X-Band TWT Transmitter

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Abstract: *Diversified Technologies, Inc. (DTI) in collaboration with Dynetics Technical Solutions (DTS) has developed and installed a high power X-Band Transmitter into a new radar. The transmitter uses a CPI high power broadband TWT and is integrated with a dish antenna. This presentation gives an overview of the transmitter design and construction.*

Keywords: X-band; transmitter; radar; antenna, power supply; traveling-wave tube.

Introduction

In 2021 Diversified Technologies, Inc. (DTI) completed the development and installation of an X-band radar transmitter. The transmitter design is closely based on several high power traveling-wave tube (TWT) transmitters previously delivered by DTI.

DTI's transmitter consists of state-of-the-art, solid state, high-voltage subsystems. The speed, precision, and reliability of solid state devices offer a level of performance unattainable in conventional transmitter designs. The only
vacuum electron device (VED) in the transmitter is the CPI VTX-5681 very high power coupled-cavity TWT.

Specifications

The design of the HVPS, fast fault controls, Modulator Enclosure, mod-anode modulator, filter capacitor, PLC/PC control system, and cathode switch was based on similar previously designed systems.

The DTI scope of work for this project included the transmitter, a shelter, and the cooling system. DTS supplied the TWT and focusing coil. The general transmitter specifications are shown in Table 1.

Technical Description

The TWT is mounted on the antenna to allow minimum waveguide losses from the TWT to the antenna feed. This VED and some of the DTI electronics are mounted in a weatherproof compartment mounted on the antenna yoke arm (the RF Box). The subassemblies include

- Modulator enclosure, including the solid-state high voltage switches for the TWT, the filament hot box, isolation transformer and diagnostics
- Tube stand, which firmly supports the TWT and focusing coil in any orientation
- Control electronics including fast TWT control board, fast Microwave control board and PLC interface
- Microwave components including drive amplifier and transmitter waveguide
- Cooling manifolds and hoses for TWT and waveguide with taps for customer cooling connections

The remainder of the DTI electronics are located on the ground inside the DTI-supplied Transmitter Enclosure mounted near the base of the antenna.

Table 1. Transmitter Specifications

Performance Parameter	Value
Frequency Range	X-Band, 9.5-10.5 GHz
Peak Power	70 kW (min)/130 kW (max)
Duty Factor	35% maximum, continuous
Pulse Width range	5 – 3000 µs
PRF	2 kHz (max)
PRF Sync	Transmitter Gate Pulse
RF Pulse Rise and Fall Time	50 nsec max (using RF pulse)
Pulse Droop	<0.25 dB (~1 ms pulse width)
Pulse Overshoot	< 5%
Pulse to pulse amplitude stability	0.1 dB
Power Flatness, compressed	+/-1 dB
Load VSWR	1.5:1
Power Supply PRF Synchronization	NA – HVPS Blanking During Pulse
Prime Power	480 VAC; 400 A
Cooling	Liquid
Environment	0 to 50 C
Altitude	Up to 10,000 feet

It houses the following transmitter subsystems:

- High voltage DC power supplies and high voltage filter capacitor bank
- Operator interface display, PLC and fast fault controls.
- Power distribution panel
- Auxiliary Electronics Rack
- Cooling manifold

This transmitter is powered by a 480 volt, 60 Hz, 3-phase feed. Power is fed to the RF Box through the cable wrap.

A. High Voltage Electronics Housed in the Transmitter Enclosure

Figure 1 is a simplified schematic diagram showing the high voltage circuit topology of the transmitter. The high voltage for this transmitter were supplied by two standard DTI power supplies operating in parallel. The switching inverters are synchronized in quadrature to greatly reduce voltage ripple. The use of two supplies also provides substantial power margin for this application.

This supply offers the following benefits:

- High reliability, with a predicted MTBF of over 60,000 hours

- High efficiency (typically > 95%)
- Regulation better than 0.02% with very low ripple
- Average power is 150 kW, expandable to 250 kW.

The opening switch allows the use of a substantial filter capacitor value to provide low droop on long pulses and very low ripple. The capacitor bank cabinet with the capacitor bank and the opening switch includes series resistors, safety bleeder resistors, and a high voltage safety dump circuit with Ross relay.

B. Electronics in the RF Box

High voltage, power, and control cables for these systems are provided through a cable wrap. The control circuitry is mounted within a low voltage compartment ("dishpan") incorporated into the modulator cabinet.

The electron gun of the high duty factor X-band TWT incorporates a modulating (mod) anode, rather than a grid, to gate the beam current. The mod anode allows extremely low body current interception, at the expense of much higher modulator voltage swing (compared to a gridded TWT). The mod anode is controlled by a pair of DTI high voltage switch stack assemblies which are identical to the solid-state cathode opening switch (which protects the TWT against arc damage).

The power supplies for the mod-anode and filaments are located in a 'hot box' which operates referenced to cathode potential. These hot box supplies include a regulated DC cathode filament supply, and Mod anode "off" bias voltage. The fiber optically controlled hot box is powered through a 50 kV, 60 Hz isolation transformer.

The output waveguide network is water-cooled copper WR102 waveguide.

The transmitter includes a Microwave Control Unit (MCU) which handles microwave detected signal monitoring and fast fault protection.

C. Cooling Systems

The supplied cooling system for the transmitter is complete and includes a skid-mounted chiller, cooling manifolds and hoses through the cable wrap.

Figure 2 – X-Band TWT transmitter configuration installed. The TWT is on the right (red).

D. System Controls

The transmitter is controlled and monitored through a three-level system which include a full local user interface for system setup and troubleshooting. The first level, fast control and monitoring, provides fast response, hard-wired fault detection, and safety shutdown. The second level provides supervisory automatic controls and fault detection via a commercial programmable logic controller (PLC). The third level consists of a graphical user interface (GUI) that uses a color touch screen

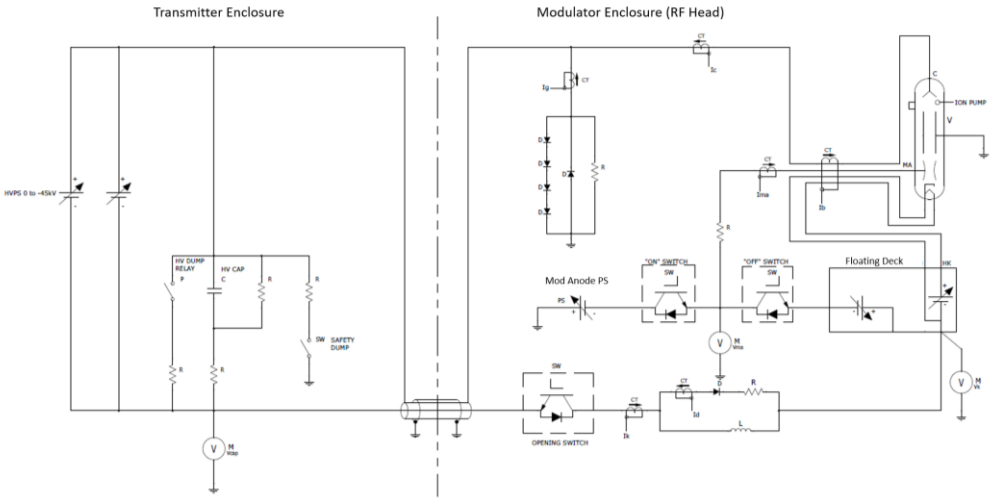

Figure 1.Simplified transmitter schematic.