Understanding FM Receivers

Part 18: FM receivers aren't much different from AM or CW/SSB receivers. But portions of the circuit are called upon to perform special functions that aren't necessary in other types of receivers.

By Doug DeMaw,* W1FB

"Why won't my SSB receiver decipher FM? All I'm getting is gibberish!" Another query could be made: "How come I can't receive CW or SSB on my FM receiver?" The answer is that the method of detecting the various kinds of signals is different. This is necessary because the transmitted signals are processed differently before they are routed to the transmitting antenna. We learned last month how an FM transmitter creates an FM signal, so you are probably aware that the transmitter output energy is varied above and below the carrier frequency during modulation. This means that a special receiver detector is needed to change the incoming FM signal to comprehensible audio-frequency energy. Generally speaking, the FM receiver circuits ahead of the detector are pretty much the same as those in other types of receivers. That is, we have RF amplifiers, mixers, oscillators and IF amplifiers. The audio chain is the same, also. That much said, let's learn how an FM receiver operates.

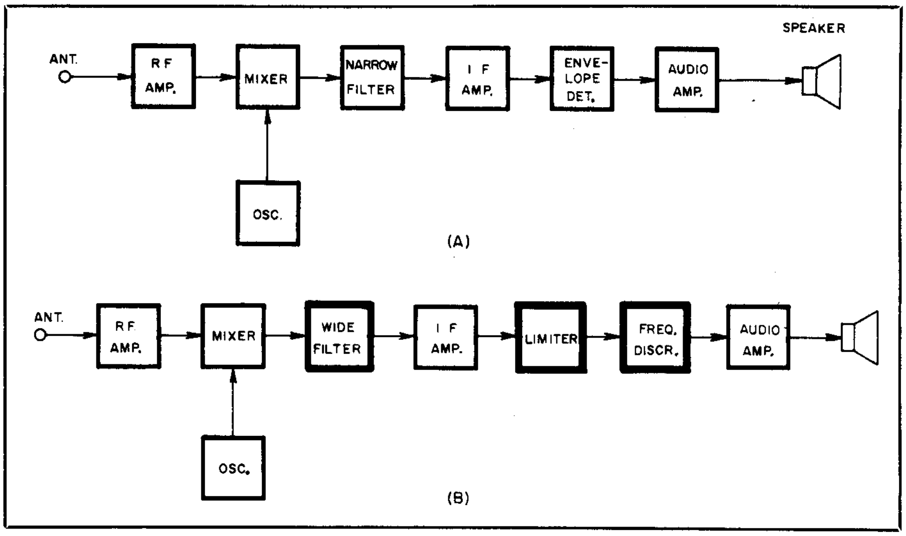


Fig. 1—Block diagram showing the fundamental difference between an AM and FM receiver. The AM version is shown at A; to make it a CW/SSB receiver, change the detector to a product type, then add a BFO that feeds an injection voltage (at the intermediate frequency) to the product detector. Illustration B shows how an FM receiver would be configured.

Comparing Circuits

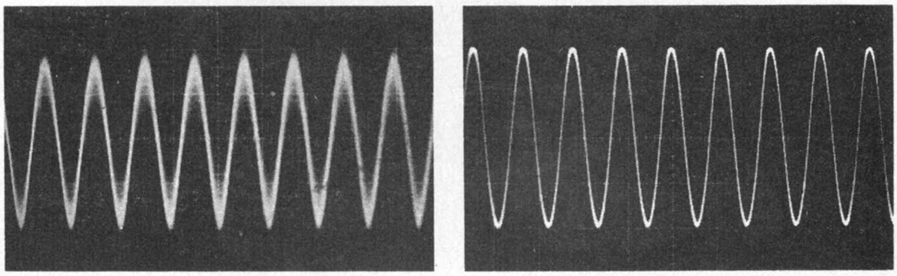
A block diagram (Fig. 1) illustrates how a CW/SSB receiver compares to an FM radio. The circuits through and including the IF amplifier are identical, except for the effective bandwidth (passband) of the IF filter: A wider filter is needed for FM reception. For example, a 2.4-kHz-wide filter might be used for SSB reception, a 500-Hz filter could be employed for CW work, and a 16-kHz filter might be used in an FM receiver. The filter need only be wide enough to accommodate the bandwidth of the transmitted signal. If the filter has a substantially wider response than the incoming signal bandwidth, unwanted signals (QRM) and noise will be passed along to the detector and audio amplifier.

Both receivers in Fig. 1 are superheterodyne types. A lot of overall receiver gain is needed to ensure high receiver sensitivity. Specifically, an FM receiver needs a gain of more than 1 million to enable us to copy a weak signal that is 1 microvolt (μV) or less at the antenna. I have seen well designed FM receivers that could make an 0.18-μV signal plainly readable above the noise generated *within* the receiver. Most commercial amateur FM receivers are rated at approximately 0.4 μV for what is called "20 dB of quieting," or 20 dBQ. This measurement is made with an audio power meter, calibrated in decibels. The instrument is attached to the receiver output (an 8-ohm resistor replaces the speaker as a dummy load), and audio power is measured across the dummy load. With no signal entering the receiver at the antenna terminal, the audio-gain control is advanced until the audio meter reads, say, 30 dB. Then, a signal generator is fed into the receiver input, and the incoming signal is increased in level until the audio-meter reading drops 20 dB, or to +10 dB on the

*ARRL Contributing Editor, P.O. Box 250, Luther, MI 49656

Need a Copy of This Article or a Previous Installment?

Although each issue of *QST* is protected by copyright, we would like to make it as easy as possible for readers to obtain copies of each installment of First Steps in Radio. Provided that copies are made *for the personal use of an individual, or of a Novice class,* ARRL hereby grants permission for photocopies to be made of any article in this series. If your club plans to teach a Novice class, feel free to make a sufficient number of copies for students' personal use. If you are missing one or more installments, back issues are available for $2.75 apiece from the Circulation Department, ARRL Hq., 225 Main St., Newington, CT 06111.



(A) (B)

Fig. 2—Waveforms of an FM signal before passing through a limiter stage (A), and after it has been cleaned up to remove noise and other AM energy by action of the limiter (B). See text.

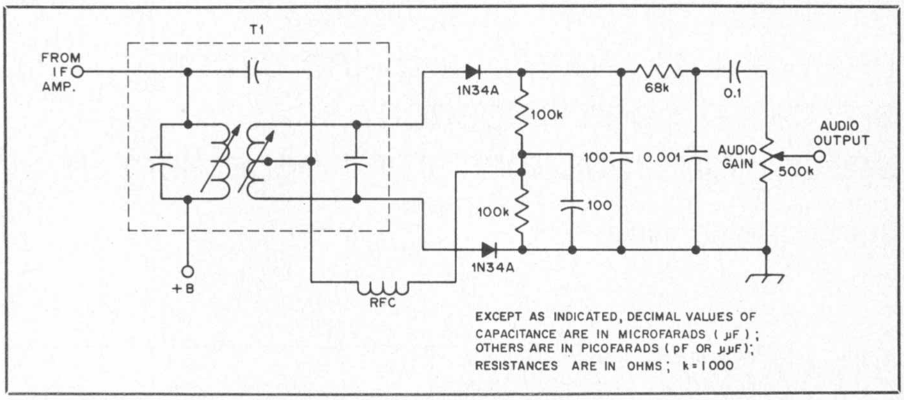


Fig. 3—Typical frequency discriminator circuit that follows a limiter in an FM receiver. This circuit is discussed in the text.

meter scale. The level of signal coming from the signal generator is noted, and that is the signal required for 20 dB of quieting. The lower the level of the input signal, the more sensitive the FM receiver is. A different measuring technique is used with CW/SSB or AM receivers.

Major Circuit Differences

You will notice that in Fig. 1B there is a stage immediately after the IF amplifier that is labeled "limiter." This part of the FM receiver is used to "sanitize" or "launder" the FM signal before it reaches the detector. It saturates (stops providing gain) in the presence of strong signals from the IF amplifier. When this happens, the signal is clipped on both the positive and negative peaks, as would be the case if diodes, reverse-connected, were placed in shunt with the signal path.

Why would we want this to occur? It is vital to take advantage of the limiting feature in order to clip high noise peaks (such as auto-ignition pulses) or any amplitude-modulated energy from other sources. We want only the FM signal to reach the detector. Fig. 2 shows a noisy FM signal (A) entering a limiter, and the cleaned-up signal (B) after leaving the limiter.

A great deal of gain (amplification) is needed ahead of the limiter because it should start functioning as a clipper at 0.2 μV or less. As soon as sufficient signal reaches the limiter, the receiver output (noise) starts quieting. The point on the limiter response curve where limiting action commences is called the "limiting knee." It is at this point that the limiter collector current no longer increases with any buildup in signal amplitude. Modern receivers have ICs rather than individual transistors or tubes in the limiter circuit. An IC may contain several transistor stages; this yields the high gain needed for proper limiter action. If tubes or transistors are used, we might find it necessary to have several such stages in cascade to achieve suitable gain.

FM Detection

There are numerous FM detectors in use today. Among them are the *discriminator, ratio detector, quadrature detector* and *crystal discriminator.* Each has its particular virtues and limitations. The objective in designing an FM detector is to have it respond to FM rather than AM energy. The exact nature of how these detectors operate is rather complex. Detailed information on the subject is contained in *The ARRL Handbook.*

The circuit for a discriminator is given in Fig. 3. The FM signal is changed to AM by means of T1. The T1 secondary *voltage* is 90 degrees out of phase with the *current* in the T1 primary. The signal from the primary winding is routed to the center tap of the secondary winding by means of a coupling capacitor. Next, the secondary voltage combines on each side of the center tap so that the voltage on one side *leads* the primary signal while the other side *lags* by an equivalent amount. When this energy is rectified (changed to dc) by the two diodes of Fig. 3, the two voltages are equal and of opposite polarity. This results in no (zero) output voltage. When voice energy is applied to an FM transmitter, there will be a shift in the received signal frequency, which will lead to a shift in phase at the detector. This phase shift causes an increase in output amplitude on one side of the T1 secondary, along with a corresponding decrease in the other half of the secondary. These differences in the pair of changing voltages (after rectification) create audio output.

Ratio Detector

Fig. 4 illustrates the workings of a ratio detector. You will see some similarity between this circuit and that of Fig. 3. The ratio detector divides the dc voltage into a ratio equal to the ratio of the amplitudes from the two halves of a discriminator transformer secondary winding. The required dc voltage in this circuit is developed across two load resistors, and there is an electrolytic capacitor in shunt across the resistors, as in Fig. 4. The sensitivity of the ratio detector is half that of the discriminator. This is a minor consideration and does not require special attention when the receiver is designed. Ratio detectors are most popular in entertainment FM receivers, whereas discriminators are more common in amateur and commercial land-mobile FM receivers.

Other Considerations

FM receivers do not have automatic gain control (AGC) circuits, but most SSB/CW and AM receivers do. For all practical purposes, the FM limiter acts as an AGC circuit to level the receiver gain after a certain input-signal level is reached. Also, most

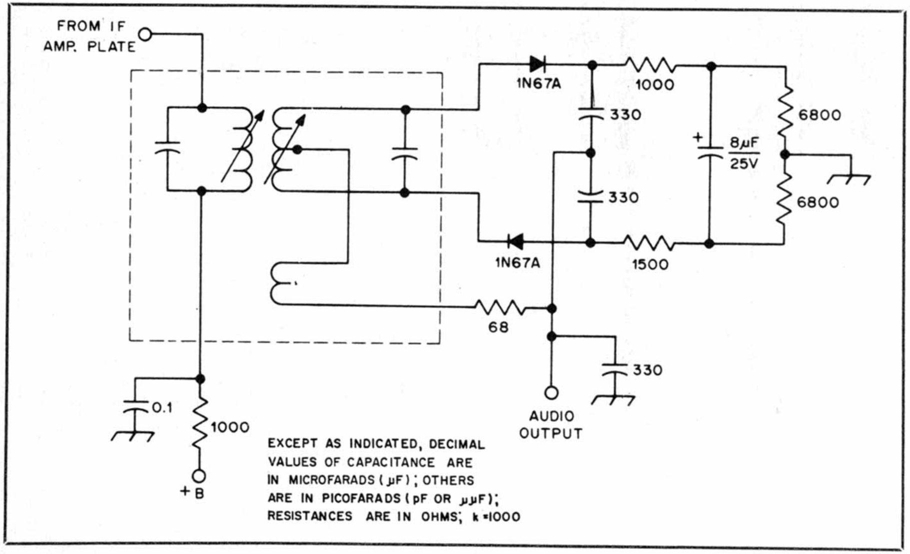


Fig. 4—An FM ratio detector of the type mentioned in the text. It is similar to the discriminator of Fig. 3, but operates in a different manner. Notice that the detector diodes in both circuits are connected in a different polarity arrangement.

amateur FM receivers do not feature continuous-tuning capabilities from the front panel. Rather, a given FM amateur band is covered by means of crystal-controlled frequencies (channels, as some call them) via a frequency-selector switch, or through the use of a synthesizer that tunes in specific frequency increments. Selected frequencies are placed in a memory for instant recall, thereby making it unnecessary to "dial up" a repeater or simplex frequency for day-to-day operation. There is no reason, however, why an amateur FM receiver cannot be made completely tunable for the purpose of covering every kilohertz of a given amateur FM band.

In Summary

We have learned that FM receivers are similar to other types of superheterodyne receivers. The major difference is that FM receivers need a limiter and a special kind of detector. FM now plays a major role in Amateur Radio, so you will certainly become involved with this mode at some point in your amateur career.

Glossary

crystal discriminator—a type of FM detector containing a quartz crystal that replaces the tuned transformer in conventional discriminators.

discriminator—a circuit or device in which amplitude variations are derived from frequency or phase variations. The circuit has many uses, but is popular as a detector in FM receivers.

limiter—in an FM receiver, located immediately ahead of a discriminator or ratio detector to clip AM energy and generally clean up a noisy FM signal.

ratio detector—a type of FM detector that relies on the ratios of voltage and current in the circuit to produce a dc output that can be used as audio-frequency energy.

repeater—a remotely controlled, unmanned (normally) transmitter and receiver that receives signals and retransmits them at high power to extend the effective range of a base station, mobile unit or portable hand-held transceiver.

simplex—as applied to FM operation, direct communications without operating through a repeater. Both stations receive and transmit on the same frequency.

synthesizer—a complex digital circuit that generates precise, very temperature-stable frequencies. It is used as a replacement for conventional VFOs and crystal oscillators.

quadrature detector—an FM detector that depends on the relationship between two periodic functions when the phase difference between them is one-fourth of a period.