

Part-I

Experiment 5:-Double Sideband Transmitted

Carrier (DSB_{TC}).

1. Introduction

1.1 Objective

This experiment deals with the basic of amplitude modulation (*AM*) for analog communication. The student will learn the basic concepts and how to build amplitude modulator and demodulator. Upon completion of the experiment, the student will:

- * Understand amplitude modulation transmitted carrier modulation
- * Learn how to construct *AM* modulators.
- * Learn how to construct *AM* demodulators
- * Acquire skills for building basic test and measure system.
- * Understand the limitation of test and measure equipment.

1.2 Prelab Exercise

1. An *AM* transmitter produce An unmodulated *AM* signal (carrier) power output 1mw on 50Ω load. The carrier is modulated by a single tone sinusoid signal, with a modulation depth of 50%

* Write the mathematical expression for the *AM* signal, assuming that carrier frequency $30MHz$, modulating frequency $5kHz$.

* Find the total average power of the *AM* signal.

* Find the power efficiency of the modulator.

2. An *AM* signal as shown in Fig.-1, Assume the modulating signal is sinusoidal

* Find the modulation depth?

* Calculate carrier power, sidebands power and power efficiency..

3. Show that the maximum power efficiency of *AM* is 50%.

4. Describe one way to generate *AM* signal.

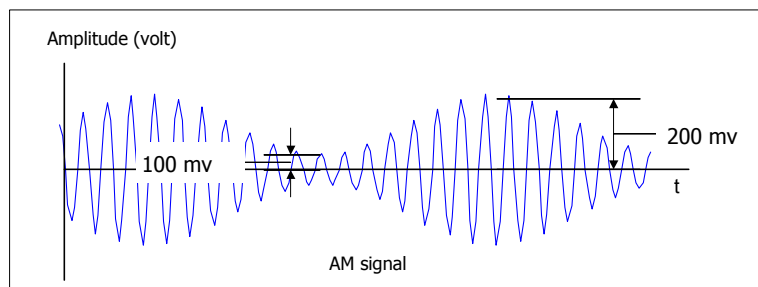


Figure -1 - : AM signal

2. Background Theory

In the previous experiment you exercise double-sideband suppressed carrier modulation. We found that the waveform resulting from the multiplication of the information signal $s(t)$ with a carrier sinusoid f_c possesses desirable properties. In particular, the modulation process shifts frequencies from a band around DC to a band around the carrier frequency. This permits efficient transmission and also allows simultaneous transmission of more than one baseband signal. In this experiment you explore a modification of *AM* in which we add a portion of the pure sinusoidal carrier to the modulated waveform. You will see that this addition greatly simplifies the demodulation process. Figure 2 shows the addition of a pure sinusoidal carrier to the double-sideband suppressed carrier waveform

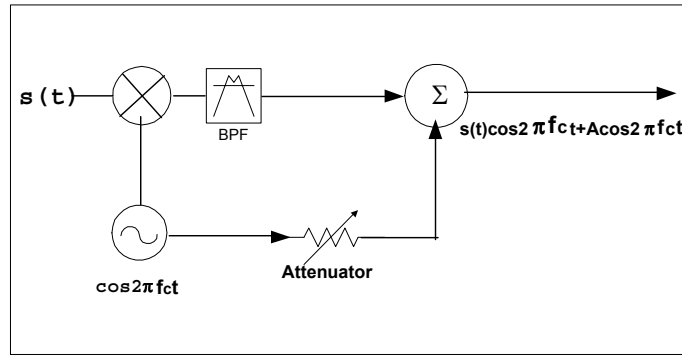


Figure -2 - : AM DSBTC modulator

. The resulting waveform is

$$S_m(t) = s(t) \cos 2\pi f_c t + A \cos 2\pi f_c t \quad (1)$$

This is known as double-sideband transmitted carrier (*DSB – TC*). The type of *AM* discussed in the previous section did not include an explicit carrier term. That is why it is labeled suppressed carrier. We begin by examining the function of time and its Fourier transform.

The Fourier transform of transmitted carrier *AM* is the sum of the Fourier transform of suppressed carrier *AM* and the Fourier transform of the pure carrier. The transform of the carrier is a pair of impulses at $\pm f_c$, The complete transform of the *AM* wave is therefore as shown in Fig.-3 The function of time can be sketched if we first combine terms in Equation.. 2. Doing so, we can rewrite the

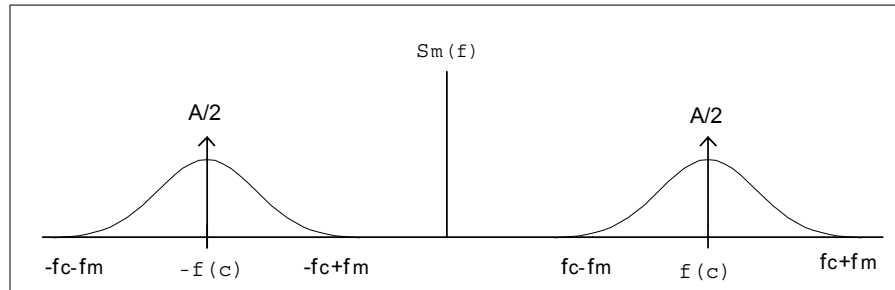


Figure -3 - : Fourier transform of AM signal

waveform as

$$S_m(t) = [A + s(t)] \cos 2\pi f_c t \quad (2)$$

and

$$m = \frac{\max s(t)}{A}$$

where m is the modulation index of the *AM* signal and $m \leq 1$. This function is sketched in the same manner as that used to draw the suppressed carrier waveform. We first draw the outlines at $[A + s(t)]$ and $-[A + s(t)]$. The *AM* waveform periodically touches these two curves. We then fill in with a smooth, oscillating waveform This is illustrated for a sinusoidal $s(t)$ in Figure-4

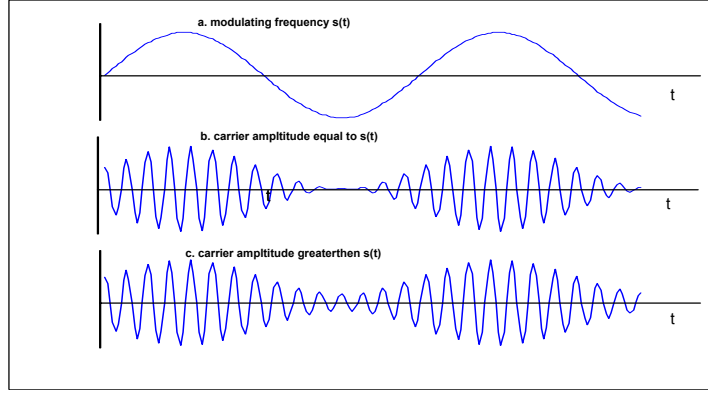


Figure -4 - :

Figure 4a shows the sinusoidal $s(t)$, Fig.-4b shows the AM waveform for value of A equal to the maximum amplitude of $s(t)$ or $m = 1$, and Fig. 4c shows the waveform where A greater than the maximum amplitude of $s(t)$ or $m < 1$. If we use oscilloscope, as in our experiment to measure AM signal, it is very simple to calculate modulation index m by simply measuring $\max[s_m(t)]$ and $\min[s_m(t)]$ where m define as(see Fig-5)

$$m = \frac{\max[s_m(t)] - \min[s_m(t)]}{2}$$

or in percentage

$$m\% = \frac{\max[s_m(t)] - \min[s_m(t)]}{2} \times 100$$

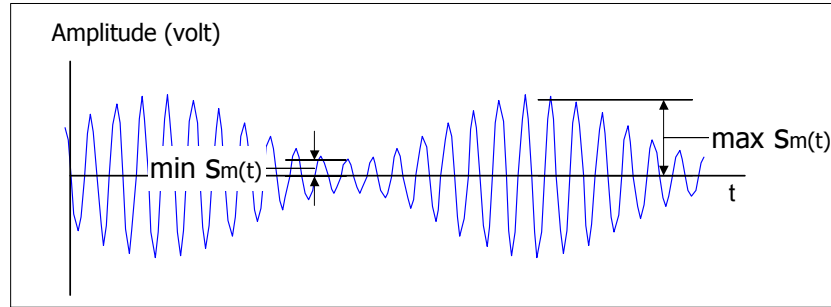


Figure -5 - : Modulation index

2.1 DSB (TC) Modulation Efficiency

Definition: the modulation efficiency is the percentage of the total power of the modulated signal that conveys information. we realize that the normalized average power of the AM signal is:

$$\begin{aligned} \langle S_m^2(t) \rangle &= \frac{1}{2} A^2 \langle [1 + s(t)]^2 \rangle \\ &= \frac{1}{2} A^2 \langle 1 + 2s(t) + s^2(t) \rangle \\ &= \frac{1}{2} A^2 + A^2 \left\langle s(t) + \frac{1}{2} s^2(t) \right\rangle \end{aligned} \quad (3)$$

If modulation contain no DC level $\langle s(t) \rangle = 0$ and the normalized power (on 1 ohm resistor) of the AM signal is:

$$\langle S_m(t) \rangle = \frac{1}{2} A^2 + \frac{1}{2} A^2 \langle s^2(t) \rangle \quad (4)$$

In AM signaling, only the sideband components convey information, so the, modulation efficiency is

$$\eta = \frac{\langle s^2(t) \rangle}{1 + \langle s^2(t) \rangle} \quad (5)$$

The highest efficiency that could be obtained for a 100% *AM* signal would be 50%, which is attained only for signal which $\langle s^2(t) \rangle = 1$ (for example square-wave signal). Another commonly used term is peak envelope power (*PEP*) of the *AM* signal:

$$P_{PEP} = \frac{1}{2} A^2 \{1 + \max[s(t)]\}^2 \quad (6)$$

2.2 Asynchronous Detector-Envelope Detector:

The detector we examine is by far the simplest. Let us observe the transmitted carrier *AM* waveform of Fig -4 If $A + s(t)$ never goes negative, the upper outline, or envelope, of the *AM* wave is exactly equal to $A + s(t)$. If we can build a circuit that follows this outline, we will have built a demodulator. The circuit of Fig. 6 is known as an envelope detector. When properly designed, it serves as a demodulator and is clearly far simpler compare to other demodulators, have discussed previously. The output follows an exponential curve between peaks of the *AM* wave.

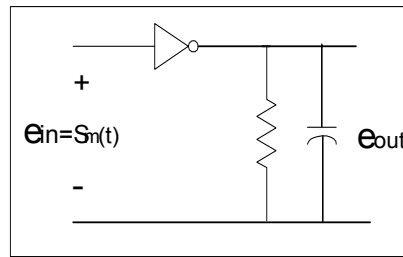


Figure -6 - : Envelope detector

This is shown in Fig. 7 If the time constant of the *RC* circuit is appropriately chosen, the output approximately follows the outline of the input curve, and the circuit acts as a demodulator. The output contains ripple at the carrier frequency (residual radio frequency), but this does not cause a problem, since we are interested only in frequencies below f_m . The *RC* time constant must be short enough that the envelope can track the changes in peak values of the *AM* waveform. The peaks are spaced at intervals equal to the reciprocal of the carrier frequency, while the heights of these peaks follow the information, $s(t)$.

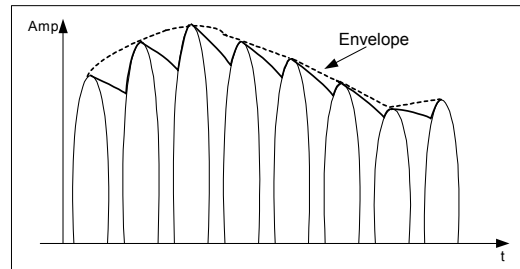


Figure -7 - : Envelope detector

We can consider a worst case where $s(t)$ is a pure sinusoid at a frequency off. This would provide the fastest possible change in peak values. At this frequency, the peaks vary from a maximum to minimum in $1/2f_m$ second.. It takes an exponential function 5 time constants to get within 0.7 percent of its final value. Therefore, if we set the *RC* time constant to 10 percent of $1/f_m$, the envelope detector can follow even the highest frequency. For example, with an f_m of 5 kHz, the time constant would be set to $1/50 \text{ msec}$, or $20 \mu\text{sec}$. This rule of thumb represents a first cut at envelope detector design

3. Experiment Procedure

3.1 Required Equipment

1. Spectrum Analyzer (SA) HP – 8590L.
2. Oscilloscope HP – 54600A.
3. Signal Generator (SG) HP – 8647A.
4. Two Arbitrary Waveform Generator (AWG) HP – 33120A.
5. Double Balanced Mixer.
6. Two Combiner/Splitter.
7. Band pass filter 10.7 MHz
8. Low pass filter 1.9 MHz
9. Envelope detector $RC = 20\mu\text{sec}$.
10. Step attenuator

3.2 DSB-TC Modulator using Signal Generator

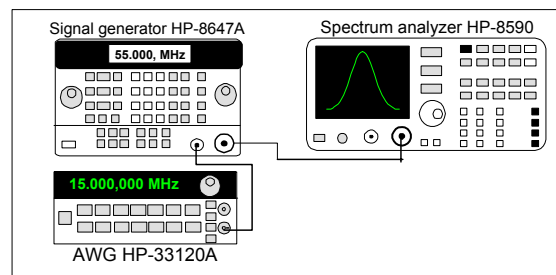


Figure -8 - : AM generation using SG

1. Connect the SG directly to the SA as indicated in Fig-8 (AWG – 1 disconnected):
2. Set the signal generator to
Frequency 50 MHz.
Amplitude 0dbm.
Modulating Frequency 1 kHz..
Setting 30% AM- Measure the AM modulation with spectrum analyzer ,by pressing **MEAS/USER** then **%AM On Off** now the spectrum analyze measure the AM depth, change the amplitude of the AWG in order to get 30% modulation.
3. Set the spectrum analyzer to frequency 50 MHz , span 50 kHz, resolution bandwidth 1 kHz.
4. Observe the spectrum analyzer why you can't see the AM spectrum correctly? print the result.
5. Change the modulating frequency continuously between 1 and 15 kHz, observe the spectrum and verify your answer in the previous paragraph. print the result.
6. Change only the modulating frequency to 3 kHz . measure the modulation depth and modulating frequency in frequency domain, and in time domain using spectrum analyze oscilloscope respectively, print the results.

3.3 DSB-TC Modulation Efficiency

In this part you measure maximum AM modulation efficiency using two waveform sinewave and squarewave.

1. Connect the system as indicated in Fig-8.
2. Set the SG and the AWG as follow:
SG- frequency 30 MHz ,amplitude 0dbm, modulation external AM 100%.
AWG-sinewave frequency 10 kHz, amplitude as necessary to external modulation.
3. Setting 100% AM- Using spectrum analyzer set the Signal generator to AM 100%.
4. Setting linear units- Press **AMPLITUDE** **More 1 Of 2** **Watts** .
5. Measuring signal power -Press **MEAS/USER** **Power Menu** **Occupied Bandwidth** now the SA display the power of the AM signal, measure the power of the carrier, print the results for and calculate the AM efficiency for sinewave modulating signal.

6. Change the waveform of the *AWG* to squarewave. adjust *SG* to *AM* 100% modulation, use the same procedure and calculate the maximum modulation efficiency for squarewave.(attached to final report).

3.4 DSB-STC Modulator using Standard Component

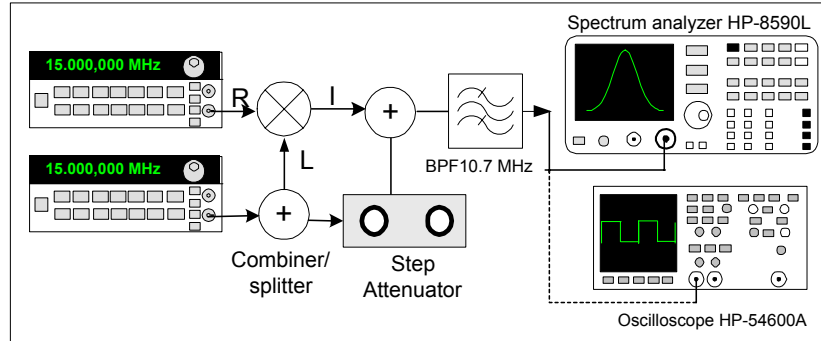


Figure -10 - : AM generation using standard components

During this experiment you generate ordinary *AM* signal using standard components ,mixer step attenuator, combiner\splitter, although you later easily produce *AM* signal using A single instrument.

1. Connect the Test and Measurement equipment according to Fig.-10

2. Adjust the Test and Measurement equipment as follow:

AWG – 1 Carrier generator frequency 10.7 MHz, amplitude 7 dBm.

AWG – 2 Baseband signal frequency 100 kHz, amplitude -20dbm.

3. Set the spectrum analyzer to frequency 10.7 MHz , span 300 kHz, bandwidth 3 kHz.

4. Adjust the attenuator steps in order to get 30%, 50%, 100% modulation depth using Equation-. 7 or table 1, Save the result on magnetic media .

$$m = \frac{2E_{sb}}{E_c}$$

$$E_{sb(db)} - E_{c(db)} = 20 \log \frac{m}{2} \quad (7)$$

| $m\%$ | d | $m\%$ | d | $m\%$ | d | $m\%$ | d | $m\%$ | d | $m\%$ | d |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|-------|------|
| 1 | -46 | 18 | -20.9 | 35 | -15.1 | 52 | -11.7 | 69 | -9.2 | 86 | -7.3 |
| 2 | -40 | 19 | -20.4 | 36 | -14.9 | 53 | -11.5 | 70 | -9.1 | 87 | -7.2 |
| 3 | -36.5 | 20 | -20 | 37 | -14.7 | 54 | -11.4 | 71 | -9 | 88 | -7.1 |
| 4 | -34 | 21 | -19.6 | 38 | -14.4 | 55 | -11.2 | 72 | -8.9 | 89 | -7 |
| 5 | -32 | 22 | -19.2 | 39 | -14.2 | 56 | -11.1 | 73 | -8.8 | 90 | -6.9 |
| 6 | -30.5 | 23 | -18.8 | 40 | -14 | 57 | -10.9 | 74 | -8.6 | 91 | -6.8 |
| 7 | -29.5 | 24 | -18.4 | 41 | -13.8 | 58 | -10.8 | 75 | -8.5 | 92 | -6.7 |
| 8 | -28 | 25 | -18.1 | 42 | -13.6 | 59 | -10.6 | 76 | -8.4 | 93 | -6.7 |
| 9 | -26.9 | 26 | -17.7 | 43 | -13.4 | 60 | -10.5 | 77 | -8.3 | 94 | -6.6 |
| 10 | -26 | 27 | -17.4 | 44 | -13.2 | 61 | -10.3 | 78 | -8.2 | 95 | -6.5 |
| 11 | -25.2 | 28 | -17.1 | 45 | -13 | 62 | -10.2 | 79 | -8.1 | 96 | -6.4 |
| 12 | -24.4 | 29 | -16.8 | 46 | -12.8 | 63 | -10 | 80 | -8 | 97 | -6.3 |
| 13 | -23.7 | 30 | -16.5 | 47 | -12.6 | 64 | -9.9 | 81 | -7.9 | 98 | -6.2 |
| 14 | -23.1 | 31 | -16.2 | 48 | -12.4 | 65 | -9.8 | 82 | -7.7 | 99 | -6.1 |
| 15 | -22.5 | 32 | -15.9 | 49 | -12.2 | 66 | -9.6 | 83 | -7.6 | 100 | -6 |
| 16 | -21.9 | 33 | -15.7 | 50 | -12 | 67 | -9.5 | 84 | -7.5 | | |
| 17 | -21.4 | 34 | -15.4 | 51 | -11.9 | 68 | -9.4 | 85 | -7.4 | | |

Table - 1

4. Verify your results in time domain, by connecting the oscilloscope in parallel to *SA* ,print the results.

3.5 DSB_TC Demodulator-Synchronous Detector

3.5.1 Product Detector

In this part of the experiment you analyze the operating concept of product detector. We choose to do it with $DSB - TC$, because it is relatively simple to lock the LO to the carrier of the input signal.

- 1 Connect the system as indicated in Fig.-11 to implement product detector.
2. Connect the two AWG 's according to appendix 1. The AM generator is master and LO is locked to the input AM signal, set the phase to 0° .

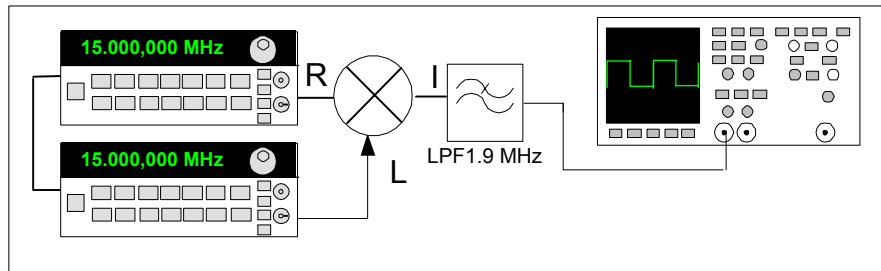


Figure -11 - : Product Detector

3. Set the $T\&M$ equipment as follow:

$HP - 33120A$ option 001 $AWG (RF)$, carrier frequency 10.7 MHz, amplitude -3 dBm, AM modulation, modulation depth 50%, modulated frequency 1 kHz. $HP - 33120A$ option 001 $AWG (Locked) - (LO)$, frequency 10 MHz, amplitude 7 dBm.

4. Observe the detected signal at oscilloscope, change the phase between the two generators to $0^\circ, 90^\circ, 180^\circ$ at which phase the detection is worst? print the best and worst detected signals explain.

3.6 DSB_TC Demodulator-Asynchronous Detector

3.6.1 Envelope Detector

The envelope detector is a simple RC circuit with input diode, in this experiment you examine the limitation of the time constant RC on various baseband frequencies and shapes.

1. Connect the system as indicated in Fig.-12

2. Set the AWG to:

frequency 2 MHz, amplitude 15 dBm, modulation AM 50%, modulated frequency 1 KHz, observe the detected signal at the oscilloscope.

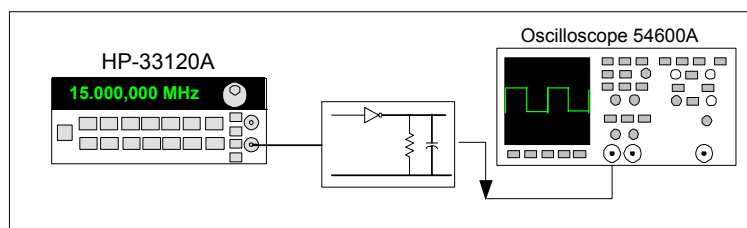


Figure -12 - : Envelope detection

3. Change the modulated frequency according to table 1 observe the detected signal on oscilloscope.

4. Observe and print the detected 1 kHz detected squarewave. signal, amplitude 15 dBms, explain why the detected squarewave. is rounded at the edges.

| Mod. Freq.\Waveform | Sine | Ramp | Triangle |
|---------------------|------|------|----------|
| 10 Hz | x | x | x |
| 100 Hz | x | x | x |
| 1 kHz | x | x | x |

5. Change the modulated frequency to sin waveform , 1kHz & the 1MHz amplitude explain what happen and why to the detected sine

4. Final Report

Attached all the print results, answers and your analyzes to the following question.

1.An amplitude modulated signal has the form

$$s_m(t) = 5[1 + 5 \cos 2\pi 1000t + 5 \cos 2\pi 2000t] \cos 2\pi 10000t \quad (8)$$

* Using Matlab or other software, draw $s_m(t)$ in time domain and frequency domain

* Find the average power content of each spectral component.

* What is the modulation index of the signal.

5. Appendix 1

5.1 To phase lock to an external 10 MHz signal

1. Connect rear- panel *Ref Out.* output terminal of the master *AWG HP – 33120A* to *Ref in* on the rear panel of the slave *HP – 33120A*(or other 10MHz clock) .Connect the two signals to input 1 & 2 of the scope, observe the phase between the signals.

2. Turn on the menu by pressing **Shift Menu On/Off** then the display look like **A: MOD MENU** .

3. Move to **G: PHASE MENU** by pressing the **↩** button.

4. Move down a level to the ADJUST command, by pressing **↓** the display look like **1: ADJUST**

5. Press **↩** a level and set the phase offset, choose any value between -360 and 360 degrees. Then you see a display like **^000.000 DEG** .

6. Turn off the menu by pressing **ENTER** . You are then exited the menu.

Important!

1. At this point, the function generator *HP – 33120A* is phase locked to another *HP – 33120A* or external clock signal with the specified phase relationship. The two signals remain locked unless you change the output frequency.

2. If you adjust the phase between two function generator, there is a phase error at the end of the coax cable due the cable phase unbalance, if it is important set a zero reference according to the next paragraph.

5.1.1 Setting a zero phase reference

After selecting the desired phase relationship as described on the previous section, you can set a zero-phase point at the end of the coax cable. The function generator then assume that its present phase is zero and you can adjust the phase relative to this new "zero"

1. Turn on the menu by pressing **Shift Menu On/Off** then the display look like **A: MOD MENU** .

2. Move across to the PHASE MENU choice on this level by pressing **↩** the display look like **G: PHASE MENU**

3. Move down a level and then across to the SET ZERO by pressing **↓** and **↩** bottoms, the display show the message **2: SET ZERO** .

4.move down a level to set the zero phase reference. Press **↓** bottom, . The displayed message indicates **PHASE = 0**

5. Press **Enter** , save the phase reference and turn off the menu.