# SIMULATION OF TRAVELING-WAVE TUBE MULTI-TONE BEHAVIOR

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## ABSTRACT

Traveling-wave tubes (TWTs) are high-power high-efficiency vacuum electronic amplifiers that are used predominantly in satellite space-to-ground communications. Recently, the modulation scheme of TWT for communication satellites has shifted from constant-envelope QPSK-modulation towards more involved schemes. This requires the development of sophisticated simulation procedures that can accurately predict the multi-carrier transmission behavior of TWTs to enable design and optimization of such an amplifier to its actual operating conditions.

During design a TWT is characterized by a range of single-carrier properties, such as the linear small-signal gain, saturation point, gain compression (AM-AM), non-linear phase shift (AM-PM), and harmonic power level. There are well-known and widely used figures of merit for multi-carrier operation which can be obtained by single-carrier simulation or measurement, as for example the intermodulation distortion IM3 and the phase transfer factor $k_T$ [1]. However, it is unclear how suitable these quantities are for the design process.

In this contribution, possible simulation approaches and recent progress in this field are presented. There are multiple distinct ways of evaluating the multi-tone behavior of a TWT. Time-domain based simulation tools, e.g., CST Particle Studio's particle-in-cell solver [2], are able to investigate a TWT with any type of input signal and allow study of, e.g., memory effects and stability issues, but have the disadvantage of being slow compared to frequency domain methods. An alternative proprietary time-domain tool [3], specialized on TWTs, is currently being developed at Thales and adapted for multi-tone excitation. It is significantly faster than general purpose tools and is very promising for this task. If the signal modulation time is substantially larger than any time constant of the TWT and the dispersion in a certain frequency band is negligible, a simple and fast approximation using a hybrid time- and frequency-domain can be utilized. This envelope-based method breaks down the TWT to a complex-valued transfer function. Each of these distinct methods is suitable under certain conditions and has its respective advantages and disadvantages. Therefore a study of the presented approaches is the focus of this work.

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