KF NOTES

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RF NOTE #25

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TRANSMITTER AGAIN

1. Screen bypass condenser

What is the purpose or function of the screen bypass condenser in a power tetrode?! The simple and correct answer is that with a sufficiently large screen bypass condenser the rf voltage on the screen can be considered to be zero (0) and that the standard method of computing tube performance will result in correct answers. If, however, the screen bypass condenser is finite, then the screen will have an rf voltage superimposed on the dc valve in phase with the plate voltage and out of phase with the grid voltage. This results in three things:

a. The transconductance, I_A/V_g, will be lowered.

b. The effective capacitance and thus the tuning of the grid circuit will be plate amplitude dependent.

c. The "feedback" capacity, anode to grid is meaningless. The major feedback capacity will be via the screen to grid capacity, and the tube will be excessively tempted to become a self-excited oscillator at a frequency where the anode is resonant and the grid drive is adequate and less power will be consumed than would be consumed by working on the desired mode. You see, the fundamental principle is that nature, and tubes, are lazy and are continuously searching ground for modes of operation that will result in the minimum amount of work.

Program "TUBE" calculates the performance of a tube, and one of the entered parameters is the ratio of the plate-screen capacity to the screen ground capacity. One interesting result is that if this ratio is .01 then the output power for a given grid drive voltage will be 1/2 of what it would be if the ratio were .001. This means that the transconductance is only 1/2 of what it would be if r = .001.

Take a typical example. The existing MSU cyclotron tubes (4CW100000D) have a feedback capacity of 1 pf, a screen bypass capacity of 3600 pf and support a plate RF voltage of 10 KV rms. The plate to screen capacity is 60 pf. Thus there will be a screen rf voltage of 160 volts rms. The plate to grid capacity of 1 pf results in a current of about 1 amp, while the screen to grid current will be about 4 amps. Thus, equivalently, the feedback capacity is 5 pfs, and the tube is half way between a triode and a tetrode. So for these reasons, and from my and others' experiences I say that the screen bypass capacity should be 1000 times the plate screen capacity. Now how to accomplish this?

Most people add discrete capacitors; usually 10 or 20 barium titanate capacitors of 4500 pfs rated at 4.5 KV distributed symmetrically around the screen flange. For a fixed frequency transmitter this works fine, but for a transmitter tunable over 2 or 4 or in our case a 7 to 1 range of frequencies, various ring modes can be excited which will destroy the capacitors. One solution is to put resistors in series with the capacitors to damp these modes. Unfortunately 0.1 ohm resistors are not for sale.

The best solution is to build a circularly symmetric disk capacitor. Some people have used a thin dielectric (polystyrene, mica, G-10, mylar, kapton etc.) pressed between metal plates. These materials can support about 5 KV/mil to 30 KV/mil. However, the metal plates are apt to miss contact with the dielectric by from 1 to 5 mils in certain places, resulting in most of the rf voltage drop taking place in air which can only support 100 volts/mil. Thus the air will ionize and soon the condenser will fail. The solution is to metalize the dielectric, forcing all the gradient to exist across the dielectric.

An aside. I find myself tempted to continue on and explain about creepage paths, choice of dielectric material, thickness, dielectric constant, loss factor, etc. But I am not writing a book. However it is appropriate to point out that the dominating factor is what happens when a plate to screen spark occurs. Assume the plate voltage is 20 KV dc and the plate blocker is 2000 pf. Assume the screen bypass condenser, good to 1 GHz is 60,000 pf. When the spark occurs, within a fraction of a nanosecond the screen voltage will rise by 20 volts and thereafter will rise at a rate determined by the anode lead filter capacitors feeding the 60000 pfs thru about 15 feet of 50 ohm line, or 400 amps into 60000 pfs $\approx 6 \times 10^9$ volts/sec. If the crowbar didn't fire, the screen voltage would become 20000 volts in about 4 μs. However, the crowbar is supposed to fire in 3 μs, so we can hope that the transient screen voltage will only be 15 KV.

The screen bypass condenser <u>must</u> be able to survive this! So a proper test of the screen bypass condenser is to dump a 50,000 pf capacitor charged to 20 KV onto it a few times (like 1000). Note that the larger the screen bypass condenser is, the smaller the voltage that appears across it will become.

The above exposition is an example of something I learned only ten years ago: high power engineering, in the main, consists of designing to protect against disaster situations.

So our screen bypass condenser will consist of a double-sided anulus 24" OD by 8" ID having an area of 400 sq. in., and using 5 mil metal clad kapton we will have a capacity of .05 μf per side or a total C=.1μf. The edges of the metal clad kapton will be etched away by 1/8" and the capacitor will be tested by dumping, a 1μf capacitor charged to 10 KV onto it! In fact we will further test it by dumping a 10μf capacitor at 20 KV onto it. The capacitor will be vacuum impregnated in RTV silicone adhesive to seal all edges from air. This sealant will also make the capacitor immune to water spills.

Grid

How to build a capacity-less inductor with a 50 to 1 range? Had I been able to afford Chevas Regal I could probably have come up with a better solution, but even with only Kesslers I think I have come up with a solution! The inductor will be in two parts, a switch being made at about 40 mHz. From 40 to 65 mHz we will use a Trombone, about 10 inches long. At 40 mHz the slider comes all the way out and then we connect the Multronics variable inductor which can tune down to 6 MHz. However, this must be built and tested before we can say it will work as planned.

Filaments

One side of the filament will be grounded. The other side must be bypassed to ground with a large capacity. It is proposed that this be done with a cylindrical condenser, ~5" diam by 8" high, using 5 mil metalized kapton; resulting in a capacity of 21,000 pf. This is a strange animal, but since it only has to survive 10 volts, will probably work O.K. In 6 places on the two filament flanges 3/8" diam welding cables will lead to two 5/8" diam 10μH coils in a manner similar to that described in RF Note #23. These will be in a separate compartment so as not to inductively couple into the grid coil.

The filament leads will then be housed in a special lossy, low-pass filter rigid line, employing ferrite cores to the filament power supply located from 2 to 6 feet away. Within the next two weeks specifications for this supply will be written. It is a volt supply rated at amps, ripple less than volts peak to peak, 6 input taps to vary the output voltage in 3% increments and a current limiting transformer feeding the rectifier.

Driver

The driver will be two 4CW2000A's connected in parallel. The 160 pf combined grid capcity will have to be resonated out with a variable inductor. How to build this? Or maybe buy it? Arkansas mountain dew will supply the answer, hopefully. However, before we get involved in this it is proposed that the 50 watt broadband pre-amplifier be used to excite the driver circuit (4CW2000A tubes, 50 pf capacitor, variable inductor, 4CW100000E grid) to full voltage to investigate the cooling requirements and the proper voltage ratios between driver anodes and final grid. Somehow it will all come out O.K.!