Part-I

Experiment 6:-Angle Modulation

1. Introduction

1.1 Objective

This experiment deals with the basic performance of Angle Modulation - Phase Modulation (PM) and Frequency Modulation (FM). The student will learn the basic differences between the linear modulation methods (AM DSB SSB). Upon completion of the experiment, the student will:

* Understand ANGLE modulation concept.
* Learn how to generate FM signal.
* Learn how to generate PM signal.
* Learn how to build FM demodulator.
* Get acquainted with Bessel Function.
* Understand the difference between the linear and nonlinear modulation.

1.1.1 Prelab Exercise

1.Find the maximum frequency deviation of the following signal; and verify your results in the laboratory. Carrier sinewave frequency 10.7 MHz, amplitude 1 Vp-p with frequency deviation constant 10.7 kHz/V ,modulated by sinewave frequency 10 kHz amplitude 1 Vp-p .

2. Explain what is Carson's rule.

3. What is the difference between NBFM and wideband FM refer to the Spectral component of the two.

4. Print a graph with Matlab or other software of the following FM signal: w$_c = 15MHz$, A=5, A$_m$=1, w$_m$=1KHz, Kf=7.5, t=0 to 12 seconds. Show

a. Modulation frequency versus time.

b. FM signal.

c. Differentiated FM signal.

d. Differentiated FM signal followed by LPF.

1.1.2 Necessary Background

To understand the properties of angle-modulated waveforms (FM and PM), you need a working knowledge of Fourier transform theory. We will also use the Bessel function, but will present the basic theory as it is needed. Finally, the actual systems for modulating and demodulating angle modulated waveforms require a knowledge of linear systems,oscillators and phase-locked loops.

1.1.3 Background Theory

An angle modulated signal, also referred to as an exponentially modulated signal, has the form

$$S_m(t) = A\cos[wt + \phi(t)] = \mathrm{Re}\{A\exp[jwt + j\phi(t)]\} \tag{1}$$

The instantaneous phase of $S_m(t)$ is defined as

$$\phi_i(t) = wt + \phi(t)$$

and the instantaneous frequency of the modulated signal is defined as

$$w_i(t) = \frac{d}{dt}[wt + \phi(t)] = w + \frac{d(\phi)}{dt} \tag{2}$$

The functions $\phi(t)$ and $\frac{d(\phi)}{dt}$ are referred to as the instantaneous phase and frequency deviations, respectively.

The phase deviation of the carrier $\phi(t)$ is related to the baseband message signal $s(t)$. Depending on the nature of the relationship between $\phi(t)$ and $s(t)$ we have different forms of angle modulation. In phase modulation, the instantaneous phase deviation of the carrier is linearly proportional to the input message signal, that is,

$$\phi(t) = k_p s(t) \tag{3}$$

where k_p is the phase deviation constant (expressed in radians/volt or degrees/volt). For frequency modulated signals, the frequency deviation of the carrier is proportional to the message signal, that is,

$$\frac{d(\phi)}{dt} = k_f s(t) \tag{4}$$

$$\phi(t) = k_f \int_{t_0}^{t} s(\lambda) d\lambda + \phi(t_0) \tag{5}$$

where k_f is the frequency deviation constant (expressed in (radian/sec)/volt) : and $\phi(t_0)$ is the initial angle at $t = t_0$,

It is usually assumed that $t_0 = -\infty$ and $\phi(-\infty) = 0$.

Combining Equations-4 and 5 with Equation-1, we can express the angle-modulated signal as

$$\begin{aligned} S_m(t) &= A\cos[wt + k_p s(t)] \; For \; PM \\ S_m(t) &= A\cos[wt + k_f \int_{-\infty}^{t} s(\tau) d\tau] \; For \; FM \end{aligned} \tag{6}$$

Equation-6 shows that PM and FM signals are similar in functional form with the exception of the integration of the $s(t)$-message signal in FM.

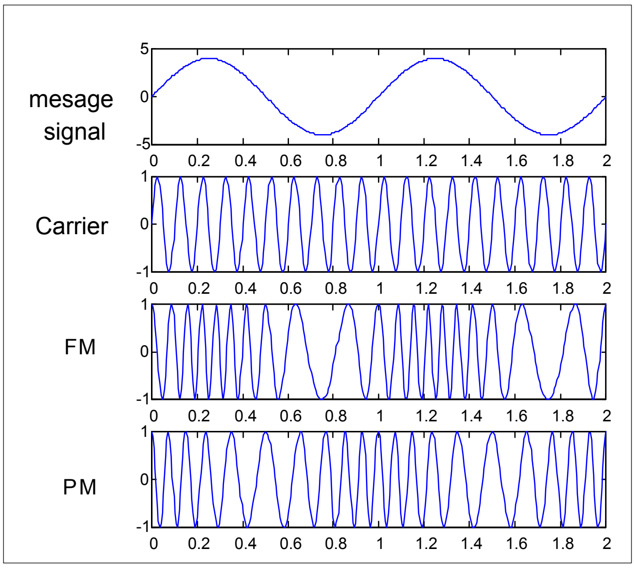


Fig - 1 :PM & FM waveforms

Figure-1 shows typical FM, and PM waveforms for tone message waveforms. This figure show an important feature of angle modulation, namely, that the amplitude of a FM or PM waveform is always constant. Because of this property we can conclude that the message exists in the zero crossings of the angle modulated signal when the carrier frequency is large. Figure 6.19 also reveals that in some cases, such as with tone-modulation, it is impossible to distinguish between FM and PM modulation.

1.1.4 Bessel Function

The Bessel function of the first kind is a solution of the differential equation

$$x^2 \frac{d^2y}{dx^2} + x\frac{dy}{dx} + (x^2 - n^2)y(x) = 0$$

Bessel function defined for negative and positive real integers. It can be shown that for integer values of n

$$j_{-n}(\beta) = (-1)^n j_n(\beta) \tag{7}$$

$$j_{n-1}(\beta) + j_{n+1}(\beta) = \frac{2n}{\beta} j_n(\beta) \tag{8}$$

$$\sum_{n=-\infty}^{\infty} j_n^2(\beta) = 1 \tag{9}$$

A short listing of Bessel function of first kind of order n and argument β is shown in table-1, and Figure 2, . Note that for very small β, $j_0(\beta)$ approaches unity, while $j_1(\beta)$ and $j_2(\beta)$ approach zero.

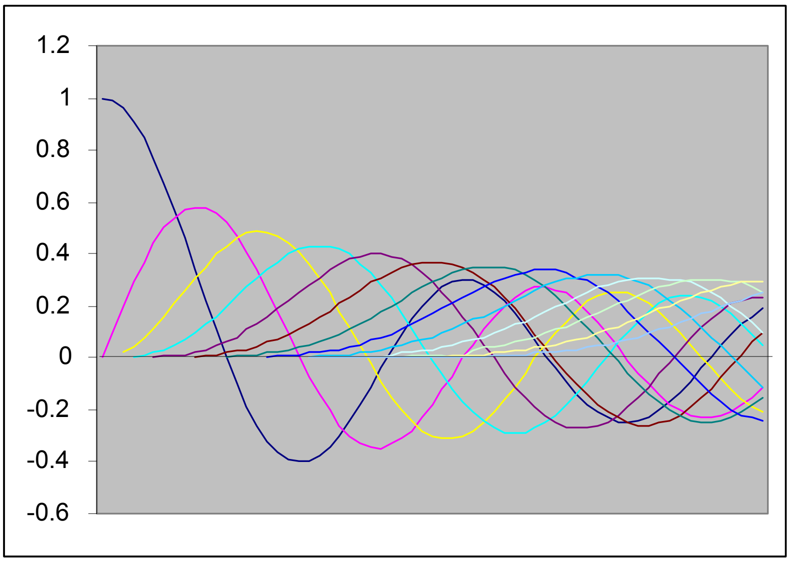


Fig - 2 - : Bessel Function

$n\backslash\beta$	0	0.2	0.5	1	2	5	8	10
0	1.00	0.99	0.938	0.765	0.224	-0.178	0.172	-0.246
1	0	0.1	0.242	0.440	0.577	-0.328	0.235	0.043
2		0.005	0.031	0.115	0.353	0.047	-0.113	0.255
3				0.02	0.129	0.365	-0.291	0.058
4				0.002	0.034	0.391	-0.105	-0.22
5					0.007	0.261	0.186	-0.234
6						0.131	0.338	-0.14
7						0.053	0.321	0.217
8						0.018	0.223	0.318
9							0.126	0.292
10							0.061	0.208
11							0.026	0.123

Table-1 Bessel function $j_n(\beta)$

Order	0	1	2	3	4	5	6
β for 1st zero	2.40	3.83	5.14	6.38	7.59	8.77	9.93
β for 2nd zero	5.52	7.02	8.42	9.76	11.06	12.34	13.59
β for 3rd zero	8.65	10.17	11.62	13.02	14.37	15.70	17.00
β for 4th zero	11.79	13.32	14.80	16.22	17.62	18.98	20.32
β for 5th zero	14.93	16.47	17.96	19.41	20.83	22.21	23.59
β for 6th zero	18.07	19.61	21.12	22.58	24.02	25.43	26.82

Table-2 Zeroes of Bessel function: Values for β when $j_n(\beta) = 0$

1. Equation -7 indicates that the phase relationship between the sideband components is such that the odd-order lower sidebands are reversed in phase .

2. The number of significant spectral components is a function of β (see Table-1). When $\beta \ll 1$, only J_0, and J_1, are significant so that the spectrum will consist of carrier plus two sideband components, just like an AM spectrum with the exception of the phase reversal of the lower sideband component.

3. A large value of β implies a large bandwidth since there will be many significant sideband components.

4. Transmission bandwidth of 98% of power always occur after $n = \beta + 1$, we note it in table-1 with underline.

5.Carrier and sidebands null many times at special values of β see table-2 .

1.1.5 Spectrum of Frequency Modulated Signal

Since angle modulation is a nonlinear process, an exact description of the spectrum of an angle-modulated signal for an arbitrary message signal is more complicated than linear process. However if $s(t)$ is sinusoidal, then the instantaneous phase deviation of the angle-modulated signal is sinusoidal and the spectrum can be relatively easy to obtained. If we assume $s(t)$ to be sinusoidal then

$$s(t) = A_m \cos w_m t \tag{10}$$

then the instantaneous phase deviation of the modulated signal is

$$\phi(t) = \frac{k_f A_m}{w_m} \sin w_m t \quad \text{For } FM \tag{11}$$

$$\phi(t) = k_p A_m \cos w_m t \quad \text{For } PM \tag{12}$$

The modulated signal, for the FM case, is given by

$$S_m(t) = A\cos(wt + \beta \sin wt) \tag{13}$$

where the parameter β is called the modulation index defined as

$$\beta = \frac{k_f A_m}{w_m} \quad \text{For FM} \tag{14}$$

$$\beta = k_p A_m \quad \text{For PM}$$

The parameter β is defined only for sinewave modulation and it represents the maximum phase deviation produced by the modulating signal. If we want to compute the spectrum of $S_m(t)$ given in Equation 11, we can express $S_m(t)$ as

$$S_m(t) = \text{Re}\{A \exp(jwt) \exp(j\beta \sin w_m t)\} \tag{15}$$

In the preceding expression, $\exp(j\beta \sin w_m t)$ is periodic with a period $T_m = \frac{2\pi}{w_m}$. Thus, we can represent it in a Fourier series of the form

$$\exp(j\beta \sin w_m t) = \sum_{-\infty}^{\infty} C_x(nf_m) \exp(j2\pi nf) \tag{16}$$

Where

$$C_x(nf_m) = \frac{w_m}{2\pi} \int_{-\frac{\pi}{w_M}}^{\frac{\pi}{w_M}} \exp(j\beta \sin w_m t) \exp(-jw_m t) dt \tag{17}$$

$$= \frac{1}{2\pi} \int_{-\pi}^{\pi} \exp[j(\beta \sin\theta - n\theta)] d\theta = j_n(\beta)$$

Where $j_n(\beta)$ known as Bessel functions. Combining Equations 14, 15 and 13, we can obtain the following expression for the FM signal with tone modulation:

$$S_m(t) = A \sum_{-\infty}^{\infty} j_n(\beta) \cos[(w + nw_m)t] \tag{18}$$

The spectrum of $S_m(t)$ is obtained from the preceding equation. An example is shown in Figure- 3 The spectrum of an FM signal has several important properties:

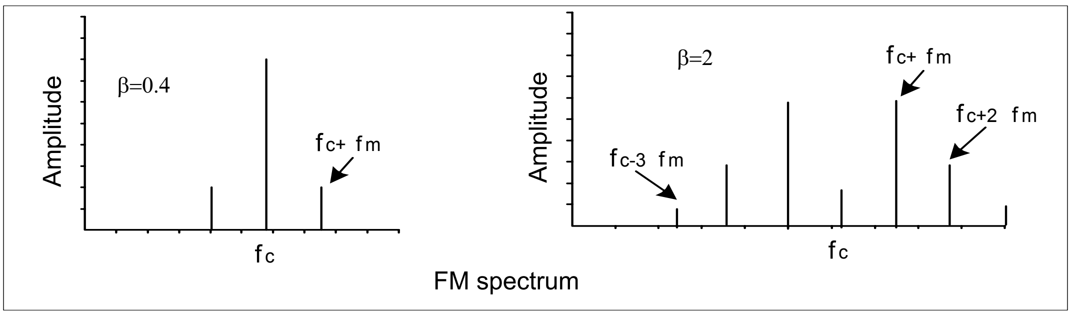


Fig - 3 - : FM spectrum

1. The FM spectrum consists of a carrier component plus an infinite number of sideband components at frequencies $f \pm nf_m$ $(n = 1, 2, 3...)$. But the number of significant sidebands depend primarily on the value of β. In comparison, the spectrum of an AM signal with tone modulation has only three spectral components (at frequencies f, $f + f_m$, and $f - f_m$).

2. The relative amplitude of the spectral components of an FM signal depend on the values of $j_n(\beta)$. The relative amplitude of the carrier depends on $j_0(\beta)$ and its value depends on the modulating signal (unlike AM modulation where the amplitude of the carrier does not depend on the value of the modulating signal).

1.1.6 Power and Bandwidth of FM Signals

In the previous section we saw that a tone modulated FM signal has an infinite number of sideband components and hence the FM spectrum seems to have infinite spectrum. Fortunately, it turns out that for any β a large portion of the power is contained in finite bandwidth. . Hence the determination of FM transmission bandwidth depends to the question of how many significant sidebands need to be included for transmission, if the distortion is to be within certain limits. The answer to this question is based on experimental fact that indicates that baseband signal distortion is negligible if 98% or more of the FM signal power is contained within the transmission band. This rule of thumb based on experimental studies, leads to useful approximate relationships between transmission bandwidth, message signal bandwidth, and modulation index.

To determine FM transmission bandwidth, let us define a power ratio S_n. as the fraction of the total power contained in the carrier plus n sidebands on each side of the carrier . That is, define S_n to be

$$S_n = \frac{\frac{1}{2}A \sum\limits_{k=-n}^{n} j_k^2(\beta)}{\frac{1}{2}A \sum\limits_{k=-\infty}^{\infty} j_k^2(\beta)} \tag{19}$$

The denominator of the preceding equation represents the average transmitted power S_T. Now the amplitude of an angle modulated waveform is always constant. Therefore, regardless of the message $s(t)$, the average transmitted power is

$$\begin{aligned} S_T &= \frac{1}{2}A^2 \\ &= \frac{1}{2}A^2 \sum_{k=-\infty}^{\infty} j_k^2(\beta) \end{aligned} \tag{20}$$

Substituting Equation-18 into 17, we have

$$S_n = \sum_{k=-n}^{n} j_k^2(\beta)$$

To find the transmission bandwidth of the FM signal for a given modulation index β, we have to find the smallest value of n that yields $S_n \geqslant 0.98$. We note that the underlines in Table- 1, which indicate the value of n for which $S_n \geqslant 0.98$, always occur just after $n = \beta + 1$. Thus, for tone modulation, the bandwidth of the FM signal is given by

$$B_T \approx 2(\beta + 1) f_m \tag{21}$$

For an arbitrary message $s(t)$, we cannot use the preceding expression to determine B_T since β is defined only for tone modulation. For arbitrary message signals bandlimited to f_m we can define a deviation ratio D (which is analogous to the modulation index β) as

$$\begin{aligned} D &= \frac{\text{peak frequency deviation}}{\text{bandwidth of } s(t)} \\ &= \frac{k_f \max[s(t)]}{2\pi f_m} = \frac{\Delta f}{f_m} \end{aligned} \tag{22}$$

Using D in place of β in Equation-23 results in the generally accepted expression for bandwidth:

$$\begin{aligned} B_T &= 2(D + 1) f_m \\ &= 2(\Delta f + f_m) \end{aligned} \tag{23}$$

Where $\Delta f = D f_m$, is the maximum frequency deviation. The preceding expression for bandwidth is referred to as Carson's rule, which indicates that the FM bandwidth is twice the sum of the maximum frequency deviation and the bandwidth of the message signal.

FM signals are classified into two categories based on the value of D (or β). If D (or β) $\ll 1$, the FM signal is called a Narrow Band FM $(NBFM)$ signal and the bandwidth of the $NBFM$ signal is equal to $2f_m$ which is the same as the bandwidth of the AM signal. When D (or β) $\gg 1$, the FM signal is called a wideband FM $(WBFM)$ signal and its bandwidth is approximately $2\Delta f$.

Narrowband FM is in many ways similar to DSB or AM signals. By way of illustration let us consider the $NBFM$ signal

$$S_m(t) = A\cos[wt + \phi(t)] \tag{24}$$

Where

$$\phi(t) = k_f \int_{-\infty}^{t} s(\tau) d\tau \tag{25}$$

For $NBFM$, the maximum value of $|\phi(t)|$ is much less than one (another definition for $NBFM$) and hence we can write $s(t)$ as

$$\begin{aligned} S_m(t) &= A[\cos\phi(t)\cos wt - \sin\phi(t)\sin wt] \\ &\approx A\cos wt - A\phi(t)\sin wt \end{aligned} \tag{26}$$

Using the approximations $cos\phi = 1$ and $sin\phi \approx \phi$, when ϕ is very small. Equation-26 shows that a $NBFM$ signal contains a carrier component and a quadrature carrier linearly modulated by (a function of) the baseband signal. Since $s(t)$ is assumed to be bandlimited to f_m therefore $\phi(t)$ is also bandlimited to f_m,. Hence, the bandwidth of $NBFM$ is $2f_m$, and the $NBFM$ signal has the same bandwidth as an AM signal.

1.1.7 Narrow Band FM Modulator

According to Equation-22, it is possible to generate $NBFM$ using a system such as the one shown in Fig-4 . The signal is integrated prior to modulation and a DSB modulator is used to generate the quadrature component of the $NBFM$ signal. The carrier is added to the quadrature component to generate an approximation to a true $NBFM$ signal. The output of the modulator can be approximated by

$$S_m(t) \approx A\cos[wt + \phi(t)] \tag{27}$$

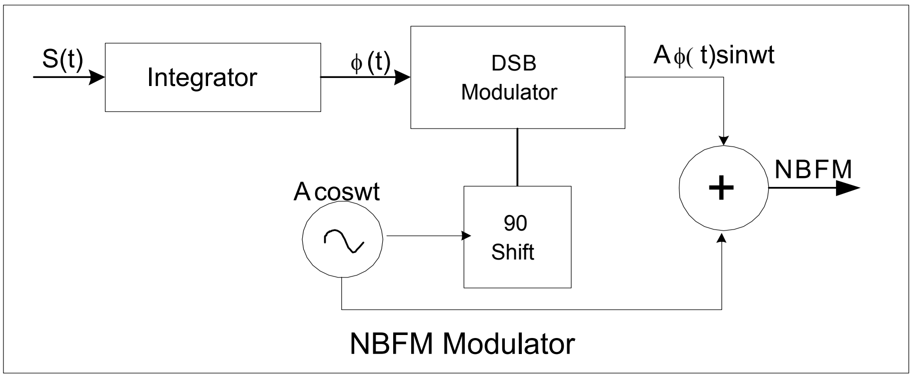


Fig - 4 - : NBFM modulator

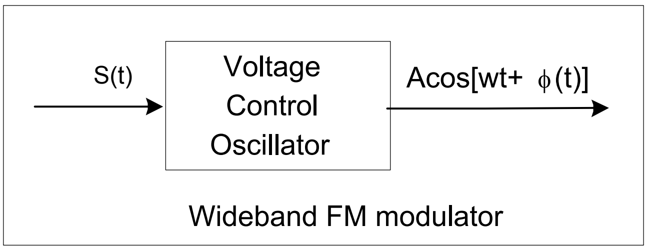


Fig - 5 - : FM modulator

The approximation is good as long as the deviation ratio $D = \frac{\Delta f}{f_m}$, is very small.

1.1.8 Wide Band FM Modulator

There are two basic methods for generating FM signals known as direct and indirect methods. The direct method makes use of a device called voltage controlled oscillator (VCO) whose oscillation frequency depends linearly on the modulation voltage.

A system that can be used for generating a PM or FM signal is shown in Figure-5. The combination of message differentiation that drive a VCO produces a PM signal. The physical device that generates the FM signal is the VCO whose output frequency depends directly on the applied control voltage of the message signal. $VCO\prime s$ are easily implemented up to microwave frequencies using the reflex klystron.. Integrated circuit $VCO\prime s$ are also used at lower frequencies. At low carrier frequencies it may be possible to generate an FM signal by varying the capacitance of a parallel resonant circuit.

The main advantage of direct FM is that large frequency deviations are possible, for relatively wide range of modulating frequency. The main disadvantage of the method is the instability of the carrier frequency.

1.1.9 Demodulation of FM Signals

An FM demodulator is required to produce an output voltage that is linearly proportional to the input frequency. Circuits that produce such response are called discriminators. If the input to a discriminator is an FM signal, is

$$S_m(t) = A\cos[wt + k_f \int_{-\infty}^{t} s(\tau)d\tau]$$

the discriminator output will be

$$y_d(t) = k_d k_f s(t)$$

where k_d is the discriminator constant. The characteristics of an ideal discriminator are shown in Figure-6.

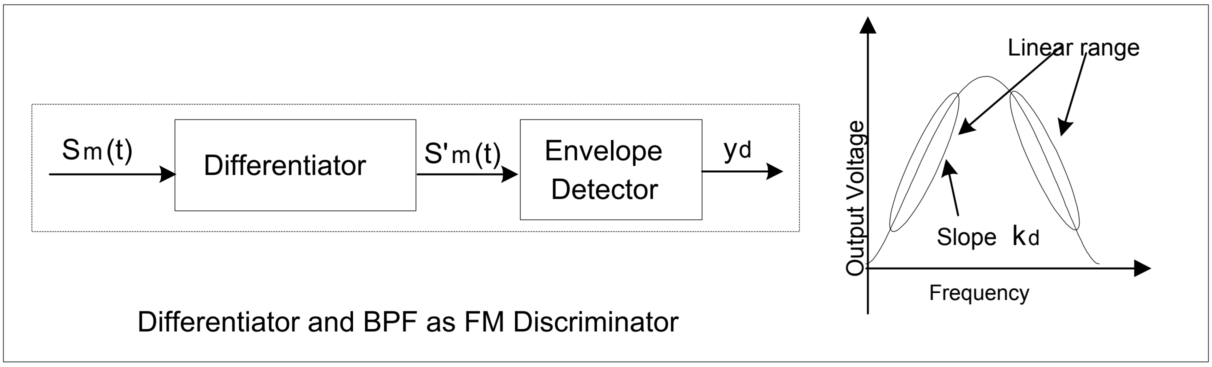


Fig - 6 - : FM discriminator

An approximation to the ideal discriminator characteristics can be obtained by the use of a differentiator followed by an envelope detector (see Figure-6) . If the input to the differentiator is $S_m(t)$, then the output of the differentiator is

$$S_m^{'}(t) = -A[w + k_f s(t)]\sin[wt + \phi(t)] \quad (28)$$

With the exception of the phase deviation $\phi(t)$, The output of the differentiator is both amplitude and frequency modulated. Hence envelope detection can be used to recover the message signal. The baseband signal is recovered without any distortion if $\text{Max}\{k_f s(t)\} = 2\pi\Delta f < w$, which is easily achieved in most practical systems.

1.2 Required Equipment

1.Spectrum Analyzer (SA) $HP - 8590L$.

2.Oscilloscope $HP - 54600A$.

3.Signal Generator (SG) $HP - 8647A$.

4. Arbitrary Waveform Generator (AWG) $HP - 33120A$.

5.Double Balanced Mixer Mini-Circuit $ZP - 2$.

6. Two Combiner/Splitter Mini-Circuit

7. 20 MHz low pass filter.

8.Envelope detector $RC = 20\mu\sec$

1.3 Experiment procedure

During this experiment you learn how to measure the FM modulation characteristics and Bessel function using spectrum analyzer, in frequency domain.

1. Connect the Test and Measurement $(T\&M)$ equipment as indicated in Fig.. 7).

2. Adjust the AWG as follow: DC volt, amplitude 530 mV.

3. Signal-generator $HP - 8647A$,frequency 10.7 MHz, amplitude 0 dBm. External DC FM modulation, frequency deviation 20 kHz.

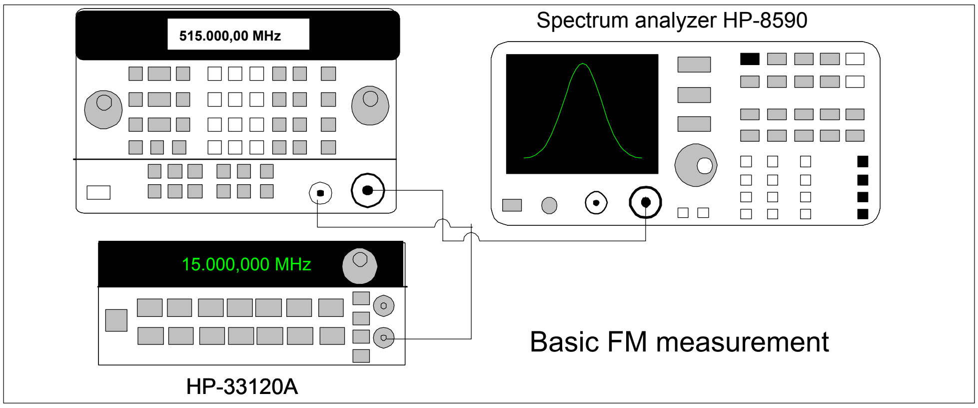


Fig - 7 - :Basic FM measurement

4. Adjust the amplitude (if necessary) of the AWG in order to get amplitude of 1 volt (Refer to $Hi\ LO$ indication of the SG),remember the impedance of the modulation input is 600Ω,that's why the "see" amplitude of AWG is 1 volt.

5. Measure and record the frequency of the signal with spectrum analyzer.

6. Switch off the modulation, measure and record the frequency of the signal with spectrum analyzer.

7.Compute the frequency deviation constant. and compare it to your calculation in prelab question.

1.3.1 Modulation frequency

1. Set the AWG to sinewave frequency 4 kHz, amplitude As necessary to correct external FM modulation,

2. Measure the amplitude and frequency of each sideband , print the results.

3. Compare your results to the Bessel function, what is frequency difference between the carrier and sidebands.

1.3.2 Frequency Deviation

The right way to measure frequency deviation is to use dedicate instrument such as frequency deviation meter. If such an instrument didn't exist there are several methods with serious limitation to replace the dedicated instrument. One method to calculate β or Δf ,is to use the amplitude information of first five sidebands. This information are used to find β with proper software. Another way to find Δf is to change the modulation frequency in order to get a carrier or sideband null as indicated in table-2.

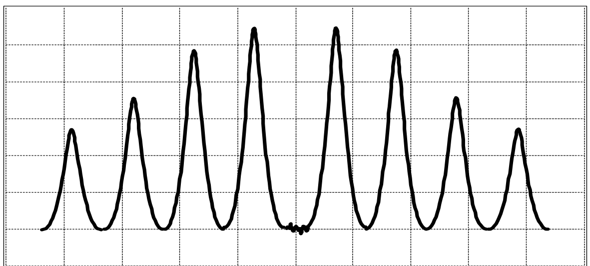
Suppose that you have to check the accuracy of the frequency deviation of the signal generator $HP-8647A$, at 3 points 20kHz, 40 kHz, 100 kHz , or you have to check frequency deviation of unknown FM modulator and you have the possibility to change the frequency of the modulation signal. Using Bessel function zero of the carrier for example at $j_0(2.4)$ we can do the job as follow:

1.Set the signal generator $HP-8647A$ to frequency 10.7 MHz , amplitude 0 dBm, external $AC\ FM$ modulation, 20 kHz.

2. Set the AWG to sinewave frequency 8 kHz, amplitude As necessary to proper external FM modulation (about 530 mv).

3. Set the spectrum analyzer to 10.7 MHz, span 100 kHz, bandwidth 1 kHz.

4. Change slightly the frequency of the AWG to about 8.33 kHz in order to get first null of the carrier.(see Figure-8).



First carrier null

Fig - 8 - : First Null

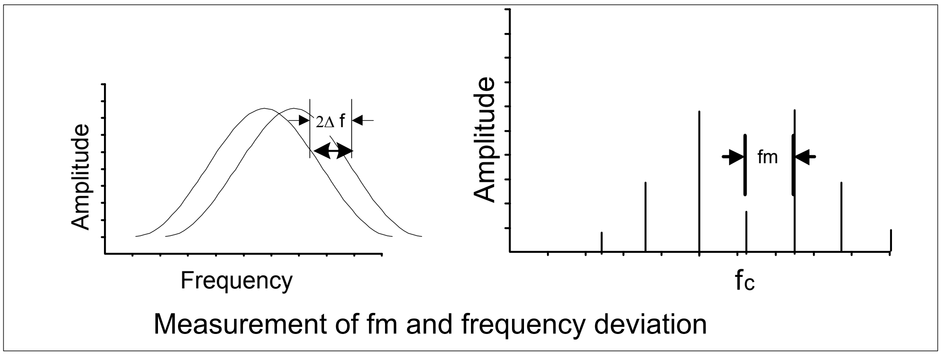


Fig - 9 - :

5. In that state you tune the system to accurate frequency deviation $\Delta f = \beta * f_m = 2.4 * f_m$. now calculate Δf print the results.

6. Repeat the above procedure for $\Delta f = 50, 100$ kHz and compare your measurement to the specification of the signal generator $HP - 8647A$.

Another way to approximately measure Δf with spectrum analyzer is to find carrier frequency, then measuring the sideband spacing using a sufficiently small IF filter and then the peak frequency deviation is measured by selecting an IF bandwidth wide enough to cover all major sidebands.

1. Set the IF bandwidth of the spectrum analyzer to 1 kHz and measure the modulation frequency.

2. Set the IF bandwidth of the spectrum analyzer to 100 kHz and measure the frequency deviation (see figure 9) print the results.

1.3.3 FM Spectrum and Bessel Function

FM spectrum based on properties of Bessel function. We start to verify FM spectrum according to Equations-7,8 and 9.

1.Set the signal generator $HP-8647A$ to frequency 10.7 MHz , amplitude 0 dBm, external $AC\ FM$ modulation, FM-2 kHz.

2. Set the AWG to sinewave frequency 10 kHz, amplitude As necessary to proper external FM modulation (about 530 mv).

3. Set the spectrum analyzer to 10.7 MHz, span 200 kHz, bandwidth 1 kHz.

4. The spectrum of the signal look like AM-modulation, set marker on the carrier and two sidebands, print the results. what is the value of β? And what is the bandwidth of the FM signal? Is it narrow or wideband FM ?

5. Change FM deviation to 50 kHz , record the amplitude of every spectral line, press $MOD-\ OFF$ on Signal generator and measure the amplitude of the carrier without modulation.

6. Calculate β,and verify Equations-7,8 and 9 with carrier and sidebands what is the bandwidth of the FM signal? Is it narrow or wideband FM ? How many sidebands contains 98% of signal energy?

7. Set the AWG to triangle wave frequency 10 kHz, amplitude As necessary to proper external FM modulation (about 530 mv).

8. Measure and record with spectrum analyzer the highest spectral component of the triangle signal (f_m).

9. Connect the AWG to signal generator as indicated in Figure-7- and measure the bandwidth of the modulated signal,print the results and compare them to Carson's rule

1.3.4 Narrow Band FM Modulator

In this part of the experiment, we generate $NBFM$ signal, without the first stage- integrator, since our input signal will be the integral of the modulating signal.

1. Connect the Test and Measurement $(T\&M)$ equipment according to Fig.-10.

2. Adjust the $T\&M$ equipment as follow:

$AWG\ LO$- Sinewave frequency 10.7 MHz amplitude 7dbm.

$AWG\ R$- Sinewave frequency 10 kHz amplitude -10dbm.(integral of the cosine input wave).

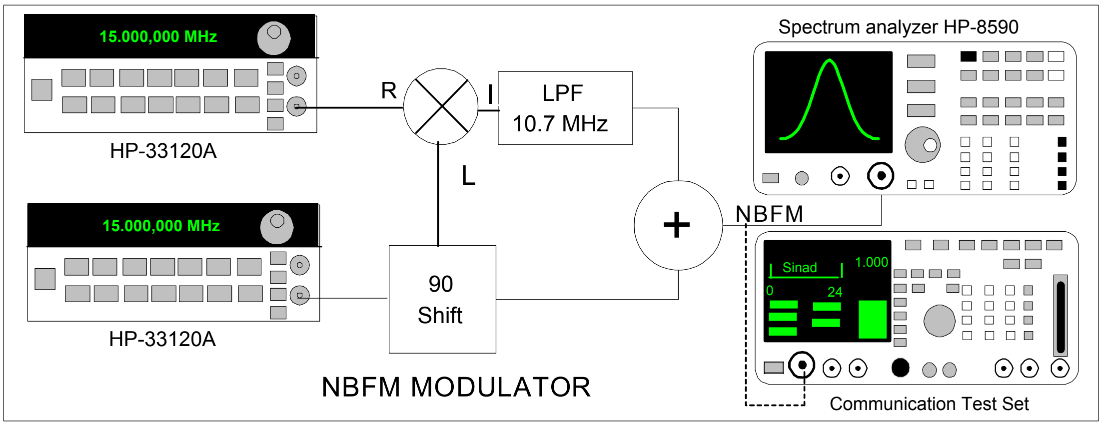


Fig - 10 - :

3. Set the spectrum analyzer to 10.7 MHz span 50kHz , watch the FM signal at spectrum analyzer, change the amplitude and frequency of the modulating frequency generator, which component of the FM signal changed?

$n\backslash\beta$	0	0.1	0.15	0.2
0	0.00(Ref.)	0.00(Ref.)	0.00(Ref)	0.00(Ref.)
1	-∞	-26.0(dB)	-22.5(dB)	-19.95(dB)
Table-3 Small β logarithmic values for NBFM				

4. Change the amplitude and frequency of the local oscillator , which component of the FM signal changed?
5. According to table-3 set the system to $NBFM\ \beta = 0.1$, calculate the frequency deviation and print the results.
6. Calculate the proper DC voltage that cause the same frequency deviation.
7. Verify your results by setting the AWG to the calculated DC voltage and measure on spectrum analyzer the frequency difference of the signal, with and without DC signal.

1.3.5 Power and Bandwidth of FM Signal

Set the spectrum to single sweep and make the measurement of the above signal as follow

1. Measure the power of each component of the FM above signal (signal with null carrier), measure the total bandwidth of the FM signal (signal with all the sidebands).
2. According to the criterion of 98% power calculate the power of the FM signal and the bandwidth of the signal.
3. what is the difference in percent between the measured and calculated power and bandwidth?

1.3.6 IF Filter as FM Discriminator

In this part of the experiment you demodulate FM signal using the linear region of the IF filter of the spectrum analyzer as frequency discriminator. You have to choose If bandwidth and video bandwidth wide enough to pass all sidebands of the signal, but with proper slope so the amplitude of the demodulated signal will be measurable.

1. Connect the AWG directly to spectrum analyzer as shown in figure-11.

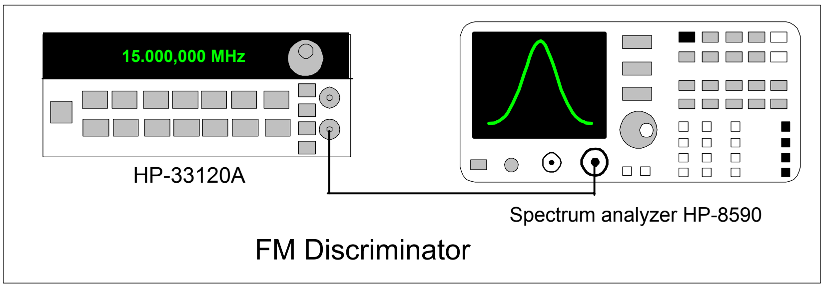


Fig - 11 - :

2. Set the AWG to frequency 10.7 MHz, amplitude 0 dBm, FM modulation frequency 1 kHz, deviation 4 kHz.
3. Set the spectrum analyzer to Center frequency 10.7 MHz, Span 100 kHz, Bandwidth as necessary to pass all the signal $B = 2 * (\Delta f + f_m)$, Amplitude linear (why) ?
4. Place the signal near the top of the screen and in the center of the screen.
5. Set the span to 0 kHz, and sweeptime to 20 ms, you see the time domain of modulation frequency near the top of the screen.

6. Change slightly clockwise the center frequency (center frequency＞10 MHz) until you see in the middle of the screen sinewave demodulated by the negative slope of the IF filter, change the sweep to single sweep and measure the frequency of the signal.

7. Change slightly counterclockwise the center frequency (center frequency＜10 MHz)until you see on the middle of the screen sinewave demodulated by the positive slope of the IF filter, change the sweep to single sweep and measure the frequency of the signal, print the results.