Chapter 3 Objectives

At the conclusion of this chapter, the reader will be able to:

- Explain conceptually how an AM signal is created.
- Use an oscilloscope to measure the percentage of modulation of an AM signal.
- Predict the frequency-domain characteristics of simple AM signals.
- Measure the various parameters of an AM signal using a spectrum analyzer.

Chapter 3: Amplitude Modulation

Of all the methods of impressing information onto a carrier signal, AM is the oldest. It dates back to the beginning of radio. Although it's old technology, it is still widely used in the following applications:

- Local broadcast (535 - 1620 kHz in the USA)
- Aircraft communications in the 118-138 MHz band.
- Short wave broadcasts in the HF bands (3-30 MHz), which affords worldwide coverage.
- Analog television, in which an AM carrier is used for the picture, and a separate FM carrier frequency is used to carry the sound.
- Data communications, in which AM and PM (Phase Modulation) are used together in high-speed modems, the subject of a later chapter.

With all of these applications (and more), "Ancient Modulation" is hardly obsolete technology. *AM is an electronic fundamental!*

3-1 Generating an AM Signal

As you recall, radio uses a high-frequency sine wave called a *carrier* to move information from the transmitter to the receiver. Intelligence can be impressed onto a carrier signal in three ways:

- Amplitude Modulation (AM): The *amplitude* or *strength* of the carrier signal is changed in step with the information. (In place of the word *amplitude* we can substitute voltage, power, or current.)
- Frequency Modulation (FM): The *frequency* of the carrier is changed with the intelligence signal. The frequency changes are normally small and hard to see on an oscilloscope (but you probably already guessed, they are easy to see on a spectrum analyzer!)
- Phase Modulation (PM): The *phase angle* of the carrier signal is changed to convey the information. PM is very similar to FM, and is very hard to observe accurately on an oscilloscope.

Figure 3-1 shows two carrier signals that have been modulated by the same information signal. Note how the *shape* of the AM signal is quite distinctive. The information is actually contained in this shape.

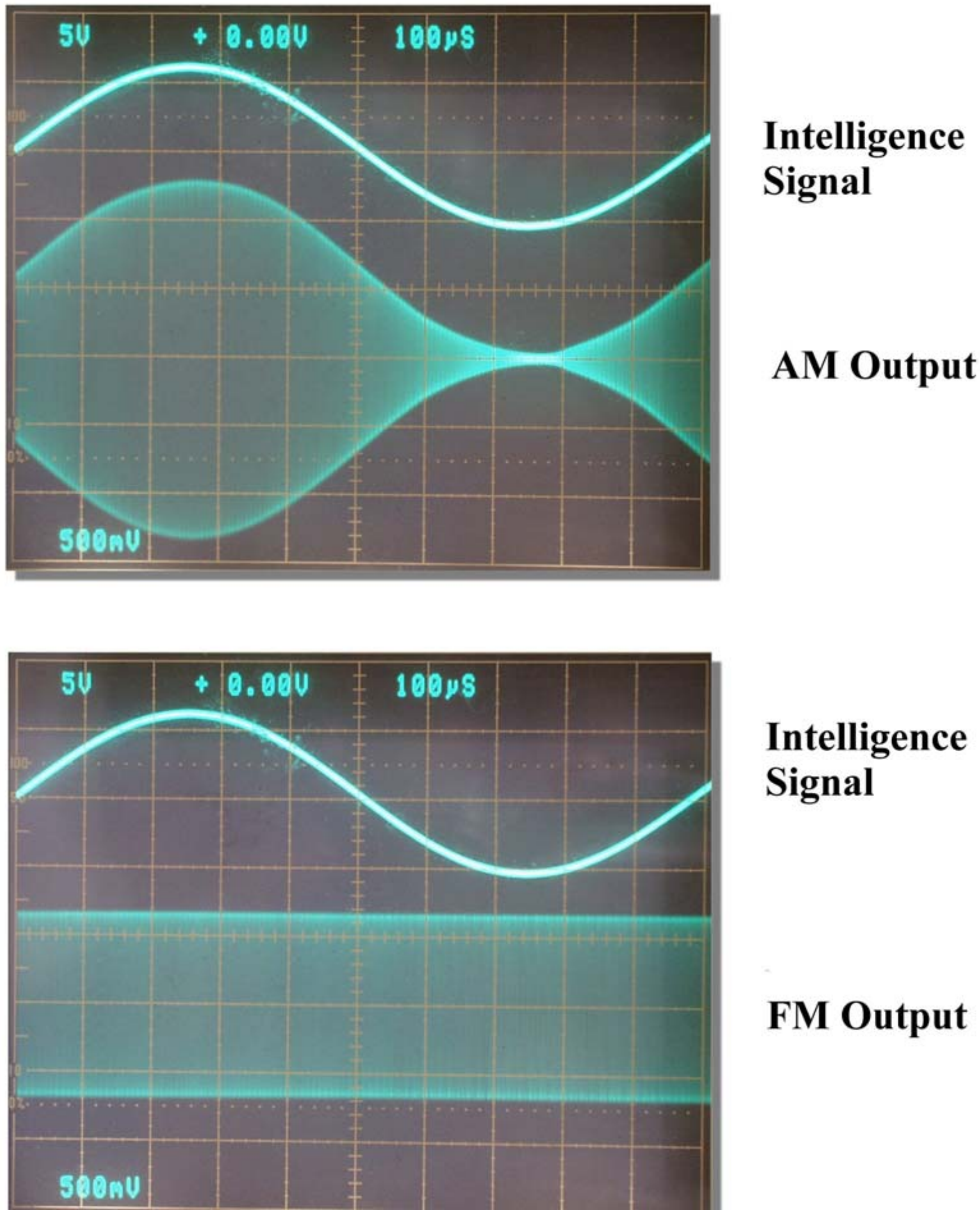

Figure 3-1: AM and FM signals on a scope

In contrast, the FM signal looks like a solid horizontal band. You really can't see much here at all! In fact, when the carrier frequency is much higher than the information frequency (like it is here), both FM and PM will look identical on a scope. FM and PM signals have a constant power. We need to use a spectrum analyzer to measure an FM or PM signal accurately.

Example 3-1

What is the frequency of the *information* signals in Figure 3-1? The horizontal timebase is set for 100 µS / division.

Solution:

The scope is measuring in the time domain, so we must first calculate the time period of the waveform:

$$T = (10 Divisions)(100 \mu S / Division) = \underline{\underline{1 mS}}$$

and the frequency is therefore:

$$F = \frac{1}{T} = \frac{1}{1mS} = \underline{\underline{1\ kHz}}$$

Example 3-2

Why do the modulated waveforms of Figure 3-1 appear as solid areas? Why can't we see the individual sine wave cycles of the AM and FM carriers?

Solution:

The *frequency* of the RF carriers is much higher than that of the information. In fact, the carrier frequency of both the AM and FM waveforms is 1 MHz. Recall that the information frequency is 1 kHz. Since 1 MHz is the same as 1000 kHz, *1000 cycles of carrier take place for every cycle of information*. Since the oscilloscope is adjusted to show one cycle of information, it also sees 1000 cycles of carrier. The carrier sine waves blend together, forming a solid figure.

Tip:

When observing modulated signals on a scope, it usually best to use two scope channels. One of the scope channels is connected to the information, and the other is connected to the modulated output. *The trigger must be set to the channel providing the information, in order to obtain a stable display*. Many techs forget this and have trouble getting accurate scope readings of transmitter outputs!

Making an AM signal

Figure 3-2 shows the conceptual process of amplitude modulation. Almost all AM transmitters work this way. When analyzing an actual circuit, it helps to keep this picture in mind.

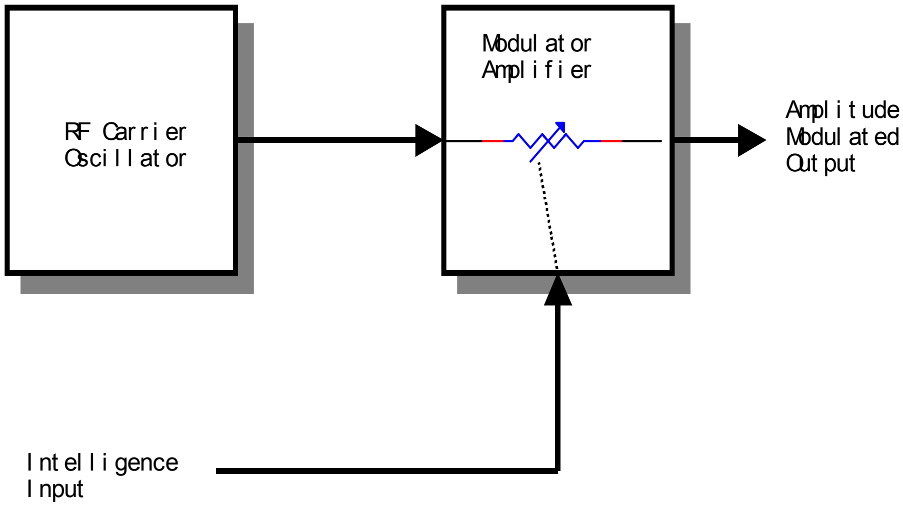

Figure 3-2: Generating an AM signal

The first stage in any transmitter is an *oscillator*. In a radio transmitter, it is usually called the *RF carrier oscillator*. The carrier oscillator converts the DC power supply energy into a radio frequency (RF) carrier wave. Oscillators will be studied in detail later.

The RF carrier wave contains no information until it is modulated. In order to amplitude modulate the carrier, its voltage (or power) must be changed. In order for the amplitude to be changed, the *voltage* or *power* gain of a subsequent stage must be changed.

The AM generator above has a special amplifier with a *variable* voltage gain called a *modulator*. This is really strange! The amplifiers you studied in fundamentals had a *constant* voltage or power gain, and only one input (this one has two!) An amplifier with a constant gain is called a *linear amplifier*.

What controls the gain of this amplifier? That's right -- there's a *second* input signal, the *information signal*. When the information signal goes positive, the amplifier's gain increases. This causes the output voltage (the AM signal) to swell or grow in amplitude. The opposite happens on the negative half-cycle of the information. The AM signal shrinks in amplitude because the amplifier's gain has decreased. Thus, amplitude modulation is created.

The variable-gain amplifier is a *nonlinear* amplifier because it has a gain that is not constant. One way of thinking of this amplifier is as a variable-resistor that controls the amount of carrier signal that gets through. The value of the "resistor" is controlled by the instantaneous value of the information signal.

A nonlinear amplifier distorts or changes the input signal. This is normally a bad thing! However, RF engineers carefully control this nonlinearity when they design modulators so that only a proper AM signal is produced.

A linear amplifier has a constant gain, and generates no distortion of the input signal. The graph of input-versus-output for a linear amplifier is a straight line (hence, the word "linear.") A nonlinear amplifier has a variable gain; its input-output graph is a curve. A nonlinear amplifier is always required to generate AM.

Section Checkpoint

3-1 List three applications of AM.
3-2 Why are FM and PM hard to observe on an oscilloscope?
3-3 What instrument is preferred for measuring FM and PM signals?
3-4 Why does the variable-gain amplifier stage in Figure 3-2 generate AM?
3-5 A non-________ amplifier stage is required to generate AM.

3-2 Measuring AM Signals in the Time Domain

By interpreting the display of an AM signal on an oscilloscope, a technician can determine a lot about the operation of an AM transmitter. By examining the waveform, a technician can determine what type of information is modulating the transmitter, as well as the *percentage of modulation*.

Where is the information?

In an AM signal, the information is carried on top of the RF carrier. The actual shape of the carrier is altered by the addition of the information during the process of modulation. When we look at a modulated AM carrier wave, we tend to see an overall shape. The imaginary lines that make up this shape are called the *envelope*.

Can you tell what is significant about the envelope? Take a look at Figure 3-3.

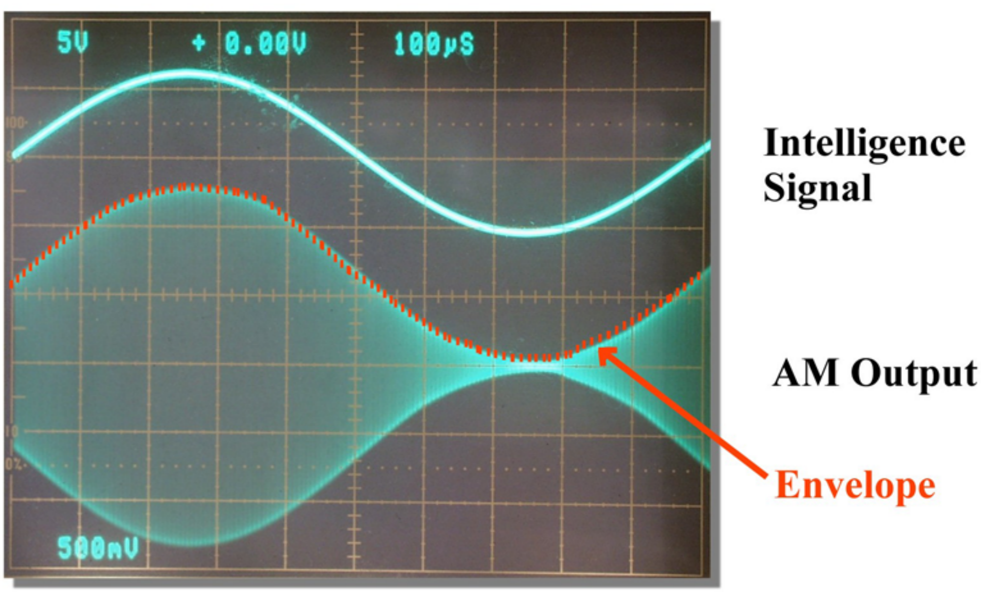

Figure 3-3: The envelope of an AM signal

Yes -- the envelope is copy or duplicate of the intelligence signal! No matter what the information is, the envelope will always imitate it. Take a look at Figure 3-4.

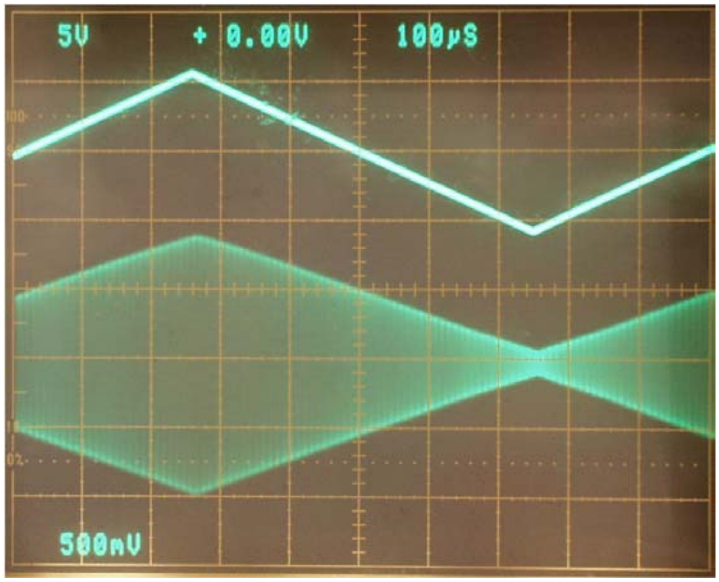

Figure 3-4: A triangular information signal

Again, the envelope looks just like the information signal on top. Another case might look like Figure 3-5.

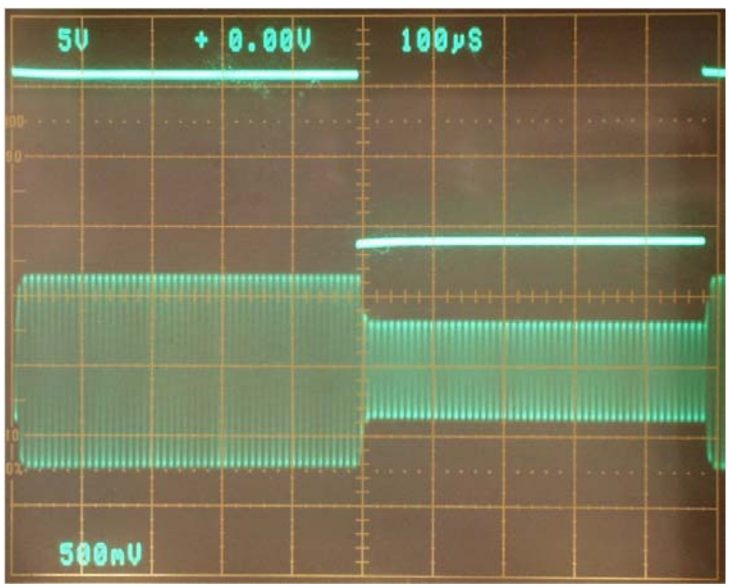

Figure 3-5: A square wave information signal

As you can see from Figures 3-4 and 3-5, the envelope always matches the shape of the information. Figure 3-5 is a special case; can you tell what the source of the information might be? If you're thinking *digital*, you're on the right track. The information signal of Figure 3-5 is *digital data*, which is sent as a sequence of binary ones (highs) and zeros (lows). We'll study digital data communications in a later chapter.

Percentage of Modulation and AM Modulation Index