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RF Book

RF Note # 66

September 9, 1980
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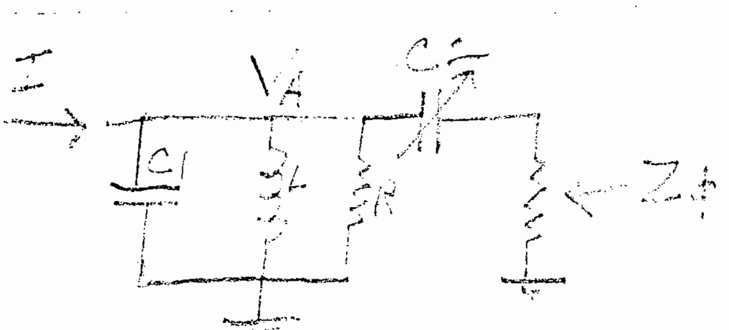
Contents

1. Transmitter Output Coupler Change

History. At the end of the long run at 100 kV described in the last rf note the output coupler capacitor was scrogged (shorted out). We replaced it and soon the replacement also became shorted, although it recovered after changing its capacity to its minimum value. We then disected the first bad capacitor and noted that the copper electrodes on one side were melted, so we added water cooling to this side's flange. Then, on trying to break through multipactoring into the single stem resonator we observed sparking across the capacitor.

Suddenly I realized why! I am ashamed that I hadn't foreseen this a few years ago. The initial design called for only using the output coupling loop into the transmission line, but we soon learned that it was necessary to also use an output coupling capacitor in series with this loop to resonate out the loop's self inductance. This works fine into a terminated line. But when we fail to break through multipactoring, or when we get a spark, a very low reactive impedance is presented to the transmitter output, and since we have a series resonant circuit there, the voltage across the capacitor will be Q times the normal voltage. Now Q is of the order of 1000, so under these conditions the capacitor voltage can rise to well over 100 kV and it will obviously spark down and eventually be destroyed!

What to do? Then I remembered that at a recent visit by some gentlemen from Japan I learned that they propose to couple out of their transmitter with a single capacitor. This was immediately analyzed with a computer program and it worked well. The equivalent circuit is as below:



$C2 = \frac{\sqrt{W}}{\omega}$

FIG. 1

given C1, ω, Zφ, and VA the equations are

$$C2 = 1 \Big/ \left(\omega_0 Z_\phi \sqrt{\frac{V_A^2}{Z_\phi W} - 1} \right)$$ where W is the output power

and

$$L = \left(\omega_0^2 C_2^2 Z_\phi^2 + 1\right) \Big/ \left(\omega_0^2 \left(\omega_0^2 C1\, C2^2 Z_\phi^2 + C1 + C2\right)\right)$$

We immediately tried this output coupling method on our test stand at 1/3 normal voltage, and it worked fine, so we purchased a properly rated condenser and tried it at full voltage and it works perfectly. In fact, there is a great advantage in using this output coupling method, for simply by changing C2 and retuning the transmitter we can vary the ratio of anode to dee voltage and thus always set it for optimum impedance matching (maximum efficiency). Also we can add a fixed capacity at the entrance to the line and change the mode pattern to avoid bad places.

So the decision is made: we will use this new output coupling method.

2. Dee phasing scheme

Figure 2 shows the final dee phasing scheme which we will use. This will permit manual differential phase control for the three dees. These can be on the console. The manual adjustment capability in the fast pahse shifter module may not be needed. Its purpose is to permit the electronic shifter to operate in the middle of its limited range ($\pm 30^{\circ}$) and it will not change the dee phase, which is forced to be whatever is necessary to keep the output of the phase detector zero. The reason why the manual shifter may be necessary is beacuse the new output coupler scheme results in a phase difference between the transmitter and the dee that cannot be corrected for by a cable length. Cable lengths L1 & L2 still must be carefully selected to assure equality of phase of the two signals entering the phase detector.

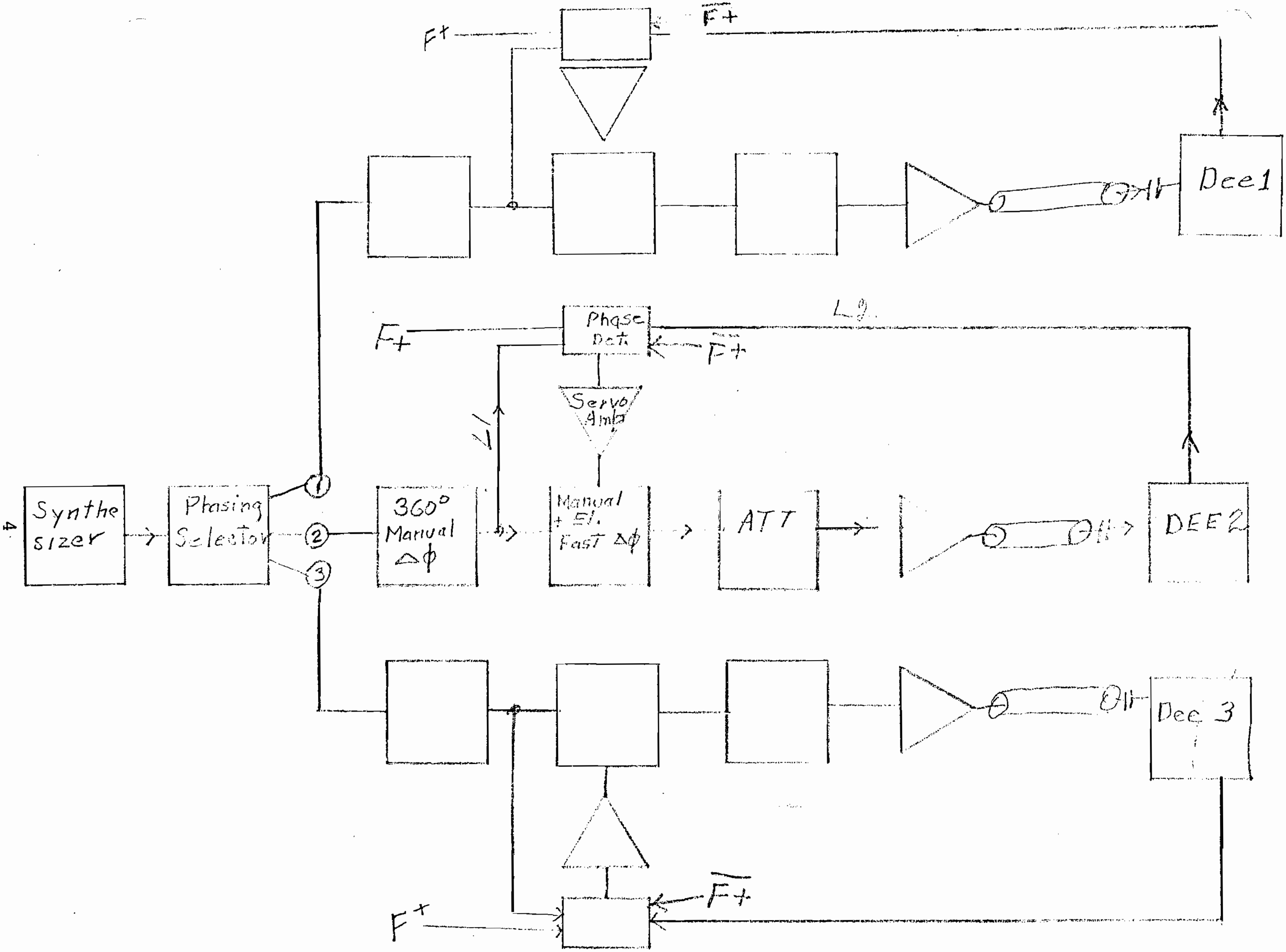


FIG 2 Phasing Plan

3. Parasitics

R.F. Note #65 describes our quandary regarding this subject as of July 25, 1980. When we received the rental Tectronix spectrum analyzer good to 1500 MHz we were able to get a straight story together. As soon as screen current starts to flow, harmonics start appearing and their amplitude sort of falls off linearly with frequency and are about .5% at the 20th harmonic. This agrees fairly well with a calculation of the Fourier components of the plate current and is no cause for concern. No parasitics were observed when working at 50 kW CW into the water load, nor at 90 kW with a 30% duty factor into this same load.

One of the ostensibly solid reasons for suspecting the existence of a parasitic was the occurance of sparking at the transmitter output coupler when trying to break through multipactoring in the vacuum resonator. This reason has now ceased to exist as is explained in the section under output coupler.

4. Calculations

We have finally figured out a way to write a program in BASIC to calculate everything about the coupled three dees + transmission lines + transmitter circuit, called TRED 2, and written by T. Miyanaga. It works fine. Two tricks were used to avoid having to solve a bunch of simultanenous transcendental equations. The first of these was to make a transform of the delta dee to dee coupling to a floating WYE coupling. The second was to use the superposition theorem. This involves first calculating the three complex impedances looking from the Y center to the tube anodes, then supply, sequentially, only one anode current at a time and calculate three different values of currents and voltages everywhere, then vectorially adding these three sets of values.

The detailed results of these calculations will be presented in a later rf note. Here we can say that for 3 phase operation everything is in order except that at certain frequencies there are mode problems. Also, in-phase operation seems to be a problem, in that detuning one dee results in all dees seeming to be detuned with no criteria existing to determine which dee is detuned. More work is needed here. We are going back to our low Q model (see RF Note #7) to verify this.

5. Single Stem Operation

This has been all bad. The main purpose of single stem operation was to provide a high Q load so that we could prove out the fine tuner servo. With the resonator at STP we operated at 25 kV and endeavored to measure the open loop response of the fine tuner phase servo. We found that as we neared 18 Hz in the driven motion of the fine tuner, the fine tuner follow pot behaved well, but the dee phase showed wild oscillations at 18 Hz. This is due to the mechanical movement of the fine tuner exciting mechanical vibrations of the dee at 18 Hz. Now if we had always to live with this test resonator we could, perhaps, solve this problem. But this problem won't exist when the tuner is firmly tied to the enormous mass of the magnet. Therefore, we have decided to not continue to work on the dee phase servo until the final installation of the three dees into the magnet is accomplished. There is no question in my mind that closing this servo loop will be easy.

Meanwhile, although initially we managed to achieve a good vacuum (5×10^{-6}), suddenly the vacuum went sour and we don't understand why. After the vacuum problems are solved, we plan to have another long run at 100 kV to possibly uncover other weak spots in the rf system.

Before the test stand is desassembled various measurements (in air and at low power levels) can be made to study the mode problems and see if there is a good correlation with the results from TRED 2 or TRED 3. Then, to see if the problems at the Bad Frequencies can be solved by adding a capacitor at the exit point from the transmitter, we can dodge these bad mode problems. To study the behavior under multipactoring conditions, we would like to remove the dee and operate the transmitter into the thus open ended transmission line and study the mode behavior.

6. Water Load for K800 RF System

The K800 transmitters may have to deliver 250 kW of rf power, so to test them it is desirable to have a 300 kW load. This is not a catalog item. There are various ways of transforming into six 50 kW standard water loads, but these are expensive and probably mean a fixed frequency load. Nevertheless, we are asking for quotations from three firms for a 300 kW water cooled load.

Meanwhile we are pursuing the possibility of making this load ourselves, utilizing the magnetic properties of iron. We constructed an 8 ft long $\lambda/4$ resonator of 1/2" inner cond. 1 1/2" outer conductor and found that the ratio of the Q using a copper inner conductor to the Q using standard hydraulic iron pipe was 16 to 1. Calculations show that if a 600 ft. length of this line is tied to the transmitter it would make an excellent load, water flowing through the 1/2" inner conductor removing the heat. At the beginning of the line the dissipation will be 70 watts/inch. The load would consist of 30, 20 ft lengths connected in series with elbows, and in parallel for water.

However, iron pipe cannot be used as it would contaminate our processed water. One can buy magnetic stainless steel (incond 600) at $10 a foot which may or may not be satisfactory, but it is certainly expensive. Therefore we propose to iron plate a copper or brass pipe and measure the loss factor. Iron (or nickel) plating, to a thickness of between 1/4 and 1 mil should be satisfactory.

7. Screen Bypass Condenser

We are presently using the original design of the screen by-pass condenser. On hand are two unmodified kapton pieces and 4 modified ones. Also we have two sets of brass pieces of the original design and one modified set. We have decided to modify all brass pieces and re-etch the kapton pieces to provide for 1/4" underlap of the copper from the kapton at all holes and at the inner and outer peripheries. It is my opinion that the reason the last two capacitors failed is that the RTV did not adhere to the metal surfaces properly because of dirt. The metal surfaces should really be cleaned in a vapor degreaser and afterwards only handled with surgical rubber gloves. And then, improvements to the vacuum impregnation technique can be made and D. Lawton is going to study this and establish the proper method.

The longer goal is to buy more kapton pieces, suitable for both the 500 and 800 machines. D. Lawton has the ball on this.