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IREAP

Traveling-Wave Tube Chaotic Oscillators and Application as a Source of RF Effects in Advanced CMOS

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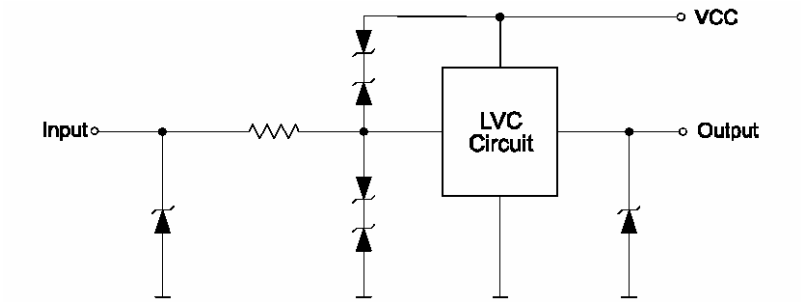
Motivation

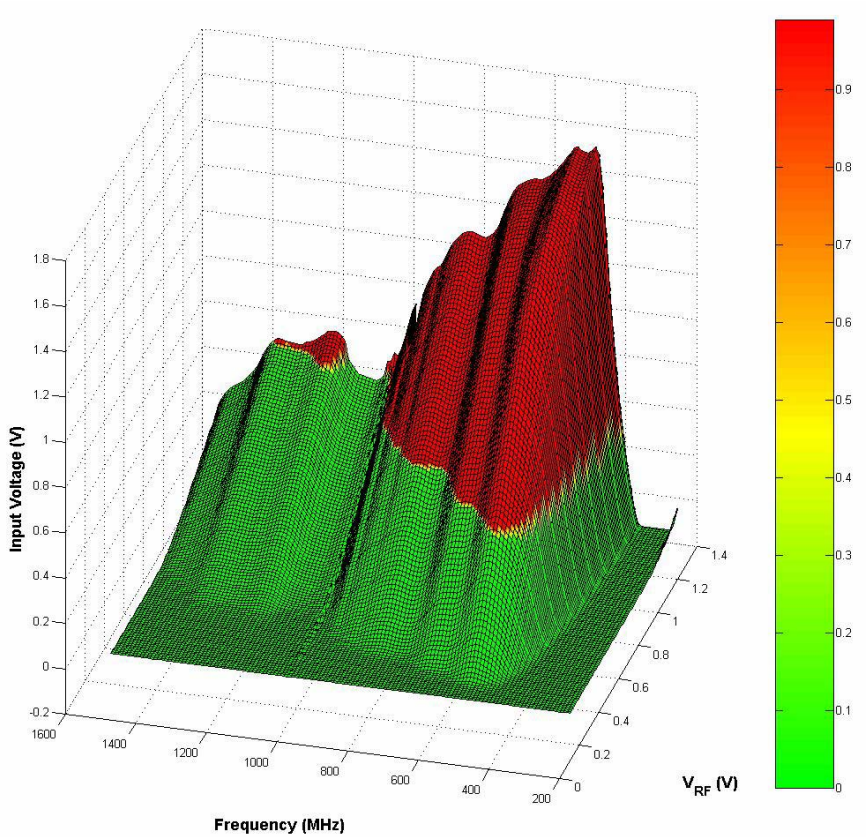


•Advanced CMOS circuits have complicated networks of nonlinear devices designed to protect sensitive gates from high static voltages (ESD).

•Coupled with the parasitic inductance of bonding wires and traces, many CMOS circuits resonate at microwave frequencies, or the diodes may rectify the modulation frequencies off the carrier and generate circuit instability.

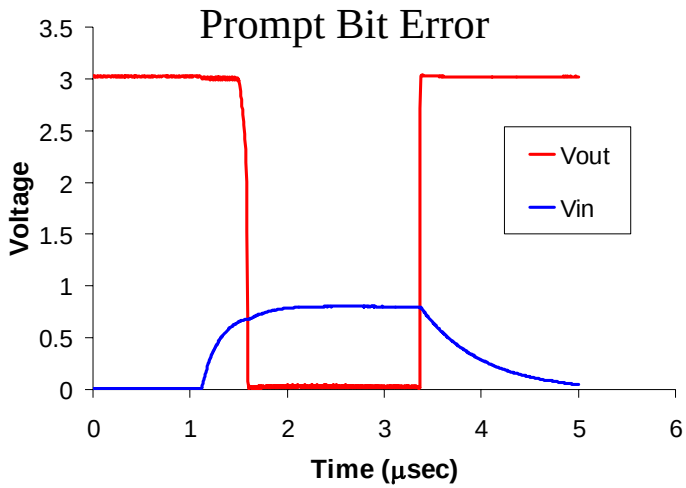
•We are studying nonlinear response in circuits and are developing sources that take advantage of these vulnerabilities.

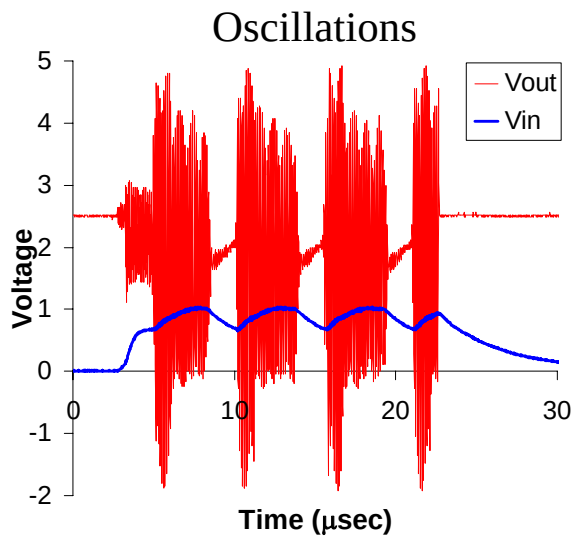
•Microwave amplifiers configured as chaotic oscillators have proven to be effective at generating upset in advanced CMOS.

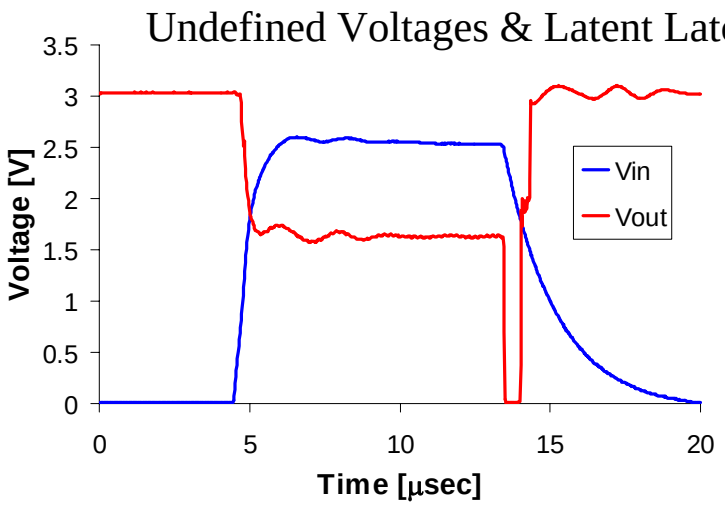


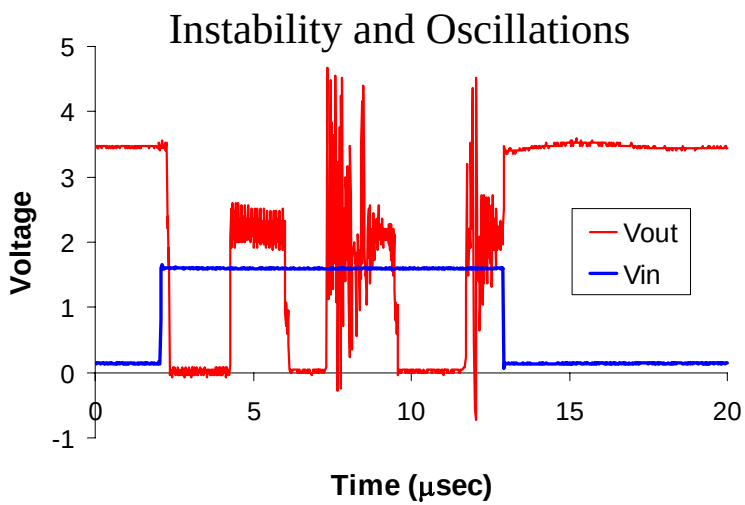
Measured mapping of CMOS response characteristics: red regions are where microwave pulses cause upset (sustained latch of output at error bit)

Effects Caused by Rectification and Parasitic Resonances when Microwave Pulses Excite ESD Networks at CMOS Input

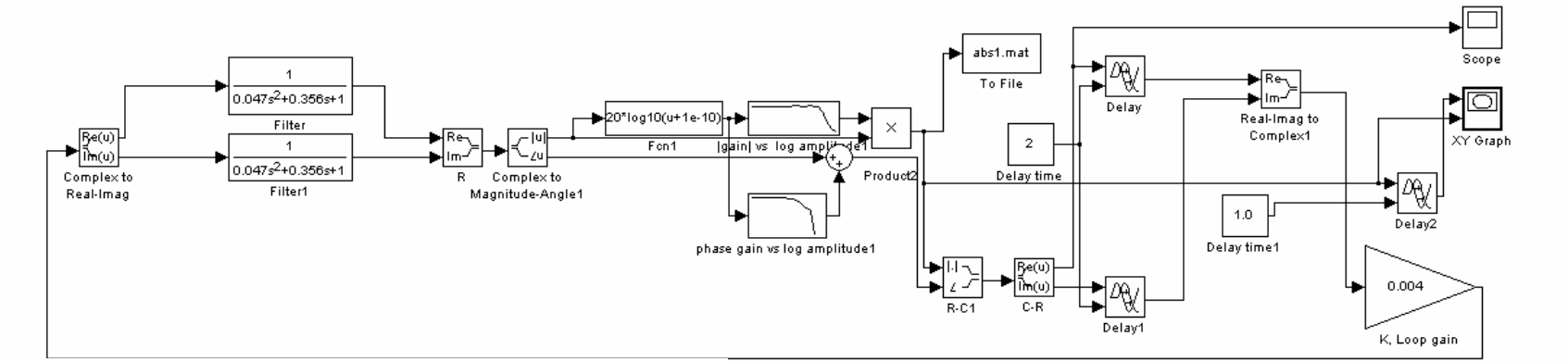


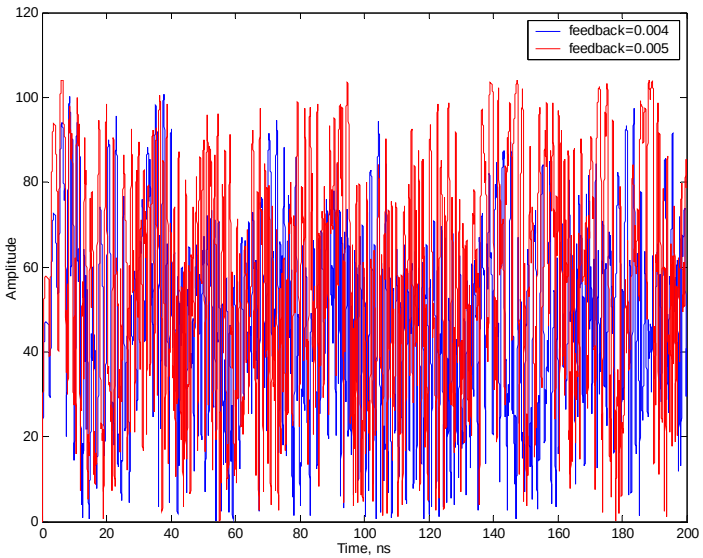




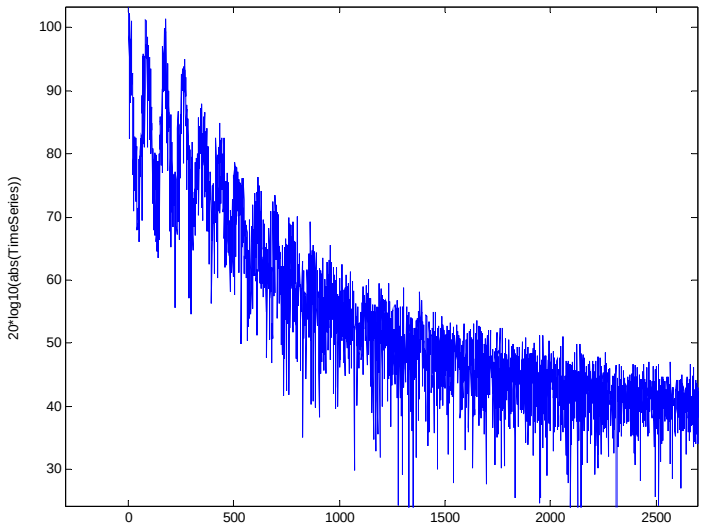


Model of Chaotic Oscillations in a TWT with Time-delayed Feedback



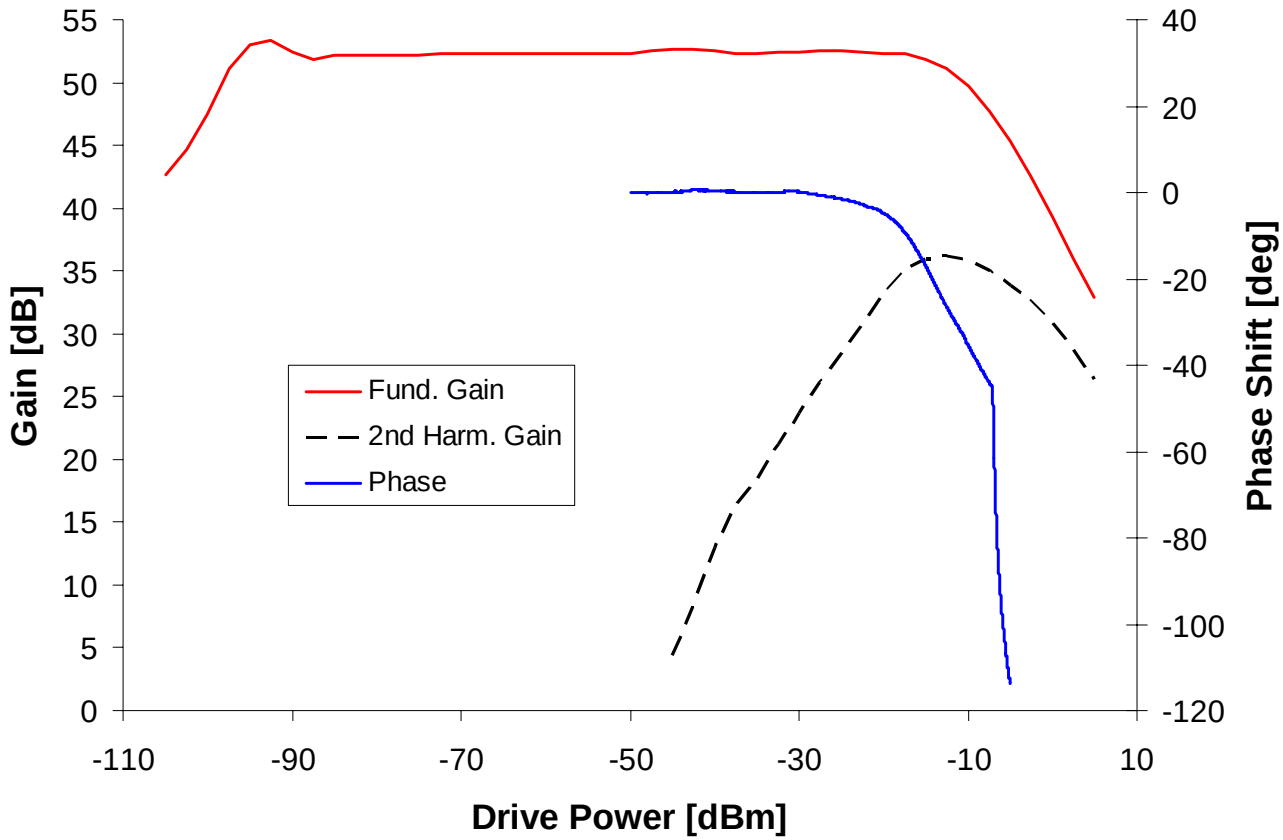


Amplitude vs. Time

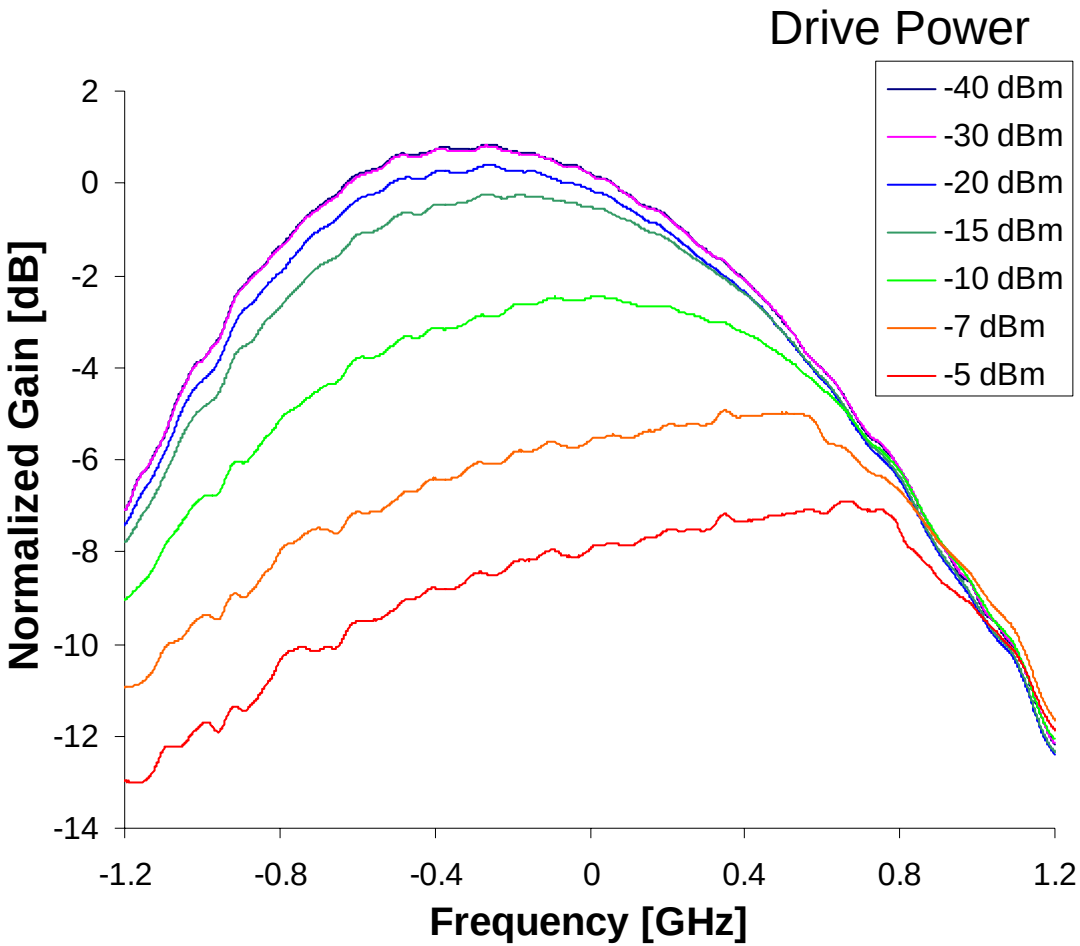


Spectrum

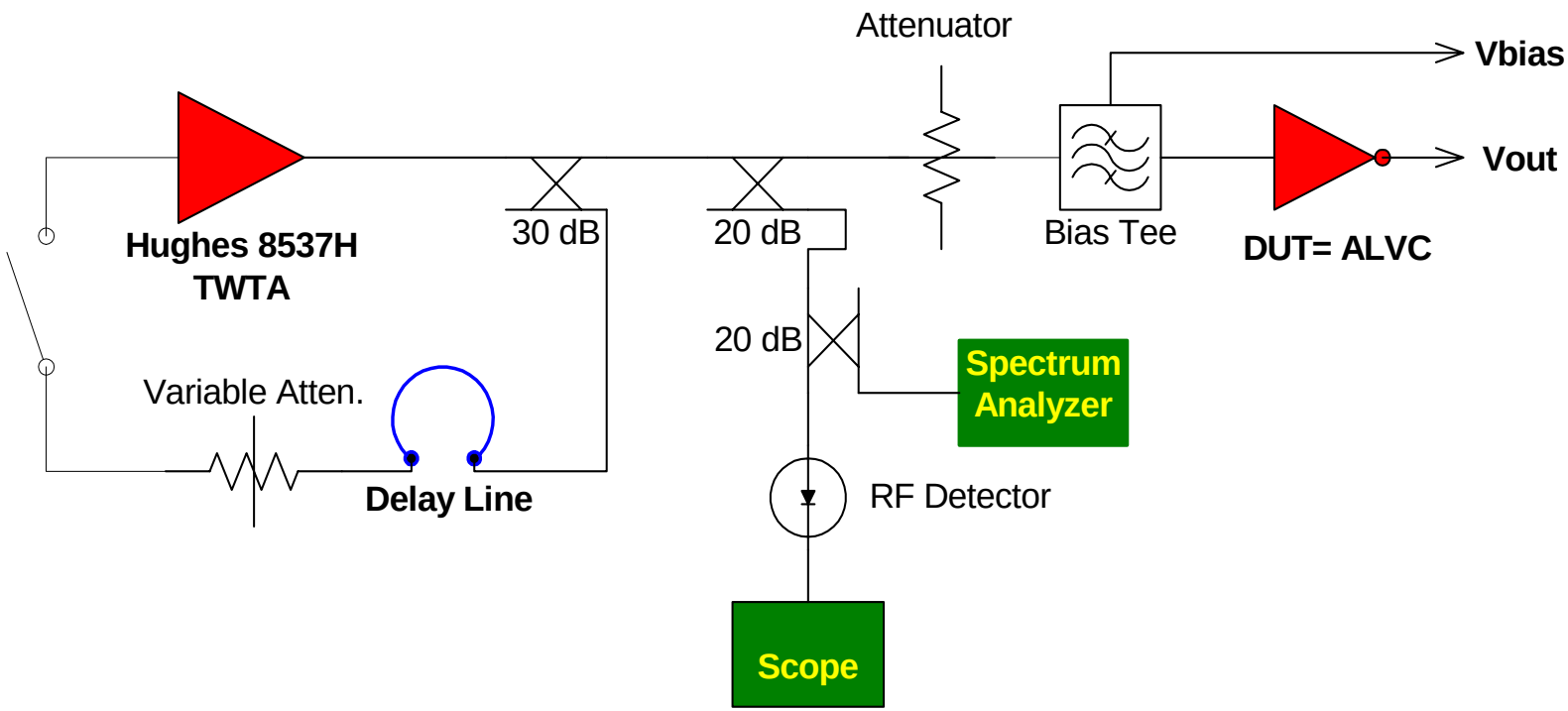
Measured Mid-band Gain and Phase Characteristics of L-band TWT



Measured Saturated Gain Characteristics

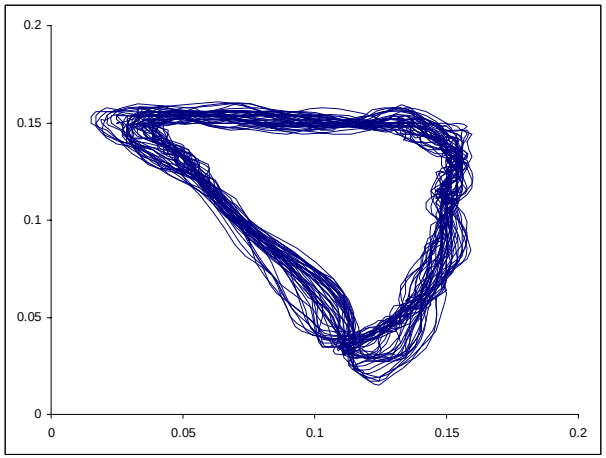


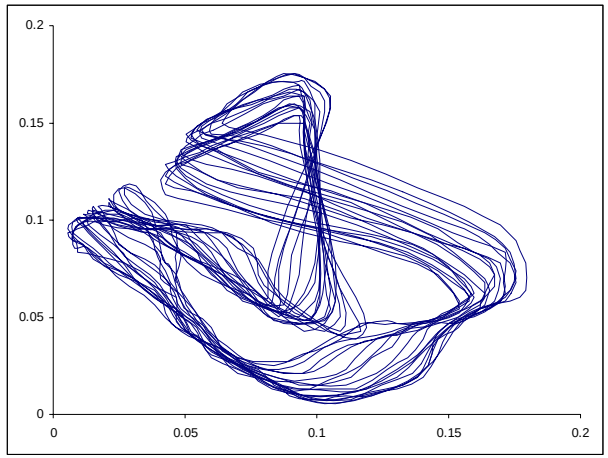
Schematic of Chaotic Oscillator Circuit



Sequence of Attractor Maps as Feedback Gain is Increased

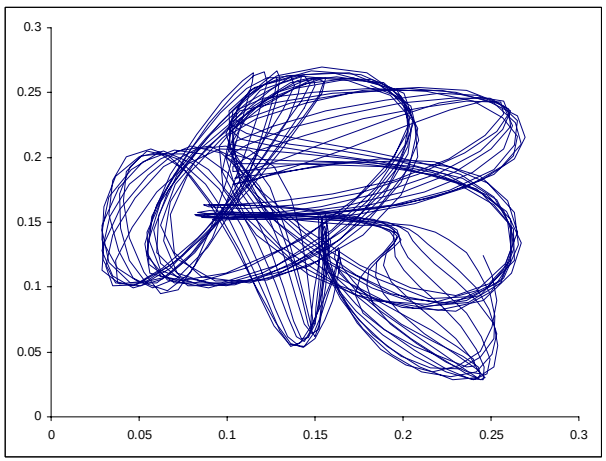
0.2 dB

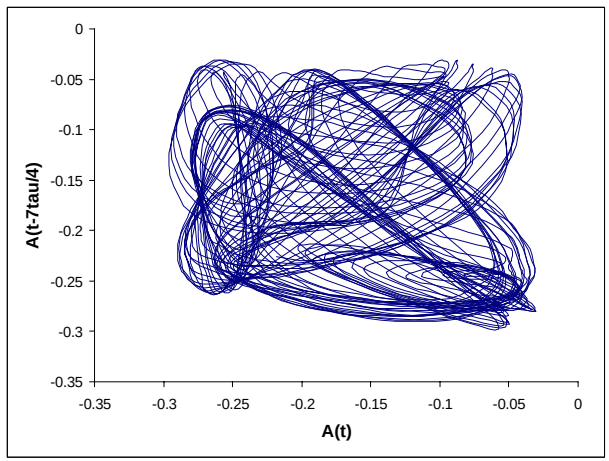




0.5 dB

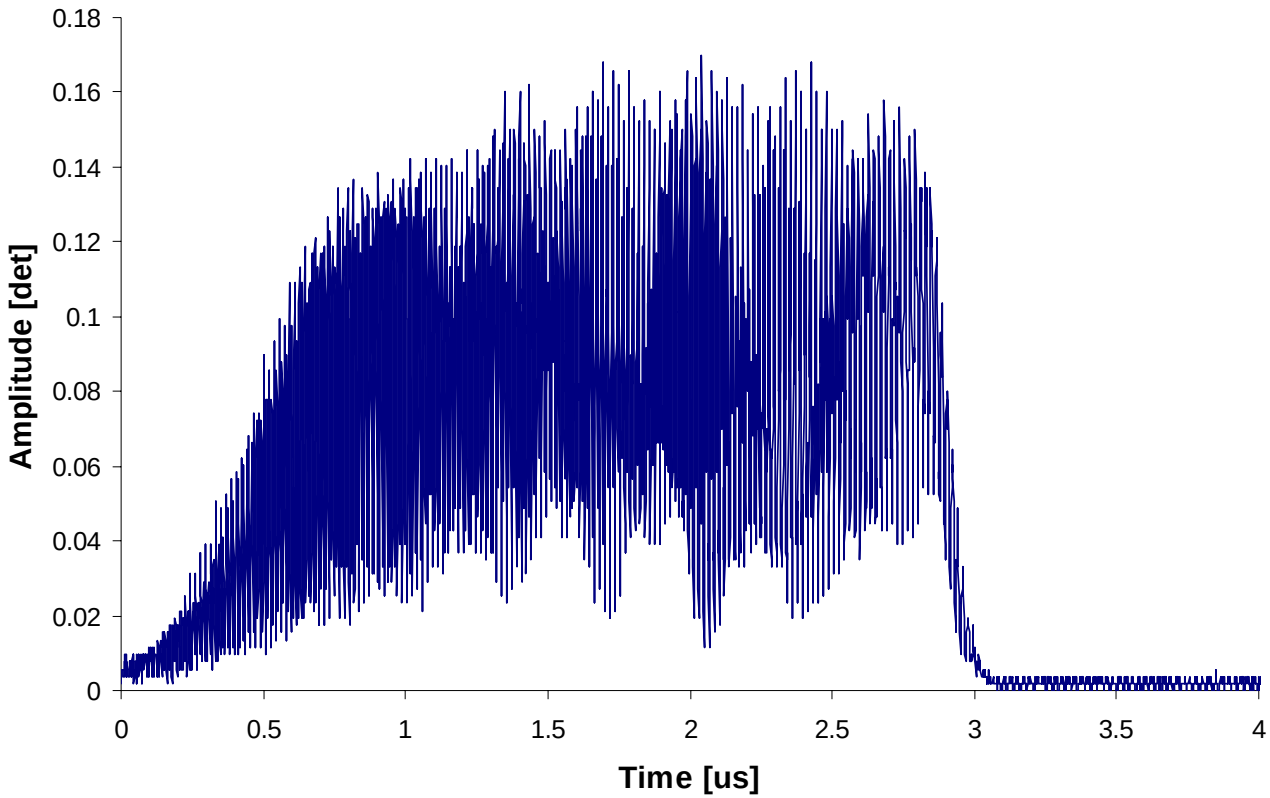
0.7 dB



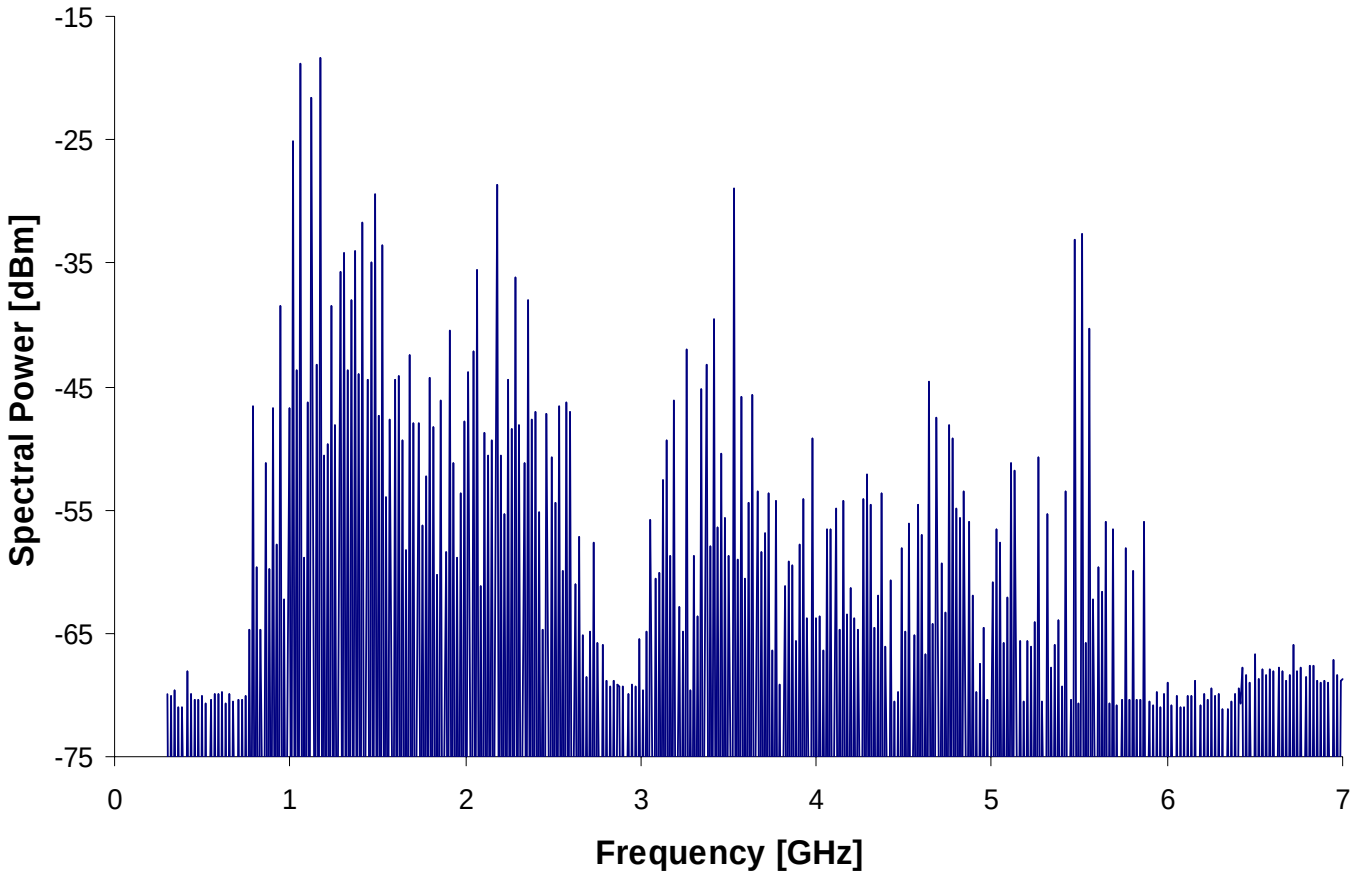


2.0 dB

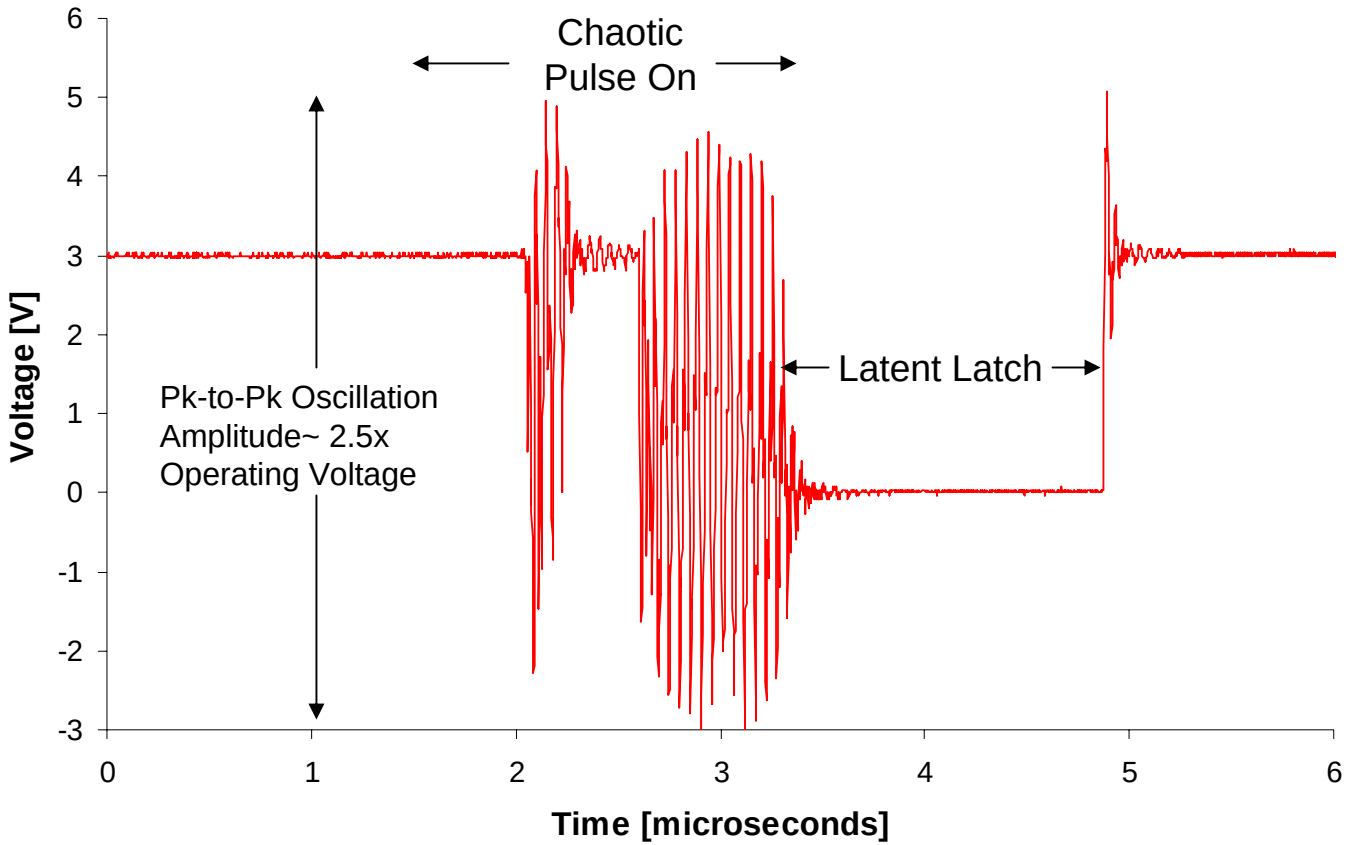
TWT Output Amplitude vs. Time



Spectrum of RF Pulse from TWT

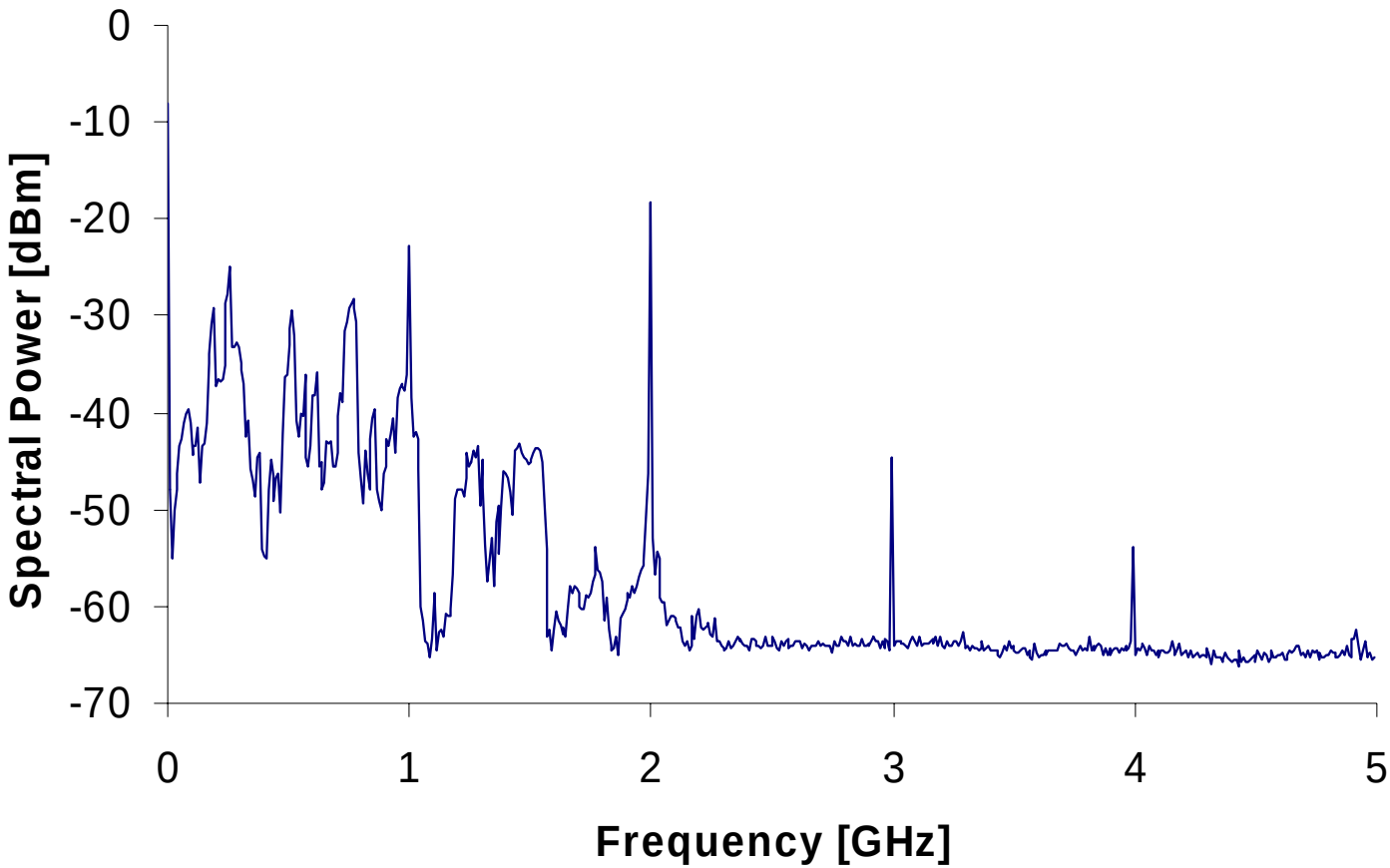


Output Voltage from Advanced CMOS (3.3V ALVC) Inverter Excited by Pulsed, Chaotic Signal (500 mV RMS)



Parasitic elements in the CMOS circuit are driven into oscillation by the wideband modulation on the chaotic RF pulse. These frequencies are demodulated off the carrier by nonlinear elements (ESD protection diodes) at the device input.

Spectrum of the CMOS Output Voltage



Conclusions

- The nonlinear gain characteristics of TWT's along with time-delay in the feedback circuit generate extremely wideband oscillations with amplitude swings from near noise to saturated levels in a few RF cycles.
- This fast amplitude modulation takes advantage of high-frequency resonances and nonlinearity in advanced CMOS and makes an effective source that exploits these vulnerabilities.
- **Future Work**: We will study the PASOTRON (1-3 MW, 1.2 GHz tube w/plasma cathode) configured as a chaotic oscillator for applications such as vehicle stopping, explosive device clearing and WMD countermeasures.