequency in the frequency domain. By virtue of this property step recovery diode is thus used for harmonic generation.

Bias section:

Analysis of a step recovery diode harmonic generator usually include a negative bias voltage on the diode. The bias appears to be necessary so that the charge stored by the forward current is removed by the reverse current at the time corresponding to peak current. Negative dc bias is provided to the diode to set the time when the conduction starts during positive portion of the input wave. This bias voltage may be provided by a resistor across the input circuit. Rectified current from the diode flows through the bias resistor to generate the negative bias voltage. This type of self-bias using a resistor is chosen because of the advantages such as low cost, temperature compensation and self-adjustment for different input power levels.

A Choke coil is used in conjunction with the bias resistor. On application of the RF signals, this choke blocks the RF entering the bias resistance. At the same time it provides any easy path for the dc return.

Input filter:

The input filter circuit is a low pass filter which allows all the input power to be absorbed by the diode. The input filter is so designed that it matches the source impedance and the diode impedance thus preventing any reflections. As a result all the input power goes to the diode. In addition to impedance matching, this filter blocks any harmonics of the input signal from entering the diode.

Output filter:

The output filter is a bandpass filter which offers a low loss path to the desired frequency while reflecting all other harmonics back to the diode by properly spacing the diode and the filter, much of the power in the unwanted frequencies can be converted to the desired output. The filter also provides output impedance matching.

Since most of the analog backends have a center frequency of 150MHz, the bandpass filter is designed with the center frequency of 150MHz with a bandwidth of 80MHz.

Design:

The circuit diagram of the harmonic generator block diagram is shown in Fig 2.3(c).

STEP RECOVERY DIODE (SRD) - HP 5082-0112

Maximum Junction Capacitance	$C_j = 1.55pF$
Carrier life time	$\tau = 50ns$
Input frequency	$f_{in} = 10Mhz$
Input power	$P_{in} = 10dBm$
Expected output frequency	$f_o = 150MHz$

CALCULATIONS:

Pulse width, t_p should be such that it satisfies the condition

$$1/2f_o < t_p < 1/f_o$$

Accordingly we chose

$$t_p = 1/(3/2)f_o = 4.44ns$$

Number of harmonics, n = 150MHz / 10MHz = 15

Bias section

Bias resistance, $R_b = 2\tau / (\pi(n*n)C_j)$ = 91.27Ω
Choke coil = 10μH

Input filter

$Rg = 50\Omega$
$L = (t_p*t_p) / ((\pi*\pi)C_j)$ = 1.3μH
Input resistance, $R_{in} = 2\pi f_{in} L$ = 81.68Ω
$Lm = (\sqrt{R_g R_{in}}) / (2\pi f_{in})$ = 1μH
$Cm = 1 / (2\pi f_{in} \sqrt{R_g R_{in}})$ = 250pF
$Ct = Cj / (4(f_{in}*f_{in})(t_p*t_p))$ = 196pF

Output filter

$Ln = L = 1.3\mu H$
$Zo = 100\Omega$
$Q = 2.5n = 37.5$
$Cc = 1 / (\omega_o\sqrt{(\omega_o L Q Z_o)})$ = 0.5pF
$Cn = (1/(\omega_o*\omega_o)L) - C_c$ = 0.36pF

[Ref:8 (AN 913)]

EFFICIENCY:

The efficiency of a harmonic generator using a step recovery diode can be a maximum of 1 / 2n which depends upon the Q factor of the filters and proper bias conditions.

n = Expected Harmonic Frequency / Input Signal Frequency

n = 150MHz / 10MHz = 15

Efficiency = 1/2n

Efficiency (in dB) = -15dB.

An input power of 10dBm at 10 MHz is given. So, the expected output power at 150Mhz is –5dBm.

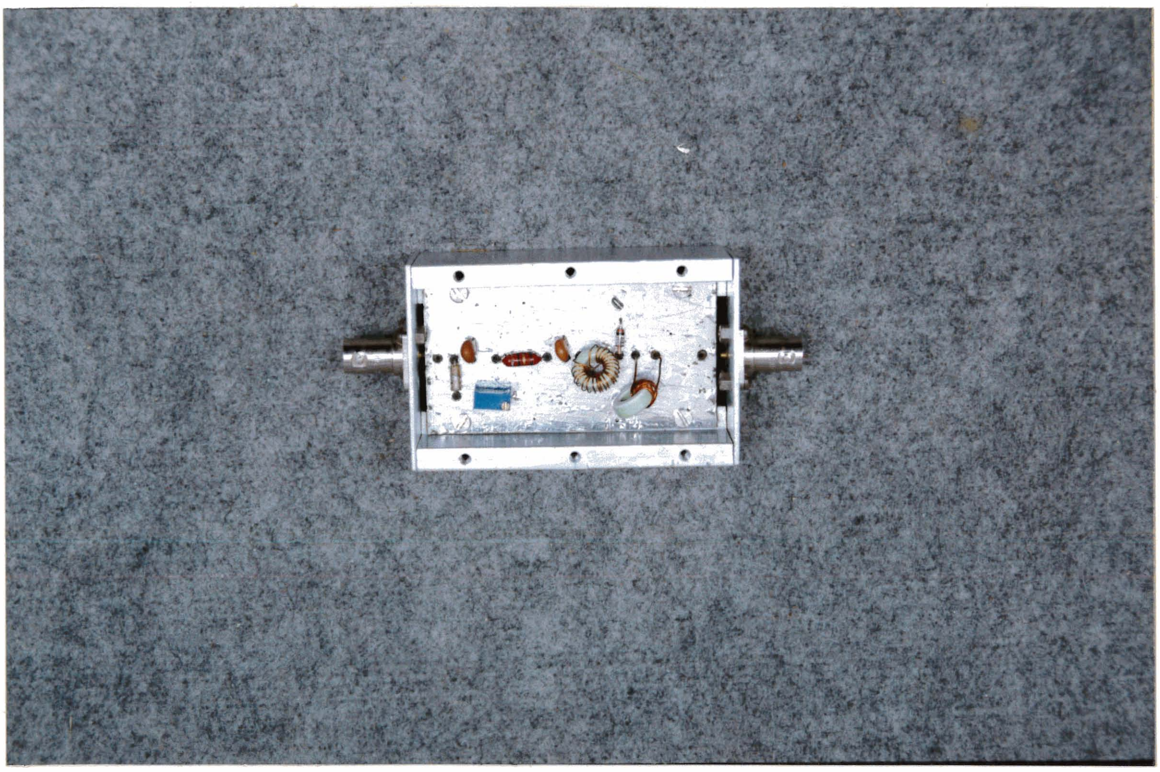
FABRICATION:

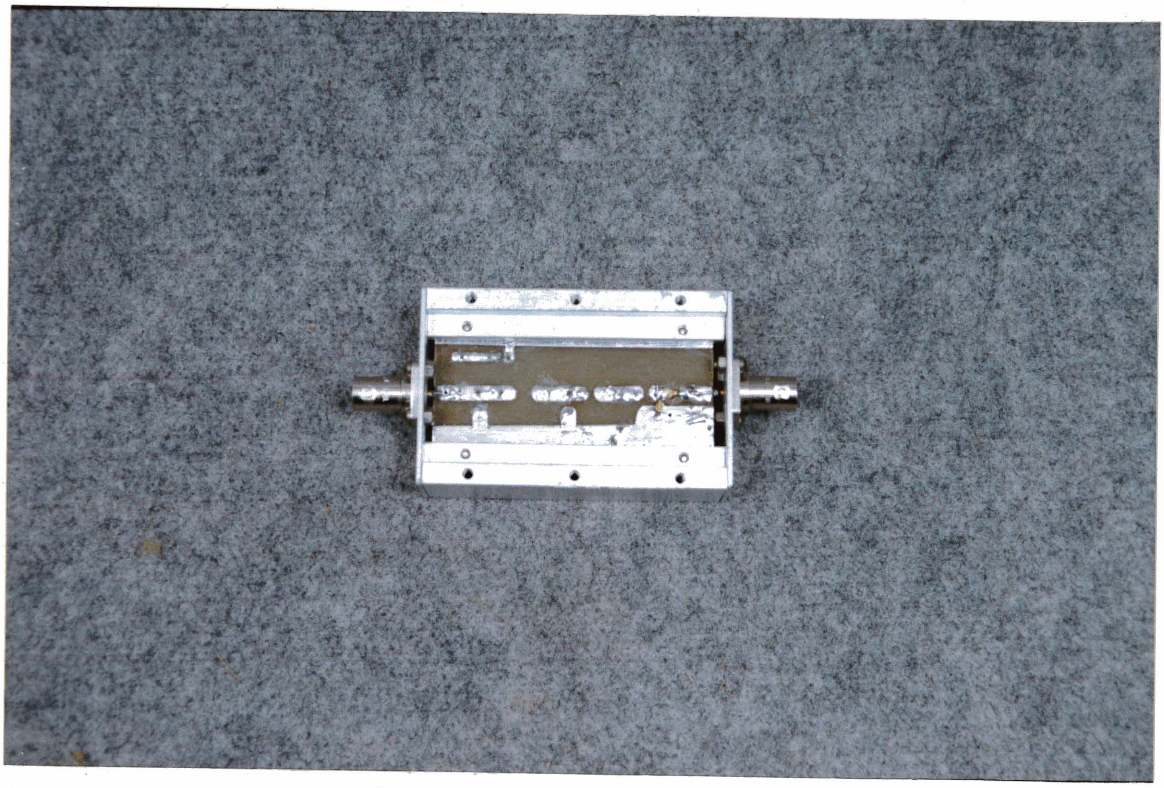
A glass-epoxy plate with a dielectric constant of 4.5 with a double sided copper clad was provided to make the PCB. Based on the requirement and design considerations the layout was laid and the PCB was made. The track width is 3mm, for the copper laminate. This is required to maintain an impedance of 50ohms, as all RF devices are matched for 50ohms impedance only. One side of the PCB was totally grounded for shielding purposes. Isolated holes were drilled to insert the components. Connections were provided by means of BNC connectors.

TEST RESULTS:

An input signal of 10dBm at 10Mhz was fed as input to the harmonic generator. The output was seen on a spectrum analyzer. The harmonics were observed and the power level at 150Mhz is tabulated below.

PARTICULARS	EXPECTED	EXPERIMENTAL
O/P POWER at 150MHz	-5dBm	-4.9dBm



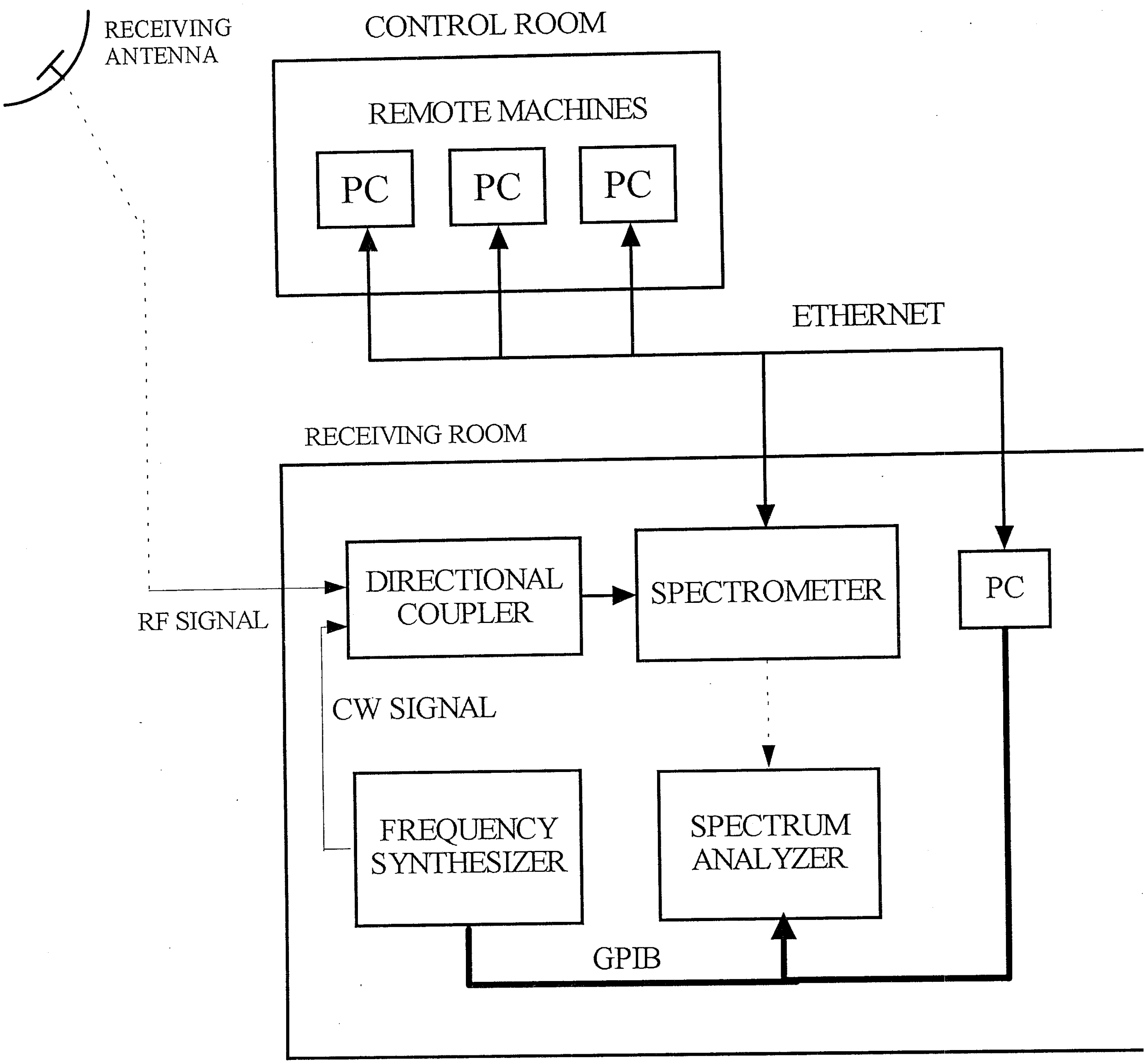


SOFTWARE SECTION

3.1 INTRODUCTION

The 10.4m dish antenna receives the radiation emitted from a region of space. These signals will be received in the receiver room and processed by means of a Spectrometer. Routine measurement of various parameters of the Spectrometer such as frequency resolution, dynamic range, noise performance and band pass characteristics are to be carried out. A frequency synthesizer will generate a CW signal required to measure the parameters of the Spectrometer. A spectrum analyzer is used to characterize the analog sections of the Spectrometer. Manual operation of instruments (spectrum analyser and synthesizer) is a time consuming process. To automate this process, these instruments are controlled by a PC via GPIB, for which **GPIB codes** were developed.

The measurement of various parameters of the Spectrometer are done in the control room. Every time we want to change the settings of the frequency synthesizer, we have to come from the control room to the receiver room, which is a very tedious process. This process is simplified using remote control of instruments, for which Network communication software were developed [Fig (3.1)] .



RECEIVING ANTENNA
CONTROL ROOM
REMOTE MACHINES
PC
PC
PC
ETHERNET
RECEIVING ROOM
DIRECTIONAL COUPLER
SPECTROMETER
PC
RF SIGNAL
CW SIGNAL
FREQUENCY SYNTHESIZER
SPECTRUM ANALYZER
GPIB

Fig 3.1

3.2 SOFTWARE ARCHITECTURE

PROCESS DIAGRAM

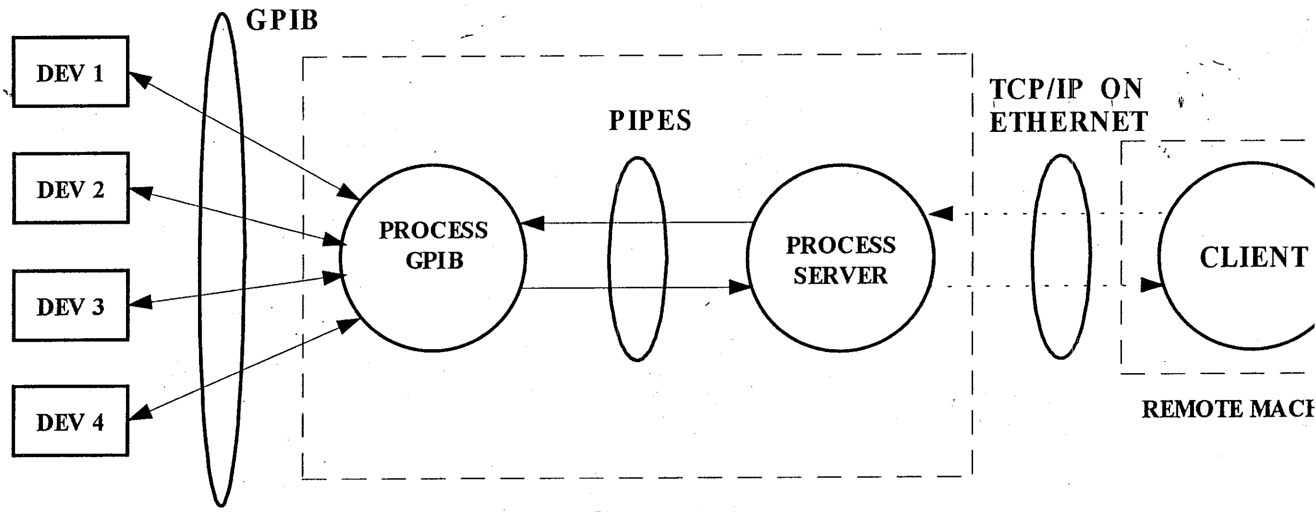


Fig 3.2

To achieve remote control of instruments a GPIB based approach with network capabilities is used. The instruments or devices to be controlled are connected to a PC through a bus called **General Purpose Interface Bus (GPIB).** GPIB Codes are developed making use of GPIB functions. These codes are written in C language on **LINUX** platform. To achieve remote control of these instruments. Network communication software was developed by making use of Client-Server model, Berkeley Sockets and Interprocess communication. The Client and Server are connected through **TCP/IP** on **Ethernet.** The Interprocess Communication is a communication between the Server and the GPIB codes. For IPC's **pipe** mechanism is used[Fig (3.2)].

Why LINUX ?

- LINUX operating system is a multi-user, multitasking operating system.
- This operating system supports variety of GPIB cards.
- It supports network capabilities, hence this is useful for remote communication or control of instruments.
- Kernel can be upgraded to soft RT kernel.
- Can run on cheap 486 class PC's.
- LINUX is free ware.

3.3 GPIB Codes:

General Purpose Interface Bus (GPIB) :

The GPIB is a link or interface system through which most instruments communicate. The original GPIB specifications and interface was designed by Hewlett-Packard to connect and control programmable instruments manufactured by Hewlett-Packard. Because of its high data transfer rates of up to one Megabytes/sec, GPIB quickly gain popularity in other applications such as intercomputer communication and peripheral control. It was later accepted as the industry standard IEEE 488 bus. The versatility of the system prompted the name **general-purpose interface bus[Ref:10].**

The IEEE 488 interface digital system is one in which up to 16 instruments or devices may communicate with each other. In the GPIB interface system the instruments connected can be categorized as Talkers, Listeners and Controllers.

- **TALKER:**

A talker is a unit, which is able to transmit on a bus pertinent measurement data or information concerning its status, either asynchronously or in response to a command from the controller. There can be only one active talker on the bus at any given time. Some examples of talkers are voltmeters, frequency counters and tape readers. Talkers are generally listeners as well.

- **LISTENER:**

A listener is a device, which can receive commands and data when addressed and may or may not be capable of the talk function. There can be up to fourteen active listeners simultaneously on the bus. Examples of listeners, which usually have no talk capability, are printers, display and programmable power supplies.

- **CONTROLLER:**

The controller is the brain of the system; it provides the commands that cause each and every instrument and device on the bus to perform its task. The controller is usually both a talker and listener.

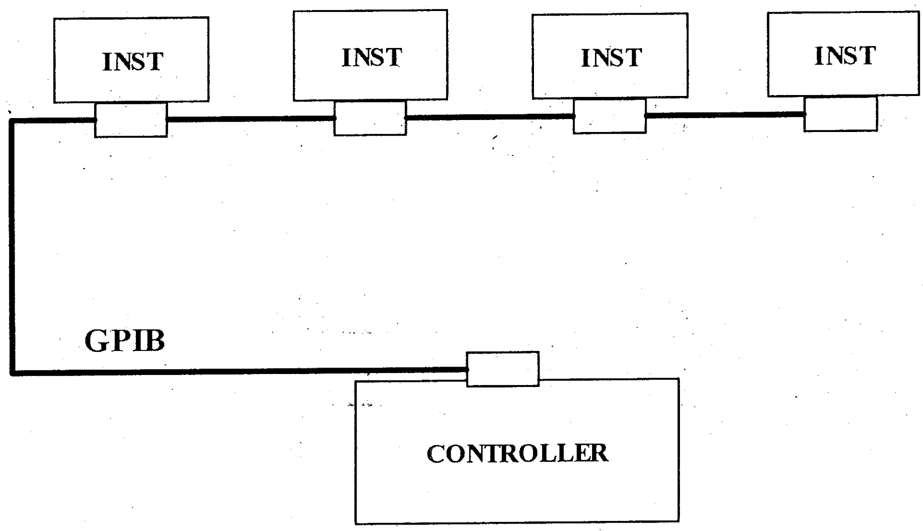
Interconnection of instruments in a GPIB Interface system:

All instruments in the interface system are connected together either in **STAR** or **DAISY CHAIN** configuration as shown in Fig 3.3.

Daisy chain configuration has limitations in the maximum length. This is about 14m for a particular variety of card we use. The longer the cable, access becomes slower. Cross-talk can be a problem at higher transfer rates.

Star connection is generally used when instruments are closely placed, as in that of a measurement setup. In general, the speed of the bus is limited by the slowest of instruments connected.

DAISY CHAIN



STAR

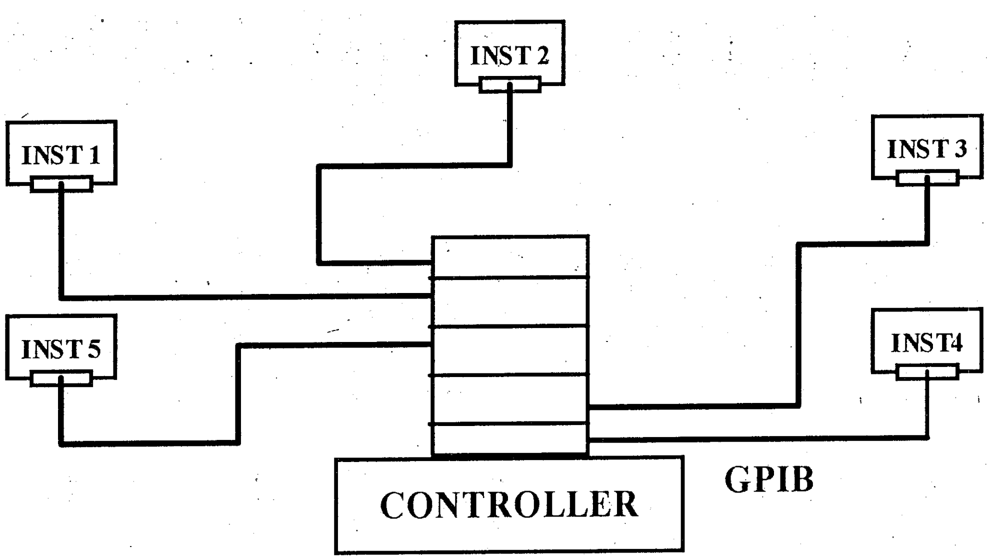
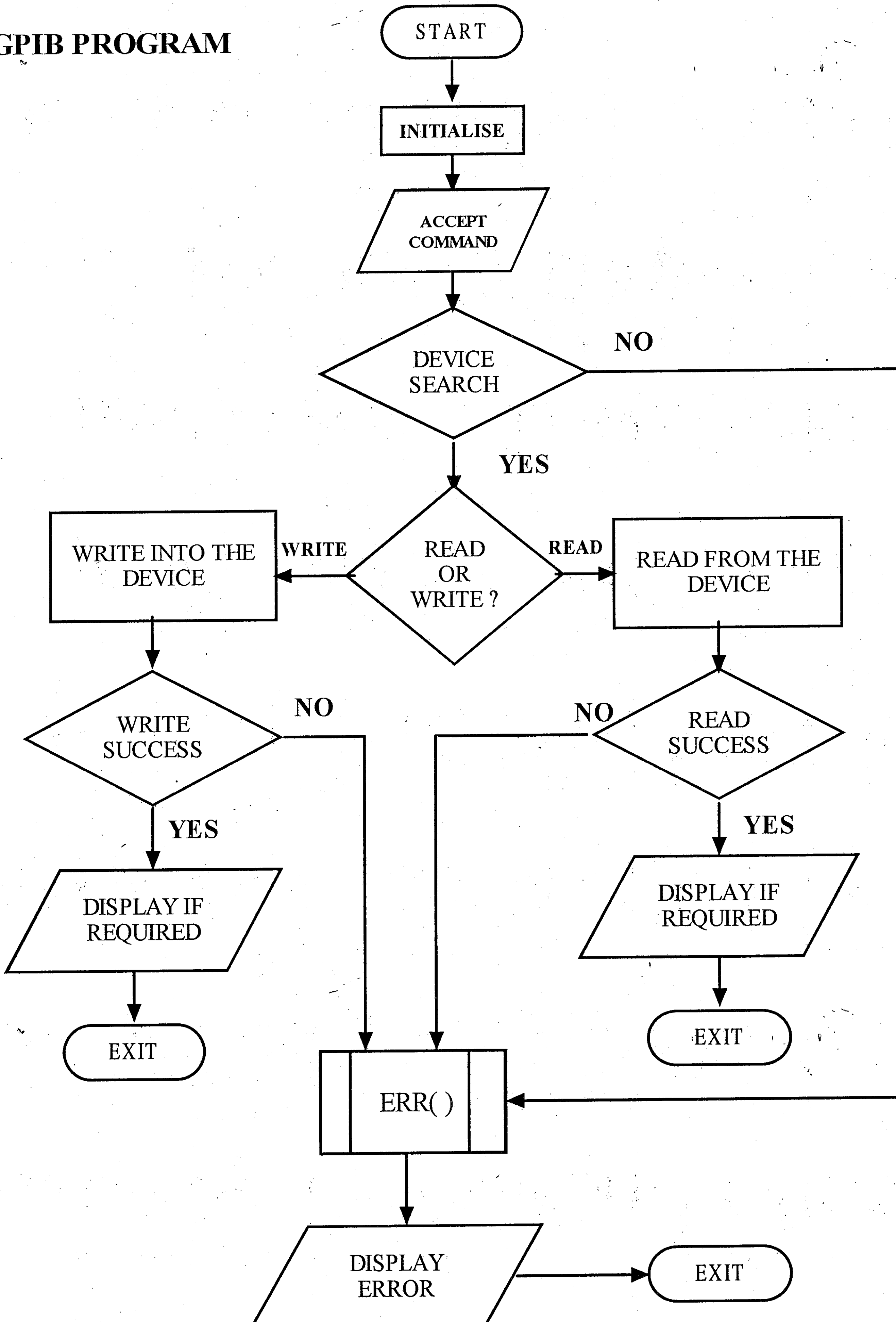


Fig 3.3

GPIB PROGRAM



The PC is the controller in the GPIB interface system. The instruments to be controlled are mainly spectrum analyzer and frequency synthesizer.

Device search:

A GPIB card will be inserted in the PC serving as the controller. The instruments in the interface system will be defined in the card. Whether the instrument (device) to be controlled is defined in the card or not is checked by means of a GPIB function called **ibfind( ).**

Syntax: int **ibfind("Device name")**

Writing into the device:

The instruments to be controlled are the frequency synthesizer and the spectrum analyzer, i.e., the parameters of these instruments need to be changed. Some of the most commonly used parameters are frequency, span and amplitude. The value of a parameter to be changed is sent by the controller by means of a GPIB function called **ibwrt( ).**

Syntax: int **ibwrt(Device name, "parameter value", string length (value))**

Reading from the device:

In some cases it would be necessary to know the value of a parameter of the device before and after it is changed. To know the value, a request is sent to the device by the controller PC by means of a GPIB function called **ibrd( ).**

Syntax: int **ibrd(device name, buffer, sizeof(buffer))**

Status word:

Every GPIB function returns a value when executed. This is stored as a status word. The details of this status word are given by a GPIB function called **ibsta( ).** The status word will have different values for different operations carried out. Every value gives an indication of a particular status. A bit value of 1 indicates that the corresponding status is in effect while a bit value of 0 indicates that the corresponding status is not in effect. The following table lists the bit positions and the corresponding function types. Some of them are device function calls while some of them are board function calls while some of them are both[Ref:11].

STATUS WORD TABLE

MNEMONICS	BIT POSITION	HEX VALUE	FUNCTION TYPE	DESCRIPTION
ERR	15	8000	Dev,brd	GPIB error.
TIMO	14	4000	Dev,brd	Time limit exceeded
END	13	2000	Dev,brd	END or EOS are detected
SRQI	12	1000	Brd	SRQ interrupt received
RQS	11	800	Dev	Device requesting service
CMPL	8	100	Dev,brd	Input/output completed
LOK	7	80	Brd	Lockout state
REM	6	40	Brd	Remote state
CIC	5	20	Brd	Controller in charge
ATN	4	10	Brd	Attention is asserted
TACS	3	8	Brd	Talker
LACS	2	4	Brd	Listener
DTAS	1	2	Brd	Device trigger state
DCAS	0	1	Brd	Device clear state

ERROR FUNCTIONS:

There may be a possibility that the GPIB functions are not completely executed due to reasons such as the device was not defined in the GPIB card or the device was not active (ON) and so on. Hence it is necessary to know whether the command is completely executed or not. So, we make use of GPIB error function **iberr( )** which give suitable details regarding the error that has occurred so that it could be rectified. The error table below gives the list of possible occurring errors. [Ref:11]

ERROR FUNCTION TABLE

SUGGESTED MNEMONIC	DECIMALVALUE	DESCRIPTION
EDVR	0	DOS error
ECIC	1	Function requires GPIB error to be CIC
ENOL	2	Write handshake error(ex: No listener)
EADR	3	GPIB board not addressed correctly
EARG	4	Invalid argument to function calls
ESAC	5	GIPB board not system controller as required
EABO	6	I/O operation aborted
ENEB	7	Non existent GPIB board
EDMA	8	Windows 3 only , virtual DMA device error
EOIP	10	Asynchronous input output in progress
ECAP	11	No capability for operation
EFSO	12	File system error
EBUS	14	GPIB bus error
ESTB	15	Serial poll status byte queue overflow
ESRQ	16	SRQ stuck in ON position
ETAB	20	Table problem

The GPIB codes were developed using the GPIB functions and error functions. The parameter values of the frequency synthesizer and the spectrum analyzer can now be changed through a PC instead of manually controlling these instruments.

3.4 Network Codes:

To achieve remote control of the instruments Network codes were developed by making use of-

- Client - Server Model
- Berkeley Sockets
- Interprocess Communication.

- **Client - Server Model**

The standard model for network applications is the **client–server model.** A server is a process that is waiting to be contacted by a client process so that the server can do something for the client. The server process is started on the Controller PC in the receiver room. It initializes itself, then goes to sleep waiting for a client process to contact it requesting some service. A client process is started on another system in the control room connected to the server system with the TCP/IP network on Ethernet. Client process sends a request across the network to the server to change the parameter values of the frequency synthesizer or spectrum analyzer. When the server process has finished providing its service to the client, the server goes back to sleep, waiting for the next client request to arrive.

- **Berkeley Sockets**

The communication between the client and the server is brought about by means of Application Protocol Interfaces(API) such as Berkeley Sockets and System V Transport Layer Interface(TLI).

The network connection can be connection oriented or connectionless. The TCP/IP is a connection oriented protocol. A typical scenario that takes place for a connection oriented transfer is shown in Fig 3.4(a). [Ref:12]

STANDARD CLIENT – SERVER ARCHITECTURE

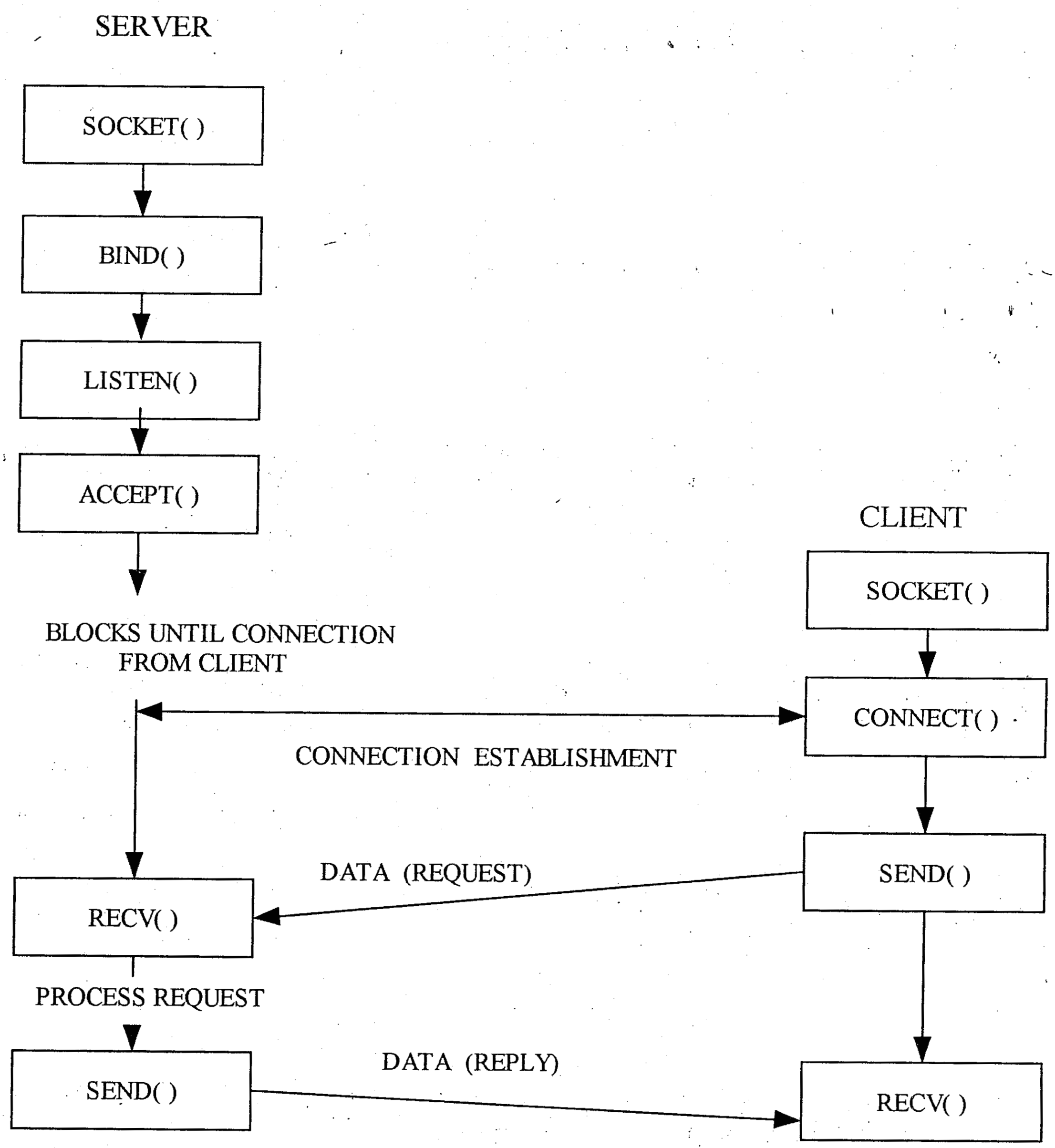


Fig 3.4(a)

The library calls used are:

SOCKET ( )

To do network I/O, the first call a process must execute is the socket system call, specifying the type of communication protocol desired (Internet TCP), address family (AF_INET) and the socket type (SOCK_STREAM).

Syntax: int socket(int ***family***, int ***type***, int **protocol**);

The socket system call returns a small integer value similar to a file descriptor. This is called as socket descriptor or **sockfd.**

BIND ( )

The bind system call assigns an address to an unnamed socket. The server informs the system about its socket address so that any request from client be forwarded to this address.

Syntax: int bind (int ***sockfd***, struct sockaddr ****myaddr***, int ***addrlen***);

LISTEN ( )

The listen system call is used by a connection – oriented server to indicate that it is willing to receive connections. There may be more than one client requesting a connection with the server at a time . All these requests are put in a queue or backlog.

Syntax: int listen(int ***sockfd*** , int ***backlog***);

ACCEPT ( )

The accept system call takes the first connection request on queue and creates another socket with same properties as **sockfd**. If there are no pending requests then the system call waits for a connection request from client.

Syntax: int accept(int ***sockfd***, struct sockaddr *****peer***, int ***addrlen**);

The peer and addrlen arguments are used to return the address of the connected peer process (client).

CONNECT ( )

This system call brings about the actual connection between a client and the server. It also assigns an address to the client and informs the server that the requested data must be forwarded to this address.

Syntax: int connect(int ***sockfd***, struct sockaddr *****servaddr***, int ***addrlen***);

SEND ( ) and RECV ( )

These system calls are used to send requests from client to the server and get back the data from the server.

Syntax: int send (int sockfd, char *****buff***, int ***nbytes***, int ***flags***);
Syntax: int recv (int ***sockfd***, char *****buff***, int ***nbytes***, int ***flags***);

The "nbytes" indicate the number of bytes written or read.

• INTERPROCESS COMMUNICATION (IPC)

The client sends a request to the server to change the parameters of the instrument. It is the GPIB program through which the control of instruments is brought about. Hence, it is necessary that a communication be established between the server process and the GPIB process for which we make use of IPC.

IPC can be used between processes on the same system or on different systems.

Several different mechanisms of IPC on the same system are -

Pipes

FIFO

Message queues

Semaphores

Shared memory

FIFO, message queues, semaphores and shared memory are different forms of IPC in System V TLI, whereas **a pipe** is the only form of IPC in Berkeley Sockets.

What is a Pipe?

The term pipe is used when a data flow is established between two processes. Generally we attach, or pipe, the output of one process to the input of another. The pipes are unidirectional providing a one way flow of data. When a two way flow of data is desired, we must create two pipes and use one for each direction as shown in Fig 3.4(b). [Ref:13]

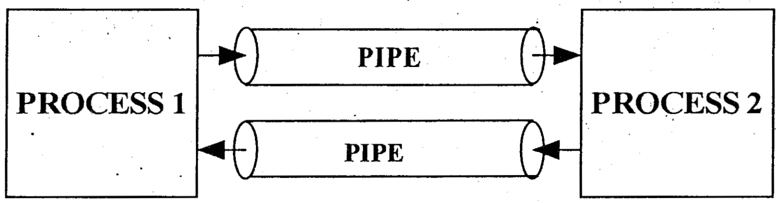


Fig 3.4(b)

The standard I/O library provides function such as **popen** that creates a pipe and initiates another process that either reads from the pipe or writes to the pipe. The pipe is closed using the **pclose** function.

Syntax: FILE *popen (char ****command***, char ****open_mode***);

The command string is the name of the program to run (GPIB program) together with any parameters. Open mode must be either "r" or "w",

Syntax: int pclose (FILE ****stream***);

The function closes an I/O stream that was created by popen.

The popen function opens a pair of pipes for two processes to communicate. One of the pipes is opened in write mode while the other pipe is opened in read mode. The data written onto the standard output of process1 will be fed to the write end of the pipe1. In our case, pipes will be used for communication between two processes-server process and the GPIB process. The command required to change the parameter value of the instrument is sent by the client to the server. This command will be written onto the standard output which will be fed to the pipe opened in write mode only. At the other end of the pipe the GPIB process will receive the command and will suitably control the instrument. On the other hand, if the client wants to know the value of the parameter of an instrument, it sends a read request to the server. This read request is sent to the GPIB program through the pipe opened in write mode. The GPIB program accepts this request, reads the value from the device and writes it onto the standard output. This will be fed to the other pipe opened in read only mode. This value will be received by the server process at the other end of the pipe. The server will now send back the data to the client.

SUMMARY

The **distribution units** built with different power outputs will provide the power reference for different frequency synthesizers to generate the required CW signals.

The **harmonic generator** built will be used for frequency resolution characterization of filter bank spectrometers.

The **GPIB codes** developed will help in controlling the instruments through a PC thus simplifying the process of manual control of instruments.

The Network **codes** developed will help in controlling the instruments from any remote place thus reducing the time in coming to the location of the instruments.

REFERENCES

1.	Methods of Experimental Physics vol - 12 Part C Astrophysics Radio Observation	**Marton**
2.	1986 Modular Product data book (GPD Amplifiers)	
3.	RF/IF Designers guide (Mini circuits catalogue)	
4.	µA Linear Integrated Circuits	**Fairchild**
5.	S - Parameters circuit analysis and design application note 95, 1287-1	
6.	Electronics Engineering Handbook	**Fink**
7.	Microwave Semiconductor Devices and their circuit Applications	**Watson**
8.	HP Application Notes : 918, 928, 983, 984, 989 (www.agilent.com/semiconductor)	
9.	Electronic Microwave Circuits	**Stephen Adams**
10.	IEEE 488 GPIB Manual	
11.	GPIB NI - 488.2 Software reference Manual	
12.	UNIX Network Programming	**W. Richard Stevens**
13.	Beginning LINUX Programming foreword by	**Alan Cox**
14.	6060B Sythesized RF signal generator Instruction Manual	
15.	HP 8593 E-Series Spectrum Analyzers Programmer's Guide	

APPENDIX

Selection Guide

GPD TO-12 Amplifiers (Guaranteed Specifications @ 0° to 50°C Case Temperature)

Model	Frequency Range (MHz) Minimum	Gain (dB) Minimum	Noise Figure (dB) Typical	Power Output for 1 dB Gain Compression (dBm) Typical	Gain Flatness (± dB) Typical	3rd Order Intercept Point (dBm) Typical	Input Power (± 1% Reg.) Voltage (VDC)	Input Power (± 1% Reg.) Current (mA) Typical	Page No.
GPD-201	5–200	30	3.5	+5	1.0	+13	+15	30	18
GPD-202	5–200	25	5.5	+9	1.0	+14	+15	60	20
GPM-552	5–500	33	4.5	0	0.2	+14	+15	34	40
GPM-1052	5–1000	20	7.0	+8	0.3	+20	+15	60	48
GPD-251	5–200	25	4.0	+1	1.0	+10	+5	30	22
GPD-252	5–200	15	4.0	0	1.0	+12	+5	11	24
GPD-401/461[1]	5–400	13	4.5	−2	1.0	+5	+15	10	28
GPD-411	5–400	12	3.2	−6	1.0	+4	+15	7	38
GPD-402/462[1]	5–400	13	6.0	+6	1.0	+18	+15	24	30
GPD-403/463[1]	5–400	9	7.5	+15/+10	1.0	+25	+24/+15	65	32
GPD-404/464[1]	5–400	9	7.5	+15	1.0	+26	+15	70	34
GPD-405	10–400	13	6.5	+20	1.0	+29	+15	60	36
GPD-1001/1061[1]	5–1000	12	6.0	0	1.0	+12	+15	15	42
GPD-1002/1062[1]	5–1000	12	7.0	+6	1.0	+16	+15	27	44
GPD-1003/1063[1]	5–1000	10	8.0	+14	1.0	+24	+15	55	46

Note 1: The 60 Series is the same as the standard series except that three external capacitors are required to establish low frequency roll-off.

PlanarPak™ Surface Mount Amplifiers (Guaranteed Specifications @ 0° to 50°C Case Temperature)

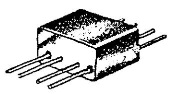
Model	Frequency Range (MHz) Minimum	Gain (dB) Minimum	Noise Figure (dB) Maximum	Power Output at 1 dB Gain Compression (dBm) Minimum	Power Requirements Voltage (VDC)	Power Requirements Current (mA) Nominal	Page No.
PPA-210	10–200	8.0	2.0	+11	+15	15	50
PPA-211	10–200	7.5	2.7	+17	+15	30	52
PPA-253	5–200	29.0	4.0	0	+5	30	26
PPA-543	10–500	10.0	2.5	+6	+15	25	118
PPA-544[1]	10–500	10.0	3.0	+12	+15	35	120
PPA-519	5–500	13.0	5.5	+13	+15	70	106
PPA-509	5–500	13.0	5.5	+20	+15	90	86
PPA-520	5–500	14.0	4.5	+12	+5	33	108
PPA-1043(P)1	10–1000	10.0	4.0	+6	+15	25	154
PPA-1044(P)1	10–1000	10.0	4.5	+10	+15	35	156
PPA-1005	5–1000	11.0	6.0	+20	+15	90	138
PPA-1006	5–1000	11.0	6.0	+17	+15	70	140
PPA-1007	5–1000	12.5	5.0	+11	+5	33	142
PPA-2012[2]	500–2000	9.0	4.0	+12	+15	50	176
PPA-2013[2]	500–2000	9.0	5.5	+19	+15	100	178
PPA-4132	1000–4000	20.0	6.0	+17	+8	150	202
PPA-6232(P)	2000–6000	17.0	6.0	+17	+8	150	204
PPA-18232(P)	2000–18000	9.0	9.5	+11	+8	155	206

(P) Preliminary

Notes: 1. Both RF input and RF output pins are at DC ground. No blocking capacitor.

2. RF input pin is at DC ground. No input blocking capacitor.

2 WAY-0° 4 kHz to 2.5 GHz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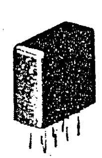
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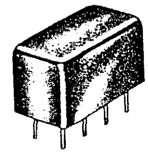
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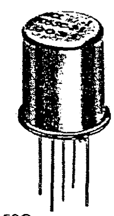
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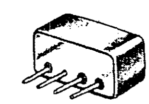

TSC

MODEL NO.	FREQ. RANGE MHz	ISOLATION dB						INSERTION LOSS, dB Above 3dB						PHASE UNBALANCE Degrees			AMPLITUDE UNBALANCE dB			CAPD DATA (see RF/IF Designer hand-book)	CASE STYLE	CONNECTION	PRIC $
	f_L-f_U	L Typ.	L Min.	M° Typ.	M° Min.	U Typ.	U Min.	L Typ.	L Max.	M° Typ.	M° Max.	U Typ.	U Max.	L Max.	M° Max.	U Max.	L Max.	M° Max.	U Max.	Page	Note B	N.	Qty. (1-9
LPS-109	10-500	35	25	30	25	30	25	0.3	0.5	0.4	0.6	0.5	1.1	2.0	3.0	4.0	0.15	0.2	0.3	2-84	BB48	an	17.95
MSC-2-1	0.1-450	20	15	30	20	30	20	0.3	0.5	0.4	0.75	0.6	1.0	2.0	3.0	4.0	0.15	0.2	0.3	2-89	A03	ap	18.95
MSC-2-1W	2-650	22	18	30	20	22	18	0.3	0.5	0.5	0.8	0.8	1.2	1.0	2.0	4.0	0.3	0.2	0.3	2-89	A03	ap	20.95
MSC-2-5	5-1500	18	16	20	16	20	14	0.6	0.8	0.6	0.8	0.6	1.1	2.0	3.0	5.0	0.2	0.3	0.4	2-29	A03	ap	24.95
MSC-2-11	5-2000	18	16	20	16	18	11	0.6	0.8	0.6	0.8	1.2	1.8	2.0	3.0	5.0	0.2	0.3	0.5	2-94	A03	ap	29.95
PSC-2-1	0.1-400	20	15	25	20	25	20	0.2	0.6	0.4	0.75	0.6	1.0	2.0	3.0	4.0	0.15	0.2	0.3	2-84	A01	ap	10.95
~~PSC-2-1W~~	1-650	25	20	35	20	25	20	0.3	0.6	0.5	0.9	0.7	1.0	2.0	3.0	4.0	0.15	0.2	0.3	2-85	A01	ap	16.95
✧ PSC-2-2	0.004-60	27	20	30	20	27	20	0.3	0.6	0.3	0.6	0.6	1.0	2.0	3.0	4.0	0.15	0.25	0.3	2-85	A01	ap	23.95
PSC-2-4	10-1000	30	25	25	20	25	20	0.6	1.0	0.6	1.2	0.7	1.3	2.0	4.0	8.0	0.15	0.2	0.4	2-86	A01	ap	23.95
PSC-2-5	10-1400	28	18	22	17	24	17	0.3	0.6	0.6	1.0	0.9	1.6	2.0	3.0	4.0	0.15	0.2	0.4	2-29	A01	ap	29.95
PSC-2-11	5-2000	21	16	22	18	19	9	0.5	0.8	0.6	0.9	0.7	1.5	1.0	3.0	6.0	0.20	0.4	1.0	2-126	A01	ap	34.95
PSC-2-45	700-900			20	17					0.2	0.4			--	3.0			0.2		2-86	A01	ap	22.95
PSC-2-1000	400-1000			35	25					0.5	1.0				2.0			0.3		2-126	A06	ap	22.95
■ PSC-2-1-75	0.25-300	20	15	30	20	20	15	0.4	0.75	0.4	0.75	0.4	1.0	2.0	3.0	5.0	0.15	0.2	0.3	2-87	A01	ap	13.45
■ PSC-2-1-75A*	1-200	35	27	46	35	36	25	0.1	0.3	0.2	0.4	0.35	0.6	1.0	1.0	2.0	0.1	0.15	0.15	2-97	A06	ap	14.45
■ PSC-2-1V-75	40-450			31	27					0.5	1.0				4.0			0.3		2-96	A01	ap	14.45
■ PSC-2-1W-75**	30-600	30	22	—	—	30	20	0.4	0.8	—	—	0.6	1.2	2.0	—	4.0	0.2	—	0.3	2-97	A06	ap	18.95
✧■ PSC-2-2-75	0.008-60	35	20	40	25	30	22	0.1	0.4	0.15	0.4	0.3	0.8	1.0	1.0	1.0	0.15	0.15	0.15	2-96	A01	ap	23.95
■ PSC-2-4-752	10-850	31	20	32	23	23	15	0.3	0.5	0.4	0.6	0.5	1.0	2.0	5.0	10.0	0.1	0.2	0.5	2-88	A01	ap	23.95
■ PSC-2375	55-85			35	25					0.3	0.5				1.0			0.1		2-87	A01	ap	23.95
PSC-2-500-1W	225-500			27	20					0.2	0.6				2.0			0.2		2-127	A01	ap	21.95
PSC-2-960-1W	300-960			27	20					0.5	1.2				3.0			0.4		2-127	A01	ap	25.95
TO5SC-110	5-500	36	20	40	25	36	20	0.3	0.6	0.3	0.7	0.6	1.0	1.0	2.0	2.0	0.10	0.20	0.2	2-128	PP163	ak	19.95
TO5SC-2-1	1-500	30	20	28	20	26	20	0.2	0.5	0.3	0.7	0.7	1.5	2.0	1.0	2.5	0.25	0.25	0.4	2-95	PP163	ak	18.95
TSC-2-1	1-400	30	25	30	25	30	20	0.25	0.5	0.4	0.75	0.8	1.0	2.0	3.0	4.0	0.15	0.2	0.6	2-90	B02	aj	15.95
		L2		U2				L2		U2				L2	U2		L2	U2					
NEW TSC-2-1W	200-1000	26	20	23	14			0.3	0.8	0.7	1.5			5	10		0.7	0.5		2-129	B02	aj	19.95

L = low range (f_L to 10 f_L) M = mid range (10 f_L to f_U/2) U = upper range (f_U/2 to f_U)

L_2 = (f_L to f_U/2) U_2 = (f_U/2 to f_U)

NOTES:

- ❋ Smaller size package available. See outline drawing CA531, TP model series.
- ◆ For aqueous washable units add suffix J to L model number. See outline QQQ532. Footprint for L models and L models suffix J are the same.
- ❑ Non-hermetic
- O When only specification for M range given, specification applies to entire frequency range.
- ✧ At low range frequency band (f_L to 10 f_L), linearly derate maximum input power by 13 dB.
- ■ Denotes 75 Ohm model, for coax connector models 75 Ohm BNC connectors are standard.
- * VSWR typical 1.1:1 over total range of frequency, max 1.2:1 for low and upper range, max 1.15:1 for mid range.
- ** VSWR low range 1.1:1 typical, 1.3:1 max; upper range 1.15:1 typical, 1.25:1 max.
- *** Price for quantities 10-49

A. General Quality Control Procedures, Environmental Specifications, Hi-Rel and MIL description are given in General Information (Section 0).

B. Connector types and case mounted options, case finishes are given in section 0, see "Case styles & Outline Drawings".

C. Prices and specifications subject to change without notice.

1. Absolute maximum power, voltage and current ratings:

1a. Matched power rating,

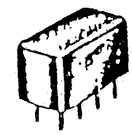
Models BP2C, BP2G, BP2P	1.5 Watts
Models JYPS-2-4-75, PSC-2-11	0.5 Watt
All other models	1 Watt

1b. Internal load dissipation,

Models BP2C, BP2G, BP2P	0.375 Watt
Models PSC-2-500-1W, PSC-2-960-1W	0.5 Watt
All other models	0.125 Watt

POWER SPLITTERS/COMBINERS 50 & 75Ω

4 WAY-0° 10 kHz to 1000 MHz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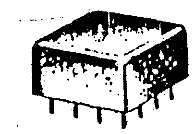
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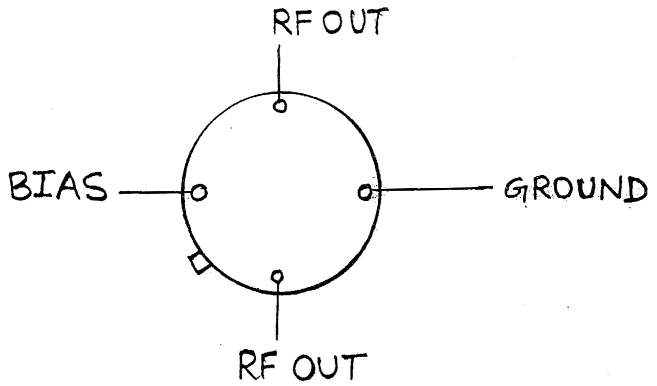
MODEL NO.	FREQ. RANGE MHz	ISOLATION dB						INSERTION LOSS, dB Above 6dB						PHASE UNBALANCE Degrees			AMPLITUDE UNBALANCE dB			CAPD DATA (see RF/IF Designer handbook)	CASE STYLE	CONNECTION	PRICE $
	f_L-f_U	L Typ.	L Min.	M Typ.	M Min.	U Typ.	U Min.	L Typ.	L Max.	M Typ.	M Max.	U Typ.	U Max.	L Max.	M Max.	U Max.	L Max.	M Max.	U Max.	Page	Note B		Qty. (1-9)
PSC-4-1	0.1-200	33	20	30	20	27	20	0.4	0.6	0.5	0.75	0.7	1.	4	6	8	0.15	0.2	0.25	2-54	A01	bf	35.95
PSC-4-1W	1-500	29	20	27	18	25	18	0.4	0.8	0.5	1	0.8	1.5	1	3	5	0.2	0.3	0.5	2-106	A01	bf	38.95
■ PSC-4-1-75	1-200	30	20	25	20	25	20	0.4	0.7	0.5	0.9	0.7	1.2	2	3	4	0.15	0.2	0.3	2-62	A01	bf	32.95
PSC-4-3	0.25-250	33	20	30	20	27	20	0.4	0.7	0.5	0.75	0.7	1.2	4	6	8	0.15	0.2	0.25	2-55	A01	bf	31.95
PSC-4-5	1-800	29	20	24	18	25	17	0.4	0.8	0.6	1.5	1.3	2.5	1	4	5	0.2	0.5	0.6	2-106	A01	bf	45.45
✦ PSC-4-6	0.01-40	35	18	32	25	25	18	0.4	0.8	0.3	0.5	0.5	1	2	2	2	0.1	0.15	0.2	2-55	A01	bf	36.95
■ PSC-4-1W-75	5-650	38	22	40	22	25	18	0.6	0.9	0.65	1.2	0.9	1.5	1	3	5	0.2	0.3	0.6	—	A05	bf	39.95
PSC-4A-4	10-1000	25	20	21	15	18	15	0.5	0.8	0.8	1.8	1.5	2.5	4	16	20	0.2	0.5	0.7	2-54	C07	bg	64.95
■ PSC-4A-475	10-800	30	20	33	20	25	18	0.4	0.7	0.6	0.9	1.2	1.6	—	—	—	0.2	0.4	0.8	2-62	C07	bg	64.95
■ PSC-4A-1W-75'	30-600	27	20	—	—	22	18	0.6	0.8	—	—	0.8	1.1	2	—	5	0.2	—	5	2-107	C07	bg	49.95

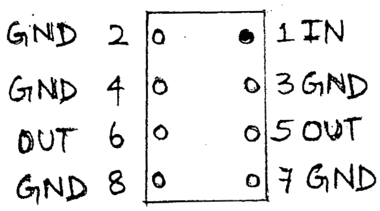
L = low range (f_L to 10 f_L) M = mid range (10 f_L to f_U/2) U = upper range (f_U/2 to f_U)

NOTES:
- ❒ Non-hermetic
- ■ Denotes 75 Ohm model
- o When only specification for M range given, specification applies to entire frequency range.
- ✦ At low range frequency band (f_L to 10f_L), linearly derate maximum power by 13 dB.
- • Maximum VSWR: input 1.5:1, output 1.3:1
- ••• Price for quantities 10-49
- A. General Quality Control Procedures, Environmental Specifications, Hi-Rel and MIL description are given in section 0, see "Mini-Circuits Guarantees Quality" article.
- B. Connector types and case mounted options, case finishes are given in section 0, see "Case styles & Outline Drawings".
- C. Prices and specifications subject to change without notice.
- 1. Absolute maximum power, voltage and current ratings:
  - 1a. Matched power rating.
    - Models PSC-4-5, PSC-4-1W, SCP-4-1W-75 — 0.5 Watt
    - Models BP4C, BP4P — 1.5 Watt
    - All other models — 1 Watt
  - 1b. Internal load dissipation.
    - Models SCP-4-1W-75, SCP-4-4-75, BP4C, BP4P — 0.375 Watt
    - All other models — 0.250 Watt

PIN CONFIGURATIONS



GPD 405/403



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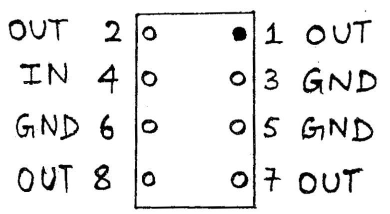

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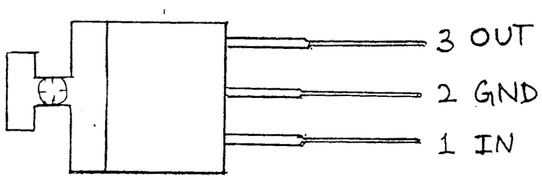


VOLTAGE REGULATOR

[MC 7815]

ELECTRICAL SPECIFICATIONS | TYPICAL PARAMETERS

Part Number 5082-	Output Frequency, f_o [GHz]	N Order	Minimum Output Power, P_o [5] [W]	Junction Capacitance at -10V, C_j [1] [pF] Min.	Junction Capacitance Max.	Breakdown Voltage at $I_R = 10\mu A$ V_{BR} [V] Min.	Breakdown Voltage Max.	Maximum Thermal Resistance, θ_{jc} [°C/W]	Package Outline	Transition Time t_t [ps]	Transition Time Charge Level [pc]	Lifetime, τ [ns]
0300	2	X 10	2.0	3.2	4.7	75	100	14	40	450	2400	200
0303	2	X 10	2.0	3.2	4.7	75	100	14	65[6]	450	2400	200
0310	6	X 10	0.4	1.6	2.7	40	60	30	41	160	1000	75
0320	10	X 5	0.23	0.35	1.0	25	40	60	41	75	300	20
0335	16	X 8	0.03	0.25	0.5	20	30	75	31	60	100	15

DC Tested Diodes (All Specifications at $T_A = 25°C$)

ELECTRICAL SPECIFICATIONS | TYPICAL PARAMETERS

Part Number 5082-	Maximum Junction Capacitance at -10V, $C_{j(-10)}$ [1] [pF]	Minimum Breakdown Voltage at $I_R = 10\mu A$ V_{BR} [V]	Maximum Transition Time t_t [ps]	Maximum Transition Time Charge Level [pC]	Package Outline	Lifetime τ [ns]	Thermal Resistance Θ_{jc} [°C/W]
0113[7]	4.85	35	250	1500	11	100	300
0241	4.6	65	275	1500	31	150	20
0180	4.45	50	220	1500	11	150	300
0114[7]	3.85	35	225	1500	11	100	300
0112	1.55	35	175	1000	11	50	300
0132	1.5	35	175	1000	31	50	40
0243	1.2	35	110	600	31	40	50
0151	0.65	15	90	200	15	20	600
0253[7]	0.6	25	80	200	31	20	75
0153	0.4	25	90	200	15	20	600

uggested output frequency, $f_{o(max)} < 1/t_t$

.OTES:

1. Capacitance selection is available upon request. Cont..ct your local sales office.
2. $f_c = \frac{1}{2\pi R_s C_{j(-6)}}$
3. As a doubler at midband.
4. For package outline 15 typical thermal resistance is 600° C/W with adequate heat sink.
5. ... multiplier tested results. Input power is: 5082-0300 15W; 5082-0310 4W; 5082-0320 2W; 5082-0335 0.65W
6. Package 65 is a modified version of the package 40. It features a 6-tooth, 1.21mm (.048 in) Bristol socket rather than a screw driver slot. A Bristol socket wrench is shipped with each order for 5082-0303.
7. The 5082-0113, -0114 and -0253 are also available by EIA registration numbers 1N5163, 1N5164 and 1N4547 respectively.

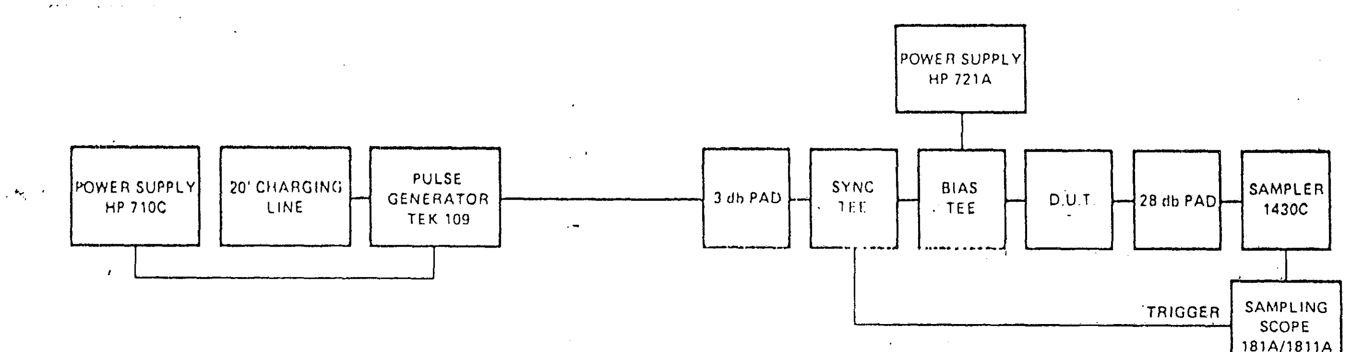
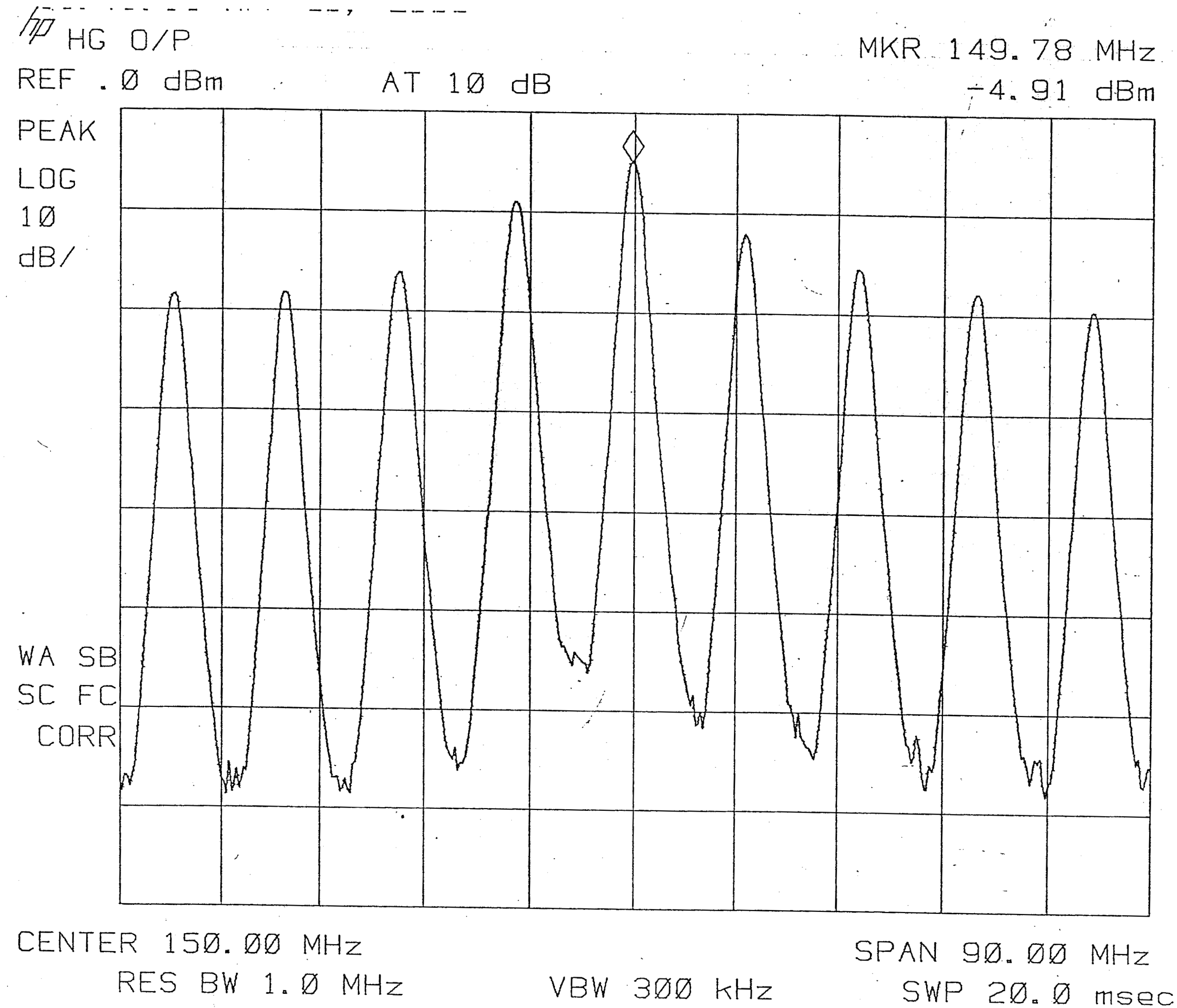


Figure 1. Test circuit for transition time. The pulse generator circuit is adjusted for a 0.5 A pulse when testing 5082-0151, 0253, 0335, 0835, 0836, 0885 and 0840. A pulse of 1.0 A is used for all other diodes. The bias current is adjusted for the specified stored charge level. The transition time is read between the 20% and the 80% points on the oscilloscope.



HG O/P
REF .0 dBm
AT 10 dB
MKR 149.78 MHz
-4.91 dBm
PEAK
LOG
10
dB/
WA SB
SC FC
CORR
CENTER 150.00 MHz
RES BW 1.0 MHz
VBW 300 kHz
SPAN 90.00 MHz
SWP 20.0 msec

PIN DIAGRAM OF GPIB CONNECTOR