A Novel Waveform for a Joint Radar and Communication System

Joint communication and radar applications with a promising waveform

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Introduction & Motivation
A congested frequency spectrum forces the users of allocated radar frequency bands to find methods to coexist with a growing number of communication applications. Also, there is a huge demand from many customers to merge different systems into a single front-end assembly to reduce system complexity and, hence, improve utilization of existing hardware. Military users are also interested in making their radar and its current operating mode as difficult to identify as possible. Hence, there is a strong need to develop methods for a coexistence of both systems. This also includes techniques for a joint use of the electromagnetic signal for remote sensing and communication. By merging various radar and communication systems together, one can utilize the electromagnetic signal from each other to enrich the sensing capability and to enhance the robustness of communication. Our proposal is to extend the OFDM/OTFS waveform in such a manner that radar and communication systems can profit from each other.

Waveforms
From the many known waveforms, very different signals are used for Radar and communication systems.

- For radar its the FMCW waveform, where a mono-frequency signal is chirped over the bandwidth during the pulse duration.

\[ f(t) = f_0 + k f_1 t, \quad 0 \leq t < \tau_p \]

- pulse compression, fast processing, high probability of detection, low SNR
- Doppler sensitive for exact range, 1 Bit per Pulse

Modified FMCW using the LORA protocol enables a low bit rate communication over a huge distance.

- Communication prefers OFDM, a multi frequency carrier waveform with many different amplitude & phase coding schemes.

\[ x(t) = \sum_{k=-N}^{N} X_k e^{j2\pi f_k t}, \quad 0 \leq t < \tau_p \]

- high density of information due to multi frequency carrier system
- Doppler sensitive, sidelobe behaviour at pulse compression, need of cycle prefix, ...

Proposed Waveform
The Orthogonal Time Frequency Space (OTFS) waveform (derivated from OFDM), shows several advantages, e.g. strong resilience to delay-Doppler shifts. An OTFS signal is designed by symbols in the delay-Doppler plane and has always several OFDM frames:

An OTFS signal always has several OFDM frames. Frequency behaviour and characteristic is similar to that of an OFDM. → strong impact of Doppler shifts.

Using OFDM/OTFS waveforms for radar applications the exact structure must be known. For a monostatic setup this is always true. However, for a bistatic radar setup the additional decoding step has to be included. Hence, we propose an extension of this waveform in a manner to overcome this. For a waveform more suitable for radar operation, in the proposed OTFS waveform, the modulation symbol \( X[m, n] \) is replaced by:

\[ \hat{X}[m, n] = X[m, n] \cdot X_{rad}[m, n] \]

The elements of matrix \( X_{rad}[m, n] \) are assigned in such a manner that the output of the MF shows a behavior like a chirp.

- This allows to separate signal processing stage. One for the radar unit with the very fast pulse compression via an optimized matched filter stage and the communication path, fully independent from the first one.

Verification
The performance of the proposed waveform was verified using the following parameters: \( \tau_p = 100 \text{us}, \ b = 10 \text{MHz}, \ N_{\text{subsymbol}} = 16, \ M_{\text{ots}} = 62, \) Symbol Coding = 4QAM.

- easy detection of signal (Doppler insensitive),
- improved MF,
- reduction of PAPR from 9.19 \rightarrow 7.77,
- almost no degradation of BER.

Conclusion
The focus of this poster is the design of a dedicated waveform for JCR systems. Hence, a possible configuration is shown. Presented simulation results confirm the feasibility of the waveform. Future work will include a performance analysis of the radar subsystem and its dependence on E\text{SNR} under realistic constraints (multipath). Another task is to extend the used framework towards MIMO processing for radar- and communication subsystems and modelling of multi-user scenarios.

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