Week 2: Information carrying signals

Week 2: Signal Modulation

- Introduction
  - Importance of modulation to transmit information across large distances
  - Overview of Signal Modulation
  - Importance in Radio Communication and SETI

- Main Content (2 to 3 days)
  - Hands-On Experiment 2: Signal Modulation Using GNU Radio
    - Understanding Different Types of Modulation (AM, FM, QAM, etc.)
    - Tutorial: Modulating a Basic Signal Using GNU Radio
    - Visualizing and Analyzing the Modulated Signals
- SETI-Inspired Experiment 2: Analyzing Simulated Extraterrestrial Signals
    - Understanding the Characteristics of Extraterrestrial Signals
    - Analyzing Simulated Extraterrestrial Signals Using GNU Radio
    - Discussing the Implications of Signal Analysis in the Search for Extraterrestrial Intelligence
- Recap
  - Open Discussion on Signal Modulation and SETI Experiments
  - Introduction to Homework and Assignment (5 mins)

Worksheet: Working with GNU Radio to perform different types of signal modulation and analyzing them.
Assignment:
Report: Students will analyze a simulated extraterrestrial signal using the concepts and tools learned during the day, and prepare a report on their findings.

Signal modulation of speech using GNU radio

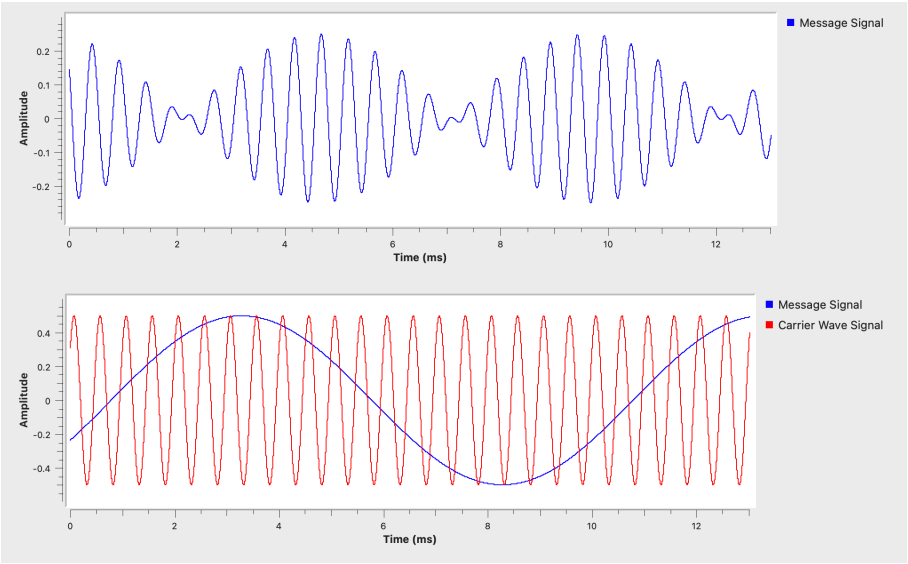
Why modulation is required to transmit signal across large distances?
Due to following reasons.

1. Size of antenna is directly related to the wavelength of the signal
2. Propagation range is proportional to frequency.
3. Modulation enables effective utilization of the available bandwidth.

Different types of modulations

1. Amplitude Modulation (amplitude_modulation.grc)

Amplitude Modulation (AM) is a method of radio broadcasting where the amplitude of the carrier wave is varied to match the amplitude of the input signal. For example, message signal is shown below which has lower frequency while carrier wave has higher frequency. The plot show multiplication of message signal with carrier waves. Operating typically in the frequency range of 530 kHz to 1700 kHz, AM is well-suited for long-range transmission and is widely used for talk radio, news broadcasting, and sports commentary due to its effective transmission of voice signals.waves.



$$C(t) = A_c \cos(2\pi f_c t)$$

A_c ↑ Amplitude

f_c ↑ Frequency of carrier

$m(t)$ ← Message Signal

$$AM(t) = [A_c + m(t)] \cos(2\pi f_c t)$$

$$\mathcal{F}(AM(t)) = A_c \mathcal{F}(\cos(2\pi f_c t)) +$$

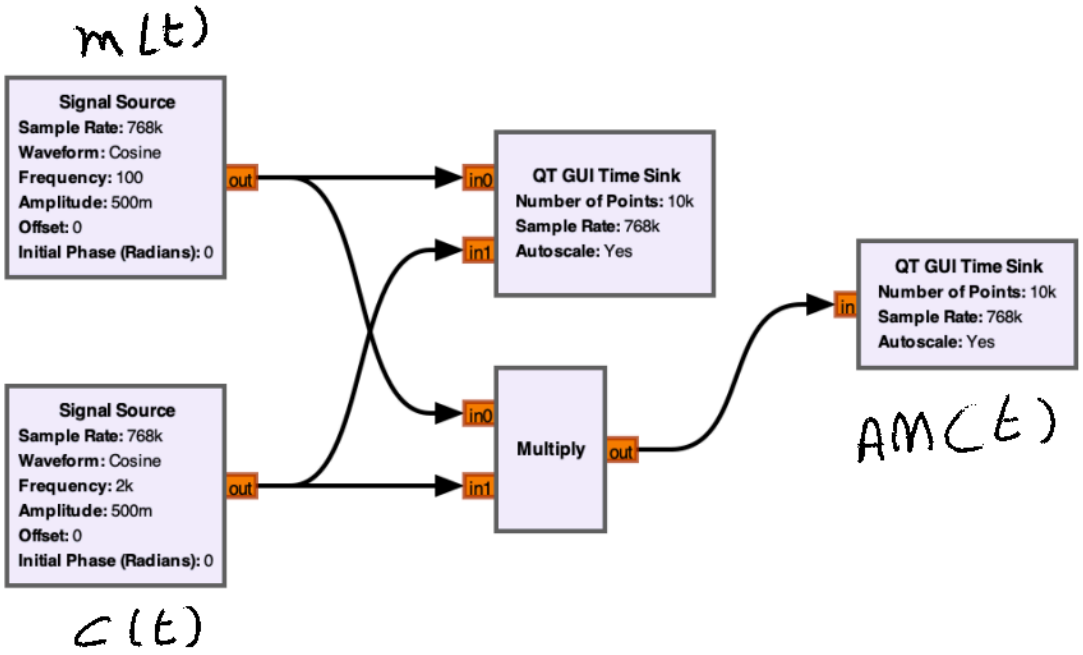
$$\mathcal{F}(m(t) \cos(2\pi f_c t))$$

$$= \frac{A_c}{2}[\delta(f - f_c) + \delta(f + f_c)]$$

$$+$$

$$\frac{1}{2}[M(f - f_c) + M(f + f_c)]$$

[where $\mathcal{F}(m(t)) = M(f)$]



Key Aspects of AM:

Broadcast Range: AM radio frequencies typically range from 530 kHz to 1700 kHz in the United States. These frequencies are particularly effective for long-range transmission because AM waves can reflect off the Earth's ionosphere, especially at night, allowing them to travel over vast distances.

Applications: While AM is widely known for its use in radio broadcasting, it's also used in other areas, such as air traffic control communication and two-way radios in certain applications.

Sound Quality: One of the limitations of AM is that it's more susceptible to noise and interference than FM. Static from various sources, including electrical equipment and atmospheric conditions, can affect the quality of the received signal.

Historical Significance: AM radio played a pivotal role in the early days of broadcasting, enabling news, entertainment, and critical information to reach a wide audience.

1. Frequency Modulation (frequency_modulation.grc)

Frequency modulation (FM) is a widely utilized method of radio broadcasting due to its inherent resilience against signal interference and noise. In FM, the frequency of the carrier wave is varied in accordance with the amplitude of the input signal (which represents the sound), providing a high-quality audio output.

One of the most familiar applications of FM is in public radio broadcasting. In the United States, the FM radio band ranges from 88 MHz to 108 MHz. Within this band, individual radio stations are assigned specific frequencies to transmit their content. These frequencies are spaced sufficiently apart to avoid interference, ensuring clear reception for listeners.

FM radio stations broadcast a variety of content, including music, news, talk shows, and other forms of entertainment and information. The widespread use of FM radio is attributed to its superior sound quality compared to AM (Amplitude Modulation) radio, particularly in terms of reducing static and background noise.

In addition to terrestrial radio broadcasting, FM is also used in various other applications:
1. Two-way Radios: Devices like walkie-talkies often use FM for clear short-distance communication.
2. Television Audio: FM was traditionally used for the audio component of analog television broadcasts.
3. Data Transmission: FM is employed in some data transmission applications where signal integrity is paramount.

The technology behind FM radio has evolved over time, with digital variations such as HD Radio in the US offering higher-quality sound and additional channels within the same FM frequency band.