214-0085-01-01_00

Riedel

R.F. Note 84

May 20, 1982
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Contents:

## 1. INTRODUCTION

The Fast Phase Shifter module can produce approximately ±40 degrees of fast phase shift by means of the DC control from the Phase Detector and ±180 (0-360) degrees of phase shift by manual adjustment of a knob on the front panel.

The Phase Trimmer module works as a ±10 degree manual phase shifter. It's shifting can be controlled locally by a knob on the front panel and remotely by a ±10V DC control voltage.

## 2. FAST PHASE SHIFTER MODULE

The Fast Phase Shifter module consists of the fast phase shifting circuit, the ±180 degree phase shifting circuit and the amplitude regulator as shown in Fig. 1. The fast shifting circuit was developed successfully as described in RF Note #54 (S. Francis); the performance was presented there, also. Exactly the same circuit was employed in the final module.

## 3. ±180° MANUAL PHASE SHIFTER (ϕ-SHIFTER)

The manual ±180° (0-360°) phase shifter circuit consists of a Quadrature Hybrid, two RF transformers and a "home-brew" Phase Control Pot (tapped potentiometer) as shown in Fig. 2.

The output signal of the Fast Phase Shifter circuit goes into the Quadrature Hybrid and is divided into two signals 90° apart. The four signals of 0°, -90°, -180° and -270° are obtained through the two broad-band RF transformers and are connected to the four taps of the ring cerment variable resistor. They are connected at the right physical angles 90° apart and the phase sequence is set positively for the knob to be adjusted clockwise.

This circuit produces a large amplitude variation in it's output signal. When the input impedance of the following buffer amplifier is infinite, the calculated amplitude variation over the range of 360° phase shift is more than 30% as illustrated in Fig. 2.

Several structures for this pot were tried to search for the best uniformity and smoothness of the phase control. The improvement of the resistance uniformity was accomplished by carbon painting, silver painting and filing the surface of the ring resistor. The smoothness was improved by adjusting the pressure or by lubricating with electronic contact lubricant.

The amplitude variation curves for two sampled pots are plotted in Fig. 2. Assembling and adjusting of these special pots was a most difficult job.

These pots worked well for the manual ±180° shifter with the additional amplitude regulator. But troubles with bad contact were found a few times after the modules were installed in the RF console. Another scheme that uses an electronic phase shifter, such as the circuit of the Phase Trimmer, may be used to avoid the problem of the mechanical contact.

## 4. AMPLITUDE REGULATOR & GAIN AMPLIFIER

The amplitude variation of the ±180° Manual Phase Shifter can be stabilized with the Amplitude Regulator circuit. This regulator uses an electronic attenuator in the form of a double balanced ring modulator (mixer).

Typical attenuation vs. control current and the operating range for the amplitude regulator are shown in Fig. 3. The regulator circuit consists of a peak detector, an operational amplifier and a current-controlled attenuator. The peak detected signal of the output amplitude is fed back to the IF port of the attenuator through the high gain op-amp. The performance of this regulator is plotted in Fig. 2. The loss by the attenuator is regained by a transistor amplifier so that the output signal of the Fast Phase Detector can be fixed at 1V rms.

The only problem of this regulator was the higher input impedance that occurred when the control current to the attenuator was lowered. The input impedance was adjusted to 50Ω using a parallel resistor connected at the output of the attenuator.

## 5. SPECIFICATIONS AND PERFORMANCE OF THE FAST PHASE DETECTOR MODULE

| | |
|---|---|
| FREQ. RANGE: | 8-32 MHZ |
| MANUAL PHASE SHIFT: | ±180 degrees (0-360 degrees) |
| FAST PHASE SHIFT: | ±40 degrees (corresponding to ±7V control voltage) |
| RESPONSE OF THE FAST PHASE SHIFTER: | DC-500 KHZ,<br>-1.8 db at 500 KHZ<br>-8.9 db at 700 KHZ<br>-17 db at 1 MHZ |
| RF INPUT: | 1V rms |
| INPUT IMPEDANCE: | 40-72Ω at 10 MHZ,<br>38-70Ω at 20 MHZ |

| | |
|---|---|
| RF OUTPUT: | 1V rms (adjustable by a trim pot inside module) |
| RF OUTPUT REGULATION: | ±1% (with Phase Shift of ±40° at 20 MHZ)<br><br>±2% (within the frequency range 8-32 MhZ) |
| RF SPECTRAL PURITY: | For operation at 20 MHZ with 1V rms output<br><br>40 MHZ -40 db<br>60 MHZ -45 db<br>80 MHZ -50 db |
| RF OK SIGNAL CONNECTION: | PIN3: RF OK1,<br>PIN4: RF OK2,<br>PIN8: GND<br>PIN1: SHIELD |
| POWER REQUIREMENTS: | +15V 500 mA,<br>-15V 500 mA<br>+12V 50 mA |
| DRAWING NUMBER: | 5-RFG-9-C (PHASE CONTROL POT)<br>5-RVE-1C-2-C (FAST PHASE SHIFTER) |

## 6. CIRCUIT DESCRIPTION OF PHASE TRIMMER MODULE

The Phase Trimmer module is fed by a 1V rms RF signal and produces two output signals that are equal in phase and amplitude (1V rms, +13 dBm). One output signal goes to the Fast Phase Shifter as a signal source for the transmitter through the Dee Voltage Amplitude Regulator. The other one goes to the MIX/ϕ-Det module controlling the Fast Phase Shifter (refer to Fig. 4).

The fundamental elements of the phase shifting circuit are a quadrature hybrid, two electornic attenuators (double-balanced mixers) and a signal combiner. The principal on which the circuit works is vector addition of quadrature signals in the same manner as the Phase Shifter. The electronic attenuator works as a bi-phase modulator.

The circuit shown in Fig. 5, modifies the amplitude and phase of the input RF signal by application IC1 and IC2 current components. Note both attenuators accept bi-polar inputs on their respective IF ports, thereby the resultant vector can be rotated through all angles 0 to 360° by varying the amount and polarity of the IC1 and IC2 control currents.

Figure 5 also shows the phase shifting range related to the control currents over the entire operating frequency range of RF system. The result shows that the lower currents produce an acceptability constant phasing range of ±10° from 10 to 30 MHZ.

The power loss of the RF signal and the amplitude variation are restored by the gain amplifiers and the amplitude regulator circuit. These circuits are the same as those of the Fast Phase Shifter module.

## 7. SPECIFICATIONS AND PERFORMANCE OF THE PHASE TRIMMER MODULE

| | |
|---|---|
| FREQ. RANGE: | 8-32 MHZ |
| PHASE TRIMMING RANGE: | ±11.0° at 10 MHZ<br>±11.3° at 20 MHZ<br>±11.2° at 20 MHZ |
| CONTROL VOLTAGE: | ±10V DC (REMOTE) |
| RF INPUT: | 1V rms |
| INPUT IMPEDANCE: | 44-90Ω at 10 MHZ,<br>43-86Ω at 20 MHZ,<br>42-82Ω at 30 MHZ |
| RF OUTPUT: | 2 Ports 1V rms (adjustable) |
| REGULATION: | ±0.2% (with variation of ±10° at 20 MHZ)<br>±2% (with the frequency range 8-32 MHZ) |
| ABSOLUTE PHASE LAG: | - 36° at 10 MHZ<br>-140° at 20 MHZ<br>-220° at 30 MHZ |
| POWER REQUIREMENTS: | +15V 210 mA<br>-15V 20 mA |
| DRAWING NUMBER: | 5-RVF-1C-2-C |

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Attached you find the figures for RF Note #84.

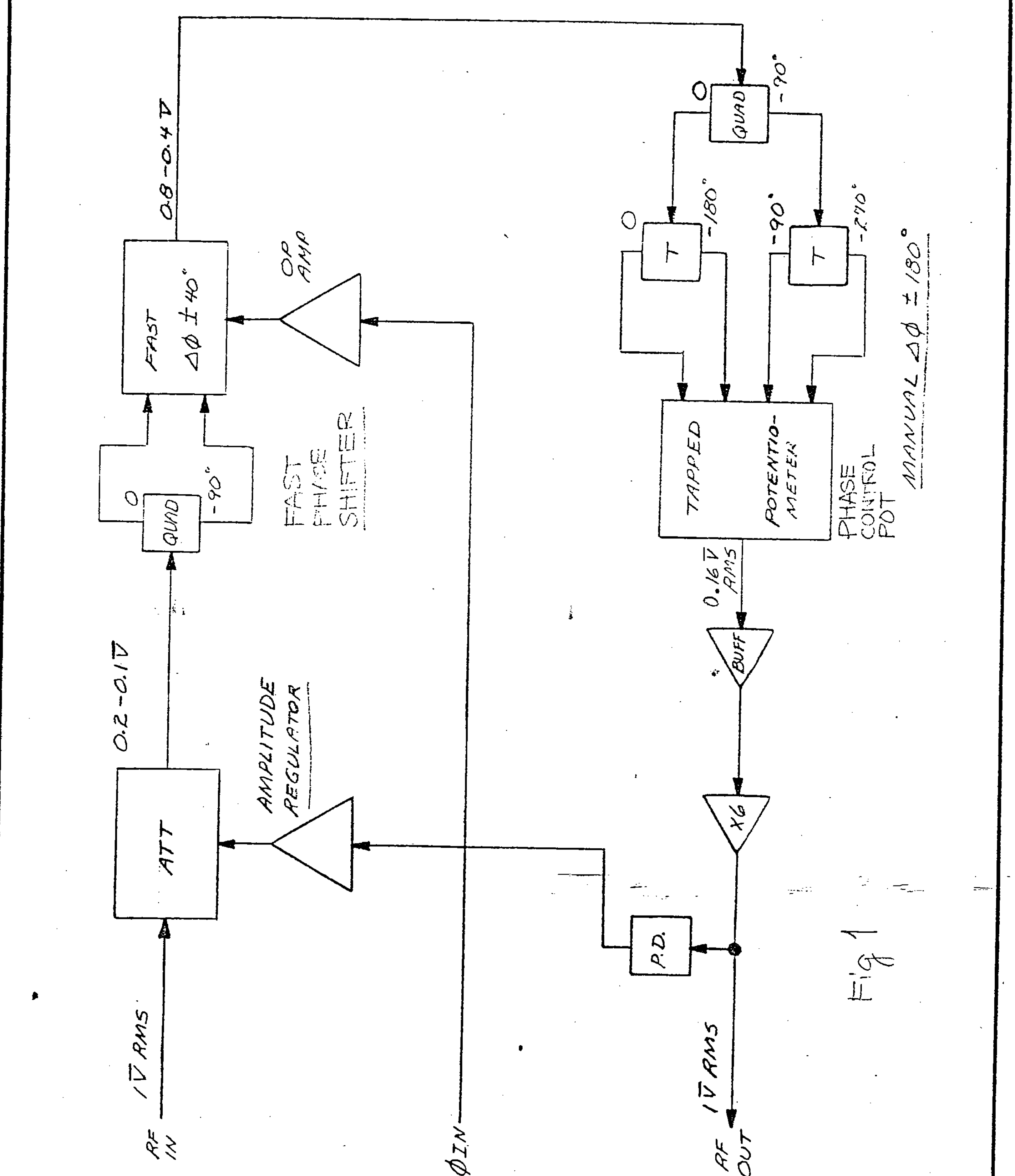



Fig 1

| MICHIGAN STATE UNIVERSITY -CYCLOTRON LABORATORY- | | EAST LANSING, MICHIGAN | |
|---|---|---|---|
| BLOCK DIAGRAM | SCALE N | DRN BY KUNKEL | APPR'D |
| TITLE FAST PHASE SHIFTER | | | |
| DATE 7-6-81 | SHEET 1 OF 1 | DRAWING NO. 5-RVE-18-1-A | REV. |

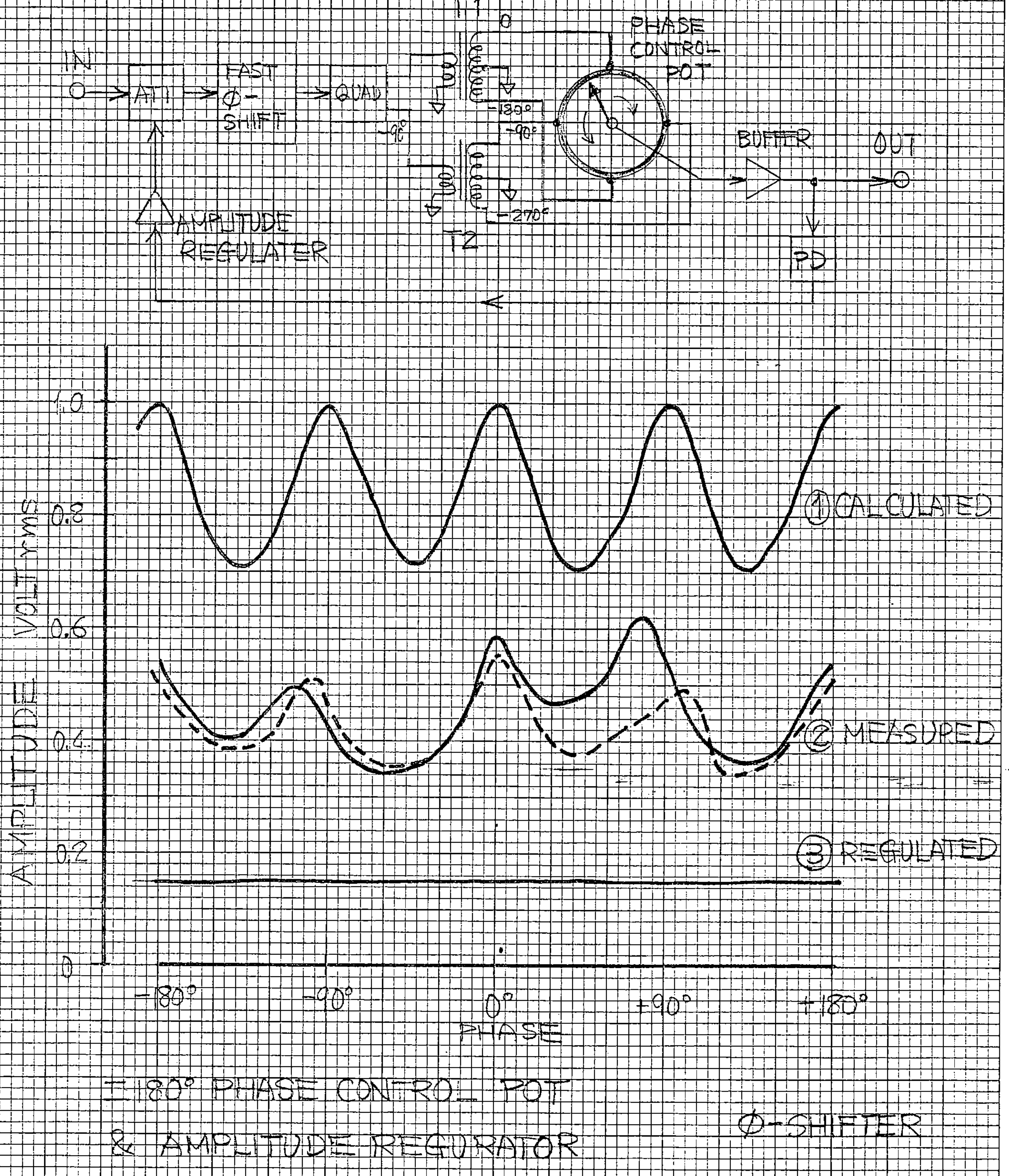

IN
ATT
FAST
Φ-
SHIFT
QUAD
-90°
T1
0
-180°
-90°
-270°
T2
PHASE
CONTROL
POT
BUFFER
OUT
PD
AMPLITUDE
REGULATER
1.0
0.8
0.6
0.4
0.2
0
AMPLITUDE VOLT rms
① CALCULATED
② MEASURED
③ REGULATED
-180°
-90°
0°
+90°
+180°
PHASE
±180° PHASE CONTROL POT
& AMPLITUDE REGURATOR
Φ-SHIFTER

FIG. 2

Fig 3

TYPICAL ATTENUATION VS CURRENT

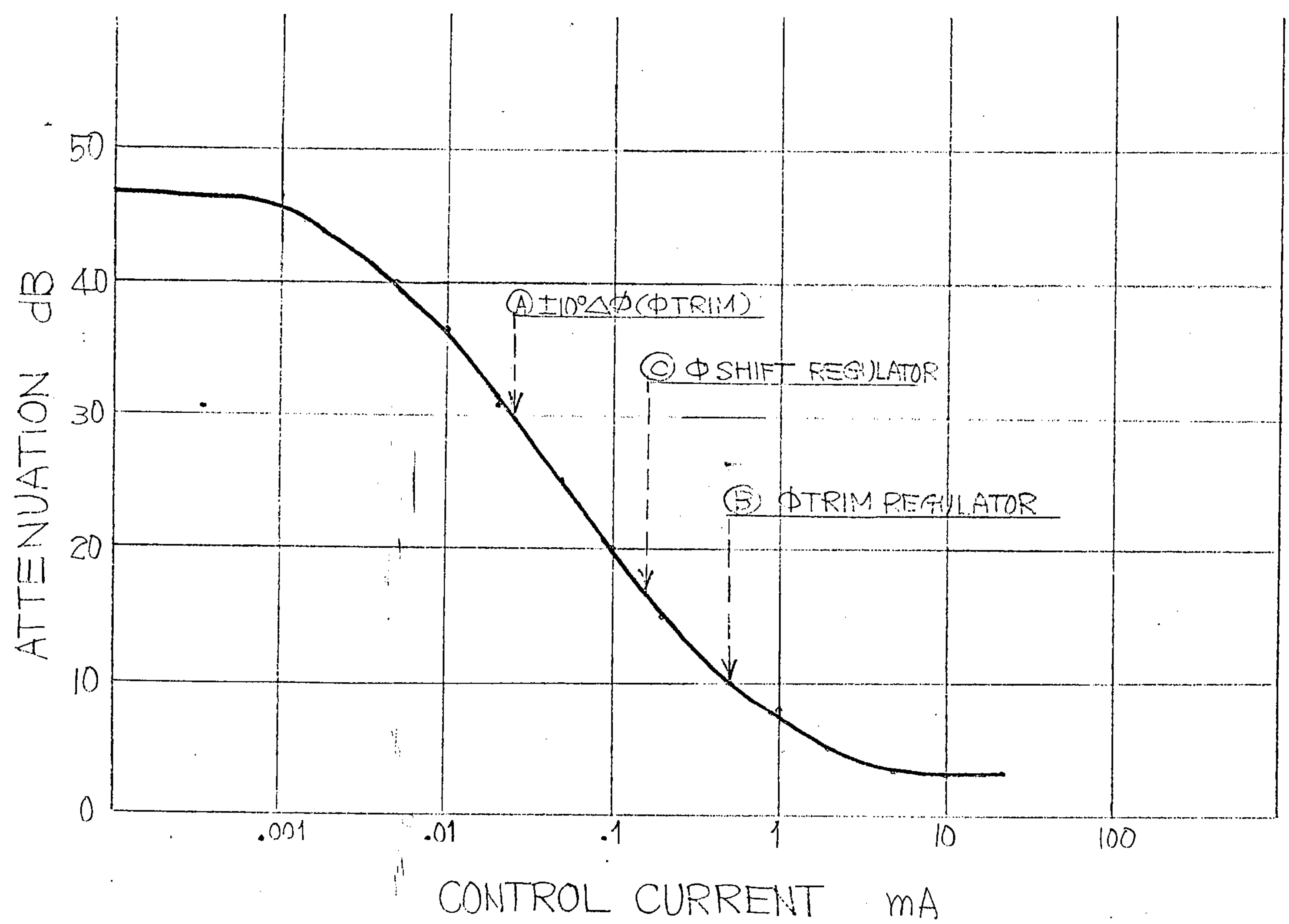
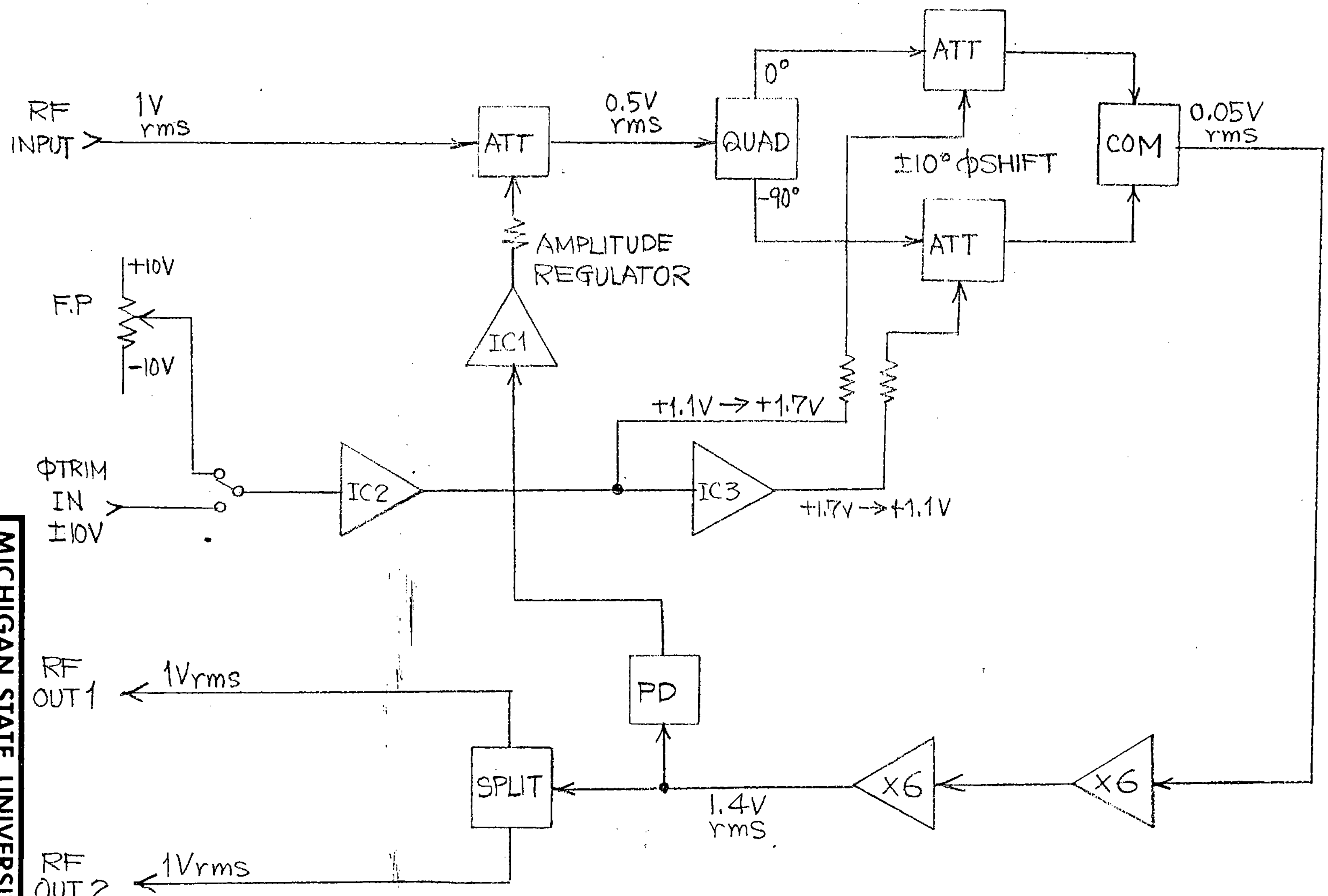



FIG. 3




ATT: ELECTRONIC ATTENUATOR (DBM) PAS-3
QUAD: QUADRATURE HYBRID (90° SPLITTER/COMBINER)
COM : 2-way 0° POWER SPLITTER/COMBINER PSC-2-1

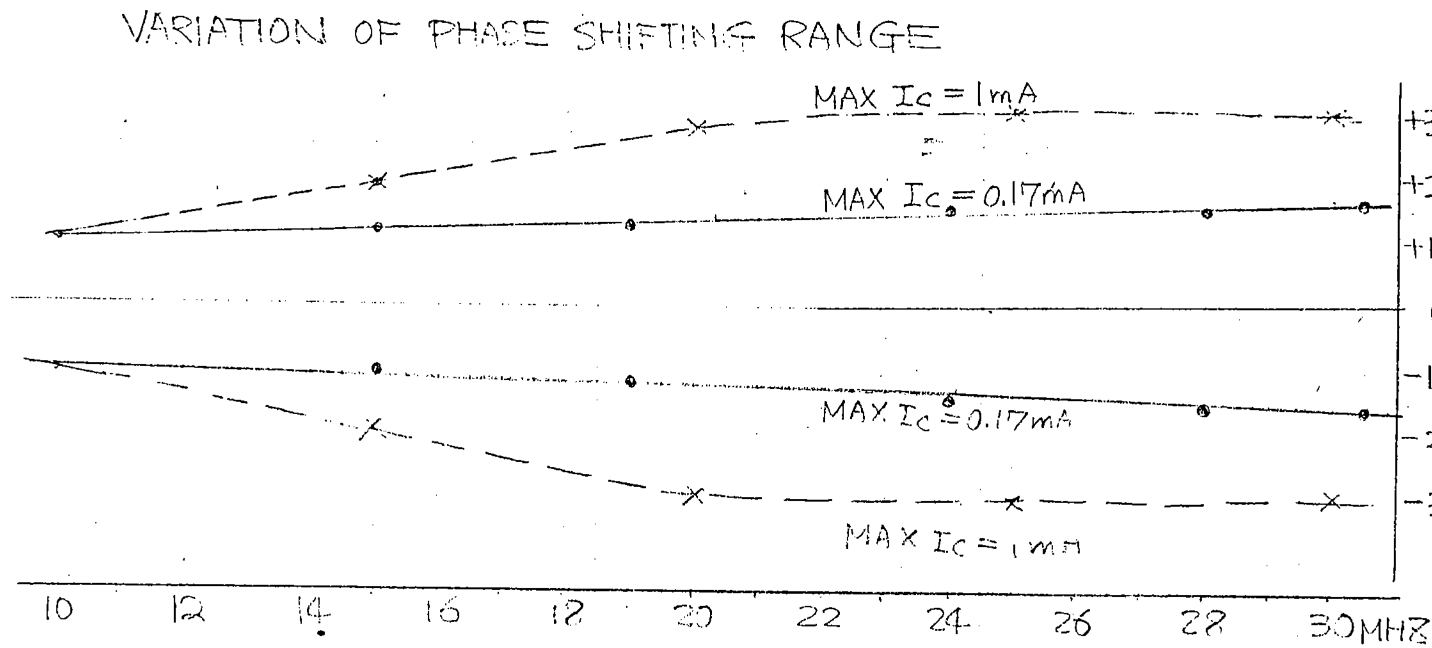
FIG. 4

MICHIGAN STATE UNIVERSITY -CYCLOTRON LABORATORY- EAST LANSING, MICHIGAN

| | | |
|---|---|---|
| | SCALE | DRN BY |
| | | APPR'D |

TITLE PHASE TRIMMER MODULE

| DATE | SHEET OF | DRAWING NO. | REV. |
|---|---|---|---|
| | | | |


VARIATION OF PHASE SHIFTING RANGE
MAX Ic = 1mA
MAX Ic = 0.17mA
MAX Ic = 0.17mA
MAX Ic = 1mA
+30°
+20°
+10°
0
-10°
-20°
-30°
10
12
14
16
18
20
22
24
26
28
30MHZ

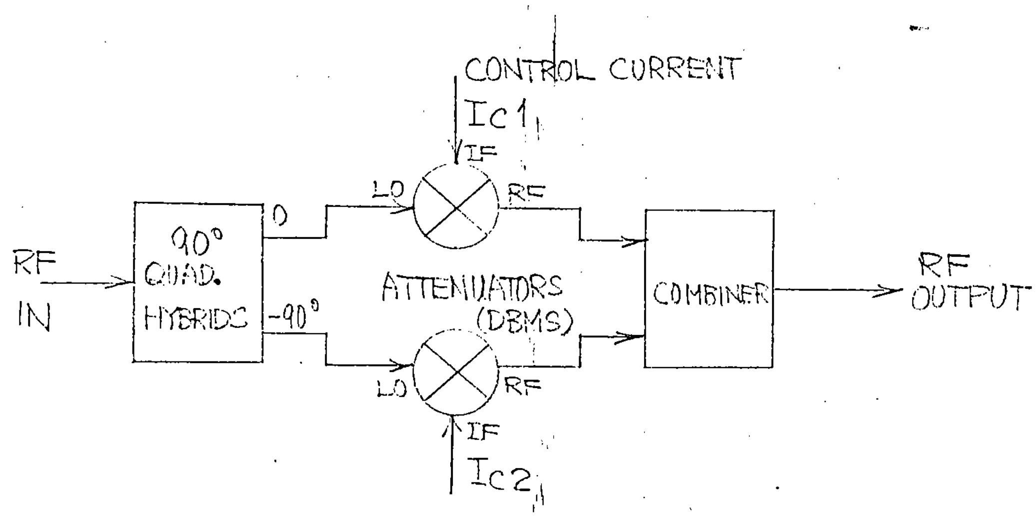

CONTROL CURRENT
Ic1
Ic2
IF
LO
RF
RF IN
90° QUAD. HYBRIDS
0
-90°
ATTENUATORS (DBMS)
COMBINER
RF OUTPUT

Fig. 5