TREND Project

Experimental Study Nonlinear and Chaotic Microwave Circuits

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Background: A recently published theory predicted that traveling-wave tube amplifiers (TWT), which are utilized as the final gain stage in many RF communications systems (e.g. space), will generate oscillations with chaotic amplitude if a small, time-delayed sample of the output power is fed back to the input [1]. The theory was based on a simplified second-order model of gain nonlinearity in these electron tubes. However, this may not be a realistic predictor of the dynamics in practice since it is often the case that fifth or higher order nonlinearities exists in real devices. Thus, it would be of significant scientific value if the theory could be validated experimentally.

Description: We propose that the TREND student conduct an experiment, which is shown schematically in Fig. 1, designed to measure the frequency, gain and nonlinear characteristics in an L-band space TWT. The student will incorporate the TWT into a delayed feedback circuit and study the conditions under which chaotic oscillations are generated. Time series of the RF amplitude will be digitally recorded as the feedback gain is varied. The data will be analyzed using chaotic attractor maps, as shown in Fig. 2, and other numerical techniques to reveal the underlying nonlinear dynamics in the system.

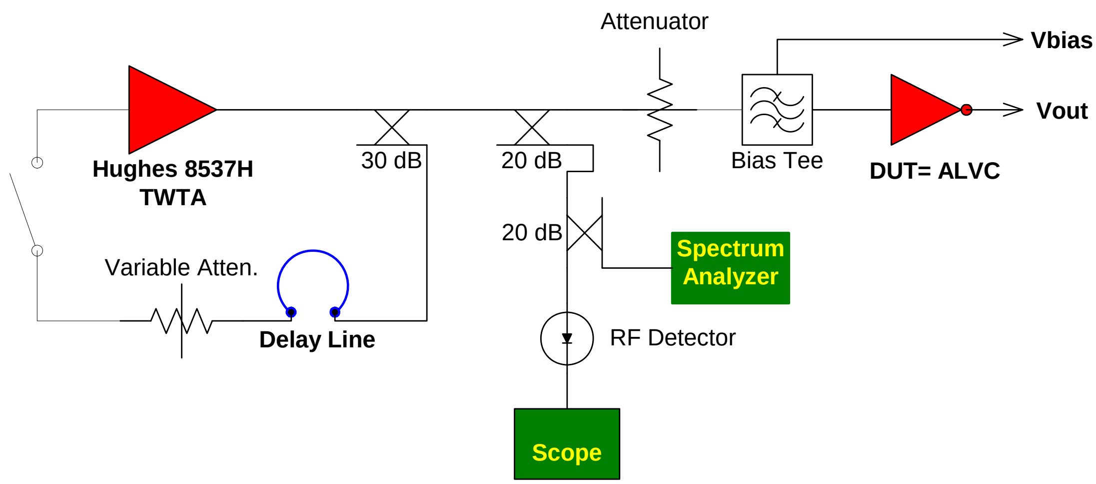

Fig. 1 Schematic of the proposed experiment showing the delayed feedback circuit and the various RF instruments for measuring the chaotic oscillations in the TWT

[1.] V. Dronov, M. R. Hendrey, T. M. Antonsen, Jr., and E. Ott, “Communication with a chaotic traveling wave tube microwave generator,” *CHAOS* 14 (1): March 30-37, 2004.

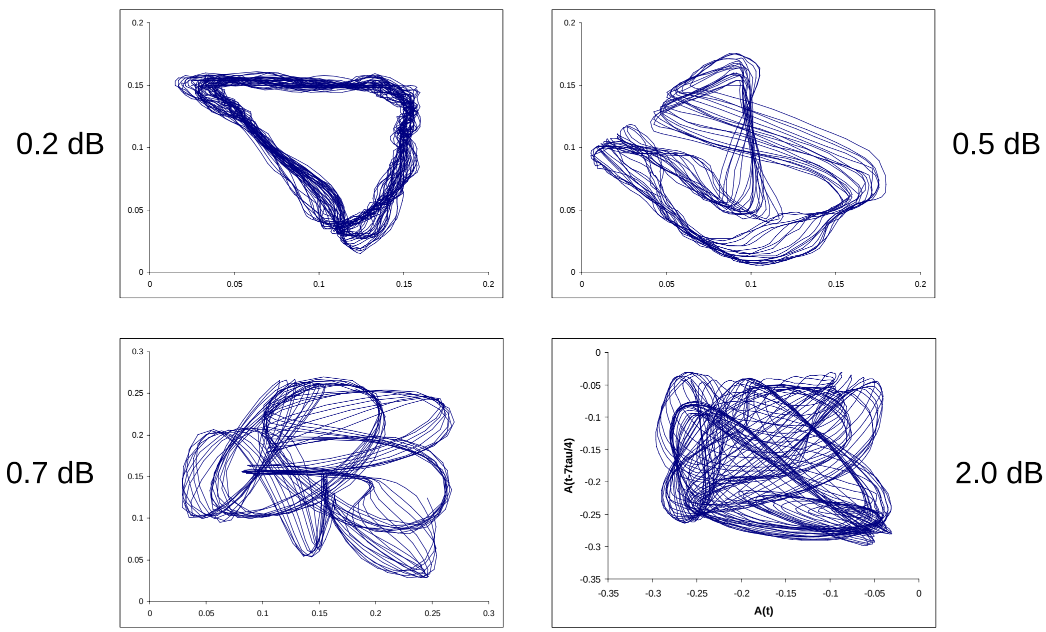

Fig. 2 Sequence of attractor maps of the RF amplitude at the output of a TWT as the feedback gain is increased. The evolution from simple periodic orbits when the gain is 0.2 dB to much more complicated behavior is observed.

If time permits, the student will also conduct a test to see if the chaotic RF generated by the TWT is more effective than a coherent signal at exciting nonlinear effects in digital communications systems. It has been suggested that simple networks of logic gates could be driven into unstable or chaotic conditions by a chaotic signal. These effects have never been experimentally demonstrated, but are of great concern because of the potential for these sources to be used in RF attacks on critical information infrastructures.

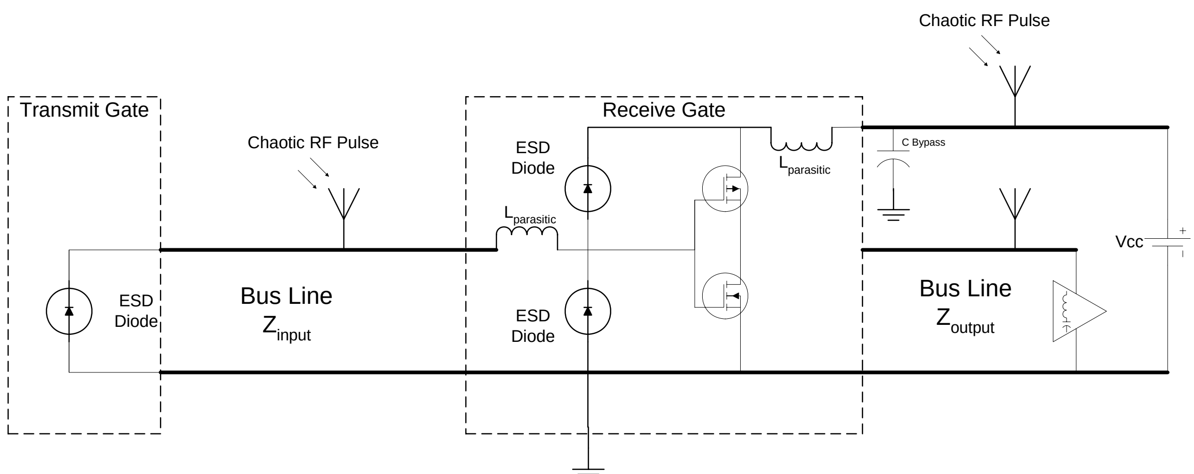

Fig. 3 Schematic of the basic electronic devices common to all digital communication systems and the circuit elements that are vulnerable to attack by chaotic RF.