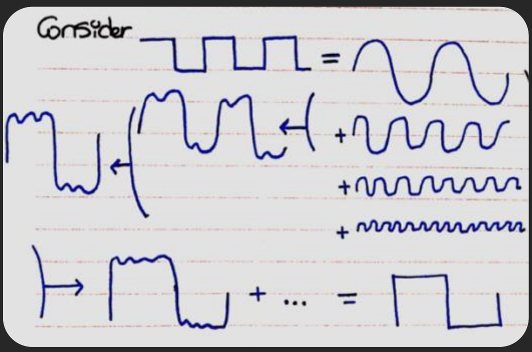
WN Sheet 1

Basic Concepts of Wireless

1) Is it possible to transmit a digital signal, e.g., coded as square wave as used inside a computer, using radio transmission without any loss? Why?

- No, it's generally not possible to transmit any signal without any loss
  - Even in the best case where it's just propagating in free space, it will suffer from path loss (attenuation)
  - Can get worse when exponential absorption, fading, interference or doppler shift are involved
- A digital signal coded as a square wave implies sending an infinite sum of sines at an infinite number of frequencies.
  - No channel will allow all such frequencies (limited bandwidth)
  - High frequencies that survive are still subject to more attenuation as in the path loss equation



2) What are the main problems of signal propagation? Why do radio waves not always follow a straight line? Why is reflection both useful and harmful?

- Attenuation, Reflection, Refraction (Bending), Scattering, Diffraction
- They don't follow a straight line since the medium they travel in makes them subject to the aforementioned signal propagation problems. All such problems divert motion along a straight line, except for attenuation.
- Reflection is useful because it allows communication when there is no line of sight (the original purpose of satellites) and is harmful because it contributes in multipath propagation which can cause interference and fading.

3) How to counter fading?

- Transmit the signal more than once through different ways
  - At different times
  - At different frequencies

- From different locations

⇒ All of these add redundancy, but reduce the chance of simultaneous destructive interference or more precisely increase the chance that at least once we it won't be destructive.

- Use Adaptive Modulation
  - Transmit a test signal to receiver and wait for it to be fed back to estimate chancel characteristics
  - Use such knowledge to modulate the signal to be sent appropriately (avoid fading)

4) What are the types of interference?

1. Adjacent Channel Interference
   - Occurs when a channel (e.g., voice or radio) exceeds its allocated range of frequencies
   - Usually, a filter guarantees that no signal exceeds the designated channel's range; however, if its non-ideal then the range can be exceeded which will interfere with the signal(s) in the adjacent channel.
2) Co-channel interference
   - Can occur when two systems use the same transmission frequency (e.g., assigned the same voice channel)
   - An example is frequency reuse in cellular
3) Inter Symbol Interference:
   - Occurs when the symbols (pulses) of the same signal overlap with each other, this can be due to

     ⇒ Symbol spreading caused by band-limited channel (3rd year)

     ⇒ Multi-path propagation (by definition)

4) A wireless base station transmits at the unlicensed carrier frequency of $f_c = 5.775\ GHz$. Its maximum transmit power is $1\ W$ according to FCC (Federal Communications Commission) rules. Assume that the base station and receiver antenna gains are 4. We use $dBm = 10\,log10(power)$, where power is represented in mW. Thus $1\ W = 30\ dBm$.

   1. What is the wavelength of the wireless channel?
   2. What is the received signal power in dBm, in the free space, of a signal from the base station to a receiver who is at a distance of $1\ mile\ (1.6\ km)$? What is the transmission delay in ns?
   3. Assume that a receiver has a sensitivity level of $-91\ dBm$, what is the maximum distance of the receiver, in the free space, from the base station?

From the givens we have,

$f_c = 5.775\ GHz$

$P_{t(max)} = 1W$

$G_t = G_r = 4$

// We already know what's dbm from the lecture

1. What is the wavelength of the wireless channel?

   Assume that the bandwidth of the signal being transmitted matches that of the channel and that its narrow enough to be described by the carrier frequency.

$$\lambda_c = \frac{c}{f_c} = \frac{3 \times 10^8}{5.775 \times 10^9} = 52 \times 10^{-3} m$$

2. What is the received signal power in dBm, in the free space, of a signal from the base station to a receiver who is at a distance of $1\ mile\ (1.6\ km)$? What is the transmission delay in ns?

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 = 1 \times 4 \times 4 \times \left(\frac{52 \times 10^{-3}}{4\pi \times 1.6 \times 10^3}\right)^2 = 1.07 \times 10^{-10}\ W$$

$$= 1.07 \times 10^{-7}\ mW$$

$$P_r^{[dbm]} = 10 \log(1.07 \times 10^{-7}) = -69.7\ dbm$$

We could have also directly done

$$P_r^{[db]} = P_t^{[db]} + G_t^{[db]} + G_r^{[db]} + 20 \log\left(\frac{\lambda}{4\pi d}\right)$$

$$= 10 \log(1 \times 10^3) + 10 \log(4) + 10 \log(4) + 20 \log\left(\frac{52 \times 10^{-3}}{4\pi \times 1.6 \times 10^3}\right)$$

$$= -69.7\ dbm$$

The delay is the time until the signal (EM wave) arrives at the receiver.

$$t = \frac{d}{c} = \frac{1.6 \times 10^3}{3 \times 10^8} = 5.33 \times 10^{-6} = 5330\ ns$$

3. Assume that a receiver has a sensitivity level of $-91\ dBm$, what is the maximum distance of the receiver, in the free space, from the base station?

The sensitivity level of the receiver is the minimum power for the receiver to detect the signal

$P_{sen} = -91\ dbm \rightarrow P_r \geq -91\ dbm$

$P_{r(min)} = -91 dbm = 10^{-\frac{91}{10}} = 10^{-9.1}\ mW = 10^{-12.1}\ W$

Given all other factors are the same, P_r is at its lowest when d is at its highest so we have

$$P_{r(min)} = P_t G_t G_r \left(\frac{\lambda}{4\pi d_{max}}\right)^2$$

That is,

$$d_{max} = \sqrt{\frac{P_t G_t G_r}{P_{r(min)}}} \times \frac{\lambda}{4\pi} = \sqrt{\frac{1 \times 4 \times 4}{10^{-12.1}}} \times \frac{52 \times 10^{-3}}{4\pi} = 18571.7\, m = 18.6\, km$$

and this can be confirmed by plugging in the original equation above with d_{max} and checking $P_{r(min)}$ in dbm