# Efficient Superposition of Communications and Radar Waveforms

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## Introduction

Our project supports simultaneous transmission of communication and radar signals through 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.

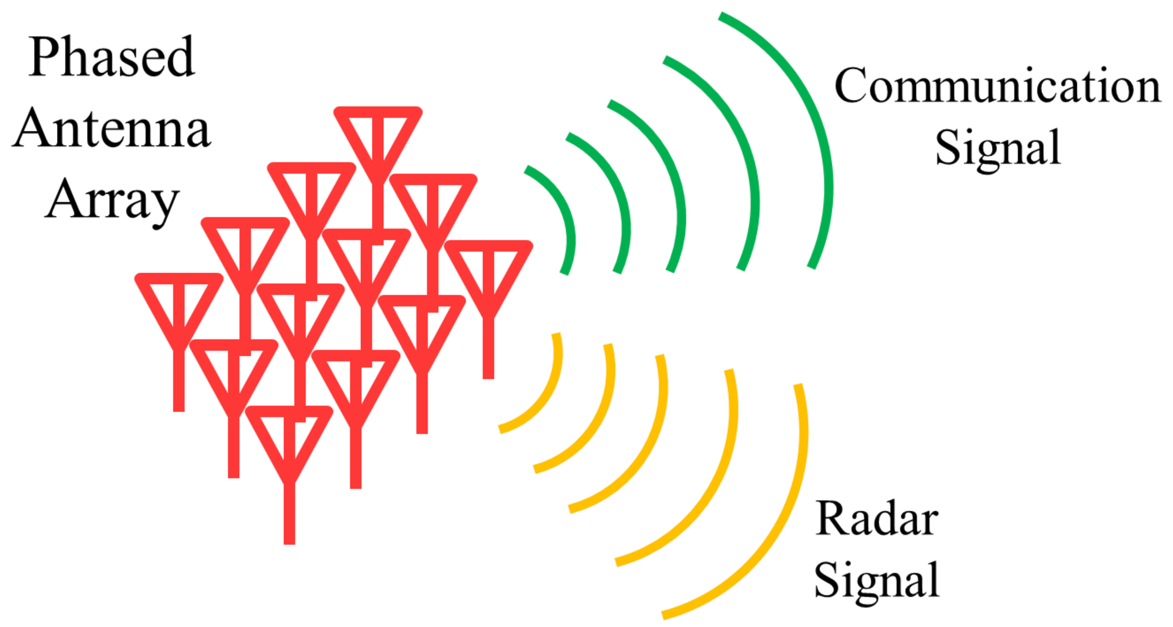


*Figure 1: Phased antenna array can transmit signals in any direction without physically moving.*

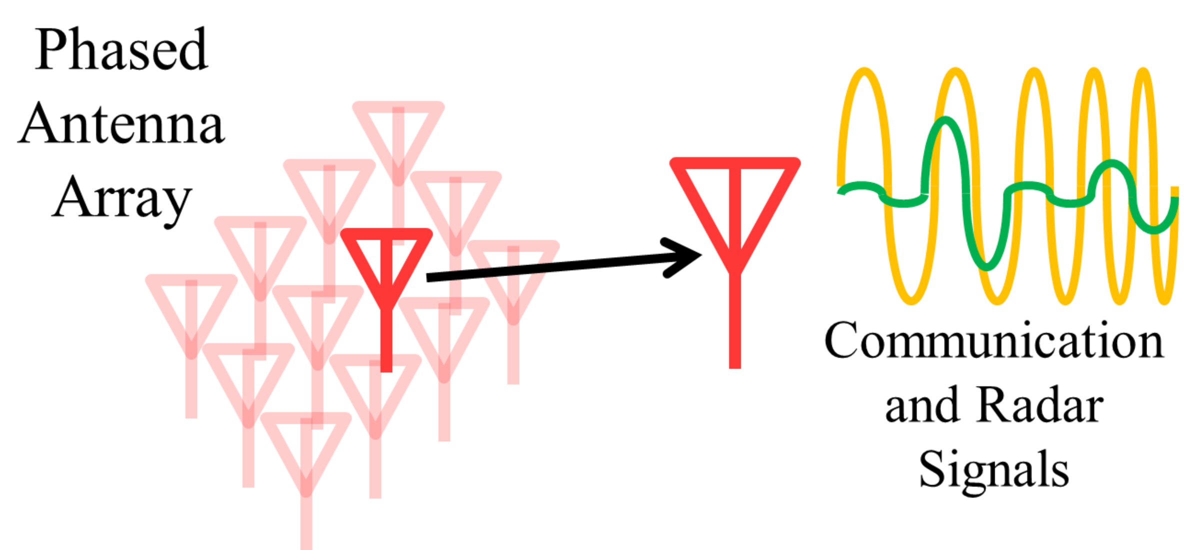


*Figure 2: The role of a single antenna in our vision*

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

We have reached our conclusions through a combination of simulation and RF hardware testing.

## 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:
- Antenna selection
- Wireless channel
- Specific applications of the signals (data and targets)
- The interference patterns of the antenna array

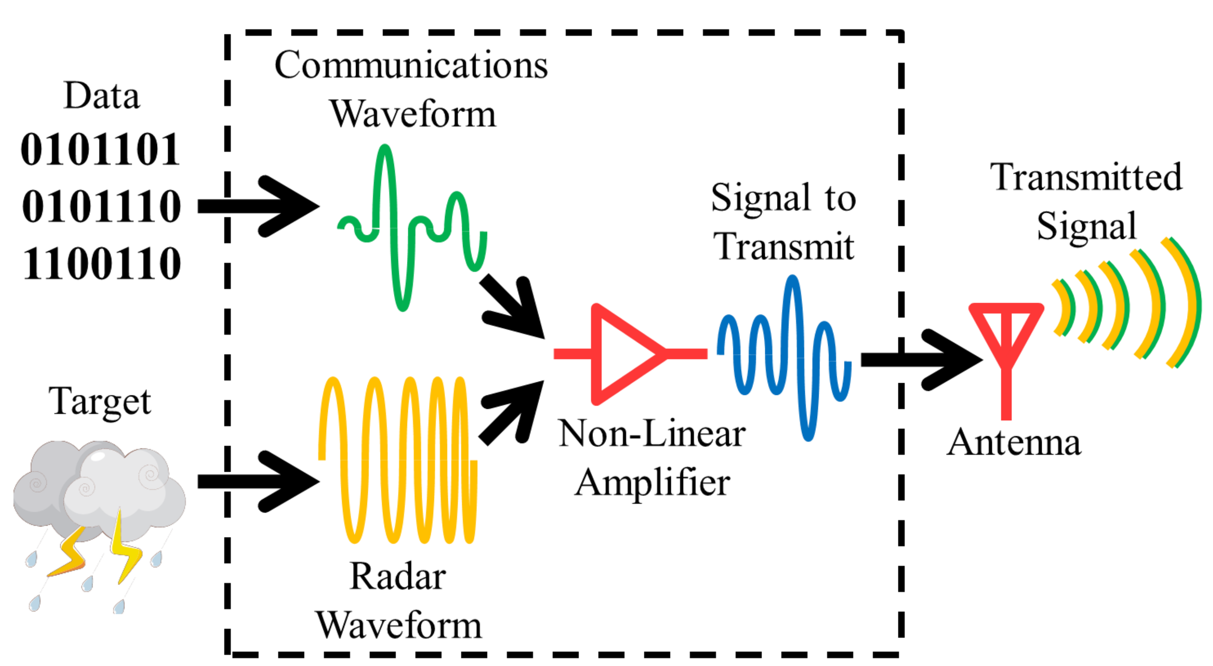


*Figure 3: The steps from signal goals, "data to send" and "target to detect," to signal transmission*

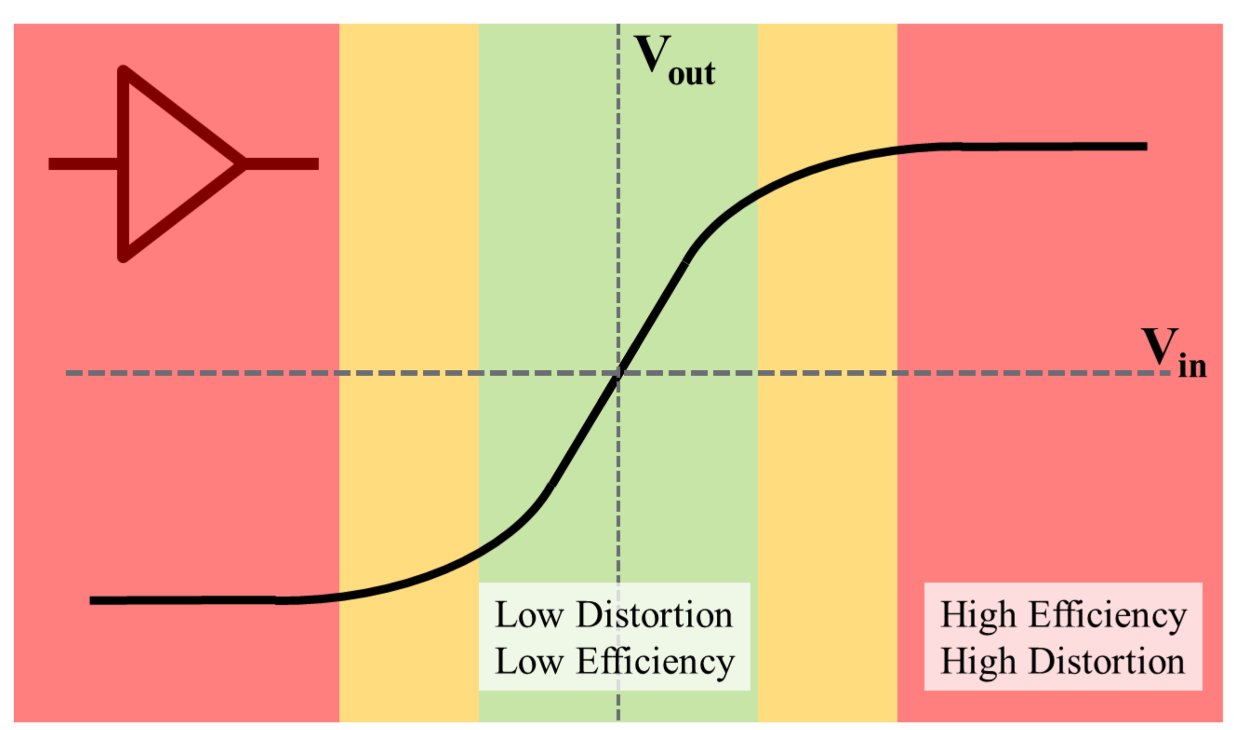


*Figure 4: A non-linear amplifier input/output curve (voltage) w/ sub-compression (green) and in compression (red)*

A non-linear amplifier has two distinct modes of operation
- Sub-Compression:
  low distortion and low power but low efficiency
- In Compression:
  high efficiency and high power 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 output power** to detect objects at a larger range

## Hardware Testbench

Understanding the performance of our superimposed communications and radar waveforms requires a good model of the behavior of high power, non-linear, radar amplifiers that would be used in such a system. The primary goal of the 2011-2012 Raytheon Scope team was to design and build a hardware testbench for realistic testing of superimposed communications and radar waveforms.

Driving the non-linear amplifier into the high distortion region requires significantly powerful input signals. Input sources are amplified by a driver amplifier to reach sufficient power levels.

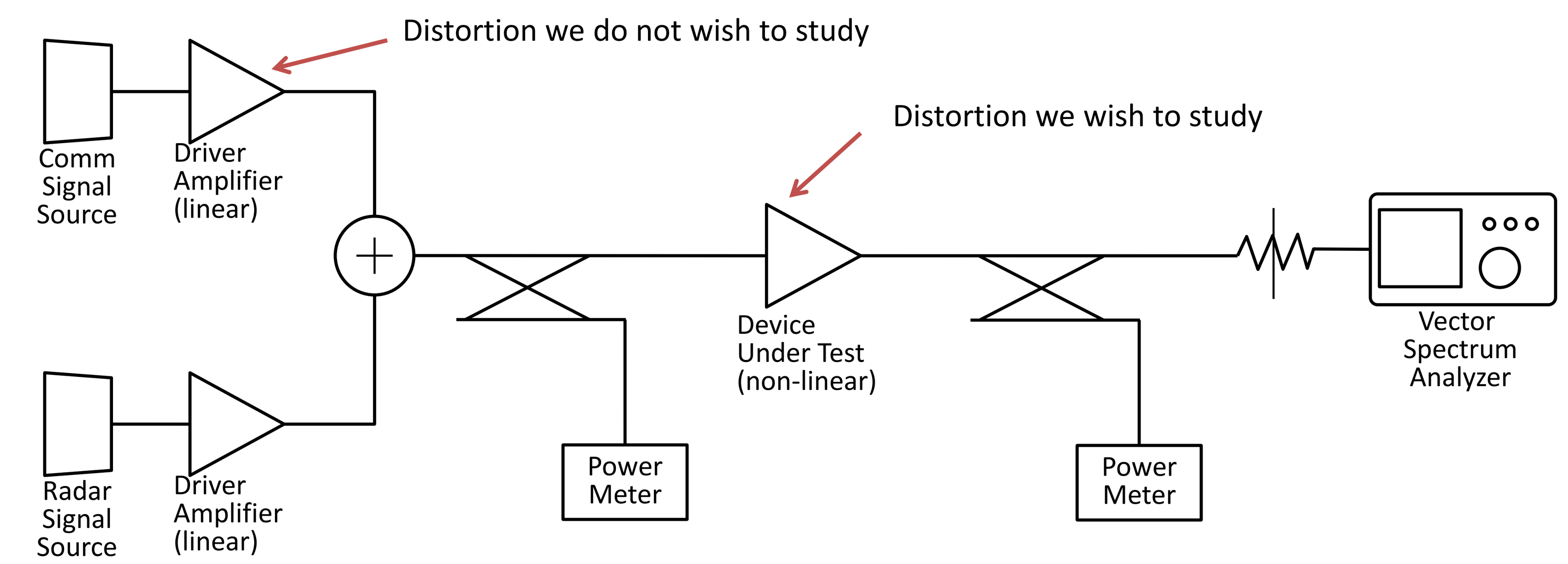


*Figure 6: Hardware test bench.*

To understand the performance of our waveforms in a non-linear system, we created a representative testbench from OTS hardware.

For safety and feasibility reasons, we selected a low power amplifier that exhibits nonlinear behavior similar to that seen in high power radar amplifiers.

Any non-linear amplification of signals with wide frequency separation comes at the cost of intermodulation distortion. Our investigation of superimposed waveforms is largely concerned with intermodulation distortion, however, we only desire to measure this distortion from the device under test. For this reason, both input signals are amplified before the combiner to avoid intermodulation.

At the output end of the testbench, output recorded by the spectrum analyzer is transferred to the computer for analysis.

## Sample Results

The radar figure of merit slightly decreases as input power decreases for each waveform.

Bit error rate increases as input power increases.

The relative adjacent channel power decreases slightly as input power increases.

Power Added Efficiency increases with higher input power. The PAE flattens out and starts to decrease at a certain input power.

All of these results were anticipated.