Next G Connect (NGC)

Radio Frequency (RF) Introduction

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Overview

- Radio Frequency (RF) is a broad term that encompasses many items that are used from commercial, consumer, utility and military applications.

- RF is used by system integrators and hardware designers involved with radio systems or its components.

- RF theory and practice typically includes these basic elements:
  - Information to be transported
  - Radio Frequency Spectrum
  - Modulation
  - Radio System
  - Antenna System
  - Propagation
  - Link Budget

RF System Engineering

From a systems aspect, RF Theory involves four basic elements of which, each has numerous subtopics that will be discussed during this module.

- **Information Transported** refers to the fundamental issue of what the system is designed to transfer. The system components needed to transport speech has different issues then that used for high speed IP data.

- **Radio Frequency Spectrum** is the spectrum used that is integral for the system designer. For instance, cellular mobility systems have defined radio spectrum allocations and that spectrum allocation is further delineated by the assignment of channels.

- **Transmitter and Receiver** are the actual hardware that is used for conveyance of the information. Typically the communication systems focus on the modulation aspects of this area only. However, there are numerous aspects of both a transmitter and receiver that allow for the information to be successfully transported.

- **Propagation** describes the effects or affects that occur to the electromagnetic wave as it travels from the transmitter to the receiver.

Information

- The information and its associated available bandwidth, i.e. spectrum and channels, heavily influence which modulation scheme to utilize in any communication system.

- Information that is transported over RF can be classified as:
  - Analog (voice, video)*
  - Digital (data)

- The information transferred from one point to another via RF requires many items.

- However the amount of information that is able to be transferred from point A to point B is determined by:
  - Spectrum required (channel bandwidth)
  - Modulation scheme utilized
  - Carrier/Signal to noise or interference + noise ratio required (S/N or SNR).

- The information transfer rate is typically expressed in Bits per Second (**bps**) or sometimes as Bits per Hertz (bpHz).

*** Not digitized**

Information

- The Shannon-Hartley equation represents the relationship between radio bandwidth, capacity, and the signal to noise ratio.

$$C = B \log_2(1+S/N)$$

Where :

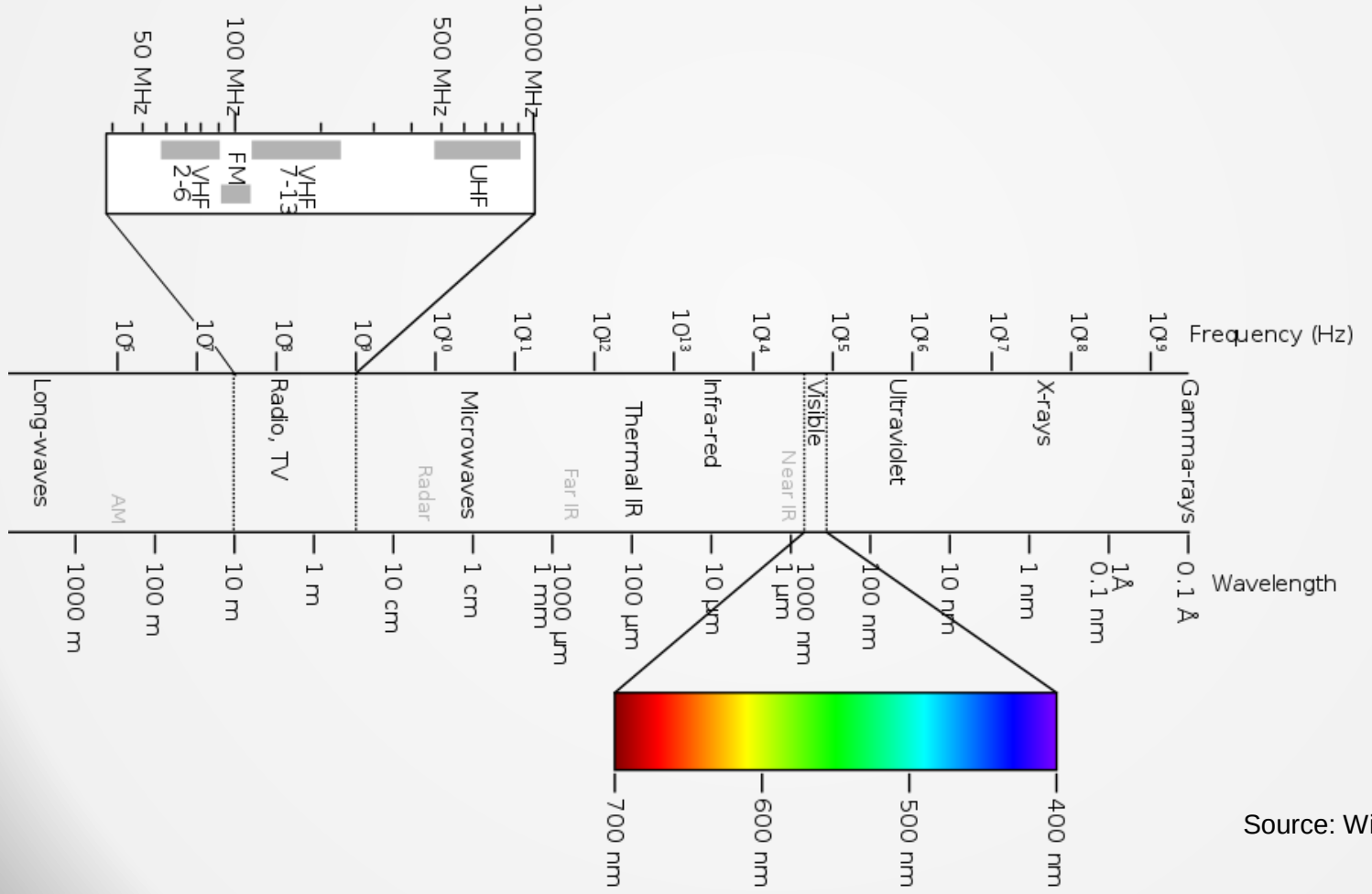
S/N = signal to noise ratio (dB)
B= bandwidth (Hz)
C = Capacity (bps)

- The higher the S/N ratio the lower the capacity, bps, the system will be able to support given the same channel bandwidth (Hz).

- Typically the channel bandwidth is pre defined by a regulatory and or standards process.

RF Spectrum

- Radio Spectrum occupies only a portion of the electromagnetic spectrum.



Source: Wiki

RF Spectrum Designation

- Radio waves are comprised of an electric and magnetic field.
- Radio waves are more commonly referred by its frequency as opposed to its wavelength.

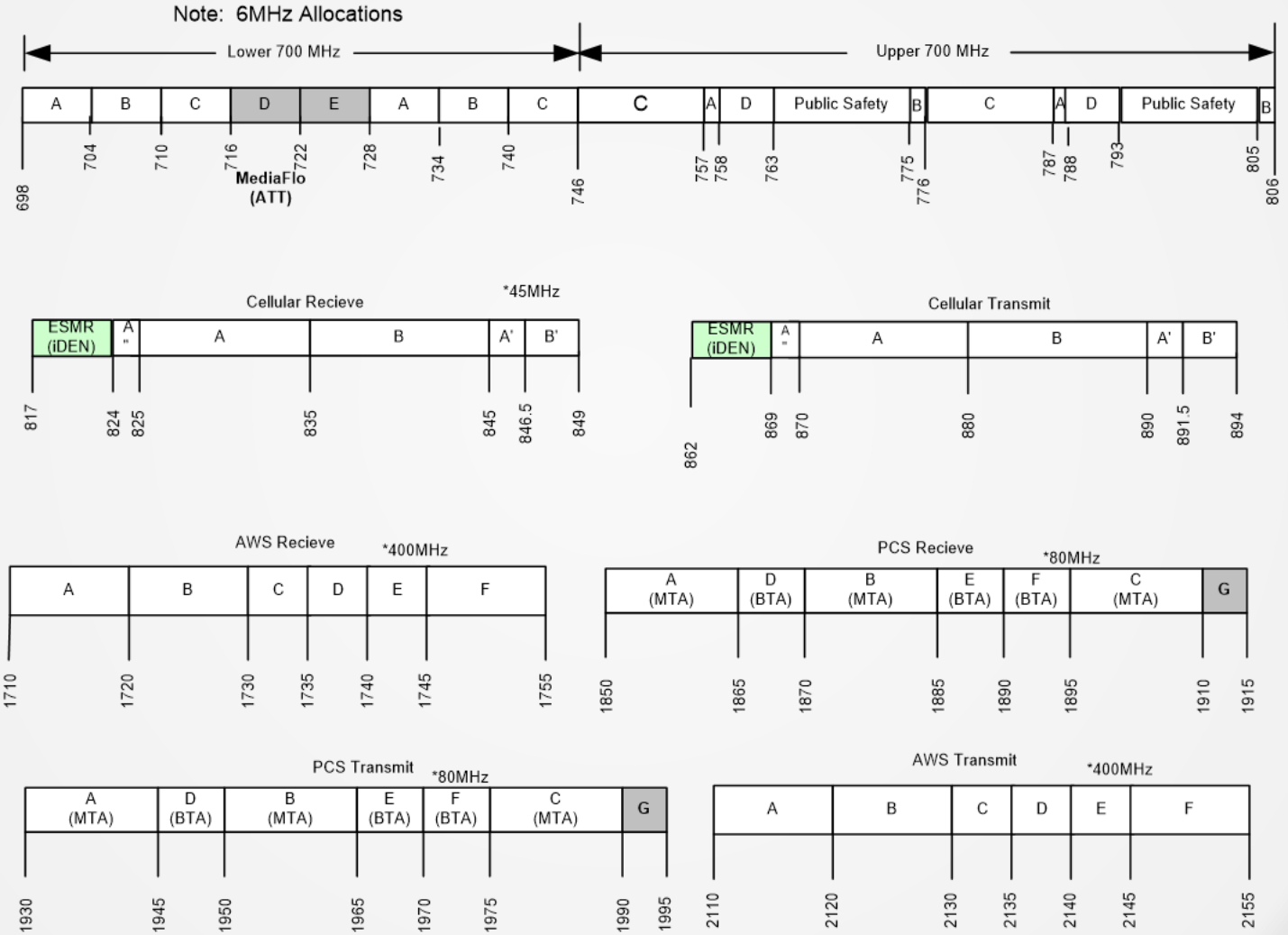
$$f=c\lambda$$

Where f= frequency (Hz)
c= $3x10^6$ m/s (speed of light)
λ= wave length in meters

- Typically a particular portion of the RF spectrum is called a frequency band.
- Frequency bands are also divided into RF channels based on the RF technology being used.
- Therefore when referencing a specific frequency band the use of a channel number is also common.

RF Spectrum Designation

The chart is an example of US cellular PCS spectrum allocations.



Modulation

- There are three types of RF modulation techniques:
  - AM – Amplitude Modulation
  - FM – Frequency Modulation
  - PM – Phase Modulation

- All of the modulation techniques can be characterized by the equation listed below:

$$E(t) = A \sin (2\pi f_c t + \phi)$$

Where:

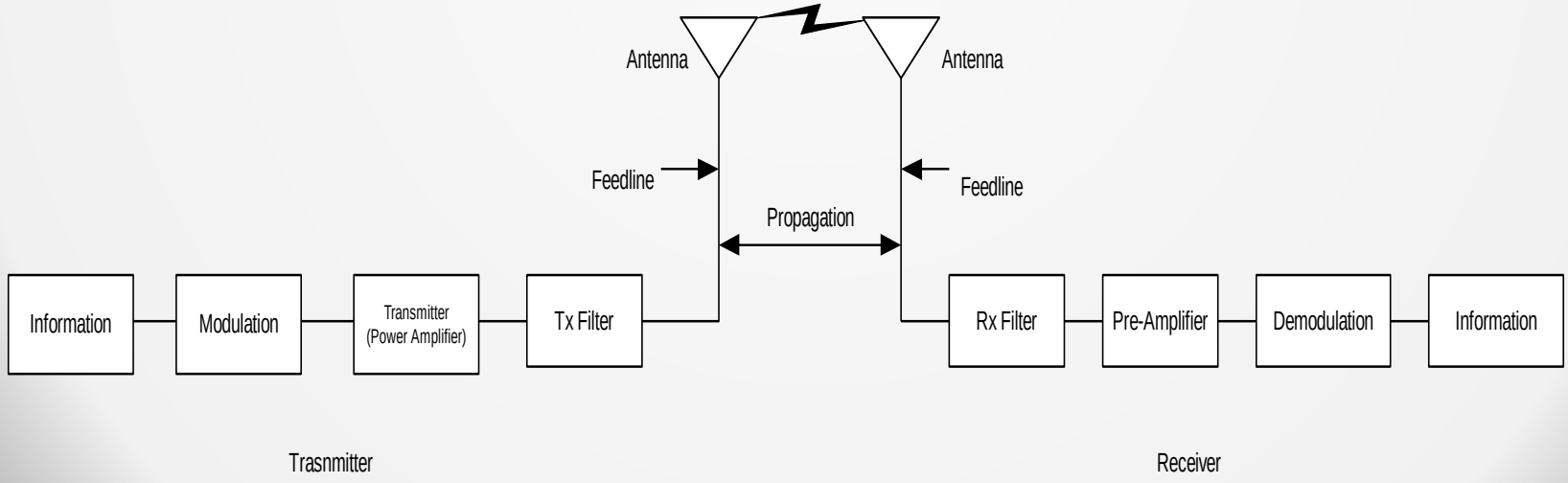
- A= amplitude
- f_c = frequency
- ϕ= Phase

Modulation

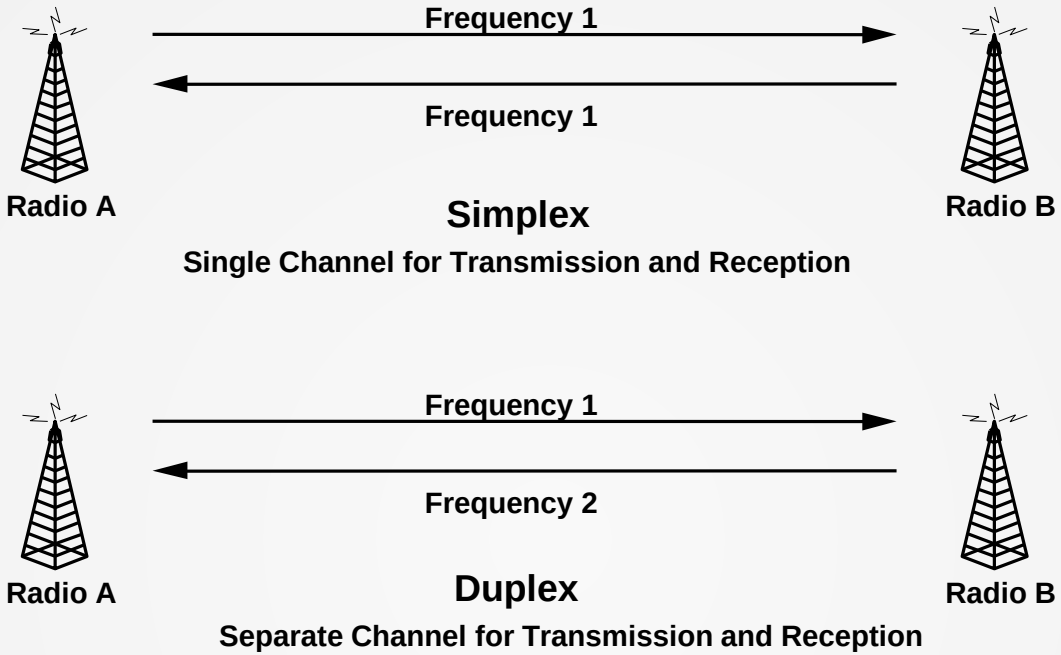
- Amplitude Modulation (AM) the frequency and phase are held constant.
- Frequency Modulation (FM), the amplitude as well as the phase are held constant.
- Phase Modulation both the amplitude and frequency are held constant.
- A particular modulation scheme used can utilize one, two or all three of the modulation techniques.
- For instance quadrature amplitude modulation (QAM), involves changing at the same time both the amplitude as well as phase but keeping the frequency the same.

Radio

- The generic radio system block diagram shown has many components that make up the system itself.
- Radio systems are either simplex or duplex in nature.
- Simplex refers to the situation when only device can communicate at a given time either typically using the same frequency.
- Duplex is the situation where both parties at either end can send and receive information simultaneously using a different frequency to send and receive information.



Simplex and Duplex



- The graphic above depicts the simplified diagrams for both a simplex and duplex radio system.
- There are of course multiple configuration options that can be envisioned with these systems.
- For simplex the same channel is used for sending and receiving information while for duplex one channel is used for sending and another channel is used for receiving.

Antenna System

- The antenna system is a key component to any radio system.
- The antenna system for any radio communication system comprises several key elements.
  - Transmit Antenna
  - Receive Antenna
  - Feedline (Cable)
  - Supporting Structure (ie tower or roof top)
- The antenna is used to transmit and receive the radio waves.
- The transmit and receive antennas can be the same physical device, which requires the use of a duplexer.
- Without an antenna the radio communication system would not function.

Antenna System

- Height is important with an antenna system.
- The higher the antenna is placed, either on a tower or building, the farther the communication system is able to reach, i.e. communicate.
- The antenna system is what is typically associated with a communication system since it is the most visible.
- Many radio communication systems utilize more than one transmit and receive antenna.
- The transmit antenna is connected to the radio transmitter via a coaxial cable referred to as the feedline. The receive antenna or antennas are connected to the radio receiver by a coax cable also.
- The antennas need to be supported by some mechanical method using mounting brackets that can be attached to a tower or the side of a building or other existing structure.

Antenna System

- The figure shown depicts a monopole, which is used in many mobility systems and consists of three sectors.
- There are other types of structures that the antenna(s) can be connected to.
- Although more sectors are possible, the typical configuration is to have three sectors with three or four antennas installed per sector.
- A three sector system consists of 3 sections, sectors, each covering 120 degrees in width out of 360 degrees.

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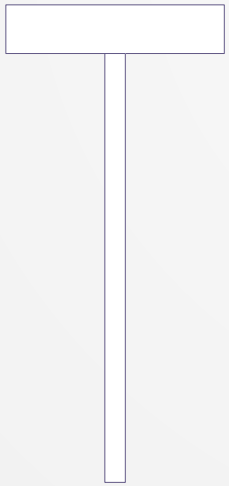
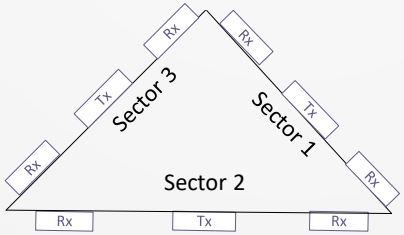
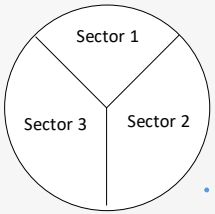


Monopole



3 Sector Monopole Antenna Platform



RF Propagation

- RF Propagation is the description of the effects encountered by the radio wave.
- RF Propagation can occur over any medium like air or copper but generally is refers to the path taken over air.
- RF Propagation analysis calculates how the radio wave is attenuated (reduced) as it travels from the transmitter to the receiver in a communication system.
- RF Propagation is also called Path Loss which is referenced as an attenuation level typically referenced in dB and can be calculated via a propagation model.
- Receiver sensitivity is expressed in dBm or μV.
- Therefore RF Propagation is usually expressed in dB or μV depending on the reference that the design engineers uses. However dB is the more common.

- Propagation is characterized by an empirical model which has its origins based on free space.
- There are many models used in the industry today to estimate the path loss and the most common are:
  - Free Space
  - Hata
  - COST231
- Each model has its own requirements that need to be met in order to be utilized correctly.

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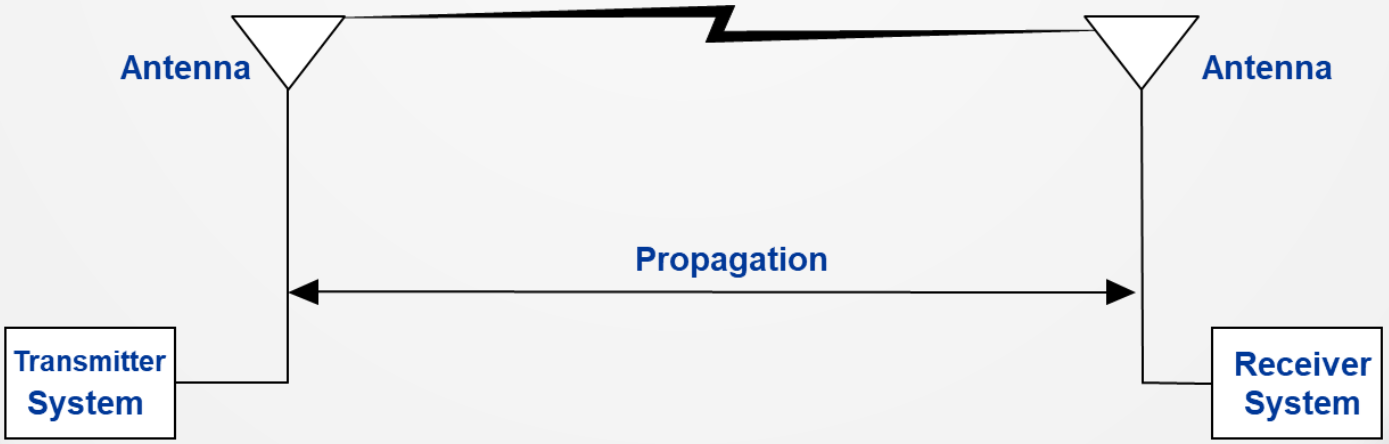

RF Link Budget

- The link budget is a critical element for any radio system design.
- The link budget is used to determine the maximum distance that can exist between a transmitter and receiver.
- The distance is defined as path loss and is represented in dB.
- Link Budget simplified formula in dB is:
  - Path Loss (dB) = Transmit Power (dBm) - Received Power (dBm)

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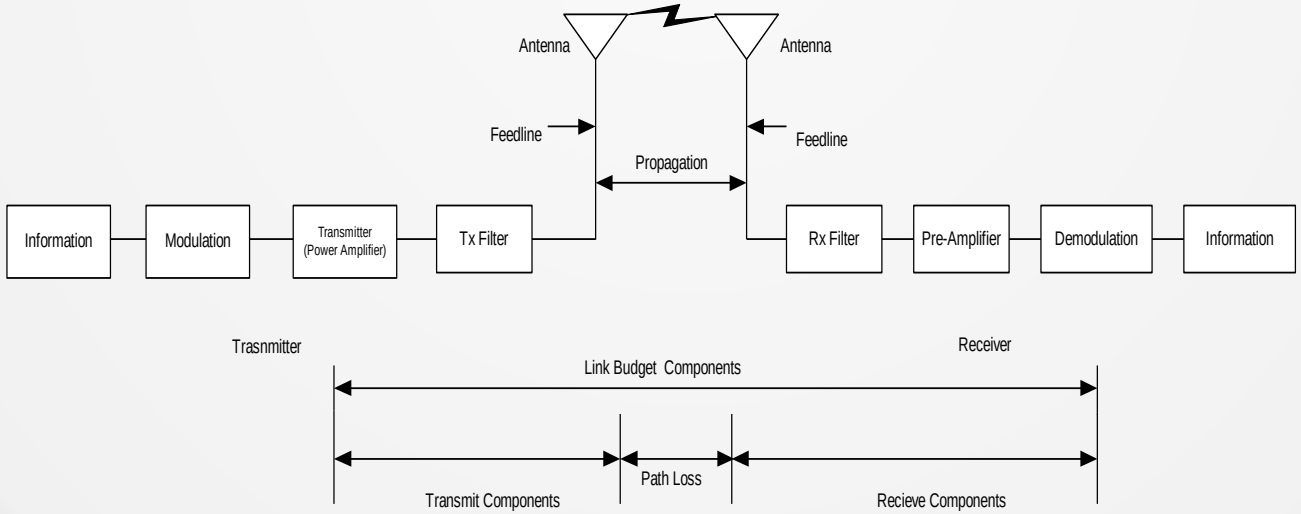

NGC (who we are)

NGC is a consulting team of highly skilled and experienced professionals. Our background is in wireless communications for both the commercial and public safety sectors. The team has led deployment and operations spanning decades in the wireless technology. We have designed software and hardware for both network infrastructure and edge devices from concept to POC/FOA.

The team has collectively been granted over 160 patents in the wireless communication space during their careers. We have also written multiple books used extensively in the industry on wireless technology and published by McGraw-Hill.

Feel free to utilize this information in any presentation or article with the simple request you reference its origin.

If you see something that should be added, changed or simply want to talk about your potential needs please contact us at info@nextgconnect.com or call us at 1.845.987.1787.

Thank you

If you want to know more please contact us at
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