Speck NET

Research Consortium in Speckled Computing

CDMA for SpeckNets

Louise Crockett

University of Strathclyde

louise.crockett@eee.strath.ac.uk

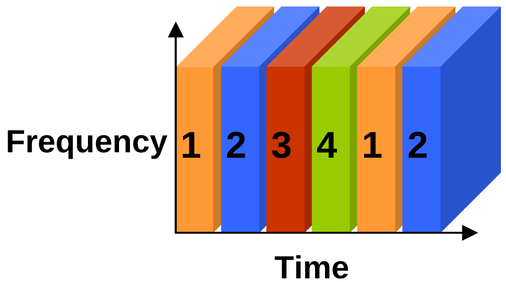
The University of Edinburgh · University of Glasgow · Scottish Funding Council (Promoting further and higher education) · Napier University Edinburgh · Research Councils UK · University of Strathclyde · University of St Andrews

Summary

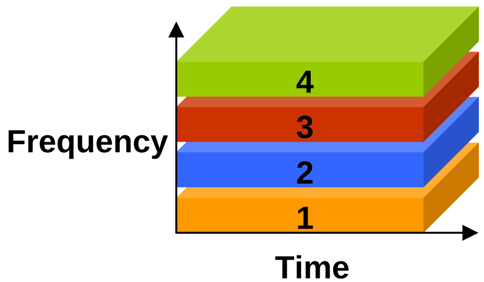
- Multiple Access
- Some CDMA concepts
  - Spreading the spectrum
  - Orthogonality and interference
  - Correlation and reception
- The two key CDMA problems
- System architectures
- A look at the Global Positioning System
- Future work
- Conclusions

Multiple Access

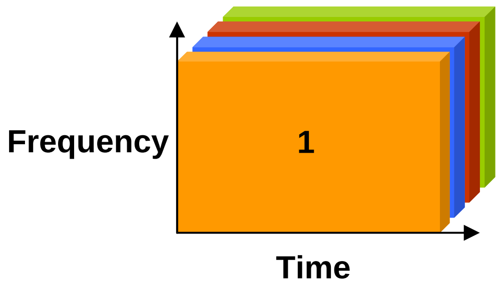
- Allows users to share the channel efficiently
  - Time division multiple access (TDMA)
  - Frequency division multiple access (FDMA)
  - Code division multiple access (CDMA)



TDMA



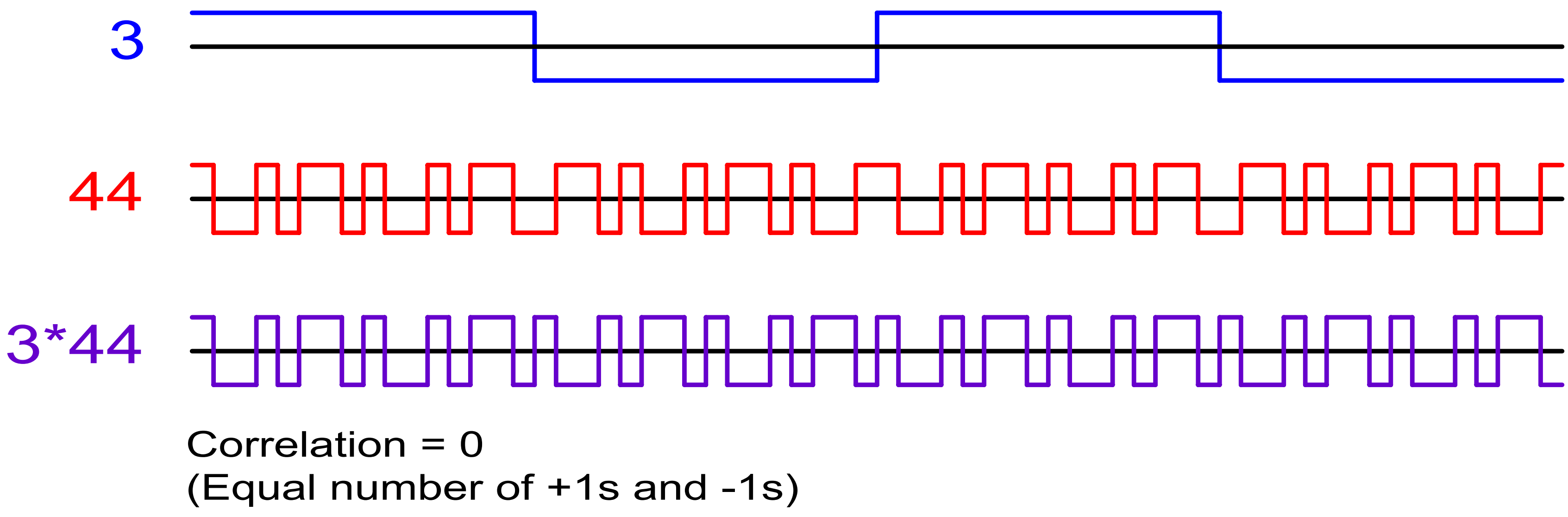
FDMA



CDMA

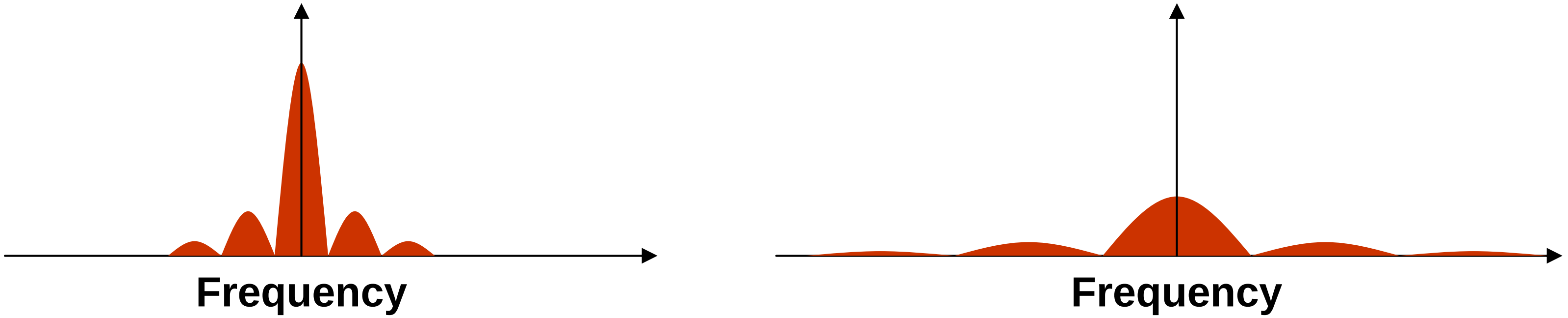
Spreading codes

- Each bit is replaced by a “chipping sequence” or “spreading code”
- Each user has its own distinct spreading code
- Spreading codes should be as different from each other as possible



Spreading

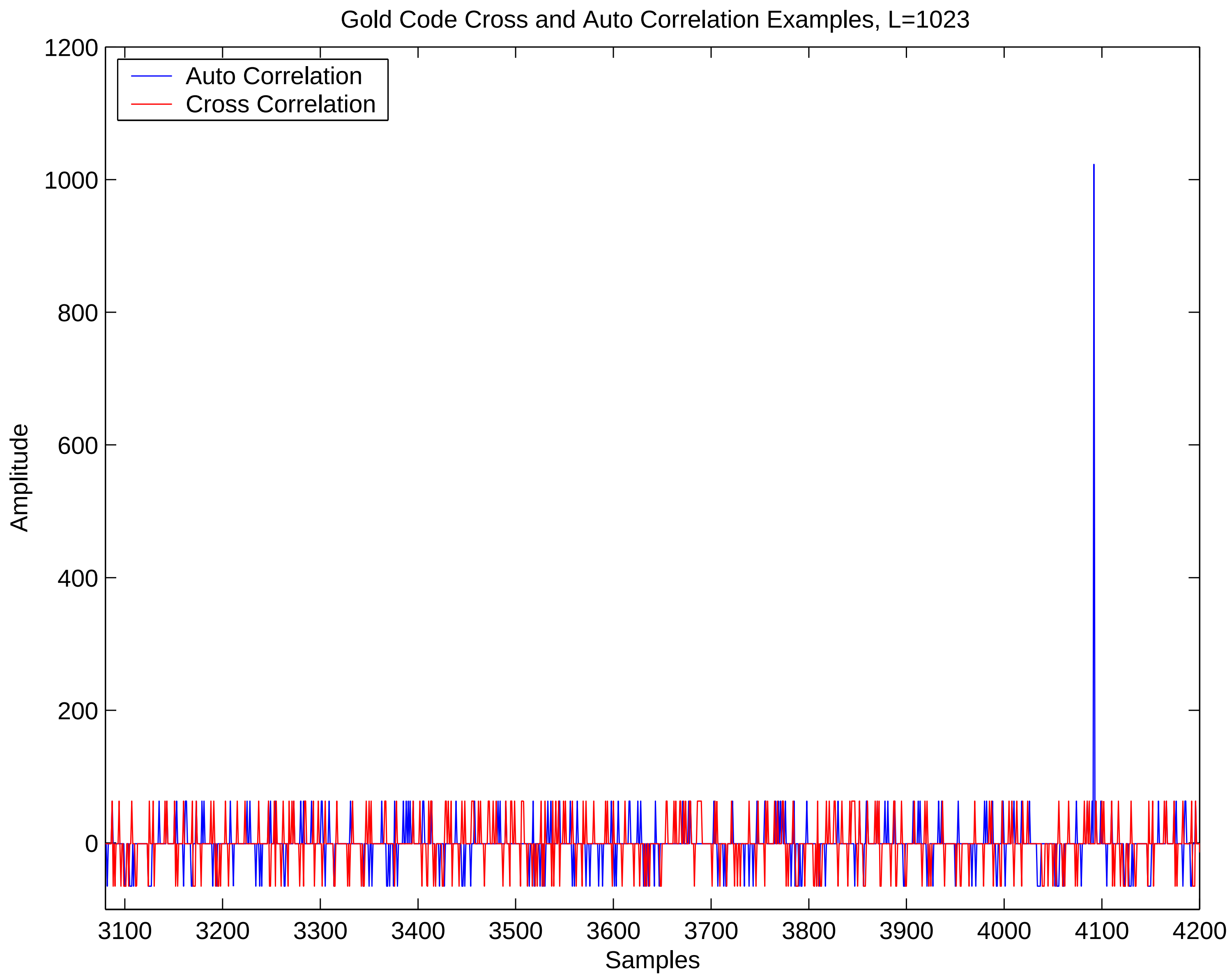
- Spreading increases:
  - Signalling rate
  - Bandwidth
  - Typically by 10’s to 1000’s
- Power is unchanged
  - Signals may appear like noise



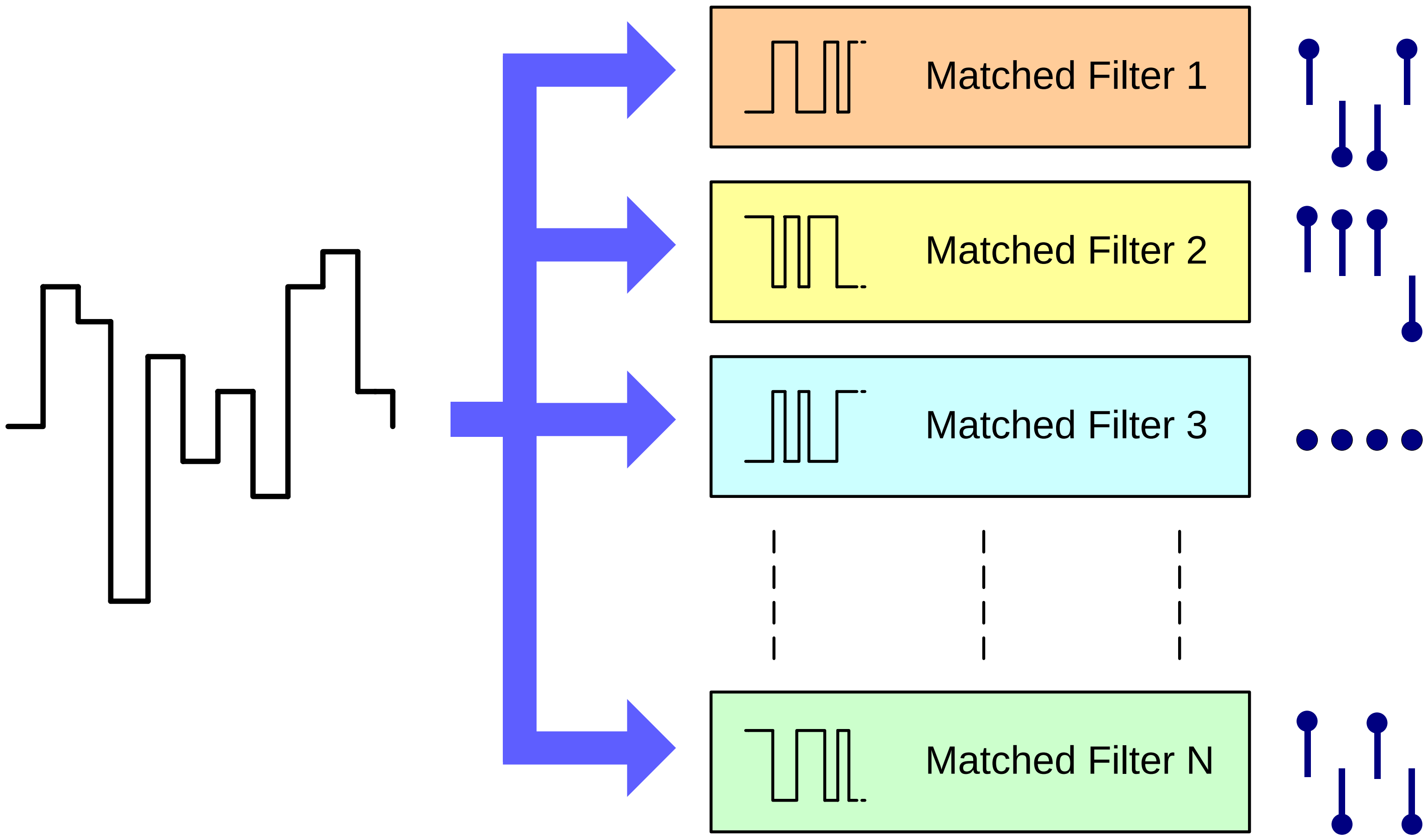
Orthogonality

- Users may access entire spectrum, all the time
- They must interfere with each other as little as possible
- Ideally, codes should be orthogonal (completely different)
  - e.g. Walsh Codes
  - Orthogonal codes do not interfere with each other
  - Synchronisation required
- Non-orthogonal codes with “good” properties
  - e.g. Gold Codes, Kasami Codes
  - Some interference
  - Can be asynchronous

Correlation



Reception



Data is recovered by correlating the received signal with known spreading codes.

Interference

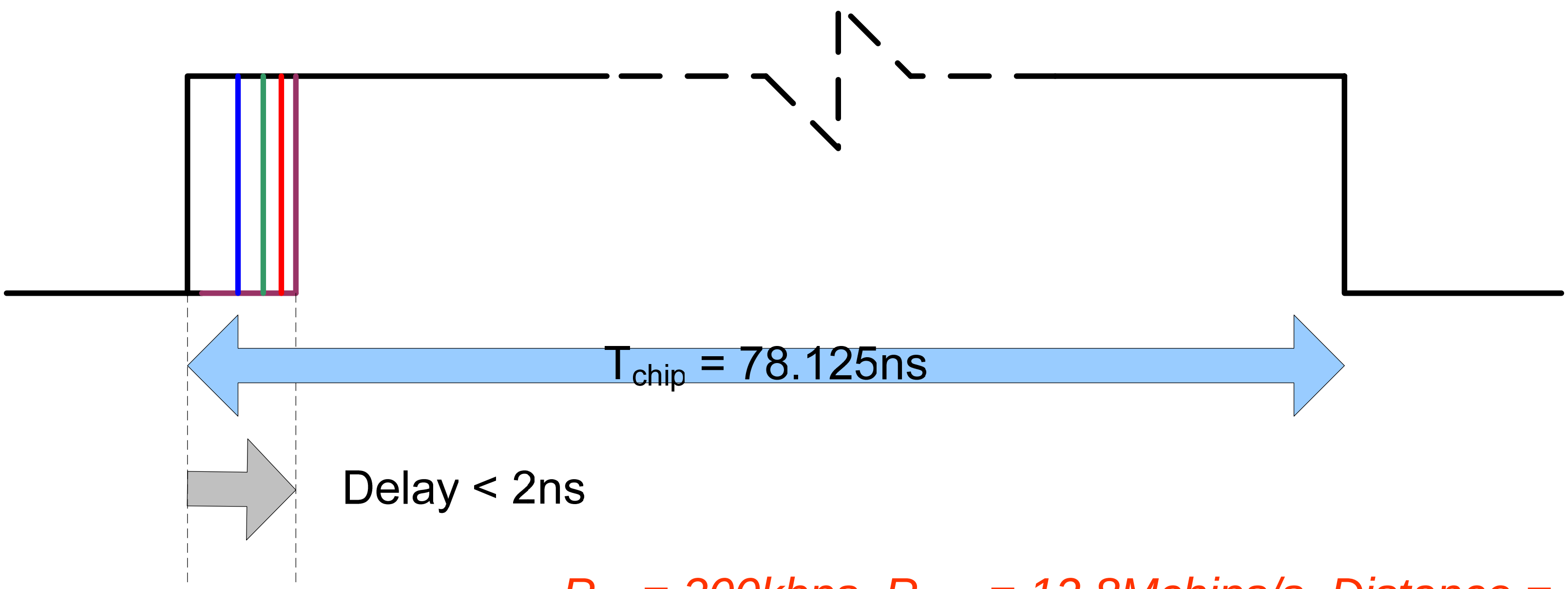
- Interference arises from codes which aren't perfectly orthogonal
  - Due to the code
  - Due to the channel
    - Propagation delays
    - Multipaths
  - Cross correlation is not zero
  - Adds to noise to degrade performance
- Interference may be predictable
  - Minimise interference…more users can be accommodated

CDMA Problem 1: Orthogonality

- Usually, propagation delay is significant
  - Signal components may be delayed by several chips
    - Orthogonality is lost
  - Unless one-to-all, better to choose non-orthogonal CDMA codes (Gold etc.)
    - Signals are never completely orthogonal
    - But better than Walsh codes if orthogonality is lost!
    - Interference is contributed by each user

SpeckNet Advantage 1: Propagation delays

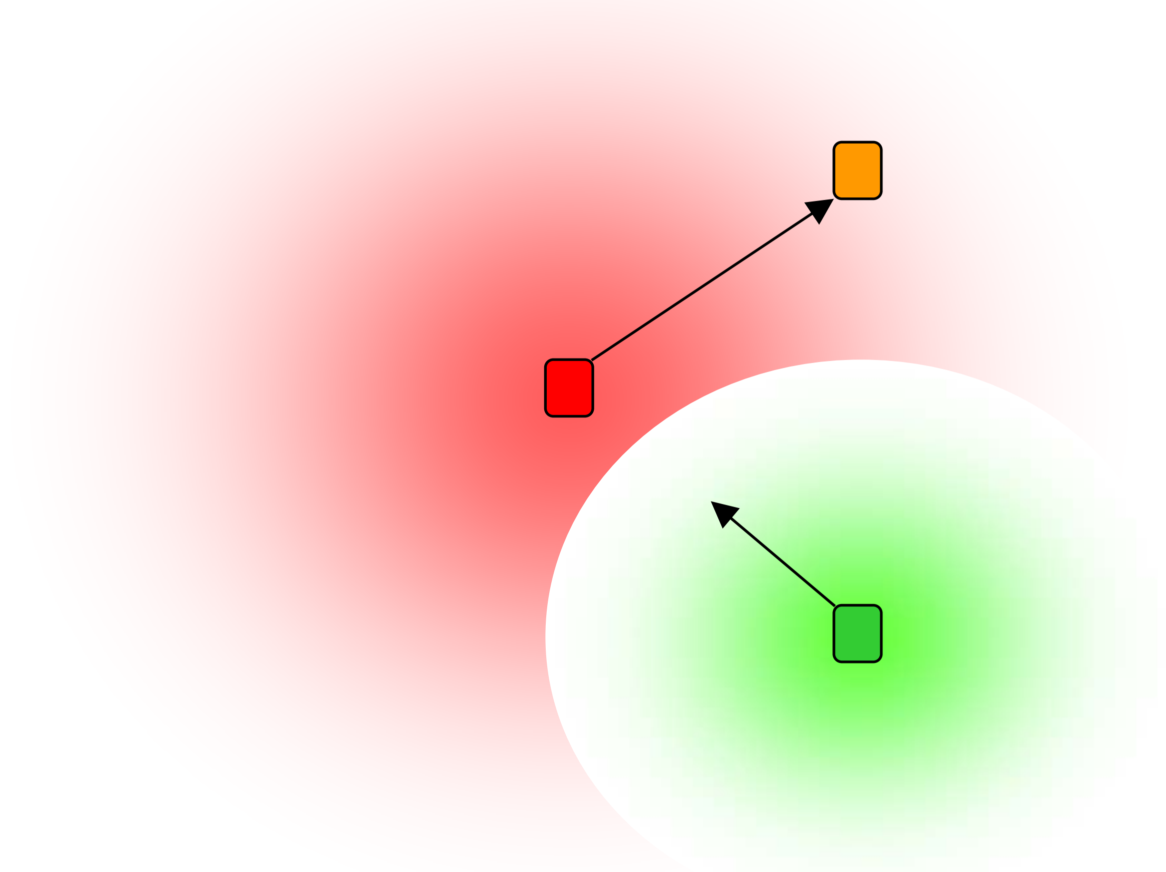
- SpeckNets have low data rates
- Transmission over short ranges
- Propagation delay small with respect to chip rate
- Little or no loss of orthogonality



R_{bit} = 200kbps, R_{chip} = 12.8Mchips/s, Distance = 50cm

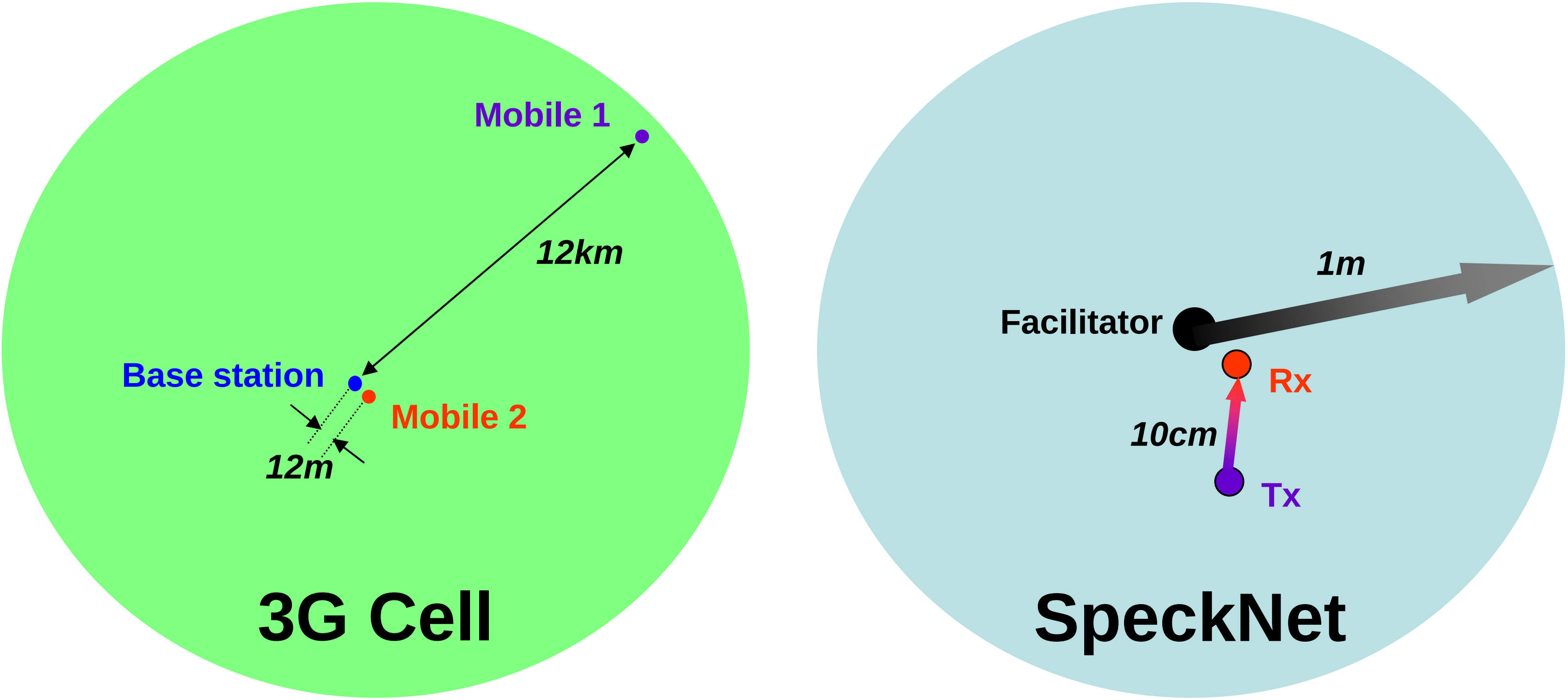
CDMA Problem 2: “Near Far” Effect

- Desired signal is “swamped” by nearby transmission
  - Orders of magnitude difference in range
  - Orders of [illegible] in amplitude

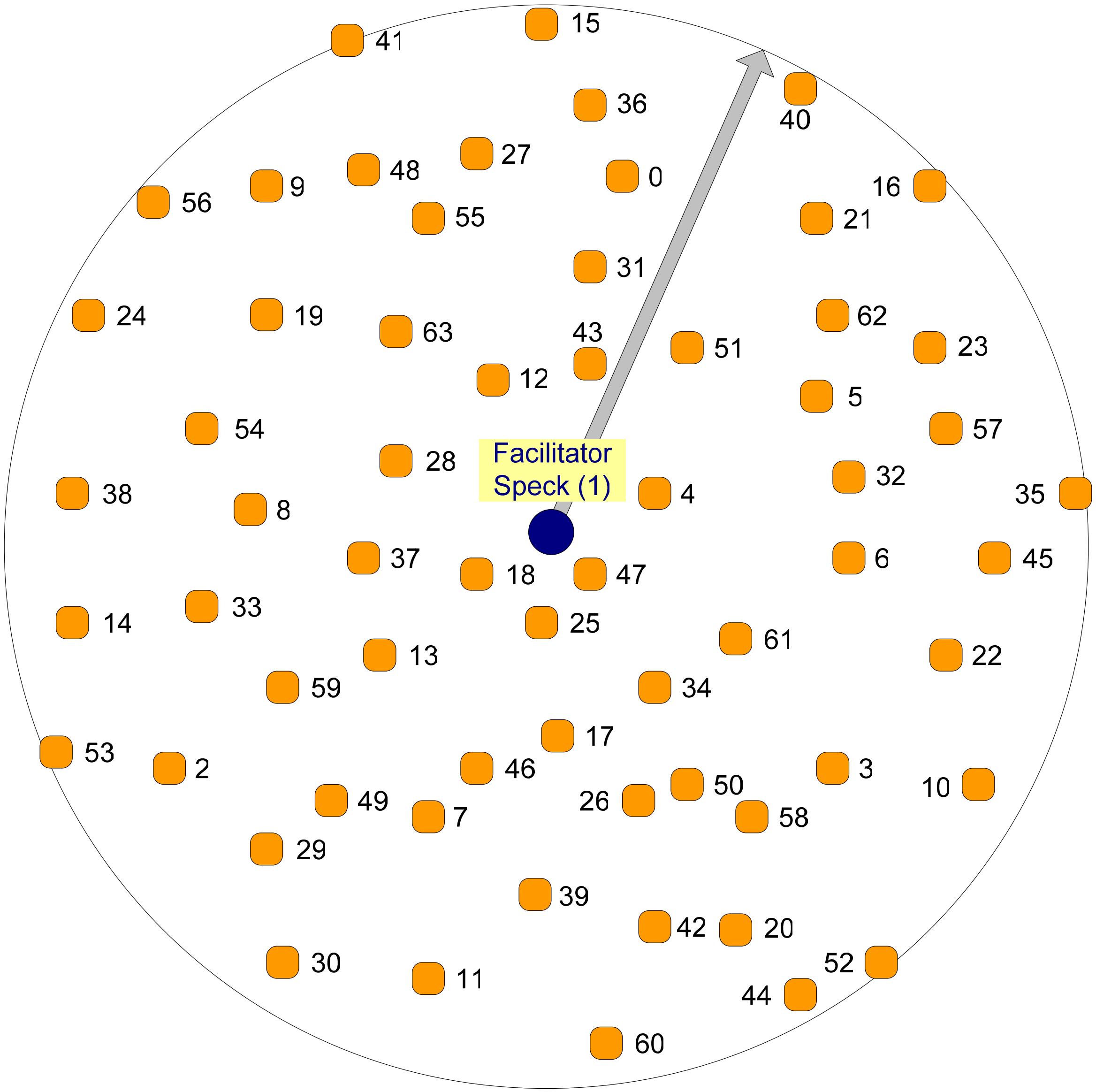


SpeckNet Advantage 2: Transmission Distances

- Near Far effect is manageable
  - Unlike cellular networks, transmission distances are always comparable

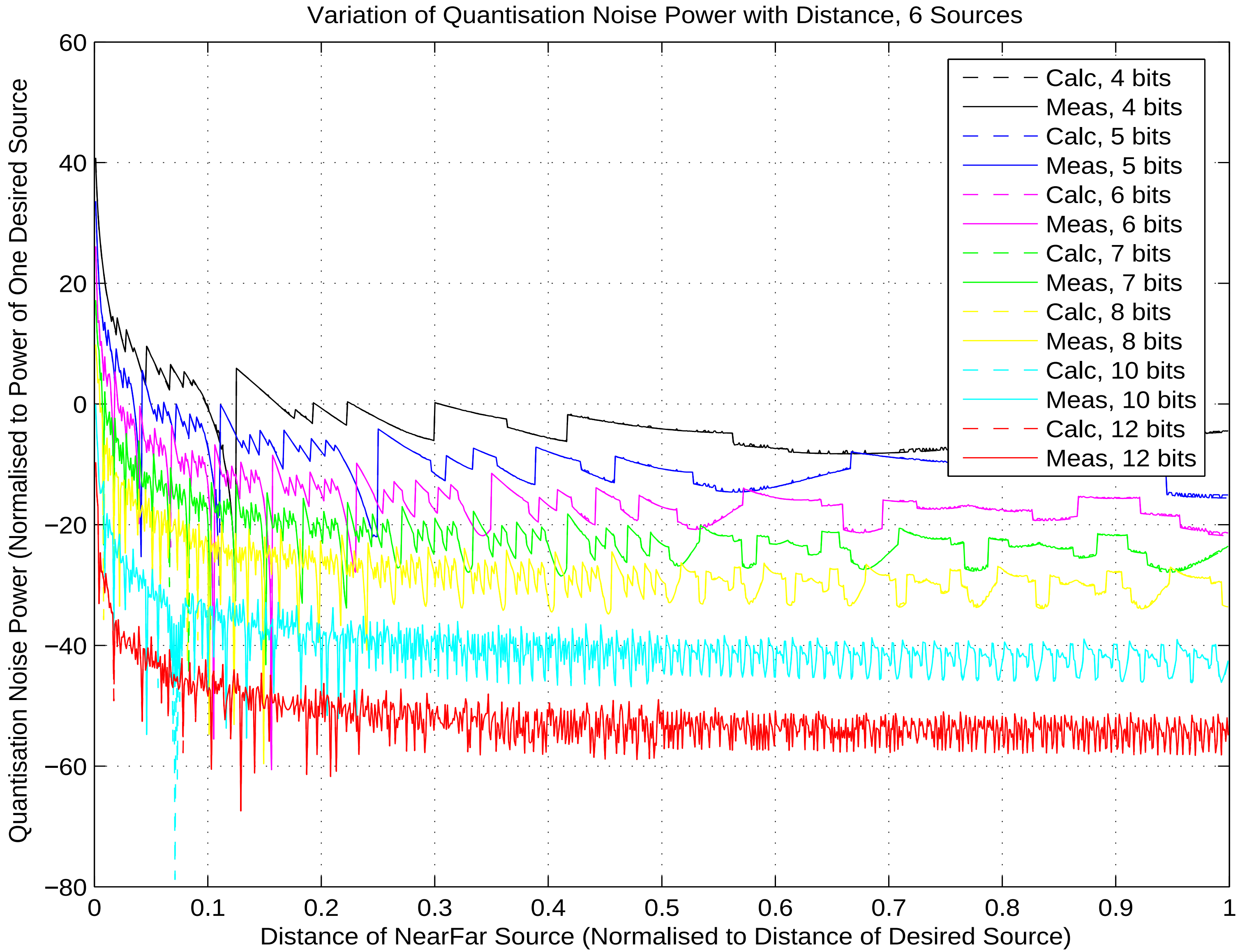


Synchronous, Orthogonal CDMA System

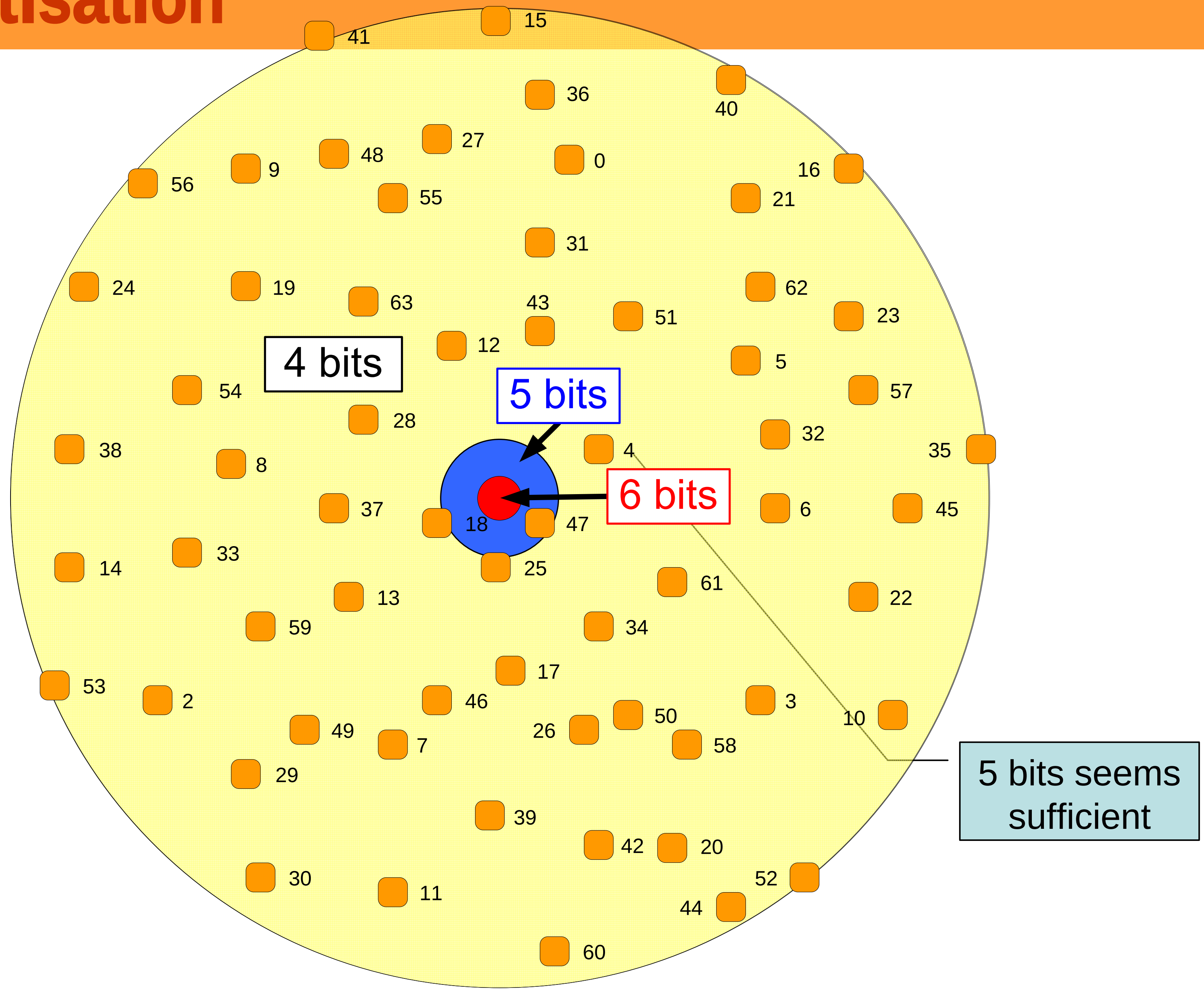


- Synchronism is required for orthogonal CDMA
- Practically no interference
- Small scales and low data rates allow orthogonality to be retained
- More users can be supported than in CSMA or asynchronous CDMA
- A Speck is needed to transmit a clock signal

Quantisation Noise

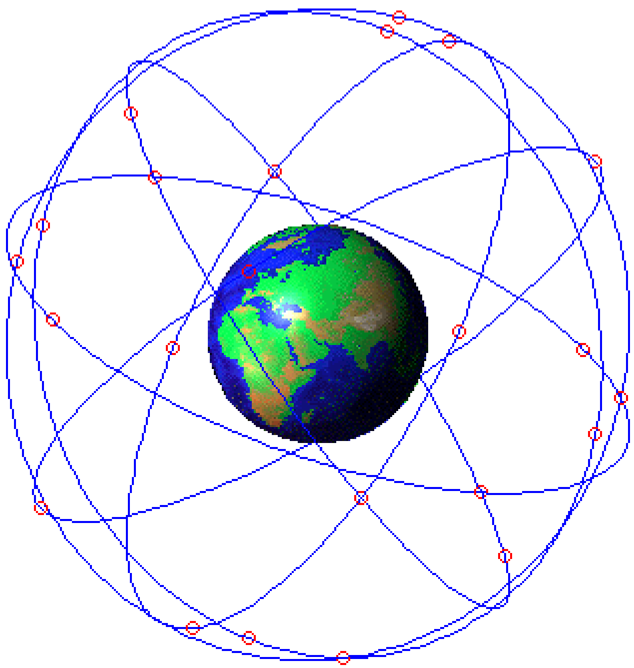


Quantisation



Some GPS Inspiration...

- CDMA allows recovery of signal from below noise floor
- As used in the Global Positioning System (GPS)
  - 50 bits per second, spread by factor 20460
  - Processing gain = 43.1dB



P_T = +56.8dBm = 480W

20,000km

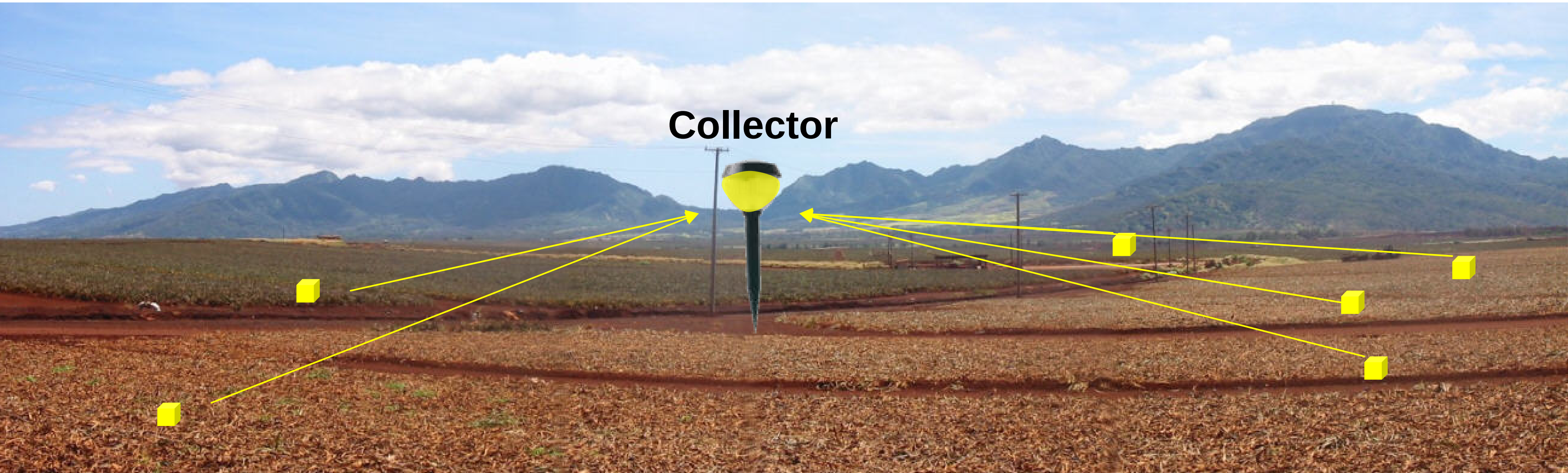
f_c = 1.575GHz

Noise Floor = -109dBm = $1.25e^{-14}$W

P_R = -127.6dBm = $1.74e^{-16}$W

Ultra Low Data Rate, Ultra Low Power

- Environmental monitoring may only require a few bits per second
- By increasing the spreading factor, power can be reduced to very low levels, for example…
  - Carrier frequency = 10GHz
  - Data rate = 50 bits per second
  - Transmit power = -25dBm (3μW)
  - Range = 250m



Future Work

- How much interference is there?
- How many users could be supported in the ULDRULP application?
- What is the best set of spreading codes?
- How best to design transmitters and receivers?

Conclusions

- CDMA provides multiple access capabilities
- SpeckNets have unique characteristics which mitigate normal CDMA problems
  - Short propagation delays
  - Low data rates
  - Short transmission distances
- CDMA benefits include:
  - Sharing the channel
  - Reducing / eliminating interference
  - Enabling ultra low transmit powers

Review

- Multiple Access and CDMA
- The problems with CDMA
- SpeckNets may not have these problems!
- A synchronous, orthogonal system
- An ultra low power, ultra low data system based on GPS
- CDMA has several power and performance benefits