Chesapeake Bay Roost Scholarship 2026

Capture the Flag Challenge

Your mission, should you choose to accept it…

The year is 2040, and the war with the machines rages on. In its hour of need, humanity turns to you for your expertise in electromagnetic warfare to help gather critical intelligence needed to overcome the machines.

In the following challenges, you'll learn about signal processing for radiofrequency communications. You'll then use this knowledge to discover clues that will help humanity in its existential struggle against the robotic foe. Students who successfully complete the challenges will be entered in a random drawing to win a $500 scholarship. Each challenge completed constitutes one entry. The challenges can be completed in any order (you can skip a challenge if you're stuck!).

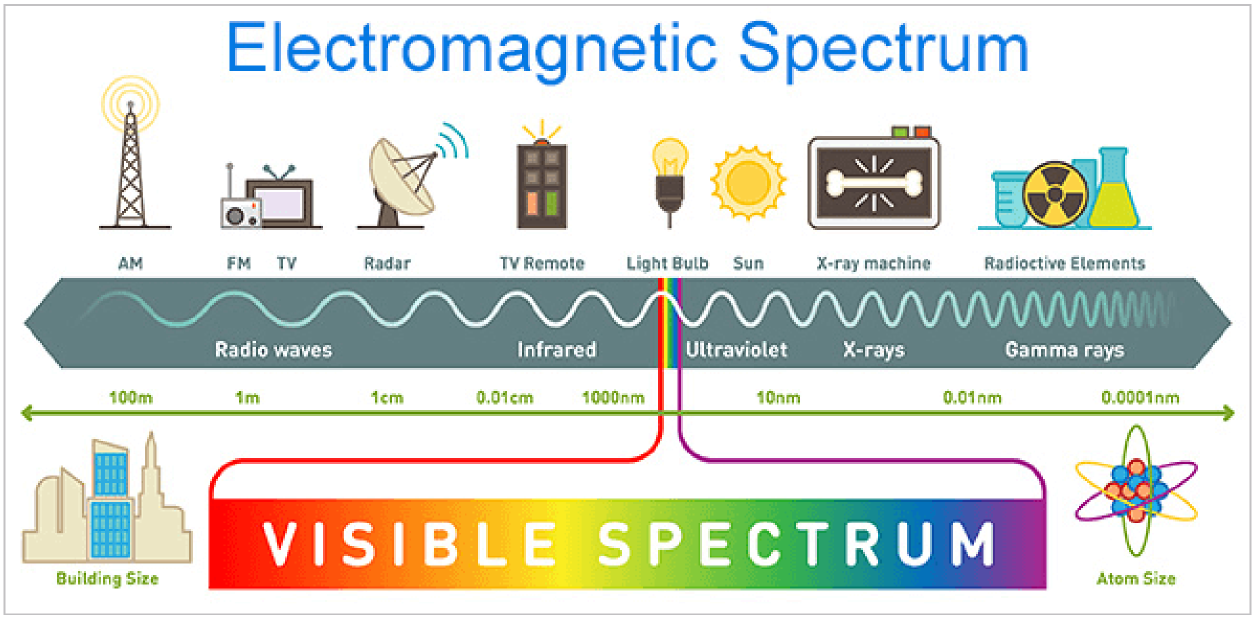
The interactive scholarship homepage can be found at: https://www.microwavejoe.com/aoc/index.html.

From the homepage, you can access the interactive capture-the-flag challenge page as well as pages to check your answers to each challenge. Note that to be considered for the scholarship, **students must email the completed answer form to AOC.Chesapeake.Scholarships@gmail.com.** The answer form is available on the scholarship homepage.

To be considered, **submissions must be received by April 12, 2026**.

Background Information

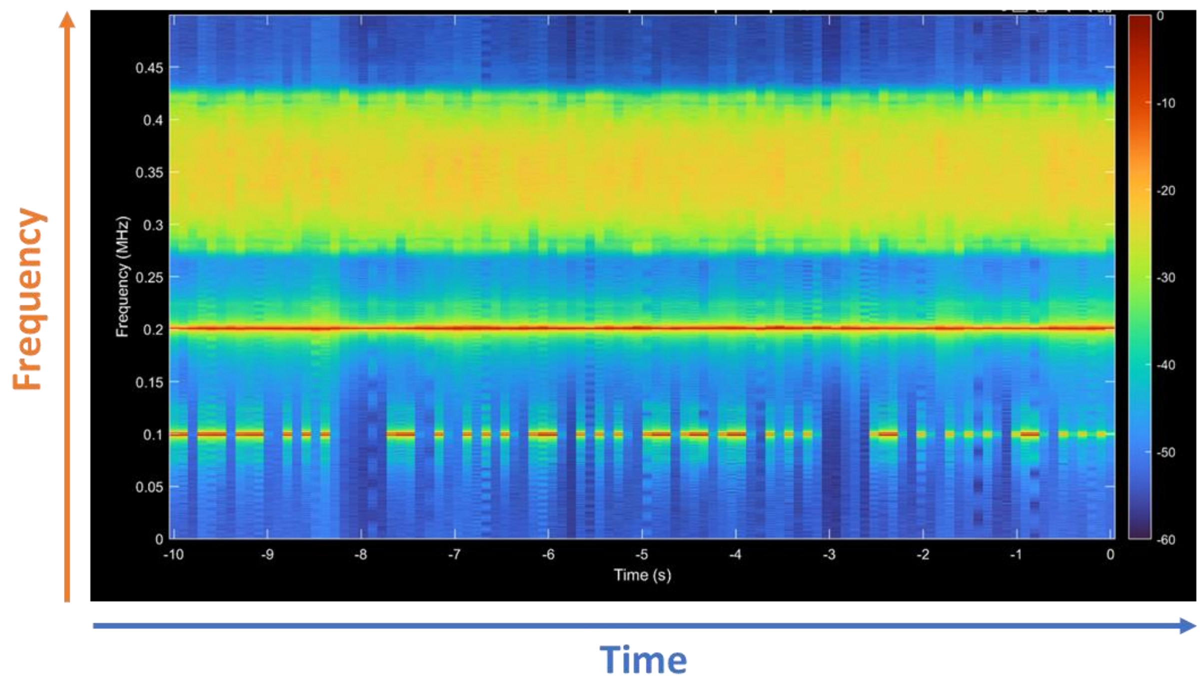
Radio frequency communications, or simply **radio**, use electromagnetic waves to convey information over distances at the speed of light.



ComputerHope.com

The process of encoding information (or messages) in the radio wave is known as **modulation**. Each of the following challenges will introduce you to a different modulation technology used to convey signals (i.e. information) in radio waves. The process of extracting the encoded informed is known as **demodulation**.

Your primary tool will be the **spectrogram**. The spectrogram will give you information about the frequency, signal strength (power), and temporal properties of the radio waves in your environment. The spectrogram is similar to sheet music in that one axis represents the frequency (i.e. the note) while the other axis represents time.



The color of the spectrogram represents the strength of the radio wave at a particular frequency at a particular time. In the figure above, red represents a strong wave and blue represents a weak wave (i.e. background noise). A spectrogram that updates with time is often referred to as a **waterfall display** due to the way the image moves like a waterfall.

Note that **all three challenges can be completed using the same interactive waterfall display** available on the scholarship homepage.

On the challenge website, when the frequency and modulation type are correctly identified, the audio will change from noise to the demodulated message and a pop-up window will open with the demodulated message. If the pop-up window does not appear when the audio changes, check your browser settings.

Challenge #1. The Spy Within

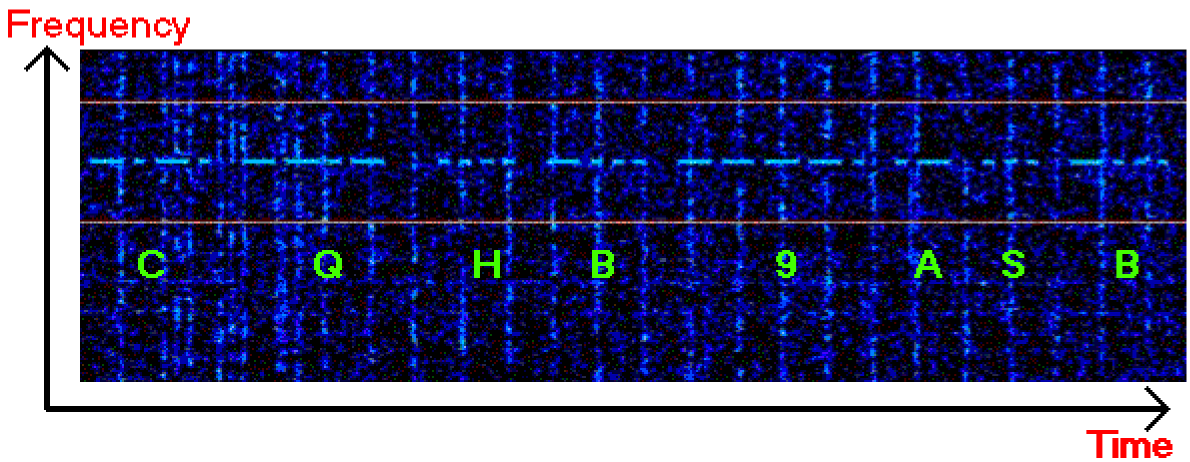
Three months ago, special agent MacGyver was sent deep into enemy territory to gather information about the robots' plans. In order to avoid detection by the machines, MacGyver avoided bringing any digital communications technology. Instead, he cobbled together a crude analog modulator used to generate Morse code transmissions. Unfortunately, we don't know what frequency MacGyver is using for his transmission. We need you to inspect the electromagnetic spectrum, identify the frequency of MacGyver's communication, decode his message, and find out the robot's plan.

Intel Report

Morse code is a simple method for encoding a message on a single frequency by turning the transmitter on and off. In this form of modulation, the duration of the signal's "on" time is used to represent a symbol. A long on time corresponds to a "dash" or "—" while a short on time corresponds to a "dot" or ".". Using these dashes and dots, letters and numbers can be encoded into the message. As you decode MacGyver's message, you can use the table below to convert from dash/dot to letters and numbers.

A	• —	U	• • —
B	— • • •	V	• • • —
C	— • — •	W	• — —
D	— • •	X	— • • —
E	•	Y	— • — —
F	• • — •	Z	— — • •
G	— — •		
H	• • • •		
I	• •		
J	• — — —		
K	— • —	1	• — — — —
L	• — • •	2	• • — — —
M	— —	3	• • • — —
N	— •	4	• • • • —
O	— — —	5	• • • • •
P	• — — •	6	— • • • •
Q	— — • —	7	— — • • •
R	• — •	8	— — — • •
S	• • •	9	— — — — •
T	—	0	— — — — —

How will you know which radio wave is MacGyver's Morse code signal? Great question! We recommend using the spectrogram to identify a signal with on and off times characteristic of Morse code as shown below.



Challenge #2: Our Last Hope

One of humanity's forward operating bases has been encircled by the enemy and needs to convey urgent information back to the resistance before they are destroyed by the machines. Their base, while austere, offers more technical capability than MacGyver's crude Morse code modulator. They employ a slightly more sophisticated modulation technique known as amplitude modulation. Unfortunately, the specific frequency and amplitude modulation scheme for their messages were not determined before the robots cut off our other forms of communication with the base. We need you to identify the frequency used, the type of amplitude modulation used, and then decode the audio message from the base. Hurry, the robots are closing in!

Intel Report

Amplitude modulation is a technique used in radio communications to encode information—like voice or music—onto a carrier wave. The **carrier wave** is a high-frequency signal that acts as a vehicle for the message. In AM, the amplitude of the carrier wave changes in proportion to the information signal (called the baseband signal).

When a signal is amplitude-modulated, it creates **sidebands**—new frequencies that appear above and below the carrier frequency.

- Upper Sideband (USB): Frequencies above the carrier.
- Lower Sideband (LSB): Frequencies below the carrier.

These sidebands carry the actual information, while the carrier itself does not.

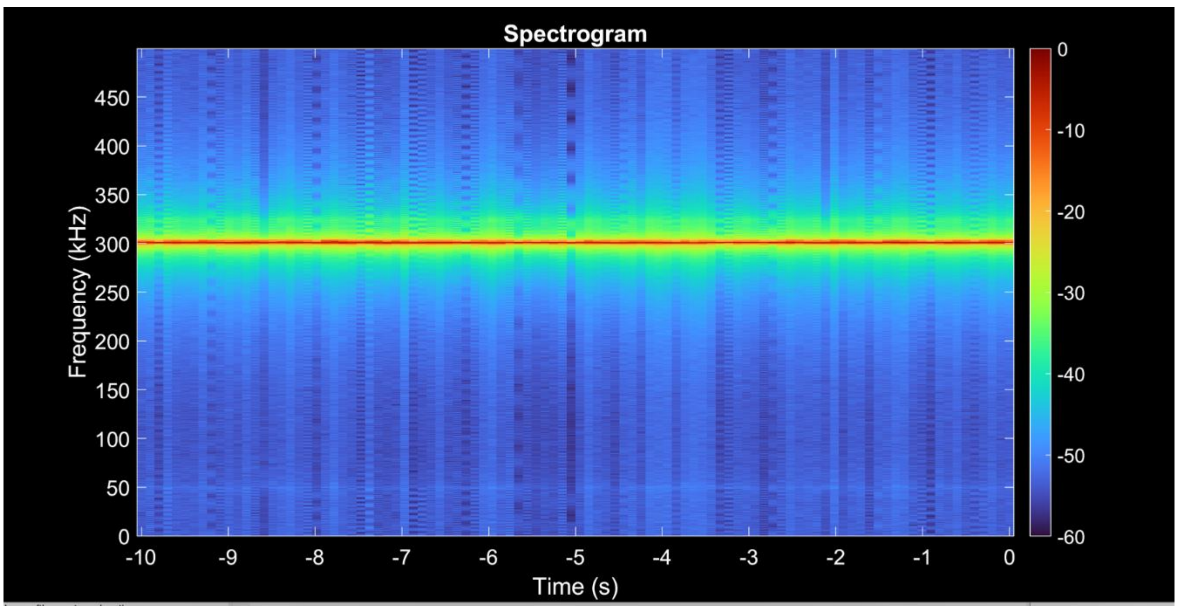
Double Sideband (DSB) modulation includes both the upper and lower sidebands. There are two approaches to DSB modulation: with carrier and suppressed carrier.

- DSB with carrier (DSB-AM): Traditional AM radio. Both sidebands and the carrier are transmitted.
  - Pros: Easy to demodulate with simple receivers.
  - Cons: Inefficient—transmits redundant information and wastes power on the carrier.
- DSB-Suppressed Carrier (DSB-SC): Transmits both sidebands but removes the carrier.
  - Pros: More power-efficient.
  - Cons: Requires more complex receivers to reconstruct the signal.

Single Sideband (SSB) modulation transmits only one sideband—either USB or LSB—and usually suppresses the carrier.

- Pros:
  - Highly efficient: Uses less bandwidth and power.
  - Ideal for long-distance communication (e.g., aviation, maritime, amateur radio).
- Cons:
  - Requires precise tuning and more complex receivers.

SSB is especially useful when bandwidth is limited or when transmitting over long distances where power conservation is critical.



Upper Sideband Modulation Spectrogram

Challenge #3: Interception

Your efforts have led to great successes for the resistance. One of our intel officers returning from the FOB you saved has informed us that the machine's central hive mind uses radio transmissions to remotely control the individual robots. This is great news! If we can discover this signal and decode it, we'll know the enemy's every move. But here lies your greatest challenge yet, not only do we not know the frequency of this waveform, we also are not certain how their commands are modulated. Special Agent MacGyver suspects the machines are using either amplitude modulation or frequency modulation. It's up to you to find and intercept the enemy's most sensitive messages and bring this war to an end.

Intel Report

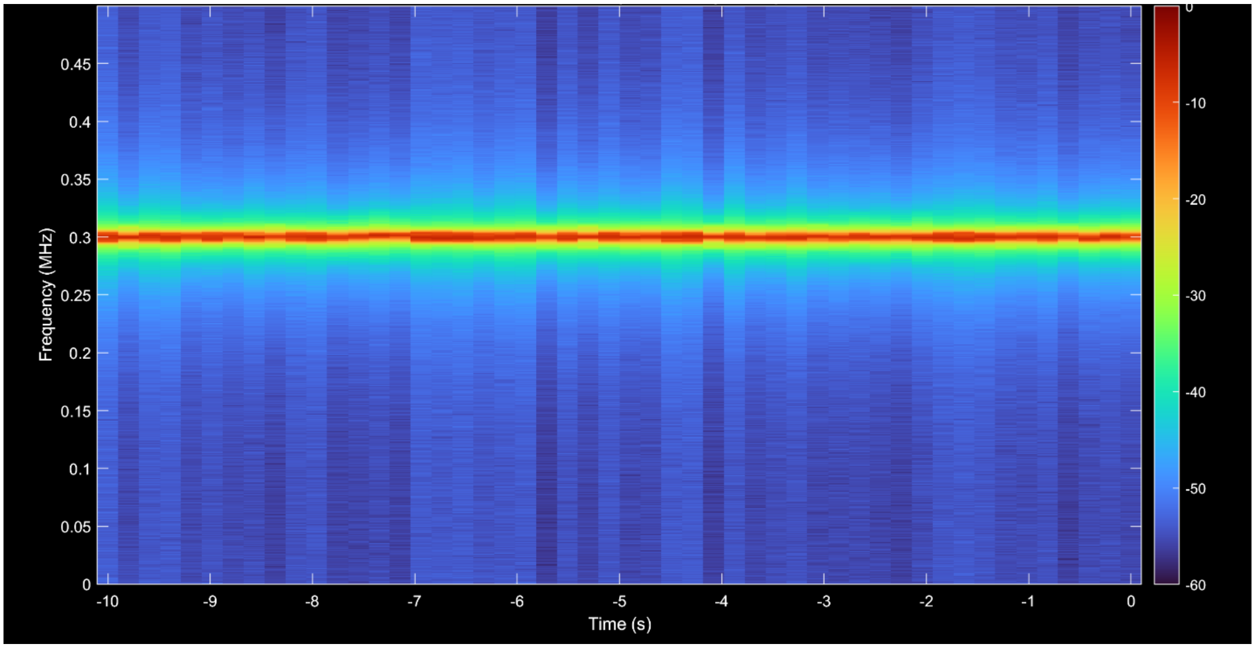
Frequency modulation (FM) is a technique used in radio communications where the frequency of a carrier wave is varied in accordance with the information signal. Compared to amplitude modulation (AM), FM offers superior sound quality and resistance to noise, making it ideal for high-fidelity broadcasting, but it requires a more complex receiver design.

In FM, the carrier wave's frequency changes based on the amplitude of the input signal (such as voice or music). Unlike AM, the amplitude of the carrier remains constant, which helps reduce the impact of signal degradation due to interference.

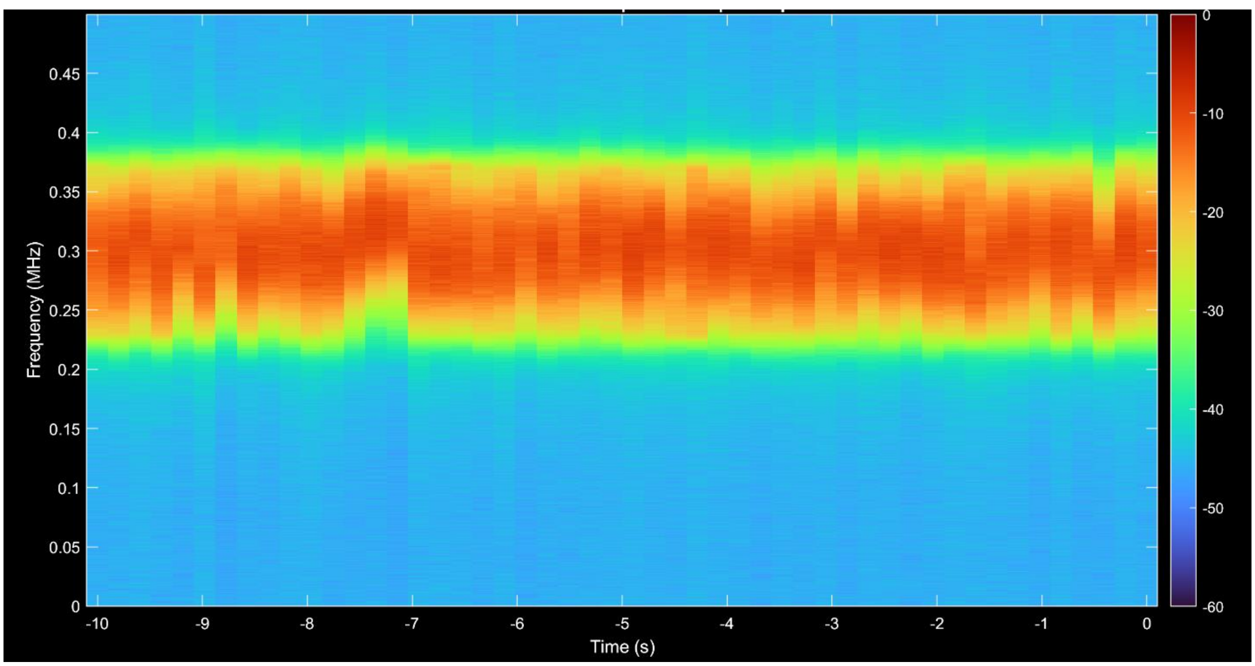
Frequency deviation refers to how far the carrier frequency moves from its central value during modulation. It's a key parameter that affects both signal quality and bandwidth usage. Commonly used frequency deviations include:

- Standard FM radio broadcast: ±75 kHz deviation
- Narrowband FM (used in two-way radios): ±2.5 kHz or ±5 kHz deviation

Greater deviation generally means better audio fidelity but requires more bandwidth.



5 kHz FM Frequency Deviation



75 kHz FM Frequency Deviation

End Credits

We hope you've enjoyed this capture the flag exercise. Maybe it even sparked an interest in radio communications and electromagnetic warfare! This program was inspired by the Army Cyber Institute at West Point's "RF Village" capture-the-flag exercises. The scholarship is sponsored by the Chesapeake Bay Roost of the Association of Old Crows.

Would you like to know more?

Additional information about the Association of Old Crows can be found on our website at https://crows.org/.

If this capture-the-flag exercise sparked your interest, there are a number of great online resources for RF and EW including your local amateur radio club. If you'd like to take the next step and search for signals in the real world, there are a number of low-cost software defined radios (SDRs) such as the RTL-SDR that can be coupled with free software such as SDR# (SDR Sharp) to monitor and demodulate over-the-air signals. Fun challenges include listening to FM radio, tracking airplanes (https://www.rtl-sdr.com/adsb-aircraft-radar-with-rtl-sdr/) or receiving images from the international space station (https://www.rtl-sdr.com/tag/international-space-station/).