Analizador de espectro de barrido: aplicaciones

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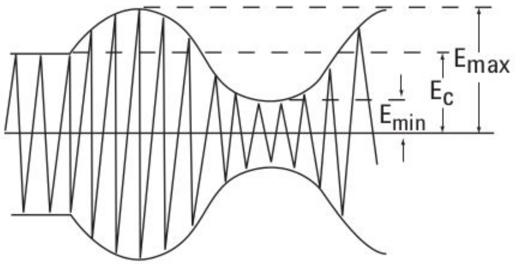
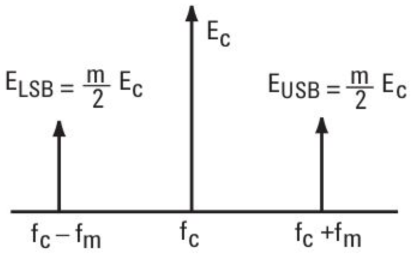
Mediciones de modulación en AM



(a)



(b)

$$m = \frac{E_{max} - E_c}{E_c}$$

Since the modulation is symmetrical,

$$E_{max} - E_c = E_c - E_{min}$$

and

$$\frac{E_{max} + E_{min}}{2} = E_c$$

From this, it is easy to show that:

$$\boxed{m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}}$$

Calculo en el dominio del tiempo

$$\boxed{E_{max} = E_c + E_{USB} + E_{LSB}}$$

Relacion tiempo-frecuencia

$$m = \frac{E_{max} - E_c}{E_c} = \frac{E_{USB} + E_{LSB}}{E_c}$$

and, since $E_{USB} = E_{LSB} = E_{SB}$, then:

$$\boxed{m = \frac{2E_{SB}}{E_c}}$$

Calculo en el dominio de la frecuencia

Si m=100%:

$E_{USB} = E_{LSB} = 0{,}5\ E_C = -6$ dB

- Each sideband will be 6 dB less than the carrier, or one-fourth the power of the carrier.

- Since the carrier component does not change with amplitude modulation, the total power in the 100% modulated wave is 50% higher than in the unmodulated carrier

Presentaciones en tiempo y frecuencia, según índice de modulación

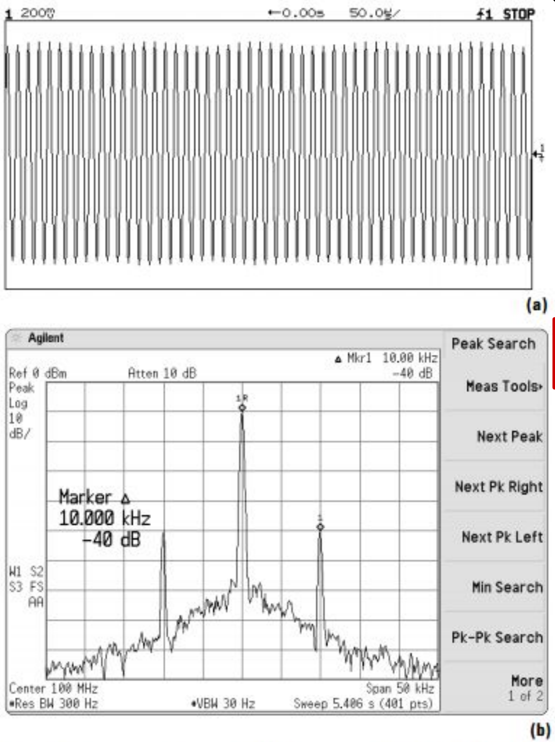
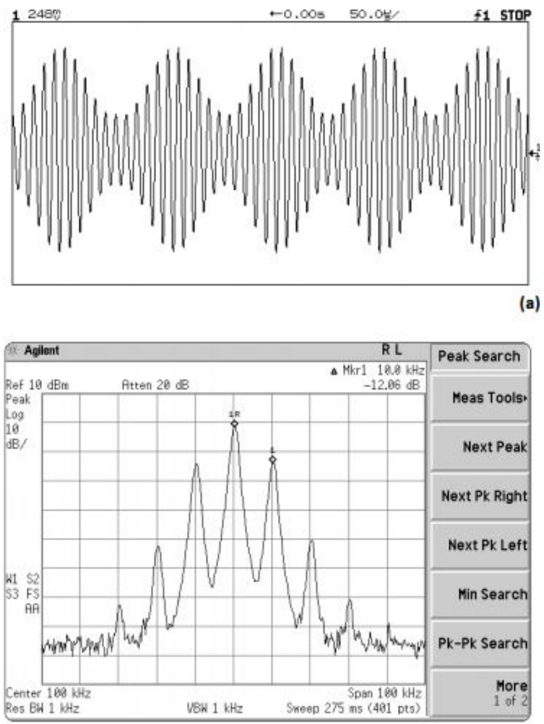


Figure 3. Time (a) and frequency (b) domain views of low level (2%) AM.



The minimum peak-to-peak value is one third the maximum peak-to-peak value, so **m = 0.5 and m = 50%**. Figure 5b shows the same waveform measured in the frequency domain. Since the carrier and sidebands differ by **12 dB, m= 50%**

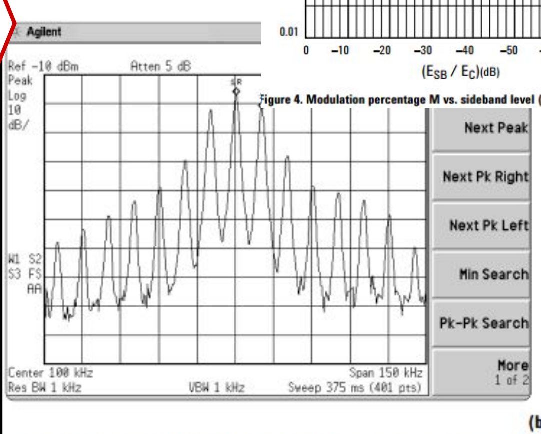


Figure 6. (a)An overmodulated 60 MHz signal in the time domain, (b) The frequency domain display of the signal

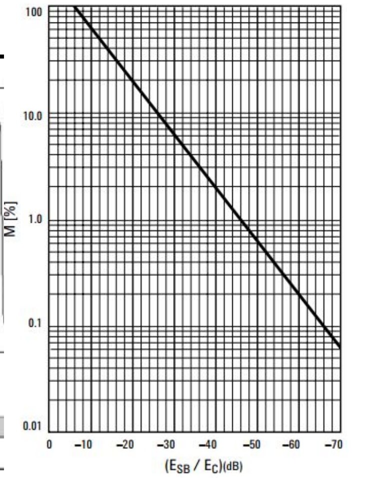


Figure 4. Modulation percentage M vs. sideband level (log display)

Mediciones con SPAN = 0

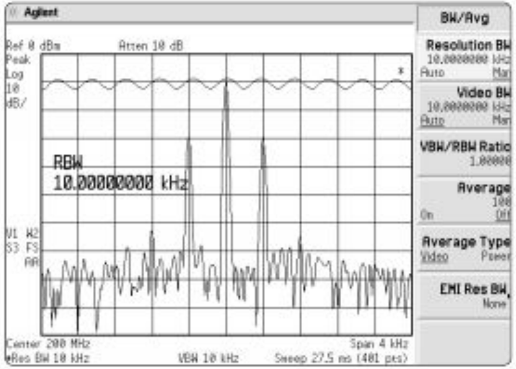


Figure 7. Resolution bandwidth is set wide enough to encompass the modulation sidebands without attenuation

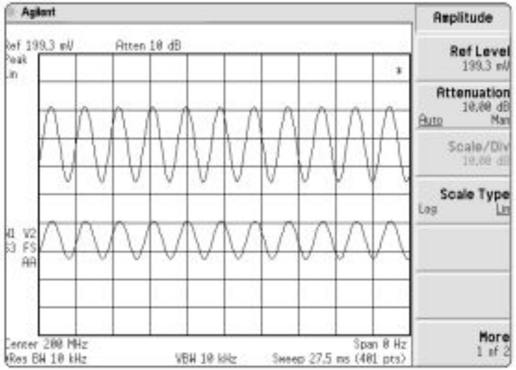
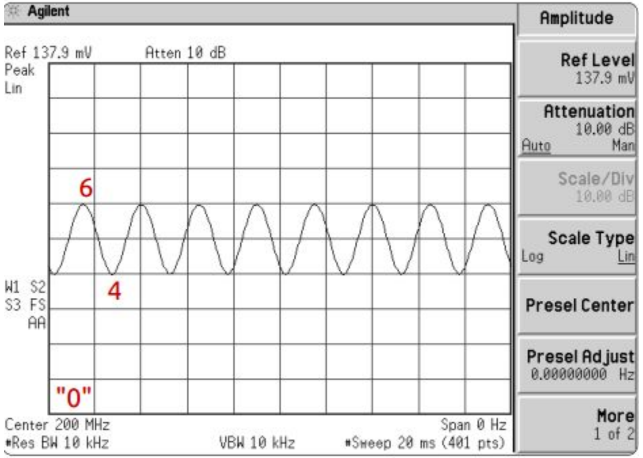


Figure 8. Moving the signal up and down on the screen does not change the absolute difference between Emax and Emin, only the number of display divisions between them due to the change of display scaling



m = (6 - 4) / (6 + 4) = 0.2, or 20% AM.

The frequency of the modulating signal can be determined from the calibrated sweep time of the analyzer. In figure 9 we see that 4 cycles cover exactly 5 divisions of the display. With a total sweep time of 20 msec, the four cycles occur over an interval of 10 msec. The period of the signal is then 2.5 msec, and the frequency is 400 Hz.

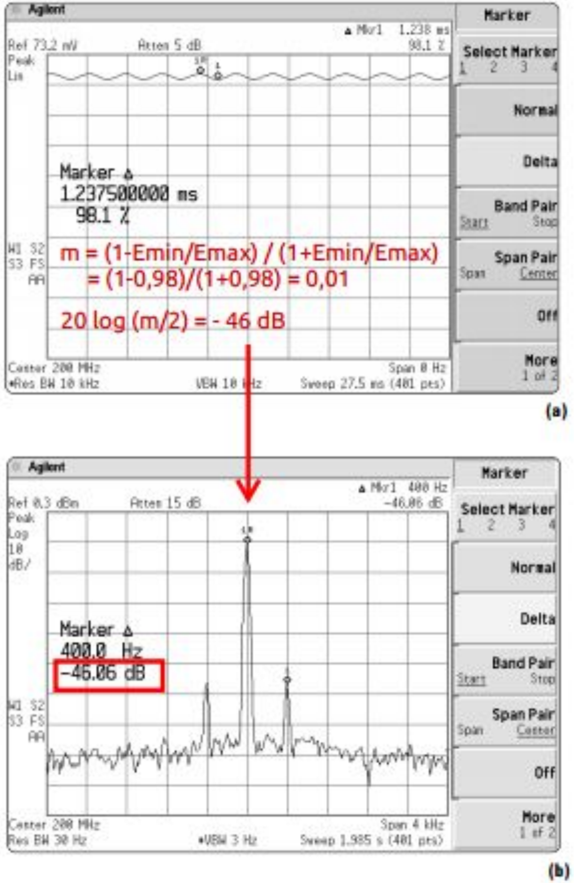
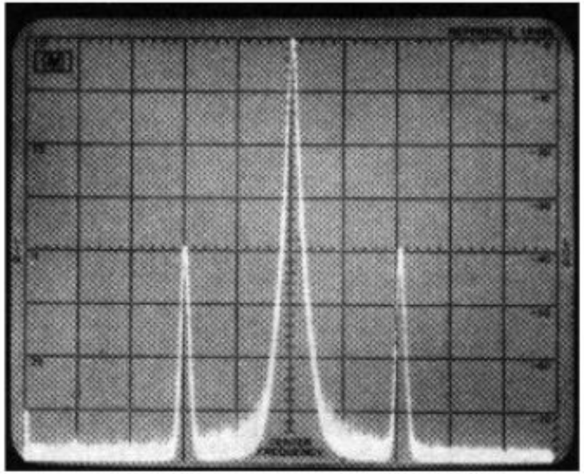
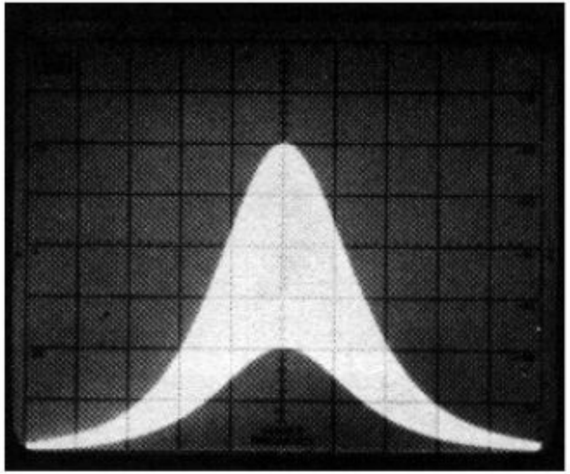


Figure 11. (a) Using markers to measure percent AM works well even at low modulation levels. Percent AM computed from ratio in A agrees with values determined from carrier/sideband ratio in (b)

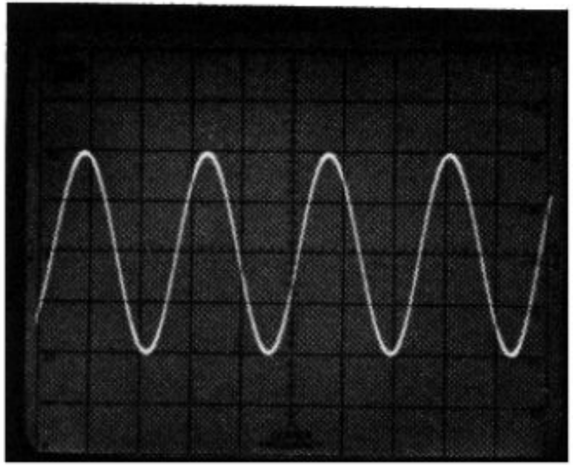
Mediciones de AM, desde el dominio de la frecuencia al dominio del tiempo



RES BW 3 kHz
LOG SCALE 10 dB/
FREQUENCY 1.067 GHz,
FREQ SPAN/DIV 50 kHz



RES BW 1 MHz,
LOG SCALE 10 dB/
FREQUENCY 1.067 GHz,
FREQ SPAN/DIV 50 kHz



RES BW 1 MHz,
LOG SCALE 10 dB/
FREQUENCY 0.550, GHz
FREQ SPAN/DIV 0 kHz

frecuencia → tiempo y frecuencia → tiempo

Mediciones de modulación en FM

$$e = A\cos(\omega t + \boxed{\phi})$$

Frequency modulation. The instantaneous frequency deviation of the modulated carrier with respect to the frequency of the unmodulated carrier is directly proportional to the instantaneous amplitude of the modulating signal.

Phase modulation. The instantaneous phase deviation of the modulated carrier with respect to the phase of the unmodulated carrier is directly proportional to the instantaneous amplitude of the modulating signal.

For angle modulation, there is no specific limit to the degree of modulation; there is no equivalent of 100% in AM. Modulation index is expressed as:

$$\boxed{\beta = \Delta f_p / f_m = \Delta\phi_p}$$

where

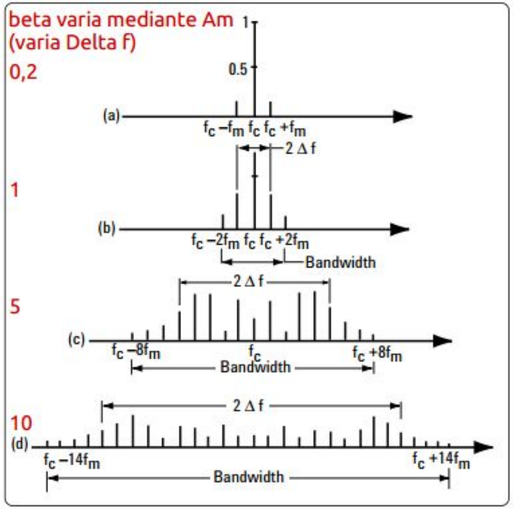
β = modulation index,
Δf_p = peak frequency deviation, (Proporcional a *Am*)
f_m = frequency of the modulating signal, and
$\Delta\phi_p$ = peak phase deviation in radians.

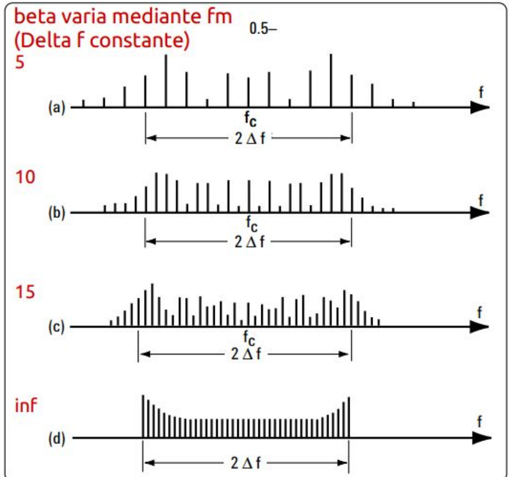
- the angle modulation index is really a function of phase deviation, **even in the FM case.**

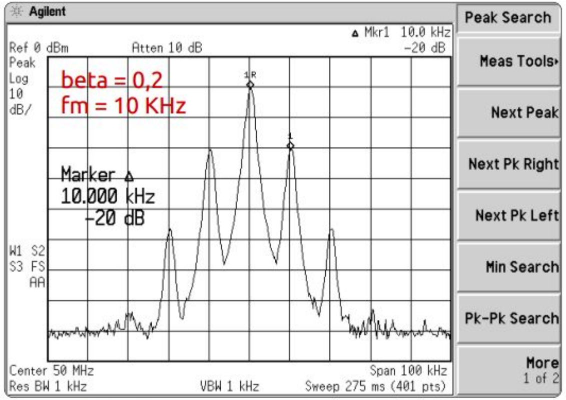
- In each case, **the modulated property of the carrier, frequency or phase, deviates in proportion to the instantaneous amplitude of the modulating signal,** regardless of the rate at which the amplitude changes. However, **the frequency of the modulating signal is important in FM** and is included in the expression for the modulating index

- The spectral components (including the carrier component) change their amplitudes when β is varied

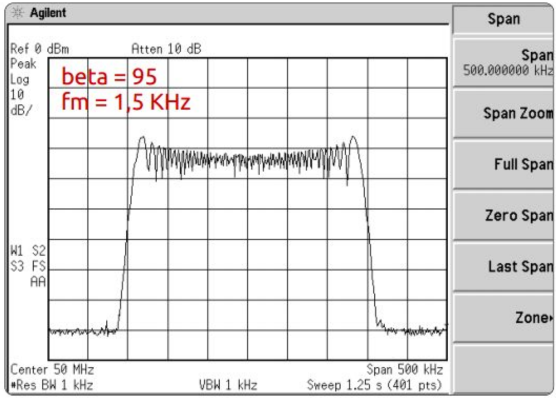
- In practice, the spectrum of an FM signal is not infinite. Significant sidebands are those sidebands that have a **voltage at least 1 percent (–40 dB) of the voltage of the unmodulated carrier** for any β between 0 and maximum.







FM de banda angosta (m < 0,2) => **BW = 2 fm**



FM de banda ancha (m > 100) => **BW = 2 Δfp**

We can calculate the necessary bandwidth B using the approximation:

$$B = 2\,\Delta f_{peak} + 2\,f_m$$

$$B = 2\,f_m\,(1 + \beta)$$

An FM broadcast station has a maximum frequency deviation (determined by the maximum amplitude of the modulating signal) of Δfpeak = 75 kHz. The highest modulation frequency fm is 15 kHz. This combination yields a modulation index of β = 5, and the resulting signal has eight significant sideband pairs. Thus the required bandwidth can be calculated as 2 x 8 x 15 kHz = 240 kHz. For modulation frequencies below 15 kHz (with the same amplitude assumed), the modulation index increases above 5 and the bandwidth eventually approaches 2 Δfpeak = 150 kHz for very low modulation frequencies.

Calibración de Δfpico

The spectrum analyzer is a very useful tool for measuring Δfpeak and β and for making fast and accurate adjustments of FM transmitters. It is also frequently used for calibrating frequency deviation Meters.

Method 1: A signal generator or transmitter is adjusted to a precise frequency deviation with the aid of a spectrum analyzer using one of the carrier zeros and selecting the appropriate modulating frequency.

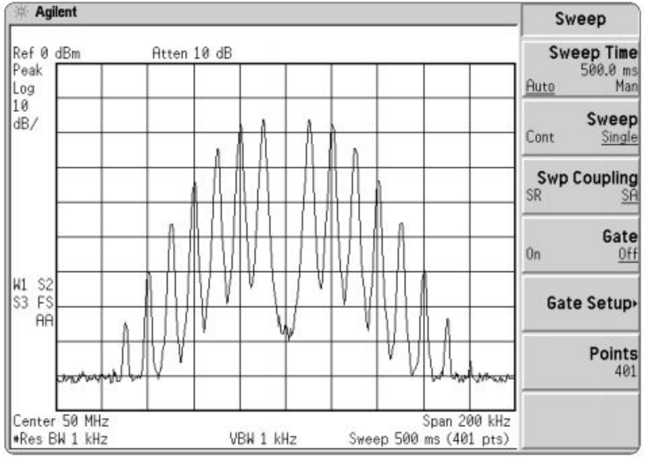
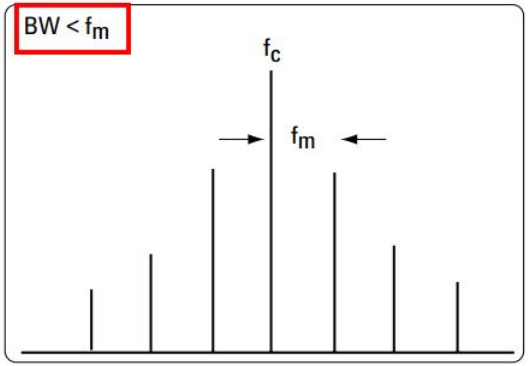


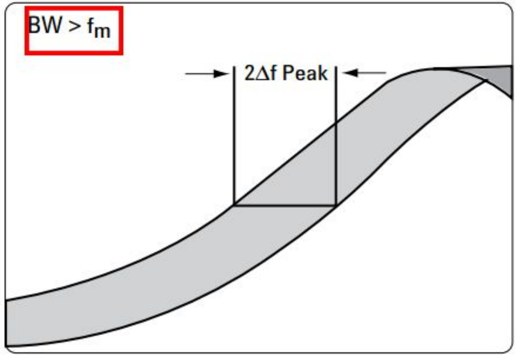
Figure 27. This is the spectrum of an FM signal at 50 MHz. The deviation has been adjusted for the first carrier null. The f_m is 10 kHz; therefore, Δf_{peak} = 2.4 x 10 kHz = 24 kHz

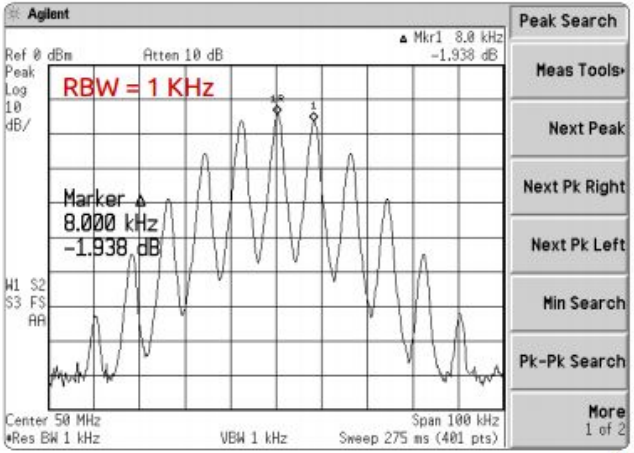
If it is not possible or desirable to alter the modulation frequency to get a carrier or sideband null, there are other ways to obtain usable information about frequency deviation and modulation index:

Method 2: First, the sideband spacing of the modulated carrier is measured by using a sufficiently small RBW, to give the modulation frequency fm.

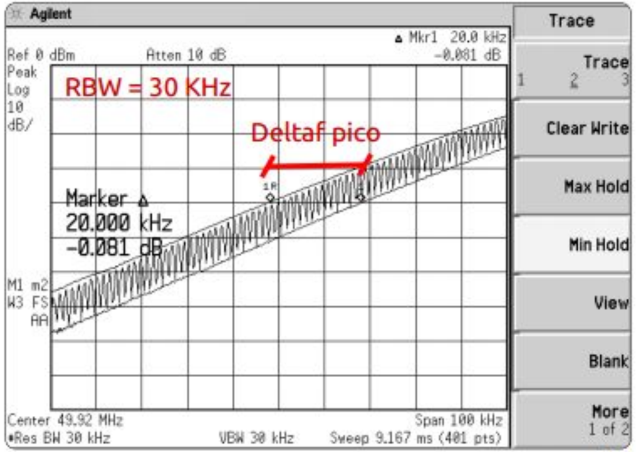
Second, the peak frequency deviation Δfpeak is measured by selecting a convenient scan width and an **RBW wide enough to cover all significant sidebands.** Modulation index β can then be calculated easily.







(a)



(b)

Medición práctica siguiendo el método 2 de la filmina anterior

SPAN CERO:

Metodo de deteccion de FM por flanco

It is possible to recover the modulating signal, even with analyzers that do not have a built-in FM demodulator. The analyzer is used as a manually tuned receiver (zero span) with a wide IF bandwidth. However, in contrast to AM, the signal is not tuned into the passband center but to one slope of the filter curve as illustrated in figure 32.

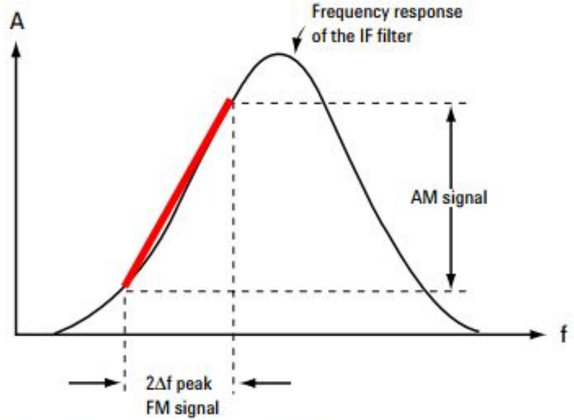
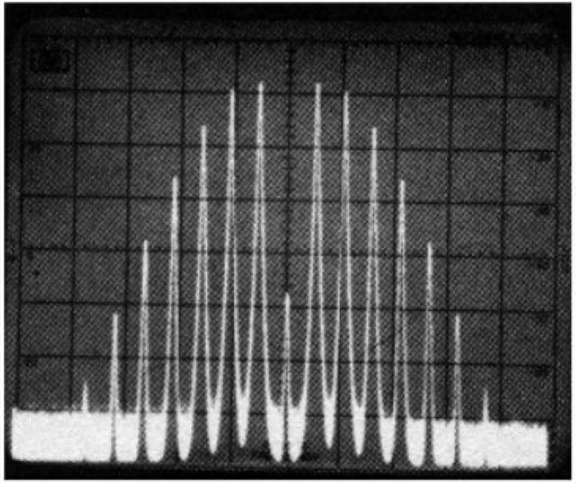


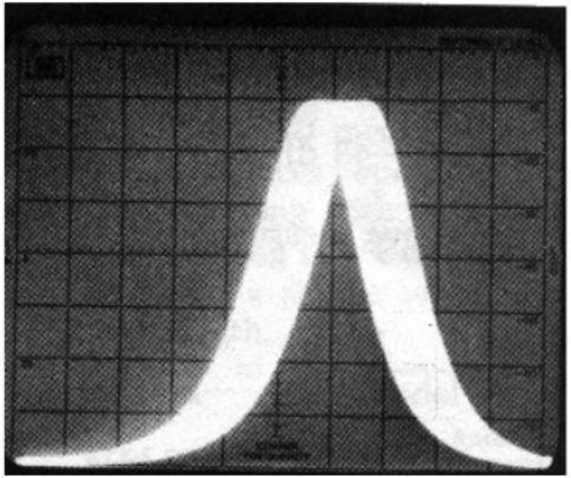
Figure 32. Slope detection of an FM signal

Here the frequency variations of the FM signal are converted into amplitude variations (FM to AM conversion). The resultant AM signal is then detected with the envelope detector. The detector output is

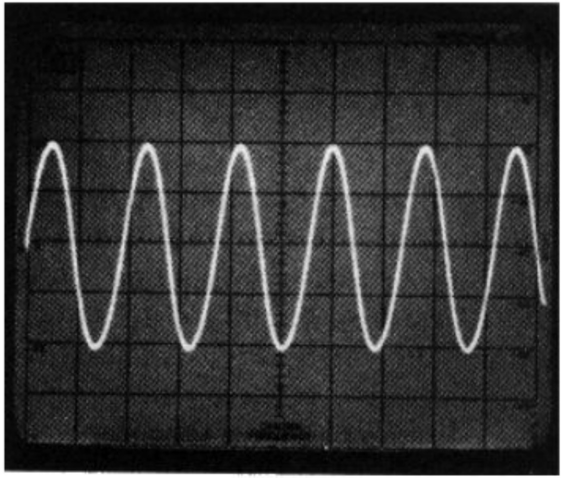
Mediciones de modulación en FM



RES BW 3 kHz
FREQUENCY 0.098 GHz,
FREQ SPAN/DIV 100 kHz



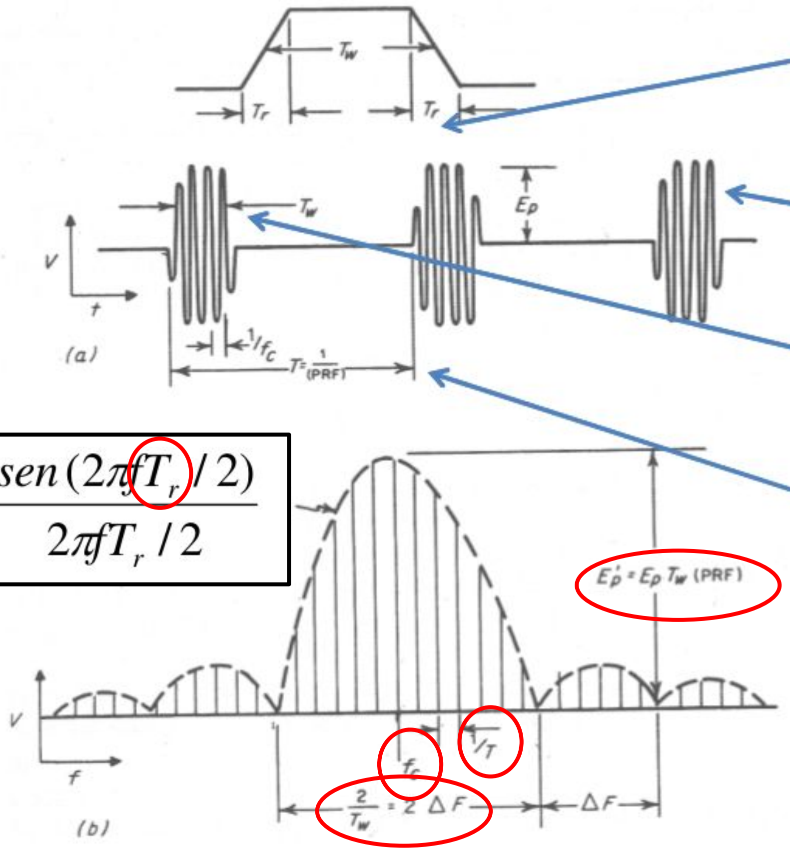
RES BW 300 kHz,
FREQUENCY 0.098 GHz,
FREQ SPAN/DIV 200 kHz



RES BW 300 kHz,
FREQUENCY 0.098 GHz,
FREQ SPAN/DIV 0 kHz

Primer nulo => m=2,4
Fm = 50 KHz => Δf = 140 KHz

Mediciones de modulación en PRF



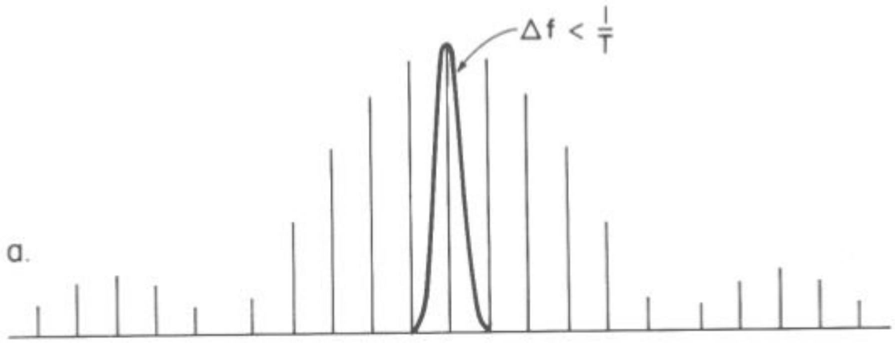
$$\frac{sen(2\pi f T_W/2)}{2\pi f T_W/2} \cdot \frac{sen(2\pi f T_r/2)}{2\pi f T_r/2}$$

- SI EL Tr DISMINUYE Y NO LO HACE Tw LA FORMA DE LA ENVOLVENTE VARAIARA SIN VARIAR LA AMPLITUD O LA POSICION DE LOS NULOS
- SI FC VARIA EL ESCPECTRO SE MANTIENE INVARIABLE PERO CON OTRA FRECUENCIA CENTRAL
- SI Tw AUMENTA LA AMPLITUD DE LA ENVOLVENTE AUMENTARA ACHICANDOSE LA DIMENSIONES EN FRACUENCIA
- SI T DISMINUYE (AUMENTA LA Fr DE PULSOS) LA FRECUENCIA DE ENVOLVENTE PERMANECERA INVARIABLE AUMENTANDO LA AMPLITUD Y ESPACIANDOSE LAS LINEAS ESPECTRALES

Mediciones de modulación en PRF: línea espectral

En la pantalla se obtiene la verdadera característica de un espectro en el dominio de las frecuencias cuando:

1. El espacio entre líneas en la pantalla no varía cuando se altera el tiempo de barrido del analizador, en Div/seg. o ST.
2. La amplitud de cada línea en la pantalla no varía cuando varía el RBW. Por supuesto, que debe permanecer por debajo de la frecuencia de repetición de los pulsos para permanecer en el modo de línea espectral. Su altura puede variar si al variar RBW varia la ganancia del analizador, pero no lo hará la amplitud medida.

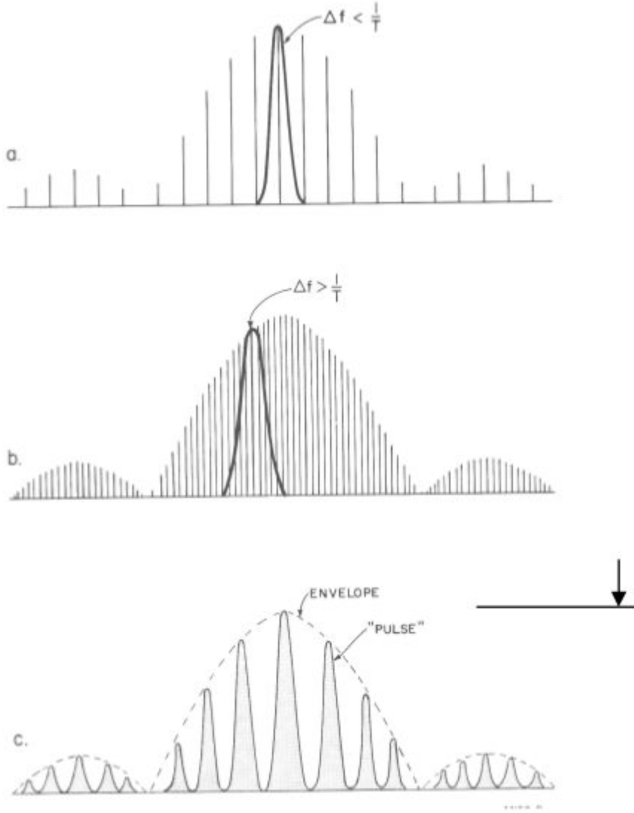


Mediciones de modulación en PRF: pulso o *intensidad espectral*

Es una presentación en el dominio del tiempo para los pulsos espectrales va que cada pulso se produce cuando se produce un pulso de RF, y para la envolvente es una presentación en el dominio de las frecuencias.

1. El espacio entre líneas de pulsos incrementa linealmente con la velocidad de barrido. Los pulsos espectrales se producen a la frecuencia de repetición de los pulsos (PRF) y se encuentran espaciados en tiempo real por 1/ PRF. La forma del espectro de la envolvente no varía con la velocidad de barrido.
2. El espacio entre las líneas impulsivas en la pantalla no varía cuando se modifica el ancho de la presentación (SPAN o Hz/Div). Tal como es de esperar varía horizontalmente el espectro de la envolvente.
3. Como la respuesta es exactamente como el ruido impulsivo, la amplitud de la envolvente, como se ha medido por sustitución de una onda continua, incrementa linealmente con una pendiente de 6 dB por octava a medida que el BWR incrementa. Este incremento de B persiste hasta que B se hace aproximadamente igual a la mitad del lóbulo principal, y de ahí en adelante no se producen más incrementos. En este punto, B ha recogido casi toda las componentes espectrales. La pantalla se encuentra ahora en el dominio del tiempo.

Mediciones de modulación en PRF: pulso o *intensidad espectral*



a). Espectro de líneas

b). Ancho de banda que contiene varias líneas espectrales

$$Ep'' = IB \times Tw \times Ep$$

c). A) y b) son promediados cuando se hace presente el pulso graficando la "intensidad espectral"

$$BWR = \frac{prf}{10}$$

Criterio límite para línea espectral

Line Spectrum Desensitization Factor

$$\alpha_L = 20\ \mathrm{Log}_{10}(\tau/T) = 20\ \mathrm{Log}_{10}(\text{duty cycle})$$

Pulse spectrum Desensitization Factor

$$\alpha_p = 20Log(\tau \cdot B_{imp}) = 20Log(\tau \cdot K \cdot RBW)$$

$$\frac{\textit{respuesta espectral por pulsos}}{\textit{respuesta espectral por líneas}} = \frac{IB}{prf}$$

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