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# Anode Choke Redesign

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# Introduction

The final anode chokes used in the K1200 transmitter were showing signs of excessive heating and sparking which caused crowbars of the final anode power supply. On several occasions the coils were completely destroyed which led to an analysis of the problem and a redesign of the anode choke and filter box assembly.

# 1. Original Design and Trouble Analysis

The original anode filter choke was constructed of 20 turns of 1/4" copper tubing wrapped around the Thomson TH555 tetrode, situated between the magnetic shield and the anode blocking capacitor. A cross-sectional view of this arrangement is shown in Figure 1. The coil in this geometry possessed a capacitance per unit length due to capacitance between its windings and both the blocker capacitor and magnetic shield. In addition, of course, the coil had a specific inductance per unit length. Combining these two effects created a transmission line instead of the intended inductance, which caused several problems resulting in complete destruction of the coil.

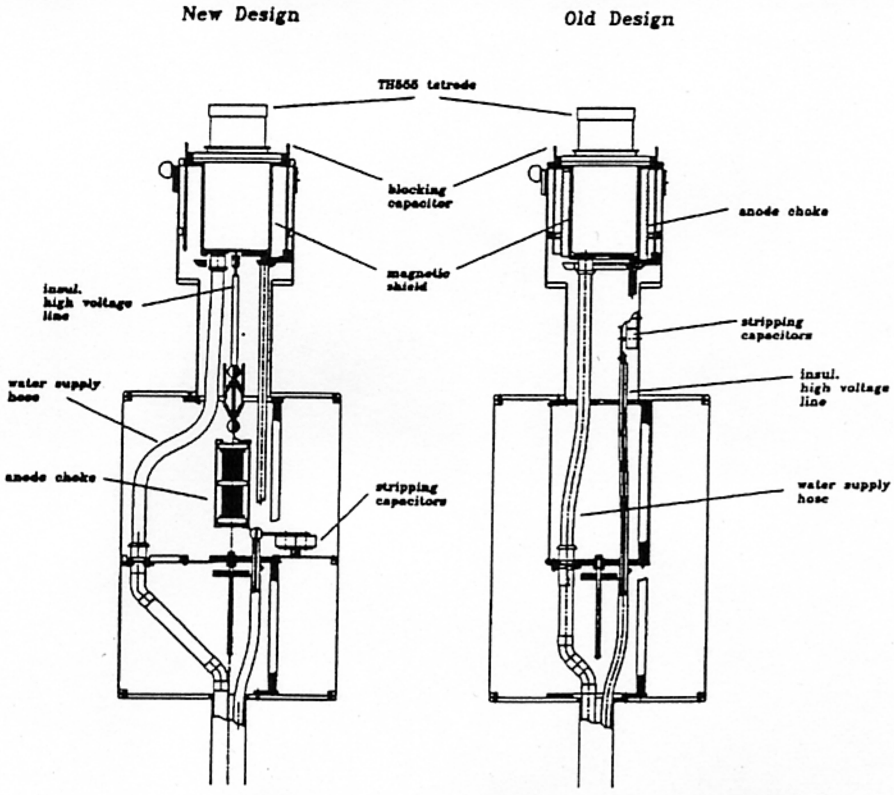


Figure 1: Transmitter cross-section showing two anode filter choke designs.

As in any unterminated transmission line, the coil exhibited a standing wave along its length containing both high current and high voltage nodes. The high voltage points arced to the shield or capacitor, while the high current nodes caused intense localized heating of the coil. Over most of the operating range the magnitude of these voltages and currents was not significant enough to cause damage. However, at resonance where this transmission line appeared as a half, three-quarter, and full wavelength resonator, the voltage maxima and minima caused significant damage.

Turn-to-turn arcing and melting of the coil were observed several times after we had operated near the three resonance points. These resonances were measured with a vector impedance meter to be very high Q modes at approximately 13, 17, and 26 MHz. The 13 and 26 MHz points corresponded to series resonances (half-wave and full-wave resonators), while the 17 MHz point corresponded to a parallel resonance (3/4-wavelength resonator).

The equivalent circuit was simulated as a transmission line driven by a constant voltage source (the tetrode swinging at 17kV RF), and loaded by a large capacitance (0.01uF). Because the losses for this configuration were very small, enormous voltages and currents were shown to exist at their respective maxima and minima when resonant. For example, the magnitude of the current through the coil can be estimated by observing that the 1/4" copper tubing had melted through at one point while we unknowingly operated on a resonance.

Here we have only discussed the destruction of the coil through resonant processes, but have neglected another important concern related to the transmission line behavior of the inductor. The coil was intended to act as a pure inductor, followed by a capacitance to ground in order to prevent RF from getting back to the anode power supply. Following this initial choke and capacitor are several smaller series inductors and shunt capacitors used as additional RF filters (see Figure 2). Because the main coil behaved as a transmission line, the RF voltage present after this coil was significantly larger than the voltage which the filter box components were designed to handle. This caused destruction of these less robust elements. Particularly severe conditions were imposed on these filter components when we operated near a series resonance, since the transmission line was effectively transparent, passing a large peak RF voltage down to the rest of the components. This led to rapid component failure, causing the anode power supply to crowbar.

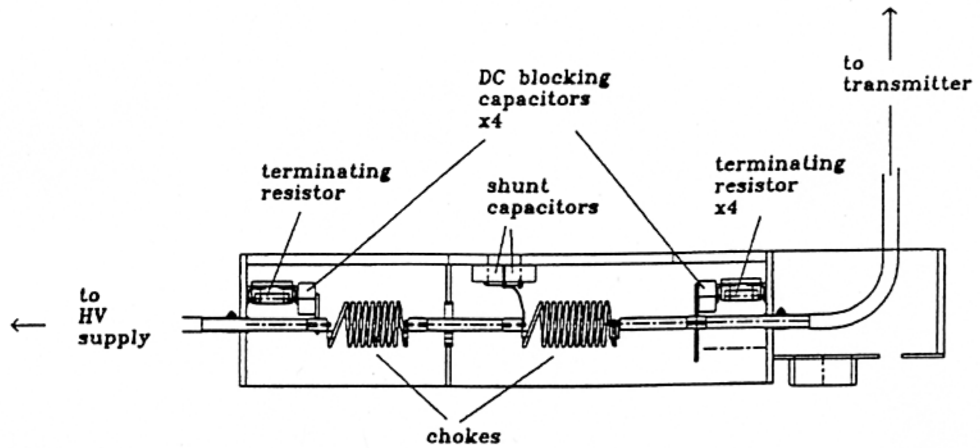


Figure 2: New B+ filter box design.

A decision was made to try to place the main filter choke elsewhere in the transmitter to avoid the transmission line effect. The primary difficulty with such a modification was that the space available for filter components was very limited. A compromise had to be reached between coil inductance, intrinsic coil capacitance, and voltage holding within the available space.

## 2. New Design/Testing

The initial design looked at several coil configurations, with the final version being a 40 turn coil of 0.128" O.D. copper wire wrapped around a rigid polystyrene frame. The length of the coil is 10 inches and its diameter 4 inches across. The inductance was derived from a databook formula, actual measurement, and a program which computes a 3D line integral along the coil. All these measurements agreed within 2%, giving a value of about 56.6 uH. The equivalent series resistance of the coil due to skin and proximity effects was calculated to be about 3.1 Ohms at 27 MHz.

Using a grid-dip meter on the installed coil, a fundamental resonance around 17.7 MHz was detected on all three transmitters, which was assumed to be the self-resonance of the coil. Simulating the circuit with SPICE (see Appendix A) gives a coil shunt capacitance of about 1.5 pF for such a parallel resonance and is primarily due to the turn-to-turn capacitance of the windings.

Normally, anode chokes are designed to have their resonance in the middle of the operating frequency band. From circuit simulations, however, it was found to more desirable to have the resonance point towards the lower end of the spectrum. This was because the magnitude of both the RF current through the coil and the RF voltage at the coil end were reduced more in the capacitive regime of the resonance. A graph showing the simulated coil dissipation and RF voltage at the power supply side of the main coil is shown in Figure 3. Here we can see that if the self-resonance was lowered several megahertz, the power dissipation at low frequencies could be reduced. These voltages and dissipation levels, however, are not expected to cause problems so this design will be used permanently.

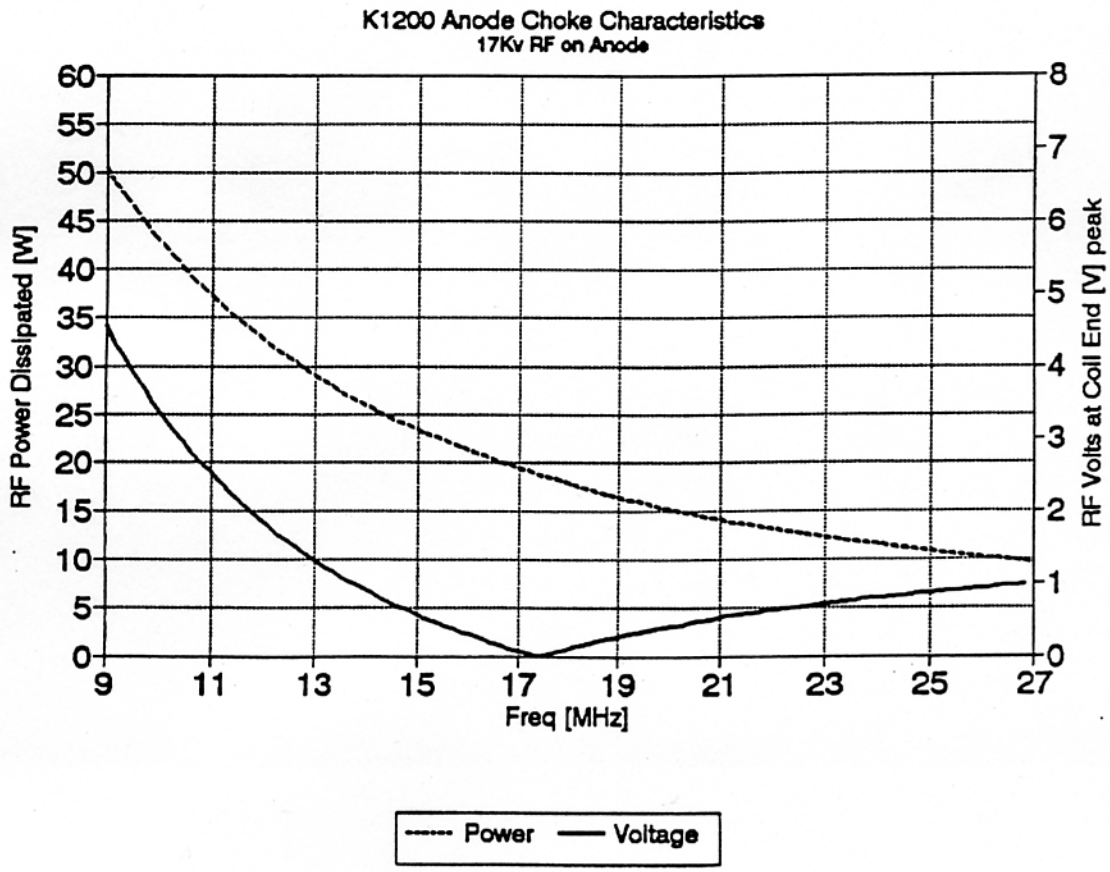


Figure 3

Changes were also made to the filter box components which are located between the choke and supply (see Figure 2). The initial design had placed the terminating resistors on the high voltage side of series blocking capacitors. Since these components are not designed to hold the high DC voltages present on the line, they were flipped to the ground side of the blocking capacitors. These resistors at each end of the B+ filter box are used to properly terminate the 50 Ohm high-voltage cable that connects the power supply to the filter box, and the filter box to the anode choke assembly. This prevents ringing of the transmission line and filter box assembly caused by power supply on/off transients, or similar pulses originating at the anode due to sparking.

A circuit simulation of the filter box components was performed to ensure that the transients did not reach unacceptably high voltages at the various components. This circuit file is listed in Appendix A, and the circuit itself is shown in Figure A. The steady-state RF voltage present at the end of the main choke for various frequencies is shown in Figure 3, though the RF voltage is reduced from this level to several millivolts by the end of the B+ filter box.

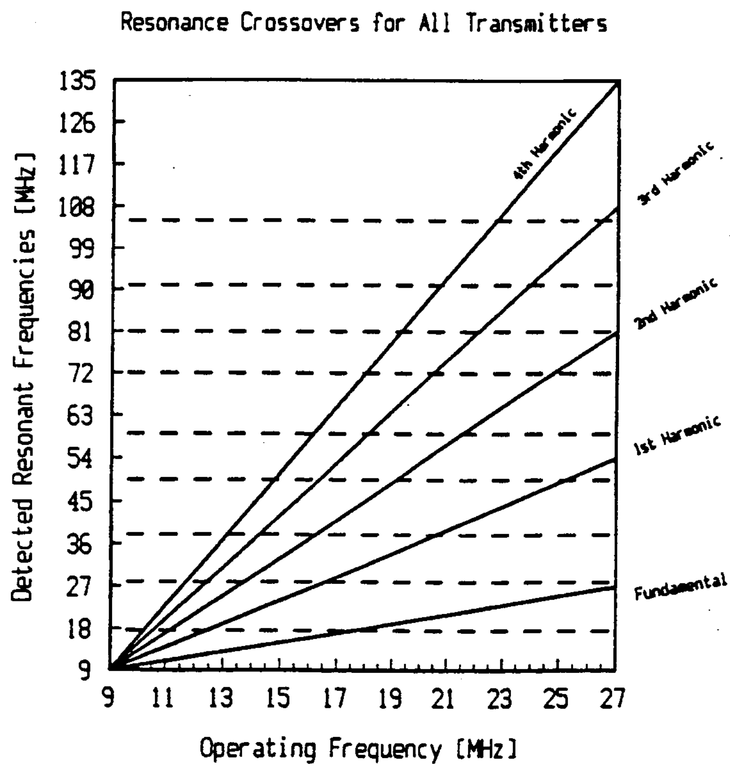


Figure 4

Multiple parallel resonance points of the coil were detected with the grid-dip meter and these points are displayed in Figure 4. The frequency of the resonance is plotted against the operating frequency, but since the coil resonances do not change with operating frequency, they are represented by the horizontal dashed lines. The frequency of the harmonics of the operating frequency are also plotted versus the operating frequency. These are the solid lines of varying slope. The points where the dashed lines and solid lines intersect are places where a resonance may be excited by a harmonic of the driven signal. These points are noted for future reference in case of problems at a particular frequency. It is not expected that any of these resonances will cause problems since they are not high-Q modes, and the coils do not have the distributed reactances of the earlier design.

# Appendix A: B Plus Filter Line for K1200, New Design

```
** b plus filter line for k1200. New design.
**
IA 1 0 AC 62
RA 1 0 600
CA 1 0 62E-12
**
** filter choke
**
L1 9 2 56.6E-6
CB 10 2 1.5E-12
RB 10 9 3.0
VM 1 10 AC 0.0
**
**
C1 2 0 14400E-12
TL1 2 0 4 0 Z0=50 TD=8.46E-9
*RT1 2 4 1  * use in place of TL1 for .tran
CT 4 11 14400E-12
RD2 11 0 50
L2 4 5 4.5E-6
C2 5 0 7200E-12
L3 5 6 4.5E-6
C3 6 7 3600E-12
RT 7 0 50
***
** supply
**
RS 6 0 50
*
* .tran source
*IP 0 12 PULSE(0 400 0 0.1E-6 10E-6 100E-3)
* step start rc
*RP 12 6 130
*CP 6 0 3.2E-6
**
.AC LIN 100 9E+6 27E+6
.PRINT AC V(1) I(VM) V(2) V(7)
.PLOT AC V(1) I(VM)
*.TRAN 20E-6 400E-6
*.PRINT TRAN V(12) V(6) V(7)
*.PLOT TRAN V(12) V(6) V(7)
.END
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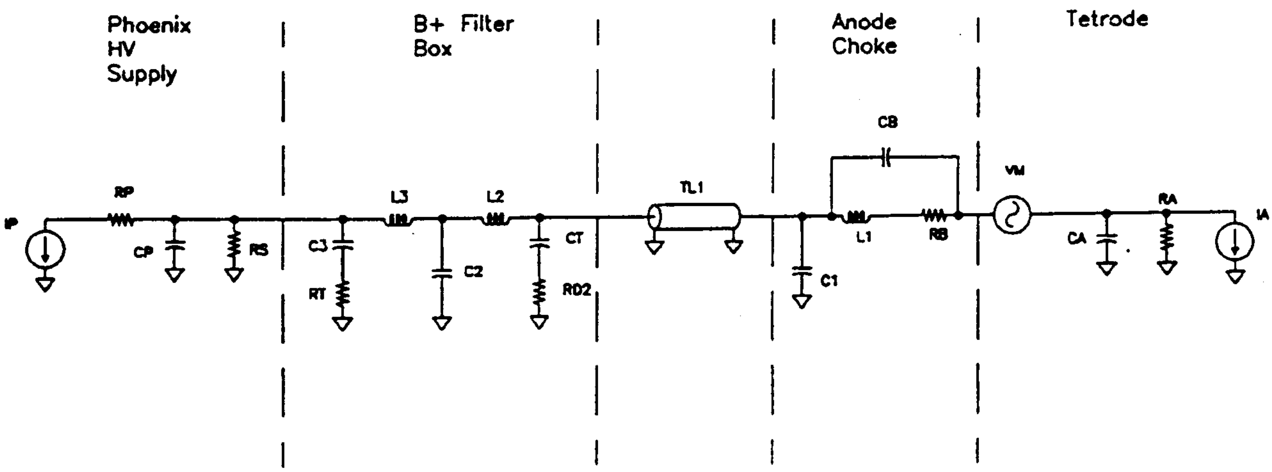


Figure A: Transmitter SPICE circuit.