Synchronization and Transition to Chaos in a Driven Traveling Wave Tube Oscillator with Delayed Feedback

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Application of chaos in communication and radar systems offers new and interesting possibilities. Among chaotic waveform vacuum microwave sources, a broadband delayed feedback traveling wave tube (TWT) oscillator is one of the most promising. Generation of chaos in a TWT oscillator has been studied in many works, both theoretical and experimental. Recently its application to chaotic communication has been considered theoretically (V. Dronov et al., Chaos, Vol. 14, 30-37, 2004). A concept of TWT delayed feedback oscillator driven by an external harmonic signal has been suggested and proved in experiment and numerical simulations in (C. Marchewka et al., Phys. Plasmas, Vol. 13, No. 1, 2006). The oscillator consists of a TWT amplifier with an external recirculated feedback circuit containing a passband filter, variable attenuator, and phase shifter. Those elements are used for precise control of the oscillation regimes. An external driving source is applied to provide stable “robust” chaotic generation in a wide range of parameters. A feasibility of information transmission with chaotic TWT oscillator has been demonstrated experimentally for the first time.

In this paper, a numerical model of the TWT oscillator in a form of a time-delayed differential equation will be described, and detailed results of numerical simulations of the driven TWT oscillator will be presented. Bifurcation maps on the parameter plane driving amplitude — driving frequency will be plotted. Basic scenario of synchronization as well as transition to chaos with the increase of the driving power will be investigated. A special attention will be paid to a “fine structure” of the loss-of-frequency-locking chaos which has been discovered experimentally in (C. Marchewka et al., Phys. Plasmas, Vol. 13, No. 1, 2006) in a close vicinity of synchronization tongues. The numerical results will be compared with the experimental ones.