New Travelling Wave Tubes for L-Band and S-Band in Orbit Applications

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Abstract: *The ongoing development in satellite application requires more and more high power Travelling Wave Tubes (TWT) to relieve the requirements for end user terminals and to improve the quality and channel capacity of the satellite down link. Also more types of TWTs are demanded by the customers to obtain a higher flexibility in satellite design with respect to output power, weight and thermal requirements. THALES ELECTRON DEVICES (TED) therefore has filled up its portfolio of different TWTs for L-Band and S-Band. This paper will present some technical details and illustrate the performance of state-of-the-art tubes.*

Keywords: Travelling Wave Tube; TWT; L-Band; S-Band; Navigation Systems; Galileo; Giove A

Introduction

Satellite navigation systems operating in L-band and direct broadcast systems in S-band meanwhile have become well known satellite based systems. Both applications require more and more high power Travelling Wave Tubes (TWT) types. For navigation systems there is a need of increased resolution and high accuracy. This automatically leads to a demand for higher output power with simultaneous high stability requirements. For broadcast systems the robustness and the channel capacity is linked to higher output power. Typical the power requirement here is in the range of several kilowatts, which could at the moment only be realised by power combining of a high number of TWTs. With higher output powers on a satellite the thermal budget represents an important parameter in the development of a satellite system, and a radiation cooled type of a TWT which has heat dissipation directly into space could help here a lot.

THALES Electron Devices (TED) has now filled up the portfolio of the tubes for L- and S-band to react to actual market requirements. In L-Band the following TWTs can be offered: a new conduction cooled tube with an output power of up to 230 W, operating from 1.45 GHz to 1.65 GHz, and two radiation cooled tubes with an output power of up to 150 W, operating either from 1.15 GHz to 1.3 GHz or from 1.45 GHz to 1.65 GHz. For S-band there is a new radiation cooled tube with an output power of up to 230 W between 2.45 GHz and 2.65 GHz. Naturally all radiation cooled tube types are also available in conduction cooled version and could also be used with a linearisер in a non saturated operation mode.

Design and Typical Values

All L-band tubes are electrically based on a TWT which has meanwhile acquired an in-orbit-heritage in a satellite navigation system: the first Galileo test satellite (Giove-A) [1]. This tube was designed to operate in the range between 1.15 GHz and 1.6 GHz, which is now split in two bands. The TWT was increased in power, especially in the upper frequency band. The instantaneous bandwidth of these tubes ranges from 150 MHz at the lower band edge to 200 MHz at the higher band edge. The efficiency is in excess of 61 %, also for the 230 W tube. The efficiency can be further increased for narrowband designs. Table 1 shows the most important Figures for the L-band tubes.

	Medium Power	**High Power**
Output power	150 W	230 W
Efficiency	>62%	>61.5%
Phase shift	45 deg at 1.65 GHz	45 deg at 1.65 GHz
AM/PM conversion	3.2 deg/dB	3.5 deg/dB
Gain in Saturation	50 dB	42 dB
Mass for conduction cooled design	1950 g	1950 g
Mass for radiation cooled design	2675 g	-

Table 1. Typical figures of the L-band TWTs

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Figure 1 and Figure 2 shows the new types of L-band tubes.

Figure 1. L-band TWT with an output power of 150 W in radiation cooled design

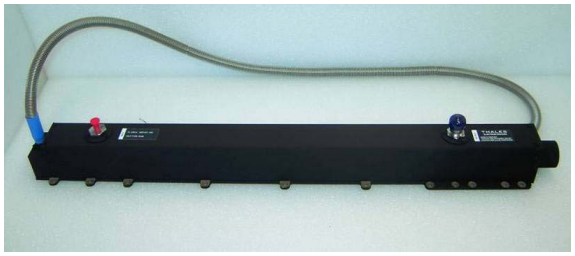

Figure 2. L-band TWT with an output power from 90 to 230 W in conduction cooled design

The new S-Band tube also has an electrical heritage in orbit: a 250 W conduction cooled narrowband tube is in operation on a Digital Radio broadcast satellite system. The new tube for Digital Radio application is also used in power combination and shows an excellent phase, amplitude and matching performance, as is needed in a power combining system. For thermal radiation cooling the big challenge was to design a radiator capable of radiating such a high power while not providing a too high mass with respect to the payload of the satellite.

Here a radiator diameter of 230 mm was chosen which radiates in saturation about 50 % of the dissipated power and in zero drive about 60 %. A white coating of the radiator leads to a low absorption but still a high emission coefficient (see Figure 3).

The tube design has a conspicuously increased efficiency with respect to the S-band tube today in orbit. This was reached with higher beam efficiency by a new helix design. The radiator is directly shrunken to the collector to obtain good thermal transfer characteristics and to provide the necessary mechanical stability. This results in remarkably high shock and vibration resistance. Table 2 summarises the figures of the new 230 W S-band tube.

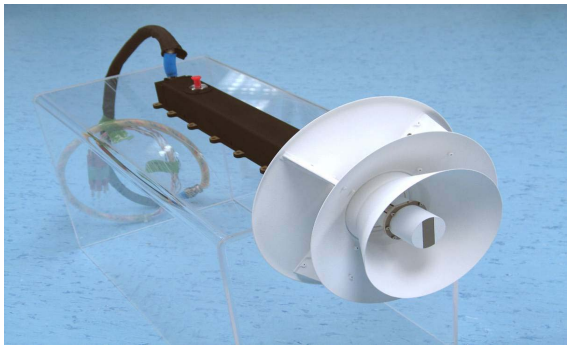

Figure 3. S-band TWT with an output power of 230 W in radiation cooled design

Output power	230 W
Efficiency	> 63 %
Phase shift	45 deg at 2.65 GHz
AM/PM conversion	3.8 deg/dB
Gain in Saturation	38 dB
Mass incl. radiator	2175 g
Random vibration (20Hz to 2000Hz)	> 20 g rms
Shock	4000 g

Table 2. Typical figures of the S-band 230 W TWT

Conclusion

With respect to satellite design requirements of the customers, calling for increasing power and higher flexibility, the portfolio of the L-band and S-band tubes of TED was significantly increased. In L-band meanwhile a tube with 230 W and an efficiency of more than 61 % is available. In S-band a radiation cooled tube with an output power of 230 W, an efficiency of more than 63 % and lowest possible mass was fully qualified.

Acknowledgement

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References:

1. Ehret, P., Monsees, T., Bosch, E. and Gerum, W. “Space Applications for L-Band Traveling Wave Tubes”, IVEC 2006, Monterey, CA.