EXPERIMENTAL STUDY OF CHAOTIC OSCILLATION IN TRAVELING WAVE TUBE AMPLIFIERS

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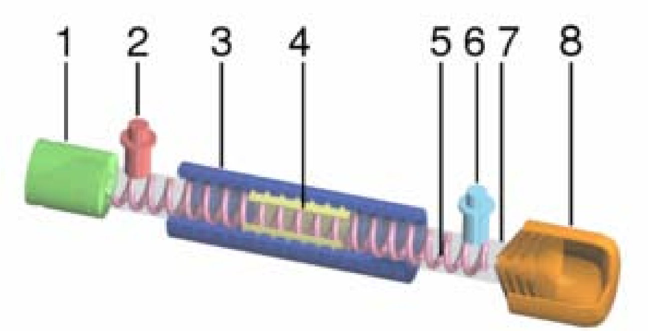
TRAVELING WAVE TUBE (TWT) AMPLIFIERS



Cutaway view of a TWTA.

(1) Electron gun

(2) RF input

(3) Magnets

(4) Attenuator

(5) Helix coil

(6) RF output

(7) Vacuum tube

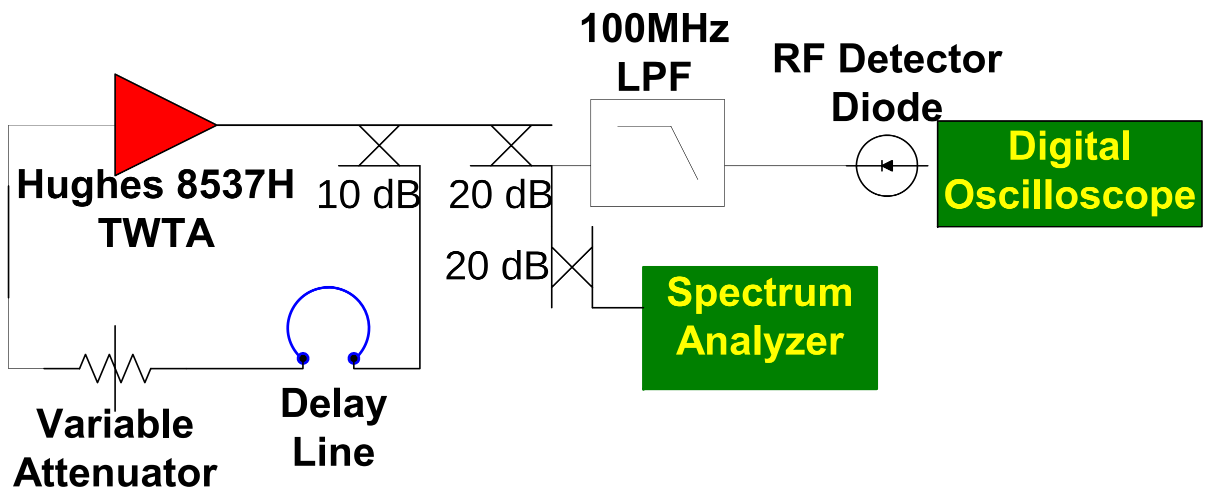
(8) Collector

- 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

GOAL AND EXPERIMENT

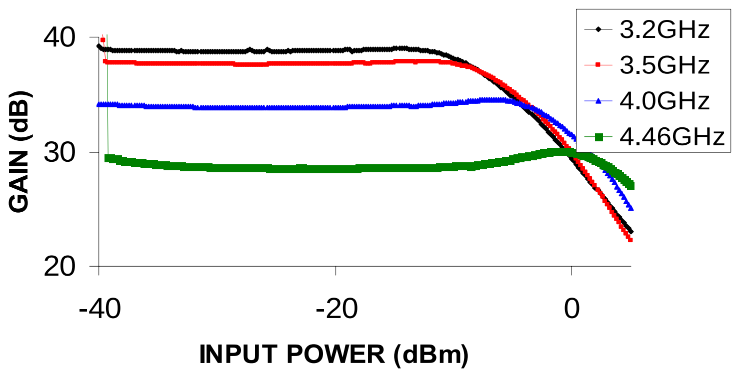
- Investigate gain characteristics of the Hughes 10 watt 8524H TWT
- Study nonlinear dynamics of a TWT feedback oscillator
- Experimentally determine conditions leading to generation of chaotic oscillations by the system

Schematic of Time Delayed Feedback Experiment

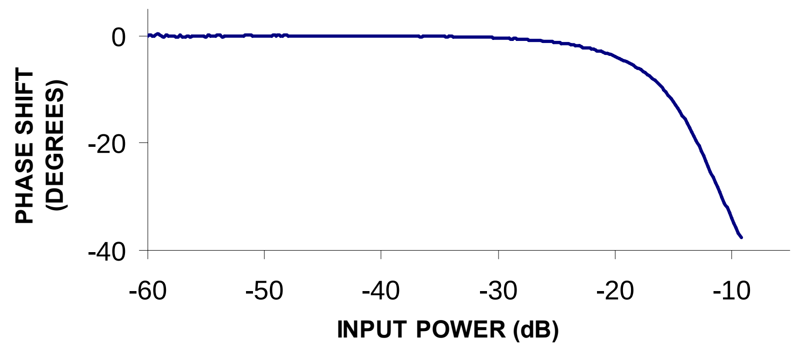


EXPERIMENTAL INVESTIGATION OF NONLINEAR GAIN CHARACTERISTICS

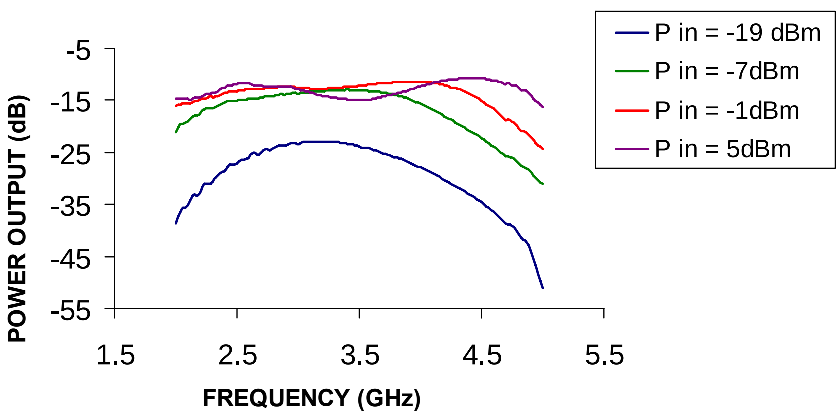
GAIN CURVES



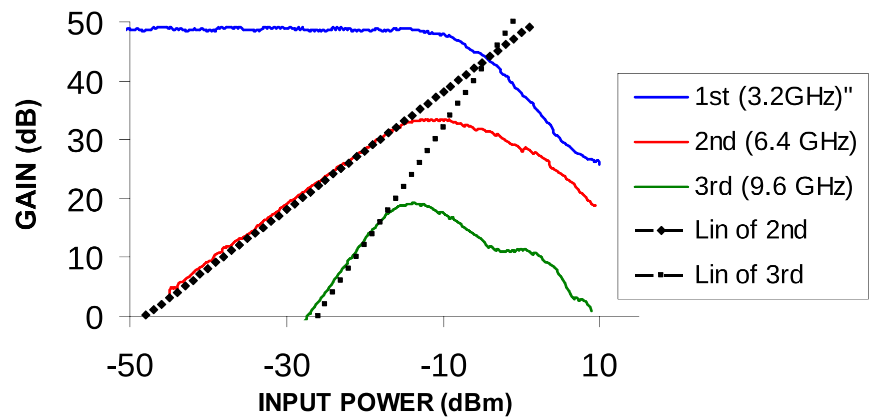
PHASE NONLINEARITY
AM-PM CONVERSION



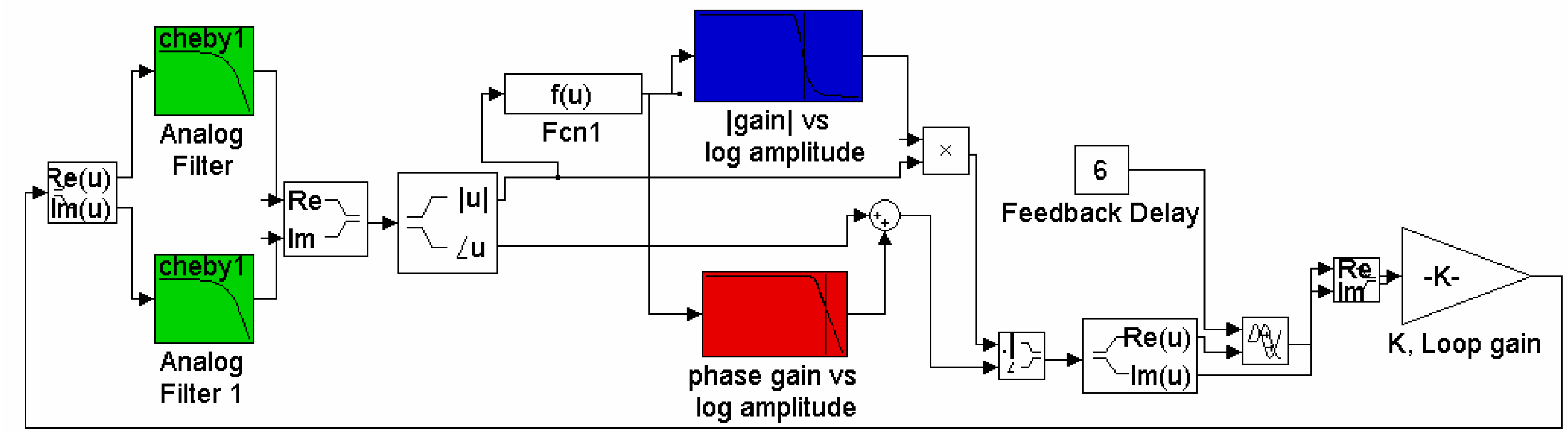
GAIN BANDWITH OF 8524H TWT AMPLIFIER



HARMONIC GAIN, DRIVEN AT 3.2GHz



MODEL



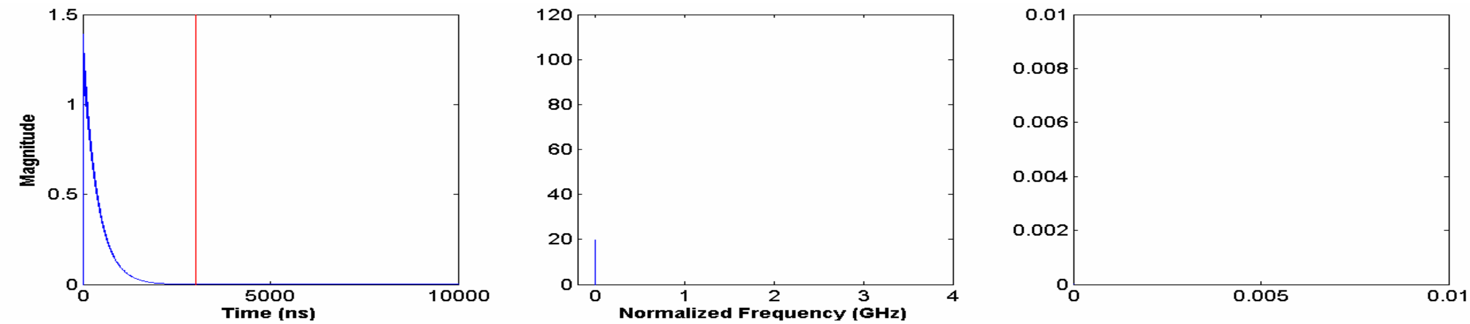
Consisting of

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

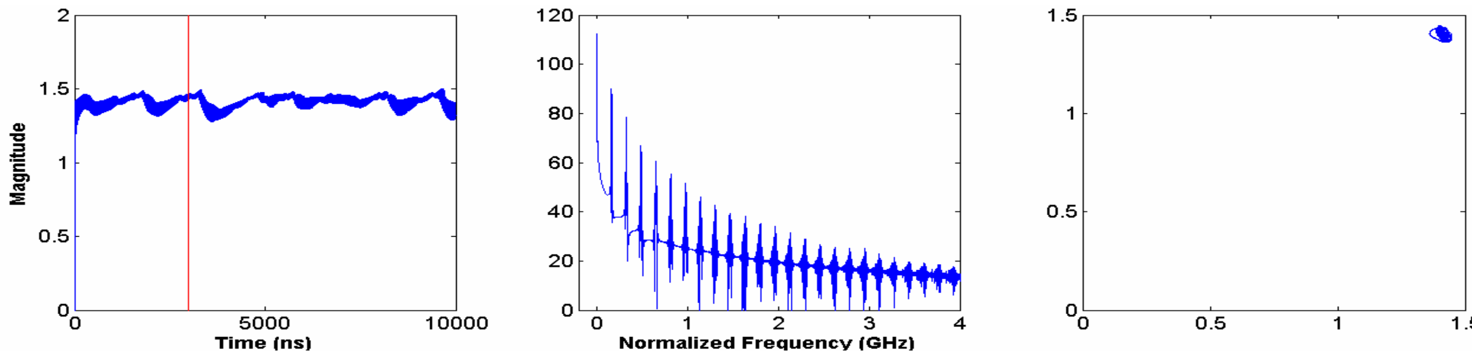
RESULTS - MODEL

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

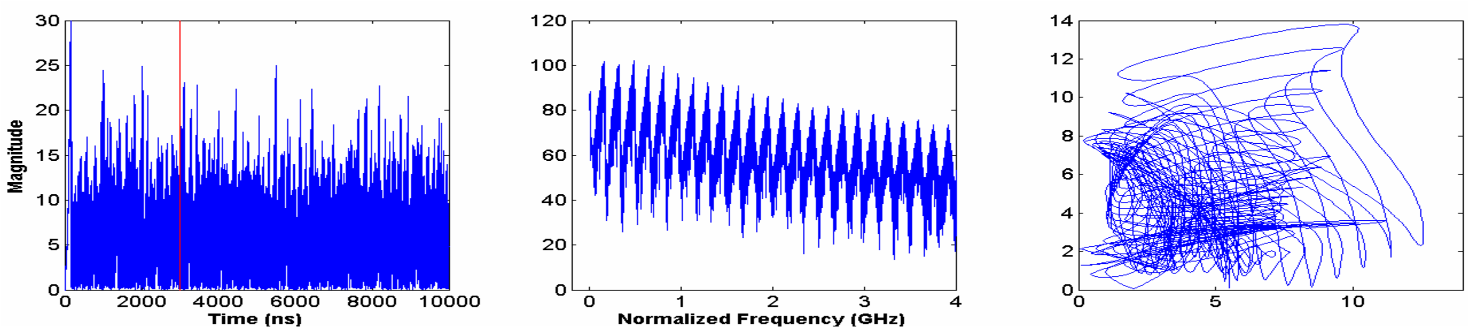
Gain < 1



Gain ~ 1



Gain >> 1



RESULTS- EXPERIMENTAL

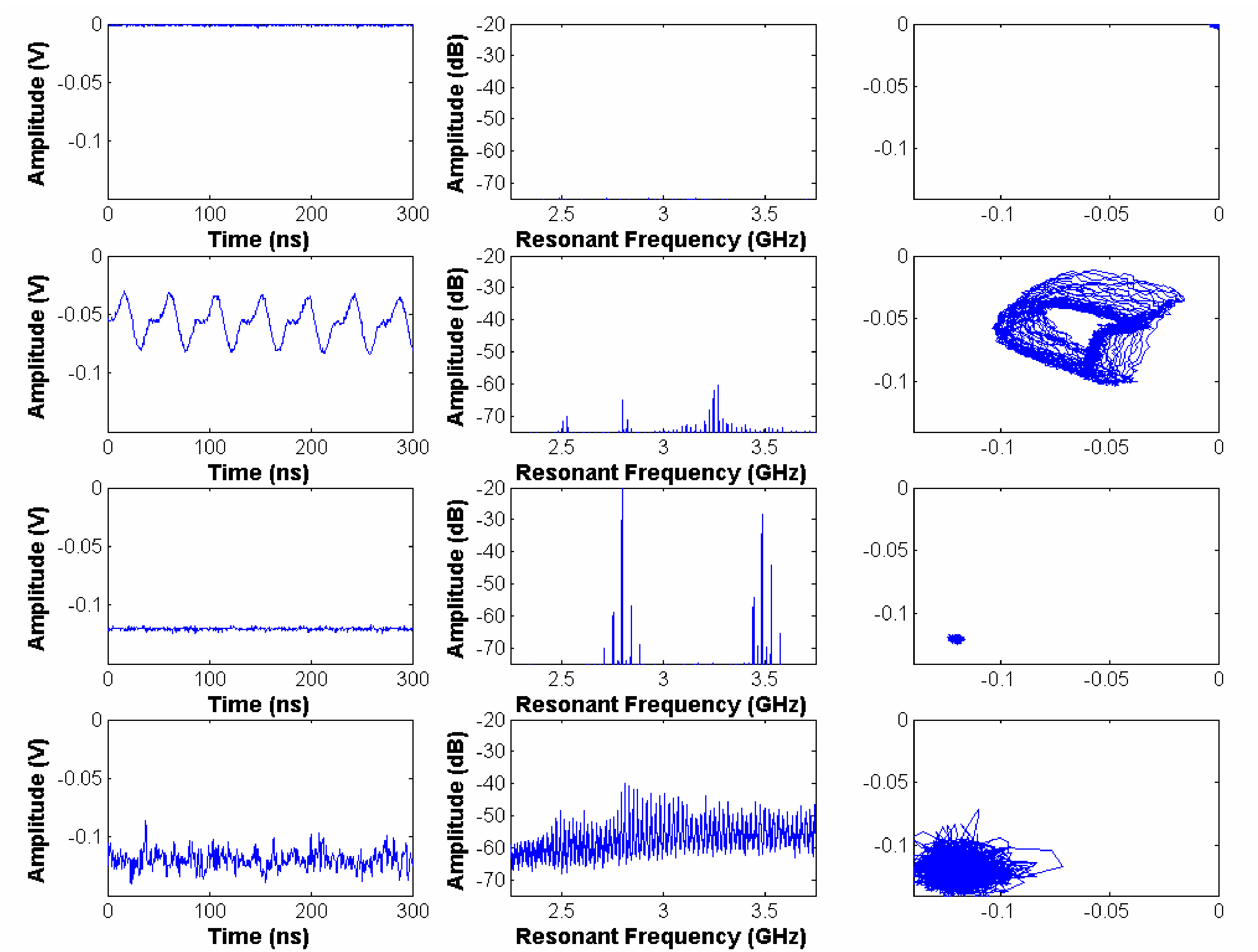
REGIME:

Stable, gain <1

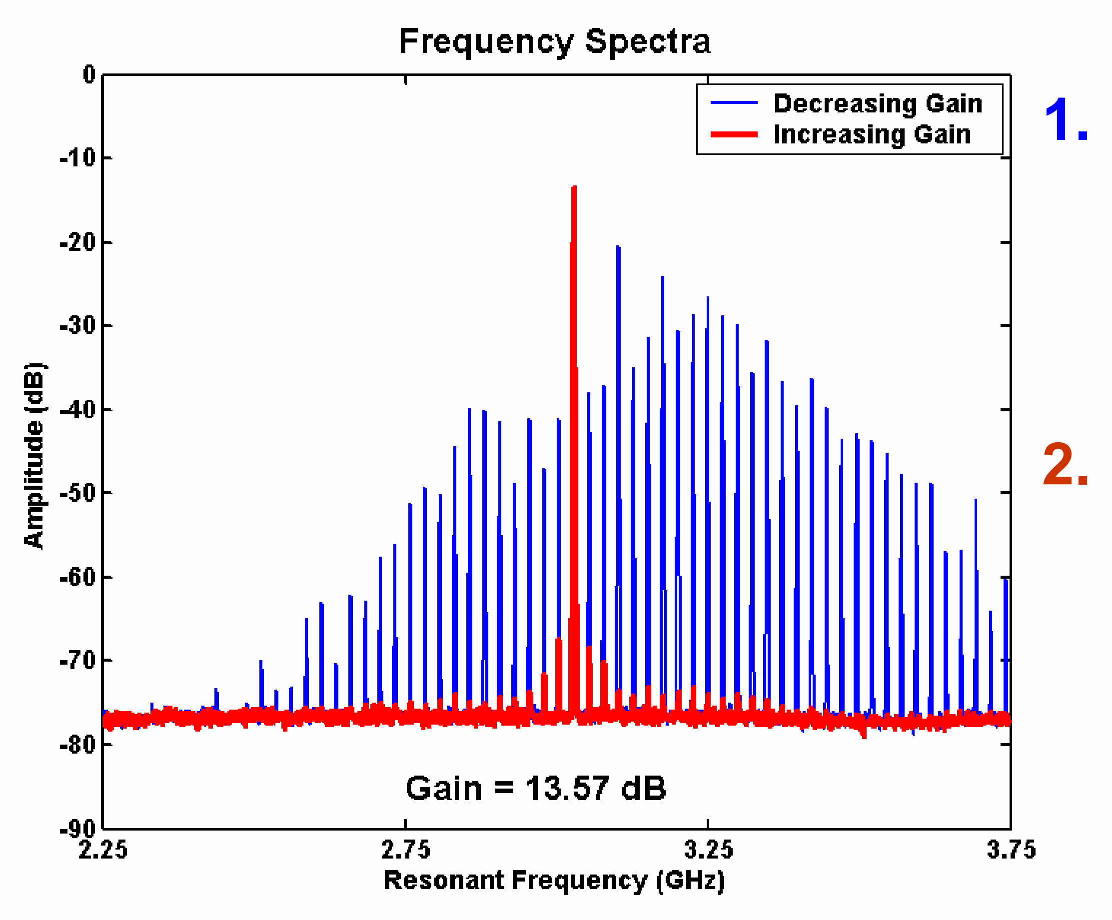
Linear, gain ~1

Nonlinear, gain >1

Chaotic, gain >>1



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