Broadband L-Band Traveling Wave Tubes for Navigation Satellites

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ABSTRACT

Satellite navigation systems are an integral part of today's life and many countries have defined their own standards regarding frequency, output power and modulation schemes. The power amplifiers onboard the satellites have to fulfil these requirements, especially concerning the signal quality and linearity. The first navigation systems used solid-state power amplifiers (SSPAs) which limited power at that time. Later generations also used Traveling Wave Tube (TWT) amplifiers, which provide high output power and efficiency and which are also very robust with regards to the space environment. They are very resistant to radiation and also less sensitive to temperature swings than SSPAs and have demonstrated a life-time of more than 15 years with excellent Failure-In-Time (FIT) rates.

Despite these advantages, TWTs remain in a constant competition with SSPAs, which are improving with respect to power and efficiency and which can be easily combined with flexible array antennas. This competition drives the development of more efficient and better integrated concepts for TWT-based navigation satellites. The currently used concept employs three TWTs, one for each of the frequency bands E5, E6 and E1, along with a spare for each TWT, for a total of 6 TWTs.

There are currently some ideas for a lower-cost "augmented reconfigurable payload" (AURE-PL [1]) under discussion, with the goal to replace the three TWTs by a single broadband TWT, which would reduce the total number of TWTs from 6 to 2.

The E5 and E6 bands extend from (approx.) 1.15GHz to 1.3GHz, and the E1 band from 1.55GHz to 1.6GHz. The total necessary bandwidth is therefore ~33%, which is very high for a TWT, especially when operating in L-Band. At the same time, the power requirements are also high, between 200W in E5/E6 band to 230W in E1 band. To fulfil these requirements, a new broadband high-power TWT is developed on the basis of the TL1060, a low-power broadband tube which was used in the Galileo Giove-A mission. The large bandwidth requires trade-offs with respect to the efficiency of the tube.

A TWT itself is significantly nonlinear when operated near saturation for high efficiency. The gain compression and the phase compression are often compensated by a pre-distortion linearizer. In parallel to the development of the TWT there is also a development of a broadband linearizer, which puts further constraints on the TWT. The linearizer requires the gain and phase compression to not vary too strongly over the operating band. A concept of operating the TWT in frequency-dependent back-off has recently been developed, and there have been preliminary broadband measurements with navigation signals (BPSK and BOC modulation schemes). Further results on the new high-power TWT are expected shortly.

Figure 1: Thales L-Band Navigation TWT

[1] https://h2020nav.esa.int/project/h2020-011-01