

AMPLITUDE MODULATION - AM

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AMPLITUDE MODULATION - AM

ACHIEVEMENTS: *introduction to amplitude modulation - AM*

PREREQUISITES: *familiarisation with TIMS; completion of the experiment entitled **Getting Started with TIMS** would be an advantage.*

Introduction

In this experiment you will model an AM generator, making a signal of the type transmitted by your local AM broadcasting station.

The important property of an AM signal is that the shape of its envelope is the same as the shape of the message.

You will later be able to choose the message (program material) by selecting it from the signals available at the TRUNKS panel on your TIMS SYSTEM UNIT. But first you will use a single tone from an AUDIO OSCILLATOR, since this results in 'text book' oscilloscope pictures and stable displays for measurement purposes.

Modelling the AM Generator

You can model an AM generator with the arrangement of Figure 1.

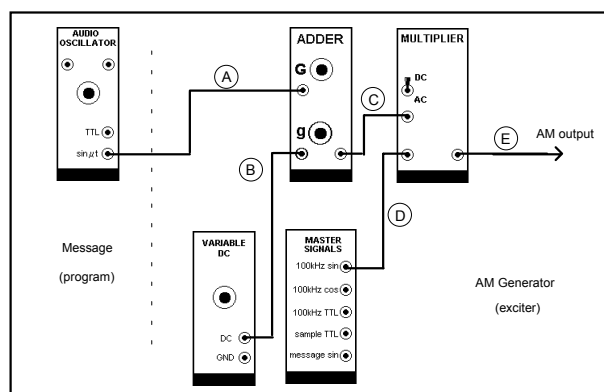


Figure 1: AM Generator.

This model uses a single sine wave - a 'tone' - as the message (or program) to be transmitted. This is a very convenient type of signal for initial setting-up, as it results in easy-to-recognise oscilloscope pictures, although not very interesting as a 'program'. After setting up, it will be possible for you to use speech or music.

The module inter-connections in Figure 1 have been labelled. The waveforms and amplitudes at these points, for 100% depth of amplitude modulation, are illustrated in Table 1. In first setting up the experiment you should duplicate these voltages.

The signal labelled (A) is the message, and its amplitude can be controlled with the gain control *G* of the ADDER. This should be considered as the *depth of modulation* control.

To commence the experiment:

T1: patch up the system of Figure 1. Make sure the MULTIPLIER front panel AC/DC switch is set to DC.

It is now necessary to adjust the amplitude of the voltage from the VARIABLE DC supply, and the gain controls of the ADDER. When you have finished, the various voltages and waveforms should be as shown in Table 1 below. You can either work straight from Table 1, or follow the tasks 2 to 7 below.

T2: rotate the control on the VARIABLE DC module fully clockwise. This will provide an output of about +2 volt, but the exact amplitude is not critical. If you want to measure it exactly, as a matter of interest, you could set it to 2 volts as suggested in Table 1 below.

T3: check that the output from the AUDIO OSCILLATOR is at the approximate TMS STANDARD REFERENCE LEVEL (2 v peak), and adjust its frequency to about 1 kHz by checking with the FREQUENCY COUNTER.

Now it is necessary to adjust their relative values, at the *output* of the ADDER, to *exact equality*. This will result in a depth of modulation of *exactly* 100%.

Reference to Table 1, waveform 'C', shows that this equality will be achieved if the troughs of the message sine wave fall to precisely zero volts.

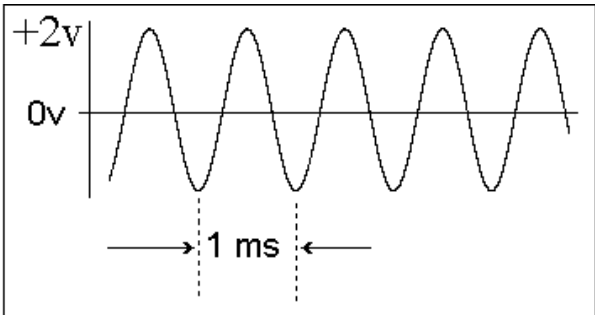
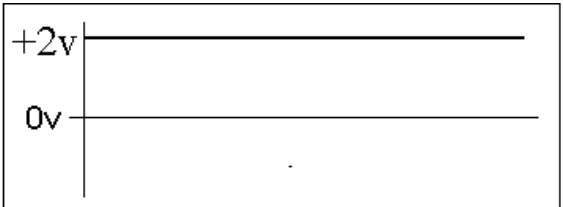
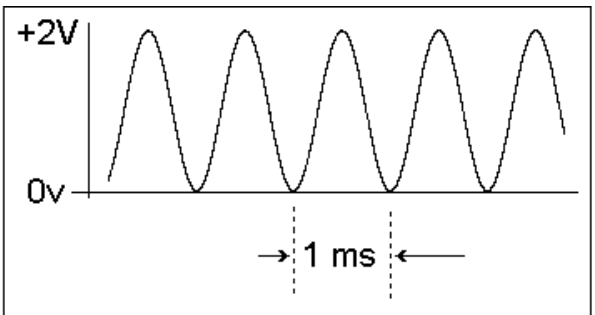
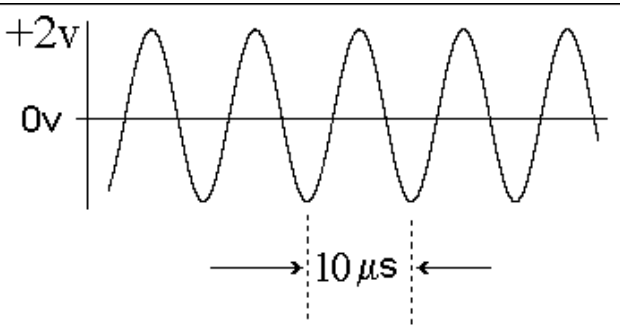
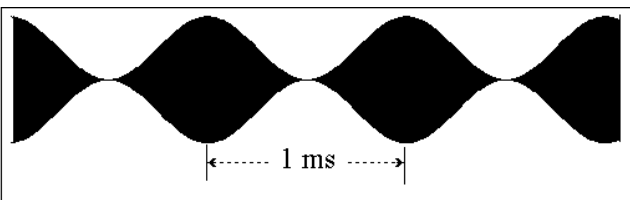
A	a 1 kHz message from the AUDIO OSCILLATOR. Amplitude will be about 2V peak, or the TIMS STANDARD REFERENCE LEVEL.	
B	a DC voltage adjusted to about 2V	
C	the AC message and the DC voltage have been added, and their amplitudes adjusted so they are <i>exactly</i> the same (1 volt) at the ADDER output.	
D	the 100 kHz carrier waveform from the MASTER SIGNALS module. The amplitude will be about 2V peak, or the TIMS STANDARD REFERENCE LEVEL.	
E	the 100% modulated AM signal. Amplitude will be about 2 volt peak.	

Table 1: generator waveforms

T4: connect the oscilloscope to the output of the ADDER. Make sure it is switched to accept 'DC' input. Adjust the gain control 'G' of the ADDER until the sinewave at the output has an amplitude of approximately 1 volt peak.

T5: vary the DC voltage magnitude with the gain control 'g' of the ADDER. Notice that the sine wave will move up and down as the DC is varied, its mean value equalling the DC value. Set 'g' so that the sinewave peaks just fall to zero.

The ratio of AC (sine wave) to DC, at the ADDER output, is now exactly unity, the condition for 100% AM.

T6: check that there is a 100 kHz sinewave, at about the TIMS STANDARD REFERENCE LEVEL, at one input to the MULTIPLIER (waveform 'D' of Table 1).

T7: now check that, at the output of the MULTIPLIER, there is, as predicted, a 100% amplitude modulated waveform, similar to that of waveform 'E' of Table 1.

The AM generator, or 'exciter', as such a low power source of modulated signal is often called, is now set up.

The depth of modulation, defined below, can be adjusted with the ADDER gain control 'G'.

Depth of Amplitude Modulation - 'm'

When you have completed the previous work you will be displaying a picture like that of 'E' in Table 1.

This is described as a '100% amplitude modulated' signal.

As the amplitude of message is reduced then the depth of modulation is reduced. You can observe this by reducing the amplitude of the message with the control **G** on the ADDER.

T8: rotate the gain control **G** on the ADDER, first in an anti-clockwise direction. You should see the amplitude modulated signal change according to the shapes shown in Figure 2 below. For comparison, the message waveform is also shown.

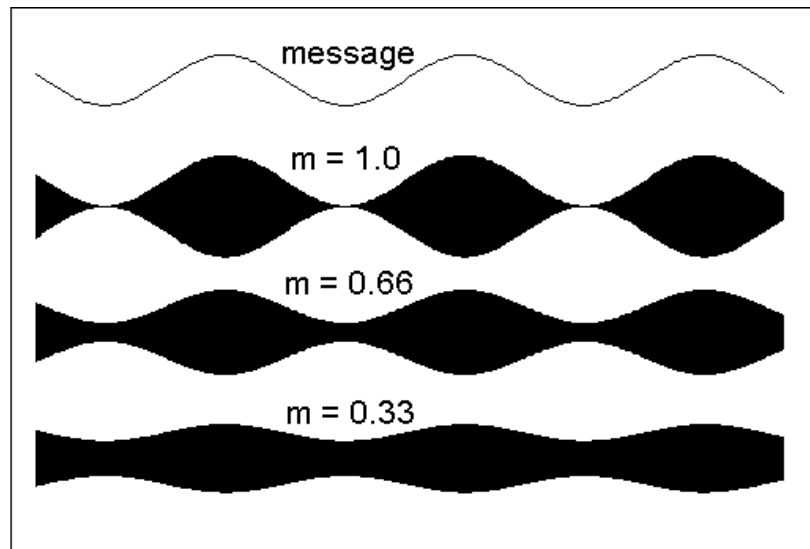


Figure 2: different values for ‘m’

Intuitively you can see that the depth of the trough in the shape is reduced.
The depth of modulation is defined as ‘m’, where:

$$m = \frac{\text{amplitude of AC component}}{\text{amplitude of DC component}}$$

the AC and DC component amplitudes being measured at the input to the MULTIPLIER (or the output of the ADDER). Note that the ratio is exactly unity, thus setting $m = 1$, in waveform C of Table 1.

In practice ‘m’ is usually expressed as a percentage, by multiplying it by 100.

Thus, when $m = 1$, the depth of modulation is 100%

measurement of ‘m’

The magnitude of ‘m’ can be measured directly from the AM display itself.

Thus:

$$m = \frac{P - Q}{P + Q} \quad \dots\dots\dots 1$$

where P and Q are as defined in Figure 3.

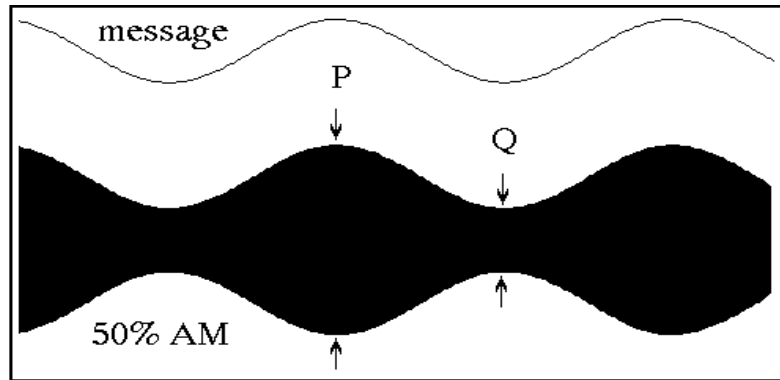


Figure 3: the oscilloscope display for the case $m = 0.5$

When the message is a sine wave it is easy to set up the conditions for $m = 1$. But how is it done for messages of other shapes ?

other message shapes.

It can be shown that the envelope of the AM will always be a faithful copy of the message provided $m \leq 1$. Thus, to ensure this, make sure that:

for the envelope to be the same shape as the message the peak amplitude of the AC component must not exceed the magnitude of the DC at the input to the MULTIPLIER

This is easy to understand, but how easy is it to achieve, with say speech as the message ?

T9: replace the output from the AUDIO OSCILLATOR with a speech or music signal, available at TRUNKS.

T10: adjust the depth of modulation, using the ADDER gain control ' G ', to 100% AM.

If you found that difficult, or uncertain, that is normal. But there is another way to achieve the desired result.

The Modulation Trapezoid

With the display method already examined, and with a sinusoidal message, it is easy to set the depth of modulation to any value of ' m '. This method is less convenient for other messages, especially speech or music.

The so-called *trapezoidal display* is a useful alternative for more complex messages. The patching arrangement for obtaining this type of display is illustrated in Figure 4 below, and will now be examined.

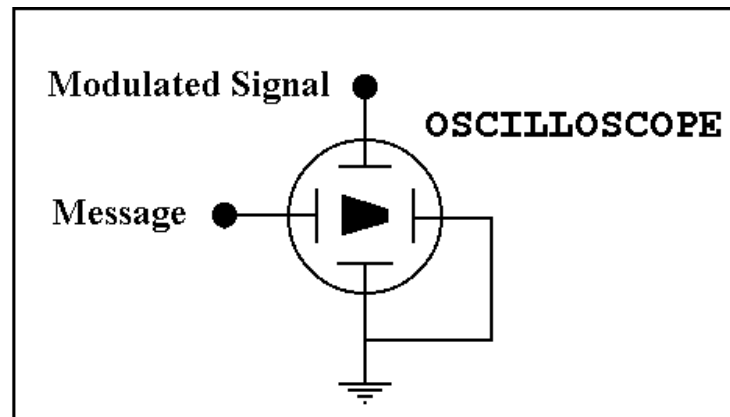


Figure 4: the arrangement for producing the TRAPEZOID

T11 patch up the arrangement of Figure 4. Note that the oscilloscope will have to be switched to the 'X - Y' mode; the internal sweep circuits are not required.

T12 with a sine wave message show that, as m is increased from zero, the display takes on the shape of a TRAPEZOID (Figure 7).

T13 show that, for $m = 1$, the TRAPEZOID degenerates into a TRIANGLE

T14 show that, for $m > 1$, the TRAPEZOID extends beyond the TRIANGLE, into the dotted region as illustrated in Figure 5

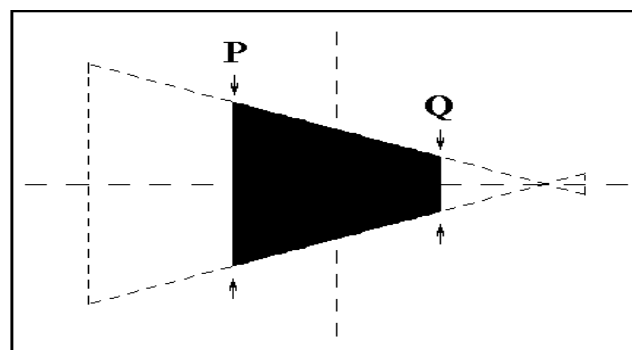


Figure 5: the AM trapezoid for $m = 0.5$. The trapezoid extends into the dotted section as m is increased to 1.2 (120%).

So here is another way of setting $m = 1$. But this was for a sinewave message, where you already have a reliable method. The advantage of the trapezoid technique is that it is especially useful when the message is other than a sine wave - say speech or music.

T15 use speech or music (from TRUNKS) as the message, and show that this also generates a TRAPEZOID, and that setting the message amplitude so that the depth of modulation reaches unity on peaks (a TRIANGLE) is especially easy to do, using the gain control **G** of the ADDER.

PRACTICAL NOTE: if the outline of the trapezoid is not made up of straight-line sections then this is a good indicator of some form of distortion. For $m < 1$ it could be phase distortion, but for $m > 1$ it could also be overload distortion.

Phase distortion is not likely with TMS, but in practice it can be caused by long leads to the oscilloscope, especially at higher carrier frequencies.

Tutorial Questions

Q1 notice that 'this AM generator can produce depths of modulation exceeding 100% without introducing distortion'. Do you agree with this statement? Sketch the waveform of a 120% amplitude modulated signal.

Q2 what is the purpose of the 'AC/DC' switch on the MULTIPLIER.

Q3 suppose the generator output was a 2 volt peak-to-peak 100% amplitude modulated signal, with the message being a 1 kHz sine wave. Sketch this, showing time and amplitude scales. Now sketch, using the same amplitude and time scales, the output waveform which would result if the MULTIPLIER AC/DC switch was changed to AC.

Q4 what would the FREQUENCY COUNTER indicate if it was connected to the waveforms of Figure 2, starting with (for example) the top (message) waveform. Explain.

