A NEW HIGH-POWER WIDE-BAND MM WAVE TWT FOR MIL-STD-461

New high power traveling wave tubes have applications in radar simulators, radar cross section measurements, ECM and radiated susceptibility testing.

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INTRODUCTION

More than 40 years have elapsed since R. Kompfner invented the helix traveling wave tube (TWT); during this time the product has matured and advanced beyond all speculation in terms of gain, output power, and frequency range. It was not until comparatively recently, however, that tubes have become available in K band. Although they produced only modest power (a few watts), they represented a major technical achievement. Even so, once the initial wonderment that tubes existed with any power performance at these frequencies had passed, designers almost immediately demanded more power and wider bandwidths. To help meet this demand, a new high-power broad-band TWT has been developed. Such a device should find many applications in radar simulators, radar cross-section measurement, radiated susceptibility testing, and ECM.

TECHNICAL FEATURES OF THE NEW TWT

Much has been written about the engineering difficulties in the design of the millimeter wave helix TWT. The larger part of these all stem from two fundamental constraints imposed directly by the frequency of operation: small dimensions and high operating voltages. The dimensional problem subdivides into two areas: the generation and focusing of narrow high-density electron beams, and the extraction of heat generated in the helix and output window.

The electron gun in the TWT is a fairly conventional convergent-flow Pierce gun. Extensive use was made of computer modeling techniques, including the effects of space charge, thermal velocities, and periodic permanent magnet to generate a laminar electron beam of 0.016-inch diameter focused through a helix with an 0.027-inch bore. Because of the small clearances between beam and helix, concentricity and parallelism tolerances through the gun and drift tube to the helix must be held to ±0.001 inch.

For long life, a conventional impregnated tungsten cathode is used. The grid 1 electrode, which normally operates in the range of −1 to −25 volts, can cut off the electron beam if it is biased to −800 volts. Focusing is by samarium cobalt periodic permanent magnet. Again, concentricity and parallelism of associated polepieces are of extreme importance.

The main thermal management problem is with the helix since heat is being generated by electron beam interception and by the resistance loss of the wire of the helix. Both effects tend to be most pronounced over the last few turns of the helix near the output. The helix consists of an 0.008- x 0.005-inch molybdenum tape supported on 0.025- x 0.015-inch beryllium rods. A copper tube, thermally shrunk to compress the bundle of helix and support rods, completes the assembly and provides a good thermal path.

The broad-band characteristics of the tube have been enhanced by careful dispersion control, achieved by profiling the support rods to reduce dielectric loading on the helix and by use of anisotropic loading vanes. The vanes consist of copper wires located 0.007 inch from the helix. In this case, a tolerance of ±0.0005 inch is needed for consistency of performance.

The input and output windows are coaxial and are provided with a good thermal path to the waveguide adapters, which also act as heat sinks. Typically, matching of better than 10 dB return loss is obtained across the full bandwidth.

A major problem with the high-voltage helix TWT is the onset of backward wave oscillation (BWO), which occurs at the frequency where one helix turn equals approximately 1/2 wavelength. Methods of raising the starting current of such oscillations range from frequency selective attenuation to resonant loss. The former, which consists of distributed attenuation along most of the helix, is relatively ineffective for broadband tubes where the oscillation frequency is close to the top of the band. The latter, resonant loss, is more properly described as a series of tuned reflections which produce a stop band at the resonant frequency of the BWO. In the case of mm tubes, the physical dimensions make it difficult to achieve the definition of the resonant circuit (or meander line). For these reasons, the velocity step method was chosen, in which a pitch change in the helix effectively desynchronizes the BWO frequency, making use of the high voltage sensitivity. A large signal computer simulation program is useful here to reduce the adverse effect of such pitch changes on tube efficiency and bandwidth.

SPECIFICATIONS AND CHARACTERISTICS

Graphs of typical saturated gain and power performance against frequency are given in Figure 1 and specifications and operating characteristics of the mm TWT are given in Table 1.

POWER SUPPLY

A power supply suitable for a laboratory environment should be available to drive the TWT. A typical TWT and its power supply are shown in Figure 2.

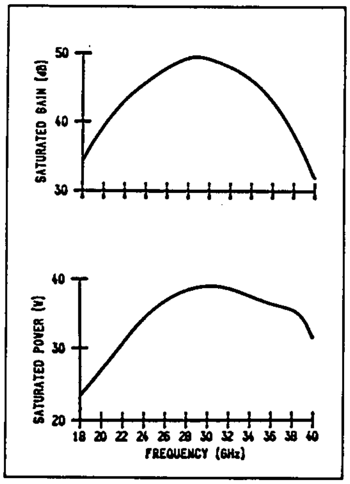

Figure 1. Typical Performance of MM Wave TWT: Saturated Gain and Power Versus Frequency.

The power supply is an off-line pulse width modulated switched type. The unit is modular, with individual cathode-helix voltage, collector voltage, heater/Grid 1 voltage, Grid 2 (anode) voltage, logic board, and primary voltage input assemblies. Pulse width modulation is used in each of the supply modules for regulation against input and load variations.

MOSFETs are used in half-bridge rectifiers in the helix, collector, and heater modules. The logic board assembly provides control of the start up sequence, fault monitoring, and shutdown sequence. The front panel LED indicators are driven from the logic circuitry. Voltage and current are monitored on front panel meters.

The power supply is substantially short-circuit proof. Tube protection is provided by a dual-trip system acting on both peak and mean helix overcurrent. Over-temperature and reverse-power overload trips are also provided. All trips apply Grid 1 cutoff bias and remove all operating voltages except heater.

CONCLUSION

With the development of a new high power broadband mm wave TWT, high frequency TWT technology has now advanced sufficiently to provide reliable devices for use in both industrial and military applications. ■

Frequency Range[1]	18.0 to 40 GHz
Saturated Power Output	
18 to 40 GHz	15 W Minimum
20 to 35 GHz	25 W Minimum
Gain at 15 W (18 to 40 GHz)	30 dB Minimum
Gain at 25 W (20 to 36 GHz)	40 dB Minimum
Noise Figure	37 dB Nominal
Cold Insertion Loss	80 dB minimum
Noise Power (18 to 40 GHz)	
Beam Off	−30 dB maximum
Beam On	+20 dBm maximum
Input and Output VSWR (cold)	2.3:1 maximum
Load VSWR	2.0:1 maximum
Typical Operating Conditions:	
Heater Voltage	6.5 V
Heater Current	0.55 A
Grid 1 Voltage	
Beam Off	−800 V
Beam On	−10 V
Grid 2 Voltage	4.5 kV
Cathode Voltage[2]	9.5 kV
Cathode Current	65 mA
Helix Current	1.5 mA
Collector Voltage[3]	3.5 kV
Physical Characteristics:	
Length	14.5 inches
Weight	2.5 kg

Notes:
1. Input and output are in double-ridged guide WRD-180C24 because the frequency range covers two waveguide bands. For applications not requiring the full frequency range, there are other designs which provide 20 watts at 18 to 26.5 GHz and 25 watts at 26.5 to 40 GHz.
2. Referenced to ground. All other voltages are referenced to cathode.
3. A two-stage depressed collector is available which increases efficiency.

Table 1. Specifications for MM Wave TWT.

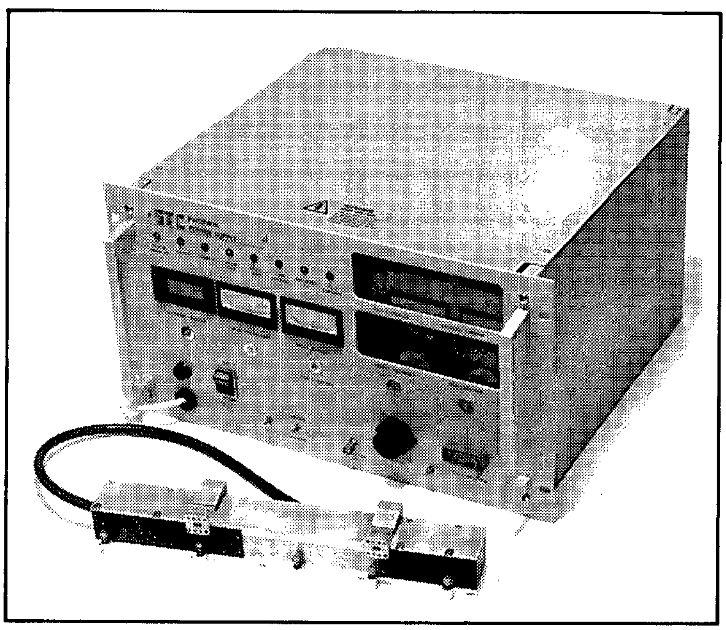

Figure 2. MM Wave TWT and Power Supply.