Efficient Superposition of Radar and Communications Waveforms

RAYTHEON SCOPE 2012-2013

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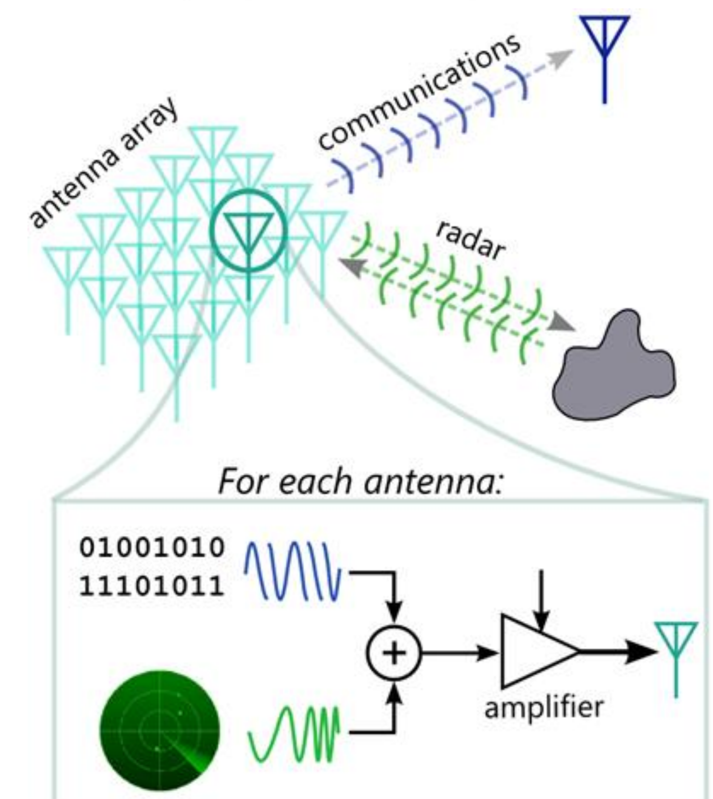
INTRODUCTION

Antennae on a space-constrained ship.

Modern radar application areas often require communications and radar antennae to be co-located, **introducing interference and consuming space and power**.

Multiple antennae can be combined into a single integrated device through phased array antenna, which enables the transmission of **multiple signals in different directions.**

Using this technology to combine radar and communications signals requires transmitting both signals through the same radio-frequency amplifier, distorting the input signal.



Phased array antenna can be used to direct waveforms in different directions.

The goal of this project was to enhance potential applications for multi-function radar arrays by researching methods for **transmitting communications and radar waveforms through the same nonlinear amplifier.** The major objectives of the 2012-2013 team were to:

- **Validate** the experimental test setup developed by the 2011-2012 Raytheon SCOPE team.
- **Develop** a reliable hardware and software testing protocol to model amplifier nonlinearities.
- **Quantify** distortion effects in combined radar and communications signals.
- **Identify** signal modulation and combination techniques that enable acceptable performance, outlined below.

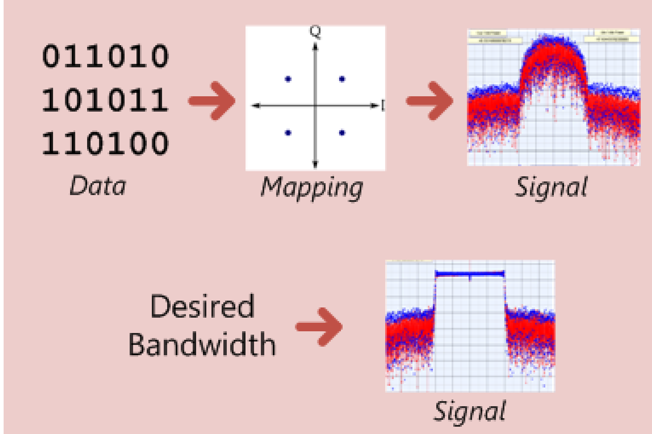
TESTING PROTOCOL

The team developed and validated a testing platform using both **industry-standard simulation software** (Agilent's SystemVue and Advanced Design System) and **commercially available hardware**.

Generation

Data for each signal was generated in simulation.

Baseband waveform generation
Generate communications and radar waveforms in SystemVue

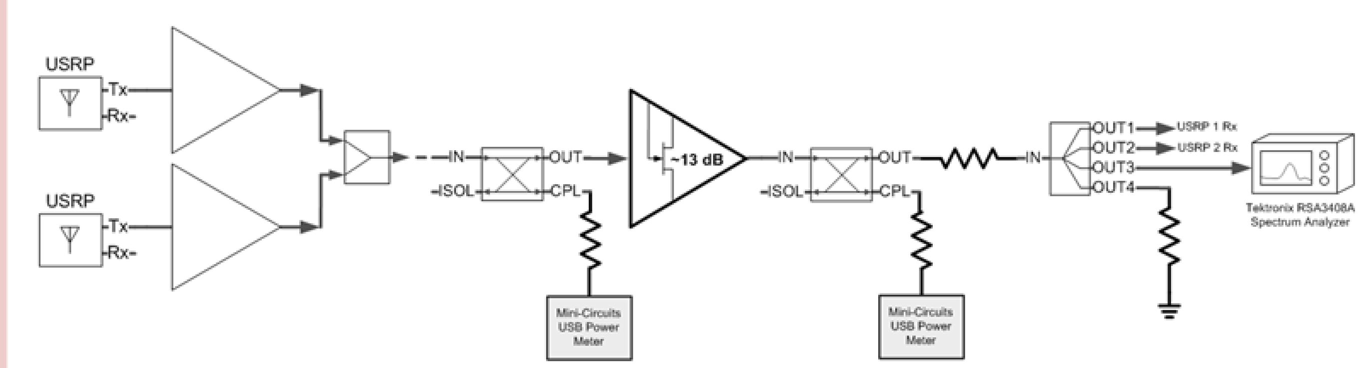


Amplitude Scaling
Adjust the signal magnitude to match realistic power levels

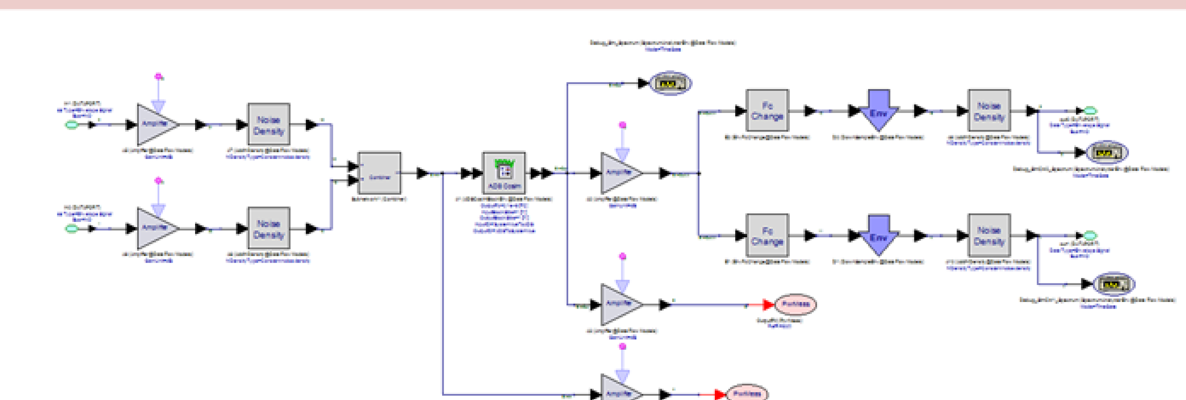
Modeling

The same data was transmitted through a parallel process of experiment and simulation.

Experimental Hardware



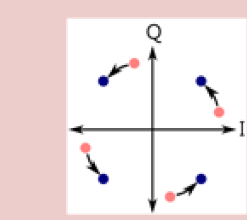
Simulation



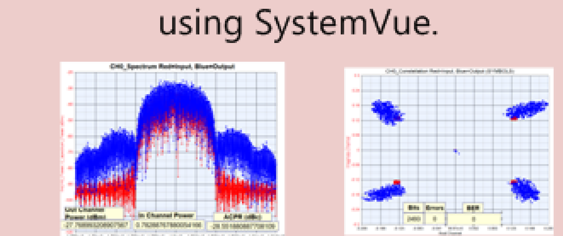
Analysis

Both data sets were analyzed using the same method.

Data processing
Crop received data and compensate for phase shift in transmitted communications constellation

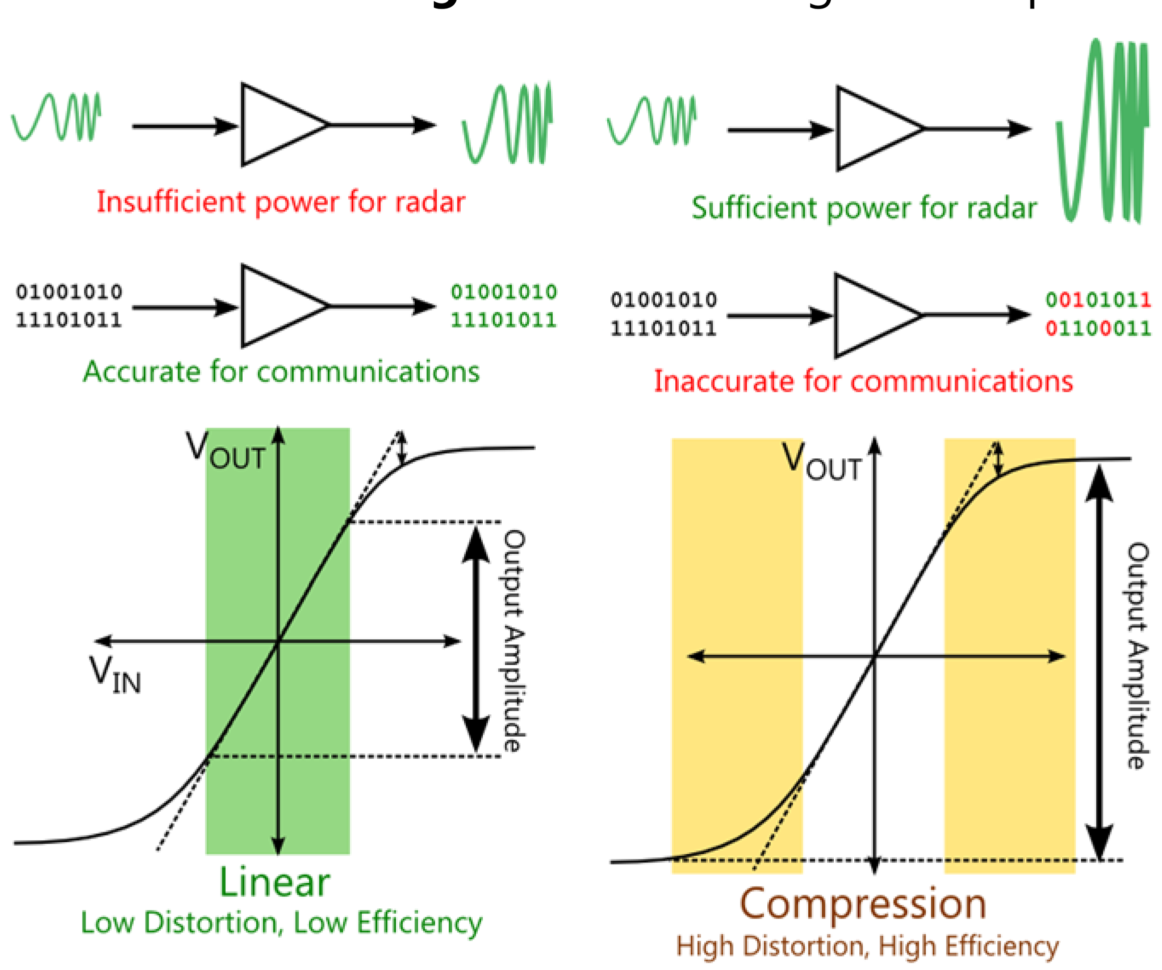


Analysis
Generate frequency-domain comparisons and constellation plots using SystemVue.



PROJECT CHALLENGE

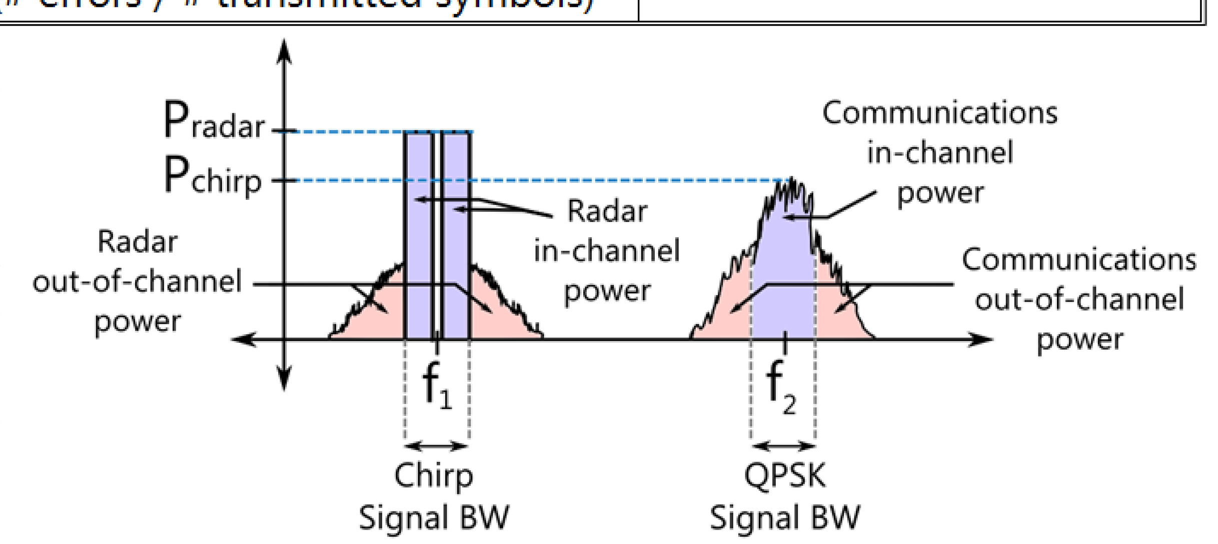
Radio frequency amplifiers are **linear at low powers**, which is useful for communications but results in output power inadequate for radar transmission. However, transmitting communications signals in **high-power regimes distorts the transmitted signal**. The challenge of this problem is to find waveform types robust to this distortion.



*Amplifiers exhibit a tradeoff between power and distortion. Our goal is to **transmit superimposed radar and communications signals through an amplifier in compression**.*

Metrics for acceptable performance defined by the team include:

Metric	Acceptable Range
Amplifier Power-Added Efficiency (PAE)	>=90% of peak power under single tone operation
Combined out-of-channel power	<=30 dBc
Symbol Error Rate (# errors / # transmitted symbols)	$<=10^{-4}$



Sample frequency-domain spectrum of combined radar (left) and communications (right) signal, with relevant parameters labeled.

RESULTS

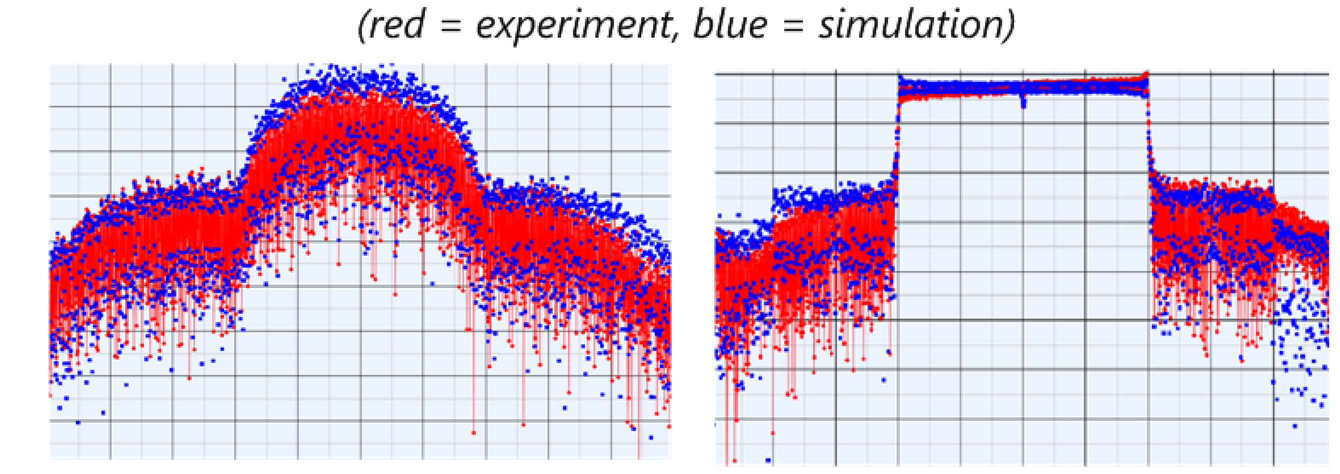
The frequency-domain spectrums of the simulated (red) and experimental (blue) quadrature phase-shift keying (QPSK) and radar chirp signals under compression are shown at right. These demonstrate the predicted **side-band distortion** and **good correlation between simulation and experiment.**

With this testing setup, the team tested the response of the performance metrics indicated at left to the following input waveform parameters:

Variable	Description	Values
$f_1 - f_2$	Radar and communications separation frequency	10 to 600 MHz
P_T	Total input power to DUT	0 to 32 dBm
$P_{chirp} - P_{QPSK}$	Difference between QPSK and chirp channel power	0 to-20 dB

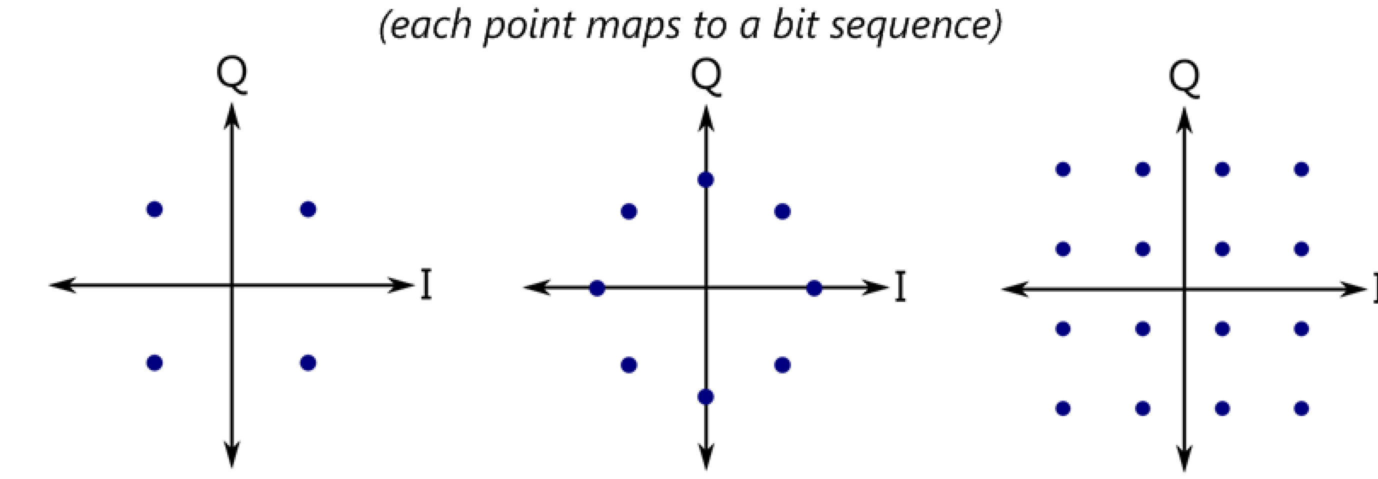
We defined areas of acceptable operation for certain ranges of the above parameters with the three different waveform combinations shown at right.

Frequency Spectrum of Received Signals
(red = experiment, blue = simulation)



QPSK spectrum. *Radar spectrum.*

Communications Waveform Types
(each point maps to a bit sequence)



Quadrature phase-shift keying *8-level phase-shift keying* *16-level quadrature amplitude modulation*