EXPERIMENTAL STUDY OF CHAOTIC OSCILLATION IN TRAVELING WAVE TUBE AMPLIFIERS

Lindsey Goodman
Dr. John Rodgers, Advisor
Todd Firestone, Graduate Student
TREND, Summer 2005
University of Maryland, College Park
TRAVELING WAVE TUBE (TWT) AMPLIFIERS

- Used in satellites and terrestrial communications to amplify RF signals

- RF wave on helix interacts with electron beam to become amplified

- Gain characteristics of each tube are different and dependent on
  - Input wave frequency
  - Input wave amplitude

- TWT amplifies signals within a specified bandwidth
  - Much like a bandpass filter

Cutaway view of a TWTA.

(1) Electron gun
(2) RF input
(3) Magnets
(4) Attenuator
(5) Helix coil
(6) RF output
(7) Vacuum tube
(8) Collector
GOAL AND EXPERIMENT

- Investigate gain characteristics of the Hughes 10 watt 8524H TWT
- Study nonlinear dynamics of a TWT feedback oscillator
- Experimentally determine conditions leading to generation of chaotic oscillations by the system

Schematic of Time Delayed Feedback Experiment
EXPERIMENTAL INVESTIGATION OF NONLINEAR GAIN CHARACTERISTICS

Gain Curves

Gain Bandwidth of 8524H TWT Amplifier

Harmonic Gain, Driven at 3.2GHz

Phase Nonlinearity

AM-PM Conversion

Input Power (dB)

Frequency (GHz)

Power Output (dB)

Gain (dB)
MODEL

Consisting of

- Bandpass filter
- Transfer functions that modulate the simulated feedback
  - AM-AM
  - AM-PM
RESULTS - MODEL

FROM LEFT: AMPLITUDE TIME SERIES, FREQUENCY SPECTRA AND ATTRACTOR PLOTS FOR VARIOUS FEEDBACK GAIN VALUES

Gain < 1

Gain ~ 1

Gain >> 1
REGIME:

- Stable, gain $<1$
- Linear, gain $\sim 1$
- Nonlinear, gain $>1$
- Chaotic, gain $>>1$

RESULTS: EXPERIMENTAL
**DEPENDENCE ON INITIAL CONDITIONS**

1. Start with high feedback gain (chaotic state), steadily decrease

2. Start with low feedback gain (stable state), steadily increase

**Hysteresis:**
State of the system tends to depend on previous conditions as well as the current state
CONCLUSIONS

Experimental waveforms and frequency spectra show:

• **Feedback Gain <1**: Output is a steady signal of zero amplitude

• **Feedback Gain ≈ 1**: Tube operates in linear regime. Output appears periodic. Resonant frequencies slightly amplified. Gain fluctuates close to 1 due to noise in the system

• **Feedback Gain >1**: Amplification of a single frequency. Stable oscillations

• **Feedback Gain >>1**: Wide band chaotic oscillations

• **Hysteresis**: Tube does not have discrete states for each gain. Current state is dependent on initial conditions and history of the system

**THANK YOU**