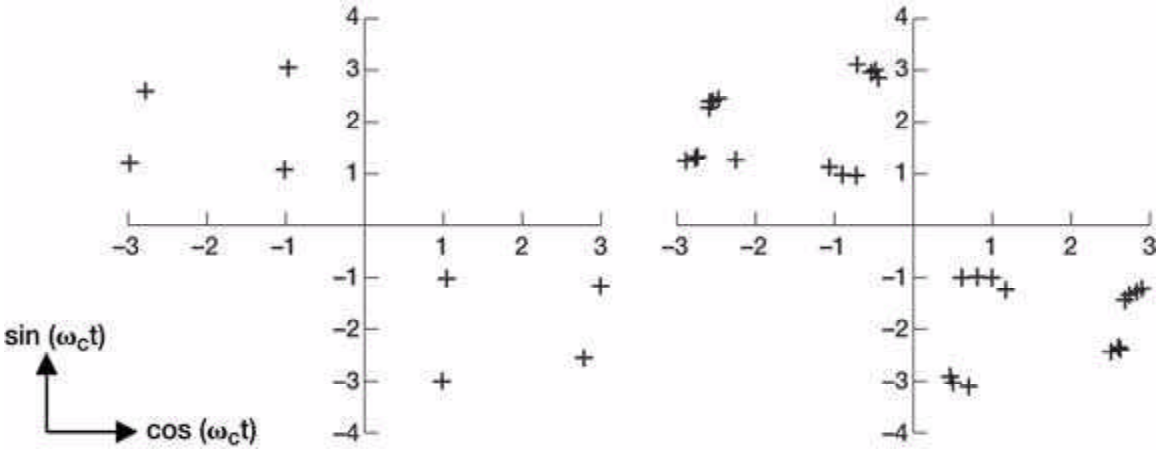
Digital Distortion Caused by Traveling-Wave-Tube Amplifiers Simulated

Future NASA missions demand increased data rates in satellite communications for near real-time transmission of large volumes of remote data. Increased data rates necessitate higher order digital modulation schemes and larger system bandwidth, which place stricter requirements on the allowable distortion caused by the high-power amplifier, or the traveling-wave-tube amplifier (TWTA). In particular, intersymbol interference caused by the TWTA becomes a major consideration for accurate data detection at the receiver. Experimentally investigating the effects of the physical TWTA on intersymbol interference would be prohibitively expensive, as it would require manufacturing numerous amplifiers in addition to acquiring the required digital hardware. Thus, an accurate computational model is essential to predict the effects of the TWTA on system-level performance when a communication system is being designed with adequate digital integrity for high data rates.

A fully three-dimensional, time-dependent, TWT interaction model has been developed (ref. 1) using the electromagnetic particle-in-cell code MAFIA (Solution of Maxwell's equations by the Finite-Integration-Algorithm, ref. 2). It comprehensively takes into account the effects of frequency-dependent AM (amplitude modulation)/AM and AM/PM (phase modulation) conversion, gain and phase ripple due to reflections, drive-induced oscillations, harmonic generation, intermodulation products, and backward waves. This physics-based TWT model can be used to give a direct description of the effects of the nonlinear TWT on the operational signal as a function of the physical device. Users can define arbitrary excitation functions so that higher order modulated digital signals can be used as input and that computations can directly correlate intersymbol interference with TWT parameters.



16-ary quadrature amplitude modulation (16-QAM) constellation diagram (7-dB input backoff). Left: SPW. Right: MAFIA.

Long description: Center frequency, 4.2 GHz; input backoff, 7 dB; sin $\omega_c t$ versus cos $\omega_c t$.

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Standard practice involves using communication-system-level software packages, such as SPW (ref. 3), to predict if adequate signal detection will be achieved. These models use a nonlinear, black-box model to represent the TWTA. The models vary in complexity, but most make several assumptions regarding the operation of the high-power amplifier. When the MAFIA TWT interaction model was used, these assumptions were found to be in significant error (ref. 4). In addition, digital signal performance, including intersymbol interference, was compared using direct data input into the MAFIA model and using the system-level analysis tool SPW for several higher order modulation schemes. Results show significant differences in predicted degradation between SPW and MAFIA simulations, demonstrating the significance of the TWTA approximations made in the SPW model on digital signal performance. For example, the figure compares the SPW and MAFIA output constellation diagrams for a 16-ary quadrature amplitude modulation (16-QAM) signal (data shown only for second and fourth quadrants). The upper-bound degradation was calculated from the corresponding eye diagrams (not shown). In comparison to SPW simulations, the MAFIA data resulted in a 3.6-dB larger degradation.

Find out more about this research:
Electron Device Technology Branch http://ctd.grc.nasa.gov/5620/5620.html
Digital Communications Technology Branch http://ctd.grc.nasa.gov/5650/5650.html

References

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