1 Experiment 2:-Double Sideband Transmitted Carrier (DSB-TC).

1.1 Objective

This experiment deals with the basic idea of amplitude modulation DSB-TC . AM is primary used in analog radio communication. In this experiment you will learn the elementary concept of amplitude modulation (AM). Upon completion of the experiment, you will:

- Understand the advantage and disadvantage of carrier transmit.
- Acquire a knowledge how to construct an AM modulators using elementary components.
- Understand why the asynchronous AM demodulators is used is used in the commercial AM receiver.
- Learn How to analyze a modulated signal in time and frequency domain.

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%
   (a) Write the mathematical expression for the AM signal, assuming that carrier frequency $30MHz$, modulating frequency $5kHz$.
   (b) Find the total average power of the AM signal.
   (c) Find the power efficiency of the modulator.
2. An AM signal is shown in Fig.-1, assume the modulating signal is sinusoidal
   (a) Find the modulation depth?
   (b) Calculate carrier power, sidebands power and power efficiency..

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

4. Describe one way to generate AM signal.

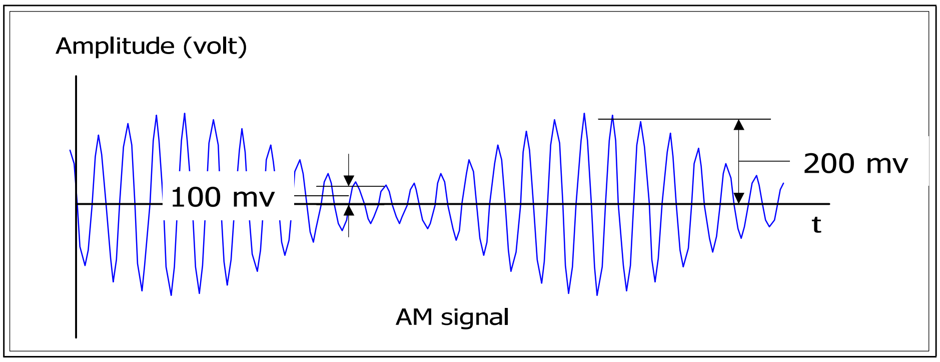

Fig. 1 Time domain of AM signal

1.3 Background Theory

In the previous experiment you exercised 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 suppressed carrier (see Fig. 2)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 .

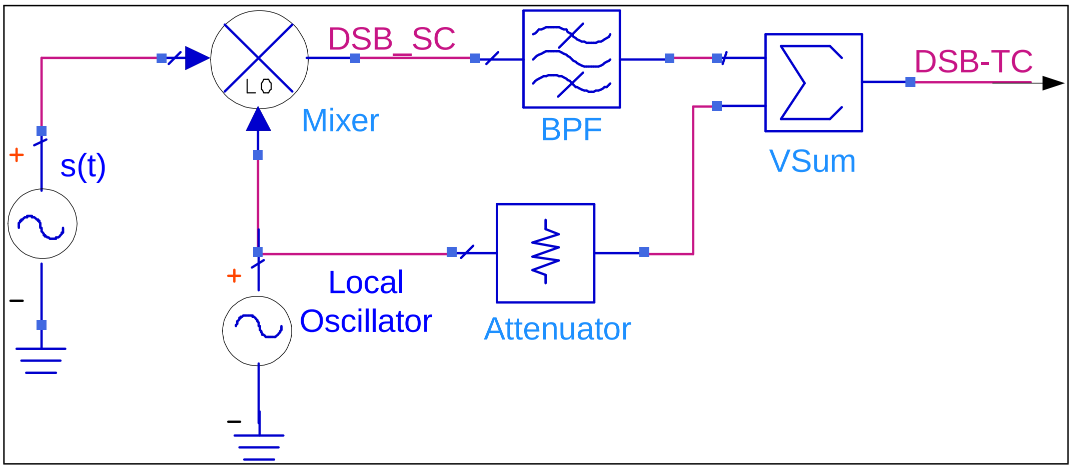

Fig. 2 AM transmitted carrier modulator

The resulting waveform is

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

, we assume that $s\,(t) = \cos\left(2\pi f_m t\right)$ the information is a single tone sinusoidal signal. We begin by examining the $DSB-TC$ at time domain, and its Fourier transform in frequency domain.

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

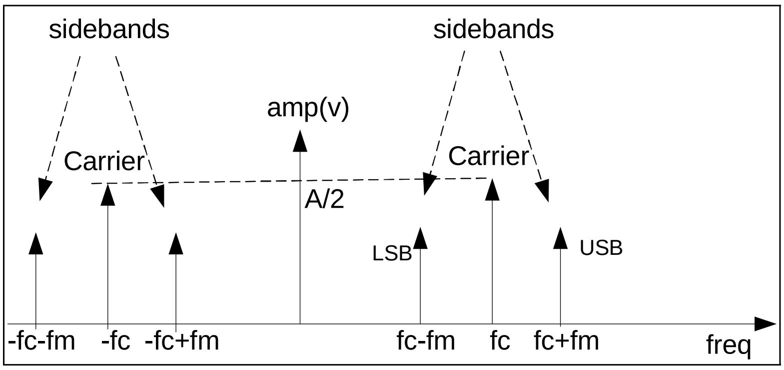

Fig. 3 AM signal, carrier sinewave signal f_c modylated by a sinewave signal $s\,(t)$, frequency f_m .

The time domain signal can be sketched if we first combine terms in Eq(2). 2. Doing so, we can rewrite the
waveform as

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

and

$$m = \frac{\max s(t)}{A} = \frac{\max\left(S_m(t) - \min\left(S_m(t)\right.\right.}{\max\left(S_m(t) - \min\left(S_m(t)\right.\right.} \tag{3}$$

where m is the modulation index of the AM signal and $0 \leq m \leq 1$ for non distorted AM signal. Figure 4 shows a typical AM signal, in two cases, case b. m=1, case c $m < 1$.

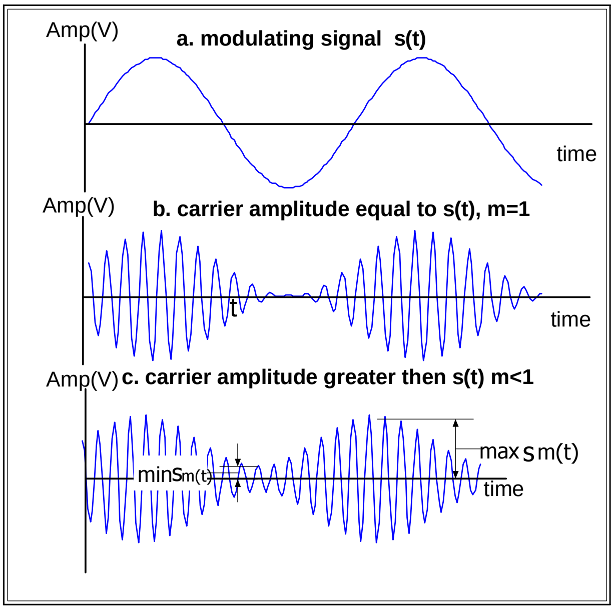

Fig. 4 AM signal a. data signal $s(t)$. b. AM signal where $m = 1/$ c. Modulation where $m < 1$.

1.3.1 Power and Efficiency of DSB (TC)

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:

$$\begin{aligned}\left\langle S_m^2(t)\right\rangle &= \frac{1}{2}A^2\left\langle[1+s(t)]^2\right\rangle \\ &= \frac{1}{2}A^2\left\langle 1+2s(t)+s^2(t)\right\rangle \\ &= \frac{1}{2}A^2+A^2\left\langle s(t)+\frac{1}{2}A^2(s^2(t)\right\rangle \end{aligned}\tag{4}$$

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

$$\left\langle S_m^2(t)\right\rangle = \frac{1}{2}A^2+\frac{1}{2}A^2\left\langle s^2(t)\right\rangle \tag{5}$$

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

$$\eta = \frac{\langle s^2(t)\rangle}{A^2+\langle s^2(t)\rangle} \tag{6}$$

In a case of a single tone modulation, maximum efficiency could be obtained while $m = 1$ or $\max s(t) = 0.5A$, therefore modulation efficiency, $\eta = 1/3$.

Peak Power Another important definition of power related to amplitude modulation, is a peak envelope power (PEP),the maximum instantaneous power, this quantity is important to a device which is sensitive to a peak power (semiconductor) especially in a case while the $\langle s^2(t)\rangle << \max\left(s^2(t)\right)$, .

$$P_{PEP} = \max\left\langle S_m^2(t)\right\rangle = \frac{1}{2}A^2\{1+\max[s(t)]\}^2 \tag{7}$$

1.3.2 Asynchronous Detector- Envelope Detector

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. 5 is known as an envelope detector. When properly designed, it serves as a demodulator and is clearly far simpler compare to other demodulators. The output follows an exponential curve between peaks of the AM wave.

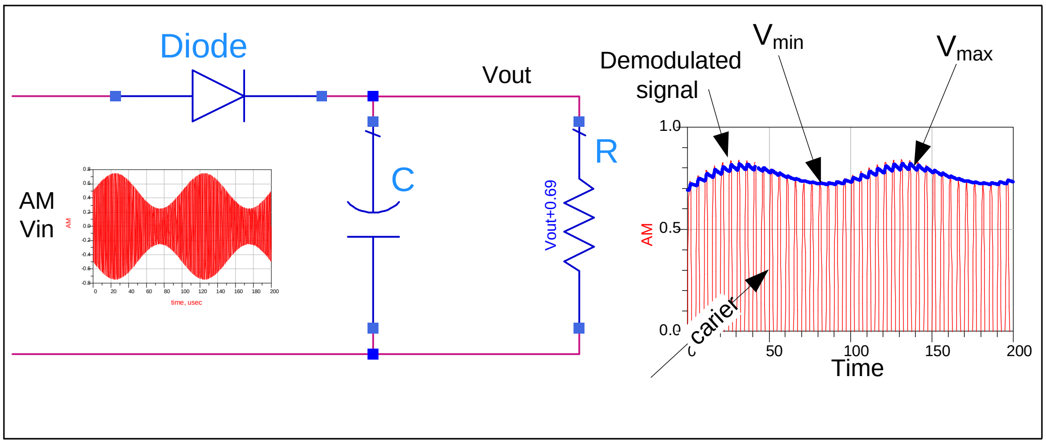

Fig. 5 envelope detector

This is shown in Fig. 5 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.
A measure of the degree of modulation is m, the modulation index. This is usually expressed as a percentage called the percent modulation. In the

time domain, the degree of modulation for sinusoidal modulation is calculated as follows, using the variables shown in Fig. 5

$$m = \frac{V_{\max} - V_{\min}}{V_{\max} - V_{\min}}$$

2 Experiment Procedure

2.1 Required Equipment

1.Spectrum Analyzer (SA) $HP-8590L$.
2.Oscilloscope $HP-54600A$.
3.Signal Generator $HP-8647A$.
4. Two Arbitrary Waveform Generator (AWG) $HP-33120A$.
5.Double Balanced Mixer.
6. Two Combiner/Splitter Minicircuits ZFRSC 2050-N.
7. Band pass filter 10.7 MHz

8. Low pass filter 1.9 MHz
9. Envelope detector $RC = 20\mu\sec$.
10. Step attenuator.
11. Microphone with preamplifier Shure model 550L
12. Antenna Cushcraft.

3 Generating AM signal using Standard components.

3.1 Simulation

1. Simulate an AM modulator as indicated in Fig. 6.

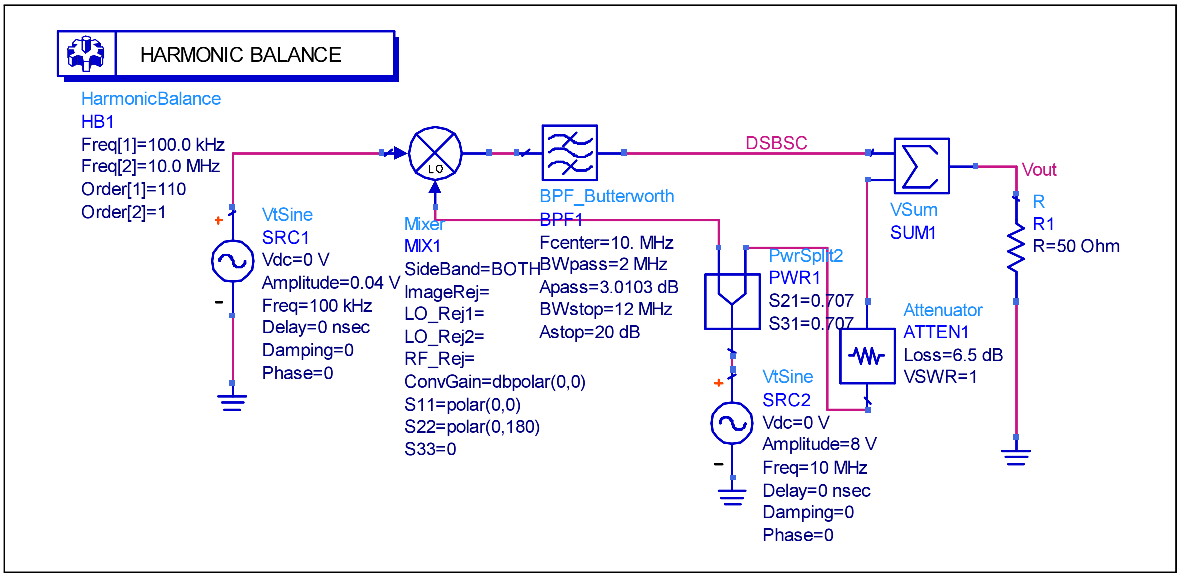

Fig. 6 AM modulator

2. Draw a graph of frequency domain and time domain of DSB-TC signal.

3. Adjust the attenuator to such a value, that modulation index will be 5%,50%, 100%.

3.1.1 Measurement

During this part of the experiment you generate an ordinary $AM(DSB-TC)$ signal using commercial connectorized coaxial elements, such as mixer, step attenuator, and power splitter/combiner.

1. Connect the system according to Figure-7.
2. Adjust the modulating generator to frequency 100 kHz, amplitude -20dbm.
3. Adjust the Carrier generator to frequency 10 MHz, amplitude 7 dBm.
4. Set the spectrum analyzer to center frequency 10 MHz, span 300 kHz, bandwidth 3 kHz.
5. Adjust the attenuator steps in order to get 100%, 50%, 5% modulation depth **Save the images on magnetic media.**

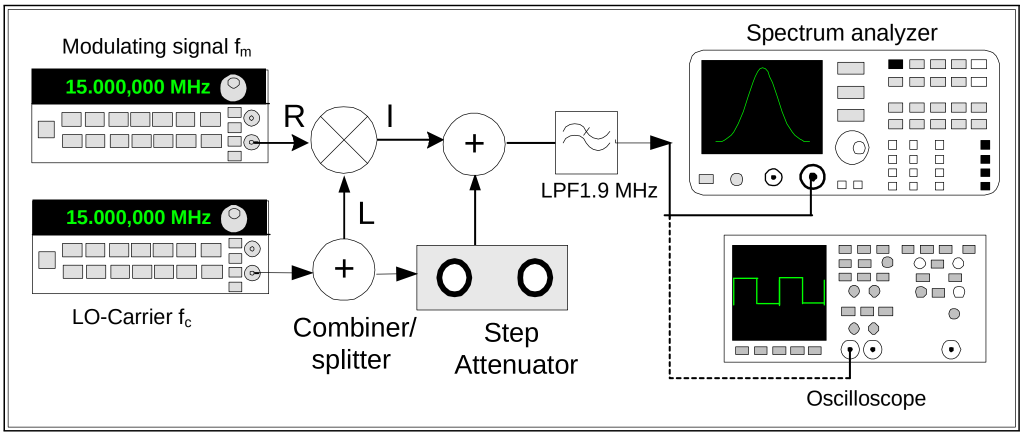

Figure 7. AM modulator using commercial elements

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

$$E_{sb(db)} - E_{c(db)} = 20 \log \frac{m}{2} \tag{8}$$

$m\%$	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

3.2 Exploring an AM signal.

3.3 Simulation of AM Signal.

1. Simulate an AM signal, using the component of Fig. 8.

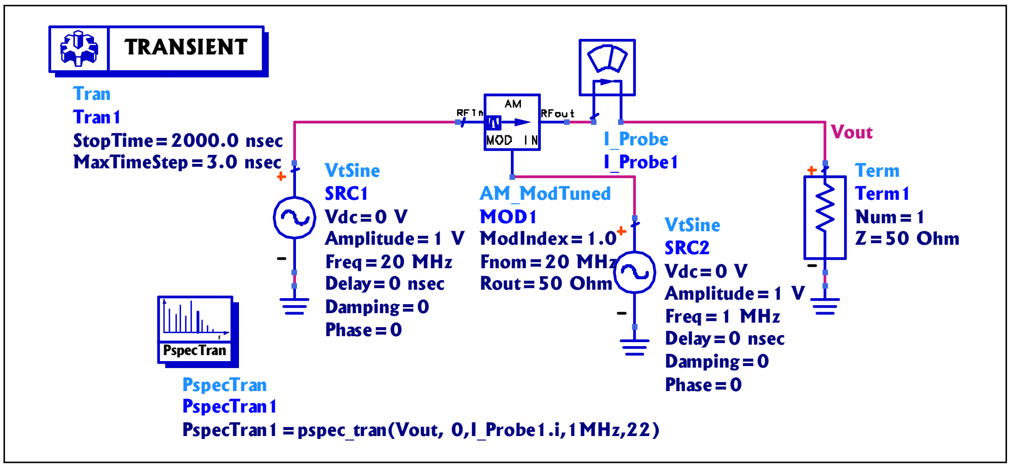

Fig. 8 Simulationg AM signal generated by a function generator

2. The carrier frequency is set to 20MHz, and amplitude 1V, modulation index amplitude 0dBm.

3. Draw a graph of time domain signal, and frequency domain signal. (set the graph to logarithmic mode, 'dBm' measurement).

4. Find the power of the carrier f_c, and the sidebands, $f_c + f_m$ and $f_c - f_m$, Calculate the maximum AM efficiency for sinewave modulating signal. Compare the results to the theoretic value. **Save the simulation results on magnetic media**.

5. Replace the modulation frequency source to, squarewave source (Vt-Pulse), frequency 1MHz, amplitude 1V$_p$. Draw a proper frequency domain graph.

6. Use the data of the graph to prove that the maximum efficiency of the AM signal, in a case of squarewave modulating signal is close to theoretical value of 50%.

3.4 Measurement of AM Signal

In this part of the experiment you simply generate AM signal using function generator, and test the signal in frequency domain, measure the depth of the modulation by Spectrum analyzer.

1. Connect the signal generator directly to the spectrum analyzer as indicated in Fig-9.

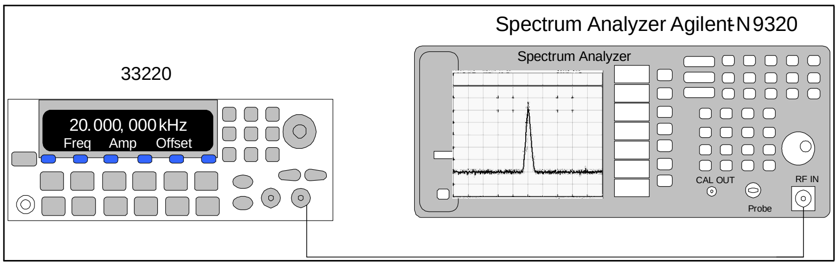

Fig. 9 AM Modulator using signal generator

2. Set the function generator to frequency 10 MHz,.amplitude 0dbm, AM modulation, modulating depth 30%, modulation frequency 1kHz.

3. Set the spectrum analyzer to frequency 10 MHz , span 50 kHz, resolution bandwidth 1 kHz. Explain why the signal is not displayed correctly.

4. Change the modulating frequency, by steps to 15 kHz ,observe the spectrum and verify your previous answer.

5. Measure the AM modulation depth oscilloscope in time domain, and spectrum analyzer in frequency domain (see table -1). **Save the measurement results on magnetic media**.

6. Measuring modulation efficiency -Measure the power of the carrier f_c and the sidebands $f_c + f_m$ and $f_c - f_m$, Calculate the AM efficiency for sinewave modulating signal.

7. Change the modulating signal to squarewave, frequency 1kHz, consider only the major sidebands (-20dB of the largest sideband),and calculate the modulation efficiency of a squarewave modulating waveform, **Save the measurement results on magnetic media**.

3.5 Demodulator-Synchronous Detector-Product Detector.

3.5.1 Simulation of Synchronous Detector

1. Simulate an AM signal modulated by synchronous detector (see Fig. 10).

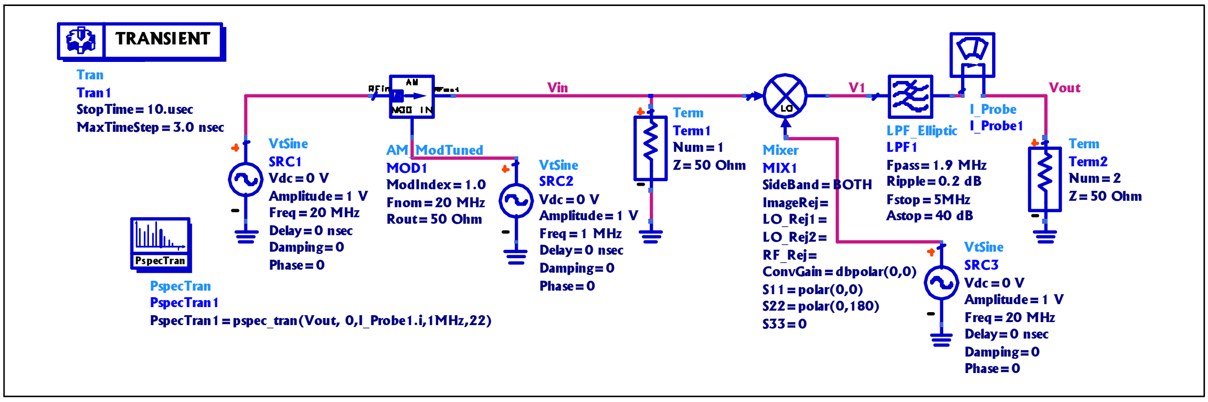

Fig. 10 AM modulated signal, detected by Synchronous demodulator

2. Draw a graph of Vout in time domain and show that the AM signal is demodulated. **Save the simulation results on magnetic media**.Change

In this part of the experiment you analyze the operating concept of product detector and the influence of carrier phase shift on demodulating signal.

3.6 Synchronous Demodulator Measurement

1. Connect the system as indicated in Fig.-11 to implement product detector.

2. Set the function generator (R) ,carrier frequency 10 MHz ,amplitude -3 dBm. , AM modulation , modulation depth 50%, modulated frequency 1 kHz.LO function generator to , frequency 10 MHz ,amplitude 7 dBm.

3. Set the phase to 0° between the two function generators.

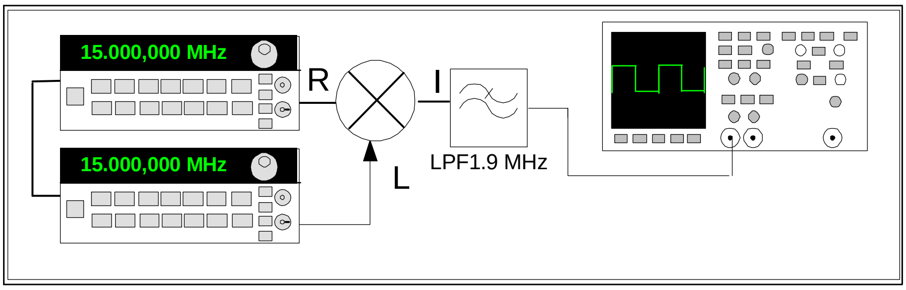

Fig. 11 Synchronous AM demodulator.

4. Observe the detected signal on the oscilloscope display , change the phase between the two generators to 0° 30°,60° ,90°. **Save the measurement results on magnetic media**.

3.7 Demodulator-Asynchronous Detector -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, choose proper RC components.

2. Set the function generator to frequency 1 MHz ,amplitude 10 dBm, AM modulation, modulation depth 50%, modulation frequency 1KHz sinewave.

3. Change the modulated frequency according to table below, and examine the demodulation capability of the detector.**Save the measurement results on magnetic media**.

Mod. Freq.\Waveform	Sine	Ramp
100 Hz	x	x
1 kHz	x	x

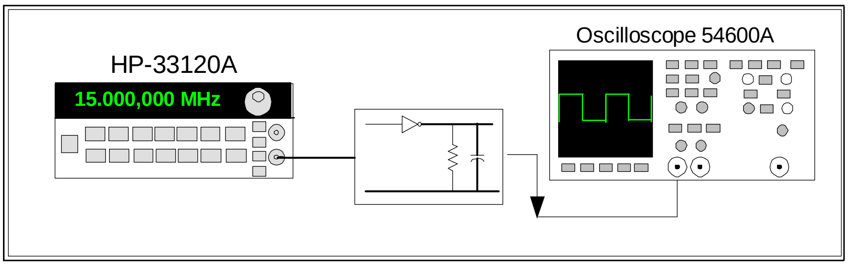

Fig. 12 AM demodulator envelope detector

3.8 Final Report

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

1.An amplitude modulated signal has the form

$$S_m(t) = 15[1 + 0.5\cos 2\pi 1000t]\cos 2\pi 10000t \tag{9}$$

* 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.

2. You have to measure residual AM (unwanted AM signal) signal modulation depth 1%, explain how you intended to do it, draw a graph of the signal in frequency domain.

3. Using your test result prove that the maximum AM efficiency is 50%.

4. In which cases you prefer to use product detector instead of envelope detector explain?