Radar Modulator

Radio frequency energy in radar is transmitted in short pulses with time durations that may vary from 1 to 50 microseconds or more. A special modulator is needed to produce this impulse of high voltage. The hydrogen thyratron modulator is the most common radar modulator. It employs a pulse-forming network that is charged up slowly to a high value of voltage. The network is discharged rapidly through a pulse transformer by the thyratron keyer tube to develop an output pulse, The shape and duration of the pulse are determined by the electrical characteristics of the pulse-forming network and of the pulse transformer.

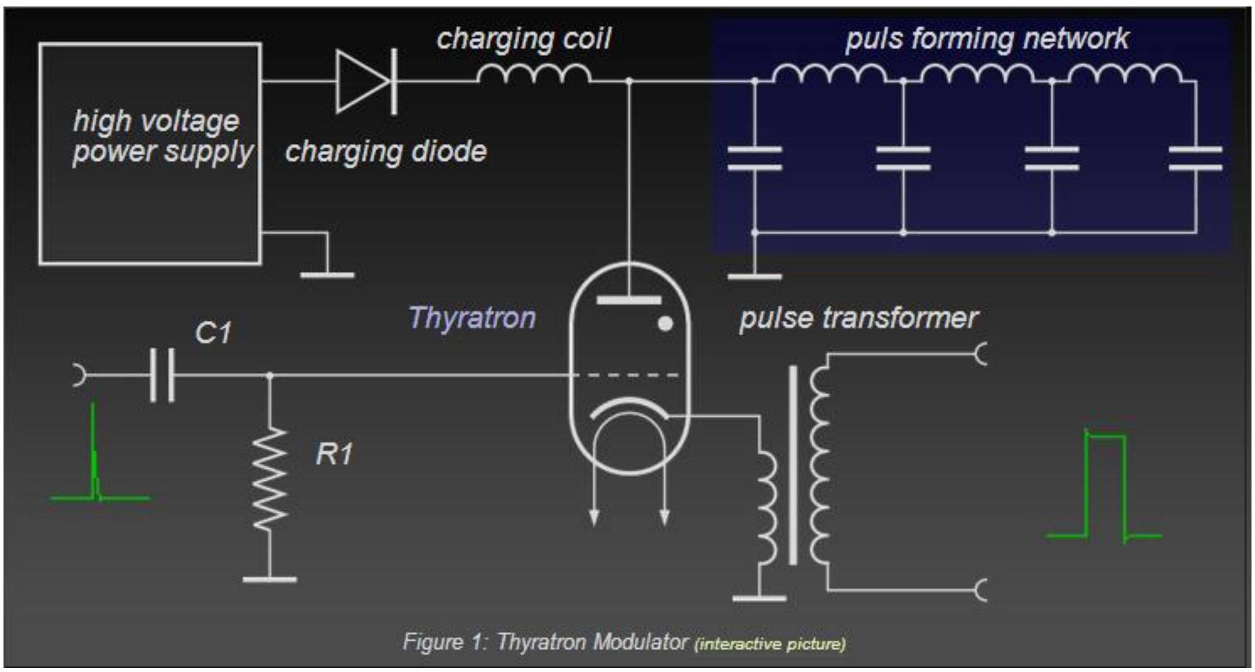

Figure 1: Thyratron Modulator (interactive picture)

Figure 2: Thyratron Modulator of the Russian P-18

As circuit for storing energy the thyratron modulator uses essentially a short section of artificial transmission line which is known as the pulse- forming network (PFN). Via the charging path this PFN is charged on the double voltage of the high voltage power supply with help of the magnetic field of the charging impedance. Simultaneously this charging impedance limits the charging current. The charging diode prevents that the PFN discharge himself about the intrinsic resistance of the power supply again.

The function of thyratron is to act as an electronic switch which requires a positive trigger of only 150 volts. The thyratron requires a sharp leading edge for a trigger pulse and depends on a sudden drop in anode voltage (controlled by the pulse- forming network) to terminate the pulse and cut off the tube. The R-C Combination acts as a DC- shield and protect the grid of the thyratron. This trigger pulse initiates the ionization of the complete thyratron by the charging voltage. This ionization allows conduction from the charged pulse-forming network through pulse transformer. The output pulse is then applied to an oscillating device, such as a magnetron.

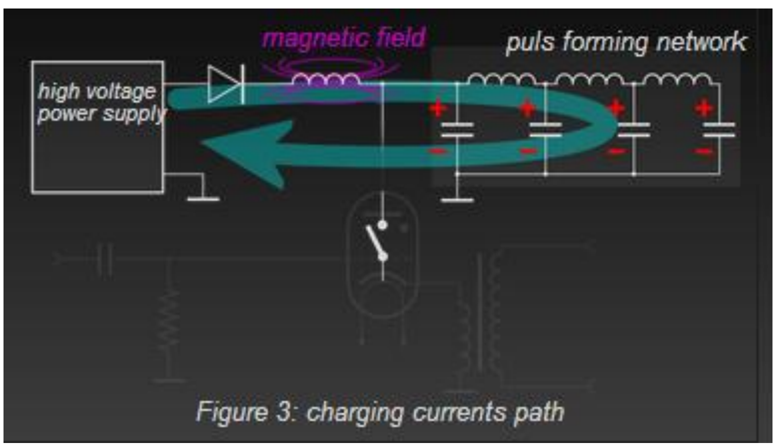

Figure 3: charging currents path

The Charge Path

As an initial condition is assumed that the circuit is not energized. In the figure the thyratron is shown to as an open switch.

Once the power supply is switched on (look at the brown voltage jump in the right diagram), the current flows through the charging diode and the charging coil and charges the capacitors of the pulse forming network (PFN). The coils of the PFN are not yet functional (having too small impedance).

However, the induction of the charging impedance offers a great inductive resistance to the current and builds up a strong magnetic field. The charging of the capacitors follows an exponential function (line drawing green). The self- induction of the charging coil overlaps for this.

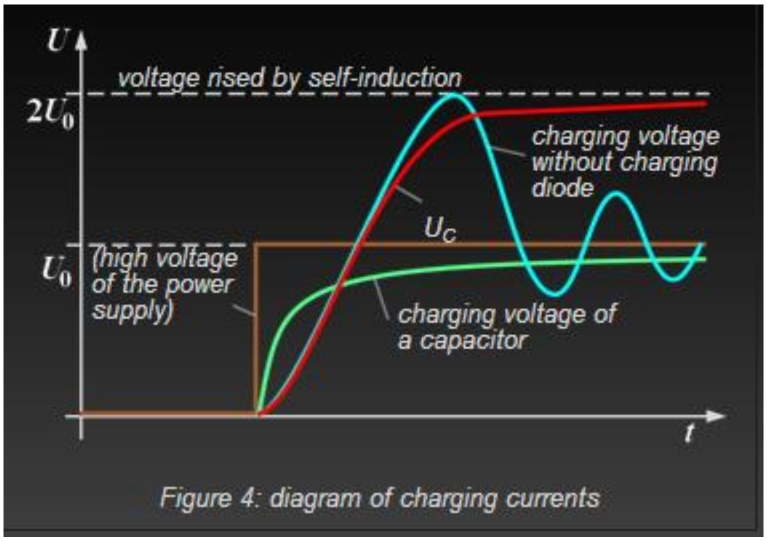

Figure 4: diagram of charging currents

$U_C = U_0 \cdot (1 - \cos\omega_r \cdot t)$

$\omega_r^2 = 1 / L_{Dr} \cdot \Sigma C$ (1)

If the capacitors are charged with the power supplies voltage, decreases the current and the magnetic field breaks down. The breaking down magnetic field causes an additional induction of a voltage. This one continues the charging of the capacitors up to the double voltage of the power supply. Now the capacitors would discharged (ice blue curve) about the power supplies resistance, but the charging diode cut off this current direction and the energy remains stored therefore in the capacitors.

The Discharging Path

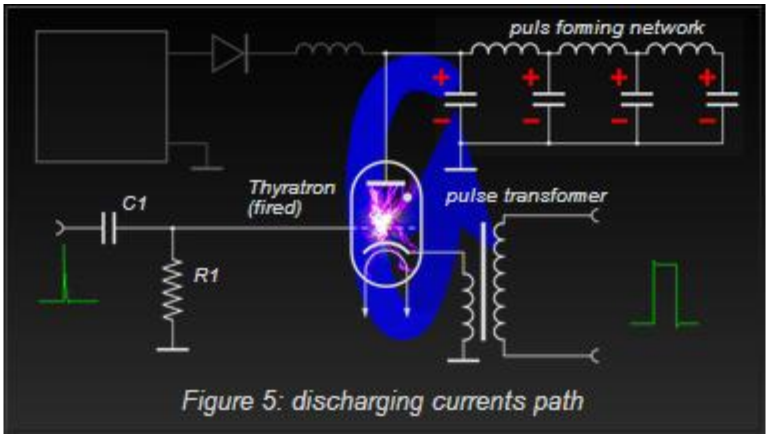

Figure 5: discharging currents path

When a positive trigger pulse is applied to the grid of the thyratron, the tube ionizes causing the pulse-forming network to discharge through the thyratron and the primary of the pulse transformer. (The tyratron is „fired")

The fired thyratron grounds the pulse line at the charging coil and the charging diode effectively. Therefore, a current flows for the duration PW through the pulse transformer primary coil to ground and from ground through the thyratron, which is now conducting to the other side of the pulse forming network. The high voltage pulse for the transmitting tube can be taken on the secondary coil of the pulse transformer. Exactly for this time an oscillating device swings on the transmit frequency. Because of the inductive properties of the PFN, the positive discharge voltage has a tendency to swing negative.

If the oscillator and pulse transformer circuit impedance is properly matched to the line impedance, the voltage pulse that appears across the transformer primary equals one-half the voltage to which the line was initially charged.

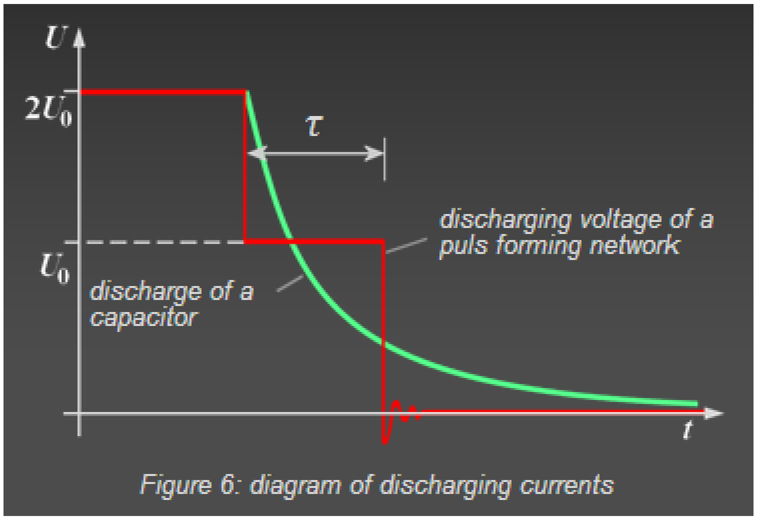

Figure 6: diagram of discharging currents

Source: http://www.radartutorial.eu/08.transmitters/Radar%20Modulator.en.html