Amateur Radio Technician Class License Study Guide

Week 3

SUBELEMENT T8 – SIGNALS AND EMISSIONS [4 Exam Questions - 4 Groups]

March 21, 2023

Question pool sections: T8

Terms and concepts:

T8A – Basic characteristics of FM and SSB; Bandwidth of various modulation modes: CW, SSB, FM, fast-scan TV; Choice of emission type: selection of USB vs LSB, use of SSB for weak signal work, use of FM for VHF packet and repeaters

T8B - Amateur satellite operation: Doppler shift, basic orbits, operating protocols, modulation mode selection, transmitter power considerations, telemetry and telecommand, satellite tracking programs, beacons, uplink and downlink mode definitions, spin fading, definition of "LEO", setting uplink power

T8C – Operating activities: radio direction finding, contests, linking over the internet, exchanging grid locators

T8D – Non-voice and digital communications: image signals and definition of NTSC, CW, packet radio, PSK, APRS, error detection and correction, amateur radio networking, Digital Mobile Radio, WSJT modes, Broadband-Hamnet

Corresponding pages of Gordon West book
T8: 67, 77, 78, 102-107, 109-120, 122, 126, 127, 170, 171

Signals and Emissions: In this session we'll be discussing some of the mechanisms that make communication by radio possible. Topics include modulation (adding information to a radio signal), use of amateur radio satellites, some operating activities that hams commonly participate in, and digital and other non-voice mode.

We'll start with a quick review of the last 4 sections that we've covered.

Radio Communications:

The universe is filled with electromagnetic energy at all wavelengths, including RF. Most all of it is random, what we call noise. This energy simply exists, it doesn't contain any intentionally added information. In order to use RF to communicate, information needs to be added and extracted from the RF signal.

Let's look at what happens during radio communications. From the transmitting end, the information to be sent is first converted to an electronic form. This electronic information is added to a radio wave. That radio wave then radiates from the transmitter's antenna. On the receiving end, that radiated signal is intercepted by the receiving antenna, the receiver extracts the information that was added to the wave by the transmitter, and then the information is converted into a form that can be understood.

The process of adding information to a radio wave is called modulation. The very simplest form of modulation is to simply turn the transmitted signal on and off, which is what's done when Morse code, or “CW” is sent. It's also possible to encode speech or other sounds. Some of these techniques are used to send digital data. There are several ways to modulate a signal. Different techniques alter different characteristics of the radio wave, such as amplitude or frequency.

The process of adding information to an unmodulated radio wave creates additional signals called sidebands. The sidebands and carrier work together to carry the information. The combination of carrier and sidebands creates a composite signal. This brings up the concept of bandwidth. The carrier plus the sidebands occupy a range of spectrum space, known as the bandwidth of the composite signal. Different types of modulation and information results in different signal bandwidths.

As mentioned before, CW or Morse code is the simplest forms of modulation, and has fairly narrow bandwidth. The earliest voice modulation used was amplitude modulation or AM. With AM, the amplitude or intensity of the radio signal varies in response to the information (modulating) signal. AM signals consists of three components, the carrier, the lower sideband (LSB), and the upper sideband (USB). All of the information needed to recover the modulated signal is contained in just one sideband, as the sidebands are mirror images of each other. As such, the AM signal bandwidth is twice the information bandwidth.

Here's an image to help you visualize the bandwidth of a shortwave AM broadcast station, in this case All India Air, operating just above the amateur 40 meter band, on 7.550 Mhz or 7550 kHz. This spectrum analysis shows all of the energy detected across a range of frequencies, here ranging from 7510 to about 7580 kHz. The AM carrier of All India Air is clearly visible at 7550 kHz, with the lower and upper sidebands running from 7545 to 7555 kHz. This yields a total bandwidth of 10 kHz.

Before moving on to other voice modulation techniques, let's look at two very different non-voice modes. A Morse code or *CW signal has a very narrow bandwidth, only about 150 Hz*. This means you can fit a bunch of CW signals in a fairly narrow chunk of spectrum, Hams are also authorized to transmit full-motion color video and sound, using *the **NTSC** standard for analog fast-scan color TV*, as was used for decades for over-the-air TV broadcast. This *AM mode of fast-scan TV* takes up much more *bandwidth, at approximately 6 MHz*. This is why amateur fast-scan TV is only permitted on 70 cm (430 MHz) and above.

When you consider that usable spectrum is a valuable resource, it makes sense to keep the working bandwidth as narrow as possible, to allow more efficient use of the spectrum. Since the upper and lower sidebands contain duplicate information, why not transmit just one sideband? That's what done with a mode called single sideband or SSB. Efficiency is improved, as the *bandwidth of a SSB signal is about half that of an AM signal. SSB is a form of amplitude modulation. It is a popular voice mode for long distance or "weak signal" VHF/UHF contacts. The approximate bandwidth is 2.4 to 3 kHz for voice signals, which is narrower than an FM signal.* Although either sideband will work, hams use *upper sideband (USB) used on 10m HF, VHF, and UHF.*

Let's get back to other methods of modulating a signal. First we'll review the concept of "phase" in an AC signal. Phase describes a position within a cycle, going from zero to 365 degrees as the signal cycles from zero volts to the maximum voltage at 90 degrees, back to zero at 180 degrees. Phase is also used to describe a relative position between two waves, or their phase shift.

Both frequency and phase of a signal may be varied or modulated. If the information signal used to vary the carrier's frequency (instead of amplitude), ***frequency modulation (FM)*** is produced. *The FM bandwidth (for voice) is between 5 and 15 kHz,* depending on the design of the transceiver. The phase of the carrier signal may be shifted in response to the information signal, creating phase modulation (PM), which is very similar to FM. *FM and PM are commonly used on VHF/UHF voice repeaters and VHF packet radio. The approximate voice bandwidth of these signals runs between 10 and 15 kHz. One disadvantage versus SSB is that only one FM signal can be received at a time on a given frequency*.

To recap, here is a summary of approximate bandwidths of various signal types.

<u>Amateur Satellites:</u>
Now we'll move on to a part of amateur radio that is truly out of this world. It wasn't far into the 1960's that hams got the opportunity to communicate with each other using artificial satellites. The OSCAR series of "birds" (**O**rbiting **S**atellites **C**arrying **A**mateur **R**adio) have been designed and built by hams. There are multiple amateur satellites orbiting the earth today, accessible to any ham with the right equipment. *All common operating modes, FM, analog modes, (SSB and CW), and digital are used for satellite communications*. Believe it or not, another well known satellite, the International Space Station is also available for some amateur operations.

Here is some terminology you'll need to know regarding satellite communications.
Uplink *– Earth stations transmission to satellite*
Downlink *– Satellite transmission to stations on Earth*
Beacon *– Transmission (telemetry) from satellite that contains status information (health/status), anyone can receive telemetry*
Doppler Shift *– Observed change in signal frequency due to relative motion between satellite and Earth station*
LEO *– Low Earth Orbit*

Gyroscopic forces are needed to keep satellites from tumbling in orbit, so they spin on their axis. This results in ***spin fading****, caused by rotation of satellite and it's antennas*. In order to operate through satellite, you need to know when and where it will be in the sky above you. To do this, hams use ***tracking software***. These programs use *Keplerian elements to provide orbital details, including real-time maps of the track across the earth, the time, azimuth, and elevation of the satellites at the start, maximum altitude, and end of pass.* You need this information to determine where to point your antenna at the sky. Programs will also *calculate the apparent frequency, adjusted for Doppler shift.*

The mode that a satellite operates reflects the bands satellite is using for uplink and downlink. *A satellite using a 70 cm (UHF) uplink and a 2 meter (VHF) downlink) is operating in mode* ***U/V***.

Regardless of the emission mode you use, here are some guidelines for satellite operation. Use the minimum necessary uplink transmit power. If you don't, and your *uplink signal has excessive effective radiated power (ERP), your signal may block access by other users.* A good way to *properly set the uplink transmit power is to listen to your downlink signal, and adjust the transmit power so your signal strength is approximately equal to the satellite's beacon signal*.

<u>Operating Activities:</u>
While there are endless on-the-air operating activities, the test mentions two. One is radio direction finding, or RDF. *You'll need to have a directional antenna* for this activity (more on that coming up). With the right techniques, that antenna *could be used to locate the source of interference or jamming signals, or to locate a hidden transmitter* in a competition often called a foxhunt.

Contesting is another popular on-the-air activity. The goal of *contesting is to contact as many stations as possible in specified period* and limitations laid out for that contest. Most people operating in a contest are not there to chat, they want to make a contact, then move onto the next. *Good operating procedure* is to *provide the minimum information for contest exchange*, which on VHF and UHF is often the station *call sign and grid locator*. *The two letter two digit grid locator* is based on the Maidenhead grid coordinates. This system divides the entire world into rectangles, 1° in latitude by 2° longitude. Mendocino county is grid CM89,

<u>Digital modes:</u>
There are numerous modes that use digital techniques to send sound or data. Using technology developed for general telecommunications, hams use ***Voice over Internet Protocol (VoIP)*** *to deliver voice communications digitally over the internet.* The ***Internet Radio Linking Project (IRLP)*** uses this technology to *connect amateur radio systems and repeaters via the internet with VoIP*. Using IRLP, it's possible to connect your local IRLP repeater with other repeaters around the world. *The commands to access IRLP nodes are sent using DTMF (touch tone) signals*. That's why many ham radio microphones have a keypad on them.

Echolink *is a unique internet based system that allows transmission via repeater without using radio, using a computer as the interface. In order to use Echolink, you must register and have your valid license status verified*. You may wonder how all of this amateur traffic get connected to the internet. This is done by a ***gateway*** *station, an amateur station that connects other amateur stations to internet.*

There are a growing number of digital data modes available to hams. These include *packet radio, IEE 802.11, and FT8. FT8 is a digital mode capable of low signal-to-noise*, where the signal is barely above the noise floor. *WSJT-X* is another data mode often *used for earth-moon-earth (EME or moon bounce), weak signal beacons, and meteor scatter*, where signals are often weak. Many digital modes use ***PSK*** *or Phase Shift Keying* as the modulation technique.

Packet radio is used by the ***Automatic Packet Reporting System (APRS)***. *This system can transmit GPS and mapping data, text messages, and weather information*. *Packet transmissions utilize error correction* techniques to maximize accuracy. These *include using a check sum, a header with call and destination information, and automatic repeat request* if the accuracy of the transmission is questionable. ***ARQ*** *is an error correction scheme, where if the receiving station detects an error, it requests a re-transmission* of the data.

Digital Mobile Radio (DMR) is a voice mode, where the audio is converted to a digital format for transmission. *DMR utilizes time multiplexing to put two digital voice signals on a single 12.5 kHz repeater channel. A DMR repeater talkgroup allow users to share a channel without hearing others* by time-sharing.

Wireless internet communications (IEE 802.11) is also available on an ***amateur radio mesh network***. These networks *use commercial Wi-Fi equipment, running with modified firmware*. The unlicensed Wi-Fi band. used by your home router, overlaps with amateur microwave frequency allocations. This allows amateurs to legally run greater transmit power with the modified firmware.