Electron Tube RF Power Amplifier (RFPA)

Neutralizing a Grounded Grid Configuration

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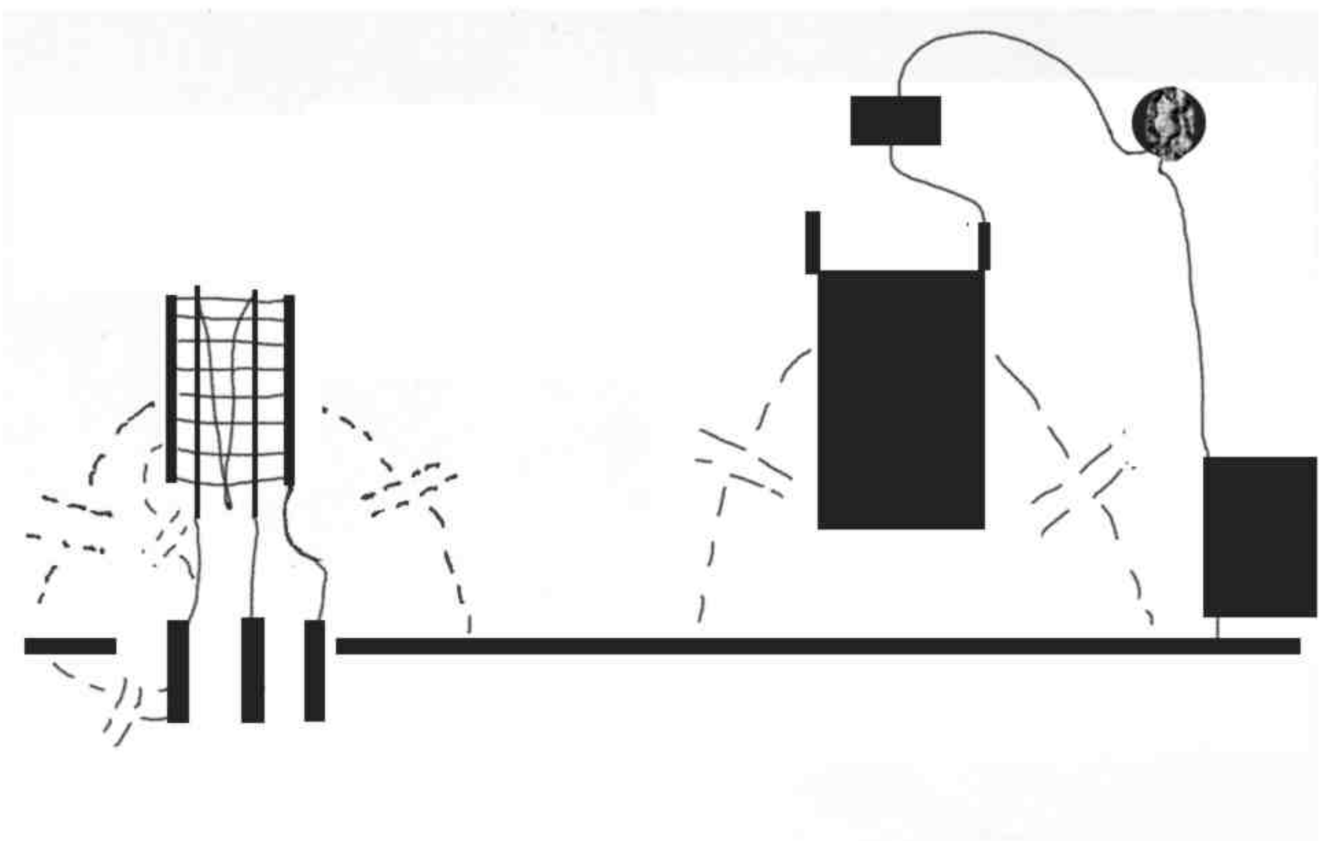
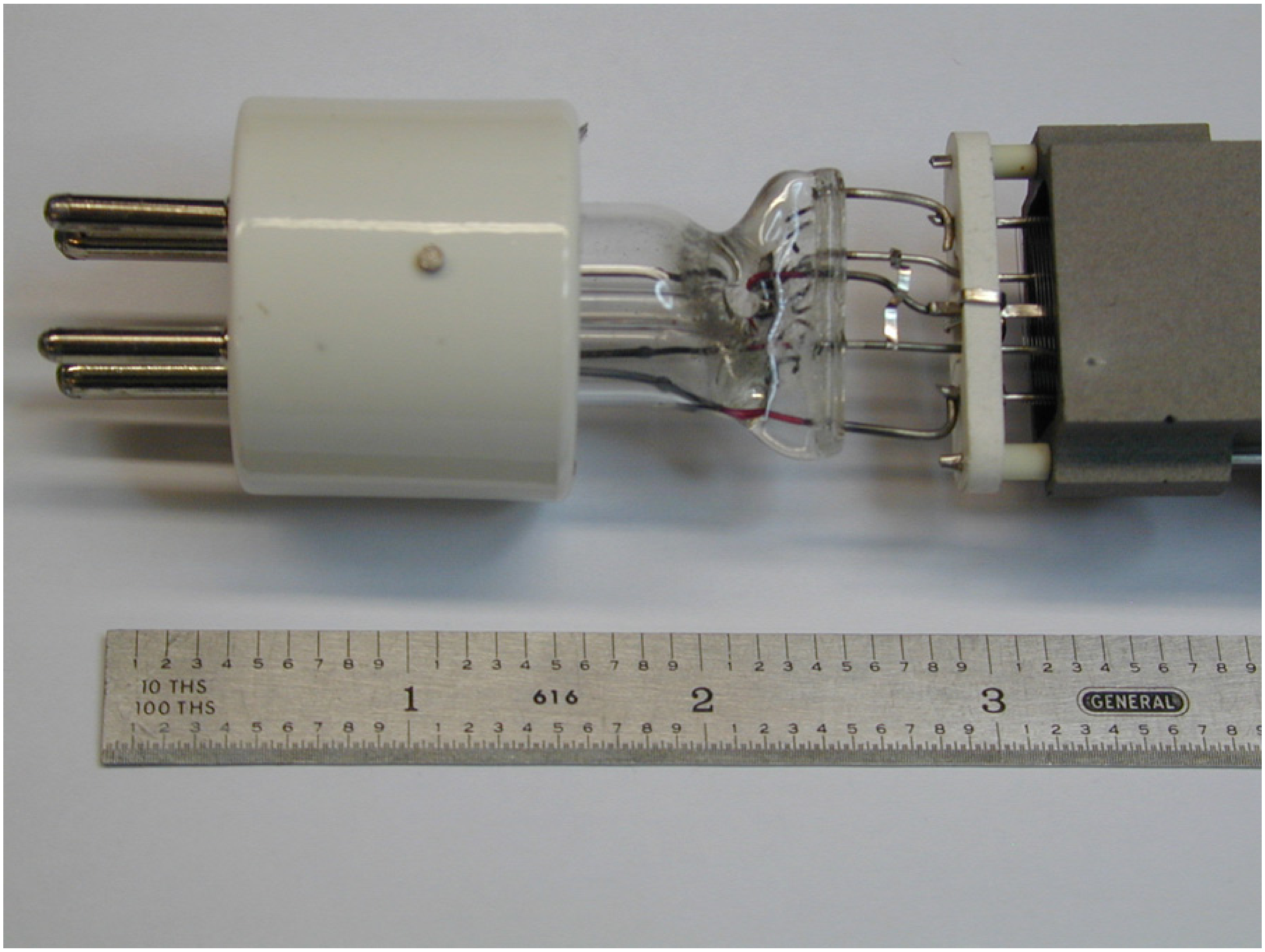
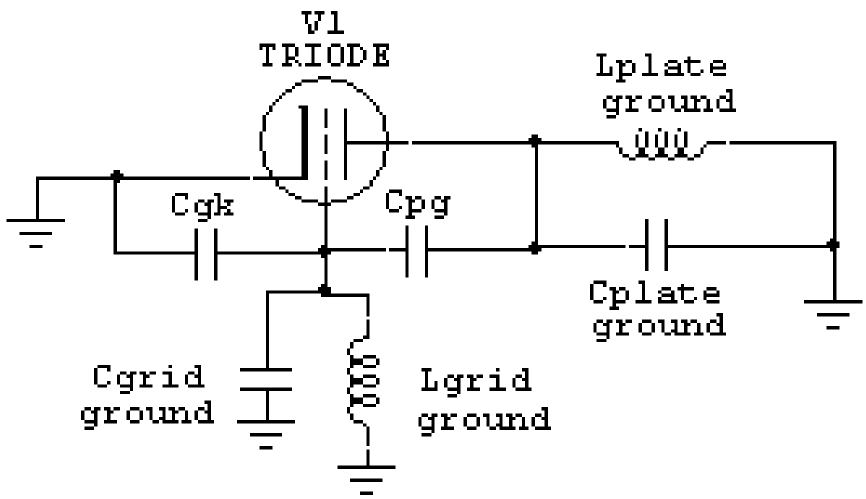
While there may be very rare exceptions to this, nearly 100% of the time neutralization of a Vacuum Tube MF / HF Power Amplifier has virtually nothing to do with VHF / UHF oscillations. VHF / UHF oscillations are most always caused by a high impedance (parallel resonant) path from a grid to ground. The high impedance prevents the grid from being "clamped" or held at ground potential for RF at some frequency or range of frequencies. If this high impedance resonance happens to occur at a frequency range where the anode path to ground is parallel resonant, the tube can act like a tuned-plate tuned-grid oscillator.



Long grid path of 572B tube:





parasitic oscillation circuit

Grounded Grid (GG) Cathode Driven (CD) RF Power Amplifier

Many people think Grounded Grid (GG) Cathode Driven (CD) MF / HF Power Amplifiers never require neutralization. In many cases this is true, but in some cases it is not true.

Tubes with low impedance compact grid structures and grid connections that come out of the envelope with very short leads, like the 3CX1500A7/8877, have very little feedthrough capacitance and is unconditionally stable all the way up to UHF. With the grid ring grounded directly to the chassis with a very low impedance connection, it will not require neutralization or parasitic suppression.

Some tubes are much different. Tubes like the 3CX1200A7 or 3CX1200D7 have significant feedthrough capacitance, and exhibit "out of neutralization" behavior above 20 MHz. This behavior is characterized by maximum RF output occurring well off the plate current dip, and in some cases (i.e. open circuit input terminations) by actual HF instability.

Triode tubes **generally not requiring** neutralization in Grounded Grid (GG) Cathode Driven (CD MF / HF power amps are the:

8873, 8874, 8875, **3-500Z**, 3CX800A7, 3CX1200Z7, 3CX1500A7/8877, 3CX3000 series, 3CX5000 series and 3CX10000 series

Triode tubes **generally benefiting** from neutralization in Grounded Grid (GG) Cathode Driven (CD MF / HF power amps are the:

810, **811A**, 833, **572B**, 100TH, 304TH, 8005, 3CX1200A7, and 3CX1200D7.

Tetrodes and **Pentodes** generally have very low feedback when their grids operate at RF ground potential. **Connecting a beam forming plate, screen grid, or control grid to the cathode changes things where feedback can increase to the point of instability**. Some amplifiers, such as the Amp Supply LA1000 or Dentron sweep tube amps, were unstable on ten meters because the control grid was tied back to the cathode. While these amplifiers could have been stabilized through neutralization, the operator was left to simply load them heavily enough to stabilize them.

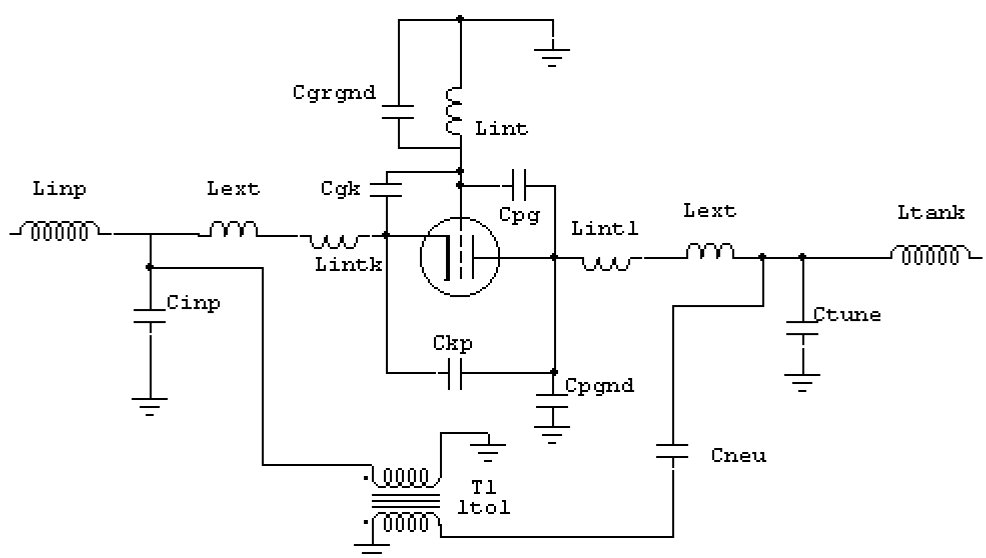
Tubes not requiring neutralization in GG circuits are generally those with conical grid supports and grid connections made via a very short wide internal grid lead or leads. Stable tubes (tubes with low internal feedback) often have compact control grid structures inside the tube.

Tubes benefiting from neutralization are those with long thin (often single) grid leads to single pins, widely spaced grid wires, and poor or no internal shielding from anode-to-cathode.

Tubes with better internal shielding, short wide grid leads, compact grid structures, and close spacing not only work better at upper high frequencies, they are also significantly more stable at VHF. Such tubes rarely require neutralization or parasitic suppression! The most stable tubes are designed to work at VHF and higher; the least stable tubes generally make poor choice for VHF amplifiers.

How Do We Neutralize a Grounded Grid Amplifier?

Electrical Equivalent Grounded Grid Amplifier

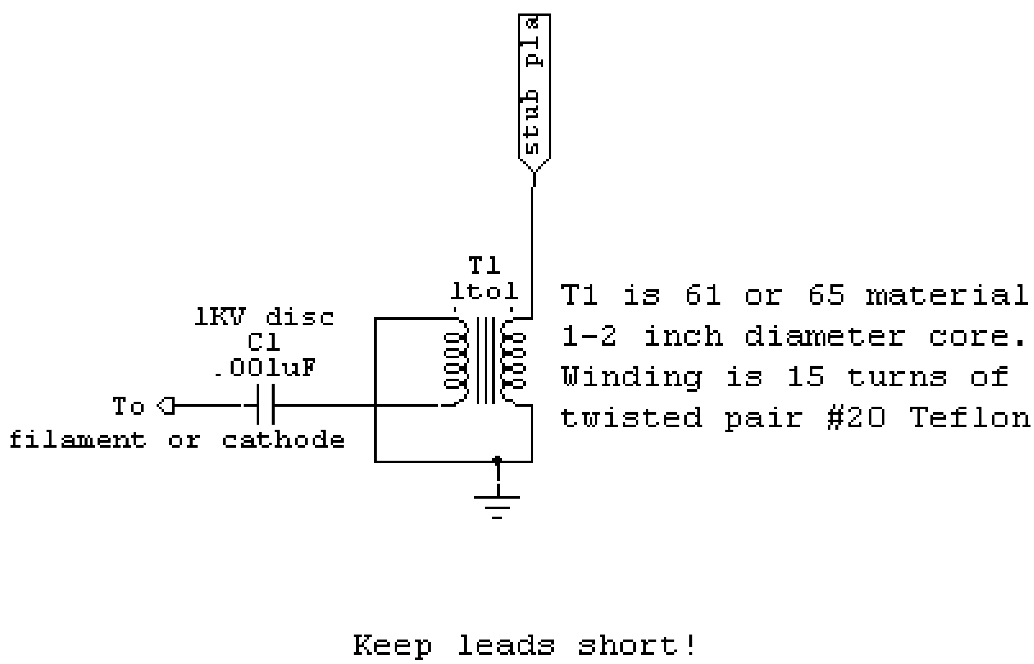


In the circuit above, T1 inverts phase 180 degrees. Cneu approximately equals Ckp, the cathode plate capacitance (or feedthrough capacitance) of the tube. Unwanted feedthrough capacitance, Ckp, varies widely with frequency. This capacitance is not frequency linear. It has less reactance at higher frequencies, and higher reactance at lower frequencies. The absolute equivalent value of Ckp varies more than a pure capacitor would with frequency because all stray inductances, including L_{int} (internal lead inductance) and L_{ext} (external lead inductance), causing Ckp to have a reactance versus frequency slope much more rapid than a normal fixed capacitor. This means we can really only neutralize a PA perfectly over a small range of frequencies.

In the Ameritron AL-811H Power Amplifier, neutralization is almost perfect on fifteen through ten meters. The typical feedthrough null is 35 to 45 dB. The AL-811H neutralization does a good job from 7 to 45 MHz, where feedthrough is less than -20 dB. Feedthrough capacitance is so low, perfect neutralization is not required below 10 MHz. Above 45 MHz the parasitic suppressors load the circuit enough to greatly decrease gain and stabilize the stage.

The AL-811H is perfectly stable and will not break into oscillation on any band if we remove the antenna or exciter, key the PA without drive, and rotate the tuning and loading controls throughout their range.

If we repeat this test with a Clipperton-L, Yaesu FL-2100, or a Collins 30L1 (all un-neutralized amplifiers) most of these amplifiers (if not all) will break into self-oscillation on 15 and 10 meters. **This instability occurs because the 811A and 572B tubes have similar poor construction.** The tubes have very poor shielding from anode-to-cathode. Both tube types exhibit very high amounts of feedthrough capacitance, enough feedthrough capacitance to make un-neutralized amplifiers unstable near the operating frequency on higher bands, such as 15 and 10 meters.

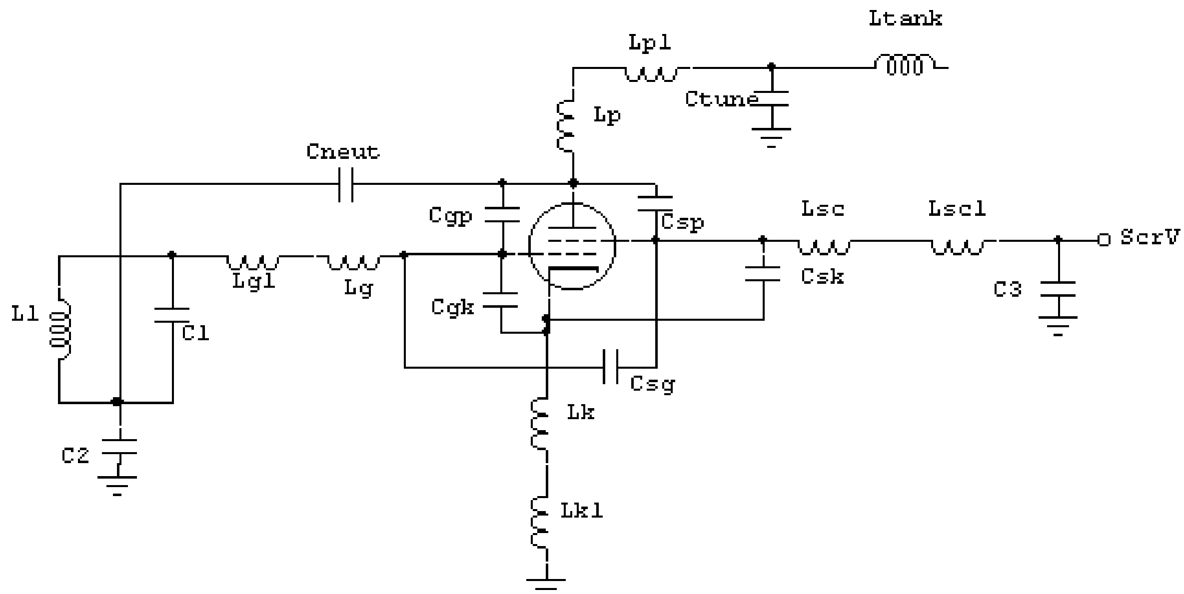


The circuit above is a typical neutralization system for a grounded grid amplifier. The ferrite core is a 1 to 2 inch diameter, 1/2 inch thick, using a higher Q (low loss tangent) 61 or 65 material.

Grounded Cathode (GC) Grid Driven (GD)

Grounded Cathode (GC) Grid Driven (GD) Tetrodes like the 807 or 4CX250 have high power gain. **High gain systems require very little feedback to become unstable, so they are generally neutralized.** The also often require some form of grid loading resistor to reduce or stabilize gain.

The following circuit shows a commonly used Tetrode Grounded Cathode (GC) Grid Driven (GD amplifier with neutralization:



L1/C1 is the normal input tuning coil. Being resonant on the operating frequency, it inverts phase 180-degrees from end-to-end. C2 is a voltage divider to control the feedback voltage ratio and provide a return path for grid excitation. Cneut is adjusted so its voltage feedback equals the voltage fed through Cgp from plate to control grid inside the tube.

Note that this system depends heavily on L1/C1 being resonant at the operating frequency. This proves the tube is only neutralized at the frequency where C1/L1 is set. It does not stabilize the tube on any frequency except where L1/C1 is resonant.

Lp, Lsc, Lk, and Lg are inductances of leads inside the tube. Lp1, Lg1, Lk1, and Lsc1 are lead and component inductances that occur outside the tube.

While the feedback adjustment setting of Cneut holds true for multiple bands near the initial adjustment frequency, it only actually neutralizes the tube on the band in use at any moment of time!

In a 160 - 10 meter PA, Cneut generally only works properly over two or three bands. It is usually set near 15 meters so it has the most effect where it is needed most. By the time we get down to 40 meters and lower, feedback voltage through Cgp is generally through such a high reactance that the lack of proper balancing is meaningless.

Additional stability can be added by loading the grid with a broadband termination resistance. This makes neutralization much less critical, and may at times even eliminate the need to neutralize. This resistor would go from the control grid to ground and ideally be added right at the tube. Unless the resistor is an integral part of the bias system, it must be "dc blocked" with a low impedance series capacitance so it does not affect grid bias.

Neutralization

Neutralization generally only affects operation near or at the desired operating frequencies. Neutralization is normally optimized near the upper frequency end of operation, perhaps between 15 and 30 MHz in a 1.8-30 MHz transmitter or amplifier.

Neutralization is sometimes needed because tubes have unwanted internal capacitances. The capacitance between the output element and the input element inside the tube will cause the output circuit to couple back to the input. If large enough, this regenerative feedback could cause a loss of efficiency. It might cause the output maximum to occur off the plate current dip, reducing efficiency. It might increase Intermodulation Distortion (IMD) or in rare severe cases may cause the amplifier to oscillate someplace near the operating frequency. (This problem is common with grounded grid amplifiers using 572B's like the Dentron Clipperton L, or quads of 811A's, like the Collins 30L1. Yaesu has this problem is some of their FL-2100's.)

While a need to neutralize does occur in some MF / HF grounded grid amplifiers, it is more common in very high gain grid-driven amplifiers.

Neutralization Adjustment Methods

Neutralization is generally accomplished by adding an external capacitance that is excited exactly 180 degrees out-of-phase with the feedthrough capacitance. One typical adjust procedure is to disable the PA stage by removing anode and screen or filament voltage. A sensitive RF detector is connected to the transmitter output. Neutralizing a totally cold tube is perfectly fine, because there is very little capacitance shift in a tube with temperature changes.

Normal drive is applied, and the neutralizing capacitor is adjusted until feedthrough power is minimum. The tuning controls are continually peaked for maximum power on the sensitive detector throughout the process.

A second less accurate method is to watch the plate current dip in a properly tuned normally operating transmitter. The neutralization capacitor is adjusted until ***maximum power output and minimum plate current*** occur simultaneously as the plate capacitor is tuned.

The best method varies with the PA design, but in general the most accurate method is by applying drive to a cold PA stage (generally either screen and plate or filament power is removed) and feedthrough power is measured with a sensitive detector.

What Happens If We Don't Neutralize a New Tube?

Many times nothing noticeable occurs if we don't neutralize a PA. The results really depend on how much different the internal capacitance is in the new tube(s) when compared to the capacitance of the tube(s) being replaced.

If the PA requires neutralization and we don't neutralize or re-neutralize it, we could find IMD higher. We would probably find maximum output power occurring well off the plate current dip. The un-neutralized stage, in severe cases, might oscillate somewhere near the operating frequency under certain conditions of tuning and loading.

Neutralization is generally only accurate over a limited range of frequencies, but fortunately it is almost always at the higher frequency end of the operating range where the PA needs neutralized. The manufacturer probably knows the optimum adjustment point. In the AL-1200 and AL-811H, the optimum null frequency is 21.5 MHz.

Unrelated Problems are sometimes blamed on Neutralization

Since neutralization is the canceling of feedthrough capacitance, and since capacitance doesn't change over the life of a tube (or even much from a hot tube to a cold tube), neutralization won't "drift out" with certain tube types.

A tube will either neutralize right from the start, or it won't. If it appears to drift out of adjustment something other than the neutralization is at fault. Tubes in MF / HF Power Amplifiers cannot drift in and out of neutralization because the capacitance is set by the tube's physical construction, not by emission, age, or any other time-variable parameter.

People sometimes blame neutralization for problems when they really have gassy or defective emission. Gassy tubes can go into current runaway or even flash over inside. Doing this for 35 years for a living, I've never yet seen a tube in a HF or lower VHF amplifier "drift" or age out of neutralization.

The capacitance is for the most part related only to the physical characteristics of the tube, like internal lead length, size of the elements, and spacing of the elements. That's why it is perfectly acceptable to neutralize a cold tube (no filament voltage). The change in feedthrough is very small when the tube is operating compared to when it is cold.

Advantages of The Ameritron AL-811H over the Dentron Clipperton-L

Ameritron AL-811H

1. Input coupling 'Pi' or 'L' Network for each band.
2. Neutralizing Circuit for 811A Vacuum Tubes.
3. Negative Feed Back Circuit for 811A Vacuum Tubes.
4. Sufficient Load Capacitance for good output loading on 160 Meters.

Dentron Clipperton-L

1. No input coupling 'Pi' or 'L' Network for each band.
2. No Neutralizing Circuit for 572B Vacuum Tubes.
3. No Negative Feed Back Circuit for 572B Vacuum Tubes.
4. Insufficient Load Capacitance for good output loading on 160 Meters.