FUNDAMENTALS OF RADIO COMMUNICATIONS

Dr Chris Dennett

Objectives

- By the end of this session you will be able to:
  - Understand the underlying concepts of redundancy, error control, modulation and multiple access techniques
  - Describe the techniques relevant to radio communications and therefore mobile computing
  - Discuss the relative merits of these concepts when applied to existing protocols

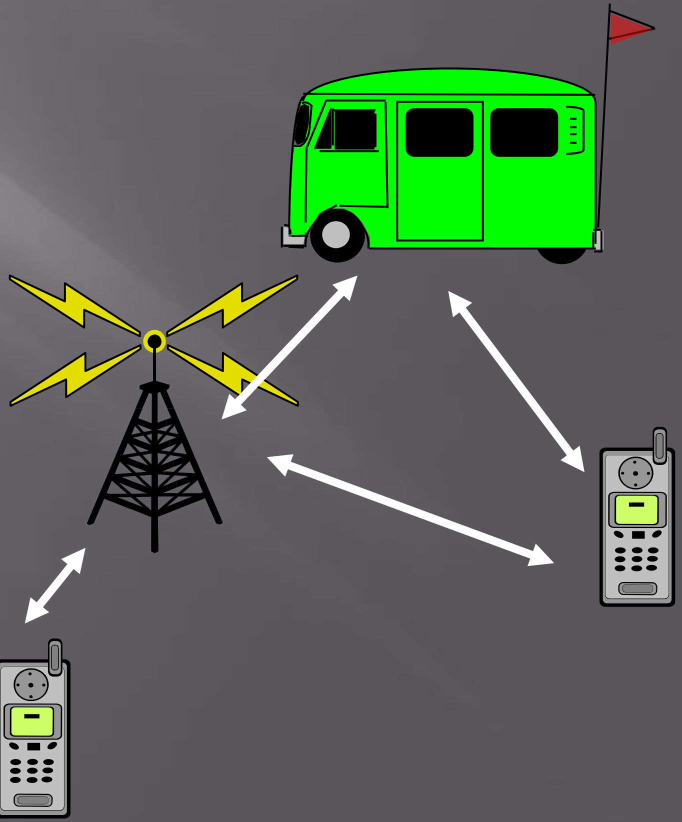
(Mobile) Radio Channels

- A very simplistic view of radio communications

Radio transmission is not direct. Radio waves are transmitted in all directions

So a receiver gets multiple versions of the same signal separated by time (refraction, reflection). Multiplicative distortion.

Other people are also transmitting (additive noise)



(Mobile) Radio Channels

- Radio waves are distorted
- The data contained in these waves is also corrupted
- Corrupted data is next to useless
  - ‘Next to useless’ – Why not completely useless?
- We can retransmit corrupted information but this is long winded, takes up valuable bandwidth and there is still no guarantee that the resent info will be correct

Redundancy

- The fundamental rule on which all digital radio communications is based
  - Allows us to know whether a piece of information has been affected by errors during transmission
  - Used in practice, it is possible to correct transmitted information at the receiver

Redundancy

- Based on an 'alphabet' of possible transmitted information

0	0
0	1
1	0
1	1

Possible Info Words

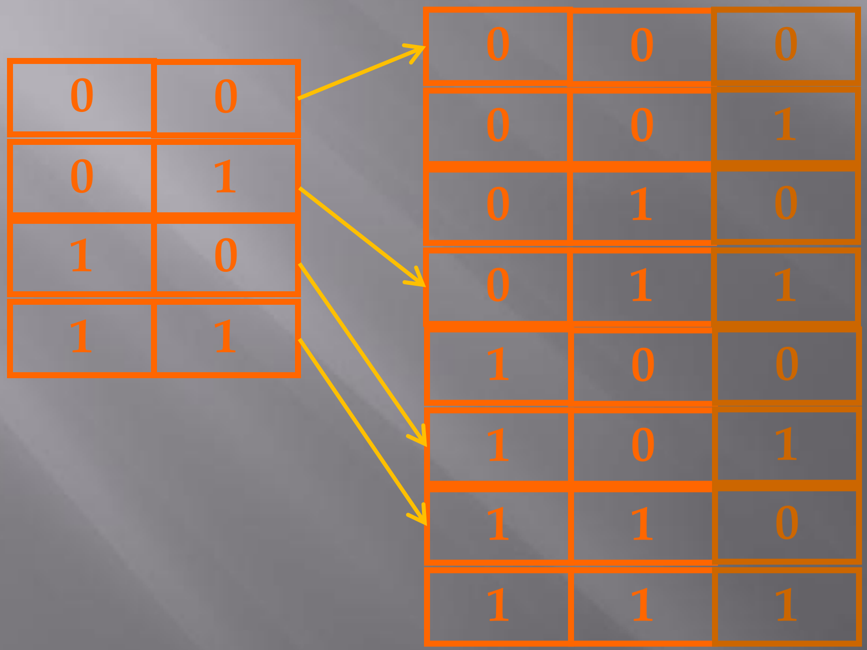
Consider all possible 2 bit words

We know that errors in transmission can (and do) occur

At the receiver, how can we tell that the received word '00' is what was actually sent?

Redundancy

- Instead of using *all* of the possible 2-bit words, consider using four of all possible 3-bit words



Now we have *redundant* information

This offers us some idea of whether the data we have received has been affected by errors

Of course, this idea gets better if we choose 4 words from 4-bit alphabet etc…

Error Control Techniques

- Redundancy only becomes useful if we can use it to correct information at the receiver
- Once we use redundancy in this way, we begin to develop error control codes
- How do we achieve this?

Controlled redundancy

- Simplest idea is to add 'parity' to the transmitted information
- Note the difference between data, information and codes.
  - Data is useful information
  - Coded data is useful information plus error checking data
- Implication?
  - Not everything we send is useful information

Code rate

- Code rate is a method of describing the amount of useful information transmitted as part of a code.
  - In our previous example, the number of information bits is 2, but the number of transmitted bits is 3.
  - Therefore the code rate is 2/3 or 0.66

Redundancy and Efficiency

- Absolute Redundancy (D) = (number of code bits) – (number of data bits)
  - In our example D = 3 – 2 = 1
- Relative Redundancy = D/(number of code bits)
  - 1/3
- Efficiency = (number of data bits)/(number of code bits)
- Also Relative Redundancy + Efficiency = 1
  - 1/3 + 2/3 = ?

Block codes

- Addition of parity bits to useful information

Example (C = codeword bit, D = data bit)

C1 = D1

C2 = D2

C3 = D1 + D2

D1	D2
0	0
0	1
1	0
1	1

C1	C2	C3
0	0	0
0	1	1
1	0	1
1	1	1

Block Codes

- Now if we receive the codeword ‘001’, we know there’s been an error during transmission
- Do we know what though?

D1	D2
0	0
0	1
1	0
1	1

C1	C2	C3
0	0	0
0	1	1
1	0	1
1	1	0

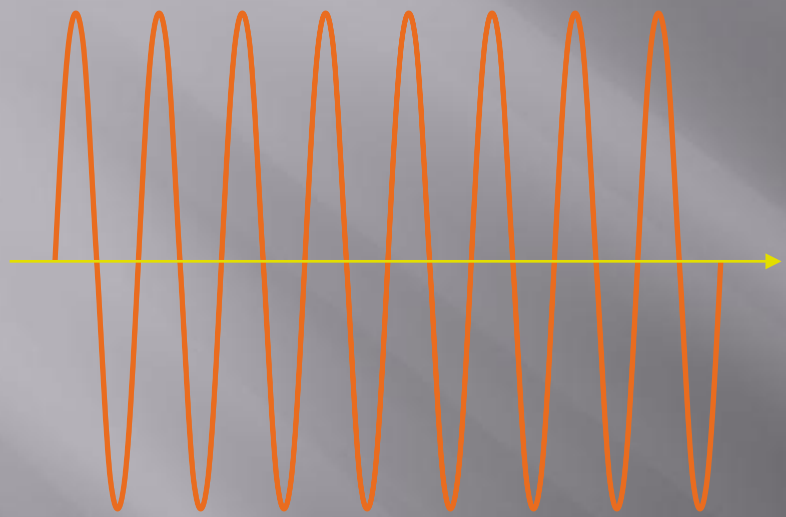
Hamming Distance and Error Detection and Correction

- The Hamming Distance (d) is the difference between one code word and any another from the code
  - For our example, it is 2
- A block code can detect d-1 errors
  - For our example 2-1 = 1
- A block code can correct (d-1)/2 errors
  - For our example ½, rounded down to 0
- In our example, if 1 bit is changed, we can detect the error BUT NOT correct it.
- What if we have two bits in error?

Radio Waves

- Continuous electromagnetic waveforms
- Shaped by the encoder before transmission
  - Modulation

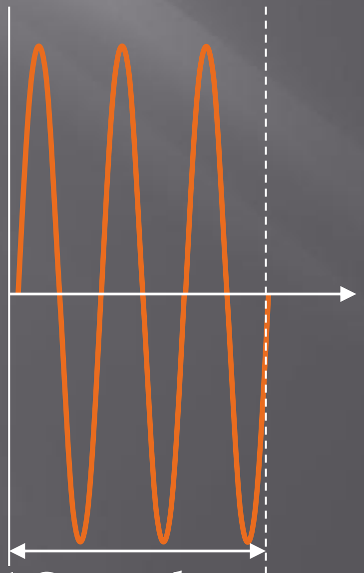
Analogue Modulation (FM)



More resilient to noise than Amplitude Modulation (AM). Think how much better the move from AM radio 2 to FM radio 2 was!

Frequency = Number of waves/Sec

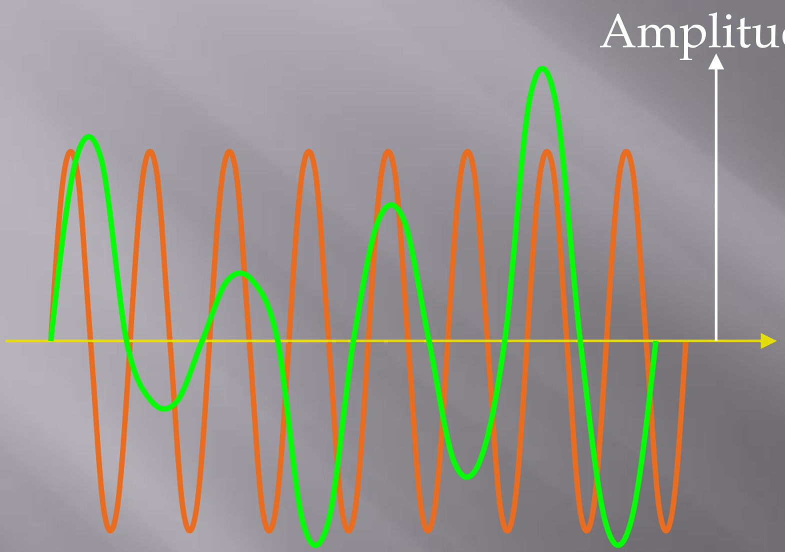
One Wave

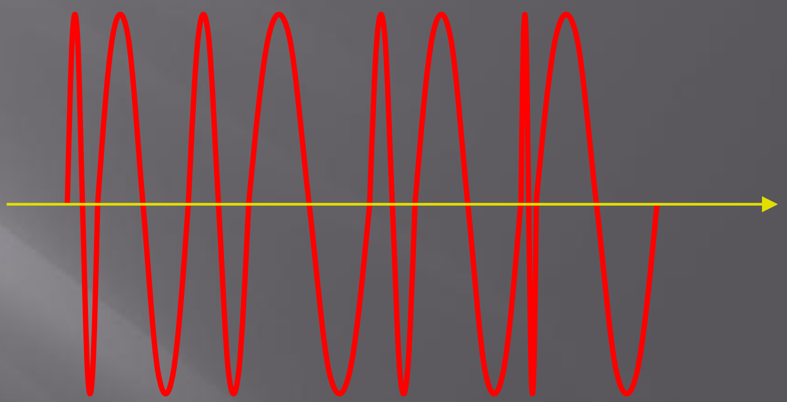


1 Second

F = 3Hz

Analogue Modulation (FM)





Carrier Signal…

Voice Signal (Note the changes in amplitude)…

Transmitted signal. Frequency of carrier is altered according to amplitude of voice signal

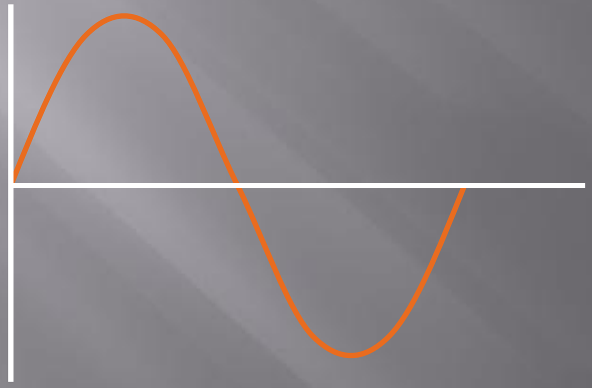
Digital Modulation

- Frequency modulation does not apply to digital transmissions
- There are an infinite number of changes in the frequency of the carrier wave
- Digital information only has a finite number of possibilities
- In digital modulation, each waveform represents a digital word

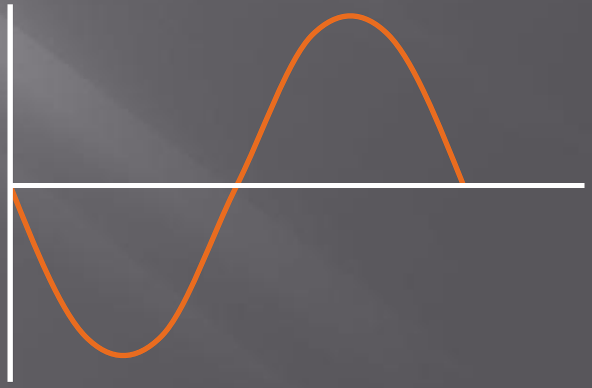
Digital Modulation

- Each digital word corresponds to a specified amplitude/frequency/phase

Binary 1



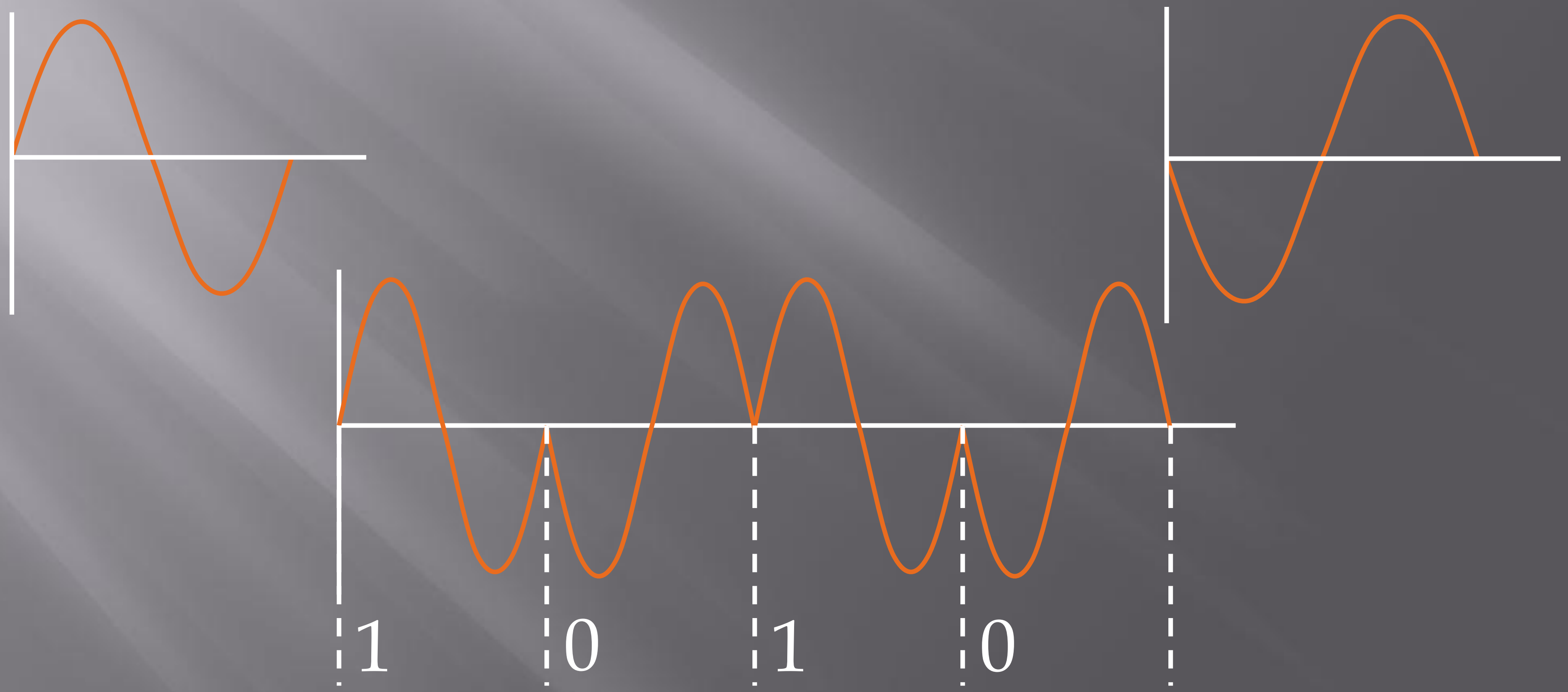
Binary 0



Phase-Shift Keying is probably the most common example. Binary Phase-Shift Keying is the most basic. Here the waveform corresponding to a binary 1 has a 180 degree phase difference to that for a binary 0

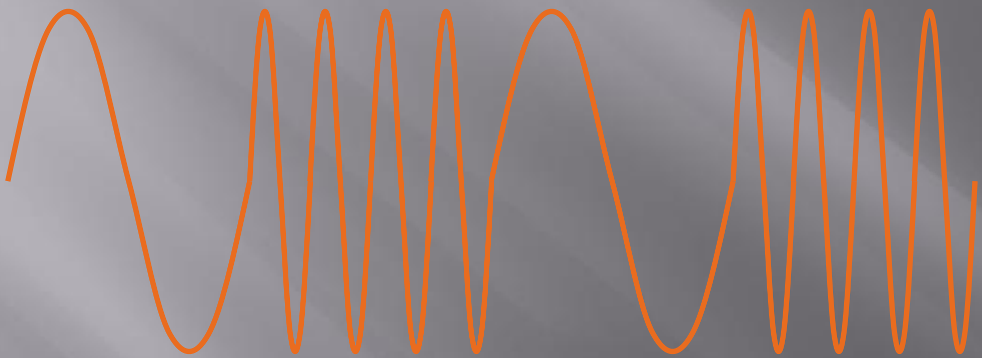
Transmitting Digital Information

- Therefore, the dataword 1010 becomes:



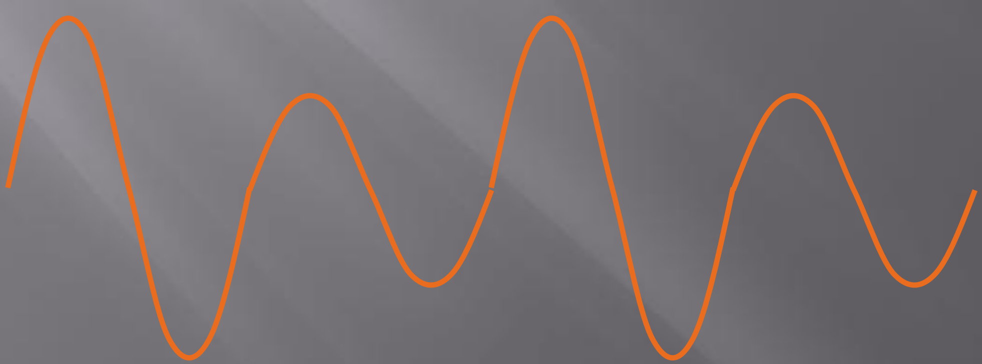
Digital Modulation

- As well as Phase Shift Keying, there is



Frequency Shift Keying

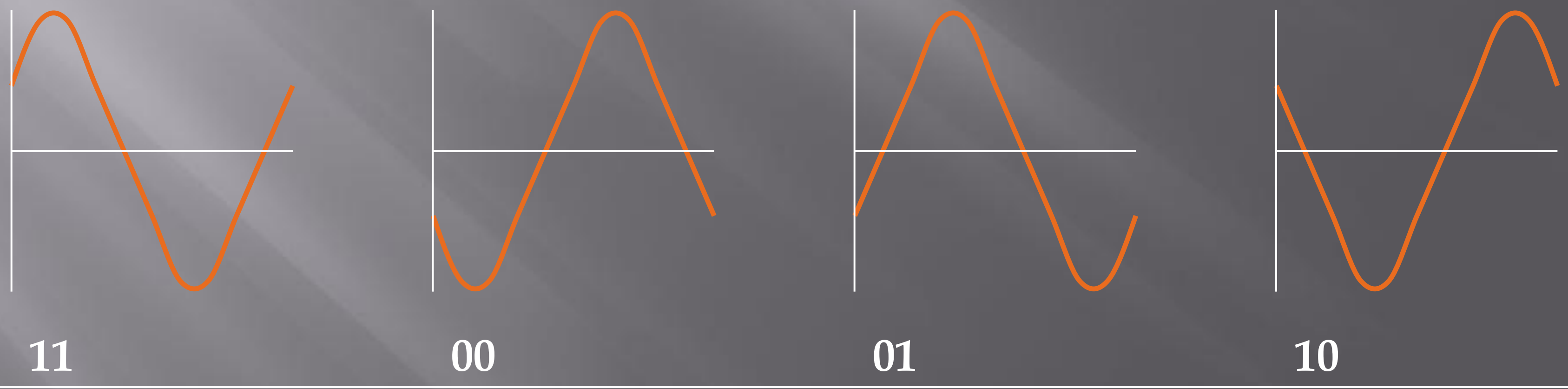
1 0 1 0



Amplitude Shift Keying

Digital Modulation

- More information can be transmitted within one waveform by increasing the number of bits associated with it.
  - Quadrature Phase-Shift Keying



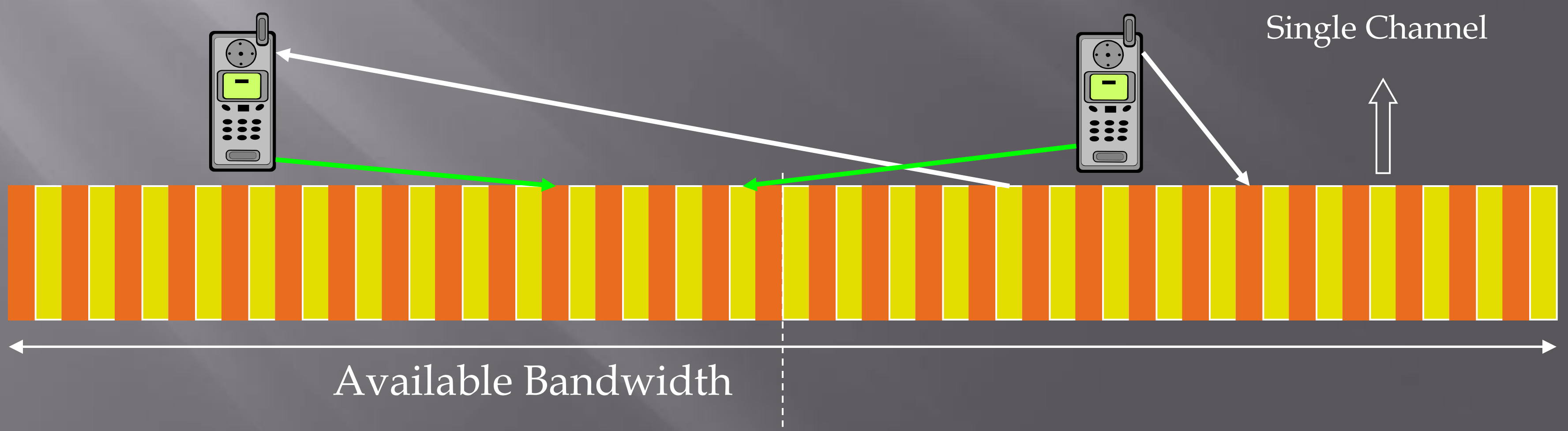
Each Waveform is separated from its nearest neighbour by 90 degrees

Multiple Access Techniques

- Available bandwidth for radio communications is divided into multiple channels – Like radio stations
- How many radio stations can you tune-in to?
- Not really equivalent to the number of phone calls/wi-fi connections going on at one time is it?
- Answer is to use Multiple Access Techniques

FDMA

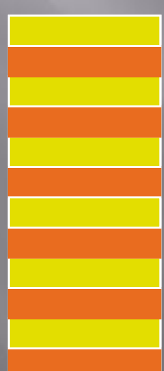
- Frequency Division Multiple Access
  - Method used to break available bandwidth into separate channels
  - Each communication stream is allocated an ‘up’ and a ‘down’ link frequency

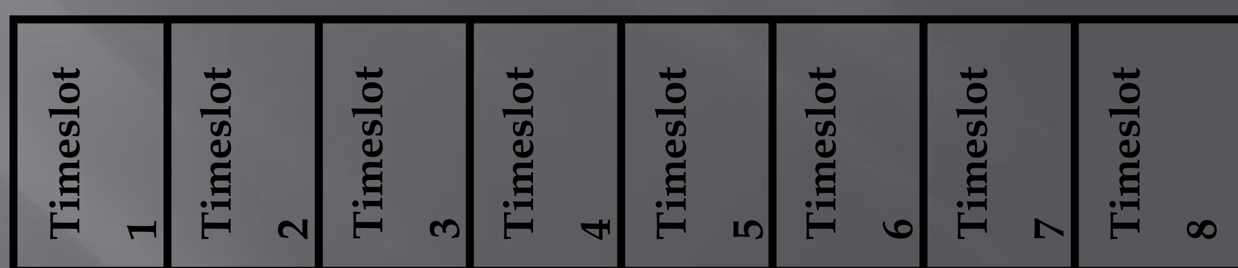


FDMA Combined with TDMA Access Techniques

FDMA with Time Division Multiple Access (TDMA)

- FDMA breaks total bandwidth up into smaller channels
- TDMA then breaks each channel frequency into time slots





Improved Quality

- Transmitting digital information means that it can be encoded and decoded…
- Which means less information is lost…
- Which means sound quality is improved!