Modulation - Volume I - Amplitude Modulation

An Online Continuing Education Course for Engineers

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Modulation – Volume I – Amplitude Modulation

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Introduction

People have always had the desire to communicate their ideas to others. Communications have not only been desired from a social point of view, but have been an essential element in the building of civilization. Through communications, people have been able to share ideas of mutual benefit to all mankind. Early attempts to maintain communications between distant points were limited by several factors. For example, the relatively short distance sound would carry and the difficulty of hand-carrying messages over great distances hampered effective communications.

As the potential for the uses of electricity were explored, scientists in the United States and England worked to develop the telegraph. The first practical system was established in London, England, in 1838. Just 20 years later, the final link to connect the major countries with electrical communications was completed when a transatlantic submarine cable was connected. Commercial telegraphy was practically worldwide by 1890. The telegraph key, wire lines, and Morse code made possible almost instantaneous communications between points at great distances. Submarine cables solved the problems of transoceanic communications, but communications with ships at sea and mobile forces were still poor.

In 1897 Marconi demonstrated the first practical wireless transmitter. He sent and received messages over a distance of 8 miles. By 1898 he had demonstrated the usefulness of wireless telegraph communications at sea. In 1899 he established a wireless telegraphic link across the English Channel. His company also established general usage of the wireless telegraph between coastal light ships and land. The first successful transatlantic transmissions were achieved in 1902. From that time to the present, radio communication has grown at an extraordinary rate. Early systems transmitted a few words per minute with doubtful reliability. Today, communications systems reliably transmit information across millions of miles.

The desire to communicate directly by voice, at a higher rate of speed than possible through basic telegraphy, led to further research. That research led to the development of *modulation*.

Modulation is the ability to impress intelligence upon a *transmission medium*, such as radio waves. A transmission medium can be described as light, smoke, sound, wire lines, or radio-frequency waves.

In this course, we will learn about modulation as it applies to radio-frequency communications. To modulate is to impress the characteristics (intelligence) of one waveform onto a second waveform by varying the amplitude, frequency, phase, or other characteristics of the second waveform. First, however, we will review the characteristics and generation of a sine wave. This review will help better understand the principles of modulation. Then, an important principle called *heterodyning* (mixing two frequencies across a non-linear impedance) will be studied and applied to modulation. Nonlinear impedance will be discussed in the heterodyning section. Next, we will study amplitude modulation of radio-frequency carrier. Companion courses include the study of angle and pulse modulation and demodulation techniques.

Chapter 1: Sine Wave Characteristics

The basic alternating waveform for all complex waveforms is the sine wave. Therefore, an understanding of sine wave characteristics and how they can be acted upon is essential to understand modulation.

Since numbers represent individual items in a group, arrows can be used to represent quantities that have magnitude and direction. This may be done by using an arrow and a number, as illustrated in Figure 1. The number represents the magnitude of force and the arrow represents the direction of the force.

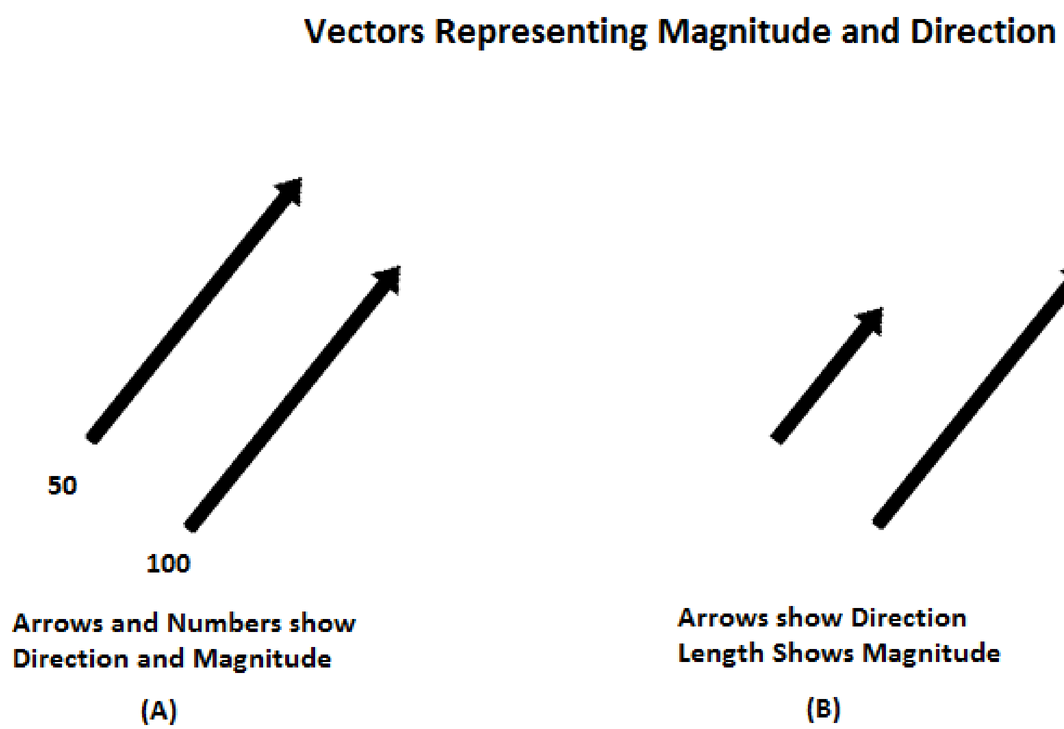

Figure 1

Part B of Figure 1 illustrates a simpler method of representation. In this method, the length of the arrow is proportional to the magnitude of force, and the direction of force is indicated by the direction of the arrow. Thus, if an arrow 1-inch long represents 50 pounds of force, then an arrow 2-inches long would represent 100 pounds of force. This method of showing both magnitude and direction is called a *vector*. To more clearly show the relationships between the amplitude, phase, and frequency of a sine wave, we will use vectors.

An alternating current is generated by rotating a coil in the magnetic field between two magnets. As long as the magnetic field is uniform, the output from the coil will be a sine wave, as shown in Figure 2. This wave shape is called a sine wave because the voltage of the coil depends on its angular position in the magnetic field.

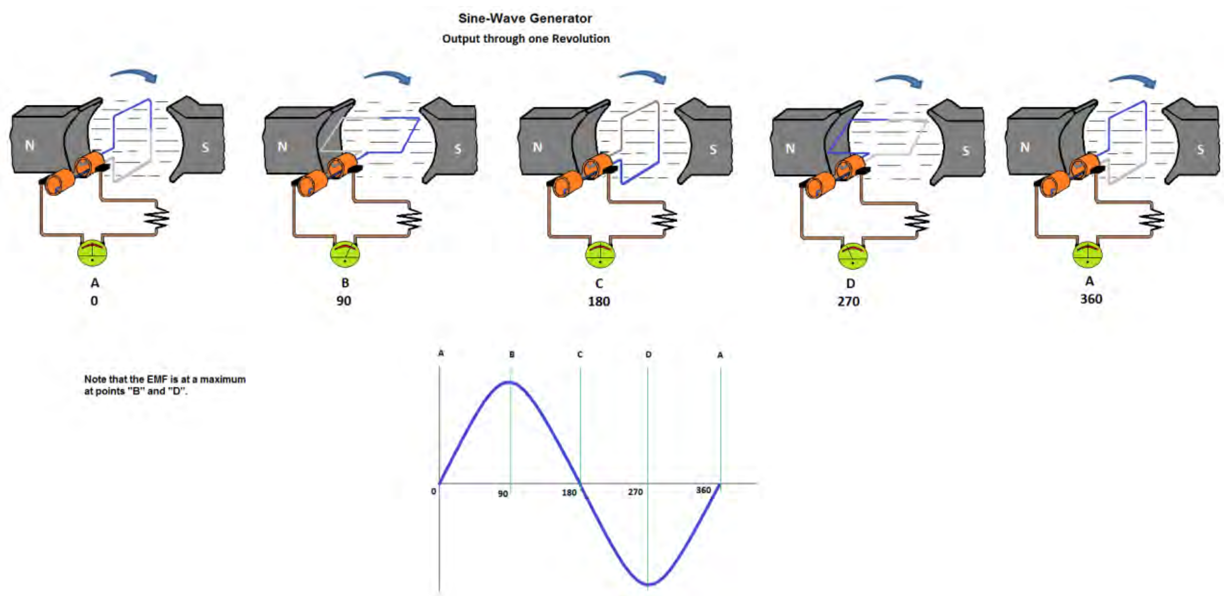

Figure 2

This relationship can be expressed mathematically by the formula:

$$\mathbf{e = E_{max} * Sin(\theta)}$$

Where,
e = Instantaneous value of the voltage developed when the coil is at some angle (θ)
E_{max} = Maximum value of the voltage
θ = Angular position of the coil

Recall that the trigonometric ratio (inset in Figure 3) for the sine in a right triangle (a triangle in which one angle is 90 degrees) is:

$$\mathbf{Sin(\theta) = \frac{Opposite\ side}{Hypotenuse}}$$

Where,
θ = Acute angle

Opposite Side = Side of the triangle that is opposite the angle θ.
Hypotenuse = The longest side of the triangle

When an alternating waveform is generated, the coil is represented by a vector which has a length that is equal to the maximum output voltage (E_{max}). The output voltage at any given angle can be found by applying the above trigonometric function. Because the output voltage is in direct relationship with the sine of the angle θ, it is commonly called a sine wave.

We can see this relationship more clearly in Figure 3 where the coil positions in relation to time are represented by the numbers 0 through 12. The corresponding angular displacements, shown as θ, are shown along the horizontal time axis. The induced voltages (V_1 through V_{12}) are plotted along this axis. Connecting the induced voltage points, shown in the Figure, forms a sine-wave pattern. This relationship can be proven by taking any coil position and applying the trigonometric function to an equivalent right triangle. When the vector is placed horizontally (position 0), the angle θ is zero degrees. Since E_{max} = 100 and the sine of 0 degrees is zero, the output voltage is zero volts, as shown below:

$e = E_{max} * \sin(\theta)$
$e = 100v * 0$
$e = 0$ volts