Session 1532

Ham Radio and Engineering Education

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Abstract
If you still think of amateur radio as just communication by Morse code, you are out of date. In addition to Morse code (CW) and voice (AM, FM, and SSB), image modes (SSTV, FSTV. FAX), various digital modes (RTTY, AMTOR, PACTOR, G-TOR, CLOVER, and PSK-31), packet networking modes (APRS, AX.25), and even spread spectrum modes are available for providing a means of enlivening classroom theory and laboratory experience. It is even possible to link amateur radio voice communications, using VoIP, on the Internet (IRLP). Besides being appropriate to circuits, communications, electronics, transmission lines, and antenna courses, other areas such as networking, digital signal processing, embedded computer systems, telemetry and instrumentation can benefit from developing interest in amateur radio.

At SDSM&T, amateur radio is being used many places in the curriculum. In a first year introduction to engineering class, students launch a high altitude balloon and return data via packet radio. The solar car team uses packet radio to send telemetry data on the 2 meter band to the pit area or chase car while communicating to the driver on the 70 cm band using the same radio. The second semester electronics class builds a 40 meter CW transceiver in the lab while studying rf and electronics theory in class. The microprocessor systems design class builds a system for generating and decoding Morse code. The computer networking class investigates the AX.25 packet protocol. A student and faculty team built the data acquisition and control system that flew on the Starshine 3 satellite returning data on the 2 meter band using APRS packets.

Most of the educational benefits of amateur radio are available with the easy to acquire Technician license that requires passing a multiple-choice test with no Morse code. Most campuses have an amateur radio club available as an enthusiastic resource. In addition to the educational benefits to the student, amateur radio also provides benefits of life-long learning by keeping abreast of technology with this enjoyable hobby.

Introduction

The US government began licensing amateur (ham) radio operators in 1912 to provide for backup emergency communications in times of need, to advance technical knowledge, and to enhance international goodwill. Ham radio has continued as a popular hobby encompassing a variety of interests, from “appliance operators” to those who build their own equipment.

Amateur bands range from 1.8 MHz to above 300 GHz with sub-bands assigned to particular frequencies depending on the modes used and the license held [1].

The three amateur license levels are:

- Technician class with VHF and above privileges that requires passing a 35 question multiple choice test,
- General class with additional privileges in the HF bands that requires passing another 35 question multiple choice test and a five words per minute Morse code test,
- Extra class with full privileges on all amateur bands that requires passing an additional 50 question multiple choice test.

The original communication mode used “spark” transmitters sending Morse code via damped sinusoidal oscillations. This soon changed to CW (continuous wave) code transmissions as vacuum tubes became available. General and Extra classes still require passing a five word per minute (WPM) Morse code test justified by the argument that it is the common international language of amateurs and can be used in poor conditions in which more advanced modes fail. Portions of some bands are reserved for CW only.

The original voice mode was amplitude modulation (AM) replaced by single-side band (SSB) that uses less bandwidth and FM in the VHF and UHF bands. Recently, amateurs have been experimenting with digital voice [2]

Text communication using digital modes has become more popular with the advent of inexpensive PCs and sound cards; however, one of the early digital modes, radio teletype (RTTY) using electromechanical teletypes, began in the late 1940’s. RTTY uses FSK with a 1 represented by 2125 Hz and a 0 by 2295 Hz. Data is sent at a rate of 45 baud or 60 WPM using the 5-bit Baudot code. RTTY is still popular, but now using PCs rather than teletypes. Many of the digital modes were developed using Digital Signal Processing (DSP) development boards that have been replaced by current fast, inexpensive PCs using sound cards. Some modes use a TNC (Terminal Node Controller), basically a modem with a built-in protocol, but these also can often be replaced by a PC with a sound card and appropriate software. Refer to the Appendix for web sites from which software can be downloaded to support RTTY and the following modes discussed below [3] [4].

Amateur Teleprinting Over Radio (AMTOR), debuted in the early 1980’s, is also an FSK mode using the Baudot code. It has been replaced by more advanced modes and is now seldom heard on the ham bands.

PACTOR is an FSK mode from 1991 offering a 200 baud rate with Huffman compression transmitting true binary data. PACTOR-II, a PSK mode, is up to eight times faster than PACTOR.

G-TOR is an FSK mode that sends data at 300 baud dropping to 200 or 100 baud as conditions require. It is an adaptation of the protocol that returned pictures of Saturn and Jupiter from the Voyager.

PSK-31 is a relatively new very popular digital mode using narrow band (31 Hz) binary PSK with Viterbi decoding [5]. It is designed for real-time keyboard communication at 31 baud, about as fast as most can type. A second version uses QPSK and includes forward error correction at the cost of a reduced signal-to-noise ratio.

Packet communications using frequency shift keying (FSK) are primarily used in the VHF bands. The AX.25 protocol provides a means of networking packet stations, popular on the two meter VHF band prior to the rise of the Internet. TCP/IP over AX.25 can be used with packet radio and gateways can provide virtual circuits through the Internet.

In another linking through the Internet, the Internet Radio Linking Project (IRLP) links radios through Voice over IP (VoIP) on the internet connecting worldwide repeaters normally limited to local communication [6] [7]. With IRLP, a small VHF or UHF hand-held HT (Handi-Talki) can be used to communicate worldwide.

APRS (Automatic Position Reporting System) uses 2 meter band transmitters connected to a GPS receiver to send packets containing GPS coordinates. Mapping software on a PC connected to an APRS receiver displays the position of APRS transmitters. APRS uses a subset of the AX.25 protocol.

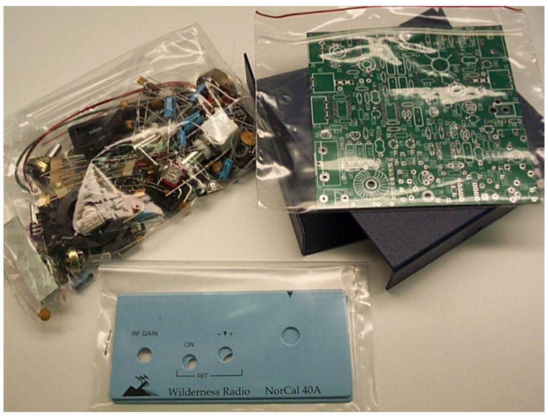
The "Fuzzy Modes" use a FAX technology to paint characters on the PC screen rather than encode/decode characters. The HELLSCHREIBER mode is based on the 1927 invention of Rudolph Hell (Hellschreiber means bright writer, a play on the name of the inventor). The transmitter sends a series of timed dots that are displayed as the black positions in a dot matrix representation at the receiver. With a bandwidth of 75 Hz, 122.5 dots per second can be sent equivalent to about 35 WPM.

A variety of image modes are available to the ham. Slow-Scan TV (SSTV) sends still pictures by means of audio tones on the HF bands with transmission times of seconds to minutes. ATV (Amateur TV) or FSTV (Fast-Scan TV) is the same as full-color motion commercial TV [8].

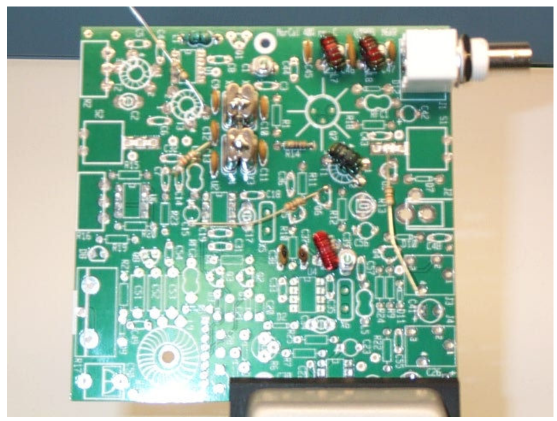
A new area being developed to achieve the flexibility to meet the requirements of various incompatible standards with a single radio is the software defined radio. Amateurs are in the forefront of experimenting with this new form [9] [10]. The front-end converts the RF to an IF signal where it can be digitized by a fast A/D and processed using DSP methods. With an appropriate front-end design, it is possible to use a sound card as the A/D and perform the digital signal processing on a PC.

Related Engineering Education Topics at SDSM&T

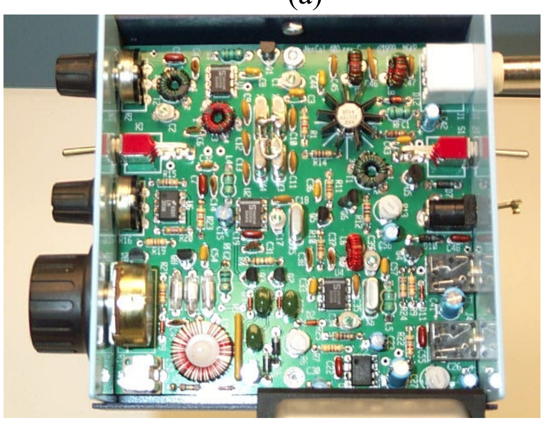
EE 322 (Electronics II) uses the text “The Electronics of Radio” [11] in which students learn electronics by building a 40 meter CW transceiver, the NorCal 40A. The NorCal 40A has a superheterodyne receiver and a two watt transmitter operating in the CW sub-band of 40 meters from 7.000 MHz to 7.040. In the lecture, students learn the theory of filters, transformers, transistor switches, transistor amplifiers, power amplifiers, oscillators, mixers, audio circuits, noise and intermodulation, and antennas and propagation. In the lab over the course of the semester, they build and test the portion of the transceiver currently studied in the lecture. Refer to Photo One.



(a)



(b)



(c)

Photo One

The NorCal 40A kit is built in the EE 322 lab. Each team starts with the parts kit (a). As each subsystem is studied in the lecture it is completed and tested in the lab (b). Each team must demonstrate that the completed transceiver meets all specs (c).

With the increased activity in the area of RF, students requested development of a new course in antennas. In EE 492, students design, build and test antennas ranging from dipoles, Yagi-Uda, to patch antennas. Photo Two shows one antenna being constructed for use by the Ham Club.

Photo Two
Circularly Polarized Two Meter Antenna being constructed by the K0VVY Ham Club

Related Engineering Education Applications at SDSM&T

With the ABET emphasis on project teams, communications among team members in the field is often a requirement. SDSM&T students participate in the Formula Sun solar car race, the Formula SAE Mini-Indy Race, the SAE Mini-Baja competition. These require that team members stay in contact over a local area, ideal for VHF or UHF handheld HTs.

Telemetry is an application available through amateur radio. Complete packet radio systems such as the VHF/UHF band Kenwood TM-D700A base/mobile unit or TH-D7A(G) handheld unit can connect directly to a PC serial port. These units provide FM voice communication but additionally contain a Terminal Node Controller (TNC). The TNC is a modem plus the AX.25 packet protocol. The usual application is amateurs communicating by radio through their PCs displays and keyboards; however, a data acquisition system with a serial port can transmit data just as well as text.

For example, the SDSM&T solar car team [12] uses the TH-D7A(G) unit to send data on battery voltages, solar array voltages, battery currents, solar array currents, motor currents, amp-hour capacity, temperatures, and vehicle speed from the solar car to the pit (during a closed course race) or the chase car (for a cross-country race). As shown in Photo Three, the TH-D7A(G) is a dual band unit that can send packet data on 2 meters and voice for driver communication on 70 centimeters.

(a) Solar Car Telemetry Group (b) TH-D7A(G)

Photo Three Kenwood HT used to send data packets from the solar car

As another example of telemetry, SDSM&T faculty, alumni, and students designed the telemetry system for the Starshine 3 satellite [13] that reported data on advanced experimental solar cells being tested by NASA. The primary goal of the satellite was involving K-12 students in an experiment to determine upper atmosphere density by tracking reflections from many small polished aluminum mirrors. Students from 1,000 schools in 30 countries polished the 1500 mirrors and then tracked the satellite in orbit by reflections from the sun at dusk. The secondary goal was reporting data on the experimental solar cells [14] with a 1.5 watt two meter transmitter sending packet radio data to the ground to be picked up by amateurs around the globe and reported by the Internet. Starshine 3 completed 7434 orbits of the earth 470 km high before flaming out in the earth's upper atmosphere on January 21, 2003. This was nearly two years earlier than originally predicted, because of the double peak in Solar Cycle 23 causing an expansion of the upper atmosphere. Photo Four shows the Starshine 3, PICOSat, PCSat, and SAPPHIRE satellites being assembled for launch.

Photo Four [10]

Satellites Starshine 3 PICOSat, PCSat, SAPPHIRE being readied for launch.

Position reporting is another amateur radio application. The SEESat (Student Engineered Electronic Satellites) project [15] organized for GE 115, a first year engineering course required for all engineering majors, flys a balloon up to 100,000 feet. The payload includes data recording systems build by students plus a GPS receiver and Kenwood TH-D7A(G) HT transceiver that transmits APRS packets. The APRS system allows easy tracking of the balloon for recovery when the payload descends by parachute.

The UAV (unmanned aerial vehicle) team at SDSM&T is planning to enter the Aerial Robotics Competition that requires transmission of pictures or video of a remote facility. The team is experimenting with an ATV transmitter on the 70 cm ham band.

One of the projects in CENG 442, micro-based system design, was to design a PIC microcontroller system that converts ASCII character data to output as Morse code and conversely accepts Morse code returning the equivalent ASCII characters.

The capstone design requirement provides another venue for projects involving amateur radio. For example, the previously mentioned telemetry for the solar car was a senior design project [16]. Another example is a project [17] designing a hidden transmitter system for a "fox hunt" [18] [19]. The competition involves locating a hidden low power transmitter that transmits a Morse code message intermittently.

Meeting ABET Program Outcomes

ABET criterion three specifies the program outcomes that graduates must meet. Amateur radio can contribute to meeting these outcomes, for example lifelong learning, effective communication, and engineering solutions in a global context. Many of the amateur radio projects organized through the Internet have participants from around the globe, for example, the MixW project (see the appendix) has developers from the Ukraine, Russia, US, and Japan.

Summary

Besides being appropriate to circuits, communications, electronics, transmission lines, and antenna courses, other areas such as networking, digital signal processing, embedded computer systems, telemetry and instrumentation can benefit from applications in amateur radio. Most of the educational benefits of amateur radio are available with the easy to acquire Technician and most campuses have an amateur radio club available as an enthusiastic resource. In addition to the educational benefits to the student, amateur radio also provides benefits of life-long learning by keeping abreast of technology with this enjoyable hobby.

Appendix
Examples of Amateur Radio Software Available on the Internet

DigiPan	http://www.digipan.net/ PSK31, PSK63, Pactor (RX only)
Ham Radio Deluxe	http://www.kns.ch/sysgem/hb9drv/HamRadioDeluxe.htm Includes PSK31 Deluxe, Mapper, and computer control of most modern transceivers
WinPSK	http://www.qsl.net/ae4jy/winpsk.htm Visual C++ source code is available for download.
MixW	http://mixw.net./ supports: SSB, AM, FM, CW, BPSK31, QPSK31, FSK31, RTTY, Packet (HF/VHF), Pactor (RX only), AMTOR (FEC), MFSK, Hellschreiber, Throb, Fax (RX only), SSTV, MT63.
WinAPRS	http://www.winaprs.org/ Mapping software for (APRS) Automatic Position Reporting System

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