



Computer Aided Design Tools for Traveling Wave Tubes

Traveling wave tubes (TWTs) are used to provide micro-wave and millimeter-wave power amplification in modern radar, communications, and electronic countermeasures systems. Figure 1 shows a schematic diagram of a traveling wave tube employing a helix slow wave circuit.

Design of these complex devices relies heavily on computer simulations that solve the differential equations governing electron motion in electromagnetic fields that are due both to external sources and to the electron beam itself. Sophisticated models of (i) the emission of electrons from a cathode, (ii) beam forming in an electron gun, (iii) interaction between the electron beam and a synchronous wave carried on a periodic structure, and (iv) collection of the spent beam have all been developed and implemented in modern simulation codes by ESTD personnel and their collaborators at SAIC, AWR/STAAR, Gnosys, University of Maryland, and Los Alamos National Laboratory. In addition to being heavily used in ESTD

research, these well validated codes have become widely used standards for design and analysis in the U.S. vacuum electronics manufacturing industry.

The suite of codes includes MICHELLE, an R&D 100 award winning 3D electron optics code for the design of electron guns and collectors; CHRISTINE, a family of steady-state beam-wave interaction codes for small and large signal multifrequency analysis of helix, coupled-cavity, and folded-waveguide TWTs; and TELSA, a 2D simulation code for the analysis of coupled-cavity and folded waveguide TWTs.

Figure 2 illustrates a MICHELLE simulation of an electron gun used in a pulsed TWT built by Communications and Power Industries. This gun employs a fine wire grid placed very close to the cathode to turn the beam on and off. MICHELLE was the first code to simulate such a gridded gun successfully.

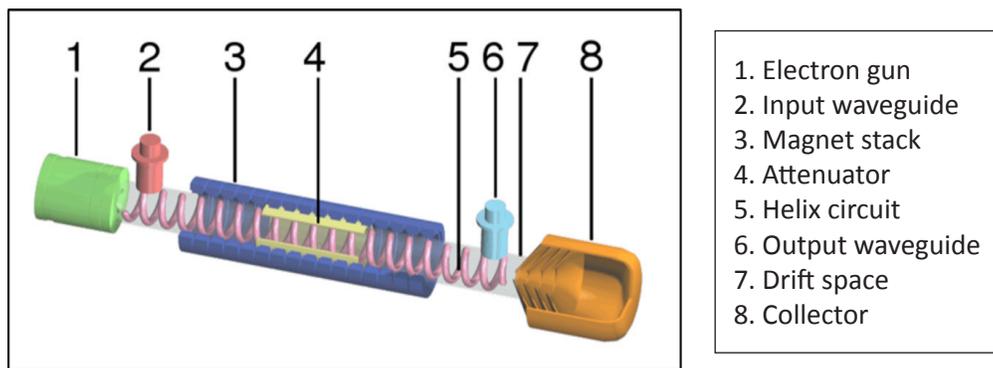


Fig. 1: Schematic diagram of a helix traveling wave tube (from Wikipedia).

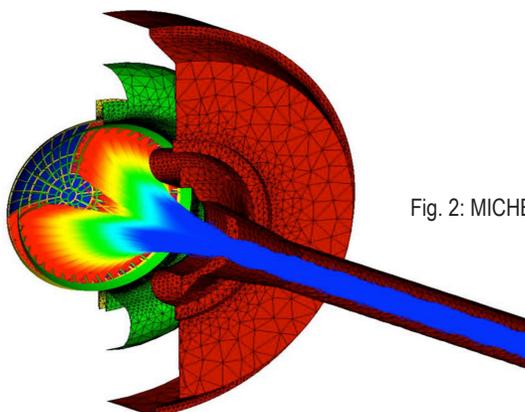


Fig. 2: MICHELLE 3D simulation of a gridded electron gun.

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(continued)

Figure 3 is an example of results from the large-signal simulation code TESLA applied to a Ka-band coupled-cavity TWT using periodic permanent magnet (PPM) focusing. The figure illustrates the excellent agreement between code predictions and measurements of output power vs. frequency, under both small and large signal conditions.

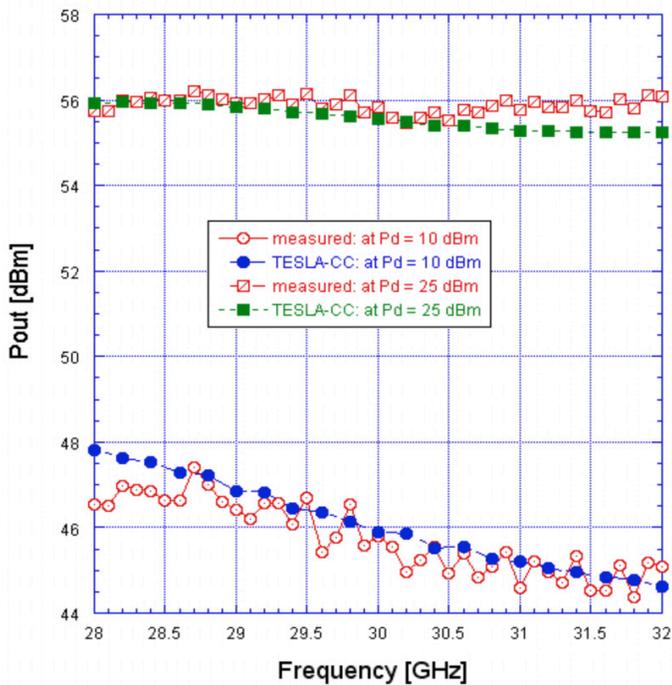


Fig. 3: Output power of a coupled-cavity TWT as computed by TESLA and as measured, for two different values of input power.

The CHRISTINE code family is designed to simulate the amplification of either single or multi-tone signals. The nonlinear theory on which the codes are based ensures that harmonic generation and intermodulation of the tones are properly modeled. A stringent test of this capability is illustrated in Figure 4, where we demonstrate the accuracy with which the noise-power ratio (NPR) may be computed for a helix TWT. This quantity is an important figure of merit for digital communications systems. It is obtained by applying an input signal to the TWT in the form of Gaussian noise from which a finite width “notch” in the power spectrum has been removed. The NPR is then defined as the ratio of the power of the spectral components in the passband to those in the notch, at the output of the amplifier.

The predictive capabilities of MICHELLE, TESLA, and CHRISTINE, demonstrated in many applications by many users over many years, enables users to rely on these codes with confidence to help optimize their designs and meet their customers’ requirements quickly, efficiently, and inexpensively.

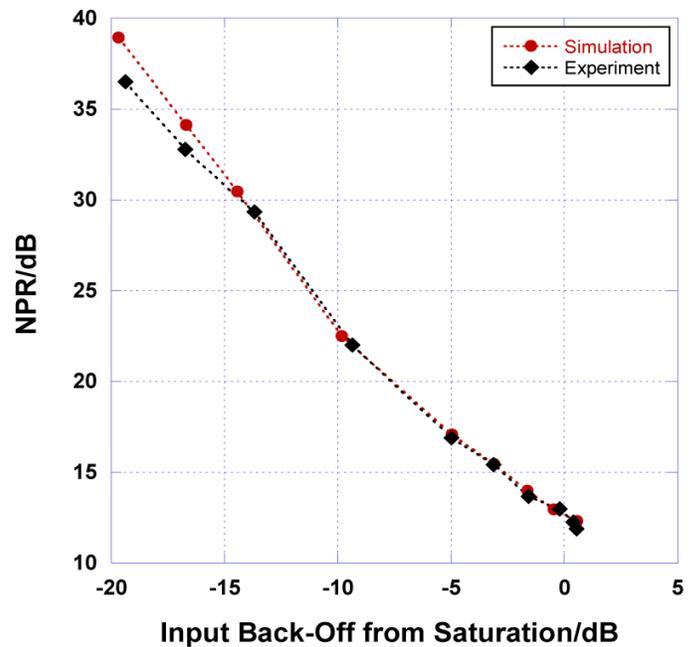


Fig. 4: Noise-power ratio vs. input power for a Hughes 8537H L-band helix TWT as computed by CHRISTINE and as measured.