<u>Amateur Radio General Class License Study Guide</u>

Week 3

<u>Element 8: SIGNALS AND EMISSIONS</u>

October 17, 2023

Question pool sections: G8

Concepts covered:

G8A – Carriers and modulation: AM, FM, and single sideband; modulation envelope; digital modulation; overmodulation; link budgets and link margins

G8B – Frequency changing; bandwidths of various modes; deviation; intermodulation

G8C – Digital emission modes

Corresponding pages of ARRL *General Class license manual*:
3-8, 5-1 through 5-12, 5-16 through 5-19, 5-24, 5-25, 6-1 through 6-9, 6-12, 6-13, 6-15, 6-16

Technician Review - Signals and Emissions:
Let's start off with a quick review of some concepts from the Technician class exam. There are several types of signals or emissions which can come from your station. The simplest form of emission is that produced by switching the output of a transmitter on and off, to produce a CW signal. There are other, more complex ways of combining an information signal (such as the audio from your voice) with a radio signal. This process, regardless of how it is done, is called “modulation”. In this element, we'll discuss a wide variety of modulation techniques.

Three common ways to add voice information to an RF carrier are Amplitude Modulation (AM), Frequency Modulation (FM) and Phase Modulation (PM). *Amplitude modulation varies the instantaneous power level of the RF signal, while frequency modulation is the name of the process that changes the instantaneous frequency of an RF wave to convey information. Phase modulation changes the phase angle of an RF signal to convey information*. *Phase modulation may be produced by a reactance modulator connected to a transmitter RF amplifier stage.*

Each form of modulation requires some “bandwidth” to add the information signal to the radio signal. CW has one of the lowest bandwidths, meaning several CW signals can occupy a fairly narrow range of frequencies. Voice modes using the modulating techniques listed above have varying bandwidths. *Single sideband* (SSB) is a type of amplitude modulation that *produces phone emissions using narrower bandwidth than FM or PM.*

The waveform created by connecting the peak values of the modulated signal is the modulation envelope of an AM signal. Too much modulation, is not a good thing. *Excessive bandwidth is an effect of overmodulation,* which causes the signal to spread out, or “splatter” on to adjacent frequencies. Over modulation can produce *“flat-topping,” of an amplitude-modulated phone signal, resulting in signal distortion caused by excessive drive or speech levels*.

Digital modes and modulation
There are numerous digital modes that utilize an array of modulating techniques, but we'll start with one of the older modes, radio-teletype or RTTY. RTTY utilizes the *Baudot code, which is a 5-bit code with additional start and stop bits*. With only 5 bits to work with, the Baudot code can define just 32 unique characters, so all letters are sent as upper case. HF RTTY signals are usually produced by frequency-shift keying (FSK) an RF signal. This means the transmit frequency is shifted between discrete frequencies. *These two separate frequencies of a Frequency Shift Keyed (FSK) signal are identified as the mark and space frequencies.* This *direct binary FSK modulation (*binary = switching between two frequencies*)* may be *generated by changing an oscillator's frequency directly with a digital control signal.*

RTTY lacks some of the features of more modern digital modes, including error detection and correction. If a signal fade or static crash distorts the received mark or space frequency, an incorrect or missing character can result. More sophisticated digital modes may use Automatic Repeat reQuest (ARQ) protocol. *When ARQ is utilized, the receiving station will reply with* ACK when the information is correctly received, or *NAK (a request to re-transmit the packet)* if a transmission error is detected. *The failure to exchange information due to* *excessive transmission attempts (*repeated NAK) *when using an ARQ mode will cause the connection to be dropped.*

A different way of eliminating errors is to use *forward error correction (FEC) to allow the* *<u>receiver</u>* *to correct data errors. FEC is accomplished by transmitting redundant information with the data.* This reduces the need to request re-transmission of the data.

Most modern digital modes utilize a structured or packet-based format. The structure of a *packet frame consists of a header, which contains the routing and handling information*, followed by the data or payload, and ending with the trailer, which contains status or error detection data.

Common digital transmission modes include QPSK31, PSK31, FT8, and WSPR. *WSPR is a digital mode used as a low-power beacon for assessing HF propagation. QPSK31 is sideband sensitive, its encoding provides error correction, and its bandwidth is approximately the same as BPSK31 (all of the above). QPSK modulation is modulation in which digital data is transmitted using 0-, 90-, 180- and 270-degrees phase shift to represent pairs of bits.*

Varicode is the type of code is used for sending characters in a PSK31 signal. Upper case letters use longer Varicode bit sequences and thus slow down transmission of PSK31 data.

FT8 is an increasingly popular *narrow-band digital mode.* *<u>FT8</u> uses <u>8-tone</u> frequency shift keying modulation, and can receive signals with very low signal-to-noise ratios* (when you can barely hear the signal over the noise). *An FT8 signal report of +3 means the signal-to-noise ratio is equivalent to +3 dB in a 2.5 kHz bandwidth.* This is not a particularly robust signal, compared to voice signals with a +30 dB noise margin. This relates to the concept of link budget and link margin. The *link <u>budget</u> is the sum of transmit power and antenna gains minus system losses as seen at the receiver*. The *link <u>margin</u> is the difference between received power level and minimum required signal level at the input to the receiver.*

There is a very common digital mode that amateurs also have access to and that is Wi-Fi. *Amateurs share channels with the unlicensed Wi-Fi service on the 2.4 GHz band*. This is the same band that your home Wi-Fi router likely uses. While there are some restrictions on using encrypted links, hams can use commercially available Wi-Fi equipment to build mesh networks. *Mesh network microwave nodes* provide a robust network as *if one node fails, a packet may still reach its target station via an alternate node.*

A tuning aid often used with digital modes is a “waterfall” display. This is a dynamic display, that flows down the display screen, much like water cascading over a waterfall. In a *waterfall display, frequency is horizontal, signal strength is intensity, and time is vertical.* This means the most recent information is displayed at the top of the display, with different colors used to indicate the signal strength. When *one or more vertical lines on either side of a data mode or RTTY signal appears on a waterfall display, it's an indication of overmodulation*.

Nearly all of the digital modes discussed so far are designed to send data, but digital voice communication modes exist as well. The voice waveform is translated into digital data and transmitted. The receiver decodes the data and recreates the voice waveform as audio. *DMR, D-STAR, and SystemFusion are all examples of digital voice modes.*

Regardless of the mode being used, there is a *relationship between transmitted symbol rate and bandwidth, with higher symbol rates requiring wider bandwidth.* This is why the symbol transmission rates or "baud" rates are limited on the HF bands (more on this in element G1, FCC regulations). Being aware of the signal bandwidth is important as *matching receiver bandwidth to the bandwidth of the operating mode results in the best signal-to-noise ratio.*

There are two questions in the pool regarding bandwidth and frequency deviation in FM transmitters. Rather than delving into the calculations, it may be easiest to memorize the following. *The total bandwidth of an FM phone transmission having 5 kHz deviation and 3 kHz modulating frequency is* ***16 kHz*** *and the frequency deviation for a 12.21 MHz reactance modulated oscillator in a 5 kHz deviation, 146.52 MHz FM phone transmitter is* ***416.7 Hz***. See pages 5-10 and 5-11 if you want to find the explanation of how the answers are calculated.

A factor to consider when operating a digital mode is *the importance of knowing the duty cycle of the mode you are using when transmitting, as some modes have high duty cycles that could exceed the transmitter's average power rating.* When running a high duty cycle mode, you may need to limit the transmit time or reduce the transmit output power to avoid overheating the transmitter.

Wanted and unwanted signal transformations
Some of the practical circuits discussed during the first week included oscillators, mixers, and multipliers. Oscillators are used to create signals at a desired frequency, while mixers and multipliers can transform the frequency from an oscillator into different frequencies. *Frequencies* from t*wo* oscillators may be *combined in a mixer in a process known as heterodyning,*

The <u>combination</u> of a mixer's Local Oscillator (LO) and RF input frequencies found in the output is <u>equal to the sum and difference of the two frequencies</u>. If you have a local oscillator running at 5 MHz mixed with a 21 MHz RF signal, the output of the mixer will have two signals, one at 16 MHz (21-5) and one at 26 MHz.(21+5). This is an example of using a local oscillator (LO) to produce an output at an intermediate frequency (IF). *The local oscillator input is varied or tuned to convert signals of different frequencies to an intermediate frequency (IF).*Sometimes *interference* occurs *from a signal at <u>twice the IF frequency</u> from the <u>desired signal</u>*. The *term for this is <u>image response</u>.*

A <u>frequency multiplier</u> is used to transform the input frequency to an output at a harmonic or integer multiple of the input frequency*. The stage in a VHF FM transmitter that generates a harmonic of a lower frequency signal to reach the desired operating frequency is the multiplier. (49 MHz X 3 = 147 MHz)*

Mixing and multiplying frequencies can be handy, but <u>unwanted</u> mixing and multiplying of signals can present problems. A *<u>process that combines two signals</u> in a <u>non-linear</u> circuit to produce <u>unwanted spurious outputs</u> is known as <u>intermodulation</u>*, or just intermod. Intermodulation can be a real headache, with two signals combining in a bad electrical connection (non-linear circuit) producing interference on a desired frequency.

There are two other questions in the pool relating to intermodulation. The book, however, does not offer an explanation regarding the correct answer. Here are the two questions and the correct answers

G8B05
Which of the following is an odd-order intermodulation product of frequencies F1 and F2?
2F1-F2

G8B13
Which intermodulation products are closest to the original signal frequencies?
Odd-order