OFDM-based Joint Radar and Communication

By *Dylan Boland*

Project Motivation:

- With the advance of IoT devices, especially in the automotive industry, more and more services are being integrated into single devices. For example, many modern-day cars are equipped with Radar, GPS, and communication functionality.

Principal Aim:

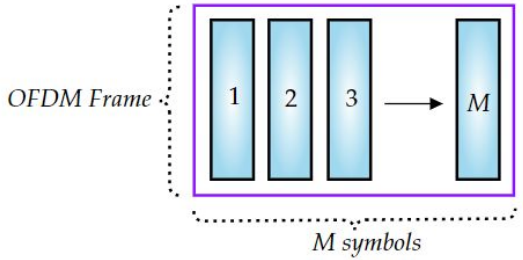
- The OFDM waveform has been adopted by 4G and 5G communication systems. With this in mind, it seems worthwhile to explore and analyse the possibility of adapting the waveform so that the communication system can *also* perform Radar functionality, thereby **combining** the two systems into one.

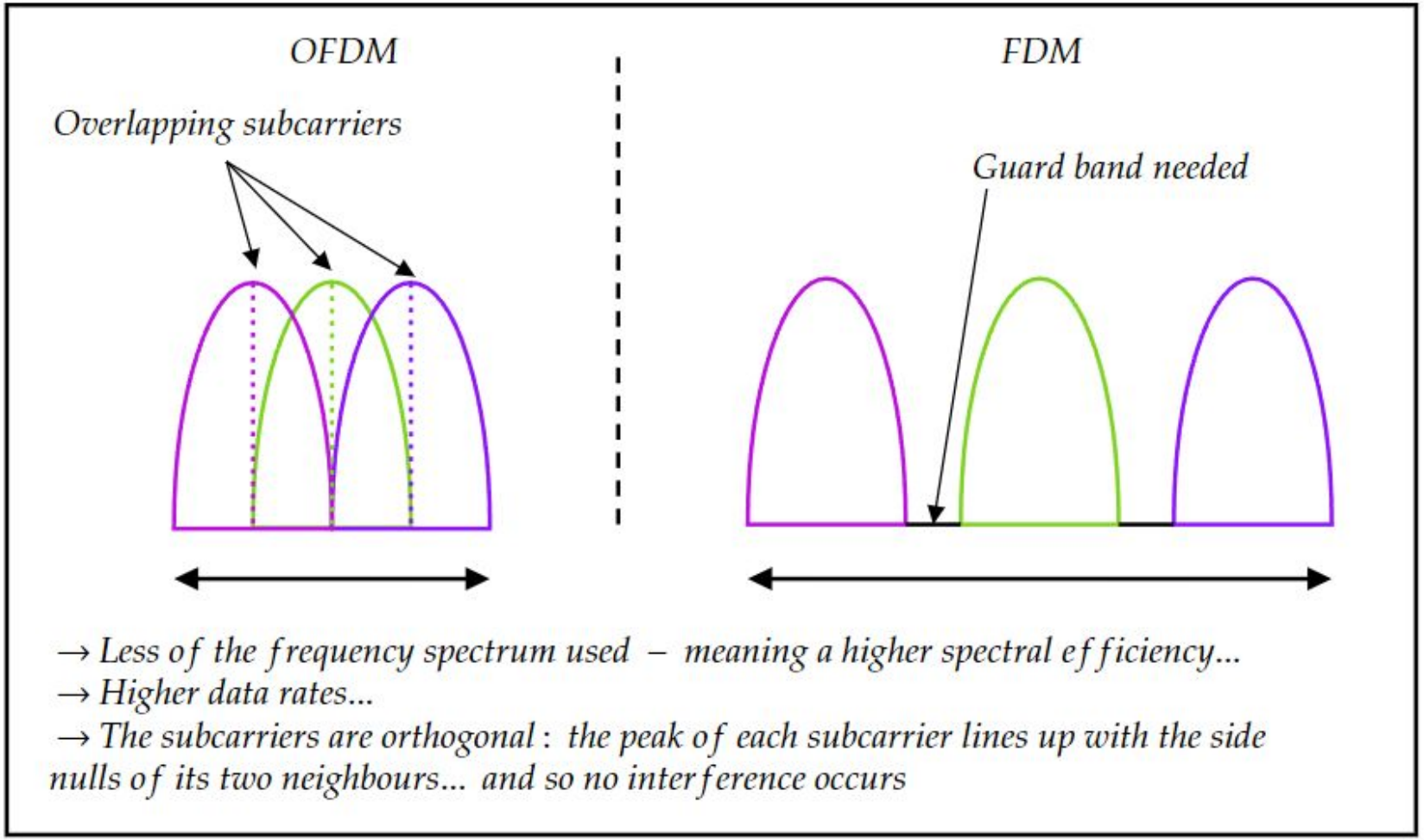
The Benefits:

- Less Hardware
- Reduced Costs
- Possibility for less of the frequency spectrum needing to be used - especially beneficial given how valuable it is.

OFDM (Orthogonal Frequency-Division Multiplexing):

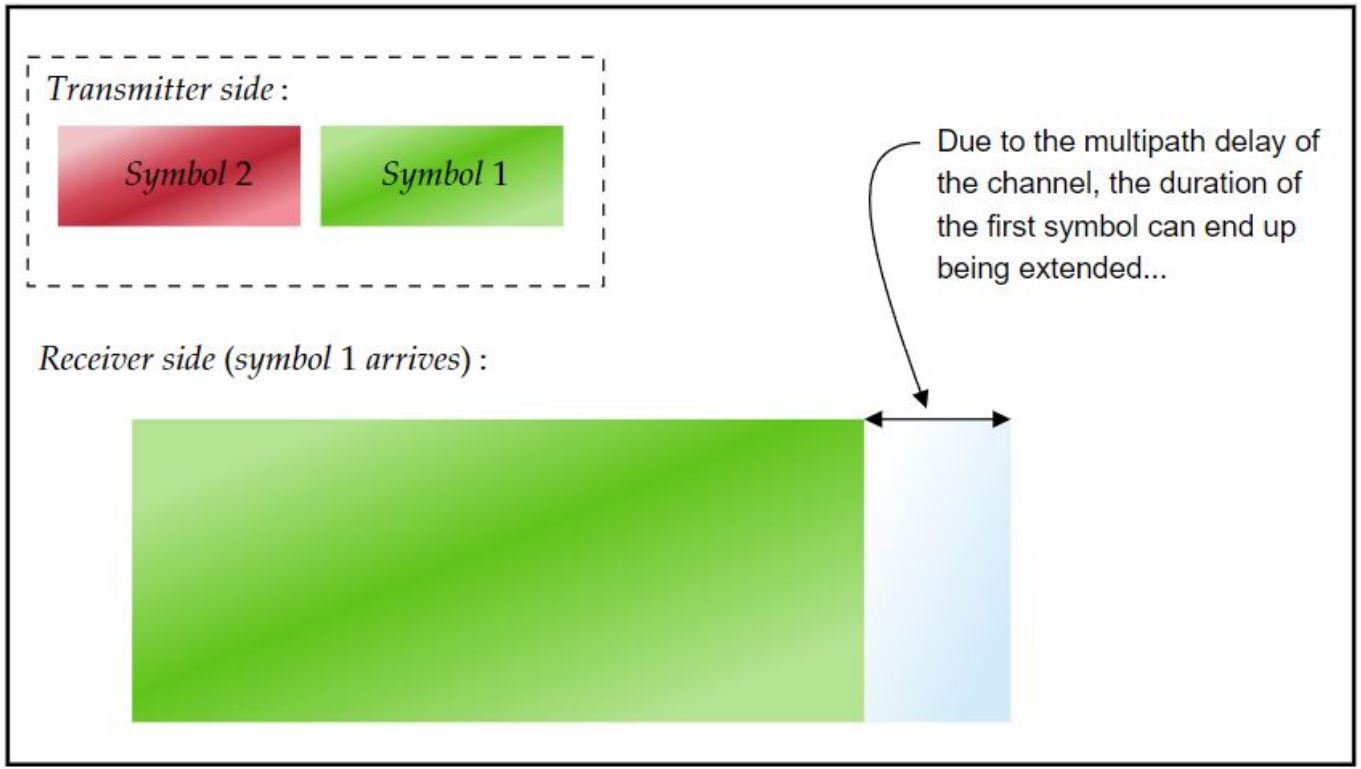
- Data is transmitted in parallel over separate subcarrier channels.
- The subcarriers are **orthogonal** and partly overlapping: in this way, the frequency spectrum is used more efficiently, and a very high data rate can be achieved.
- The data output of all the subcarrier channels constitutes an OFDM **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)**



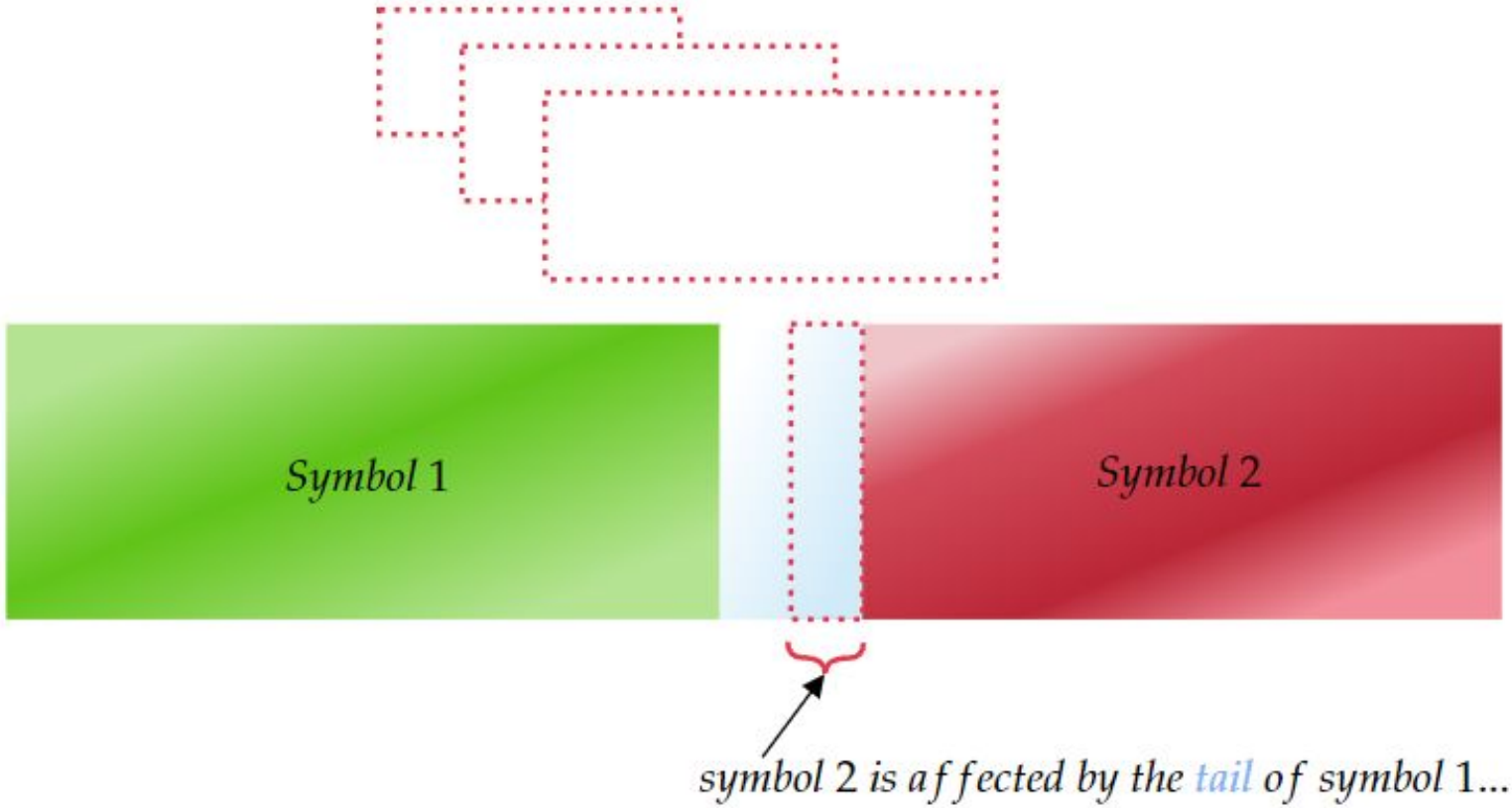


→ *Less of the frequency spectrum used – meaning a higher spectral efficiency...*
→ *Higher data rates...*
→ *The subcarriers are orthogonal : the peak of each subcarrier lines up with the side nulls of its two neighbours... and so no interference occurs*

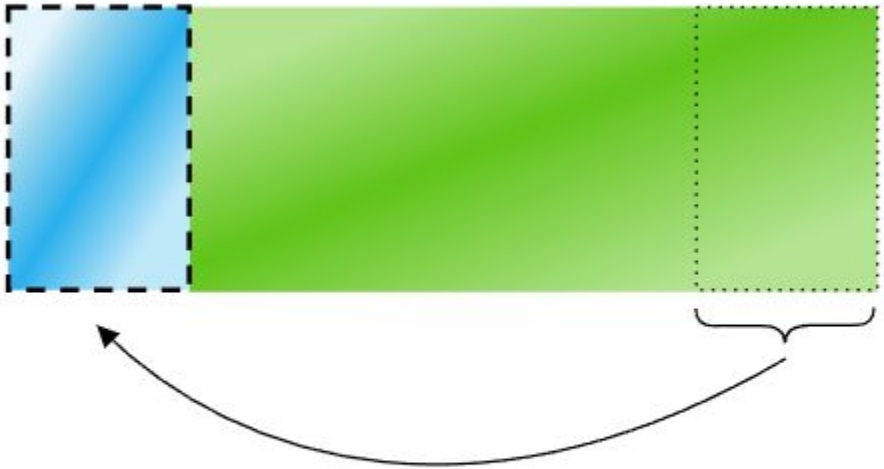
Cyclic Prefix (Why is it useful?):



Receiver side (symbol 2 arrives) :



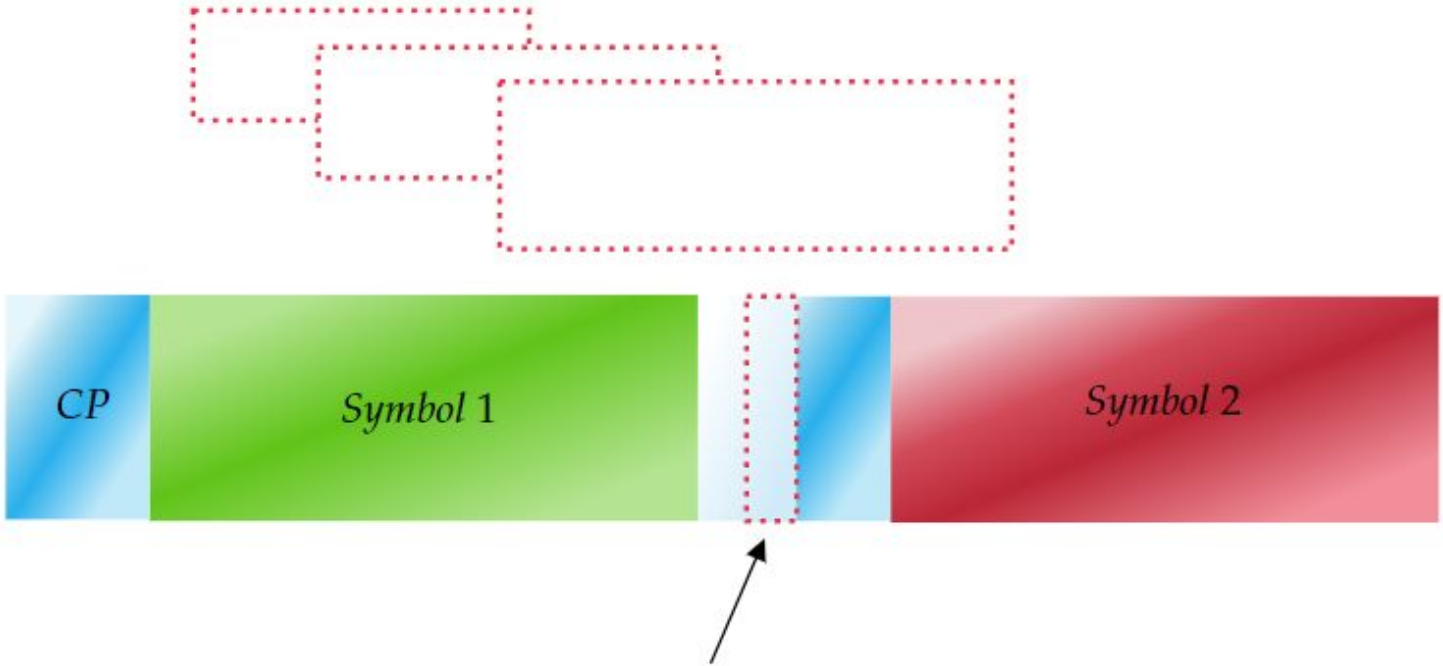
Adding the Cyclic Prefix



The end of symbol 1 is prefixed to its front. The symbol now appears cyclical to the receiver...

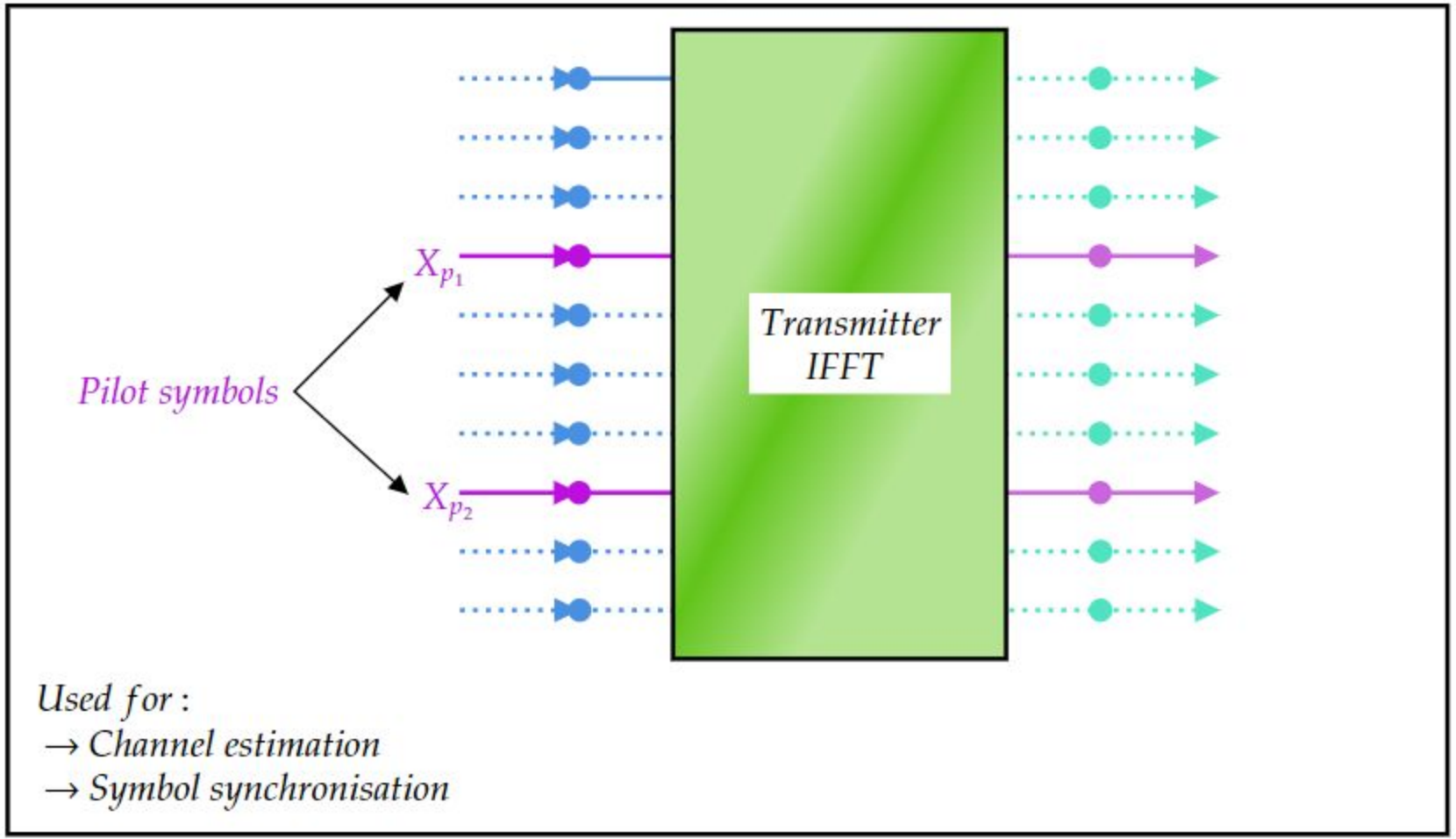
**The Cyclic Prefix acts as a guard interval, and helps protect against ISI...*

Now when symbol 2 arrives at the receiver :



Channel Estimation with Pilot Tones:

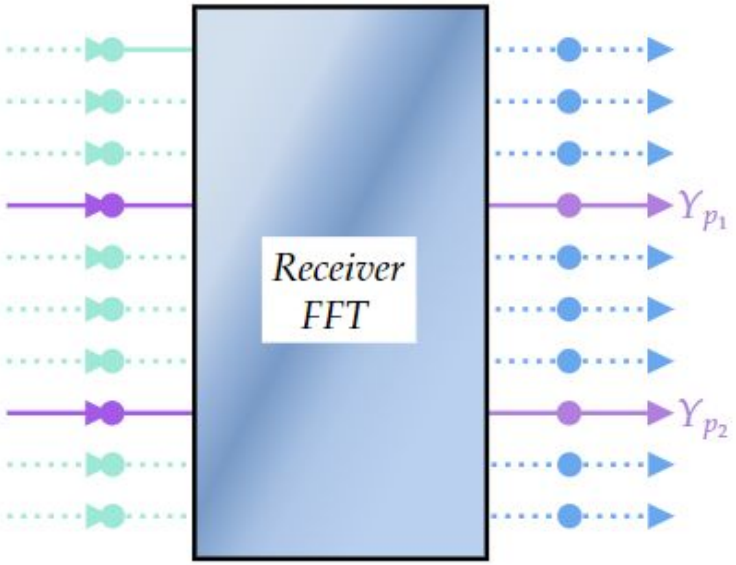
- Not *all* of the subcarriers are used for transferring data: some are used for estimating the channel, as well as to help the receiving side to synchronize itself with the incoming symbols.
- **Pilot tones** (symbols) are uniformly inserted onto subcarrier channels. At the receiver side, an estimation of the channel's effect on the pilot tones can be made - in this way the channel can be estimated, and interpolation can be used to estimate the channel's effect on the **other subcarrier** channels.



Used for :

→ *Channel estimation*

→ *Symbol synchronisation*



...Information
about the channel
can be obtained
based on how it
affects the pilot tones
that were transmitted

Pilot tone transmitted : $\longrightarrow X_{p_1}$

Pilot tone received : $\longrightarrow Y_{p_1}$

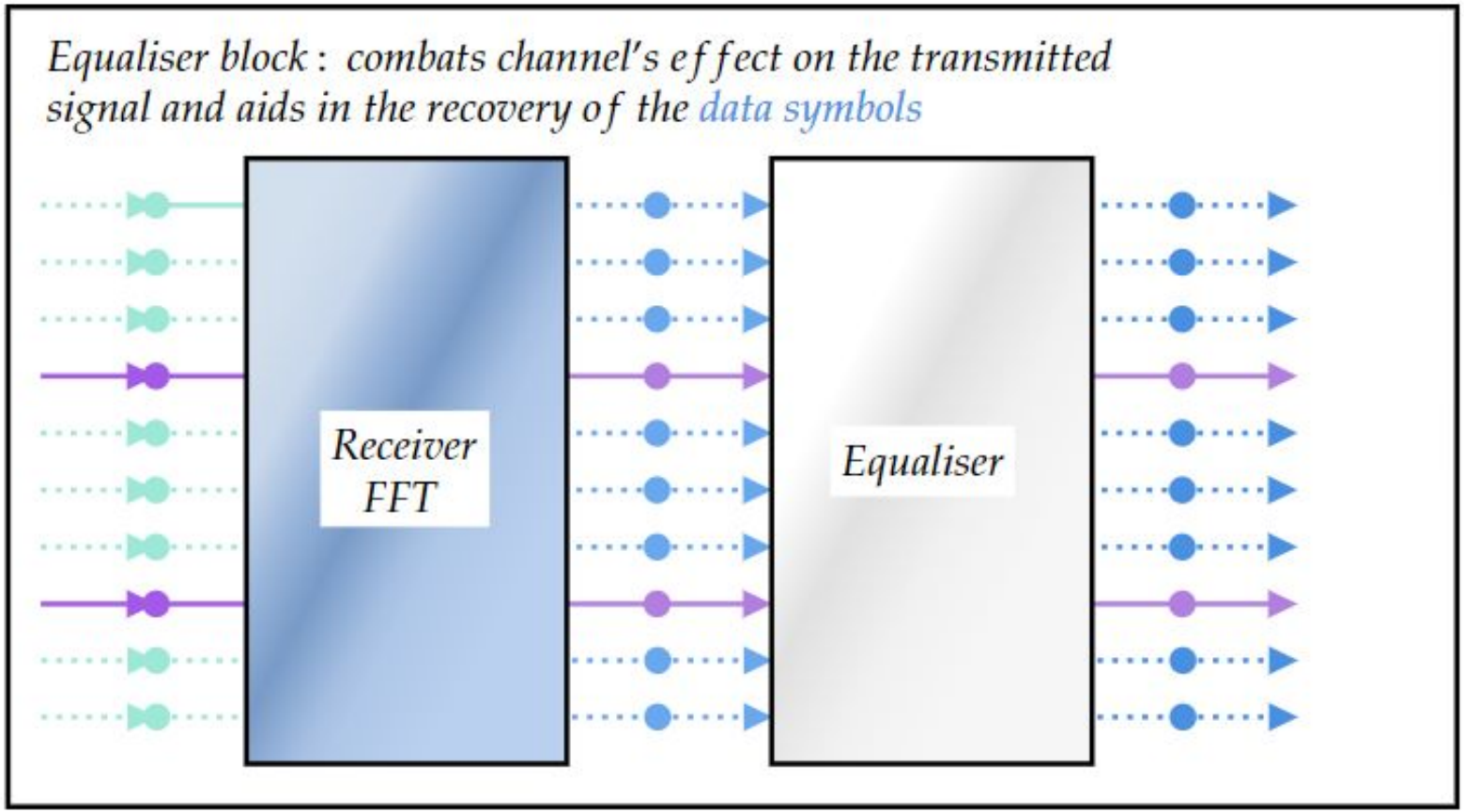
$$Y_{p_1} = X_{p_1}\hat{H}_{p_1} + Z_{p_1} \qquad \therefore \hat{H}_{p_1} = \frac{Y_{p_1}}{X_{p_1}} - \frac{Z_{p_1}}{X_{p_1}}$$

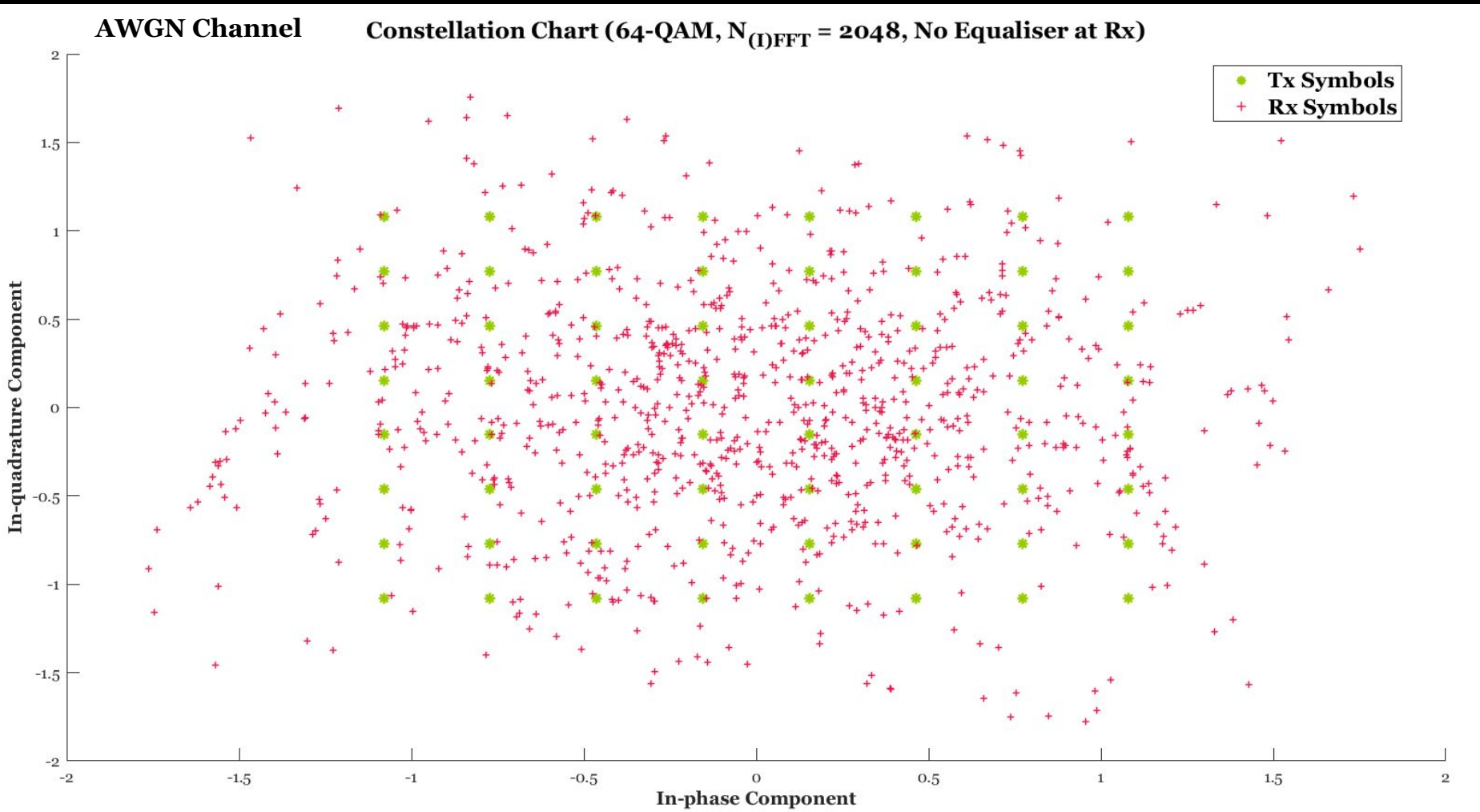
**The receiver knows which subcarriers correspond to the pilot tones...*

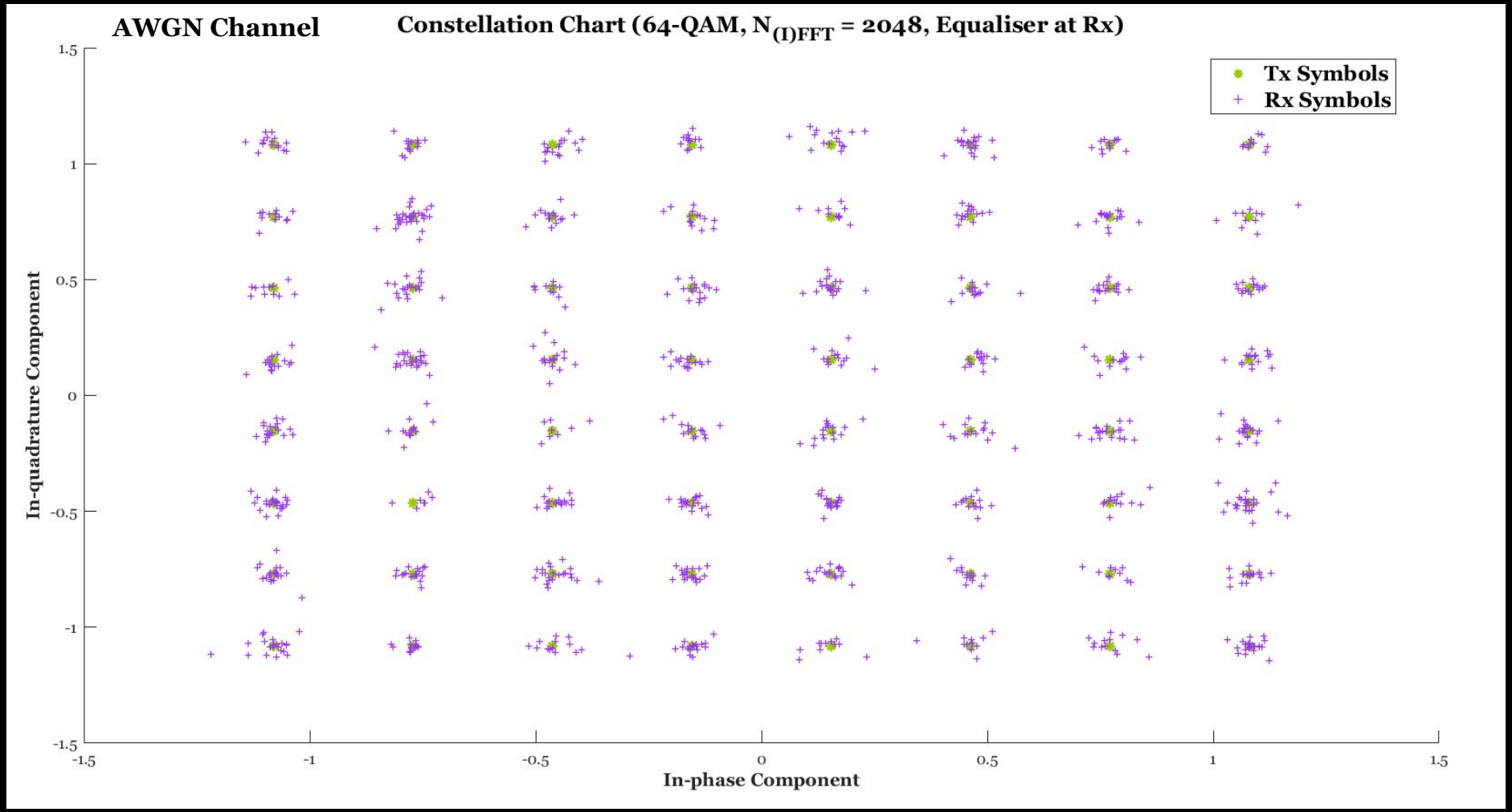
$$Y_{p_2} = X_{p_2}\hat{H}_{p_2} + Z_{p_2} \qquad \therefore \hat{H}_{p_2} = \frac{Y_{p_2}}{X_{p_2}} - \frac{Z_{p_2}}{X_{p_2}}$$

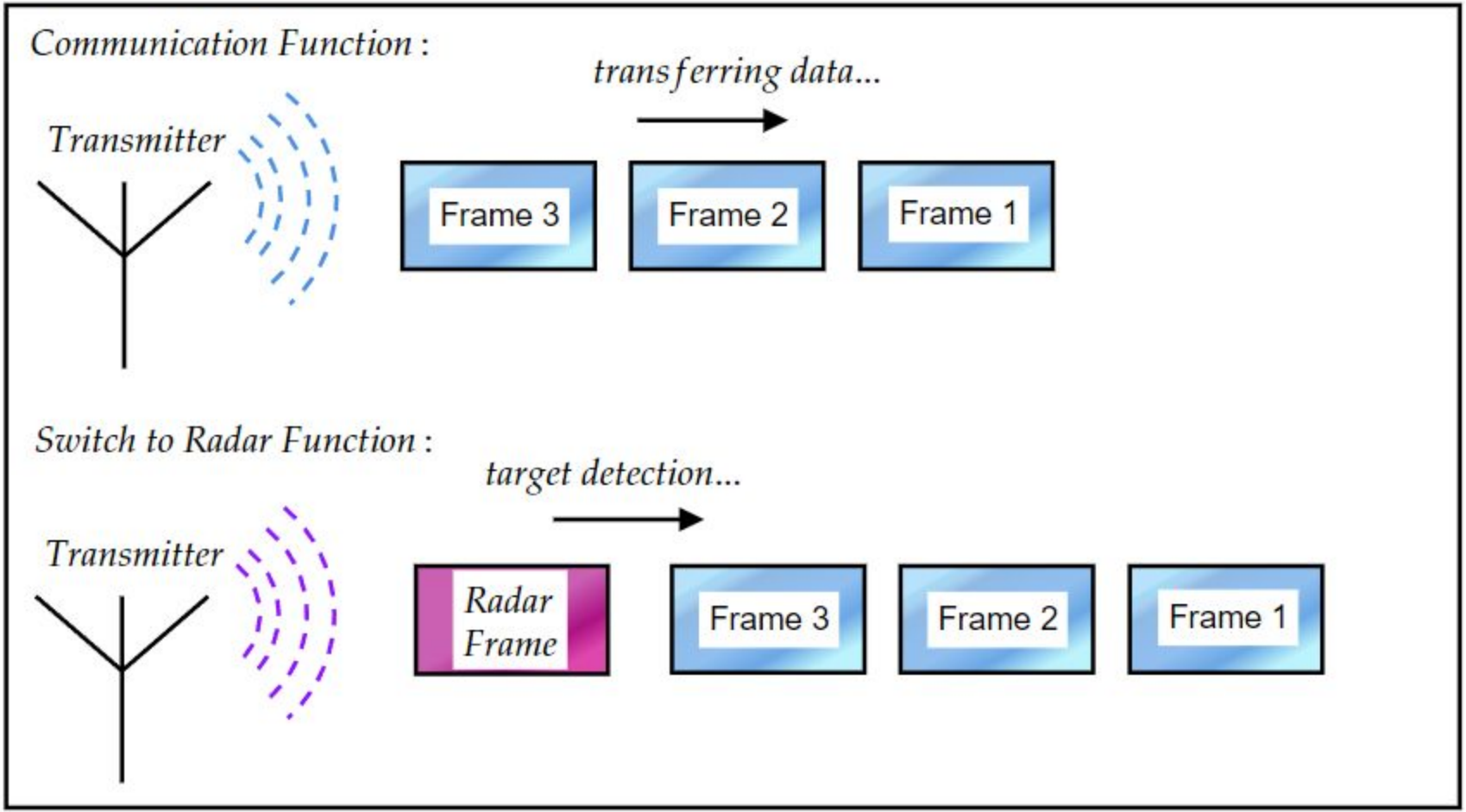
Noise

Equaliser Block:



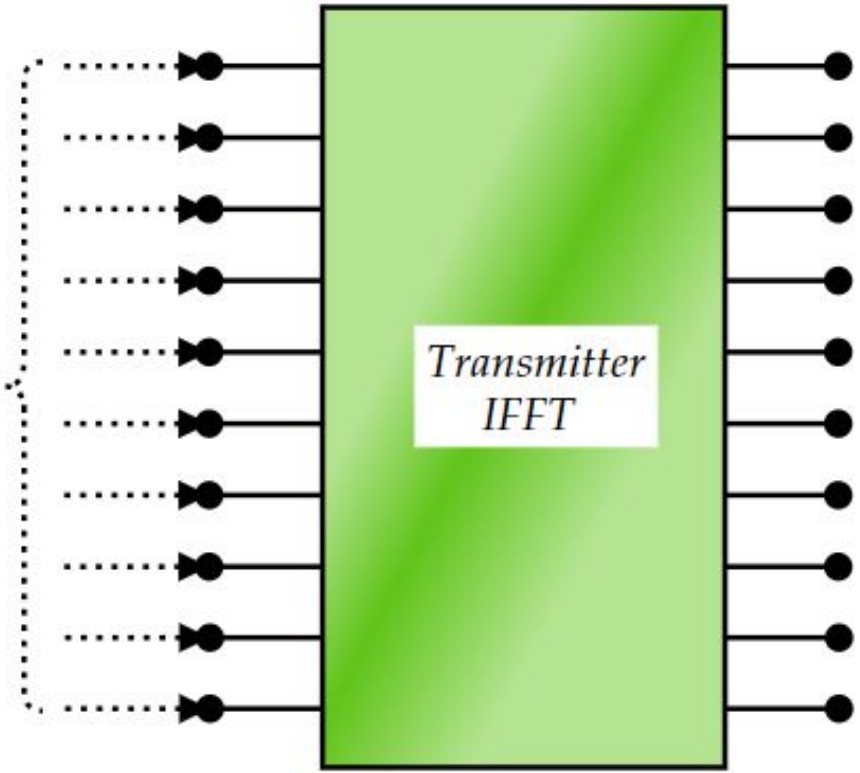

AWGN Channel
Constellation Chart (64-QAM, N(I)FFT = 2048, No Equaliser at Rx)
Tx Symbols
Rx Symbols
In-quadrature Component
In-phase Component
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2


AWGN Channel
Constellation Chart (64-QAM, N(I)FFT = 2048, Equaliser at Rx)
Tx Symbols
Rx Symbols
In-quadrature Component
In-phase Component
1.5
1
0.5
0
-0.5
-1
-1.5

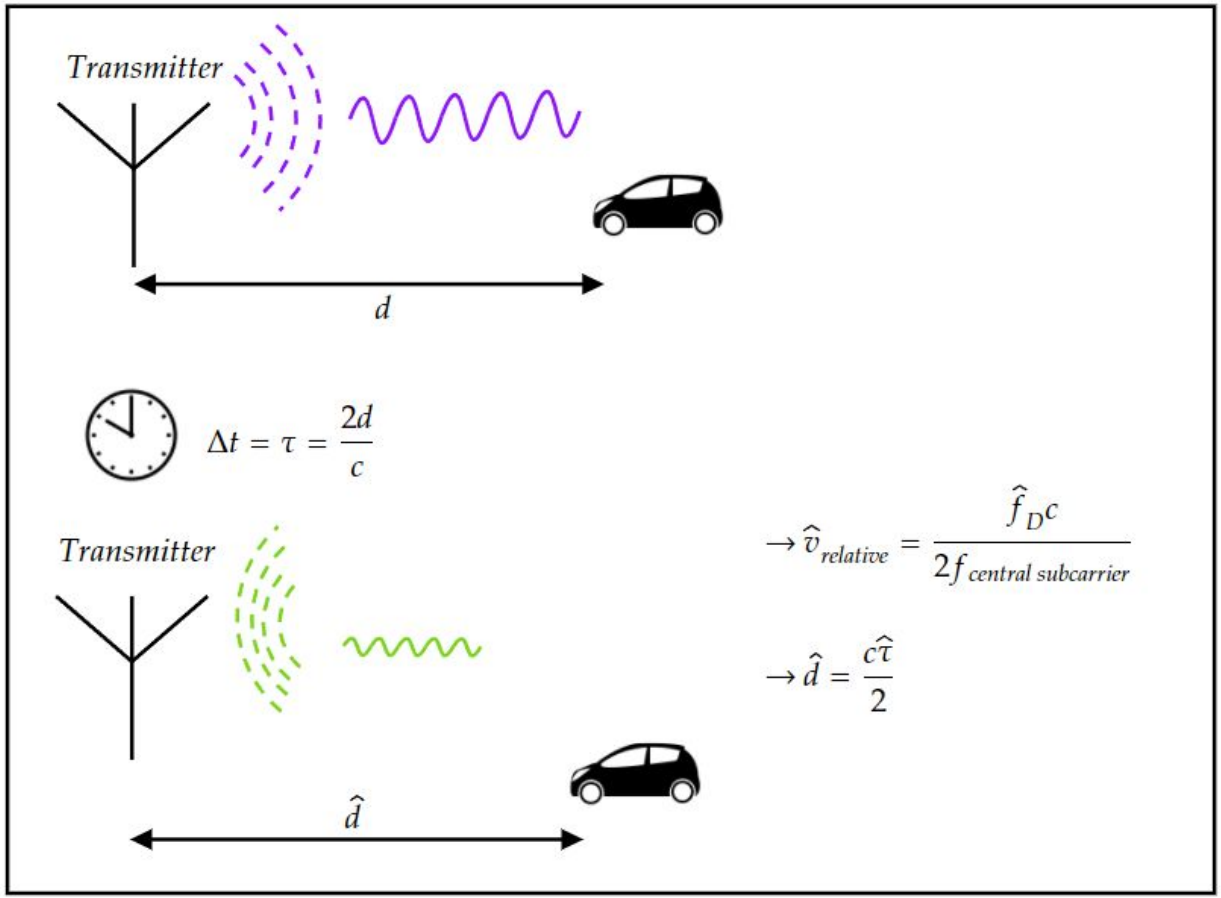

Communication Function :
transferring data...
Transmitter
Frame 3
Frame 2
Frame 1
Switch to Radar Function :
target detection...
Transmitter
Radar Frame
Frame 3
Frame 2
Frame 1

Radar Function :

How should we load the subcarriers in order to best perform the radar function?

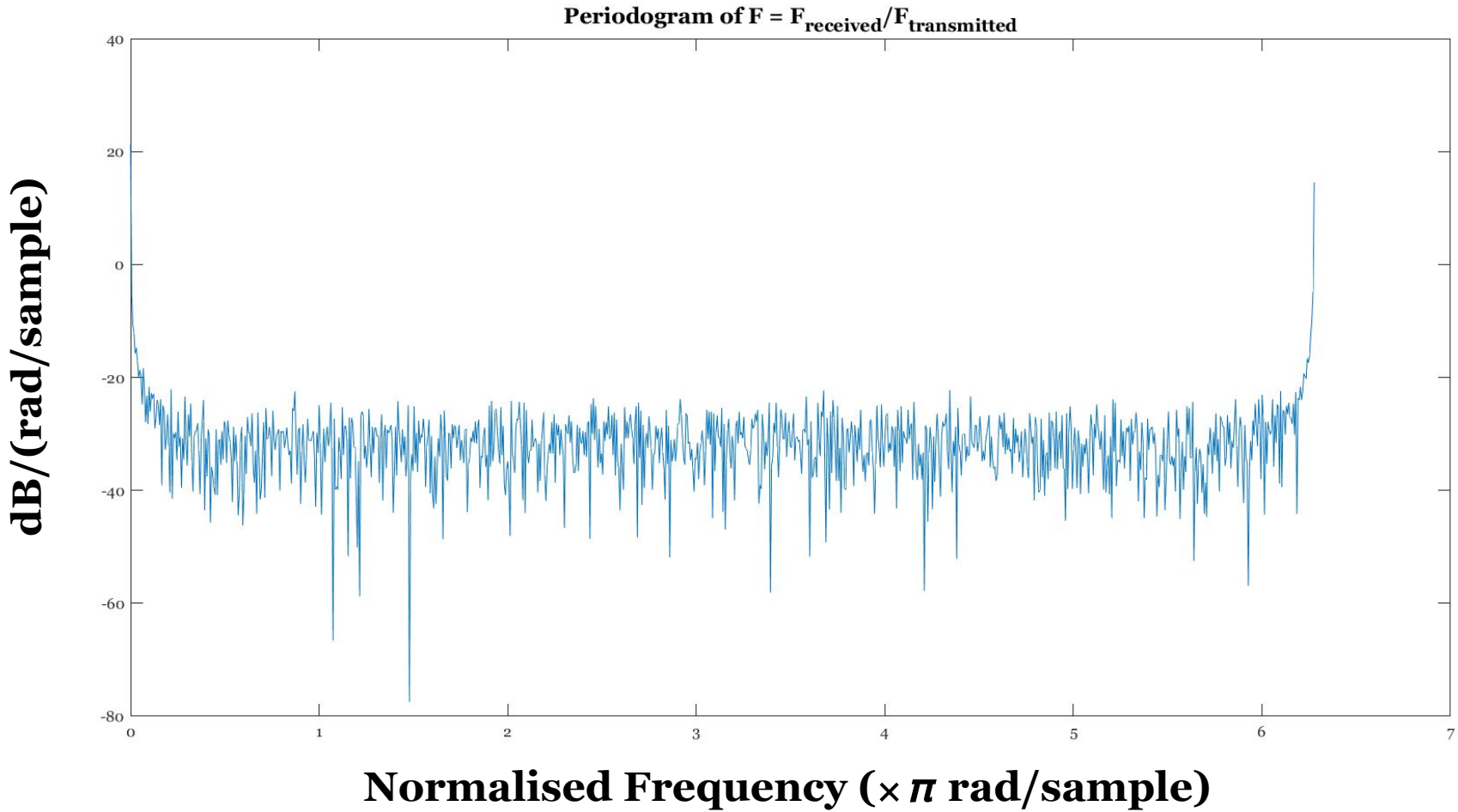


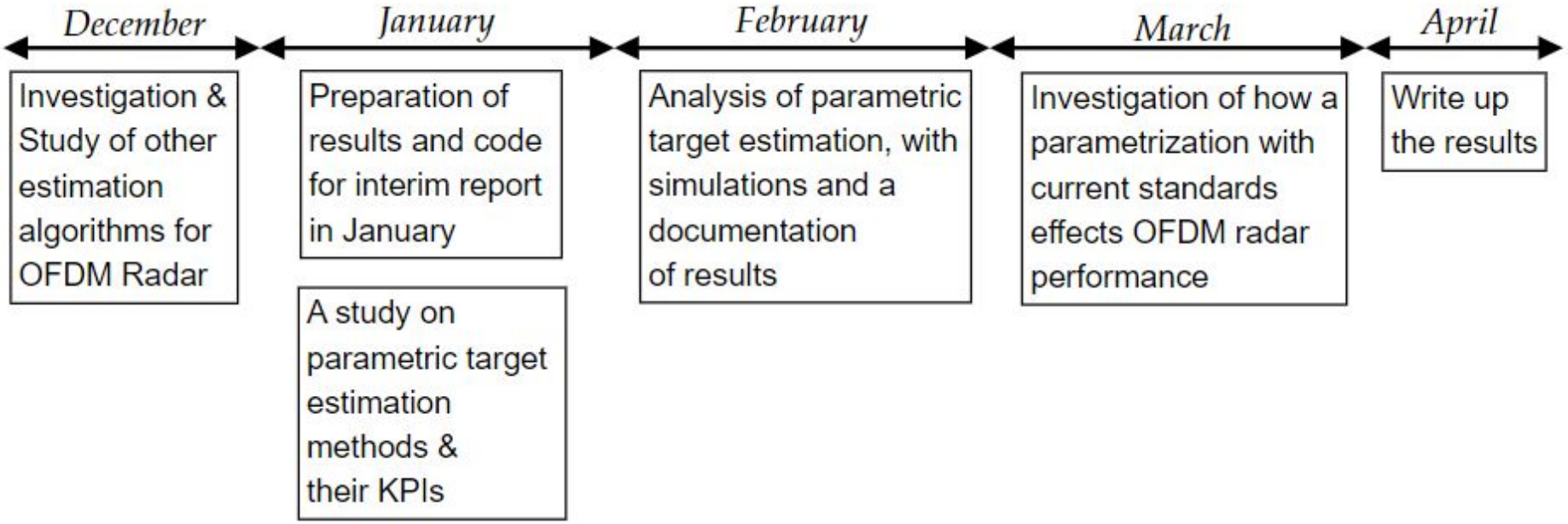
Estimation of the Time Delay and the Doppler Shift:



Some of the key performance measures of Radar systems are its:

- Its maximum range
- Its accuracy
- Its resolution
- Its ability to detect the desired echo


Periodogram of F = F_received/F_transmitted
dB/(rad/sample)
40
20
0
-20
-40
-60
-80
0
1
2
3
4
5
6
7
Normalised Frequency (× π rad/sample)


December
January
February
March
April
Investigation & Study of other estimation algorithms for OFDM Radar
Preparation of results and code for interim report in January
A study on parametric target estimation methods & their KPIs
Analysis of parametric target estimation, with simulations and a documentation of results
Investigation of how a parametrization with current standards effects OFDM radar performance
Write up the results