A Prototype Positioning System based on Digital Audio Broadcast Signals

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Overview

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- Why use the DAB signal?
- Technical Characteristics
- Positioning Potential
- Hardware/Software
- Network Geometry Simulation (HDOP)
- Early results
- Conclusions

DAB Digital Audio Broadcasting

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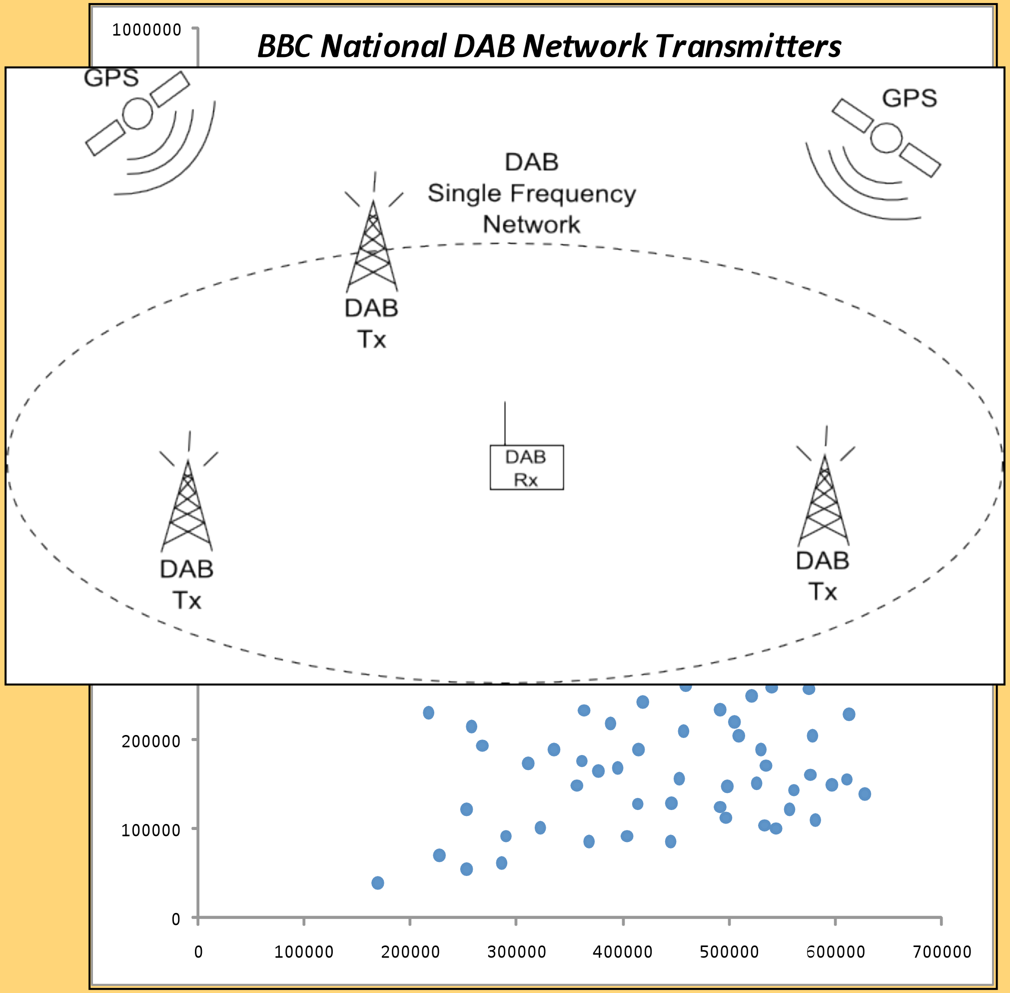
Digital Audio Broadcast Signal

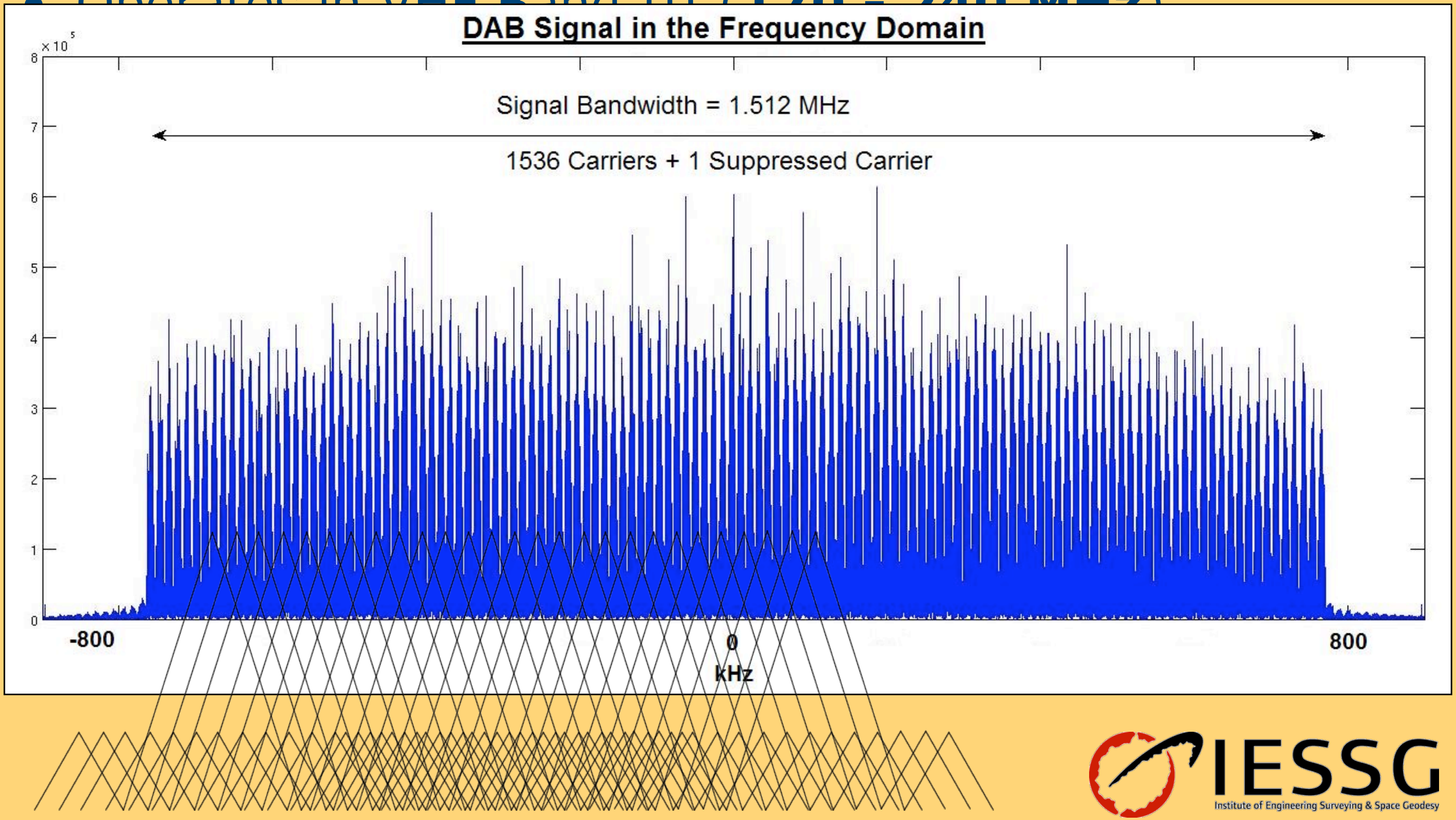
Why use the DAB signal?

- Designed for dynamic receivers (car radios)
- Uses Single Frequency Networks (SFNs) synchronised by GPS
- Two National and many Local/Regional SFNs
- > 85% UK coverage
- Terrestrial signal power up to 1000× higher than GNSS signal power



DAB Signal Characteristics
Signal Basics

- Operates in VHF Band III (**170 – 240 MHz**)



DAB Signal Characteristics
System Clock

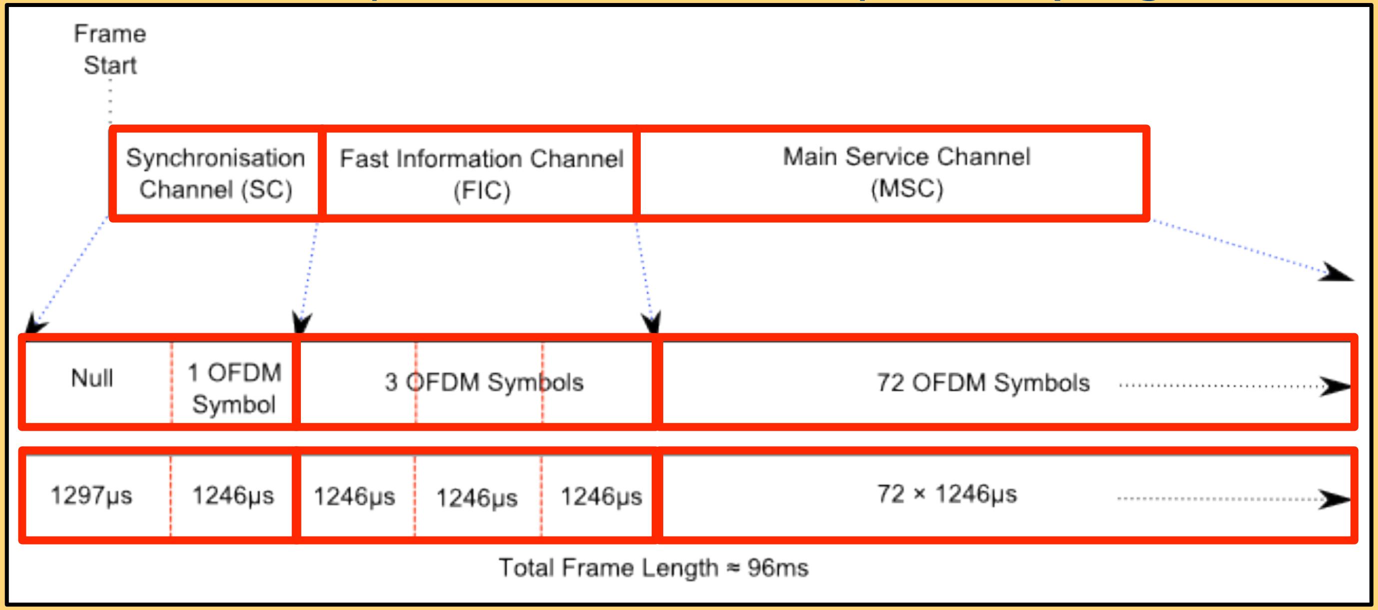
- DAB system clock frequency = **2.048MHz**
- Fundamental DAB Unit ***T*** obtained by:

$$\boxed{T = \frac{1}{2.048e^{6}} = 0.48828\mu s}$$

- All units in system can be derived from this value
- Describes time periods in the temporal domain
- Speed of light travels ≈ **146m** in one unit of ***T***

DAB Signal Characteristics
Transmission Frame

- Consists of three channels broadcast sequentially:
  - **Synchronisation Channel** – used for signal acquisition
    - Composed of 1 Null and 1 OFDM symbol (length **≈ 2.5ms**)
  - **Fast Information Channel** – used for multiplex data
    - Composed of 3 OFDM symbols (length **≈ 3.7ms**)
  - **Main Service Channel** – used for "music" data
    - Composed of 72 OFDM symbols (length **≈ 89.7ms**)



Total Frame Length <u>96ms</u>

DAB Signal Characteristics
Synchronisation Channel Structure

- Fir ... &
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- Gu
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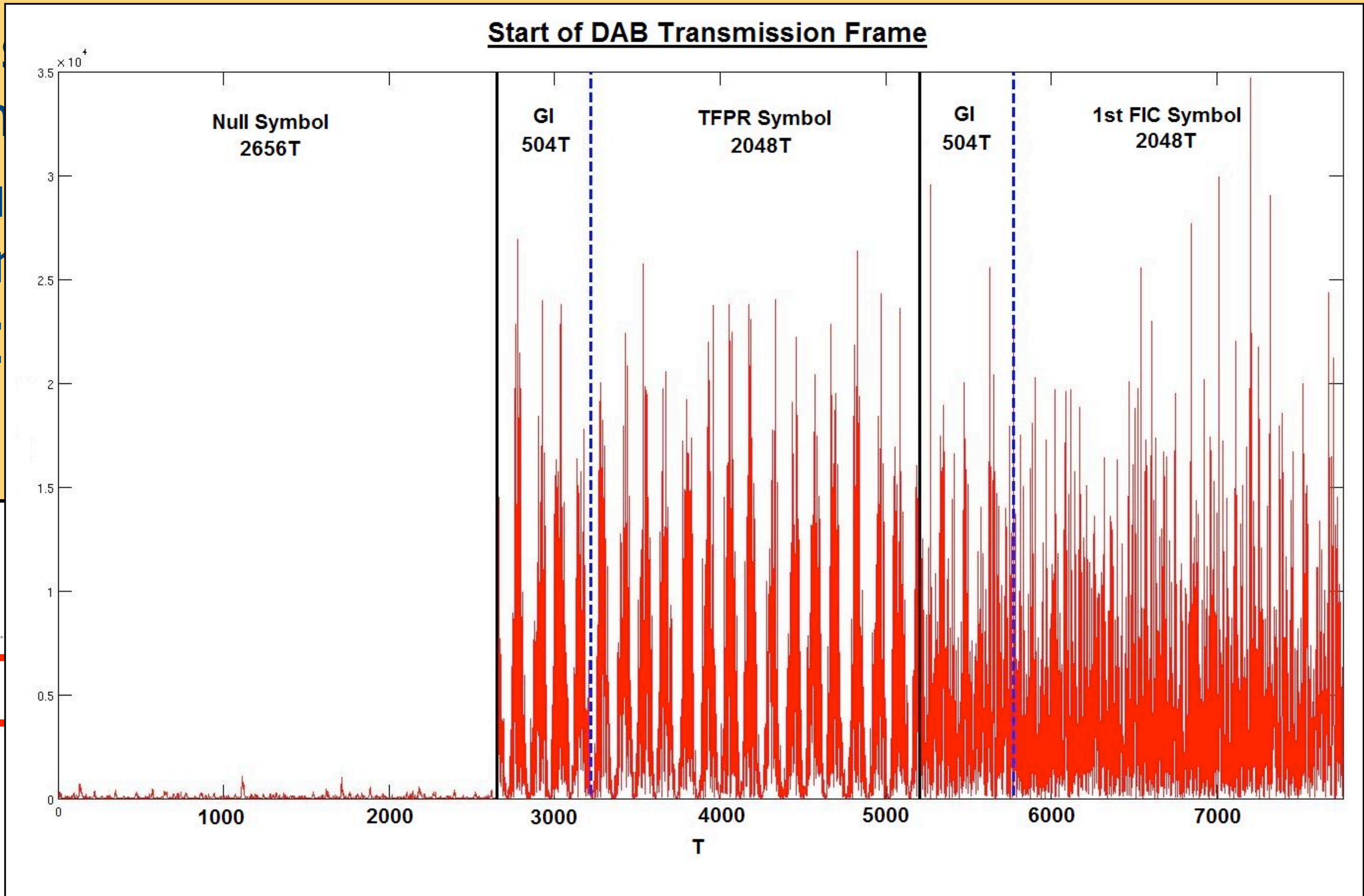
- **GI** ... bol
  & i



Start of
Transmission
Frame

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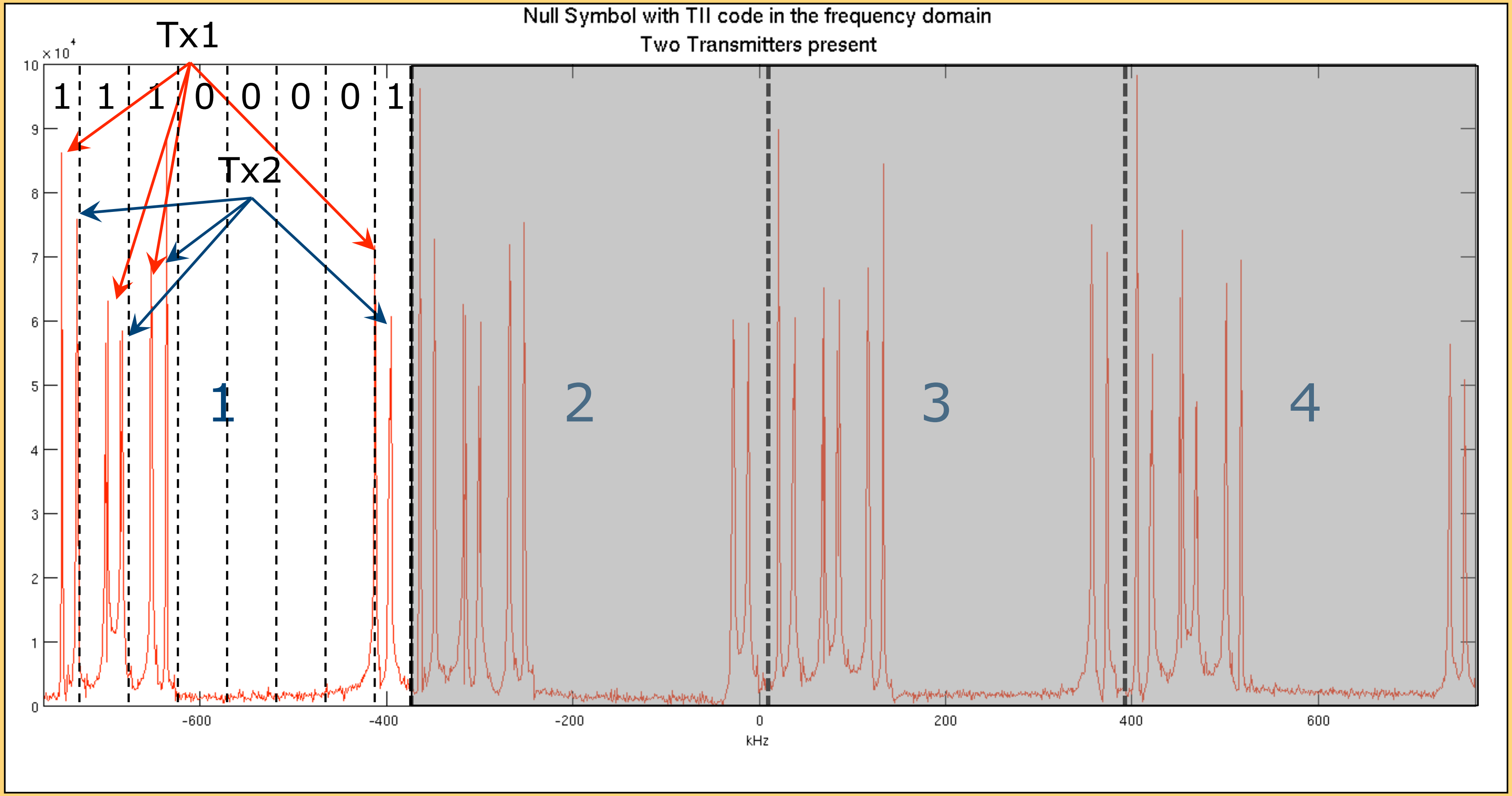
DAB Signal Characteristics
Transmitter Identification (TII)



8 bit pattern where 4 of 8 sub-carriers switched on

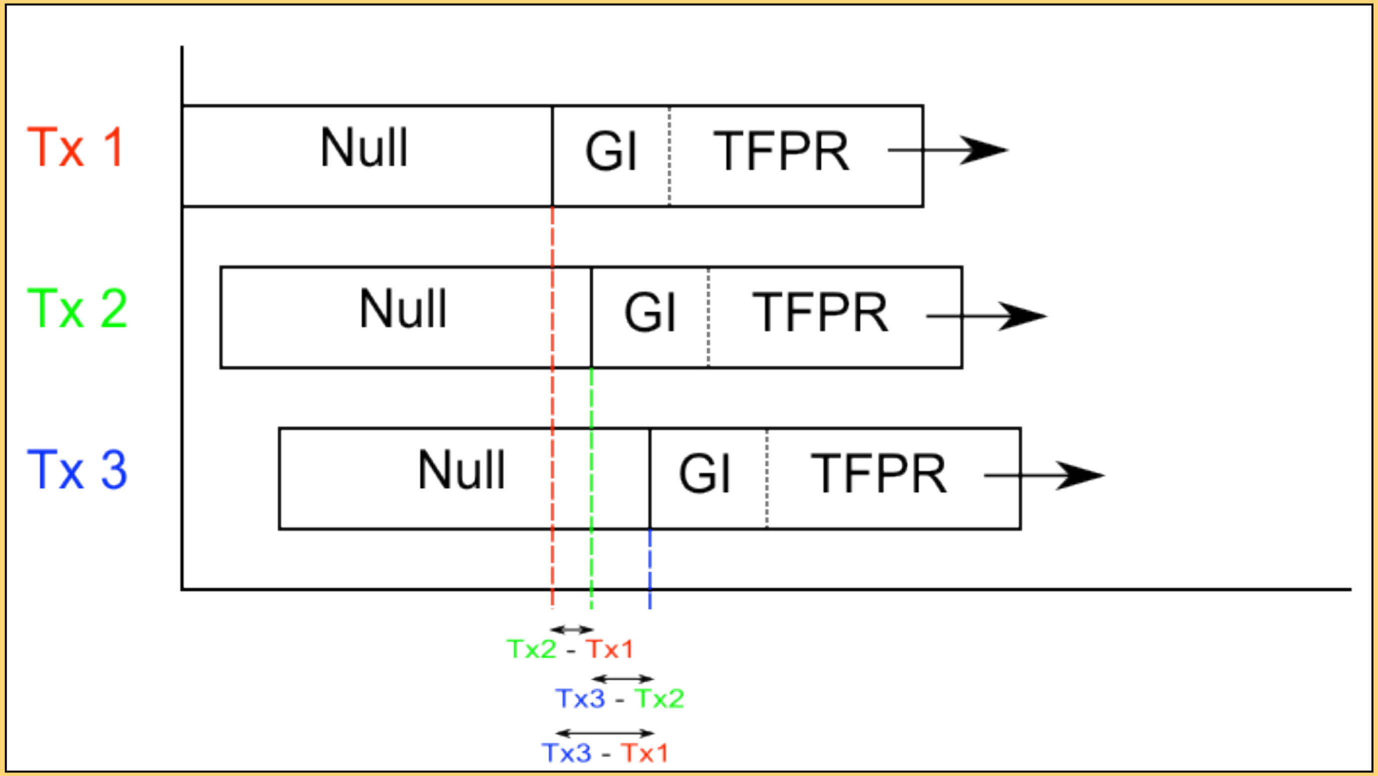
11100001 Pattern ID defines Region as: East Midlands

Tx1 = Waltham

Tx2 = Mapperley

Positioning Potential of DAB

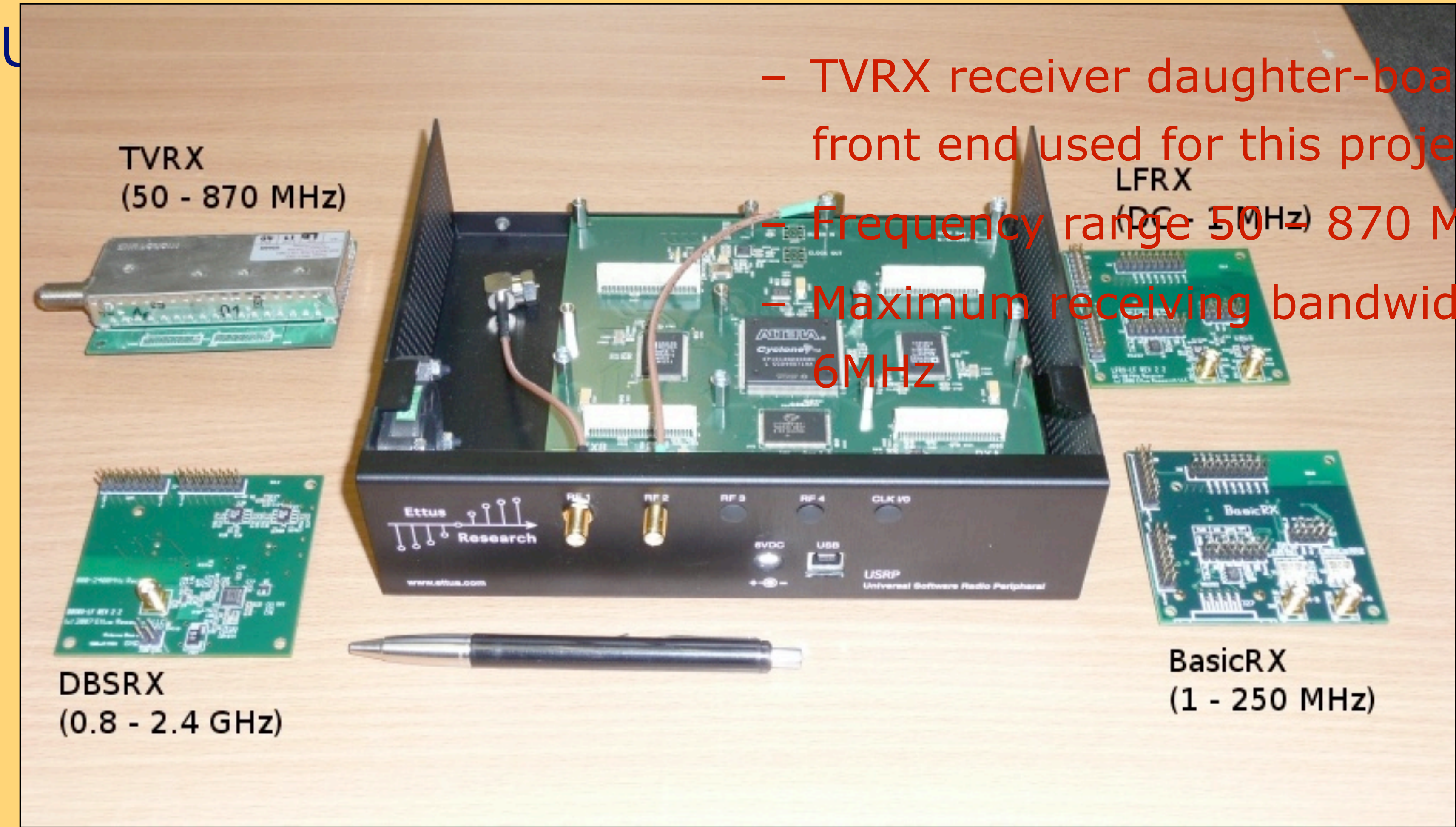
- To use the Synchronisation Channel for **Time Difference of Arrival** (TDOA) measurements
  - Subsequent transmissions start in the Guard Intervals of first received transmission
  - Transmitter locations are known from TII



Hardware

The Universal Software Radio Peripheral (USRP)

- U



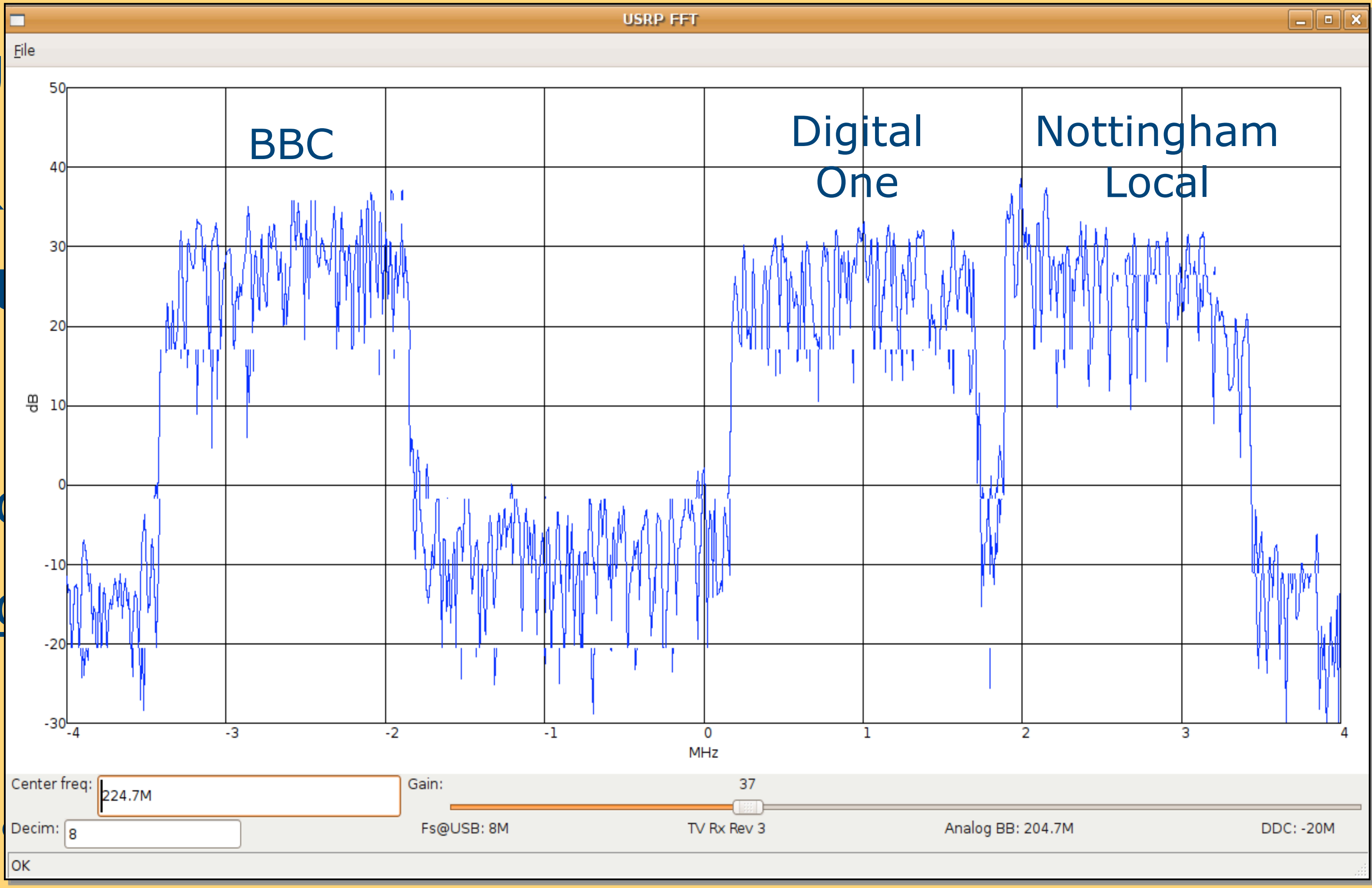
  - TVRX receiver daughter-board front end used for this project
  - Frequency range 50 – 870 MHz
  - Maximum receiving bandwidth 6MHz

Hardware

DAB Antenna

- 360° Beamwidth
- Frequency Range:
  - 200 – 240 MHz
- Gain 2.2 dBd

Software
GNU Radio



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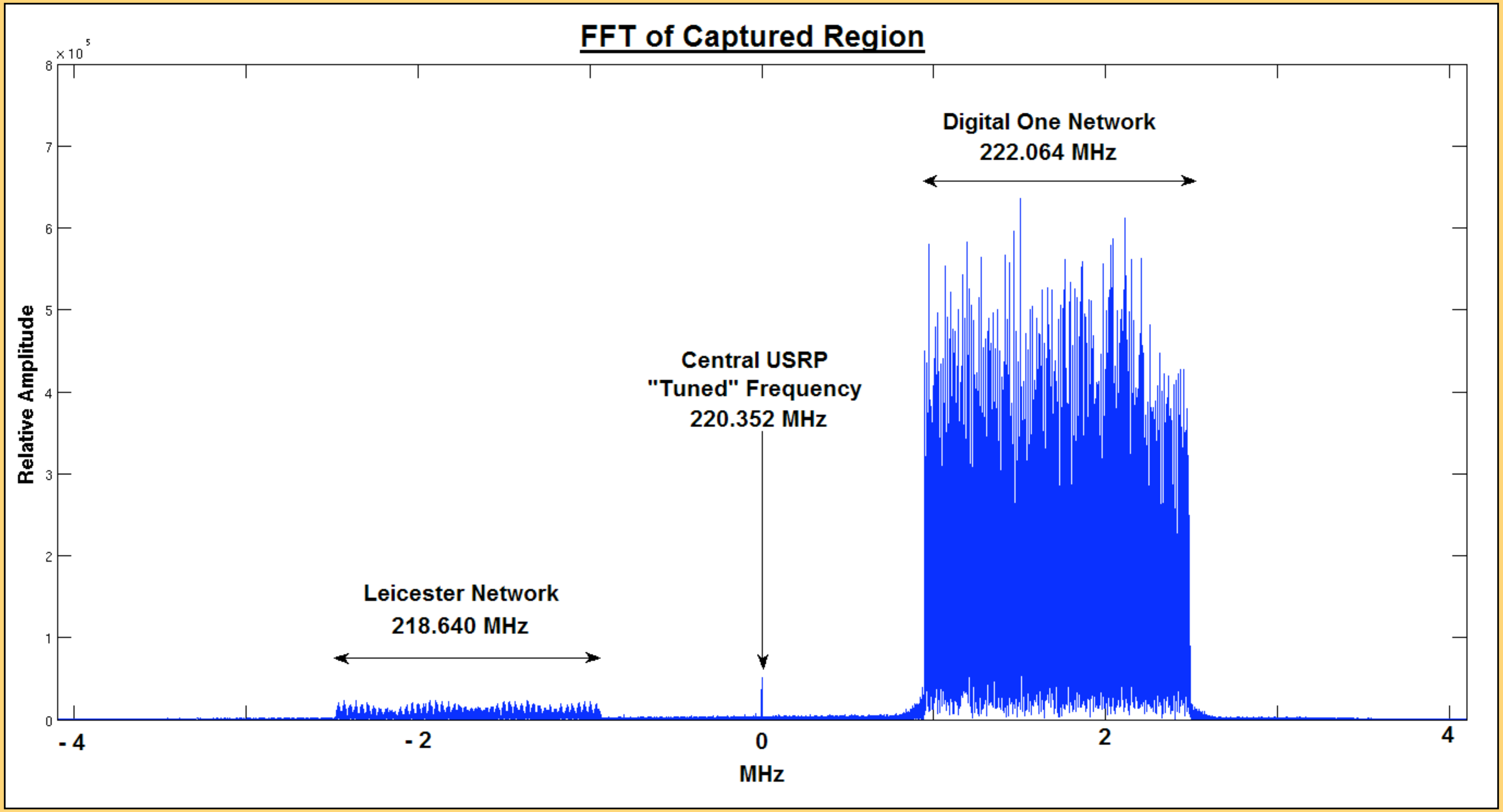
– Matlab or similar to post-process data

Two DAB Signals
Captured in Frequency Domain



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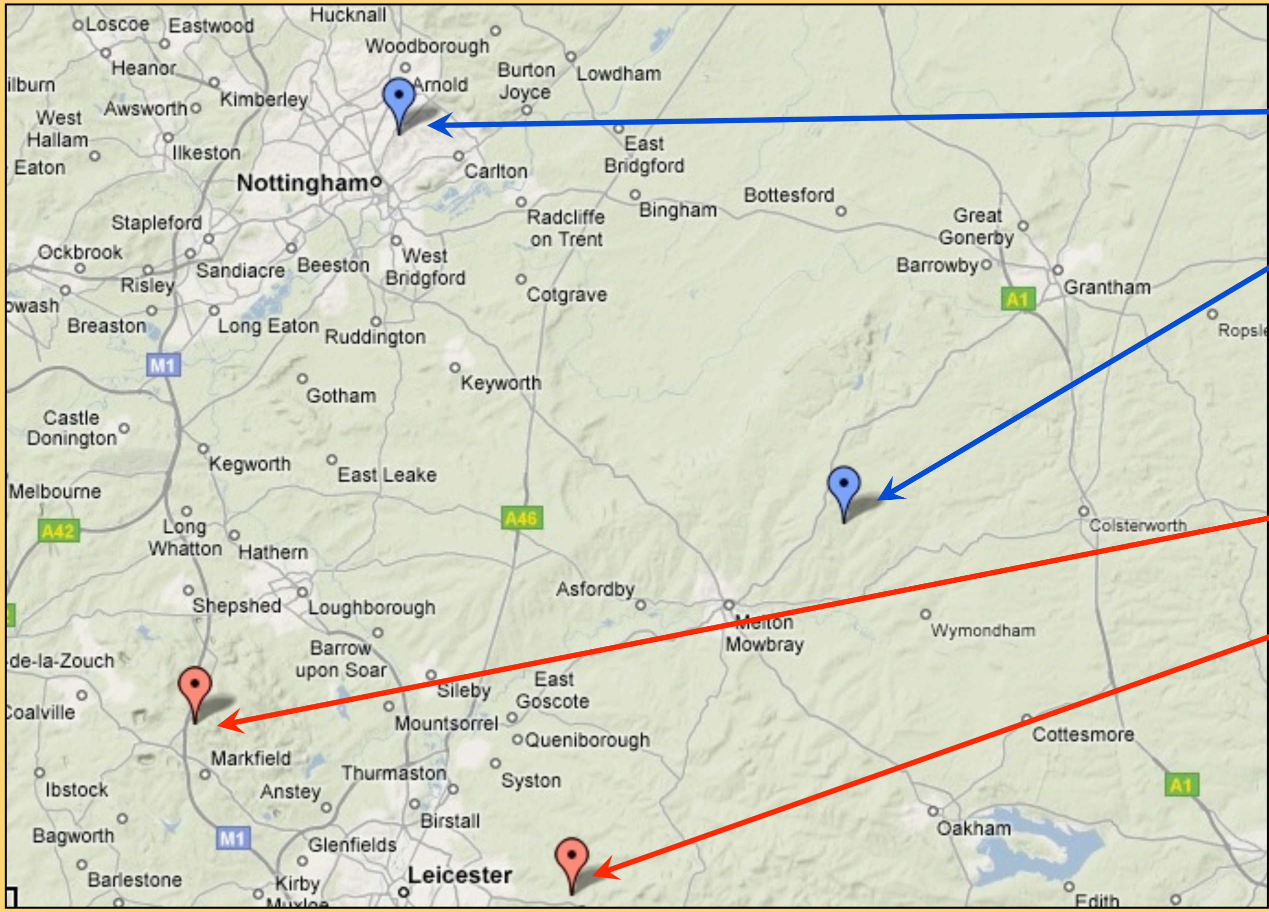
Initial Test Region
Nottinghamshire/Leicestershire



Nottingham:

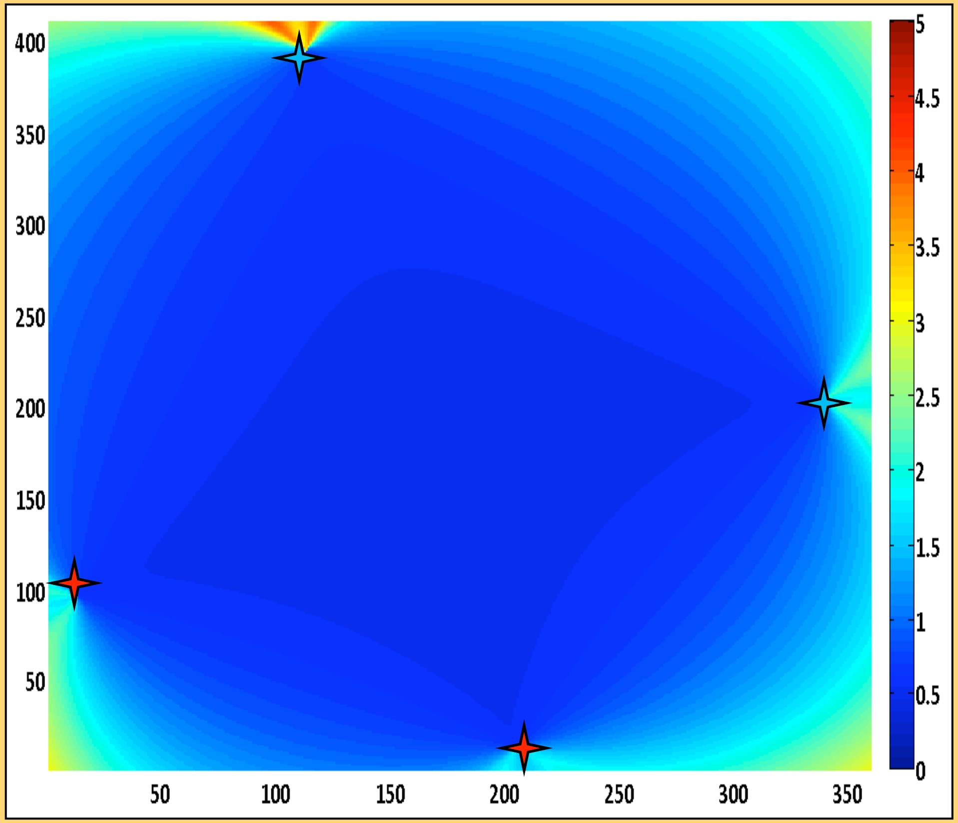
- *Mapperley*
- *Waltham*

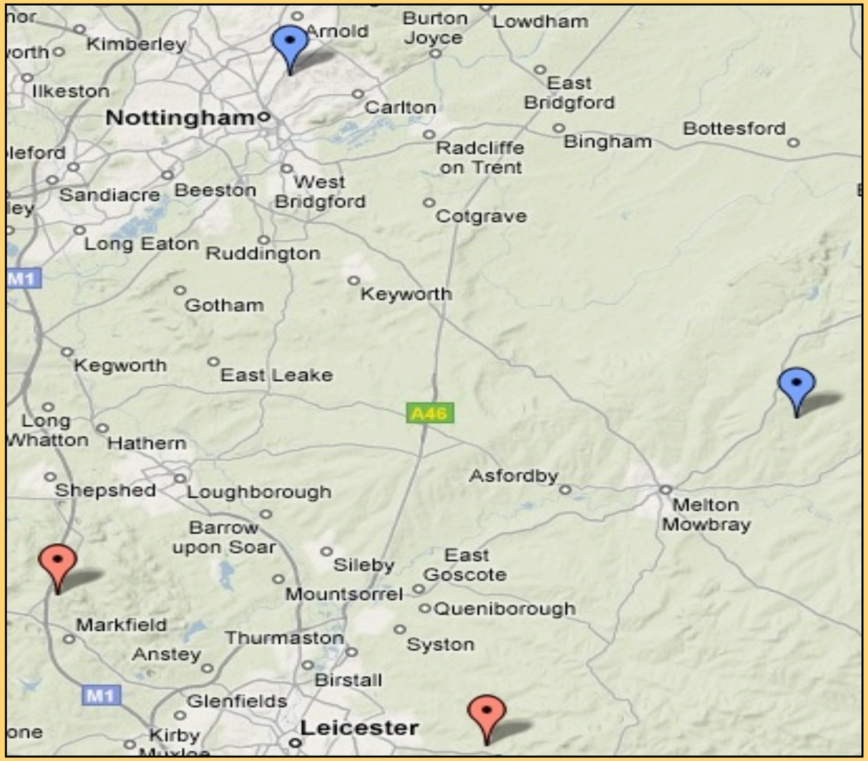
Leicester:

- *Copt Oak*
- *Houghton-on-the-Hill*

Matlab Simulation Results
TDOA HDOP Map – Approach 1

- TDOA HDOP Simulation based on 4 synchronised DAB Tx locations in the Notts/Leics area using a single network
- Gives three independent TDOA measurements





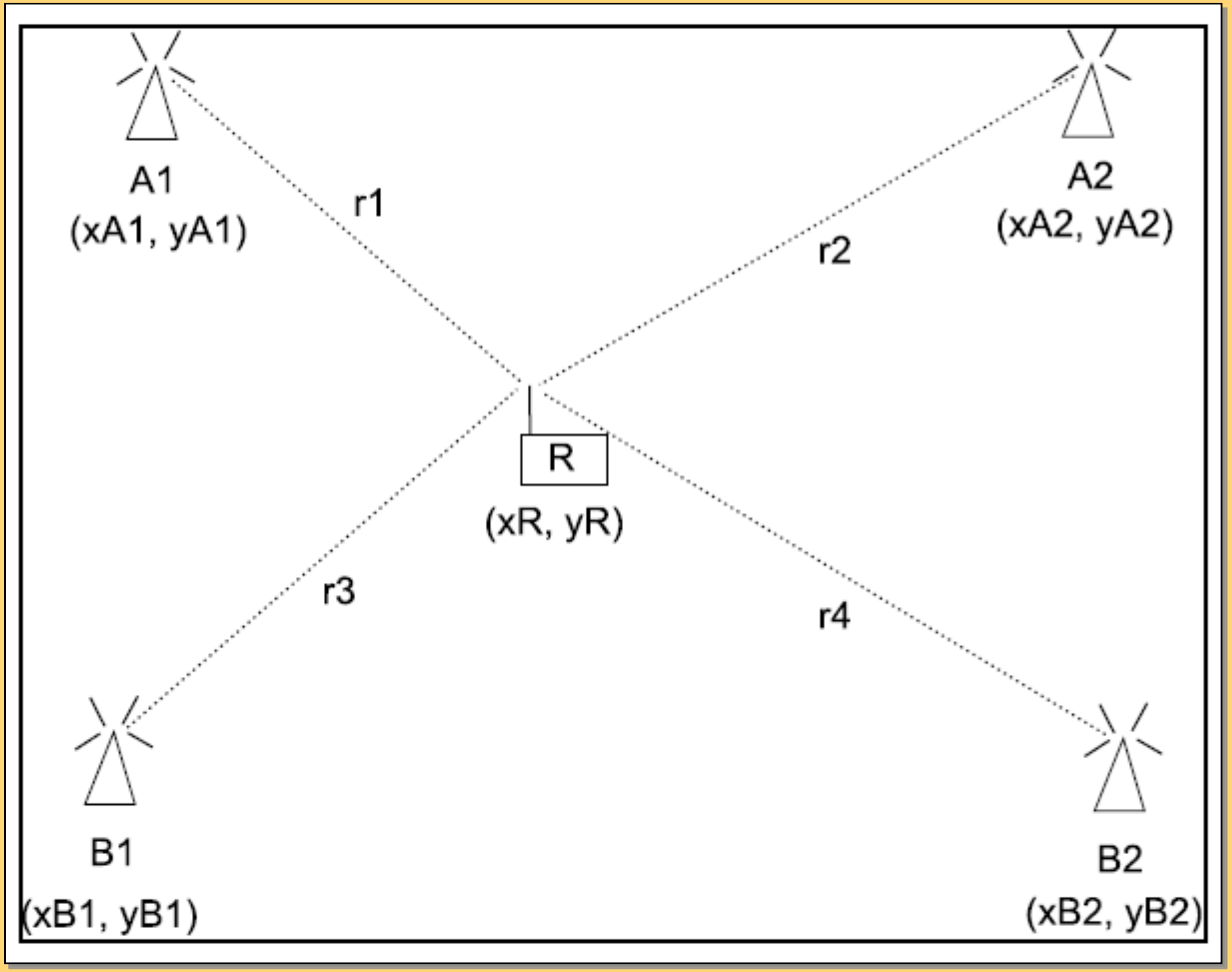
Matlab Simulation Results
Difficulties to overcome

- **Problem 1**: Many areas will not receive national signals from more than two transmitters
  - Solution: Multi-network solution (i.e. Both National networks simultaneously)

- **Problem 2**: Most transmitter sites broadcast more than one network (e.g. Both National networks and a local network)
  - Solution: Combination of two local networks which are unlikely to share transmitter sites
  - Involves a different strategy using two pairs of synchronised transmitters

Conceptual Network

Time Difference of Arrival



A1 & A2
Synchronised

B1 & B2
Synchronised

Differences

r1-r2 & r3-r4

Matlab Simulation Results
TDOA HDOP Map – Approach 2

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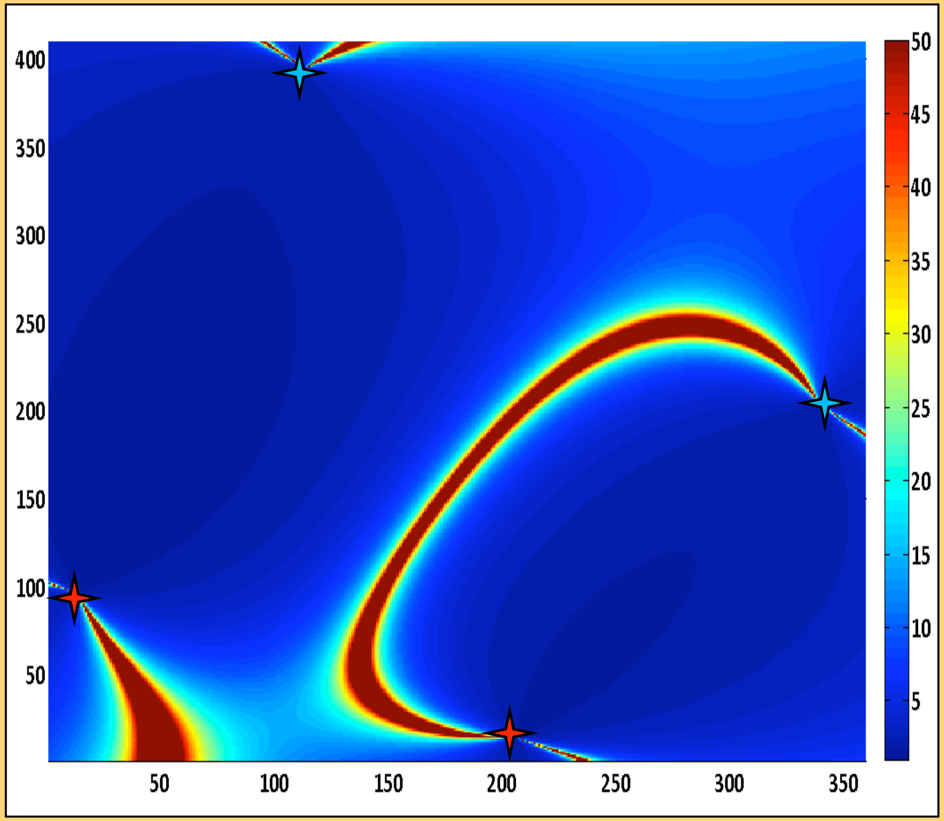
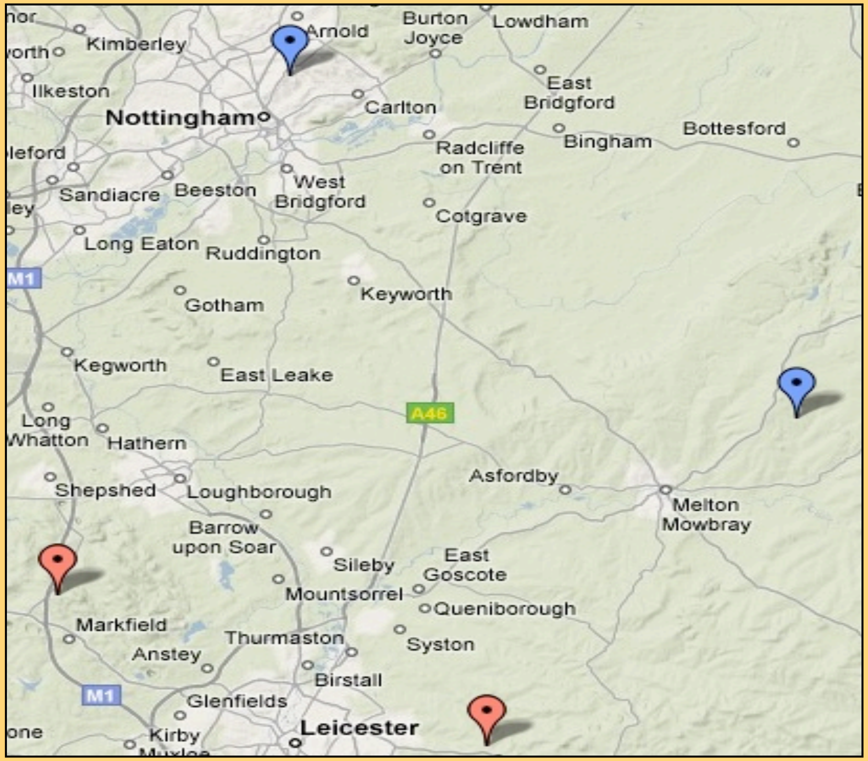
- TDOA HDOP Simulation based on the same transmitters but using 2 pairs of synchronised transmitters – two local networks
- Gives two independent TDOA measurements





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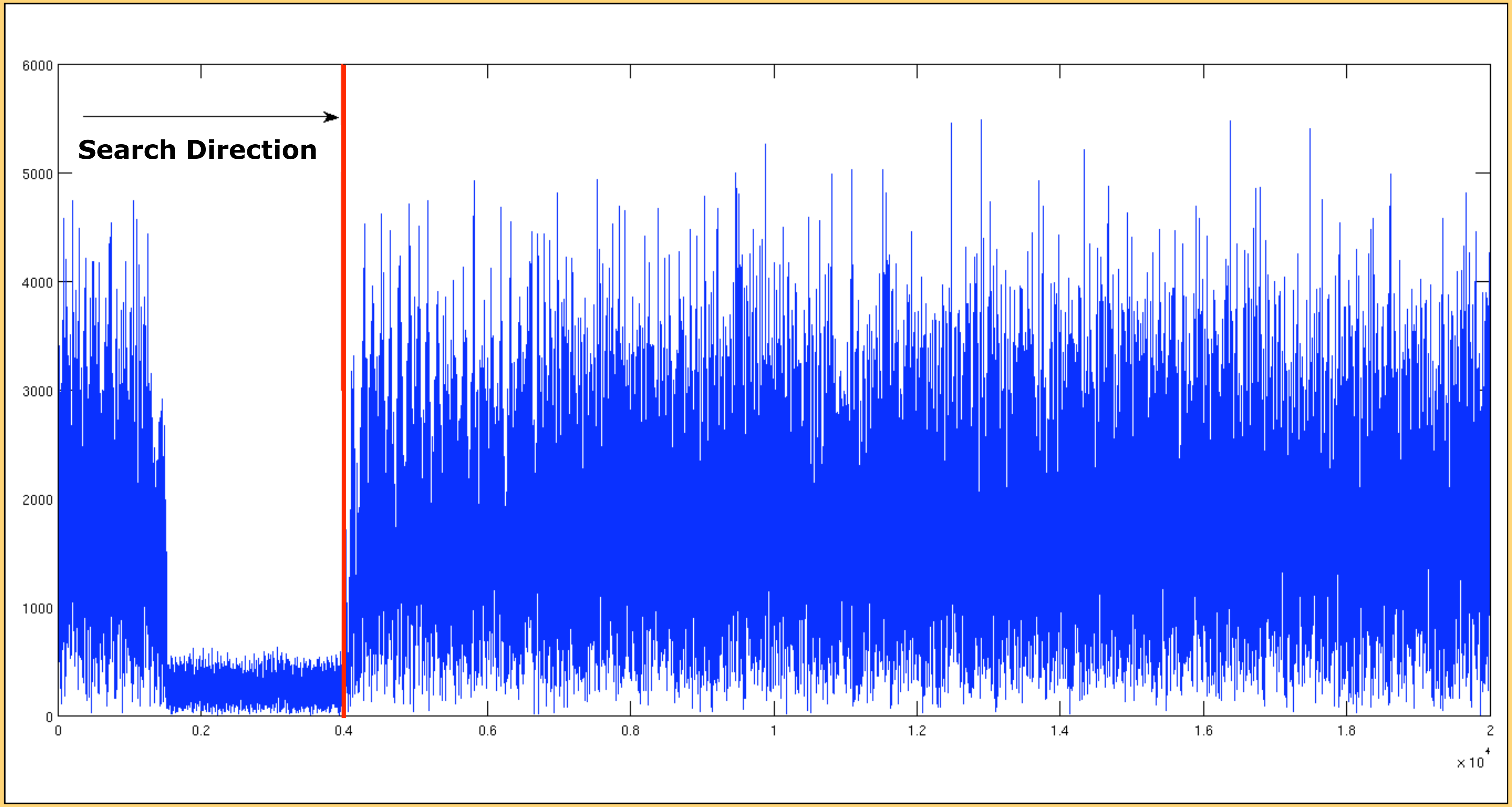
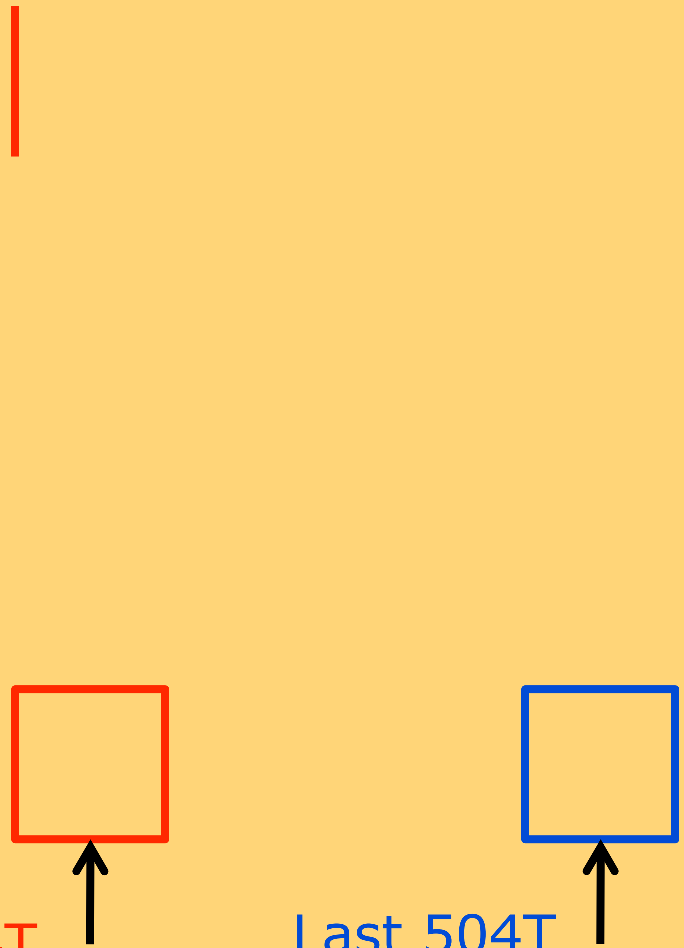
TDOA Measurement Process

Find First Null Symbol



Find end of first Null Symbol in the temporal domain by testing against pre-defined value

TDOA Measurement Process
Define Symbols



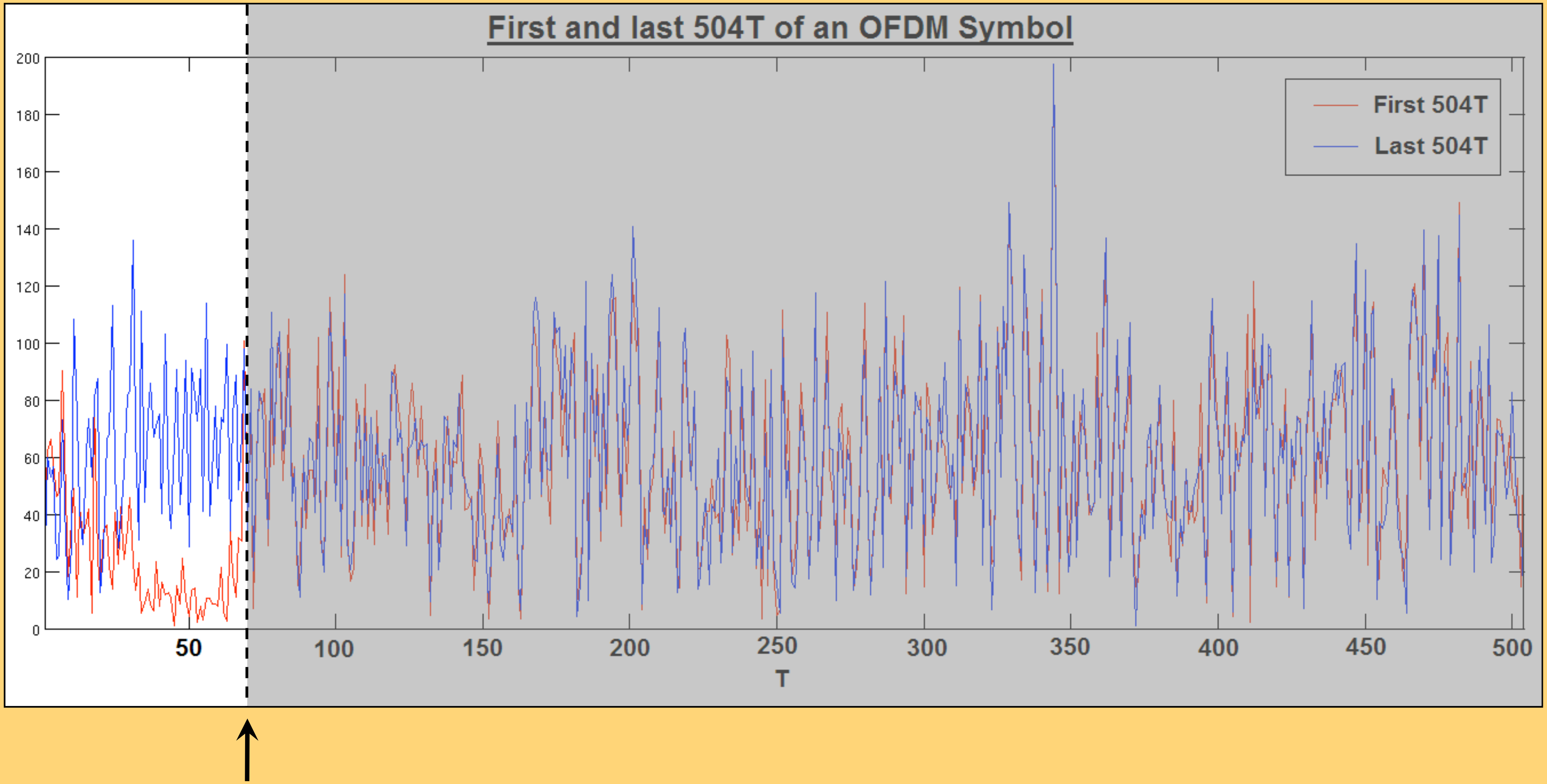
Both extracted in time domain

First 504T
(GI)

Last 504T

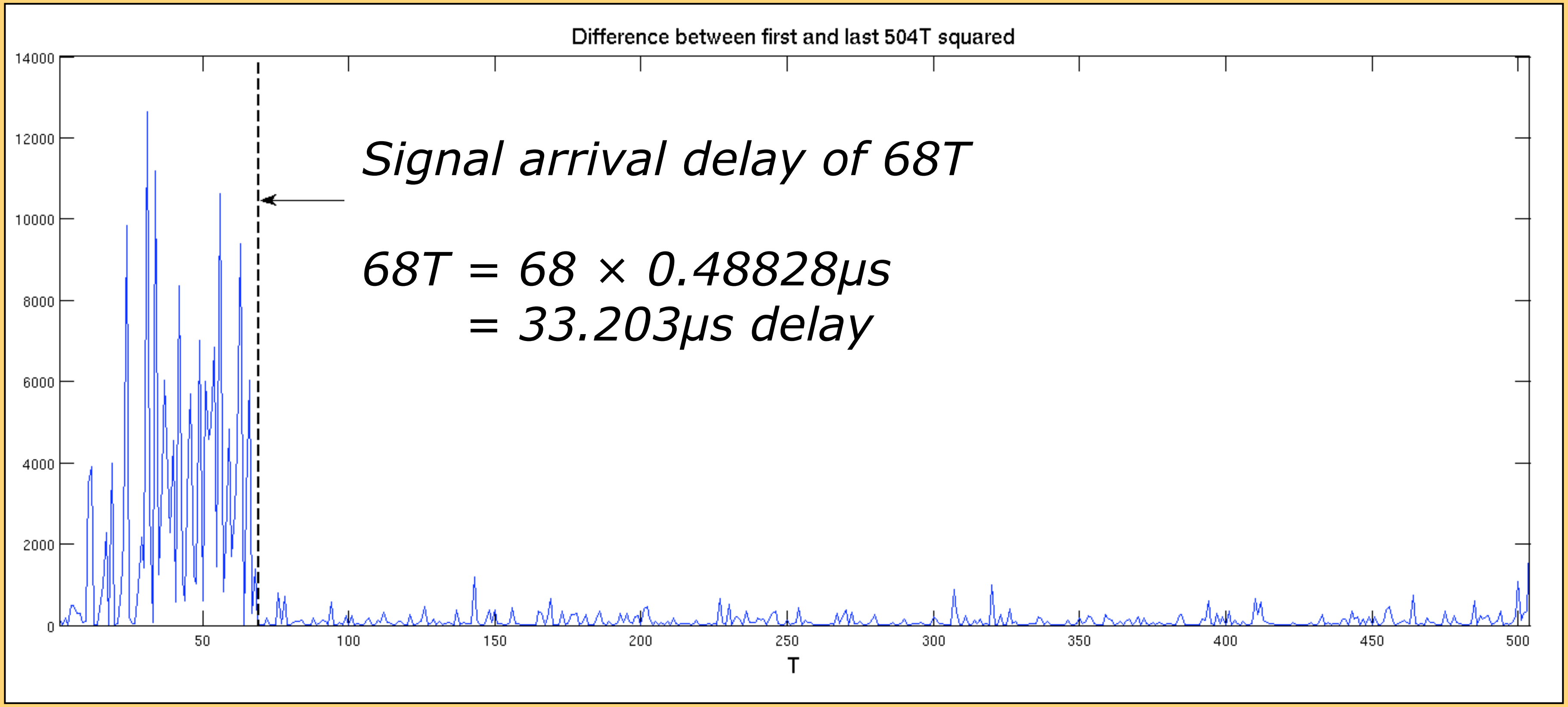
TDOA Measurement Process

Compare Extracted Data



From right to left, data practically overlaps perfectly until this cut-off point

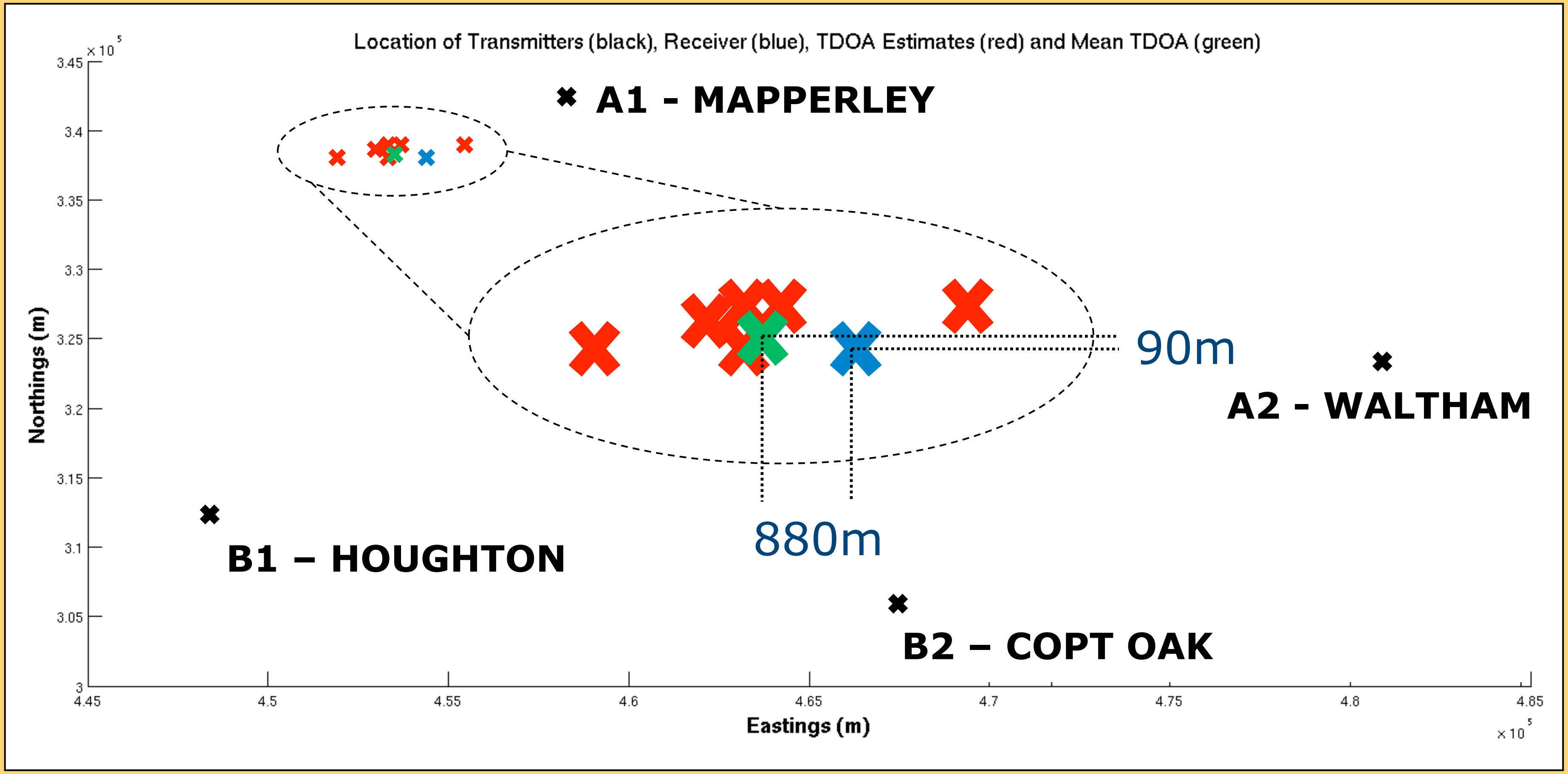
TDOA Measurement Process
Calculate Time Delay



$$T = \frac{1}{2.048e^{6}} = 0.48828\mu s$$

0.48828μs ≈ 146m

Initial Positioning Results
East Midlands Test Region



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TDOA Measurement Process
New TFPR CIR Approach

- Described measurement system used for rough signal acquisition
- New algorithm to use Channel Impulse Response (**CIR**) Method using the TFPR symbol
- TFPR values known to receiver, so cross-correlation technique used
- Will provide multiple TDOA measurements per network

Error Sources

- TII information indicates that only 2 transmitters are received per network...
  - A 3rd much weaker transmitter in some areas could make timing cut-off measurement "diffuse"
- Although synchronised by UTC, deliberate timing biases can be inserted as part of the SFN design to avoid ISI
- Cross-correlation of TFPR symbol should give better TDOA than time delay measurement
- Geometry of each network affects HDOP values
- No terrain correction currently
  - Possible Multipath interference

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Summary

- DAB signal contains components usable for positioning purposes
- Low-frequency, terrestrial signal provides good power and horizontal geometry of transmitters
- Early HDOP simulations indicated good coverage in UK, particularly in urban areas where GPS difficulties could occur
- Geometry of networks affects HDOP values
  - Network designed for comms **NOT** navigation
- Use of 2 pairs of transmitters from different local networks most likely solution
- Improvements expected using second algorithm
  - CIR approach over the TFPR symbol

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Questions?