Efficient Superposition of Radar and Communications Waveforms

RAYTHEON SCOPE 2012-2013

INTRODUCTION

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.

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.

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.

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.

Metrics for acceptable performance defined by the team include:

- **Amplifier Power-Added Efficiency (PAE)**
- **Combined out-of-channel power**
- **Symbol Error Rate (errors / # transmitted symbols)**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Acceptable Range</th>
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<tbody>
<tr>
<td>PAE</td>
<td>&gt;90% of peak power under single tone operation</td>
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<tr>
<td>Out-of-channel power</td>
<td>&lt;=30 dB</td>
</tr>
<tr>
<td>Error rate</td>
<td>&lt;=10^-5</td>
</tr>
</tbody>
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With this testing setup, the team tested the response of the performance metrics indicated at left to the following input waveform parameters:

- **f1, f2**: Radar and communications separation frequency
- **P_T**: Total input power to DUT
- **P_{T\text{amp} - P_{QPSK}}**: Difference between QPSK and chirp channel power

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