

Envelope and Envelope Recovery:

Aim:

Definition and examination of envelopes; the envelope of a wideband signal. The ideal 'envelope detector' is defined, and then modelled.

Introduction:

Envelope Definition:

Qualitatively, the envelope of a signal $y(t)$ is that boundary within which the signal is contained, when viewed in the time domain. *It is an imaginary line.*

This boundary has an upper and lower part. You will see these are mirror images of each other. In practice, when speaking of the envelope, it is customary to consider only one of them as 'the envelope' (typically the upper boundary).

Although the envelope is imaginary in the sense described above, it is possible to generate, from $y(t)$, a signal $e(t)$, having the same shape as this imaginary line. The circuit which does this is commonly called an *envelope detector*.

Suppose the spectrum of the signal $y(t)$ is located near f_0 Hz, where:

$$\omega = 2\pi f_0 \quad \dots\dots 1$$

We state here, without explanation, that *if $y(t)$ can be written in the form:*

$$y(t) = a(t) \cdot \cos[\omega t + \phi(t)] \quad \dots\dots 2$$

where $a(t)$ and $\phi(t)$ contain only frequency components much lower than f_0 (ie., at message, or related, frequencies), *then we define* the envelope $e(t)$ of $y(t)$ as the absolute value of $a(t)$.

That is,

$$\text{envelope } e(t) = |a(t)| \quad \dots\dots 3$$

Remember that an AM signal has been defined as:

$$y(t) = A.(1 + m \cdot \cos \mu t) \cdot \cos \omega t \quad \dots\dots 4$$

Example 1: 100% A.M

Consider first the case when $y(t)$ is an AM signal.

From the definitions above we see:

$$a(t) = A.(1 + m \cdot \cos \mu t) \quad \dots\dots 5$$

$$\phi(t) = 0 \quad \dots\dots 6$$

The requirement that both $a(t)$ and $\varphi(t)$ contain only components at or near the message frequency are met, and so it follows that the envelope must be $e(t)$, where:

$$e(t) = |A(1 + m \cos \mu t)| \quad \text{..... 7}$$

For the case $m \leq 1$ the absolute sign has no effect, and so there is a linear relationship between the message and envelope, as desired for AM.

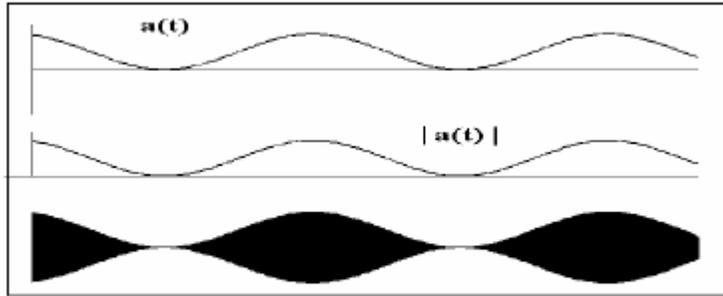


Figure 1: AM, with $m = 1$

This is clearly shown in Figure 1, which is for 100% AM ($m = 1$). Both $a(t)$ and its modulus is shown. They are the same.

Example 2: 150% A.M

For the case of 150% AM the envelope is still given by $e(t)$ of eqn. 7, but this time $m = 1.5$, and the absolute sign does have an effect.

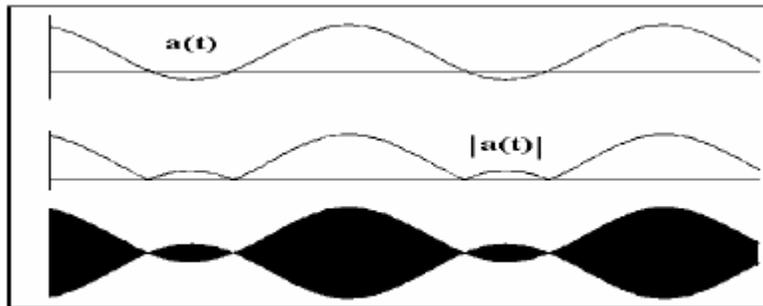


Figure 2: 150% AM

Example 3: DSBSC

For a final example look at the DSBSC, where $a(t) = \cos \mu t$. There is no DC component here at all. Figure 3 shows the relevant waveforms.

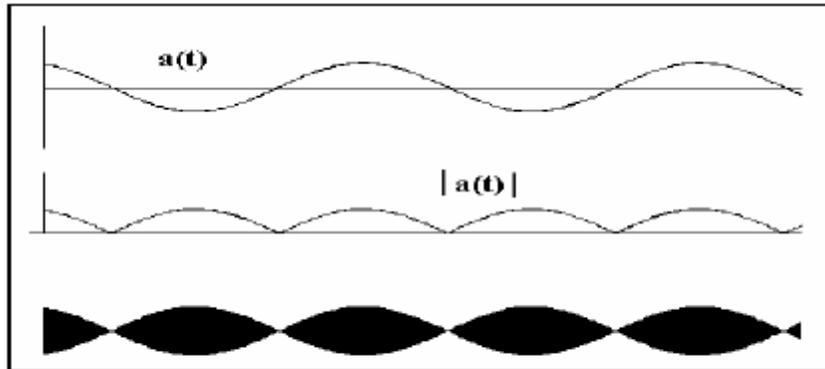


Figure 3: DSBSC

Experimental Procedure:

The validity of the envelope definition can be tested experimentally. The arrangement of Figure 4 will serve to make some envelopes for testing.

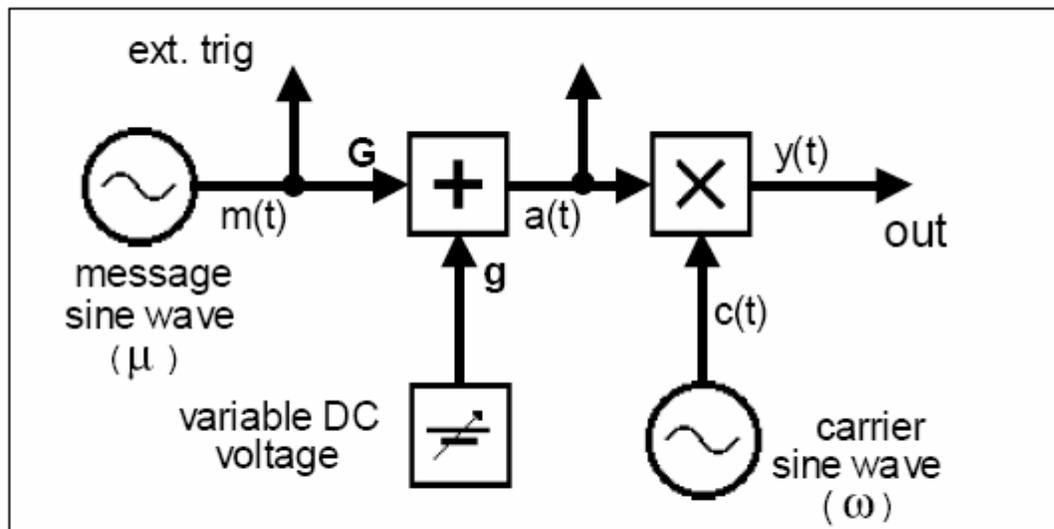


Figure 4: a test signal generator

T1 patch up the model of Figure 4, to generate 100% AM, with the frequency of the AUDIO OSCILLATOR about 1 kHz, and the high frequency term at 100 kHz coming from the MASTER SIGNALS module.

T2 make sure that the oscilloscope display is stable, being triggered from the message generator. Display $a(t)$ - the message including the DC component - on the oscilloscope

channel (CH1-A), and $y(t)$, the output signal, on channel (CH2-A). Your patching arrangements are shown in Figure 5 below.

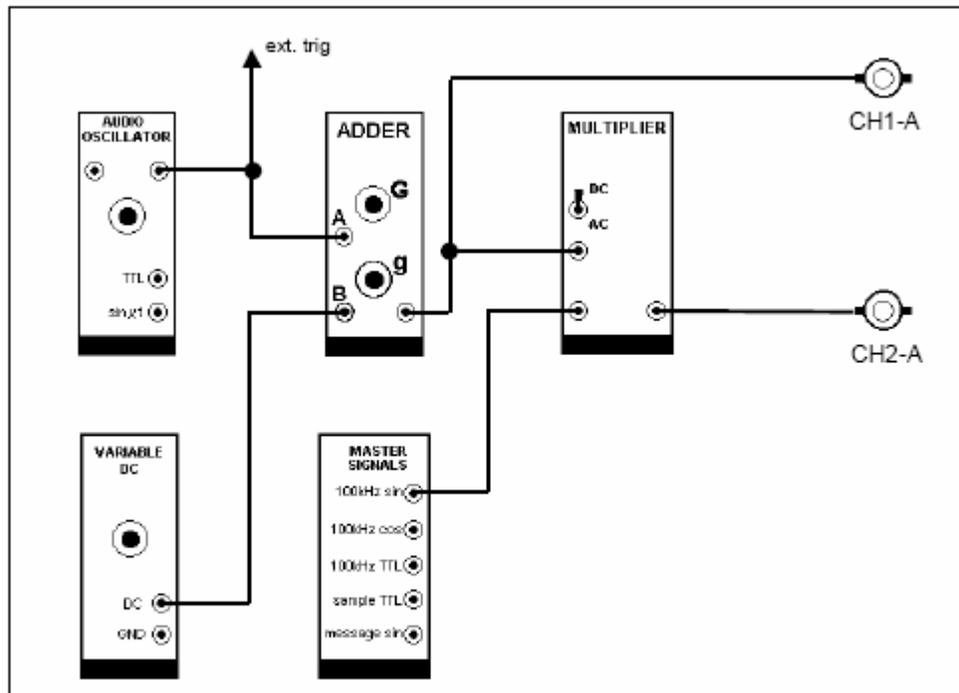


Figure 5: the generator modelled by TIMS

T3 confirm that, for the case $m \leq 1$ the value of $e(t)$ is the same as that of $a(t)$, and so the envelope has the same shape as the message.

T4 set $m = 1.5$ and reproduce the traces of Figure 2.

T5 remove the DC term from the ADDER; this makes the output signal a DSBSC. Confirm that the analysis gives the envelope shape as $|\cos \mu t|$ and that this is displayed on the oscilloscope.

Envelope visualization for small (ω/μ)

For some more insight we will examine the situation as the ratio (ω/μ) is reduced, so that the relation $\omega \gg \mu$ is no longer satisfied. To do this you will discard the 100 kHz carrier, and use instead a variable source from the VCO.

As a first check, the VCO will be set to the 100 kHz range, and an AM signal generated, to confirm the performance of the new model.

T6 before plugging in the VCO set it into 'VCO mode' with the switch located on the circuit board. Select the HI frequency range with the front panel toggle switch. Plug it in, and set the frequency to approximately 100 kHz.

T7 set the message frequency from the AUDIO OSCILLATOR to, say, 1 kHz.

T8 remove the patch cord from the 100 kHz sine wave of the MASTER SIGNALS module, and connect it to the analog output of the VCO.

T9 confirm that the new model can generate AM, and then adjust the depth of modulation to somewhere between say 50% and 100%.

T10 slowly vary the VCO frequency over its whole HI range. Most of the time the display will be similar to that of Figure 1 but it might be possible obtain momentary glimpses of the AM signal as it appears Figure 6.

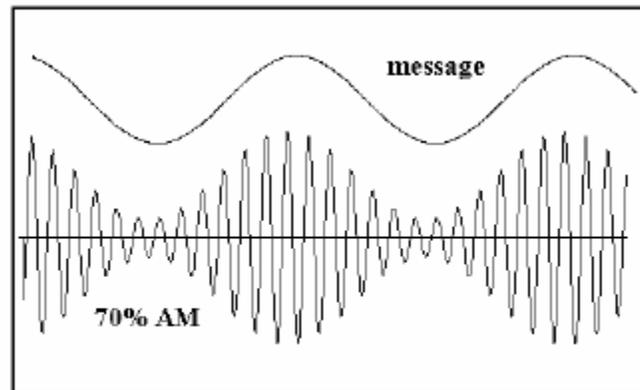


Figure 6: single sweep of a 70% AM

T11 rotate the frequency control of the VCO fully clockwise. Change the frequency range to LO, with the front panel toggle switch.

T12 slowly reduce the VCO frequency, and thus the ratio (ω / μ). Monitor the VCO frequency with the FREQUENCY COUNTER, and keep a mental note of the ratio. Most of the time the display will be similar to that of Figure 6, although the AM signal will be drifting left and right, perhaps too fast to see clearly.

T13 set the VCO close to 2 kHz. With the 1 kHz message this makes the carrier to-message ratio approximately 2. **What do you observe?**

Envelope Recovery:

Although the envelope is imaginary in the sense described above, it is possible to generate, from $y(t)$, a signal $e(t)$, having the same shape as this imaginary line. The circuit which does this is commonly called an *envelope detector*. A better word for envelope detector would be *envelope generator*, since that is what these circuits do.

The ideal envelope detector is a circuit which takes the *absolute value* of its input, and then passes the result through a *lowpass filter*. The output from this lowpass filter is the required envelope signal.

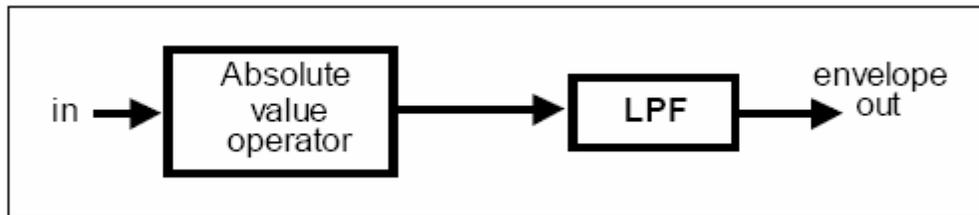


Figure 7 : the ideal envelope recovery arrangement

The absolute value operation, being non-linear, must generate some new frequency components. Among them are those of the wanted envelope. It is the purpose of the lowpass filter to separate the wanted from the unwanted components generated by the absolute value operation.

AM envelope:

For this part of the experiment we will use the generator of Figure 4, and connect its output to the envelope detector of Figure 7.

Note: Please try to verify and justify your results using the spectrum analyzer.

T14 plug in the TUNEABLE LPF module. Set it to its widest bandwidth, which is about 12 kHz (front panel toggle switch to WIDE, and TUNE control fully clockwise). Adjust its passband gain to about unity. To do this you can use a test signal from the AUDIO OSCILLATOR, or perhaps the 2 kHz message from the MASTER SIGNALS module. For the lowpass filter use the TUNEABLE LPF module. Your whole system might look like that shown modelled in Figure 8 below.

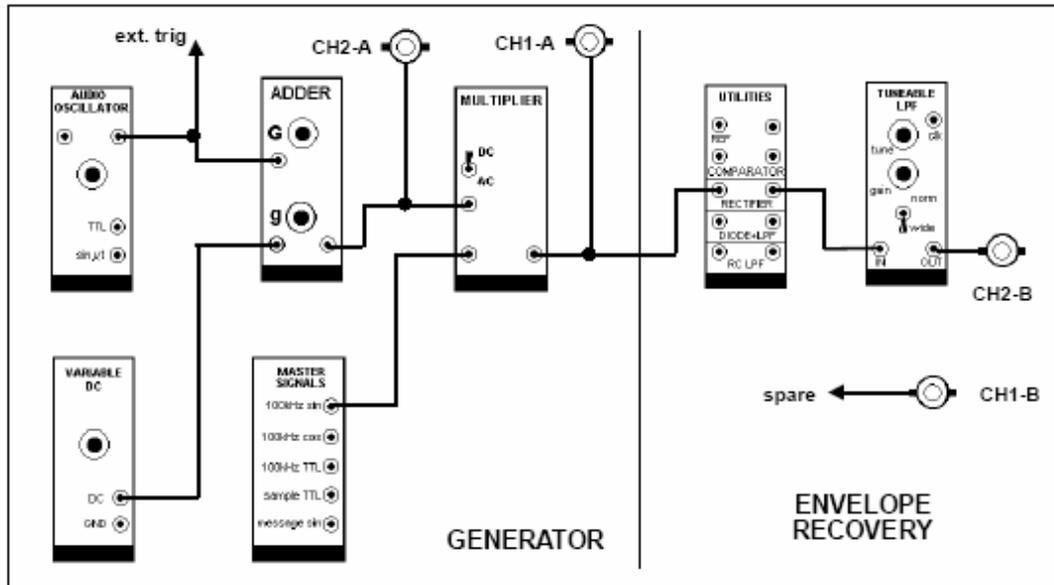


Figure 8: modulated signal generator and envelope recovery

T15 set the frequency of the AUDIO OSCILLATOR to about 1 kHz. This is your message.

T16 adjust the generator to produce an AM signal, with a depth of modulation less than 100%. for the case $m < 1$ observe that the output from the filter (the ideal envelope detector output) is the same shape as the envelope of the AM signal – a sine wave.

DSBSC Envelope:

T17 remove the carrier from the AM signal, by turning 'g' fully anti-clockwise, thus generating DSBSC. Alternatively, and to save the DC level just used, pull out the patch cord from the 'g' input of the ADDER (or switch the MULTIPLIER to AC). You have to observe in the oscilloscope waveforms similar to Figure 3.

You may not have seen the expected waveform. Why not ?

T18 lower the frequency of the AUDIO OSCILLATOR, and watch the shape of the recovered envelope. When you think it is a better approximation to expectations, note the message frequency, and the filter bandwidth, and compare with predictions of the bandwidth of a fullwave rectified sinewave.

Questions:

Q1 Define narrow band signal and Wide band signal

Q2 An envelope detector has a rectifier and a low pass filter . Analyse the performance of a square-law device as an envelope detector, assuming an ideal filter may be used. Draw the full wave rectifier output spectrum.

Q3 Explain the major difference differences in performance between envelope detectors with half and fullwave rectifiers.