Design and Development of Grid Modulator for Transmitters

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Abstract:

Modulator plays an important role in pulsed Travelling Wave Tube (TWT) based system. The design of the modulator is very critical because it is floating at cathode potential, special care is required for the high voltage isolation and thermal management of modulator components. This paper describes the design of a grid modulator floating at cathode potential. The development also involves selection of insulating materials for high voltage isolation and for better thermal management.

Key words: Grid Modulator, TWT, Transmitter

I INTRODUCTION

The main blocks of a high power pulsed microwave transmitter are Electronic Power Conditioner (EPC), TWT and other RF components. The EPC is used for generating all the electrode voltages required for the TWT along with protection and communication of the transmitter. Figure1. shows the block diagram of a transmitter.

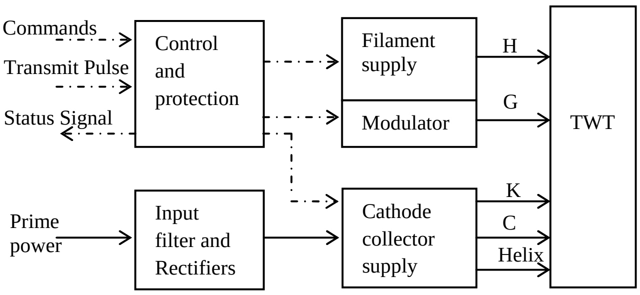

Figure 1. Block diagram of a transmitter

A grid supply and a fast switching modulator is designed and developed for a pulsed TWT. This modulator is suitable for a transmitter which belongs to Radar and EW systems. To counter the diverse array of threats and their associated frequencies in an integrated air defense system, a self-protection jamming system must be able to simultaneously jam multiple signals operating in a wide frequency range. A very fast switching floating deck modulator with very wide frequency range is required for this purpose and the proposed modulator design will address the needs like size, weight, reliability etc. This grid modulator can also be used for radar transmitters with very wide pulse widths. The specifications of the grid supply and the modulator is as shown in the table 1.

PRF	250KHz
Burst Mode PRF	3.3MHz
Max No. of Burst	16
Rise, Fall time	<25 ns
Minimum on time	100nsec
Grid Gate Voltage	+125V to +250V Adjustable
Grid Bias	-200V
Through put delay	80ns
Isolation	15KV

Table 1: Specifications

II DESIGN APPROACH

The grid supply and modulator consists of three main sub modules, the push-pull converter, the floating secondary side regulators and the floating deck modulator. The block diagram of the grid supply and grid modulator is as shown in figure 2. A push pull converter is used for generating the grid and heater voltages. All the floating secondary sections have their own regulators for regulating the output.

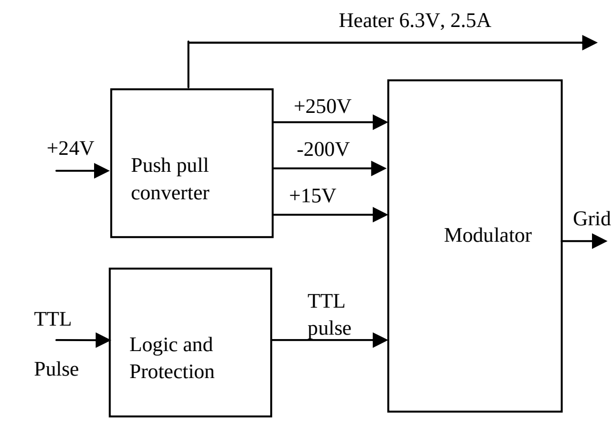

Figure 2. Block diagram of Grid supply and modulator

The modulator is floating at cathode potential of about 12KV. The TTL pulses are applied to the modulator using pulse transformers. The pulse transformers are selected because of its very low propagation delay compared to fiber optic links. The following section explains the three sub modules of the grid supply and modulator.

1. Push pull converter

Push- pull converter is used for generating the grid gate (+250V), grid bias (-200V), heater (+6.3V) and +15V vcc required for the modulator. All these voltages are with respect to the cathode voltage. For obtaining high voltage isolation, primary of the push pull transformer is made using 18KV high voltage wire. The input to the push pull converter is regulated to 24V, and the push pull PWM is working in open loop with fixed pulse width. All the secondaries are having individual regulators for regulating the output.

2. Secondary side regulators

Regulators are used for regulating +250V, -200V and 6.3V heater. The TWT heater will have very low cold resistance, so during cold turn-on condition the heater regulator will limit the maximum peak current to allowable surge current of the heater. Transistor based regulators are used for regulating the +250V and -200V regulators for grid supply. To adjust the beam current while integrating with TWT the +250V regulator is made adjustable from the low voltage control board.

3. Grid modulator

The main requirements of the grid modulator design are,

a. The circuit must be floating at cathode potential
b. Very low pulse to pulse voltage regulation of the grid gate voltage and very low pulse top ripple to get very low phase noise.
c. Grid pulse rise and fall time should be minimum to reduce body current
d. Very low propagation delay from TTL pulse to grid pulse

Pulse transformers are used for applying the modulator trigger pulse to floating deck modulator circuit. High voltage wires are used for winding the pulse transformer secondary to get very high voltage isolation. The modulator board splits into two sections, LV section and HV section. The mono-stable multi-vibrator in the LV section generates SET and RESET pulses from the modulator trigger pulse. Rising edge of the trigger pulse generate the SET pulse and the falling edge generates the RESET pulse. The pulse width of this pulse is only 50ns. Figure 3 shows the mono-stable block and the output pulses.

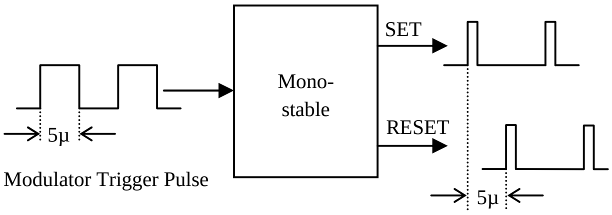

Figure-3 Mono-stable multi-vibrator in the LV section

Using a pulse transformer this SET and RESET pulses are applied to NOR latch in the HV section, the NOR latch output will be same as the modulator trigger pulse. Figure 4 shows the grid pulse generation from the set and reset pulse.

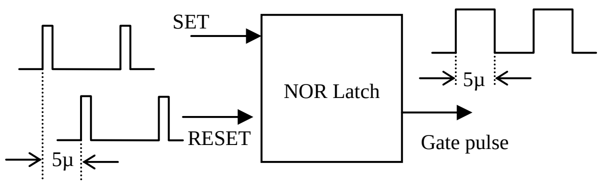

Figure-4 NOR Latch in the HV section

The pulse transformers never see larger pulse widths, it will always operate with 50ns, and this avoids the saturation of the pulse transformers. This technique helps the modulator to operate from a very low pulse width to CW.

Two RF switches are connected in totem pole arrangement to switch the grid voltage from -250V to +200V. Fast switching power MOSFETS of 1000V are used to get a very low voltage rise and fall time (<25ns).

Figure 5. Totem pole arrangement

The arrangement of totem pole switches is shown in figure 5. The switching speed of the modulator depends on the capability of the switching device to charge and discharge grid capacitance of the TWT and output capacitance of the MOSFET. Peak charging and discharging current of the MOSFET will be very high to get very low rise and fall times. Resistor R_1 will prevent cross conduction of the Q_1 and Q_2 MOSFETs. Resistor R_2 is a pull down resistor which ensures that a cut off voltage is available during a fault condition when Q_2 goes open circuit. Figure 6 shows the assembled modulator card with MOSFET heat sink.

Figure 6. Modulator Card

Power handling

The power dissipation of the modulator transistors includes dissipation due to the current drain of the grid electrode, as well as the energy losses associated with charging and discharging the grid electrode and the switching MOSFETs themselves [5]. The resistive losses in the MOSFET are less because the current required for the grid is very less, but the capacitive switching losses will be much higher due to very high Pulse Repetition Frequency (PRF) of 250 KHz. The Q_1, Q_2 MOSFETs each will dissipate a power P, where

$$P = \frac{1}{2}(c.v^2.\mathrm{f})$$

c = sum of MOSFET output capacitance and grid capacitance
v = total grid voltage swing
f = maximum PRF

Each of these MOSFETs will dissipate about 10W, Aluminum Nitride (AlN) wafers and epoxy potting compounds with high thermal conductivity are used for packaging this MOSFETs floating at high cathode potential.

III EXPERIMENTAL RESULTS

The grid modulator is successfully integrated with CPI make TWT. In pulse mode the TWT is pulsed up to 250 KHz and in burst mode it is pulsed up to 3.3MHz.The pulse width is varied from 100ns to 5us.The pulse rise and fall times found less than 25ns and propagation delay close to 80ns.

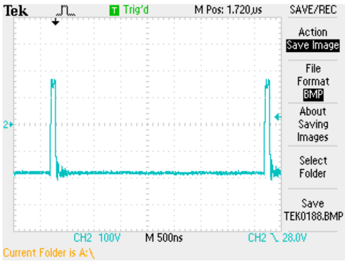

Figure 7. Grid voltage swing at 250KHz PRF

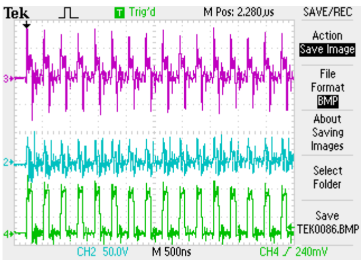

Figure 8. TWT pulsing at 3.3MHz, 100ns pulse width, 16 pulses
Channel 1 – Beam current, Channel 2- Cathode ripple, Channel 3 – Helix current

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