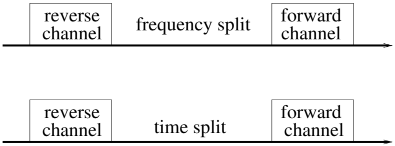
Agenda for discussion

The lecture contains:
Different techniques for **partitioning** frequency band into channels. Also deals with certain important technical requirements which enables physical medium to carry signals.

- FDMA, TDMA and CDMA.
- Modulation.

Multiple access techniques

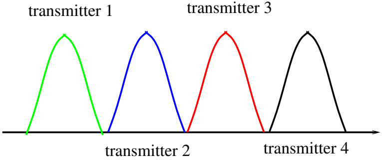
Duplex techniques



- Allows users to talk and listen simultaneously.
- **Frequency split**: two distinct bands for every user.
- **Time split**: a forward time slot and a backward timeslot.

Frequency division multiple access

FDMA features



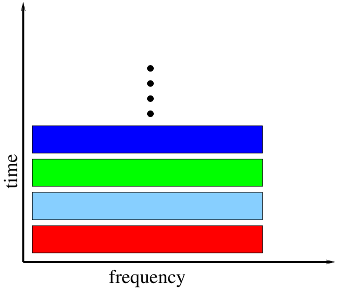
- Two different frequency bands are used for each duplex channel.
- Different transmitters operated continuously.
- If a channel is not used it sits idle.
- Normally used for narrowband systems.
  - Symbol time is large compared to the average delay spread.

Frequency division multiple access

FDMA features

- Continuous transmission requires fewer overhead bits for synchronization and framing.
- FDMA uses a duplexer (switch) since TX and RX operate at the same time.

Time division multiple access



TDMA features

- Transmitters share a common channel.
- One transmitter allowed at each time slot.
- Synchronous TDMA: access to channel is regular.
  - Slot time is between 100-20 μs
  - Used for digital signal only.
- Asynchronous TDMA (CSMA): allows transmitter to access when channel is free.

Time division multiple access

TDMA features

- Transmits data using buffer-and-burst method.
  - Transmission for any user is not continuous.
- No duplexer necessary as different time slots are used for transmission and receiption.
- Strong signal can not capture receiver as different slots are used.
- Different number of time slots could be used for different users.
  - Can adjusts bandwidth on demand.

Time division multiple access

Synchrnous TDMA and FDMA

- Primary disadvantage compared to FDMA is precise synchronization requirements.
  - Frame and bit timings must be maintained.
- Other disadvantage is only digital traffic is possible.
- Synchronous TDMA usually combined with FDMA due to limitations of transmitter and linearity of receiver.

Time division multiple access

Advantage of TDMA over FDMA

- In TDMA, the carrier of only one transmitter is present in a receiver at any given time.
- In FDMA, each station should be able to transmit and receive multitudes of carrier frequencies. So receiver is complex.
- TDMA is more suitable for digital signals
  - Acclimatised for storage, rate conversion and processing in time domain.

Time division multiple access

Asynchronous TDMA

- Often known as CSMA.
- Allows transmitter to access channel when not used.
- Two transmitters can be active at the same time.
- Can not achieve more than 50% throughput.
- Provides multiple access both for digital and analog communication systems.
- CSMA can not guarantee that two transmitter never arrive at the same time
    - CSMA is usually combined with collision detection.

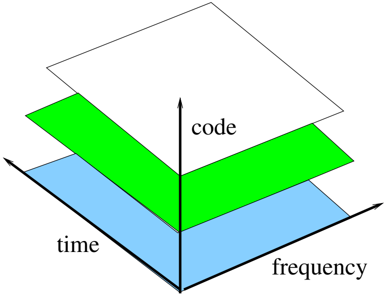
Code division multiple access

CDMA features

- Spreads signal over the entire band.
- Each transmitter has a separate spreading sequence.
- For sending 1 bit of information a (chipping) sequence of bits are used.
  - Each user has a unique chipping pattern.
  - So, logically a channel is made out of a code.

Code division multiple access

Time frequency characteristics



Code division multiple access

Example

Trans.	Chipping sequence	Data
TX1	0→ 001, 1→ 110	0011 → 001001110110
TX2	0→ 011, 1→ 100	1010 → 100011100011
TX3	0→ 111, 1→ 000	1101 → 000000111000

Recv.	Combined bit stream	Ex-OR (0's chip seq)
RX1	000001110010	001001110011
RX2	000001110010	011010101001
RX3	000001110010	111110001010

- A receiver finds the majority value of groups of 3bits.
- Eg. from bitstream 001001110011, RX1 gets back 0011.

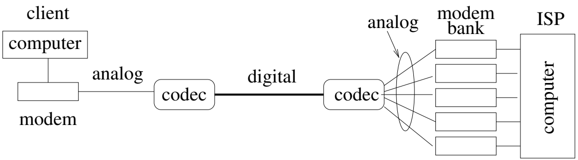
Code division multiple access

Features of CDMA

- Performance of CDMA gracefully degrades with load.
  - Others tend to crash with load.
- With under use system improves automatically.
- Most notable advantage is immune to jamming.
- Advantage of using entire bandwidth is somewhat cancelled as spreading requires more bandwidth.

Modulation

Communication medium



There are three part to a communication medium:

1. Information called baseband.
2. Medium.
3. Carrier.

Modulation

Problems in transmission line

- **Attenuation**: loss in energy when signal propagates forward.
- **Delay distortion**: caused by varying propagation time of different frequency components of signal.
- Thermal noise: thermally agitated electrons in conducting line.
- **Cross talks**: when cable nearby carry multiple signals and wanted coupling happen.
- **Impulse noise**: may be generated by faults or eletromagnetic disturbances.

Modulation

Need for modulation

- Digital signals have a wide frequency spectrum, so are affected by strong attenuation and distortion.
- Baseband signal can not reach too far.
- So a carrier wave is introduced whose amplitude, phase or frequency can be modulated.
- Modulation allows a small signal to regulate the carrier

Modulation

Need for modulation

- There are other technological limitations.
- If wire length is smaller than wavelength then it will radiate signal acting as an antenna.
- In wireless transmission, antenna length is directly proportional to wavelength.
- Modulation also used for separating different signals thus needed for multiplexing a single channel.

Modulation

Modulation reduces antenna height

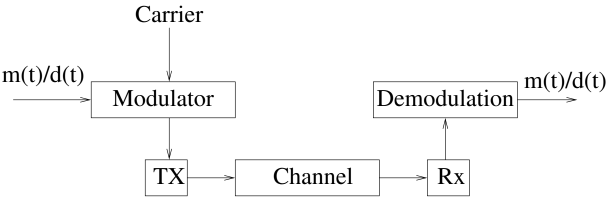
Suppose we have audio communication with signal bandwidth 3000Hz.

- $\lambda = \frac{c}{f} = \frac{3.10^8}{3.10^3} = 10^5$m= 100Km
- So required height of antenna (approx) $\lambda/4 = 25$km!
- But if we modulate carrier wave at 100MHz, then $\lambda = \frac{3.10^8}{100.10^6} = 3$m. So antenna height $= 75$cm

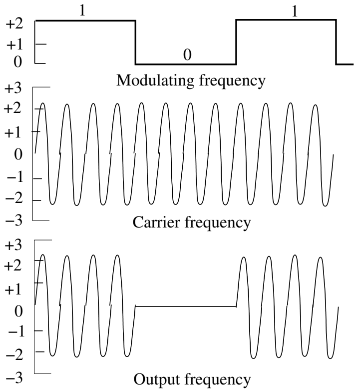
Modulation

Modulation process

Signal is modulated by data to be sent, and at receiving end it is demodulated to recover data.



Modulation



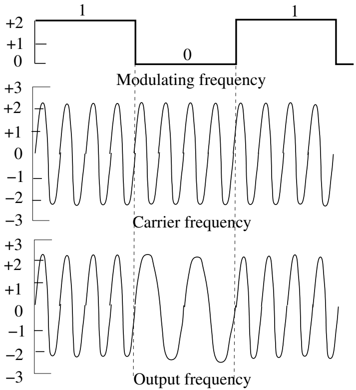
ASK

1 is transmitted by carrier at one amplitude. Absence or no carrier represents 0.

$$ASK(t) = s(t)sin(2\pi ft)$$

- Simple to design
- Noise spikes interferes transmission.
- Loss of connection read as 0.

Modulation



FSK

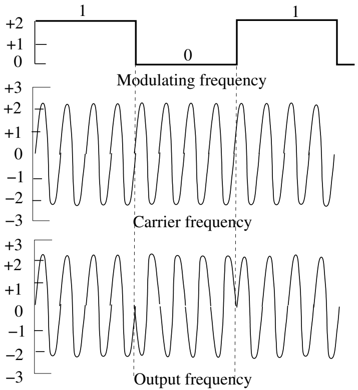
1 and 0 are transmitted by discrete frequency changes of carrier wave.

- Immune to noise.
- Loss detected easily .
- Two frequencies required:

$$FSK(t) = \begin{cases} sin(2\pi f_1 t), \text{ for } 1 \\ sin(2\pi f_2 t), \text{ for } 0 \end{cases}$$

- Circuit for recognition.

Modulation



PSK

1 and 0 are transmitted by discrete phase changes of carrier wave.

$$PSK(t) = \begin{cases} sin(2\pi ft), \text{ for } 1 \\ sin(2\pi ft + \pi), \text{ for } 0 \end{cases}$$

- Only one frequency used.
- Carrier loss detection is easy.
- Complex circuitry needed to generate/detect phase change.

Modulation

Shannon's theorem

- How fast transmission is possible over a communication channel?
- If M messages, each of H bits, are transmitted per second then the rate of information $R = MH$.
- Intuitively, increase in R leads to increase in errors per unit time.
- Shannon theorem says

  It is possible to transmit information with arbitrarily small probability of errors if $R < C$.
- But, Shannon's theorem does not provide a constructive proof.

Modulation

Channel capacity

- Channel capacity $C = B.\log_2(1 + S/N)$, where B is bandwidth and S/R is **SNR**.
- $S/N = 2^{\frac{C}{B}} - 1$
- Consider a bandwidth = 3000 Hz, and SNR is 30dB, i.e., $10\log_{10} S/N = 30$, so $S/N = 10^3 = 2^{\frac{C}{3000}} - 1$.
- Capacity $= 3000 \times \log_2(1 + 1000) = 30$Kbps

Summary

- This module primarily deals with channel partitioning.
- The partitioning is based frequency, time and code.
- Relative advantages and disadvantages of partitioning were discussed.
- Importance of modulation techniques were also discussed.
- Finally, we discussed how Shannon theorem is important in connecting bandwidth and channel capacity.