Liverpool NMR Module , Q-Meter Fundamentals, and Circuit Testing

Liverpool NMR Module

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Chapter 1

CHAPTER 1

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1) INTRODUCTION

The Liverpool NMR module provides a complete RF signal processing system for making very high precision measurements of the polarisation in polarised nuclear targets using Q meter measurements of the nuclear magnetic resonance of the polarised nuclei. The Q meter method involves arranging for all or part of the polarised material to be within the inductive part of a LC circuit. The resonant frequency of this circuit is adjusted to be the same as the nuclear resonance frequency at the particular value of external magnetic field being used.

The polarised nuclei have a complex magnetic susceptibility χ ($\chi = \chi' - i\chi''$) and so they modify the inductance L so that

$$L_p = L(1+4\pi\eta\chi)$$

where η is the filling factor of the system.

The polarised nuclei therefore produce a change of Q, and hence impedance, of the tuned circuit at the nuclear magnetic resonance frequency. This change in Q is measured by applying a frequency swept RF voltage to the tuned circuit and detecting the change in impedance as a change in current or voltage.

It may be shown that, provided certain conditions are satisfied, the nucleon polarisation is directly proportional to the quantity

$$\int_0^\infty \chi''(\omega)\,d\omega$$

where ω is the angular frequency of the applied RF voltage. As it is in general not possible to determine η the system is normally calibrated using the calculable nucleon polarisation obtained when the nuclei are in thermal equilibrium with the material lattice at a known temperature.

In these circumstances the RF magnetic field and hence the coil current must be kept very low so that the spin state populations are not significantly disturbed by the measurement, otherwise large errors will be introduced in the calibration. The combination of low coil current and small signal size due to the low polarisation obtained in thermal equilibrium conditions (typically 0.5% or less) results in a relatively poor signal to noise ratio and this is an important limitation on the accuracy with which absolute polarisation measurements can be made.

This signal to noise ratio can be maximised by using as high a Q tuned circuit and as high a value of η as possible. There are, however, limitations in the degree to which these measures can be applied. If the change in Q is measured as a change in voltage (or current) via an RF amplifier and a conventional diode detector, the magnitude of the complex susceptibility (χ) is obtained, while it is the absorptive part of the susceptibility (χ'') which is actually required. It is therefore necessary to make an uncertain and tedious correction to take account of the dispersive part of the signal (χ'). The size of this correction depends upon the signal modulation level and is typically $\approx$ 3% at modulation levels in the region of 10% and rises rapidly at high modulation levels. In general these problems have, in the past, been avoided by operating with low values of Q and η which gave modulation levels of less than 10% at the maximum value of polarisation obtained, with consequent limitation on the signal to noise ratio with the thermal equilibrium calibration signals. It is possible to improve the situation by using a detector system which measures only the absorptive part of the complex susceptibility although it should be noted that the dispersive corrections do not even then vanish completely if the coil is coupled to the tuning capacitor via a $\frac{n\lambda}{2}$ cable, which is normally the case. However, it is possible to use modulation levels between 30 and 50% with very small errors using absorptive part detection.

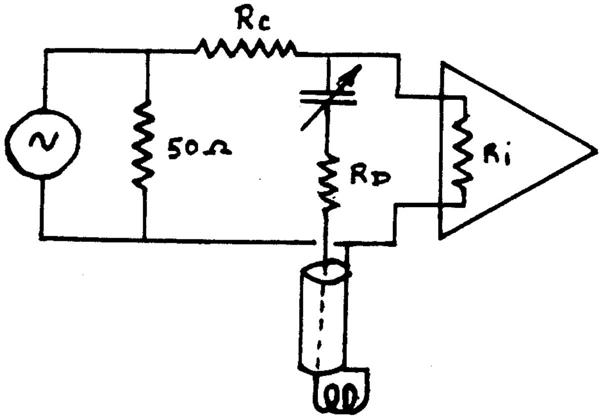
The Liverpool NMR module uses a balanced ring modulator operating as a synchronous rectifier for absorptive part detection. This system has the secondary advantage that it has a much higher intrinsic linearity than a conventional diode detector, which gives great flexibility in the choice of operating conditions. It should be stated that these advantages are only obtained at the cost of extra circuit complication and a somewhat more complex setting up procedure.

It has been observed that many conventional polarised target NMR systems, which generally have to operate in a rather unfavourable electrical environment, do not reach the noise performance of which they are theoretically capable largely because of the presence of line frequency interference and other parasitic effects. The Liverpool NMR module has been designed to minimise these effects, even in a very hostile environment, and provided that the interface circuits are correctly designed they can be made negligible compared with the intrinsic circuit noise.

2) Q METER CIRCUITS

There are two possible Q meter circuits which give a signal the area of which is proportional to the nucleon polarisation (neglecting dispersive corrections).

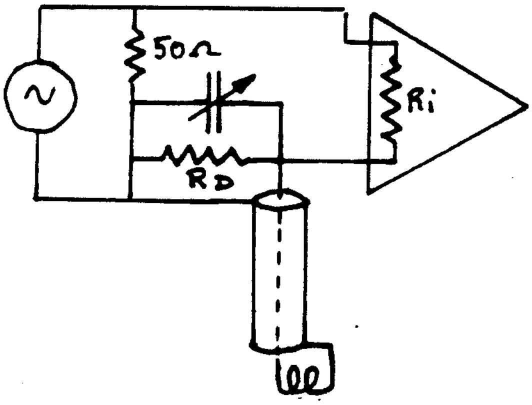
a) Constant current series tune



R_c = Constant current resistor
R_i = Amplifier input impedance
R_D = Damping resistor

Conditions - i) R_c must be large compared with 50Ω
ii) Resonant damped tuned circuits impedance must be small compared with R_c
iii) R_i must be large compared with resonant damped tuned circuit impedance

b) Constant voltage parallel tune



R_D = Parallel damping resistor
R_i = Amplifier input impedance

Conditions - i) Resonant damped tuned circuit impedance must be large compared with 50Ω
ii) R_i must be small compared with resonant damped tuned circuit impedance.

In general circuit a) is to be preferred as conditions i) and ii) can be simply satisfied to levels which give negligible errors under most circumstances. However, if it is necessary to use a large coil with a relatively high inductance difficulties may arise because the parallel self resonant frequency, due to stray capacity, may be so close to the series resonant frequency that it is impossible to tune the system. Circuit b) can then be used, although it should be noted that it requires either an amplifier with a balanced input or the use of two cables in the target cryostat.

The Liverpool module has been designed for use with circuit a) but it can be modified for use with circuit b) (single cable) with certain limitations in use. The main modification involves the addition of a balanced to unbalanced transformer at the input of the first stage amplifier.

In general the amplifier input impedance for use with circuit a) should be as high as possible. There are, however, very great advantages, both in terms of noise performance and availability, in using standard 50Ω input impedance amplifiers, so this has been done. As a result there is an approximate upper limit of 20Ω for the total damped tuned circuit impedance at resonance. At an operating frequency of 107 MHz using L $\approx$ 0.1μH and C $\approx$ 20pF with a $3\lambda/2$ length solid conductor cable (type UT85 with the cryogenic version in the cryostat) the undamped series resonant impedance is typically $\approx$ 3Ω. This inductance corresponds to a coil of almost any shape made from $\approx$ 12 cms of 1 mm diameter wire. In these conditions even with the maximum possible value of η (i.e. a coil buried in the target material) it is possible to keep maximum modulation levels in the region of 30% using damping resistors of 18Ω or less. Much higher inductance coils have been used with circuit b) although not with very high values of η. Also condition i) of circuit b) was difficult to satisfy in these conditions and it was necessary to calculate a non-constant voltage correction.

3) BALANCED RING MODULATOR

The balanced ring modulator used in the Liverpool module operates as a full wave synchronous rectifier. It is a three port device with two inputs (labelled RF and LO) and one output (X). If a constant high level reference signal is fed to the LO port, the DC output at the X port is linearly proportional to the voltage of a coherent signal fed to the RF port. It is also proportional to cos ϕ, where ϕ is the phase difference between the two signals. Therefore if the phase difference is set equal to zero it detects only the absorptive component of the RF signal. Oscilloscope pictures which show the waveforms obtained when the modulation is operated in this mode, at two different frequencies (10 MHz and 107 MHz) using the test circuit in figure 1, are illustrated in figure 2. Test data obtained with the type SRA-1 modulator which is used in the module is given in figures 3, 4, 5 and 6.

The range of linear rectification of this device increases with increasing magnitude of signal at the LO port up to a specific limit. There is also an upper limit on this level determined by the maximum allowable power dissipation in the switching diodes inside the modulator. The maximum LO port signal level for the SRA-1 modulator is 500mV rms (+ 7 dbM). The corresponding maximum signal voltage for optimum linearity is 250mV rms which gives a DC output level of 140mV.

It is necessary to set the phase difference between the two signals at the two input ports of the modulator to zero to measure the absorptive part of the RF signal. This can be done crudely by phase measurement at the input ports using a vector voltmeter; however, the final setting must be done experimentally by observing the modulator output as a function of a deliberate phase change (e.g. by varying a cable length in the feed to one input port). This will only work however if the Q meter circuit is already correctly set up (tuned) and it is therefore necessary to include a conventional diode detector in the system to allow initial setting up of the Q meter independently of the modulator. It should be noted that as the modulator contains ferrite cored transformers its performance is affected by magnetic fields. We have found that there is no detectable effect in fields up to 10mT. If operations in higher magnetic fields are required then some magnetic shielding is necessary.

4) GENERAL CIRCUIT PRINCIPLES

The module has been designed for use, if necessary, in a multichannel system operating from a single signal generator and without any switches or relays in low level RF circuits. One module is then required for each channel. Tests were made with a number of systems using a single module and RF coaxial relays to change channel. All such systems were found to be unsatisfactory in some respect mainly with regard to reliability and the introduction of extra noise.

In a multichannel system it is generally undesirable to apply the RF voltage to all coils simultaneously, firstly because of the interaction which can occur between neighbouring coils, and secondly as most multichannel systems only have a single data analysis channel. The optional facility is therefore included to remotely remove the RF voltage from the tuned circuit using a reed relay switch. It should be noted that it is important that this is not done by switching the RF input to the module. The reason for this is that the modulator output for a given signal input shows a small temperature dependence (see figure 4). Also the reference signal is at such a high level at the modulator that it represents an appreciable power dissipation. Therefore if the reference signal is switched off there will be an appreciable delay, due to the thermal time constants involved, before the modulator performance becomes stable after switching on again. A block diagram of the circuit of the module is shown in figure 7.

a) Input configuration

A constant RF voltage from the signal generator is fed into the module at socket B. The tee pad attenuator A1 combined with the input impedance of amplifier G1 provide a 50Ω terminating impedance for the generator. The constant current resistor is also connected at this point, but as its value is always high compared with 50Ω it causes a negligible mismatch. The resistor is actually made up of two identical resistors connected in series. The centre connection between the two resistors can then be grounded (by means of a reed relay) to remove the voltage from the coil, with negligible effect on the generator matching impedance. The tuning capacitor and damping resistor are included in the module and the cable and coil are connected at socket H. The amplifier G3 is the first stage of the signal channel.

b) Reference channel

Amplifier G1 provides gain and amplifier G2 a high output to provide the necessary voltage for feeding the reference port of the modulator. The relative phase of this signal can be adjusted by altering the length of cable between sockets E and F. Attenuators A_1 and A_2 allow the gain tolerances of the amplifiers to be accommodated and also provide some isolation between stages. They are not changed once the system has been initially set up.

c) Signal channel

Amplifier G3 has a very low noise figure (2db) but rather low gain. It is therefore followed by a medium gain medium output amplifier (G4) before the signal is fed to a two way splitter (S) One output of the splitter is then fed via a buffer amplifier (G5) to the RF port of the modulator. As the signal channel contains one extra amplifier and a splitter compared with reference channel the signal delay is somewhat greater. It is therefore necessary to insert approximately 60 cm of cable in the reference channel to make the delays the same (corresponding to 0^o phase difference). The other output of the splitter is fed to a full wave diode detector via a buffer amplifier (G6) (see section 3). The attenuators serve the same purposes as in the reference channel.

d) Post detector stages

The most sensitive point for the pick up of line frequency and other low frequency interference is the input to the post detector stage. The modulator is therefore operated in balanced mode and feeds a low noise DC coupled differential input amplifier, so exploiting the large common mode spurious signal rejection obtainable with this configuration. This stage has a gain of 30 so giving a signal output of about 4.5 volts at the upper end of the modulator linearity range. For convenience and simplicity the same arrangement is used in the diode channel.

5) LAYOUT AND CONSTRUCTION

A number of factors needed to be taken into account when the layout and form of construction was originally decided.

a) There is an intrinsic ground loop in the system as there is a common ground both at the signal generator and at the modulator.

b) There are high RF voltages (at the LO port of the modulator) in close proximity to very low level circuits (the input to G3).

c) The RF amplifiers used are rather inefficient so there is an appreciable total power dissipation (∿ 8 watts per module).

To minimise noise pick up the area of the ground loop should be made as small as possible. In conventional circuitry this requirement tends to be in conflict with the requirements for avoiding problems with factors b) and c). The solution adopted is to build the module in a compact but rather complex and massive copper box which serves the dual purpose of providing a heat sink and very good internal and external RF shielding. This avoids difficulties with factor b) provided that all power supply and signal leads have efficient RF filters.

The mass of the box is such that the thermal time constant is quite long, so that once it has reached equilibrium operating temperature the short term stability is very good, and under normal laboratory conditions (i.e. 23 ± 5°C) no further control of temperature has been found to be necessary. However, if very high stability is required over a wide range of ambient temperatures it is necessary to clamp the module to a temperature stabilised plate. Also in no case should the case temperature be allowed to rise above 35°C.

It should be noted that the amplifiers are cooled only by conduction to the case via the circuit boards. It is therefore important that they are mounted correctly on the circuit boards which in turn are in good thermal contact with the case.

6) POWER SUPPLIES

Each module requires the following supplies:

+ 24V	at	190ma	RF amplifiers
+ 15V	at	64ma	
± 15V	at	15ma	LF amplifiers
+ 5V	at	10ma	Reed relay

To obtain the best possible noise performance separate well filtered isolated power supplies are required. The use of CAMAC or NIM crate supplies has been found to be unsatisfactory because it is then not possible to avoid further ground loops. In the Liverpool system five separate isolated power supplies are used, each having a residual output noise level of less than 1mV (100 KHz bandwidth) under working conditions. A separate zero volt line is run from each power supply to the module and they are not grounded or connected together anywhere other than at the module. It is permissable to run two or more modules from a single set of power supplies.

7) INTERFACE TO THE DATA ANALYSIS SYSTEM

The interface must include facilities for measuring the DC level at the output of the modulator and for removing the DC component of the signal before it is fed to a high precision variable gain amplifier. The modulator output DC level is a parameter which needs to be observed when setting up, and this voltage also provides a good monitor of the general stability of the system during operation. It is possible to remove the DC component of the signal by using AC coupling to the precision amplifier, but it has been found preferable to use DC coupling throughout, when using signal average techniques, as this ensures that the signal background DC level does not vary with sampling repetition rate. With DC coupling it is necessary to provide a very stable source of "back off" voltage and a summing amplifier to remove the DC component. As in the previous circuits it is necessary to take precautions to avoid ground loops to keep extraneous noise pick up to a minimum.

When the system is correctly set up for observing thermal equilibrium signals a precision amplifier gain in the range 200 to 400 is necessary to obtain a 1 volt signal using the modulator channel. The signal is superimposed on a background having an approximately parabolic shape with a maximum amplitude also in the region of 1 volt.

One method of subtracting this background is to apply a separately generated equal amplitude antiphase parabolic signal to the summing amplifier. This method has been used successfully by many groups working in the field. We consider, however, that if a digital sampling data acquisition system having a memory facility is used, a much simpler and potentially more accurate method is to record signal plus background and background separately and then make an off-line subtraction. It should be noted that this method requires that a small change in magnetic field can be made simply, quickly, and repeatedly.

This method is facilitated with the Liverpool module as the amplitude of the parabolic background is somewhat less when using absorptive component detection than it is with a conventional diode detector (see figure 9). A block diagram of the interface system used at Liverpool is shown in figure 8.

8) OPERATION

A test arrangement has been devised which approximately simulates working conditions. It may be used to test the module and also allows some preliminary setting up to be on the bench. The test arrangement uses the series tuned Q meter circuit described in section 2.

a) Test Configuration

I **Coil.** This consists of 3 turns of approximately 0.6mm diameter copper wire wound on a 12mm diameter former. The coil is removed from the former and the turns spaced out to give approximately 8mm overall length. The ends of the coil are connected directly to a SMA bulkhead connector with as short leads as possible. The connector is mounted in the centre of one face of a 40mm cube copper screening box.

II **Cable.** This is a $3\lambda/2$ length of UT85 cable, corresponding to a length of 1.84 metres (including connectors) at a frequency of 107.7 MHz.

III **Module Parameters**

i) Damping resistor 10Ω
ii) Constant current resistor 2 x 330Ω
iii) Fixed tuning capacitor 10pf
iv) Phase cable length 0.56 metres plus one adjuster

b) Test Procedure

The signal generator frequency is set to a frequency of 107.7MHz with no frequency modulation and the output adjusted to give 100mV rms at socket B of the module. The tuning capacitor is then adjusted to give minimum DC output level on the diode channel. This level should be between 3.5 and 4.5 volts. Approximately ± 200KHz frequency modulation with a repetition rate which allows the signal to be observed on an oscilloscope should then be applied. If a Liverpool type post detector signal processing system is being used the "back off" voltage should be adjusted to precisely balance the DC level at the output of the diode channel. With the total gain set to X100, observe the amplified output on an oscilloscope with a sensitivity of 1 volt cm^{-1}. Alternatively AC couple an oscilloscope direct to the diode channel output with a sensitivity of 10mV cm^{-1}. A parabolic background signal should be seen which is a part of the tuned circuit Q curve. The tuning can now be precisely adjusted to the correct tune point which is when the curve is symmetric. (See figure 9.)

If the output from the modulator channel is now observed, the DC level will be approximately 3 volts with a much reduced amplitude parabolic signal, which will also be asymmetric unless the phase is fortuitously correct. The length of phase cable can then be adjusted (by using the adjuster and/or adding or removing connectors) to give a symmetric signal. The module is now correctly set up.

Note 1 The module should be switched on for at least half an hour before setting up to allow it to reach thermal equilibrium.

Note 2 A test signal which has approximately the same shape and width as a thermal equilibrium NMR signal can be generated using a quartz crystal loosely coupled to the dummy NMR coil. The crystal used at Liverpool was an AT cut with fundamental frequency 11.97MHz, and so operating on the ninth overtone. It is mounted inside the test coil screening can and the coupling coil is a single loop of wire mounted directly on the crystal pins. The amplitude of the test signal can be varied by altering the position of the coupling coil relative to the test coil.

c) Operation in Working Conditions

Suggested procedure:

I With the cryostat at room temperature

i) Choose the damping resistor and constant current resistors. As cryogenic cables usually have higher losses than standard cable starting values of 6.8Ω and 2x220Ω are suggested.

ii) Adjust the total cable length between the coil and socket B to be nλ/2 at the chosen operating frequency.

iii) Check that the coil-cable combination can be tuned using the procedure described in section b).

iv) Check that the diode channel output is in the range ~~1~~ 0·75 to 4.5 volts when the system is correctly tuned. If it is too high the total value of the constant current resistors should be increased, if too low, reduced. The corresponding modulator channel voltage will be in the range ~~0.75~~ 1·0 to 3.5 volts when the phase is set correctly. The output level can also be increased by increasing the value of the damping resistor and this will probably be the most satisfactory procedure to use if the L/C ratio and/or the intrinsic circuit Q is very high.

v) Check that the phase can be set correctly using the procedure specified in section b).

II With the cryostat loaded and operating in thermal equilibrium conditions

i) Reset the tuning and check that the voltage levels are correct. Under some circumstances the intrinsic circuit Q can have a large temperature dependence. If this is the case it may be necessary to alter the module parameters using the procedures given in the previous section.

ii) Check the phase adjustment. It should not have changed if the constant current resistors have not been changed.

NOTE - In principle the phase should not vary even if the constant current resistors are changed. However this is not in practice true, as the stray capacitance associated with the resistors varies with the resistance value.

iii) Measure the area of the thermal equilibrium signal and the associated peak signal voltage using the modulator channel.

iv) Calculate the peak signal voltage at the maximum possible polarisation likely to be attained. If this value exceeds 30% of the static level on the modulator channel (i.e. if the modulation will be greater than 30%) the damping resistor value should be increased and the setting up procedure repeated.

v) When the optimum level change has been attained adjust the constant current resistors to give the maximum modulator channel output consistent with the output voltage never exceeding 4.5 volts (with 30% modulation this corresponds to a static level of about 3.5 volts)

Note 1 Using the above procedure will give the best possible signal to noise ratio under thermal equilibrium conditions. There may, however, be circumstances where it is either not possible or not desirable to use such high modulation levels. These conditions can occur for example, if the tuned circuit L/C ratio is very low, if the signal size is very small, or the filling factor is very low. This situation is perfectly acceptable although it should be noted that higher post detector gains may be necessary.

Note 2 The modulator signal transfer characteristic is linear through zero so there is also great flexibility in the choice of working output level and hence coil current. Again however the best possible signal to noise ratio will be obtained by using the maximum possible coil current (but see section 9 a) v).

Note 3 Although there is no lower limit on the modulator channel output voltage there is a practical lower limit on the diode channel output of about ~~1~~ 0·25 volt (corresponding to a modulator channel level of ~~0.75~~ 1·0 volt) due to the diode non-linearity. This makes the system difficult or impossible to set up below these levels.

Note 4 The output levels must not be adjusted by altering the signal level at socket B on the module, as this will alter the RF level at the LO port of the modulator which will completely alter the operating parameters of the system.

9) PERFORMANCE

a) Thermal equilibrium signals

The performance of the system when measuring thermal equilibrium signals is heavily dependent on factors external to the module, such as the signal generator noise level and stability. Therefore the level of performance attained and the limitations which have been found for one particular set of parameters, used at Liverpool and CERN, are discussed.

I System Parameters

i) Signal generator - Singer type 6201 with modified power supplies (see section 9a) III.

ii) Materials - Protons in diols and monohydric alcohols at temperatures in the range 0.75 to 1K and at a field of 2.5T.

iii) Data acquisition and analysis system - as shown in figure 8 with signal averaging using up to 500 sweeps and a 10m sec sweep time. Each signal averaging measurement was repeated ten times and the background subtraction was carried out in software.

iv) Coil - An inductance of about 0.1μH and rather closely coupled to the material (i.e. $\eta \approx 0.5$). An approximately 0.5mm thickness of Teflon insulation was used on the coil to prevent material being in the very high RF field close to the surface of the wire.

v) Q meter - as described in section 2(a)

Constant current resistor = 2 x 220Ω
Damping resistor = 6.8Ω

II Circuit Signal to Noise Ratio

The signal to noise ratio as measured at the input to the data acquisition ADC is typically 10:1 (peak signal height to RMS noise voltage) with 100KHz low frequency amplifier bandwidth. After signal averaging this gives a statistical error in the signal area of less than 1%. Some typical signals are shown in figure 9.

III Line Frequency Interference

This is negligible compared with the intrinsic circuit noise. However to achieve this it was necessary to modify the signal generator power supplies to reduce their ripple level. The unmodified generator was found to have a line frequency amplitude modulation on its output which gave a line frequency signal at the module output about a factor of two larger than the circuit noise.

IV Stability

Small drifts in the background DC level have been observed during the time that it takes to change the magnetic field ($\sim$ 30 sec) in order to obtain the background signal. It has not been possible to determine whether these drifts are due to the generator, the module or post detector signal processing system. Therefore, to eliminate any possible errors a software check is made on the DC level using 16 channels at both extremes of the scan. If drift has occurred then a correction is applied to the subtraction. No drifts in the background shape have been observed.

V Disturbance of the Thermal Equilibrium Spin State Population Ratio

The coil current with the standard operating conditions is approximately 0.2mA. Tests have been made to determine the level of disturbance by comparing the thermal equilibrium signal area obtained immediately after the RF voltage has been switched off for a long period with that obtained immediately after completing 10^4 scans. No change in area was detectable at the accuracy level of the measurement ($\sim$ 1%). The material used had a relaxation time of about 40 min. The test was repeated with the same result using a material having a relaxation time of about 3 hours. It may be concluded that this value of coil current causes negligible disturbances over a wide range of experimental conditions. It is recommended, however, that this check is done for any new set of working conditions particularly if coils which are closely coupled to the material are used and/or relaxation times are unusually long.

b) Enhanced Signals

I Module Linearity

This has been measured for large signals, and errors due to non-linearity are less than 1% over the range of operating conditions specified.

II Q Meter Linearity and Dispersive Corrections

These depend on the particular values chosen for the constant current resistor and the level change. It has been shown that errors caused by these effects are less than 1% when the standard conditions are used (Proceedings of the Second Workshop on Polarised Target Materials, October 1979, Rutherford Laboratory).

III Long Term Stability

This again depends on many factors other than the module. The modulator DC level has been found to be a good monitor of the system stability once the module has reached thermal equilibrium (but see section 5). It has been found possible to keep long term variations to less than 1% in favourable conditions.

IV General

We consider that when the Liverpool module is used in favourable conditions relative polarisations can be measured to an accuracy in the region of 1%. In our experience the error on the absolute polarisation measurement has usually been dominated by other factors such as the accuracy of the temperature measurement in thermal equilibrium conditions, or the NMR sampling non-uniformity when taking scattering data.

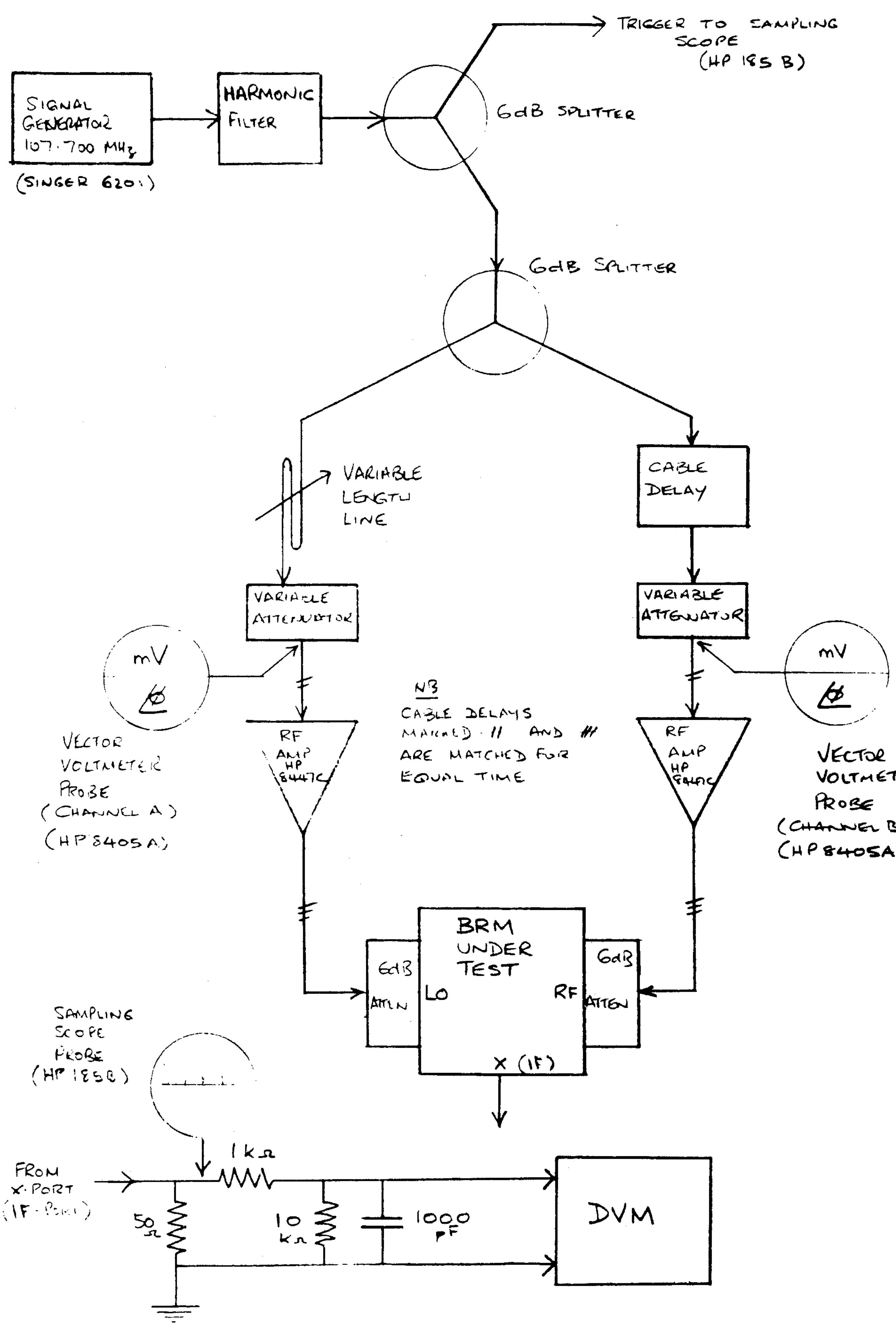
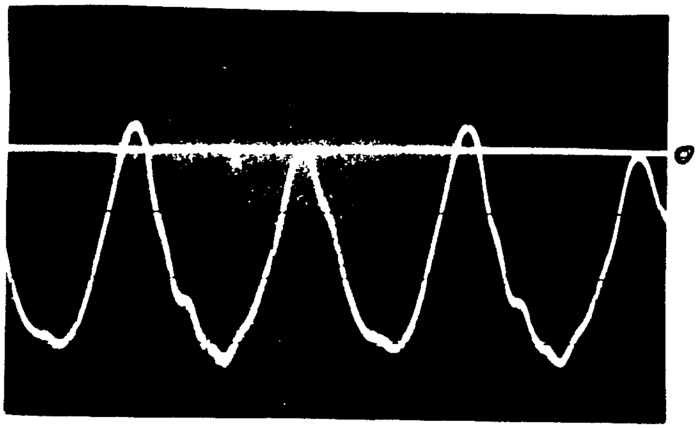
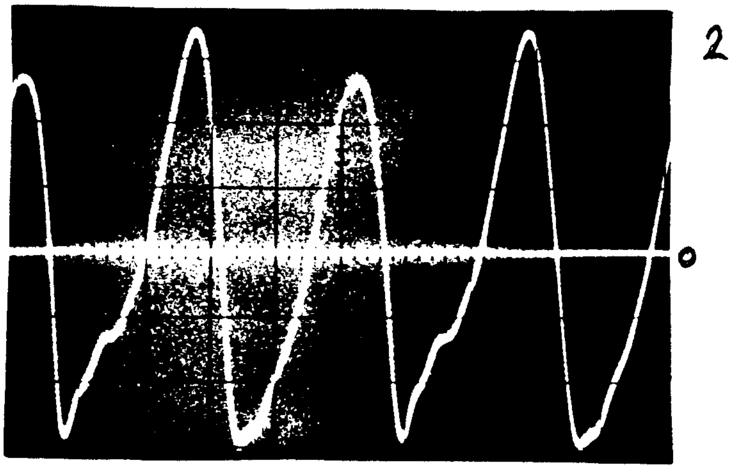


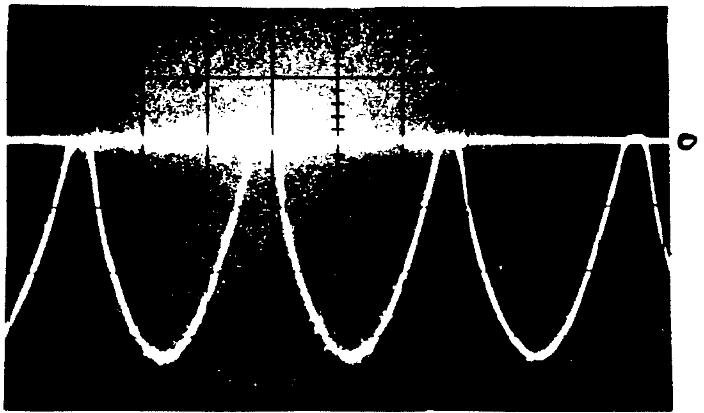
FIG 1. STANDARD TEST SET-UP FOR BALANCED RING MODULATORS



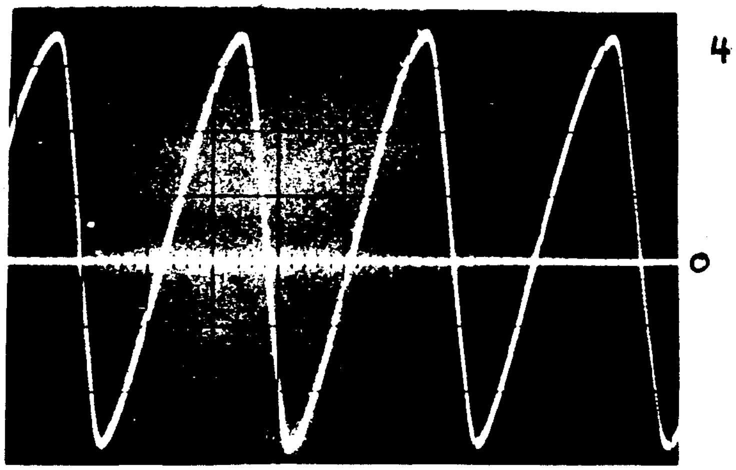
1. f = 107·700 MHz
STANDARD TEST CONFIGURATION
SIGNALS IN PHASE (0°)
REF ~ 500 mV
SIGNAL ~ 125 mV
SCOPE TB 2nS/cm
SCOPE Y-AXIS 50 mV/cm



2. AS ABOVE, BUT WITH SIGNAL
90° AHEAD OF REFERENCE

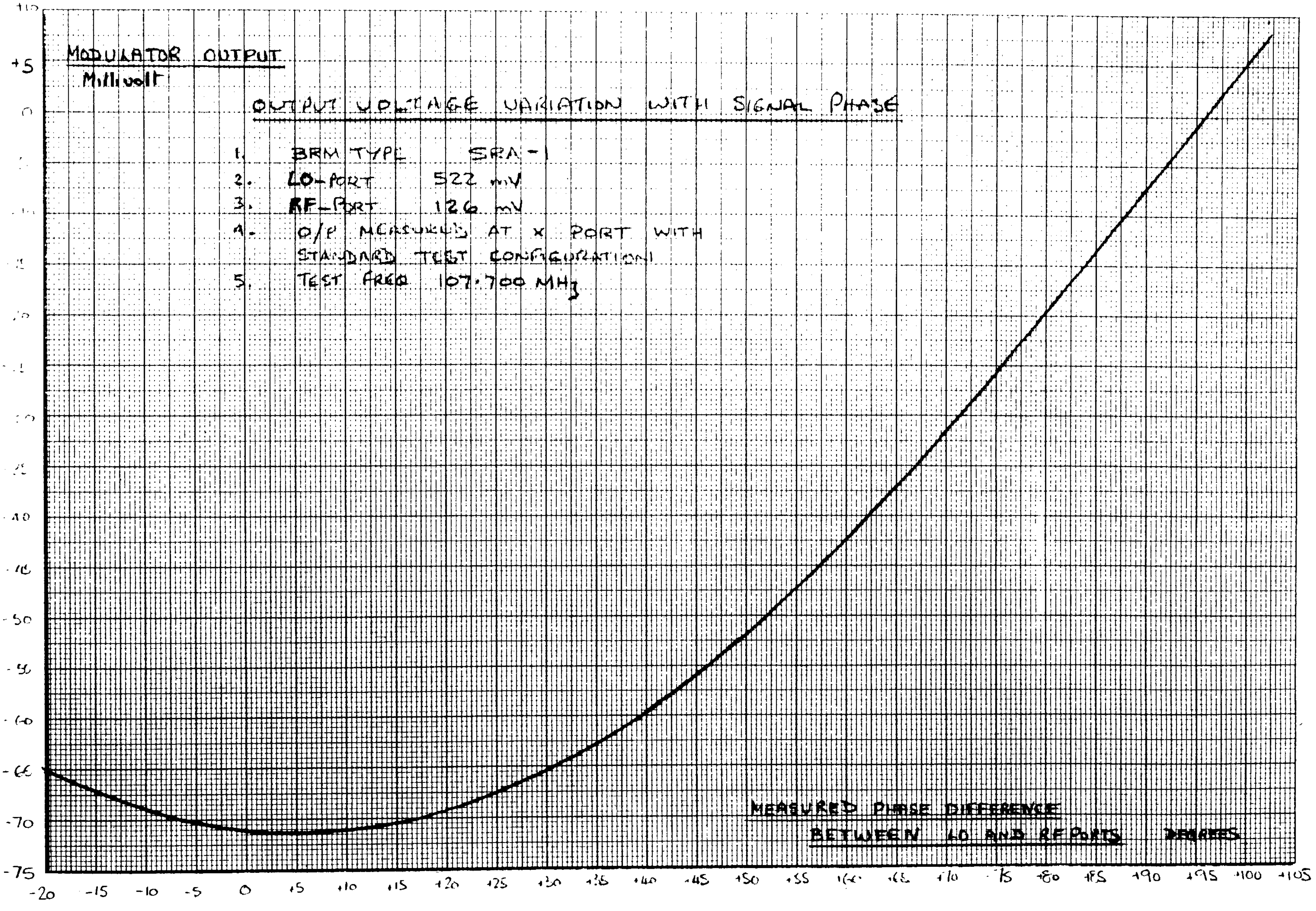


3. f = 10.000 MHz
SCOPE TB 20 nS/cm
OTHERWISE AS 1.



4. AS 3, BUT WITH SIGNAL
90° AHEAD OF REFERENCE

FIG 2. OUTPUT WAVEFORMS OF TYPE SRA-1 MODULATOR



OUTPUT VOLTAGE VARIATION WITH SIGNAL PHASE

1. BRM TYPE SRA-1
2. LO-PORT 522 mV
3. RF-PORT 126 mV
4. O/P MEASURED AT X PORT WITH STANDARD TEST CONFIGURATION
5. TEST FREQ 107.700 MHz

FIG 3 PHASE CHARACTERISTIC

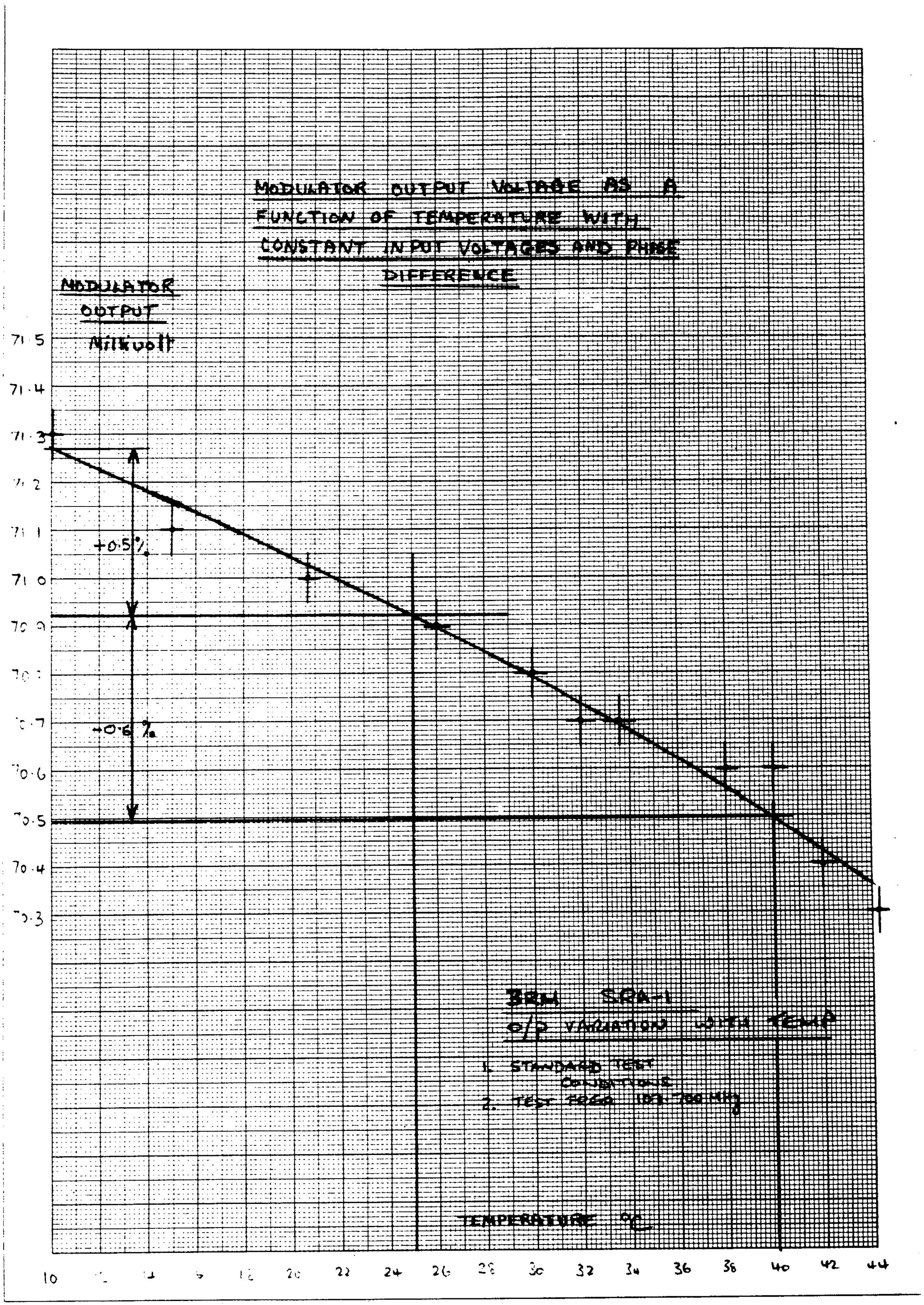

MODULATOR OUTPUT VOLTAGE AS A FUNCTION OF TEMPERATURE WITH CONSTANT INPUT VOLTAGES AND PHASE DIFFERENCE
MODULATOR OUTPUT
Millivolt
71·5
71·4
71·3
71·2
71·1
71·0
70·9
70·8
70·7
70·6
70·5
70·4
70·3
+0·5%
-0·6%
BRM SRA-1
O/P VARIATION WITH TEMP
1. STANDARD TEST CONDITIONS
2. TEST FREQ 103·700 MHz
TEMPERATURE °C
10
20
22
24
26
28
30
32
34
36
38
40
42
44

FIG 4

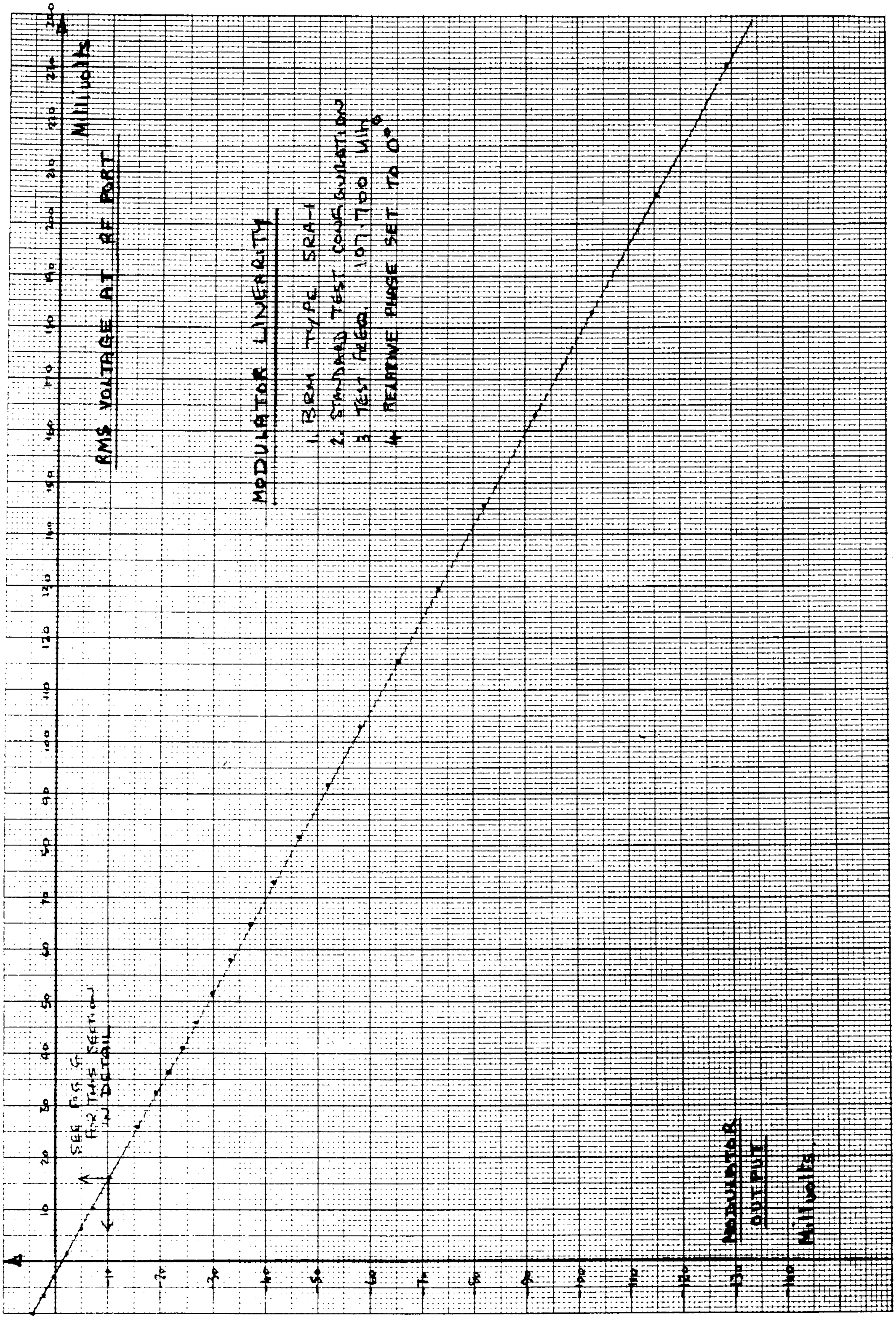
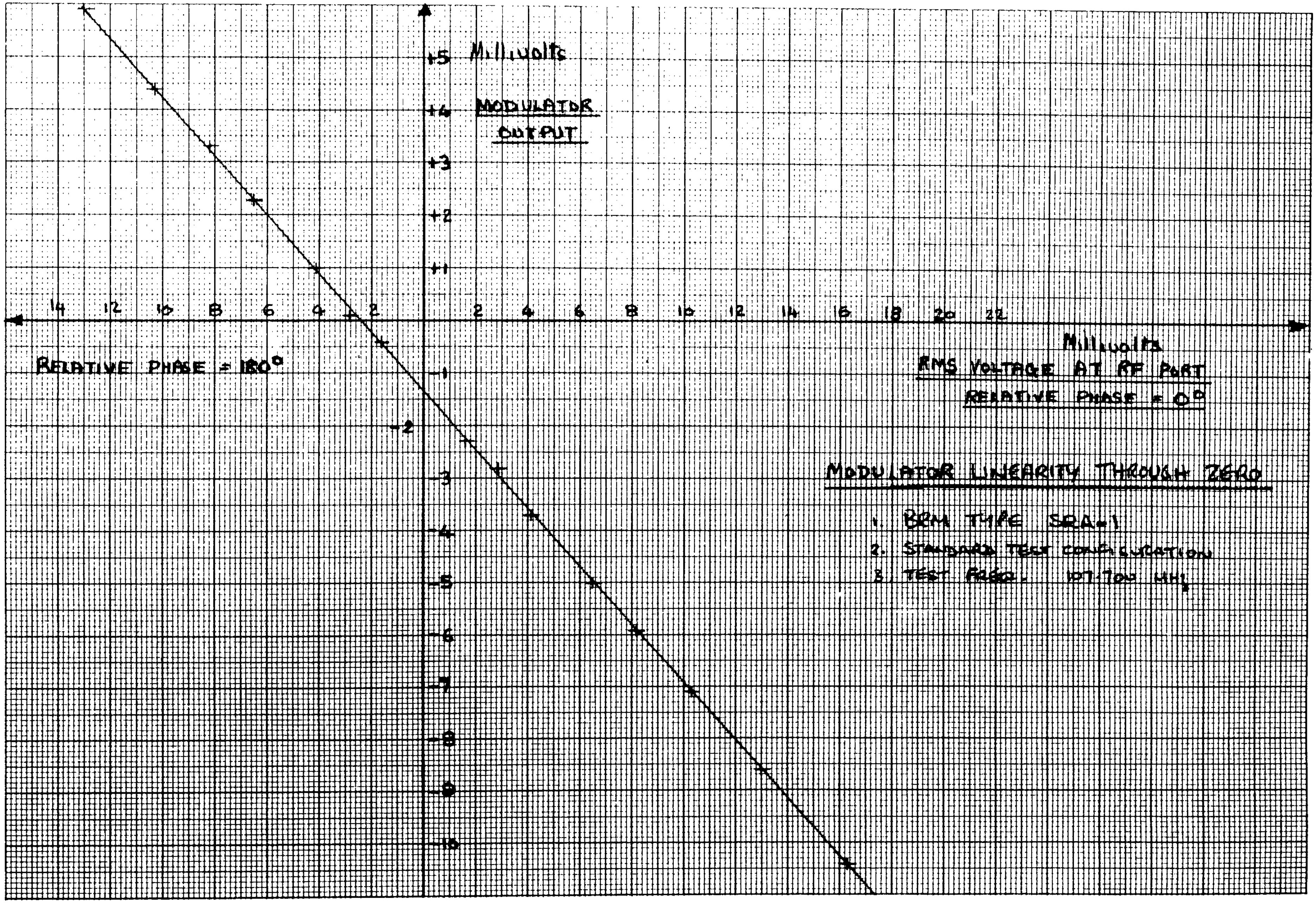
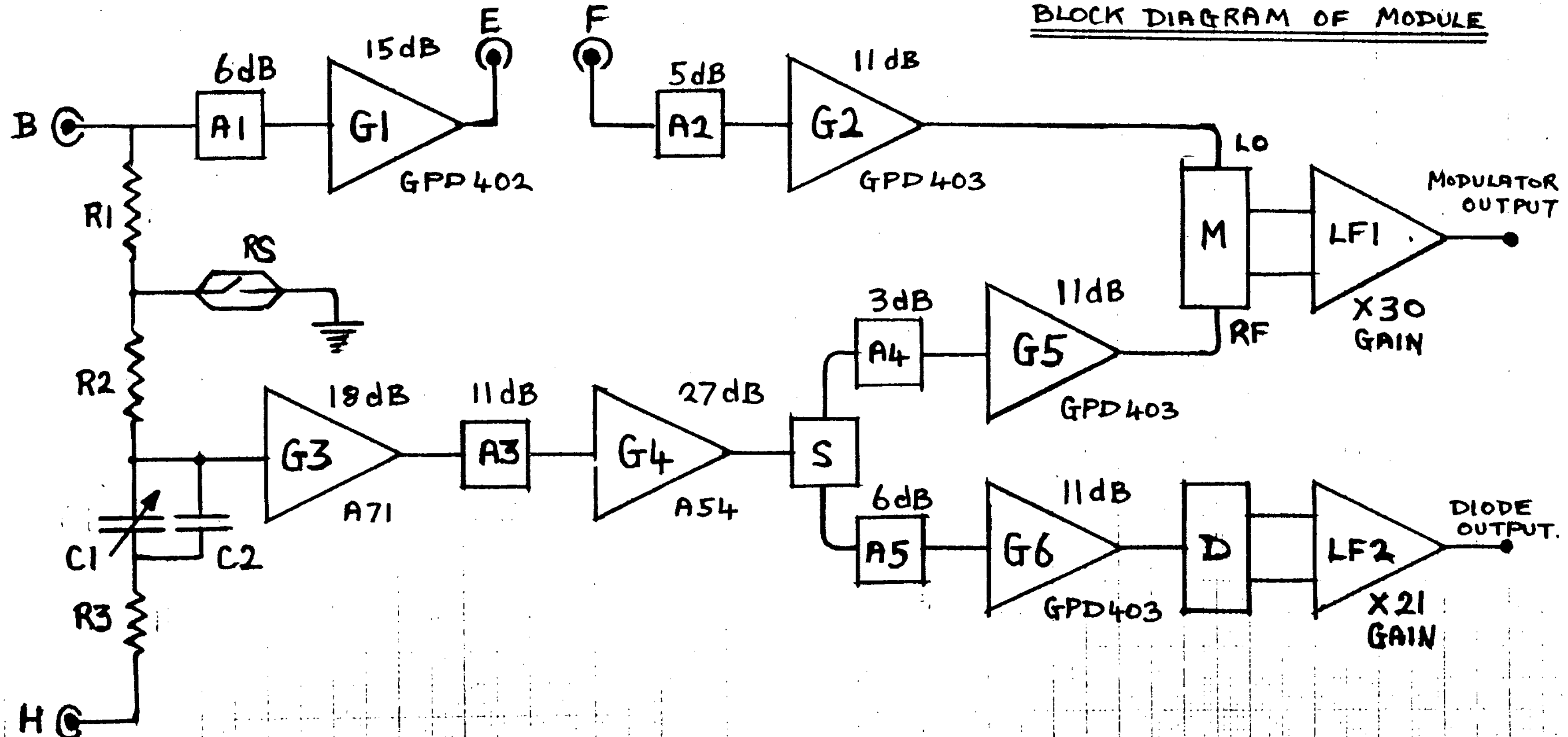

RMS VOLTAGE AT RF PORT
Millivolts
MODULATOR LINEARITY
1. BRM TYPE SRA-1
2. STANDARD TEST CONFIGURATION
3 TEST FREQ. 107,700 KHz
4 RELATIVE PHASE SET TO 0°
SEE FIG 6
FOR THIS SECTION
IN DETAIL
MODULATOR
OUTPUT
Millivolts
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
10
20
30
40
50
60
70
80
90
100
110
120
130
140

FIG 5


Millivolts
MODULATOR OUTPUT
+5
+4
+3
+2
+1
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
14
12
10
8
6
4
2
2
4
6
8
10
12
14
16
18
20
22
RELATIVE PHASE = 180°
Millivolts
RMS VOLTAGE AT RF PORT
RELATIVE PHASE = 0°
MODULATOR LINEARITY THROUGH ZERO
1. BRM TYPE SRA-1
2. STANDARD TEST CONFIGURATION
3. TEST FREQ. 107.700 MHz

Fg 6

BLOCK DIAGRAM OF MODULE

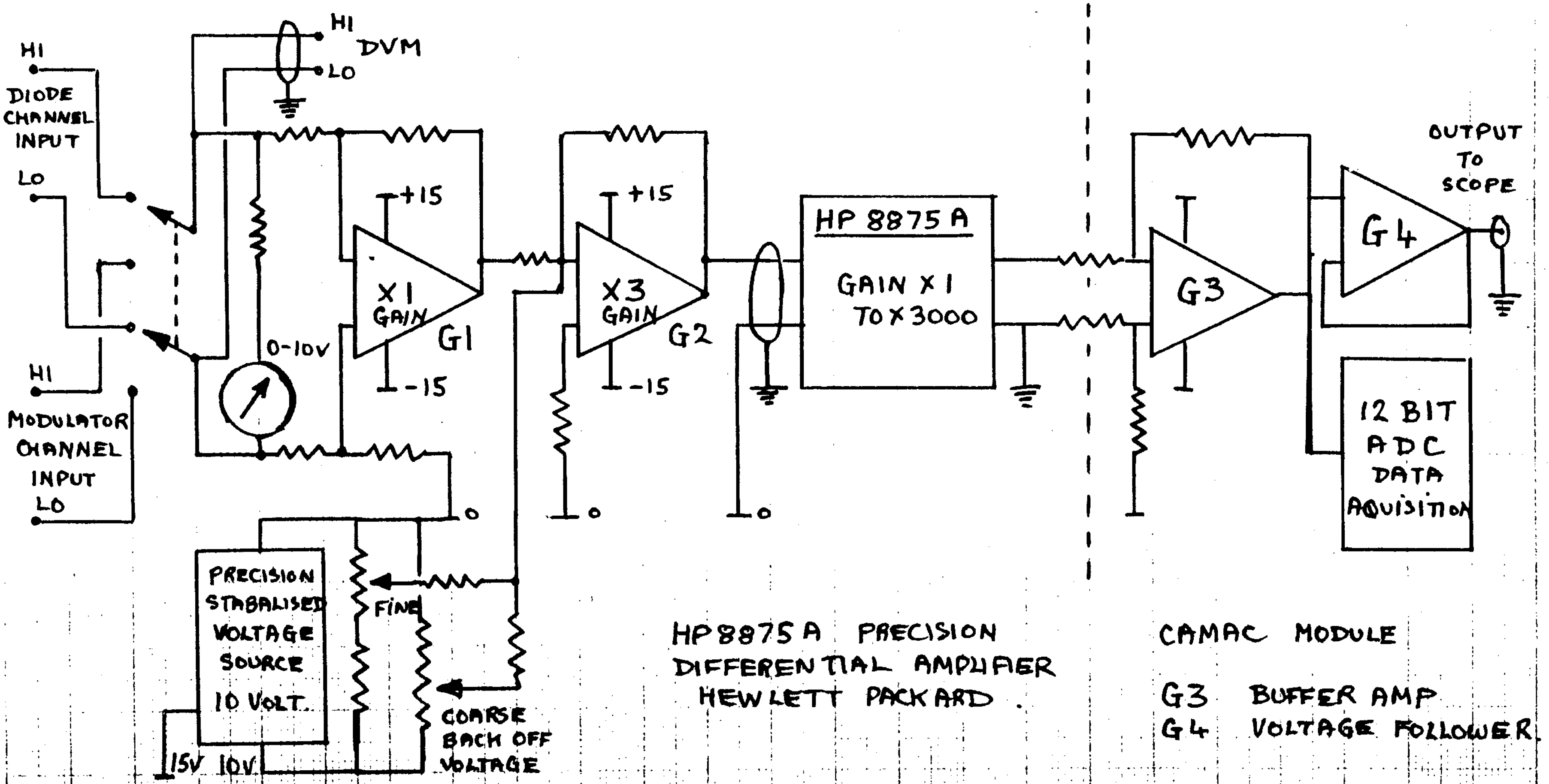


R1 R2	CONSTANT CURRENT RESISTORS
R3	DAMPING RESISTOR.
C1	TUNING CAPACITOR
C2	FIXED TUNING CAPACITOR.
S	TWO WAY SPLITTER.
M	MODULATOR TYPE SRA - 1
D	FULL WAVE DIODE RECTIFIER TYPE BD3
LF1	DIFFERENTIAL AMPLIFIER } OP-10 EY PLUS BUFFER STAGE
LF2	DIFFERENTIAL AMPLIFIER } OP-10 EY PLUS BUFFER STAGE
RS	REED SWITCH.

ALL AMPLIFIER GAINS AND ATTENUATOR VALUES ARE NOMINAL

ATTENUATORS A3 AND A5 ARE MADE UP OF TWO IN SERIES

FIG 7



HP 8875 A PRECISION DIFFERENTIAL AMPLIFIER HEWLETT PACKARD.

CAMAC MODULE

G3 BUFFER AMP
G4 VOLTAGE FOLLOWER.

G1 BUFFER AMPLIFIER.
G2 SUMMING AMPLIFIER.

BLOCK DIAGRAM OF THE POST MODULE SIGNAL PROCESSING SYSTEM USED AT LIVERPOOL.

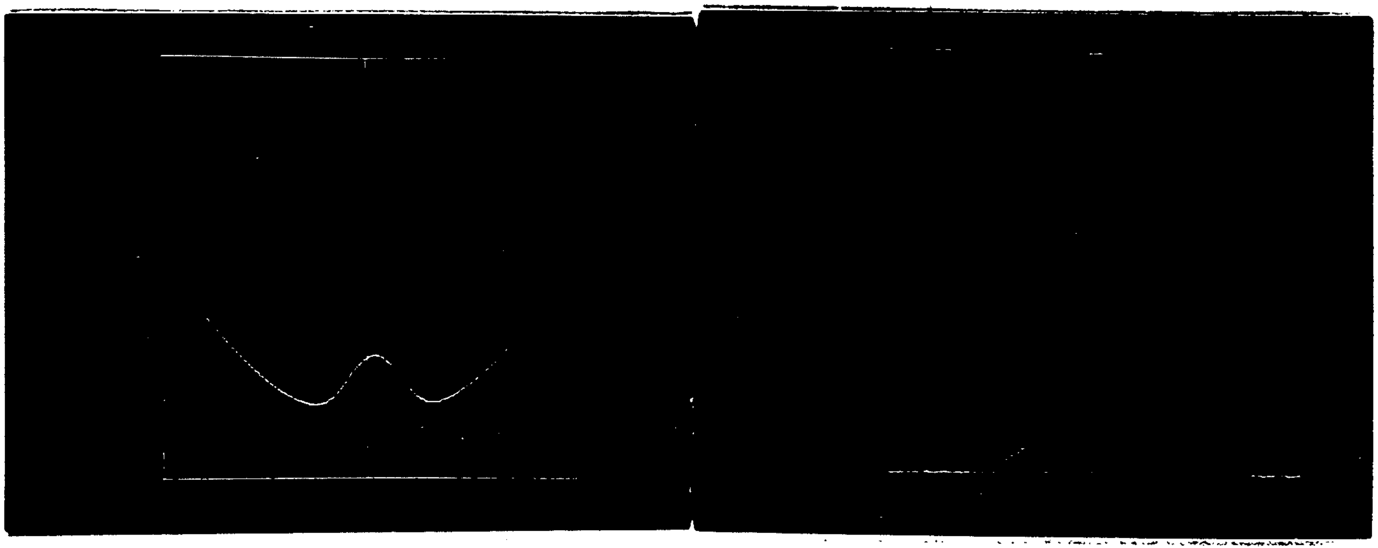
FIG 8

A. BACK GROUND SIGNALS USING TEST CIRCUIT. SCAN = 400 KHz GAIN x 100
TOP - DIODE CHANNEL
BOTTOM - MODULATOR CHANNEL

B. AS A. WITH GAIN x 300

C. THERMAL EQUILIBRIUM SIGNAL PROTONS AT 0·85 K SCAN 400 KHz GAIN x 1000

D. AS C. DIODE CHANNEL.



E. SIGNAL AS IN C.-SIGNAL AVERAGED

F. SIGNAL AS IN C.-SIGNAL AVERAGED AND WITH BACKGROUND SUBTRACTION.

FIG. 9

NMR RF MODULE

PARTS LIST	PTG/NMR/001/1	Parts List
	/2	Notes
	/3	Component Manufacturers
MODULE FRAME ASSEMBLY	PTG/NMR/002/1	Complete Assembly
	/2	Module Frame
	/3	Bulkheads
	/4	Bulkhead Fitting
	/5	Leadthrough Bulkhead
	/6	Cover
	/7	Hole Detail - 1
	/8	Hole Detail - 2
	/9	Hole Detail - 3
CAPACITOR DRIVE ASSEMBLY	PTG/NMR/003/1	Capacitor Drive Assy
REED RELAY ASSEMBLY	PTG/NMR/004/1	Coil Former Detail
	/2	Assembly Details
PCB # 1	PTG/NMR/005/1	Assembly
	/2	Component Mounting
	/3	Circuit Diagram
	/4	Drilling Detail
PCB # 2	PTG/NMR/006/1	Assembly
	/2	Component Mounting
	/3	Circuit Diagram
	/4	Drilling Detail
PCB # 3	PTG/NMR/007/1	Assembly
	/2	Component Mounting
	/3	Circuit Diagram
	/4	Drilling Detail
PCB # 4	PTG/NMR/008/1	Assembly
	/2	Component Mounting
	/3	Circuit Diagram
	/4	Drilling Detail
PCB # 5	PTG/NMR/009/1	Assembly
	/2	Component Mounting
	/3	Circuit Diagram
	/4	Drilling Detail
CANNON CONNECTOR ASSEMBLY	PTG/NMR/010/1	Connector Assy

LEADTHROUGH BULKHEAD ASSEMBLY	PTG/NMR/011/1	Component Preparation
	/2	Assembly Instructions
	/3	Final Assembly
MODULE ASSEMBLY INSTRUCTIONS	PTG/NMR/012/1	
	/2	
	/3	
	/4	
	/5	
	/6	
MOUNTING INSTRUCTIONS FOR "CHIP" COMPONENTS	PTG/NMR/013/1	
MODULE TEST PROCEDURE	PTG/NMR/014	Seperate Booklet

Chapter 2

Liverpool NMR Module--Module Test Procedure

G. Court D. W. Gifford

PTG/NMR/014

November 1980

CONTENTS

1) INTRODUCTION

These test procedures are primarily to check out a newly completed module, but can also be used to fault find on a previously operational unit. Before commencing any electrical work on a module it is advisable to read the User Handbook as well as all of these test procedures. It has been presumed that the following items (or similar in the case of 3 and 4) are available:-

1. The NMR RF Module - assembled as described in drawing PTG/NMR/012.
2. Power Supplies for RF Module - see User Handbook Section 6.
3. R.F. Signal Generator - e.g. Singer 6201, see User Handbook Section 9(a)1(i).
4. R.F. Voltmeter - high input impedance, preferably a Vector Voltmeter, e.g. HP 8405A, with probe for printed circuit measurements.
5. Standard lab scope.
6. Digital Voltmeter.
7. All items for making up lengths of UT85 co-ax cable with connectors and adaptors.

2) POWER SUPPLIES

The five power requirements are:-

+24V	(for RF amps)	at about 190mA
+15V	(for RF amps)	at about 64mA
+15V	(for LF amps)	at about 15mA
-15V	(for LF amps)	at about 15mA
+5V	(for relay switching)	at about 10mA

Voltage tolerance ± 5%

Noise on power lines < 1mV rms (to 100kHz)

i) Connect mating socket DB-25S to power supplies, see drawing PTG/NMR/010 for pin connections. Do not common 0v lines of the separate power supplies outside the NMR module. (See User Handbook, Section 6).

ii) Switch on power supplies and check voltage and polarity before plugging onto the module. Note that the +5V for reed relay switching is normally "off" i.e. RF is applied to the tuned circuit.

iii) With the power supplies switched off, connect them up to the module, preferably including the facility to measure the currents drawn.

iv) Switch power supplies on and check currents as above. Also check voltages inside the module. A convenient place to do this is at the filters on the Leadthrough Bulkhead. If anything is incorrect, switch off and investigate.

3) RF SYSTEM

i) Make up the following items

a) NMR Coil
b) Shielding Box } See User Handbook, section 8(a)I

c) NMR Coil Lead - 1.84 metres of semi-rigid, UT85, co-ax cable with SMA connectors

d) Reference Cable - 0.56 metres of semi-rigid, UT85, co-ax cable with SMA connectors, plus one Phase Adjuster Adaptor

ii) Using the above items, connect the NMR module into the test system shown in Figure 1.

iii) Set the signal generator output to minimum level, and a frequency of 107.7 MHz (for the above coil and cable dimensions).

iv) Using a high grade, high input impedance RF voltmeter, measure the RF level at the input end of the constant current feed resistors (TPI in Figures 2 and 3). Increase the generator output level until this measured RF level is 100mV ± 0.5mV. This level MUST remain constant at all times during the operation of the module.

v) Monitor the diode output with a DVM. Adjust the tuning capacitor for tuned circuit resonance, i.e. a minimum output from the diode detector. This should be about -4 volts if all is well. If for any reason the diode detector channel is not functioning correctly, a similar result can be attained by looking for a minimum RF level (with the RF voltmeter) anywhere in the RF signal channel (Amplifiers G3-G4-G6).

vi) Measure the RF levels as shown in Figure 2. They should correspond to the typical values given to within about 1 dB. Investigate any major discrepancies but do not change any chip attenuators at this stage.

vii) Now apply ∿ ± 200kHz frequency modulation to the RF input voltage (keep its level constant at 100mV), at a repetition rate of ∿ 20-50 per sec. Display the output of the diode detector channel on an oscilloscope (time base synchronous to the frequency scan). If a Liverpool type post detector signal processing system is being used the "back-off" voltage should be adjusted to precisely balance the DC level at the output of the diode channel. With the total gain set to X100, observe the amplified output on an oscilloscope with a sensitivity of 1 volt cm^{-1}. Alternatively AC couple an oscilloscope direct to the diode channel output with a sensitivity of 10mV cm^{-1}. A parabolic background signal should be seen which is a part of the tuned circuit Q curve. The tuning can now be precisely adjusted to the correct tune point which is when the curve is symmetric. (See Figure 9 in the User Handbook).

If the output from the modulator channel is now observed, the DC level will be approximately 3 volts with a much reduced amplitude parabolic signal, which will also be asymmetric unless the phase is fortuitously correct. The length of phase cable can then be adjusted (by using the adjuster and/or adding or removing connectors) to give a symmetric signal. The module is now correctly set up.

viii) Remove frequency scan and re-check levels.

ix) At this stage the chip attenuators can be changed if necessary.

a) Modulator Detector: The RF level at the LO port of the modulator (pin 7) should be + 7dBM ± 0.5dBM. This level cannot be measured directly, because of impedance mis matches etc., so it is necessary to assume the typical gain for a GPD 403 amplifier of 11dB and measure a level of -4dBM at the input of G2. Adjust this level if necessary by changing either attenuator A1 or A2. The typical levels are shown in Figure 2.

b) Signal Paths: The RF levels on the two signal paths should be within about 1dBM of the values shown in Figure 2. The levels can be adjusted by changing the values of A3, A4 and A5 as necessary - BUT - this should only be done when you are sure that the RF level at the input of G3 is correct and the problem is not elsewhere.

c) L.F. Amplifiers: Check these by measuring the levels shown in Figure 2.

x) If all the RF and DC levels check out OK then the module can be assumed to be working correctly. There are, however, two more tests that can be made to ensure that all is well.

4) MEASUREMENT OF RF SIGNAL PHASE SHIFTS THROUGH THE MODULE

Figure 4 shows phase shifts of the 107.7 MHz RF waveform through the module (referenced to the input). These figures were measured with the HP 8405A Vector Voltmeter and are accurate to about 2^o. It must be stressed that these measurements are only a guide as to what to expect in a typical module. The modulator used does not have a particularly good spec on phase balance between the input ports and the measured phase difference at the amplifier inputs may differ from the "correct" value by up to $\pm 10^o$.

5) MEASUREMENT OF DETECTOR OUTPUT LEVELS AS A FUNCTION OF TUNED CIRCUIT DRIVE VOLTAGE

Using the system as shown in Figure 5, it is possible to change the RF level to the tuned circuit without affecting the level to the LO port of the modulator (phase) detector. The detector therefore continues to function as it should, and it is thus possible to check its linearity. The diode channel linearity can also be checked at the same time. Note the inclusion of a variable length line in the reference channel. This is included to correct for minor changes in phase lag through the attenuator as different values of attenuation are selected. To measure the linearities of the two detectors, record and plot the detector outputs as a function of input attenuation setting. Note that at each change of attenuator setting it is necessary to trim the phase delay with the adjustable length line as described in paragraph 3(vii). It is advisable to do a dummy run through the measurements to ensure that all phase changes can be accommodated within the range of the variable length line. To insert or remove cable connectors may affect the RF voltage at G2 input, which should remain a constant -4dBM (about 150mV). It is also useful to measure the RF input to the module (at TP1) at one or two settings of the attenuator as this provides a simple means of relating the input attenuator settings to the standard RF input level and hence detector output levels. Figure 6 shows a plot of the data taken from such a measurement on a typical module.

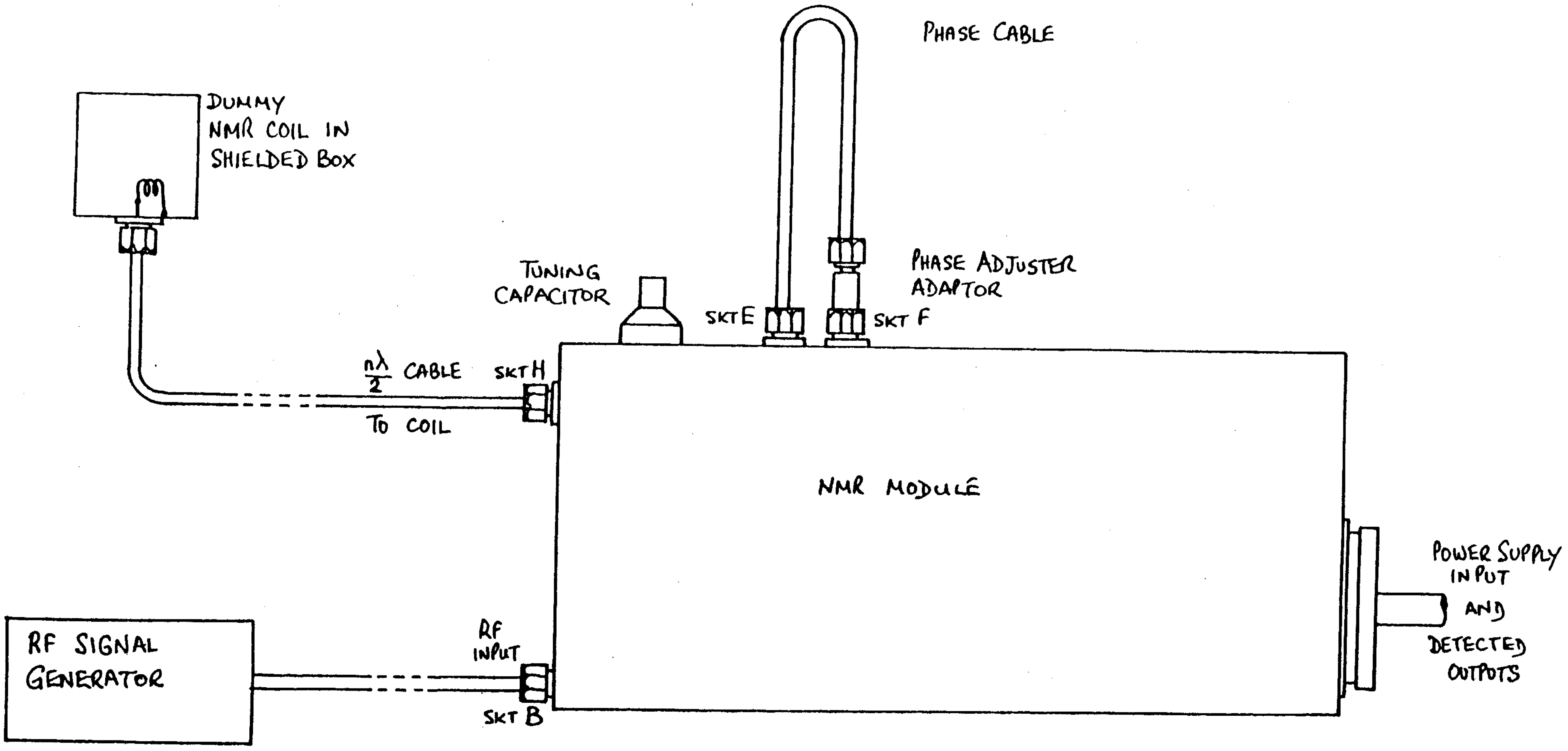

PHASE CABLE
DUMMY NMR COIL IN SHIELDED BOX
TUNING CAPACITOR
SKT E
SKT F
PHASE ADJUSTER ADAPTOR
$\frac{n\lambda}{2}$ CABLE
TO COIL
SKT H
NMR MODULE
POWER SUPPLY INPUT AND DETECTED OUTPOTS
RF SIGNAL GENERATOR
RF INPUT
SKT B

FIGURE 1.

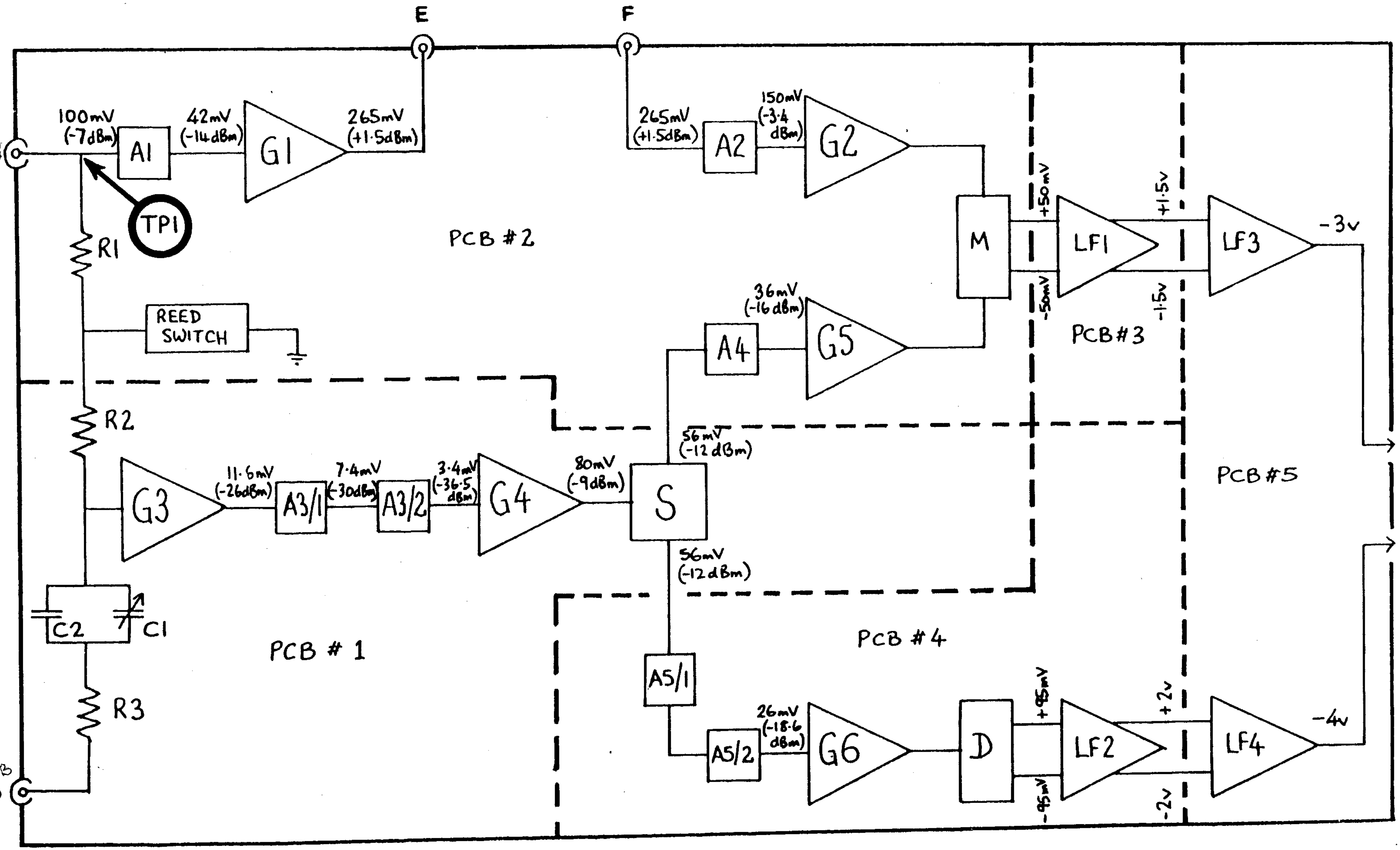

E
F
100mV (-7dBm)
A1
42mV (-14dBm)
G1
265mV (+1.5dBm)
TP1
R1
REED SWITCH
R2
G3
11.6mV (-26dBm)
A3/1
7.4mV (-30dBm)
A3/2
3.4mV (-36.5 dBm)
G4
80mV (-9dBm)
S
56mV (-12 dBm)
56mV (-12 dBm)
C2
C1
R3
PCB #1
PCB #2
265mV (+1.5dBm)
A2
150mV (-3.4 dBm)
G2
M
A4
36mV (-16 dBm)
G5
+50mV
-50mV
LF1
+1.5v
-1.5v
LF3
-3v
PCB #3
PCB #5
PCB #4
A5/1
A5/2
26mV (-18.6 dBm)
G6
D
+95mV
-95mV
LF2
+2v
-2v
LF4
-4v

FIGURE 2

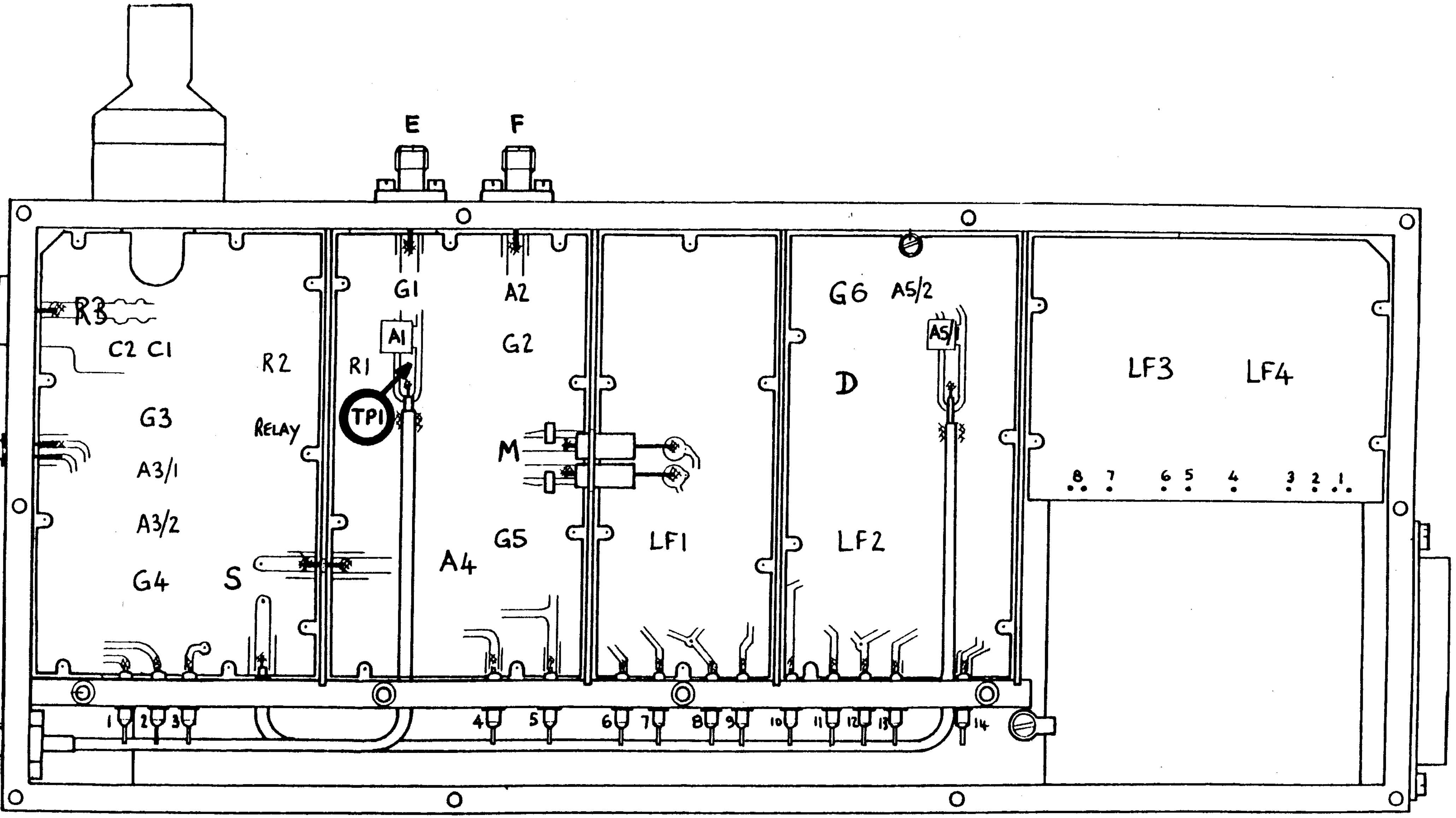

E
F
R3
C2 C1
R2
G3
RELAY
A3/1
A3/2
G4
S
G1
A1
R1
TP1
A2
G2
M
A4
G5
LF1
G6
A5/2
A5/1
D
LF2
LF3
LF4
8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIGURE 3.

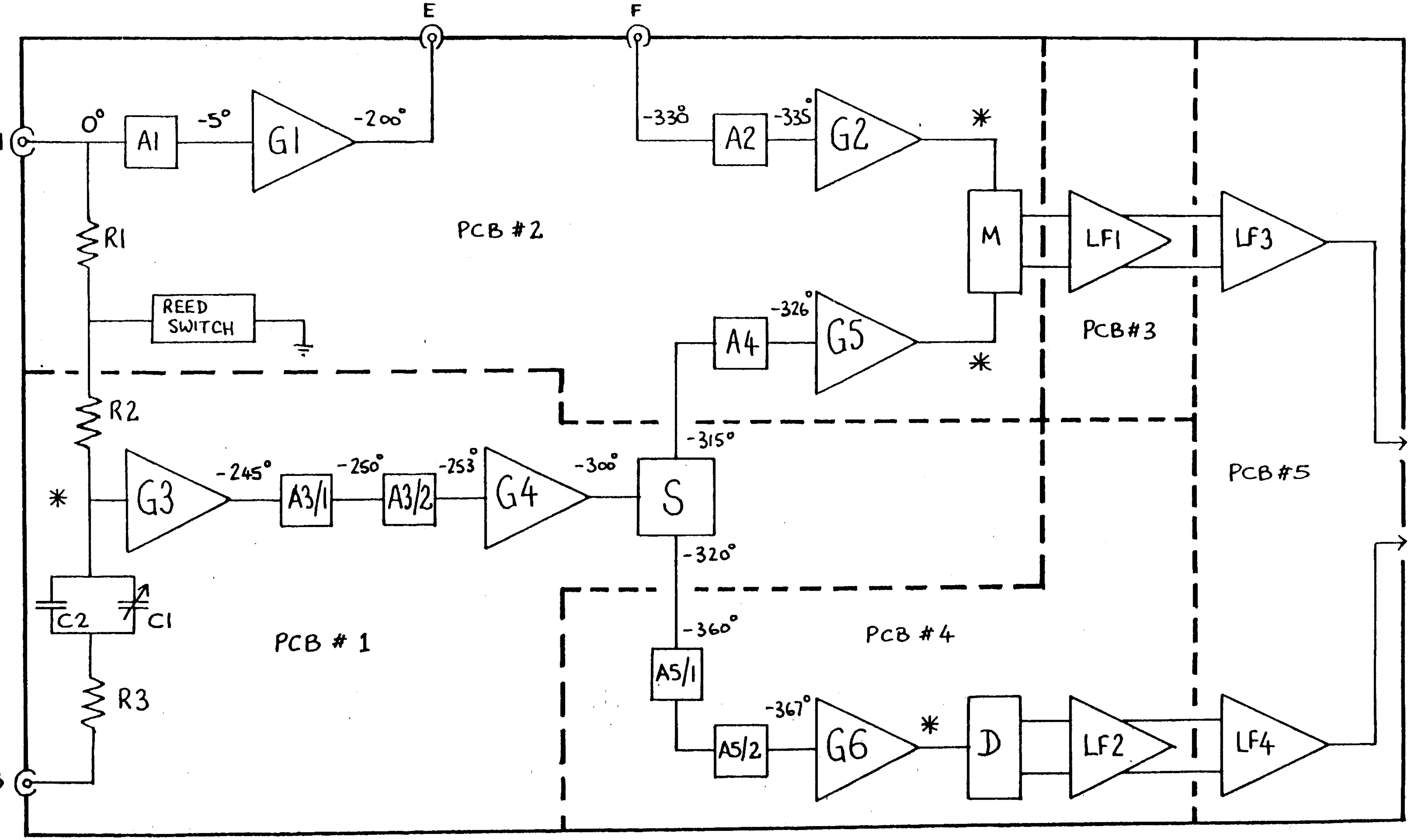
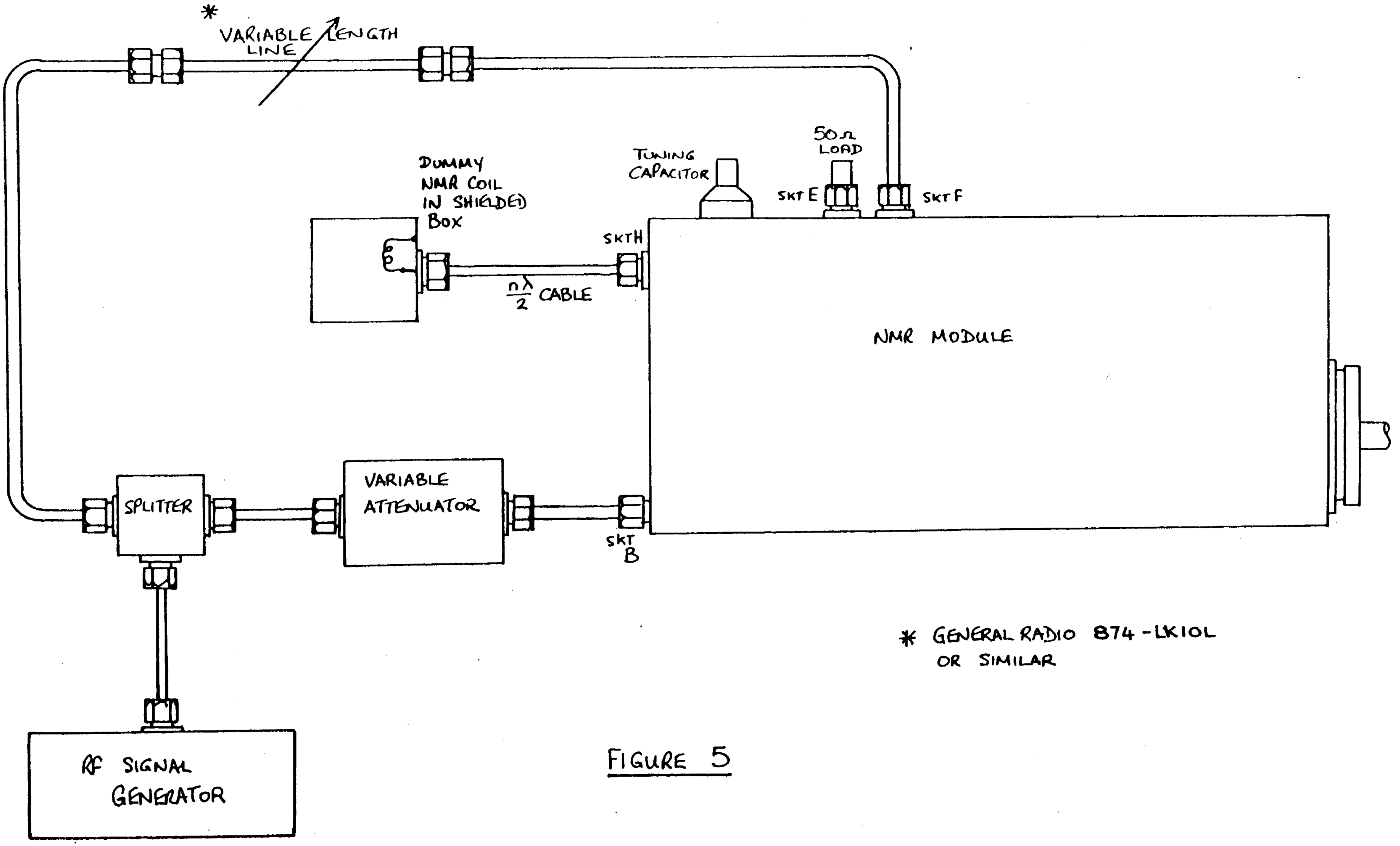


FIGURE 4

* PHASE CANNOT BE MEASURED AT THESE POINTS BECAUSE OF IMPEDANCE MISMATCHES



* GENERAL RADIO 874 - LK10L
OR SIMILAR

FIGURE 5

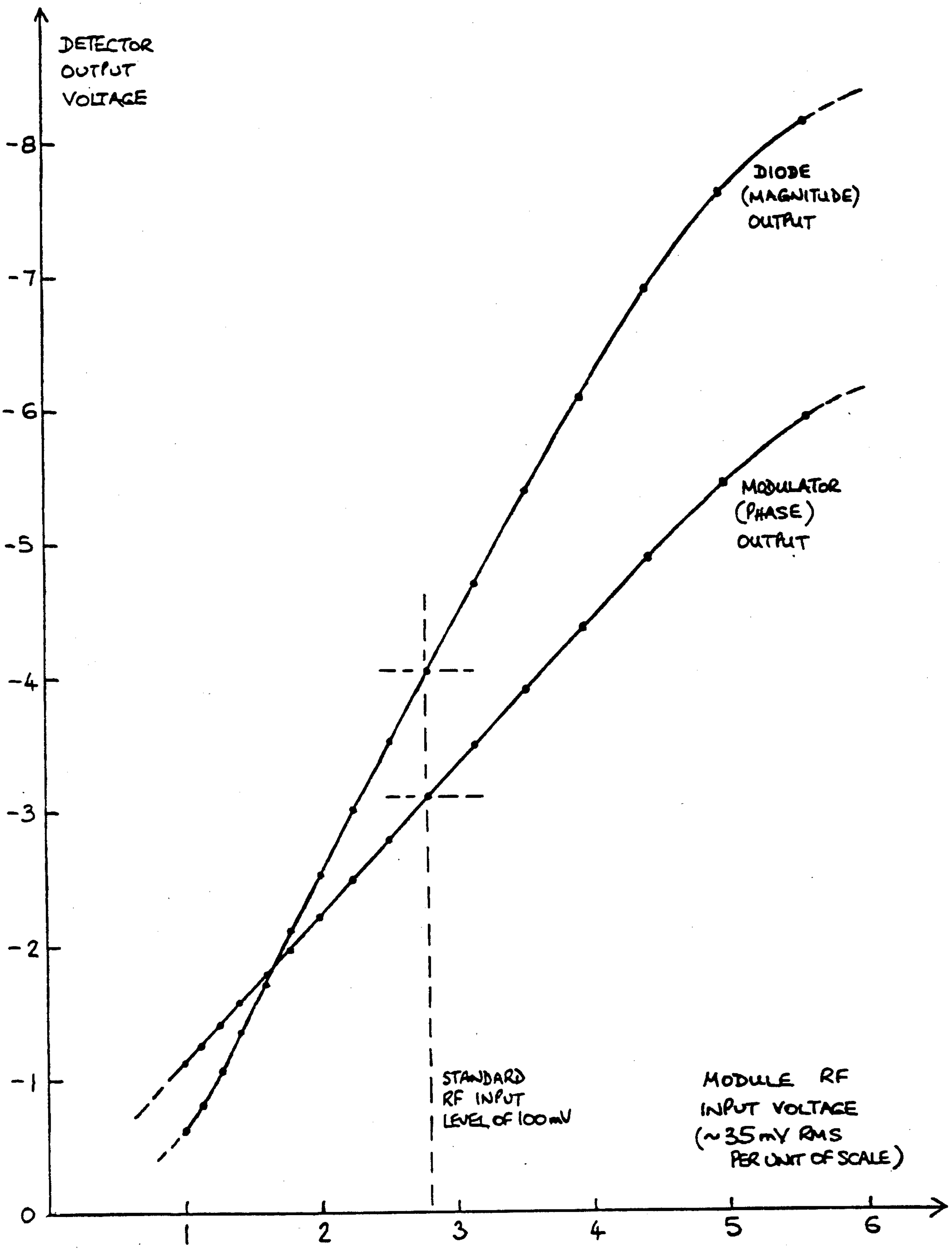

DETECTOR OUTPUT VOLTAGE
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
DIODE (MAGNITUDE) OUTPUT
MODULATOR (PHASE) OUTPUT
STANDARD RF INPUT LEVEL OF 100mV
MODULE RF INPUT VOLTAGE (~35mV RMS PER UNIT OF SCALE)

FIGURE 6

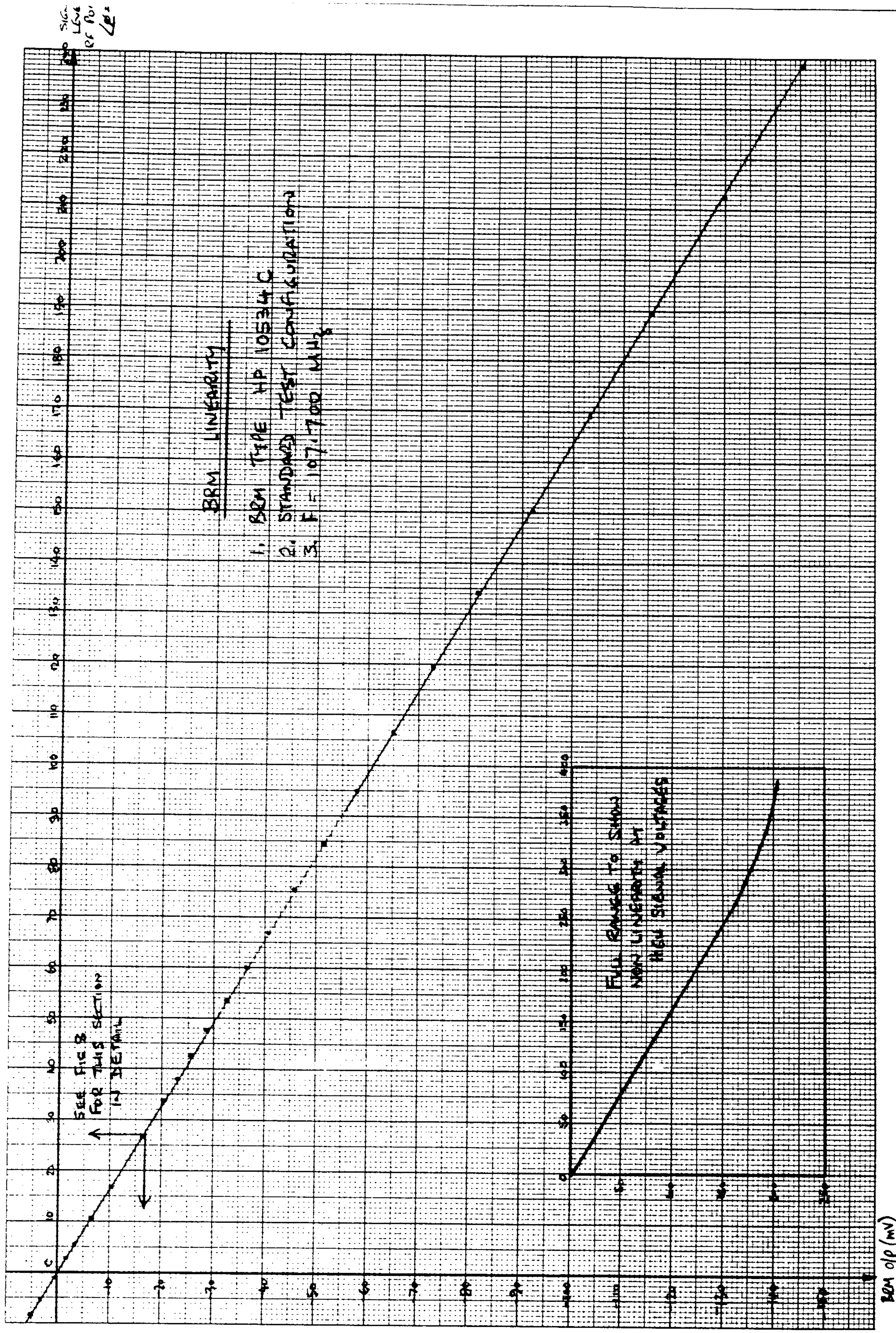


FIG 7. BRM (HP 10534C) LINEARITY

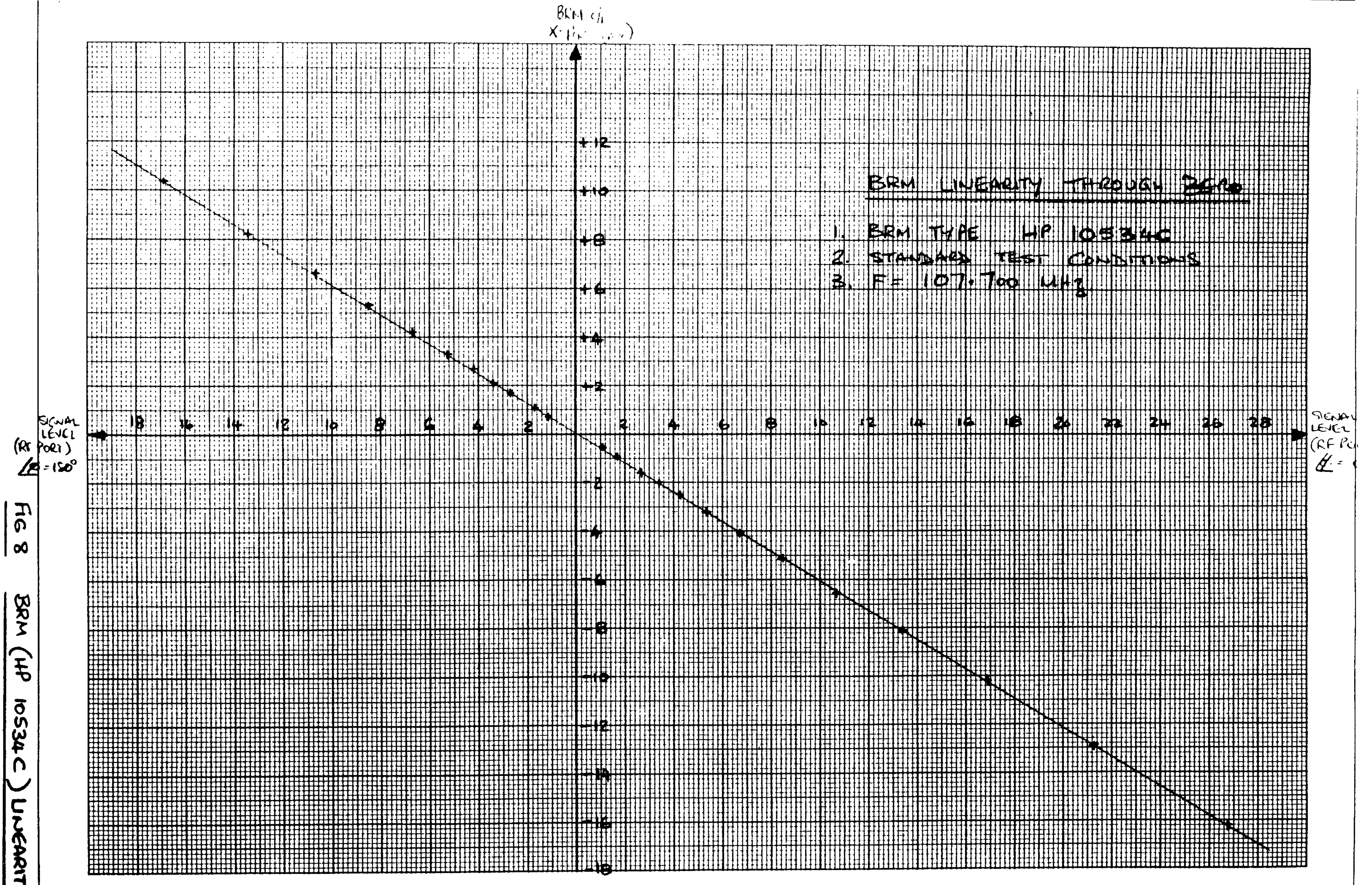


FIG 8 BRM (HP 10534C) LINEARITY

Chapter 3

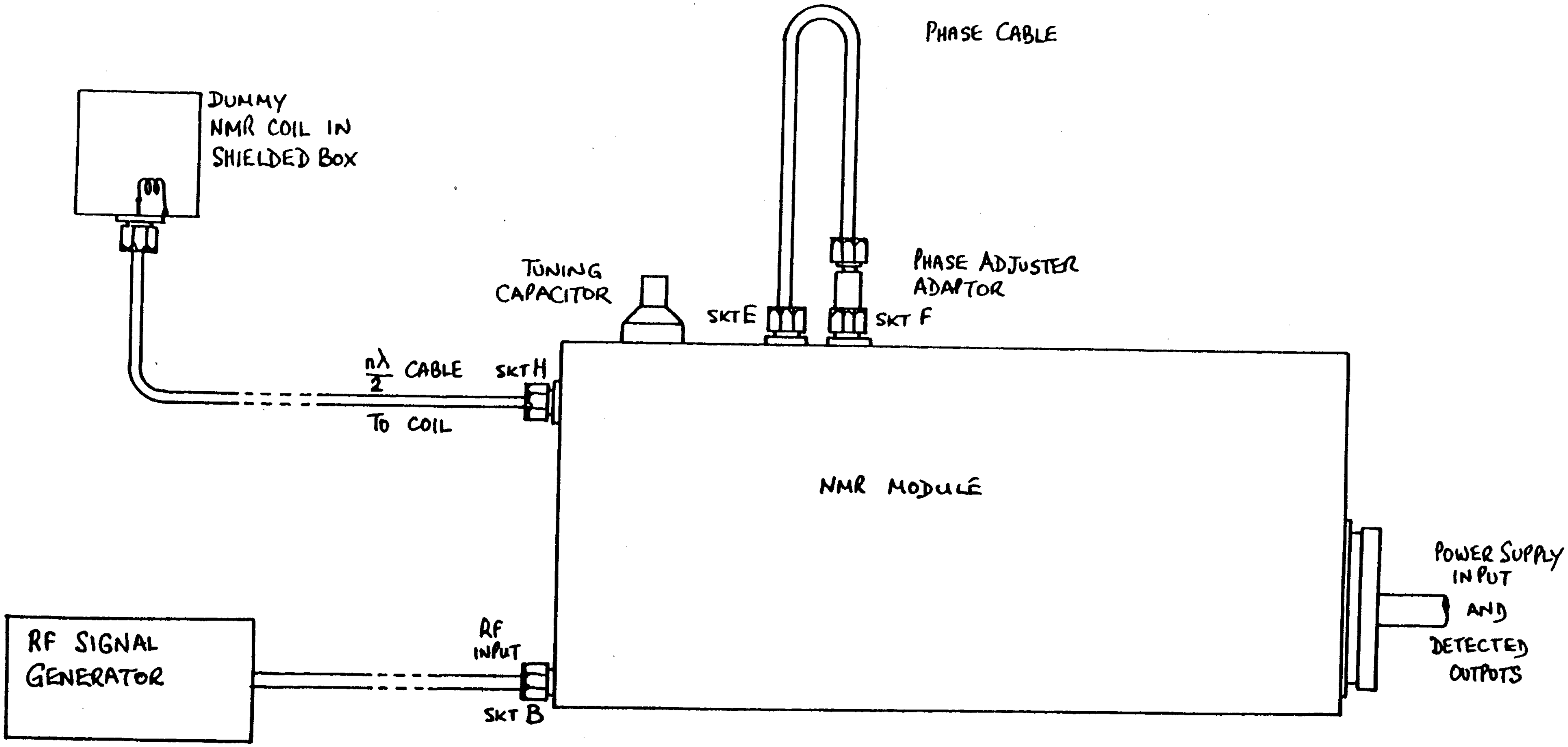

DUMMY
NMR COIL IN
SHIELDED BOX
PHASE CABLE
TUNING
CAPACITOR
SKT E
PHASE ADJUSTER
ADAPTOR
SKT F
$\frac{n\lambda}{2}$ CABLE
TO COIL
SKT H
NMR MODULE
POWER SUPPLY
INPUT
AND
DETECTED
OUTPUTS
RF SIGNAL
GENERATOR
RF
INPUT
SKT B

FIGURE 1.

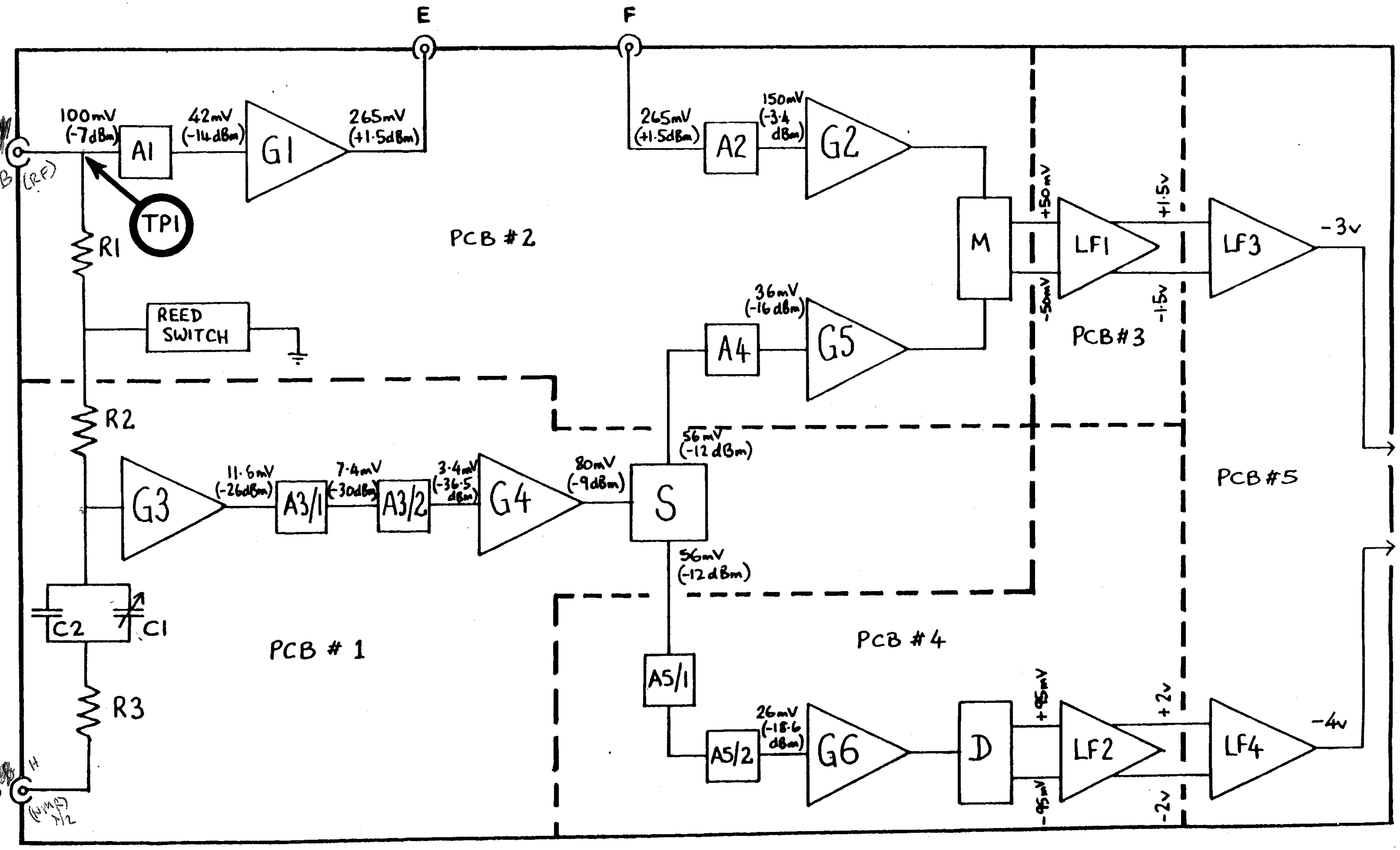

E
F
B (RF)
100mV (-7dBm)
A1
42mV (-14dBm)
G1
265mV (+1.5dBm)
TP1
R1
REED SWITCH
PCB #2
265mV (+1.5dBm)
A2
150mV (-3.4 dBm)
G2
M
+50mV
-50mV
LF1
+1.5v
-1.5v
LF3
-3v
PCB #3
36mV (-16dBm)
A4
G5
R2
G3
11.6mV (-26dBm)
A3/1
7.4mV (-30dBm)
A3/2
3.4mV (-36.5 dBm)
G4
80mV (-9dBm)
S
56mV (-12dBm)
56mV (-12dBm)
PCB #5
C2
C1
PCB # 1
PCB # 4
A5/1
R3
H
(NMR) X/2
26mV (-18.6 dBm)
A5/2
G6
D
+95mV
-95mV
LF2
+2v
-2v
LF4
-4v

FIGURE 2

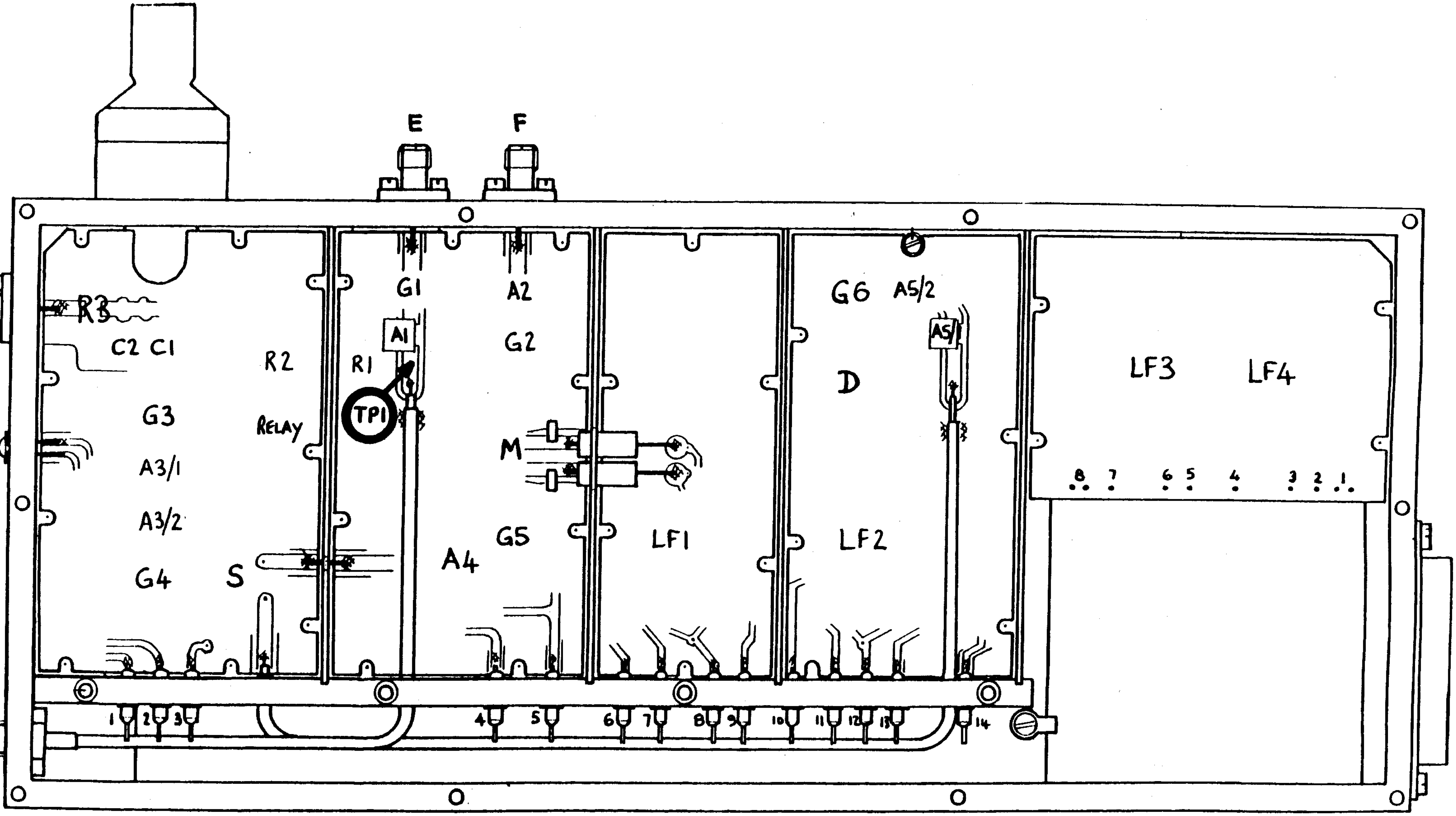

E
F
R3
C2 C1
G3
A3/1
A3/2
G4
R2
RELAY
S
G1
A1
R1
TP1
A2
G2
M
G5
A4
LF1
G6
A5/2
A5/1
D
LF2
LF3
LF4
8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIGURE 3.

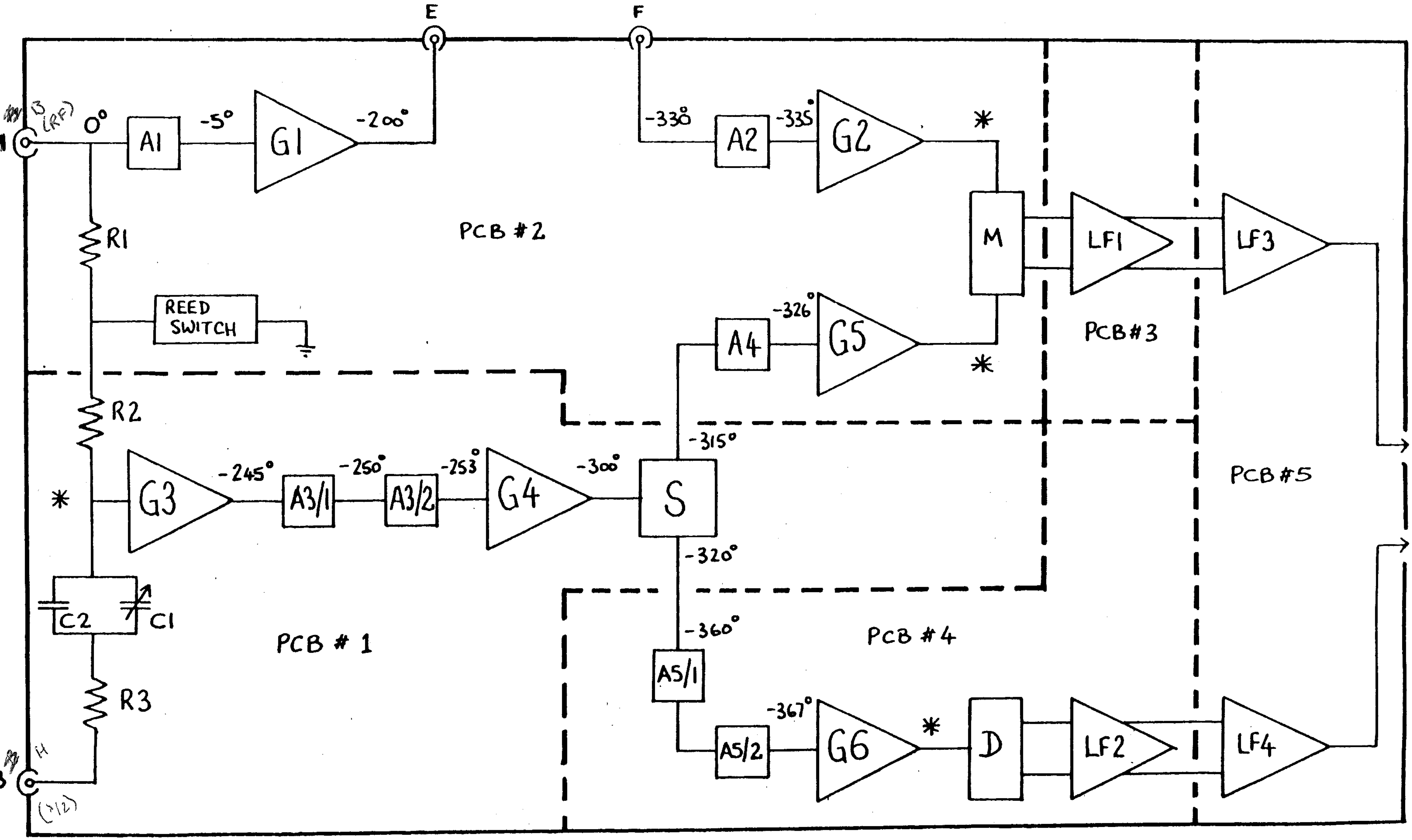


FIGURE 4

* PHASE CANNOT BE MEASURED AT THESE POINTS BECAUSE OF IMPEDANCE MISMATCHES

Appendix

'LIVERPOOL' NMR MODULE
CHECKOUT PROCEDURE

Module number = 90/11

Set up test procedure as in Fig 5 in manual with

1) 10 Ω ✓ damping resistor 2) f = 107.7 MHz 3) Tuned coil and cable.

4) Allow **warm up** time of at least 15 mins with DC and RF inputs

5) Measure RF levels with Hewlett Packard 8405A vector voltmeter or the equivalent, using a **two pin board probe.** TAKE CARE NOT TO SHORT THE MODULE'S POWER TRACKS TO GROUND WHEN USING THIS PROBE.

Test Procedure

First set RF levels so that A1 input = 100 mV ✓

a) Measure G1 input 42
b) Measure G1 output 275

Now set RF generator to give A2 input of 270mV
reset RF variable attenuator to give G3 output = 12 mV (12.5)

c) Read G4 input 3.6 mV
d) Read G4 output 95 mV
e) Read A4 input 63
f) Read A4 output 44
g) Read A5 input 67
h) Read A5 output 46

Using a high quality DVM measure the following DC levels with respect to ground (the module's case)

i) BRM out +ve ( ) +52
j) BRM out -ve ( ) -52 (balance check)

k) Diode out +ve ( ) +33
l) Diode out -ve ( ) -34 (balance check)

m) REAL PART out ( ) 3.25
n) MAGNITUDE out ( ) 1.82

Now with frequency scan and 'scope on Magnitude output , check tune is ok
TUNE OK ? [✓ yes] no

With 'scope on REAL PART output, check phase adjust

PHASE OK ? [✓ yes] no

Visual noise check on output [✓ OK] noise

Check options : LED and Reed relay switch OK ? [✓ yes] no

Comments :
Higher than average overall gain. This is OK

13 DEC 1990

'LIVERPOOL' NMR MODULE
CHECKOUT PROCEDURE

Module number = 90/12

Set up test procedure as in Fig 5 in manual with

1) 10 Ω damping resistor 2) f = 107.7 ✓ MHz 3) Tuned coil and cable.

4) Allow **warm up** time of at least 15 mins with DC and RF inputs

5) Measure RF levels with Hewlett Packard 8405A vector voltmeter or the equivalent, using a **two pin board probe.** TAKE CARE NOT TO SHORT THE MODULE'S POWER TRACKS TO GROUND WHEN USING THIS PROBE.

Test Procedure

First set RF levels so that A1 input = 100 mV

a) Measure G1 input 42 mV
b) Measure G1 output 285

Now set RF generator to give A2 input of 270mV
reset RF variable attenuator to give G3 output = ~~12~~ mV 11.5 mV used *

c) Read G4 input 3.3 mV
d) Read G4 output 75 mV
e) Read A4 input 50
f) Read A4 output 35
g) Read A5 input 54
h) Read A5 output 37

Using a high quality DVM measure the following DC levels with respect to ground (the module's case)

i) BRM out +ve ( ) +42
j) BRM out -ve ( ) -42 (balance check)

k) Diode out +ve ( ) +19
l) Diode out -ve ( ) -16 (balance check)

m) REAL PART out ( ) 2.59
n) MAGNITUDE out ( ) 0.952

Now with frequency scan and 'scope on Magnitude output , check tune is ok
TUNE OK ? [✓ yes] no

With 'scope on REAL PART output, check phase adjust

PHASE OK ? [✓ yes] no

Visual noise check on output [✓ OK] noise

Check options : LED and Reed relay switch OK ? [✓ yes] no

Comments :

magnitude output appears low because G3 output was 11.5mV not 12 mV

13 Dec 1990

'LIVERPOOL' NMR MODULE
CHECKOUT PROCEDURE

Module number = 90/13

Set up test procedure as in Fig 5 in manual with

1) 10 Ω damping resistor ✓ 2) f = 107.7 MHz ✓ 3) Tuned coil and cable.

4) Allow **warm up** time of at least 15 mins with DC and RF inputs

5) Measure RF levels with Hewlett Packard 8405A vector voltmeter or the equivalent, using a **two pin board probe.** TAKE CARE NOT TO SHORT THE MODULE'S POWER TRACKS TO GROUND WHEN USING THIS PROBE.

Test Procedure

First set RF levels so that A1 input = 100 mV

a) Measure G1 input 43 mV
b) Measure G1 output 290 mV

Now set RF generator to give A2 input of 270mV
reset RF variable attenuator to give G3 output = 12 mV

c) Read G4 input 3.5 mV
d) Read G4 output 80 mV
e) Read A4 input 54 mV
f) Read A4 output 37 mV
g) Read A5 input 57 mV
h) Read A5 output 39 mV

Using a high quality DVM measure the following DC levels with respect to ground (the module's case)

i) BRM out +ve ( ) +43 mV
j) BRM out -ve ( ) -44 mV (balance check)

k) Diode out +ve ( ) +20 mV
l) Diode out -ve ( ) -20 mV (balance check)

m) REAL PART out ( ) 2.716 mV
n) MAGNITUDE out ( ) 1.096 mV

Now with frequency scan and 'scope on Magnitude output , check tune is ok
TUNE OK ? [✓ yes] no

With 'scope on REAL PART output, check phase adjust

PHASE OK ? [✓ yes] no

Visual noise check on output [✓ OK] noise

Check options : LED and Reed relay switch OK ? [✓ yes] no

Comments :

'LIVERPOOL' NMR MODULE
CHECKOUT PROCEDURE

Module number = ______________

Set up test procedure as in Fig 5 in manual with

1) Ω damping resistor 2) f = 107.7 MHz 3) Tuned coil and cable.

4) Allow **warm up** time of at least 15 mins with DC and RF inputs

5) Measure RF levels with Hewlett Packard 8405A vector voltmeter or the equivalent, using a **two pin board probe.** TAKE CARE NOT TO SHORT THE MODULE'S POWER TRACKS TO GROUND WHEN USING THIS PROBE.

Test Procedure

First set RF levels so that A1 input = 100 mV

a) Measure G1 input ____________
b) Measure G1 output____________

Now set RF generator to give A2 input of 270mV
reset **RF variable attenuator** to give G3 output = 12 mV

c) Read G4 input ________________
d) Read G4 output ________________
e) Read A4 input________________
f) Read A4 output________________
g) Read A5 input______________
h) Read A5 output_______________

Using a high quality DVM measure the following DC levels with respect to ground (the module's case)

i) BRM out +ve ( ) ______________
j) BRM out -ve ( )______________ (balance check)

k) Diode out +ve ( ) ______________
l) Diode out -ve ( ) ______________ (balance check)

m) REAL PART out ( ) ______________
n) MAGNITUDE out ( )______________

Now with frequency scan and 'scope on Magnitude output , check tune is ok
TUNE OK ? yes no

With 'scope on REAL PART output, check phase adjust

PHASE OK ? yes no

Visual noise check on output OK noise

Check options : LED and Reed relay switch OK ? yes no

Comments :

'LIVERPOOL' NMR MODULE
CHECKOUT PROCEDURE

Module number = ______________

Set up test procedure as in Fig 5 in manual with

1) Ω damping resistor 2) f = 107.7 MHz 3) Tuned coil and cable.

4) Allow **warm up** time of at least 15 mins with DC and RF inputs

5) Measure RF levels with Hewlett Packard 8405A vector voltmeter or the equivalent, using a **two pin board probe.** TAKE CARE NOT TO SHORT THE MODULE'S POWER TRACKS TO GROUND WHEN USING THIS PROBE.

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TUNE OK ? yes no

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PHASE OK ? yes no

Visual noise check on output OK noise

Check options : LED and Reed relay switch OK ? yes no

Comments :