Yet Another KW Amplifier for 432

Luis Cupido, CT1DMK

Abstract: The Russian VHF triode GS35b is specified to operate up to 1000MHz with 1.5KW anode dissipation. Although the tube geometry makes the construction of a compact, stripline amplifier very difficult. This paper presents one solution for a stripline amplifier with the GS35b for 1.5KW output power at 432MHz.

Introduction: The GS35b has become available at low cost and since its specifications seemed interesting for a 432MHz power amplifier some effort was done to obtain the best from this tube with a simple mechanical construction. A 432MHz power amplifier employing a stripline as the anode/output circuit can provide very compact plate cavity dimensions comparing with coaxial designs. Also the cooling could be more efficient, since less restrictions for the air inlet are presented. And the most important of all, the construction is much less demanding and can be accomplished by almost anyone with little mechanical expertise.

Design considerations: The GS35b has geometry not very suitable for the stripline configuration. The tube has 176mm high and 100mm diameter at the anode cooler.
One of the design problems lies in the grid to plate distance, that is 56mm.
Employing the most common configuration for the stripline connection to the anode, at the anode cooler /1/ /2/ /3/ will result in a much higher impedance than the recommended for best efficiency. Or would result in striplines too large to work at 432MHz, probably larger than longer !!!
Two solutions are possible.
1- The grid ring goes deeper into the chassis, making the distance from anode to ground suitable.
2- The anode line connects to a tube with the anode connection that allows the line to be lower than the plate cooler.
The first solution would result in an good anode cavity configuration but the problem was now transferred to the cathode. If the cathode circuit is coaxial this would not be a problem, but since we envisaged a compact design it is also desirable to have a stripline configuration at the cathode. I must stress that the tube itself has 176mm high.
The second solution would work perfectly and only requires little extra mechanical work to be done. This solution results in a stripline with identical dimensions as the GS23 design by N7ART /3/.
Another problem is the size of the anode cooler which is 76mm high. With a reasonable anode compartment dimensions the top of the anode would be some cm below the top plate. Along the vertical dimension of the tube a $\lambda/4$ resonance appeared in the 400 to 500MHz region, depending on the top plate distance to the anode cooler

(since the anode cooler is 100mm in diameter it presents a significant capacity with the top plate of the amplifier even if it is several centimetres apart).
Taking this resonance out of the 432MHz region by more than 100MHz would be enough. The solution was to cut the cooler by 15mm and compensate for the lost dissipation by increasing the air flow. The recommended airflow for 1.5KW dissipation is 150m^3/h. This value can be exceeded easily. (note: the cooler is not a part of the tube as most of the power triodes for VHF/UHF)
For a compact design the anode cooler will not be too far from the top plate of the anode compartment and the capacity between the anode cooler and ground is of some significance. Since the tube is not operated at constant temperature (intermittent CW operation) the tube and cooler thermal expansion (the cooler is made of cooper) will produce tuning drift at this point. It is known that there are some internal variation of the anode-grid capacity with temperature responsible for thermal drifts that for most modern tubes is very small. In our case the external variation resulted from the tube and stripline expansion is certainly much larger than any internal variation (despite the fact that the tube design is somehow old) and therefore some countermeasure should be considered.
For a $\lambda/2$ stripline the tuning and loading could be done both at the open end of the stripline. The convenient placement of the tuning and loading knobs on the amplifier front panel suggested vertical tuning and loading flappers instead of K1FO technique /2/ that uses horizontal flappers.
Not only it will result in a much simpler mechanical interface between the flappers and the knobs (a treaded shaft pushing the flappers) but it provides a mean for thermal drift cancellation making the amplifier operation very comfortable.
By using a differential capacitor configuration it is possible to cancel the stripline thermal variations.

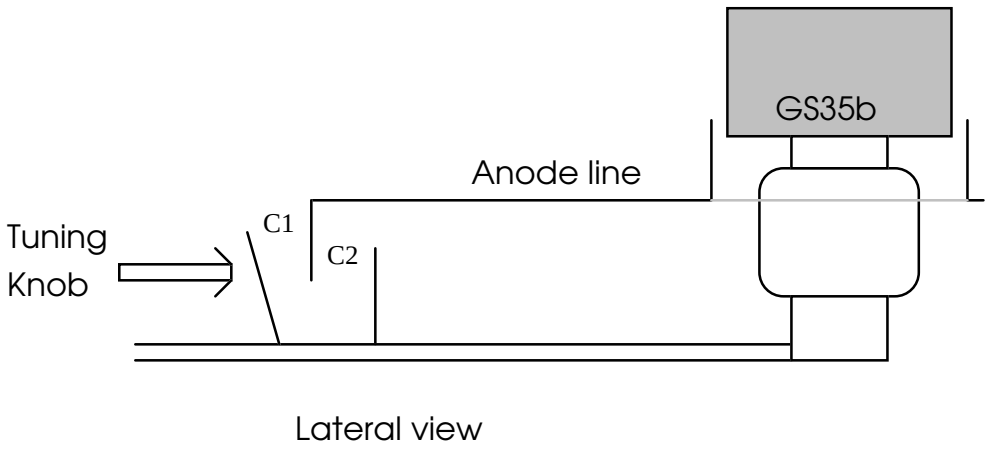

Figure 1 - The tuning arrangement with two tuning flappers for thermal drift cancellation.

The tuning capacitor is obtained by the sum of the capacities C1 and C2. With the stripline expansion C2 decreases its capacity linearly while C1 increases. The balance

for thermal drift cancellation can be found by adjusting C2 (which is a fixed flapper) while C1 remains the tuning element.

The cathode circuits could simply be λ/2 type since the internal input capacity of the tube is not too large, 21pF.

The output circuit: The output uses a λ/2 75 Ohm stripline with both tuning and loading at the open end, it is constructed with silvered cooper 1mm thick with 125mm width and 220mm overall length. The line has a 25mm collar to reduce the spacing to ground while the finger stock contacts the tube anode on the lower cooper ring of the anode cooler. The line is fixed at 45mm from ground by ceramic or Teflon insulators (Teflon insulators are recommended). The output on a 7/16 connector (or a good quality N connector) is connected directly to the loading flapper. This flapper is 15mm by 30mm at a distance from 10 to 30mm from the end of the line. A choque connects the output to ground to avoid the presence of high voltage in the case of a flash over at the output flapper.
The movable tuning flapper "C1" is 76mm wide by 45mm high, and tunes at 432MHz aprox. at 16mm distance from the line.
The fixed flapper "C2" is 76mm wide by 35mm high, and is about 15mm from the inner side of the end of the plate line.
The use of a kapton sheet between the flappers and the stripline has eliminated arcing from the flappers to the stripline.

The input circuit: With a resistive part of the cathode impedance near 35Ohm for full drive, and about 21pF input capacity it was possible to design an input circuit using a λ/2 stripline with 67 Ohm impedance.
The λ/2 circuit resulted in a stripline with a length is 96mm by 75mm wide which fits well into the cathode ring. With this line the tuning and coupling capacitors are around 4 pF. Air spaced Johnson type capacitors would be appropriated. The power level at this point could reach 100W so a only air spaced variable capacitors should be used. Since the input impedance changes with the input and output power it is convenient to have the input controls on the front panel.

Construction: The amplifier chassis are based on several aluminium plates 2mm thick with 90° 15mm edges, joint together by M3 screws 50mm apart from each other. The box has two compartments. The plate compartment is 50mm bigger than the plate line and tube (25mm is the minimum distance from anything to the chassis). The cathode compartment has the same width as the plate one but only 200mm long.
The plate box internal dimensions are 280 x 180 x 145 mm. The cathode box internal dimensions are 180 x 180 x 65mm
Input and output lines and flappers are 1mm thick silvered cooper. The plate line is silver soldered to the tube extension and the finger stock can be stain soldered. All joints, specially the ones without superimposing or 90° bending , must be filled with some beryllium cooper gaskets. Also the box must be air tight.
The cooling blower must supply the air into the plate compartment that must be exhaust by the tube anode cooler equipped with a ptfe or glass chimney.

Some cooling should be also provided for the cathode compartment, preferably with a another blower (e.g. with a small size computer fan).

Operation: The GS35b is a triode and only the plate voltage and heater voltage are necessary to run the amplifier. The recommended plate voltage is 3KV to 3.5KV and the grid biasing can be as simple as a power zener or any other transistor arrangement for a 10 to 25 V in the cathode to ground. Power supply and biasing circuits can be found in extensively in the literature /1/ /2/ /4/.
The tuning procedure for both input and output does not differ from the 3CX800 or 3CX1500 designs, for which K1FO articles are a good reference /1/ /2/.

Results: Comparing with most amplifiers employing modern UHF tubes this one would have less performance, not just by the design restrictions and difficulties encountered but also by the tube characteristics and internal design. Never the less it proved to be usable at 432MHz for 1.5KW output power.
The following table presents 3 regimens of operation tested on the prototype.

For:	**Maximum gain**	**Modest power**	**Full power**
Anode voltage	3000 V	3500 V	3500 V
Anode bias current	200 mA	100 mA	50 mA
Anode total current	0.62 A	0.68 A	0.95 A
Drive power	35 W	70 W	100 W
Output power	700 W	1200 W	>1500 W
Gain	13 dB	12.2 dB	12.0 dB
Overall Efficiency	37 %	50 %	48 %

Conclusion: An amplifier with the Russian VHF triode GS35b was designed to operate on the 432MHz band. The design employed stripline configurations on both output and input. It was possible to obtain an output power exceeding 1.5 KW.
The required drive power for full output is 100W, this is now a standard of the solid state bricks for the 432MHz band.
The construction of this amplifier knowing its lower gain and efficiency compared with the ones employing modern triodes or tetrodes is well justified by the low prices and availability of the GS35b at swap meetings and flea markets.

References:

1 - A 3CX800A7 Amplifier for 432, Steve Powlishen, K1FO
The ARRL UHF/Microwave Projects Manual

2 - A 1500W Output amplifier for 432, Steve Powlishen, K1FO
The ARRL UHF/Microwave Projects Manual

3 - Tetrode Power on 432, Russel L. Miller , N7ART
Dubus 1/1994

4 - The ARRL handbook - (several triode amplifiers for HF to UHF)