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DIRECTIONAL ANTENNA PHASING SYSTEM

TUNING PROCEDURE:

I. GENERAL:

The instructions below were originally written to assist a station chief engineer in the tune-up of a three-tower dog-leg directional antenna system. Although he had had no previous experience in the tuning of a directional array, this procedure enhanced by telephone calls, allowed him to tune the antenna successfully.

The following are a few general comments on the tuning of A. M. directional antenna systems:

1. Calculated driving point impedances and the resulting power distribution of a system represent only a close approximation of the final values of a system tuned to produce the required directional pattern.

2. Most particularly, the reactance portion of the driving point impedance <u>can vary greatly</u> from the calculated values. This makes the output arm of each of the Antenna Tuning Units (sometimes called ATU or LTU) of special significance.

3. There is no such thing as a power dividing network or a phase-shifting network which does only one thing. Every network, unfortunately, acts as a power divider <u>and</u> a phase-shifter simultaneously.

4. A transmission line is a network. When mis-matched it is as though its "<u>network</u>" had been tuned; and it acts like a power divider <u>and</u> a phase-shifter simultaneously. Its "<u>effective</u>" electrical length changes (introducing phase change and power change into the system) until it becomes "<u>matched</u>"; <u>it then regains its original "length" and impedance</u>. Some mismatch conditions can create very large differences in expected phase shift, therefore, it is important to keep track of the VSWR on a line when trying to account for differences in phase shift.

5. Regardless of all of the above, it is still a matter of convenience to talk in terms of power dividing networks, phase-shifting networks, and impedance matching networks, just as if they were discrete devices.

6. For purposes of "Tuning a system" it is best to think of the "arms" of the various networks in relation to the "measurement points" of the network. The measurement points being:

   a. The input of the input arm;

   b. The output of the output arm;

   c. The junction point between the input & output arms.

   R. F. Bridge readings are to be taken at these points during the tune-up process. It is important to note that the arm of a network is not just the capacitors & inductors appearing in that arm, but, includes any other components in series with these (meters, switches, contactors, etc.,) and all interconnections between the measurement points.

7. The object in tuning a system is to "produce" specific impedances at the various measurement points of the system such that you finally produce the set of driving point impedances required for the desired pattern. The only "Real" values in a system are the self and mutual impedances of the towers; all other values are produced by the system. Consequently the tuning of any component in the system, in effect, produces a new directional pattern. The best and most stable systems are those wherein the tuning process produces the least abrupt change in the directional pattern.

8. Finally, bandwidth is the most important aspect of any phasing system; and networks with a minimum of stored energy (in our computer print-outs this is referred to as "VAT" or Volt-Amperes-Total) are best suited for obtaining good bandwidth.

II. Recommended Procedure:

The following procedure is recommended in setting up the phasor and ATU's:

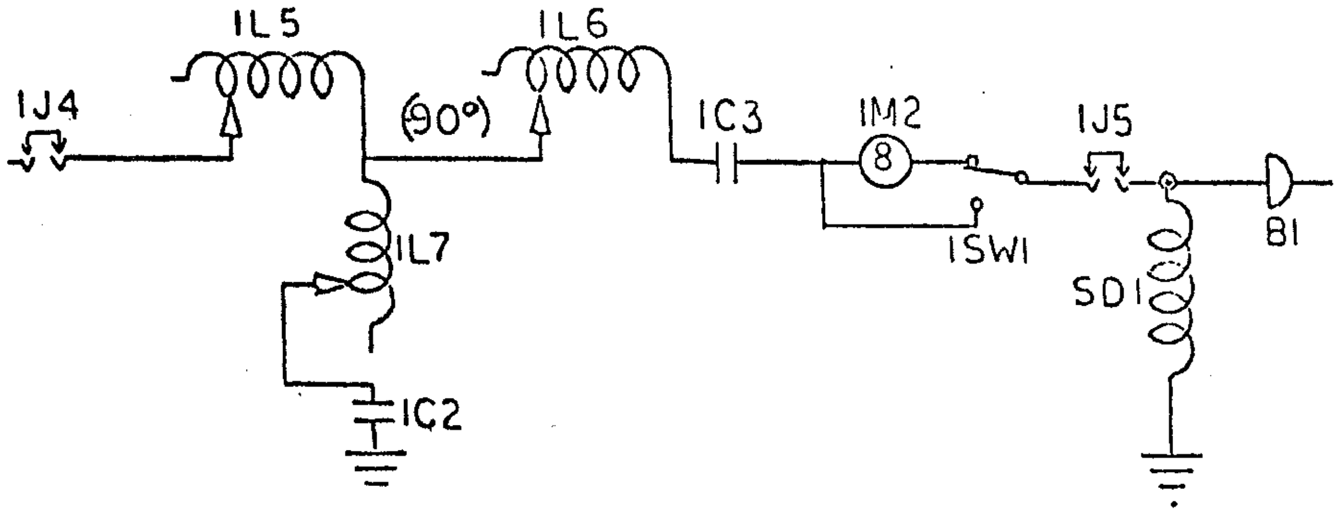
1. Make calibration tables for each arm of each network consisting of columns for:

   Turn: Delta X: Corrected X:

These tables will enable you to set the various network arms to the reactances specified in the design sheets, for initial tuning. Don't forget that a coil or a capacitor should have practically no resistance at broadcast frequencies, hence you do not have to tabulate this parameter. If you find that a given arm has several ohms of resistance, it usually indicates that you have a bad connection, or have made a mistake in balancing or use of your bridge. A resistance of greater than 1 ohm will only be noted in very large coils.

If you are measuring an inductance in an arm, tune one turn at a time, and tabulate the resulting reactance. Be sure to indicate if you are measuring a plus or minus reactance. Inductive reactances are always noted as jX, while capacitive reactances are noted as -jX. Put a title on each tabulation so you will know which arm the tabulation refers to. It is best to note all arms in one network on the same page, if possible, so as to make reviewing the material as easy as possible. Also mark from the design notes the expected value of reactance or the value you are trying to tune to on the same sheet. When you are all through measuring a given arm and have the tabulation listed, go back and find the turn which will produce the desired design value and tabulate this value.

2. As an example lets assume you are measuring ATU #1 to make up your tabulation. Lets assume that this network looks as follows:



Now we will make our measurements. For the input and output arms X1 (which is the same as 1L5) and X2 (which is the same as 1L6, 1C3):

a. Ground the "junction point" of 1L5, 1L6, & 1L7.

b. Go to the output side of 1J4 (with plug open); you are now looking at 1L5 to ground. Now make your turn-by-turn measurements and tabulate the results.

c. Next, go to the input side of 1J5 (with plug open); you will be looking at 1SW1, 1M2, 1C3 & 1L6 to ground. Now make your turn-by-turn measurements and tabulate the results. Be sure to note any change in the sign of the reactance because you have both a plus and minus reactance in series; the sign of the net reactance depends upon the comparitive magnitude of the reactances of the coil and capacitor.

You are now ready to measure the X3 arm (which is same as 1L7 & 1C2) to ground. Proceed as follows:

d. Remove the ground from the junction point (see a. above); and bridge from that point to ground, with the coil clips lifted from both 1L5 & 1L6.

e. Make turn-by-turn measurements and tabulate the results. Note that this arm should normally measure negative reactance (-jX), (unless coil inductance is too large), so your tabulation should be primarily -jX, except possibly with maximum coil inductance. You would never operate this arm with a plus jX because negative reactance to ground is required to obtain a lagging phase shift, assuming a purely resistive input.

3. The calibration table for the arms of phase network #1 (-75.23°) should be performed as above.

4. Follow the same procedure for the Input T network's arms, except that the bridge should be placed at B4 when calibrating its input arm. J5 should be pulled for all measurements made in the Phasor cabinet.

5. For the power dividing coils 1L1, 2L1, & 3L1 (which have an input arm, a shunt arm & a zero reactance output arm) the measurements are made as follows;

<u>For the Input Arm</u>:

a. Ground the roller contact stud on the end plate of the coil. This is the junction point of the network.

b. Make bridge readings at 1J1 for the shunt arm, & tabulate your results.

<u>For the Shunt Arm</u>:

c. Remove the ground & pull 1J1.

d. Make bridge readings at 1J2 & tabulate your results.

6. For the Re-resonator L Network (L4, J3, M2, L5, C3 & C4) the measurements are made as follows;

For the Output Arm:

a. Ground the junction point between J2 & J3.

b. Make bridge readings at J4, & tabulate your results.

For the Shunt Arm:

c. Remove the ground & pull J3.

d. Make bridge readings at J2, & tabulate your results.

7. For the Phase 3 network (3J2, 3L2, 3C1, 3M1 & 3J3) make the measurements as follows;

a. Pull 3J2 & ground its output terminal.

b. Make bridge readings at 3J3 & tabulate your results.

8. For the Phase 2 Network (2J2, 2L2, 2C1, 2J3 & 2M1) the measurements are made as follows:

a. Attach the coil clip lead of 2C1 to turn 6 of 2L2 (it is a 12 turn coil). Ground this junction point.

b. Make bridge readings at 2J2, as the result of moving its coil clip.

The procedure described above completes the making of the phasor calibration tables.

III. ADJUSTMENT OF SYSTEM TO PRODUCE REQUIRED DA PATTERN:

A. General: (Refer to schematic)

1. Pull 1J4, 2J4 & 3J4, at the tower ATU's.
2. Put 50 ohm resistors (carbon, 2% or better) at the input terminals of 1J4, 2J4 & 3J4.
3. Pull 1J3, 2J3 & 3J3, at the phasor line outputs.
4. Put 50 ohm resistors (carbon, 2% or better) at the input terminals of 1J3, 2J3 & 3J3, in the phasor.

B. Adjustment at Phasor:

1. Set the arms of the Phase networks to the design sheet values of reactance. Initially, the objective is to produce 50 j0 at the inputs of each of the Phase networks.
2. Consequently, tune 1L2/1L3, 2L2 & 3L2; making bridge readings at 1J2, 2J2 & 3J2, until you produce 50 j0 at these points.
3. Next, set the Power Dividing Coils (1L1, 2L1 & 3L1) to their design sheet values. Make bridge readings at:

   a. 1J1 (with 2J1 & 3J1 pulled)
   b. 2J1 (with 1J1 & 3J1 pulled)
   c. 3J1 (with 1J1 & 2J1 pulled)
   d. J4 (with all J-Plugs on the output side of J4 IN).

   The impedance reading at J4 should be close to the design sheet value. (In this example= 17.76 j11.) But, this is not critical. What is of great importance is the "equivalent parallel resistances" that have resulted at J4, 1J1, 2J1, & 3J1. They determine the amount of power that will be delivered to 1J4, 2J4 & 3J4 at the end of the lines. (Assuming that 50 j0 impedances were obtained at 1J2, 1J3; 2J2, 2J3; & 3J2, 3J3).

C. Equivalent Parallel Resistances:

The equivalent parallel resistances at the referenced measurement points for the system should be: (example)

Location:	Resistance (ohms): -1/
J4	24.58
1J1	136
2J1	50
3J1	75.03

These parallel resistances are obtained by calculating as follows:

$$Rp = R + \frac{(X)^2}{R} \qquad (1)$$

Where:
R & X are the corrected bridge measurements at J4, 1J1, 2J1 & 3J1.

For any type system with any desired distribution of power, the "parallel resistance" at the point that is "common" to all the power dividing networks will be: (J4 in this example)

$$R_{pt} = \frac{P_{reference}\,(R_{p\ reference})}{P_t} \qquad (2)$$

The required "parallel resistances" to be produced at the input of each power dividing network will be:

-1/These values cannot be read on an R F bridge (Such as GR or Delta) because such bridges read "series resistance". The exception would be X=0, in which case parallel and series resistance are equal.

$$R_{p1} = \frac{P_t (R_{pt})}{P_1} = \frac{P_{ref}}{P_1} (R_{p\ ref}) \quad (3)$$

$$R_{p2} = \frac{P_t (R_{pt})}{P_2} = \frac{P_{ref}}{P_2} (R_{p\ ref}) \quad (4)$$

$$R_{p3} = \frac{P_t (R_{pt})}{P_3} = \frac{P_{ref}}{P_3} (R_{p\ ref}) \quad (5)$$

Where:

$P_{reference}$ = the power of the greatest magnitude.

R_p reference = the parallel resistance at the input of the network for the power of greatest magnitude.

The power distribution produced by the power dividing networks will always be:

$$P_1 = \frac{P_t (R_{pt})}{R_{p1}} = \frac{P_{ref}}{R_{p1}} (R_{p\ ref}) \quad (6)$$

$$P_2 = \frac{P_t (R_{pt})}{R_{p2}} = \frac{P_{ref}}{R_{p2}} (R_{p\ ref}) \quad (7)$$

$$P_3 = \frac{P_t (R_{pt})}{R_{p3}} = \frac{P_{ref}}{R_{p3}} (R_{p\ ref}) \quad (8)$$

Where:

P_t = The total power in the system.

R_{pt} = The calculated parallel reasistance at the "common point" (J4).

R_{p1} = The calculated parallel resistance at 1J1.

R_{p2} = The calculated parallel resistance at 2J1.

R_{p3} = The calculated parallel resistance at 3J1.

D. Matching The COMMON POINT:

Once the power distribution has been obtained, in the manner described above, the objective becomes the matching of the impedance seen at the combined point of the power dividing networks (J4) to the impedance of the transmitter, which may be 50 or 54 ohms, j0; (54 ohms is selected to provide an even 10 Amperes Common Point Current for 5400 Watts ($I^2R = P$). This is accomplished by the Re-resonator L Network and the Input T Network.

1. Set the arms of the Re-resonator L Network (J4, L4, J3, M2, L5, C3 & C4) to the design sheet values of reactance. Then tune the network to produce a pure resistance at J2. The design value calls for approximately 178 ohms (example.) The primary control to produce a pure resistance at J2 is L5.

2. Set the output arm and shunt arm of the Input T Network (L2, L3, C1 & C2) to the design sheet values of reactance. Set the input arm (L1) at 0 turns with with unused turns "floating". Then tune the shunt coil (L3) to produce a 50 (54) ohm resistance at the transmitter connection point (B4). There will also be a reactance measured at this point; subsequent tuning of the input coil (L1) is needed to produce 50 j0 (or 54 j0).

E. Adjustment at the ATU's:

Now, the Antenna Tuning Units can be individually tuned.

1. Pull the input J-plugs (1J4, 2J4 & 3J4; ref. to III.A.1.above.)

2. Put the 50 ohm resistors at the output terminals of these J-Plugs (Ref. to III.A.2.above.)

3. Set the input arms and shunt arms of the networks to the design sheet reactance values.

4. Remove the coil clips from the coils of the output arms.

5. Set the bridge to the driving point resistance value shown on the schematic for the network being tuned.

6. Now, with the bridge at the "junction point", tune the shunt arm (1L7, 1C2) to obtain a bridge "null" indicating that the 50 ohm resistor has been transformed to produce the driving point resistance at the junction point.

7. When this procedure has been accomplished for each of the antenna tuning units:

   a. Set the output arms to the design sheet values of reactance.

   b. Take out the 50 ohm resistors and replace the input J-plugs (1J4, 2J4 & 3J4).

8. The system would now be in perfect adjustment if the driving point impedances (both R & X) were exactly as calculated for the specific directional pattern desired. However, this will rarely be the case.

9. Most important, now, is the further tuning of the output arms of the antenna tuning units; an "operating impedance bridge" (such as the Delta Electronics OIB-1) should be used. With low power applied to the system, the output arms of the antenna tuning units should be tuned in an attempt to produce 50 j 0 as seen by the "operating impedance bridge" at the input of each of the antenna tuning units, with 1J4, 2J4 & 3J4 pulled. Obviously, if the output arm is not an insulated, variably controlled component, the power must be shut off between adjustments.

   If the tuning of the output arm will not produce 50 j0 at the input, it simply indicates that the calculated resistance value is somewhat off; hence, the shunt arm must be slightly retuned to produce a 50 ohm resistance at the input. Finally, the input arm must be retuned to wash out any reactance, producing 50 j0 at the input.

   Inasmuch as each tower interacts with the others whenever an adjustment is made at any of the ATU's it will require some jockeying around to obtain optimum match for each ATU. Once you obtain as close a match as possible at each of the ATU's you can bring your transmitter up to full power.

F. Final Adjustments at the Phasor:

It has been presumed, all along that you have kept detailed notes and tabulations for each of the settings throughout the Phasor and ATU's. If at any time you do not obtain measurement values close to those called for in this paper and on the design sheets, contact us to discuss the problem.

Once the power has been brought up to normal, have someone log the antenna current (and line current, if plug-in meter is available) at each of the ATU's.

Next set up a chart or log sheet to keep track of all dial settings on the Phasor and salient parameters of the array & transmitter. Refer to your first set-up as TRY #1, and after each change of settings, assign a new TRY number. This will help you keep track of which controls what etc. A suggested format for such tabulation is shown below.

RADIO STATION:_____(CALL) TRY #__ DATE:_______19____

TWR#:	POWER DIAL:	PHASE DIAL:	BASE CURRENT:	CURRENT RATIO:	MONITOR PHASE:°	PHASOR LINE I:	ATU LINE I:
1.							
2.							
3.							
#etc.							

L5 = _____, E_p = ______, I_p = ______, I_{cp} = ______

M.P. BEARINGS:°	NON-DIR.(mV/m):	DIR.(mV/m):	ID(mV/m):
1.			
2.			
3.			
4.			
#etc.			

Your TRY#1 parameters should be within plus-or-minus 5° on phases, and plus-or-minus 15% on base current ratios. If this is the case, run five or six field intensity measurements on each monitor point (M.P.) radial, plus the major lobe, to get a feeling for the shape and fields being produced by TRY#1. These measurements can be converted to directional inverse distance fields in mV/m by the expression:

$$ID = \frac{DA}{NDA} (NDI) \qquad (9)$$

Where:

ID = Directional Inverse Distance field in mV/m;
DA = Directional field at a measuring point in mV/m;
NDA = Non-Directional field at a measuring point in mV/m.

Take each set of measurements for a given radial and average each of the final ID's to obtain the final ID for a radial.

A cut-and-try procedure, making small adjustments in phase and power at the phasor, and sometimes slight adjustments at the ATU's will help you to obtain your final pattern. Two-way radio is the best way to make the final adjustments; place at least two operators with field meters at M.P. locations. Also check some other check-points to make certain that you have the final pattern before starting your final DA measurements.

CALL US AND GO OVER YOUR WORK, BEFORE STARTING THE FINAL MEASUREMENTS RUNS. GOOD LUCK & GOOD TUNING.

DIRECTIONAL ANTENNA PHASING SYSTEM

TUNING PROCEDURE

APPENDIX:

I. Special Note: Handling of "Negative Power" Towers

When there is one (or more) "Negative Power" Towers in a system, the equation for the power distribution and required "Parallel Resistance" does not change, but, it must be noted that:

a. The required "parallel resistance" to be produced at the input to the power dividing network associated with the "negative power" tower(s) will be a negative resistance. All the resistances (whether series or parallel equivalent) for the negative power are minus. The antenna resistance is minus. The transmission line resistance is minus; ($50 \angle 180^{o} = -50\ j0$). The resistance at the input of the phase shifting network is minus; and, this resistance is the "load" for the power dividing network, whose input is therefore a negative resistance.

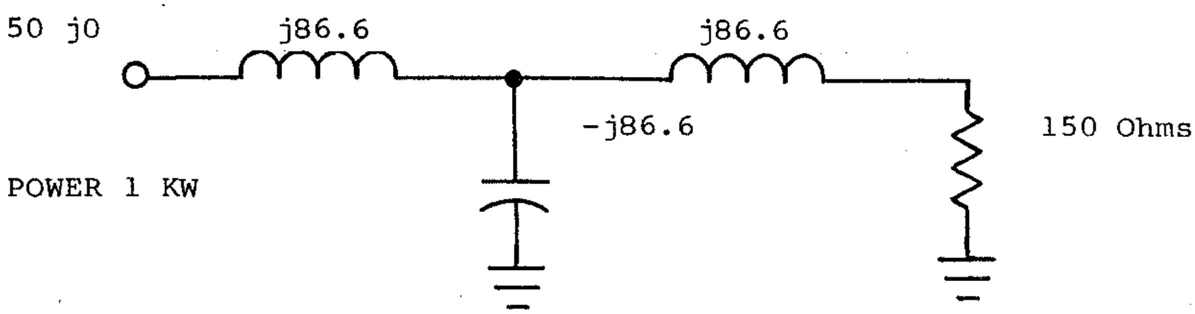
b. The total equivalent parallel resistance appearing at the point common to the input of all the power dividing networks will be a value greater than it would be if all the powers were positive. Consequently, the series resistance at this point will be greater. The negative power has caused a step-up in resistance.

II. A Method for Determining Phase Shift in a T Network:

GIVEN:

T-Network: 1 kW., 50 Ohm Input, 150 Ohm Output,

Determine: I_{IN}, I_{OUT}, I_{SHUNT}:



Each leg of T-Net (for 90° phase shift) =

$$R_{IN} \times R_{OUT} = (50 \times 150)^{1/2} = j86.6$$

(Note: Shunt Leg is -j for -90°, or +j for +90°. Input & output legs are opposite sign, but, equal in magnitude.)

In order to determine current in the shunt leg we must know the output impedance across the shunt reactance. Knowing this value we can then determine the output voltage, and inasmuch as the output voltage across output leg plus load is in parallel with shunt reactance, the voltage divided by shunt reactance determines shunt current.

In our case:

Output Leg Impedance = 150 + j86.6 = 173.2 $\angle 30^{\circ}$

Output Current = $(1000/150)^{1/2}$ = 2.58 Amperes

Output Voltage = I x Z = 2.58 x 173.2 = 446.86 V.

Shunt Current = E/Z = 446.86 / -j86.6 = -5.16 Amperes

Input Current = $(1000/50)^{1/2}$ = 4.47 Amperes

The above currents can be verified by means of an R.F. Ammeter. Having determined the currents, we can now determine the phase shift for the network, irrespective of the transformation;

$$\cos\theta = \frac{I_{IN}^2 + I_{OUT}^2 - I_{shunt}^2}{2 \times I_{IN} \times I_{OUT}}$$

Substituting in the above:

$$\cos\theta = \frac{4.47^2 + 2.58^2 - 5.16^2}{2 \times 4.47 \times 2.58}$$

$$\theta = 90^{\circ}$$

Note: Sign of reactance in shunt leg determines if network is leading (+) or lagging (-). It should be noted that the phase shift of the network will be correct regardless of whether or not the impedance transformation is as required.

III. Measurement of Transmission & Sampling Lines:

So far no mention has been made of the measurement of transmission line impedance or phase shift in the tuning of a directional antenna system. The RF Transmission Lines carry the RF power to the Antenna Tuning Units at the Towers. The Phase Sampling Lines supply the Antenna Monitor with array field and phases for each tower.

In the case of the Phase Sampling Lines, the lines should be ordered pre-cut to equal length, and be of the same type, and impedance (typically 50 ohms.) These lines should be checked to insure being within 5^{o} of equal length.

The RF Transmission Lines must also be checked for impedance and phase shift. If the Transmission Line phase shift differs from that proposed in the original design of the phasing and branching system, it will be necessary to make adjustments in some of the networks to compensate for the difference.

A. Impedance Measurement:

The surge or characteristic impedance of a coaxial line can be measured with an RF Bridge (either GR or Delta). Two measurements are required: First, the bridge should be connected between the center conductor and ground (outer conductor), with the far end of the line open-circuited. This is called the open-circuit impedance. Next, the line should be shorted at the far end, and the line re-measured. This is called the short-circuit impedance. The line impedance is then determined from the following equation:

$$Z_o = (Z_{oc} \times Z_{sc})^{1/2}$$

Where:

Z_o = The Line Surge or Characteristic Impedance

Z_{oc} = The Open-Circuit Impedance

Z_{sc} = The Short-Circuit Impedance

B. Phase Shift Measurement:

There are several methods to measure the phase shift in a coaxial transmission line. We recommend the 180^{o} short test. Use of this method eliminates any confusion as to length.

In order to make this measurement, it will be necessary to have a signal generator covering approximately 500 to 4000 kHz. This generator should have a high impedance output. You will also need a VTVM or a receiver with an output meter, and a frequency counter.

The Test is made as follows:

1. Place a short "short-circuit" across the far end of the transmission line being measured. (By short "Short-circuit" we mean as short a jumper as possible from from the sheath of the coax to the inner conductor.)

2. Next, connect the output of your signal generator to the inner conductor at the input to the coax, with generator ground connected to the outer conductor.

3. Connect your VTVM or receiver across the output of the generator.

4. Turn on your generator and start tuning the dial of the generator either up or down in frequency. Keep going in the same direction until you obtain a deep null on the meter.

5. Using your frequency counter, determine the frequency on which the generator is operating; call this F_1.

6. Now continue tuning the signal generator in the same direction as originally determined and keep going until you obtain a second deep null.

7. Determine the frequency of the 2nd null using the counter, and record this as F_2.

8. You can now determine the phase shift in electrical degrees by the use of the following formula:

$$\text{Electrical Length}^{\circ} = \frac{F_o}{F_1 - F_2}(180)$$

Where:

F_o = Station operating frequency*

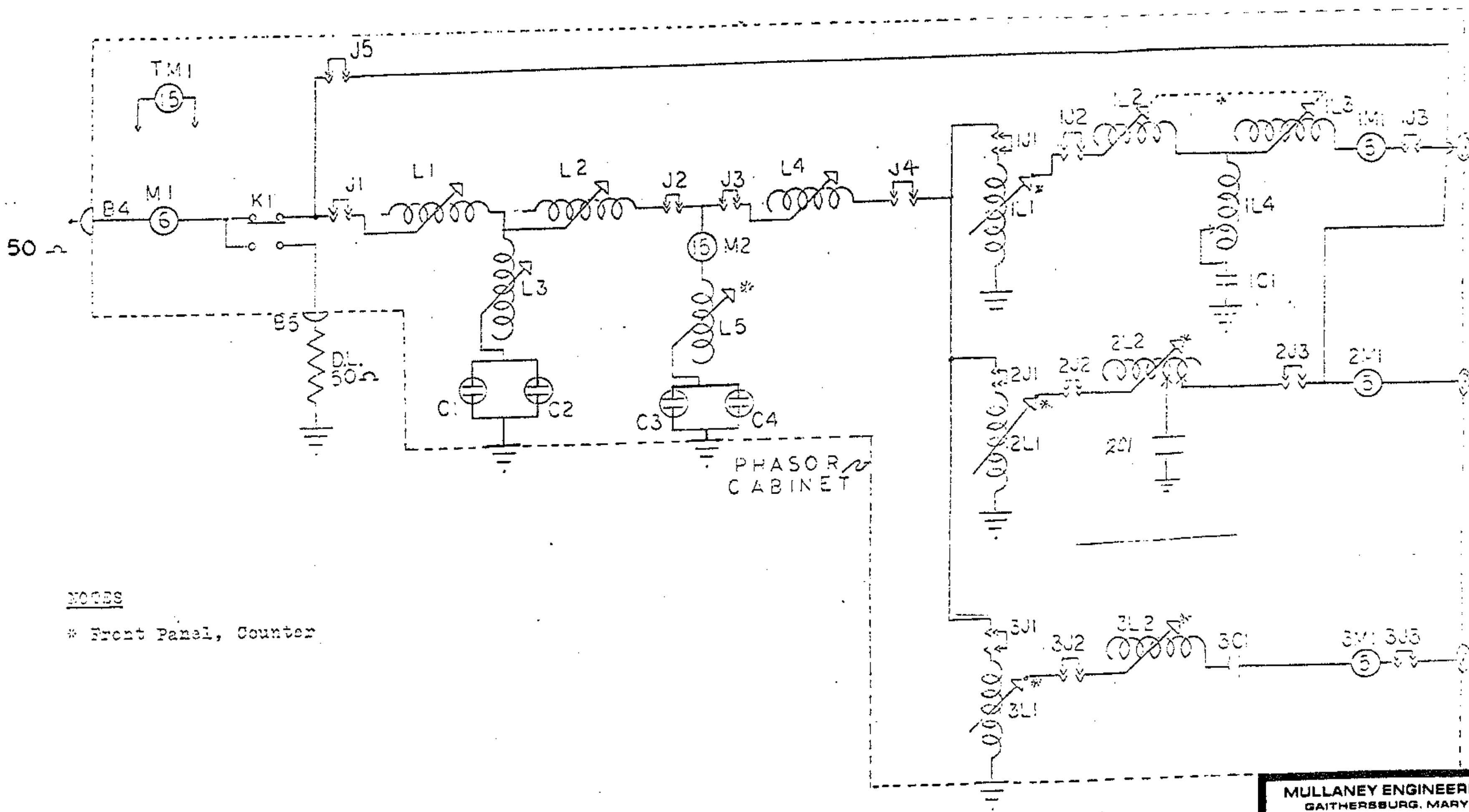
F_1 = 1st Null frequency*

F_2 = 2nd Null frequency*

* - All frequencies must be either kHz, or mHz.

You will note that F_1 and F_2 will not be exactly two-to-one difference, because of normal loss in a transmission line.

Be sure that the VTVM or receiver used does not load down the generator output. This is the reason for using high impedance in this test procedure.



NOTES

* Front Panel, Counter

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FIGURE 1A

PHASOR CABINET

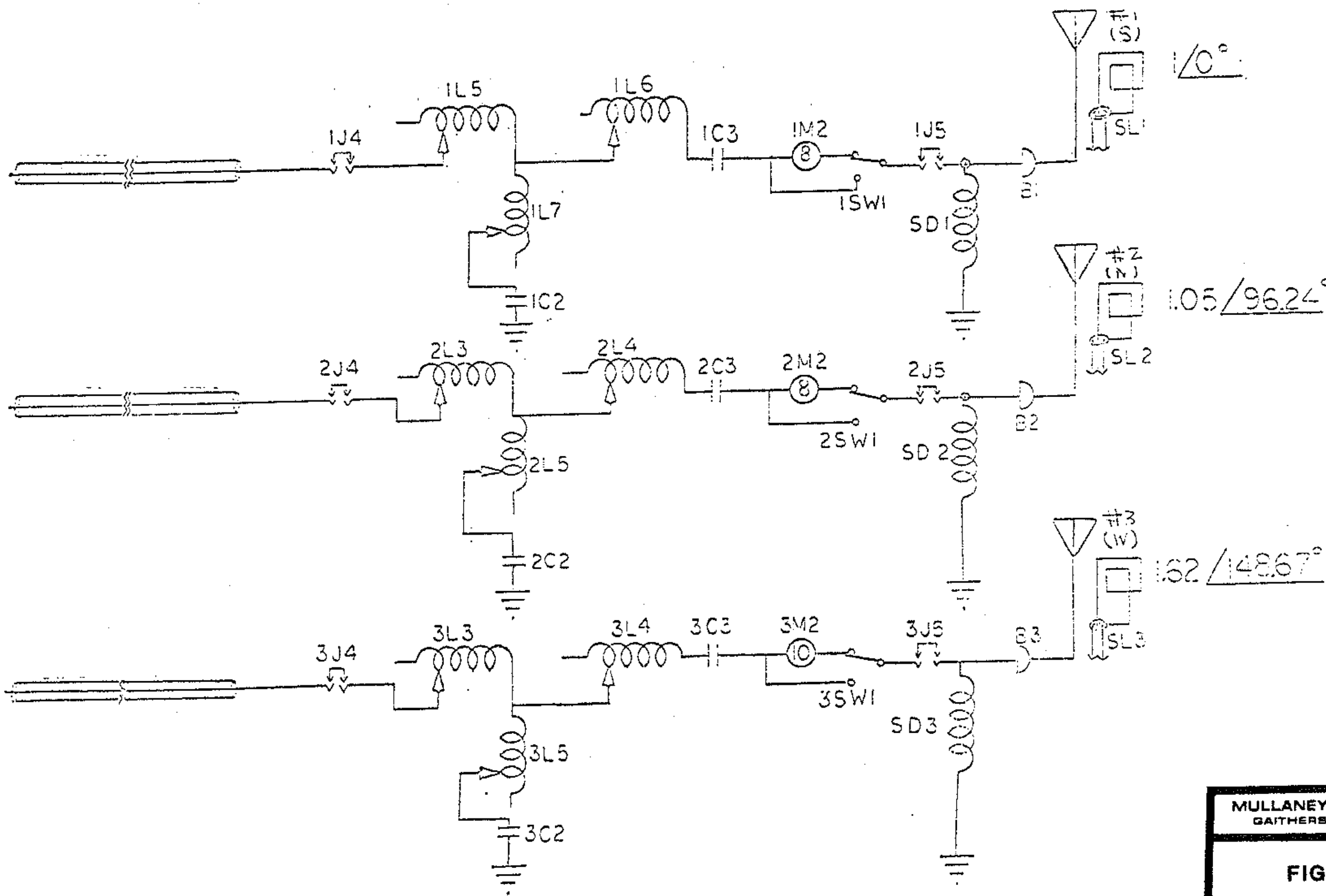

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FIGURE 1B

ANT. TUNING UNITS

POWER, COMBINED POINT IMPEDANCES

```
INPUT # OF INPEDANCES ? 3

    MAGNITUDE,PHASE

  1 ? 79.01,54.48

  2 ? 48.73,12.92

  3 ? 59.31,37.77


    THE PARALLEL EQUIVALENT IMPEDANCE
       IS  MAG.:     20.8924   PHASE:    31.7921
          REAL :     17.7578   IMAGE: +j 11.0069
```

POWER #1:

```
INPUT RA,XA,X2,X3,X1 ? 50,0,0,167.4,50.6

RS  =   45.90   XS =   64.31   THETA-TOTAL =  -37.85
RPS =  136.00   ZS =   79.01   THETA-ONE   =   54.48
```

POWER #2 (REFERENCE):

```
INPUT RA,XA,X2,X3,X1 ? 50,0,0,218,0

RS  =   47.50   XS =   10.89   THETA-TOTAL =   -0.00
RPS =   50.00   ZS =   48.73   THETA-ONE   =   12.92
```

POWER #3:

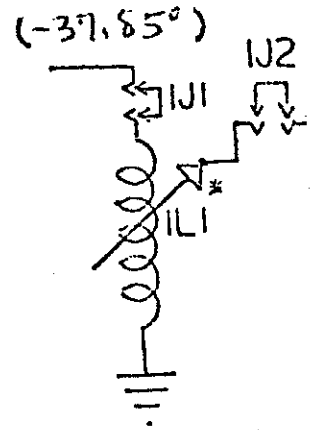
```
INPUT RA,XA,X2,X3,X1 ? 50,0,0,193.77,24.23

RS  =   46.88   XS =   36.33   THETA-TOTAL =  -23.30
RPS =   75.03   ZS =   59.31   THETA-ONE   =   37.77
```

POWER #1

```
INPUT   FREQ.(MHZ.), POWER(WATTS) ? .74,180.73

INPUT   RA,XA,RS,THETA-TOTAL ? 45.9,-64.31,50,-37.85

INPUT   X1,X2,X3 ? 0,50.6,167.4
```

```
X1,X2,X3
C1/L1,C2/L2,C3/L3
I1,I2,I3
I1M,I2M,I3M
E1,E2,E3
E1PK,E2PK,E3PK
VAT
```

X2	X1	X3
0.000	50.600	167.400
0.000	10.883	36.003
1.901	1.984	0.568
2.328	2.430	0.695
0.000	100.406	95.056
0.000	283.991	268.858
253.212		

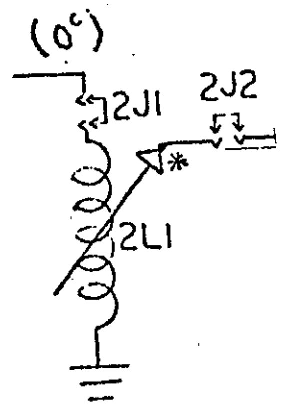


POWER #2

```
INPUT   FREQ.(MHZ.), POWER(WATTS) ? .74,491.62

INPUT   RA,XA,RS,THETA-TOTAL ? 47.5,-10.89,50,0

INPUT   X1,X2,X3 ? 0,0,218
```

```
X1,X2,X3
C1/L1,C2/L2,C3/L3
I1,I2,I3
I1M,I2M,I3M
E1,E2,E3
E1PK,E2PK,E3PK
VAT
```

X2	X1	X3
0.000	0.000	218.000
0.000	0.000	46.886
3.136	3.217	0.719
3.840	3.940	0.881
0.000	0.000	156.778
0.000	0.000	443.435
112.749		

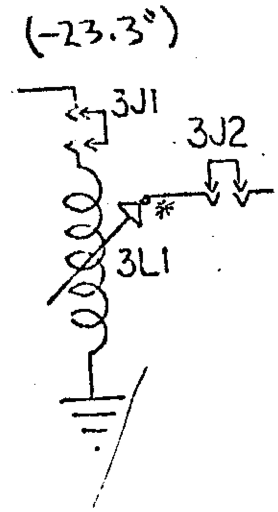


POWER #3

```
INPUT  FREQ.(MHZ.), POWER(WATTS) ? .74,327.65

INPUT  RA,XA,RS,THETA-TOTAL ? 46.88,-36.33,50,-23.3

INPUT  X1,X2,X3 ? 0,24.23,193.77
```

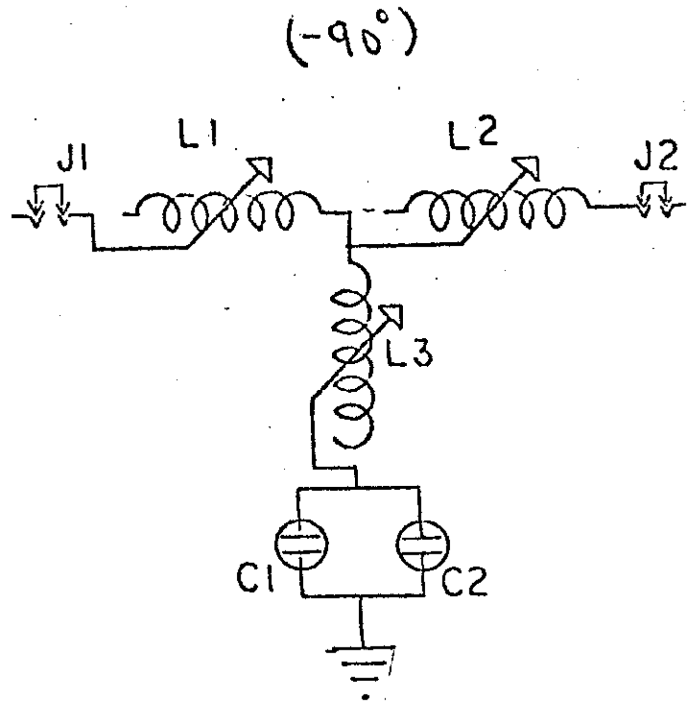
```
X1,X2,X3
C1/L1,C2/L2,C3/L3
I1,I2,I3
I1M,I2M,I3M
E1,E2,E3
E1PK,E2PK,E3PK
VAT
```

X_2	X_1	X_3
0.000	24.230	193.770
0.000	5.211	41.675
2.560	2.644	0.661
3.135	3.238	0.809
0.000	64.057	127.998
0.000	181.180	362.033
253.898		



INPUT T NETWORK

```
INPUT  FREQ.(MHZ.), POWER(WATTS) ? .74,1000

INPUT  RA,XA,RS,THETA-TOTAL ? 177.578,0,50,-90

INPUT  X1,X2,X3 ? 94.228,94.228,-94.228
```



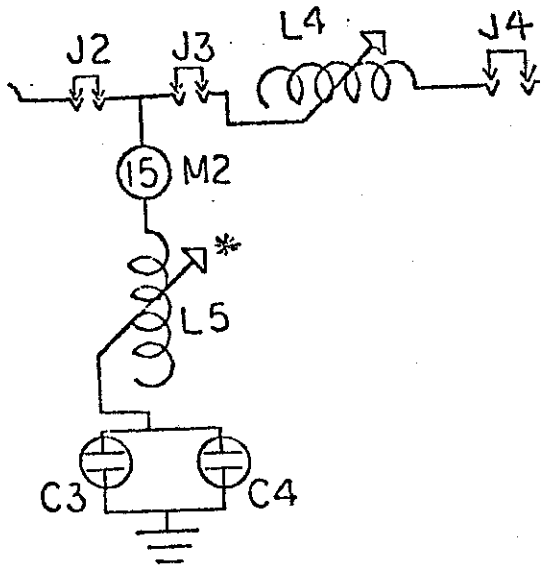

```
     X1,X2,X3
     C1/L1,C2/L2,C3/L3
     I1,I2,I3
     I1M,I2M,I3M
     E1,E2,E3
     E1PK,E2PK,E3PK
     VAT

        94.228        94.228       -94.228
        20.266        20.266      2282.487
         4.472         2.373        -5.063
         5.477         2.906        -6.201
       421.400       223.607       477.051
      1191.900       632.456      1349.305
      4830.374

DO YOU WISH TO TRY AGAIN ?
```

```
INPUT  RA,XA,RS,THETA-T ? 177.578,0,50,-90
```

X1	X2	X3
94.228	94.228	-94.228

OHMS LAW RE-RESONATOR L NETWORK:

```
INPUT  FREQ.(MHZ.), POWER(WATTS) ? .74,1000

INPUT  RA,XA,RS,THETA-TOTAL ? 17.7578,11.0069,177.578,-71.5650512

INPUT  X1,X2,X3 ? 0,42.267,-59.193



    X1,X2,X3
    C1/L1,C2/L2,C3/L3
    I1,I2,I3
    I1M,I2M,I3M
    E1,E2,E3
    E1PK,E2PK,E3PK
    VAT

         0.000        42.267       -59.193
         0.000         9.091      3633.440
         2.373         7.504        -7.119
         2.906         9.191        -8.719
         0.000       317.181       421.404
         0.000       897.123      1191.909
      5380.227

 DO YOU WISH TO TRY AGAIN ?
```




```
INPUT  RA,XA,RS,THETA-T ? 17.7578,11.0069,177.578,-71.5650512
```

X_1	X_2	X_3
0.000	42.267	-59.193

Q = 3

PHASE #1

INPUT RA,XA,RS,THETA-T ? 50,0,50,-75.23

X_1	X_2	X_3
38.526	38.526	-51.709

PHASE #2

INPUT RA,XA,RS,THETA-T ? 50,0,50,-23.75

X_1	X_2	X_3
10.514	10.514	-124.148

ATU #1

INPUT RA,XA,RS,THETA-T ? 13.35,31,50,-90

X_1	X_2	X_3
25.836	-5.164	-25.836

ATU #2

INPUT RA,XA,RS,THETA-T ? 32.87,8,50,-90

X_1	X_2	X_3
40.540	32.540	-40.540

ATU #3

INPUT RA,XA,RS,THETA-T ? 9.25,8,50,-90

X_1	X_2	X_3
21.506	13.506	-21.506

PHASE #1

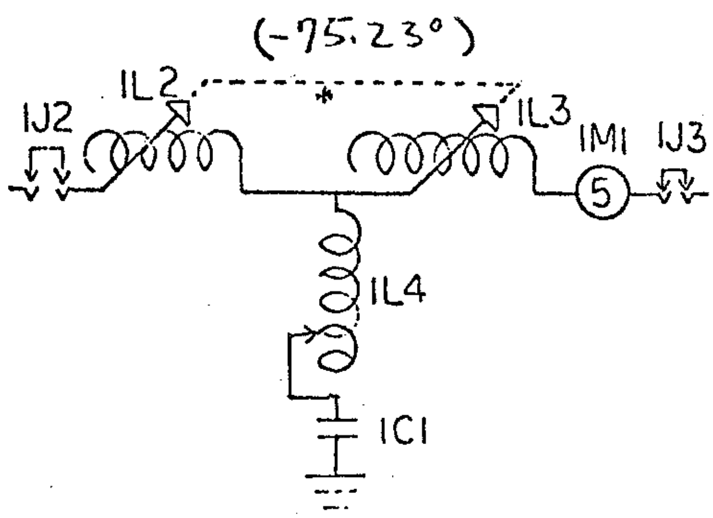
INPUT FREQ.(MHZ.), POWER(WATTS) ? .74,180.73

INPUT RA,XA,RS,THETA-TOTAL ? 50,0,50,-75.23

INPUT X1,X2,X3 ? 38.526,38.526,-51.709

	X2	X1	X3
X1,X2,X3	38.526	38.526	-51.709
C1/L1,C2/L2,C3/L3	8.286	8.286	4159.318
I1,I2,I3	1.901	1.901	-2.321
I1M,I2M,I3M	2.328	2.328	-2.842
E1,E2,E3	73.246	73.246	120.006
E1PK,E2PK,E3PK	207.171	207.171	339.429
VAT	557.022		

DO YOU WISH TO TRY AGAIN ?



PHASE #2(REFERENCE)

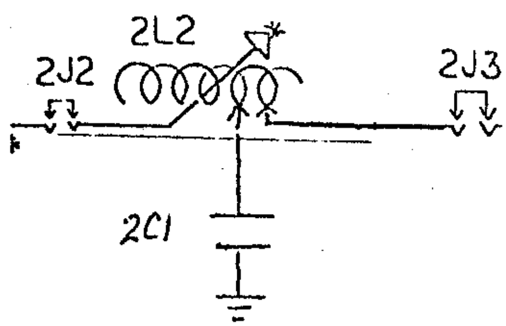
```
INPUT  FREQ.(MHZ. , POWER(WATTS) ? .74,491.62

INPUT  RA,XA,RS,THETA-TOTAL ? 50,0,50,-23.75

INPUT  X1,X2,X3 ? 10.514,10.514,-124.148
```

```
X1,X2,X3
C1/L1,C2/L2,C3/L3
I1,I2,I3
I1M,I2M,I3M
E1,E2,E3
E1PK,E2PK,E3PK
VAT
```

X_2	X_1	X_3
10.514	10.514	-124.148
2.261	2.261	1732.402
3.136	3.136	-1.290
3.840	3.840	-1.581
32.968	32.968	160.212
93.249	93.249	453.148
413.508		

DO YOU WISH TO TRY AGAIN ?

(-23.75°)



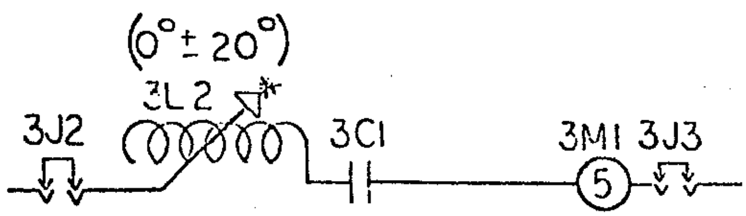
PHASE #3

```
INPUT  FREQ.(MHZ.), POWER(WATTS) ? .74,327.65

INPUT  RA,XA,RS,THETA-TOTAL ? 50,0,50,0

INPUT  X1,X2,X3 ? 0,0,.1E+15
```

X1,X2,X3
C1/L1,C2/L2,C3/L3
I1,I2,I3
I1M,I2M,I3M
E1,E2,E3
E1PK,E2PK,E3PK
VAT

X2	X1	X3
0.000	0.000	*********
0.000	0.000	*********
2.560	2.560	0.000
3.135	3.135	0.000
0.000	0.000	127.994
0.000	0.000	362.022
0.000		

DO YOU WISH TO TRY AGAIN ?



ATU #1

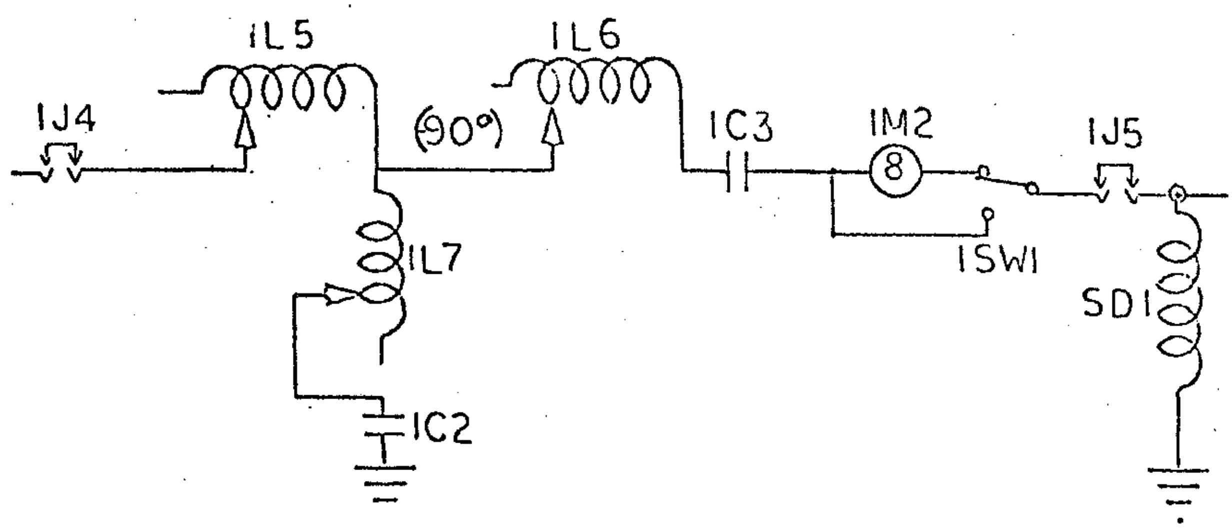
INPUT FREQ.(MHZ.), POWER(WATTS) ? .74,180.73

INPUT RA,XA,RS,THETA-TOTAL ? 13.35,31,50,-90

INPUT X1,X2,X3 ? 25.836,-5.164,-25.836

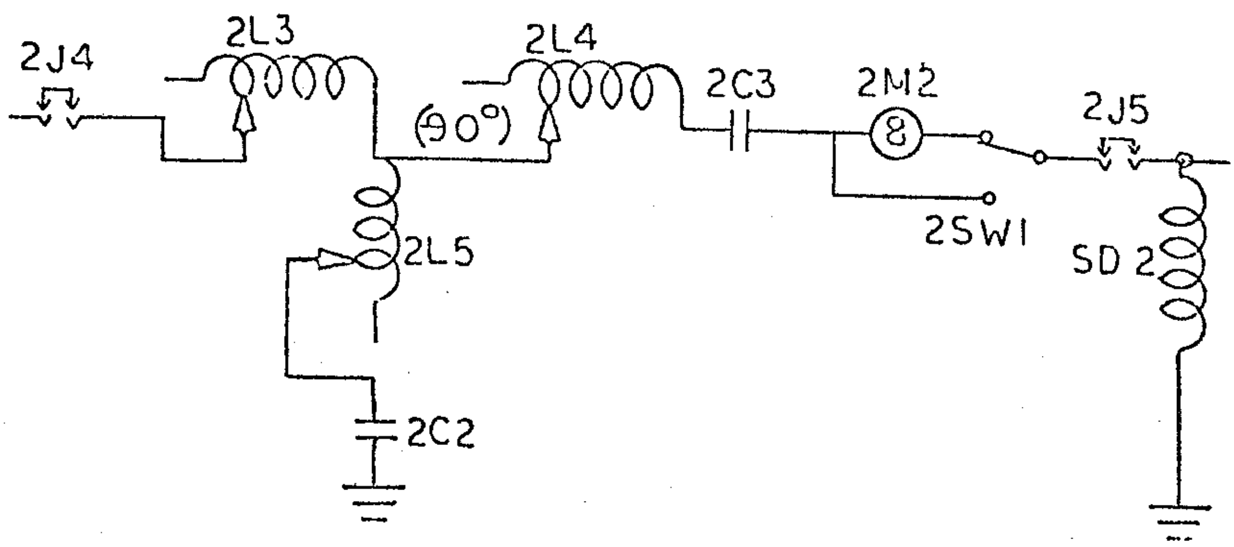
X1,X2,X3
C1/L1,C2/L2,C3/L3
I1,I2,I3
I1M,I2M,I3M
E1,E2,E3
E1PK,E2PK,E3PK
VAT

25.836	-5.164	-25.836
5.557	41648.759	8324.593
1.901	3.679	-4.142
2.328	4.506	-5.072
49.120	-19.000	107.001
138.931	-53.741	302.645
606.446		



ATU #2

```
INPUT  FREQ.(MHZ.), POWER(WATTS) ? .74,491.62

INPUT  RA,XA,RS,THETA-TOTAL ? 32.87,8,50,-90

INPUT  X1,X2,X3 ? 40.54,32.54,-40.54


     X1,X2,X3
     C1/L1,C2/L2,C3/L3
     I1,I2,I3
     I1M,I2M,I3M
     E1,E2,E3
     E1PK,E2PK,E3PK
     VAT

        40.540        32.540        -40.540
         8.719         6.999       5305.234
         3.136         3.867         -4.979
         3.840         4.737         -6.098
       127.120       125.844        201.843
       359.549       355.941        570.897
      1890.234
```

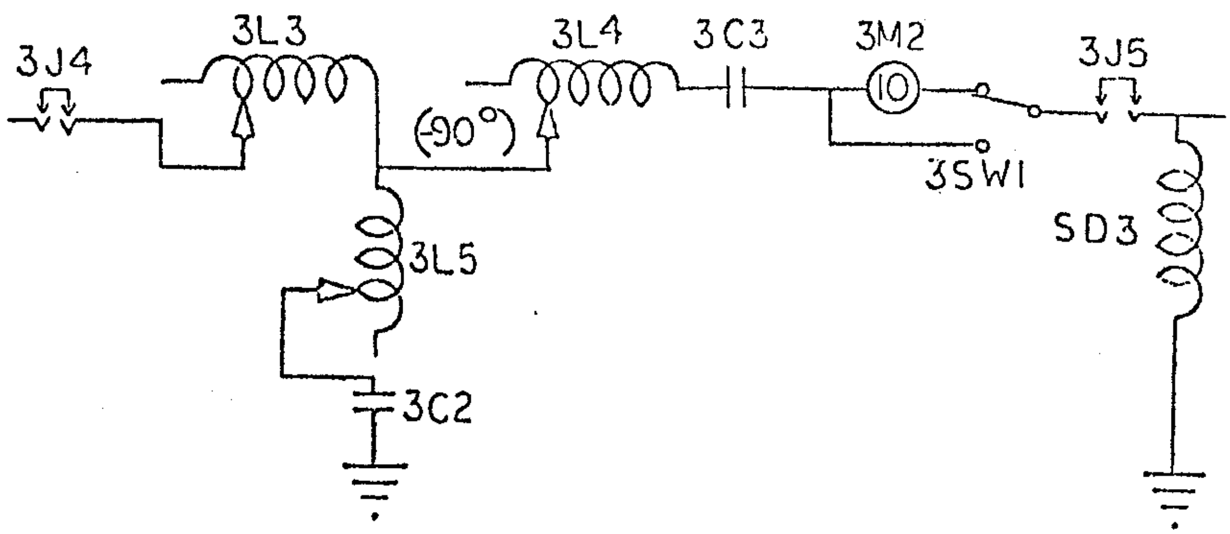


ATU #3

```
INPUT   FREQ.(MHZ.), POWER(WATTS) ? .74,327.65

INPUT   RA,XA,RS,THETA-TOTAL ? 9.25,8,50,-90

INPUT   X1,X2,X3 ? 21,\,\.506,13.506,-21.506
```

X1,X2,X3
C1/L1,C2/L2,C3/L3
I1,I2,I3
I1M,I2M,I3M
E1,E2,E3
E1PK,E2PK,E3PK
VAT

21.506	13.506	-21.506
4.625	2.905	10000.660
2.560	5.952	-6.479
3.135	7.289	-7.935
55.053	80.382	139.333
155.713	227.356	394.092
1522.037		



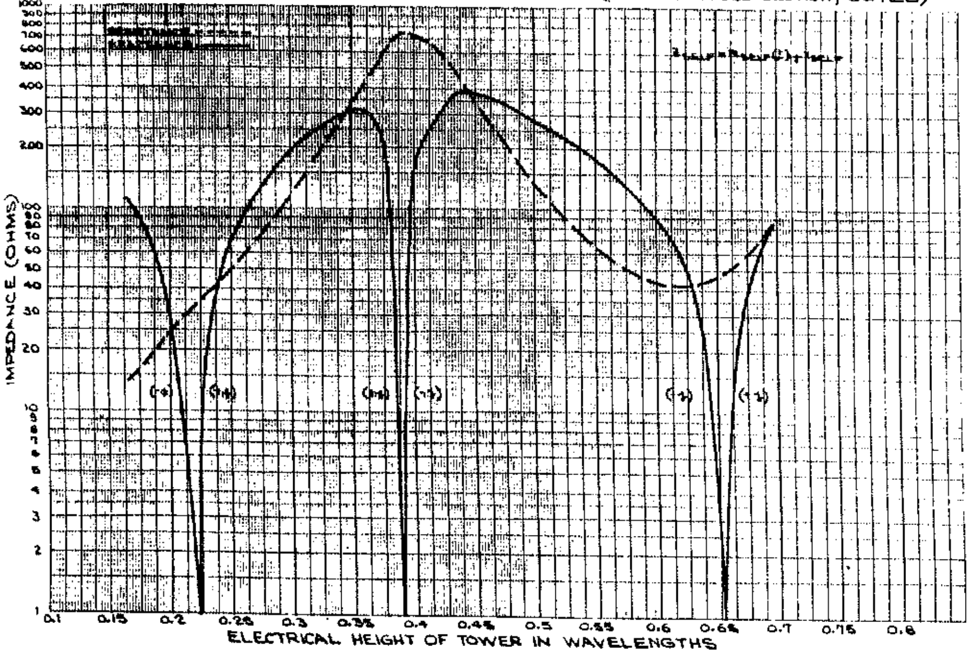
RADIO STATION:_____(CALL) TRY #__ DATE:_______19____

TWR#:	POWER DIAL:	PHASE DIAL:	BASE CURRENT:	CURRENT RATIO:	MONITOR PHASE:°	PHASOR LINE I:	ATU LINE I:

L5 = _____, E_p = ______, I_p = ______, I_{cp} = ______

M.P. BEARINGS:°	NON-DIR.(mV/m):	DIR.(mV/m):	ID(mV/m):

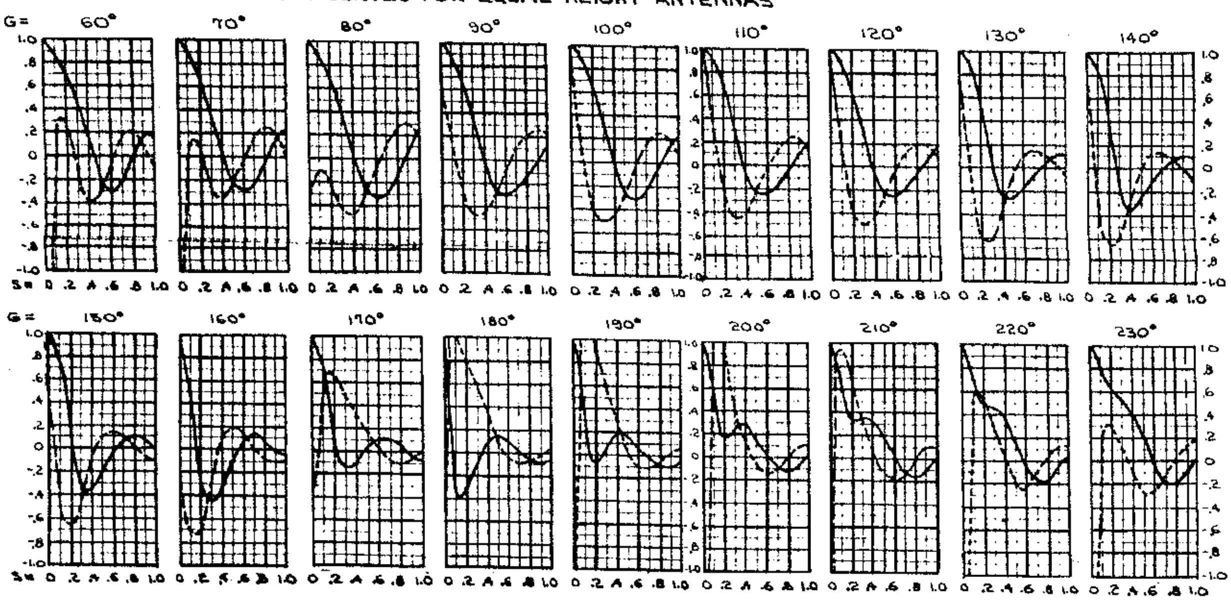
BASE SELF IMPEDANCE CURVE FOR VERTICAL ANTENNA (UNIFORM CROSS SECTION; GUYED)

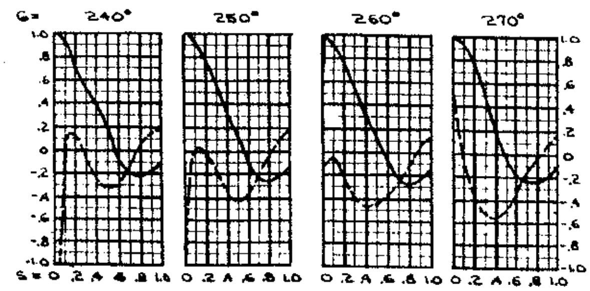


TABULATION OF BASE IMPEDANCES

DEGREES	WAVELENGTHS	R(±) ± jX
60°	0.1666 λ	14 - j110
65°	0.1806 λ	17 - j80
70°	0.1844 λ	21 - j50
75°	0.2083 λ	25 - j25
80°	0.2222 λ	34 j0
85°	0.2361 λ	40 + j40
90°	0.25 λ	50 + j70
95°	0.2639 λ	63 + j105
100°	0.2778 λ	80 + j130
105°	0.2917 λ	100 + j170
110°	0.3056 λ	135 + j210
115°	0.3194 λ	180 + j245
120°	0.3333 λ	235 + j280
125°	0.3472 λ	320 + j310
130°	0.3611 λ	420 + j310
135°	0.375 λ	600 + j230
140°	0.3889 λ	760 j0
145°	0.4028 λ	720 - j180
150°	0.4167 λ	660 - j260
155°	0.4306 λ	500 - j375
160°	0.4444 λ	385 - j385
165°	0.4583 λ	300 - j370
170°	0.4722 λ	230 - j350
175°	0.4861 λ	170 - j320
180°	0.5 λ	132 - j285
185°	0.5139 λ	105 - j255
190°	0.5278 λ	83 - j225
195°	0.5417 λ	70 - j195
200°	0.5556 λ	62 - j170
205°	0.5694 λ	56 - j140
210°	0.5833 λ	48 - j120
215°	0.5972 λ	44 - j92
220°	0.6111 λ	43 - j74
225°	0.625 λ	42 - j42
230°	0.6389 λ	44 - j25
235°	0.6528 λ	46 j0
240°	0.6667 λ	55 + j20
245°	0.6806 λ	64 + j50
250°	0.6944 λ	80 + j80

BASE MUTUAL IMPEDANCE CURVES FOR EQUAL HEIGHT ANTENNAS





$\frac{R_M}{R_o}$ CURVE ———— $\frac{X_M}{R_o}$ CURVE - - - - -

R_M = BASE MUTUAL RESISTANCE

$R_M = \left(\frac{R_M}{R_o}\right)\left(R_{SELF}\right)$

jX_M = BASE MUTUAL REACTANCE

$jX_M = \left(\frac{X_M}{R_o}\right)\left(R_{SELF}\right)$

Z_M = BASE MUTUAL IMPEDANCE

$Z_M = R_M + jX_M$

LOG OF FIELD INTENSITY MEASUREMENTS

STATION ____________ NON-DA ☐

POWER ____________ DA-DAY ☐

FREQUENCY ____________ DA-NIGHT ☐ ENGINEER ____________

REMARKS: ____

DATE	TIME	MAP NUMBER	DA MV/M	NON-DA MV/M	RATIO	BEARING (DEGREES)	DESCRIPTION