Telecommunications & Satellite Operations

Self Studies

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CONTENTS

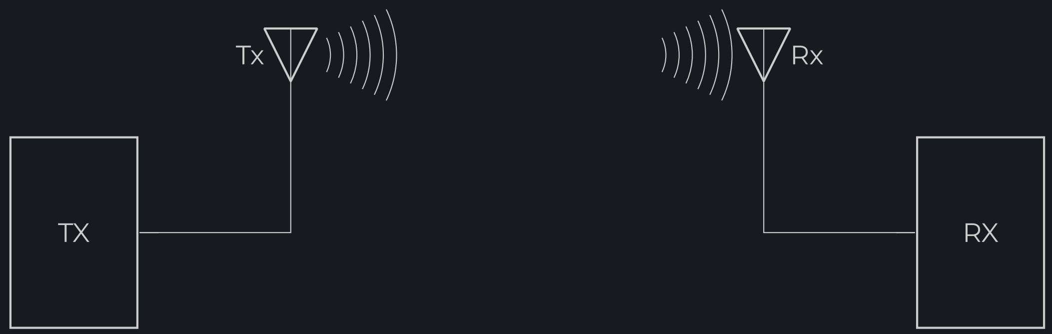
1 ~ TELECOMMUNICATIONS

1.1 ~ BASICS

Telecommunications is the exchange of information through wire, radio, optical, or other EM based systems.

Information can be transmitted wirelessly through EM-waves. Most commonly we use EM waves in the range of 300 kHz to 300 GHz (1km to 1mm wavelengths).

Radio waves for communication are created by a transmitter (abbreviated tx) and detected on the other side of a radio link by a receiver (abbreivated rx). A basic radio link is shown below.



1.2 ~ NOISE

A receiver will receive everything in its reception bandwidth, including noise. Noise corrupts the signal and introduces errors into the received data.

To help deal with this, an important figure of merit is called the signal-to-noise ratio (SNR). It is defined as the ratio between the received signal power to the received noise power

$$\text{SNR} = \frac{P_S}{P_N}$$

1.3 ~ OTHER DECIBELS

Building off the base notion of decibels, where an increase of 10dB means a multiplication of 10. Recall that they are defined as:

$$G_{dB} = 10 \log R$$

Another useful quantity is decibel-watts (dBW) . To do this, we use a reference quantity, typically $P_0 = 1\text{W}$

> $$P_{dBW} = 10 \log \frac{P}{P_0}$$

This lets us simplify gain-calculations using addition. A -27dbW signal going through a 26dB gain will have a resulting strength of -1dbW.

1.4 ~ ANTENNAS

An antenna is a device which couples EM-waves to and from free space. This means that they can be used to transmit and/or receive data. Each antenna also intrinsically has a gain which refers to the amount that they appear to amplify a transmitted or received signal.

Antennas are generally considered to be reciprocal , which means that tx gain is the same as rx gain. Antennas also also passive devices so how does the concept of gain work?

Gain is actually considered to be a geometric effect. It is essentially the focusing of a signal onto a point. This means that we actually need to point the antenna to the other end of the radio link!

2 ~ MODULATION

A radio wave of constant frequency and amplitude carries no information - its just a wave. We can encode information into this wave by changing some of its properties in a way that both the TX and RX know, this process is referred to as modulation.

Each EM wave has two properties we can adjust - its amplitude and phase. We can adjust these properties with respect to time to serially encode a message.

2.1 ~ ON OFF KEYING

The simplest way to send a digital message is to turn the wave on and off to send a 1 or 0. This is called on-off-keying (OOK). In other words, we set amplitude $A = 1$ to send a 1, and set $A = 0$ to send a 0. We also leave the phase φ untouched

This is very easy to implement, but it is very susceptible to noise, and it features a wide range of spectral content.

Due to these limitations OOK is only really used for simple and low-cost systems.

2.2 ~ PHASE SHIFT KEYING

Here we do the opposite, we leave the amplitude A untouched, and only change the phase φ. This is called phase-shift-keying (PSK). In binary PSK (BPSK) we choose phase shifts as far apart as possible (ex. 0, and π).

This is much more robust to noise, and is moderately complex to implement. This is very commonly used for telemetry and control links between spacecraft and earth.

2.3 ~ FREQUENCY SHIFT KEYING

We can also send a signal through frequency modulation. This is called frequency-shift-keying (FSK) and we can do this easily by choosing two frequencies, the lower one representing a 0, and the higher one representing a 1. This is called binary FSK (BFSK).

This is popular due to its reasonable noise immunity, and it is more power efficient due to it using a continuous waveform. It is also reasonably easy to implement.

2.4 ~ OTHER MODULATION TYPES

Amplitude Phase Shift Keying (APSK) is very similar to another form of modulation called Quadrature Amplitude Modulation (QAM), but designed to allow the use of more power-efficient amplifiers. This is common on space missions for very high rate data down-link.

Guassian Minimum Shift Keying (GMSK) is a special-case of FSK. GMSK uses the minimum possible frequency shift (1/2 the baud rate) and a gaussian pulse shape to ensure spectral efficiency. This effectively combines the error performance of PSK with the power efficiency of FSK (only through use of a special algorithm on the Rx end). This is becoming more common on space missions.