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RF Fusion

RF NOTE #23

2/22/78
by J. Riedel

H.F. R.F.

It now seems that we will have two rf systems for the 500 MeV cyclotron. The first one, described in RF Note #17, called "Dee Stem with Insulator", is to satisfy the requirements of the cyclotron when it is to be used as an injector into the 800 MeV second cyclotron. It covers the frequency range 7.5 to 32.5 MHz.

But the first use of the 500 MeV cyclotron will be to conduct experiments on low mass heavy ions at greater energies than attainable by presently existing accelerators. This "stand alone" cyclotron could best be served by an rf system encompassing the range 30 to 65 MHz. The principle reason why our ideas of the rf requirements have changed is that, as a result of central orbit studies, working on harmonic one (3 ϕ operation) is very difficult if not impossible, whereas operation on H=2, 3 or 4 yields satisfactory results. Thus we propose to start up with a H.F.R.F. (High Frequency RF) system, and when the second cyclotron is built, modify it to the DSWI (dee stem with insulator) system! Voila!

Dee-Stem Structure

The dees, the fine tuner and the drive coupler will be the same for the two systems. The dee stem for the HFRF system will be only five (5) feet long and entirely in vacuum. The dee stem inner conductor will be a uniform 4.125" OD. The moving short, divided into 6 angular segments, which, by virtue of springs and ceramic wheels will accommodate mechanical distortions of straightness and roundness of the conductors, will be driven by push rods enclosed in long bellows.

Program HFRF was written and run and the gory details are available for anyone to see in Riedel's computer folder. The significant results are summarized in Table I below, and a plot of short position vs. frequency, as well as power requirements, are displayed in Fig. 1.

TABLE I.*

F MHz	ΔL INCH	L INCH	W KW	I_{MAX} RMS A	Q	R_S KΩ	C_{eq} pf	C_c pf
30	52	62	53	1900	4300	93	247	2
35	40	50	52	2000	4700	95	222	2
40	31	41	51	2100	5000	97	202	1
45	25	35	50	2200	5200	99	185	1
50	20	30	49	2300	5400	101	170	1
55	16	26	47	2400	5600	104	155	1
60	14	24	46	2400	5800	107	142	1
65	11	21	44	2500	5900	111	130	1

*See RF NOTE #17 for definitions

Transmitter

Fortuitously the anode and output circuitry of the transmitter can remain unchanged while accommodating both HFRF and DSWI alternatives. The 12-foot long stem with moving short can achieve the frequency range 15 to 32.5 MHz on the $\lambda/4$ mode, and with the addition of plug-in vacuum capacitors lower it to 7.5 MHz for the DSWI requirements. For the HFRF requirement, it is possible, and entirely feasible to operate on a $3/4\lambda$ mode. The maximum transmitter stem currents are about 300 amps, and the maximum voltages will be about 30 KV. The total power dissipated in the transmitter stems will be about 2 KW, easily removed by moving air. Because of using only a 12-foot stem instead of a 14-foot stem we will have to switch in a 100 pf loading capacitor to breach the range 32.5 to 40 MHz, but this is a trivial complication. Figure 2 shows the short position vs. frequency.

Driver

Although possible, it is believed impractical to tune the driver stages over the combined range of DSWI and HFRF, as this would require a variable inductor of 64 to 1 range. The idea of driving on the first subharmonic was toyed with, but abandoned, because of the complication of phase detecting a signal against its 2nd harmonic.

So we propose to have two sets of inductors, which can be interchanged when moving from one range to the other. We have the final tube on hand, as well as a tube socket, and within a week we will make measurements on a plywood and sheet metal model transmitter box to permit us to design the inductors. The inductors for the HFRF range will be homemade, the others purchaseable. No problems are foreseen here.

Pre-Driver

We have ordered (and it has been sent) a 50-watt solid state amplifier which is rated only up to 32 mHz. The manufacturer reports via phone that it will actually be OK up to 45 mHz. To get one that will extend to 65 mHz means that we will have to buy one rated to 200 mHz, at twice the cost ($2000 to $4000). Maybe, after we receive this first one we will see that we should build our own at considerably less cost.

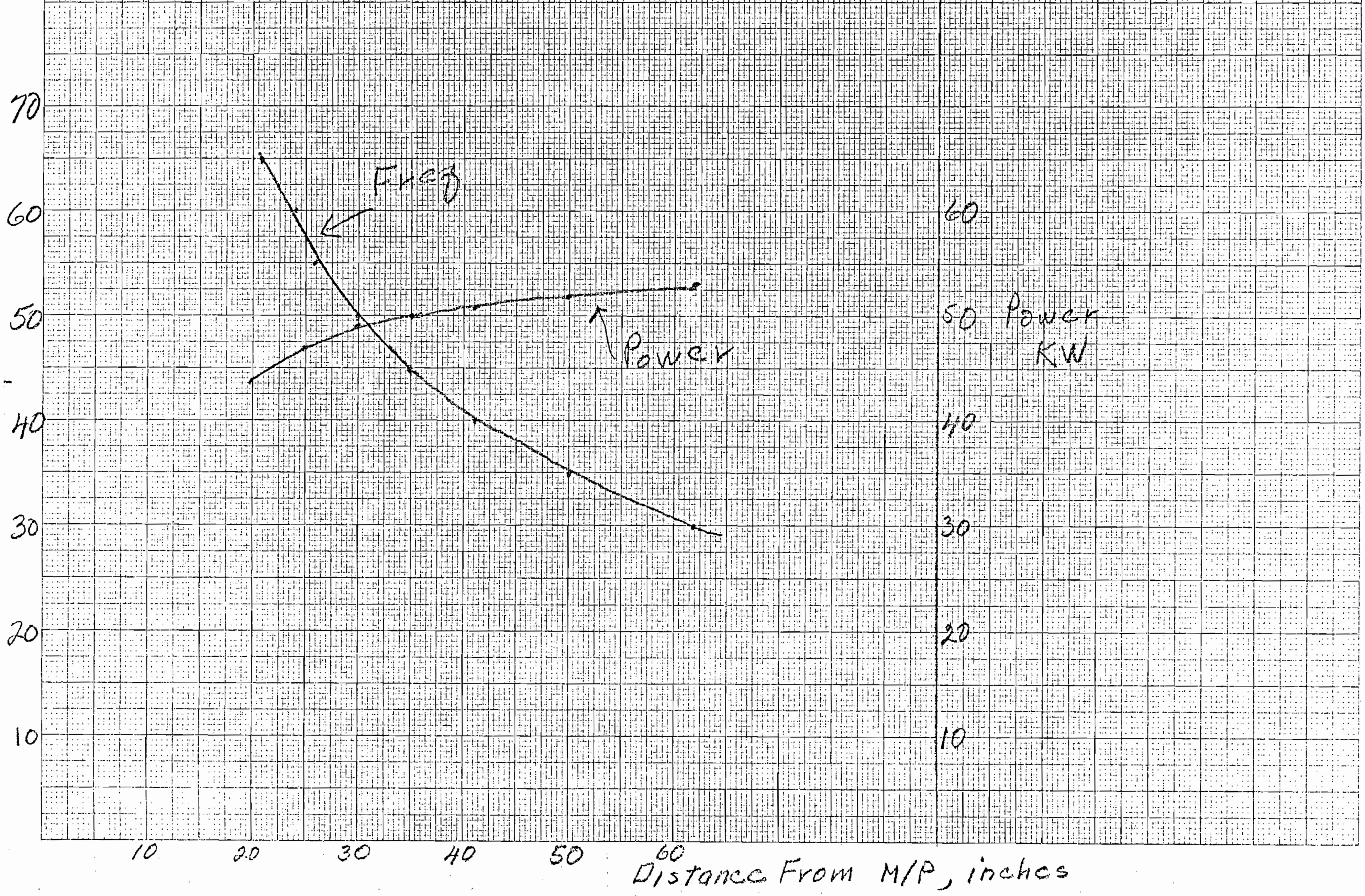
Low Level

The biggest impact of the combined range is on the low level circuitry. First the F^1 generator and the two crystal oscillators will have to have at least 35 mHz added to them. But in order to reduce the 8 to 1 range to about 3 to 2, let it be arbitrarily decided that F^1 will be from 142.5 to 200 mHz. The two crystal oscillators will be at 135 and 133 mHz.

The 50 to 100 mHz stable continuously tunable oscillator that we have on hand can still be used. For HFRF operation we will beat this up to F^1 with a 110 mHz crystal Osc., and for the DSWI range, a 90 mHz crystal Osc. The low, high and band pass filters will have different specifications. Fig. 3 shows the new block diagram.

Fortunately the electronic attenuators, electronic phase shifters and the phase detector schemes remain as before, with the exception that we will mix crystal oscillator #2 with the $F\phi$ signals to be phase shifted and the phase shifter will work between 140 and 200 mHz.

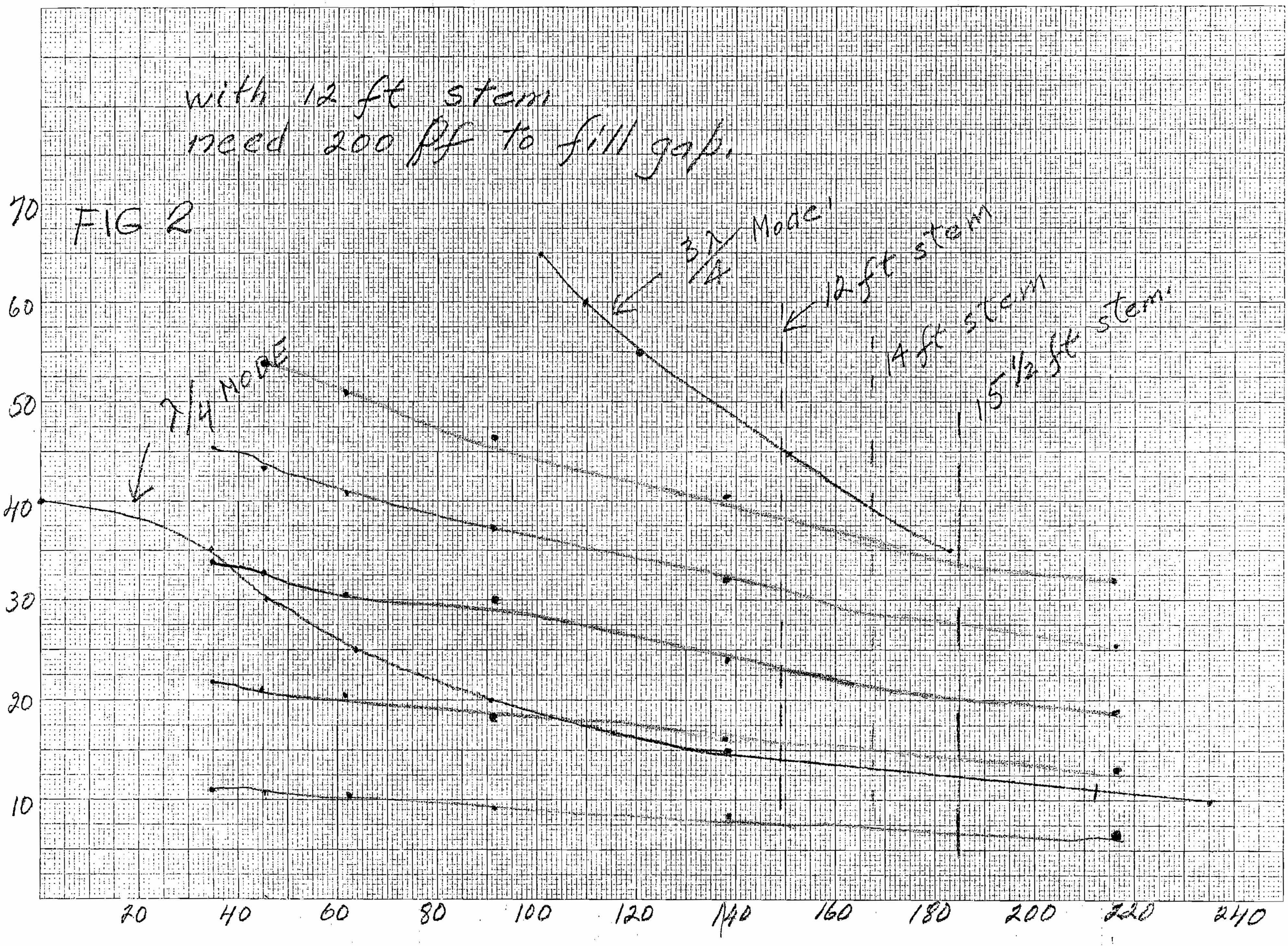
FIG 1

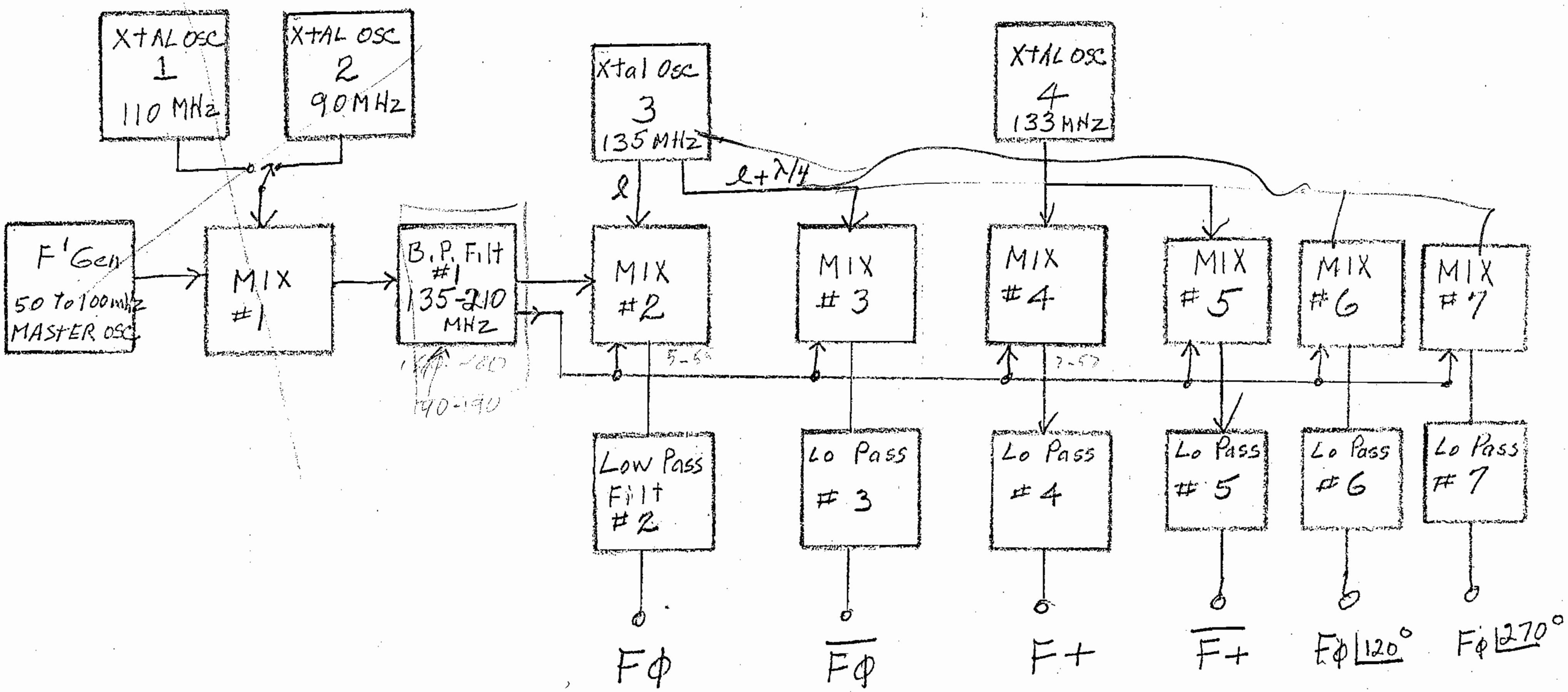

70
60
50
40
30
20
10
Freq
Power
60
50
40
30
20
10
Power
KW
10
20
30
40
50
60
Distance From M/P, inches

46 1512

with 12 ft stem
need 200 pf to fill gap.

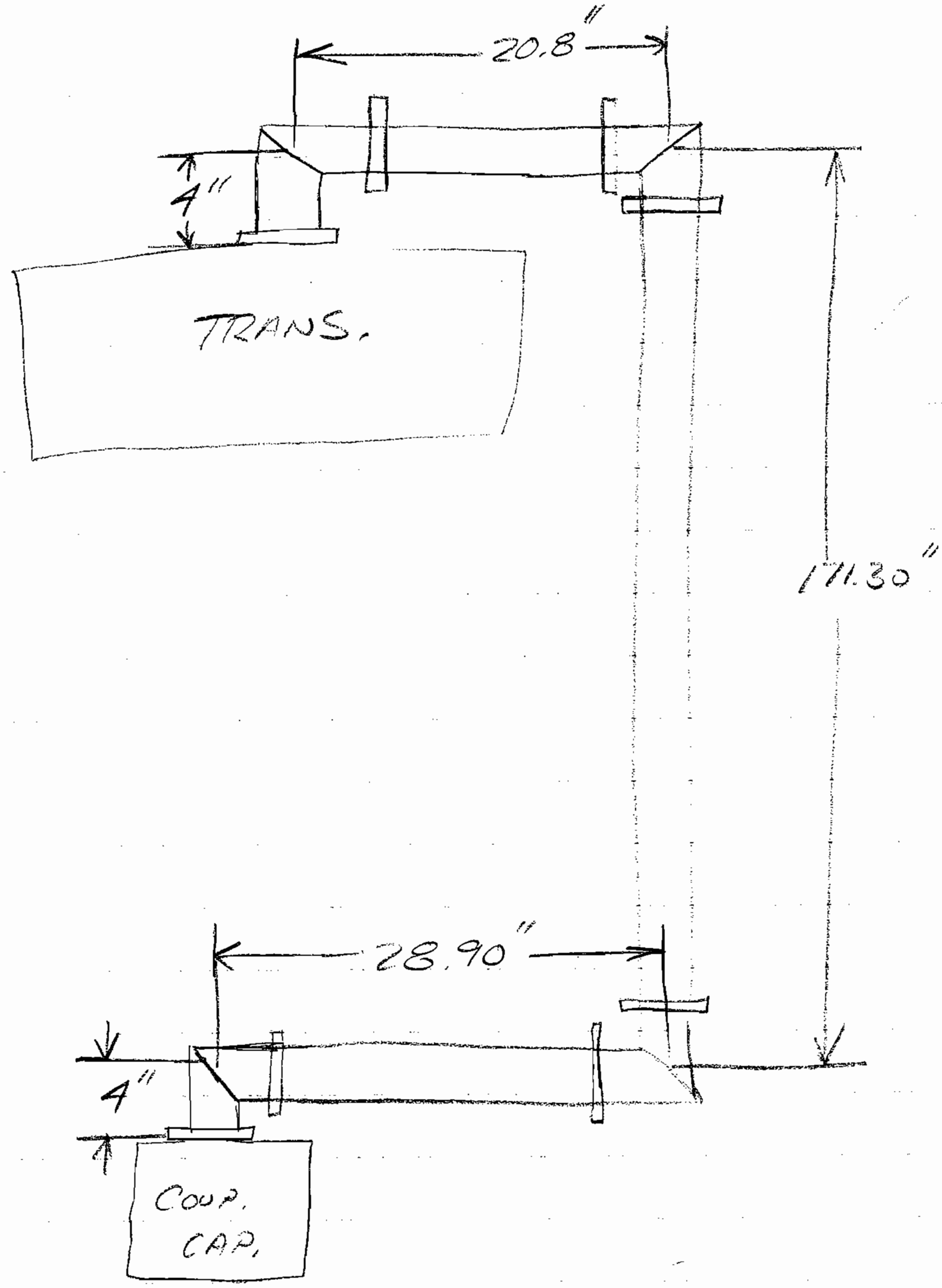
FIG 2





XtAL OSC 1 110 MHz
XtAL OSC 2 90 MHz
F' Gen 50 to 100 mhz MASTER OSC
MIX #1
B.P. Filt #1 135-210 MHz
Xtal Osc 3 135 MHz
XtAL OSC 4 133 MHz
MIX #2
MIX #3
MIX #4
MIX #5
MIX #6
MIX #7
Low Pass Filt #2
Lo Pass #3
Lo Pass #4
Lo Pass #5
Lo Pass #6
Lo Pass #7
Fφ
F+
F+
Fφ∠120°
Fφ∠270°

FIG 3.



TOTAL LENGTH → 229"