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

Satwika Bhogavalli[a], Eric Grivel[b], K.V.S. Hari[a] and Vincent Corretja[c]
[a]Dept. of Electrical Communication Engineering, Indian Institute of Science, Bangalore, India
[b]University of Bordeaux, INP Bordeaux IMS - UMR CNRS 5218, Talence, France
[c]Thales Defence Mission Systems, Campus Thales Merignac, France
Email-id: bhogavallis@iisc.ac.in
This project is a part of the collaboration between IISc, Bordeaux INP and Thales

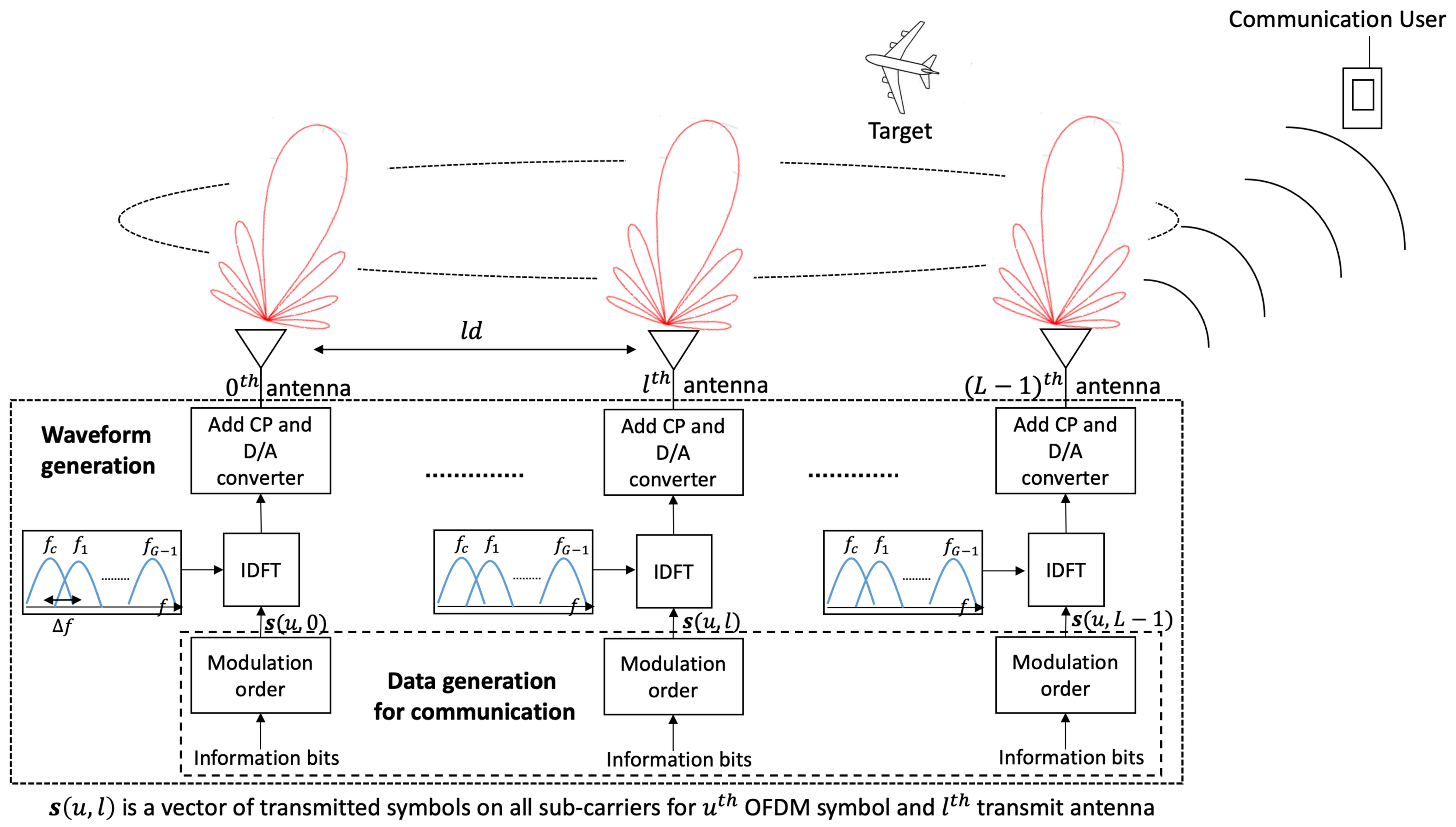
ICASSP 2023
4 - 10 JUNE, RHODES ISLAND, GREECE

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:

$$y(g,u,m) = \sum_{k=1}^{K} \alpha_k \sum_{l=0}^{L-1} s(g,u,l)\exp(-j\,l\omega_k)\exp\left(-j2\pi g\Delta f\frac{2D_k}{c}\right)\exp\left(j2\pi uTf_k^d\right)\exp(-jm\omega_k) + \eta(g,u,m)$$

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

where θ_k, D_k, v_k represents the DOA, range and velocity of the k^{th} target respectively and $\omega_k = 2\pi d\sin\theta_k\left(\frac{f_c+g\Delta f}{c}\right)$

3. Proposed Methodology

Limitation of FT [1]

- 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 $\boldsymbol{s}^T(g,u)$ and a vector depending on ω_k.
- Transmit the symbols along the L antennas such that $\boldsymbol{s}(g,u) = [1 \ \ldots \ \exp(-j(L-1)\beta + j\beta_0)]^T$ where β and $\beta_0 \in b$-ary PSK constellation.

Consequence

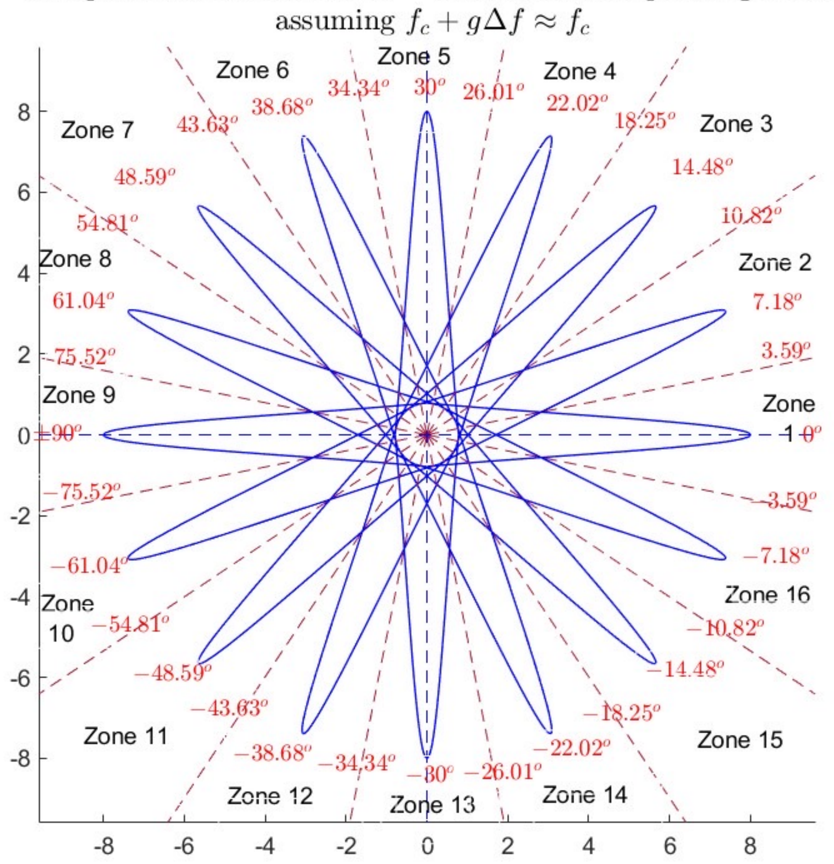
- $|A'(k,g,u)| = \left|\frac{\sin\frac{L(\beta-\omega_k)}{2}}{\sin\frac{(\beta-\omega_k)}{2}}\right|$

$|A'(k,g,u)|$ can be controlled by choosing β.

- Selecting different values of β to define different angular zones (scanned by different sub-carriers).
- Individual target DOA estimation.

$\Rightarrow$

The partition of zones for L = 8 and the corresponding DOA assuming $f_c + g\Delta f \approx f_c$



- When $b\uparrow$, the number of zones $\uparrow$.
- When $L\uparrow$, the side-lobe width of $|\widehat{A}'(k,g,u)|\downarrow$.

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:

$\{y(g_i,u,m)\}_{m=0,\ldots,M-1}$ → Fourier analysis across the spatial domain → DOA estimate

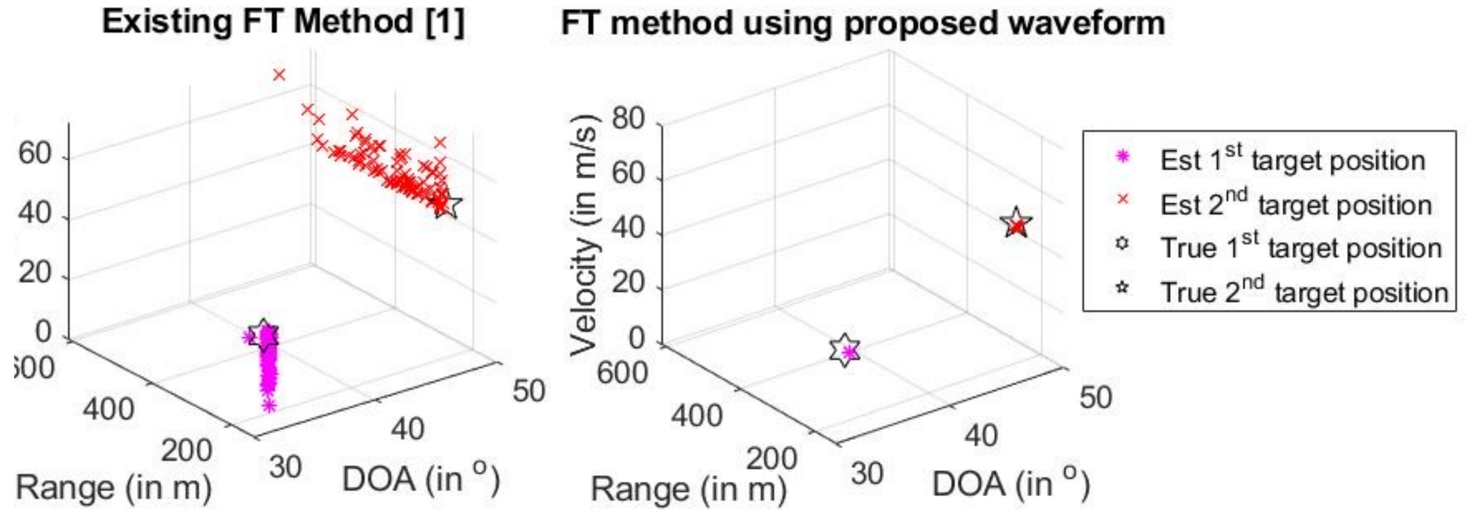
Step 2:

$\{y(g_i,u,m)\}_{m=0,\ldots,M-1}$ and DOA estimate → Total least-squares based method → Range estimate

$\{y(g_i,u,m)\}_{u=0,\ldots,U-1}$ → Fourier analysis across the time domain → Velocity estimate

5. Simulation Results

$(\theta_1, D_1, v_1) = (31.2^o, 153.73\text{m}, 31.72\text{m/s})$, $(\theta_2, D_2, v_2) = (47.8^o, 201.52\text{m}, 51.21\text{m/s})$



The estimations of the target parameters are clearly improved.

6. Selected References

1. Xu, Zhaoyi, et al. "A Joint Design of MIMO-OFDM Dual-Function Radar Communication System Using Generalized Spatial Modulation," 2020 IEEE Radar Conference, Florence, Italy, 2020, pp. 1-6.
2. Liu, Fan, et al. "Joint Radar and Communication Design: Applications, State-of-the-Art, and the Road Ahead," in IEEE Transactions on Communications, vol. 68, no. 6, pp. 3834-3862, June 2020.