

# Double Side Band Full Carrier Amplitude Modulation (DSBFC - AM) Systems

By Larry E. Gugle K4RFE, RF Design, Manufacture, Test & Service Engineer (Retired)

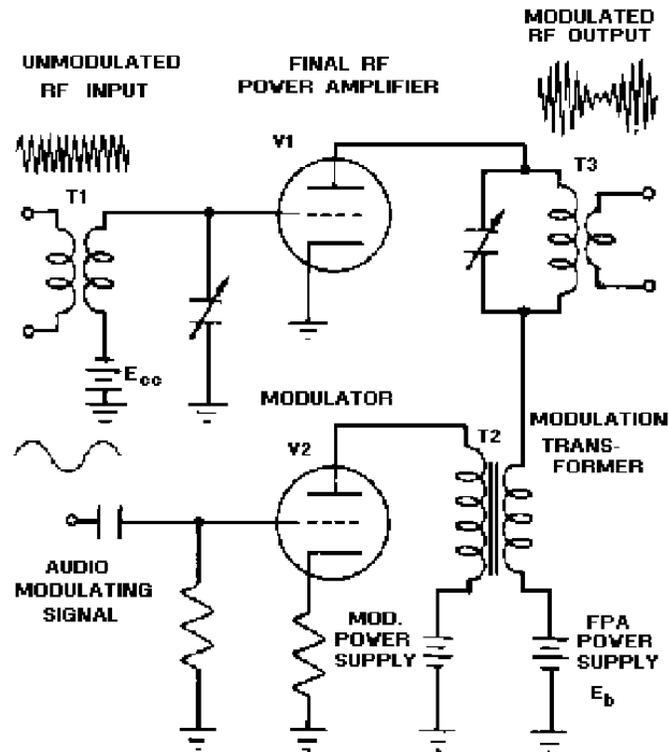
To complete an understanding of systems using the mode of Double Side Band Full Carrier Amplitude Modulation (DSBFC - AM) Telephony, emission designator 6K00A3E:

1. A detailed circuit description and operation will be discussed of a typical Triode Electron Tube:
  - a. *Plate Modulator.*
  - b. *Control-Grid Modulator.*
  - c. *Cathode Modulator.*
  
2. A detailed circuit description and operation will be discussed of a typical Bipolar Junction Transistor (BJT):
  - a. *Collector-Injection Modulator.*
  - b. *Base-Injection Modulator.*
  - c. *Emitter-Injection Modulator.*

## Plate Modulator

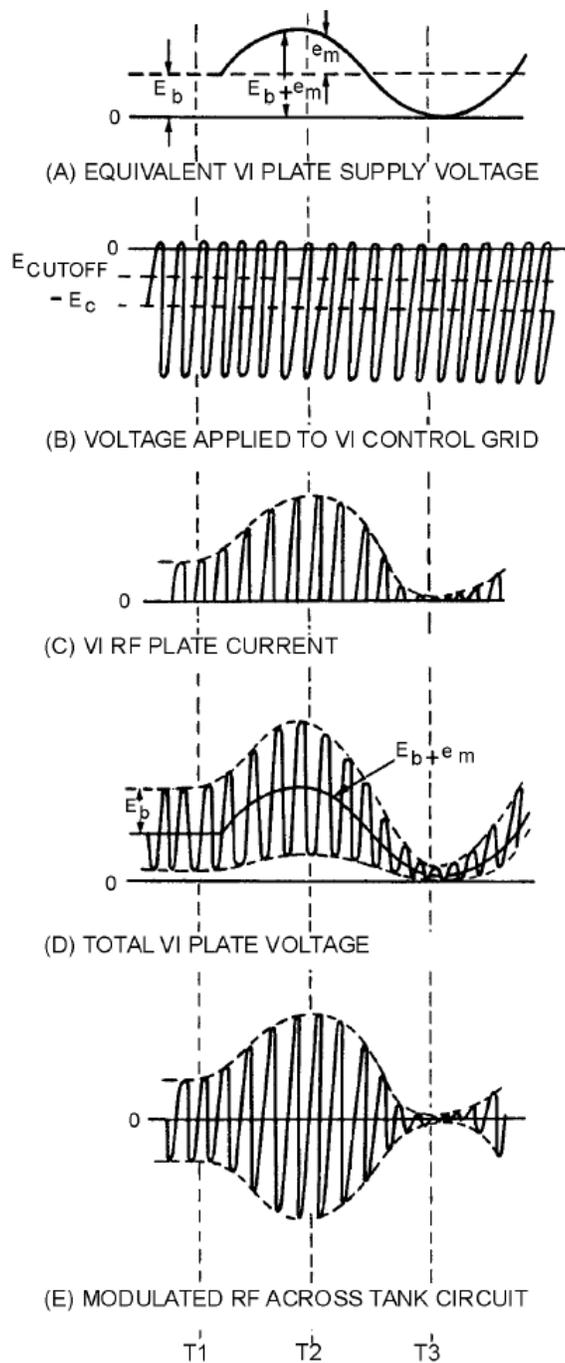
**Figure-1** below is a basic plate-modulator circuit. Plate modulation permits the transmitter to operate high efficiency operation of the amplifying device. It is the simplest of the modulators available and is also the easiest to adjust for proper operation. The modulator is coupled to the plate circuit of the final RF amplifier through the modulation transformer. **For 100-percent modulation, the modulator must supply enough power to cause the plate voltage of the final RF amplifier to vary between '0' and twice the DC operating plate voltage.** The Modulator Vacuum Tube (V2) is a power amplifier biased in the linear portion of its operating range so that it operates Class A. The final RF Power Amplifier Vacuum Tube (V1) is biased in the nonlinear portion of its operating range and operates Class C. This provides for efficient operation of V1 and produces the necessary heterodyning action between the RF carrier wave and the AF modulating wave frequencies.

The RF power amplifier (V1) acts as a class C amplifier when no modulation is present in the plate circuit. V2 is the modulator, which transfers the modulating wave voltage to the plate circuit of V1. Let's see how this circuit produces a modulated RF output.



**Figure-1: Plate-modulation circuit.**

**Figure-2** below, views (A) through (E), shows the waveforms associated with the plate-modulator circuit shown in **Figure-1**. Refer to these two figures throughout the following discussion.



**Figure-2: Plate-modulator waveforms.**

View (A) of **Figure-2** shows the plate supply voltage for V1 as a constant DC value ( $E_b$ ) at time 1 (T1) with no modulating signal applied. V1 is biased at cutoff at this time. The incoming RF carrier wave [view (A)] is applied to the control grid of V1 by transformer T1 and causes the plate circuit current to PULSE (SURGE) each time the grid is driven positive. These RF pulses are referred to as current pulses and are shown in view (C). The plate tank output circuit (T3) is shocked into oscillation by these current pulses and the RF output waveform shown in view (E) is developed. The RF plate voltage waveform is shown in view (D).

An audio-modulating wave voltage applied to the control grid of V2 is amplified by the modulator and coupled to the plate of V1 by modulation transformer T2. The secondary of T2 is in series with the plate-supply voltage (E) of V1. The modulating wave voltage will either add

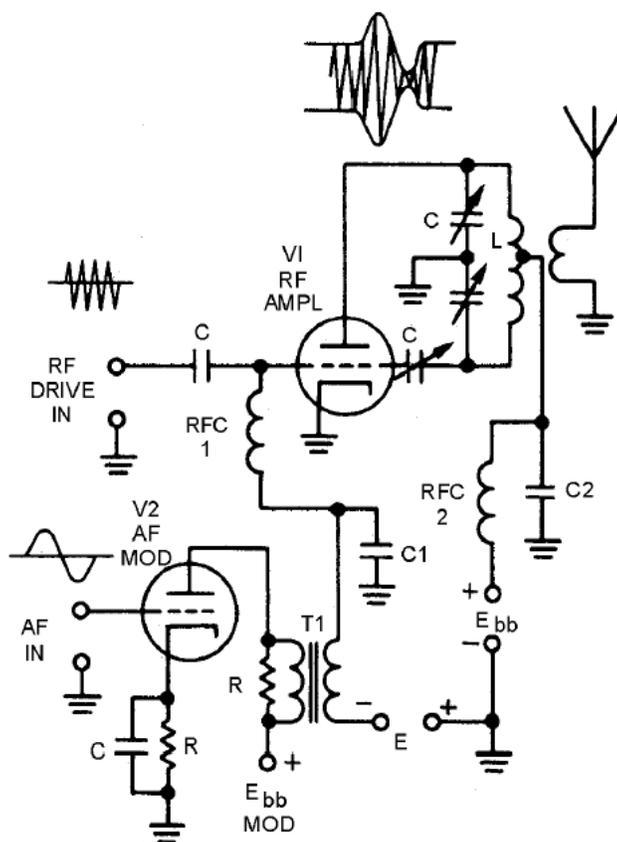
to or subtract from the plate voltage of V1. This is shown in view (A) at time 2 and time 3. At time 2 in view (A), the plate supply voltage for V1 increases to twice its normal value and the RF plate current pulses double, as shown in view (C). At time 3 in view (A), the supply voltage is reduced to '0' and the RF plate current decreases to '0', as shown in view (C). These changes in RF plate current cause RF tank T3 voltage to double at time 2 and to decrease to '0' at time 3, as shown in view (E). This action results in the modulation envelope shown in view (E) that represents 100-percent modulation. This is transformer-coupled out of tank circuit T3 to an antenna. Because of the oscillating action of tank circuit T3, V1 has to be rated to handle at least four times its normal plate supply voltage ( $E_b$ ), as shown by the plate voltage waveform in view (D).

Heterodyning the audio frequency wave intelligence from the modulator (V2) with the carrier wave in the plate circuit of the final power amplifier (V1) requires a large amount of audio power. **All of the power or voltage that contains the intelligence must come from the modulator stage. This is why plate modulation is called high-level modulation.**

The heterodyning action in the plate modulator effectively changes an audio frequency wave to a different part of the frequency spectrum. This action allows antennas and equipment of practical sizes to be used to transmit the intelligence. Now, let's look at several other typical modulators.

## Control-Grid Modulator

**In cases when the use of a minimum of AF modulator power is desired, a form of low-level modulation** is necessary. The CONTROL-GRID MODULATOR is used widely in portable and mobile equipment to reduce size and power requirements. It is also used in extremely high-power, wideband equipment such as television transmitters where high-level or plate modulation is difficult and costly to achieve. **Figure-3** below is a basic schematic for a typical control-grid modulator.



**Figure-3: Control-grid modulator.**

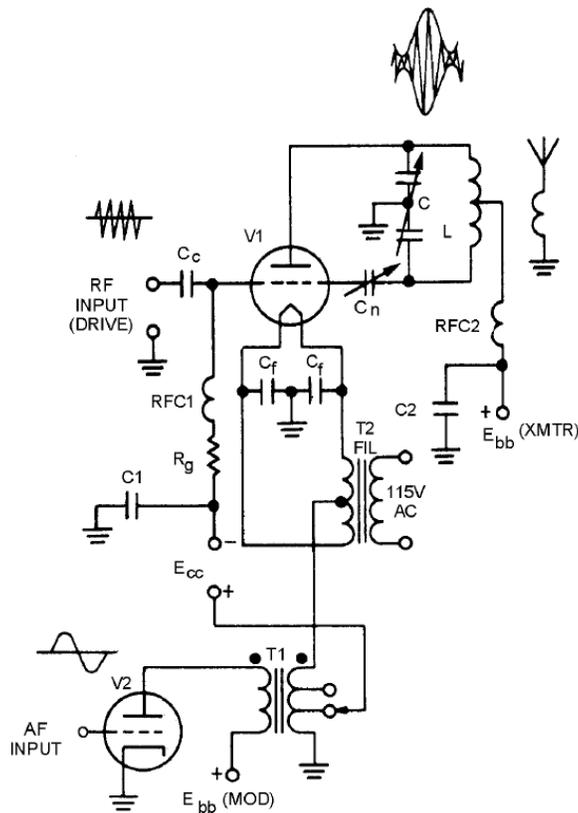
The control-grid modulator uses a variation of control grid bias (at the frequency of the modulating signal) to vary the instantaneous plate voltage and current. These variations cause modulation of the carrier frequency. The carrier frequency is introduced through coupling capacitor  $C_c$ . The modulating frequency is introduced in series with the control grid bias through  $T1$ . As the modulating signal increases and decreases (positive and negative), it will add to or subtract from the bias on RF amplifier  $V1$ . This change in bias causes a corresponding change in plate voltage and current. These changes in plate voltage and current add vectorially to the carrier frequency and provide a modulation envelope in the same fashion, as does the plate modulator. Since changes in the plate circuit of the RF amplifier are controlled by changes in the control grid bias, the gain of the tube requires only a low-level modulating signal. Even when the input signals are at these low levels, occasional modulation voltage peaks will occur that will cause  $V1$  to saturate. This creates distortion in the output. Care must be taken to bias the RF amplifier tube for maximum power out while maintaining minimum distortion. The power to develop the modulation envelope comes from the RF amplifier. Because the RF amplifier has to be capable of supplying this additional power, it is biased for (and driven by the carrier frequency at) a much lower output level than its rating. This reduced efficiency is necessary during nonmodulated periods to provide the tube with the power to develop the sidebands.

Compared to plate modulation, control grid modulation is less efficient, produces more distortion, and requires the RF power amplifier to supply all the power in the output signal. Control Grid modulation has the advantage of not requiring much power from the modulator.

# Cathode Modulator

Another **low-level modulator**, the CATHODE MODULATOR, is generally employed where the Audio power is limited and distortion of the control grid-modulated circuit cannot be allowed. The cathode modulator varies the voltage of the cathode to produce the modulation envelope. Since the cathode is in series with the grid and plate circuits, you should be able to see that changing the cathode voltage will effectively change the voltage of the other tube elements. By properly controlling the voltages on the tube, you can cause the cathode modulator to operate in a form of plate modulation with high efficiency. Usually, the cathode modulator is designed to perform about midway between plate and grid modulator levels, using the advantages of each type. When operated between the two levels, the modulator provides a more linear output with moderate efficiency and a modest audio power requirement.

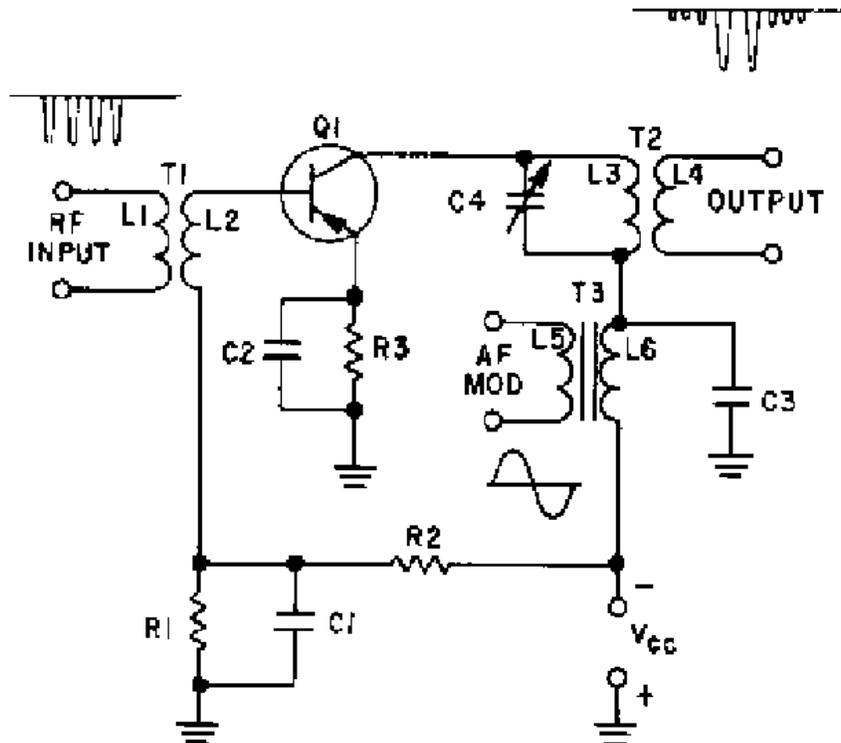
In **Figure-4** below, the RF carrier is applied to the control grid of V1 and the modulating signal is applied in series with the cathode through T1. Since the modulating signal is effectively in series with the grid and plate voltage, the level of modulating voltage required will be determined by the relationships of the three voltages. The modulation takes place in the plate circuit with the plate tank developing the modulation envelope, just as it did in the plate modulator.



**Figure-4: Cathode modulator**

## Collector-Injection Modulator

The **COLLECTOR-INJECTION MODULATOR** is the **transistor equivalent of the Vacuum Tube Plate Modulator**. This transistor modulator can be used for low-level or relatively high-level modulation. It is referred to as relatively high-level modulation because, at the present time, transistors are limited in their power-handling capability. As illustrated in **Figure-5** below, the circuit design for a transistor collector injection modulator is very similar to that of a plate modulator. The collector-injection modulator is capable of 100-percent modulation with medium power-handling capabilities.



**Figure-5: Collector-injection modulator.**

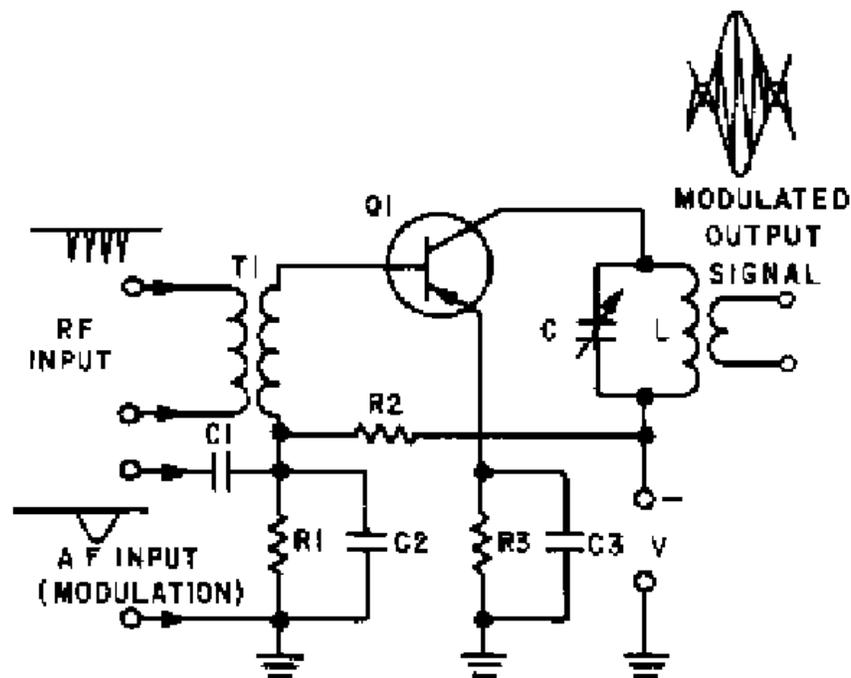
In **Figure-5**, the RF carrier wave is applied to the base of modulator Q1. The modulating signal wave is applied to the collector in series with the collector supply voltage through T3. The output is then taken L4 (from the secondary of T2). With no modulating signal, Q1 acts as an RF amplifier for the carrier frequency. When the modulation signal wave is applied, it adds to or subtracts from the collector supply voltage. This causes the RF current pulses of the collector to vary in amplitude with the collector supply voltage. These collector current pulses cause oscillations in the tank circuit C4 and L3 (the primary of T2). The tank circuit is tuned to the carrier wave frequency. During periods when the collector current is high, the tank circuit oscillates strongly. At times when the collector current is small, or entirely absent, little or no energy is supplied to the tank and oscillations become weak or die out. Thus, the modulation envelope is developed as it was in a plate modulator.

As transistor technology continues to develop, higher power applications of transistor collector injection modulation will be employed. Plate and collector-injection modulation are the most commonly used types of modulation because the modulating signal can be applied in the final stages of RF amplification. This allows the majority of the RF amplifier stages to be operated class C for maximum efficiency. The plate and collector-injection modulators also require large

amounts of AF modulating power since the modulator stage must supply the power contained in the sidebands.

## Base-Injection Modulator

The **BASE-INJECTION MODULATOR** is the transistor equivalent of the Vacuum Tube Control-Grid Modulator. It is used to produce low-level modulation in equipment operating at very low power levels. In **Figure-6** below, the bias on Q1 is established by the voltage divider R1 and R2. With the RF carrier input at T1, and no modulating signal, the circuit acts as a standard RF amplifier. When a modulating signal is injected through C1, it develops a voltage across R1 that adds to or subtracts from the bias on Q1. This change in bias changes the gain of Q1, causing more or less energy to be supplied to the collector tank circuit. The tank circuit develops the modulation envelope as the RF frequency and AF modulating frequency are mixed in the collector circuit. Again, this action is identical to that in the plate modulator.



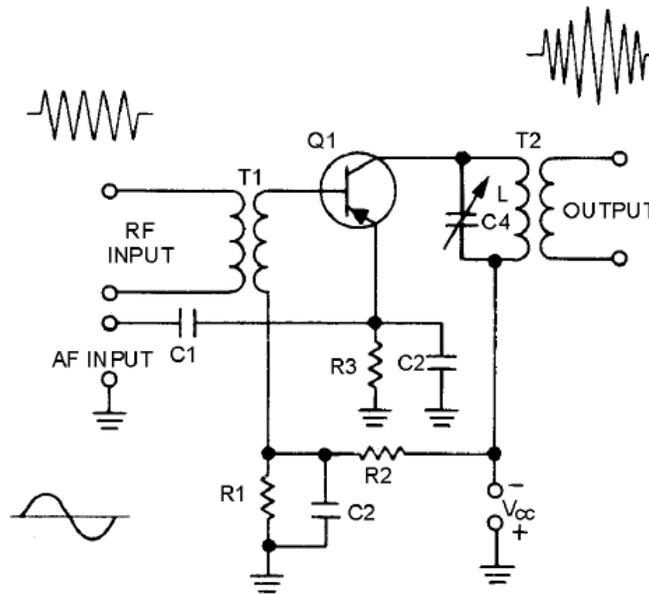
**Figure-6: Base-injection modulator**

Because of the extremely low-level signals required to produce modulation, the Base-Injection Modulator is well suited for use in small, portable equipment, such as "walkie-talkies," and test Equipment.

You have studied six methods of amplitude modulation. These are not the only methods available, but they are the most common. All methods of AM modulation use the same theory of heterodyning across a nonlinear device. AM modulation is one of the easiest and least expensive types of modulation to achieve. The primary disadvantages of AM modulation are susceptibility to noise interference and the inefficiency of the transmitter. Power is wasted in the transmission of the carrier frequency because it contains no AM intelligence. In the next chapter, you will study other forms of modulation that have been developed to overcome these disadvantages.

# Emitter-Injection Modulator

The **EMITTER-INJECTION MODULATOR** is the **transistor equivalent of the Vacuum Tube Cathode Modulator**. The EMITTER-INJECTION MODULATOR has the same characteristics as the Base-Injection Modulator discussed earlier. It is an extremely low-level modulator that is useful in portable equipment. In emitter-injection modulation, the gain of the RF amplifier is varied by the changing voltage on the emitter. The changing voltage is caused by the injection of the modulating signal into the emitter circuitry of Q1, as shown in **Figure-7** below. Here the modulating voltage adds to or subtracts from transistor biasing. The change in bias causes a change in collector current and results in a heterodyning action. The modulation envelope is developed across the collector-tank circuit.



**Figure-7: Emitter-Injection Modulator**