Waveform Design for Joint Radar-Communication System

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Introduction

• Conventional radar is unable to operate in a future dynamic spectrum access (DSA) environment due to:
  1. Fixed frequency
  2. High power

• Solution:
  1. Make it frequency flexible
  2. Ability to respond to its surroundings

Problem Formulation

• Assuming Gaussian distributed communication signals and channels and their second order statistics are given, we derive the optimal radar waveform for:

  1. Detection (objective = SINR)

  \[
  \begin{align*}
  \text{maximize} & \quad \text{SINR}_{y_1} \\
  \text{subject to} & \quad \text{SINR}_{y_2,i} \geq \alpha_i, \quad \forall i \in I \\
  & \quad x^H x \leq \epsilon \\
  \quad \text{SINR}_{y_1} = \frac{x^H P^H C_{G_1} P x}{\text{tr} \{C_{G_2} R_w \} + n_r \sigma_n^2} \\
  \quad \text{SINR}_{y_2,i} = \frac{x^H P^H C_{G_{2,i}} P x + n_r \sigma_n^2}{\text{tr} \{C_{G_{2,i}} R_w \}} 
  \end{align*}
  \]

  2. Characterization (objective = Mutual Information)

  \[
  \begin{align*}
  \text{maximize} & \quad I(y_1; g_1 | x) \\
  \text{subject to} & \quad I(y_{2,i}; w_i) \geq \beta_i, \quad \forall i \in I \\
  & \quad x^H x < \epsilon \\
  \quad I(y_1; g_1 | x) = \sum_{k \in N_c} \frac{1}{2} \log \left( 1 + \frac{|X[k]|^2 \sigma_{2,i}^2}{\text{E} [Y_{1,c,k}^2] + \sigma_n^2} \right) \\
  \quad I(y_{2,i}; w_i) = \sum_{k \in N_c} \frac{1}{2} \log \left( 1 + \frac{\text{E} [Y_{2,i,c,k}^2]}{|X[k]|^2 \sigma_{2,i}^2 + \sigma_n^2} \right) 
  \end{align*}
  \]

Results

• Under the same conditions (power of communication signal, noise variances and gain of channel $G_1$), the basic case,

  \[
  \hat{x_{\text{SINR}}} = \sqrt{e_{1,P}} \\
  \quad \text{where} \quad e_{1,P} \text{ is the eigenvector of } P = e^P C_{G_1}, \Phi \text{ correspond to the largest eigenvector.}
  \]

  \[
  |X_M[k]|^2 = \frac{N}{|V|} E \left[ \sum_{i \in N} \frac{|Y_{1,c_i}|^2}{\sigma_d^2} \right] - \frac{E [Y_{1,c_i}^2]}{|X[k]|^2} \frac{\sigma_d^2}{\sigma_n^2}
  \]

Joint R-C Model

• Block Diagram

  - Radar Signal
  - Communication Signal
  - Power Spectrum Analyzer

Transmitter Design

• DSA Adaptive Radar Transmitter

  - Radar Signal Generator
  - Spectrum Sharing Environment
  - Communication Systems