Waveform design to improve the estimation of target parameters using the Fourier Transform method in a MIMO OFDM DFRC system

Satwika Bhogavalli, Eric Grivel, K.V.S. Hari and Vincent Corretja

1. Key Contributions
- Improving the way to estimate target DOAs based on Fourier Transform (FT) by designing a waveform that controls the amplitude of the back-scattered signals.
- Instead of jointly estimating the target DOAs, individual estimations are proposed by favouring angular zones of interest with almost the same complexity as the FT method.
- There is a trade-off between the accuracy of the target parameter estimates and the transmitted data rate.

2. Dual Function Radar Communication (DFRC) systems

System Model of MIMO OFDM DFRC:

Given \( K \) targets, the received data over the \( g^{th} \) sub-carrier during the \( u^{th} \) OFDM symbol along the \( m^{th} \) antenna is:

\[
y(g, u, m) = \sum_{k=0}^{K-1} a_k \sum_{l=0}^{L-1} s(g, u, l) \exp(-j \omega_k) \exp(-j 2\pi g \frac{\Delta f}{c}) \exp(j 2\pi u T) \exp(-j \omega_k) + \eta(g, u, m)
\]

Also, \( A'(k, g, u) = \sum_{l=0}^{L-1} s(g, u, l) \exp(-j \omega_k) \exp(-j \omega_k) \)

where \( \theta_k, \omega_k, uT \) represents the DOA, range and velocity of the \( k^{th} \) target respectively and \( \omega_k = 2\pi \sin \theta_k (\frac{c}{c}) \)

3. Proposed Methodology

- A low-resolution method \( \Rightarrow \) High risk to get inaccurate DOA estimates.
- Our suggestions:
  - \( A'(k, g, u) \) is a dot product between the symbol vector \( s'(g, u) \) and a vector depending on \( \omega_k \).
  - Transmit the symbols along the \( L \) antennas such that \( s(g, u) = [1 \ldots (L-1)\beta + j\beta_0]^T \)

Consequence
- \( |A'(k, g, u)| = \frac{\sin \theta_k}{\sin \theta_k} \)
- \( |A'(k, g, u)| \) can be controlled by choosing \( \beta \).
- Selecting different values of \( \beta \) to define different angular zones (scanned by different sub-carriers).
- Individual target DOA estimation.

4. Target parameter estimation using our proposed waveform

Assumption: A target is present in the \( i^{th} \) zone which is scanned by the \( i^{th} \) sub-carrier.

Step 1:

\[
(y'_{g, u, m})_{m=0 \ldots M-1} \rightarrow \text{Fourier analysis across the spatial domain} \rightarrow \text{DOA estimate}
\]

Step 2:

\[
(y'_{g, u, m})_{m=0 \ldots M-1} \rightarrow \text{Total least-squares based method} \rightarrow \text{Range estimate}
\]

5. Simulation Results

\( (\theta_1, D_1, v_1) = (31.2^0, 153.73m, 31.72m/s), (\theta_2, D_2, v_2) = (47.8^0, 201.52m, 51.21m/s) \)

The estimations of the target parameters are clearly improved.

6. Selected References