Generation of Amplitude Modulated Signals

AM Modulation

OBJECTIVES

The purpose of this experiment is to show how the amplitude-modulated signals are generated and the importance of it. This experiment will show the AM DSB and AM DSB SC cases. Also, in this experiment you will be able to see the modulated signal in the oscilloscope and its power spectrum.

EQUIPMENT LIST

1. Spectrum analyzer
2. N to BNC connector adapter.
3. Spectrum and signal generator cables
4. Oscilloscope with probes
5. Arbitrary function generator
6. ANACOM 1/1 trainer
7. Power supply with cables
8. Microphone

DISCUSSION

Modulation is a process that causes a shift of the range of frequencies in a signal. It is used to facilitate transmission over a given channel. Baseband signals produced by various information sources are not always suitable for direct transmission over a given channel. These signals are usually further modified to facilitate transmission. This conversion process is known as modulation. In this process the baseband signal is used to modify some parameter of a high frequency carrier signal.

A carrier is a sinusoid of high frequency, and one of the parameters such as amplitude, frequency or phase is varied in proportion to the baseband signal \( m(t) \). In AM modulation the amplitude of the carrier is modified in proportion to the baseband. A baseband signal is used to designate the band of frequencies of the signal delivered by the source.

Another advantages of modulation are the ease of radiation of electromagnetic energy allowing antenna sizes to be reasonable and simultaneous transmission of several signals over the same channel.

Amplitude Modulation: Double Sideband Suppressed Carrier (DSB-SC)

In amplitude modulation, the amplitude \( A_c \) of the unmodulated carrier \( A_c \cos(\omega_c t + \theta_c) \) is varied in proportion to the baseband signal (known as modulating signal). The frequency \( \omega_c \) and the phase \( \theta_c \) are constant. We can assume \( \theta_c=0 \) to simplify the analysis.
If the carrier amplitude $A_c$ is made directly proportional to the modulating signal $m(t)$, the modulated carrier is

$$m(t) \cos(\omega_c t)$$

This type of modulation simply shifts the spectrum of $m(t)$ to the carrier frequency (see figure 1; that is, if

$$m(t) \leftrightarrow M(\omega)$$

$$m(t) \cos(\omega_c t) \leftrightarrow \frac{1}{2} [M(\omega + \omega_c) + M(\omega - \omega_c)]$$

![Figure 1](image)

The bandwidth of the modulated signal is $2B$ Hz, which is twice the bandwidth of the modulating signal $m(t)$. From the figure, we observe that the modulated carrier spectrum centered at $\omega_c$ is composed of two parts: a portion that lies above $\omega_c$, known as the upper sideband (USB), and a portion that lies below $\omega_c$, known as the lower sideband (LSB). Similarly, the spectrum centered at $-\omega_c$, has upper and lower sidebands.

For instance, if $m(t) = \cos(\omega_m t)$, then the modulated signal

$$m(t) \cos(\omega_c t) = \cos(\omega_m t) \cos(\omega_c t)$$

$$= \frac{1}{2} [\cos((\omega_c + \omega_m) t) + \cos((\omega_c - \omega_m) t)]$$

The component of frequency $\omega_c + \omega_m$ is the upper sideband and that of frequency $\omega_c - \omega_m$ is the lower sideband. Thus, each component of frequency $\omega_m$ in the modulating signal gets translated into two components, of frequencies $\omega_c + \omega_m$ and $\omega_c - \omega_m$, in the modulating signal. Note that the modulated signal $m(t)\cos(\omega_c t)$, from the above equation, has components of frequencies $\omega_c \pm \omega_m$ but not have a component of the carrier.
frequency $\omega_c$. For this reason, this scheme is referred to as double-sideband-suppress-carrier.

**Amplitude Modulation: Double Sideband Transmitted Carrier (DSB)**

We now explore a modification of the AM DSB-SC modulation where we add a portion of the pure sinusoidal carrier to the modulated waveform. We will see that this addition greatly simplifies the demodulation process. The block diagram is shown in figure 2.

![Figure 2](image_url)

The resulting waveform is given by

$$s_m(t) = s(t)\cos(\omega_c t) + A\cos(\omega_c t)$$

The Fourier transform of transmitted carrier AM is the sum of the Fourier transform of suppressed carrier AM with the Fourier transform of the pure carrier. The transform of the carrier is a pair of impulses at $\pm f_c$ in frequency. The complete transform of the AM wave is therefore as shown in figure 3. Figure 4 shows the time waveform.

![Figure 3](image_url)

![Figure 4](image_url)
Modulation Factor

A modulating wave that has low amplitude will produce a smaller amplitude variation in the modulated wave than a high amplitude modulating wave will. This fact gives to a need for expressing the degree of modulation produced by a wave of some particular amplitude. This is expressed by a ratio called the modulation factor, $M_a$. The modulation factor is simply the ratio of the peak amplitude variation used ($A_m$) to the maximum design variation ($A_c$). Under proper operating conditions $A_m$ will always equal or less than $A_c$, therefore, the modulation factor, $M_a$ will not be allowed to exceed unity. See figure 5.

$$M_a = \frac{A_m}{A_c} = \frac{E_{\text{max}} - E_{\text{min}}}{E_{\text{max}} + E_{\text{min}}} \times 100$$

AM Spectrum

It has been shown that when modulating with a single frequency, a modulated wave is generated. This complex wave consists of three frequencies: the carrier, a sum
frequency (upper side band) and a difference frequency (lower sideband). These three components of the modulated wave constitute the spectrum of the AM modulated wave when the modulating wave is but a single frequency. See figure 6.

When the modulating wave consists of more than a single frequency (which is the usual case), each of the components of the complex modulating wave must create its own pair of side frequencies during the modulation process. See figure 7.

The upper sideband is an exact replica of the spectrum of the modulating wave. The spacing between spectral components is the same in the upper sideband as the modulating wave. Since the spacing of all components of the upper sideband are identical to those same relationship among the harmonics in the modulating wave, it can
be readily concluded that both the modulating wave and the upper sideband contain exactly the same bandwidth.

The lower sideband is an inverted replica of the spectrum of the modulating wave. This fact makes everything that was said about the upper sideband true of the lower sideband also, except that the order of components is reversed.

**AM Generation Circuits**

In this experiment we are going to use a Balanced modulator to modulate our input signal. Figure 8 shows a typical balanced modulator block diagram. We can generate the DSB-SC signal using two such generators in a balanced configuration that will suppress the carrier term.

![Figure 8](image)

**PROCEDURE**

1. Connect the power supply to the trainer with all equipment turned off. Follow the following diagram.

![Power Supply Diagram](image)

2. Select the following conditions in the trainer
   a. Audio Input Select : EXT
   b. Mode : DSB
   c. Output Amplifier Gain : Maximum in clockwise direction
   d. Speaker Switch : OFF

3. Set the signal generator to a sinusoidal wave with frequency of 10 kHz and amplitude of 2 Vpp. This signal will be the modulating signal. Connect the signal generator to test point 16.
4. In the BALANCED MODULATOR AND BANDPASS FILTER CIRCUIT I block set the Balance dial to the maximum position. This secure maximum power to the carrier.

5. Connect the oscilloscope’s probe to **test point 9**. This signal is the **carrier**. Determine its frequency and draw oscilloscope output indicating the signal frequency. Determine the peak voltage value.

\[ V_p = \quad \text{__________} \]
\[ f = \quad \text{__________} \]

6. Disconnect the oscilloscope of test point 9. Connect the Spectrum analyzer in **test point 1** and ground. Set Center frequency to 10 kHz and Span to 10 kHz. Did you see the modulating frequency spectrum? Determine the peak power level (dBm). Print the spectrum.

\[ P_{\text{peak}} = \quad \text{__________} \]

7. Connect the Spectrum analyzer to **test point 9**. Set Center frequency with the frequency determined in step 5 and Span to 50 kHz. Did you see the carrier frequency spectrum? Determine the peak power level (dBm).

\[ P_{\text{peak}} = \quad \text{__________} \]

8. Connect the spectrum analyzer in **test point 11**. Set the Center frequency to 1 MHz and Span of 50 kHz. Did you see the modulated signal frequency spectrum? Determine the frequency and power level of the USB and LSB components. Also, determine the power level of the carrier. Record in table 1.

9. Connect the Spectrum analyzer in **test point 12**. Set the Center frequency to 1 MHz and Span of 50 kHz. Determine the power level of the carrier and the sideband components. Record in table 1.

10. Connect the oscilloscope’s probe to **test point 11**. Determine the percentage modulation.

\[ A = \quad \text{__________} \]
\[ B = \quad \text{__________} \]
\[ \%m = \quad \text{__________} \]
11. Connect the spectrum analyzer in **test point 11**. Determine the percentage modulation.

\[ \%m = \ldots \]

12. Set the **BALANCE** of the **BALANCED MODULATOR & BANDPSS FILTER CIRCUIT 1** to the middle position. This is the case of DSB-SC modulation.


14. Turn off the power supply and connect the microphone with the external audio input and the trainer. Connect the power supply to the external audio amplifier. Change the **AUDIO INPUT SELECT switch** to **EXT**. Connect oscilloscope channel one to point test 1 and channel 2 to point test 3. Try to tune a note with your voice and determine the maximum frequency. Look how speech looks like in the oscilloscope.

\[ F_{\text{max}} = \ldots \]

**RESULTS**

*Table 1: DSB Case*

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Power Level (dBm)</th>
<th>Power Level (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_m = ) @ 1 =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_c = ) @ 9 =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_c+F_m = ) @ 11 = @ 12 =</td>
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<td></td>
</tr>
<tr>
<td>( F_c-F_m = ) @ 11 = @ 12 =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_c = ) @ 11 = @ 12 =</td>
<td></td>
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</tbody>
</table>

*Table 2: DSB-SC Case*

<table>
<thead>
<tr>
<th>Frequency</th>
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<tr>
<td>( F_c = ) @ 11 = @ 12 =</td>
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</tbody>
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\[ @ = \text{test point #} \]

**QUESTIONS**

1. Calculate the output amplifier gain in dB (step 9). **Hint**: Subtract the carrier power level of test point 12 and test point 11.

2. Calculate the modulation factor. Explain this result.

3. Compare your results between the DSB and DSB-SC cases.