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R.F. Note 83

May 6, 1982
T. Miyanaga

SIGNAL GENERATION SYSTEM (SYNTHESIZER SYSTEM)

PAGE

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Letters inside parenthesis indicate the drawing number.

1. INTRODUCTION

The purpose of this note is to present the circuit description and characteristics of the Signal Generation System (Synthesizer System). Data, measured during installation into the RF console, is also presented.

Some discussion and descriptions of this system have been presented in the following RF Note's: #10, #16, #23, #30, #35, #36, #40, #42 and #43.

2. SYSTEM DESCRIPTION

The SIGNAL GENERATION SYSTEM consists of a commercial synthesizer oscillator and the following modules: 140-170 MHz SIGNAL SPLITTER, 135 MHz OSCILLATOR/MIXER, 133 MHz OSCILLATOR/MIXER, LOW PASS FILTERS, BROADBAND AMPLIFIERS, QUADRATURE HYBRIDS, F1/$\overline{F1}$ BUFFERS, F2/$\overline{F2}$ BUFFERS, F3/$\overline{F3}$ BUFFERS, F+/$\overline{F+}$ (7. - 35 MHz) SPLITTERS, F+ BUFFERS (2 modules), $\overline{F+}$ BUFFERS (2 modules) and ±15 V/+24 V Power Supplies. This system has multiple outputs of the following signals;

F1: $A\sin(2\pi fo+120°)$, $\overline{F1}$: $A\sin(2\pi fo+120°-90°)$

F2: $A\sin(2\pi fo)$, $\overline{F2}$: $A\sin(2\pi fo-90°)$

F3: $A\sin(2\pi fo-120°)$, $\overline{F3}$: $A\sin(2\pi fo-120°-90°)$

F+: $B\sin(2\pi(fo+2\ \mathrm{MHZ}))$

$\overline{F+}$: $B\sin(2\pi(fo+2\ \mathrm{MHZ})-90°)$

These signals are required for the signal source of 3-transmitters and the reference signals of the pahse control scheme in the RF system. Figure 1 shows the block diagram of this system.

The power supply units distribute +15V, -15V and +24V for requirements of all modules in the SIGNAL GENERATION SYSTEM, PHASE SHIFTERS, PHASE TRIMMERS, and PHASE DETECTORS. Note the PHASE DETECTOR was redesigned as the new MIXER/ϕ-DETECTOR, which works at the NIM standard power supply voltages. (Refer to RF Note 81).

All modules and power units are installed in the RF control console as shown in Figure 2.

3. DIGITAL FREQUENCY SYNTHESIZER PTS-200

A commercial synthesizer PTS 200 serves as a primary signal source for the Signal Generation System. Practical operating frequency is in the range from 143 (for fo = 8 MHZ) to 167 MHZ (for fo = 32 MHZ). Resolution (settability) is 10 HZ. The amplitude of the output signal is adjustable, however, the amplitude of signal to the 140-170 MHZ Power Splitter module must be set at 1 V rms (+13 dBm) in order to stabilize the amplitude of output signal from the Signal Generation System, over the entire operating frequency.

Detailed specifications and additional information are presented in the Instruction Manual of the PTS-200. Further discussion is presented in RF Note #43.

4. 140-170 MHZ SIGNAL SPLITTER MODULE

This module splits an input signal into 5 in-phase outputs. The BNC RF INPUT on the front panel is fed from the PTS-200 commercial synthesizer.

On the rear panel, there are five RF OUTPUTS each in an Amphenal 27-11 panel jack. OUTPUTS 1 through 3 go to RF inputs 1 through 3 on the rear panel of the 135 MHZ OSCILLATOR/MIXER module. RF OUTPUT 4 goes to the RF INPUT on the 133 MHZ OSCILLATOR/MIXER rear panel, and RF OUTPUT 5 goes to the 3-ϕ Digital Phase Meter. The commercial eight-way power divider, ANZAC model DS-309, part no. 8251, is used in this module. The 5-output ports are connected to the rear panel connectors and the 3 remaining ports are terminated by 50Ω resistors. (Refer to Fig. 12).

Acutal operating specifications are as follows:

Frequency: 143 - 167 MHZ

Input Amplitude: 1 V rms (+13dBm)

Output Amplitude: 0.35 V rms (+4dBm)

Impedance: 50Ω

5. 135 MHZ OSCILLATOR/MIXER

Figure 9 shows the block diagram of 135 MHZ OSC/MIXER module. Xtal OSC is a commercial oscillator unit. It's specifications are 135 MHZ $\pm$ 10 ppm and $\pm$5 ppm stability.

The 135 MHZ signal from the Xtal OSC is amplified up to 1 V rms by the V-MOS FET gain amplifier which was described in RF Note #30, and divided 3 way using transistor buffer amplifiers. These three output signals are connected with three coaxial cables (RG-178B/u) whose lengths were cut to produce the relationship of 120° delay differences at 135 MHZ.

At the cable connection points on the PC Board, strip lines are provided for fine adjustments of the phases among 3-phase 135 MHZ signals by changing soldering positions on the strip lines. The 3 phase output signals 120° apart each other are adjusted within an accuracy of 0.5 degree at the filtered outputs.

The 3-output signals include higher order component, however, they are already named as F1, F2 and F3 respectively and go to the Low Pass Filters module.

Specifications:

Input Signals: 143-167 MHZ (F_H), 0.35V rms, 50Ω

Local Osc.: 135 MHZ (F_{L01})

Output Signals: FO=FH-FL01, and higher order components
F1=+120° F2=0° F3=+120°

Power Requirement: +24V 14mA
+15V 300mA
-15V 550mA

6. 133 MHZ OSCILLATOR/MIXER

The block diagram of this module is shown in Fig. 10. The scheme is as same as the 135 MHZ OSC/MIX module except that the single output is 2 MHZ higher than Fo. This output is named F+ signal.

Specifications:

Input Signal: 143-167 MHZ (F_H), 0.35V rms, 50Ω

Local Osc.: 133 MHZ (F_{L02})

Output Signal: $(F+)-(F_H)-(F_{L02})$ and higher order components

Power Requirement: +24V 14mA
+15V 350mA
-15V 120mA

7. LOW PASS FILTER MODULE

The schematic and characteristics were described in RF Note #31. Eight identical low-pass-filters which pass the frequencies up to 70 MHZ are mounted in the double width module case. The Signal Generation System requires but four filters for F1, F2, F3 and F+ signals. The rest of the filters are spares.

8. BROAD BAND AMPLIFIER MODULE

This module consists of an IC gain amplifier and PIN diode attenuator for the four signals as shown in Fig. 3. The functions of this circuits are to give the desired amplitude at the output of the Signal Generation System and to regulate that amplitude at a constant value over the entire frequency range.

The typical frequency dependence of the amplitude without ALC (Automatic Level Control) is shown as curve 1 in Fig. 7.

Amplitude regulation is accomplished with a simple diode peak detector, an operational amplifier circuit (abbreviated as ALC) and a PIN diode attenuator as shown in Fig. 7.

The peak detector has the characteristics shown in Fig. 5. It samples the amplitude at one of many outputs of the Buffer Amplifier module. The peak detected DC signal is fed back to the ALC amplifier to control the forward current of PIN diode attenuator.

PIN diodes are so called "RF current controlled resistor diodes". Three of them are connected in series, in order to prevent distortion of the RF signals as shown in Fig. 6.

The performance of the amplitude regulation scheme is presented as curve 2 in Fig. 7.

Specifications:

Input Amplitude: 0.1 V rms

Output Amplitude: 1.4 - 2 V rms

Amplitude Regulation: 1% at the buffer output over the frequency range of 8-32 MHZ

Power Requirements: +15V 1.3A
-15V 50mA

9. CROSSTALK PROBLEM

During the Signal Generation System installation and adjustment in the RF console, a cross talk problem was found inside the Broad Band Amplifier module.

This problem caused modulation of 2 MHZ and it's level was nearly 10% of the F+ and $\overline{F+}$ signals. RF-OK signals, which are used for the control of the servo circuits were always turning on, even if no RF signals existed at various points of the transmitter and Dees.

The Broadband amplifier module has four IC gain amplifiers on the one bread board. The input wiring of each amplifier is located close to the output of the other amplifiers.

In Fig. 4, the data concerning isolation is listed. The values listed are levels of the outputs induced when only one amplifier is fed by the input signals under the condition that gives 1 V rms output from that amplifier in the configuration shown by the block diagram. Some attempts to reduce crosstalk were made by enlarging the ground plane on the circuit board, by increase the decoupling capacitance or by adding filter choke coils in the +15V power line. The results were about 10dB improvement in the isolation. But 2 MHZ modulation remained in the F+ signals (which was amplified by amplifier 4) because the crosstalk to the amplifier 4 from the output 3 was worse than 50db isolation. Only the input of amplifier 1 is distant from the other output terminals and has enough isolation from the other 3 amplifiers. Finally, in order to avoid the problem, amplifier 1 was changed to use the F+ signals and the 2 MHZ modulation was eventually reduced to less than 0.5%. Slight modulation still remains when the complete Signals Generation System is operated. RF OK signals of the phasing servos are not affected by the remaining crosstalk.

Crosstalk levels in the other modules of the Signal Generation System that could cause the same problem were less than measurable values for 100μV full scale (80dB isolation refer to 1 V rms signal) of the RF voltmeter when they were measured individually.

10. QUADRATURE HYBRIDS MODULE

This module consists simply of 4 commercial RF components: Quadrature Hybrids, ANZAC JH-6-4. The three Fϕ signals (F1, F2 and F3) and the F+(Fϕ+2MHZ) are fed into this module. A pair of signals, 90 degrees different in phase, for each input signal goes out to Buffer Amplifiers as shown in Fig. 11.

The frequency range of these Quadrature Hybrids is 2-32 MHZ and phase deviation measured with a 50Ω termination was less than 0.5 degree up to 50 MHZ.

11. F+/$\overline{F+}$ SIGNAL SPLITTER MODULE

F+ and $\overline{F+}$ signals are respectively divided two ways by this module and fed into the Buffer Amplifiers Two power splitters, PSC-2-1(MCL), are mounted in the module. Originally T type BNC adapter connectors were used for this splitting. After input impedances of all Buffer Amplifier modules were adjusted to 50Ω, the splitter module was added between the Quadrature Hybrids modules and the Buffer Amplifiers.

12. BUFFER AMPLIFIER MODULE

Seven Buffer Amplifier modules are installed as shown in Fig. 1. They are classified into four kinds as shown in Fig. 13-16, although all amplifier circuits are identical.

Outputs from the Buffer Amplifiers go to the Phase Trimmer modules as a 3-phase signal source and to the MIX/ϕ- Detector modules as the 90 degree phase reference signal. Amplitude characteristics of these outputs have already been described in section 8.

The output amplitude proposed originally (refer to RF Note #28) was higher, however the amplitude eventually set to 1 V rms 1 V rms (+13dBm) in order to keep in the operating range of the amplitude regulator and to reduce the slight distortion of the output signals.

The most important characteristic of the output signals is the phase deviation: especially the phase between the pair F+ and $\overline{F+}$ which are used as the phase reference signals in phase detection.

The typical measured curve of the phase vs. the operating frequency is shown in Fig. 8. Near the lower end of the operating frequency (Fϕ), the phase behave as good enough 90 degree phase reference. As the frequency Fϕ goes higher, the phase changes in each output are not identical. Trim pots (shown in Fig. 13-14) in series at the input of each IC amplifier are provided for the phase adjustment. Figure 8 shows the results measured after a rather tedious adjustment at 30 MHZ (F+ = 32 MHZ). Adjustment procedures are simply to turn the trim pots until the same phase is obtained at all outputs. Iteration in turning the pots is needed.

As a result, the frequency dependence of the phase between F+ and $\overline{F+}$ is satisfied 90±1.5 degree over the range from 8 to 32 MHZ of Fϕ frequency. Similar curves of phase relationship among the 3-phase signals (F1, F2 and F3) were obtained.

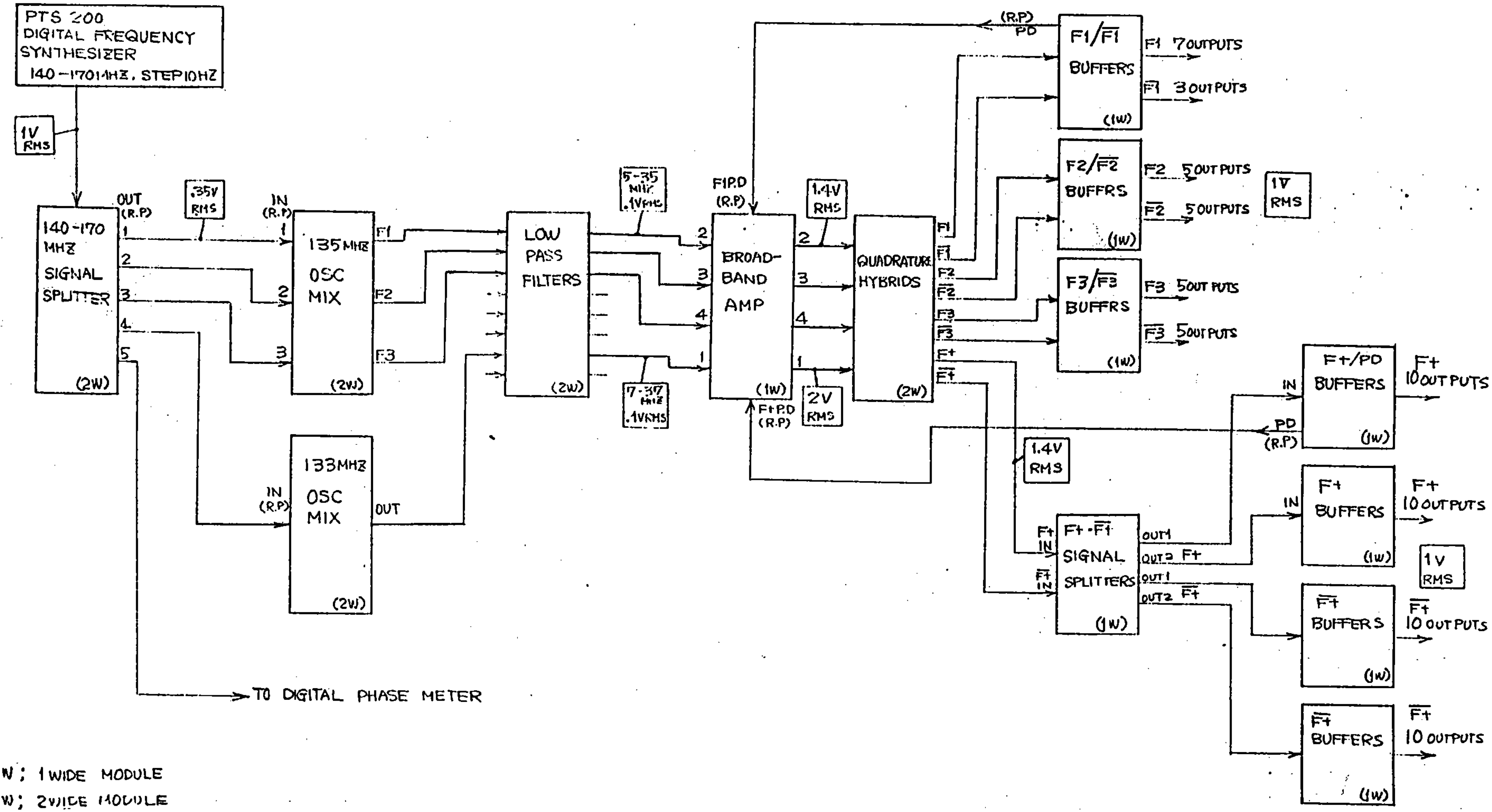
Specifications: (each module)

Frequency: Fϕ = 8-32 MHZ, F1 = -120°, F2 = 0°, F3 = -120°

Output amplitude: 1 V rms

Phase deviation: ±1.5°

Power Requirement: ±15V 560mA
-15 560mA

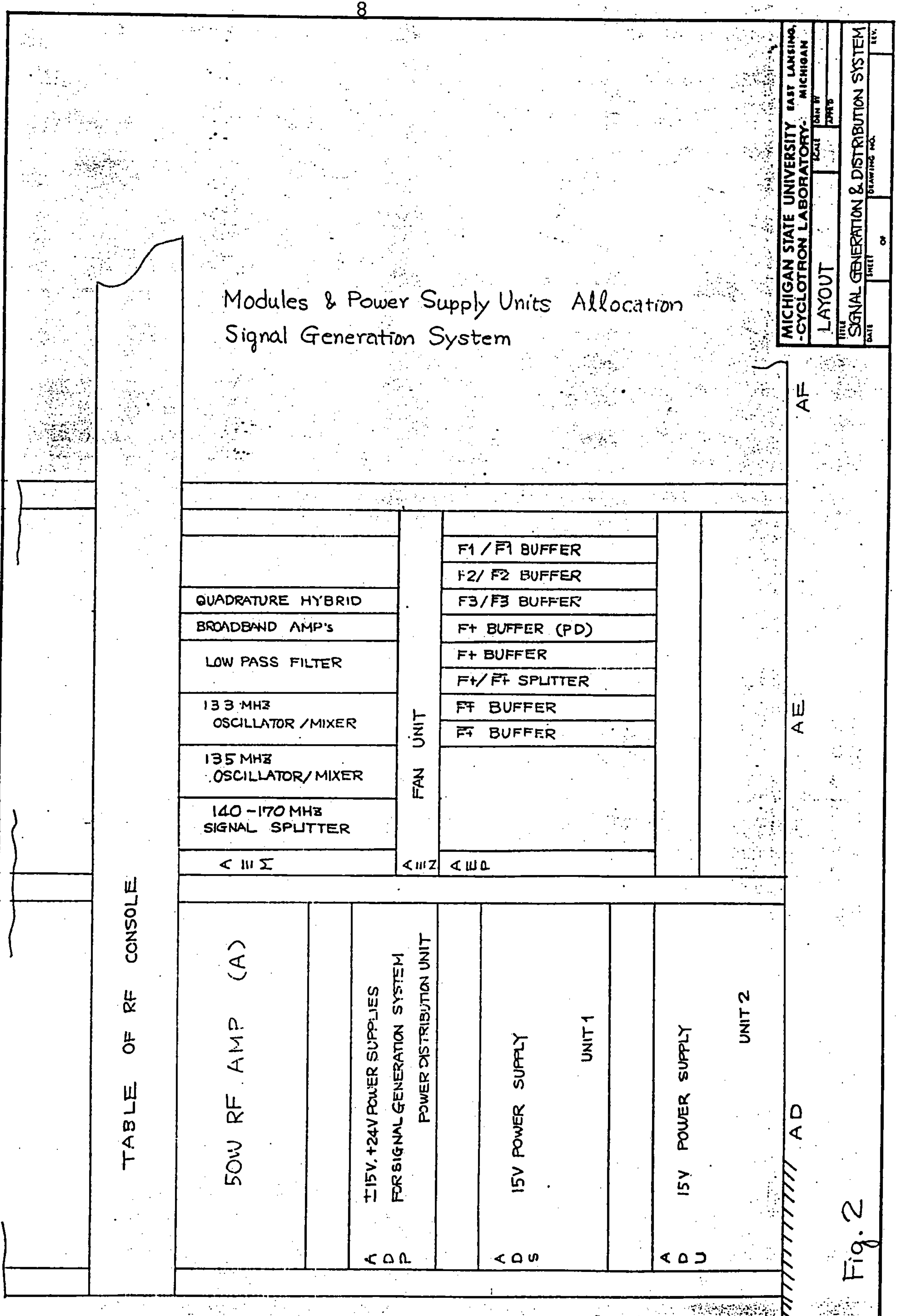


1W; 1WIDE MODULE
2W; 2WIDE MODULE

CONNECTORS ON REAR PANEL : 27 SUBMINAX Cable RG174/U
ALL OTHER CONNECTORS; BNC, Cable RG58/U

Fig. 1

MICHIGAN STATE UNIVERSITY EAST LANSING,
-CYCLOTRON LABORATORY- MICHIGAN
BLOCK DIAGRAM
SCALE
DRN BY J. HIYANAGA
APP'D
TITLE
SIGNAL GENERATION SYSTEM
DATE 7-28-81
SHEET 1 OF 1
DRAWING NO. 5-KWA-1A-1-E
REV.



Modules & Power Supply Units Allocation
Signal Generation System

Fig. 2

PTS 200 SYNTHESIZER IS LOCATED AT THE TOP OF "AE" LACK.

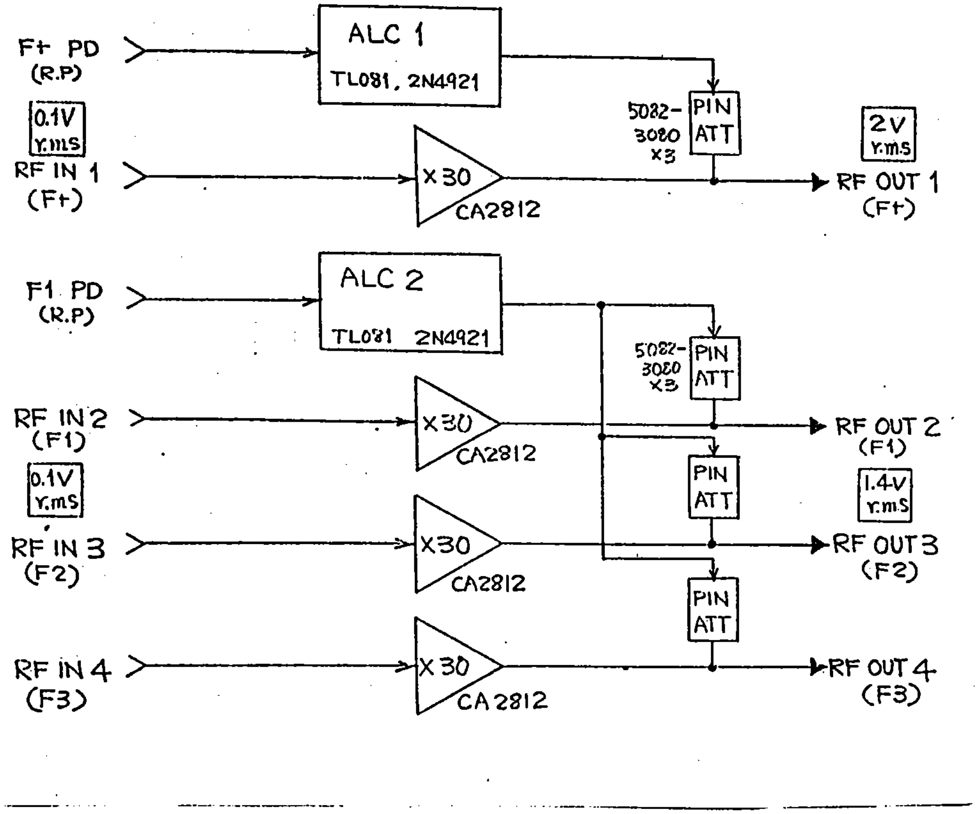


FIG. 3

1 ORIGNAL ISOLATION

INPUT	OUT 1	OUT 2	OUT 3	OUT 4
1	—	35 dB	58 dB	71 dB
2	54 dB	—	35 dB	70 dB
3	65 dB	60 dB	—	40 dB
4	70 dB	70 dB	60 dB	—

2 IMPROVED ISOLATION

INPUT	OUT 1	OUT 2	OUT 3	OUT 4
1	—	48 dB	82 dB	85 dB
2	82 dB	—	52 dB	83 dB
3	88 dB	85 dB	—	46 dB
4	91 dB	91 dB	82 dB	—

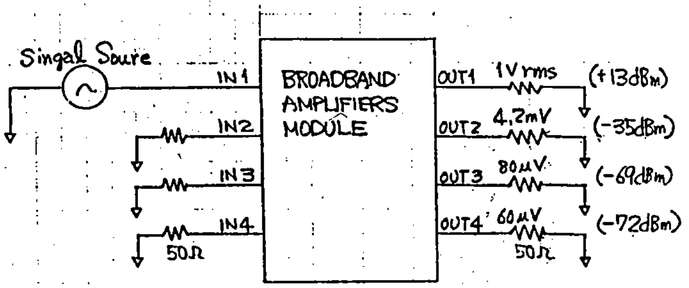


FIG. 4

CROSS-TALK MEASUREMENT AND IMPROVEMENT ISOLATION

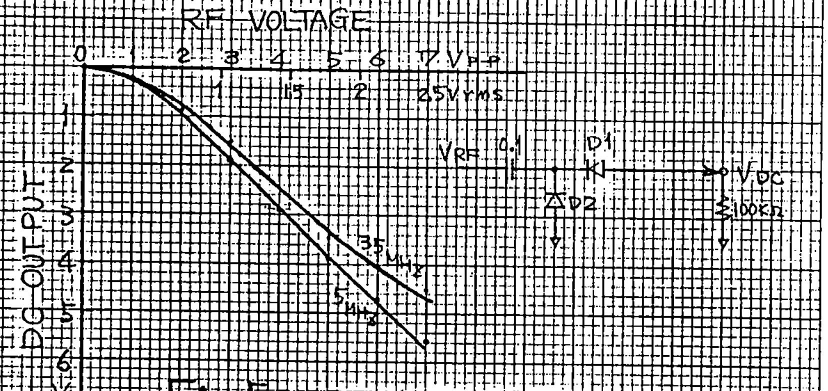


Fig. 5 PEAK DETECTOR

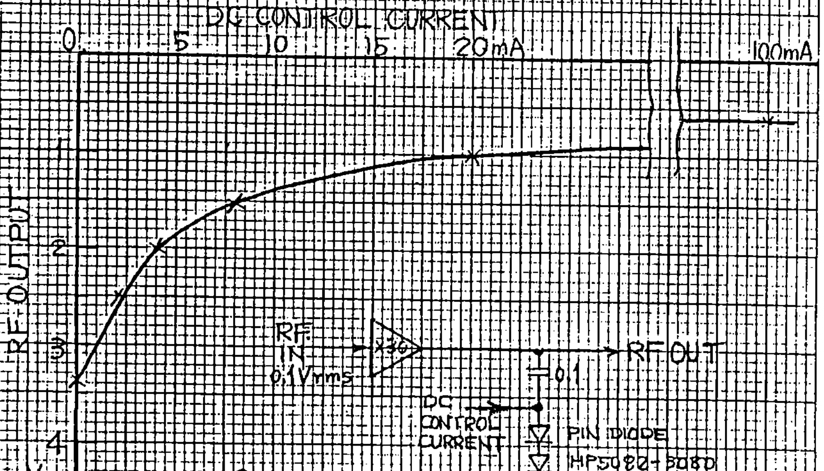
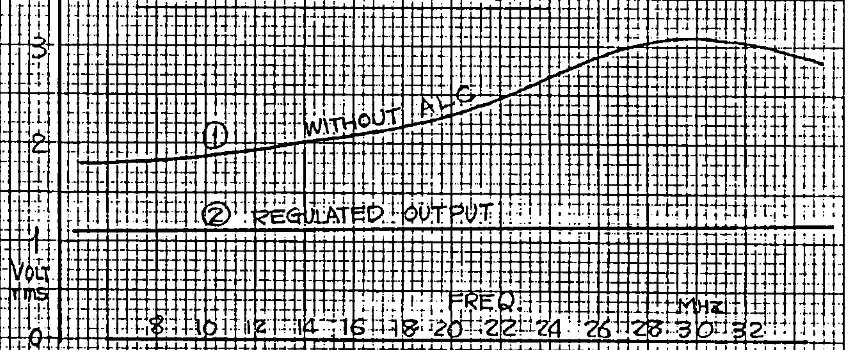


Fig. 6
PIN DIODE ATTENUATOR

Fig. 7
BUFFER OUTPUT AMPLITUDE



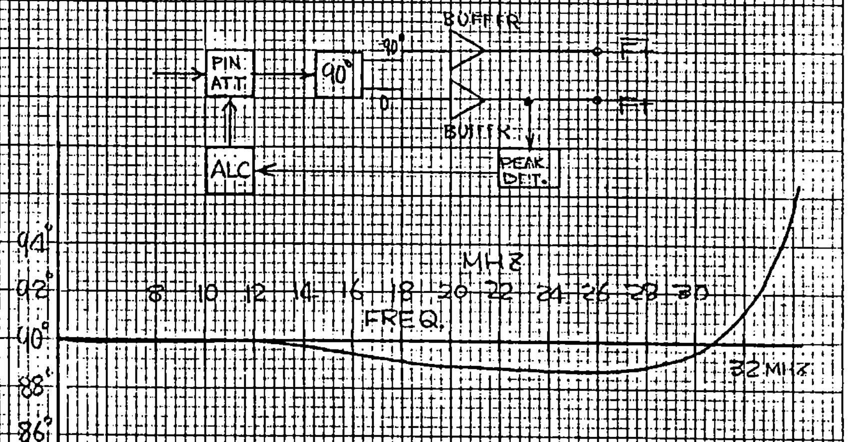


Fig. 8
PHASE BETWEEN F1 and F1

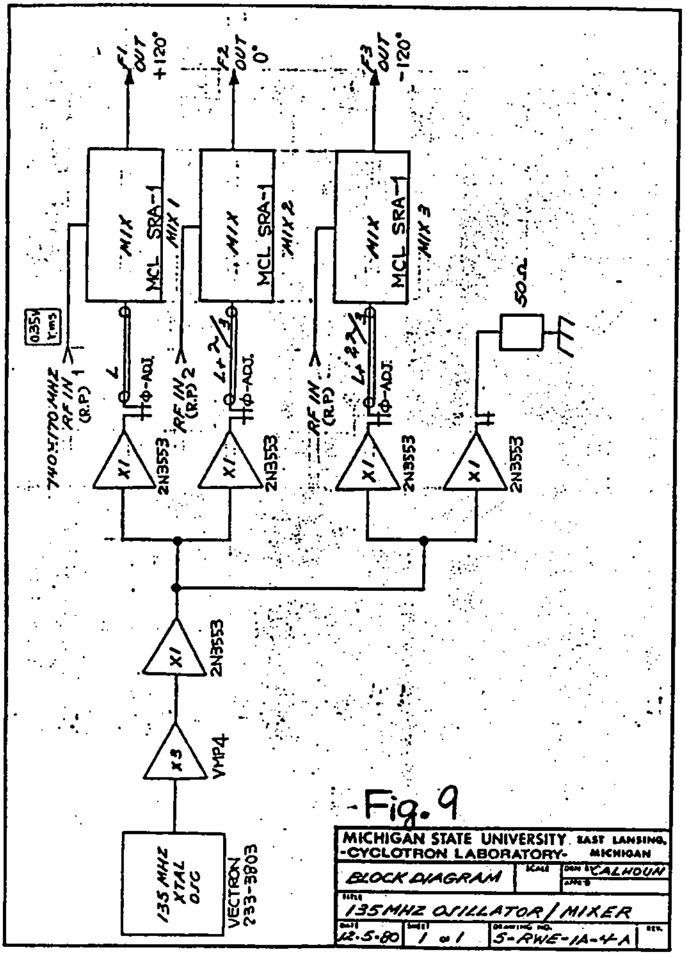


Fig. 9

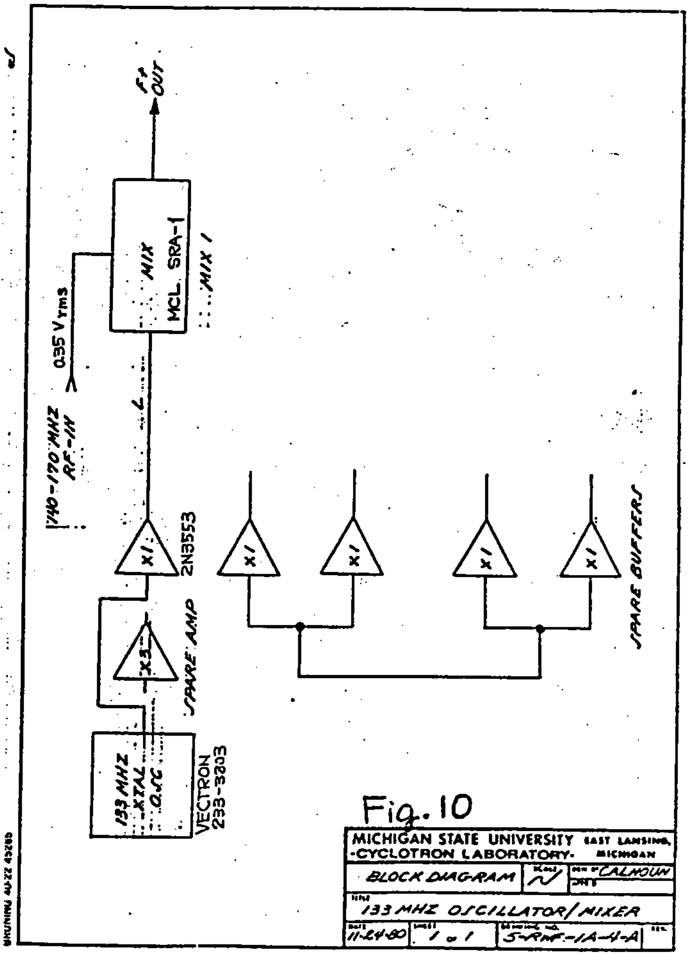


Fig. 10

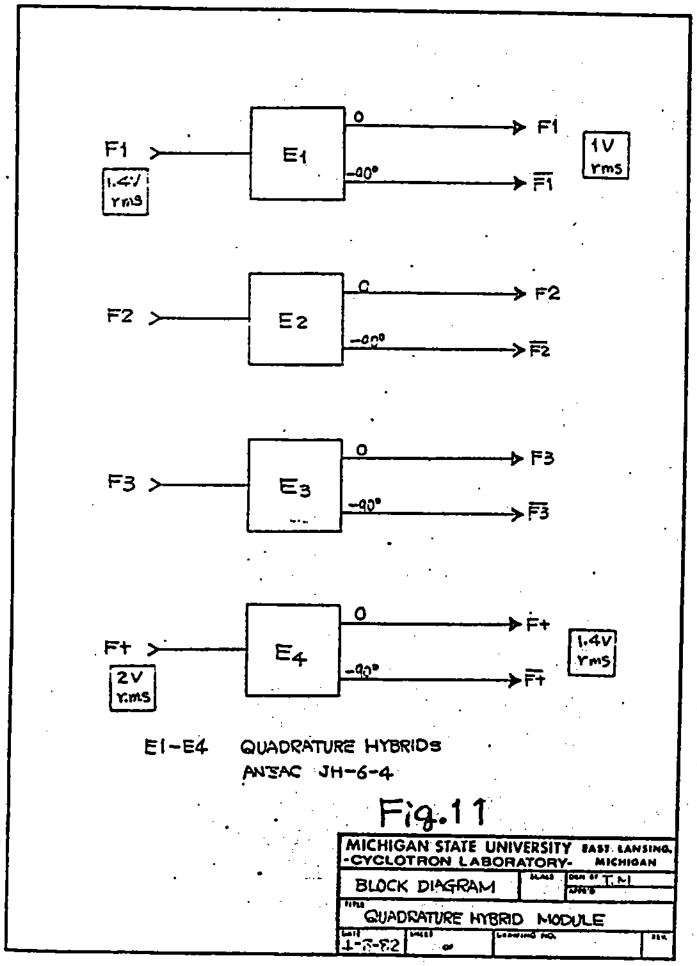


Fig. 11

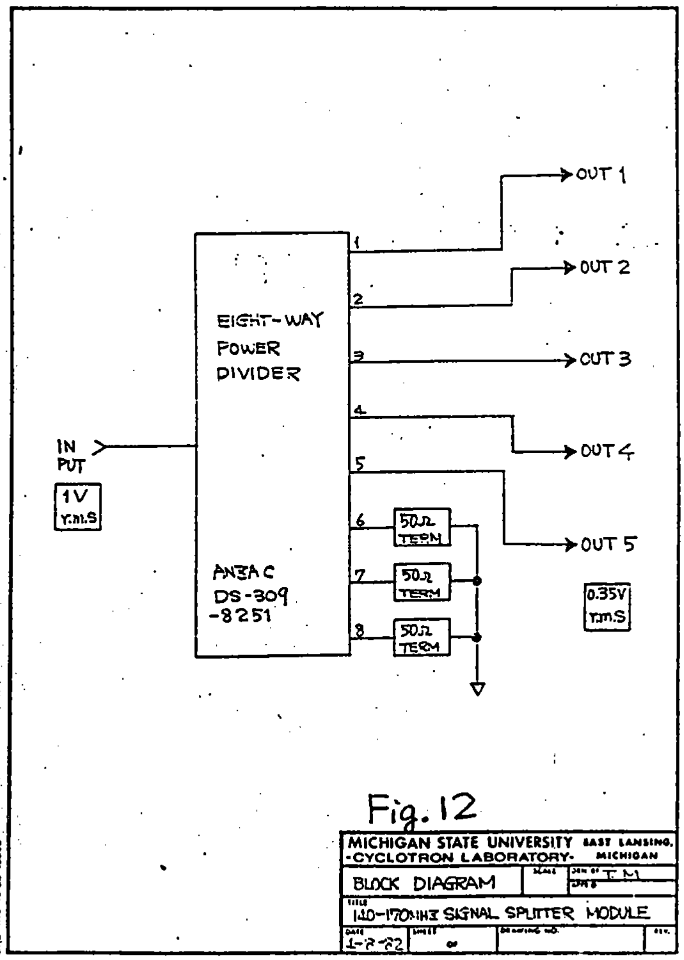


Fig. 12

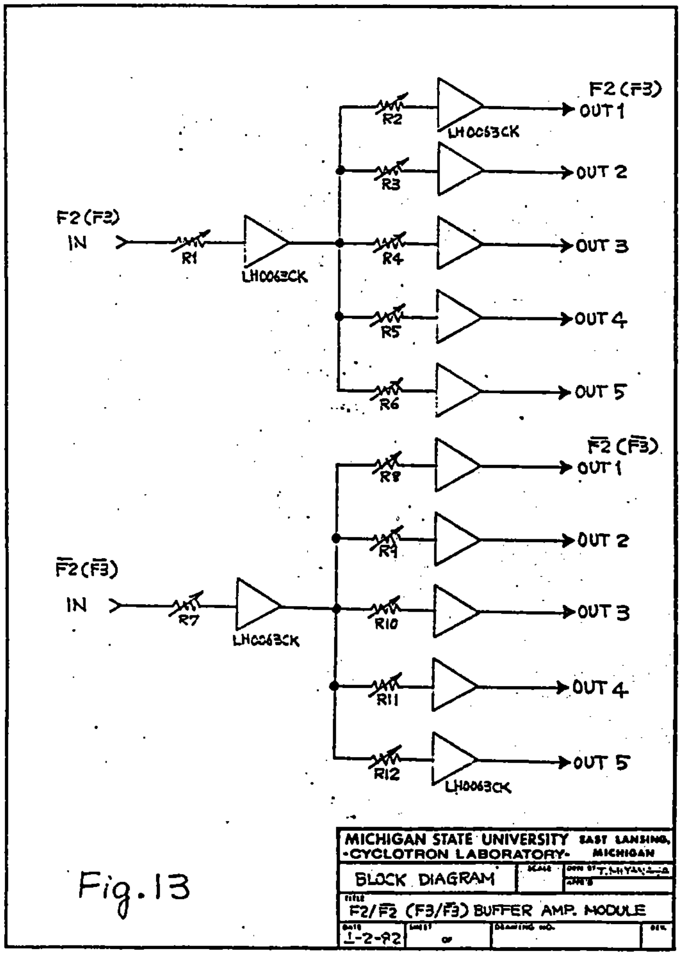


Fig.13

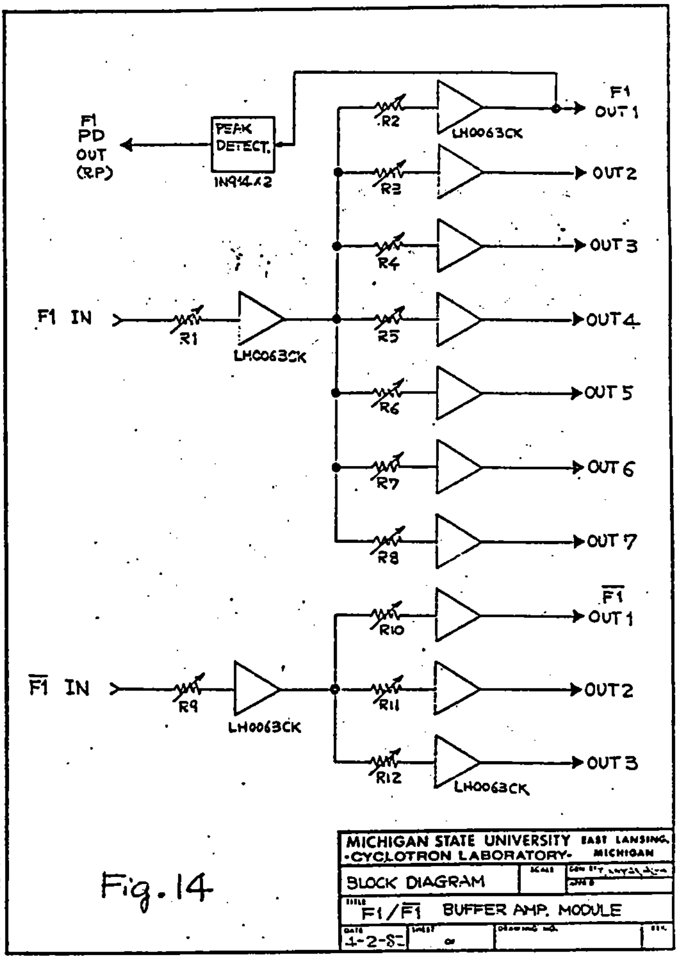


Fig.14

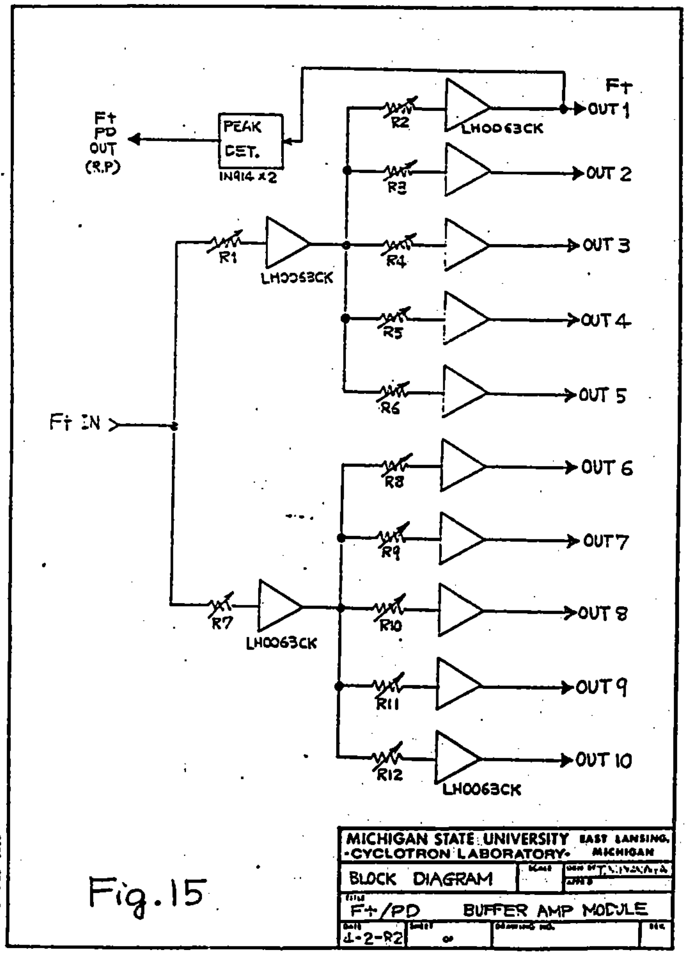


Fig.15

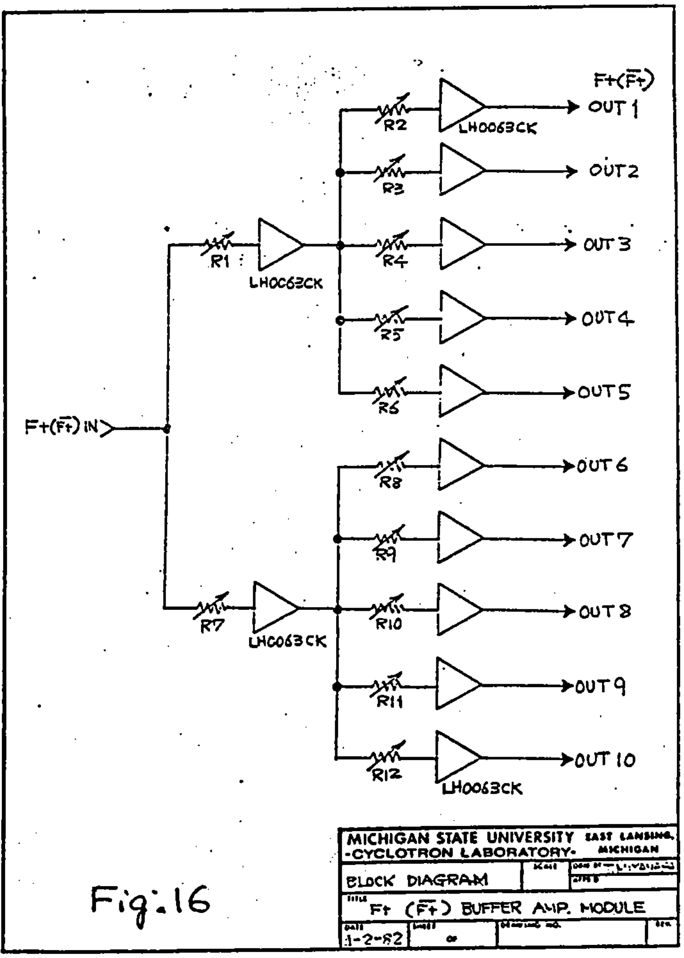


Fig.16

5/8/82

R.F. Memo #5

by J Riedel

Dee Coupler Failure

About 4 PM, 5/7/82, while running all three r f systems at high voltage we lost the vacuum and soon discovered that the "window" into B dee was broken. After disassemblying it the cause was obvious. Before disassembly we could hear broken pieces of insulator in the air part of the line. Although not absolutely certain, it is most likely that this is the assembly known to have a cracked part of the insulator on the air side. We could verify this by high potting the other two lines

On page 38 of the r f log book couplers #1 & #2 held 15 kV in air and #3, the broken one held only 13 kv. What happens is that an ~~arc~~ r f arc forms due to the sharp edges of the broken insulator and for some reason the r f was not turned off. Either the $-dV/dt$ or the reflected power signals should have turned the r f off and thus prevent damage. Obviously they did not turn the r f off and an arc lived there for some time, evaporating a few cubic mm of copper and, due to overheating from this arc the insulator cracked.

It was heartening to observe that on the vacuum side, although there was evidence that multipactoring had existed, the insulator surfaces visible between the corona shields were clean and healthy.

To prevent a reoccurance of this sort of distructive behavior when an air arc develops, either in the vicinity of the window or elsewhere in the transmission line or transmitter, I recommend that we add an additional protective feature.

I think it's about time that we get a microprocessor involved. The logic would be as follows: The micro would be repetitively sampling the dee voltage, the forward and reverse power, the anode rf and the drive rf and perhaps some other quantities. It would then take the ratios V+/V-, Vdee/V+, Vdee/VAnode, VAnode/Vdrive and when operation is good the operator pushes a button and these ratios are stored. After this, the sampling is inhibited for 50 μs after a rf turn on gate appears, then it compares the new ratios with the stored ratios and shuts the rf off if the ratios change by a certain factor (20% seems reasonable to start) and displays the condition. The micro should be fairly fast so that the compute sequence can be repeated at least every millisecond.

5/5/82

4648 test information from RCA

During the course of their tests they observed parasitics at the following frequencies 1243, 1205, 1845, 2035, 3690 GHz.
Their setup was almost the same as ours.
They tried to damp the parasitics by wrapping ethylene glycol filled polyethylene tubes around the anode insulator.
They were able to get the data up to 120 amps by looking at only the first part of the pulse, as it took about 5 μs for the parasitic to appear.

With 1000 V on the screen they got the following results

at $V_A = 5$ KV a 1243 GHz parasite existed above $I_p = 44$ am
at $V_A = 7.5$ KV from 0 to 20 amps they had 1243 GHz
but it stopped ~~above 40 amps~~ from
20 to 36 amps after which a 3690 parasite appeared.
at 20 KV quiet till ~~20~~ 5 amps.
from 5 to 7 they had 1243 MHz.
7 to 47 nothing
47 to 55 → 1243 MHz.

when they removed the ethylene glycol it was quiescent up to 18 amps at 20 KV.

info from Jerry Stabley.

J Riedel

RCA | Electronic Components | Lancaster, Pennsylvania 17604

RCA

Mr. Jack Riedel
Cyclatron Laboratory
East Lansing, MI 48824

May 7, 1982

Dear Jack:

Enclosed is the data we obtained on the 4648 during video pulse tests here at Lancaster. As I said previously, we have not, nor have any of our customers, experienced difficulty with these frequencies when the tube is being used in RF service.

For your information, the screen by-pass capacitor we were using for our tests at 425 KHz is comprised of 24 6800 pfd low inductance capacitors in parallel.

If you have any questions after receiving this data, give me a call.

Sincerely,

Jere

Jere D. Stabley
Power Devices
Marketing & Application Engineering

JDS:ab

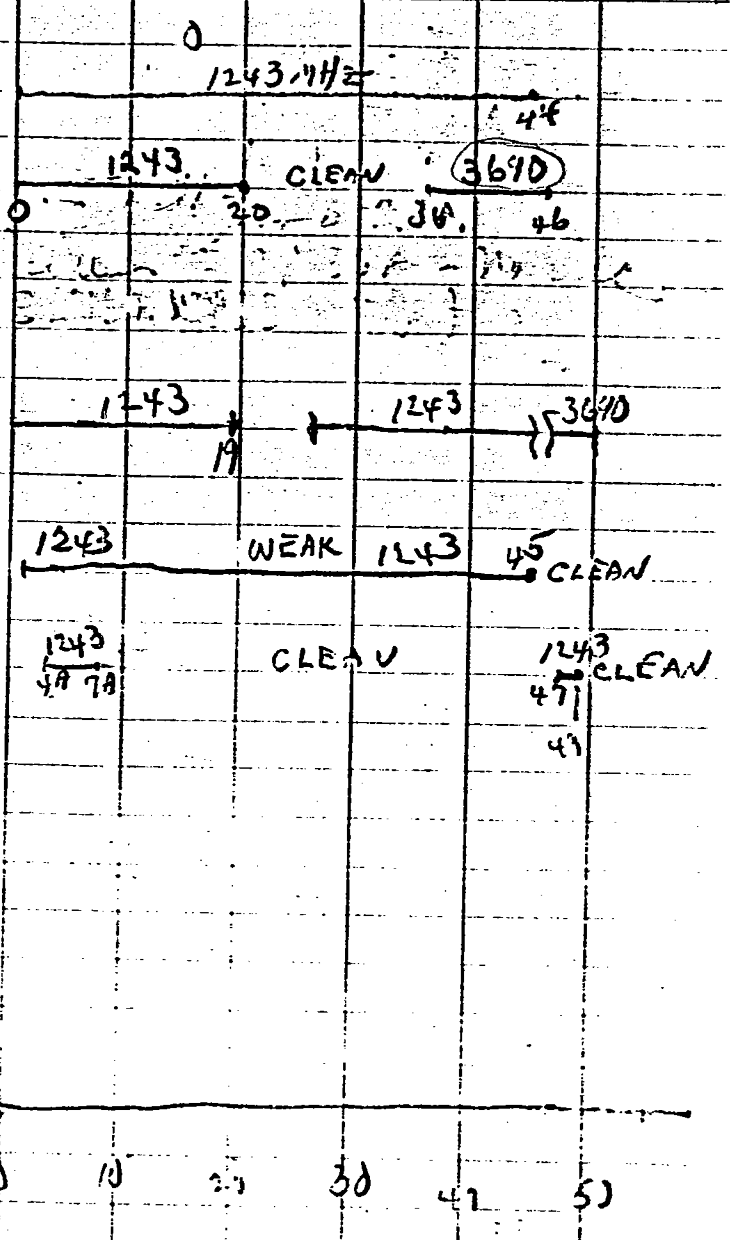
Enclosure

[illegible] TEST WITH ETHYLENE
FILLED HOSE O.)

JDS
ELD

kV Eb	[illegible] 0 ib	kV Ecz	eq	FRE
5.0	44	1.3	* 0 - 0	
7.8	46	1.0	0 - 0	
10	50	1.0	"	
15	52	1.0	"	
20	55	1.0	"	

ib vs FRE



Cut Off to '0' Units

4648 ' [illegible] TEST

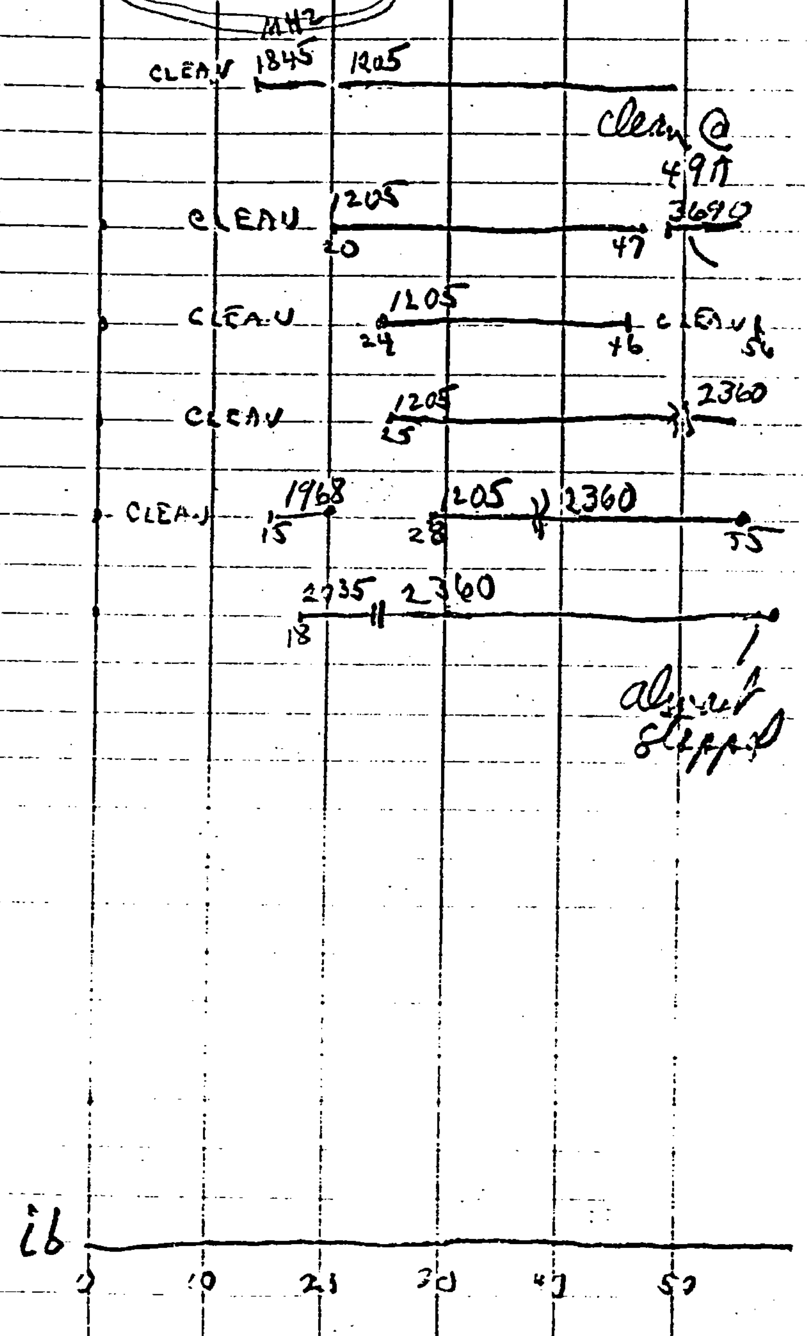
4/31/18

	@eg=0		
Eb	ib	kV Ec2	eg
5.0	50	1.000	* c0 - 0
7.5	52	1.0	c0 - 0
10	54	1.0	"
12.5	55	1.0	"
15	55	1.0	"
20	57	1.0	"

* Cut off to 0!

WITH ETHYLENE GLYCOL

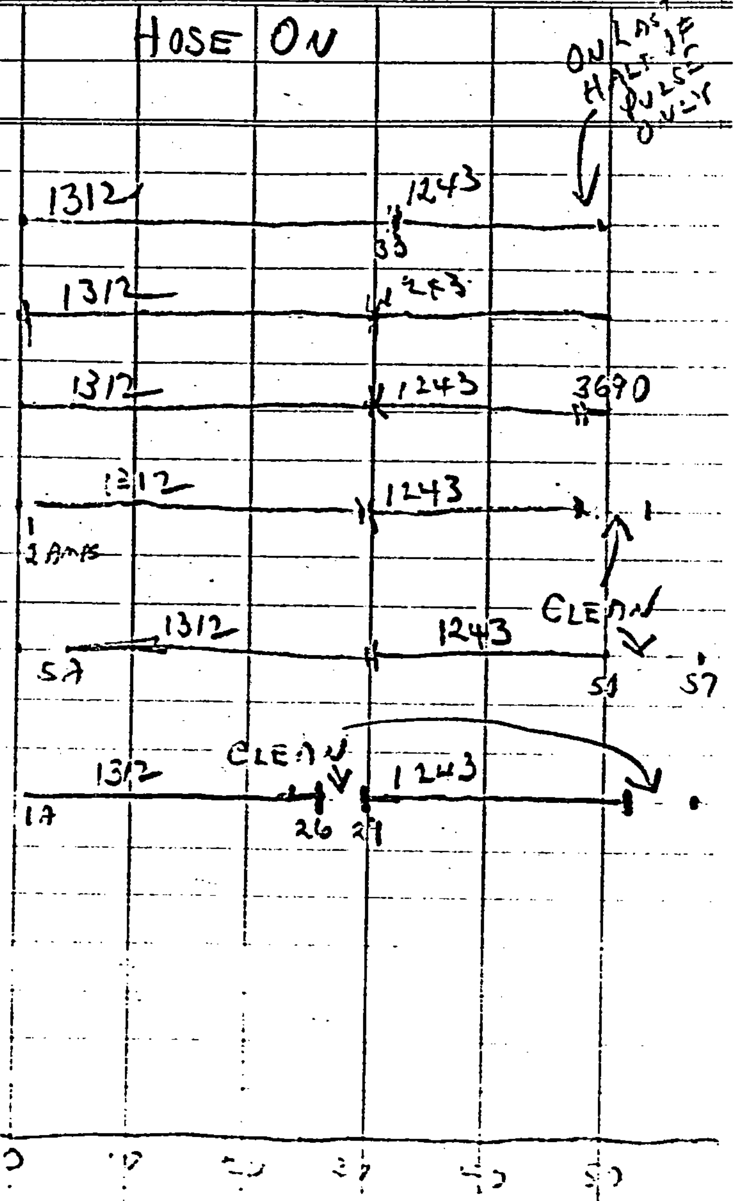
HOSE OFF



4.5-? [illegible] A103

WITH OIL FILLED

Ef	$e_c=0$ ib	E_{c2}	e_{c1}
5.0	48	1000	CO - 0
7.5	50	"	"
10.0	52	"	"
12.5	54	"	"
15.0	57	"	"
20	57	"	"



Trip Report

May 6, 1982
By J. Riedel

Visit to CERN, (Geneva) DCI (ORSAY) and GANIL (Caen)

Preamble: The purpose of the trip was to see how some laboratories in Europe build their highpower r.f. transmitters, and especially to find out how they suppress the parasitic oscillations that sometimes are present in such transmitters. This was important because we are having a parasitic problem with our K800 transmitter tube.

CERN: The major activity at CERN is to construct LEP (large electron positron storage ring) which is to provide 50 GEV on 50 GEV at high luminosity. Orsay is to build the electron linac. The electrons or positrons will then be put into an accumulator and injected into the 30 GEV AGS and then into the SPS and finally into LEP. The rf for accelerating protons and antiprotons in the SPS will not accelerate electrons, so additional standing wave cavities will be installed in the SPS and the same group, under a Mr. Zettler, which built the rf system for the SPS,is building this new rf system.

They are building cavities and transmitters operating at 200 Mhz and 100 KW must be supplied to each of some 20 cavities. They had had a lot of experience which became obvious as I inspected the rf system for the SPS. Here they use 40 KW transmitters, and with a complicated system of 12" diam hybrid transmission line commercial combiners finally provide some 2 MW to the travelling wave accelerating structure.

Zettler told me of his philosophy to achieve reliability and minimize down time. It is that it is preferrable to use many transmitters rather than one large one, so that if a transmitter fails, and there are N transmitter, then, because of the isolators, it can be disconnected at the combiner and worked on while the rest of the transmitters need only supply I/N more than their nominal power.

Their "window" for feeding this 2 MW of power into the vacuum was interesting. It was a 6" diam alumina disk inside a 30 ohm transmission line. Its only problem was that periodically it had to be replaced due to gold plating onto it when multipactoring exists. Initially it and the accelerating structures have a 1 or 2 micron layer of titanium evaporated on their surfaces.

The water load that they use for testing a transmitter and for absorbing the power from the travelling wave structure is also interesting. It is simply a 6" outer conductor transmission line of inner conductor sized so that with air the Z is 30 ohms (maximum power transfer with minimum gradient) and loaded with city water in a closed system to make Z = 3 ohms. A $\lambda/4$ section of tapered line matches this to the 50 ohm 12" lines. These loads are about 15 feet long, with most of the power being absorbed in the first two feet.

The n^{th} prototype of the 100 KW transmitter for the standing wave cavities was being tested for the first time on the very day I arrived. Previous prototypes had to be discarded because they parasited catastrophically at about 1.3 Ghz. This one had 16 parasitic suppression loops mounted in it, each tuned to 1.3 Ghz and feeding a 50 ohm line to 10 watt terminating resistors. Zettler feels he understands the nature of this parasitic, and what to do about it. He believes that <u>all</u> tubes will parasite at some level of dc plate current, in a ring mode intrinsic to the internal tube geometry.

Further, he believes that the reason transmitters operating at low frequences (30 Mhz) don't parasite, or if they parasite one can live with the parasitics, is that though the Ghz parasitic may start to build up it won't reach disastrous amplitudes during the short conducting time, and, since the Q of these parasitics ~ is quite low (N 200) they decay away before the next conduction cycle. However, at 200 Mhz they don't have time to decay and so will build up. He believes these are ring modes and the frequency can be calculated from the tube geometry as $F=3E8/2\pi r$, one wavelength around the circumference. They become excited due to an assymmetry in the radial spacing of the electrodes (non coaxial cylinders).

However, since it is a ring mode with the currents orthagonal to the normal currents, it is possible to damp these modes external to the tube with coupling elements that absorb no power from the fundamental. He was very happy to observe, as I did also, that the tube did not parasite with 10 amps of plate current. We celebrated the success with beer for all.

To feed the 100 KW to the cavity he uses a 3" diam alumina vacuum window with a Δr from inner to outer conductor of only 1 cm. This window, and the larger ones used for the 1.5 MW system, are 99.5% pure alumina metalized on the inner and outer cylindrical surfaces and brazed onto ss pipes. They are about 1 cm thick.

For testing the transmitter he uses a divider feeding two of the same 50 KW water loads we purchase from Dielestric Communications.

The transmitter is completely coaxial and very complicated mechanically. I have a large drawing of this transmitter and will show it to anyone wanting to see it.

I saw many other interesting things at this laboratory, such as N Way Wilkenson hybrid power dividers, and I was able to get information on how to build them. If the parasitic suppressors installed in this transmitter had failed to do their job he was proposing to install some Siemans ferrites in the cavity which have a [illegible] of 10 and Q of 200 below 200 Mhz, but for higher frequencies the Q is very low. This sounds like a good idea.

On the third day I visited W. Schnell who is building the rf system for LEP. This will be a klystron fed standing wave series of cavities operating at 500 Mhz. Since LEP will have only one pair of bunches, power can be saved by transferring the rf energy to a storage cavity mounted on top of the accelerating cavities when the bunch is elsewhere in the ring and returning it to the accelerating cavities when needed. Very complicated. Zettler wanted to use telrodes at 200 Mhz but was over-ruled.

<u>Orsay</u>: DCI (1.5 GEV electrons on 1.5 GEV positrons) was operating for experimenters. The visual display of interaction events from their large detector was very impressive. The beams have a lifetime of 16 hours. They had just recovered from a three day shut down due to the 12" transmission line feeding 350 KW to the cavities having burned up. The solder joints on the innter conductor came apart and various parts of the line melted.

The transmitters, employing RCA 4648 tubes have never had any problems with parasitics. The tubes (operating at 25 Mhz) have racked up some 10000 hours of operation with no problems.

The Orsay group (Laboratoire de L'accelerateur Linear) has received funding to build "Super ACO", a 1 GEV storage ring exclusively for synchrotron light. It will operate at 100 and 500 Mhz. Most of the people who built DCI are designing and developing the 3 Ghz linac to be built there and then transported to CERN for LEP. They were in the process of developing manufacturing techniques for the iris cavities and had a 10 foot section under test.

Elsewhere at Orsay, the group of whom Laisne is a member, are designing a K 200 superconducting proton cyclotron for precision experiments. When super ACO is operational, in about 3 years according to Marin, DCI will be shut down.

GANIL

The train trip to GANIL takes 2 hours and it is very pleasant to view the French countryside at 90 MPH in comfort. I was met by Bieth and quickly shook hands with many of the staff whom I had previously worked with. Gouttefangeas was difficult to recognize in his beard.

CSS, the injector cyclotron, was running. They were accelerating C4 + with a 1 mos wide pulse and 25% duty factor. Bieth says that with this Russion ion source they get a much higher average yield of high charge state ions by pulsing it than they would get operating CW. The beamline to the first large cyclotron was installed and test beams have been guided thru it. However, rf has not been applied to the buncher cavity which is installed in this line. Their original plans called for a second buncher to be installed in the line between the two large cyclotrons, but they now believe this second buncher will not be necessary.

The first of the two accelerating structures is now installed in the cyclotron after having previously been tested in their large vacuum test chamber. They were in the process of trying to make everything vacuum tight. During their tests in the test chamber they had quite a few problems with their hydraulic piston that adjusted the capacitor. This was solved with the addition of a screw mechanism for fine adjustment. Apparently, the transmitter behaves properly over most of the frequency range by appropriately adjusting 4 large vacuum variable capacitors in their output network with a microprocessor. However, they are plagued with excitation of 2nd, 3rd, 4th and 5th harmonic modes in this large and complicated network and have added suppressors and are developing criteria for differentially adjusting the various capacitors to stay 4 or 5 parts in Q away from these modes. They gave up trying to build a choke to feed in the B+ and I gather they haven't completely solved this problem.

But they report there are no parasitics, and their phase control (via what we call our fast phase shifter) can keep the phase of the injector cyclotron and the large cyclotron dee rf to ±.1 degrees.

On arrival I was informed that I was to give a talk at 1 P.M. This meant I wasn't able to take much time for the usual gourmet meal which one expects in France. At 1O 'Clock some forty people, most of whom I knew, evinced great interest in the MSU K 500 operation and after I briefly told them about our successes and problems I received a barrage of questions from the audience. Fortunately, I am poor of hearing so I was successfull in ducking a good many of them.

Later Bieth told me about the design he had worked out for the rf system for the K 200 superconducting cyclotron at Orsay. He will be in charge of this rf system and expects to move back to Orsay soon. Some of the ideas he has for this system are very original and interesting, but hardly relevant to our work here. But who can tell but that they might become relevant.

For instance, he proposes to have a compound moving short in the vacuum and a loop coupling which automatically matches the feeder to the dee stem. I had played around with such a design for the K 500 but decided it was too complicated. He has developed criteria for moving fingers and concludes that the maximum current that fingers can carry depend on the geometric tolerances. If the tolerances are large the finger have to be long and thus will overheat if required to carry the same current that shorter fingers would carry. He concludes that the current carrying ability is proportional to $1/T^2$ where T is the tolerance. For GANIL, with tolerances of ± .8 mm and using Thompson CSF carbon tipped fingers he claims a current carrying capability of 100 amps/cm.

On Coating Aluminum

Everywhere I went I asked about what coating they used on aluminum. At CERN all aluminum is silver plated in their own shops.

At Orsay they use unplated aluminum with no problems, however they bolt everything together with 5mm bolts spaced very closely.

At GANIL the transmitters were built by Phillips, who use an irriditing process to coat the aluminum. Bieth didn't know what the process was. Again, closely spaced bolting was used.

Epilogue

I feel that I learned a good many useful and relevant things during my visit to these laboratories and that the expense to the laboratory and effort on my part were worth it. I believe that every few years the senior engineers should visit other laboratories which are doing work in his field, and especially before understating the design of a new and expensive undertaking. The Laboratory should insist that the conceptual designer should visit other laboratories known to have expertise in his field.