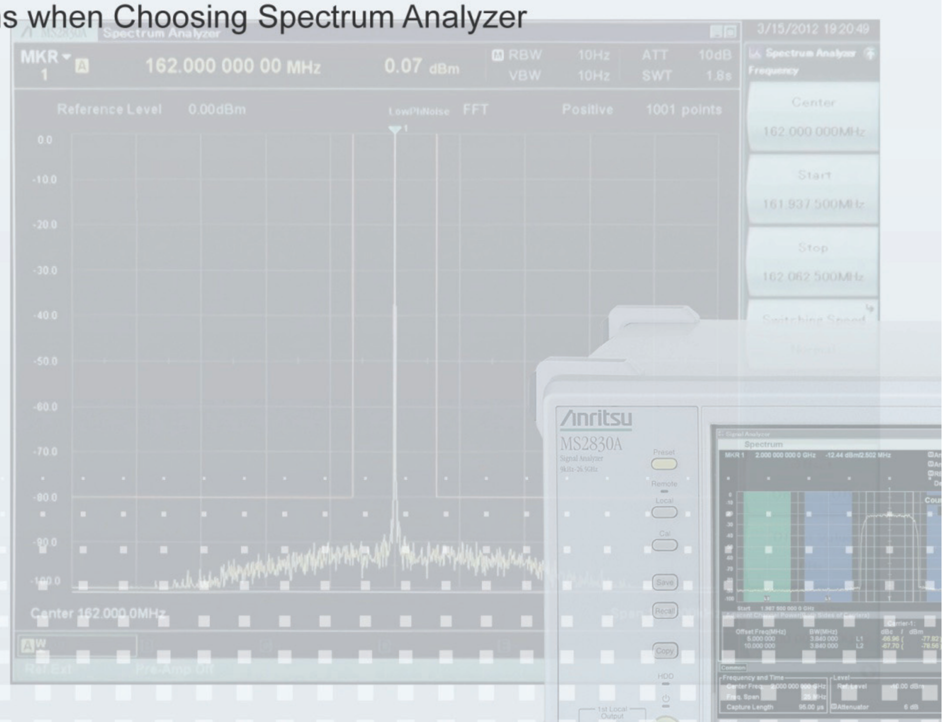
Technical Note

Spectrum Analyzer Supporting Narrowbanding/Digitalized Land Mobile Radio (LMR) Equipment Measurements

Spurious Measurement and Adjacent Channel Power Ratio (ACPR)

Contents



1. Trends in Land Mobile Radio Market

There are increasing calls worldwide for more efficient use of operating frequencies for Land Mobile Radio as the background to expansion of frequency bands resulting from the rapid growth in demand for mobile communications equipment including mobile terminals.

To increase the number of usable channels in allocated frequency bands, it is essential to narrow bandwidths and countries worldwide are moving towards legislation allowing operations in the 6.25 kHz and 12.5 kHz channel intervals.

Due to this band narrowing, it is difficult technically to maintain the previous degree of communications quality using analog modulation technology, which is a key factor driving the transition from analog to digital wireless communications.

Even with the digital transition, there are still mainstream non-linear modulation methods like 4-FSK that can use non-linear Tx amplifiers, taking into consideration the same power efficiency as analog wireless, like F3E, etc.

Moreover, radio equipment using linear modulation, such as QPSK with excellent BER characteristics, are starting to appear in P25 terrestrial base stations and train radio in N. America, as well as in wireless communications used by firefighters in Japan.

As a consequence of the trend to narrowing bandwidth, at Tx testing, national radio regulations (RR) define both the level of unwanted emissions in the conventional spurious region as well as the level of out-of-band unwanted emissions or adjacent channel power ratio (ACPR).

In Japan, part of the basic RR was revised from December 1, 2005 to define tests for measuring the level of out-of-band spurious as well as the performance of spectrum analyzers required for such tests.

2. Overview of Level Measurement of Spurious and Unwanted Emissions

The frequency regions defined by RR can be broadly separated into three—the required frequency bandwidth, the out-of-band area, and the spurious area (Fig. 1) as follows:

a. Required frequency bandwidth (Bn): Channel interval

b. Out-of-band area (fc ±2.5 Bn): Dominated by unwanted emissions out of required frequency bandwidth

c. Spurious area: Dominated by out-of-band spurious emissions

Level measurement of unwanted emissions in the spurious band can be grouped into the following three areas.

c-1. Carrier frequency ±(62.5 kHz to 1 MHz): Close-in spurious area 1

c-2. Carrier frequency ±(1 MHz to 10 MHz): Close-in spurious area 2

c-3. Carrier frequency ±(10 MHz to >100 MHz): Other areas

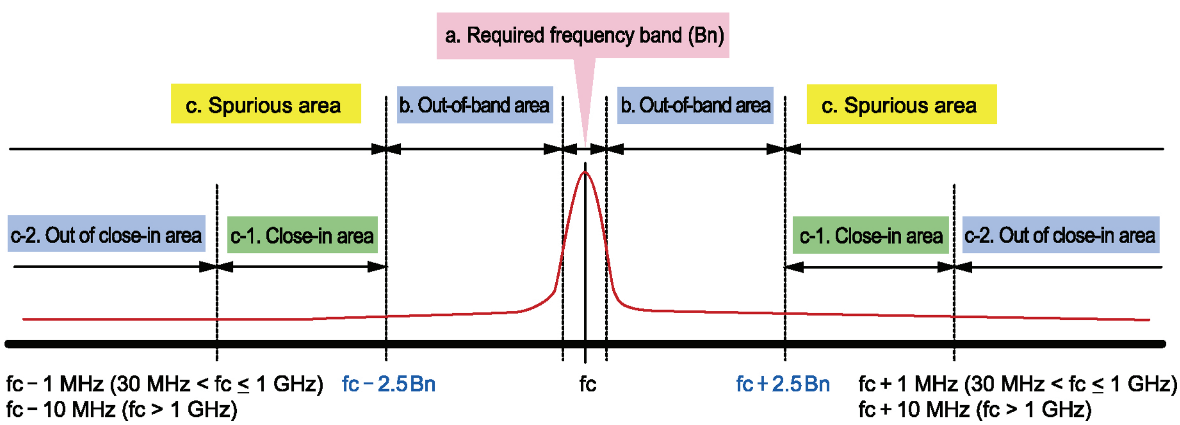


Figure 1 Frequency area

Frequency interval for out-of-band area in Japan defined by Radio Regulations (RR)

Frequency range	Narrowband		Normal interval	Wideband	
	Bn<	Frequency interval		Bn>	Frequency interval
9 kHz<fc≤150 kHz	250 Hz	625 Hz	2.5 Bn	10 kHz	1.5 Bn + 10 kHz
150 kHz<fc≤30 MHz	4 kHz	10 kHz	2.5 Bn	100 kHz	1.5 Bn + 100 kHz
30 MHz<fc≤1 GHz	25 kHz	62.5 kHz	2.5 Bn	10 MHz	1.5 Bn + 10 MHz
1 GHz<fc≤3 GHz	100 kHz	250 kHz	2.5 Bn	50 MHz	1.5 Bn + 50 MHz
3 GHz<fc≤10 GHz	100 kHz	250 kHz	2.5 Bn	100 MHz	1.5 Bn + 100 MHz
10 GHz<fc≤15 GHz	300 kHz	750 kHz	2.5 Bn	250 MHz	1.5 Bn + 250 MHz
15 GHz<fc≤26 GHz	500 kHz	1.25 MHz	2.5 Bn	500 MHz	1.5 Bn + 500 MHz
fc>26 GHz	1 MHz	2.5 MHz	2.5 Bn	500 MHz	1.5 Bn + 500 MHz

Reference data: December 1995 MIC Telecommunication Bureau

3. Measurements using Spectrum Analyzer

This section explains level measurement of 150-MHz band digital citizens' band radio (4-FSK) spurious emissions and investigation of the level of unwanted spurious using a spectrum analyzer.

3-1. Measuring Level of Out-of-Band Emission

3-1-1. Settings

Unmodulated (CW) Tx signal

Carrier Frequency Bandwidth	Carrier frequency ±62.5 kHz Excludes carrier frequency ±(channel interval/2)
Resolution Bandwidth (RBW)	30 Hz ≤ RBW ≤ 1 kHz
Video Bandwidth (VBW)	Same degree as RBW
Sweep Time	Minimum time assuring measurement accuracy
Y-axis Scale	10 dB/div
Input Level	Value with maximum dynamic range
No. of Data Points	≥400 points (eg: 1001 points)
Sweep Mode	Single sweep
Detection Mode	Positive peak

Supplementary Explanation

The RBW of the spectrum analyzer used when measuring the level of out-of-band spurious should be better than 30 Hz and less than 1 kHz. In the Japanese Technical Standards Certificates and rules on testing the characteristics of radio equipment, measurement is usually performed at 100 Hz and when the maximum permissible spurious level is exceeded, measurement is performed by narrowing the RBW down to 10 Hz.

Reference Text

TELEC-T249 (V. 4.0) defines the spectrum analyzer settings for investigating simple digital spurious and the level of unwanted emissions 2(4) in the out-of-band spurious area.

3-1-2. Evaluation

The level amplitude of detected spurious emissions must not exceed the permitted value (Fig. 2). Moreover, in out-of-band areas, the detected maximum amplitude is used as the measured value.
The measurement time increases when the spectrum analyzer RBW is set to a small value.
In addition, investigation is better performed over shorter time spans because the Tx amplifier characteristics deteriorate due to the negative impact of heat as measurement times for unmodulated and CW Tx signals lengthen. This problem can be avoided by using fast Fourier transformation (FFT). However, care is required using this method because the VBW cannot be set for some spectrum analyzer models.

Target radio equipment		>1 W		≤1 W	
		Spurious emissions	Unwanted emissions	Spurious emissions	Unwanted emissions
30 MHz to 54 MHz		1 mW and –60 dBc	–60 dBc	100 μW	50 μW
54 MHz to 70 MHz		1 mW and –80 dBc	–60 dBc	100 μW	50 μW
70 MHz to 100 MHz		1 mW and –60 dBc	–60 dBc	100 μW	50 μW
100 MHz to 142 MHz		1 mW and –60 dBc	–60 dBc	100 μW	50 μW
142 MHz to 144 MHz		1 mW and –80 dBc	–60 dBc	100 μW	50 μW
148 MHz to 162.0375 MHz		1 mW and –80 dBc	–60 dBc	100 μW	50 μW
162.0375 MHz to 200 MHz		1 mW and –60 dBc	–60 dBc	100 μW	50 μW
335.4 MHz to 470 MHz	>25 W	1 mW and –70 dBc	–70 dBc	—	—
	≤25 W	2.5 μW	2.5 μW	25 μW	25 μW
810 MHz to 960 MHz	>25 W	20 mW and –60 dBc	–60 dBc	—	—
	≤25 W	2.5 μW	2.5 μW	100 μW	50 μW
1215 MHz to 2690 MHz	>25 W	100 mW and –50 dBc	50 μW or –70 dBc	—	—
	≤25 W	100 μW	50 μW	100 μW	50 μW

Figure 2 Permissible values for level of spurious emission and unwanted emissions

3-2. Investigating Power of Unwanted Emissions in Spurious Region

3-2-1. Settings

	Close-in spurious area 1	Close-in spurious area 2	Other areas
Sweep Frequency Width	Carrier offsets ±1 MHz	Carrier offsets ±10 MHz	100 MHz
Resolution Bandwidth (RBW)	3 kHz	100 kHz	1 MHz
Video Bandwidth (VBW)	3 kHz		
Y-axis Scale	10 dB/div		
Input Level	Value with maximum dynamic range		
Sweep Time	≥1 burst/sample		
Sweep Mode	Single sweep		
Detection Mode	Positive peak		

Reference Text

TELEC-T249 (V. 4.0) defines the spectrum analyzer settings for investigating simple digital spurious and the level of unwanted emissions 2(2) in the spurious band.

3-2-2. Evaluation

For close-in spurious area 1, the value converted using Eq. 1 below must not exceed the permissible value (Fig. 2).

Converted Value = Measured Amplitude + 10 log [Reference Bandwidth[Note1]/RBW at Measurement]
= Measured Amplitude + 15.2 dB ....(Eq. 1)

(Note 1): 100 kHz (30 MHz < Carrier frequency ≤ 1 GHz), 1 MHz (Carrier frequency < 1 GHz)

Primarily, the reference bandwidth for digital citizens' band radio in the 150-MHz band is 100 kHz, but when measuring close-in spurious area 1 in this condition, accurate measurement is impossible due to the effect of surrounding carrier leakage power on measurement.
To ameliorate this effect, measurement is performed with the reference bandwidth set to 3 kHz.
Measurement is executed when the investigated amplitude exceeds the converted value.

For close-in spurious areas 2 and 3, check whether or not the amplitude of the investigated unwanted emissions exceeds the permissible value (Fig. 2).
However, if the amplitude value satisfies the permissible value of –3 dB, the amplitude becomes the measured value without performing measurement.
If the amplitude exceeds the permissible value at investigation of the level of unwanted emissions in the spurious area, measurement is executed.

3-3. Measuring Power of Carrier and Unwanted Emissions in Spurious Area

3-3-1. Settings

	30 MHz < f ≤ 1 GHz	> 1 GHz
Center Frequency	Unwanted emissions frequency	
Sweep Frequency Width	0 Hz	
Resolution Bandwidth (RBW)	100 kHz	1 MHz
Video Bandwidth (VBW)	About three times RBW	
Y-axis Scale	10 dB/div	
Input Level	Near maximum of mixer straight line region	
Sweep Time	Minimum time assuring measurement accuracy However, at least time for one continuous burst using burst signal	
Sweep Mode	Single sweep	
Detection Mode	Sample	

Reference Text

TELEC-T249 (V. 4.0) defines the spectrum analyzer settings when investigating simple digital spurious emissions, the level of unwanted emissions 2(3), or the level of unwanted emissions in the carrier wave or spurious areas.

For close-in spurious area 1, the detection mode at the settings in section 3-3-1 is switched to the positive peak and the average of the carrier wave amplitude is measured. The in-burst average is measured for burst signals.
Next, the frequency where the amplitude exceeds the converted value (Eq. 1 in section 3-2-2) is set as the center frequency and setting is performed as for close-in spurious area 1 (section 3-2-1). The sweep frequency at this time is ±(Ref. Bandwidth/2) = ±50 kHz.
In addition, when the frequency exceeding the permissible value is within the carrier wave ±112.5 kHz, the center frequency becomes the carrier wave ±112.5 kHz. Then, sweeping is performed using the spectrum analyzer, the values for all data points are integrated, and the total power is calculated as shown below.

Total Power Calculation:

$$Ps = \left(\sum_{i=1}^{n} Ei\right) \times \frac{Sw}{RBW \times k \times n}$$

Ps: Measured total power in reference bandwidth at each frequency (W)
Ei: Measured value for 1 sample (W)
Sw: Sweep frequency (MHz)
n: Number of sample points in reference bandwidth
k: Equivalent noise bandwidth correction
RBW: Resolution Bandwidth (MHz)

In close-in area 1, the RBW is set to 3 kHz not the reference bandwidth (100 kHz). Then the integrated value for the 100-kHz bandwidth is measured.

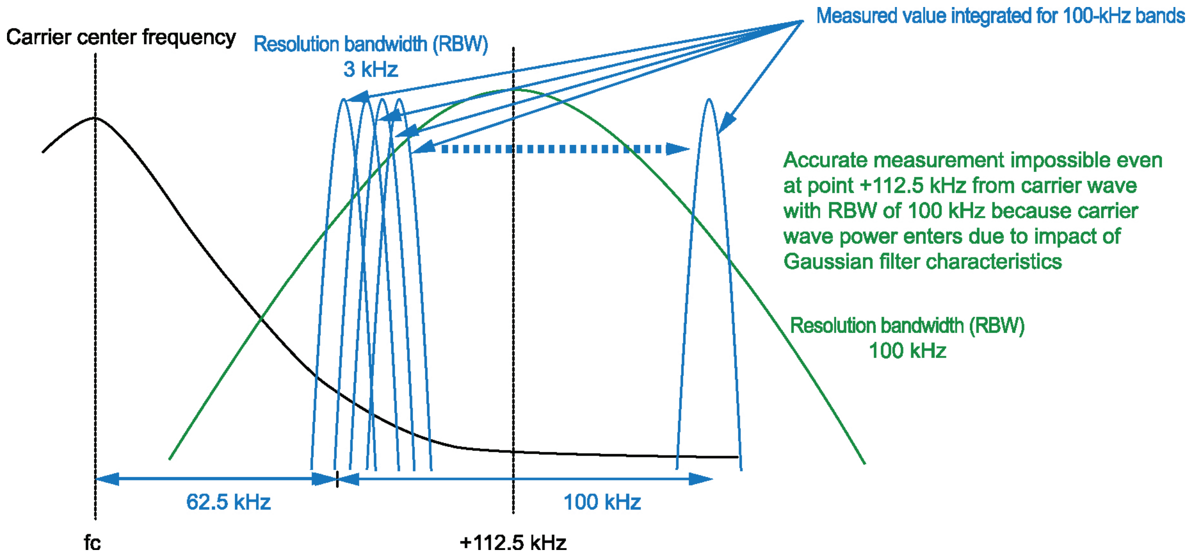


Figure 3 Measurement condition when frequency exceeding permissible value within +112.5 kHz of carrier wave

The total power calculation uses the common channel power function (RMS) for integration found in many current spectrum analyzers and there are no problems using the obtained value.

We recommend using the spectrum analyzer channel power value as the measured value rather than using a value calculated using a PC, etc.

4. Performance Considerations when Choosing Spectrum Analyzer

This section explains the key points to consider when choosing a spectrum analyzer for measuring spurious of land mobile radio.
The dynamic range of a general middle-range spectrum analyzer is determined by the cross-point between 2nd harmonic distortion or 2-tone 3rd-order intermodulation distortion generated by the internal mixer and the average phase noise.
At level measurement of out-of-band spurious and close-in spurious area 1 unwanted emissions for narrowband land mobile radio, the single side band (SSB) phase noise performance of the internal reference oscillator is the key factor determining the measurement dynamic range.

The performance required to measure the level of out-of-band spurious for 150-MHz-band digital citizens' band radio is calculated by Eq. 2.

SSB Phase Noise Performance = Permissible Spurious Level – 10 log (Search RBW) – 6 dB
= –80 dB – 10 log (30 Hz) – 6 dB
= –100.8 dBc/Hz @ 3.125-kHz offset ....(Eq. 2)

Note

Sometimes, level measurement of out-of-band emission for the 150-MHz band can be stricter than the permissible value for level measurement of unwanted emissions in the spurious area. The effect on the measured value is small, but the spectrum analyzer residual spurious response should be checked first.

The performance required to measure the level of unwanted emissions in close-in spurious area 1 is calculated by Eq. 3.

SSB Phase Noise Performance = Conversion Value = (Eq. 1) – 10 log (Search RBW) – 6 dB
= –75.2 dB – 10 log (3 kHz) – 6 dB
= –115.8 dBc/Hz @ 61 kHz (62.5 kHz – Search RBW/2) offset ....(Eq. 3)

Note

The permissible value for the level of unwanted emissions of 400-MHz band digital citizens' band radio is –70 dB (Fig. 2) and the conversion value is –85.2 dB, so the required SSB phase noise performance is –125.8 dBc/Hz @ 61 kHz.

Generally, it is believed that the performance for close-in spurious areas 2 and 3 is determined by the 2nd harmonic distortion generated by the internal mixer but the characteristics test for radio equipment in the technical compliance certification defines the use of a carrier wave suppression filter if necessary, and if this is used, it is not necessary to consider the spectrum analyzer 2nd harmonic distortion performance.

In the TIA-603 standard for train control radio in N. America, the adjacent channel power ratio (ACPR) standard is an extremely severe value of <–70 dBc/ch for the ratio of the carrier wave power to the power of 16 kHz bandwidth centered around a ±25-kHz offset frequency.
In this case, the required SSB phase noise performance must be better than that required for level measurement of out-of-band Emission. The required performance for measurement is calculated by Eq. 4.

$$\begin{aligned}\text{SSB Phase Noise Performance} &= \text{Adjacent Power Ratio Permissible Value} - 10\log(16\text{ kHz}) - 6\text{ dB}\\ &= -70\text{ dBc} - 42\text{ dB} - 6\text{ dB}\\ &= -120\text{ dBc/Hz @17 kHz (25 kHz – Measured Channel Bandwidth/2) offset}\end{aligned} \qquad \text{......(Eq. 4)}$$

Next, the validity of this calculation is confirmed.
Fig. 4 is a graph of the SSB phase noise performance of the internal reference oscillator in the Anritsu MS2830A signal analyzer (spectrum analyzer).
On confirming the ACPR dynamic range for a spectrum analyzer with an SSB phase noise performance of –126.6 dBc/Hz (10-kHz offset), a measurement dynamic range of –77.96 dBc/16 kHz (25-kHz offset is confirmed) (Fig. 5).

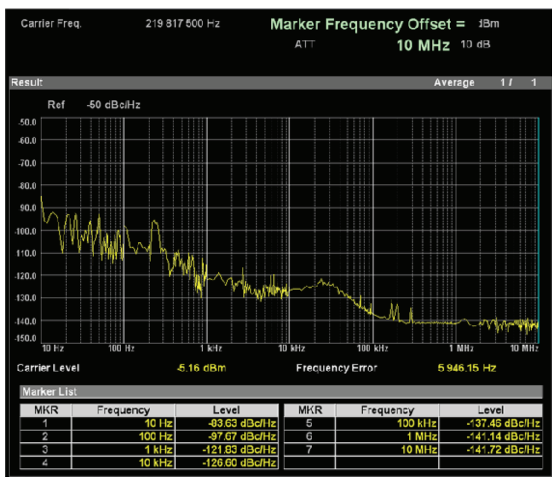


Figure 4 SSB phase noise performance of internal reference oscillator (MS2830A Example)

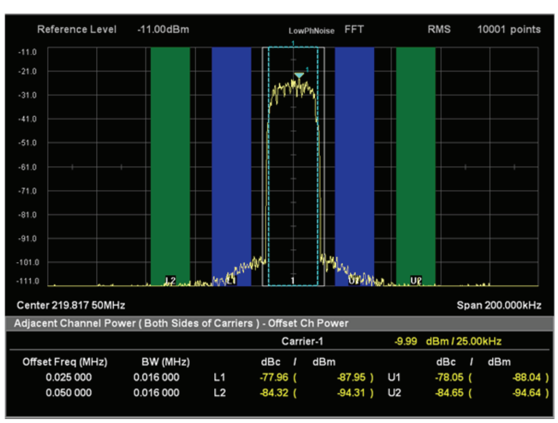


Figure 5 ACPR measurement dynamic range (MS2830A Example)

Moreover, when measuring adjacent channel power ratio (ACPR), since 2-tone 3rd-order intermodulation distortion generated by the internal mixer sometimes has an effect on dynamic range, the cross-point between the 2-tone 3rd-order intermodulation distortion and the average noise level must also be confirmed.
This confirmation is easy using the graph of spectrum analyzer distortion characteristics (Fig. 6).

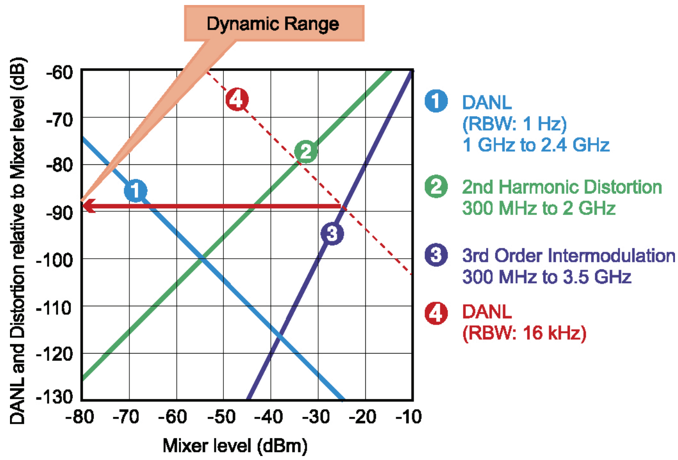


Figure 6　Cross-point of 2-tone 3rd-order intermodulation distortion and average noise level (MS2830A distortion characteristics)

5. Summary

When measuring the level of unwanted emissions and adjacent channel power ratio (ACPR) of narrowband and digital land mobile radio equipment, the SSB phase noise performance of the internal reference oscillator equipped in spectrum analyzer is the key factor affecting dynamic range.

Many land mobile radio equipment like the P25 in N. America and the TETRA in Europe are already shipping. When performing Tx tests defined by radio regulations (RR) for these narrowband land mobile radio equipment, generally, most existing radio equipment can be tested if the SSB phase noise performance is better than –120 dBc/Hz (1 kHz to 10 kHz offset).
Moreover, although spectrum analyzers with excellent close-in SSB phase noise performance are usually regarded as expensive, the Anritsu's MS2830A Signal Analyzer (Spectrum Analyzer) has all the functions and performance needed to measure narrowband digital land mobile radio equipment while only costing the same as a middle-range spectrum analyzer.

Anritsu

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