Speck NET

Research Consortium in Speckled Computing

FFT-Based Data Extraction for Specknets

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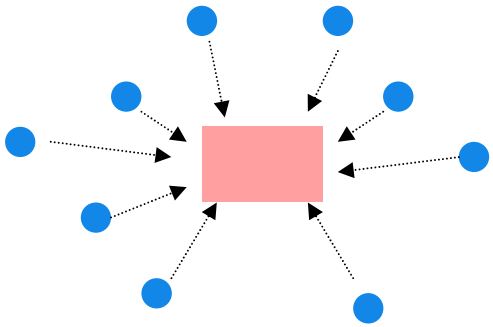
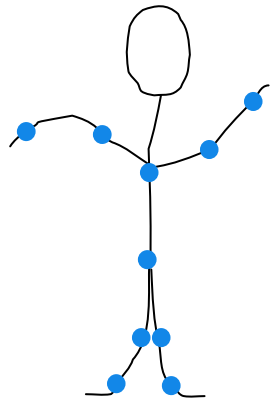
Outline

- Data extraction
- OFDM and OFDMA for data extraction
- FFT-based data extraction
- Time offsets
- Frequency offsets
- Future work

Data Extraction

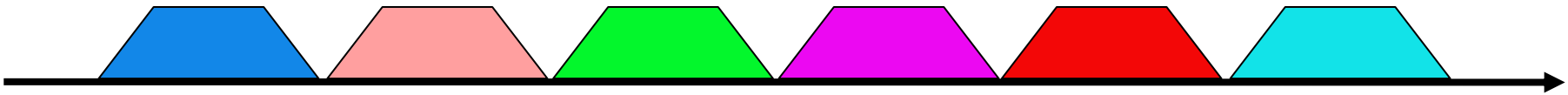
- Situations where it is useful to extract data as efficiently as possible
  - Embedded Specknet with a stationary or mobile sink
- Wireless motion tracking
  - Data from motion tracking sensors collated at a single point





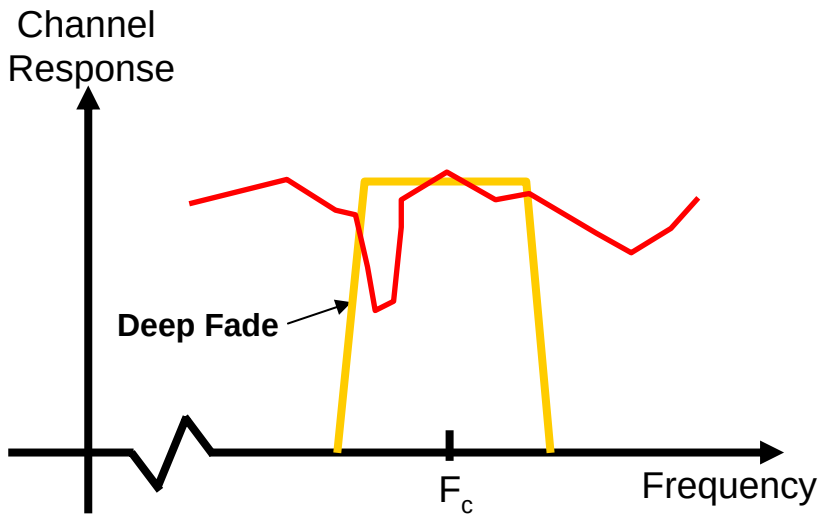
Data extraction channel sharing

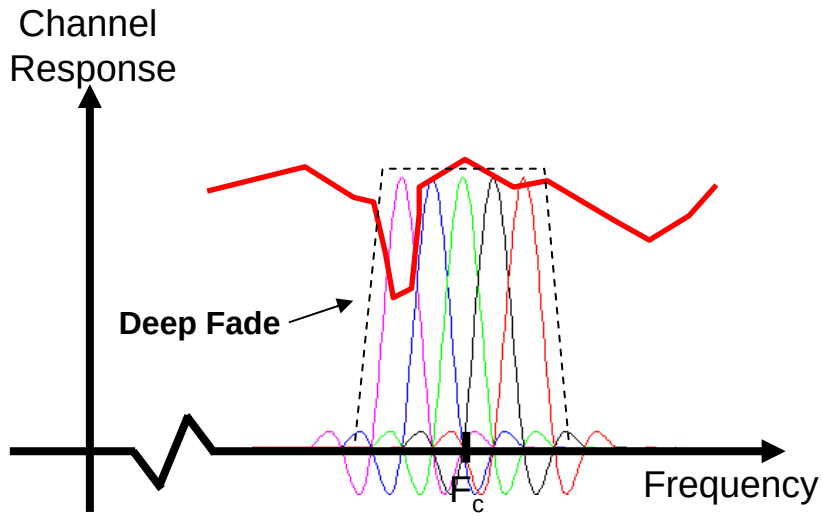
- TDMA
  - Scheduled transmissions, polling
- CDMA
  - “Multiple” receivers
- FDMA
  - OFDM-based data extraction



Multicarrier techniques

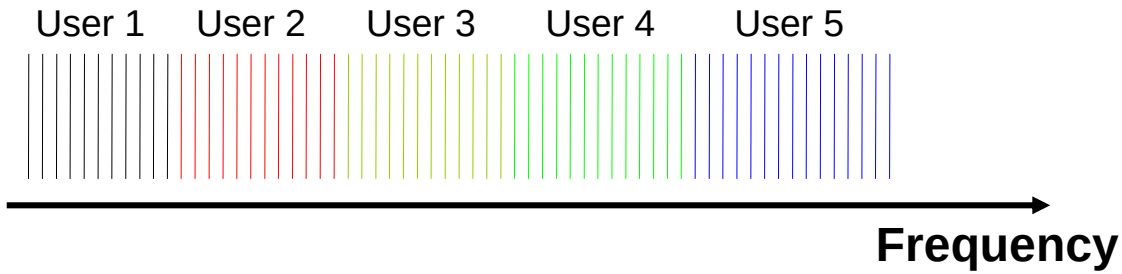
- Orthogonal Frequency Division Multiplexing (OFDM)
- Relatively simple DSP used to modulate data onto multiple carriers
- Main advantage is resilience to fading
  - Fading introduced by multipath effect, movement





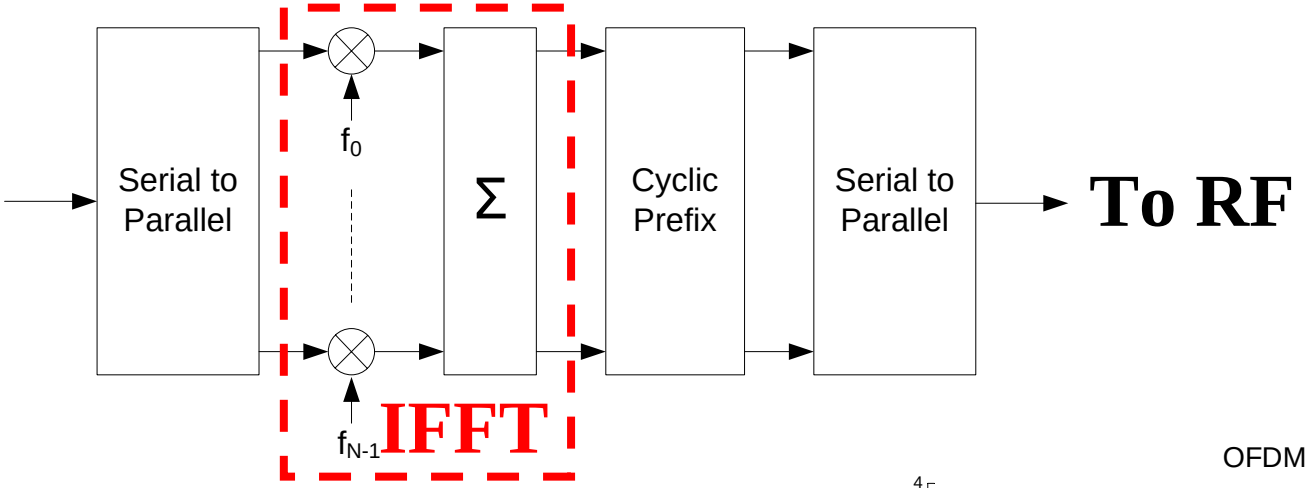
Multicarrier multiple access (MC-MA)

- OFDM can be combined with CDMA, TDMA or FDMA techniques to provide a multiple access solution

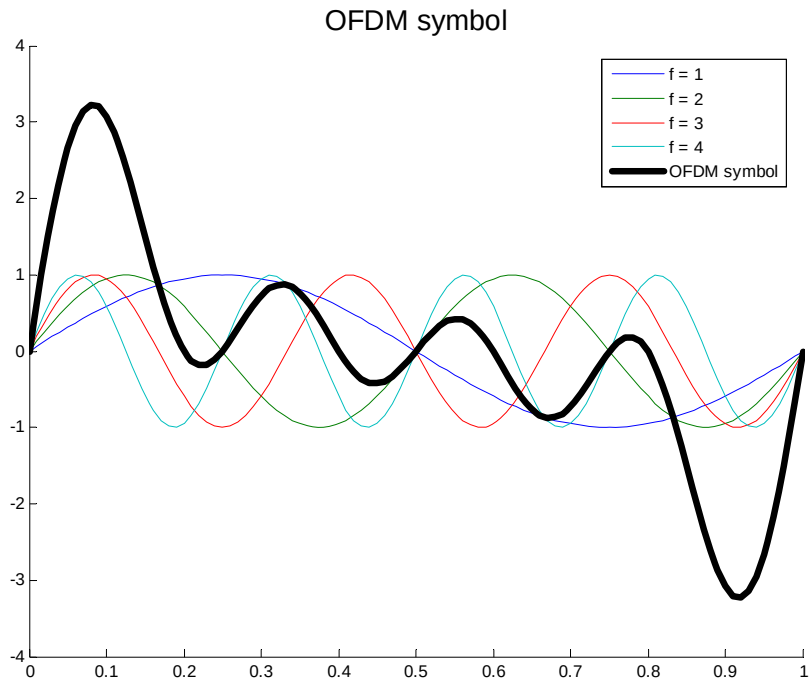


  - FDMA - Individual users are allocated subcarriers, which are separated in the frequency domain using baseband DSP techniques
  - Data is modulated in the transmitter using an IFFT
  - In the receiver, the FFT is used to demodulate the received signal

Transmitting with the IFFT

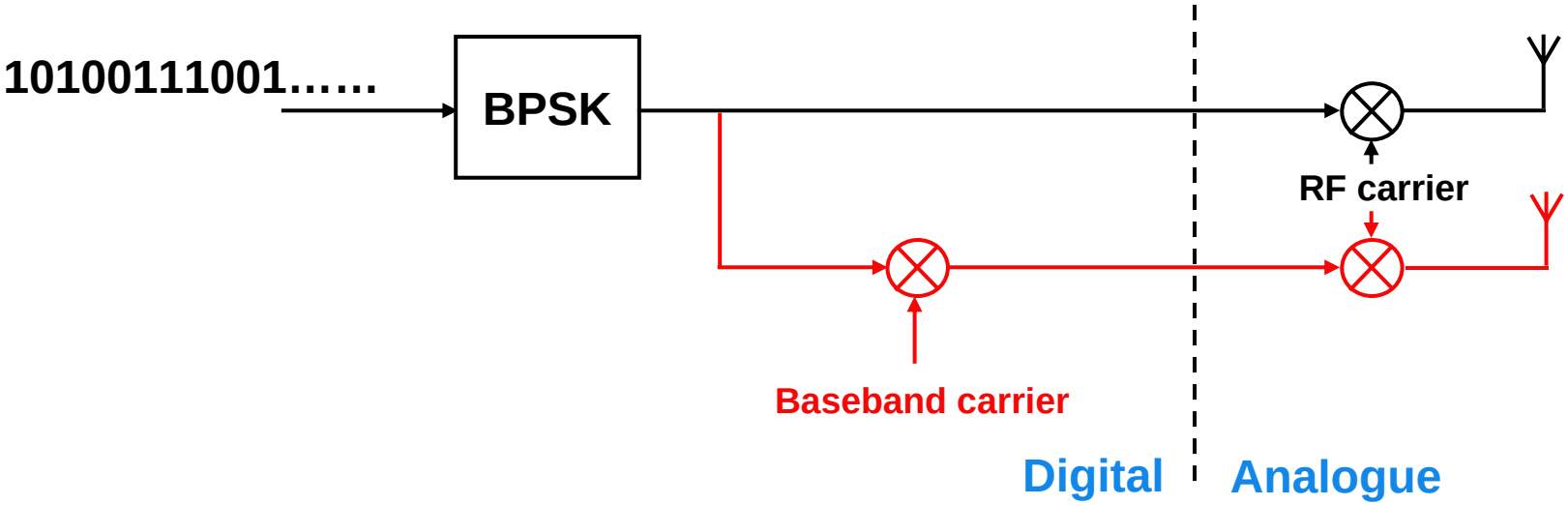


- Full speed data stream split up into multiple lower-speed streams
- Placed onto orthogonal carriers using IFFT



A sum of sinusoids

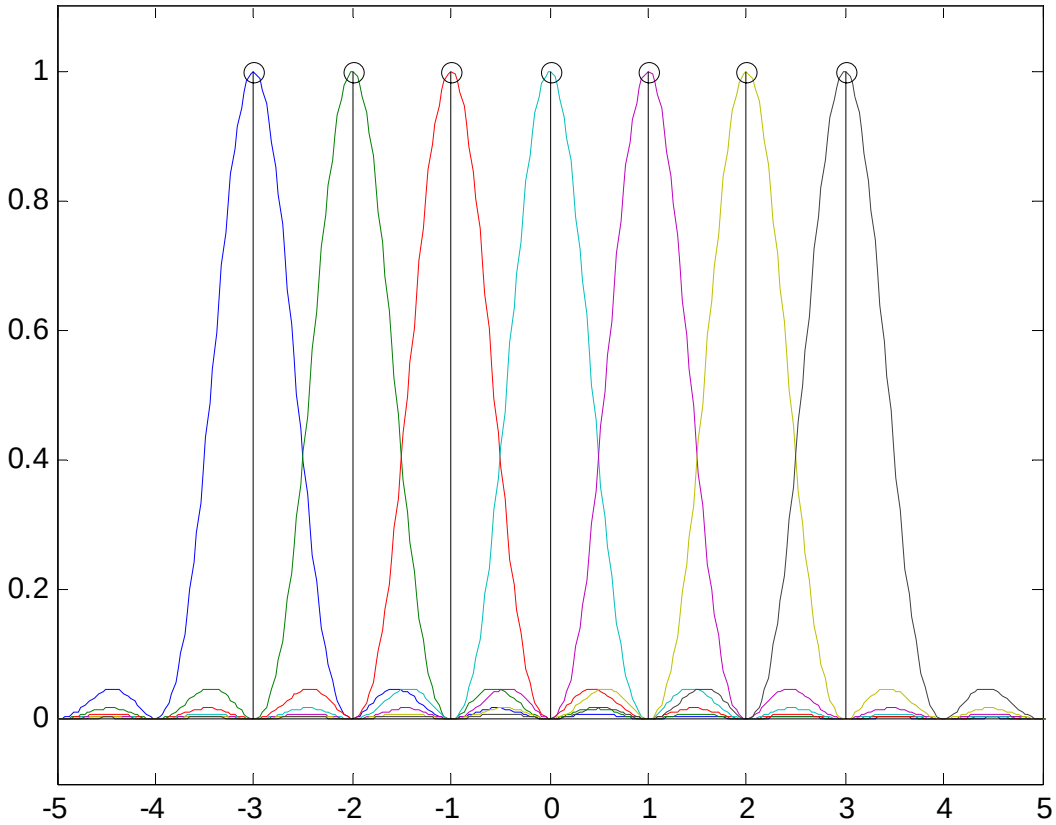
- An OFDM symbol is a sum of sinusoids at orthogonal frequencies
- A transmitter using only a single subcarrier can modulate with standard techniques



- A very simple transmitter architecture

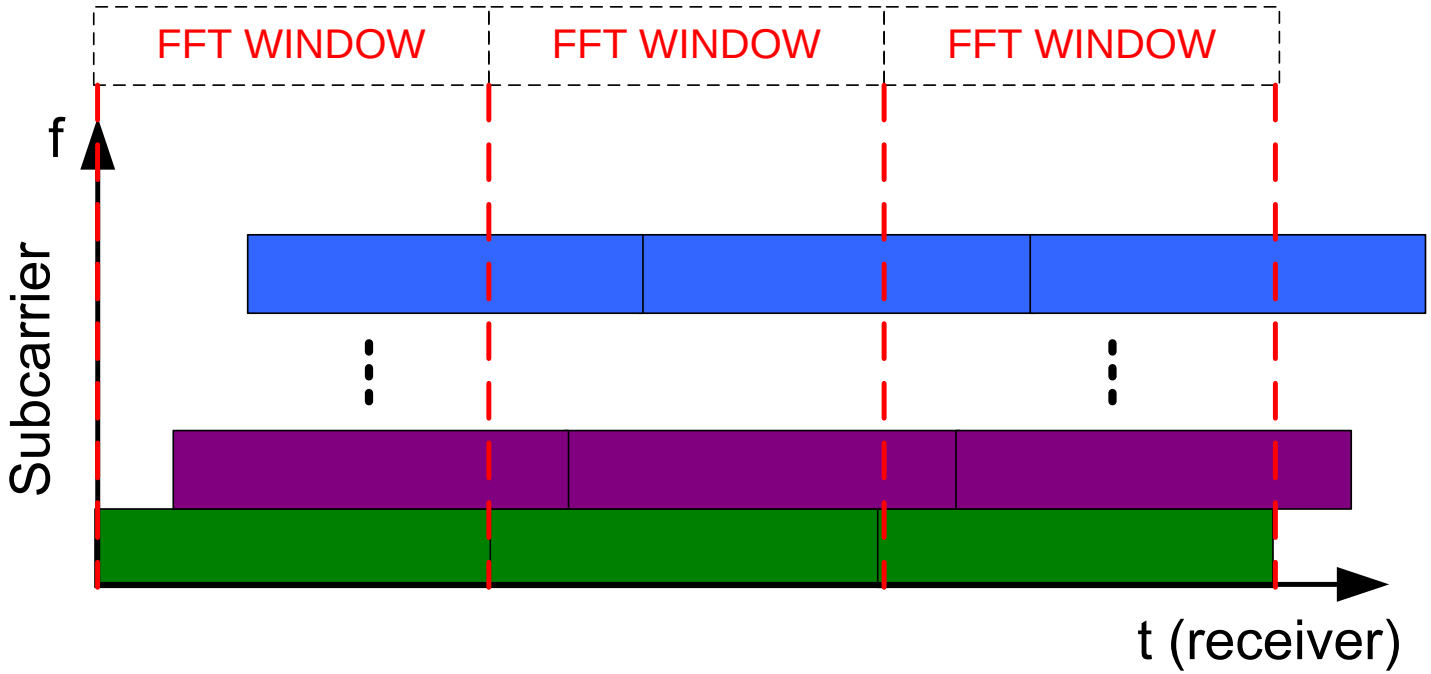
Receiving with the FFT

- Receiving with the FFT is equivalent to sampling at orthogonal frequencies

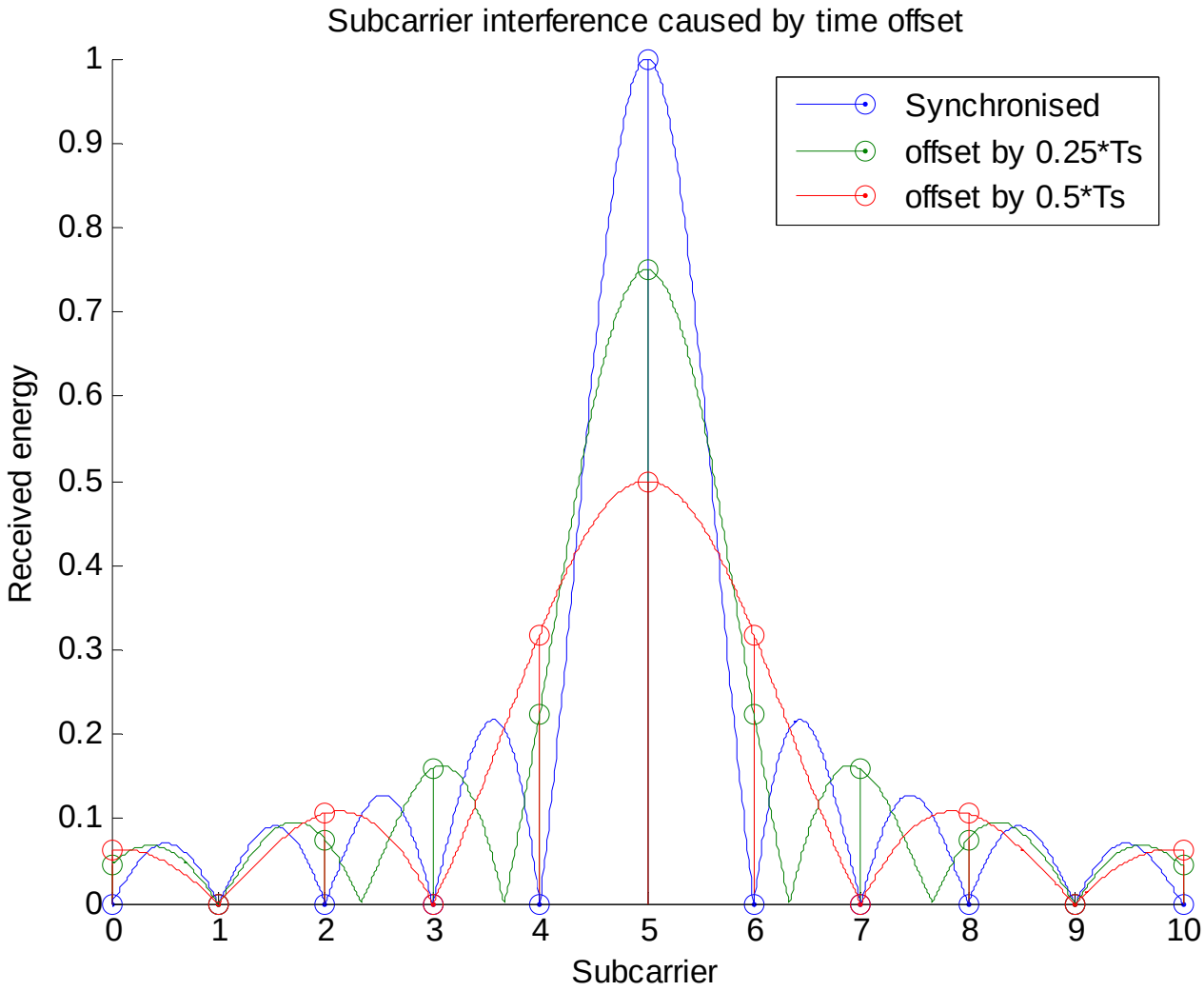


Not as easy as it first seems…

- In ideal conditions this is a perfect solution
- However, time misalignments and frequency offsets cause interference between users



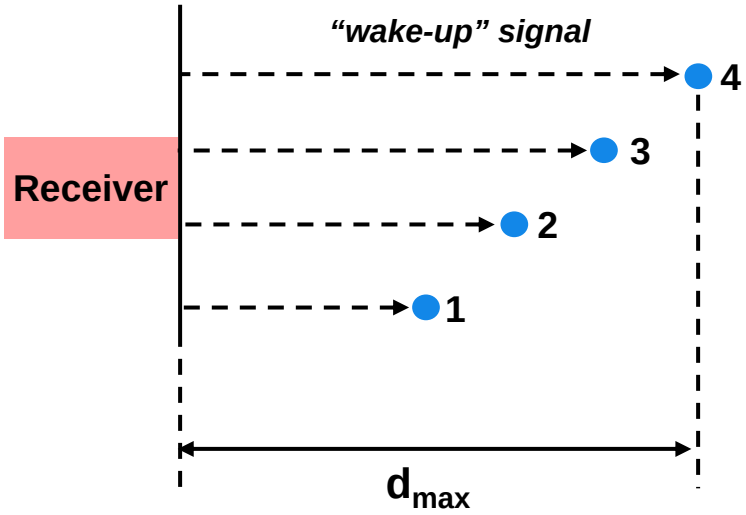
Interference caused by time misalignments



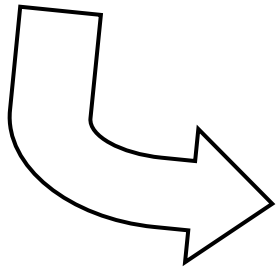
Time offsets

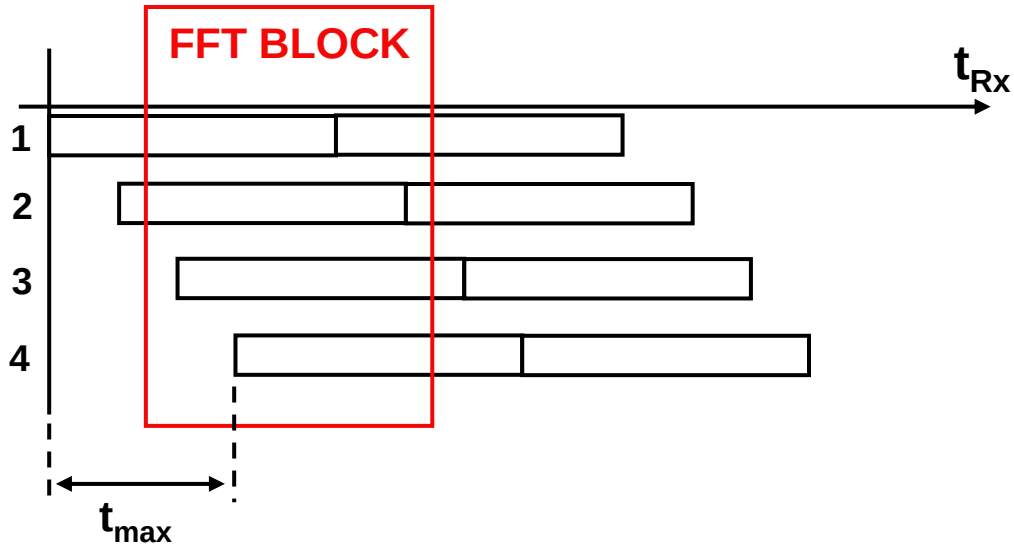
- Offsets relative to symbol length
  - Problem less of an issue at lower data rates
  - Symbol length is a function of desired data rate
- Need some synchronisation
  - Cannot transmit randomly
- Assume the receiver initiates transmission - all nodes use this as a *wake-up and transmit* prompt
  - Offsets become a function of relative range

Receiver synchronisation signal



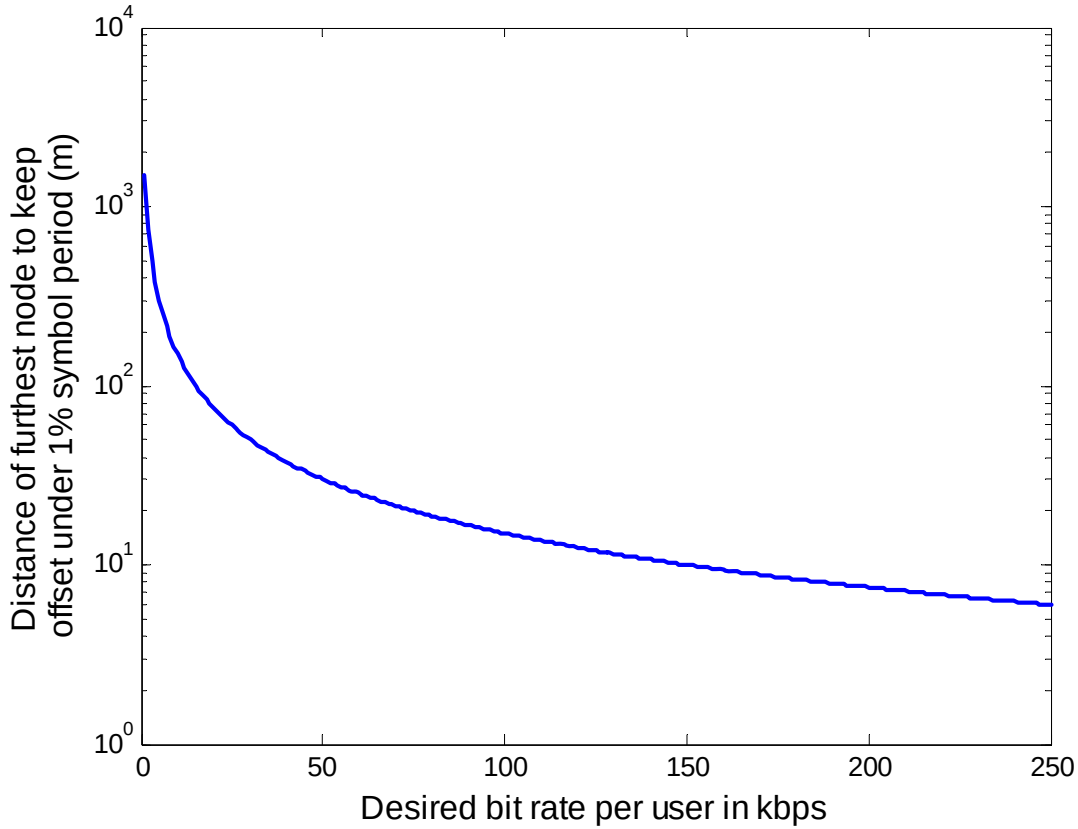
- t_{max} must be small compared to symbol period
- FFT block positioned to minimise interference





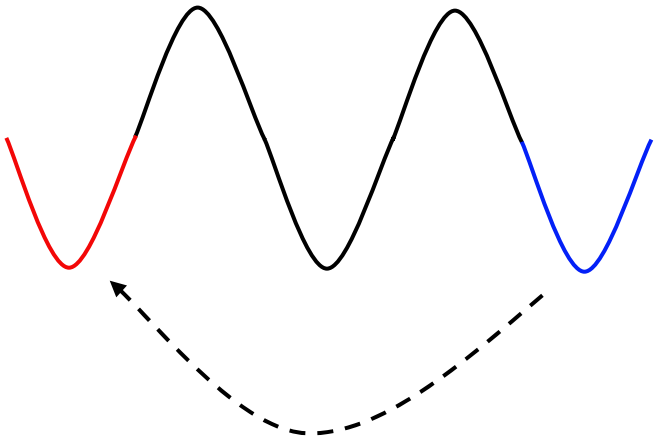
Maximum range

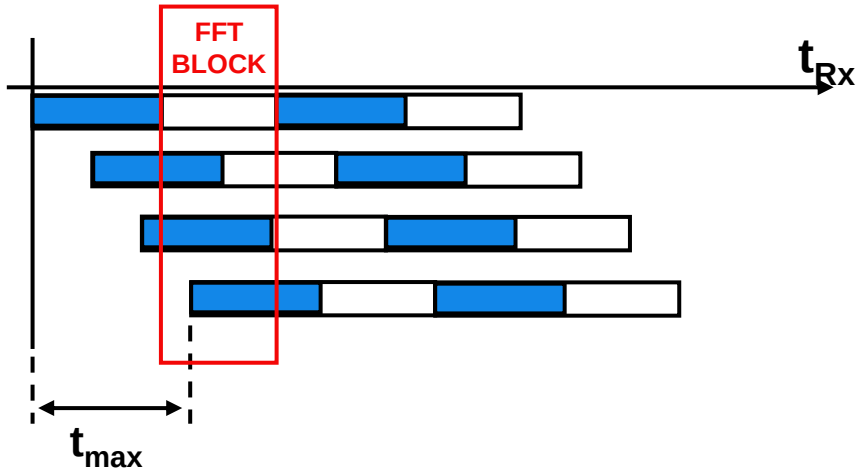
- Maximum possible range of furthest node
  - Keep maximum offset under 1% of symbol period



Cyclic prefix

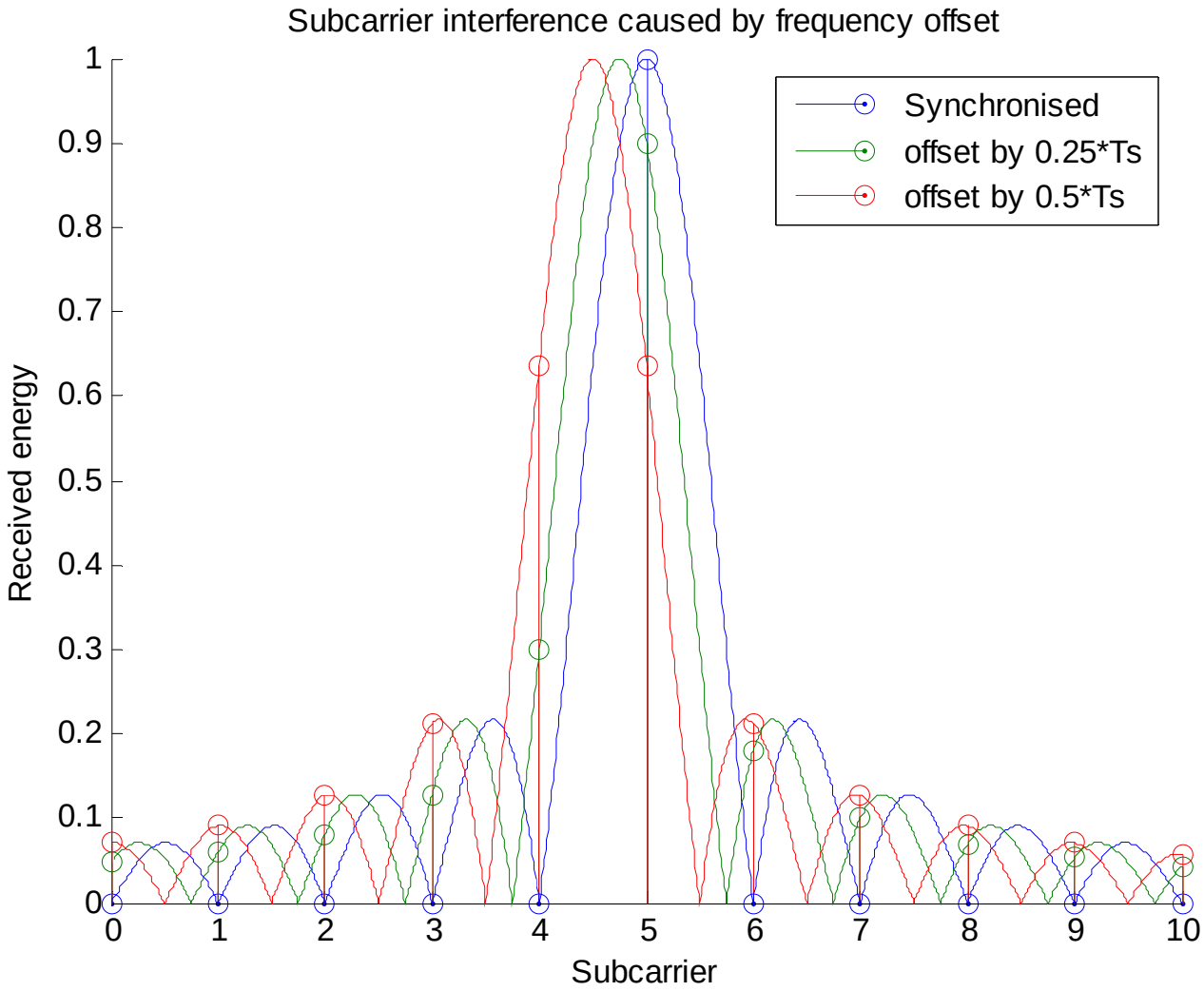
- Introduce redundancy into the transmitted signal
- Copy end of symbol to the start





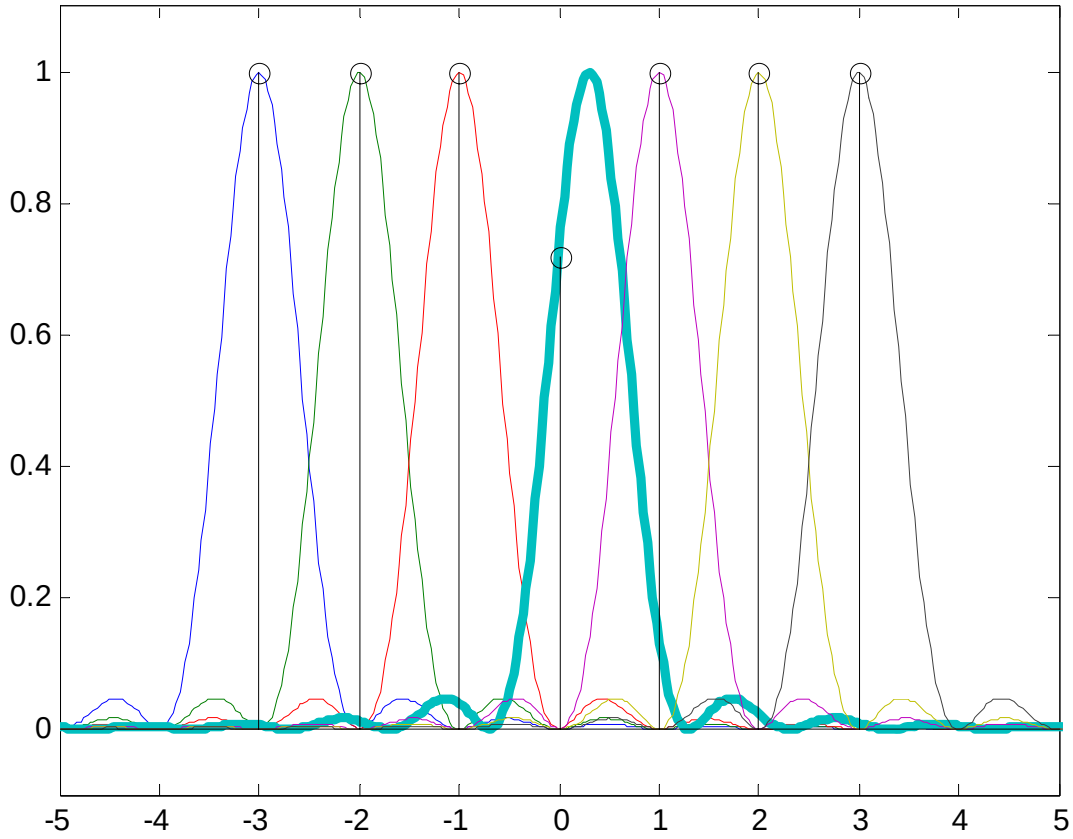
- Minimise the interference caused by time offsets, lower the data rate

Interference caused by frequency offsets



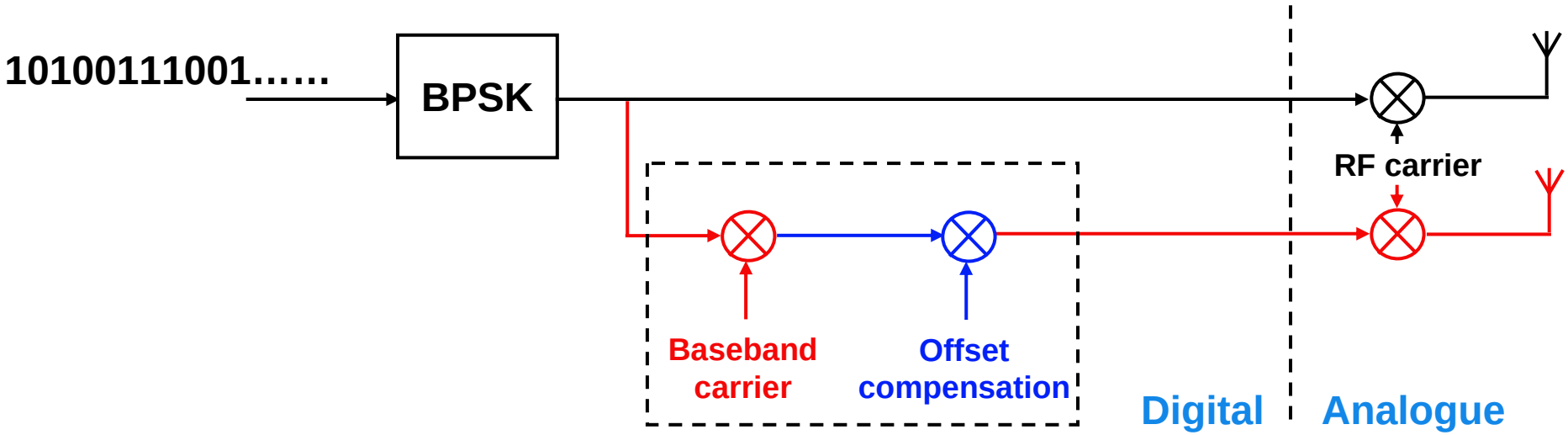
Frequency Offsets

- Receiver will have a different carrier frequency to all transmitters
- Compensation cannot be done in receiver
- All received signals must be mixed down to the correct frequency



Digital frequency compensation

- The wake-up signal is structured in such a way to enable simple estimation of frequency offset
- Transmitter then adjusts its subcarrier modulating frequency to compensate



Offset estimation

- Receiver sends packet which has some synchronisation pilot symbols
  - From this packet the transmitters can estimate the frequency offset
- Use a cyclic prefix…
  - Get phase difference between samples at start and end of symbol
  - Frequency offset is a function of this phase offset

Conclusions

- Multicarrier techniques can be used to efficiently extract data from a Specknet
- Assuming relatively synchronised transmission times, time offsets are manageable over Specknet distances
- Frequency offsets can be compensated for digitally

Future work

- Interest is in the implementation of the system

- Specknet has extremely tight power constraints
  - Large body of work in analysing the trade-off between power consumption and performance
    - Sine wave generation / frequency offset calculation & packet format / digital mixer…