Electron Tube RF Power Amplifier (RFPA)

What does a Parasitic Suppressor do?

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Most of the terms in this document are described for an Electron Tube RF Power Amplifier, but the basic information also applies to a Solid-State Semiconductor Transistor RF Power Amplifier.

What is a parasitic suppressor?

A "parasitic suppressor" is a circuit that adds dissipative resistance to a circuit path in an amplifier or oscillator. The dissipative resistance provides a load for the circuit, absorbing energy. This loading reduces available gain over some specific frequency range. Notice 'Q' is not mentioned. This is because 'Q' is not important. System *impedance* or loading of the system is important, not 'Q'. The optimum load resistance varies greatly with the circuit, the components and wiring used, and the physical layout of the circuit. We can think of a suppressor as a dummy load that is optimized for the impedance of the system at the point where the suppressor is inserted.

Review of parasitic oscillation cause

Parasitics are almost always caused by an Amplifier behaving like a Tuned-Plate Tuned-Grid (TPTG) Oscillator. The governing criteria for oscillation is 'Regenerative Feedback' has to exceed losses in the system. Low-Q circuits will oscillate quite well, so long as feedback exceeds loss. As a matter of fact, many oscillators operate with passive component circuit Q's less than '1'. RC coupled audio oscillators are a good example of very low-Q tuning systems that have no problem oscillating. In order to oscillate with low feedback, stage gain has to be quite high. With low feedback levels a system generally needs the oscillator to be formed in a conventional **Grounded-Cathode (GC) Circuit** (highest gain) with the anode and grid resonant on or near the same operating frequency. As a general rule the anode has to be resonant slightly higher in frequency than the control grid, so the anode load is inductive. This produces a more favorable phase shift. ***We might think a Grounded-Grid (GG) amplifier circuit solves this problem, but it does not. While the grid is grounded outside the tube, it is often not grounded at very high frequencies inside the tube.***

Review of unwanted resonances and gain

"<u>The most problematic resonances in an Electron tube are resonances in the control grid circuit</u>". This is because; the control grid voltage has the largest influence or control over the amplifying system. We can say, **"The gain is in the control grid".** ***The control grid is a fairly <u>large structure</u> and with physical size comes considerable <u>capacitance</u>. The control grid and the <u>leads are also long</u>, and with length comes' <u>inductance</u>. The combination of the two can be a source of significant design problem. At some frequency, control grid capacitance and series control grid connection inductance form a <u>parallel tuned circuit</u>. This parallel resonance divorces the control grid from ground near that resonant frequency. This is, without fail, the problematic frequency.***

If we put a network analyzer on the cathode and look at feedthrough voltage appearing on the anode, we will see a sharp peak in anode to cathode coupling at the frequency where the grid is parallel resonant. This is the target frequency where we want to apply dampening, and of course it varies a great deal with amplifier construction and the construction of the tube and socket. Tubes with long thin single grid leads are the most unstable at VHF, while tubes with thick wide multiple grid leads provide significantly higher grid self-resonant frequencies. The most stable tubes, contrary to what an inexperienced engineer or apprentice technician might think, are actually the tubes most useful at VHF and UHF! It might appear contrary to common sense, but the easiest to stabilize tubes are almost always the tubes with highest gain in VHF or UHF service. The reason for this is a major parameter limiting gain at VHF or UHF is shunting grid capacitance and series grid inductance. The very same things that lower grid parallel resonant frequency, also decreases useful external VHF gain. ***Useful external VHF gain is entirely different than internal VHF gain. They often run opposite to each other!*** As we alter the grid connection length, the frequency where the grid "floats" changes. As with any tuned circuit, any series inductance caused by long leads (even through capacitors or resistors) increases inductance and decreases unwanted control grid VHF resonant frequency. While hidden in components, this unwanted tuned circuit behaves like any tuned circuit. If we add inductance to the path unwanted grid resonance moves lower in frequency. The closer grid resonance moves to the operating frequency, the more difficult building a stable workable amplifier becomes.

If we clamp the leads of a 3-500Z directly to the chassis with nearly zero length from the pins, the grid resonance can be as high as 200MHz in a 3-500Z. This makes suppression easy.

Other than moving the grid resonance higher through shorter leads, anything we do to the grid reduces the frequency where self-oscillation might occur. We generally must attack instability outside of the grid path, although on rare occasions we can modify the grid path to aid stability. To suppress any potential oscillation, the VHF anode path to the chassis must be dampened by a resistance that at least nearly equals or exceeds anode path distributed reactance. The anode system problem is generally one of adding a dissipative resistance that loads the anode enough to reduce gain so the feedback to the grid cannot sustain oscillation.

This is where it gets complicated. There are dozens of ways to dampen the anode, none of them universally better than others. For any particular application or situation the solution can be quite different. For a tube in a cavity, the walls might be lined at a critical point with low-Q ferrite. **The 3-500Z for example at HF, we would try to have the shortest anode to chassis path through the tuning cap, and insert a series inductance with a parallel resistance**. At 150-200 MHz we would want the anode path to have a low impedance, and the resistor / inductor combination we place in series to appear mostly like a dissipative resistance. This generally means a wide short anode lead or short parallel wires spaced some distance apart (to minimize inductance) and enough turns on the suppressor so it, in combination with plate capacitance, resonates at the unwanted frequency (150-200MHz). The resistor across the inductance then becomes a load, and if a modest value dampens the anode and reduces VHF gain.

In short form with a 3-500Z what you need to do is make sure the grid pins are grounded directly with nearly zero length connections directly to the chassis. You need to be sure there is some shunting low impedance reactance at 150-200 MHz that you can apply a series resistance to the path, and that the added series inductance does not get so large that excessive current flows through the resistor at the operating frequency.

This is where the problem is. Despite what some people say, there is no specific universal cure for all situations. What works in one situation might not be best in another. There are many cases where a suppressor is not even required! There are cases where a suppressor will make the system worse. There are cases where the design is critical. There are cases where almost anything will work. Without getting a feel for what actually happens, it becomes a matter of guesswork. This really where all the non-technical nonsense and arguments come from. People don't take the time to learn or understand how the system works, and look for magical snake-oil universal cures. Easy answers are almost always far from optimum solutions and some easy answers can be worse than no answer at all.

The only hard and fast rule is keeping grid grounding short and direct will almost always increase stability of a power amplifier. What we do in the anode really depends heavily on the physical and electrical construction, and without knowing the system in great detail it becomes impossible to suggest the optimum system.

Where is the suppressor placed?

A suppressor is normally placed in the lowest impedance portion of the path involved in the unwanted instability. When using an Electron Tube, suppression is normally (but not always) placed in the Anode lead. **The Anode is the best place because the impedance from the physical element inside the tube to the external anode connection point is almost always a very short, heavy, direct connection.** This means a very low amount of additional external resistance has a large effect on system gain. When using a Bipolar Junction Transistor (BJT) it is placed in the collector lead. When using a Junction Field Effect Transistor (JFET), or Insulated Gate Field Effect Transistor (IGFET), it is placed in the drain lead.