

Amplitude & Frequency Modulation Observing & Analyzing The AM Envelope, Measuring FM Deviation

By: Walter Banzhaf, P.E.
Professor of Engineering Technology
University of Hartford
Ward College of Technology

Purpose:

The automatic measurement capabilities of the HP 54601A digitizing oscilloscope make it simple to observe and determine the percentage of modulation for an AM signal, and the frequency deviation of an FM signal.

Note: If you don't have your own modulation board, an HP 33120A Function/Arb Generator can be used in place of both the modulations board and the function generator.

Equipment Required:

- HP 54600 - Series Oscilloscope
- HP 33120A, or custom-built modulation board

Circuit Explanation:

This procedure will use the AM/FM/FSK modulation board, which is a built-up circuit with switches and connectors. This circuit produces a sinusoidal carrier, which may be amplitude or frequency modulated by an external input voltage. First, the modulation board should be connected to a +20 VDC power supply (with current limiting set above the minimum value so the current limit light goes out). A sine generator will be used as the input to the AM input, and later to the FM input, using a BNC/BNC cable.

Note: An HP 33120A may be substituted in place of the above-mentioned modulation board.

Procedure A - Determining % Modulation For An Am Signal:

- 1) Connect the modulation board to the power supply, as described above. Set the **FREQ** control to **LO**, and the **FREQ ADJ** potentiometer to mid-range.
- 2) Set the sine wave generator to produce a 2 kHz sine wave, about (250 mVpp), and connect it to the **AM IN** BNC connector on the modulation board front panel.
- 3) Return the oscilloscope to its default settings by pressing the SETUP hardkey, and then the DEFAULT SETUP softkey.
- 4) Connect channel 1 to the negative lead of the 100 μ F/25V capacitor adjacent to the **AM IN** test point on the circuit board, using a 10X probe. Connect channel 2 to the **RF OUT** test point, using a 10X probe. **For both channels, be sure to make the probe setting correct (10X) by using the PROBE softkey for that channel (press 1 or 2 to select that channel, and then press the PROBE softkey as needed to toggle between a divide by 1 or 10 or 100 probe).**
- 5) Press the **AUTOSCALE** hardkey on the oscilloscope. A rather unsatisfactory display should be seen, as the oscilloscope has chosen to trigger on channel 2, the modulated carrier (see Figure 1).



- 6) Press the **SOURCE** hardkey and press the **1** softkey, to select channel 1 as the trigger source. Now you should see that channel 1 is synchronized (with only a small part of the modulating sinusoid visible), but channel 2 is not synchronized (see Figure 2).
- 7) Adjust the **Time/Div** control on the front panel for a display that makes sense to you (fine tuning of the modulating frequency, by adjusting the knob on the function generator), should produce a classic AM display (see Figure 3). Notice in Figure 3 that the **Measure Time** hardkey, followed by the **Freq.** softkey, was used on both channel 1 (the 2.044 kHz modulating frequency) and channel 2 (the 20.4 kHz modulated carrier), and that there 10 cycles of carrier within each cycle of the RF carrier “envelope”.

Note: Alternative to steps 1,2,6,7:

Set HP 33120A to 20.4 kHz, with AM on and f mod = 2044 Hz, modulation depth =50%. Use the Sync. out to externally trigger the scope.

- 8) Given that the modulation index, m, for an AM (DSB-FC, double sideband-full carrier) signal can be determined by $m = \frac{B - A}{B + A}$, where B is the maximum peak-peak value of the envelope, and A is the minimum peak-peak value of the envelope, determine m for this signal. Use the **Measure Cursors** hardkey, and the **V1** and **V2** softkeys (and the knob under the **Measure** hardkey) to determine B and A for this AM signal. Figure 4 shows B = 7.00 Vpp. Alternatively, if you are incredibly lazy, and if you trust the oscilloscope, you can use the **Measure Voltage Voltage** hardkey, and the **Vp-p** softkey to measure B.

Determination of Modulation Index for AM Signal

B	A	m

Procedure B - Determining The Deviation For An Fm Signal:

- 1) Move the BNC from the sine generator the **FM IN** BNC connector, and move the channel 1 10X probe to the **FM IN** test point on the circuit board. The display, with some fine tuning of amplitude and frequency of the sine generator, should look like Figure 5. Notice that the carrier frequency increases as the modulating voltage decreases, and the frequency decreases as the modulating voltage increases. While this certainly shows the basic operation of a frequency modulator, obtaining accurate information about the carrier frequency is not possible with this display. Read on.

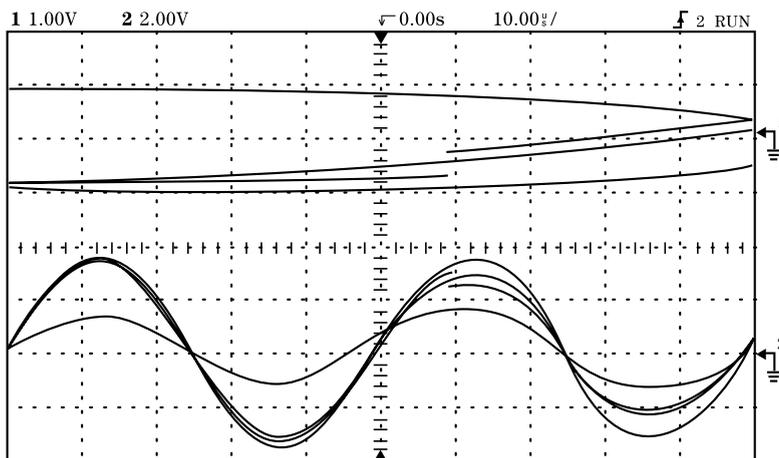
Note: Alternative to step 1:

Set HP 33120A to 20.4 kHz, FM on, f_{dev} = 2.044 kHz, mod. time: 0.5 sec.

- 2) Turn off channel 1. Lower the sine generator modulating frequency from about 2 kHz to about 2 Hz, and the sine generator amplitude to minimum (which is not zero!). Change the trigger source to channel 2. Change the Time/Div to 10µs. Move the **Time Ref** to **Lft** (under the **Main/Delayed** hardkey menu of softkeys). You should now have a display that will make you seasick in very short order.
- 3) Press the **Autostore** hardkey. A display like Figure 6 should result, where the minimum and maximum periods can clearly be seen. Using the **Measure Cursors** hardkeys, and the **T1** and **T2** softkeys (and the knob under the **Measure** hardkey) to determine, $1/\Delta t_{min} = f_{max}$ and $1/\Delta t_{max} = f_{min}$ for your FM signal.

Determination of FM Signal Parameters

1/Δt _{min}	f _{max}	1/Δt _{max}	f _{min}	f _{Carrier(no mod)}	deviation



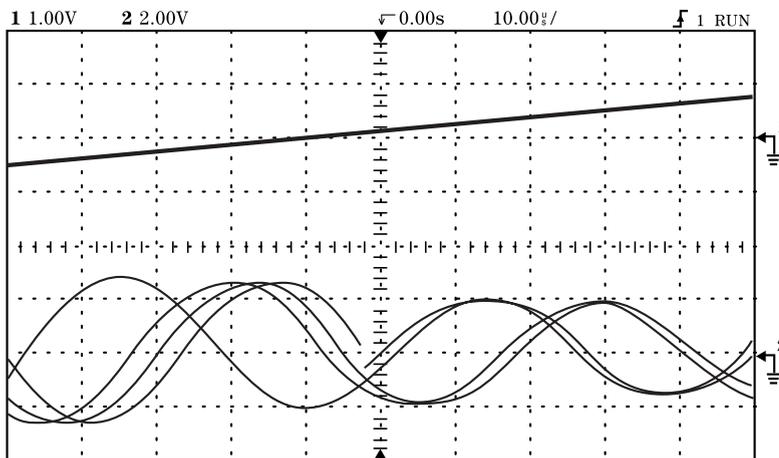
Chan	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	1.000 V	2.047 V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-4.062 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	10.00us/	0.000 s	Cntr	-----	-----

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	AutoLv1	Ch 2	62.50mV	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Figure 1 - Triggered on Chan. 2, the AM Carrier



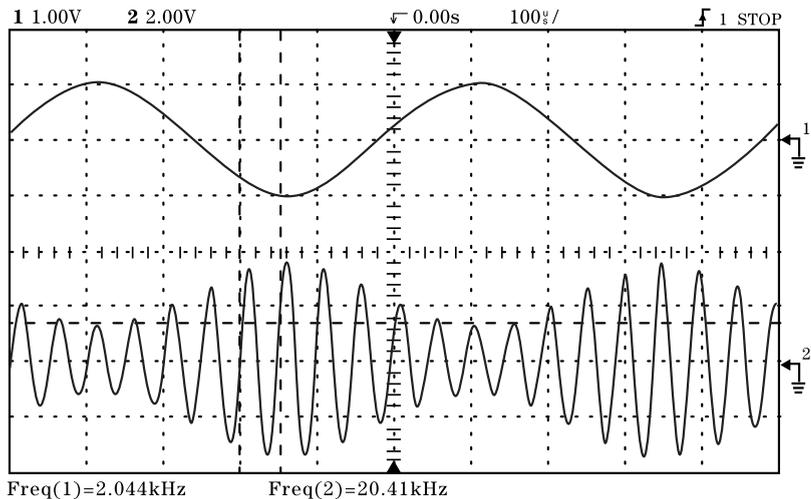
Chan	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	1.000 V	2.047 V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-4.062 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	10.00us/	0.000 s	Cntr	-----	-----

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	AutoLv1	Ch 1	62.50mV	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Figure 2 - Triggered on Chan. 1, The modulating sine



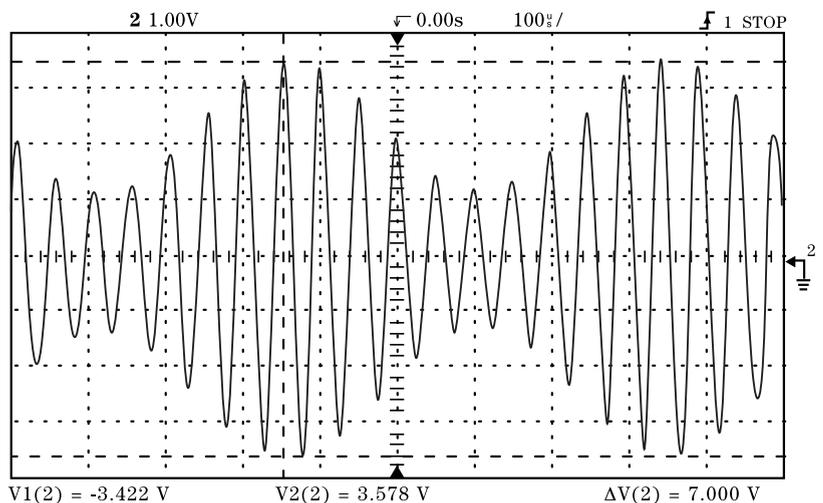
Chan	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	1.000 V	2.047 V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-4.062 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	100.0us/	0.000 s	Cntr	-----	-----

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	AutoLv1	Ch 1	62.50mV	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Figure 3 - Classic Display of AM Carrier and Modulating Voltage



Chan	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	Off	1.000 V	2.047 V	DC	Off	Off	10:1
Chan 2	On	1.000 V	-93.75mV	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

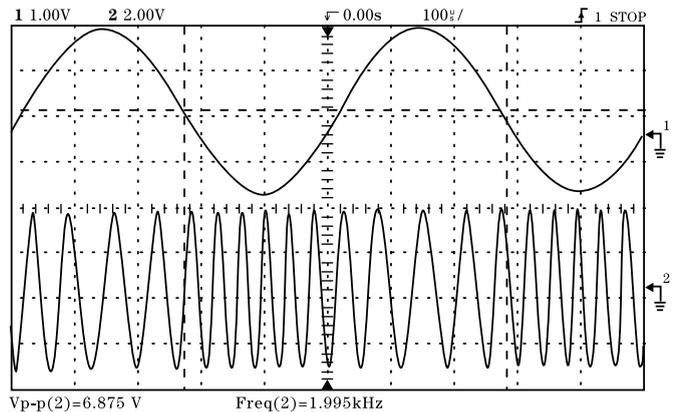
	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	100.0us/	0.000 s	Cntr	-----	-----

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	AutoLv1	Ch 1	62.50mV	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Cursors: t1=-207.3us t2=-158.3us V1(2) = -3.422 V V2(2) = 3.578 V

Figure 4 - Showing Measurement of "B", the maximum p-p value of the carrier envelope



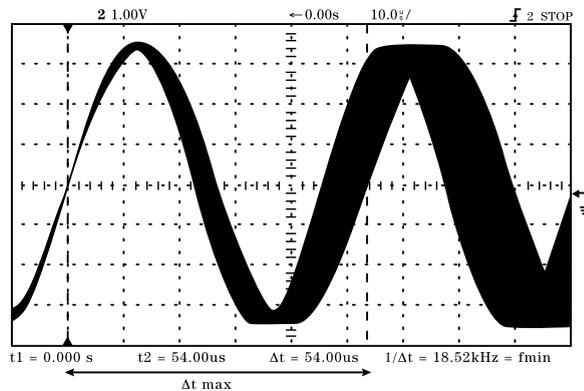
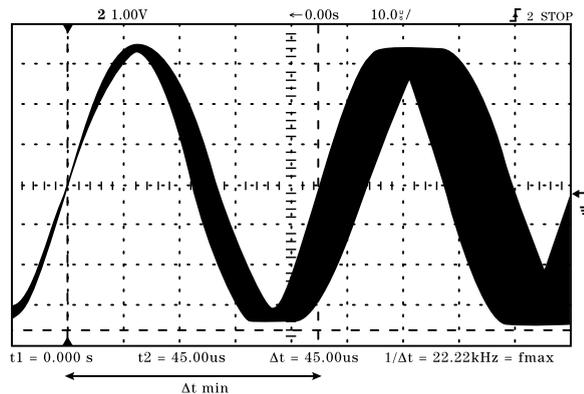
Chan	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	1.000 V	1.531 V	DC	Off	Off	10:1
Chan 2	On	2.000 V	-3.625 V	DC	Off	Off	10:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

Horizontal	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	100.0us/	0.000 s	Cntr	---	---

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
Trigger	Auto	Ch 1	-15.63mV	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Figure 5 - Classic Display of FM Carrier and Modulating Voltage



$f_{\text{carrier(no mod)}} = (22.22\text{kHz} + 18.52\text{kHz})/2 = 20.37\text{kHz}$
 $\text{deviation} = (22.22 - 20.37)\text{kHz} = 1.85\text{kHz}$

Figure 6 - Measurement of Minimum Period and Maximum Period of FM Carrier.

