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Guide to Spectrum Analysis

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CONTENTS

Introduction

Engineers and technicians involved in modern RF or microwave communications have many measuring instruments at their disposal, each designed for specific measurement tasks. Among those available are:

a) The Oscilloscope -primarily developed for measuring and analyzing signal amplitudes in the time domain. The resulting composite signal is displayed on a swept CRT display.

b) The Field Strength Meter (F.S.M.) - essentially the same as a Selective Level Meter but with additional capabilities to calculate and display the power density of an electrical signal incident on a calibrated antenna and thus give a direct reading of field strength in dBμV/m.

c) The Modulation Analyzer - invaluable for measuring the modulation characteristics of electromagnetic waves. These units demodulate AM, FM and Phase modulated signals for a set carrier frequency. Newer models provide demodulation of digitally modulated signals used in most of today's communications systems. Measurements are normally displayed numerically.

d) The Frequency Counter - a digitally based instrument that measures and displays the frequency of incoming signals. Some models can also count 'pulse' and 'burst' signals.

e) The Signal Generator - an essential item of equipment for any communications test laboratory or workshop. The cost of a signal generator largely depends on the additional functions and facilities available as well as the type and quality of the frequency reference used.

f) The Spectrum Analyzer - designed to measure the frequency and amplitude of electromagnetic signals in the frequency domain. Most modern analyzers also have the capability to demodulate AM and FM signals. While some higher performance swept-tuned analyzers can provide demodulation of digitally modulated signals, with the use of digital signal processing (DSP), this is not an inherent capability.

The spectrum analyzer remains the most versatile tool available. This guide will describe the critical performance characteristics of the spectrum analyzer, the types of signals measured, and the measurements performed.

Frequency Domain / Time Domain

As mentioned in the introduction, electromagnetic signals can be displayed either in the time domain, by an oscilloscope, or in the frequency domain using a spectrum analyzer. Traditionally, the time domain is used to recover the relative timing and phase information required to characterize electrical circuit behavior. Circuit elements such as amplifiers, modulators, filters, mixers and oscillators are better characterized by their frequency response information. This frequency information is best obtained by analysis in the frequency domain.

In order to visualize these 'domains' refer to Figure 1 over.

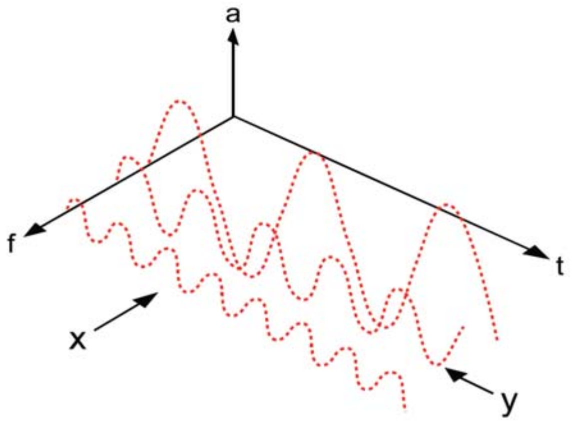


Figure 1

This represents an electromagnetic signal as a 3-dimensional model using:

(i) a time axis (t)

(ii) a frequency axis (f) and

(iii) an amplitude axis (a)

Observing from position X produces an amplitude - time display where the resultant trace is the sum of the amplitudes of each signal present. This time domain view facilitates analysis of complex signals, but provides no information on the individual signal components (Figure 2).

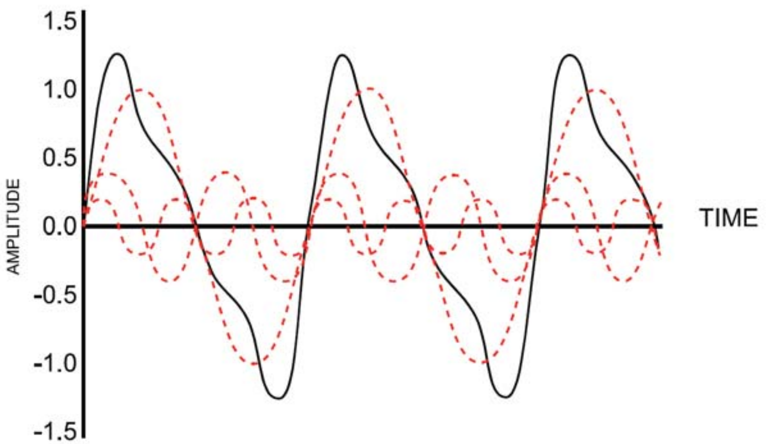


Figure 2

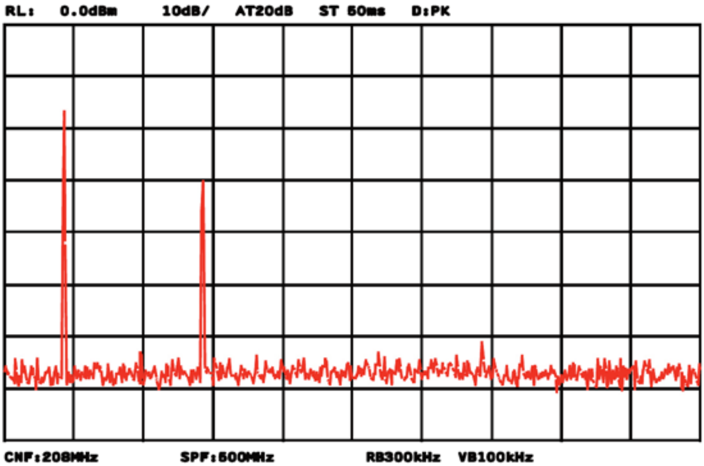


Figure 3

Viewing the model in Figure 1 from position Y, however, produces an amplitude vs. frequency display showing each component of the signal in the complex waveform. Observation in this frequency domain permits a quantitative measurement of the frequency response, spurious components and distortion of circuit elements (Figure 3).

SPECTRUM ANALYZERS

Types

There are two basic forms of spectrum analyzers, swept tuned and real-time. As the description suggests, a swept tuned analyzer is tuned by electronically sweeping its input over the desired frequency range thus, the frequency components of a signal are sampled sequentially in time (Figure 4). Using a swept tuned system enables periodic and random signals to be displayed but does not allow for transient responses.

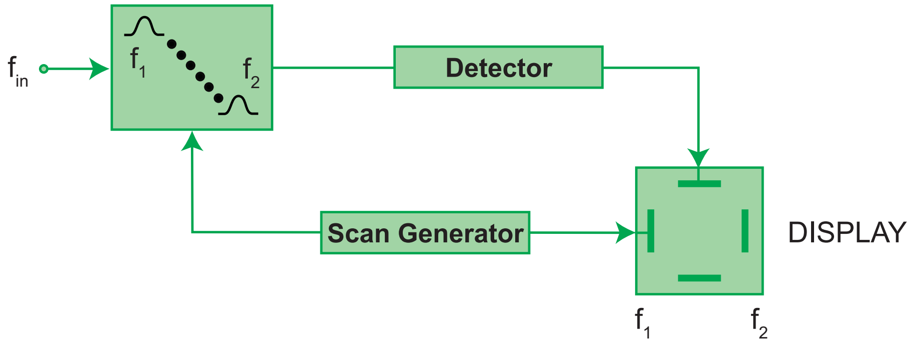


Figure 4

Real time analyzers however, sample the total frequency range simultaneously, thus preserving the time dependency between signals. This technique allows both transient and periodic / random signals to be displayed (Figure 5). Since there are fewer examples of real time analyzer available, this guide will focus on swept tuned spectrum analyzers.

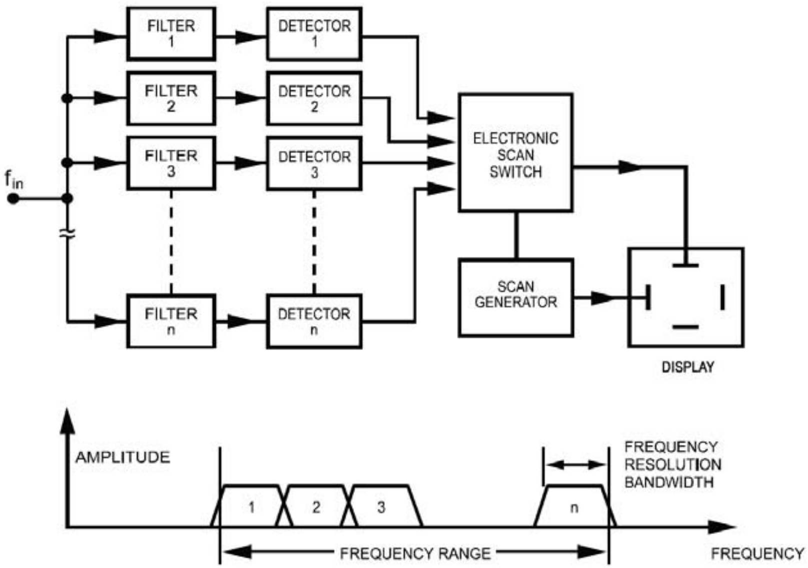


Figure 5

Basic Operation

Modern swept tuned spectrum analyzers are based on a super heterodyne receiver principle (Figure 6). The input signal, fIN, is converted to an intermediate frequency, fIF, via a mixer and a tunable local oscillator fLO. When the frequency difference between the input signal and the local oscillator is equal to the intermediate frequency then there is a response on the display.

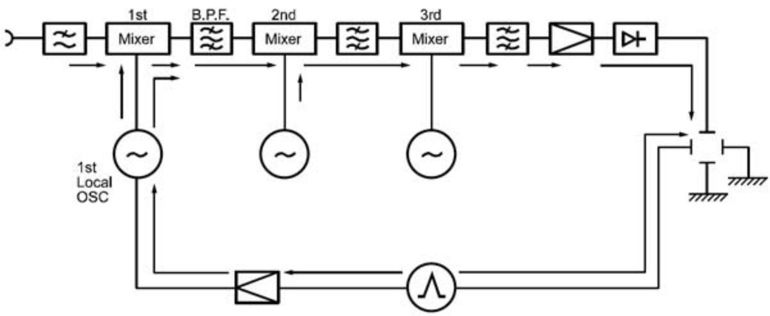


Figure 6

$$f_{IN} = f_{LO} \pm f_{IF}$$

This is the basic tuning equation that determines the frequency range of a spectrum analyzer. Using the super heterodyne technique enables high sensitivity through the use of intermediate frequency (IF) amplifiers and extended frequency range by using the harmonics of the local oscillator (LO). This technique is not, however, real time and sweep rates must be consistent with the IF filter bandwidth charge time.

Characteristics

Spectrum analyzers have the following characteristics:

a) Wide frequency range.

b) Amplitude and frequency calibration via internal calibration source and error correction routines.

c) Flat frequency response where amplitude is independent of frequency.

d) Good frequency stability using synthesized local oscillators and reference source.

e) Low internal distortion.

f) Good frequency resolution.

g) High amplitude sensitivity.

h) Linear and logarithmic display modes for amplitude (voltage and dB scaling).

i) Absolute and relative measurement capabilities.

Frequency Range

The lower frequency limit of a spectrum analyzer is determined by the sideband noise of the local oscillator. The local oscillator feedthrough occurs even when there is no input signal present.

The sensitivity of a spectrum analyzer at the lower frequency is also limited by the LO. sideband noise. Figure 7 shows typical data of average noise level vs. frequency for various IF bandwidths.

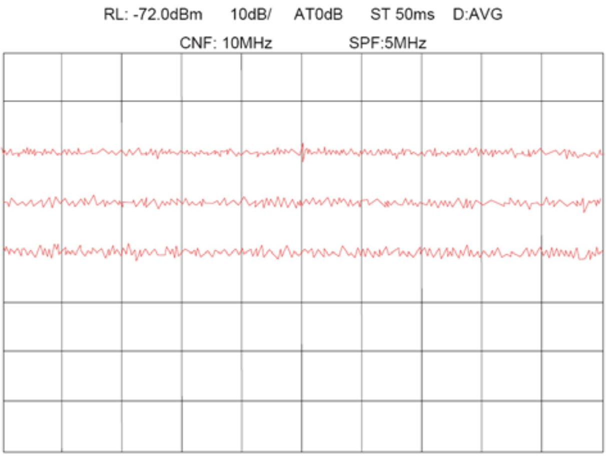


Figure 7

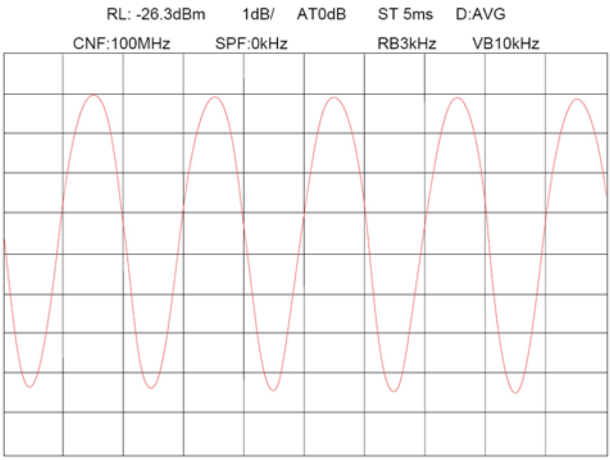


Figure 8

It should be noted however, that as the IF bandwidth is reduced so the time to sweep a given frequency range increases since the charge time of the IF filter increases. This means that the sweep time is increased to allow the IF filter to respond and therefore present an undistorted signal to the detector. These variables are generally taken into account automatically within a spectrum analyzer and are referred to as 'coupling'. Beyond the detector can be more filtering known as Video Bandwidth and this can also be coupled to IF bandwidth and sweep time. These functions are coupled together since they are all inter-dependent on each other, i.e. change one parameter setting and it affects the others.

An additional facility available on most modern analyzers is a Zero Frequency Span mode. As mentioned earlier, most analyzers are based on the super heterodyne receiver design, where the local oscillator is swept continuously. If the local oscillator is manually tuned, the spectrum analyzer becomes a fixed-tuned receiver whose frequency is determined by that of the local oscillator. In this mode the analyzer will display the time domain function since the frequency component is fixed even though the scan generator is still sweeping the display i.e. the display is now amplitude vs. time (Figure 8).

Frequency Resolution

The frequency resolution (typically called "resolution bandwidth") of a spectrum analyzer is its ability to separate and measure two signals in close proximity. This frequency resolution is determined by three primary factors:

a) the IF filter bandwidth used

b) the shape of the IF filter and

c) the sideband noise of the IF filter

The IF bandwidth is normally specified by ⊿f at -3dB (Figure 9). From this it can be seen that the narrower the filter bandwidth the greater the frequency resolution. However, as mentioned earlier, as the IF bandwidth is reduced so the charge time for the filter increases hence increasing the sweep time. As an example, narrow IF bandwidths are required to distinguish the sidebands of amplitude and frequency modulated signals (Figure 10).

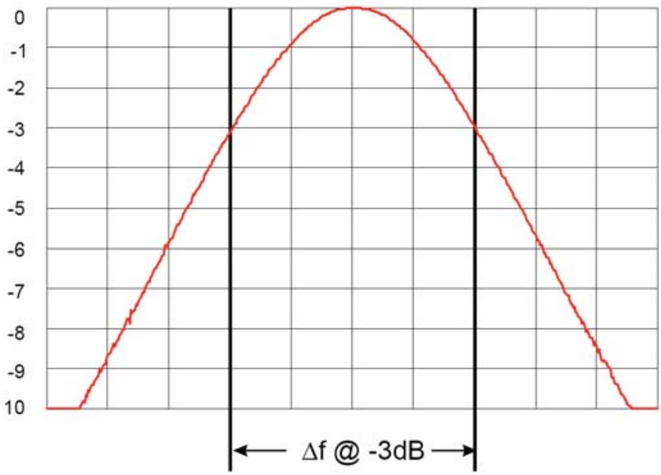


Figure 9

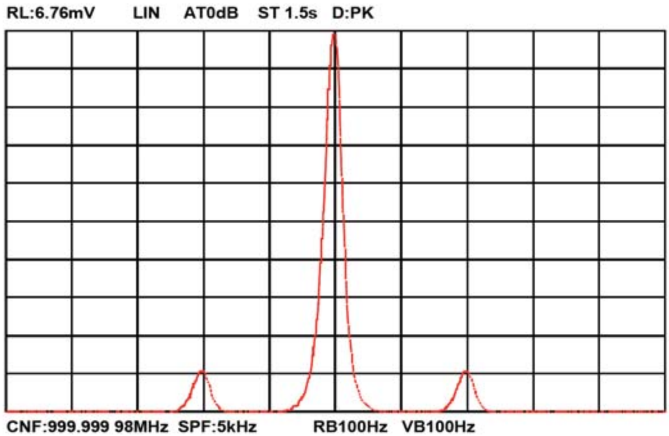


Figure 10

When measuring close-in spurious components, the shape of the IF filter becomes important. The filter skirt inclination is determined by the ratio of the filter bandwidth at ←60 dB to that at -3dB (Figure 11).

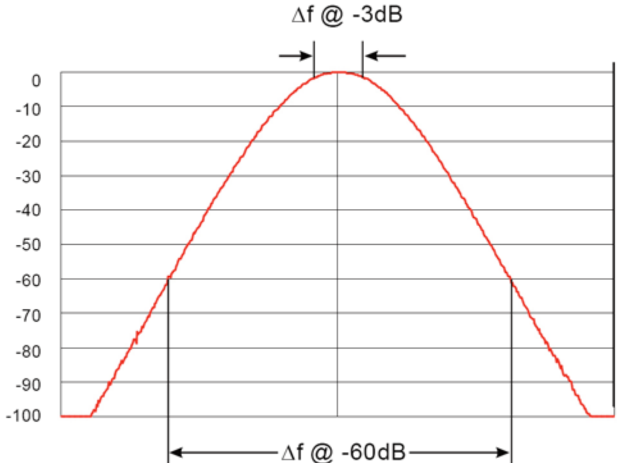


Figure 11

This skirt inclination is known as the 'shape factor' of the filter and provides a convenient guide to the filter quality. The most common type of IF filter is known as the Gaussian filter, since its shape can be derived from the Gaussian function of distribution. Typical shape factor values for Gaussian filters are 12:1 / 60 dB:3 dB, whilst some spectrum analyzers utilize digital filters where the shape factor can be as low as 3:1. Digital filters appear to be better in terms of frequency resolution, but they do have the drawback of sharply increasing the scan time required to sweep a given frequency range. Figure 12 shows the effects of scanning too fast for a given IF bandwidth filter. As the scan time decreases, the displayed amplitude decreases and the apparent bandwidth increases. Consequently, frequency resolution and amplitude uncertainty get worse, and some analyzers will warn you that you are now in an 'UNCAL' mode.

A spectrum analyzer's ability to resolve two closely spaced signals of unequal amplitude is not only dependent on the IF filter shape factor. Noise sidebands can reduce the resolution capabilities since they will appear above the skirt of the filter and so reduce the out-of-band rejection of the filter.

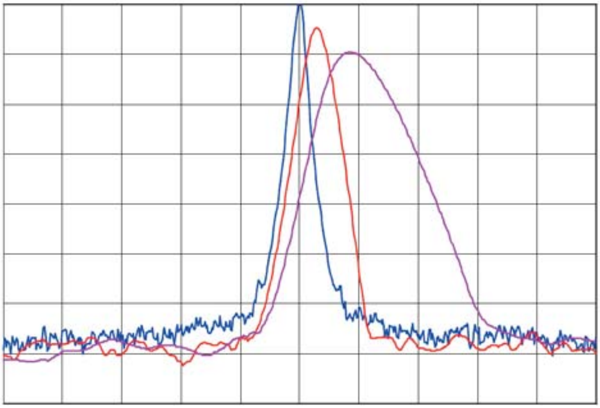


Figure 12

Sensitivity and Noise Figure

The sensitivity of a spectrum analyzer is defined as its ability to detect signals of low amplitude. The maximum sensitivity of the analyzer is limited by the noise generated internally. This noise consists of thermal (or Johnson) and non thermal noise. Thermal noise power is expressed by the following equation:

$$P_N = kTB$$

where

PN = Noise power (in Watts)

k = Boltzman's constant (1.38 x 10^{-23} JK-1)

T = Absolute temperature (Kelvin)

B = System Bandwidth (Hz)

From this equation it can be seen that the noise level is directly proportional to the system bandwidth. Therefore, by decreasing the bandwidth by an order of 10 dB the system noise floor is also decreased by 10 dB (Figure 13).

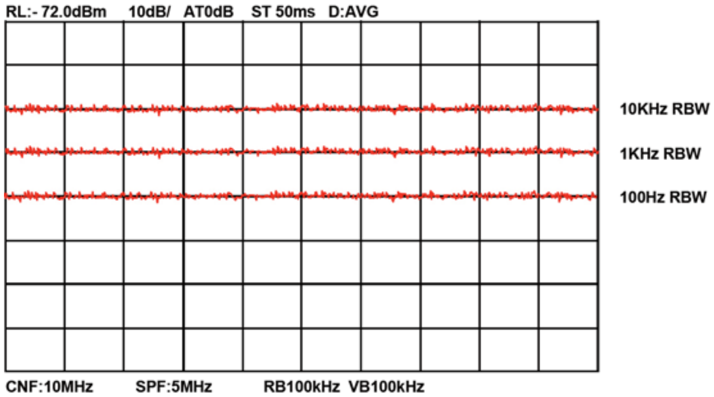


Figure 13

When comparing spectrum analyzer specifications it is important that sensitivity is compared for equal bandwidths since noise varies with bandwidth.

An alternative measure of sensitivity is the noise factor FN:

$$F_N = (S/N)_{IN} / (S/N)_{OUT}$$

where S = Signal and N = Noise

Since the noise factor is a dimensionless figure of merit we can derive the noise figure as:

$$F = 10 \log (F_N) \text{ dB}$$

Using the equation PN = kTB it is possible to calculate the theoretical value of absolute sensitivity for a given bandwidth. For example, if a spectrum analyzer generates no noise products at a temperature of 17 degrees Celsius, referred to a 1Hz bandwidth, then:

absolute sensitivity $= 1.38 \times 10^{-23} \times 290$
$= 4\times10^{-21}$ W/Hz
$= -174$dBm/Hz

To determine the noise figure of a typical spectrum analyzer where the average noise floor is specified as -120 dBm referred to a 300 Hz bandwidth:

-120 dBm = -174 dBm/Hz + 10log300 + F(dB)
F(dB) = -120 + 174 - 24.8
Noise Figure = 29.2dB

Video Filtering or Averaging

Very low level signals can be difficult to distinguish from the average internal noise level of many spectrum analyzers. Since analyzers display signal plus noise, some form of averaging or filtering is required to assist the visual detection process. As mentioned earlier, a video filter is a low pass, post-detection filter that averages the internal noise of the analyzer.

Because spectrum analyzers measure signal plus noise, the minimum signal power that can be displayed is the same as the average noise power of the analyzer. From this statement it would appear that the signal would be lost in the analyzer noise but:

if signal power = average noise power

then by definition, the minimum signal power that can be displayed will be:

$$\frac{S + N}{N} = 2$$

where

S = signal power

N = average noise power

When the signal power is added to the average noise power, the resultant signal power displayed will be 3 dB greater (Figure 14). This 3 dB difference is sufficient for low level signal identification.

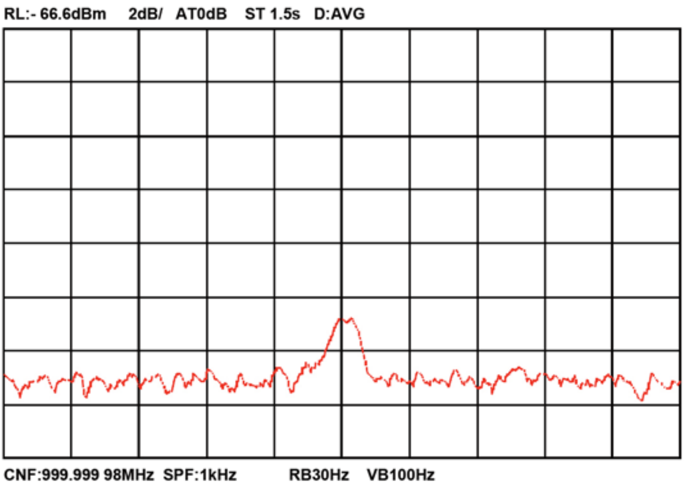


Figure 14

Signal Display Range

The signal display range of a spectrum analyzer with no input attenuation is dependent on two key parameters.

a) The minimum resolution bandwidth available and hence the average noise level of the analyzer and

b) The maximum level delivered to the first mixer that does not introduce distortion or inflict permanent damage to the mixer performance.

Typical values for these two factors are shown in Figure 15.

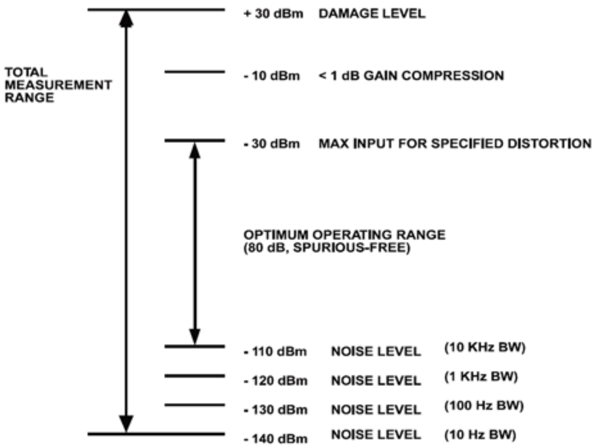


Figure 15

As the input level to the first mixer increases so the detected output from the mixer will increase. However, since the mixer is a semiconductor diode the conversion of input level to output level is constant until saturation occurs. At this point the mixer begins to gain compress the input signal, and conversion reverts from linear to near logarithmic. This gain compression is not considered serious until it reaches 1 dB.

Input levels that result in less than 1 dB gain compression are called linear input levels (Figure 16). Above 1 dB gain compression, the conversion law no longer applies and the analyzer is considered to be operating non-linearly and the displayed signal amplitude will not be an accurate measure of the input signal.

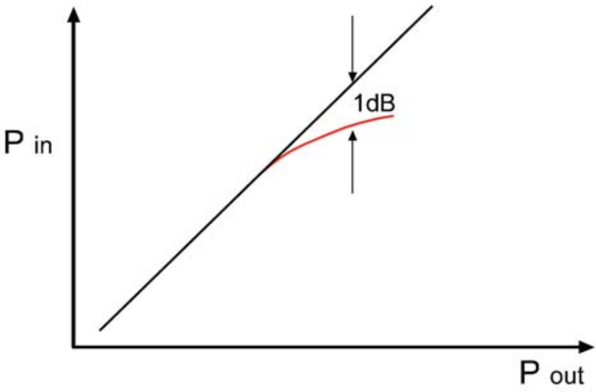


Figure 16

Distortion products are produced in the analyzer whenever a signal is applied to the input. These distortion products are usually produced by the inherent non-linearity of the mixer. By biasing the mixer at an optimum level internal distortion products can be kept to a minimum. Typically, modern spectrum analyzer mixers are specified as having an 80 dB spurious-free measurement range for an input level of -30 dBm. Obviously the analyzer will be subjected to input signals greater than -30 dBm and to prevent exceeding the 1 dB compression point, an attenuator is positioned between the analyzer input and the first mixer. The attenuator automatically adjusts the input signal to provide the -30 dBm optimum level.

Dynamic Range

The dynamic range of a spectrum analyzer is determined by four key factors.

i. Average noise level.
   This is the noise generated within the spectrum analyzer RF section, and is distributed equally across the entire frequency range.

ii. Residual spurious components.
   The harmonics of various signals present in the spectrum analyzer are mixed together in complex form and converted to the IF signal components which are displayed as a response on the display. Consequently, the displayed response is present regardless of whether or not a signal is present at the input.

iii. Distortion due to higher order harmonics.
   When the input signal level is high, spurious images of the input signal harmonics are generated due to the non-linearity of the mixer conversion.

iv. Distortion due to two-signal 3rd order intermodulation products.
   When two adjacent signals at high power are input to a spectrum analyzer, intermodulation occurs in the mixer paths. Spurious signals, separated by the frequency difference of the input signals are generated above and below the input signals.

The level range over which measurements can be performed without interference from any of these factors is the dynamic range. This represents the analyzers performance and is not connected with the display (or measurement) range. The four parameters that determine dynamic range can normally be found in the analyzer specifications.

For simplicity, some analyzer specifications state the dynamic range as “Y-dB for an input level of X-dBm". The following example shows how these parameters are related to dynamic range:

Amplitude Dynamic Range: 70 dB for a mixer input signal level of - 30 dBm (Atten. = 0 dB)

In order to achieve this value of dynamic range the following conditions are required:

a) the IF bandwidth must be narrow enough such that the average noise level is better than -100 dBm.

b) the residual spurious components must be less than -100 dBm.

c) for an input level of -30 dBm the higher harmonic distortion must be better than -70 dB (i.e. better than -100 dBm).

Analyzer manufacturers often relate the above specifications at a particular frequency or over a range of frequencies.

Frequency Accuracy

The key parameter relating to frequency accuracy is linked to the type of reference source built into the spectrum analyzer. These reference sources fall into two distinct groups:

- **Synthesized**
  The analyzer local oscillator is phase-locked to a very stable reference source, often temperature controlled to prevent unwanted frequency drifting. In this case, a precision crystal is often used and the overall frequency accuracy and stability, both short term and long term depend on its quality.

- **Non-Synthesized**
  The local oscillator operates as a stand-alone voltage controlled source.

APPLICATIONS

As stated in the introduction, spectrum analyzers are used to display the frequency and amplitude of signals in the frequency domain. Efficient transmission of information is accomplished by a technique known as modulation. This technique transforms the information signal, usually of low frequency, to a higher carrier frequency by using a third, modulation signal. But why modulate the original signal? The two primary reasons are:

1) modulation techniques allow the simultaneous transmission of two or more low frequency, or base-band signals onto a higher, carrier frequency and

2) high frequency antenna are small in physical size and more electrically efficient.

In this section we will consider three common modulation formats:

- Amplitude Modulation or AM.
- Frequency Modulation or FM.
- Pulse Modulation or PM.

Each modulation technique places emphasis on a particular area of the analyzer's specification.

Amplitude Modulation

As the name suggests, amplitude modulation is where the carrier signal amplitude is varied by an amount proportional to the amplitude of the signal wave and at the frequency of the modulation signal. The amplitude variation about the carrier is termed the modulation factor 'm'. This is usually expressed as a percentage called the percent modulation, %M.

The complex expression for an AM carrier shows that there are three signal elements.

a) the unmodulated carrier.

b) the upper sideband whose frequency is the sum of the carrier and the modulation frequency.

c) the lower sideband whose frequency is the difference between the carrier and the modulation frequency.

The spectrum analyzer display enables accurate measurement of three key AM parameters.

- Modulation Factor - m.
- Modulation Frequency - fm.
- Modulation Distortion.

Modulation Factor - m

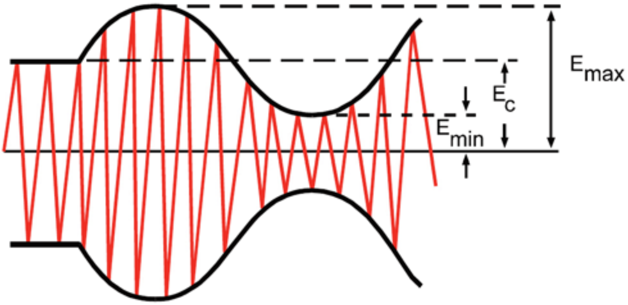


Figure 17

Figure 17 shows the time domain display of a typical AM signal. From this the modulation factor, m, can be expressed as follows:

$$m = \frac{E_{max} - E_c}{E_c} \qquad \text{Eqn 1}$$

Since the modulation is symmetrical:

$$E_{max} - E_c = E_c - E_{min} \qquad \text{Eqn 2}$$

$$E_c = \frac{E_{max} + E_{min}}{2} \qquad \text{Eqn 3}$$

$$m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \qquad \text{Eqn 4}$$

Equation 4 is true for sinusoidal modulation. If we view the AM signal on a spectrum analyzer in linear (voltage) mode we obtain Figure 18.

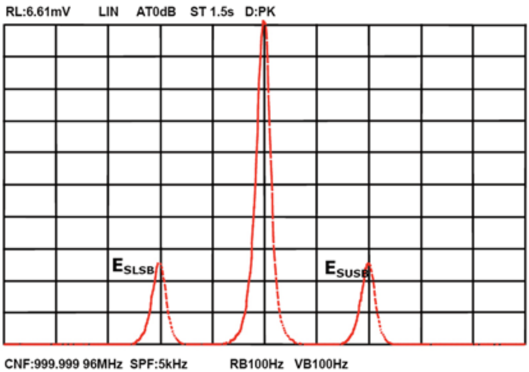


Figure 18

From this the percentage modulation, %M, can be calculated as follows:

$$\%M = \frac{(E_{S\ LSB} + E_{S\ USB})}{E_c} \times 100 \qquad \text{Eqn 5}$$

where Es = Amplitude of the sideband (volts)
Ec = Amplitude of the carrier (volts).

For low levels of modulation it is more convenient to use the analyzers logarithmic display as in Figure 19.

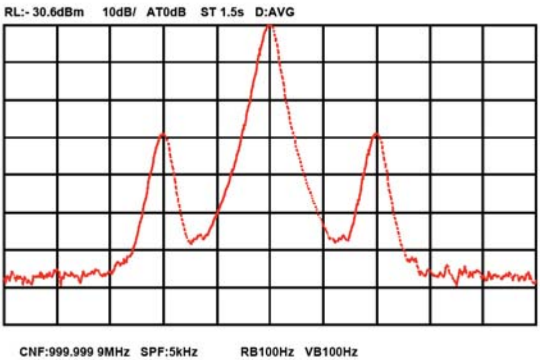


Figure 19

The relationship between the sideband level and the percentage modulation is shown in table 1.

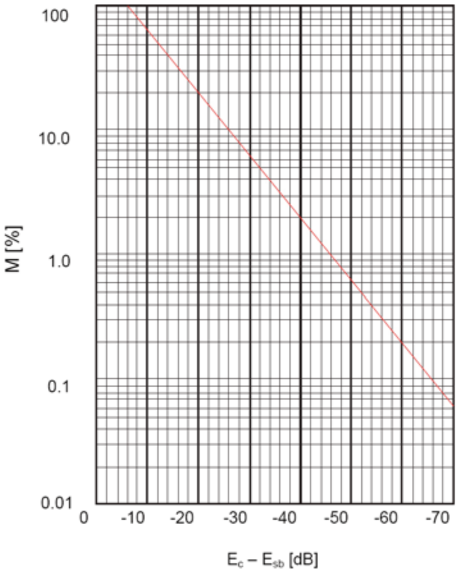


Table 1

As an example, consider a case in which the carrier frequency Fc = 1000 MHz, and the modulation frequency fm = 1 kHz.

Figure 20 shows the result of observation using an oscilloscope. From the envelope, %M = 50% (m=0.5)

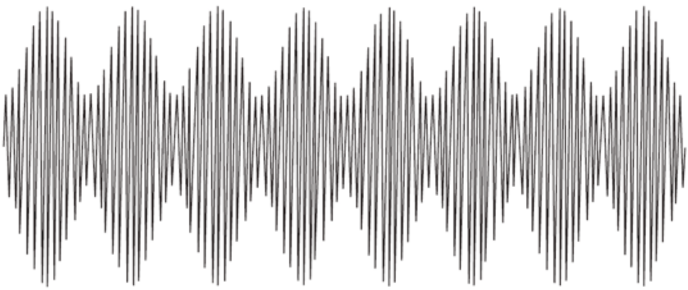


Figure 20

Figure 21 shows the same signal displayed on the linear scale (voltage) of a spectrum analyzer.

From equation 5

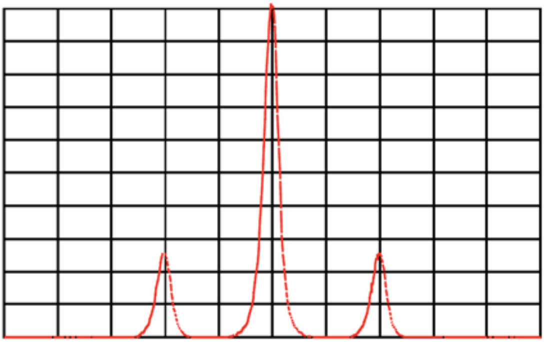


Figure 21

$$\%M = \frac{1.66 \text{ mV} + 1.66 \text{ mV}}{6.61 \text{ mV}} \times 100$$

$$\%M = 50\%$$

or m = 0.5

If m = 0.05 (%M=5%), then for the same conditions the sideband level will be 0.165 mV for a carrier level of 6.6 mV. Clearly for low modulation factors the logarithmic display is better suited (Figure 22).

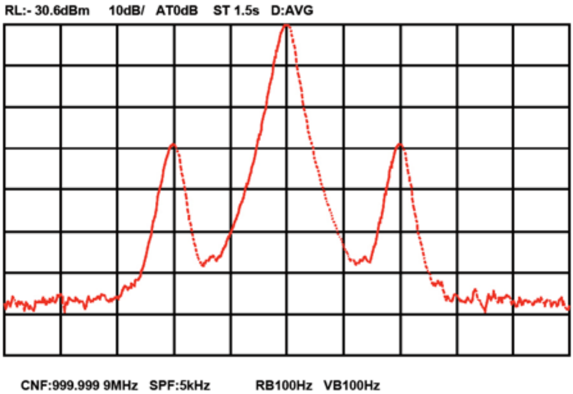


Figure 22

Modulation Frequency - fm

As stated earlier, for amplitude modulation the upper and lower sidebands displayed on a spectrum analyzer will be separated from the carrier by a frequency equal to the modulation frequency (Figure 23). This frequency domain display assumes that the IF bandwidth is narrow enough to resolve the spectral components of the modulated carrier. However, a common modulation test tone of 400 Hz will be difficult to measure if the analyzer has a minimum 1 kHz resolution bandwidth. More difficulties arise if the phase noise of the carrier masks low frequency modulation sidebands with small modulation factors.

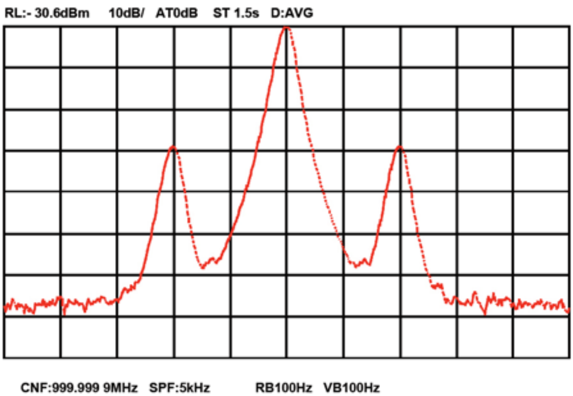


Figure 23

If the modulation factor is high enough, we can use the spectrum analyzer as a fixed-tuned receiver as follows:

a) set the carrier to the center of the display.

b) ensure that the resolution bandwidth and the video bandwidth are sufficiently wide enough to encompass the modulation sidebands without attenuation.

c) select zero span and adjust the reference level so that the peak of the signal is near to the top of the screen.

d) select linear display mode, video triggering and adjust the sweep time to display several cycles of the demodulated waveform.

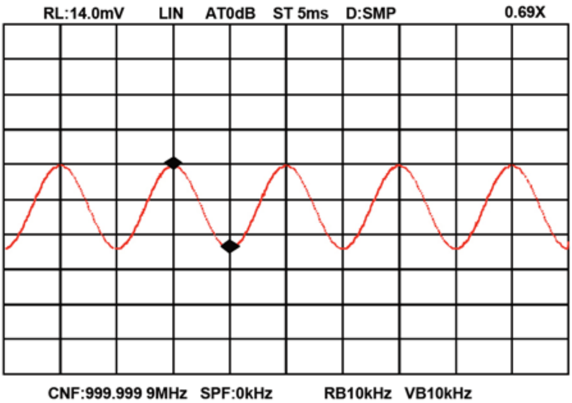


Figure 24

From this display we can measure the modulation factor, m, and the modulating frequency using the analyzers delta-marker function (Figure 24).

Note: Since this is a relative measurement, as we adjust the reference level of the analyzer, the absolute values of Emax and Emin change but the ratio remains constant. Using the delta-marker function will yield the ratio E_{MIN}/E_{MAX} so by modifying the equation for m we can use this ratio directly.

$$m = \frac{(1 - (E_{min} / E_{max}))}{(1 + (E_{min} / E_{max}))}$$

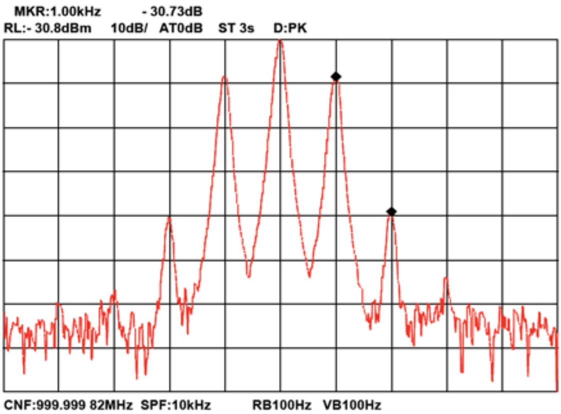


Figure 25

Modulation Distortion

Distortion of an amplitude modulated carrier wave is commonly due to either or both of the following:

a) second and subsequent harmonics of the modulation signal and,

b) over modulation of the carrier wave. i.e. %M>100%.

Measuring modulation distortion can be performed directly from the frequency domain display of a spectrum analyzer. Consider Figure 25.

The upper and lower sidebands adjacent to the carrier are the modulation components but the second and subsequent pairs of sidebands are due to the harmonics of the modulation signal. Using a logarithmic scale, the level difference between the first and second sidebands gives the 2nd harmonic distortion for the waveform. In the case of Figure 25 this is -30.73 dB. This same procedure can be used for 3rd harmonic distortion also.

Now consider Figure 26. This shows an over modulated 100 MHz carrier with fm = 2 kHz. From the time domain display (Figure 27) we can see that the carrier is cut off when the modulation frequency is at a minimum. From the corresponding frequency domain display, the first sideband pair are 6 dB lower than the carrier hence %M=100% but note also the severe harmonic distortion products.

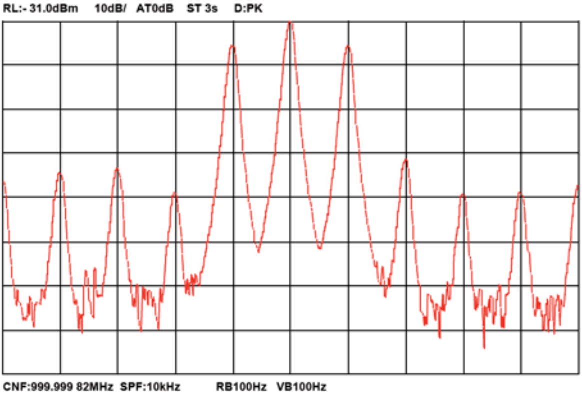


Figure 26

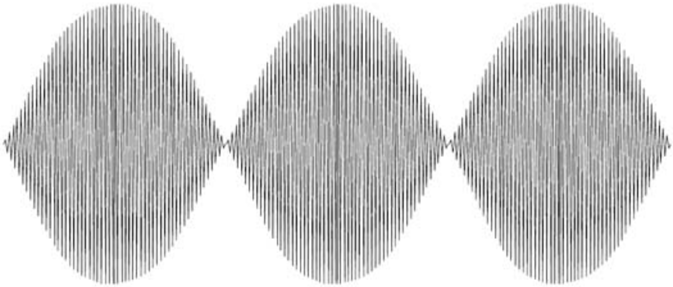


Figure 27

These distortion products effectively increase the occupied bandwidth unnecessarily.

By definition, the information transmitted by amplitude modulation is carried not by the carrier but via the sidebands. Thus varying the composite AM waveform varies only the sideband amplitude. If the carriers component was suppressed, then the overall power saving would improve the efficiency of the transmission system. This type of modulation is called Double Sideband - Suppressed Carrier or DSB-SC. In order to recover the modulation signal the carrier must be re-inserted at the receiver.

Furthermore, we could also remove one of the sidebands since the same information is carried by both. This would result in a further power saving and a reduction in the occupied bandwidth of the signal.

Frequency Modulation

Frequency modulation, FM, is a form of modulation where the frequency of a carrier wave is varied above and below its unmodulated value by an amount proportional to the amplitude of a signal wave and at the frequency of the modulating signal. In this case the carrier amplitude remains constant. Frequency modulation differs from amplitude modulation in a number of ways.

a) Since the amplitude of the modulated carrier remains constant, regardless of the modulation frequency and amplitude, no power is added to or removed from the carrier wave of an FM signal.

b) Frequency modulation of a sinusoidal carrier with a second varying sinusoid yields an infinite number of sidebands separated by the modulation frequency f_m.

c) The peak-to-peak amplitude of the signal wave determines the maximum frequency deviation of the modulated carrier.

The Bessel function curves of Figure 28 show the relationship between the carrier and sideband amplitudes of a frequency modulated wave as a function of the modulation index m.

Note that the carrier component J0 and the various sidebands JN go to zero amplitude for specific values of m. From these curves we can determine the amplitude of the carrier and the sideband components in relation to the unmodulated carrier. For example, we find for a modulation index of m=3 the following amplitudes:

Carrier J0 = -0.26

First order sideband J1 = 0.34

Second order sideband J2 = 0.49

Third order sideband J3 = 0.31

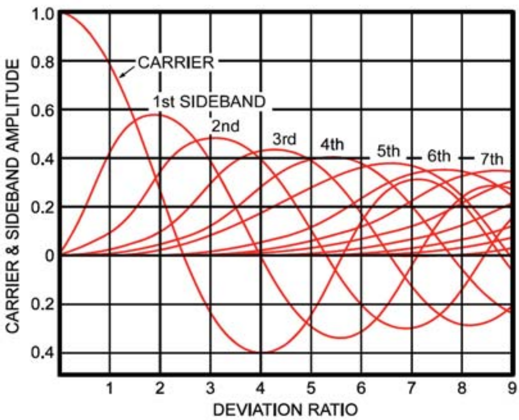


Figure 28

The sign of the values we get from the curves is not significant since a spectrum analyzer displays only absolute amplitudes. The exact values for the modulation index corresponding to each of the carrier zeros are listed in the Appendix C.

Bandwidth of FM Signals

In practice, the spectrum of an FM signal is not infinite. The sideband amplitudes become negligible beyond a certain frequency offset from the carrier, depending on the magnitude of m. We can determine the bandwidth required for low distortion transmission by counting the number of significant sidebands. (Significant sidebands usually refers to those sidebands that have a voltage at least 1 percent (-40 dB) of that of the unmodulated carrier).

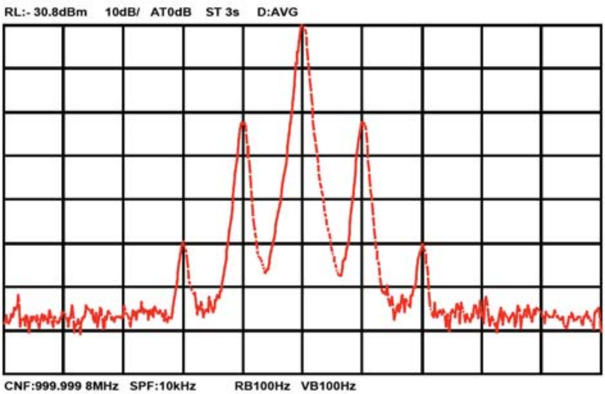


Figure 29

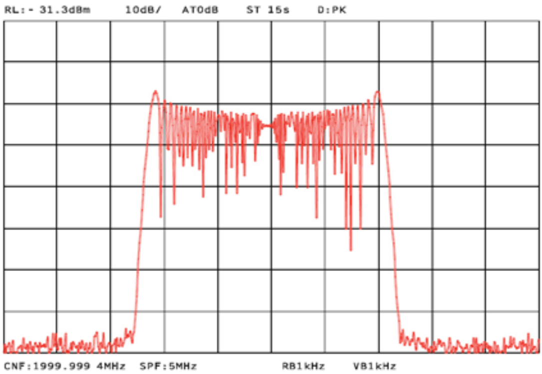


Figure 30

Figures 29 and 30 show the analyzer displays of two FM signals, one with m=0.2, the other with m=95.

Two important facts emerge from these figures:

1) For very low modulation indices (m<0.2), we get only one significant pair of sidebands. The required transmission bandwidth in this case is twice fm, as for AM.

2) For very high modulation indices (m>100), the transmission bandwidth is twice ⊿fpk.

For values of m between these margins we have to count the significant sidebands.

For voice communication a higher degree of distortion can be tolerated; that is, we can ignore all sidebands with less that 10% of the carrier voltage (-20 dB). We can calculate the necessary bandwidth B using the approximation:

$$B = 2\Delta F_{pk} + 2F_m$$

$$\Delta F_{pk} = m \times f_m \text{ maximum frequency deviation}$$

$$\text{or} \quad B = 2Fm\,(1+m)$$

So far our discussion of FM sidebands and bandwidth has been based on having a single sine wave as the modulating signal. Extending this to complex and more realistic modulating signals is difficult. We can extend this to look at an example of single-tone modulation for some useful information.

An FM broadcast station has a maximum frequency deviation (determined by the maximum amplitude of the modulation signal) of Δf_{pk}=80 kHz. The highest modulation frequency fm is 15 kHz. This yields a modulation index of m=5.33 and the resulting signal has eight significant sideband pairs. Thus the required bandwidth can be calculated as 190 kHz. For modulation frequencies below 15 kHz (with the same amplitude), the modulation index increases above 5 and the bandwidth eventually approaches $2\Delta f_{pk}$ = 160 kHz for very low modulation frequencies.

Therefore, we can calculate the required transmission bandwidth using the highest modulation frequency and the maximum frequency deviation Δf_{pk}.

FM Measurements with a Spectrum Analyzer

The spectrum analyzer is a very useful tool for measuring Δf_{pk} and m and for making fast and accurate adjustments of FM transmitters. It is also frequently used for calibrating frequency deviation meters.

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. In Figure 31, a modulation frequency of 1 kHz and a modulation index of 2.4 (first carrier null) necessitate a carrier peak frequency deviation of exactly 2.4 kHz. Since we can accurately set the modulation frequency using the spectrum analyzer or, if need be, a frequency counter and since the modulation index is also known accurately, the frequency deviation thus generated will be equally accurate.

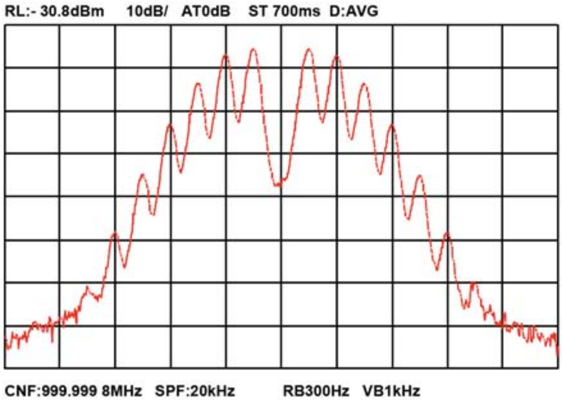


Figure 31

Table 2 gives the modulation frequencies and common values of deviation for the various orders of carrier zeros.

Order of Carrier Zero	Mod Index	Commonly Used Values of FM Peak Deviation								
		7.5 KHz	10 KHz	15 KHz	25 KHz	30 KHz	50 KHz	75 KHz	100 KHz	150 KHz
1	2.4	3.12	4.16	6.25	10.42	12.50	20.83	31.25	41.67	62.50
2	5.52	1.36	1.18	2.72	4.53	5.43	9.06	13.59	18.12	27.17
3	8.65	0.87	1.16	1.73	2.89	3.47	5.78	8.67	11.56	17.34
4	11.79	0.66	0.85	1.27	2.12	2.54	4.24	6.36	8.48	12.72
5	14.93	0.50	0.67	1.00	1.67	2.01	3.35	5.02	6.70	10.05
6	18.07	0.42	0.55	0.83	1.88	1.66	2.77	4.15	5.53	8.30

Table 2

The spectrum analyzer can also be used to monitor FM transmitters (for example, broadcast or communications stations) for occupied bandwidth. Here the statistical nature of the modulation must be considered. The signal must be observed long enough to make capturing peak frequency deviation probable. The MAX-HOLD capability, available on spectrum analyzers with digitized traces, is then used to acquire the signal. To better keep track of what is happening, you can often take advantage of the fact that most analyzers of this type have two or more trace memories.

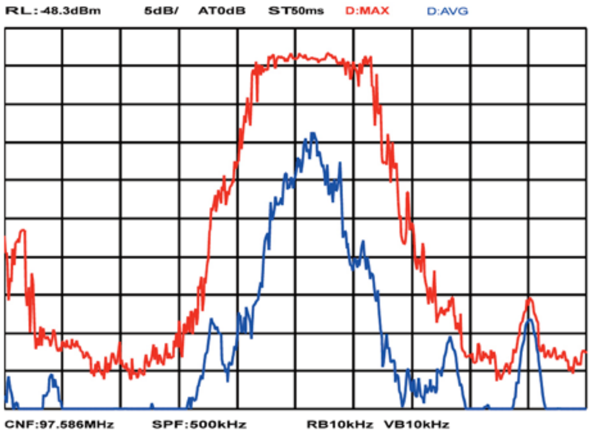


Figure 32

Select the AX HOLD mode for one trace while the other trace is live. See Figure 32 .

As with AM, it is possible to recover the modulating signal. 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 33. Here the frequency variations of the FM signal are converted into amplitude variation (FM to AM conversion).

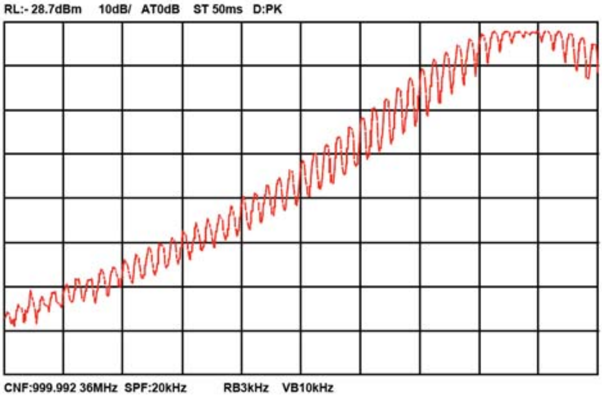


Figure 33

The resultant AM signal is then detected with the envelope detector. The detector output is displayed in the time domain and is also available at the video output for application to headphones or a speaker.

A disadvantage of this method is that the detector also responds to amplitude variations of the signal. The majority of Anritsu spectrum analyzers can provide FM and AM demodulator.

AM Plus FM (Incidental FM)

Although AM and FM are different methods of modulation, they have one property in common; they always produce a symmetrical sideband spectrum.

Figure 34 illustrates a modulated carrier with asymmetrical sidebands. One way this could occur is if both AM and FM or AM and phase modulation exist simultaneously at the same modulating frequency. This indicates that the phase relationship between carrier and sidebands are different for the AM and the angular modulation. Since the sideband components of both modulation types add together vectorally, the resultant amplitude of one sideband may be reduced while the amplitude of the other would be increased accordingly. The spectrum analyzer does not retain any phase information and so in each case displays the absolute magnitude of the result.

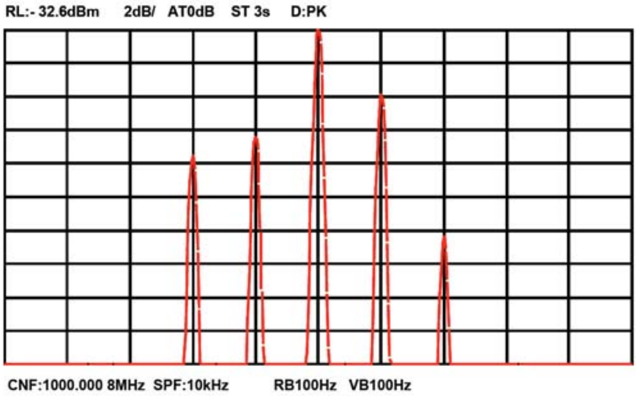

RL:- 32.6dBm 2dB/ AT0dB ST 3s D:PK
CNF:1000.000 8MHz SPF:10kHz RB100Hz VB100Hz

Figure 34

PULSE AND PULSE MODULATED SIGNALS

When a perfectly rectangular pulse waveform is transformed from the time domain to the frequency domain (Figure 35), the resulting envelope follows a function of the form:

$$y = \frac{\sin x}{x}$$

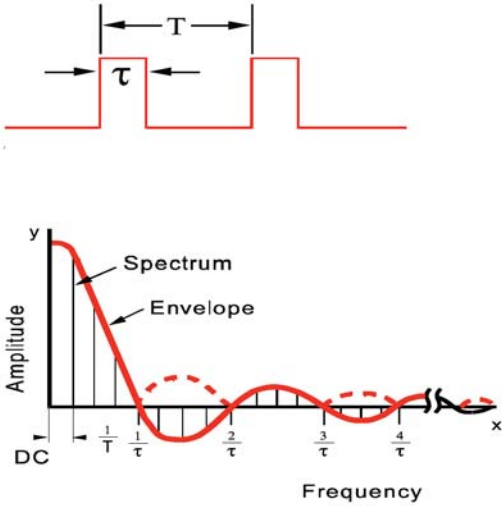


Figure 35

Figure 36 shows the spectral plot resulting from rectangular amplitude pulse modulation of a carrier. The individual lines represent the modulation product of the carrier and the modulation pulse repetition frequency with its harmonics. Thus, the lines will be spaced in frequency by whatever the pulse repetition frequency might happen to be.

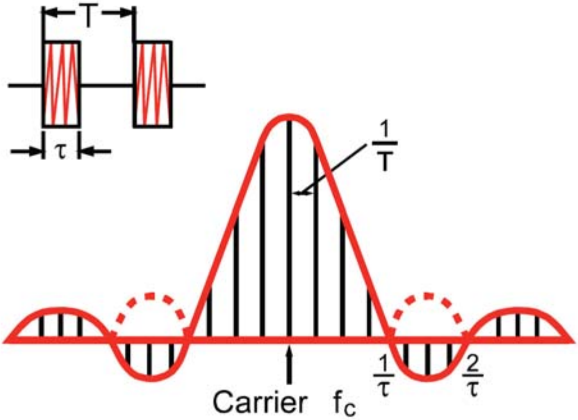


Figure 36

We know from single tone AM how the sidebands are produced above and below the carrier frequency. The idea is the same for a pulse, except that the pulse is made up of many tones, thereby producing multiple sidebands which are commonly referred to as spectral lines on the analyzer display. In fact, there will be twice as many sidebands (or spectral lines) as there are harmonics contained in the modulating pulse.

The mainlobe (in the center) and the sidelobes are shown as groups of spectral lines extending above and below the baseline. For perfectly rectangular pulses and other functions whose derivatives are not continued at some point, the number of sidelobes is infinite.

The mainlobe contains the carrier frequency and is represented by the longest spectral line in the center. The amplitude of the spectral lines forming the lobes varies as a function of frequency.

Notice in Figure 36 how the spectral lines extend below the baseline as well as above. This corresponds to the harmonics in the modulating pulse having a phase relationship of 180° with respect to the fundamental of the modulating waveform. Since the spectrum analyzer can only detect amplitude and not phase, it will invert the negative-going lines and display all amplitudes above the baseline.

Because a pulsed RF signal has unique properties, care must be taken to interpret the display on a spectrum analyzer correctly. The response that the spectrum analyzer (or any swept receiver) can have to a periodically pulsed RF signal can be of two kinds, resulting in displays which are similar but of completely different significance. One response is called a line spectrum and the other is a pulse spectrum. We must keep in mind that these are both responses to the same periodically pulsed RF input signal and that line and pulse spectrum refer only to the response displayed on the spectrum analyzer.

Line Spectrum

A line spectrum occurs when the spectrum analyzer IF bandwidth (B) is narrow compared to the frequency spacing of the input signal components. Since the individual spectral components are spaced at the pulse repetition frequency (PRF) of the pulsed RF, we can say:

$$B < PRF$$

In this case all individual frequency components can be resolved since only one is within the bandwidth at a time as shown in Figure 37. The display is a frequency domain display of the actual Fourier components of the input signal. Each component behaves as a CW signal and the display has the normal true frequency domain characteristics.

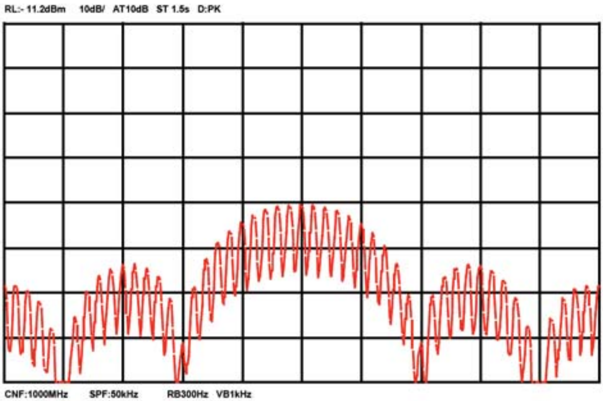


Figure 37

Pulse Response

If we increase the IF bandwidth in our example to 1 kHz, we get the display shown in Figure 38. Notice that the analyzer has lost the ability to resolve the spectral lines since B = PRF. The lines now displayed are generated in the time domain by the single pulses of the signal. We also see that the displayed amplitude of the spectrum envelope has increased. This is due to the fact that the IF filter is now sampling a broader section of the spectrum, thus collecting the power of several spectral lines.

Figure 38

A pulse repetition rate equal to the resolution bandwidth is the demarcation line between a true Fourier-series spectrum, where each line is a response representing the energy contained in that harmonic and a pulse of the Fourier-transform response.

Pulse Spectrum

A pulse spectrum occurs when the bandwidth B of the spectrum analyzer is equal to or greater than the PRF. The spectrum analyzer in this case cannot resolve the actual individual Fourier frequency domain components, since several lines are within its bandwidth. However, if the bandwidth is narrow compared to the spectrum envelope, then the envelope can be resolved. The resultant display is not a true frequency domain display, but a combination of time and frequency domains. It is a time domain display of the pulse lines, since each line is displayed when a pulse occurs, regardless of the frequency within the pulse spectrum to which the analyzer is tuned at that moment. It is a frequency domain display of the spectrum envelope.

MEASUREMENT EXAMPLES

The measurements described in this section are generally available 'one-button' functions on modern, high performance spectrum analyzers as but may not appear on all the available models.

Intermodulation Distortion

Signals generated by intermodulation distortion appear as signals that are separated from the original signals by the frequency difference of the original signals. The level of this intermodulation distortion depends on the levels and frequencies of the input signals. When two signals are input, the distortion is observed as 3rd-order distortion, and when the input signal level is decreased by 10 dB, the distortion decreases by 30 dB. Figure 39 shows this relationship and the point (where the input signal meets the distortion component) is called the intercept point.

Intermodulation distortion is even generated in the spectrum analyzer itself and this distortion component is determined by the mixer input level. Consequently, when measuring intermodulation distortion using a spectrum analyzer, it is necessary to take care about the mixer input level. It is possible to determine whether or not the DUT or the spectrum analyzer is generating the distortion by observing whether or not the distortion component changes when the spectrum analyzer input attenuation value is varied.

When the spectrum analyzer is generating the distortion, the distortion component changes by 15 dB when the input attenuation is varied by 5 dB. Consequently, in this case, it is necessary to increase the value of the input attenuator to the point where the distortion does not change. In addition, when two signals are input to the DUT, the two signal sources cause mutual interference and hence intermodulation distortion occurs. To distinguish this, confirm whether or not the distortion changes by a factor of 3 relative to the attenuation value when the attenuator in front of the DUT is varied. When the distortion component does not change by a factor of 3, insert an isolator between the signal combiner and the signal sources

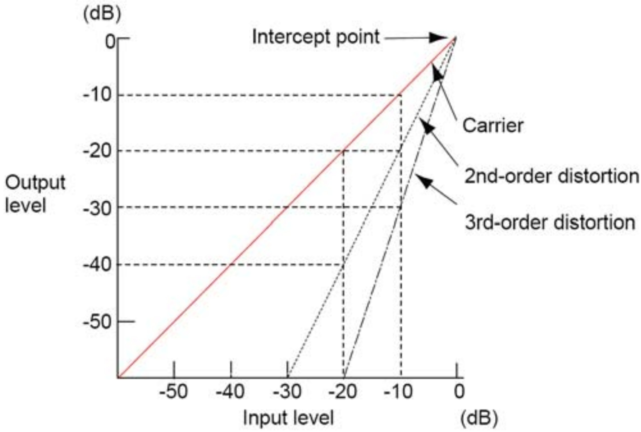


Figure 39

C/N measurement

The output signal from equipment such as a signal generator is not a pure sine wave, and as well as harmonic components, it includes noise of amplitude components and frequency components. These are generally called AM noise and FM (phase) noise. Generally, the AM noise is lesser in magnitude in comparison to the FM noise so measurement of FM noise is explained here.

The FM noise exists just above and below the carrier wave as shown in Figure 40 and is expressed as the ratio of the single sideband phase noise power to the carrier wave power within a 1 Hz bandwidth for a specified frequency offset from the carrier. When a spectrum analyzer is used, the carrier wave power and the sideband noise can be viewed directly on screen. However, the following points must be noted when using a spectrum analyzer.

1) Averaging noise power

Since a spectrum analyzer has a peak-hold circuit in front of the A/D converter, when noise is measured, the maximum power of the noise over the sampling period is displayed. Generally, noise is evaluated as the average value of the power against time. Consequently, it is necessary to use a sampling detector and to narrow the video bandwidth in order to average the noise power.

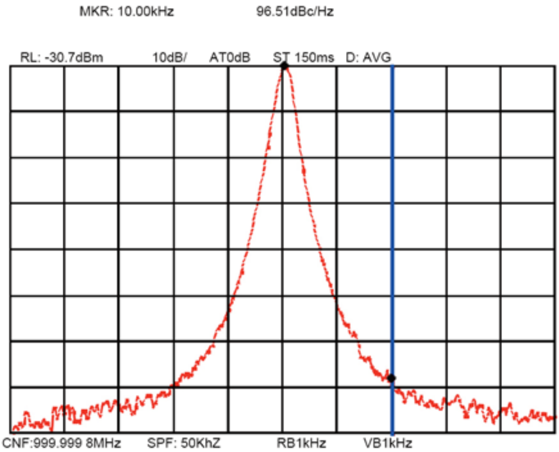


Figure 40

2) Conversion for noise bandwidth

Since the value of the measured noise power depends on the noise bandwidth used, correction for a 1Hz noise bandwidth is required.

3) Correction of average noise value

With a spectrum analyzer, since the signal is logarithmically-converted and envelope-detected, the average value of the noise appears to be lower than the actual RMS noise value, so this value must also be corrected.

Occupied Frequency Bandwidth

A common measurement carried out on radio transmitters is that of occupied frequency bandwidth (OBW). This measurement calculates the bandwidth containing the specified amount of the total integrated power of the displayed spectrum. However there are two different methods of calculation depending on the technique used to modulate the carrier.

a) XdB Down method

The occupied frequency bandwidth is defined as the bandwidth between the upper and lower frequency points at which the signal level is XdB below the peak carrier value (Figure 41).

b) N% method

The occupied frequency bandwidth is calculated as the bandwidth containing N% of the power transmitted where N can be between 1% and 99%. A typical example is shown in Figure 42.

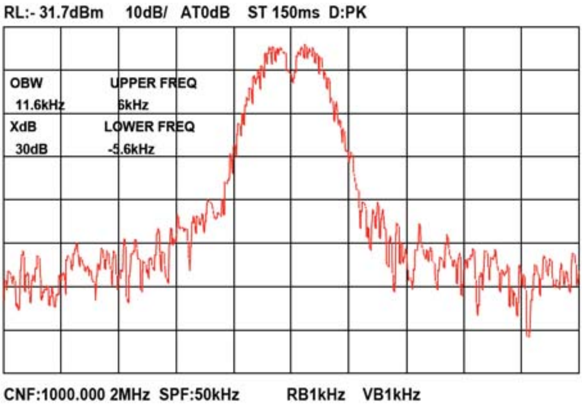


Figure 41

Adjacent Channel Leakage Power

Another common transmitter measurement is that of adjacent channel leakage power. This is defined as the ratio of the amount of leakage power in an adjacent channel to the total transmitted power. In order to calculate the upper and lower adjacent channel values, the spectrum analyzer needs three parameters to be specified:

a) the channel separation

b) the measurement channel bandwidth

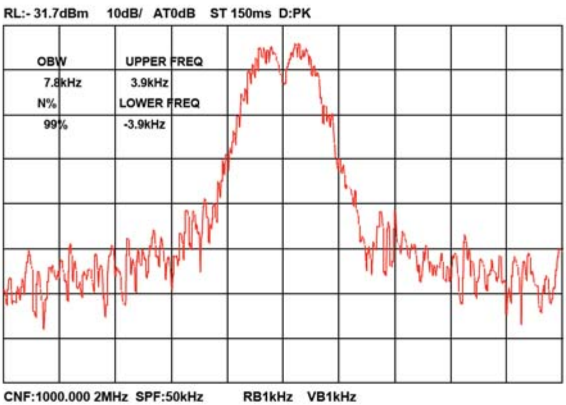


Figure 42

c) the adjacent channel bandwidth (if different from measurement channel bandwidth) and

d) the center frequency of the reference channel

The measurement is applicable to both modulated and unmodulated signals and provides a means of assessing the transmitters selectivity (Figure 43).

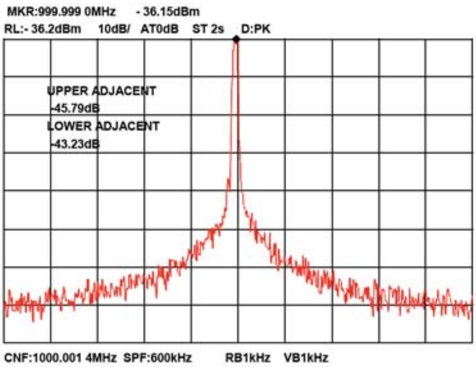


Figure 43

Burst Average Power

Time domain spectrum analysis is a vital tool for analyzing pulsed or burst signals. One important measurement is burst average power which computes the average power within the burst “on” time (Figure 44). Using the same measurement function, the average power within bursts can also be measured (Figure 45).

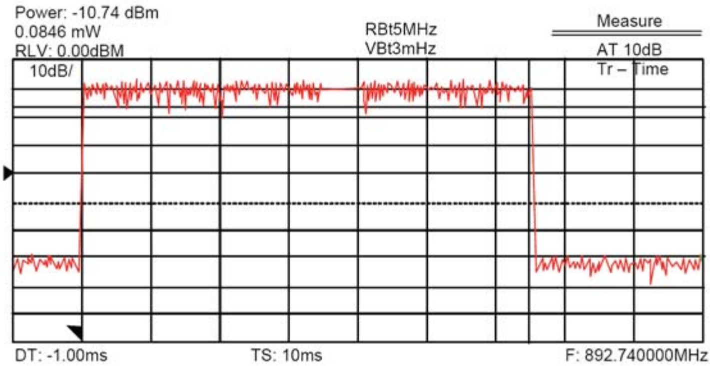


Figure 44

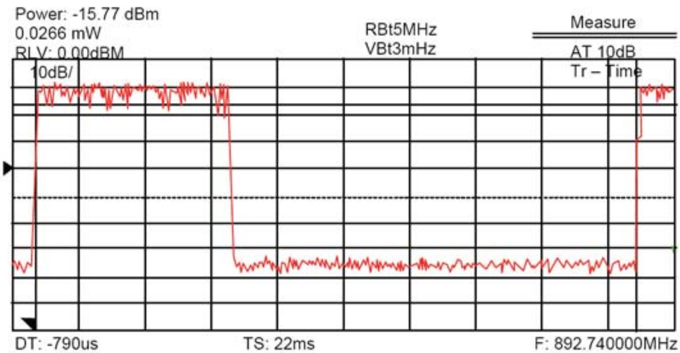


Figure 45

APPENDIX A

Spectrum Analyzer Conversion Factors

50Ω Input Impedance

TO → FROM ↓	dBm	dBV	dBmV	dBμV
dBm	0	-13	+47	+107
dBV	+13	0	+60	+120
dBmV	-47	-60	0	+60
dBμV	-107	-120	-60	0

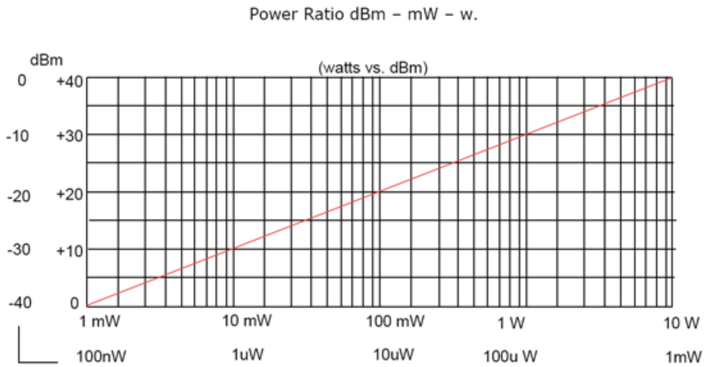
75Ω Input Impedance

TO → FROM ↓	dBm	dBV	dBmV	dBμV
dBm	0	-11.25	+48.7	+108.7
dBV	+11.25	0	+60	+120
dBmV	-48.75	-60	0	+60
dBμV	-108.75	-120	-60	0

SWR – Reflection Coefficient – Return Loss

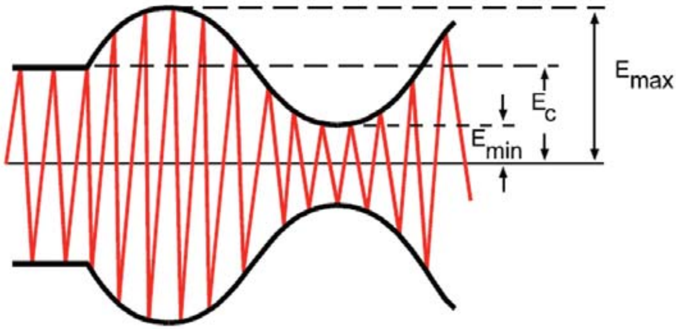
SWR	Refl. Coeff.	Return Loss (dB)	SWR	Refl. Coeff.	Return Loss (dB)
17.391	0.8913	1	1.0580	0.0282	31
8.7242	0.7943	2	1.0515	0.0251	32
5.8480	0.7079	3	1.0458	0.0224	33
4.4194	0.6310	4	1.0407	0.0200	34
3.5698	0.5623	5	1.0362	0.0178	35
3.0095	0.5012	6	1.0322	0.0158	36
2.6146	0.4467	7	1.0287	0.0141	37
2.3229	0.3981	8	1.0255	0.0126	38
2.0999	0.3548	9	1.0227	0.0112	39
1.9250	0.3162	10	1.0202	0.0100	40
1.7849	0.2818	11	1.0180	0.0089	41
1.6709	0.2512	12	1.0160	0.0079	42
1.5769	0.2239	13	1.0143	0.0071	43
1.4985	0.1995	14	1.0127	0.0063	44
1.4326	0.1778	15	1.0113	0.0056	45
1.3767	0.1585	16	1.0101	0.0050	46
1.3290	0.1413	17	1.0090	0.0045	47
1.2880	0.1259	18	1.0080	0.0040	48
1.2528	0.1122	19	1.0071	0.0035	49
1.2222	0.1000	20	1.0063	0.0032	50
1.1957	0.0891	21	1.0057	0.0028	51
1.1726	0.0794	22	1.0050	0.0025	52
1.1524	0.0708	23	1.0045	0.0022	53
1.1347	0.0631	24	1.0040	0.0020	54
1.1192	0.0562	25	1.0036	0.0018	55
1.1055	0.0501	26	1.0032	0.0016	56
1.0935	0.0447	27	1.0028	0.0014	57
1.0829	0.0398	28	1.0025	0.0013	58
1.0736	0.0355	29	1.0022	0.0011	59
1.0653	0.0316	30	1.0020	0.0010	60

Power Measurement

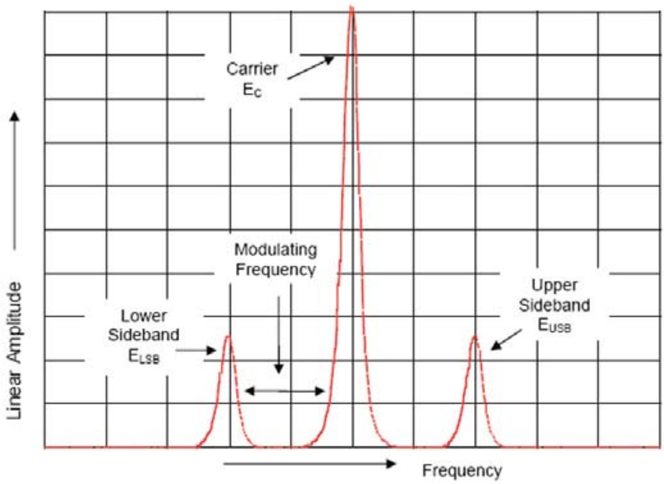


Appendix B

Amplitude Modulation



$$\%M = \frac{(E_{max} - E_{min})}{(E_{max} + E_{min})} \times 100$$

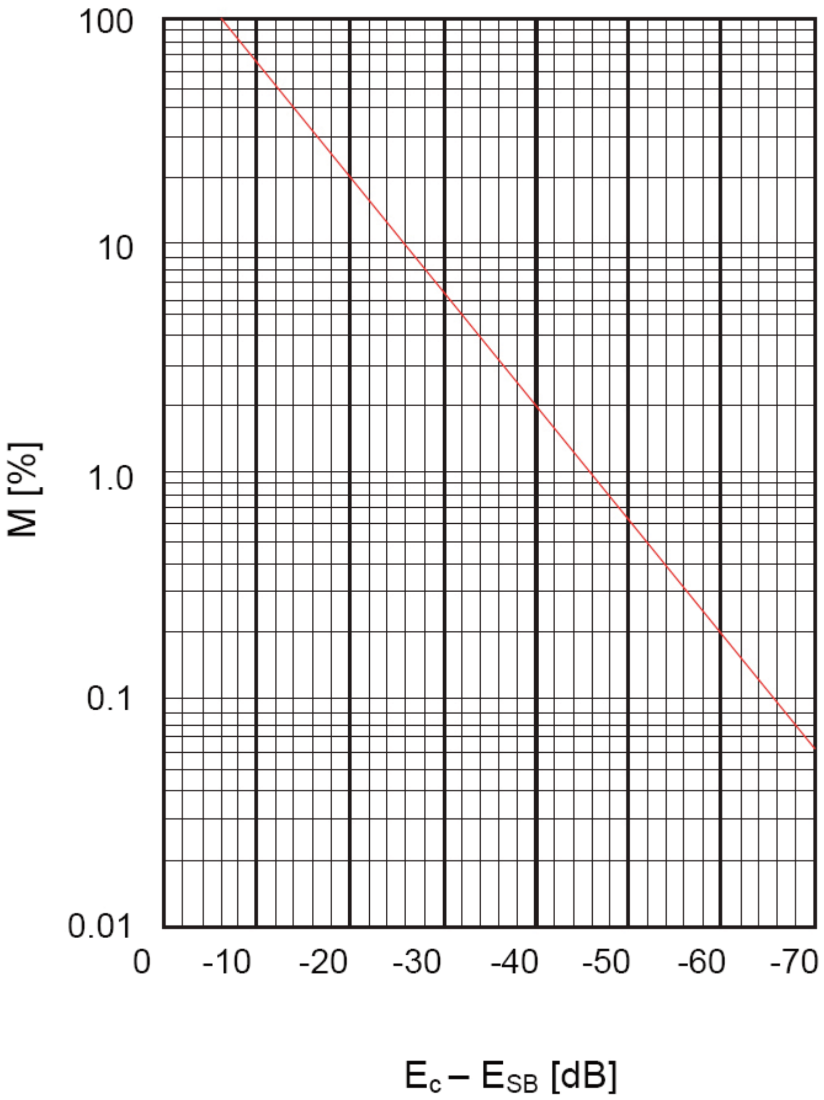


$$\%M = \frac{2E_{SB}}{E_c} \times 100$$

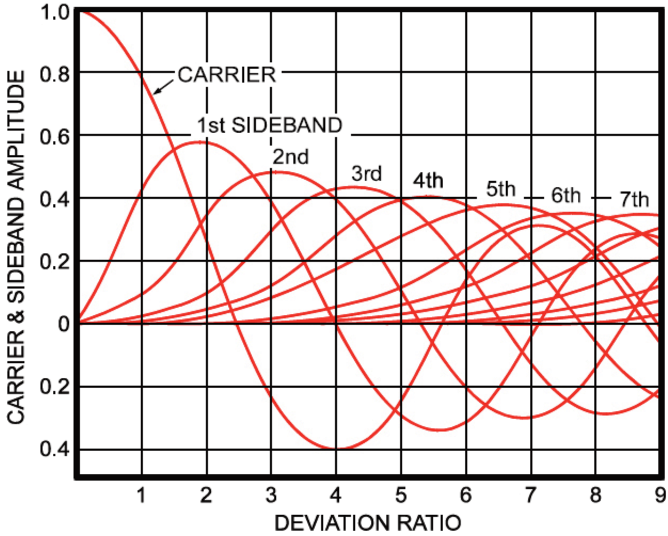
E_c

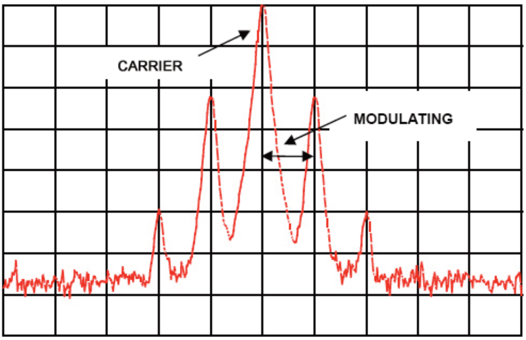
% modulation	Sideband level below carrier (dB)
1	46
2	40
10	26
20	20
30	16.5
40	14
50	12
60	10.4
70	9.1
80	7.9
90	6.9
100	6.0

Sideband level below carrier (dB)	% modulation
10	63
20	20
30	6.3
40	2.0
50	0.63
60	0.2
70	0.063
80	0.02


100
10
1.0
0.1
0.01
M [%]
0
-10
-20
-30
-40
-50
-60
-70
Ec – ESB [dB]

Appendix C


1.0
0.8
0.6
0.4
0.2
0
0.2
0.4
CARRIER & SIDEBAND AMPLITUDE
CARRIER
1st SIDEBAND
2nd
3rd
4th
5th
6th
7th
1
2
3
4
5
6
7
8
9
DEVIATION RATIO


CARRIER
MODULATING

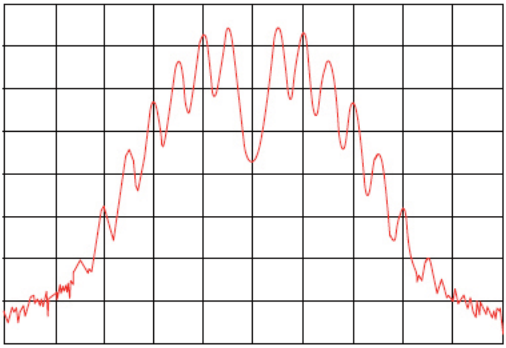
Bessel Functions

Carrier Bessel NULL Number	$M = \Delta F / f$
1st	2.4048
2nd	5.5201
3rd	8.6531
4th	11.7915
5th	14.9309
6th	18.0711
7th	21.2116
8th	24.3525
9th	27.4935
10th	30.6346

Where M = **modulation index**

ΔF = **deviation**

f = **modulating frequency**

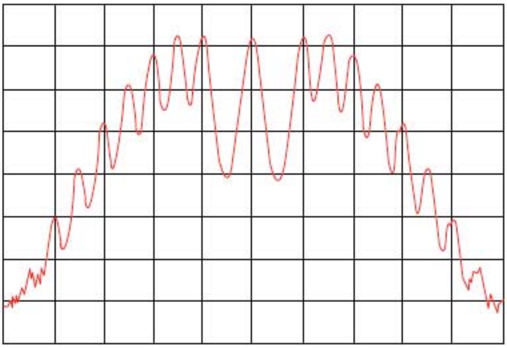


1st Sideband Bessel NULL number	$M = \Delta F / f$
1st	3.83
2nd	7.02
3rd	10.17
4th	13.32
5th	16.47
6th	19.62
7th	22.76
8th	25.90
9th	29.05

Where M **= modulation index**

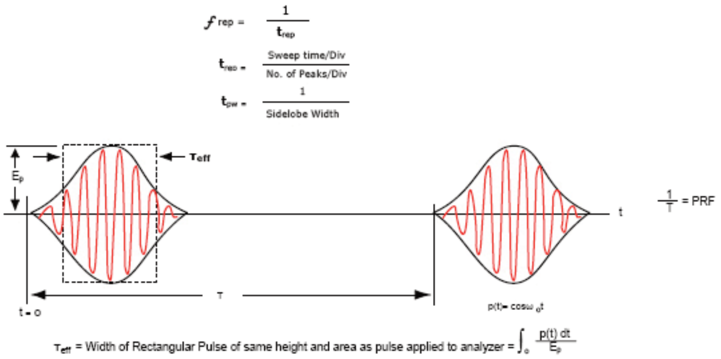
ΔF **= deviation**

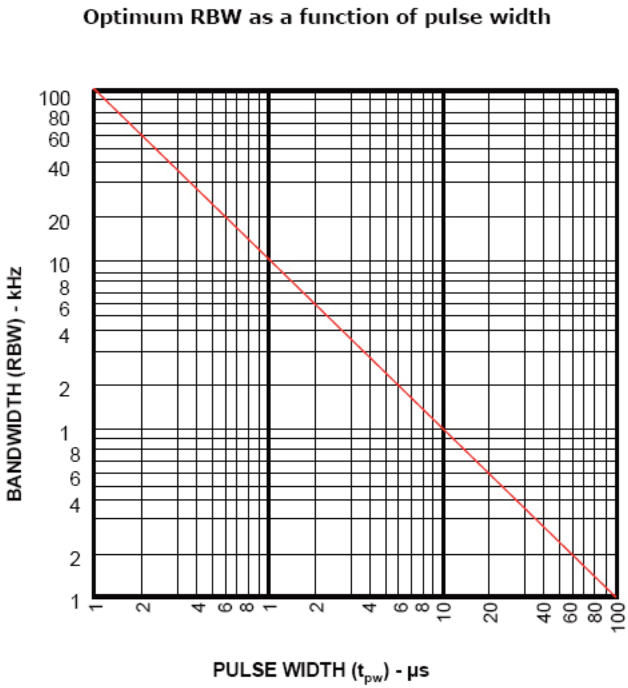
f **= modulating frequency**

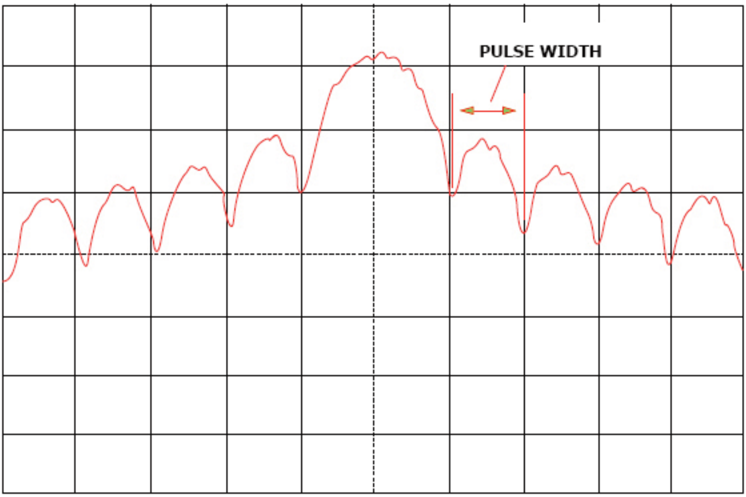


Appendix D

Pulse Modulation






PULSE WIDTH

Appendix E

Intermodulation Distortion / Intercept Points

Calculating Intercept Points requires knowledge of:

1) the order (normally 2nd or 3rd) of the distortion product.

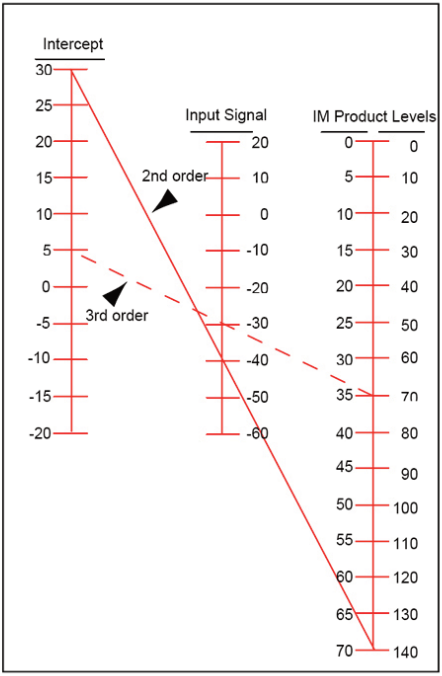
2) input drive level in dBm (example: -30 dBm).

3) the desired or specified suppression of inter-modulation products below the drive level, expressed in dB.

The equation for calculating the intercept point is:

$$I = \frac{\Delta}{(N-1)} + S$$

where: I = intercept point level in dBm for any intermodulation product order.
Δ= suppression of intermodulation products below drive level in dB.
N = order of the intermodulation product.
S = drive level of the input tones (signals) in dBm.



Anritsu Spectrum/Signal Analyzers Selection Guide

Solve all your measurement needs with Anritsu's wide line-up of signal and spectrum analyzers, ranging from high performance and multi-function, high end models for R&D to handheld types for field use.

	Model	Frequency	RBW	Noise level	Key features
	MS2830A MS2830A MS2830A	9 Hz to 3.6 GHz 9 Hz to 6.0 GHz 9 Hz to 13.5 GHz	Spectrum Analyzer 1 Hz to 3 MHz, 50 kHz, 5, 10, 20, 31.25 MHz Signal Analyzer 1 Hz to 1 MHz	Down to -153 dBm*	• Top-class measurement speed • Supports ±0.3 dB (typ.) total level accuracy • SPA, VSA and Vector SG in one box • Low price, high performance and speed • Excellent SSB phase noise (Opt 062) • Max. 31.25 MHz analysis bandwidth • Supports LTE-FDD/TDD, GSM/EDGE/EDGE evo, Mobile WiMAX, WLAN, and W-CDMA
	MS2830A MS2830A	9 Hz to 26.5 GHz 9 Hz to 43 GHz	Spectrum Analyzer 1 Hz to 3 MHz, 50 kHz, 5, 10, 20**, 31.25** MHz Signal Analyzer 1 Hz to 1 MHz		• 9 kHz to 26.5/43 GHz frequency range; 43 GHz max. built-in pre-amp option • Best-of-class wide dynamic range over 6 GHz • 110 GHz max. frequency range; built-in 1st local signal output for external mixer • For wideband down-converter; built-in 1 GHz IF output band • Analysis bandwidth options (signal analyzer and modulation analysis functions)
	MS2690A MS2691A MS2692A	50 Hz to 6.0 GHz 50 Hz to 13.5 GHz 50 Hz to 26.5 GHz	Spectrum Analyzer 30 Hz to 3 MHz, 5, 10, 20, 31.25 MHz Signal Analyzer 1 Hz to 1 MHz, 3, 10 MHz	Down to -155 dBm*	• SPA, VSA and Vector SG in one box • Top class performance - Dynamic range 177 dB - Total level accuracy ±0.3 dB (typ.) • Max. 125 MHz analysis bandwidth • High speed modulation analysis • Supports LTE-FDD/TDD, GSM/EDGE/EDGE evo and WCDMA
	MS2687B	9 kHz to 30 GHz	1 Hz to 20 MHz	Down to -146.5 dBm*	• High speed modulation analysis S/W • Opt power meter measures to 32 GHz • Fast data transmission (GPIB 120 kb/sec)
	MS2711E MS2712E MS2713E	100 kHz to 3 GHz 100 kHz to 4 GHz 100 kHz to 6 GHz	100 Hz to 3 MHz 10 Hz to 3 MHz 10 Hz to 3 MHz	-142 dBm in 100 Hz RBW -162 dBm (normalized to 1 Hz) -162 dBm (normalized to 1 Hz)	• Handheld, battery-operated design • Lightweight at only 3.5 kg • Dynamic range of >95 dB in 10 Hz RBW • DANL of -152 dBm in 10 Hz RBW • Phase noise of -100 dBc/Hz max @ 10 kHz offset at 1 GHz
	MS2717B MS2718B MS2719B	9 kHz to 7.1 GHz 9 kHz to 13 GHz 9 kHz to 20 GHz	1 Hz to 3 MHz	-153 dBm typ to 1 GHz	• Built in preamplifier (standard) up to 4 GHz • Lightweight at only 6 kg (typical)
	MS2721B	9 kHz to 7.1 GHz	1 Hz to 3 MHz	-163 dBm @ 1 GHz	• Low phase noise of -100 dBc/Hz @ 10 kHz offsets
	MS2722C MS2723C MS2724C MS2725C MS2726C	9 kHz to 9 GHz 9 kHz to 13 GHz 9 kHz to 20 GHz 9 kHz to 32 GHz 9 kHz to 43 GHz	1 Hz to 10 MHz	-160 dBm @ 4 GHz -152 dBm @13 GHz -145 dBm @ 20 GHz -154 dBm @ 32 GHz -147 dBm @ 40 GHz	• Broadband preamplifiers over the whole frequency range for increased sensitivity around 20 dB • Three Sweep Modes – with improved Sweep Speed - up to 100 times faster

*Option and frequency dependent ** Applies to 26.5 GHz model only

MS2830A Signal Analyzer

- Frequency coverage up to 3.6/6/13.5/26.5/43 GHz
- Total level accuracy: ±0.3 dB (typ.)
- Dynamic range: 168 dB
  TOI: ≥+15 dBm, DANL: -153 dBm/Hz
- SSB phase noise: -107 dBc/Hz@1 kHz offset
  -113 dBc/Hz@10 kHz offset

Signal Analyzer

- Analysis bandwidth: 10 MHz (Opt.006)/31.25 *1 MHz (Opt.005 *1 & 006)
- Modulation analysis software (LTE-FDD, LTE-TDD, WiMAX, GSM/GPRS/EDGE, W-CDMA/HSPA/HSPA Evolution, WLAN etc.)
- Capture function and Replay function *2

Vector Signal Generator

- Level accuracy: ±0.5 dB (typ.)
- Internal AWGN Generator (Opt.028)

The MS2830A is a high-speed, high-performance, cost-effective Spectrum Analyzer/Signal Analyzer. Not only can it capture wideband signals but FFT technology supports multifunction signal analyses in both the time and frequency domains. Moreover, the built-in signal generator function outputs both continuous wave (CW) and modulated signals for use as a

*1: Cannot be installed in MS2830A-045 (43 GHz model).
*2: Cannot be installed in MS2830A-044/045 (26.5 GHz/43 GHz model).

MS2690A/91A/92A Signal Analyzer

- Frequency coverage up to 6.0/13.5/26.5 GHz
- Total level accuracy: ±0.3 dB (typ.)
- Dynamic range: 177 dB
  TOI: ≥+22 dBm, DANL: -155 dBm/Hz

Signal Analyzer

- Analysis bandwidth: 31.25 MHz (Std.)/125 MHz(Opt.)
- Modulation analysis software (LTE-FDD, LTE-TDD, WiMAX, GSM/GPRS/EDGE, W-CDMA/HSPA/HSPA Evolution, WLAN etc.)
- Capture function and Replay function

Vector Signal Generator

- Level accuracy: ±0.5 dB (typ.)
- BER function, Internal AWGN Generator

The MS269xA Series Signal Analyzer has the excellent general level accuracy, dynamic range and performance of a high-end spectrum analyzer. Not only can it capture wideband signals but FFT technology supports multifunction signal analyses in both the time and frequency domains. Moreover, the built-in signal generator function outputs both continuous wave (CW) and modulated signals for use as a reference signal source.

"Take advantage of a large selection of options to handle a wider range of applications at a reasonable cost."

Anritsu handheld spectrum and signal analysers offers high performance and advanced capabilities with low pricing

MS272XC Series Handheld Spectrum Analyzer - Spectrum Master™

- Five models offering 9 kHz to 9, 13, 20, 32 & 43 GHz.
- Broadband preamplifiers over the whole frequency range.
- Increased 20 dB sensitivity.
- Three sweep modes, up to 100 time faster.

The Spectrum Master series provides the broadest frequency range ever available in a handheld spectrum analyzer. Providing frequency coverage up to 43 GHz in an instrument that weighs less than 3.6 kg (8 lbs.), the MS272xC series is also designed with an assortment of applications to test the RF physical layer, making it easier than ever for field technicians, monitoring agencies and engineers to monitor over-the-air signals, locate interferers, and detect hidden transmitters. Five models, with high-end frequency coverage of 9 GHz, 13 GHz, 20 GHz, 32 GHz and 43 GHz, respectively, are available in the family.

MS2711E Series Handheld Spectrum Analyzer - Spectrum Master™

- Measurements: Occupied Bandwidth, Channel Power, ACPR, C/I, Spectral Emission Mask
- Interference Analyzer: Spectrogram, Signal Strength, RSSI, Signal ID, Interference Mapping
- Dynamic Range: > 85 dB in 100 Hz RBW
- DANL: -142 dBm in 100 Hz RBW with preamp option 0008

Regulatory requirements are growing. You're under increasing pressure to cut costs. And improving system uptime is always a top priority. The MS2711E Spectrum Master helps you do all of this and more. Whether you are performing complex interference analyses or assessing signal quality, the MS2711E Spectrum Master delivers the ease of use, rich functionality, and best-in-class price/performance you've come to expect from Anritsu.

Models				Spectrum Analyzers					
				Spectrum Master™					
				Value	Compact			Hi Performance	
Options	Option Number			MS2711E	MS2712E MS2713E	MS2721B	MS2722C	MS2723C MS2724C	MS2725C MS2726C
Cable & Antenna Analyzer									
Frequency Range									
2 MHz Frequency Extension		0002							
1-port Measurements (Return Loss, Cable Loss, DTF)									
2-port Transmission Measurement (gain, loss, isolation)		0021		•	•				
2-port Measurements (gain, loss, isolation, phase)									
2-port Cable Loss		0022							
PIM Analyzer (Req PIM Master)					Standard	Standard	Standard	Standard	Standard
Spectrum Analyzer									
Frequency Range				100 kHz to 3 GHz	100 kHz to 4 GHz 100 kHz to 6 GHz	9 kHz to 7.1 GHz	9 kHz to 9 GHz	9 kHz to 13 GHz 9 kHz to 20 GHz	9 kHz to 32 GHz 9 kHz to 43 GHz
Frequency Extension to 6 GHz		0006							
Preamplifier		0008		•	Standard	Standard	Standard	Standard	Standard
Interference Analyzer		0025		•	•	•	•	•	•
Channel Scanner		0027		•	•	•	•	•	•
Coverage Mapping		0431			•		•	•	•
Gated Sweep		0090			•	•			
Zero Span IF Output		0089					•	•	•
I/Q Waveform Capture		0024					•	•	•
AM/FM/PM Measurements		0509		•	•				
Signal Generators									
Tracking Generator						•			
CW Generator					•				
Vector Signal Generator									
Power Meters									
Power Meter				•	•				
High Accuracy Power Meter Support (requires power sensor)				•	•	•	•	•	•
Power Monitor up to 50 GHz (requires detector)									
Wireless Signal Analyzer Options	RF	Mod.	OTA						
Demodulation Hardware		0009			•	•	•	•	•
GSM/GPRS/EDGE Measurements	0040	0041			•	•	•	•	•
W-CDMA/HSPA+ Measurements	0044	0065	0035		•	•	•	•	•
W-CDMA Measurements		0045			•	•	•	•	•
TD-SCDMA/HSPA+ Measurements	0060	0061	0038		•	•	•	•	•
LTE Measurements (up to 10 MHz BW)	0541	0542	0546		•	•	•	•	•
LTE BWs = 15, 20 MHz (requires Opt 0541, 0542, 0551, or 0552)	0543	0543					•	•	•
TD-LTE Measurements (Up to 10 MHz BW)	0551	0552	0556				•	•	•
CDMA2000 1X Measurements	0042	0043	0033		•	•	•	•	•
CDMA2000 1xEV-DO Measurements	0062	0063	0034		•	•	•	•	•
Fixed WiMAX Measurements	0046	0047			•	•	•	•	•
Mobile WiMAX Measurements	0066	0067	0037		•	•	•	•	•
Digital TV Signal Analyzer Options	Analyzer	SFN	BER						
DVB-T/H Measurements (30-990 MHz)	0064	0078	0057			•			
ISDB-T Measurements	0030	0032			•	•			
Land Mobile Radio Analyzer Options	Analyzer	Coverage							
P25 Measurements	0520	0522			•				
P25 Measurements	0521	0522							
NXDN Measurements	0530	0532			•				
NXDN Measurements	0531	0532							
DMR Measurements	0591	0592							
General Options									
GPS Receiver		0031		•	•	•	•	•	•
Bias Tee (built-in)		0010			•	•			
Secure Data Operation		0007					•	•	•
Ethernet Connectivity		0411			•	Standard	Standard	Standard	Standard
K(f) Test Port Connectors		0011							
Replaces Standard K(f) connector with N(f)		11NF							
Standard / Premium Calibration		0098/99		•	•	•	•	•	•

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Specifications are subject to change without notice.

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