Non-Peaking Independent Waveforms

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SCOPE Senior Capstone Program in Engineering

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Introduction

Our project supports the idea of simultaneously transmitting communication and radar signals through a single broadcast device known as a phased antenna array.

A phased antenna array is a grid of independent antennas that can focus different signals in different directions through constructive and destructive interference between signals from the grid of antennas.

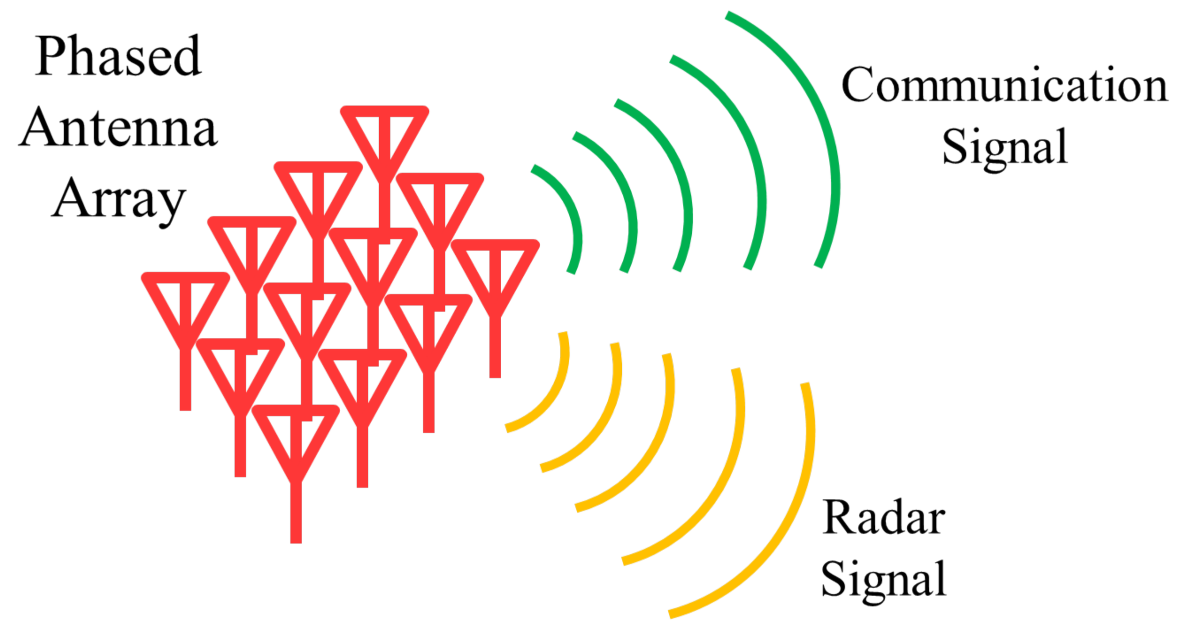

Figure 1: The vision for our project

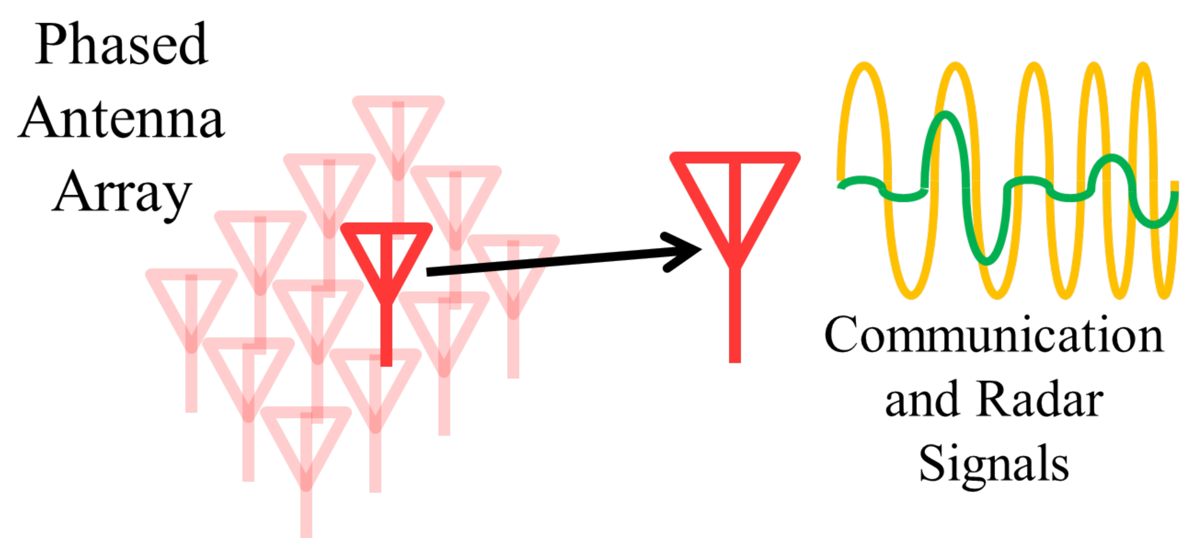

Figure 2: The role of a single antenna in our vision

In order for the phased antenna array to send multiple signals, each individual antenna must be responsible for emitting multiple signals.

While it is relatively simple to analyze a single antenna sending a single signal, the simultaneous transmission of multiple signals is complex because of imperfections in the transmission circuitry and inter-signal interference.

Our project deals with determining classes of communications and radar waveforms that can be transmitted through a non-linear amplifier with acceptable levels of signal distortion.

Project Focus

Our project focuses on:
- The non-linear amplifier
- Classes of communications and radar waveforms
- The output signal of the amplifier
- Independence between input waveforms given that this antenna is part of an antenna array

We do not consider:
- Specific applications of the signals (data and targets)
- Complexities of the antenna design
- The medium for the transmitted signal
- The interference patterns of the antenna array

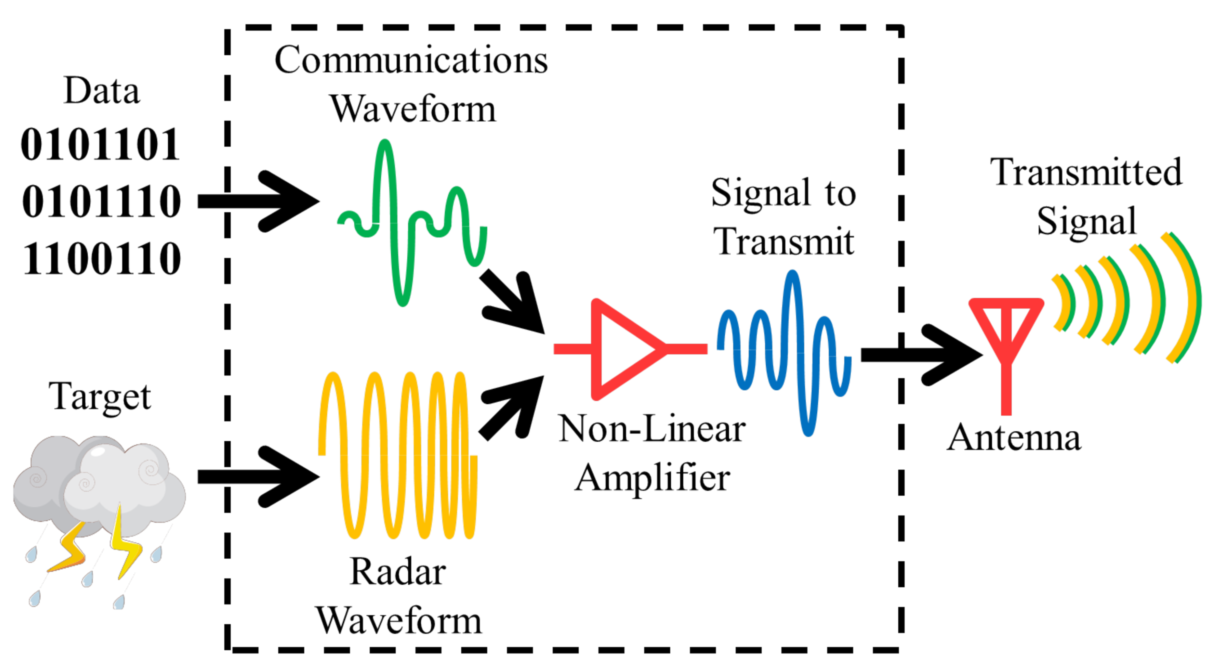

Figure 3: The steps from signal goals, "data to send" and "target to detect," to signal transmission

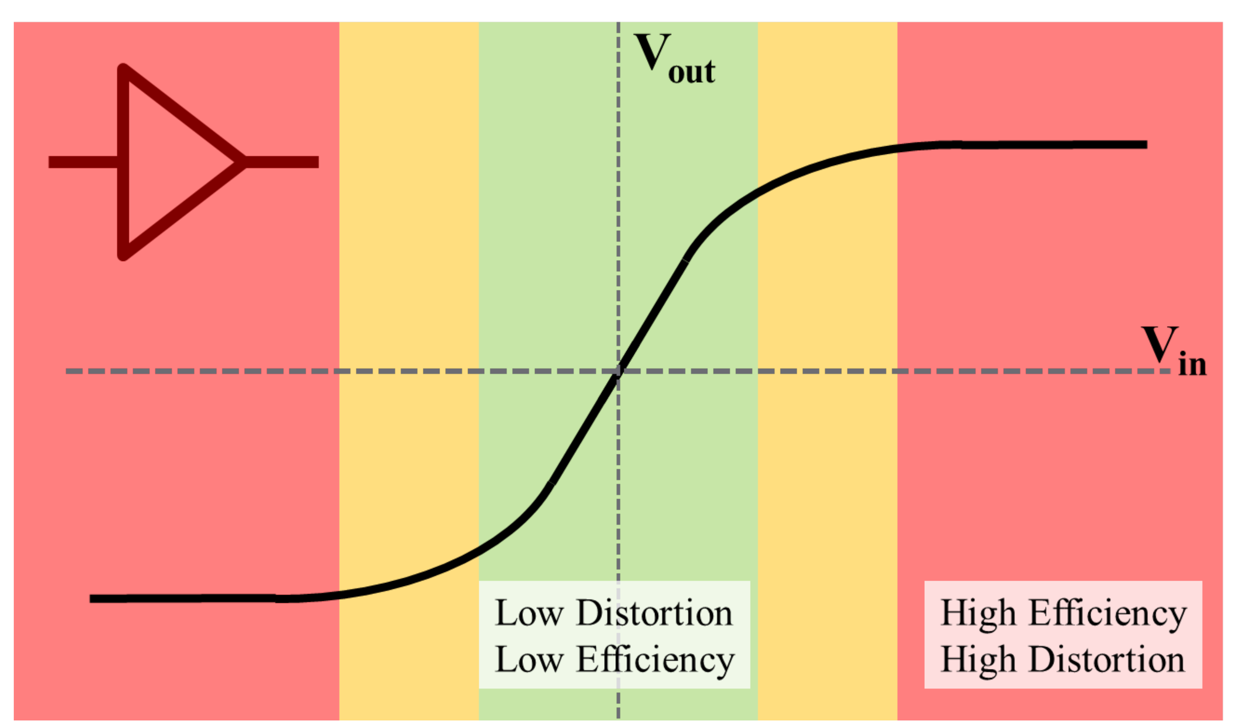

Figure 4: A non-linear amplifier input/output curve (voltage) w/ sub-compression (green) and in compression (red)

A non-linear amplifier has two distinct modes of operation
- Sub-Compression:
  low distortion but low efficiency and gain
- In Compression:
  high efficiency and gain but high distortion

We can only operate a single amplifier in one mode, but our multiple waveforms have **conflicting preferences**
- **Communications need low distortion** to avoid data corruption
- **Radar needs high gain** to detect objects at a larger range

Test Bench

Our simulations are run in an industry-standard application called Agilent Advanced Design System (ADS).

ADS is capable of simulating the behavior of circuits in both the time and frequency domain.

For experiments, we use a single test bench template with modular parts. Between experiments we change the waveform generator blocks to test different combinations of waveforms.

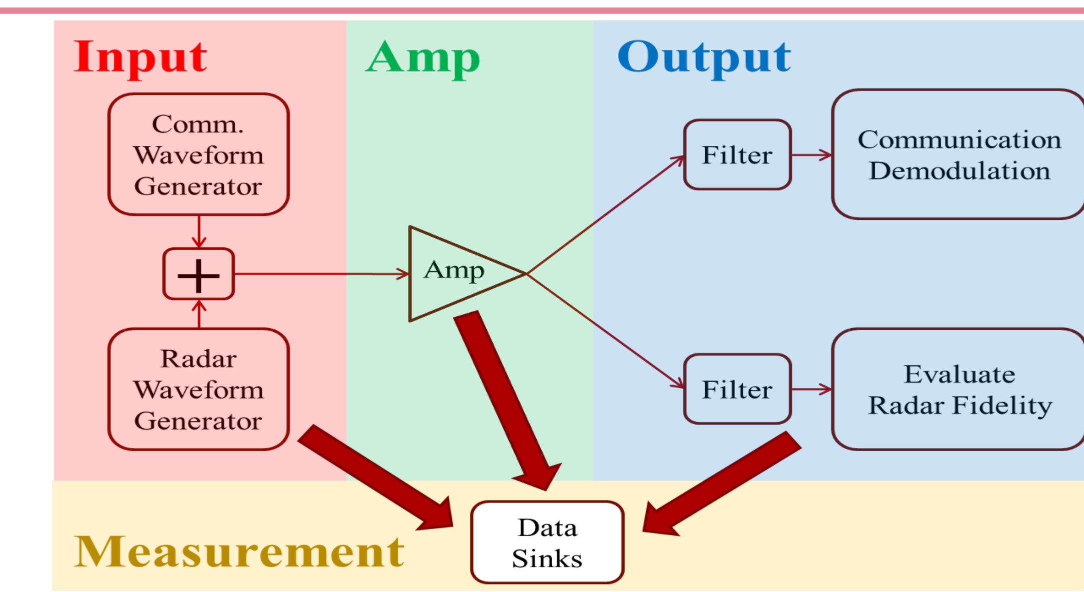

Figure 6: Our test bench block diagram

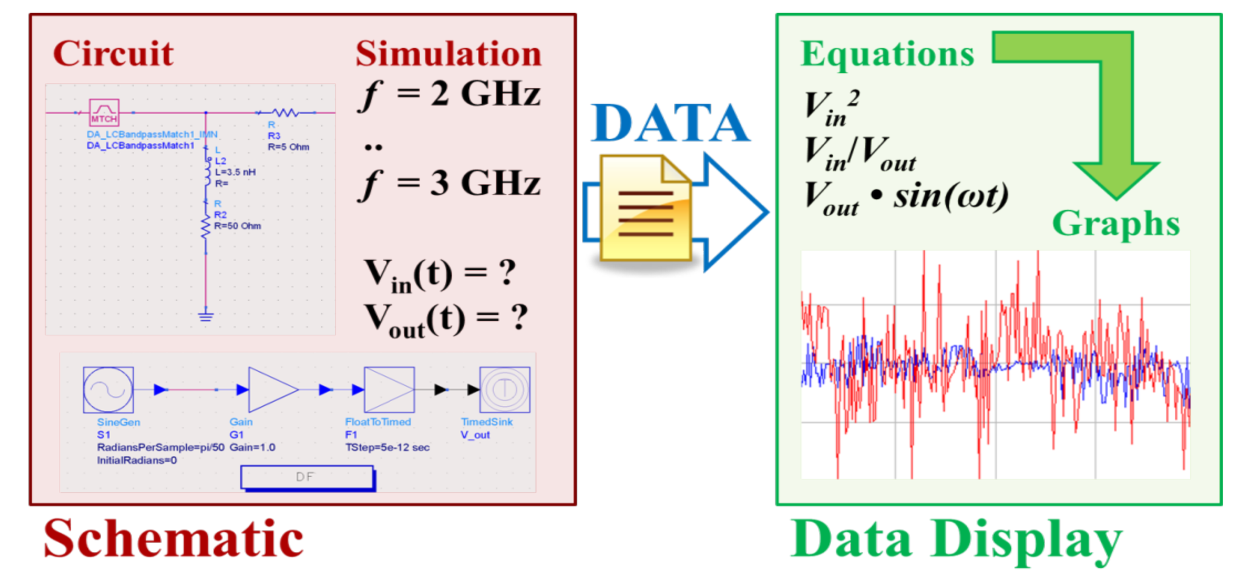

Figure 5: The ADS design flow involves two modules: a schematic (with a circuit and simulation parameters) and a data display (with equations and graphs)

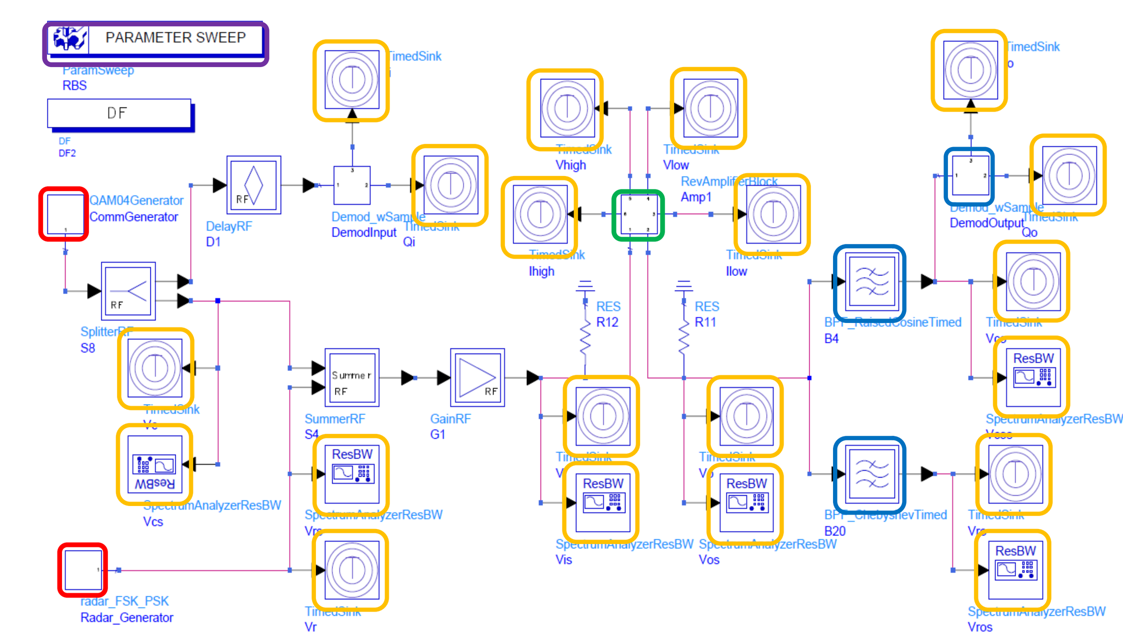

Figure 7: Our test bench schematic colored by category (note that we make measurements in many places)

Example Result

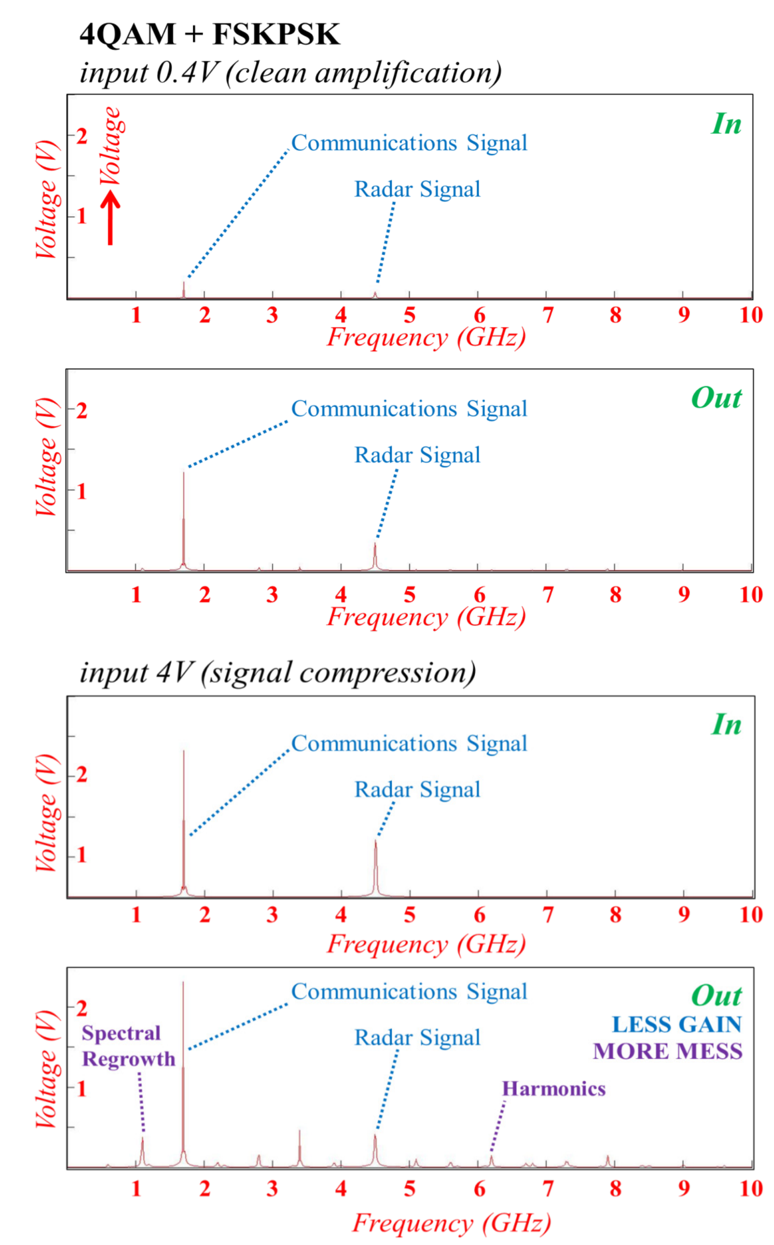

Figure 8: Spectral view of input and output data for two modes of operation (sub-compression and in compression)

Shown to the left and right are some results for an experiment using an FSKPSK radar waveform and a 4-QAM communications waveform.

In the spectral view (figure 8) we demonstrate a trade-off: as we increase the input voltage (going from sub-compression to in compression) the gain of the amplifier falls and the signal sent loses fidelity due to distortion.

In the IQ visualization (figure 9), we see that the communication signal in compression has more variance in the constellation set (normalized by gain) than the signal in sub-compression. This means that it is more likely for error to occur in receiving the data.

Overall, we see a trend of increasing SNR degradation (poorer communication performance) for operation in compression.

A more detailed description of trends, including numbers, is included in the proprietary report sent to Raytheon.

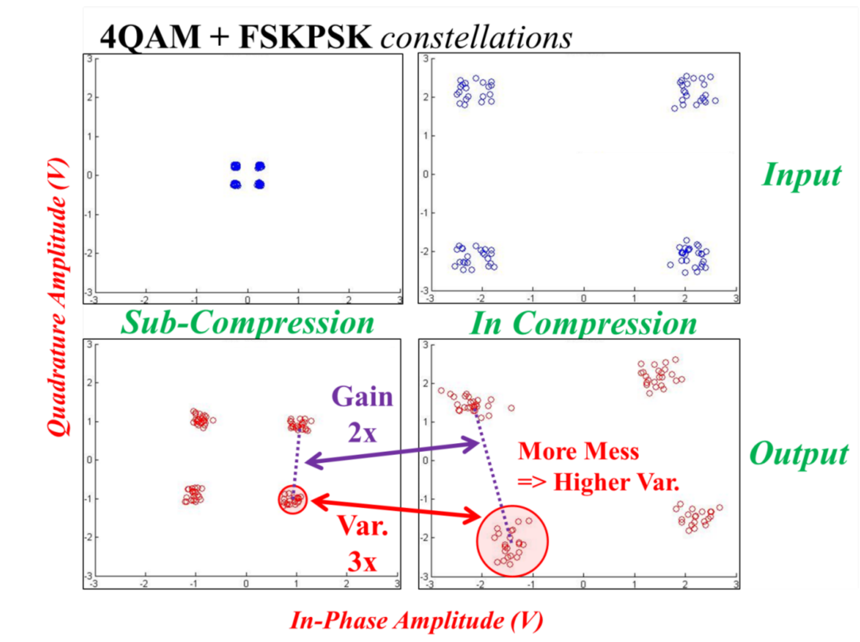

Figure 9: Constellations of input and output data for two modes of operation

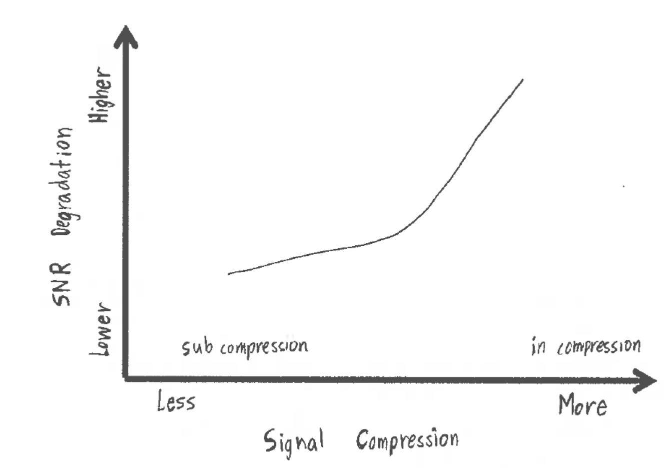

Figure 10: SNR Degradation versus Signal Compression (sketch only)
**actual data is proprietary*