PROJECT REPORT

1998-99

PHASE NOISE CHARACTERISATION OF L.O.SYNTHESIZERS

Submitted in partial fulfillment of
award of Degree
of
BACHELOR OF ENGINEERING
in
ELECTRONICS AND COMMUNICATION

by the Bangalore University, Bangalore.

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CERTIFICATE

This is to certify that the project work entitled

"PHASE NOISE CHARACTERISATION OF L.O. SYNTHESIZERS"

has been successfully carried out by

ANIL.KULKARNI.R
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in partial fulfillment of the requirement for the award of Bachelor of Engineering Degree in Electronics & Communication by the Bangalore University during the academic year 1998-99

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Certificate

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"***PHASE NOISE CHARACTERISATION OF L . O . SYNTHESIZERS***"

has been successfully completed by

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Our stay at the R.R.I was a very enlightening one. We gained insight into the practical aspect of designing a electronic circuit of a varied nature, and learnt a lot from the mistake we had committed inadvertently. We spent so much time at the R.R.I that it almost became our second home.

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CONTENTS

SYNOPSIS

PHASE NOISE CHARACTERISATION OF L. O. SYNTHESIZERS

Frequency synthesizers and local oscillators are very important subsystem in many of the sensitive microwave and radio frequency systems. Frequency synthesis is the generation of a frequency or set of frequencies which are exact multiples of the reference frequency.

Frequency synthesizers and stable local oscillators are used in many applications such as communication transmitters and receivers ,where stability of the carrier is very crucial. These are also extensively used in sensitive low noise receivers for radio astronomy.

The stability of the output frequencies are severely affected due to noise generated in the reference standard and the noise added by the external circuits used to process it . Phase noise is the unwanted spread of energy close to the frequency of interest.

The project aims at the design, development and fabrication of a radio frequency system with a suitable reference standard to characterize the phase noise of synthesizers and a stable local oscillator systems upto a frequency of 1.6GHz.

CHAPTER-ONE

INTRODUCTION

UNDERSTANDING PHASE NOISE

By definition , phase noise corresponds to instability in phase or frequency of the signal.It is measured in the ratio of the power in the noise to that in the carrier. Noise power is measured at a specific offset frequency in a specified bandwidth, since noise power is directly related to the latter. Measurement bandwidth is usually normalized to one Hertz, allowing easier comparison of sources. The unit of phase noise is "dBc/Hz".

Phase noise is a performance factor in many RF and Microwave systems such as Microwave communication links, space telemetry systems or Doppler radar. High phase noise brings about a loss of weak signal detection and can cause other problems such as high error rates , loss of radar sensitivity at low Doppler shifts and lack of definition in ultrasound imaging systems. Even digital data transmission in digital communication links is affected by phase noise. As phase noise defines the performance of these systems , it is necessary to measure it and specify the phase noise contribution of the signal sources like oscillators and synthesizers and components such as amplifiers, dividers, multipliers and phase detectors.

To give more insight to the significance of phase noise, consider a radio telescope working in the millimeterwave range . The radio telescope consists of a receiving antenna of high directivity, gain and narrow beamwidth .This is achieved by using a parabolic antenna of large diameter .

This antenna is made to receive radiations from a particular star or star forming region .This radiation will be in GHz range , with huge bandwidth of information. Analysis of such a huge bandwidth signal is very difficult. This problem is overcome by breaking the information into sub-portions with smaller bandwidths. Each sub-portion needs a carrier for analysis .Many number of such carriers are generated by a stable L.O.synthesizers . To be specific , oscillator with low phase noise . If L.O. has phase noise there will be shift in the carrier frequency which leads to loss of information .

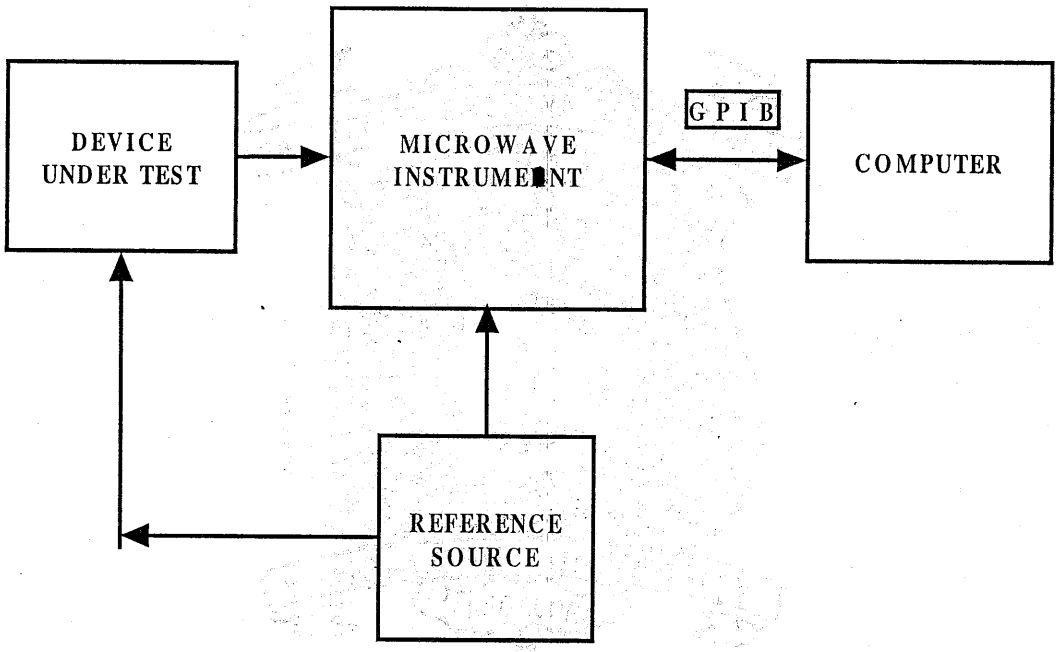
To give another example to illustrate the importance of phase noise , consider a mobile radio system which wants to receive a weak signal ,while a strong signal is present in the adjacent channel . The desired weak signal is down converted into the IF band , may get masked by down converted phase noise side bands originating from the strong signal in the adjacent channel or receiver L.O.

CHAPTER-TWO

MEASURING PHASE NOISE

MEASURING PHASE NOISE

PHASE NOISE MEASUREMENT SETUP



This is a basic block diagram of the phase noise measurement . The device under test may be any oscillator working at microwave range of frequencies , frequency synthesizers and also microwave testing and measuring devices such as spectrum analyzer .

Microwave instruments employed depends on the phase noise measuring technique . The instruments employed may be spectrum analyzer,
frequency counter , phase shifters, delay lines , oscilloscope etc...

The reference source employed for the measurement of phase noise should be very stable .It's phase noise characteristics must be better than that of the device under test . This reference is so designed to provide outputs at different frequency and power levels .

The reference source designed must be able to support an external reference input . This flexibility is provided, to replace the existing reference, with more stable reference to enhance the accuracy of measurements .

To support detailed analysis , the microwave instruments are interfaced with P.C using General Purpose Interface Bus (GPIB) . A program in C language is written to achieve interfacing and to control the microwave instruments using P.C .

PHASE NOISE MEASUREMENT METHODS :

The oscillator output instead of being concentrated around a single frequency, the power will be distributed over a range of frequencies within a bandwidth, with the desired frequency as the center frequency. This is due to phase noise. Phase noise is usually measured using a suitable reference source and can be measured both in time and frequency domain.

There are various methods for characterizing phase noise. Some of the methods are listed below :-

IN TIME DOMAIN :-

1.) Using Oscilloscope

2.) Phase Detector Method

3.) Using Time Interval Counter

IN FREQUENCY DOMAIN :-

1.) Using spectrum analyzer

2.) Phase Detector Method

3.) Frequency Discriminator Method

4.) Injection Locking Technique

The choice of method depends to some degree, on the phase stability of the device under test. With the exception of spectrum analyzer , no single instrument is able to measure phase noise. Rather phase noise measurements typically involve a setup consisting of some reference source, a phase or frequency detector, an oscilloscope to make time domain measurements at the detector output and a counter or baseband analyzer to transform the detector output to some parameters of phase noise.

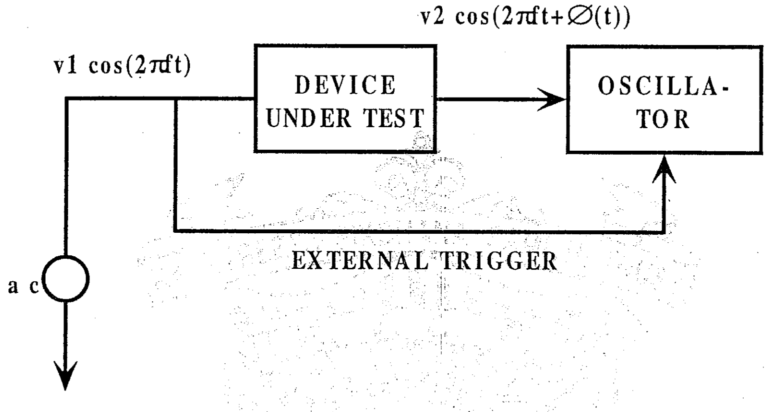
Even though a spectrum analyzer can be used to directly measure phase noise, it has some limitations listed below.

a) Phase noise contribution of the spectrum analyzer (determined mainly by its L O) needs to be significantly lower than the phase noise of the source under test.
b) Spectrum analyzer can only be used to measure phase noise at offset frequencies higher than 10KHz or 100KHz for most low 'Q' free running oscillators.
c) Potential A.M noise of the source under test poses another limitation of spectrum analyzer method. A.M noise causes symmetrical noise sidebands on the spectrum analyzer just like phase noise.
d) Additional limitation of this method is its high system noise figure resulting in a typical noise floor of -130 to –140 dBc/Hz.

TIME DOMAIN MEASUREMENTS:

1..) USING OSCILLOSCOPE :

OSCILLOSCOPE METHOD



(fig1)

The measurement done using above setup is called a residual measurement of phase noise , as only the phase jitter added by the DUT is detected. If the trigger signal would come from a reference source , the oscilloscope would display any instantaneous phase differences of signal under test to the reference signal .

The oscilloscope is externally triggered with the signal V1 $\cos(2\Pi f_0 t)$ before it enters the DUT. The processed signal displayed by the oscilloscope V2 $\cos[2\Pi f_0 t+\Phi(t)]$ shows then the instantaneous time –shifts caused by circuit under test. The instantaneous time jitter $\delta t(t)$, which may be read as a peak to peak δt at the zero crossing, is proportional to the instantaneous phase jitter Φ(t) .

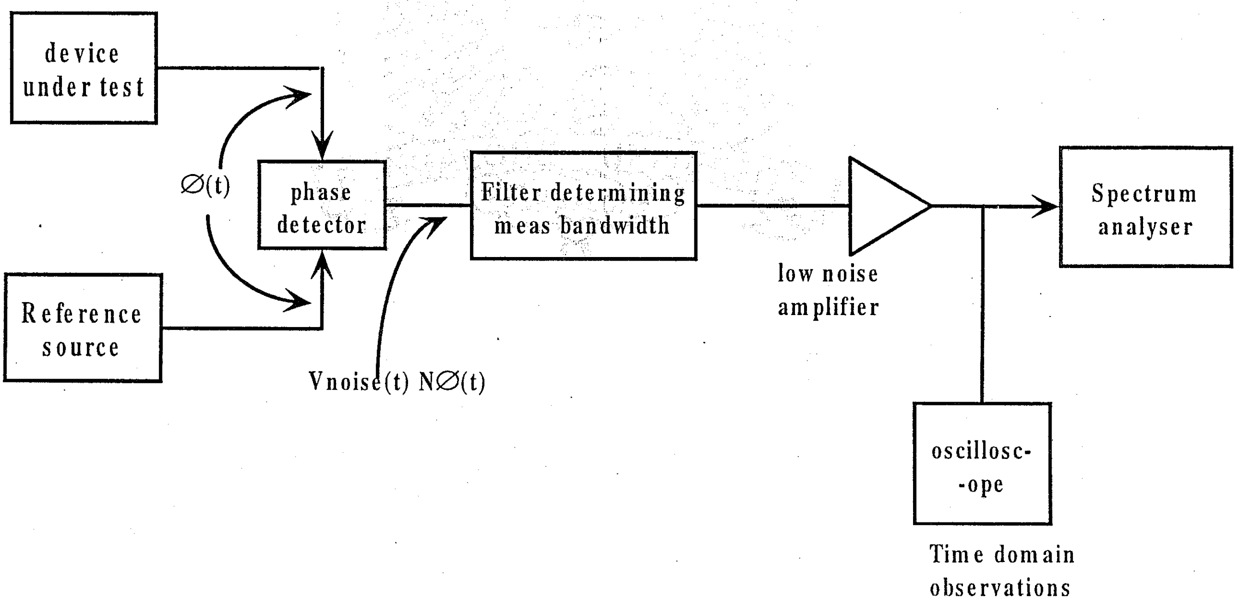
$\Phi(t) = \delta t(t)\, 2\Pi / T$ radians where T = period of the signal.

Advantages : It is the most direct way to observe time (phase) jitter.

It is well applied to pulsed signals, which may have significant noise modulation of zero crossings due to line noise or other unwanted signal coupling.

Disadvantage: Oscilloscope is too insensitive to measure phase jitter of typical R F sources.

PHASENOISE MEASUREMENT (PNM) USING PHASE –DETECTOR:



(fig 2)

A phase detector is more sensitive device to make phase noise measurements of RF sources . The phase detector produces output voltage proportional to the phase difference between it's two RF inputs .The voltage output $V_{noise}(t)$ represents the phase jitter $\Phi(t)$ between the DUT and a reference source. It is filtered and amplified before giving into oscilloscope. Typically phase jitter is stated as a peak to peak measurement for a given bandwidth

PNM USING FREQUENCY INTERVAL COUNTER :

A very sensitive tool for measuring frequency (or phase) noise in time domain is the time interval counter . The counter essentially measures the average frequency of signal under test over a sample time τ .Fig 3 shows the plot of the differences δf of consecutive measurement (referenced to the carrier frequency f_o) as a function of sample time τ . The rms average of consecutive sample pairs $\delta f\ \tau/f_o$ yields allan variance . It is one of the standard measure of frequency stability and is typically used to characterize CXO and atomic time standards .

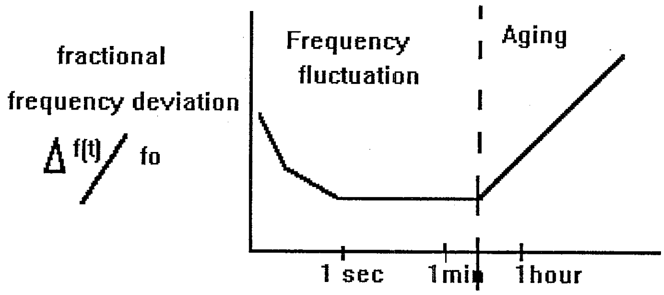


FIG: Fractional frequency deviation is plotted as afunction of sample time.

(fig 3)

FREQUENCY DOMAIN MEASUREMENTS :

More commonly , phase noise is analyzed in the frequency domain and presented as a spectral density distribution of the phase fluctuation $\phi(t)$.

$$S_\phi(f) = \phi^2_{rms}(f) \quad rad^2/Hz \text{ or } dB/Hz$$

where ,

$S_\phi(f)$ = spectral density distribution of phase fluctuation

$\phi rms(f)$ = rms phase deviation per $\sqrt{Hz}$ at f .

f = fourier frequency .

$S_{\phi}(f)$ is obtain when DUT is applied to a phase detector and phase detectors output is examined with a base band spectrum analyzer .The spectrum analyzer displays the spectral density distribution of the voltage fluctuations $S_{noise}(f)$ which can be translated into $S_{\phi}(f)$ with a calibration factor .

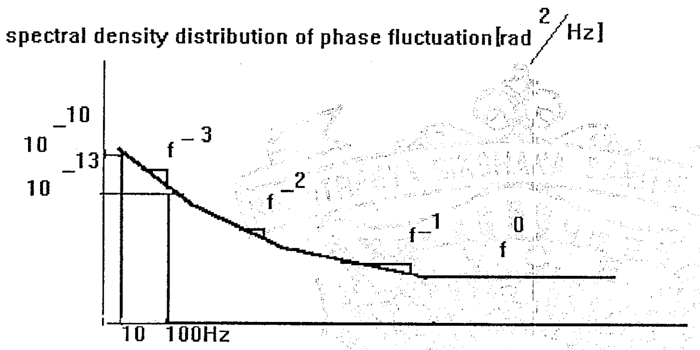
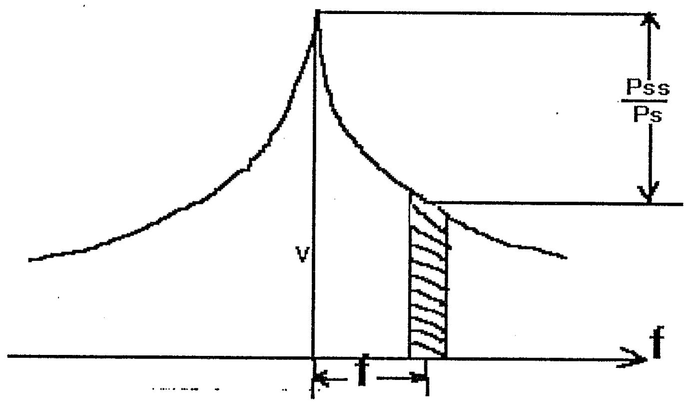


FIG :The spectral density distribution of phase fluctuation is shown approximated by segments by segments of specific distribution slopes.

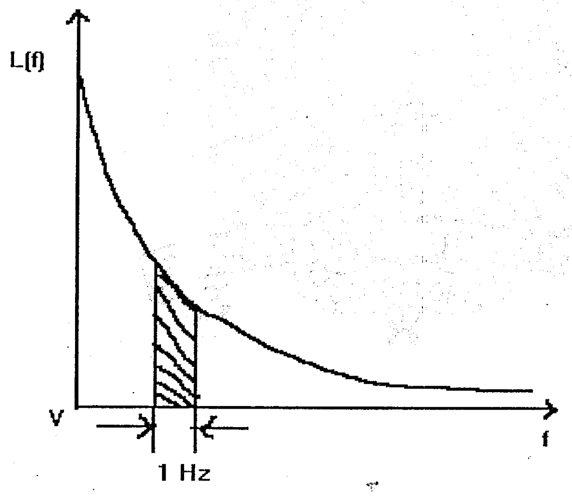
(fig 4)

Above figure shows the resulting graph Sø(f) in dB as a function of Fourier frequency f . The Fourier frequency is sometimes also called " offset frequency ", or " base band frequency ", or " sideband frequency ". In the graph , the distribution is shown being approximated by segments of specific distribution slopes like $1/f^2$ etc.. They represent an asymptotic approximation of phase noise typically measured on oscillators and are rooted in specific noise mechanisms .



The RF spectrum analyser gives a symmetrical display of phase noise modulation sideband power for a selected bandwidth

(fig5a)



L(f) displays one side of this spectrum as the ratio of the single sideband noise power in a 1-Hz BW to the total signal power.

(fig 5b)

The RF spectrum analyzer gives a symmetrical display of phase noise modulation side bands power for a selected resolution bandwidth . £(f) displays one side of this spectrum as a ratio of single side band noise power in a 1Hz bandwidth to the total signal power .

The most common, characterization of phase noise is the RF power spectrum . The phase noise component $\phi(t)$ of the signal manifests itself in modulation sidebands to the carrier which can be directly observed on RF spectrum analyzer (assumed to have no contribution by itself) .

As shown in figure above the spectrum analyzer display is symmetrical . Taking just one side and looking at side band noise in 1Hz bandwidth leads to definition of £ .

$$£(f) = [P_{ss} \text{ (per Hz)}] / [Pt]$$

where ,

P_{ss} (per Hz) = side band noise power with 1Hz bandwidth .

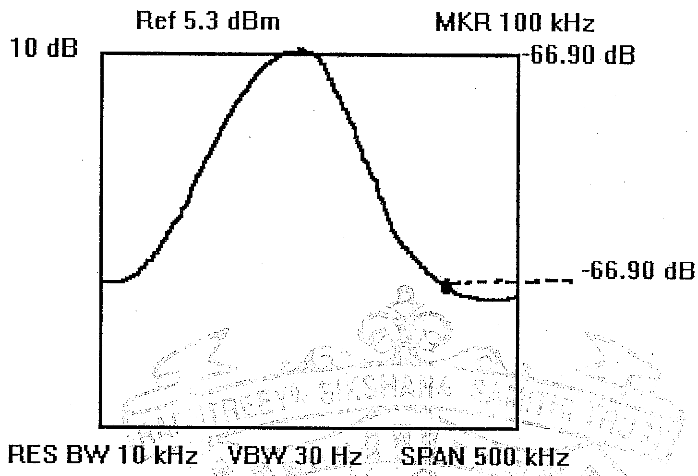
P_t = total signal power .

£(f) is defined as the ratio of single side band power of phase noise in a 1Hz band width f Hz away from the carrier frequency , to the total power of signal . It is typically expressed in dBc (dB below the carrier) per Hz .

£(f) is a viable representation of phase noise only within this constraint . It relates to the spectral density of phase and frequency fluctuations as follows :

$$£(f) = 1/2 S\phi(f) = 1/2 \; 1/f^2 \; Sv(f)$$

Measurement of RF power spectrum with spectrum analyzer :



(fig 6)

RF spectrum analyzers measures the spectral density £(f) directly as symmetrical side band noise of the RF carrier .A measurement is shown in figure 6 where the spectrum analyzer is set to cover an offset range of 250KHz (to either side of the carrier) with resolution bandwidth of 10KHz .

The single sideband to carrier ratio £(f), at a given offset is obtained by reading the difference in dB of the carrier power and sideband noise level at the offset and adjusting for the resolution bandwidth (minor corrections for noise BW verses bandwidth differences may be necessary for a given spectrum analyzer) .

£(f)(indBc/Hz)=$P_{carrier}$(dBm)-Psb(dBm)-10log(bandwidth/1Hz)

where, Pcarrier=carrier power

P_{sb}=sideband noise power.

The example, has marker set to 100KHz offset. They read a –66.9dB carrier to sideband power ratio.With the chosen resolution bandwidth of 10KHz, the reading translates to –106.9dBc/Hz (-66.9dB-40dB).

The phase noise measurement is correct only under the condition of $\phi<<1$.The presentation of phase noise as carrier sideband noise is based on the fact that a sinusoidal phase modulation with a peak deviation much smaller than 1 radian($\phi<<1$) is proportional to the ratio of sideband to signal amplitude.

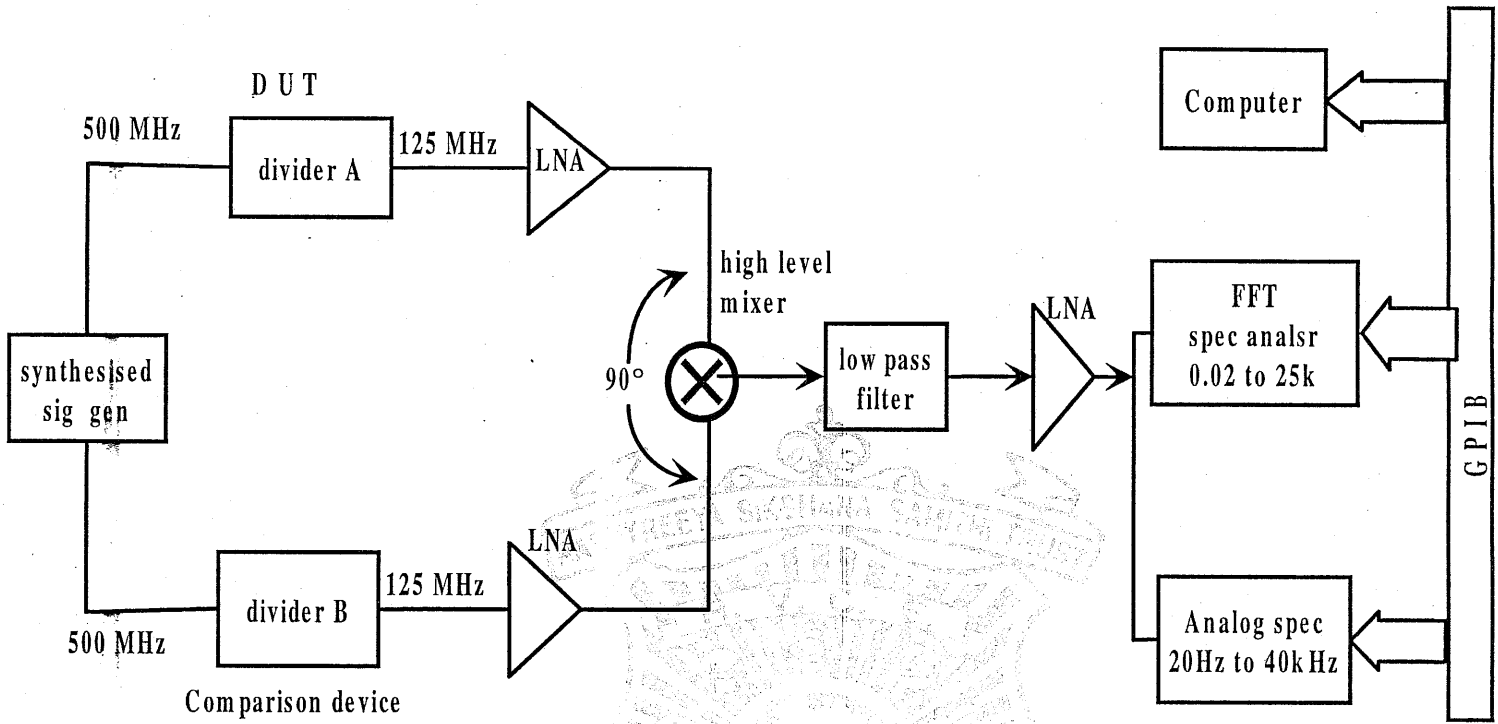
Limitations of the methods are:

1.) Phase noise contribution of spectrum analyzer(determined by its LO),needs to be significantly lower than the phase noise of the source under test.

2.) Beyond 300KHz offsets,the dynamic range of the spectrum analyzer limits it's capability to measure the far off noise of vco example which has
-130 dBc/Hz at 1MHz offset .
3.)Potential AM noise of the source under test poses another limitation of the spectrum analyzer method . AM noise causes symmetrical noise sidebands on the spectrum analyzer just like phase noise .

MEASUREMENT USING PHASE DETECTOR METHOD :

Phase noise is measured ,most directly by applying the signal under test to the phase detector as indicated in figure 7 . A phase detector is a device, which compares the phase of the signal under test with the phase reference signal. The output voltage of phase detector is proportional to the phase difference of the two signals. In terms of uncorrelated noise fluctuations, however the root mean square (rms) output voltage is proportional to the rms sum of the phase fluctuations of reference and DUT signal. A very stable source is chosen as the reference signal so that it's contributions can be neglected. The spectral density distribution of phase fluctuations $S\phi(f)$ is obtained by connecting the phase detector output to a baseband by connecting the phase detector output to a base band spectrum analyzer.

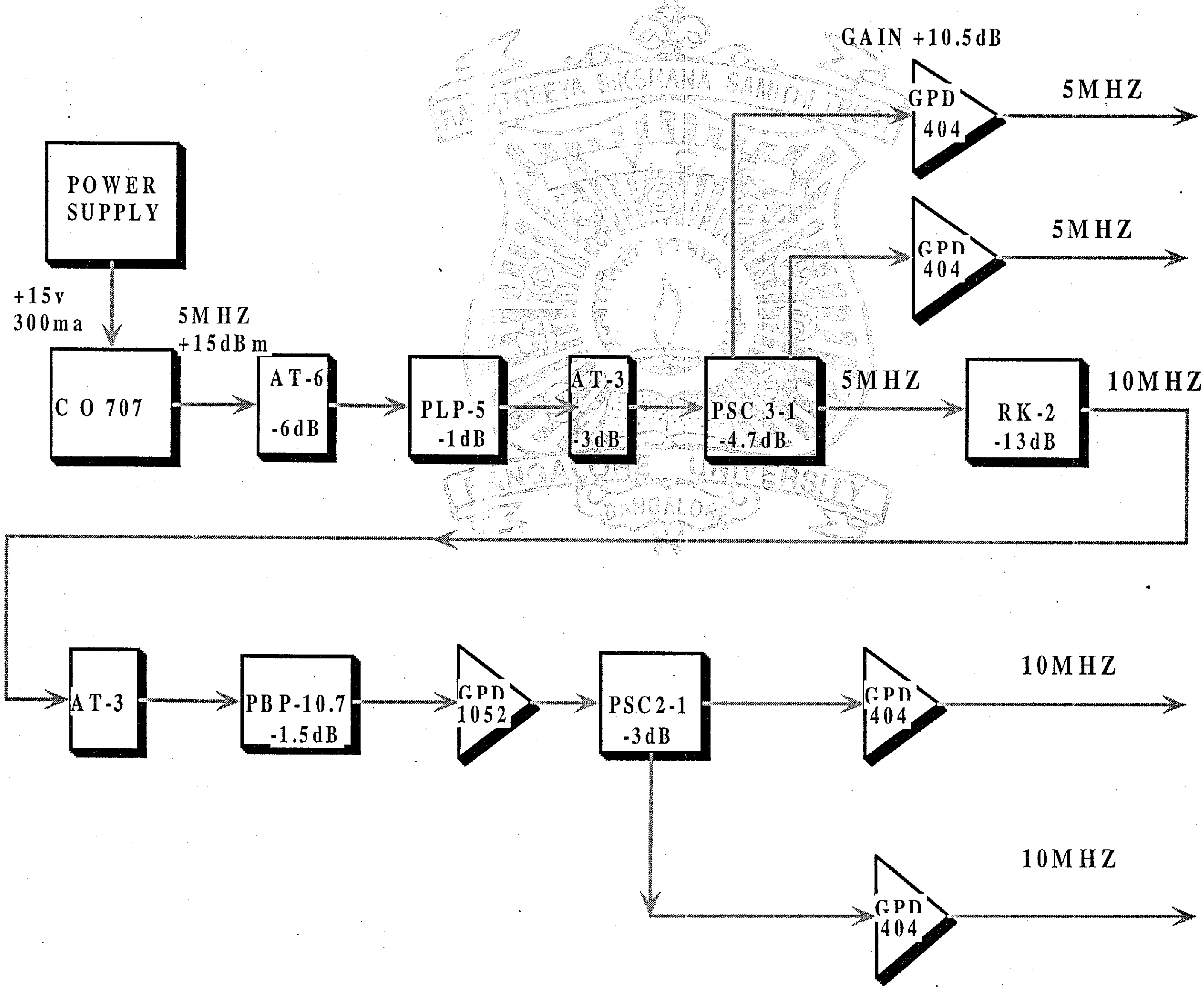

D U T
500 MHz
divider A
125 MHz
LNA
high level
mixer
90°
synthesised
sig gen
low pass
filter
LNA
LNA
500 MHz
divider B
125 MHz
Comparison device
Computer
FFT
spec analsr
0.02 to 25k
Analog spec
20Hz to 40k Hz
G P I B

CHAPTER-THREE

REFERENCE MODULE

REFERENCE MODULE

BLOCK DIAGRAM OF THE REFERENCE SOURCE



The hardware part of our project consists of the design and implementation of a reference source(module) with output at two frequency levels 5MHz (dBm) and 10MHz (dBm).

To achieve this, an oven controlled crystal oscillator(OCXO) CO-707, with very stable and low phase noise characteristics, is made use of. Output of this OCXO is power splitted into three channels. Two of them are amplified directly, to get 5MHz at required power levels. The other remaining channel, with 5MHz is fed as an input to a doubler. Output of doubler, which is twice the fundamental applied (i.e. 10MHz), is bandpass filtered to reduce harmonic levels. Output of this is then applied to a power splitter and each channel is amplified individually to get two 10MHz at required power level.

DESCRIPTION :-

This system totally draws a current of 0.65Amps. Amplifier section needs 0.35Amp and CXO draws 0.3Amp, thus totaling to 0.65Amps . Both CXO and amplifier require dc voltage of +15v. Hence power supply is of rating +15v, 0.65Amp. Output for oscillator and amplifier are drawn separately using two separate regulators, to allow sharing of load . This sharing of load, by two regulators, prevents over heating. Hence avoiding temperature sensitiveness of output voltage, also frequency variation will be avoided.

OCXO (CO-707) :-

The system makes use of OCXO as input reference. This is a low phase noise ultra stable oscillator giving 5MHz output at +15dBm.Practically, output will contain harmonics also. Harmonics levels are tabulated below –

FREQUENCY (MHz)	OUTPUT (dBm)
5	+15
10	-21
15	-15
20	-22
25	-26

To reduce harmonics level, a LPF(PLP-5) with cut off 6MHz is used. That is a LPF with fco=6MHz, where gain will be 3dB down from the maximum .

An attenuator of 6dB is used before LPF, the use of it is justified in paragraph to follow –

Oscillator must be terminated in matched impedance, in order to reduce the harmonics of oscillator. Problem however is the filter impedance (LPF) that immediately follows OCXO is highly reflective at harmonic frequencies. This will cause harmonics to be reflected back into the oscillator. Hence as a solution atleast 6dB attenuator (12dB return loss) is used immediately after OCXO and following PLP-5. This reduces effect of harmonics to greater extent.

After output of OCXO is filtered out for 5MHz, it is applied to PSC1-3 power splitter, which gives 3 output, each 4.8dB down than the input. Basically, power splitter is a passive device, which accepts input signal and delivers multiple output signals with specific amplitude and phase characteristics. The theoretical insertion loss produced depends on number of ports. Ex –

NUM OF PORTS	INSERTION LOSS(dB)
2	3
3	4.8
4	6.0

The input to power splitter is 5dBm (following attenuator of 3dB). Hence the output of each point will be down by 4.7dB giving +0.3dBm, at each one of them.

For two of the ports, amplifier with gain 10.5dB is connected, thus giving final output of (0.3+10.5)=+10.8dBm. These are two 5MHz at output power of +9.8dBm.

For the third port, which gives 5MHz at +0.3dBm power, a doubler is connected. Doubler operates in nonlinear state, hence, its output will contain all harmonics of fundamental, including fundamental . The doubler being made use of is RK-2 and it's conversion loss is 12.35dB[conversion loss :- is the difference in power output of the frequency doubler (2^{nd} harmonic) compared to the power applied to the input (fundamental) in dB].

Thus output of doubler(2^{nd} harmonic) i.e.. 10MHz will be at

(-0.8 – 12.35 = -13.35 dBm).With harmonics of fundamental present , desired 10 MHz is selected, using BPF of 10.7MHz with narrow bandwidth.

This bandpass filtered output is power splitted using PSC2-1, and each channel is amplified separately using GPD 404 amplifiers to get two 10MHz at power level of +9.3dBm.

CHAPTER-FOUR

OSCILLATOR
C O -707

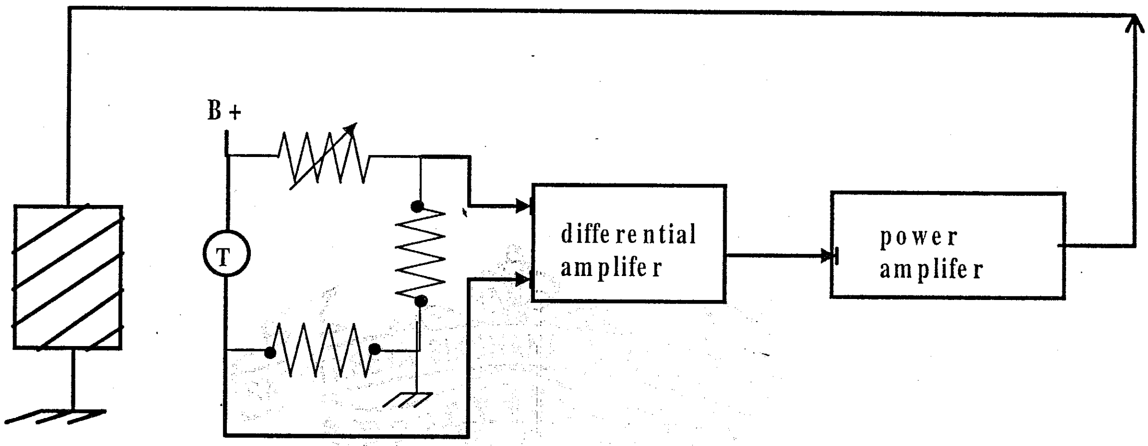
OVEN CONTROLLED CRYSTAL OSCILLATOR

In many applications, especially in microwave and millimeter wave receivers, high AM or FM phasenoise levels in synthesized local oscillators can limit system performance. As a result, crystal oscillators used in such applications must exhibit very low noise levels. Achieving low noise requires careful design of oscillator circuit as well as selecting a suitable crysyal. The crystal chosen must be having a high Q-value. By selecting a high Q-crystal, providing minimal electrical loading, minimizing circuit nonlinearities, and keeping internal noise generation low, it is possible to achieve single sideband phase noise levels as low as –137 dBc/Hz at an offset of 10 Hz from a 5MHz carrier.

If stability requirements are too stringent to be met by a basic crystal oscillator, the crystal and the electrical circuits may be temperature controlled by an oven.

A proportional control is an electronic servo system, which continuously supplies power to the oven; it varies the amount of oven power, continuously compensating for the ambient temperature changes.

In many oven controlled oscillators the thermistor is heat sunk to the ovens metal shell to sense the temperature. The thermistor is one leg of the resistance bridge shown below.



The bridge operates such that if the temperature at the oven decreases due to an ambient temperature change, the change in thermistor resistance, developing an increase in bridge output voltage. This voltage is amplified in a high gain differential amplifier. The output of this is further amplified in a power amplifier, which drives directly into the oven winding.

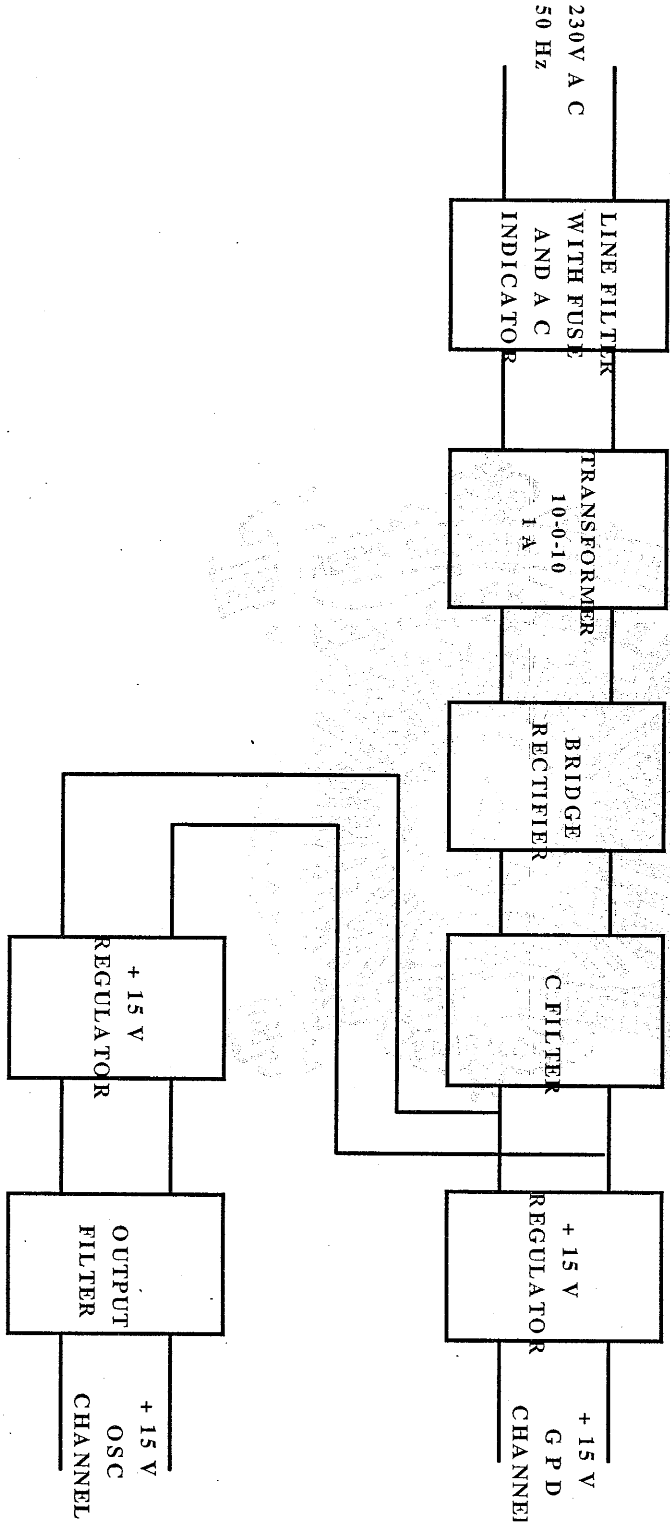
Thus, the small voltage increase resulting from the bridge unbalance generates a large voltage across the oven winding. The increase in power to the oven generates more heat, compensating for the temperature decrease, which was initially sensed by the thermistor. Similarly, an increase in temperature at the oven causes a decrease in bridge output voltage, which results in reduced power into the oven, thus compensating temperature decrease.

An alternative design to this is power amplifiers are heat sunk to the oven shell as the heat transfer mechanism, in line of having a heater winding. Employing a proportionality-controlled oven can improve oscillator temperature stability relative to crystals inherent stability by more than 5000

CHAPTER-FIVE

POWER SUPPLY

POWER SUPPLY

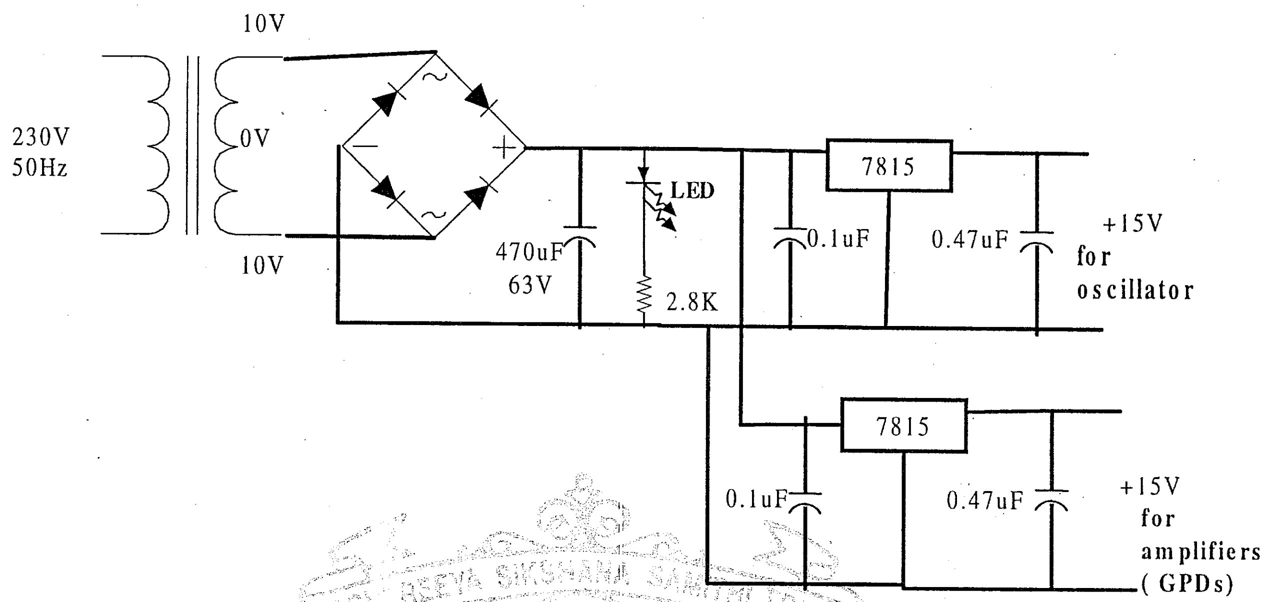


POWER SUPPLY BLOCK DIAGRAM

A power unit of some type is essential for the operation of electronic instruments and systems. This may of course be derived from batteries, but more commonly derived from single-phase a.c mains. The purpose of power unit in this is to accept local mains supply (230v, 50Hz in India) and convert it into a form that is suitable for the internal circuits of the systems or instruments. In the majority of cases a.c mains is converted to a fixed stable d.c voltage, current, mains input and temperature. This is achieved using regulated power supplies.

The block diagram of a typical power supply using i c regulators is shown in the figure. The operation is as follows. The line filter is used for noise suppression at the input a.c mains. A step down transformer is used to get 20v from 230v mains.

Bridge rectifier is used to convert input alternating current to unidirectional current. This is smoothened by using a capacitor filter. To get regulated output i c regulators are used, which maintains a constant output voltage against changes in load current, mains input and temperature.



POWER SUPPLY SPECIFICATIONS:

Output voltage=15V.

Output current=0.65A.

TRANSFORMER SELECTION:

A step-down transformer of rating 1A, 230V/10-0-10 is used with centertap not connected.

With this arrangements $V1(max)=\sqrt{2}(10-(-10))=28.28V$

Assuming bridge and transformer drop of 3V,

$$V(max)=V1(max)-drop=28.28-3=25.28V$$

Regulator 7815 requires minimum of =V0+drop out

= 15 + 3 =18v

for its operation.

Thus T/F 230v/10-0-10v provides , more than sufficient input voltage for regulator 7815.

Total load current of 0.65A is required for the system, and transformer can supply 1A of current, which is more than sufficient rating for the application.

Capacitor filter is used in power supply of our application.

Choosing 'C' Value :

To determine, the value of filtering capacitor, we have to consider maximum ripple allowed by the regulator 7815.

consider

for capacitor , maximum voltage being applied is equal to

$$V_{max} = \sqrt{2}V_{rms} = \sqrt{2}(20) = 28.28$$

Minimum voltage required at the input of regulator is

$$V_{min} = V_{reg} = V_o + \text{drop out} = (15+3) = 18v$$

$$V_{avg} = (V_{min} + V_{max}) / 2 = 23.14v$$

$$V_{ripple}(pp) = V_{max} - V_{min} = 28.28 - 18 = 10.28v$$

Vripple(rms) = Vripple(pp) / $2\sqrt{2}$= 3.634v

Ripple factor = r = Vripple(rms) / Vdc = 3.634 / 23.14 = 0.16

We use chart for selection of the proper filter capacitor. The chart plots ripple factor 'r', Vs the wCR product. The wCR product is simply the product of angular velocity, filter capacitance and the load resistance. The wCR product corresponding to r=0.16 is five, from the chart.f=frequency of the bridge.

Therefore wCR=5

$2 \times \Pi \times 100 \times C \times 35.6 = 5$

C=223.53 uF

Thus C=224 uF/50V is the minimum allowed capacitance. In our application, we used a capacitor of

C=470 uF/63V

where R=load resistance=Vavg/Il=23.14/0.65=35.6 ohms.

TESTING OF POWER SUPPLY:

The power supply is tested under noload and full load conditions. Also load regulations, line regulation and ripple factor is determined. practically. No load resistance is connected at the output for no load measurements. For fullload measurements, calculated load resistance with proper wattage rating is connected.

OSCILLATOR CHANNEL	AMPLIFIER CHANNEL
Vout=+15 V	Vout=+15 V
Io = 0.3A	Ia = 0.35A
Ro=15/0.3=50 Ω	Ra=15/0.35=43Ω
W=VI=4.5 w	W=VI=5.25w
Ro=50 Ω/4.5w	Ro=43Ω/5.25w
use Ro=50 Ω/10w	use Ro=43Ω /10 w

TABLE 1

	NO LOAD	FULL LOAD
Vac (Vrms)	22.9	21.18
Vdc (unreg)	22.9	24.6
Vdc (osc)	15.05	15.04
Vdc (amp)	15.22	15.2

TABLE-2

parameters (in volts)	12:00pm	2:00pm	4:00PM
Vac (rms)	21.18	21.05	21.09
Vdc (unreg)	24.6	24.6	24.3
Vdc (osc)	15.04	15.03	15.03
Vdc (AMP)	15.21	15.2	15.2

- **CONDITIONS:** Filtering capacitance C = 470uF/63v

  Rd= 50 ohm/10W

  Ra = 43 ohm/10W

Transformer tapping : 230v

LOAD REGULATION :

$$\% LR = (V_{nl} - V_{fl})/ V_{nl} * 100 \%$$

where, %LR = percent load regulation

Vnl = load voltage with no load current

Vfl = load voltage with full load current

From TABLE-1

%LR(osc) = (15.05 – 15.04) / 15.05 *100 % =**0.066%**

%LR(amp) = (15.22 – 15.2) / 15.22 * 100 % =**0.131%**

LINE REGULATION :

% line regulation = Δ Vo / Δ Vin

To find line regulation , input ac voltage is varied in steps of 20v,by changing transformer tapping . The corresponding output voltage is noted down, to calculate line regulation .

Vin	Vo (dc)
210v	15.03v
230v	15.04v
250v	15.05v

Line regulation (%) =(ΔVo/ ΔVin)*100 %

= (15.05 – 15.03) /(250 – 210) = **0.05 %**

POWER SUPPLY CHARACTERISTICS :

LINE REGULATION :

The change in output voltage for change in input voltage . The measurement is made under low dissipation condition , such that average chip temperature is not significantly affected.

LOAD REGULATION :

The change in output voltage, for change in load current at constant chip temperature.

MAXIMUM POWER DISSIPATION:

It is the maximum, total device power dissipation, for which regulator will operate within specification.

RIPPLE REJECTION:

The line regulation for a c input signals at or above a given frequency with a specific value of bypass capacitor and the reference bypass terminal.

THREE TERMINAL CAPACITORS

Unlike conventional two terminal capacitors which have high residual inductance within the lead wires, thereby impeding the path of high frequency noise to ground, a three terminal capacitor forms a T-filter providing high inductance in series with the line, via two integral ferrite beads, and low inductance to ground via bypass capacitor. Thus they provide increased attenuation with frequency over conventional decoupling capacitors.

Applications include :

1) High frequency noise suppression for d c power lines.
2) Noise suppression in digital high impedance circuits.
3) Noise suppression in high speed digital signals (clocks etc).
4) Noise suppression in video I F signals.

Effective frequency ranges :-

100pF -------- 500 to 2000 MHz.

1000pF ------- 30 to 1000 MHz.

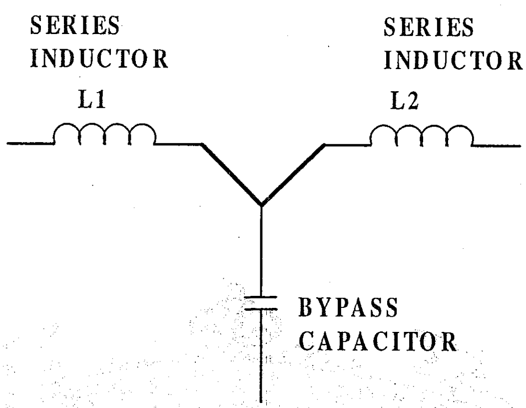
10000pF ----- 7 to 1000 MHz

Voltage rating :- 100 v.

Current rating :- 6 Amp.

Operating temperature :- -25° to +85° C.

EQUIVALENT CIRCUIT OF A THREE TERMINAL CAPACITOR



REGULATOR

LM 7815 VOLTAGE REGULATOR :

The LM 78xx series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications . One of these is local on card regulation , eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems , instrumentation , HiFi and other solid state electronic equipment . Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM 78xx series is available in an aluminium TO- 3 package which will allow over 1.0 Amp load current if adequate heat sinking is provided .Current limiting is included to limit the peak output current to a safe value . Safe area protection for the output transistor is provided to limit internal power dissipation . If internal power dissipation becomes too high for the heat sinking provided , the thermal shut down circuit takes over preventing the IC from over heating .

FEATURES :

- Output current in excess of 1Amp .
- Internal thermal over load protection .
- No external components required
- Output transistor safe area protection.
- Internal short circuit current limit .
- Available in the aluminium TO-3 package .

CHAPTER-SIX

MICROWAVE COMPONENTS

ATTENUATORS

Fixed Attenuators are found in a wide variety of electronic equipments for extending the dynamic range of measuring equipment, for preventing signal overload in transmitters and receivers and for impedance matching to reduce the effects of improper input/output termination of oscillators, amplifiers and setups.

The important parameters associated with the fixed attenuators include the amount of attenuation, the flatness over a specified frequency, range ,vswr, average and peak power handling capability ,size and height ,performance over a given temperature range .

Average power limit decreases linearly as temperature increases and burnout will result(or calibration will be altered if average power limit is exceeded).

Attenuators of 50 and 75 ohm models are available with attenuation ranging from 1 to 40 dB and DC to 1500MHz frequency range.

DEFINITIONS OF TERMS:

FIXED ATTENUATORS: A device used to reduce power levels of a signal by fixed amount with little or no reflections. The output signal is attenuated relative to the input signal while the input and output impedance is maintained close to 50 ohms (or 75 ohms)over the specified bandwidth. Hence this device is often used to improve interstage matching in a circuit.

FLATNESS: The total variation in attenuation over the specified frequency range. Flatness generally becomes worse at higher frequencies where attenuation starts to increase with increase in frequency.

VSWR: Voltage standing wave ratio is a measure of the deviation from 50 or 75 ohms of the input and the output impedance .A VSWR of 1:1 represents a perfect 50 or 75 ohm match .A VSWR slightly greater than 1:1 represents a slight impedance mismatch ,implying a small amount of signal reflection.

TERMINATION : An ideal load of impedance Zo, when connected to the end of a transmission line whose characteristic impedance is also Zo will absorb all the power in the transmission line travelling towards the load .

MAXIMUM RF POWER: The amount of power that can be applied to an attenuator or load, which does not result in excessive heating of the load.

RETURN LOSS: The minimum return loss ,that termination exhibits, when used for terminating a transmission line it is designed to match. For an attenuator return loss is measured at one port when other port is terminated in 50 or 75 ohms for which it is designed.

POWER SPLITTER

Basically, a 0° splitter is a passive device which accepts an input signal and delivers multiple output signals with specific phase and amplitude characteristics. The output signals theoretically possess the following characteristics :

- Equal amplitude
- 0° phase relationship between any two output signals.
- High isolation between each output signal.
- Insertion loss for two ports is 3.0dB and for three ports is 4.8dB.

Since the 0° power splitter is a reciprocal passive device it may be used as a power combiner simply by applying each signal singularly into each of the splitter output ports.

The vector sum of the signals will appear as a single output at the splitter input port.

The following signal processing functions can be accomplished by power splitter/combiners:

1. Add or subtract signals vectorially.
2. Obtain multi in phase output signals proportional to the level of a common input signal.
3. Split an input signal into multi-outputs.
4. Combine signals from different sources to obtain a single port output.
5. Provide a capability to obtain RF logic arrangement.

Model no	Freq range MHz		Isolation dB		Insertion loss dB		Phase unbalance deg
	fl --	fu	typ	min	typ	max	max
Psc2-1	0.1—400		25	20	0.4	0.75	3.0
Psc3-1	1---- 200		40	30	0.4	0.7	2.0

FREQUENCY DOUBLERS

Frequency doublers offer a new degree of freedom in designing frequency multiplier chains. Their multi-octave bandwidth and excellent rejection of fundamental and third harmonics enable a significant reduction in filter requirements. In addition, they operate with 50-Ohm impedance's at input and output ports and are not sensitive to input power. They perform well from 0 dBm to +20 dBm input.

The frequency doublers can also be used as quadruplers.

They are economically priced while covering the very broad frequency range from 5KHz to 3000MHz. They offer very low conversion loss, from 11dB, and high spurious rejection 40dB. These doublers give exceptional unit-to-unit matched performance.

DEFINITIONS:

Frequency Doubler: A non-linear device that efficiently produces an output that is twice the frequency of the signal applied to its input.

It generates the second harmonic of an input signal, while suppressing fundamental and odd harmonics.

<u>Conversion Loss</u>: Conversion loss is the measure of difference in power level between input signal and output signal expressed in dB.

<u>Harmonic Outputs</u>:

F1 is the input frequency.

F2 is the desired output frequency (2 x F1).

F3 is the harmonic output (3 x F1).

F4 is the harmonic output (4 x F1).

<u>RF Input Power Level</u>: The required RF Power that must be applied to the input of the frequency doubler in order that the "doubling action" will be performed and is the power range for which conversion loss is specified. At low RF input levels, the conversion loss will increase beyond its specified maximum level. At high RF input levels, the frequency doubler can burnout.

Model no	Freq MHz		RF i/p Pwr dBm		conversion loss dB		
	i/p	o/p	min	max	i/p freq	typ	max
RK-2	1-500	2-1000	1	15	5-100	13.0	16.0

FILTERS

In the operation of electronic system and circuits the function of the filter is to selectively pass , by frequency, desired signals and to suppress undesired signals. The amount of insertion loss and phase shift encountered by the signal passing through the filter is a function of the filter design . Similarly, the amount of rejection of undesired signal is a function of the filter design.

Minicircuit filters are passive, they contain inductors and capacitors.Three types of filters, low pass , high pass and bandpass filters are available. Two different types of low pass filters have been designed to (1) provide high rejection of undesired signals very close to the pass -band and (2) to provide linear phase versus frequency characteristic across the pass-band frequency range .

A linear phase characteristics is essential when passing pulse waveform in order to preserve pulse shape and avoid distorted waveform. High pass filters similarly have been designed to provide high rejection of undesired signals very close to the passband.

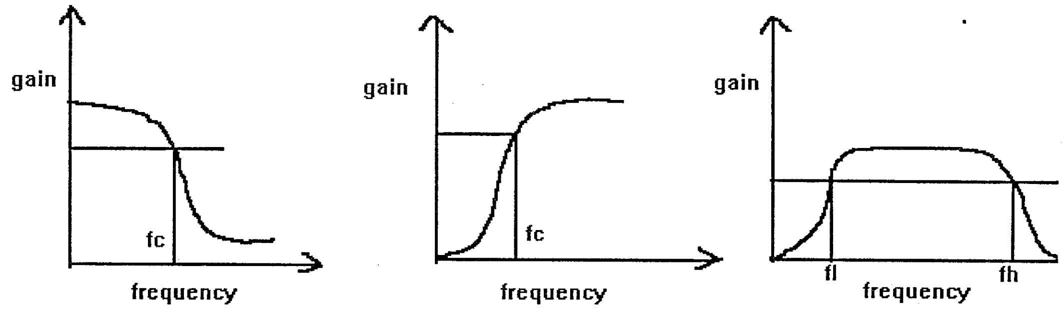
Constant impedance band-pass filters have been designed to pass signals to pass within the pass-band and to be rejected outside this band. However they provide matched impedance of 50 ohms both within and outside the passband.

This very important characteristic especially when intermodulation distortion and nonlinear devices ,such as mixers and oscillators are to be considered.

The basic filter offered by minicircuits utilizes a modified butterworth or "maximally flat" design ,and modified Bessel Thomson or flat delay design ,and Elliptic function design .

All filters are specified by their amplitude response ,both in the passband the reject-band,and also by their VSWR and phase characteristic where applicable . For convenience 20dB and 40dB reject bands are specified. The cut off frequency ,fo, is also given . this frequency corresponds to 3dB insertion loss point of the filter response. This frequency point allows the response to be normalized to fo easily.

The data and curves present very accurate description of each filter and may be used in conjunction with various software programs designed to analyze system performance.



MODERN DEFINITION OF TERMS:

INSERTION LOSS: is equal to the difference in the dB power measured at the filter input and the filter output. The power measured at the filter input is equal to the measured power when the filter is replaced by a properly matched powermeter or network analyzer. The input impedance of the measuring instrument should be equal to the characteristic impedance of the filter or the system. Usually the filters are designed to 50 ohm system. Similarly, the power measured at the output is equal to the measured power when filter is terminated by the same measuring instrument as discussed. The insertion loss is equal to the sum of the three loss factors. One is the loss due to impedance mismatch at the filter input, the second is due to the mismatch at the filter output & the third is due to dissipative loss associated with each reactive element within the filter.

PASSBAND:

is equal to the frequency range for which the filter insertion loss is less than a specified value. for example , most of the Miniciruits lowpass models are specified to have a maximum insertion loss value of 1 dB within the passband.

STOPBAND :

is equal to the frequency range for which filter insertion loss is greater than a specified value . for example most of the minicircuits low pass filter models are characterized by the frequency range where insertion loss is greater than 20 dB and 40dB in the stopband. Since 20 dB and 40 dB represent sufficient loss requirement in many systems ,these values are chosen. The reason is to allow quick calculation, of the suitability of the filter in a particular situation.

CUT-OFF FREQUENCY

is the frequency at which the filter insertion loss is 3 dB. It is very convenient point for expressing the passband and stop band boundary points.

In addition it also allows normalization of filter response of a filter. For example if frequency response of filter were divided by fo ,then resulting response would be "normalized" to fo.

VSWR:

is a measure of impedance looking into one port of the filter port is terminated in its characteristic impedance, namely ,50ohms.Many times ,the impedance match is expressed in terms of return loss. Typically the VSWR in the center of the passband is better than 1.2 to 1 and VSWR in the stopband is typically 18 to 1 ,very highly reflective.

LINEAR PHASE DELAY OR FLAT TIME DELAY:

Filters have the characteristic of enabling the signal at the filter output to have a constant phase difference for each fixed increment of frequency differences of the signal. This enables, the transmission of various frequency components contained in a pulse waveform to be delayed by the same amount while travelling through the filter thus preserving the pulse wave shape.

GROUP DELAY:

Is the amount of time it takes for a signal having finite time duration, such as a pulse , to pass through the filter. Ideally ,all frequencies present in the signal will not be distorted.

AMPLIFIERS

The GPD and GPM amplifiers ,available in TO-12(4 pin) and TO – 39(3 pin) packages, are designed for applications which require the highest performance-to-cost ratio or where size is an important factor. The GPM modules contain Si MMICs, while the GPD modules

are discrete hybrid devices. These amplifiers are excellent for IF amplification.

DEFINITIONS:

1DB COMPRESSION POINT:

Defines the output level at which the amplifiers gain, is 1 dB less than the small signal gain , or is compressed by 1dB.

DYNAMIC RANGE:

It is the power range over which amplifier provides useful linear operation, with a lower limit dependent on the noise figure and the upper level, function of 1dB compression point.

GAIN:

For RF amplifiers is the ratio of output power to input power, specified in the linear gain region, with the signal applied at the input. Gain in dB is defined as

$$G(dB)=10 \log G$$

HARMONIC DISTORTION:

It is produced by non-linear amplifier operation and appears in the form of output signal frequencies at integral multiples of input signal frequency. Since harmonic distortion is influenced by input power level it is generally specified in terms of the relative level of the harmonics to the fundamental signal power level.

ISOLATION:

It is the ratio of the power applied to the output of amplifier to that measured at the input of the amplifier.

LINEARITY:

Linearity of an amplifier signifies that its output power is a linear function of the input power. A linear amplifier produces at its output an amplified replica of the input signal with negligible or no harmonic generation.

MAXIMUM SIGNAL LEVEL:

It refers to the largest CW or pulse RF signal that can be safely applied to an amplifier's input. Exceeding the specified limit can result in noise figure degradation, increased distortion, gain reduction, and/or amplifier burn out.

NOISE FACTOR:

It is the ratio of signal to noise power ratio at an amplifier input to the signal to noise power ratio at the output. Noise figure NF in dB is related to noise factor F by

$$NF = 10 \log F \quad \text{(in dB)}$$

GAIN FLATNESS:

It indicates the variation of an amplifier gain characteristics over the full frequency response at a given temperature , expressed in dB.

CHAPTER-SEVEN

DATA ACQUISITION USING G P I B

GENERAL PURPOSE INTERFACING BUS (G. P. I. B.)

The G P I B is a link, or interface system, through which interconnected electronic devices communicate.

The original G P I B was designed by Hewlett-Packard (where it is called as H P I B) to connect and control programmable instruments manufactured by H P. The G P I B because of its high data transfer rate quickly gained popularity in other applications such as intercomputer communication and peripheral control. It was later accepted as the industry standard IEEE-488. The versatility of the system prompted the name General Purpose Interfacing Bus. The GPIB and HPIB are the two brand versions of the same IEEE-488 standard.

The GPIB is a carefully designed and defined general purpose digital interface system and associated support which simplifies the design and integration of instruments and computers into systems. It minimizes the electrical/mechanical hardware and functional compatibility problems between devices, yet has sufficient flexibility to accommodate a wide and growing range of products. As such GPIB is an interfacing concept , and a design technique . You can take advantage of these concepts to define , design, build and use your own measurement system for maximum cost – effectiveness. It's more than an interface . It's a design philosophy .

GPIB(HP-IB) applies to the interface of instrumentation systems in which :-

1.) Data exchanged among the interconnected apparatus is digital (as distinct from analog) .
2.) Fifteen devices may be interconnected to one continuos bus .
3.) Total transmission path lengths over the interconnecting cables does not exceed 20 meters or 2 meters per device which ever is less (when not using a bus extension technique).
4.) Data rate across the interface on any signal line does not exceed 1M.byte / second. .

The IEEE 488.1 standard digital interface for programmable instrumentation provides an electrical and mechanical system for interconnecting electronic measurement devices. Hewlett-Packard calls it's implementation of this standard the Hewlett – Packard interface bus (HPIB) .

KEY SPECIFICATIONS OF IEEE 488.1 :-

- Interconnected Devices – Upto 15 maximum on one contiguous bus .

- Signal Lines – 16 active lines ; 8 data lines and 8 interface and communication management lines.
- Message Transfer Scheme – Byte – serial, bit – parallel , asynchronous data transfer using interlocking three – wire handshake technique .
- Maximum Data Rate :- One megabyte per second over limited distances , 250 to 500 KB/sec typical maximum over a full transmission path . The actual data rate is determined by the devices in communication at the time .
- Address Capability :- Primary addresses, 31 Talk and 31 Listen , secondary (2-byte) addresses , 961 talk and 961 listen . There can be a maximum of one talker and upto 14 listeners at a time on a single bus.
- Pass Control :- In systems with more than one controller, only one can be active at a time. The currently active controller can pass control to one of the others. Only the controller designated as system controller can demand control.
- Interface Circuits :- Driver and receiver circuits are TTL and Schottky compatible.

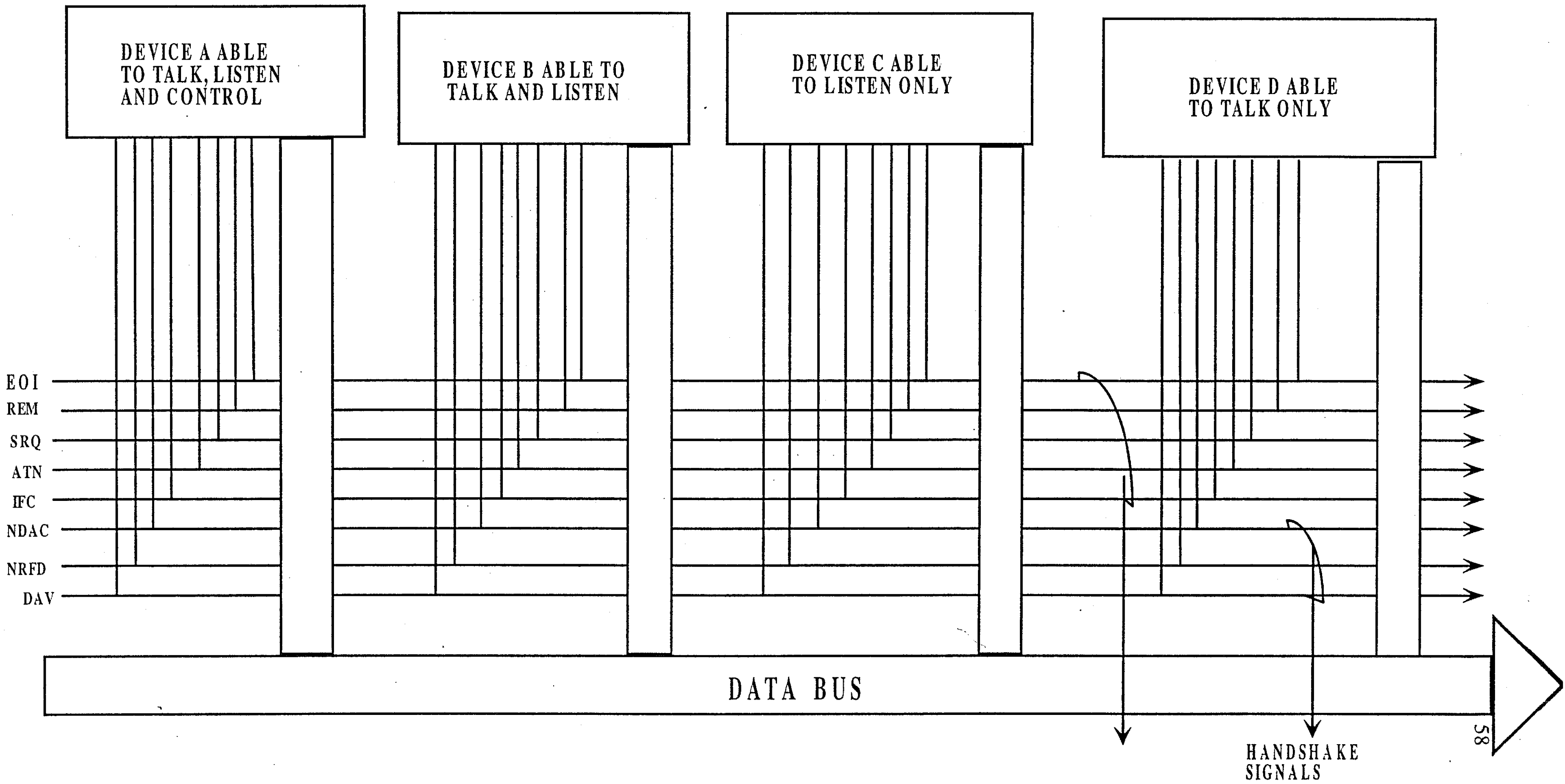
INTERFACE FUNCTIONS:

Every IEEE 488.1 device must be capable of performing one or more of the following interface functions (roles):

- Listener :- A device capable of receiving data over the interface when addressed. Examples of this devices are printers, display devices, programmable power supplies, programmable signal sources and others. There can be upto 14 active listeners simultaneously on the interface.
- Talker :- A device capable of transmitting data over the interface when addressed. Examples of this type are tape recorders, voltmeters, counters and so on. There can be only one active talker on the interface at a time.
- Controller :- A device capable of specifying the talker and listeners for an information transfer(including itself).A computer with an opposite HP-IB card is an example of this type of device. There can be only one active controller on the interface at a time in multiple controller(master).

HEWLETT-PACKARD INTERFACE BUS (HPIB)

(IEEE 488.1 BUS LINES)



IEEE 488.1 BUS LINES:

The IEEE 488.1 interface system utilizes party line bus structure(devices share signal lines) to which maximum of 15 devices may be connected to one contiguous bus .sixteen signal lines and eight ground lines are used to interconnect devices in a parallel arrangement and maintain an orderly flow of devices and interface related information.

The IEEE 488.1 interface bus signal lines all use of low true logic convention with positive polarity. They can be grouped into three sets.

1) data lines
2) byte transfer lines
3) general bus management lines

DATALINES:

The data lines are 8-bit bi-directional bus used to transfer information from device to device on the interface. The data is transferred using any commonly understood BCD, alphanumeric, or binary code. Normally this is the 7-bit ASCII code .The international equivalent to this is the 7-bit ISO code. however, other techniques may be utilized to encode information transferred includes interface commands, addresses and device dependent data.

BYTE TRANSFER LINES :-

The byte transfer lines are three lines used to co-ordinate the transfer of data over the data bus from a source (an addressed talker or a controller) to an acceptor (an addressed listener or all devices receiving interface commands) to ensure data transfer integrity . This technique has the following characteristics .

1.) Data transfer is asynchronous – The transfer rate automatically adjusts to the speed of the slowest participating device . some of the devices on the bus may not be participating in the data transfer . They would not affect the handshake .
2.) More than one device can accept data at the same time .
3.) Every byte transferred under goes the hand shake.
4.) When universal commands are sent over the data bus, the slowest device on the bus will determine the transfer rate during the transfer of that command. In this case, all devices always hand shake the bytes .
5.) The actual transfer rate of the data may also be affected by the time it takes the instrument to take the reading and the time necessary for the controller to input the information.

IEEE 488.1 signal lines use a low true logic convention to implement the wired – OR convention of the NRFD and NDAC lines , to provide active true – state assertion , and to reduce noise susceptibility in the true state .

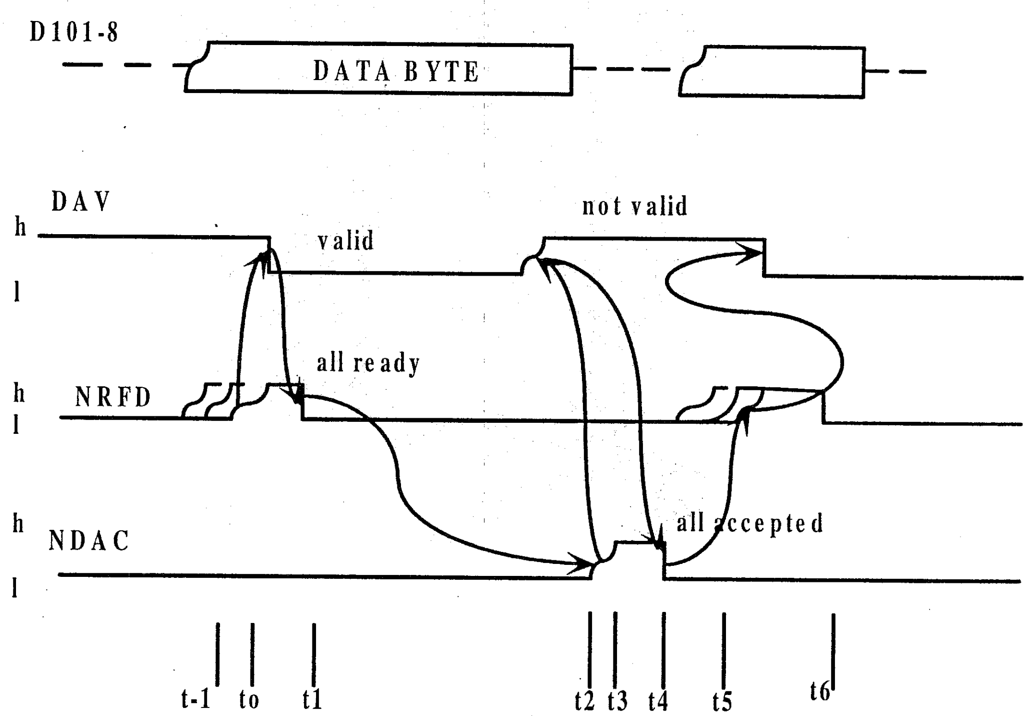
The three hand shake lines are :-

<u>DAV (Data Valid) :-</u> Used to indicate the condition of the information on the data
(D10) lines . Driven TRUE (low) by the source when data is settled and valid and NRFD FALSE (high) has been sensed .

<u>NRFD (Not Ready For Data) :-</u> Used to indicate the condition of readiness of device(s) to accept data . An acceptor sets NRFD TRUE(low) to indicate it is not ready to accept data . It sets this line FALSE(high) when it is ready to accept data . However , the NRFD line to the source will not go high until all participating acceptors are ready to accept data .

<u>NDAC (No Data Accepted) :-</u> Used to indicate the condition of acceptance of data by device(s) . The acceptor sets NDAC TRUE(low) to indicate it has not accepted data ,when it accepts data from the D10 lines , it will set NDAC line FALSE(high) . However , the NDAC line to the source will not go high untill the last/slowest participating acceptor accepts the data .

The figure illustrates the hand shake timing sequence –



GENERAL BUS MANAGEMENT LINES :-

The general bus management lines are 5 lines used to manage an orderly flow of information across the interface .

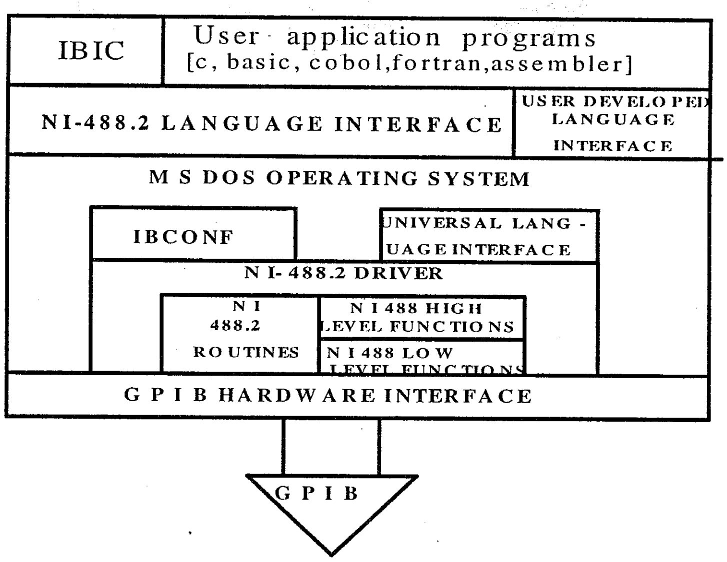
NAME	MNEMONICS	DESCRIPTION
Attention	**A T N**	Controls whether the bus is in command mode (ATN true) or data mode (ATN false) .
Interface clear	**I F C**	Initializes the interface to idle state (no activity on the bus) .
Service request	**S R Q**	Alerts the controller to a need for communication.
Remote enable	**R E N**	Enables devices to respond to remote program control when addressed to listen .
End or Identify	**E O I**	Indicates last data byte of a multibyte sequence , also used with ATN to parallel poll devices for their status bit .

NI-488 GPIB SOFTWARE

National Instruments(NI) expanded the use of GPIB among the users of computers manufactured by companies other than HP. NI specializes both in high performance , high speed hardware interfaces and in comprehensive , full function software that helps users bridge the gap between their knowledge of instruments and computer peripherals and of the GPIB itself.

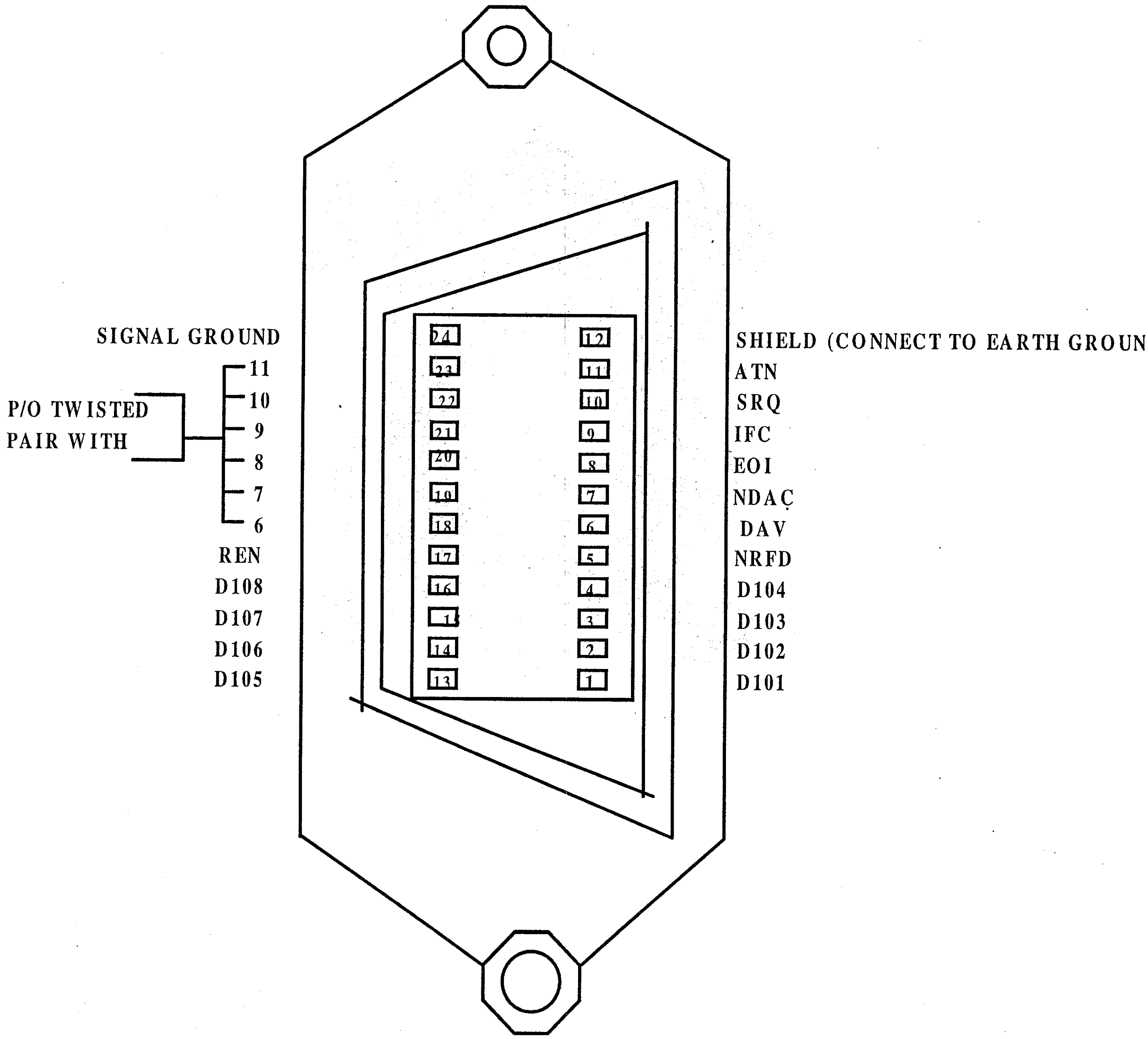
The NI-488 software is the state-of-the-art driver software from National Instruments. It was endorsed by IBM in the early 1980's and has become defacto industry standard for GPIB applications. It has evolved into a comprehensive, flexible software package with a high speed driver, language interfaces, configuration utilities, complete diagnostics and interactive control and debugging utilities. NI-488 is built to support the changing needs of GPIB programmers and is continuously updated. The below blockdiagram

G. P. I. B SOFTWARE MODEL



illustrates the GPIB software model.

HPIB CONNECTOR PIN ASSIGNMENTS

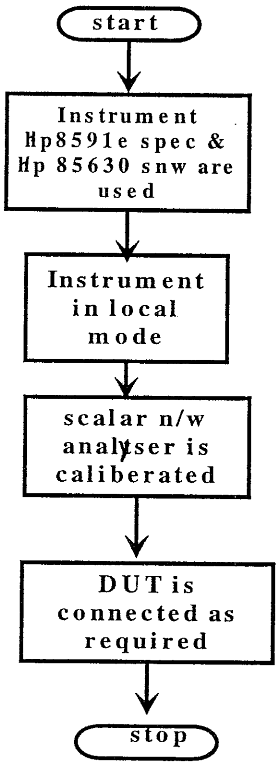


CHAPTER-EIGHT

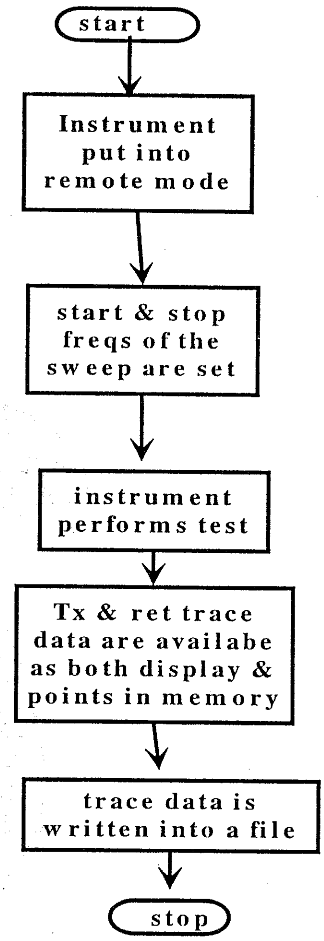
PROGRAMMING

FLOW CHARTS OF RETURN AND TRANSMISSION LOSSES

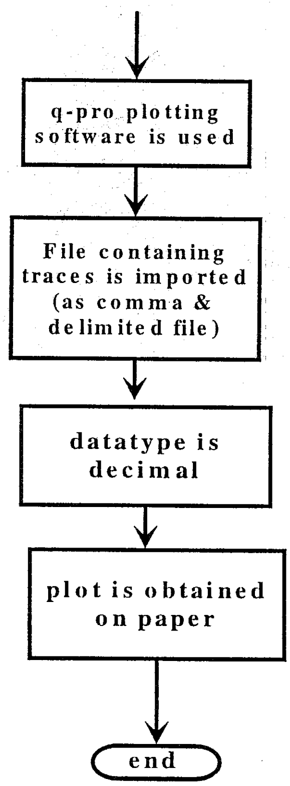
MANUAL OPERATION



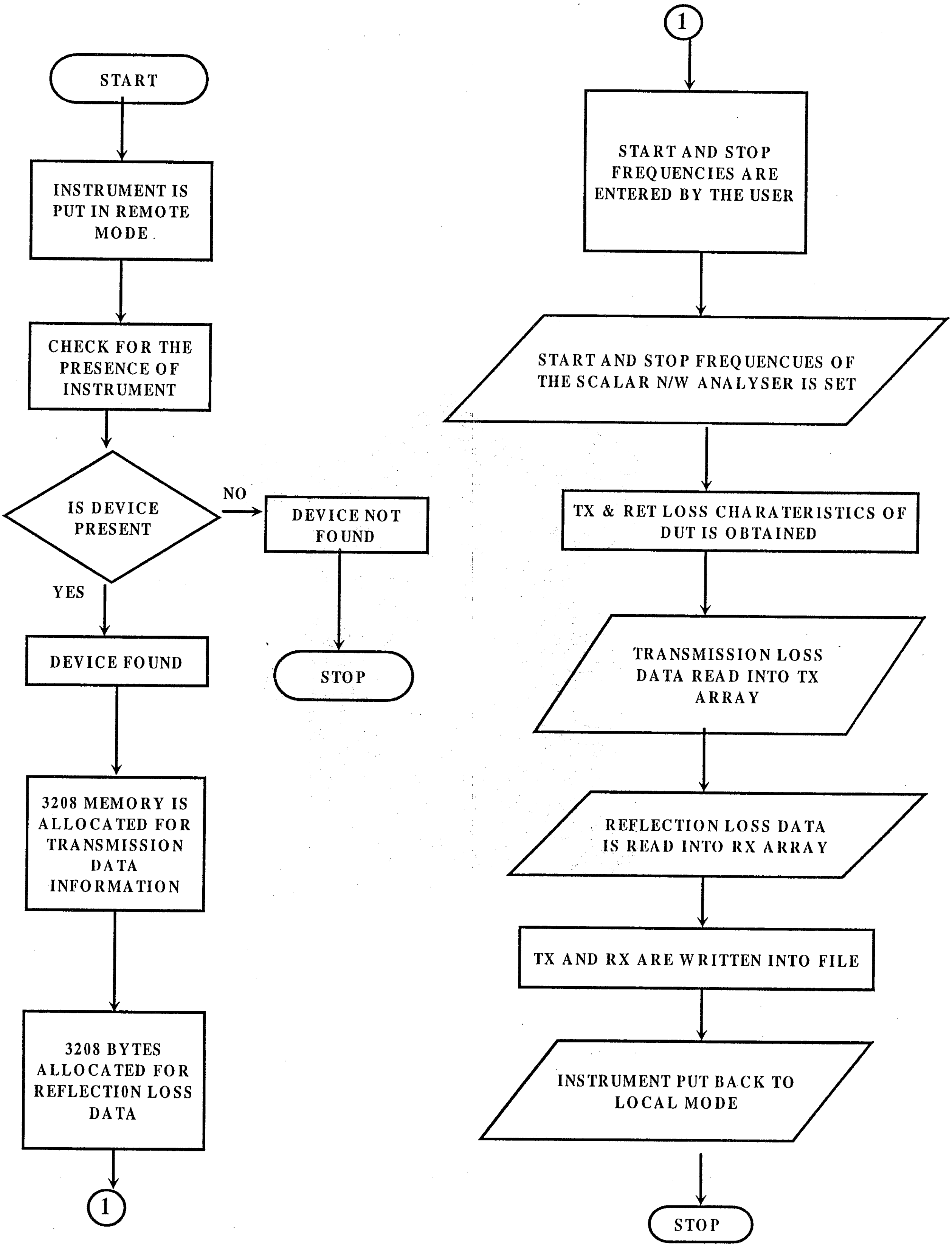
PROGRAMMING



USE OF DATA & GRAPH PLOT S/W



FLOW CHART FOR ACQUISITION OF TRANSMISSION & RETURN LOSS DATA



/* PROGRAM TO DETERMINE TRANSMISSION AND RETURN LOSSES */

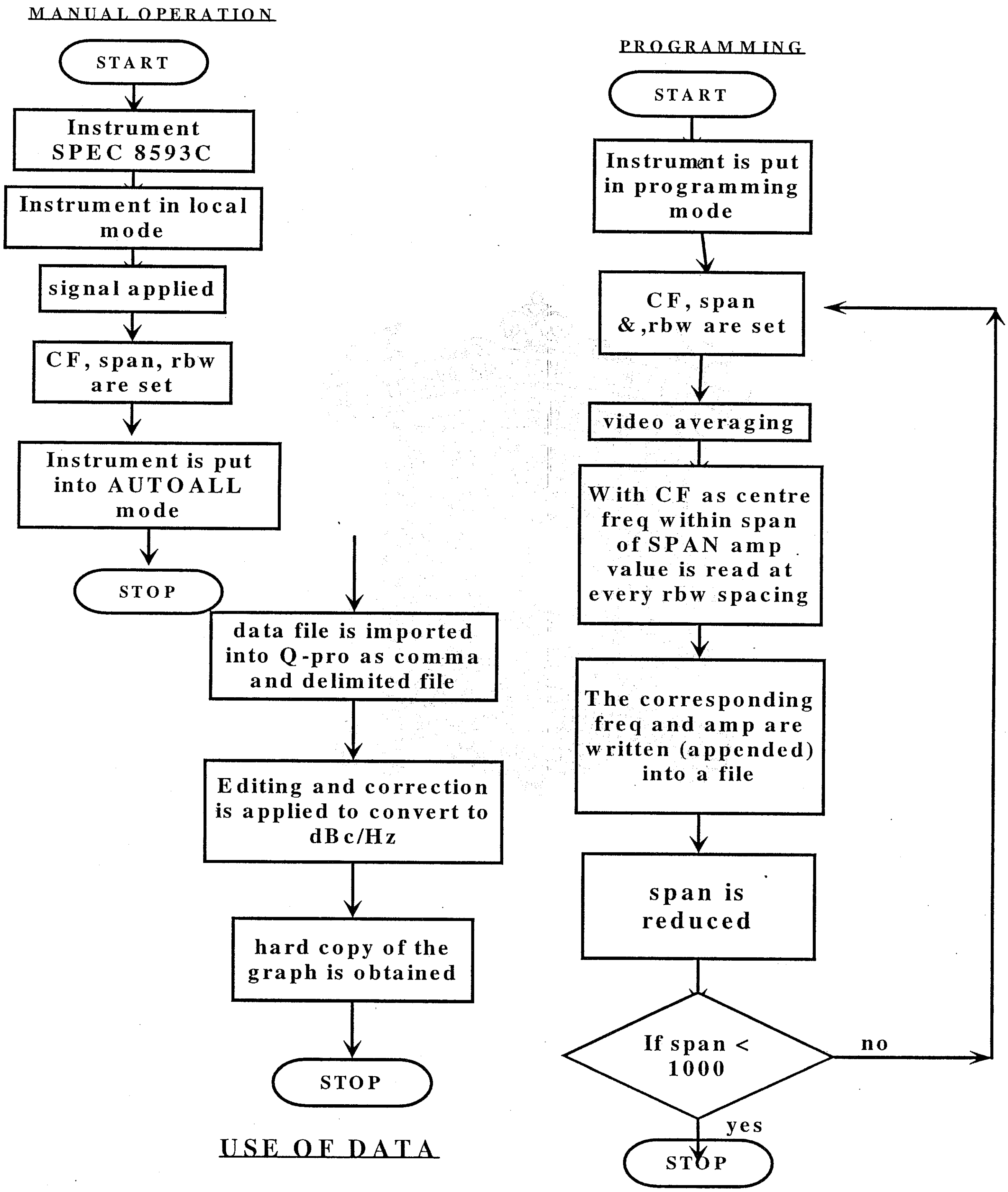
/* INSTRUMENT USED SPECTRUM ANALYSER HP-8591E */

```
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <string.h>
#include "c:\tc\include\decl.h"

main()
{       FILE *fp;
        float fl,fu,delta;
        int device,count,i;
        char  (*tx)[1] , (*rx)[1];
        char *start="FA",*stop="FB",*unit="MZ\r\n";
        char fu1[10],fl1[10],fone[10],ftwo[10];
        /*check for presence of spectrum analyser*/
        device=ibfind("SPEC");
        if(device>=0)
        printf("device found\n");
        else
        {
        printf("device not found\n");
```

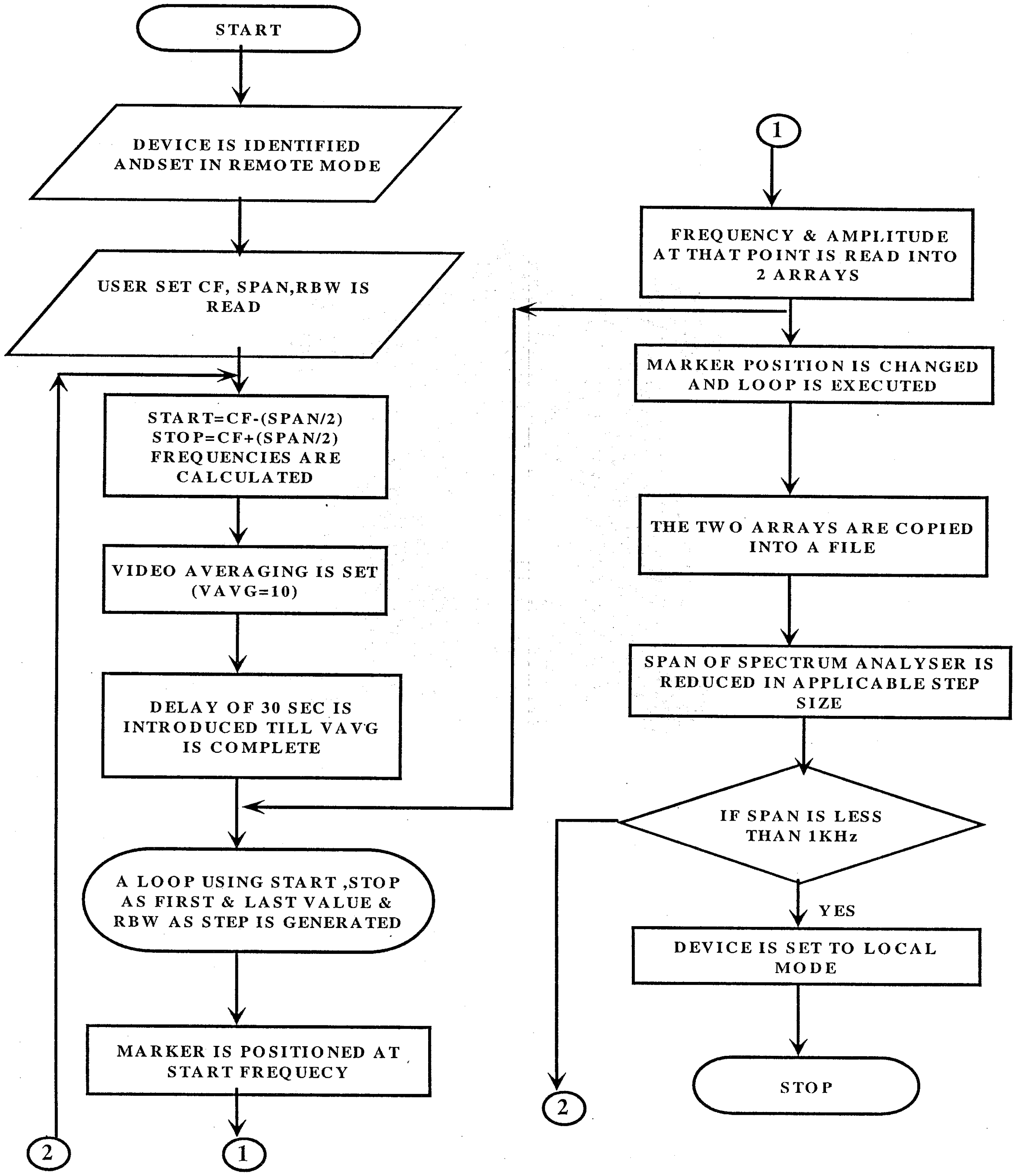
```
exit(0);
}
tx=(char *) malloc(3208);
rx=(char *) malloc(3208);
/*entering of start stop frequencies*/
printf("enter start frequency  in mz \n");
scanf("%f",&fl);
printf("enter stop freuency in mz\n");
scanf("%f",&fu);
delta=(fu-fl) /401.0;
printf("delta is:%f\n",delta);

/* string conversions*/                //float to string conversion
gcvt(fl,7,fl1);
strcpy(fone,start);
strcat(fone,fl1);
strcat(fone,unit);
printf("String1:%s",fone);
ibwrt(device,fone,9L);      //start frequency of the instrument is
set
gcvt(fu,7,fu1);
strcpy(ftwo,stop);
strcat(ftwo,fu1);
strcat(ftwo,unit);
printf("\nString2:%s",ftwo);
```

```
ibwrt(device,ftwo,9L);     //stop frequency of the instrument is set


        ibwrt(device,"TDF    P\r\n",7L);          //returns     absolute
measurement units
        ibwrt(device,"TA?",3L);       //reading trace
        ibrd(device,tx,3208L);          //reading tx trace data into an
array


ibwrt(device,"TDF P\r\n",7L);
        ibwrt(device,"TA?",3L);
        ibrd(device,rx,3208L);          //reading ret trace data into an
array


        /* storing trace data into a file*/
        fp=fopen("op.dat","w");       //opening a file in write mode
        i=0;
        fprintf(fp,"%s\t%s",*(tx+i),*(rx+i));  //writing into file
        fprintf(fp,"\n");

        ibloc(device);   //setting the instrument to local mode
        return(0);
    }
```

FLOWCHART FOR ACQUIRING PHASE NOISE DATA



FLOW CHART FOR ACQUISITION OF PHASE NOISE DATA



/* PROGRAM FOR ACQUISITION OF PHASE NOISE DATA */

/* INSTRUMENT USED SPECTRUM ANALYSER HP-8593E */

```
#include "c:\at-gpibw\c\windecl.h"
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <string.h>
#define SPAN_MIN 1000  //Specifies min span required

FILE *fp;
char *c_freq="CF",*c_mkpos="MKN",*c_quest="?";
char *c_span="SP",*c_rbw="RB",command[12];
char carray1[20],p1[25],amp[9];
double freq,fmkf,famp,start,span,m_span,stop,rbw,x[200],y[200];
double v[200],PCF;
int device,s_len,z;
long int count,count1;
float k,k1,nrbw,nspan,vag;

main()
{
   device=ibfind("8593E");          //identifing the device
```

```
if(device>=0)
printf("device found\n");
else
exit(0);

ibwrt(device,"cf?",3L);        //reading center frequency
ibrd(device,carray1,12L);
printf("cf=%s",carray1);
freq=atof(carray1);
printf("fr=%f\n",freq);

ibwrt(device,"sp?",3L);        //reading span
ibrd(device,carray1,12L);
printf("span=%s\n",carray1);
span=atof(carray1);
printf("sp=%f\n",span);

ibwrt(device,"rb?",3L);        //reading rbw
ibrd(device,carray1,8L);
printf("RBW= %s\n",carray1);
rbw=atof(carray1);
printf("rb=%f",rbw);

/*  marker movement & amp reading   */
label:  ibwrt(device,"vavg10on",8L);
```

```
    for(z=1;z<40;z++)
  {
    count1=2500000;
    delay(count1);
  }
   m_span=(span/2.0);     // calculating start & stop frequency
   start=freq;
   stop=freq+(m_span);

printf("\nStartFreq:%f\tStopFreq:%f\tRBW=%f\n",start,stop,rbw);
   printf("\n\n  PLEASE WAIT FOR  NEXT MESSAGE    \n");

 for(start;start<=stop;start=(start+rbw))
 {
   gcvt(start,10,p1);          // float to string conversion
   strcpy(command,c_mkpos);
   strcat(command,p1);
   s_len=strlen(command);           //marker movement

   ibwrt(device,command,s_len);
   count=2500000;                 //about 1sec delay
   delay(count);
   ibwrt(device,"MKF?",4L);         // reading marker frequency
   ibrd(device,carray1,18L);
   printf("\n MKF=%s\t",carray1);
   fmkf=atof(carray1);      // string to float conversion
```

```
x[k]=fmkf;
     ibwrt(device,"MKA?",4L);          // reading marker amplitude
   ibrd(device,amp,8L);
   famp=atof(amp);

y[k]=famp;
   k=k+1;
}
   k1=span/rbw;         //number of points
   fp=fopen("t.t","a");
   fprintf(fp," CF=%f SPAN=%f RBW=%f\n ",freq,span,rbw);
fprintf(fp,"%s\t%s\t%s\n","Offset(Hz),Power(dBm),PN(dBc/Hz)");

 for(k=0;k<=k1;k++)     //copying power to array y
      { v[k]=y[k]; }
 for(k=0;k<=k1;k++)     //phase noise calculations
      { PCF=y[0];     //pcf=carrier power
             if(k= =0)
             y[0]=y[0]-PCF;
             else
/* PN= Psb – Pcarrier – BW/Hz */
/* BW/Hz = 10 log (rbw) = 10 log 100 = 20 */
             y[k]=y[k]-PCF-20;
      }
```

```
// frequency and amplitude points are written into the file
        for(k=0;k<=k1;k++)    {
   fprintf(fp,"%.2lf\t%.2lf\n",x[k],y[k],y[k]);
}
   k=0;
   fclose(fp);

   ibwrt(device,"spdn",4L);      // span is reduced
   ibwrt(device,"sp?",3L);
   ibrd(device,carray1,12L);
   printf("span=%s\n",carray1);
   nspan=atof(carray1);

   if(nspan<=SPAN_MIN)     // if span goes to 1KHz stop
 {
   goto label1;
  }
   else
          span=nspan;      // otherwise acquisition is repeated,for new
span & rbw
         printf("sp=%f\n",span);

 ibwrt(device,"rb?",3L);
 ibrd(device,carray1,8L);
```

```
printf("RBW= %s\n",carray1);
nrbw=atof(carray1);
rbw=nrbw;
printf("rb=%f",nrbw);
goto label;



label1:  ibloc(device);   //instrument is set to local mode

 printf("\n  MEASUREMENT IS OVER  \n");
 return;
}


/* DELAY FUNCTION */
 delay(m)
 long int m;
{ long int j;
 for(j=0;j<=m;j++);
 return;
}
```

CHAPTER-NINE

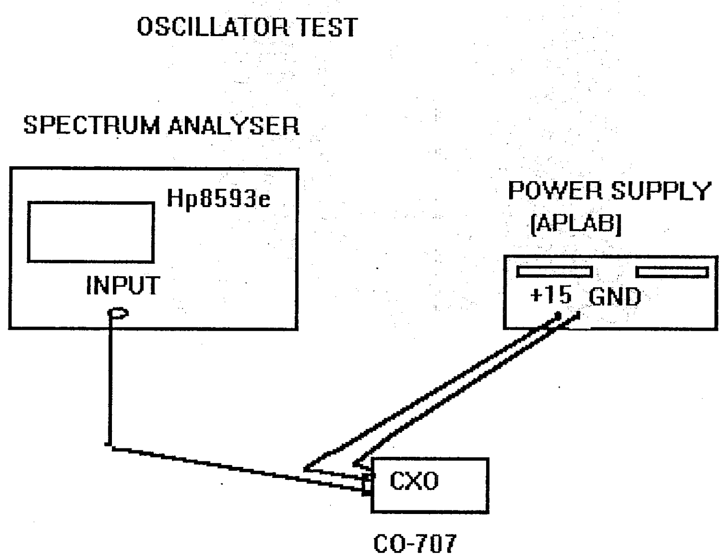
TESTS , MEASUREMENTS, RESULTS AND CONCLUSIONS

TESTS, MEASUREMENTS, RESULTS AND CONCLUSIONS

OSCILLATOR TEST :

Test to measure the fundamental and harmonic power level of the oscillator .

SET UP :



INPUT :- Voltage to oscillator (co – 707) = +15v

Current = 300mA

HARMONIC LEVEL OF OCXO – CO-707

FREQUENCY (MHz)	POWER LEVEL (dBm)
5	+15
10	-21
15	-15
20	-22
25	-26

TESTING OF COAXIAL CABLE :-

1.) DC TESTING :

Using DVM check for continuity .

For open circuit DVM will display – 1MΩ

For short circuit DVM will display – 0.16Ω

2.) RF TESTING :

Instrument used " WILTRON 6409 RF ANALYZER "

RF power input – 0dBm

frequency input – 10MHz

RF testing of cables involves measurement of insertion loss and return loss of semi rigid coaxial cable using RF analyzer with and without bending the cable. The results are tabulated below –

Cable	Cable lenth (mm)	Before bending cable		After bending cable	
		Insertion loss (dBm)	Return loss (dBm)	Insertion loss (dBm)	Return loss (dBm)
Osc I/p	110	-0.01	-35.0	-0.02	-40.0
For back panel (5MHz)	200	-0.01	-36.0	-0.03	-37.0
For back panel (10MHz)	350	-0.02	-35.0	-0.04	-48.0
Ref I/P	190	-0.01	-33.0	- 0.03	-40.0
For back panel (5MHz)	200	-0.01	-35.0	-0.03	-45.0
Front panel (5MHz)	290	-0.02	-35.0	-0.02	-38.0
Front panel (10 MHz)	150	-0.01	-34.0	-0.02	-38.0

MODULE TESTING :- (Card 1 and Card 2)

DC TESTING :

a.) Apply +15v dc , and current of 350mA using standard variable power supply .

b.) Measure voltage at feedthrough point

RESULT – We found that it is +15v.

CONCLUSION :- There is no short circuit in Card 1 and Card 2 and dc wise it is correct .

RF TESTING :

INSTRUMENTS USED – Spectrum Analyzer – 8591e
Scalar Analyzer – 85630A
Aplab 7612 – power supply
Fluke 11 – Digital multimeter

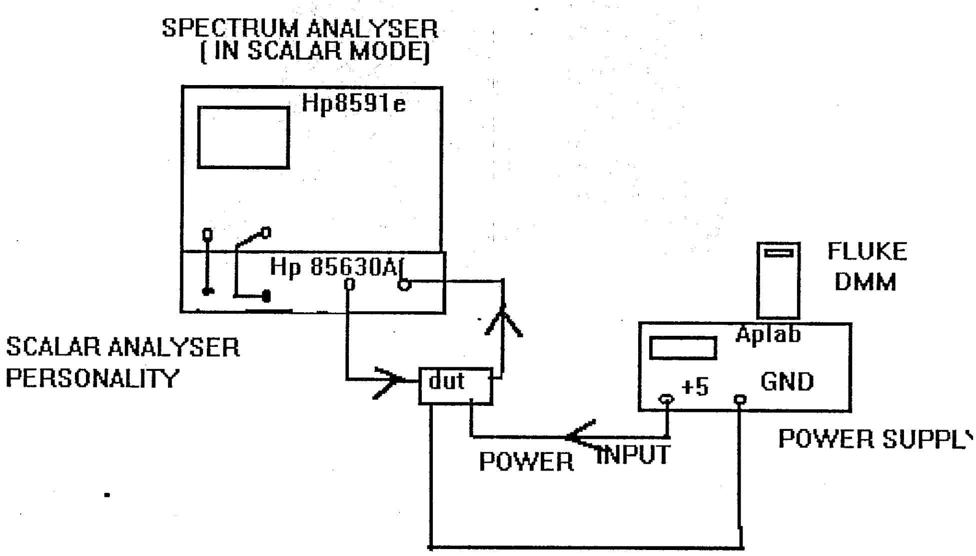


FIG: SETUP FOR RF TESTING OF CABLES

CARD 1

INPUT POWER +15 dBm

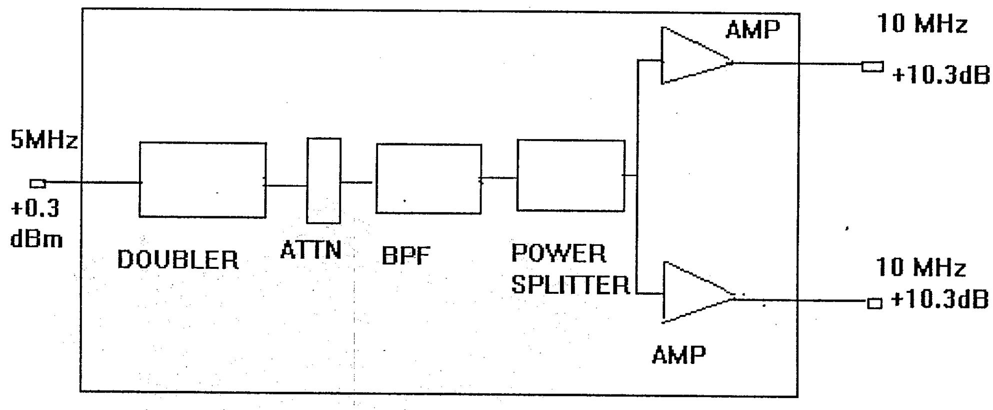
PORT	GAIN	
	EXPECTED (dB)	MEASURED (dB)
5MHz (BACK)	-4.2	-4.6
5MHZ (FRONT)	-4.2	-4.6
5MHz (REF OUT)	-14.7	-15.7

CARD 2

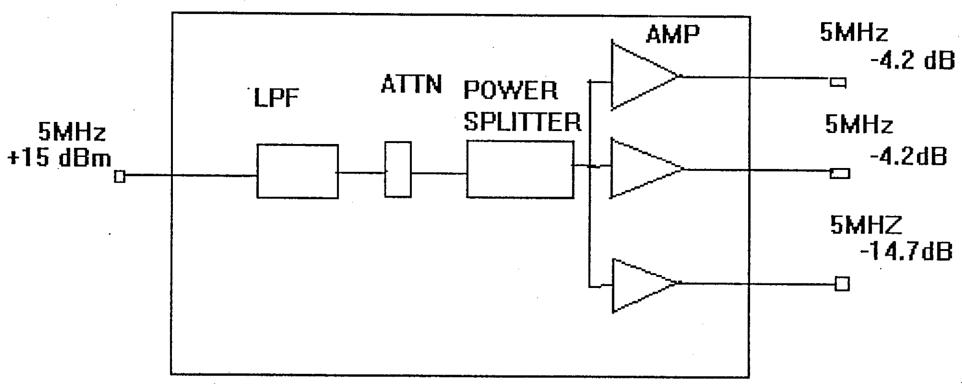
INPUT POWER =0.3 dBm

PORT	GAIN	
	EXPECTED	MEASURED
10 MHz (BACK)	+ 10.0	+ 8.4
10 MHz	+ 10.0	+ 8.4

CARD 2 GAIN AT DIFFERENT PORTS



CARD 1 GAIN AT DIFFERENT PORTS



TRANSMISSION AND REFLECTION LOSS MEASUREMENTS

PROCEDURE

1 spectrum analyzer [HP8691A] is interfaced with scalar measurement personality[HP85630A]

2 In mode menu of spectrum analyzer displayed on display ,SCALAR mode is chosen.

3 Scalar measurement personality is calibrated for measurement using steps given in CAL menu.

4 Reference module input port is connected to the port1 and one of the output port is connected to port2 of the [Hp85630A] testset.

5 Press DISPLAY button.

6 Transmission and reflection loss traces are obtained on display.

7 The corresponding trace data present in the memory is acquired , using program titled "program for acquisition of transmission and reflection loss".

8 The file containing trace data is plotted ,using Q-PRO plotting software.

INFERENCE :

Transmission loss plot follows the characteristics of a LPF, as there is LPF at the input of the circuit,following OCXO input.

5MHz outputs are obtained after amplification of this lowpass filtered output.

As can be seen from plot ,5MHz signal is transmitted with minimum loss equal to –8dBm,and for frequencies above this transmission loss increases , and from the plot for 15MHz I/p

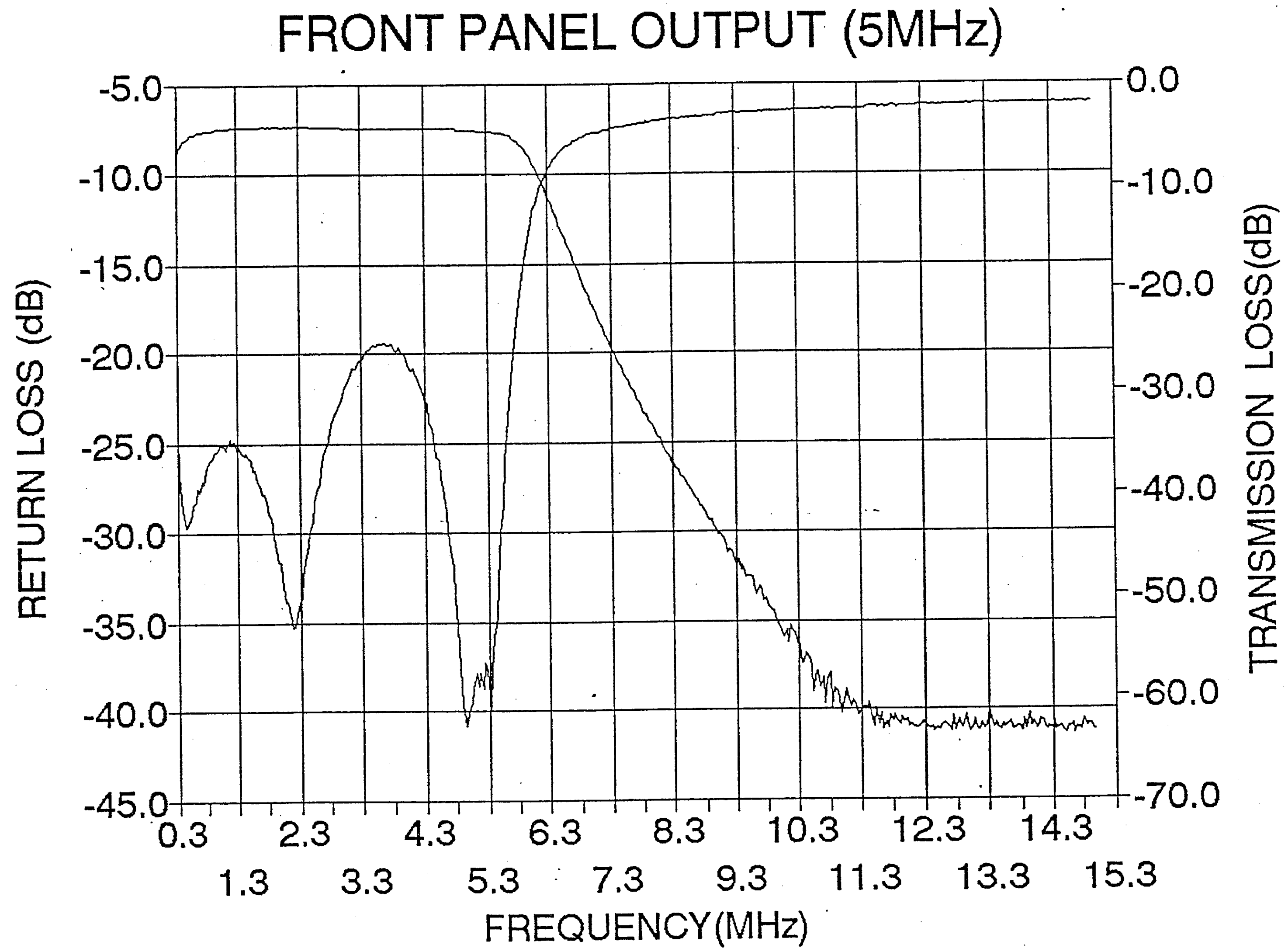
Transmission loss becomes equal to –40 dBm.

RETURN LOSS: The input applied to the input port must be fully transmitted and there must not be reflection of energy back to the i/p source itself.

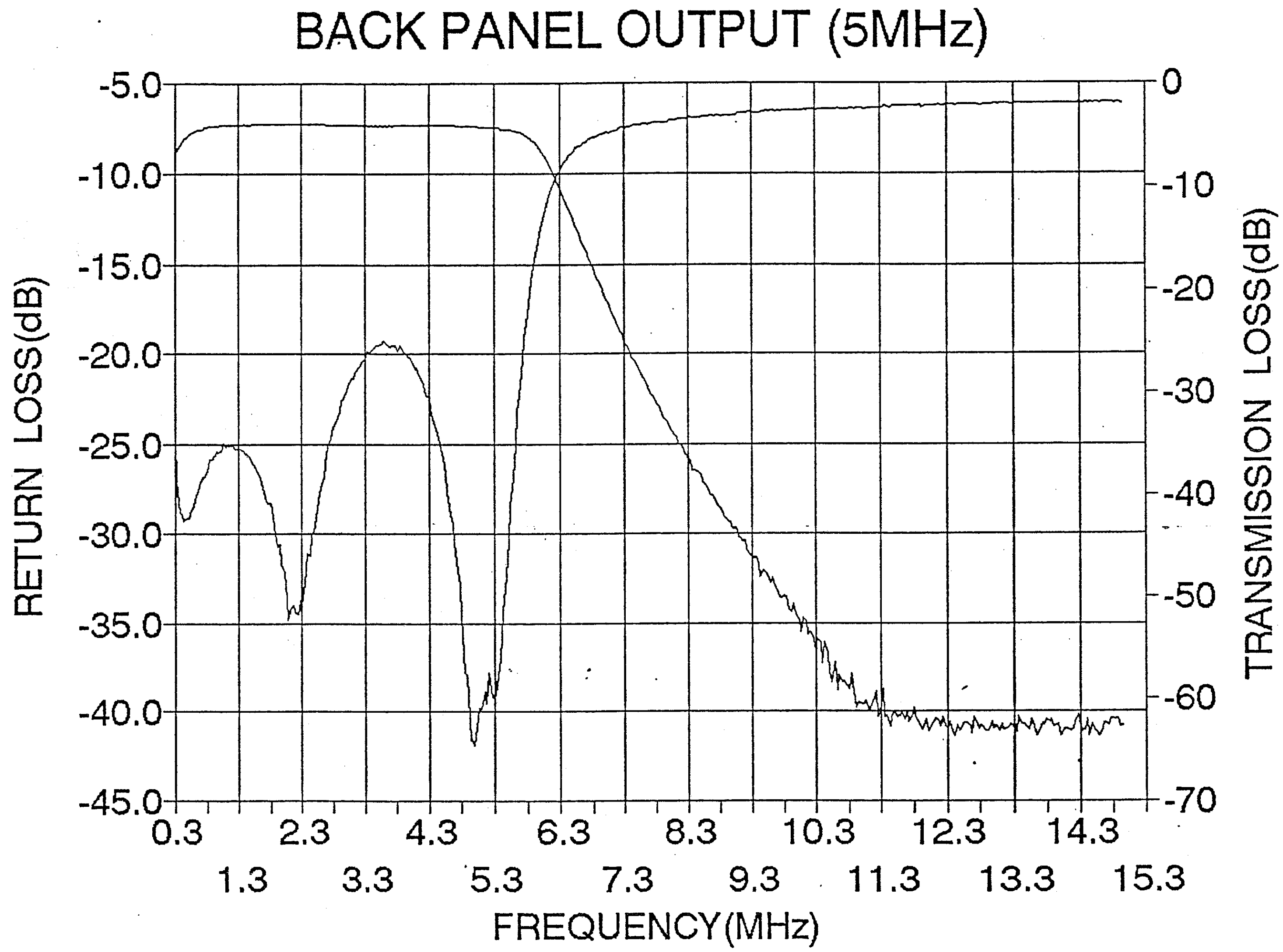
From the plot it can be seen that reflection is minimum at 5MHz frequency, equal to frequency of input from the CXO.

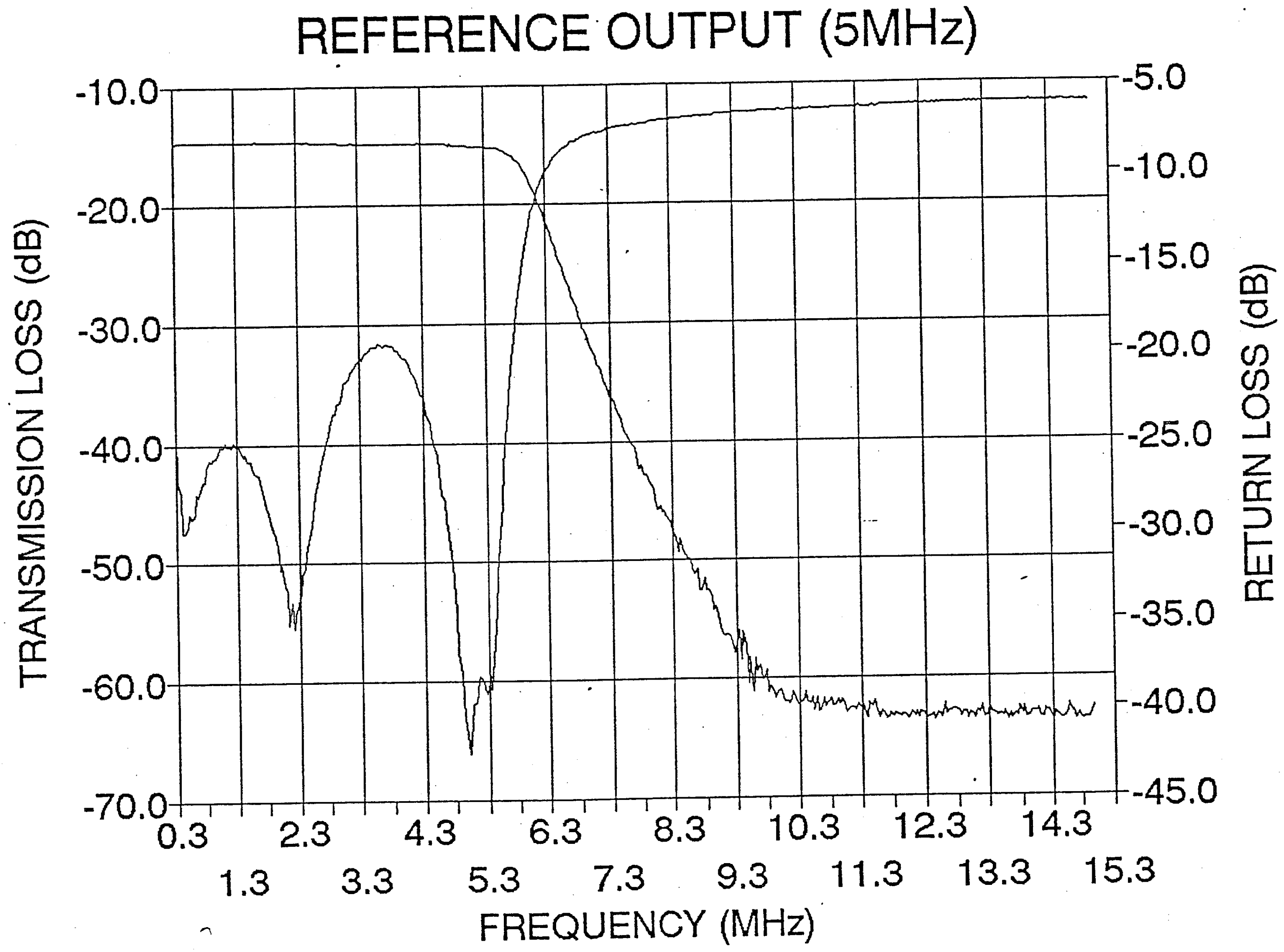
And above that frequency most of the signal is returned back to the source.Thus return loss decreases from –40dB to –2dB for

Frequency exceeding 5MHz.



FRONT PANEL OUTPUT (5MHz)
RETURN LOSS (dB)
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
TRANSMISSION LOSS(dB)
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
0.3
1.3
2.3
3.3
4.3
5.3
6.3
7.3
8.3
9.3
10.3
11.3
12.3
13.3
14.3
15.3
FREQUENCY(MHz)


BACK PANEL OUTPUT (5MHz)
RETURN LOSS(dB)
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
TRANSMISSION LOSS(dB)
0
-10
-20
-30
-40
-50
-60
-70
0.3
1.3
2.3
3.3
4.3
5.3
6.3
7.3
8.3
9.3
10.3
11.3
12.3
13.3
14.3
15.3
FREQUENCY(MHz)


REFERENCE OUTPUT (5MHz)
TRANSMISSION LOSS (dB)
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
RETURN LOSS (dB)
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
0.3
1.3
2.3
3.3
4.3
5.3
6.3
7.3
8.3
9.3
10.3
11.3
12.3
13.3
14.3
15.3
FREQUENCY (MHz)

HARMONIC LEVEL MEASUREMENT

Spectrum analyzer is used to measure harmonic levels at different output ports. To see harmonic levels, span is set to 30 MHz, center frequency to 17 MHz. With this, we can see harmonics and spurious levels of frequency range 2 MHz to 32 MHz.

Frequency (MHz)	Harmonic levels 10 MHz (FP) (dBm)	10 MHz (BP) (dBm)
5	- 42	- 42
10	+8.27	+8.36
15	- 45	- 45
20	- 38	- 37
30	- 42	- 42

This table shows the harmonic levels of 10 MHz output of the front and back panels.

Figure 1 (b) shows harmonic levels for 10 MHz back panel output. Plots in figure 2(a) and 2(b) are for same ports as above, but amplifiers being used are compressed. The compression of amplifiers, make it nonlinear thus increasing the harmonic level.

Plots in figure 3(a), 3(b) and 3(c) are similarly for 5 MHz output ports.

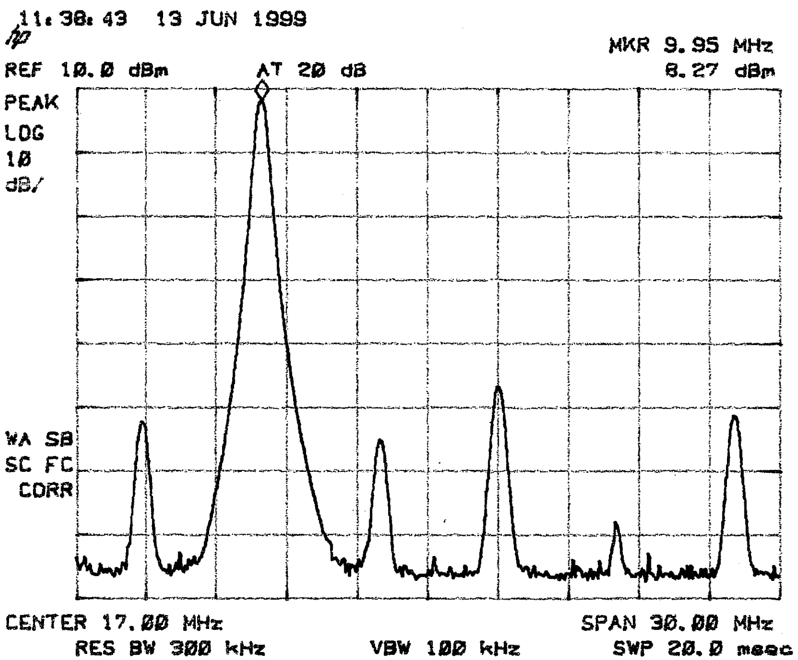

11:38:43 13 JUN 1999
MKR 9.95 MHz
REF 10.0 dBm
AT 20 dB
8.27 dBm
PEAK
LOG
10
dB/
WA SB
SC FC
CORR
CENTER 17.00 MHz
SPAN 30.00 MHz
RES BW 300 kHz
VBW 100 kHz
SWP 20.0 msec

Fig 1.a

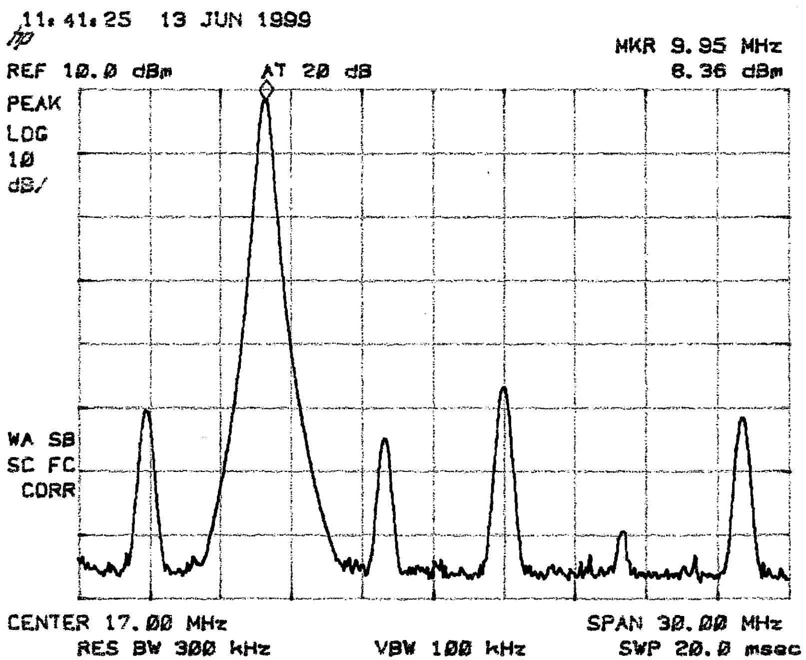

11:41:25 13 JUN 1999
MKR 9.95 MHz
REF 10.0 dBm
AT 20 dB
8.36 dBm
PEAK
LOG
10
dB/
WA SB
SC FC
CORR
CENTER 17.00 MHz
SPAN 30.00 MHz
RES BW 300 kHz
VBW 100 kHz
SWP 20.0 msec

Fig 1.b

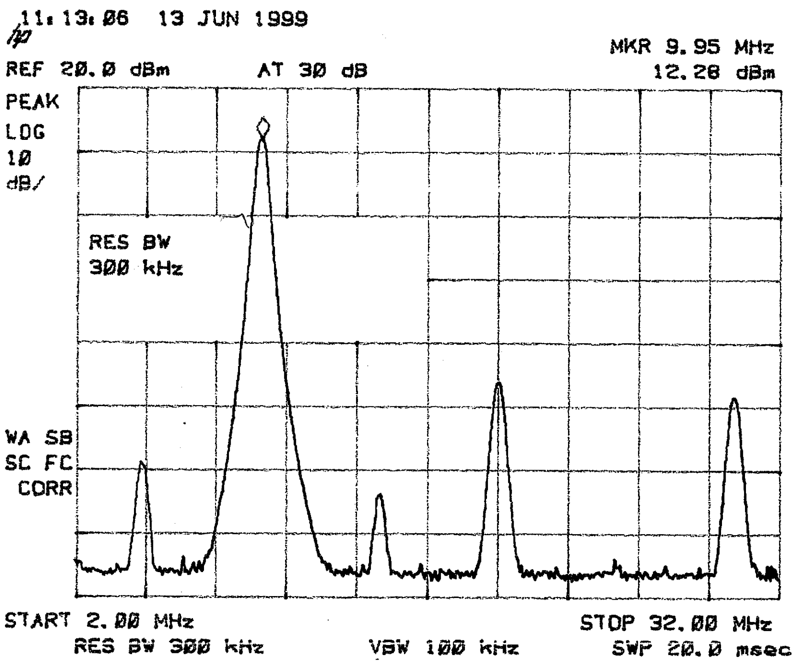


Fig 2.a

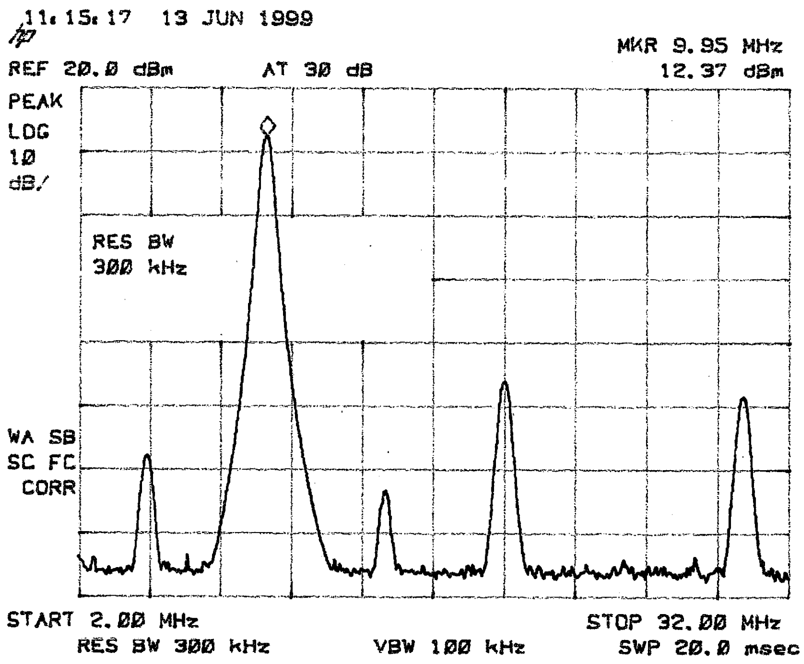


Fig 2.b

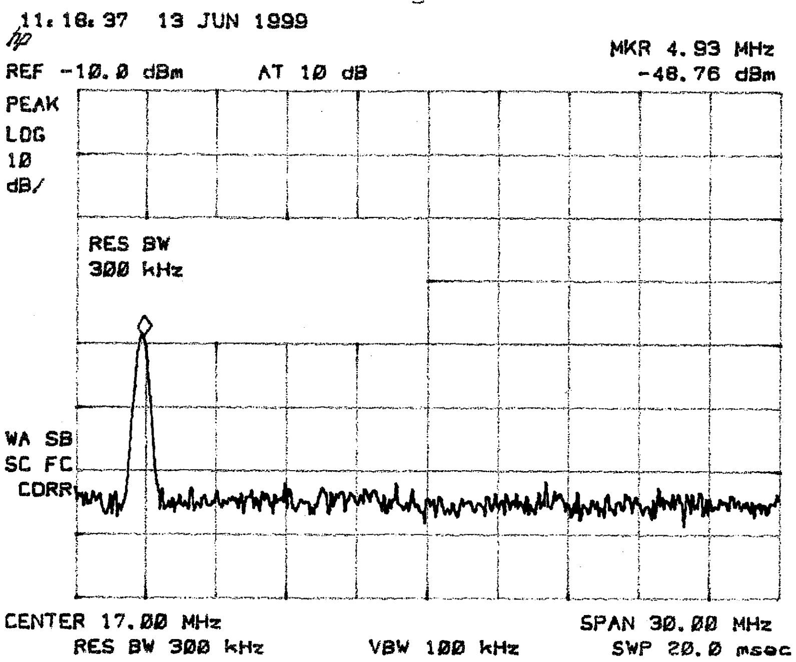


Fig 2.c

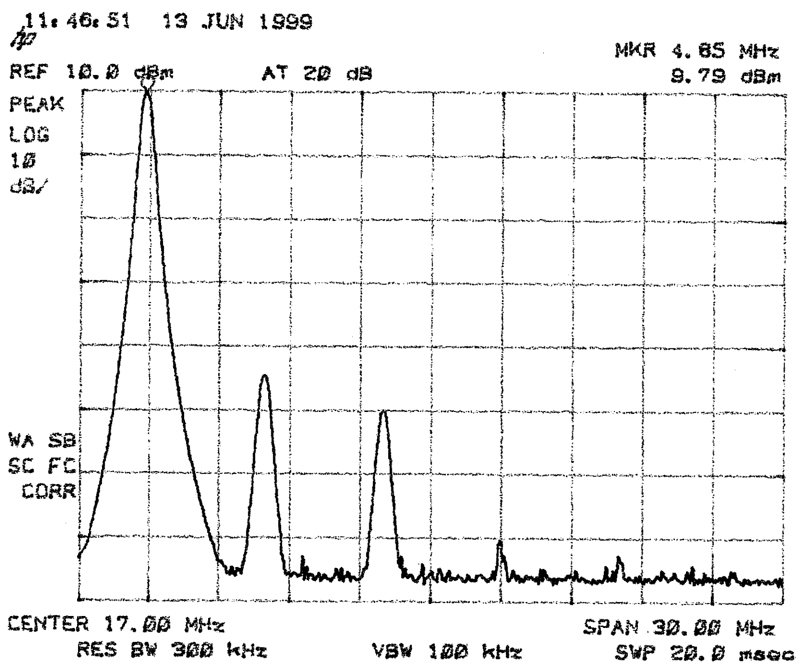


Fig 3.a

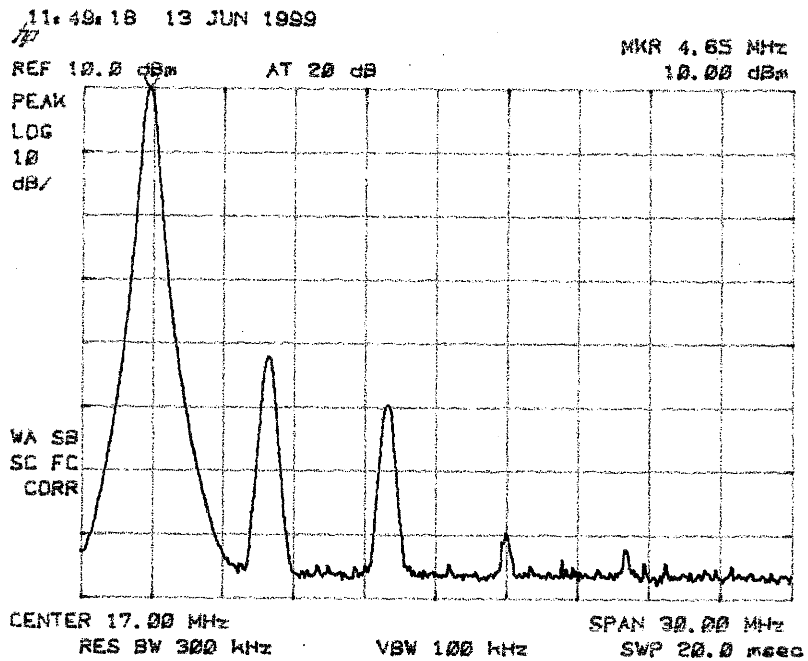


Fig 3.b

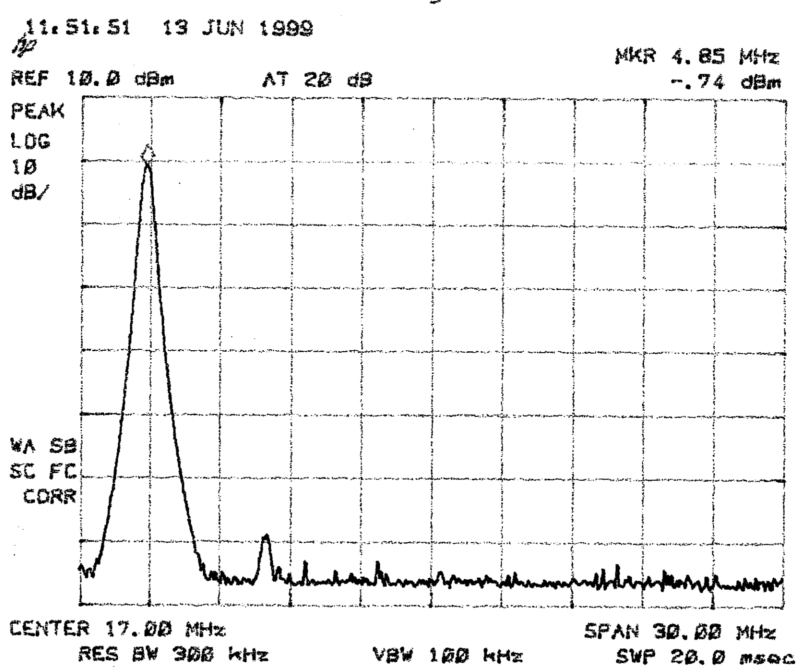


Fig 3.c

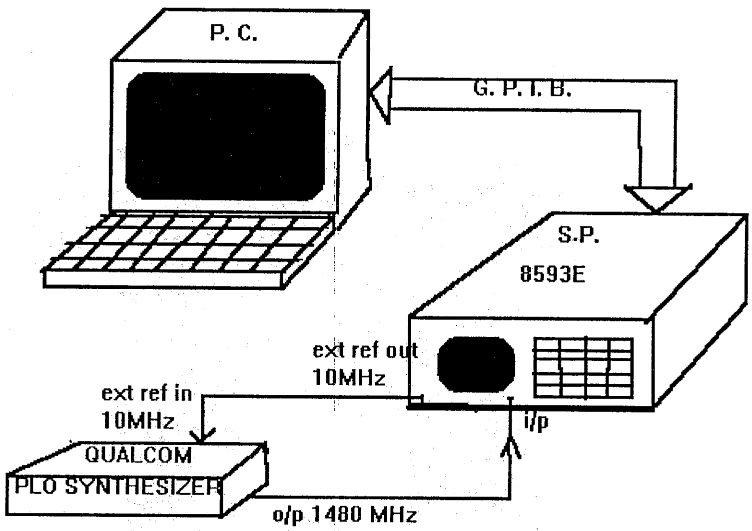
Frequency (MHz)	Harmonic Levels (dBm) 5 MHz (FP)	5 MHz (BP)	5 MHz (REF)
5	+9.79	+10.0	-0.74
10	- 35	- 32	- 60
15	- 40	- 40	- 65

PHASE NOISE MEASUREMENT

Spectrum analyzer is used to measure phase noise (PN) , of the synthesizers { RF spectrum analyser measures the spectral density directly as symmetrical sideband noise of the carrier }

Synthesizer is a circuit which provides output which is multiple of the input reference source. The PN characteristics of the synthesizer output , depends on that of it's internal reference . Stability of internal reference is directly reflected on to the output. The phase noise of the synthesizer output , increases with increase

MEASUREMENT SETUP :-



in frequency of the output . This is because PN is increased by factor given by :- 20 log n

where , n = multiplication factor

This is evident from the data acquired for PN for various devices like Qualcom , Pll synthesizer Q410 . This is illustrated by the tabular coloumn given below –

Both Spectrum Analyzer and Qalcomm Q0140 in Internal Mode

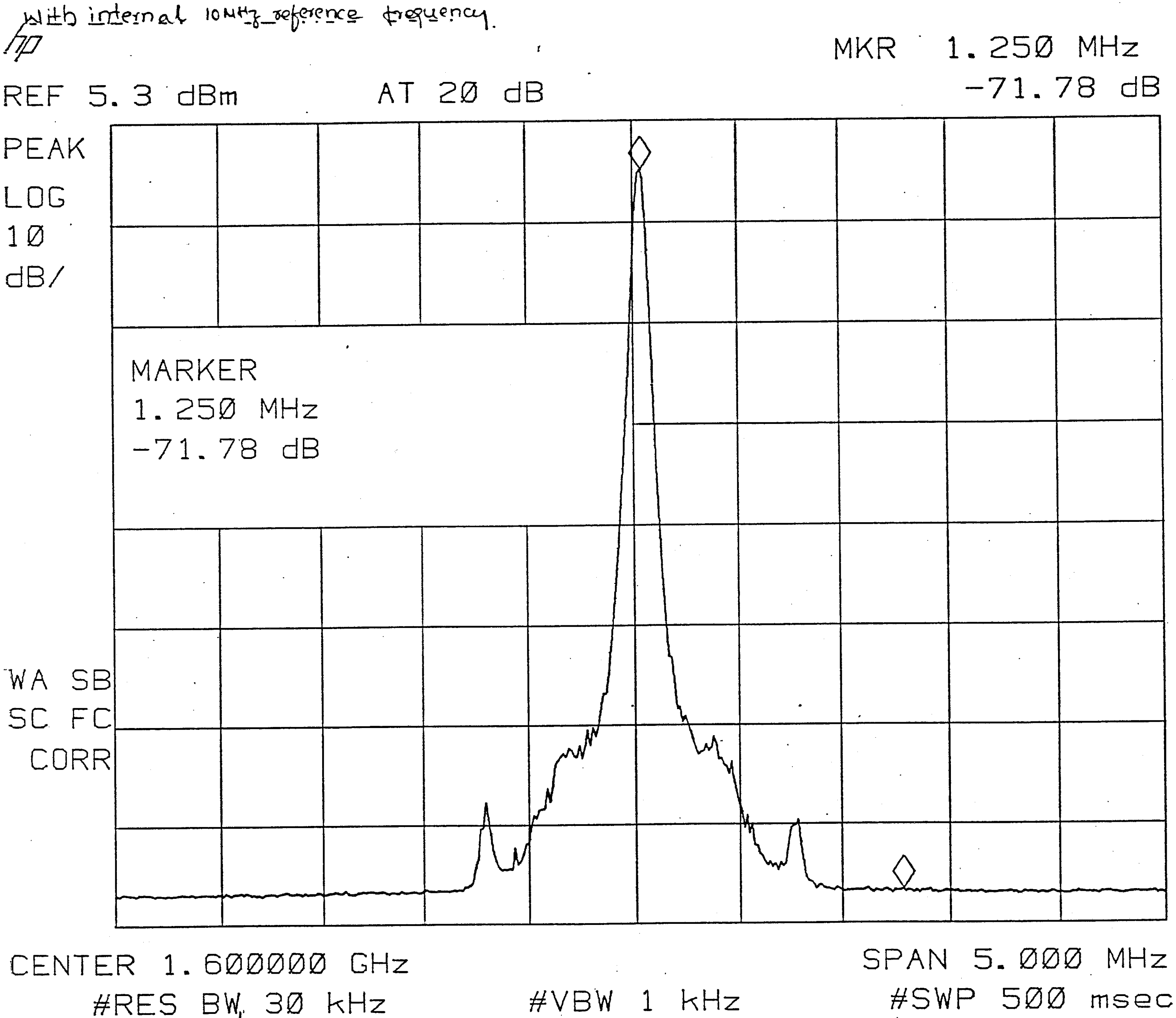
Span, rbw (Hz)	900 MHz	1480 MHz	1600 MHz
20 K, 300	-17.57	-14.70	-14.55
10 K, 100	-14.08	-13.38	-6.02
2 K, 30	-13.38	-6.08	-1.69

For same offset, Phasenoise increases with increase in the Center frequency.

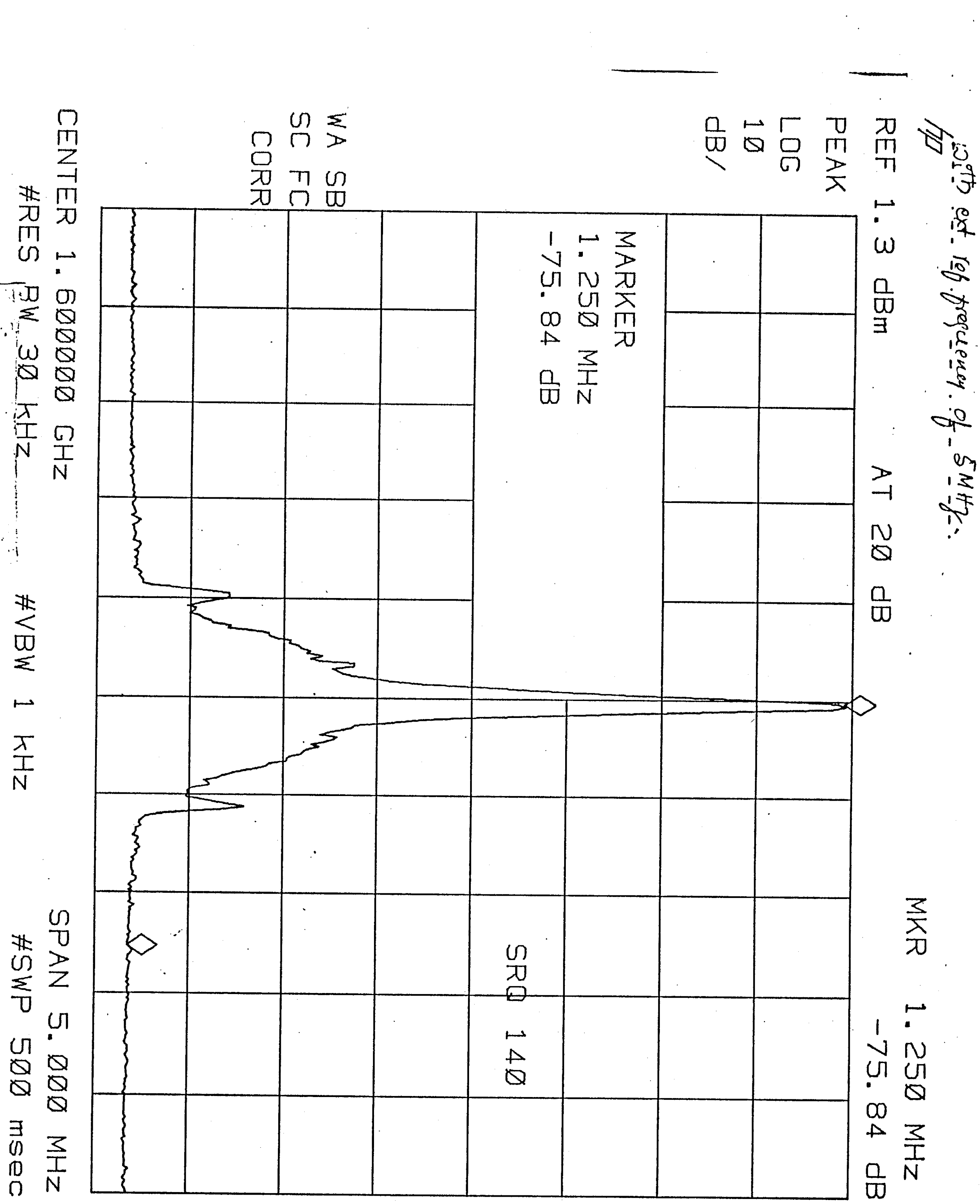
Phasenoise decreases with increase in offset.

The phase noise measurement is repeated with external references of 10MHz –1dBm given from reference module built to both spectrum analyzer and Pll synthesizer . The spectrum of output at 900 MHz to 1600MHz became more pure . This implies noise added by the reference source is lower compared to that when synthesizer was operating with it's own internal reference .

This also , allows to infer that reference source module is much more better in phase noise , than any of the internal references of spectrum analyzer , Qualcom synthesizer , etc..



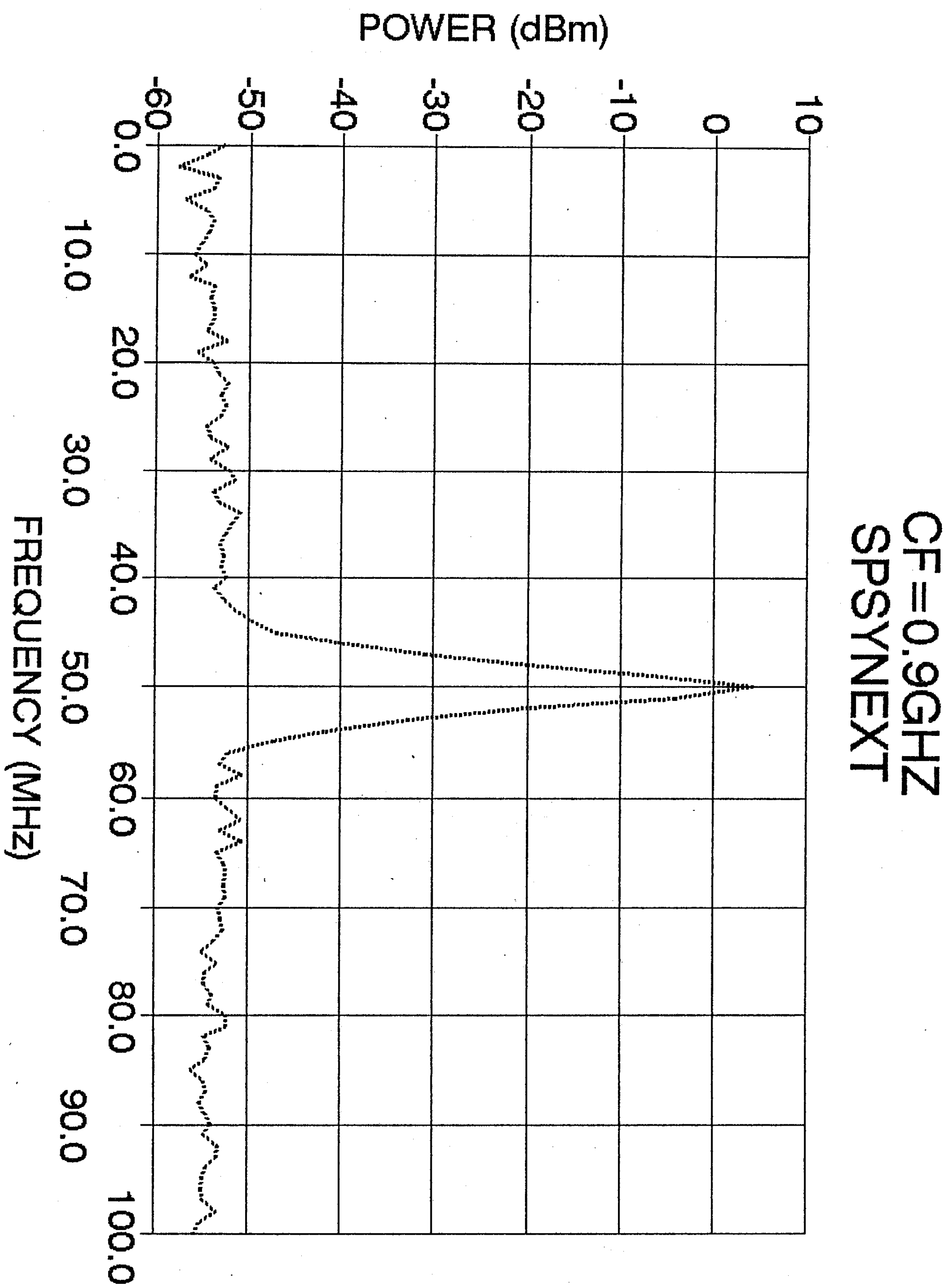
PLOT·1 [Q0410 → CF-1600MHz]



PLOT. 2 [SYNTH. Q0410, CF1600MHz]

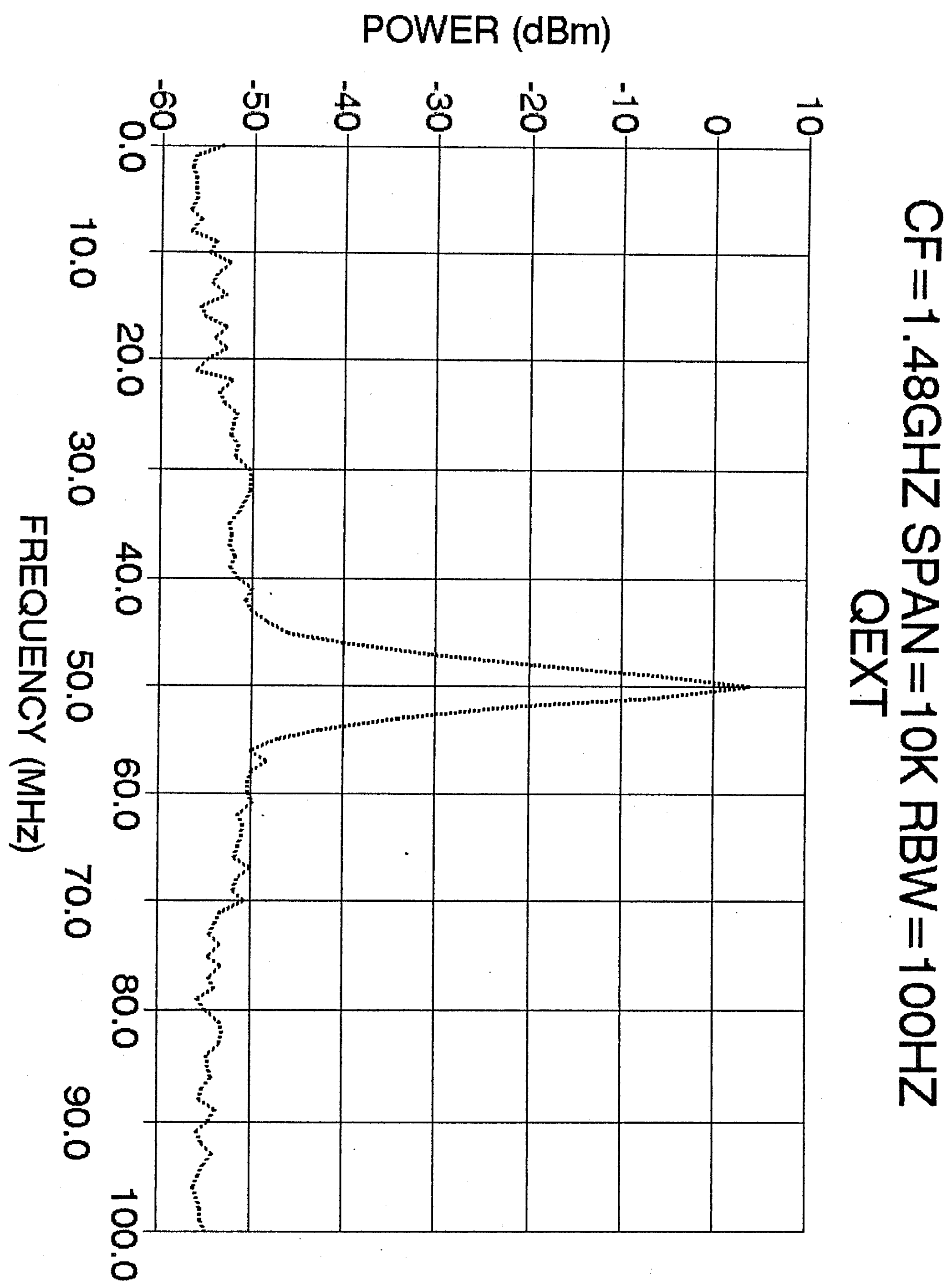
By comparing plot 1 & 2, it is observed that phasenoise has comedown, with ext - 5 MHz ref applied. [See marker-2. position at offset 1.25MHz]

GRAPH-1

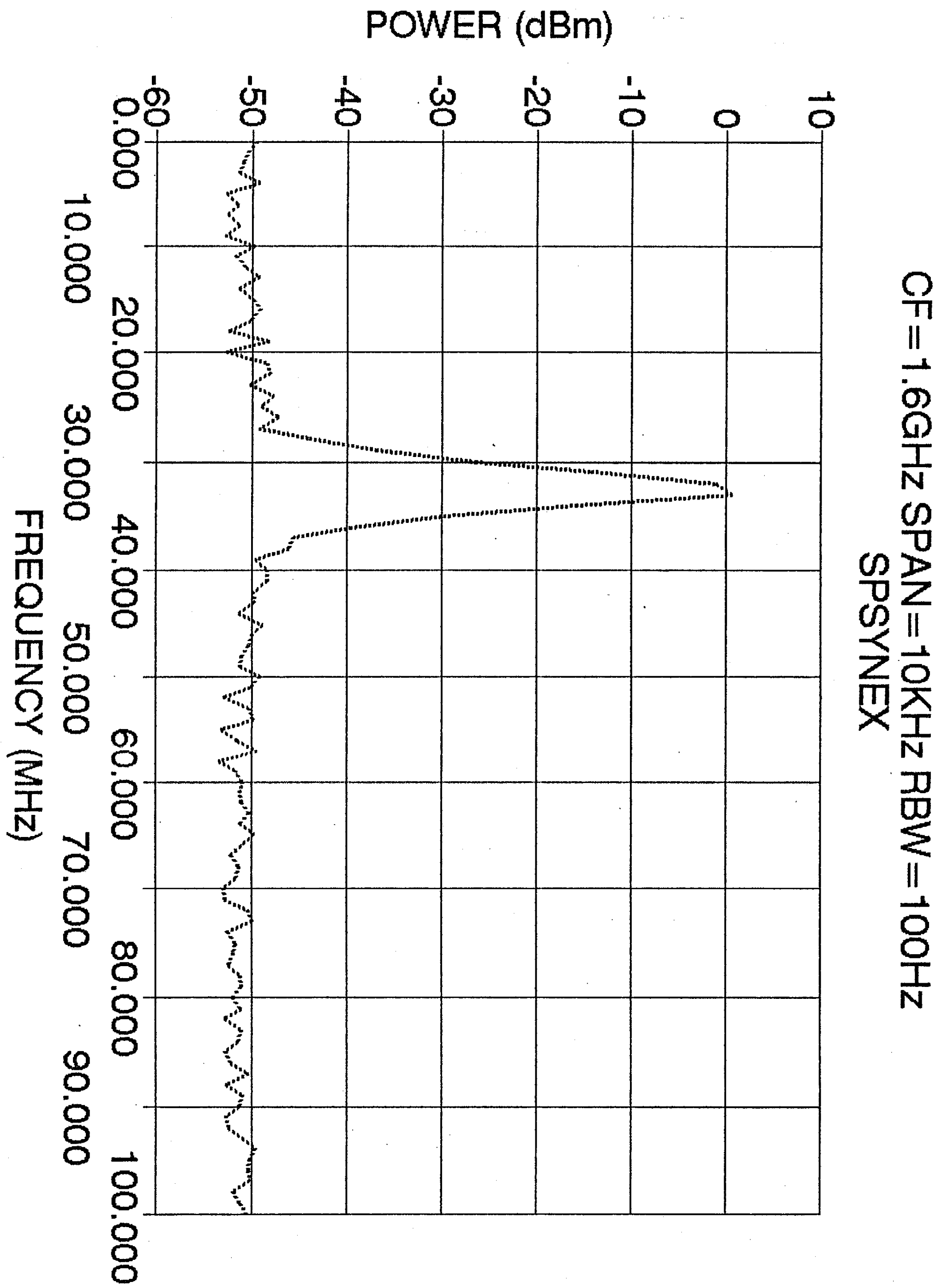


Graphs 1 to 4 are obtained using the program given in the appendix.

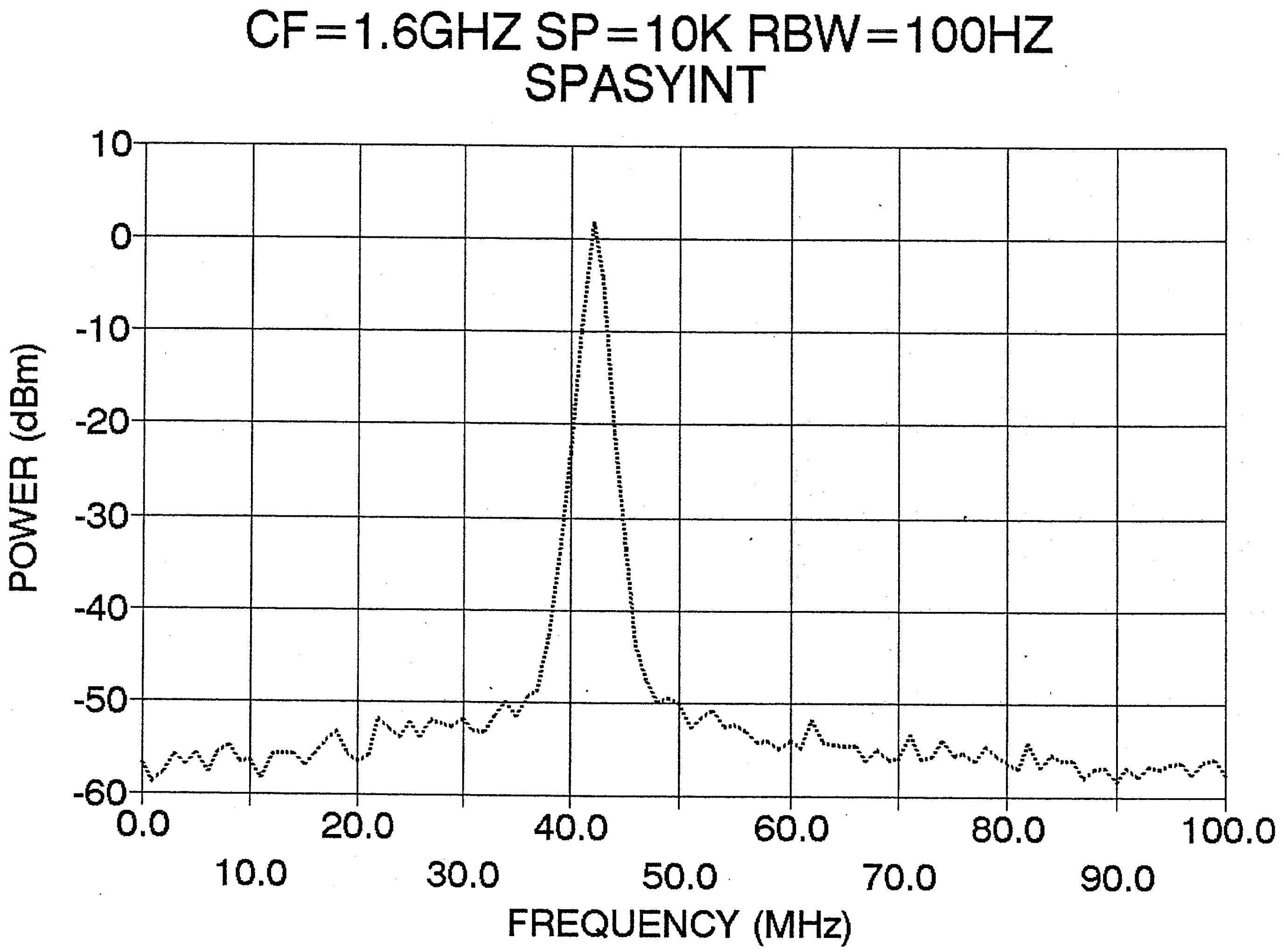
GRAPH- 2


CF=1.48GHZ SPAN=10K RBW=100HZ
QEXT
POWER (dBm)
10
0
-10
-20
-30
-40
-50
-60
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
FREQUENCY (MHz)

GRAPH-3


CF=1.6GHz SPAN=10KHz RBW=100Hz
SPSYNEX
POWER (dBm)
10
0
-10
-20
-30
-40
-50
-60
0.000
10.000
20.000
30.000
40.000
50.000
60.000
70.000
80.000
90.000
100.000
FREQUENCY (MHz)

GRAPH-4


CF=1.6GHZ SP=10K RBW=100HZ
SPASYINT
POWER (dBm)
10
0
-10
-20
-30
-40
-50
-60
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
FREQUENCY (MHz)

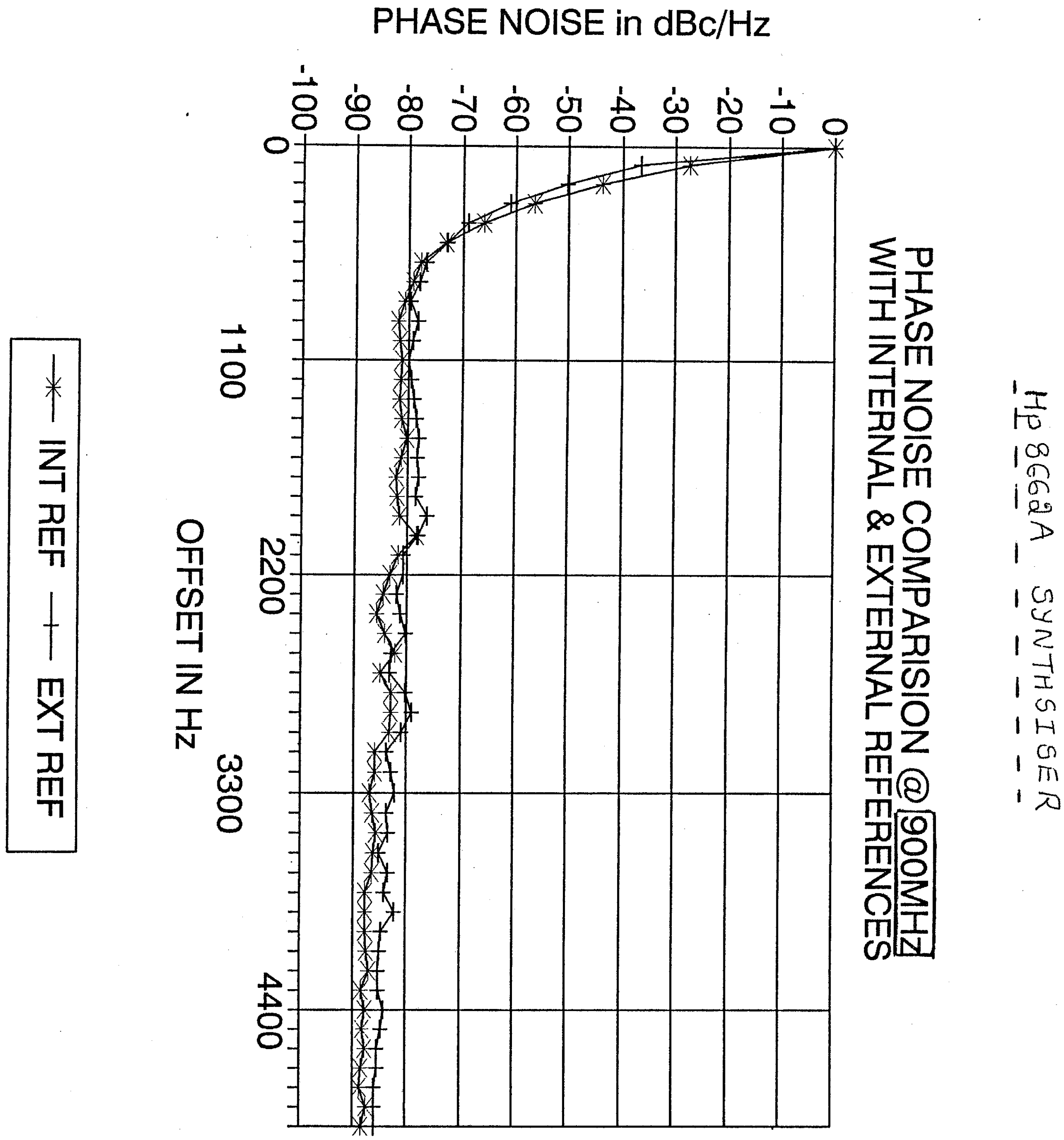
PHASE NOISE CHARACTERISATION OF HP 8662A SYNTHESIZER

Using similar setup as used for characterisation of Qualcomm Q0410 synthesizer, HP 8662A characterisation is carried out, with its own internal reference source and external reference from OCXO module. This characterisation is carried out at three different frequencies viz.. 0.9, 1.0, 1.2 GHz.

From graphs 1,2,3 it is evident that phase noise is better with external reference. It is also observed that phase noise increases with increase in carrier frequency. The acquired data corresponding to these graphs can be seen in the spreadsheet following the graph. It is also observed that the phase noise decreases as we go away from the center frequency.

Graph 4 gives phase noise comparison between synthesizers Q0410 and HP 8662A. From this graph it is evident that HP 8662A has better phase noise characteristics compared to Q0410.

Graphs 5 and 6 gives the plot of power in dBm versus offset from the center frequency at various ports of OCXO reference module.



GRAPH-1

Graphs 1 to 6 are obtained using the program given in page no 73.

DATA POINTS OF GRAPH:1

C.FREQ-900MHz SPAN-10KHz RBW-100Hz

INDEPENDENT REFS

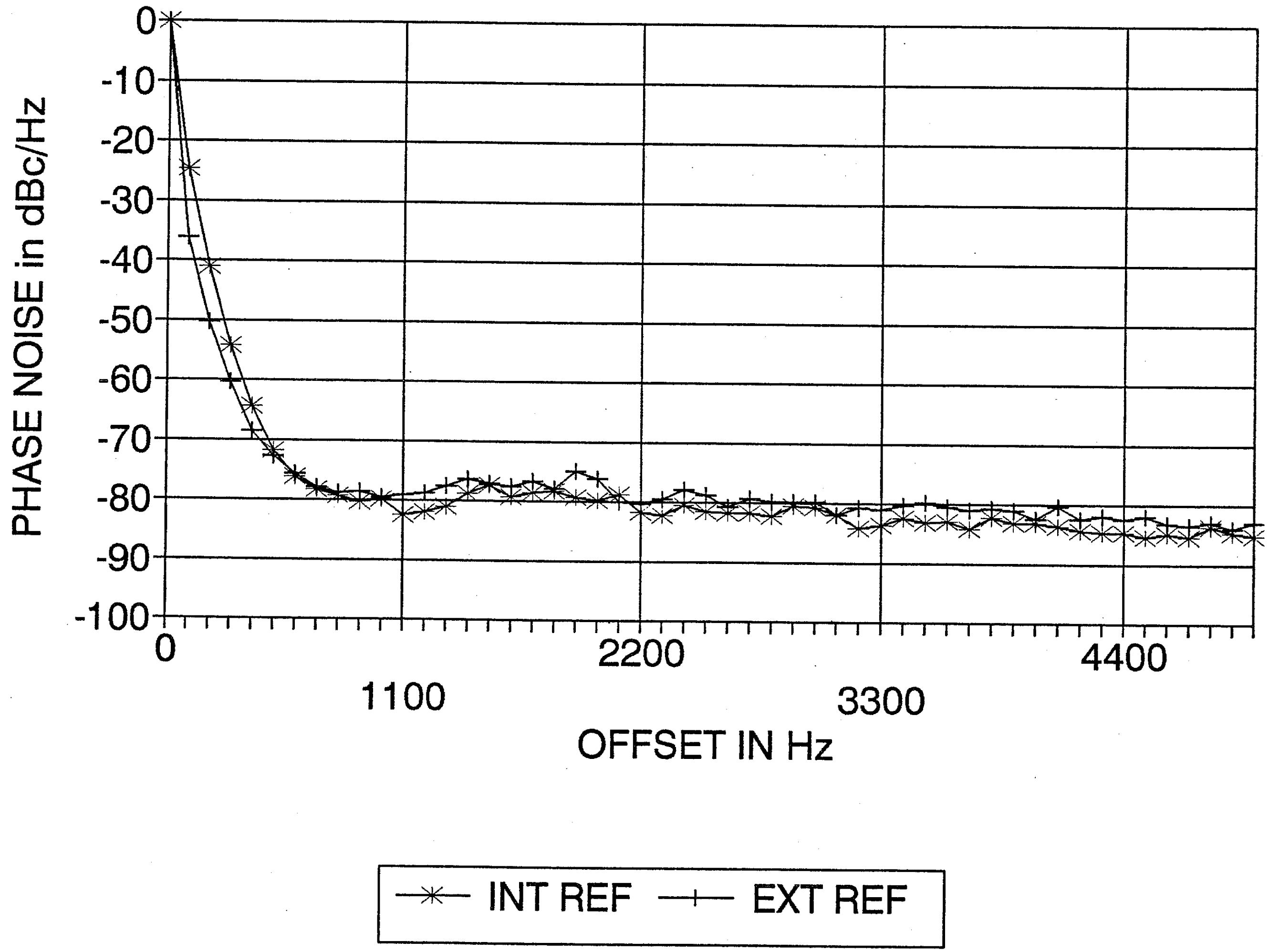
OFFSET IN Hz	POWER IN dBm	PN dBc/Hz
0	3.01	0
100	-4.46	-27.47
200	-20.71	-43.72
300	-33.48	-56.49
400	-42.98	-65.99
500	-50.04	-73.05
600	-54.72	-77.73
700	-56.25	-79.26
800	-57.82	-80.83
900	-59.01	-82.02
1000	-58.83	-81.84
1100	-58.28	-81.29
1200	-58.57	-81.58
1300	-58.74	-81.75
1400	-58.19	-81.2
1500	-57.34	-80.35
1600	-58.34	-81.35
1700	-59.22	-82.23
1800	-59.09	-82.1
1900	-58.55	-81.56
2000	-55.32	-78.33
2100	-58.78	-81.79
2200	-60.26	-83.27
2300	-61.45	-84.46
2400	-62.85	-85.86
2500	-61.19	-84.2
2600	-59.24	-82.25
2700	-62.02	-85.03
2800	-60.13	-83.14
2900	-60.09	-83.1
3000	-60.19	-83.2
3100	-62.93	-85.94
3200	-63.12	-86.13
3300	-64.08	-87.09
3400	-63.49	-86.5
3500	-62.86	-85.87
3600	-63.34	-86.35
3700	-63.59	-86.6
3800	-64.8	-87.81
3900	-64.8	-87.81
4000	-64.63	-87.64
4100	-64.43	-87.44
4200	-63.99	-87
4300	-65.5	-88.51
4400	-64.65	-87.66
4500	-65.22	-88.23
4600	-64.79	-87.8
4700	-65.49	-88.5
4800	-65.7	-88.71
4900	-64.51	-87.52
5000	-65.44	-88.45

EXTERNAL REF FOR SPA & SYNTHESIZER

OFFSET IN Hz	POWER IN dBm	PN dBc/Hz
0	0.1	0
100	-16.49	-36.59
200	-30.19	-50.29
300	-40.84	-60.94
400	-48.79	-68.89
500	-52.85	-72.95
600	-56.8	-76.9
700	-57.92	-78.02
800	-59.72	-79.82
900	-58.35	-78.45
1000	-59.12	-79.22
1100	-60.07	-80.17
1200	-59.56	-79.66
1300	-59.09	-79.19
1400	-58.55	-78.65
1500	-57.99	-78.09
1600	-58.12	-78.22
1700	-58.05	-78.15
1800	-58.6	-78.7
1900	-56.2	-76.3
2000	-57.95	-78.05
2100	-60.69	-80.79
2200	-60.81	-80.91
2300	-61.95	-82.05
2400	-61.31	-81.41
2500	-60.25	-80.35
2600	-62.93	-83.03
2700	-63.1	-83.2
2800	-60.33	-80.43
2900	-58.92	-79.02
3000	-60.85	-80.95
3100	-63.67	-83.77
3200	-62.91	-83.01
3300	-62.09	-82.19
3400	-63.7	-83.8
3500	-63.41	-83.51
3600	-65.08	-85.18
3700	-63.54	-83.64
3800	-64.11	-84.21
3900	-62.24	-82.34
4000	-64.8	-84.9
4100	-64.85	-84.95
4200	-65.23	-85.33
4300	-65.25	-85.35
4400	-64.23	-84.33
4500	-64.64	-84.74
4600	-65.3	-85.4
4700	-65.36	-85.46
4800	-65.94	-86.04
4900	-65.85	-85.95
5000	-65.89	-85.99

Hp 8662A SYNTHSISER

PHASE NOISE COMPARISION @ 1000MHz
WITH INTERNAL & EXTERNAL REFERENCES



GRAPH. 2

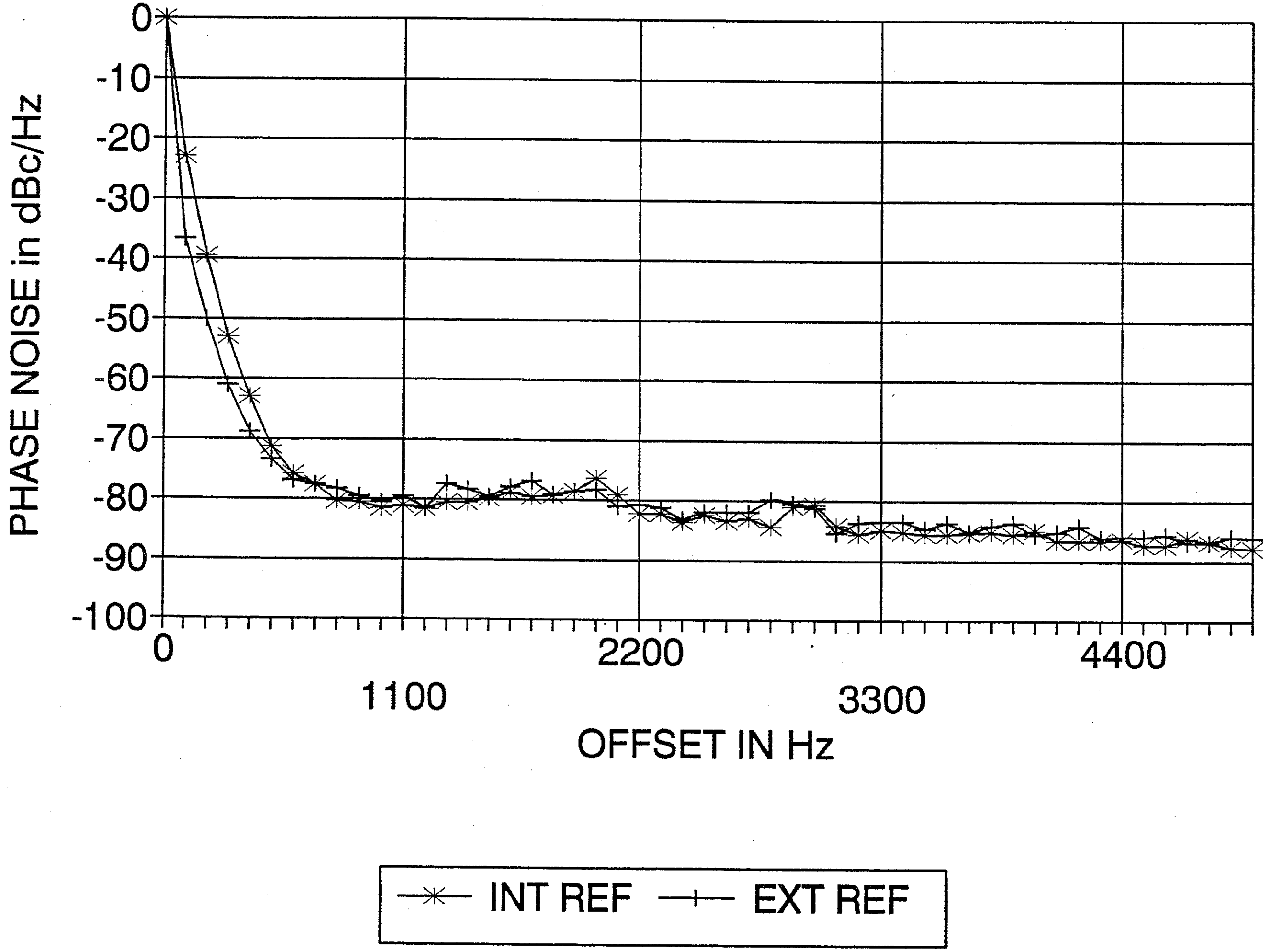
DATA POINTS OF GRAPH.2

C.FREQ-1000MHz | SPAN-10KHz | RBW-100Hz

INDEPENDENT REFS			EXTERNAL REF FOR SPA & SYNTHESIZER		
OFFSET IN Hz	POWER IN dBm	PN dBc/Hz	OFFSET IN Hz	POWER IN dBm	PN dBc/Hz
0	2	0	0	-0.08	0
100	-2.74	-24.74	100	-16.28	-36.2
200	-19.04	-41.04	200	-30.55	-50.47
300	-32.36	-54.36	300	-40.5	-60.42
400	-42.6	-64.6	400	-48.79	-68.71
500	-49.77	-71.77	500	-52.99	-72.91
600	-54.16	-76.16	600	-55.77	-75.69
700	-56.35	-78.35	700	-58.12	-78.04
800	-57.37	-79.37	800	-58.96	-78.88
900	-58.42	-80.42	900	-58.82	-78.74
1000	-57.83	-79.83	1000	-59.65	-79.57
1100	-60.51	-82.51	1100	-59.34	-79.26
1200	-60.06	-82.06	1200	-58.93	-78.85
1300	-59.02	-81.02	1300	-57.67	-77.59
1400	-56.87	-78.87	1400	-56.48	-76.4
1500	-55.51	-77.51	1500	-57.18	-77.1
1600	-57.48	-79.48	1600	-57.85	-77.77
1700	-56.57	-78.57	1700	-56.87	-76.79
1800	-56.38	-78.38	1800	-57.95	-77.87
1900	-57.46	-79.46	1900	-55.2	-75.12
2000	-57.82	-79.82	2000	-56.33	-76.25
2100	-56.88	-78.88	2100	-60.19	-80.11
2200	-59.71	-81.71	2200	-60.38	-80.3
2300	-60.24	-82.24	2300	-59.81	-79.73
2400	-58.73	-80.73	2400	-58.01	-77.93
2500	-59.65	-81.65	2500	-58.97	-78.89
2600	-59.82	-81.82	2600	-60.88	-80.8
2700	-59.9	-81.9	2700	-59.55	-79.47
2800	-60.3	-82.3	2800	-59.91	-79.83
2900	-58.53	-80.53	2900	-59.86	-79.78
3000	-58.78	-80.78	3000	-60	-79.92
3100	-60.08	-82.08	3100	-62.24	-82.16
3200	-62.23	-84.23	3200	-60.85	-80.77
3300	-61.89	-83.89	3300	-61.19	-81.11
3400	-60.44	-82.44	3400	-60.52	-80.44
3500	-61.26	-83.26	3500	-59.94	-79.86
3600	-61.12	-83.12	3600	-60.69	-80.61
3700	-62.24	-84.24	3700	-61.06	-80.98
3800	-60.39	-82.39	3800	-60.87	-80.79
3900	-61.4	-83.4	3900	-61.13	-81.05
4000	-61.25	-83.25	4000	-62.54	-82.46
4100	-61.79	-83.79	4100	-60.43	-80.35
4200	-62.4	-84.4	4200	-62.6	-82.52
4300	-62.75	-84.75	4300	-62.06	-81.98
4400	-62.71	-84.71	4400	-62.56	-82.48
4500	-63.52	-85.52	4500	-62.04	-81.96
4600	-63.01	-85.01	4600	-63.38	-83.3
4700	-63.39	-85.39	4700	-63.68	-83.6
4800	-61.74	-83.74	4800	-63.07	-82.99
4900	-62.87	-84.87	4900	-64.19	-84.11
5000	-63.24	-85.24	5000	-63.11	-83.03

Hp 8662A SYNTHSISER

PHASE NOISE COMPARISION @ 1200MHz
WITH INTERNAL & EXTERNAL REFERENCES



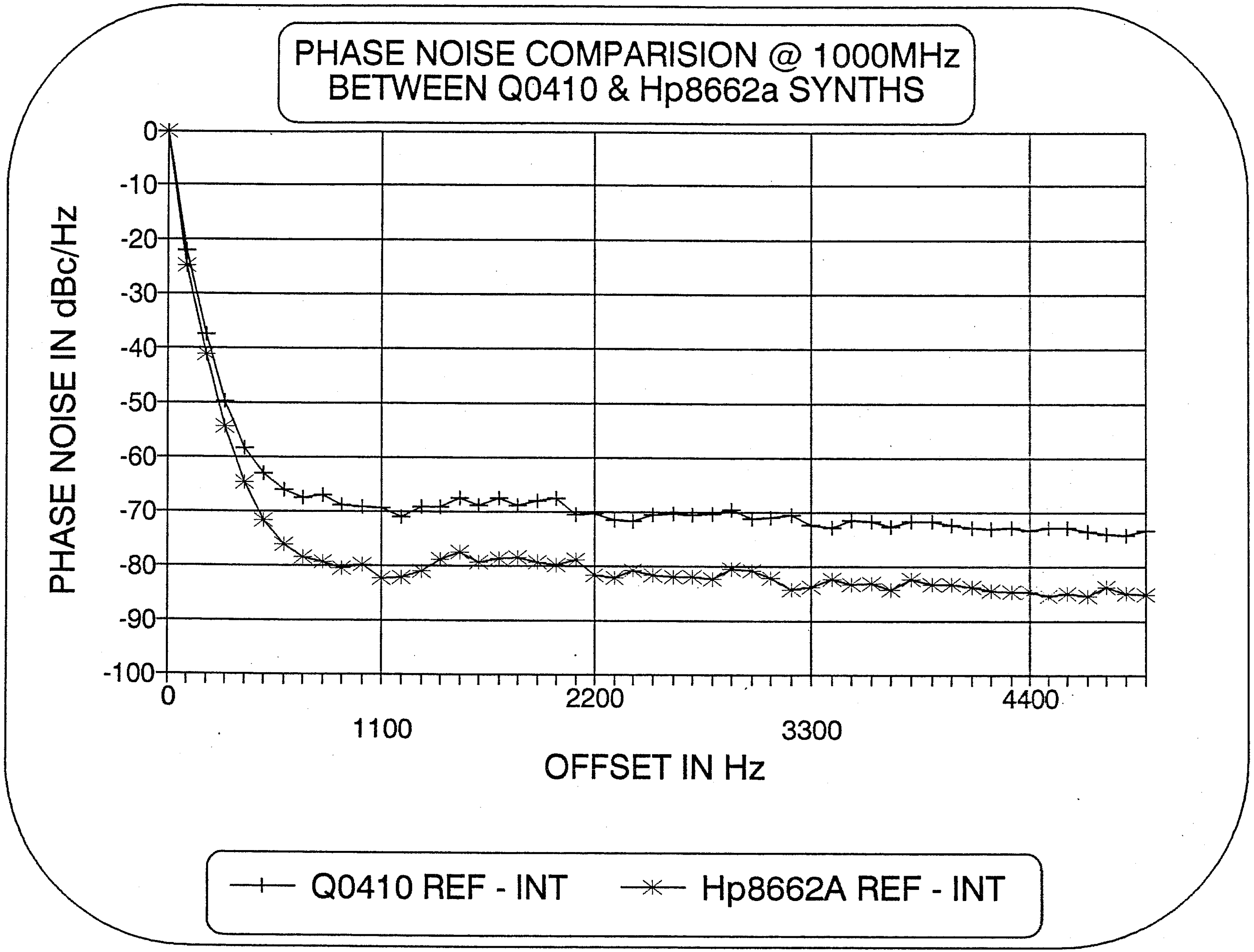
GRAPH. 3

DATA POINTS OF GRAPH.3

C.FREQ-1200MHz | SPAN-10KHz | RBW-100Hz

OFFSET IN Hz	INDEPENDENT REFS: POWER IN dBm	INDEPENDENT REFS: PN dBc/Hz
0	1.57	0
100	-1.54	-23.11
200	-18.06	-39.63
300	-31.48	-53.05
400	-41.43	-63
500	-49.68	-71.25
600	-54.36	-75.93
700	-56.21	-77.78
800	-58.7	-80.27
900	-58.97	-80.54
1000	-59.98	-81.55
1100	-59.59	-81.16
1200	-60.12	-81.69
1300	-59.09	-80.66
1400	-59.13	-80.7
1500	-58.24	-79.81
1600	-57.32	-78.89
1700	-58	-79.57
1800	-57.8	-79.37
1900	-57.07	-78.64
2000	-54.96	-76.53
2100	-57.56	-79.13
2200	-60.72	-82.29
2300	-60.66	-82.23
2400	-62.14	-83.71
2500	-61	-82.57
2600	-61.86	-83.43
2700	-61.41	-82.98
2800	-62.94	-84.51
2900	-59.51	-81.08
3000	-59.4	-80.97
3100	-62.73	-84.3
3200	-64.27	-85.84
3300	-63.52	-85.09
3400	-63.74	-85.31
3500	-64.18	-85.75
3600	-64.18	-85.75
3700	-63.86	-85.43
3800	-63.65	-85.22
3900	-64.23	-85.8
4000	-63.48	-85.05
4100	-65.08	-86.65
4200	-65.17	-86.74
4300	-65.05	-86.62
4400	-64.99	-86.56
4500	-65.84	-87.41
4600	-65.9	-87.47
4700	-64.77	-86.34
4800	-65.28	-86.85
4900	-66.12	-87.69
5000	-66.31	-87.88

OFFSET IN Hz	EXTERNAL REF FOR SPA & SYNTHESIZER: POWER IN dBm	EXTERNAL REF FOR SPA & SYNTHESIZER: PN dBc/Hz
0	0.28	0
100	-16.38	-36.66
200	-29.73	-50.01
300	-40.73	-61.01
400	-48.54	-68.82
500	-53.34	-73.62
600	-56.66	-76.94
700	-57.44	-77.72
800	-58.25	-78.53
900	-59.31	-79.59
1000	-60.22	-80.5
1100	-59.37	-79.65
1200	-61.41	-81.69
1300	-57.06	-77.34
1400	-58.03	-78.31
1500	-59.45	-79.73
1600	-57.72	-78
1700	-56.79	-77.07
1800	-58.77	-79.05
1900	-58.47	-78.75
2000	-58.23	-78.51
2100	-60.71	-80.99
2200	-60.52	-80.8
2300	-61.17	-81.45
2400	-62.9	-83.18
2500	-61.84	-82.12
2600	-61.9	-82.18
2700	-61.87	-82.15
2800	-59.59	-79.87
2900	-60.35	-80.63
3000	-61.12	-81.4
3100	-65.17	-85.45
3200	-63.58	-83.86
3300	-63.17	-83.45
3400	-63.37	-83.65
3500	-64.39	-84.67
3600	-63.42	-83.7
3700	-64.92	-85.2
3800	-63.93	-84.21
3900	-63.52	-83.8
4000	-65.35	-85.63
4100	-65.03	-85.31
4200	-63.89	-84.17
4300	-65.86	-86.14
4400	-65.81	-86.09
4500	-65.61	-85.89
4600	-65.43	-85.71
4700	-66.7	-86.98
4800	-66.57	-86.85
4900	-65.62	-85.9
5000	-65.89	-86.17


PHASE NOISE COMPARISION @ 1000MHz
BETWEEN Q0410 & Hp8662a SYNTHS
PHASE NOISE IN dBc/Hz
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
1100
2200
3300
4400
OFFSET IN Hz
Q0410 REF - INT
Hp8662A REF - INT

GRAPH. 4

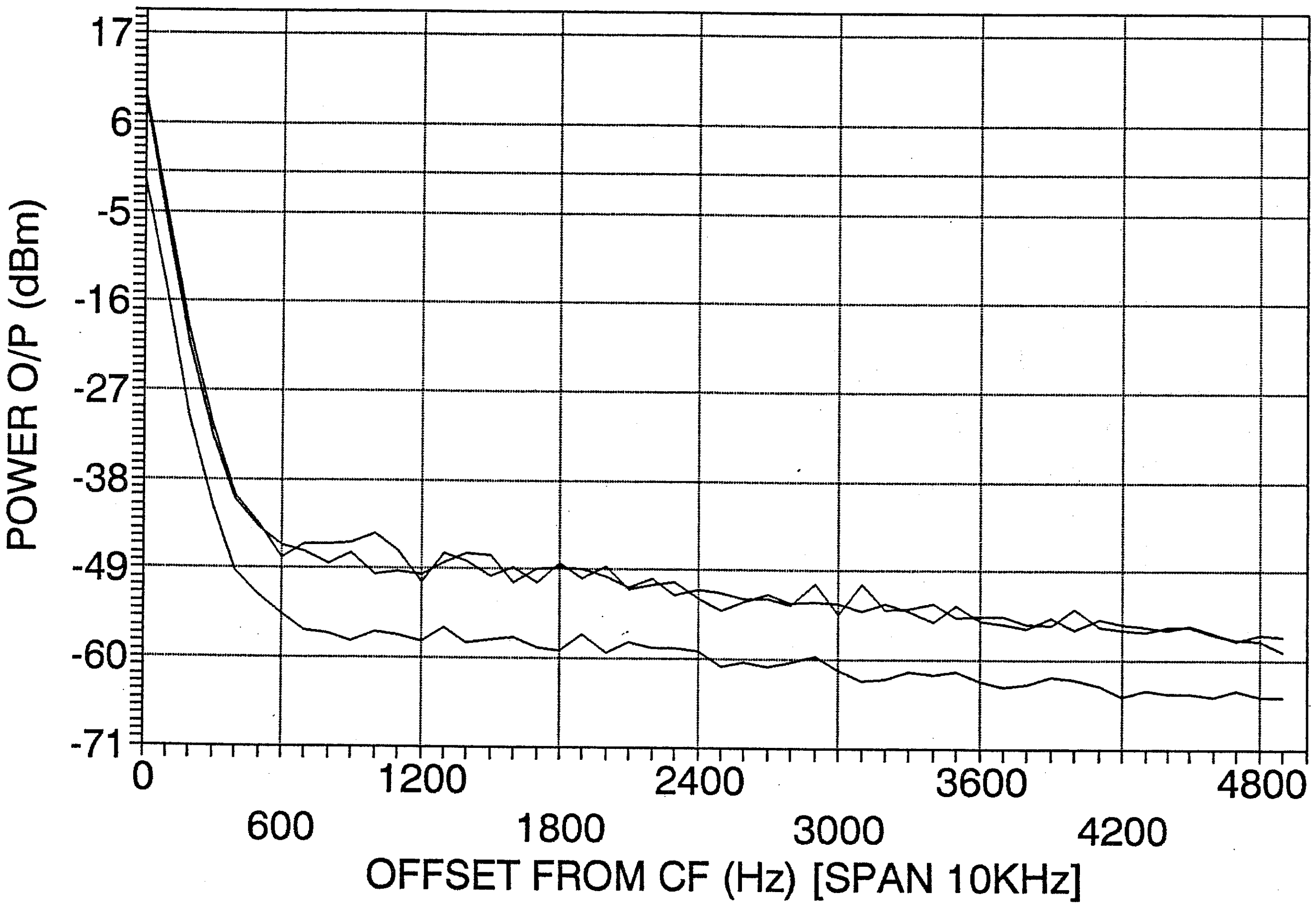
C.FREQ - 1000MHz SPAN-10KHZ RBW - 100Hz
Hp8662A Q0410

DATA - 4

	Hp8662A	Q0410
OFFSET IN Hz	PN IN dBc/Hz	PN IN dBc/Hz
0	0	0
100	-24.74	-22.1
200	-41.04	-37.37
300	-54.36	-49.72
400	-64.6	-58.41
500	-71.77	-63.1
600	-76.16	-66.09
700	-78.35	-67.46
800	-79.37	-66.94
900	-80.42	-68.96
1000	-79.83	-69.09
1100	-82.51	-69.31
1200	-82.06	-70.95
1300	-81.02	-69
1400	-78.87	-69.09
1500	-77.51	-67.58
1600	-79.48	-68.91
1700	-78.57	-67.38
1800	-78.38	-68.97
1900	-79.46	-67.88
2000	-79.82	-67.55
2100	-78.88	-70.45
2200	-81.71	-70.36
2300	-82.24	-71.33
2400	-80.73	-71.64
2500	-81.65	-70.45
2600	-81.82	-70.23
2700	-81.9	-70.59
2800	-82.3	-70.3
2900	-80.53	-69.67
3000	-80.78	-71.12
3100	-82.08	-71.08
3200	-84.23	-70.59
3300	-83.89	-72.36
3400	-82.44	-72.85
3500	-83.26	-71.36
3600	-83.12	-71.71
3700	-84.24	-72.58
3800	-82.39	-71.7
3900	-83.4	-71.58
4000	-83.25	-72.48
4100	-83.79	-72.8
4200	-84.4	-73.15
4300	-84.75	-72.84
4400	-84.71	-73.27
4500	-85.52	-72.8
4600	-85.01	-72.89
4700	-85.39	-73.51
4800	-83.74	-74.02
4900	-84.87	-74.32
5000	-85.24	-73.28

OCXO REFERENCE MODULE

POWER O/P (dBm) OF 5MHz PORTS
VERSES OFFSET FROM CARRIRE FREQUNCY

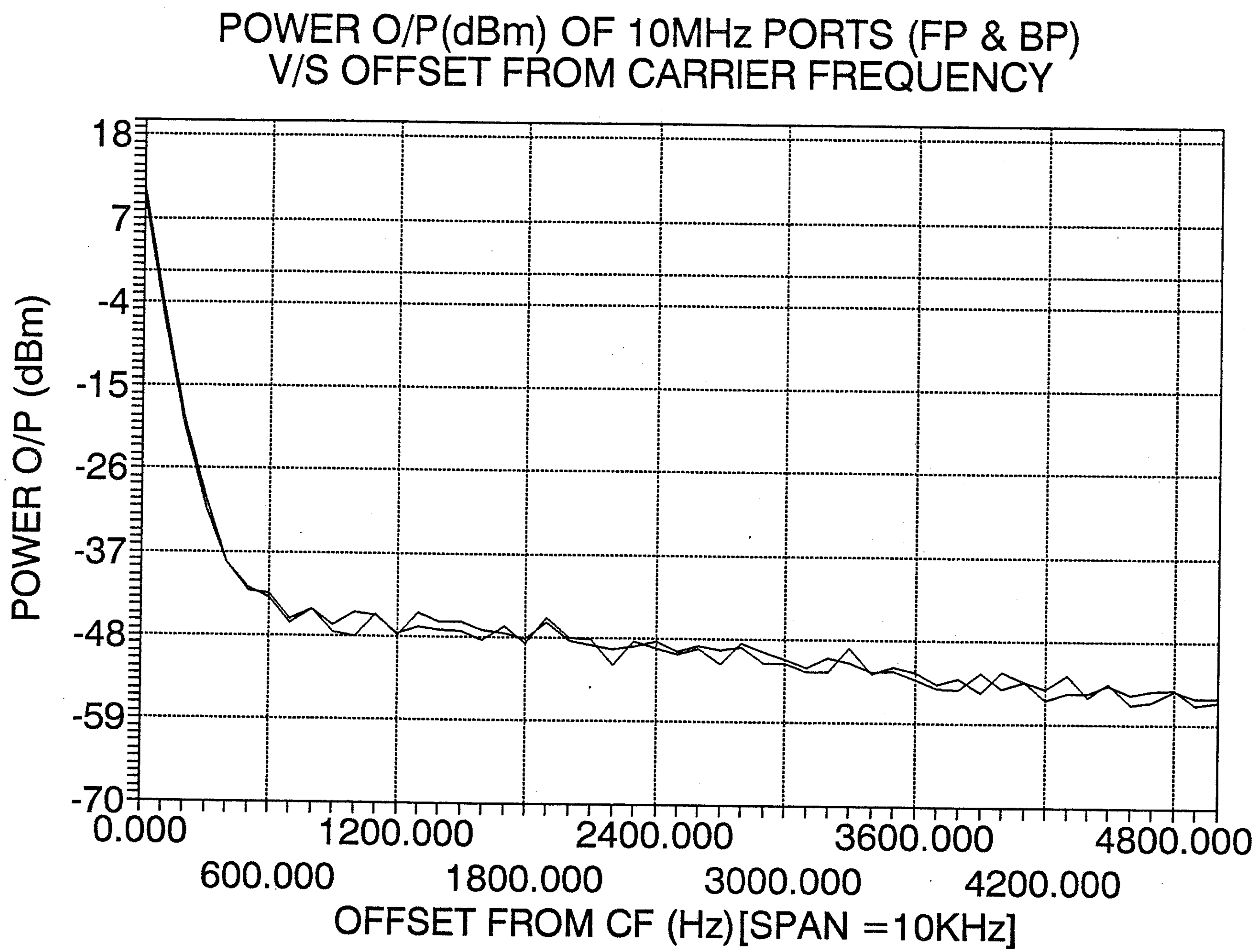


GRAPH. 5

OFFSET IN Hz	BP 5MHz REF IN	BP 5MHz OUT	FP 5MHz OUT
0	-0.84	9.67	9.02
100	-14.85	-5.03	-6.59
200	-30.21	-19.41	-21.1
300	-41.28	-31.28	-32.57
400	-49.27	-39.91	-40.6
500	-52.29	-43.46	-43.91
600	-54.67	-47.65	-46.2
700	-56.63	-45.95	-46.84
800	-57.02	-45.96	-48.48
900	-57.87	-45.77	-47.14
1000	-56.8	-44.73	-49.74
1100	-57.28	-46.64	-49.31
1200	-57.88	-50.64	-49.69
1300	-56.28	-47.03	-48.18
1400	-58.12	-48.01	-47.12
1500	-57.77	-49.94	-47.22
1600	-57.37	-48.78	-50.71
1700	-58.64	-50.58	-48.95
1800	-59.11	-48.18	-48.72
1900	-57.03	-50.16	-48.96
2000	-59.22	-48.53	-49.86
2100	-58.04	-51.43	-51.26
2200	-58.72	-50.77	-50.16
2300	-58.69	-50.39	-52.12
2400	-59.11	-52.45	-51.44
2500	-61.01	-54.08	-51.7
2600	-60.45	-52.96	-52.6
2700	-60.89	-52.04	-52.54
2800	-60.32	-52.99	-53.27
2900	-59.57	-52.89	-50.71
3000	-61.37	-53	-54.32
3100	-62.56	-54.1	-50.62
3200	-62.48	-52.99	-53.9
3300	-61.6	-54.06	-53.73
3400	-61.99	-55.26	-53.15
3500	-61.51	-53.33	-54.79
3600	-62.66	-55.22	-54.57
3700	-63.38	-55.48	-54.6
3800	-62.96	-56.15	-55.52
3900	-62.1	-54.8	-55.73
4000	-62.51	-56.34	-53.61
4100	-63.27	-54.89	-55.95
4200	-64.46	-55.45	-56.32
4300	-63.71	-55.97	-56.54
4400	-64.21	-56.34	-55.9
4500	-64.11	-55.77	-55.82
4600	-64.44	-56.62	-56.78
4700	-63.81	-57.62	-57.39
4800	-64.6	-56.76	-57.57
4900	-64.45	-56.95	-58.81

DATA · 5

OCXO REFERENCE MODULE



GRAPH. 6

OFFSET IN Hz	10MHz FP* POWER IN dBm	10MHz BP* POWER IN dBm
0	10.09	11.16
100	-6	-4.72
200	-20.14	-19.23
300	-31.24	-30.07
400	-38.27	-38.27
500	-41.7	-41.99
600	-43.05	-42.48
700	-46.26	-45.85
800	-44.48	-44.48
900	-47.53	-46.6
1000	-47.92	-44.92
1100	-45.06	-45.27
1200	-47.85	-47.71
1300	-44.88	-46.66
1400	-46.02	-47.03
1500	-45.98	-47.21
1600	-47.11	-48.47
1700	-47.5	-46.5
1800	-48.27	-48.82
1900	-45.9	-45.35
2000	-48.44	-48.08
2100	-48.97	-48.22
2200	-49.49	-51.54
2300	-49.07	-48.32
2400	-48.38	-49.33
2500	-49.72	-49.98
2600	-48.91	-49.31
2700	-49.49	-51.35
2800	-49.18	-48.49
2900	-51.23	-49.59
3000	-51.15	-50.67
3100	-52.22	-51.73
3200	-52.25	-50.42
3300	-49.21	-51.07
3400	-52.47	-52.33
3500	-51.55	-52.03
3600	-52.24	-53.15
3700	-53.73	-54.23
3800	-52.97	-54.49
3900	-54.88	-52.35
4000	-52.04	-54.23
4100	-53.34	-53.37
4200	-54.4	-55.81
4300	-52.39	-54.84
4400	-55.51	-54.92
4500	-53.55	-53.74
4600	-56.36	-55.09
4700	-55.98	-54.58
4800	-54.5	-54.41
4900	-55.47	-56.27
5000	-55.42	-56.03

DATA - 6

* FP - FRONT PANEL
* BP - BACK PANEL

CONCLUSIONS

From the above graphs, it can be concluded that the phase noise increases with increase in the carrier frequency, also phase noise decreases as we go away from center frequency.

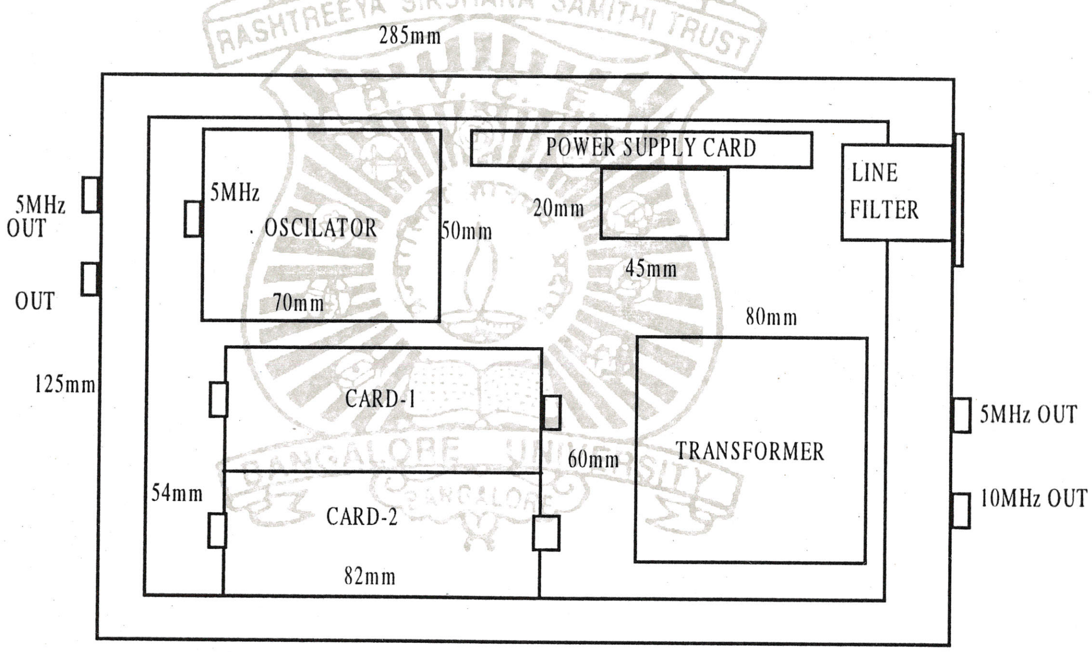
Finally it can be concluded that the phase noise of HP 8662A synthesizer has improved with the external OCXO reference module.Therefore, better the reference input to a synthesizer, better is it's phase noise characteristics.

Thus, using the external OCXO reference module designed by us, we were able to achieve our aim of phase noise characterising different L.O.Synthesizers.

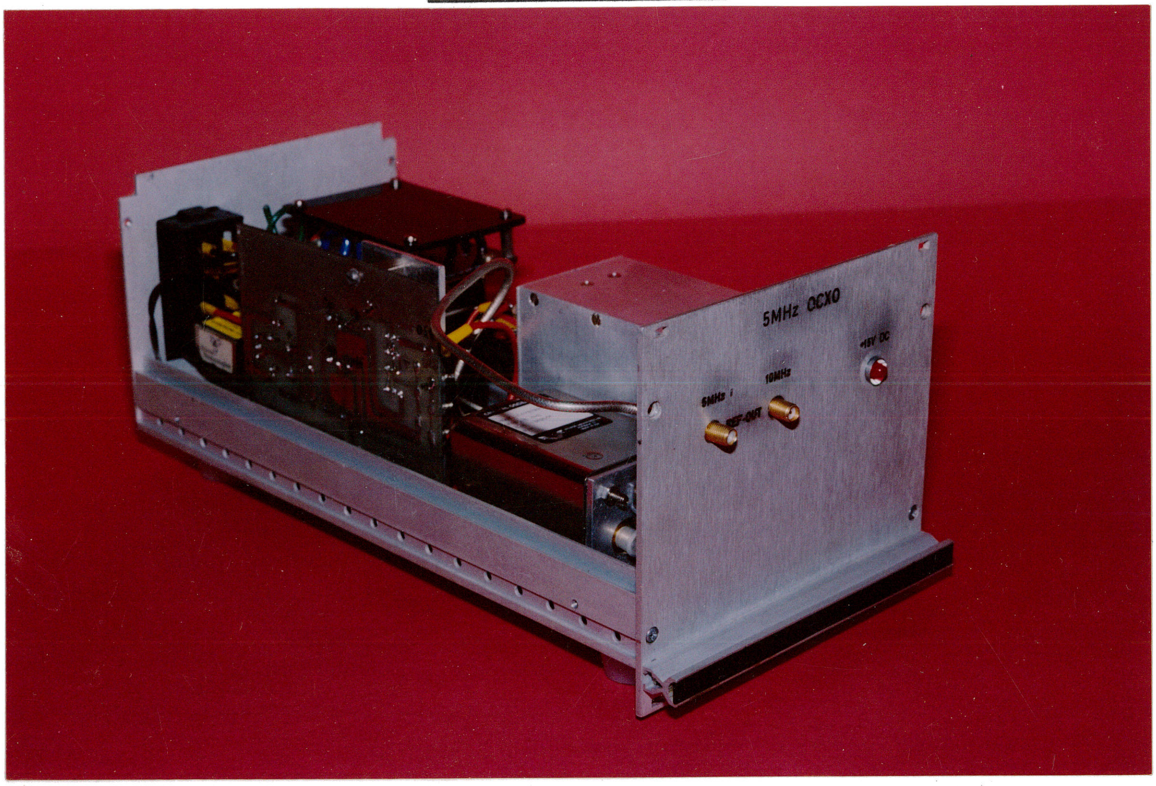
APPENDIX

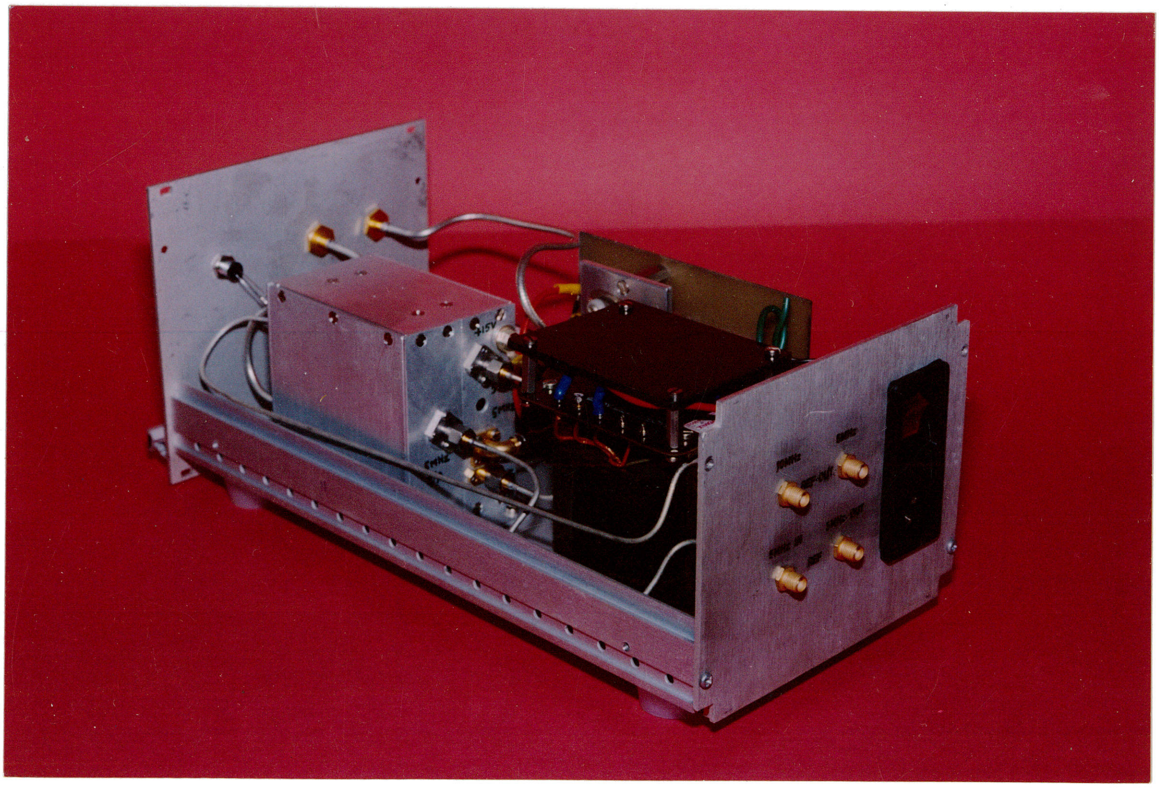
APPENDIX

BOX LAYOUT

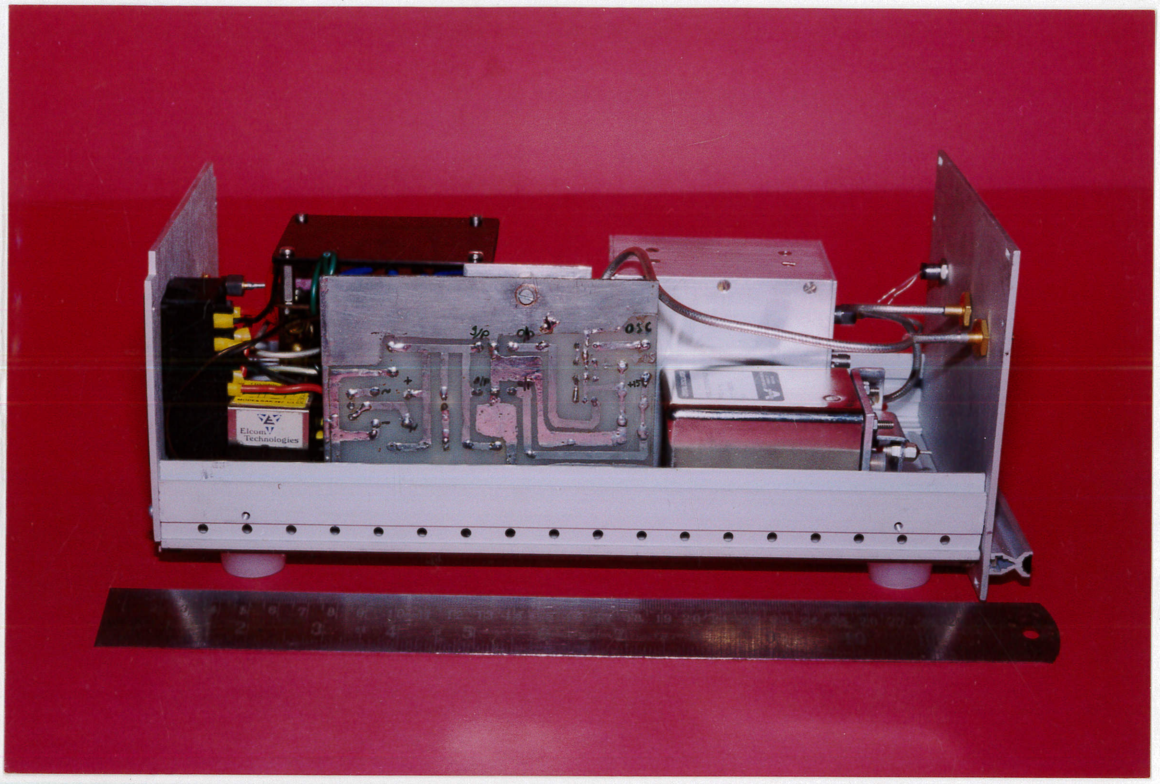


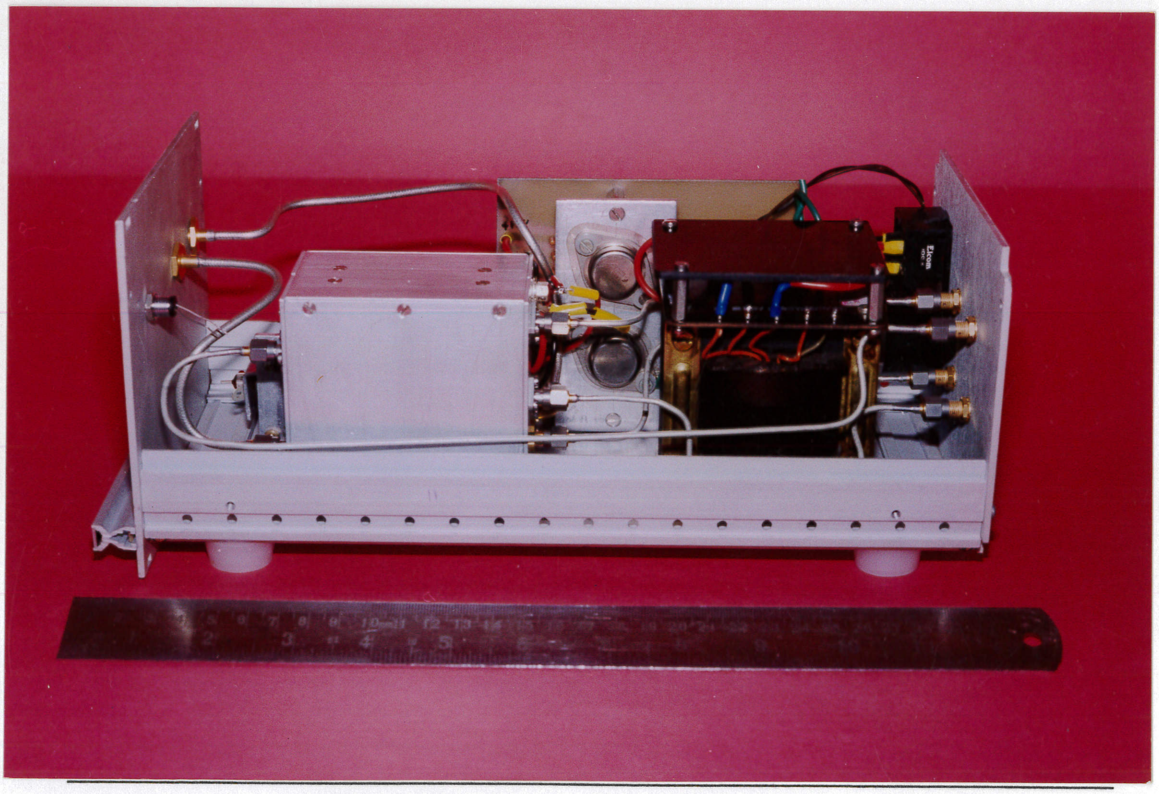
PHOTOGRAPHS





PHOTOGRAPHS

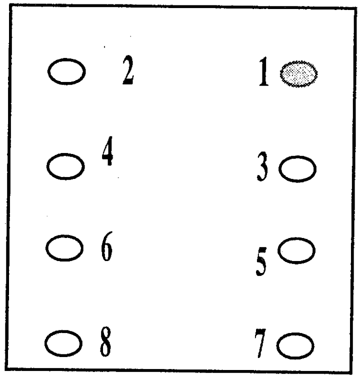




POWER SPLITTER

	MODEL NO	FREQ RANGE (MZ)	ISOLATION (dB) TYP	MIN	INSERTION LOSS(dB) TYP	MIN	PHASE UNBALANCE (DEG)	AMPLI UNBALANCE (dB)
1.	PSC2-1	0.1-400	20	15	0.2	0.6	2	0.15
2.	PSC3-1	1-200	45	30	0.6	1.0	1	0.15

	PIN CONFIGURATION				
	SUM PORT	PORT1	PORT2	PORT3	CASE GND
1.	1	5	6	■	2,3,4, 7& 8
2.	6	1	2	5	3,4,7 & 8



SPECIFICATIONS

ATTENUATOR

PIN CONFIGURATION

MODEL	FREQ RANGE (MZ)	ATTENUATION (dB)		VSWR (max)	I/P	O/P	CASE GND
AT-3	DC-1500	3+/-0.2	0.3	1.3	1	8	2 T0 7
AT-6	DC-1500	6+/-0.3	0.3	1.3	1	8	2 TO 7

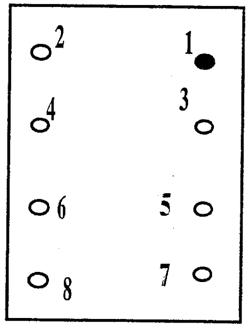
NOTE: CASE STYLE IS COMMON FOR PSC ,AT ,RK .

DOUBLER:

MODEL	FREQ (MZ)		RF I/P POWER (dBm)		CONVERSION LOSS(dB)			HARMONIC O/P(dB)			PIN CONFIG		
	I/P	O/P	MIN	MAX	I/P FREQ	TYP	MAX	F1	F3	F4	I/P	O/P	CASE GND
RK-2	0.05-150	0.1-300	0	13	0.05-50	11.5	15.0	40	45	16	1, 3, 4	8	2,5, 6,7
					5-100	13	16.0	40	50	16			

NOTE : I/P 1,3,4 MUST BE CONNECTED TOGETHER

CASE STYLE IS COMMON FOR PSC ,AT ,RK .

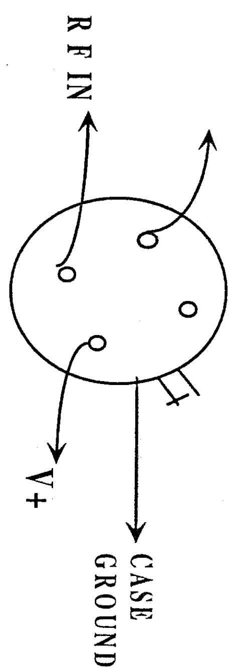


LOW PASS FILTER

MODEL	PASSBAND (MZ)	FCO(MZ) LOSS-3dB	STOPBAND LOSS >20dB	STOPBAND LOSS >40dB	VSWR PASS BAND	VSWR STOP BAND
PLP-5	DC-5	6	8-10	10-200	1.7:1	18:1

BAND PASS FILTER

MODEL	CENTER FREQ (MZ)	PASS BAND (MZ)	3dB BW (MZ)	STOP BAND(MZ) IL>20dB	STOP BAND(MZ) IL>35dB	VSWR PASS BAND	VSWR STOP BAND
PBP 10.7	10.7	9.5-11.5	8.9-12.7	7.5 & 15	0.6 & 50-100	1.7:1	16:1



AMPLIFIERS:

model	D.C vltg (V)	CONST RF I/P POWER (dBm)	OPTM CASE TEMP (DEG)	ACTIVE trn POWER DISSI (mw)	FREQ RANGE (MZ)	GAIN AT 100MZ (dB)	VSWR IN OUT	ISOL_ ATION (dB)	NOISE FIGURE (dB)	1dB COMP (dB)
GPD404	+15	+13	-55 TO +125	330	5to 400	10.5	1.32 1.11	22.94	7.5	+17
GPD1052	+15	+17	-55 TO +71	125	5to 1000	20	1.29 1.27	37.74	7.0	+8

COMPONENTS LIST

ITEMS	QUANTITY
POWER SPLITTERS	
PSC-2-1	1
PSC-3-1	1
ATTENUATORS	
AT-6	1
AT-3	1
FILTERS	
PLP-5 (LPF)	1
PLP-10.7 (BPF)	1
DOUBLER	
RK-2	1
AMPLIFIERS	
GPD-404	4
GPD-1052	1
CONNECTORS	
SMA	MALE—12 FEMALE--6

TRANSFORMER----- 10—0—10 V , 1 AMP.

PROGRAMMING COMMANDS :

1) **FA** ([.] < number > [(Hz/KHz/MHz/GHz)]

   Specifies the start frequency. Default unit is Hz. Query response : < numeric data format >

2) **FB** – Specifies stop frequency.

3) **TDF-P** : Trace data transfer for programming.

4) **TA?** : Transfers the 401 amplitude values of trace A to the controller.

5) **CF** : Specifies the center frequency. Default unit is Hz.

6) **SP** : Changes the total displayed frequency range symmetrically about the center frequency.

7) **RB** : Specifies the resolution bandwidth. Default unit is Hz.

8) **MKA** : Specifies the amplitude of the active marker (in the current amplitude units). When queried, MKA returns the marker amplitude independent of marker type .

9) **MF?** : Returns the frequency of the on screen active marker.

GPIB COMMAND :

1) **IBWRT :**

Purpose : Write data from string .

Format : C - int ibwrt (int ud, int *wrt, int cnt)
ud- specifies a device or an interface board.
wrt- the buffer of data to be sent over GPIB.

2) **IBRD :**

Purpose : Read data from a device to a string .

Format : C - int ibrd (int ud, void *rd, int cnt)
ud- specifies a board or a device.
rd- .is the storage buffer for data.

3) **IBLOC :**

Purpose : To set the device into local mode .

Format : C – int ibloc (int ud)
ud - specifies a device or an interface board.

/* PROGRAM FOR ACQUISITION OF PHASE NOISE DATA */

/* INSTRUMENT USED SPECTRUM ANALYSER HP-8593E */

```
#include "c:\at-gpibw\c\windecl.h"
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <string.h>

FILE *fp;
char *c_freq="CF",*c_mkpos="MKN",*c_quest="?";
char *c_span="SP",*c_rbw="RB",command[12];
char carray1[20],p1[25],amp[9];
double freq,fmkf,famp,start,span,m_span,stop,rbw,x[200],y[200];
int device,s_len,z;
long int count,count1;
float k,k1,nrbw,nspan,vag;

main()
{
    device=ibfind("8593E");          //identifing the device
```

```
if(device>=0)
  printf("device found\n");
  else
  exit(0);

ibwrt(device,"cf?",3L);        //reading center frequency
ibrd(device,carray1,12L);
printf("cf=%s",carray1);
freq=atof(carray1);
printf("fr=%f\n",freq);

ibwrt(device,"sp?",3L);        //reading span
ibrd(device,carray1,12L);
printf("span=%s\n",carray1);
span=atof(carray1);
printf("sp=%f\n",span);

ibwrt(device,"rb?",3L);        //reading rbw
ibrd(device,carray1,8L);
printf("RBW= %s\n",carray1);
rbw=atof(carray1);
printf("rb=%f",rbw);

/* marker movement & amp reading   */
```

```
label:  ibwrt(device,"vavg10on",8L);
        for(z=1;z<40;z++)
    {
        count1=2500000;
        delay(count1);
    }
     m_span=(span/2.0);     // calculating start & stop frequency
     start=freq-(m_span);
     stop=freq+(m_span);



    printf("\nStart              Freq:%f\tStop              Freq:%f\t
RBW=%f\n",start,stop,rbw);
    printf("\n\n  PLEASE WAIT FOR  NEXT MESSAGE    \n");

  for(start;start<=stop;start=(start+rbw))
 {
    gcvt(start,10,p1);          // float to string conversion
    strcpy(command,c_mkpos);
    strcat(command,p1);
    s_len=strlen(command);             //marker movement
```

```
ibwrt(device,command,s_len);



count=2500000;                 //about 1sec delay
   delay(count);
   ibwrt(device,"MKF?",4L);          // reading marker frequency
   ibrd(device,carray1,18L);
   printf("\n MKF=%s\t",carray1);
   fmkf=atof(carray1);      // string to float conversion
   x[k]=fmkf;

  ibwrt(device,"MKA?",4L);          // reading marker amplitude
  ibrd(device,amp,8L);
  famp=atof(amp);

y[k]=famp;
  k=k+1;
}
  k1=span/rbw;          //number of points
  fp=fopen("t.t","a");
  fprintf(fp," CF=%f SPAN=%f RBW=%f\n ",freq,span,rbw);
  fprintf(fp,"%s\t%s\n\n","FREQUENCY","AMPLITUDE");
```

```
for(k=0;k<=k1;k++)      // frequency and amplitude points are
written into the file
{
  fprintf(fp,"%.2lf\t%.2lf\n",x[k],y[k]);
}
  k=0;
  fclose(fp);

  ibwrt(device,"spdn",4L);    // span is reduced
  ibwrt(device,"sp?",3L);
  ibrd(device,carray1,12L);
  printf("span=%s\n",carray1);
  nspan=atof(carray1);

  if(nspan==1000.0)     // if span goes to 1KHz stop
{
  goto label1;
 }
  else
        span=nspan;     // otherwise acquisition is repeated,for new
span & rbw
        printf("sp=%f\n",span);

 ibwrt(device,"rb?",3L);
```

```
ibrd(device,carray1,8L);

rintf("RBW= %s\n",carray1);
  nrbw=atof(carray1);
  rbw=nrbw;
  printf("rb=%f",nrbw);
  goto label;

label1:   ibloc(device);    //instrument is set to local mode

  printf("\n   MEASUREMENT IS OVER  \n");
  return;
 }

/* DELAY FUNCTION */
  delay(m)
  long int m;
 { long int j;
  for(j=0;j<=m;j++);
  return;
  }
```

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c) HP 8657-B SYNTHESIZER

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