RF Book

RF Note #55

October 8, 1979
J. Riedel

Neutralizing the Final Amplifier

In RF notes #41 and #46 we discussed the final grid-driver anode circuit and showed why, with the 50 ohm load on the final grid, with the consequent 180-42 degree phase shift between the driver anode and the final grid, perfect neutralizing was impossible. There are two reasons for neutralizing perfectly. One, due to the amplitude dependence of the final grid to final anode voltage ratio, the feedback current (which becomes as high as 20% of the grid capacity current) causes the tuning of the grid circuit to be amplitude dependent. Two, without neutralization, when the anode rf achieves a certain high enough value, the final will self excite. This is intolerable.

However, in RF Note #41, we reported that our partial neutralization gave satisfactory results. Still it is possible that with a different tube the performance may not be satisfactory. Also, the 42 degree phase lag is bad because this will have to be compensated for with the manual phase shifters, using up most of their range.

So we propose to try for a perfect solution. Before proceeding, we decided to exactly calculate the performance, including the effect of the Miller feedback capacity and the neutralizing capacity. Figure 1 is the circuit. Initially, $R_G = 50\Omega$ and $R_A = 00$. Using Riedel's ACNET we calculate all currents and voltages as a function of frequency and V_G, find the resonant frequency (determined by when $I\phi$ is in phase with V_D) and present the results. Indeed, we find that with $R_G = 50\Omega$, complete neutralization is impossible, and that without neutralization $I\phi$ can be 0 for $V_G > 300$ (self excitation) and above that value it runs away.

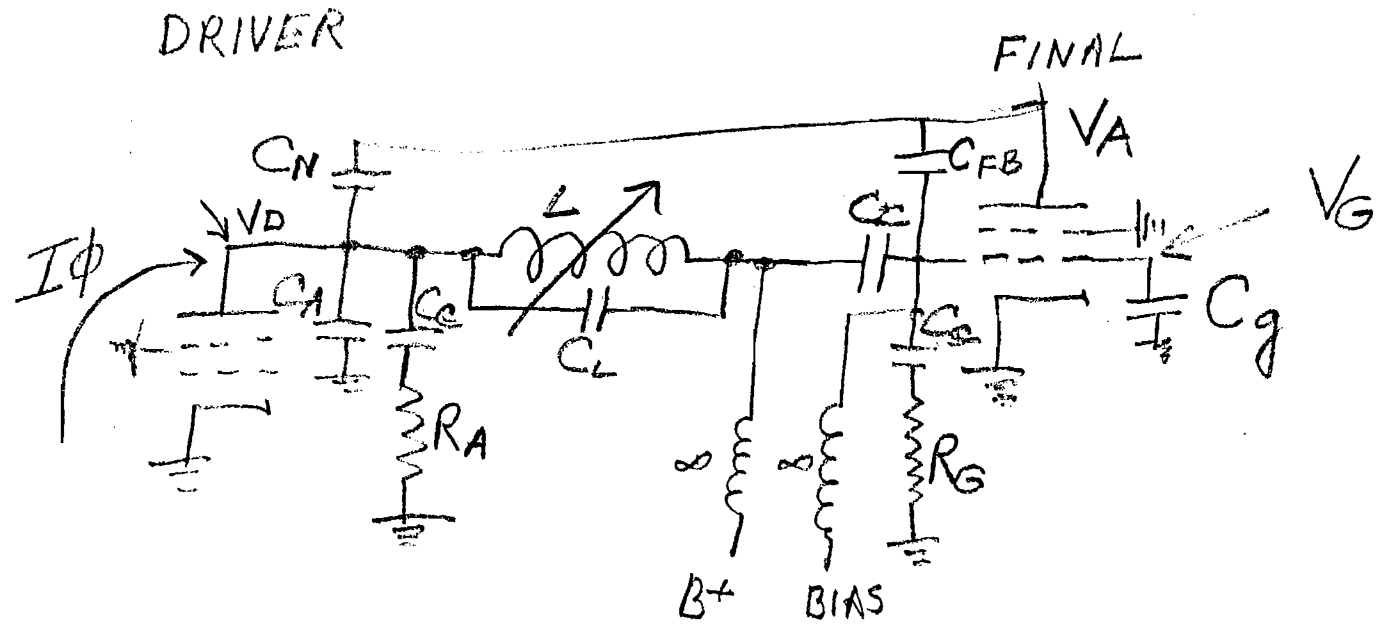
So we make $R_G = 10^4$ and $R_A = 1250\Omega$. We find that increasing C_{FB} decreases the resonant frequency and increasing C_N decreases the frequency, as expected. Also, if C_N and C_{FB} do not have the proper ratio, the frequency will be amplitude dependent. But when $C_N = C_{FB}/5$ we have exactly the same resonant frequency as we would have if $C_N = C_{FB} = 0$, and also this frequency is amplitude independent.

So the theory is ok, and we propose to remove R_G, add $R_A = 1250\Omega$, and test our transmitter. The only reason we may not be able to use this scheme is that with the removal of R_G, the Q at some higher frequency may result in the final becoming self excited in a parasitic mode. So we proceed with crossed fingers. If we have trouble we can always remove this latest improvement.

Voltage Regulator

Unfortunately, in RF Note #53 the promised computer printouts of the response did not appear, so we will present them here. The captions and indexes should be obvious with one exception. The printout and curves for the op amp gain are not the gain, but the voltage output for a command of 10 volts.

A new circuit for the amplitude regulator has been designed and a prototype should exist by 10/22/79. Also, a module called "DEE VOLTS OVER-RIDE" has been designed and should also exist by 10/22/79. The ON-OFF module should exist by that date, as well.



where $C_g = 400\ pf$, $C_A = 80 pf$, $C_{FB} = 1\ pf$, $C_L = 1 pf$
$C_N = .2 pf$, $V_c = 2000 pf$
$V_A = .17\ V_G^2$

FIG 1

18:17 SEP 27 VREG...

VOLTAGE REGULATOR

T1=1.20E-04 T2=4.64E-07 T3=1.20E-04 T4=4.00E-07 G0= 1.0E+06 P0=2.0E+06 L=' 10 METERS

OPEN LOOP FREQUENCY RESPONSE

FREQ	G OPAMP	PHASE	G LOOP	PHASE
1.00E-02	7.97E+06	-.719	-7.96E+05	-.719
1.58E-02	6.39E+06	-89.4	-6.39E+05	-89.4
2.51E-02	4.65E+06	-89.4	-4.64E+05	-89.4
3.98E-02	3.14E+06	-89.4	-3.14E+05	-89.4
6.31E-02	2.04E+06	-89.4	-2.04E+05	-89.4
.100	1.31E+06	-89.4	-1.31E+05	-89.4
.158	8.28E+05	-89.4	-8.28E+04	-89.4
.251	5.24E+05	-89.4	-5.24E+04	-89.4
.398	3.31E+05	-89.4	-3.31E+04	-89.4
.631	2.09E+05	-89.4	-2.09E+04	-89.4
1.00	1.32E+05	-89.4	-1.32E+04	-89.4
1.58	8.31E+04	-89.5	-8.31E+03	-89.5
2.51	5.25E+04	-89.6	-5.24E+03	-89.6
3.98	3.31E+04	-89.6	-3.31E+03	-89.7
6.31	2.09E+04	-89.6	-2.09E+03	-89.7
10.0	1.32E+04	-89.5	-1.32E+03	-89.7
15.8	8.31E+03	-89.3	-831.	-89.6
25.1	5.25E+03	-88.9	-525.	-89.4
39.8	3.31E+03	-88.3	-331.	-89.1
63.1	2.09E+03	-87.3	-209.	-88.7
100.	1.32E+03	-85.7	-132.	-87.9
158.	837.	-83.2	-83.6	-86.7
251.	534.	-79.4	-53.1	-84.8
398.	346.	-73.4	-34.2	-82.1
631.	231.	-64.8	-22.5	-78.4
1.00E+03	165.	-53.3	-15.4	-74.3
1.58E+03	130.	-40.4	-11.1	-71.8
2.51E+03	112.	-28.6	-8.15	-72.9
3.98E+03	105.	-19.7	-5.80	-77.4
6.31E+03	101.	-13.8	-3.93	-83.2
1.00E+04	100.	-10.7	-2.56	-89.3
1.58E+04	99.3	-9.73	-1.64	-95.7
2.51E+04	98.6	-10.8	-1.03	-104.
3.98E+04	97.1	-14.2	-.638	-114.
6.31E+04	93.9	-20.2	-.383	-130.
1.00E+05	87.2	-29.4	-.215	-152.
1.58E+05	75.1	-41.4	-.106	-183.
2.51E+05	58.5	-54.2	-4.21E-02	-221.
3.98E+05	41.5	-65.5	-1.28E-02	-264.
6.31E+05	27.7	-73.9	-2.96E-03	-306.
1.00E+06	17.9	-79.7	-5.69E-04	-345.

PH 0

50000 HALT

>B A6=2

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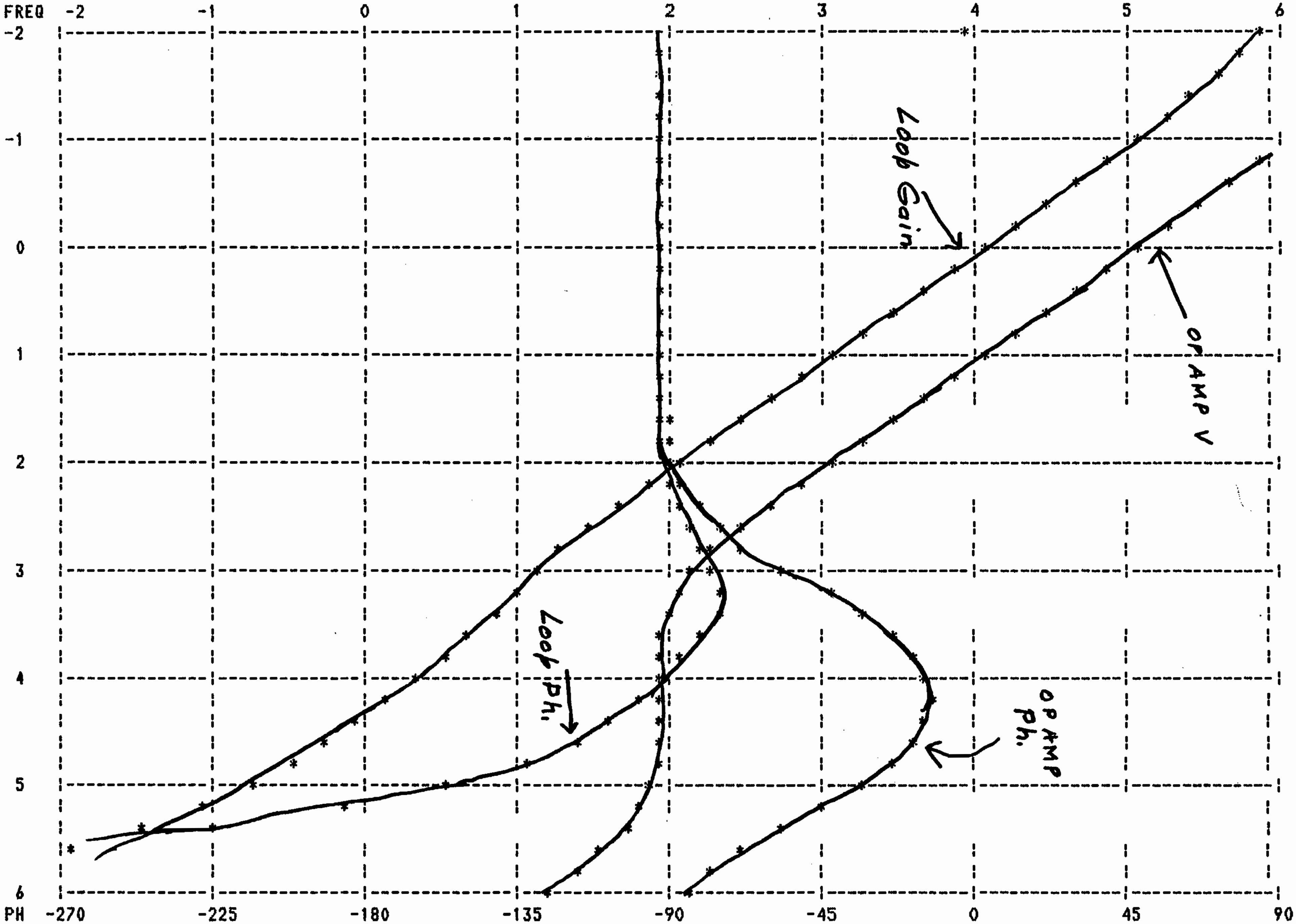
RUN
18:22 SE 7 VREG...

VOLTAGE REGULATOR
T1=1.20E-04 T2=4.64E-07 T3=1.20E-04 T4=4.00E-07 G0= 1.0E+06 P0=2.0E+06 L=' 10 METERS
OPEN LOOP FREQUENCY RESPONSE



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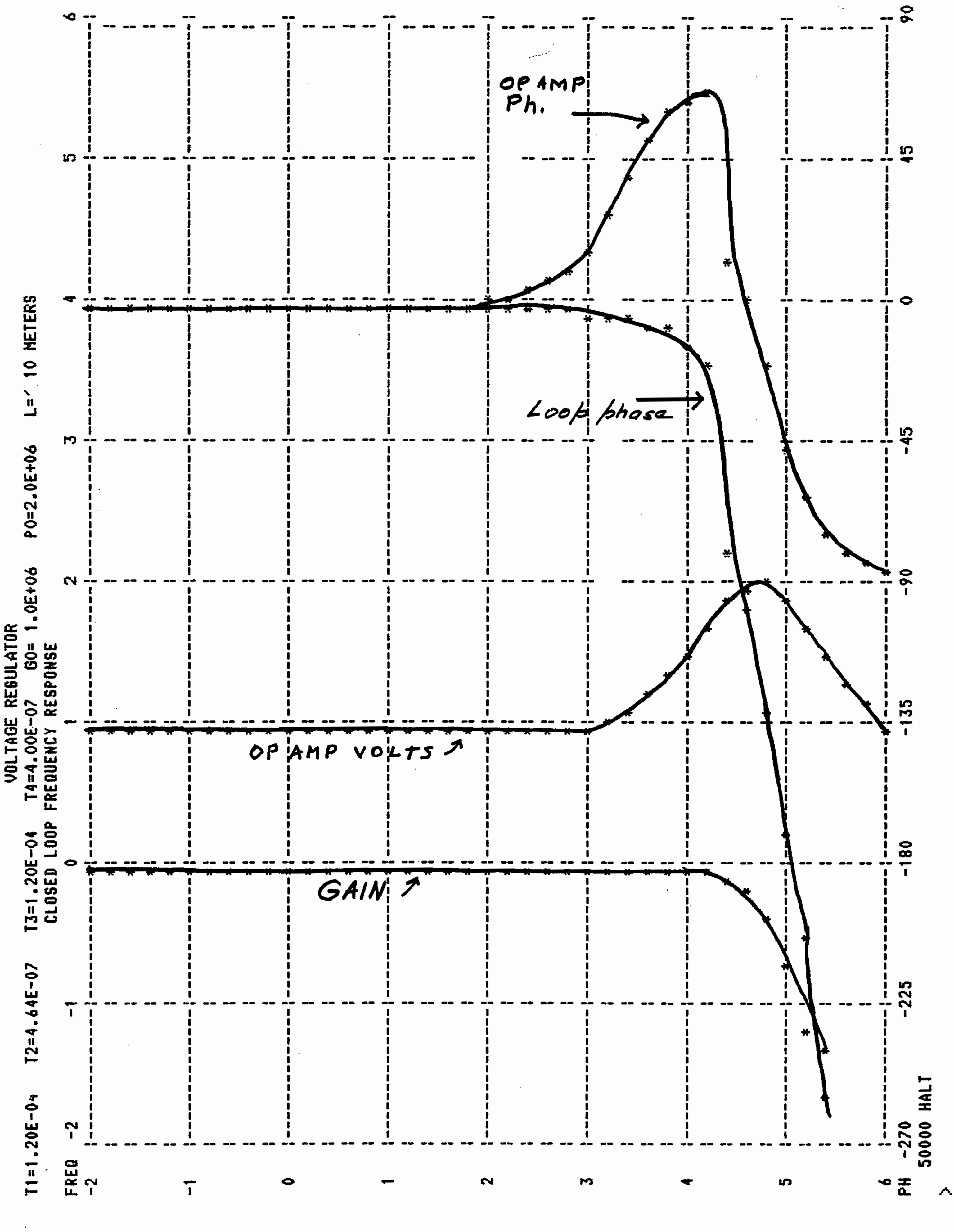
>8 A6=3


VOLTAGE REGULATOR
T1=1.20E-04 T2=4.64E-07 T3=1.20E-04 T4=4.00E-07 G0= 1.0E+06 P0=2.0E+06 L=' 10 METERS
CLOSED LOOP FREQUENCY RESPONSE
OP AMP Ph.
Loop phase
OP AMP VOLTS
GAIN
FREQ
-2 -1 0 1 2 3 4 5 6
PH
-270 -225 -180 -135 -90 -45 0 45 90
-2 -1 0 1 2 3 4 5 6
50000 HALT

)8:27 SEP 27 VREG...

VOLTAGE REGULATOR

T1=1.20E-04 T2=4.64E-07 T3=1.20E-04 T4=4.00E-07 G0= 1.0E+06 P0=2.0E+06 L=' 10 METERS

CLOSED LOOP FREQUENCY RESPONSE

FREQ	G OPAMP	PHASE	G LOOP	PHASE
1.00E-02	10.0	1.97E-04	-1.00	-2.22E-05
1.58E-02	10.0	3.13E-04	-1.00	-3.51E-05
2.51E-02	10.0	4.96E-04	-1.00	-5.57E-05
3.98E-02	10.0	7.85E-04	-1.00	-8.83E-05
6.31E-02	10.0	1.24E-03	-1.00	-1.40E-04
.100	10.0	1.97E-03	-1.00	-2.22E-04
.158	10.0	3.13E-03	-1.00	-3.51E-04
.251	10.0	4.96E-03	-1.00	-5.57E-04
.398	10.0	7.85E-03	-1.00	-8.83E-04
.631	10.0	1.24E-02	-1.00	-1.40E-03
1.00	10.0	1.97E-02	-1.00	-2.22E-03
1.58	10.0	3.13E-02	-1.00	-3.51E-03
2.51	10.0	4.96E-02	-1.00	-5.57E-03
3.98	10.0	7.85E-02	-1.00	-8.83E-03
6.31	10.0	.124	-1.00	-1.40E-02
10.0	10.0	.197	-1.00	-2.22E-02
15.8	10.0	.313	-1.00	-3.51E-02
25.1	10.0	.496	-1.00	-5.57E-02
39.8	10.0	.785	-1.00	-8.82E-02
63.1	10.0	1.24	-1.00	-.140
100.	10.0	1.97	-1.00	-.221
158.	10.0	3.13	-.999	-.349
251.	10.0	4.95	-.998	-.548
398.	10.1	7.83	-.996	-.847
631.	10.2	12.3	-.990	-1.27
1.00E+03	10.5	19.2	-.981	-1.83
1.58E+03	11.3	28.9	-.970	-2.51
2.51E+03	13.2	40.9	-.960	-3.46
3.98E+03	17.2	52.7	-.954	-4.98
6.31E+03	24.5	61.9	-.949	-7.49
1.00E+04	36.8	67.1	-.944	-11.6
1.58E+04	56.5	68.1	-.931	-17.9
2.51E+04	80.8	14.3	-.844	-78.3
3.98E+04	107.	3.60	-.702	-96.4
6.31E+04	109.	-19.1	-.446	-128.
1.00E+05	82.1	-44.6	-.203	-167.
1.58E+05	55.0	-60.7	-7.77E-02	-202.
2.51E+05	35.9	-70.5	-2.59E-02	-237.
3.98E+05	23.2	-77.0	-7.14E-03	-275.
6.31E+05	14.9	-81.5	-1.60E-03	-313.
1.00E+06	9.48	-84.6	-3.01E-04	-350.

PH -270-225-180-135-90-45 0 45 90

50000 HALT

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8 A6FE=4

RF Harmonic Switch

It has been decreed: "That the 3 position RF harmonic switch (or dee phase rotation switch), located on the station master control panel, shall be replaced with an RF harmonic patch plug arrangement." The function of the harmonic switch is to make the appropriate connections between the synthesizer/buffer outputs and the inputs to the RF amplifiers for the desired harmonic number or mode of operation.

The synthesizer/buffer has twelve outputs that must be switched between the six amplifer inputs associated with RF amplifiers B & C. (See Figure 1) (Amplifier A connections to the synthesizer/buffer are the same for all three modes and thus don't require switching.) All interconnections are coaxial and must remain phase matched when switching from one mode to another. In addition, all buffer outputs,which aren't used when operating in a given mode, have to be terminated. In order to do this switching under computer control or manually using a convenient 3 position rotary switch located on this station master control panel,requires a fairly complex and expensive relay network incorperating about 30 SPDT coaxial relays.

A much simpler method is to use individual coaxial patch chords between the buffer outputs and amplifier inputs. The drawbacks to this are the opportunity for error in making the patch connections and the fact that it must be done manually, with no possibility of computer control or interlocking to tell the computer what mode has been selected.

The switching technique we have chosen to employ is a modification of the individual patch chord in which all the patch chords, terminations, etc., for a given mode of operation are wired into a module (See Figure 2) which is simply plugged into a receptical (See Figure 3) located on the control panel when that mode of operation is desired. Although modes can't be changed by the computer, spare pins on each module's plug can be wired to tell the computer which module (and thus which mode or harmonic number) has been selected.

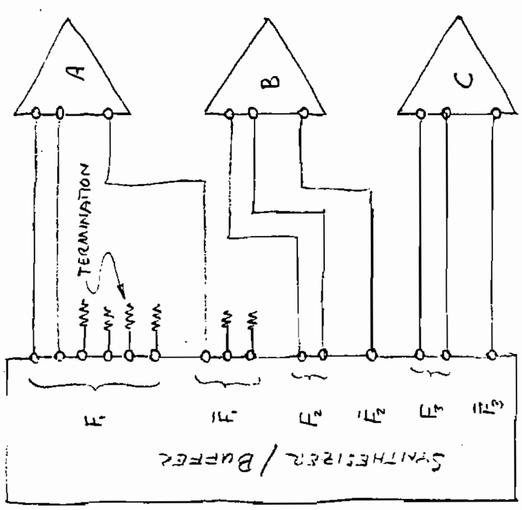

fig 1a. Second Harmonic CW Field Rotation

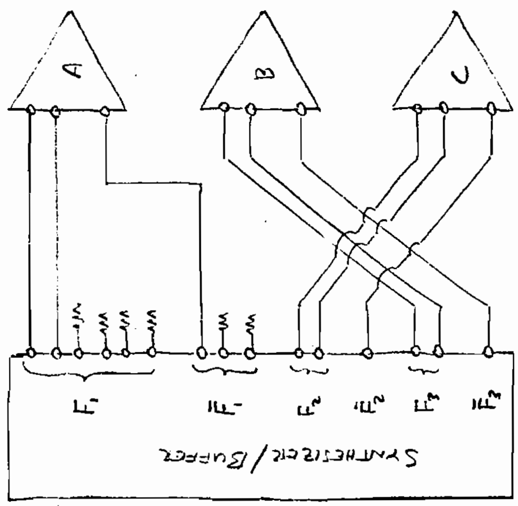

fig 1b. First Harmonic CCW Field Rotation

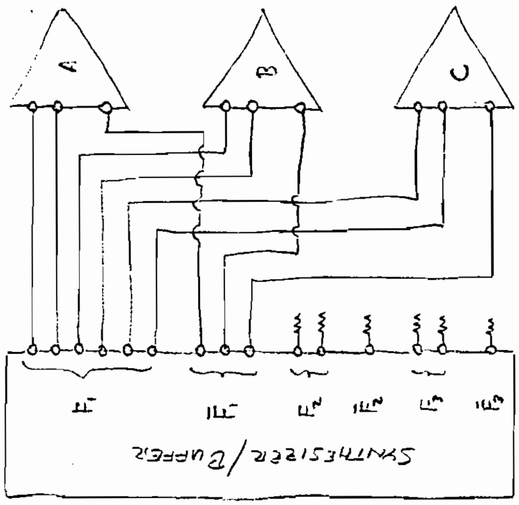

fig 1c. Third Harmonic Single Phase

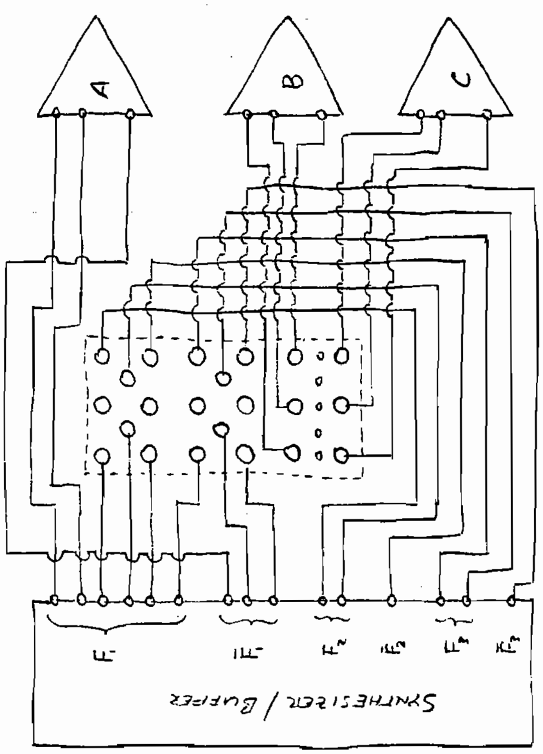

fig 3 Patch Plug Receptical

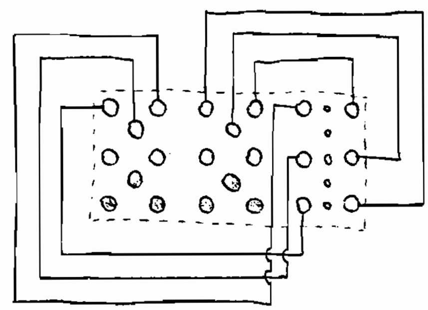
fig 2a CW Rotation

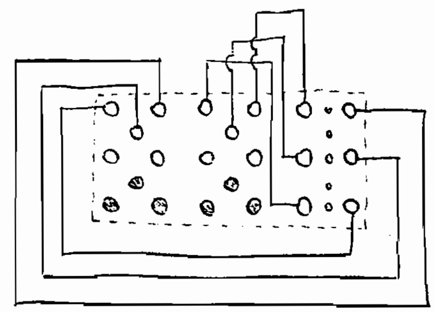
fig 2b CCW Rotation

Note: ⊗ ⇒ Termination

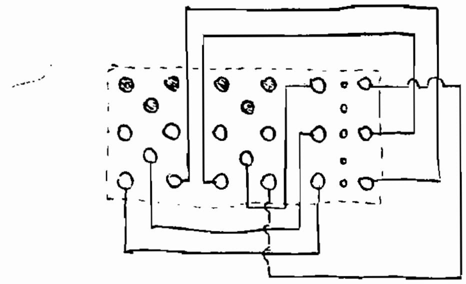
fig 2c 1ϕ Operation

Visit to Chalk River

On 10/4/79 I visited Chalk River to find out what was going on up there. From Bruce Bigham I gleaned these things:

The transmitter. The 100 KW transmitter, covering the range 30 to 60 MHz, was purchased from Continental (a Texas based frim) for $300,000. It works. There is no circuit diagram, but there was a mechanical layout and from it I was able to deduce the circuit. They start with a 200 watt broad band solid state amplifier which drives a grounded cathode 3 KW water cooled triode operating at zero grid bias. The grid and anode circuit are cylindrical cavities tuned by motor driven moving shorts (fingers) and, at the same time, the coupling is adjusted by other moving finger shorts. The final is a grounded screen, grounded grid 4 CW100,000E tetrode, again with tuned cavity and variable coupler. Thus there are six adjustments of finger shorts to be made for each frequency selection. There are only two criteria of adjustment for these tuning elements. One, a lookup table, supplied by the manufacturer, and two, the plate current which slovenly dips at resonance. Their first tube was destroyed due to a 1GHz parasitic which disappeared when a new tube was installed. They have had other parasitic problems but everything seems fine now.

Resonator

They have had trouble with a water leak appearing at high power in the outer conductor of the stem. Their multipactoring problems are worse than ours were in our test facility. They were unaware of the existence of modes in their transmission line, but I was able to demonstrate that their performance was identical to ours as shown in the curve of RF Note #17 as calculated by TRED 3.

Bigham is working on developing a new finger design which will be more tolerant of alignment errors. It will provide contact points every mm. He has removed his fine tuner and plans on only moving the stem short for fine tuning. They have tuning and amplitude loops closed, albiet with very low gain (10).

Turn On

They have a turn on scheme very similar to the one we propose to use, so that after a time T, excessive vacuum or reflected power will turn them off. As a result of witnessing this method of performance,I have decided that we should have our cake and eat it too. So we will implement the new scheme, which has however, a switch to permit us to have the option of going back to the old scheme.