CHAPTER – IV

EXPERIMENTAL WORK AND RESULTS

The *PC*-based *Interferometer* can be split, for convenience, into three functional units ***viz.***, the field unit ,the lab unit and the PC-based DAS as shown in Fig. 4.1. The field unit is made up of the following building blocks, as ***briefly*** touched upon in Section 3.1.1, and given in Fig. 3.1.

a) Two groups of 16 ***Helical*** antennas on a east west base line (700 m)

b) Primary R F power combiners

c) ***Highpass*** filters and LNA

d) ***Secondary*** *RF* power combiners

e) First Heterodyning Mixer with associated circuitry

f) Local Oscillator (LO) distribution network

The desirable characteristics of this unit are summarised in Table 4.1.

The lab unit is made up of the following building blocks as also touched upon in Section 3.1.1 and given in Fig. 3.2.

a) First IF amplifiers (in both the chains)

b) Second Heterodyning mixer with associated ***RF/IF*** circuitry

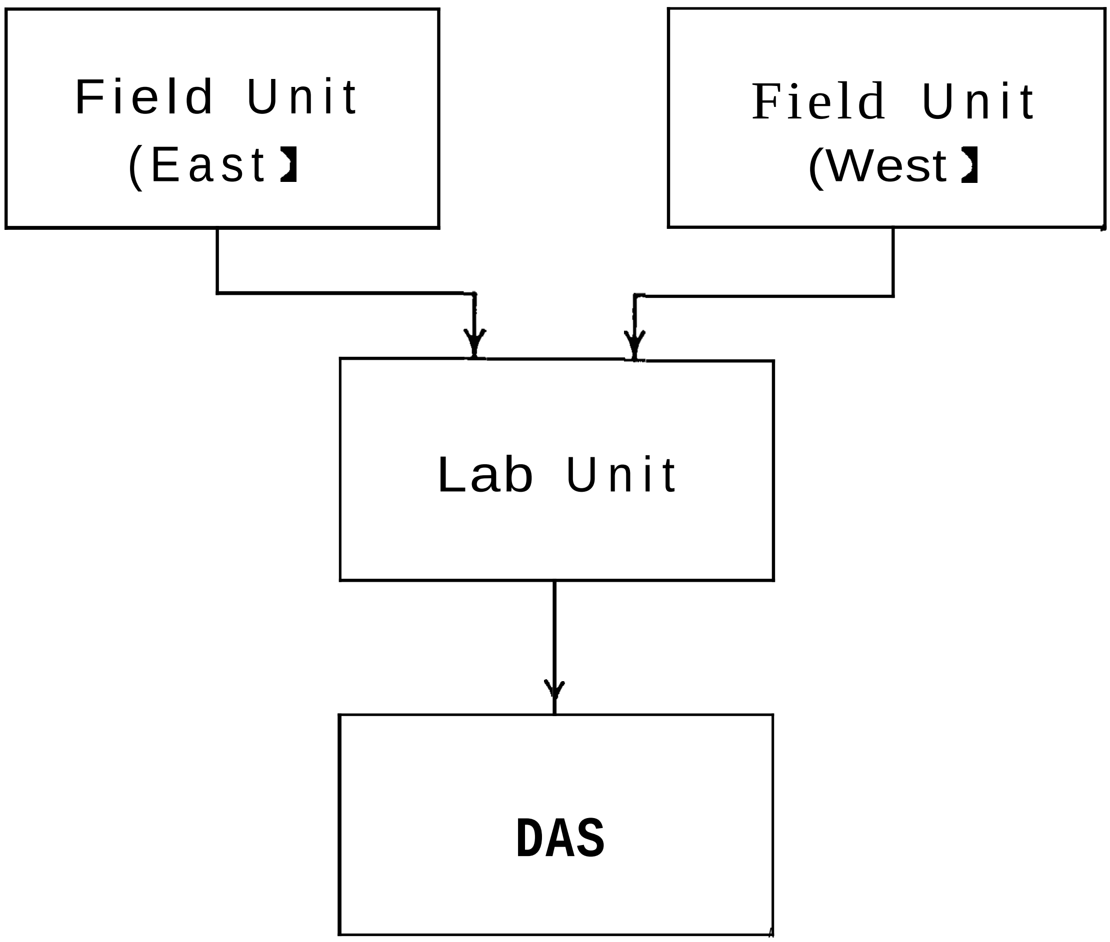
c) *Correlators* and *PSDs*

The desirable characteristics of this unit are summarised in Table 4.2.

The PC-based DAS is made up of the following building blocks as discussed in Section 3.1.2 and given in Fig. 3.3.

a) *MUX and PGA*

b) ADC with associated circuitry



Fiqure 4.1 Radio Interferometer
- Block Schematic

TABLE 4.1

FIELD UNIT - DESIRABLE CHARACTERISTICS

Stage	Specifications (value)	Remarks
Antenna a) Sensitivity b) Collecting area c) Number of elements	250×10^{-26} $watts/m^2/Hz$ *64* sqm 32	To see atleast 10 radio sources Minimum for required sensitivity 16 each in East and West
Primary RF power combiner	4 - way 0°	Combines 4 antennas to one group
Highpass filter and LNA	f_o =140 MHz G = 30 dB NF = 2.7 dB	Cuts off interference from communication band
Secondary RF power combiners and amplifier	4 - way 0° G = 30 dB	Combines 4 groups to one RF signal;
First Mixer and associated RF/IF circuitry	(in MHz) RF = 150 LO = 180 IF = 30, BW = 10	Active preferred i) Low LO power input ii) Conversion gain iii) Good port isolation
LO distribution network	East - west 700m LO power = -7 dBm	Identical phases in both chains required

TABLE 4.2

LAB UNIT - DESIRABLE CHARACTERISTICS

Stage	Specifications (value)	Remarks
First IF amplifiers	f_o = 30, Δ f = 10 MHz G = 30 dB	To compensate for cable loss from field to lab
Second Mixer and associated circuitry	(in MHz) LO = 35-45, tunable 2nd IF = 10.7 Δ f = 1	for interference rejection; Passive mixer
Correlators and PSDs	2 channel 1- 10mV	Analog; Phase correction capacity

c) Timing and Control logic

d) PC-XT

The desirable characteristics of this unit are *summarised* in Table *4.3.*

While the design and development of this DAS is the subject matter of the Thesis, it becomes necessary to have the *Interferometer sys*tem functioning to put the PC-based DAS to a *real-life* test and use. In order to achieve this goal, the various building blocks of the Interferometer, such as those mentioned earlier, were also developed and *evaluated* for their performance. Design *optimisation* was carried out in the lab, to meet the desired *char*-acteristics of the various sub-assemblies used for the building blocks.Tests were carried out by simulating their input conditions (except in the case of

TABLE 4.3

DAS - DESIRABLE CHARACTERISTICS

Stage	Specifications (value)	Remarks
MUX and PGA	2 channel G = 1 - 100	For Sine and Cosine; Programmable for better dynamic range
ADC	10 bit resolution at least 2 conversions in 100 mS	Dual slope integrating type adequate
Data storage	40 Kbytes per source	To be transferred to secondary storage later
Timing and control	to interface MUX, PGA, and ADC	PC-XT bus compatible
PC-XT	MOS memory 640 Kbytes Winch 40 Mbytes	Any standard PC-XT compatible, adequate

the helical antenna) for evaluating their performance. Standard test and measuring instruments like RF signal generators, RF power meter, Vector voltmeter, Scalar network analyser, Noise figure meter, Function generator, Oscilloscope. Logic probes etc. were used in the lab to carry out the simulation and functional evaluation. Upon their satisfactory functioning, the units were transferred to the field station at Gauribidanur for installation. The details of the test setup in each case and the results thus obtained are now briefly described.

4.1 Field Unit

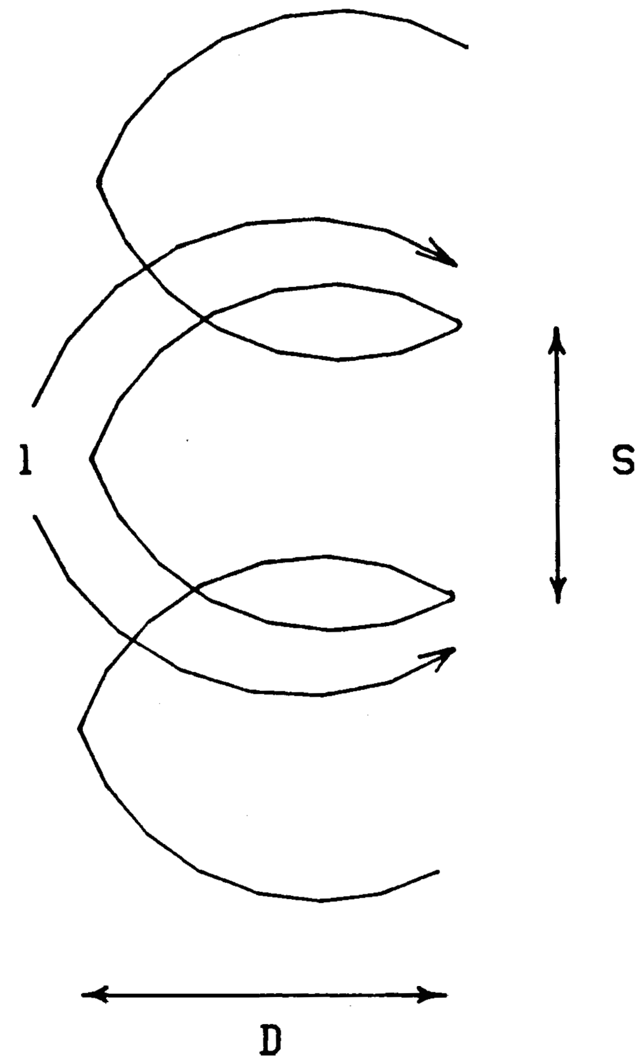
4.1.1 Antennas : A typical sketch along with the dimensions of the *Helical* antenna, suitable for the *frequency* band 80 to 160 MHz is given in Fig. *4.2a*. *All* the **32 antennas** (dimensions $D=$ 75 cm, $S=$ 54 cm, $n=$ **3)** were fabricated in the workshop using hollow *aluminium* tubes (dia 10 mm) for the radiating element and PVC tubes (dia 11 cm) for the support structure. One such antenna is shown in Fig *4.2b*. The VSWR characteristics of these helices were measured over the *frequency* band 60 to 200 MHz. A test setup for this purpose is shown in in Fig. *4.3a,* which is self explanatory. The experimental results of a typical antenna are presented in graphical form in Fig. *4.3b*. As seen from this graph the measured value of the VSWR is below 1.5 in the frequency range 80 to 160 MHz; similar results have been obtained for all the antennas. This clearly demonstrates that the antenna bandwidth is adequate for use in the radio interferometer.

4.1.2 Primary **RF power** combiners : The power combiner is ideally a *lossless* reciprocal device which can perform the vector summation of two or more *signals*. The main characteristics that govern the proper choice of power combiners are:

a) phase *difference* introduced between the R F channels combined; and

b) insertion loss through the combiner.

Such power combiners are commercially available from several sources nowadays, with considerable standardisation . Generally they are in hybrid circuit form. Hence, the hybrid circuits type *PSC4-3,* (*Mini*-Circuits USA)



Lenqth per turn (l) = 234 cm

Diameter (D) = 75 cm

Spacing [redacted] = [redacted] cm

No. of turns (n) = 3

Fiqure 4.2(a) Helical Antenna - Sketch uith Dimensions

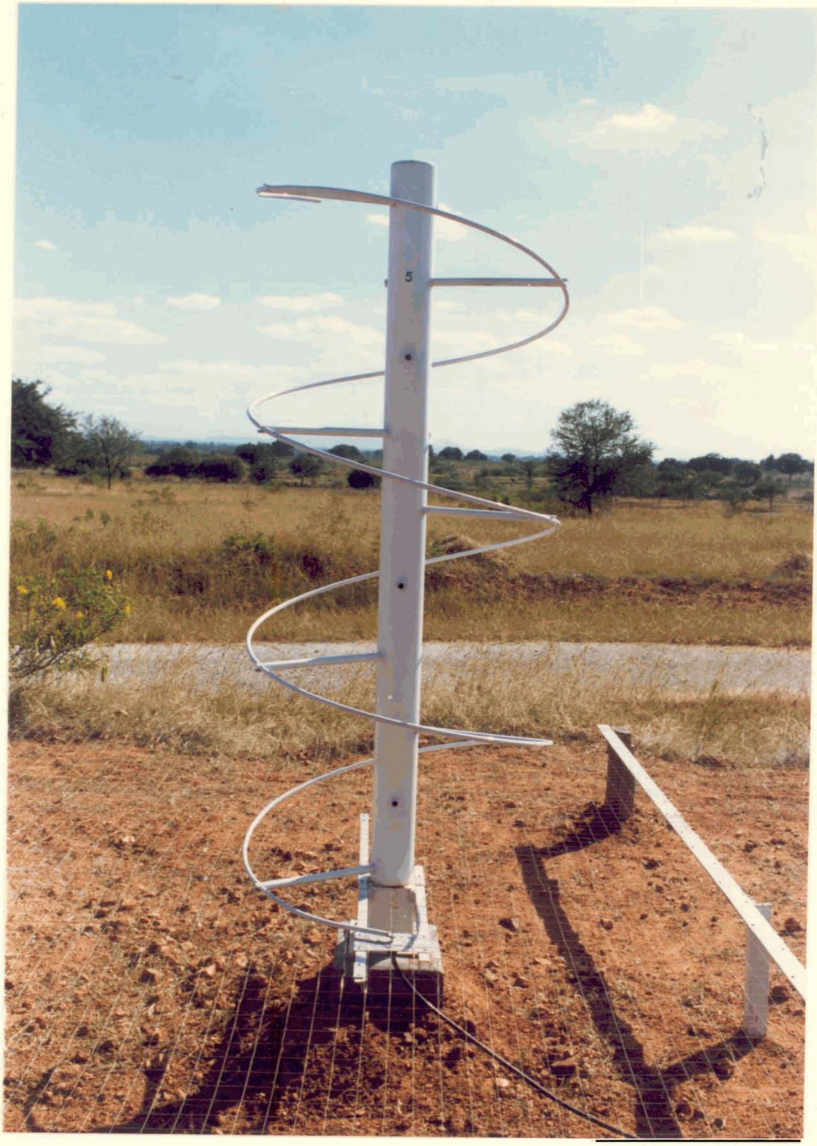
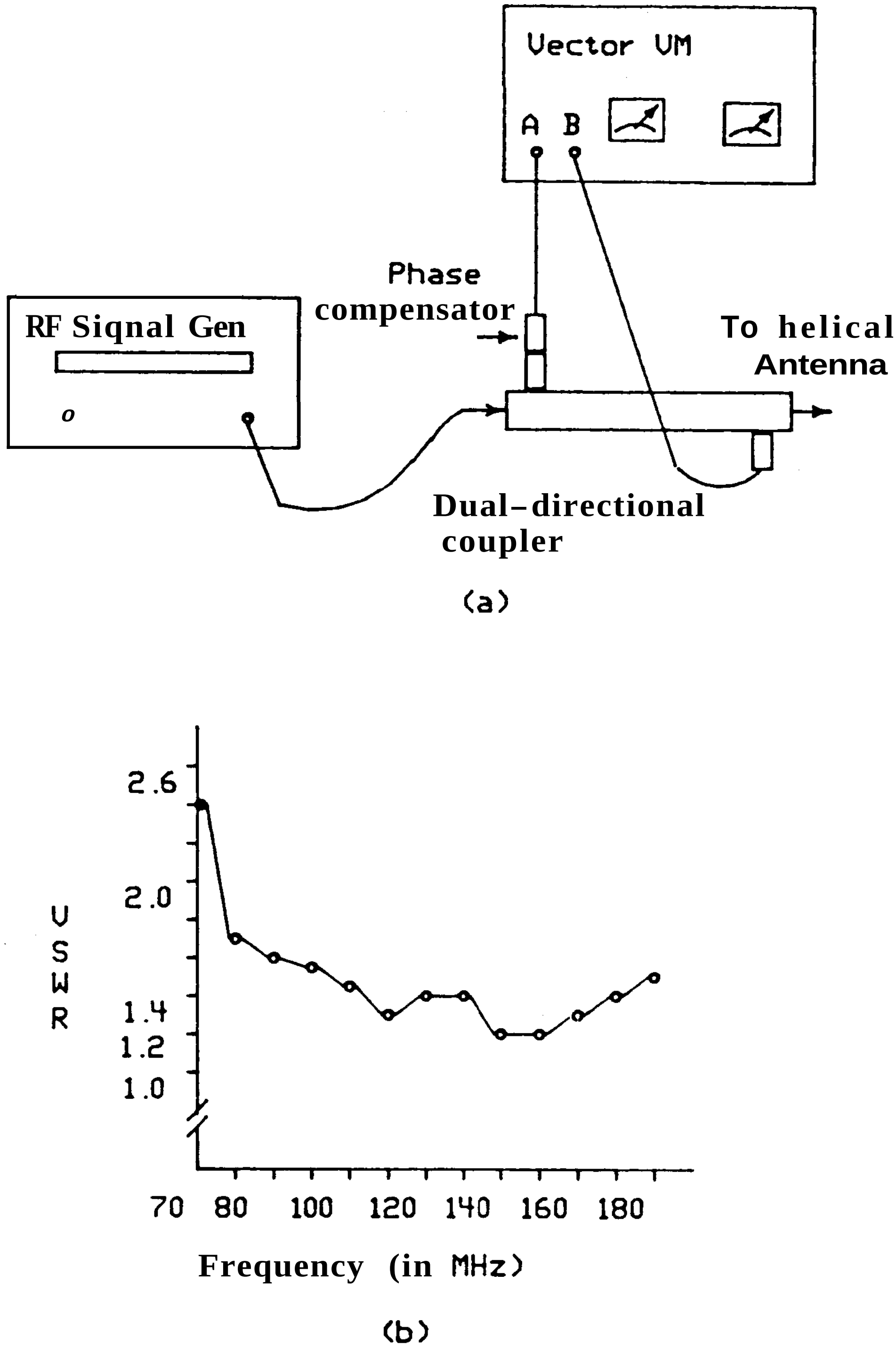


Figure 4.2(b)   A Typical Helical Antenna



Fiqure 9.3 Antenna impedance measurement - Test setup (a) uith USWR Characteristics (b)

were chosen for use as combiners in this work. The important characteristics of a typical combiner are given in Table 4.4. For ease of operation and maintenance in the field. each of these combiners is mounted on a suitable PCB with the incoming RF coaxial cable *(RG8-U* 50 Ω*)* from the antenna soldered thereon. Eight such units have been made to connect the ***32*** antennas in the field. While designing the PCB, special attention has been given to:

a) minimise interconnection loss - by directly soldering the RF coaxial cable on to the PCB; ***and***

b) maintain equal path lengths for *all* the four inputs - to avoid introduction of any phase difference between the channels.

The phase difference introduced between the *RF* channels combined *and* the insertion loss have been measured using a Vector voltmeter, RF *signal* generator, and a standard 2-way power splitter as shown in the test *setup* of Fig.4.4. The results are summarised in Table *4.5*. Similar results *have* been obtained for all the eight units. As seen from this Table, the phase difference introduced is of the order of 0.2°, which is much better than the tolerance of 0.5° set for this stage (Table 4.1).

4.1.3 <u>Hiphpass filter and LNA</u> : As the interferometer is *sensitive* to *very* weak RF signals, radiated emissions in *HF*, VHF bands as well as urban noise are the main sources of interference. In order to *minimise* the effect of such interference, it becomes necessary to use a suitable filter with the front end RF circuitry of the interferometer. **A** *highpass* filter is preferred here to a *bandpass* filter because:

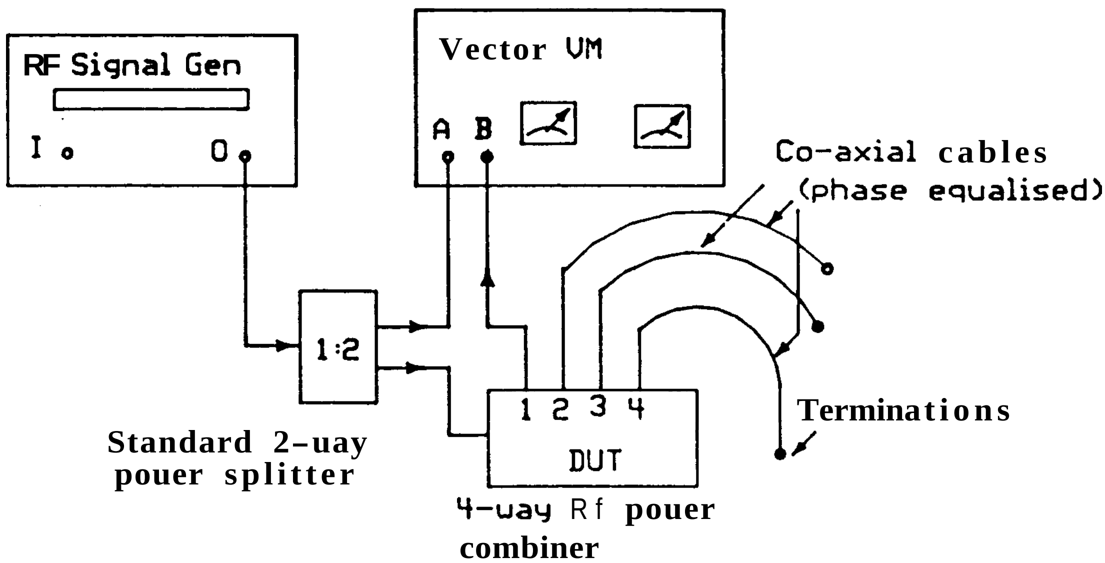


Figure 4.4 RF Pouer Combiner - Test Setup

TABLE 4.4

RF POWER COMBINER - IMPORTANT CHARACTERISTICS

Parameter	Value (typical)	Remarks
Frequency range	1 - 200 MHz	Assured BW
Isolation	30 dB	between channels
Insertion loss	0.5 dB	Maximum
Phase unbalance	5 °	Maximun
Impedance	50 Ω	Nominal

TABLE 4.5

PRIMARY RF POWER COMBINERS - TEST RESULTS

Input channel	Phase introduced	Insertion loss (dB)	Remarks
1	0°	0.6	Phase reference
2	0.2"	0.6	
3	0.15"	0.6	
4	0.1"	0.6	

a) the response of the *Helical antenna* to *UHF is* low; and

b) it has a relatively low insertion loss.

Apaxt from the pass and stop band frequency of the filter, the other parameters that govern a proper choice of the *filter* axe:

a) insertion loss, and

b) phase introduced by different units.

Filters axe available commercially nowadays, with very low insertion loss, excellent phase matching between them and low cost. Hence, a *highpass* filter type *PHP-150* (Mini-Circuits USA) has been used here. Some of the important characteristics of this filter axe *summarised* in Table 4.6.

TABLE 4.6

HIGHPASS FILTER - IMPORTANT CHARACTERISTICS

Parameter	Value (typical)	Remarks
Band width	140-600 MHz	1 dB points
Insertion loss	0.5 dB	at 150 MHz
Attenuation	> 20 dB > 40 dB	100 MHz 70 MHz
Impedance	50 Ω	Input/output

The *filter* is combined with the LNA in a single module so as to avoid the use of coaxial cables, which *are* generally lossy. This also ensures that there is no further S/N degradation. The temperature of the sky at the observing frequency (150 MHz) is about 3100 K (Appendix A). To obtain good *S/N* for the interferometer system, the noise temperature of the first amplifier chosen should be of this order or better. In earlier times, this stage was the most *difficult* to realize; but, nowadays these units are available as hybrid circuits commercially at an economical price. Hence, hybrid circuit LNA type MAN-LN-1 (Mini-Circuits USA) has been used here. The important *cahracteristics* of this LNA are summarised in Table 4.7. The noise figure of this module has been measured using an *HP* Automatic noise figure meter and the results are presented in the graph of Fig. 4.5. The gain and input impedance of this module have been experimentally determined ***by*** measuring its transmission and *reflection* characteristics. The test setup is shown in Fig. 4.6 and a plot of these parameters as obtained from the *Network-analyser* is shown in Fig. 4.7. The test results of all the eight modules developed in the laboratory are in the same range. As seen from the transmission plot, the *highpass* filter cuts-off *all* the lower RF signals (communication band) which would otherwise saturate the amplifier and lead to distortion. *From* the plot of reflection characteristics, it is evident that this module has *a* very good input impedance match (about 55 Ω) over the operating *frequency* band.

4.1.4 Secondarv RF power combiner and Amplifier : The four LNA outputs are brought to the midpoint of the group of 16 antennas through phase equdised *coaxial* cable (*RG8-U* 50 Ω) each of 15 m length. Here, these outputs from the *LNAs* are combined to form one single *RF* signal from

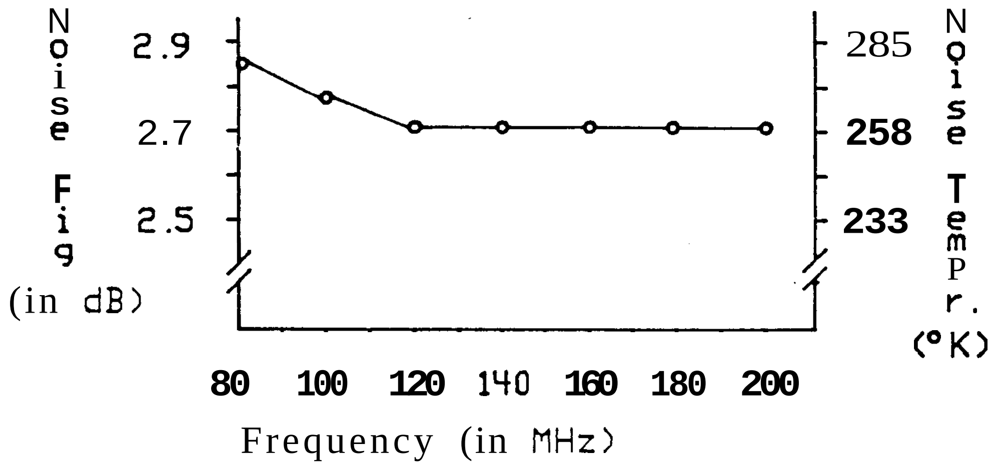


Figure 4.5 LNA - Noise Characteristics

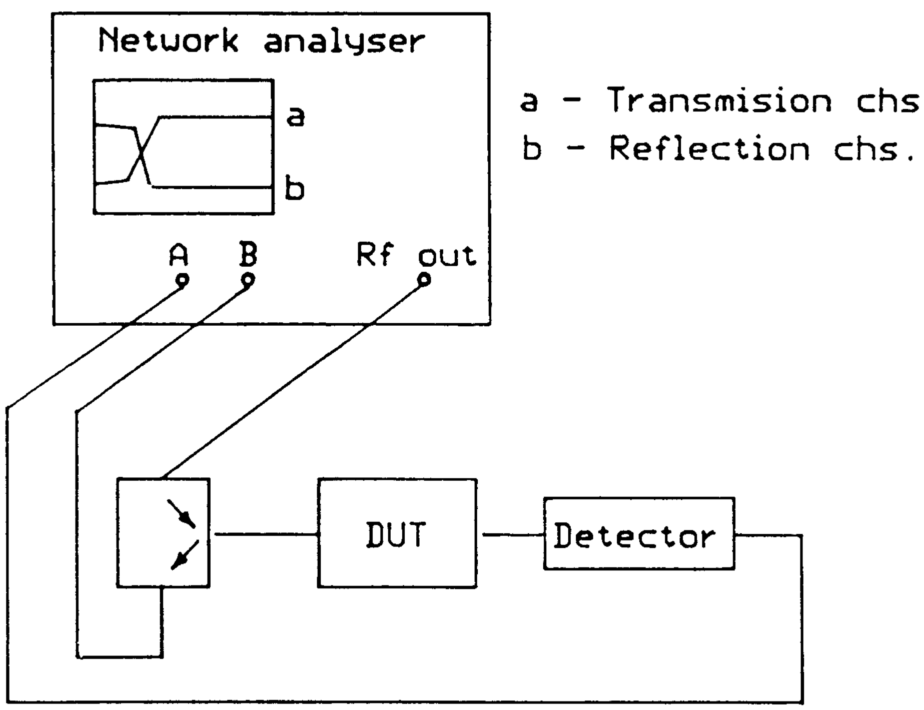
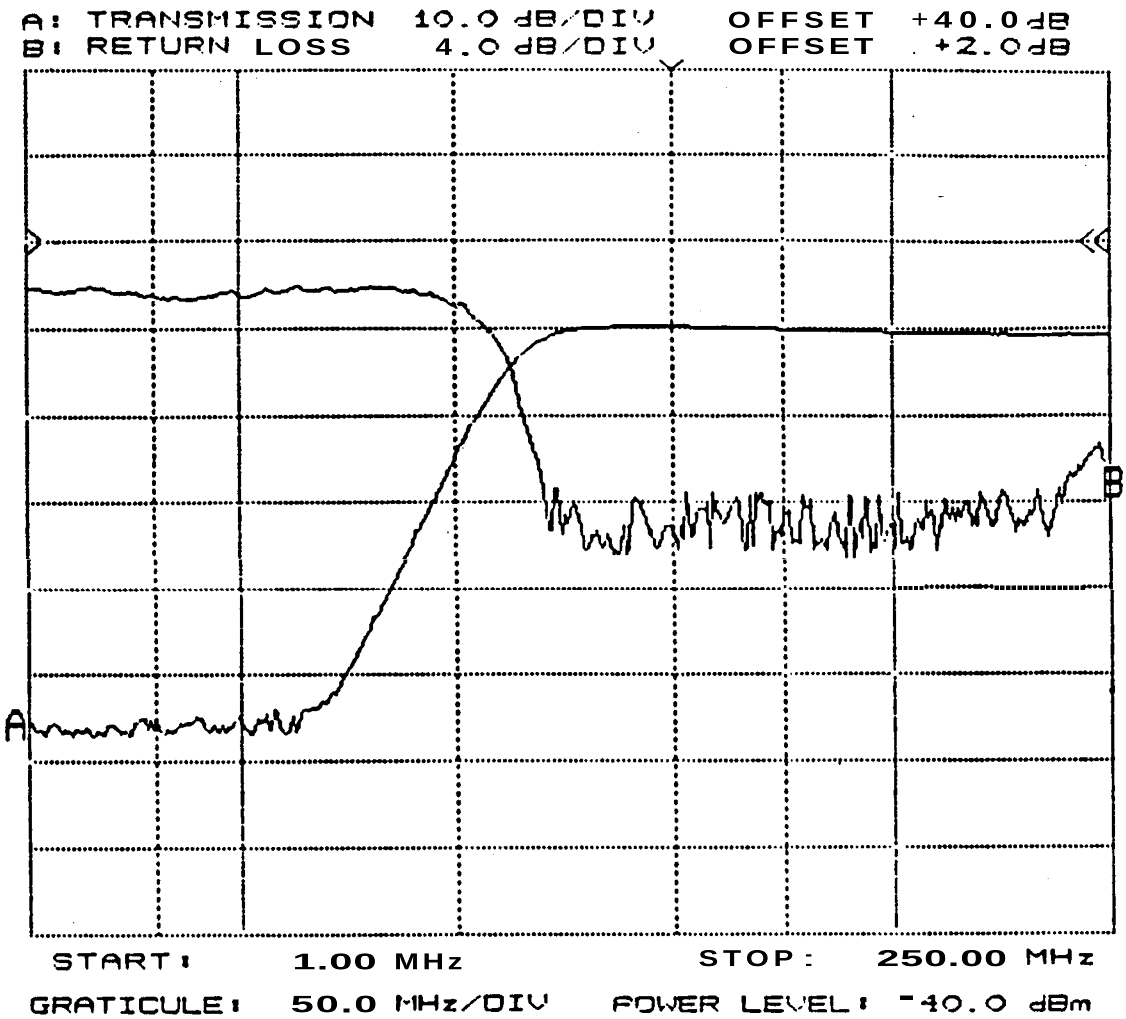


Figure 4.6 Hi-pass Filter & LNA Module - Test Setup



---------- Additional Instrument Information ---------

Channel A:	High Limit : --- off ---	Low Limit : --- off ---
Channel B:	High Limit : --- off ---	Low Limit : --- off ---

Preq Data Points : 401 Smoothing : MAX Power Level : -40.00 dBm

---------- Markers ---------- ----- Readout HB -----

HI : 30.00 MHz	M5 : --- off ---	
HZ : 100.00 MHz	M6 : --- off ---	Amplitude A : +30.01 dB
H3 : 150.00 MHz	M7 : --- off ---	
M4 : 175.00 ~ Hz	H8 : --- off ---	Amplitude B : -11.44 dB

Figure 4.7 Hi-Pass Filter and LNA Module - Transmission and Reflection Characteristics

TABLE 4.7

LNA - IMPORTANT CHARACTERISTICS

Parameter	Value (typical)	Remarks
Frequency range	0.5 - 500 MHz	Broad band device
Gain	30 dB	Nominal
Noise temperature	260° K	At room temperature
Max power output	0 dBm	1 dB compression point
Third order intercept	+18 dBm	Nominal
Impedance	50 Ω	Input/Output
DC power requirement	+12 V, 60 mA	Low power device

the *16* antennas in each arm as shown in Fig. ***3.1.*** To meet the input RF power level requirement of the mixer that follows, it is necessary to amplify this signal here. The power combiners used here axe similar to the units used in the previous section. While any RF amplifier with the required gain can be used for *amplification* at this stage, the ***LNA*** type *MAN-LN1* has been used in this stage *also,* because of ease of maintenance and convenience. Hence, the same test setup (Fig. 4.6) ***has*** been used here also for evaluating the performance. The results axe *summarised* in Table

4.8. Both the modules have yielded similar results. As seen form Table 4.8 the overall phase difference between the four groups is maintained to better then 0.2, which is more than adequate in this application. The gain and noise figure of the amplifier are consistent with results obtained in the previous stage.

TABLE 4.8

SECONDARY RF POWER COMBINERS - TEST RESULTS

Input channel	Phase introduced	Insertion loss (dB)	Remarks
1	0°	1.6	Phase reference
2	0.25"	1.6	
3	0.1"	1.6	
4	0.2"	1.6	

4.1.5 First Heterodvning Mixer: **As** seen from Table 4.1, it is necessary to use an active mixer for heterodyning in the field because of the following advantages over passive counterparts:

a) *low LO* input powerrequirement, and

b) built-in conversion gain.

Transistor based mixers are available today, which only need external passive components for biasing purposes. The choice of these components decides the conversion gain of the mixer. Mixer type *MCL* 1596 (Motorola *USA)*, which uses junction transistors as the non-linear elements for the mixer action has been chosen for use in the field unit. Two such units have been built for the two arms of the interferometer. Some of the important characteristics of this mixer are summarised in Table 4.9. The *performance* of this mixer along with the IF filter and the IF amplifier *has* been *evaluated* using the test setup shown in Fig. 4.8. The test results of this module are given in Table *4.10a* and 4.*10b*. Both the mixers have yielded similar results. It is evident from this Table that the mixer needs a LO power of *atleast* -10 *dBm* for optimum operation. This is explained further in the following section.

TABLE 4.9

ACTIVE MIXER - IMPORTANT CHARACTERISTICS

Parameter	Value (typical)	Remarks
RF input range	10 - 300 MHz	
IF output range	0.5 - 100 MHz	With conversion gain
CMRR	85 dB	Balanced device
RF supression at IF	65 dB	At highest frequency
DC power	< 50 mW	Low power device

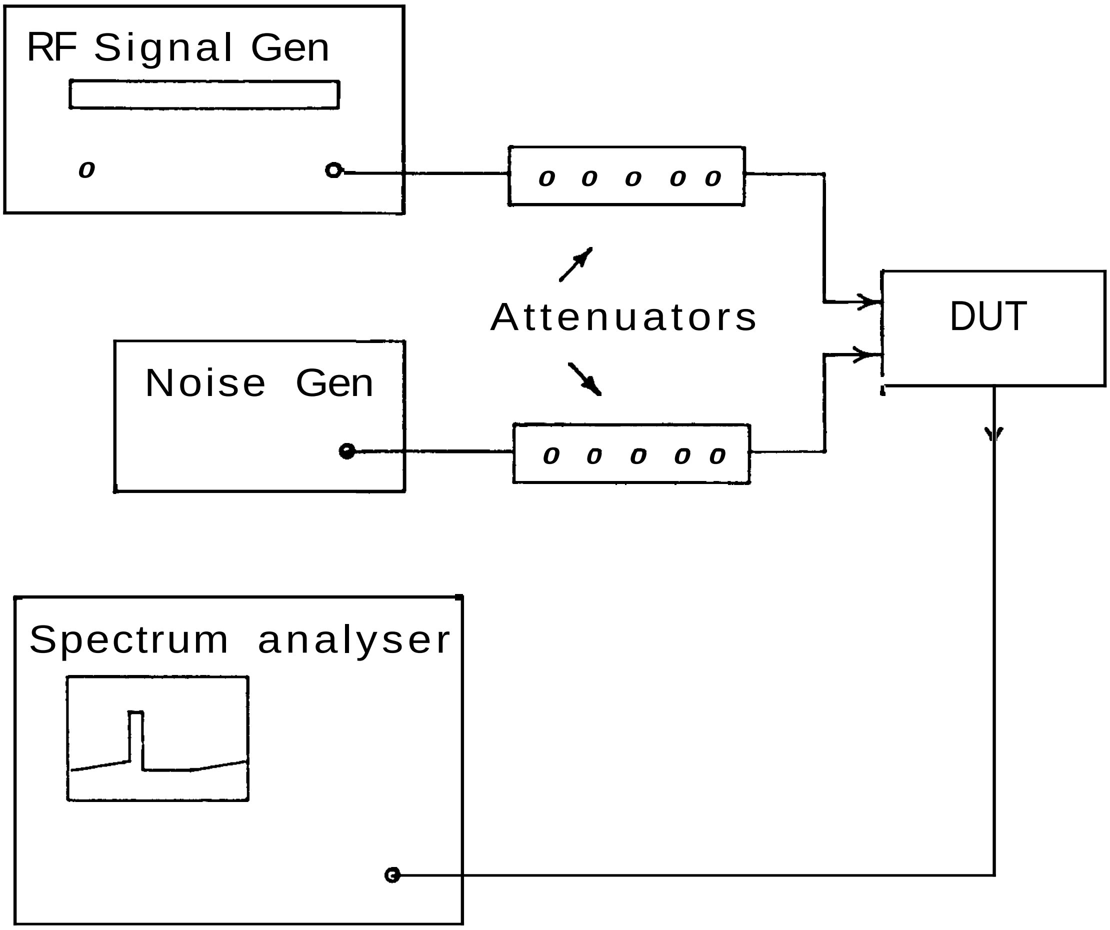


Figure 4.8 Active Mixer - Evaluation Setup

TABLE 4.10a

ACTIVE MIXER MODULE - TEST RESULTS

(RF varying, LO fixed)

RF input (in dBm)	IF output (in dBm)	Remarks LO fixed @ -10 dBm
-30	0	Amplifier saturated
-40	-3	Operating region
-50	-13	-do-
-60	-23	-do-
-70	-33	-do-
-80	-44	Nonlinearity noticed
-90	-56	Totally nonlinear

4.1.6 LO distribution Network : As this interferometer uses a double superheterodyning technique for reasons already explained in the previous Chapter, the first stage is incorporated in the field unit. One of the major requirements in such a system is that the phase of the LO at the two arms of the interferometer (*700* m apart) should be maintained the same. The LO signal generated in the lab is boosted in power *and* then sent through a coaxial cable *(RG8-U)* as shown in Fig. 4.9. As the loss in this cable at the LO frequency (*180* MHz) is of the order of *10 dB/100* m, and the distance

TABLE 4.10b

ACTIVE MIXER MODULE - TEST RESULTS

(RF fixed, LO varying)

LO input (in dBm)	IF output (in dBm)	Remarks RF fixed @ -70 dBm
0	-33	Normal operation
-5	-33	-do-
-10	-33	-do-
-15	-48	Nonlinearity noticed
-20	noise	unusable

to the *furthermost* group of antennas is about 500 m from the lab, a repeater amplifier is necessary in the field as shown. The cables used between power splitter in the field and the mixer units (350 m each) have been phase *equalised* using the test setup shown in the Fig. 4.10. The phase difference measured has been found to be less than 0.5^o at 180 MHz and its stability has been checked over *several* days and found to be satisfactory. As the temperature changes underground are much less than in open air, these cables have been buried underground to maintain better phase stabillity over an extended period, like several days.

As the *LNAs,* the mixer and its associated *RF/IF* circuitry need dc supplies,

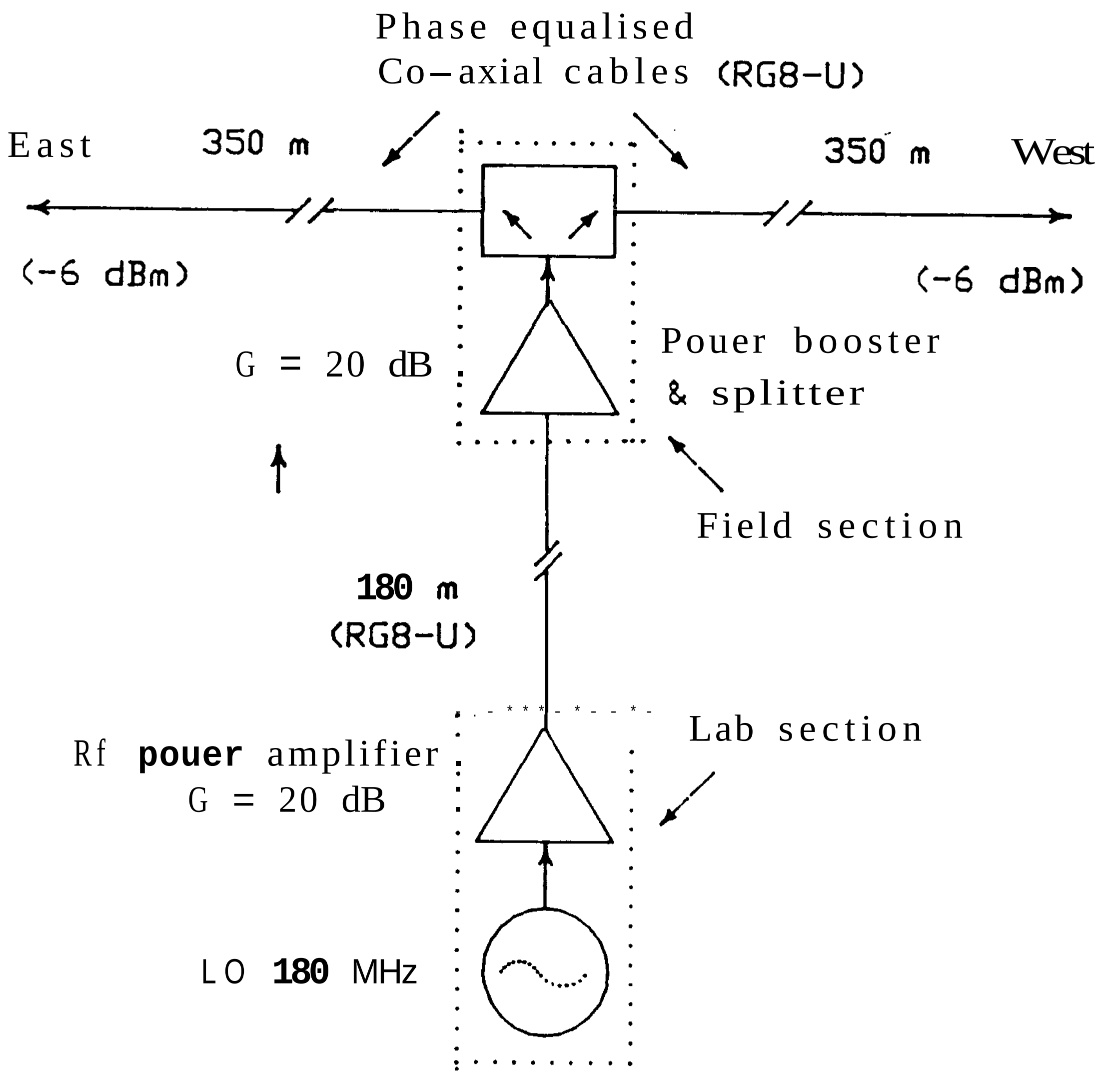


Figure 4.9 Ist LO Distribution Netuork

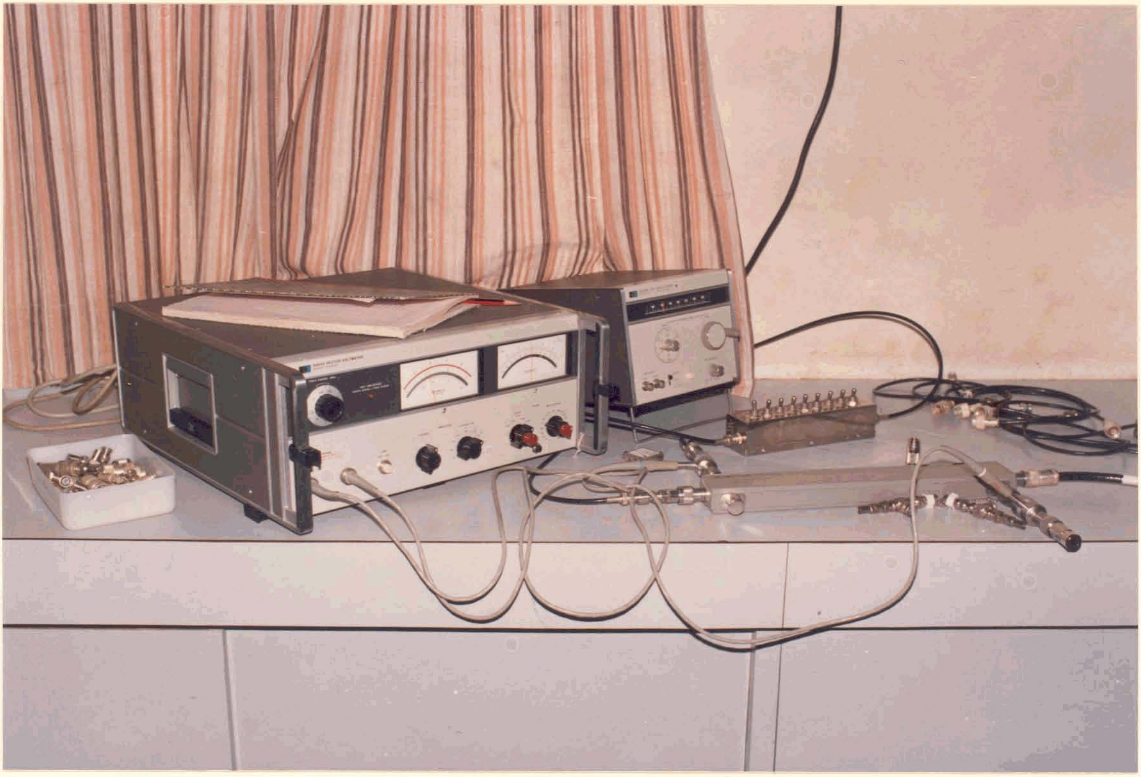


Figure 4.10 Co-axial Cable Phase Equalisation - Test setup

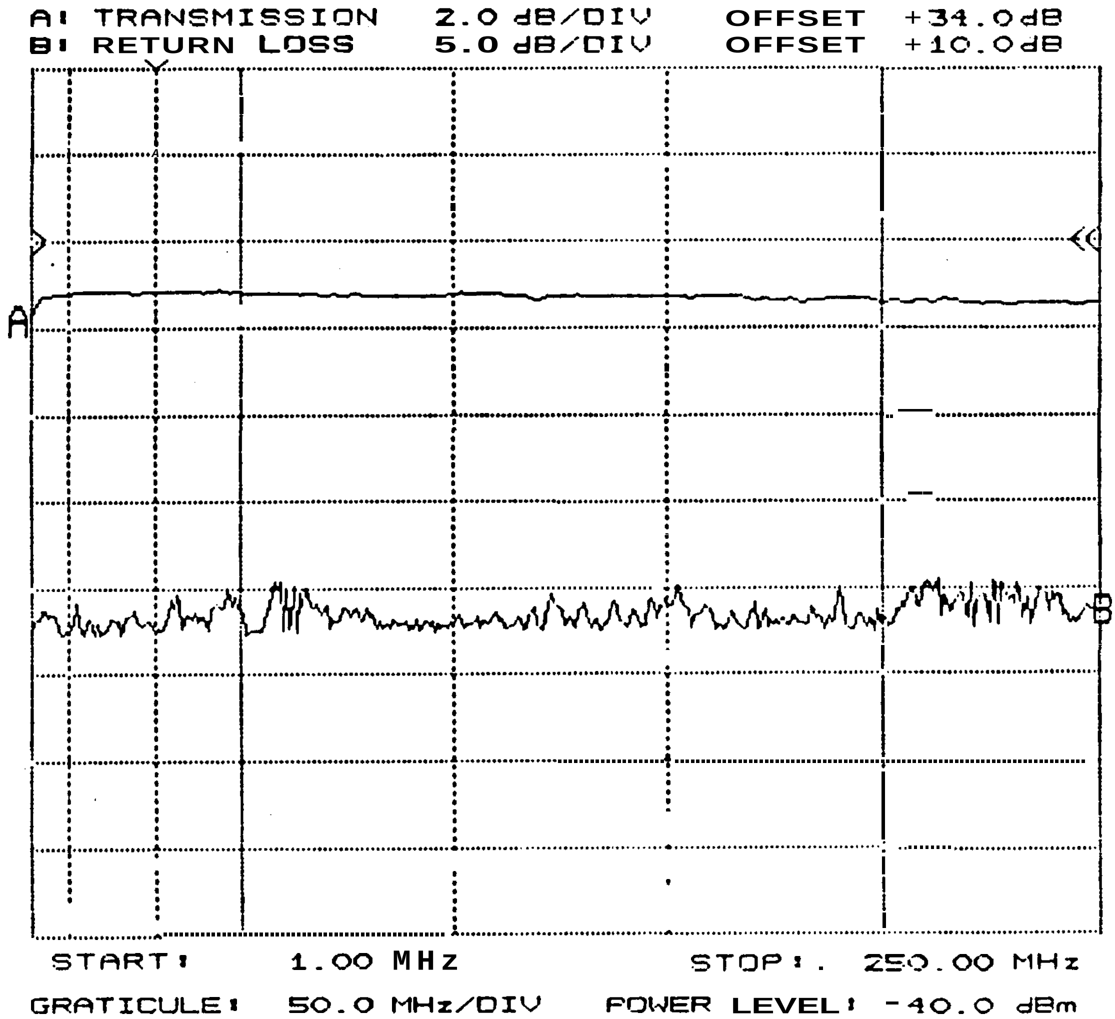
Figure 4.11 Field Pouer Supply

a dc power supply has been built using step down *transformers,* rectifiers and smoothing capacitors. This supply has to be placed in the box below the mixer housing in the field itself as shown in Fig 4.11. This unit supplies unregulated dc, as each of the modules requiring dc supply have on-board regulators. These power supplies were tested for ac ripples on full load and have been put to soak test for a few days before they were shifted for installation. The required mains power for this power supply unit has been tapped off from the existing infrastructure in the field itself. Also there is a dc switch for the supply for the four *LNAs,* which helps in testing the field unit periodically.

4.2 Lab Unit

4.2.1 First IF Amplifiers : The first IF signals (*IF*= 30 MHz B*W*= 10 MHz) are brought to the central lab from the east and west groups through buried phase *equalised* coaxial cables (600 m each). In order to compensate for the loss suffered by the signal in these cables, it is necessary to amplify them suitably. For convenience and ease of maintenance, the same amplifiers as used in field units, viz., *MAN-LN1* are used here also. As two chains are present in the system (Fig. *3.2),* two such amplifiers have been used. The test setup to *evaluate* the performance of this stage is similar to the setup given in Fig. ***4.6.*** The plot of the transmision and reflection *characteristics* measured are given in Fig. 4.12. The plots obtained for both the amplifiers are similar. The gain of these amplifiers is adequate to match the input power levels required for the mixer stage that follows.

4.2.2 Second Heterodyning mixer : Having exploited the image rejection feature



---------- Additional Instrument Information ---------

Channel A: High Limit :. --- off --- Low Limit : --- off ---
Channel B: High Limit : --- off --- Low Limit : --- off ---

Preq Data Points : 401 Smoothing : HAX Power Level : -40.00 dBm

---------- Markers ----------

M1 :	10.00 MHz	US :	--- off ---
H2 :	30.00 MHz	M6 :	--- off ---
H3 :	100.00 MHz	M7 :	--- off ---
M4 :	150.00 MHz	M8 :	--- off ---

----- Readout H2 -----

Amplitude A : +32.81 dB

Amplitude B : -12.57 dB

Figure 4.7 IF Amplifier - Transmission and Reflection characteristics

by choosing the first *IF* at a fairly high frequency, and a proper input filter, the signals are now converted to a much lower IF for ease of operation. There is a lot of standardisation in the TV IF range (10.7 MHz), and circuit elements operating at this frequency, are available commercially at low cost. Hence, 10.7 MHz (BW = 1 MHz) **was** chosen as the second IF in this system. *In* order to tune out any incoming interference in the IF signals from the field, the second LO must be tunable in the frequency range 35.7 to 45.7 MHz. This has been acheived by using a standard variable *frequency* RF signal generator (Model TF 2015, English Electric) for this purpose. Generally, signal generators of this class have output power levels programmable *upto* +13 *dBm.* This is quite satisfactory for the mixer stage even when using a passive mixer. A diode-based double balanced mixer has been chosen for use here, because of its inherent isolation between the various ports. These diode mixers dong with the RF transformers are available as standard hybrid circuits now-a-days. Such a mixer, type SBL-1 (Mini-*Circui*ts USA) has been used here. The mixer is followed by the IF *bandpass* filter as shown in Fig. 3.2. This filter is a *commercial* unit commonly used in TV sets. Two such filters type BRI 3-10.7 *CC* 10 (Cirqtel USA) have been used in the two chains of the lab unit. *Important* characteristics of the mixer and the *bandpass* filter are summarised in Tables 4.11 and 4.12. A similar test setup as shown in Fig 4.8 has been used here also. The results are summarised in a Table 4.1**3.** The *performance* of both the units has been found to be similar and adequate for the application. As seen *from* Fig 3.2, the LO *signal* fed to one of the mixers is phase switched. This is important

TABLE 4.11

2nd IF BANDPASS FILTER - IMPORTANT CHARACTERISTICS

Parameter	Value (typical)	Remarks
Band width	25 - 35 MHz	1 dB points
Center frequency	30 MHz	First IF
Attenuation	> 10 dB > 20 dB	10 - 100 MHz 2 - 200 MHz
Input/output impedance	50 Ω	Nominal

in minimising the effects of gain instability in the *RF/IF* sections in the interferometer, as already explained. Phase switching has been realised here, by using PIN diode switch type PAS-3 (Mini Circuits, USA). This unit has also been tested in the laboratory using the setup shown in Fig 4.13. Its performance has been found to be satisfactory.

For optimum results from the Correlator stage that follows, it is necessary to maintain the signal level input to this unit in the range of about 2 mV. Hence, the 2nd IF stage has an amplifier and a suitable step attenuator in tandem (in both the chains) as shown in Fig. **3.2.** Amplifier type AM 108 (Anzac, USA) has been chosen for use here. Standard RF step attenuators (1 dB steps) units have been used here. The amplifier and attenuator unit

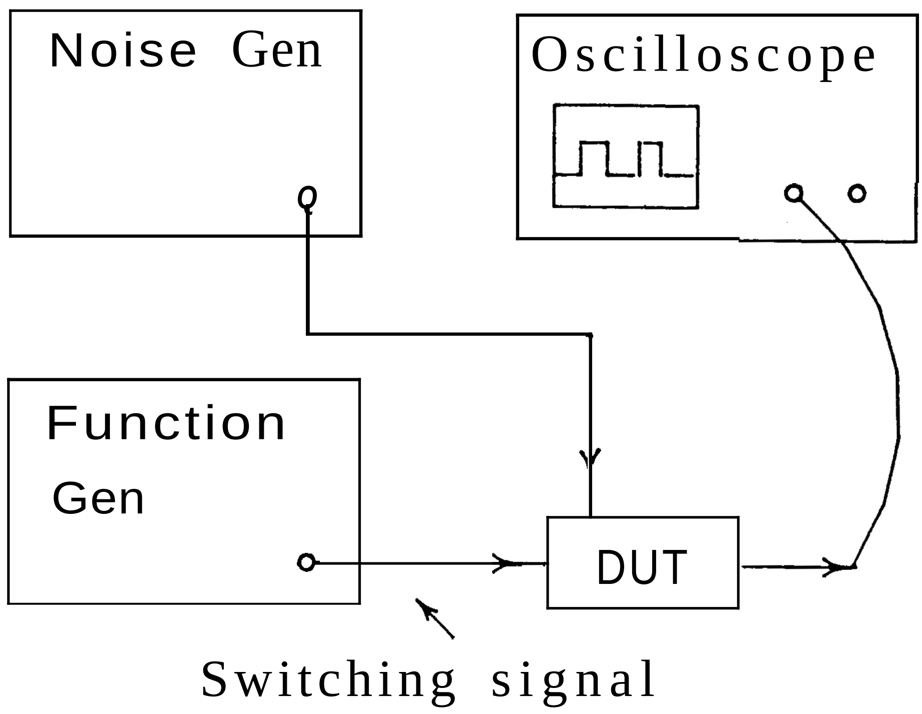


Figure 4.13 PIN Diode - Test Setup

TABLE 4.12

PASSIVE MIXER - IMPORTANT CHARACTERISTICS

Parameter	Value (typical)	Remarks
RF input range	1 - 500 MHz	Wide band
IF output range	dc - 500 MHz	Wide band
LO power input	+7 dBm	Passive devices need more LO power
LO - IF isolation	40 dB	Adequate
Conversion loss	7 dB	Inherent in passive mixers

has been tested for its linearity in the region of $2\ mV$ output, using the setup shown in Fig. 4.14. The results are presented in graphical form in Fig. 4.15. The performance of both the units has been found to be similar.

4.2.3 Correlators and PSDs : As only two correlators are required in this system, analog correlation technique is considered here. This also exploits the inherent quality of better S/N in an analog correlator as compared to its digital counterpart. Hence, these correlators have been developed and built using transistors as shown in Fig. 4.16, which is self explanatory. The fact that the correlation coefficient of noise input, is *a* maximum for Cosine correlation and a minimum for Sine correlation at the *PSD* output, has been

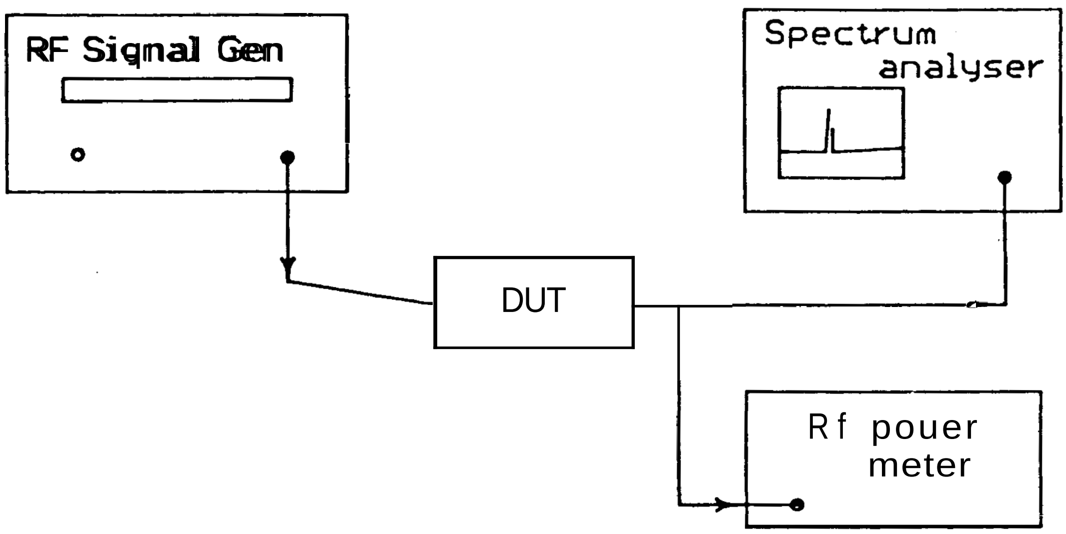


Figure 4.14 Amplifier & Attenuator - Test Setup

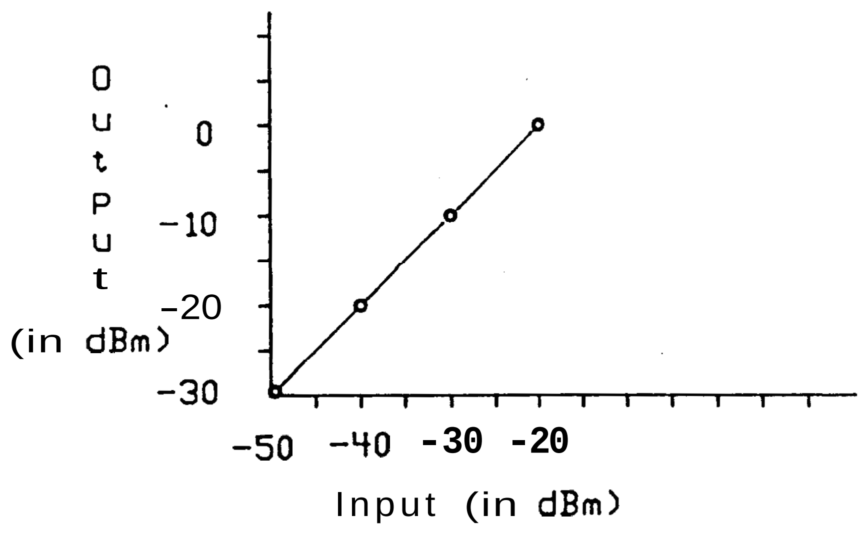


Figure L1.15 Amplifier - Transfer Characteristics

TABLE 4.13

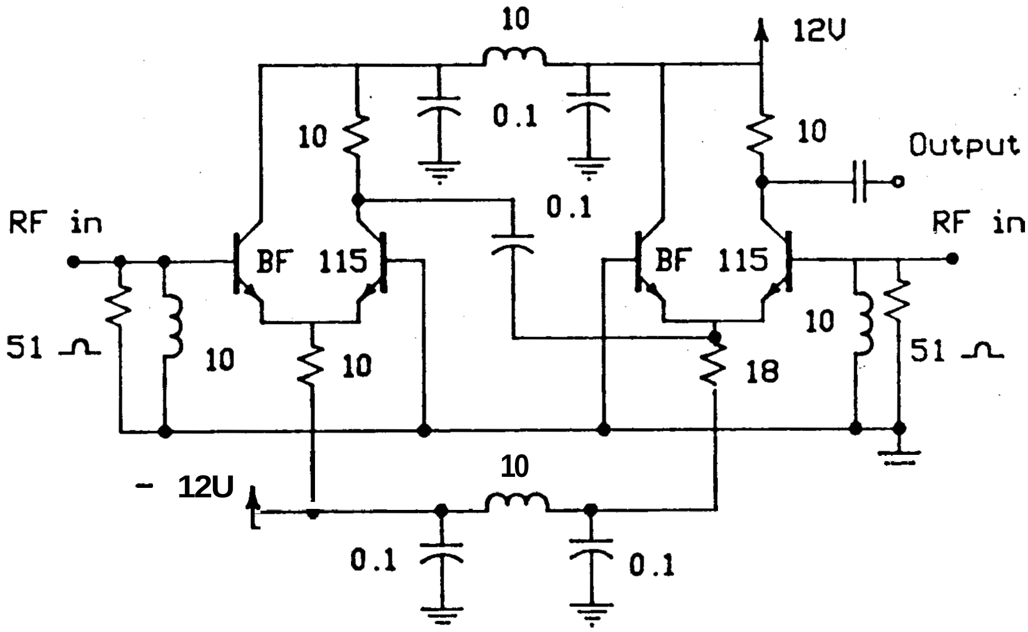
PASSIVE MIXER - TEST RESULTS

RF input (in dBm)	IF output (in dBm)	Remarks LO fixed @ +7 dBm
-20	-28	**Operating region**
-30	-38	**-do-**
-40	-48	**-do-**
-50	-58	**-do-**
-60	-68	**-do-**
-70	**-79.5**	**Nonlinearity noticed**
-80	**-92**	**Noise noticed**

used to test and evaluate these units. The test setup for this is shown in Fig 4.17a. The chart recorder output for noise input to the receiver system is shown in Fig *4.17b*. This practice is also adopted for the calibration of the entire lab unit before every observation. The *PSDs* used here are lock-in-amplifiers (model Autoloc 840, Keithley instruments).

4.3 PC-based DAS

As discussed earlier and shown in Fig. **3.3,** this DAS comprises of building blocks like MUX, PGA, ADC, *timing* and con*trol* logic in addition to a



All Resistors in K Ω
All Inductors in micro-H
All Capacitors in micro-F

Figure 16 Analoq Correlator - Circuit Schematic

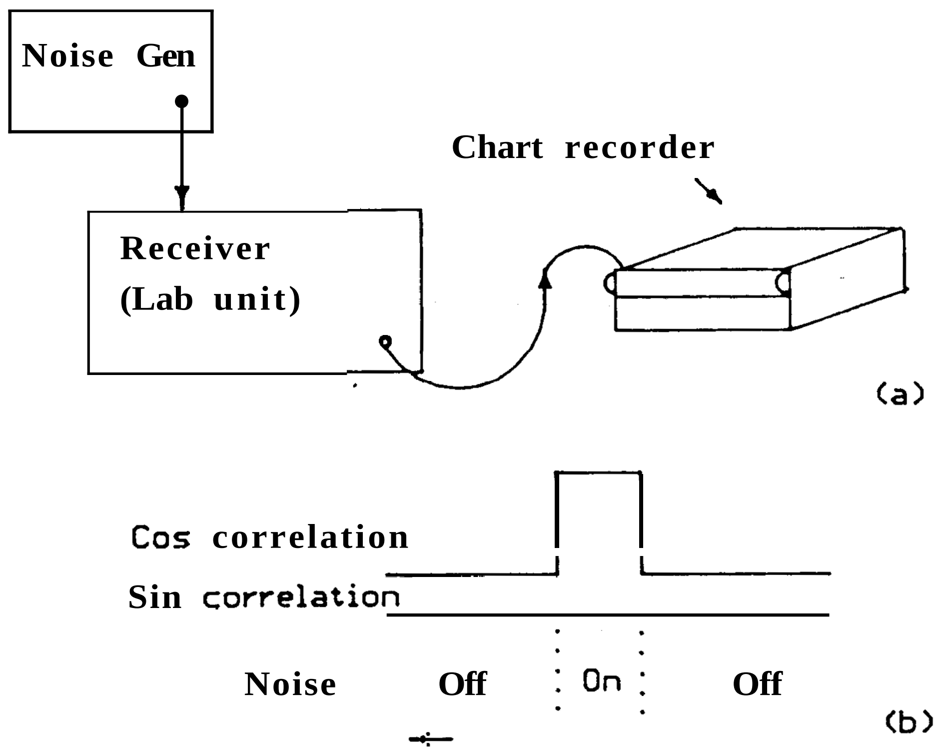


Figure 17 Correlator Test Setup (a), Test Results (b)

PC-XT. PC-XTs *(IBM* compatible) are now readily available products from several sources, and they *normally* have expansion slots for the user to facilitate insertion of specialised hardware. Therefore, the various building blocks other than the PC-XT, have been *individually* tested in the laboratory on a bread-board. Upon their satisfactory performance, these blocks have been transferred on a general purpose PCB suitable for a PC-XT expansion slot. Only after fully testing and debugging the hardware by simulating the input and control signals in the lab, has a dedicated PCB been made to cater to all the interconnections between the *ICs* used in this DAS. Major tests conducted on the various building blocks at the *bread-board* level are now discussed.

4.3.1 MUX and PGA : The test set-up is shown in Fig. 4.18. The inputs of the MUX are fed from a 16 stage resistor divider network connected to a dc standard source. When a four stage free running counter is connected to the channel select inputs (a,*b*,*c*,*d*) of this MUX, a staircase waveform pattern is seen at its output as shown. By varying the clock frequency to the counter the switching time of the MUX has been studied using an oscilloscope. The crosstalk between channels has been studied by feeding *alternate* channels with different frequency ac signals say 20 KHz and 60 *KHz* and viewing the output of the MUX on a spectrum analyser. As these tests have shown that the MUX is working satisfactorily, the PGA has been interfaced to its output. By taking care that the *amplifier* was not driven to saturation (by suitably adjusting the input signal amplitude to the MUX), the *amplifier* has been tested for its various gain settings (manual programming) and speed of

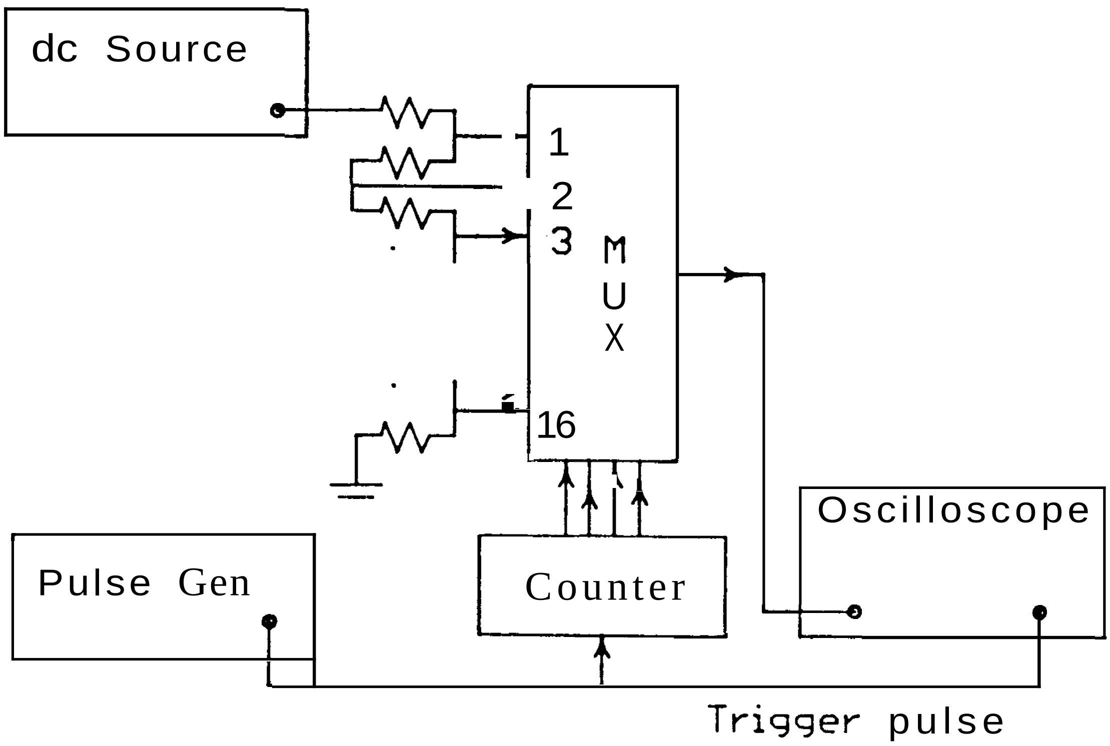


Figure 4.18 Multiplexer - Test Setup

operation. The test results of the PGA indicated satisfactory performance.

4.3.2 ADC : The ADC with its reference voltage generator and the external passive components required was wired on the bread-board. Its digital output was connected to a hexadecimal display unit (for ease of readability). An external clock (TTL) was provided from a function generator. A 100 mS pulse train was given to the *run/hold* input to make it convert continuously. The analog input was connected to a programmable dc source. The test setup is shown in Fig. 4.19. The output was studied for various input signal amplitudes and the results are given in Table 4.14. It showed satisfactory performance.

4.3.3 Timing and Control Logic : As it would be easier to test the rest of the interface, timing and control circuitry directly using the PC bus, they were *wired* on a *general* purpose *PCB* for *the* PC-XT expansion slot *and* tested using the PC itself. *As* already explained (Section ***3.3.3)*** the *ICs* on this board are supplied from the 5 V logic supply of the same PC. Small software routines have been written to check the performance of this unit.

Upon *assertaining* the satisfactory operation of this *hardware* in the laboratory, a dedicated PCB was designed. wired and tested. This became the add-on DAS PCB suitable for insertion in the PC-XT expansion slot.

4.3.4 Complete **DAS** : The add-on card realised as above was introduced in the PC-XT expansion slot and the PC-based *DAS* evaluated. The input to the DAS was fed with:

a) A time varying periodic signal (frequency range 0.1 to 1 Hz, and amplitude range 10 mV to 1 V); and

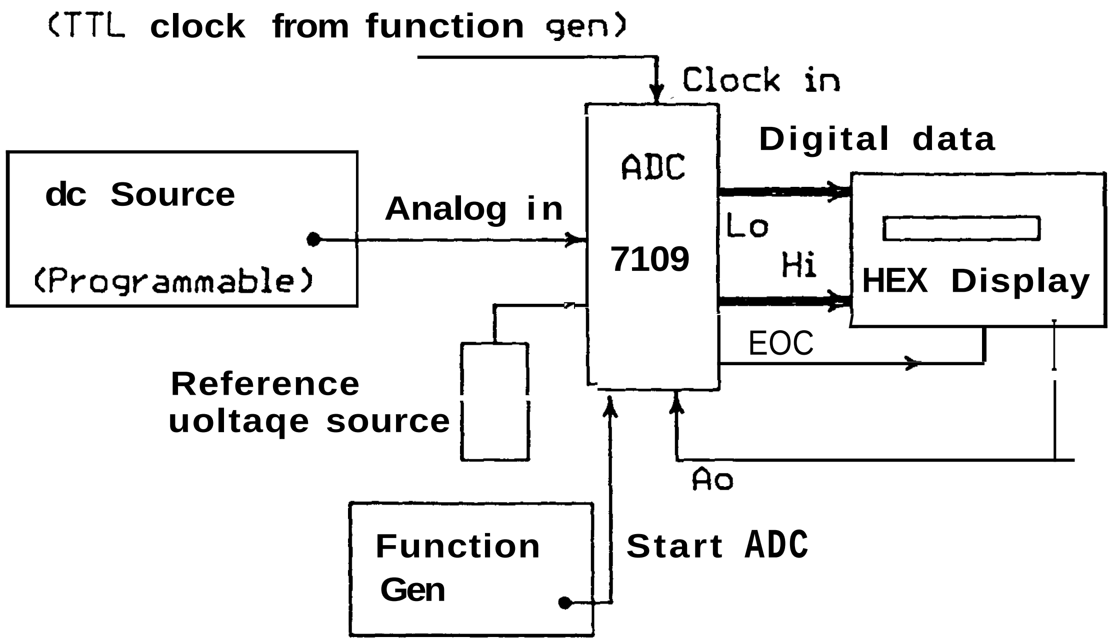


Figure 4.19 ADC - Test setup

TABLE 4.14

ADC - TEST RESULTS

dc input (in mV)	Digital output (in Hex code)	Remarks
2	001	Within tolerable error
10	00A	Operating region
100	063	-do-
1000	3E8	--do--
-2000	7DF	Neg polality bit On
4096	FFF	Full scale

b) White noise from a standard noise source.

A 100 ms pulse train to initiate the Start of Conversion has been fed using a function generator. The test setup is shown in Fig 4.20. The software resident in the PC developed for this application, enabled the data corresponding to all these *frequencies/noise* input to be acquired and stored in the hard disk as different blocks for manipulation or a detailed study. These data blocks, were treated as though they were separate obesrved radio sources. Typical plots are shown in Fig. 4.21, which clearly indicate satisfactory *overall* performance of the PC-based DAS.

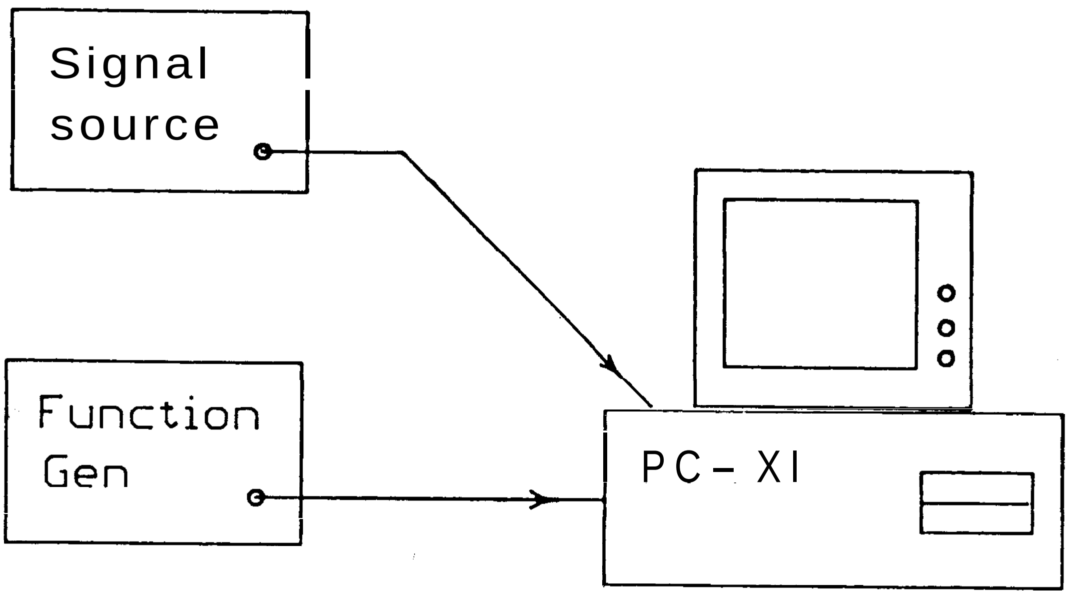
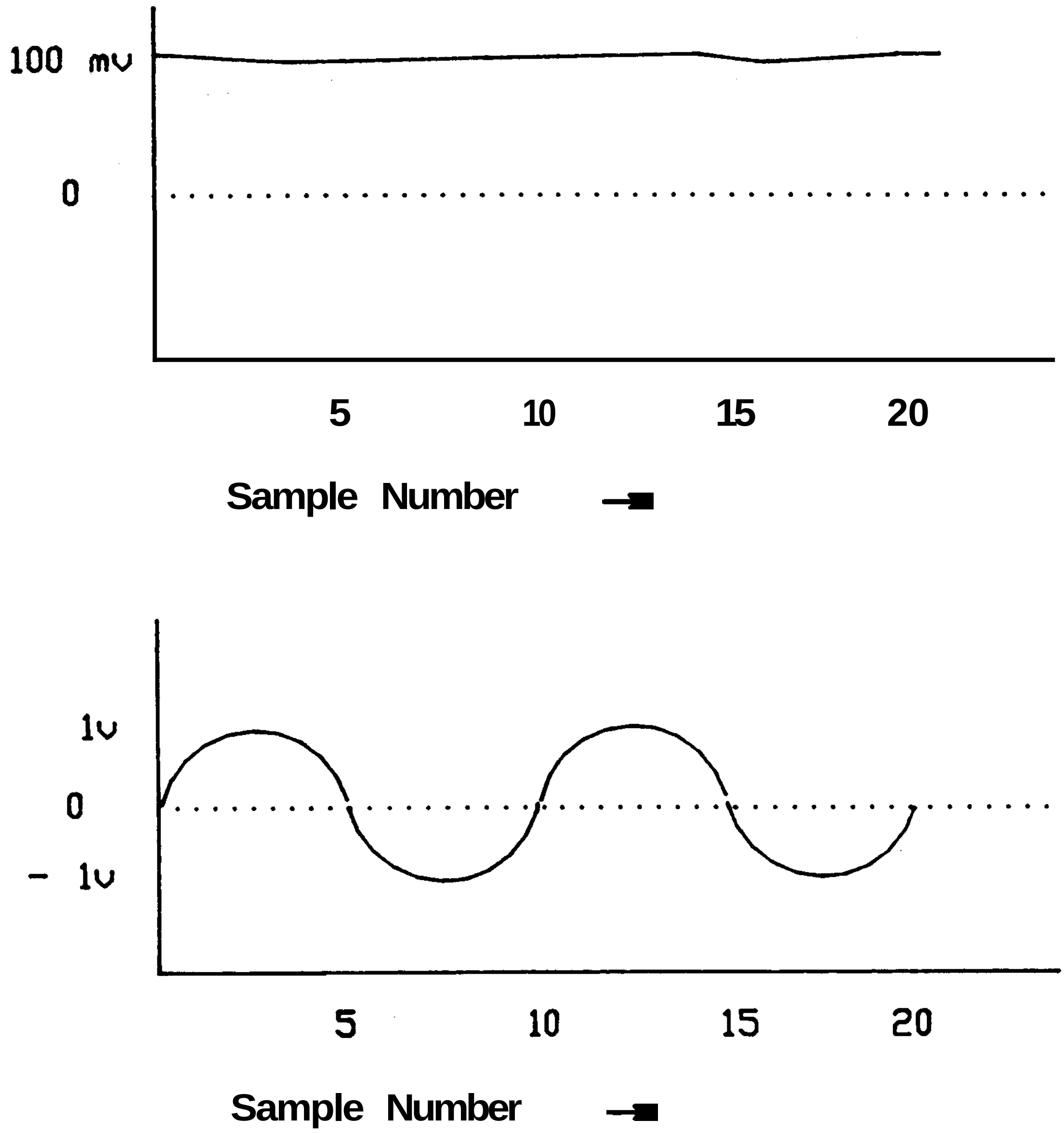


Figure 4.20 Complete DAS - Test Setup



Fiqure 4.21 DAS - Test Plots

4.4 System Integration and Results

After satisfactory testing in the laboratory, all the building blocks were transferred to the field station for installation. The group of 16 antennas on each side have been fixed on concrete bed-blocks (2 m apart), along with the ground plane *(2"x 2"stainless* steel mesh 4 m wide) *all* on the same horizontal plane as shown in Fig 4.22. The group of four *LNAs* in each arm have a common dc switch, which helps in isolating the antennas while testing the rest of the field units. The performance of the field unit after integrating all the constituent building blocks was evaluated by feeding an RF signal to the input of one LNA at a time and suitably terininating the remaining 3 inputs as shown in Fig. 4.23. After ensuring that the entire integrated RF and IF blocks were functioning satisfactorily the antennas were connected. The lab unit was tested feeding white noise (from a noise source) at its input. This noise test also serves as a means of calibration for the entire lab unit as already explained. The incoming IF signal from the fully tested and functional field unit was then connected to the lab unit. Having been satisfied with the performance of the entire integrated system, the interferometer was used in the observation of radio sources.

Some Radio sources, observed with this interferometer system are listed in Table 4.15. The fringes obtained *from* two different Radio sources using this *interferometer* are shown in Figs. 4.24 - 4.25. The number of fringes expected for these sources and the number of fringes actually measured by the system tally fully, clearly indicating satisfactory overall performance. As the strength of the radio sources at *different* declination angles could be

Figure 4.22 Group of 16 Antennas - East

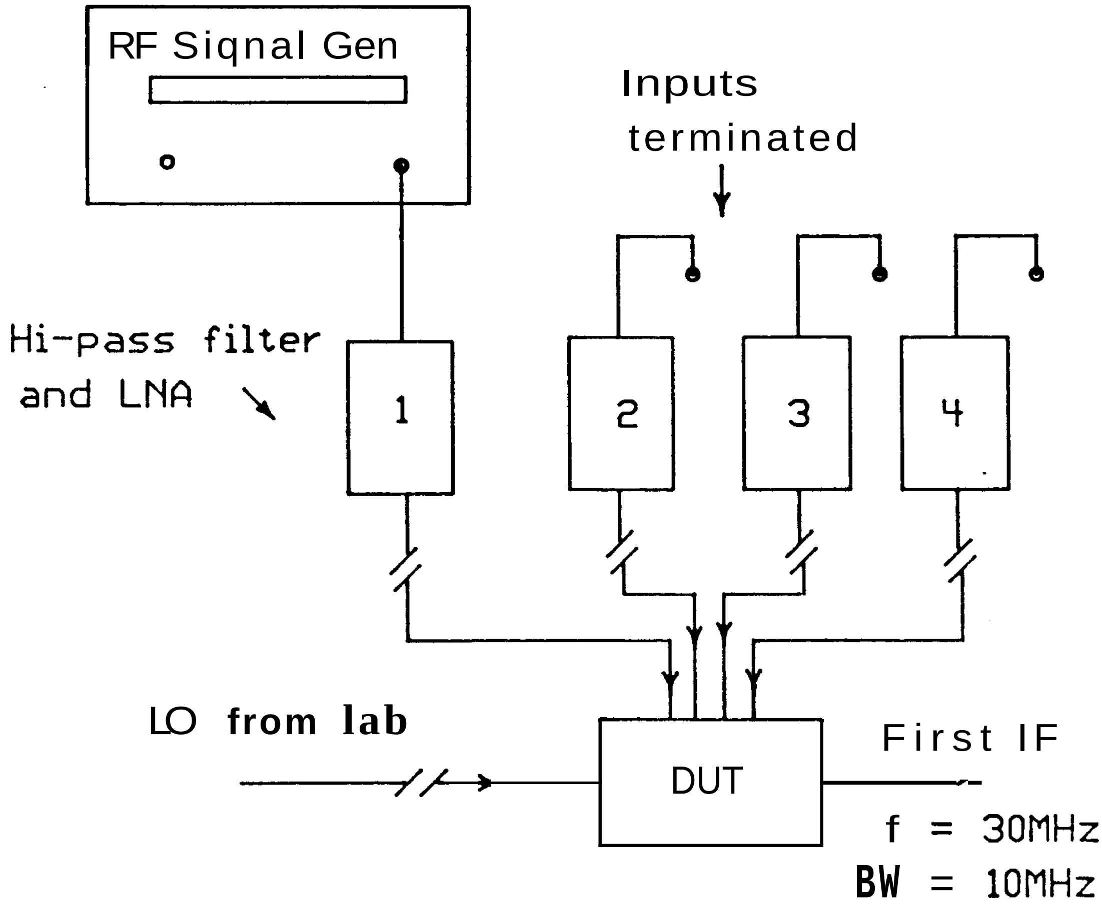


Figure 4.23 Field Unit - Test Setup

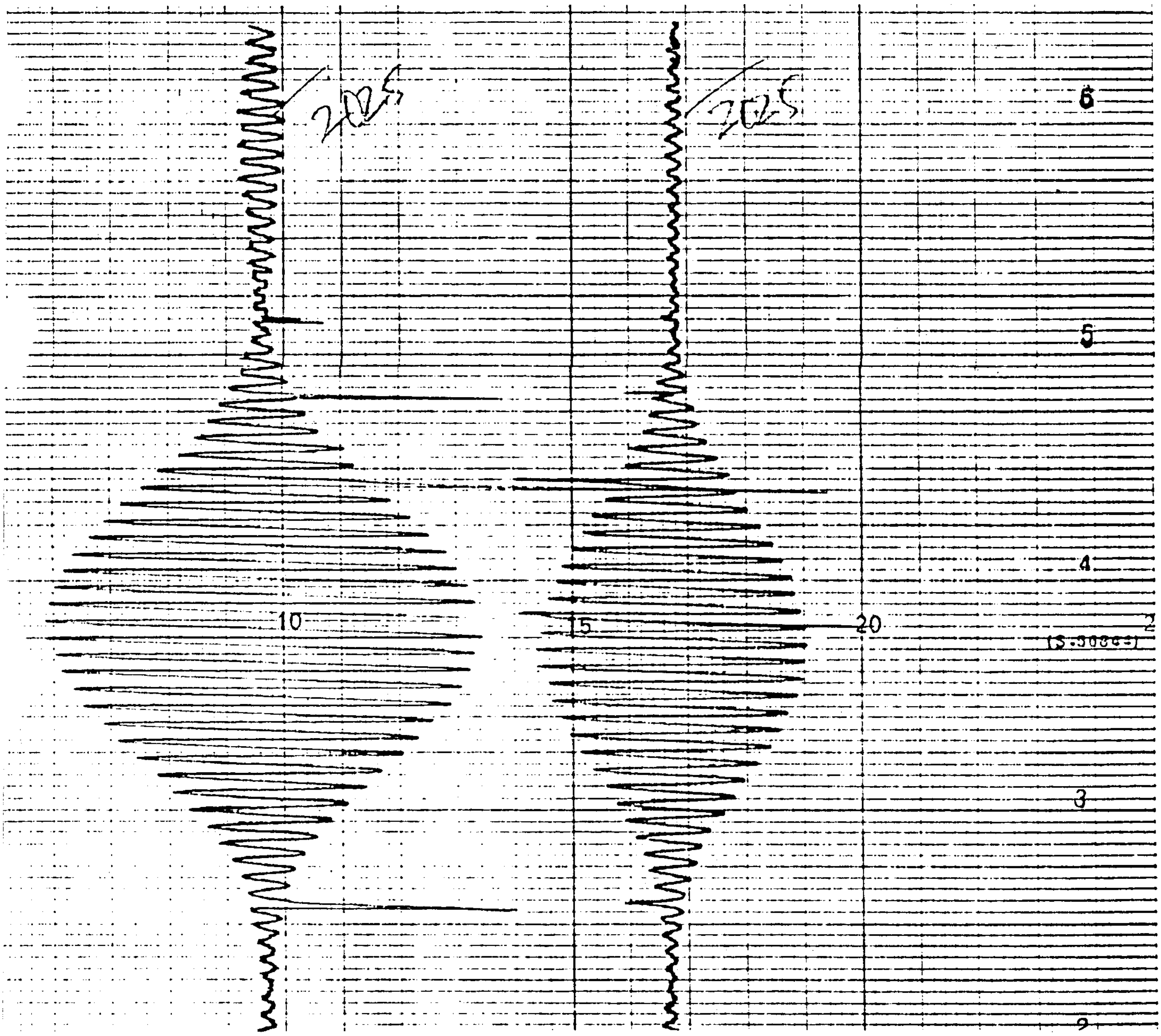


Figure 4.24 Cygnus A (3C 405) - Interferometer Fringes

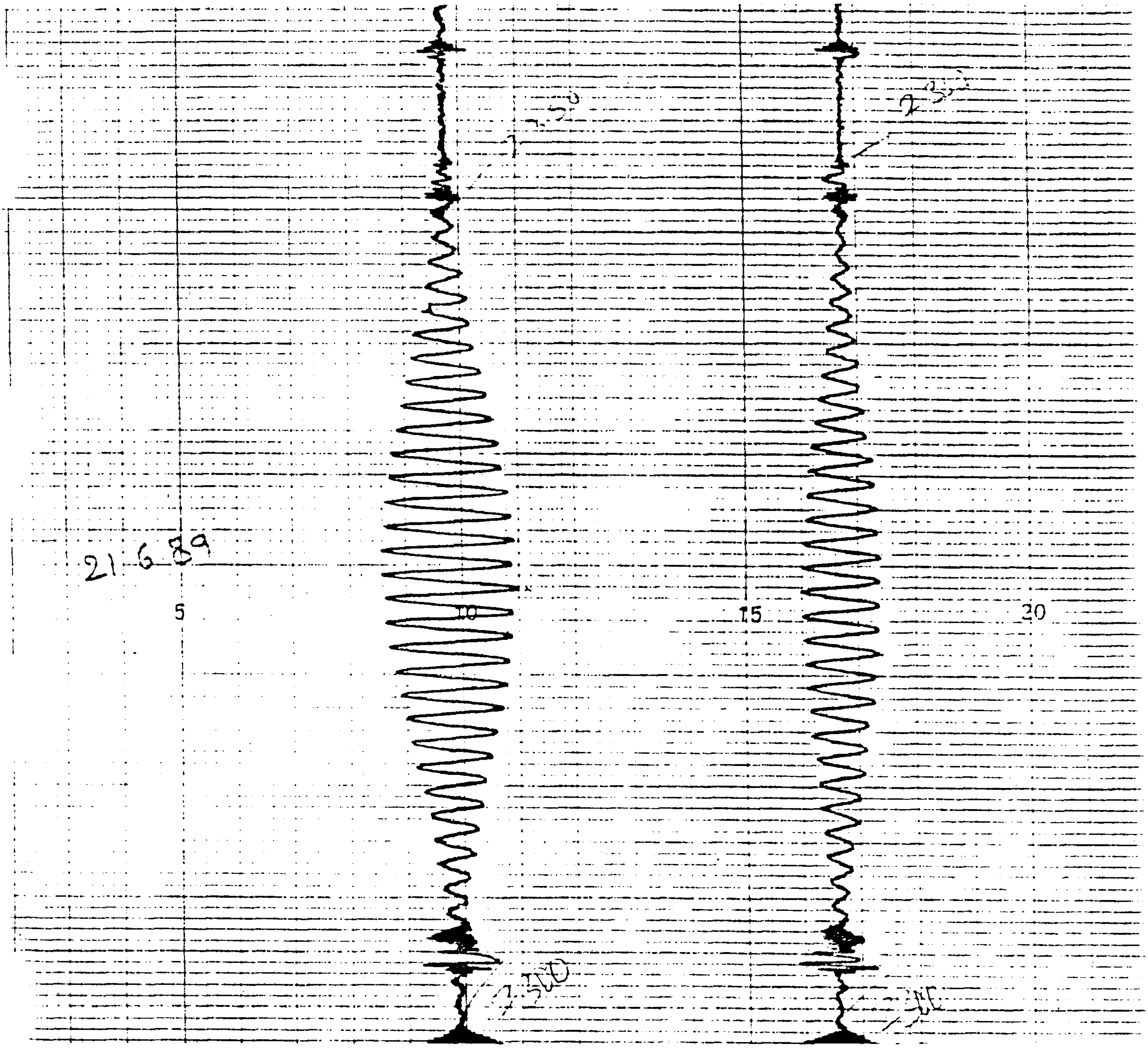


Figure 4.25 Cassiopeia A (3C 461) - Interferometer Fringes

computed by extrapolating their values available from the 178 MHz survey catalog [48], the initial data obtained were used to deternime the radiation pattern of the Helical antenna in the N-S direction as shown in Fig 4.26. This **was** *found to be in full agreement with the expected beam pattern* ***of*** *the antenna as obtained from empirical calculations (Appendix C).*

TABLE 4.15

SOME RADIO SOURCES OBSERVED WITH THE INTERFEROMETER

Source name	R.A h m s	Declination (in °)	Flux (in Jy)
3C 123	04 33 56	29 34	200
3C 144	05 31 30	21 58	1600
CTA 43	06 29 24	04 53	422
3C 274	12 28 18	12 40	1100
CTA 59	13 22 28	-42 46	8080
3C 348	16 48 41	05 04	370
3C 405	19 57 45	40 36	
3C 461	23 21 07	58 53	12500

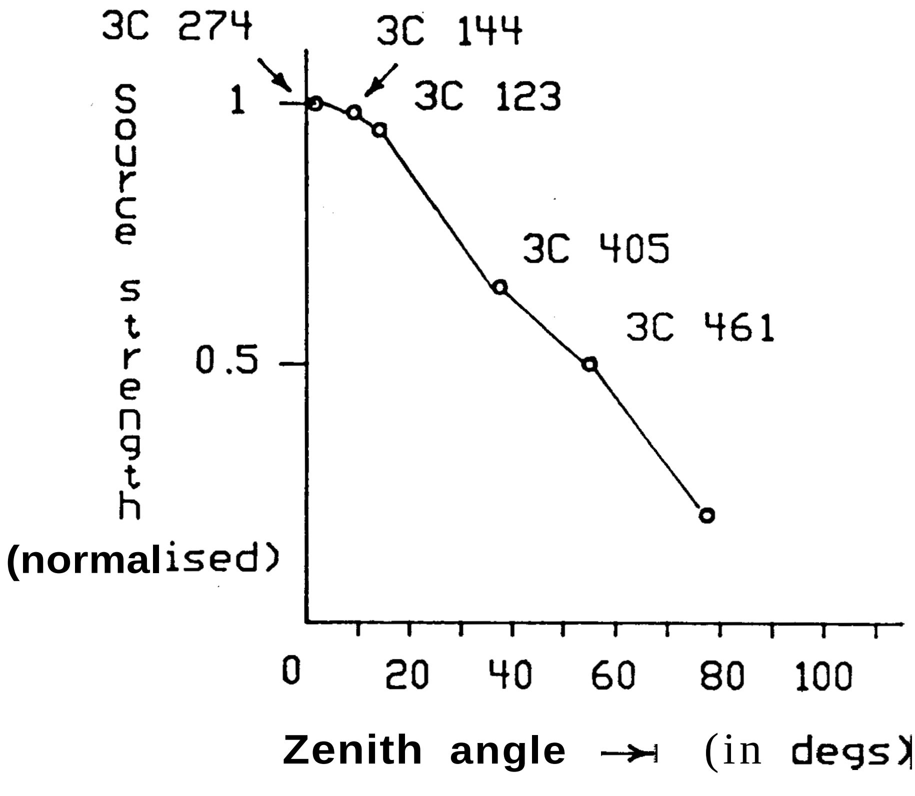


Figure 4.26 **Beam pattern** of Helix **(measured)**