Learning Communications Systems Using Amateur Radio Satellites

Augustine Brapoh Jr. KC3YNE[1], James Hankee KC3YND[1], Aidan Szabo[1], Robert Troy KC3VJC[1], Robert W. McGwier N4HY[1], and Nathaniel Frissell W2NAF[1]

[1]University of Scranton

Abstract

Introductory courses on communication systems often lack practical application. To address this, students at The University of Scranton are learning hands-on by obtaining amateur radio licenses and operating low-Earth orbit satellites. This approach provides insight into real-world communication challenges, including directional antennas and orbital mechanics.

Doppler shift

- Low-Earth Orbiting satellite communications to the ground are subject to the influence of Doppler shift
- When the maximum elevation surpasses 15 degrees, accounting for Doppler shift becomes more important.
- Our satellite communication systems account for the effects of Doppler shift by using multiple split memory channels of different up/downlink frequencies

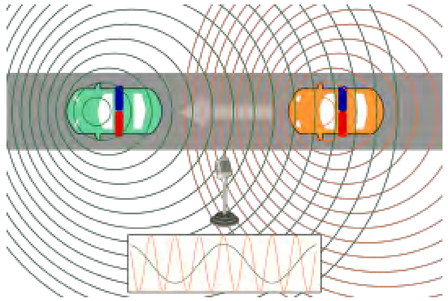


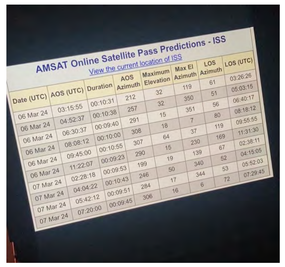
Fig 1. Doppler diagram. Creator Ekko, Kismalac. Attribution parties Inkwina, rg1024. Licensed under Creative Commons Atribution-Share Alike 3.0 Unported. CC BY-SA 3.0, https://commons.wikimedia.org/wiki/File:DopplerEffectCars.svg . DopplerEffectCars

Modulation Types

- **Amplitude Modulation (AM):** Used by shortwave broadcast stations. Modulates the amplitude of the carrier wave. Bandwidth of 6kHz.
- **Frequency Modulation (FM):** Most common analog mode for VHF and UHF land-mobile communications. Modulates the frequency of the carrier wave. Amateur radio FM has a bandwidth of about 10-15kHz.
- **Single Sideband (SSB):** Commonly used in long-distance voice transmissions, such as amateur radio (ham) and maritime communications. Suppresses one of sidebands of an AM signal. Bandwidth of 3kHz.

Contacting the ISS

- Step 1: Set up Yaesu FT-5DR Radio to correct down/uplink frequencies to five memory channels with the proper squelch tone (see Fig 2 and 3)
- Step 2: Connect antenna to radio with coaxial cable
- Step 3: Aim antenna at correct azimuth and elevation angle and follow path of ISS
- Step 4: Listen and transmit



AMSAT Online Satellite Pass Predictions - ISS

View the current location of ISS

Date (UTC)	AOS (UTC)	Duration	AOS Azimuth	Maximum Elevation	Max El Azimuth	LOS Azimuth	LOS (UTC)
15 Mar 24	02:30:01	00:09:51	282	17	342	52	02:39:52
15 Mar 24	04:07:51	00:09:40	305	15	5	71	04:17:31
15 Mar 24	05:44:47	00:10:42	309	36	42	106	05:55:29
15 Mar 24	07:21:37	00:10:24	297	27	206	151	07:32:01
15 Mar 24	09:01:26	00:02:22	251	0	239	226	09:03:48
15 Mar 24	22:28:50	00:08:29	180	10	120	76	22:37:19
16 Mar 24	00:03:54	00:10:50	232	87	165	55	00:14:44
16 Mar 24	01:41:21	00:10:07	273	20	332	51	01:51:28
16 Mar 24	03:19:20	00:09:32	301	14	1	64	03:28:52
16 Mar 24	04:56:28	00:10:18	309	25	40	95	05:06:46

Fig 2. Satellite Pass Predictions

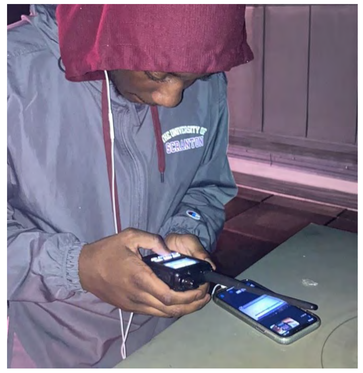


Fig 3. Programming Radio

Arrow antenna

Dual-band Arrow Antennas are an excellent choice for starting off in amateur satellite communication. The antenna we used consists of orthogonal, linearly polarized 144 MHz and 440 MHz Yagi antennas.

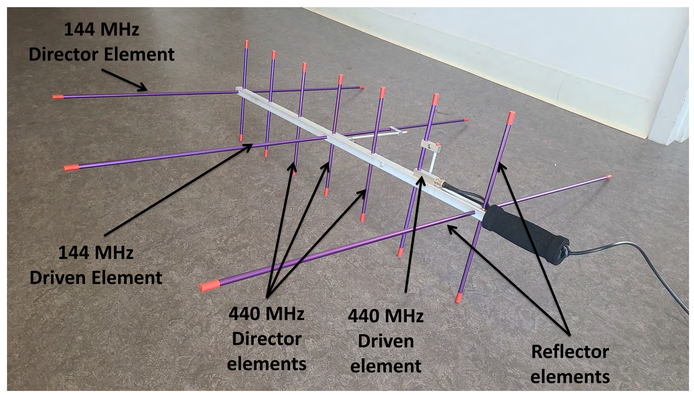


Fig 4. Antenna diagram

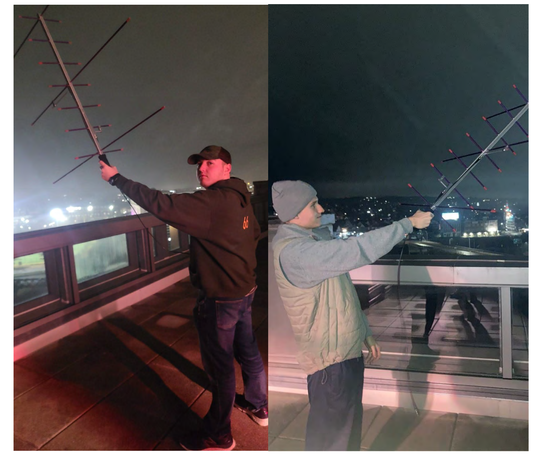


Fig 5. Aiming the antenna at the ISS

Polarization & Faraday's Rotation

Polarization refers to the orientation of the electric field vector in an electromagnetic wave. Linear polarization is when the electric field oscillates in a single plane. Circular Polarization is when the electric field vector rotates in a circular pattern as the wave propagates. Elliptical Polarization is the combination of linear and circular polarization.

Discovered by Michael Faraday in 1845, Faraday's Rotation is the rotation of the plane of polarization of light as it passes through certain materials placed in a magnetic field. It is a result of the interaction between the magnetic field and the material's electrons, causing a difference in the propagation speed of left and right circularly polarized light. Used in telecommunications to control the polarization state of light in fiber optic networks, particularly in optical amplifiers and signal processing. In the case of amateur radio satellite communications, the ionosphere and geomagnetic field are the cause of the Faraday rotation.

PL & CTCSS

PL stands for "Private Line," and CTCSS stands for "Continuous Tone-Coded Squelch System." They're sub-audible tones used in two-way radio communication to enable selective calling and reduce interference. Transmitters encode tones onto the carrier wave, and receivers have decoder circuits to filter out the tones before audio output. Tones are outside the voice frequency range, ensuring they don't disrupt voice communication. Receivers only open squelch for transmissions with the correct tone, minimizing interference.

Acknowledgements

We are grateful for the support of Amateur Radio Digital Communications (ARDC) and NSF Grant AGS-2045755.