OFDM-based Joint Radar and Communication

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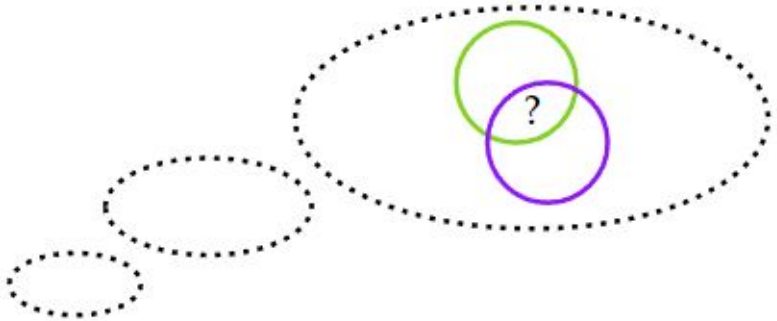
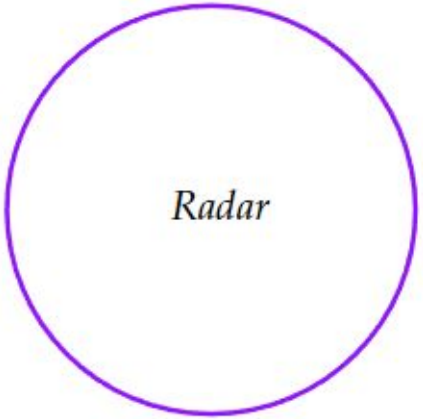
Can We Combine Radar and Communication?

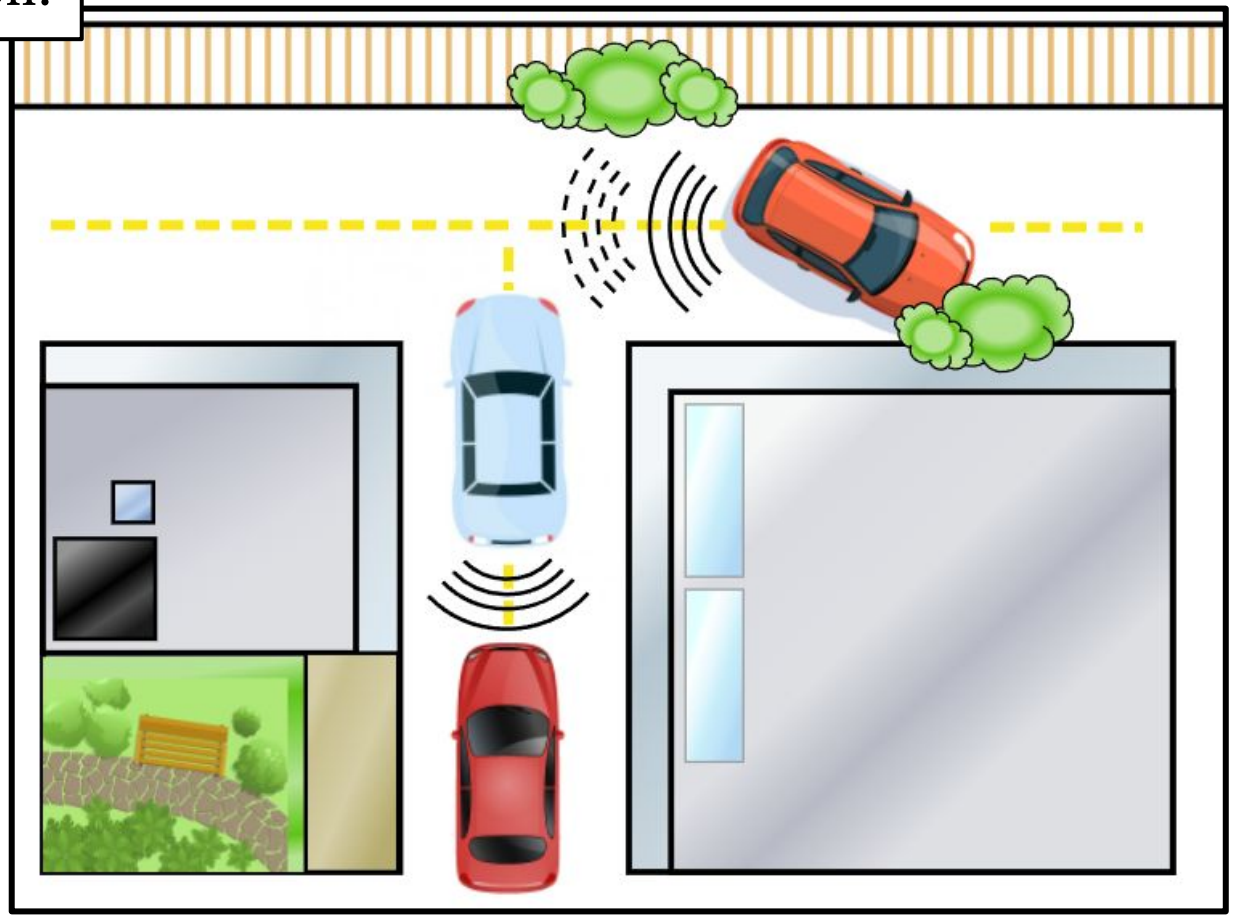


- Share hardware components common to each system.
- Attempt to use the frequency spectrum more efficiently.
- Reduce volume occupied *by* the system.

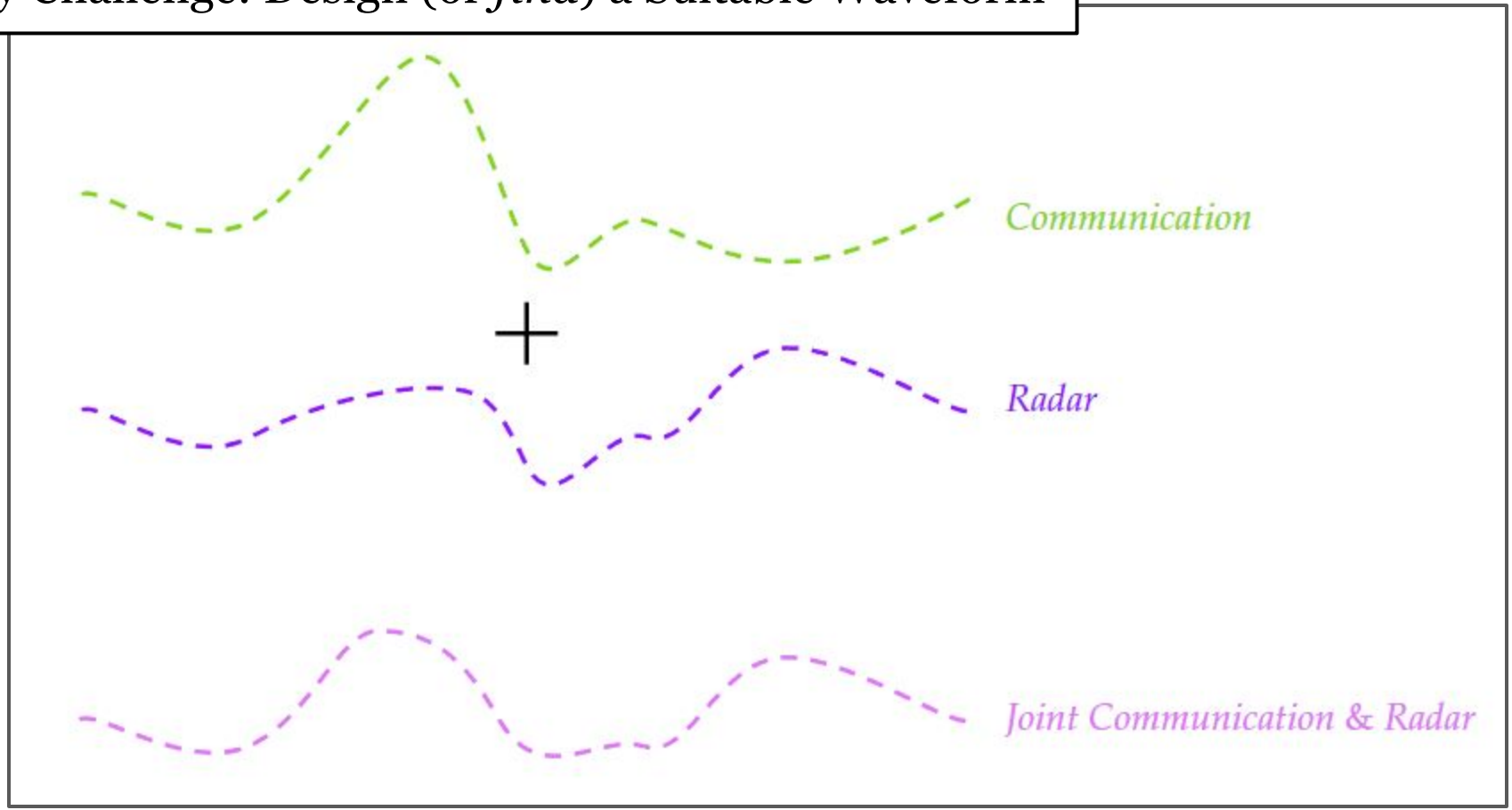


Example of ITS Application:

- One car can sense an on-road complication, and communicate this information to others that are out of range or out of sight of the event.



Key Challenge: Design (or *find*) a Suitable Waveform



Some Key Performance Metrics for each System:

Communication:

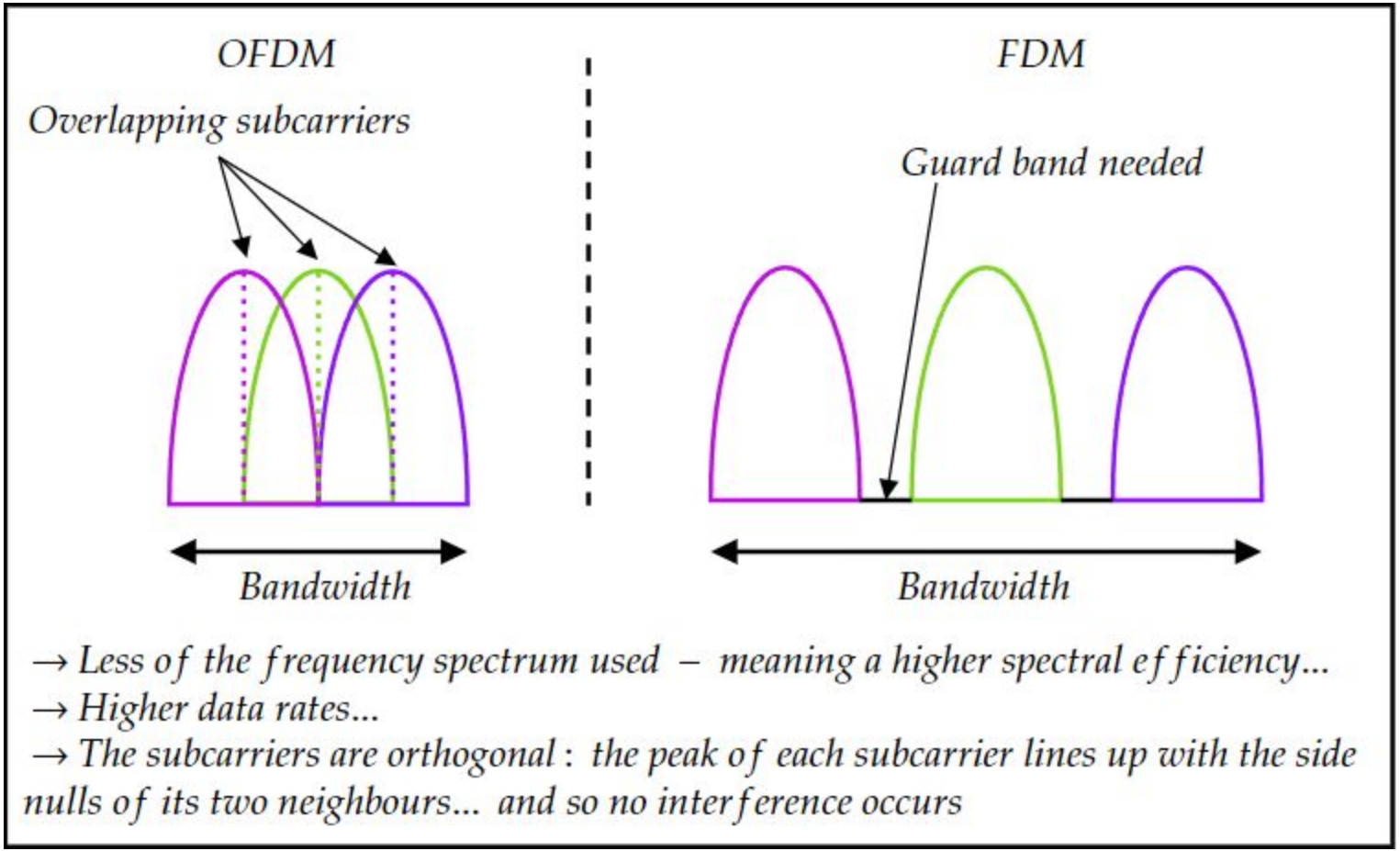
- Data rate
- Bit error rate (BER)
- Spectral efficiency (bandwidth usage)
- Its range

Radar:

- Its maximum range
- Its *resolution*
- Its accuracy

OFDM (Orthogonal Frequency-Division Multiplexing):

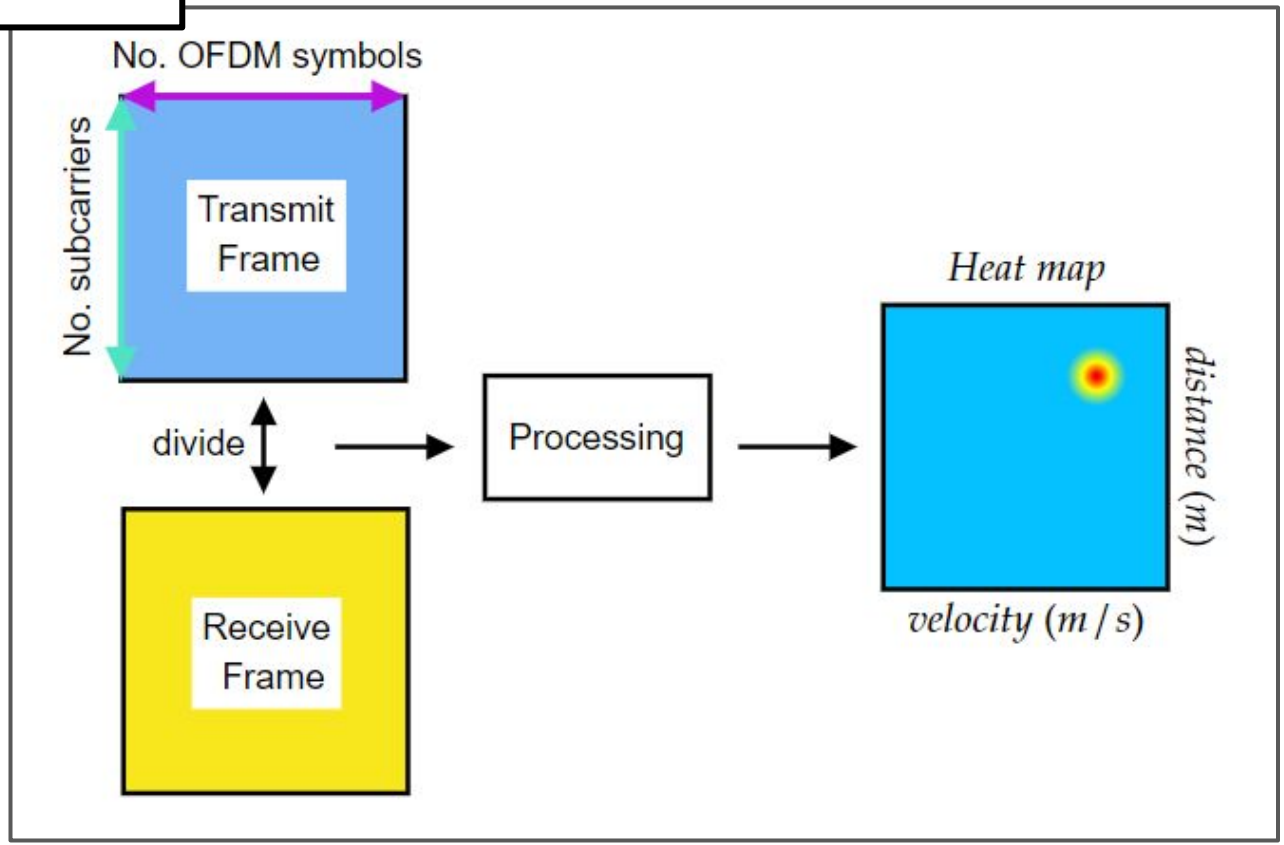
- Data is transmitted in parallel over separate subcarrier channels.
- The subcarriers are **orthogonal** and partly overlapping: in this way, the frequency spectrum is used more efficiently, and a very high data rate can be achieved.
- The data output of all the subcarrier channels constitutes an OFDM **symbol**.
- Symbols are sent in bursts, and a burst of symbols is often referred to as a **Frame**.
- The **Cyclic Prefix** is used to combat **Intersymbol Interference (ISI)**.
- The OFDM waveform tends to have a high peak-to-average power ratio (PAPR).



→ *Less of the frequency spectrum used – meaning a higher spectral efficiency...*
→ *Higher data rates...*
→ *The subcarriers are orthogonal : the peak of each subcarrier lines up with the side nulls of its two neighbours... and so no interference occurs*

Periodogram-based Algorithm:

- Independent of the transmitted data.
- Makes natural use of the structure of an OFDM frame.
- Relatively simple, and has the same processing gain as a standard correlation receiver.



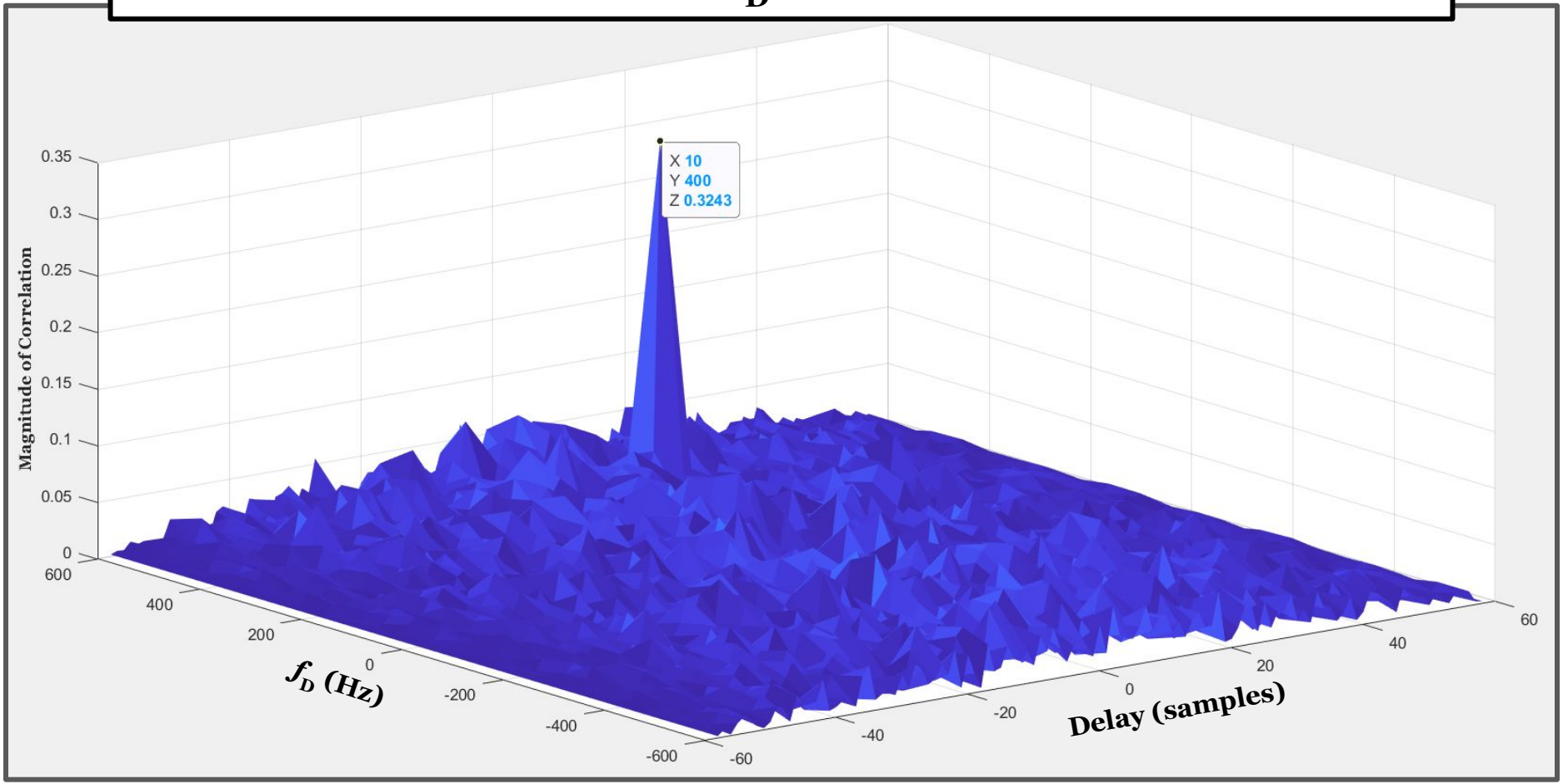
Correlation-based Algorithms:

Ambiguity function:

$$\chi_{r,s}(\tau, f) = \int_{-\infty}^{+\infty} r(t)s^*(t-\tau)e^{-j2\pi ft}dt$$

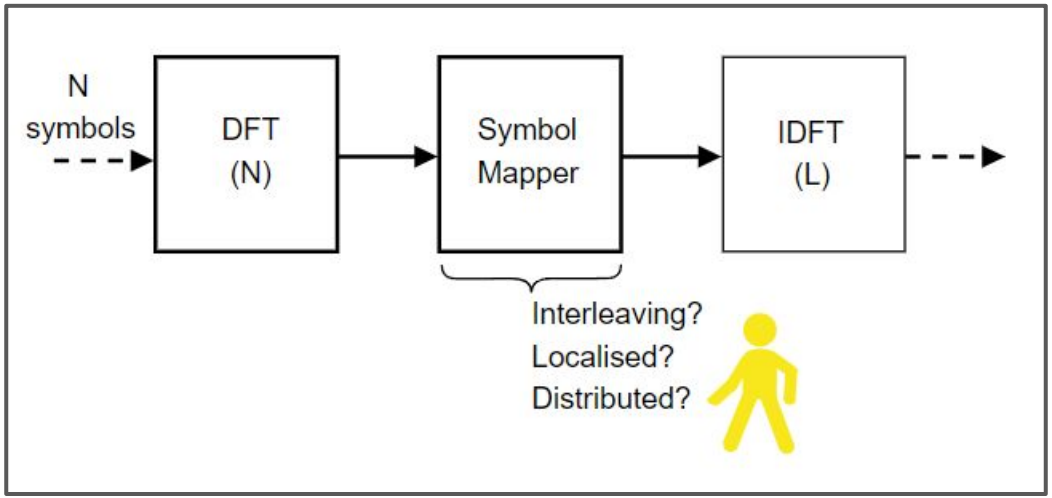
- The continuous-time return signal is sampled by an analog-to-digital converter (ADC).
- A discrete-time version of the two-dimensional cross correlation is computed. Still, the complexity can become very high.
- Random correlations in the transmitted data can lead to ambiguous peaks in the ambiguity surface [1], [2].

Ambiguity Surface: $\tau = 10, f_D = 400$, N = 52, M = 30, QPSK



DFT-Spread OFDM:

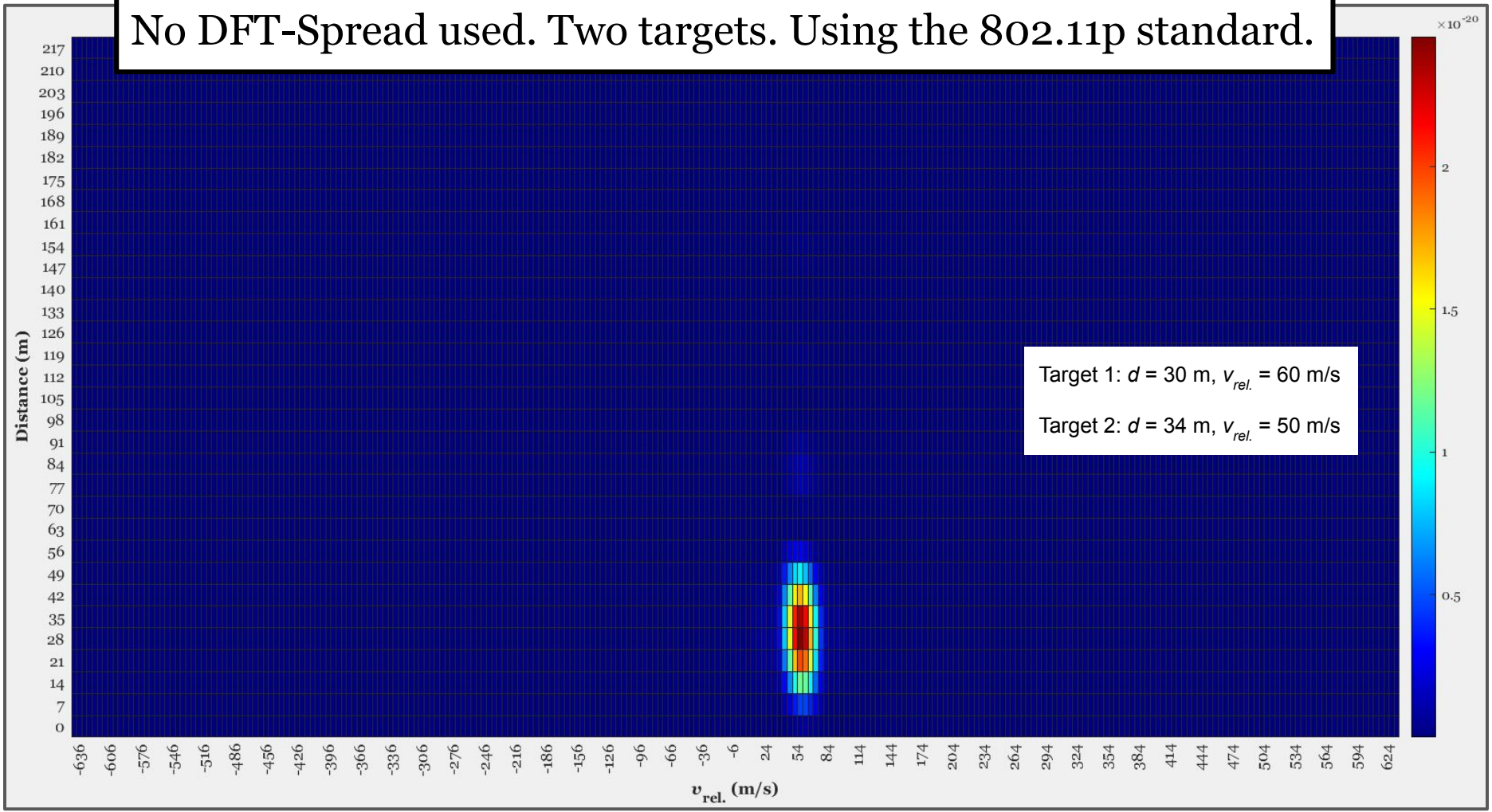
- A method for reducing the peak-to-average power of the OFDM waveform [3], [4].
- The data symbols are first passed through a Discrete Fourier Transform (DFT) block, before being mapped to the input of an inverse DFT block.
- The size of the IDFT block, *L*, is an integer multiple of the size of the DFT block, *N*.



Distance Resolution:

$$\Delta d = \frac{c}{2B} = \frac{c}{2N\Delta f}$$

No DFT-Spread used. Two targets. Using the 802.11p standard.



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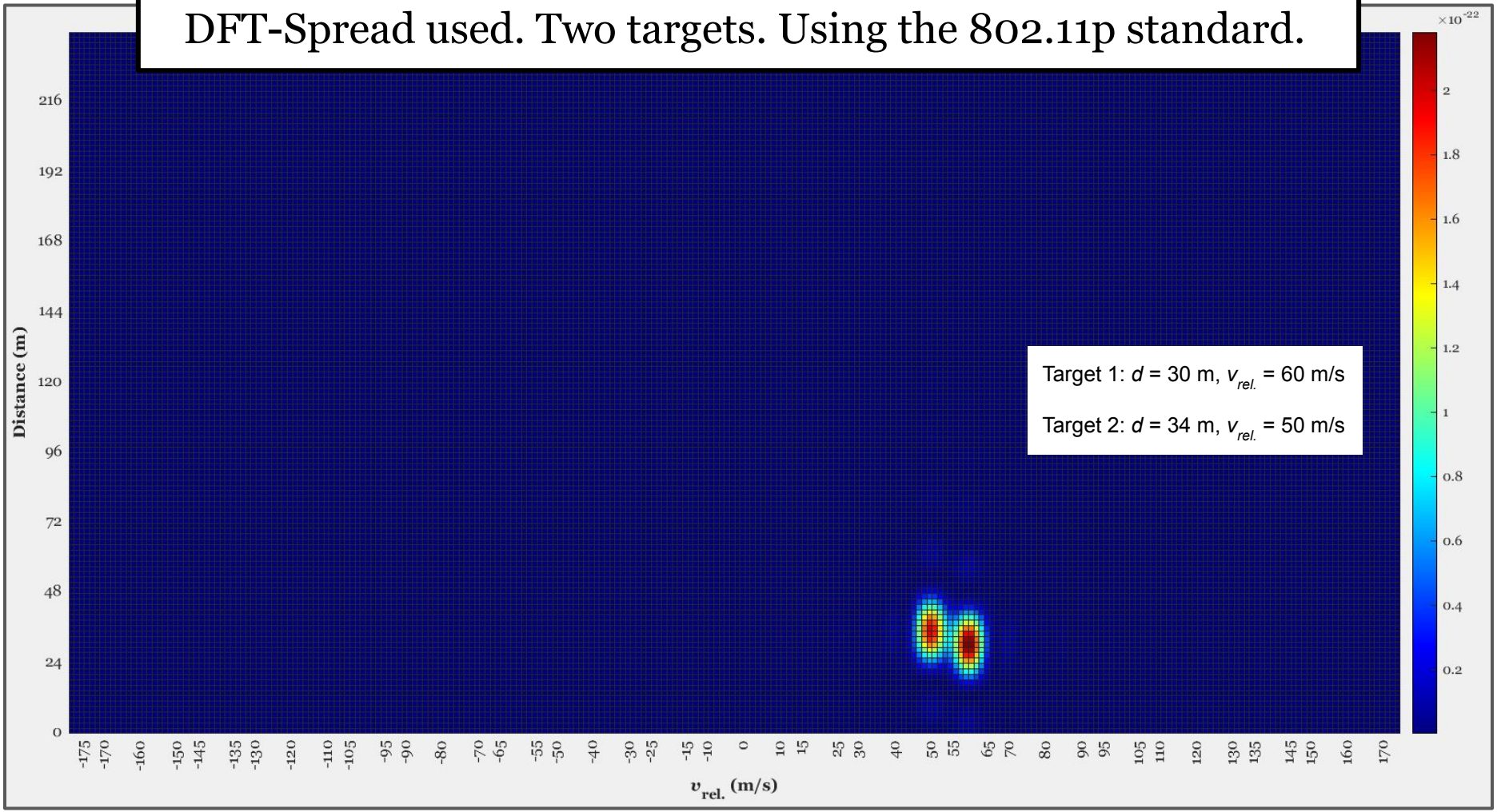
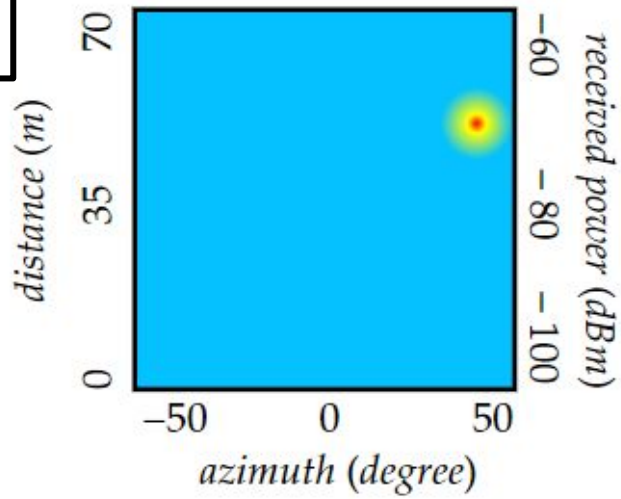
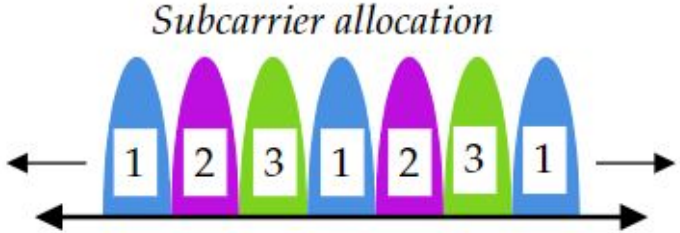
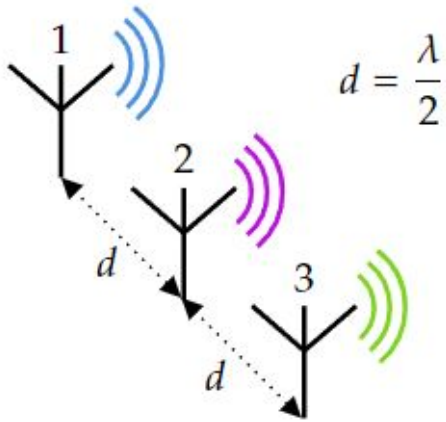


MIMO OFDM-based Communication and Radar:

- MIMO is already used in wireless communications. For example, Wi-Fi 6, 4G LTE and 5G.
- Combine signals from the various receive antennas in some way so as to improve the signal-to-noise ratio (SNR) and achieve a higher data rate.
- Estimate the target's azimuth (and therefore its position).
- MUSIC and ESPRIT algorithms are two of the main algorithms.







Thanks for listening

References:

[1] C. Sturm, T. Zwick, W. Wiesbeck, "*Performance Verification of Symbol-based OFDM Radar Processing*"

[2] M. Braun, "*OFDM Radar Algorithms in Mobile Communication Networks*"

[3] Sassan Ahmadi, "*5G NR: architecture, technology, implementation, and operation of 3GPP new radio standards*"

[4] K. Tahkoubit, A. Ali-Pacha, H. Shaiek, D. Roviras, "*PAPR reduction of BF-OFDM waveform using DFT-Spread technique*"

Project Motivation:

- Both functions are based on the principle of transmitting and receiving electromagnetic (EM) waves.
- Many systems that require communications capabilities *also* require sensing or *radar* capabilities, such as in the automotive industry, as well as the industrial automation sector.
- Some hardware components are common to both wireless communications and radar systems, such as radio-frequency modulators, antennas, and amplifiers.
- By combining the two into one, some hardware may be shared, and the frequency spectrum may be able to be utilised more efficiently.