Anritsu

# White paper

## Tricks and tips for using digital IF and sweep spectrum analyzers


Anritsu | Since 1895

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Notes:
Use the appended reference materials to obtain a basic understanding of spectrum analyzers and digital modulation analysis using a signal analyzer. The contents of these reference materials have been checked for accuracy, but Anritsu accepts no responsibility for any omissions or mistakes. In addition, the contents of this document may be changed without prior notification.

# 1. Introduction

## 1.1. Outline

These materials have been developed to deepen understanding of the changes in spectrum measurements using a digital IF type spectrum analyzer (signal analyzer) as one of the many functions of the spectrum/signal analyzer.

## 1.2. Background

Rapid recent progress in development of wireless and broadcasting technologies, such as smartphones, wireless LAN, wireless sensor networks, RFID, GPS, digital TV, etc., has seen their widespread adoption in most people's daily lives.
A variety of measuring instruments, such as frequency counters, field strength meters, power meters, etc., is used to measure, analyze, and evaluate RF signals including electromagnetic (radio) waves broadcast by antennas; the spectrum analyzer plays a central role in detailed measurement, analysis, and evaluation of RF signals. The importance of the spectrum analyzer for engineers dealing with RF signals seems unlikely to change in the future.
At the same time, progress in wireless communications technologies and the appearance of new applications have increased the complexity and level of the functions and performance required by spectrum analyzers. Among these requirements, the need to evaluate signals using new wideband digital modulation methods as well as to capture transient signal spectrums to troubleshoot problems with electromagnetic noise resulting from use of high sensitivity parts mounted at high densities requires new generations of spectrum analyzers using frequency sweep principles.
As a result, the spectrum analyzer continues to evolve to meet the needs of engineers. As an example, the digitization of internal processing has led to huge jumps in measurement speed, accuracy and stability.
As devices and computation speeds have become increasingly faster and more accurate, Anritsu has been incorporating developments in digital processing as signal analyzer functions into its MS2830A and MS2690A series.
Such improvements not only support evaluation and analysis of digital modulation signals, but also support capture of various signals with non-regular spectrums.

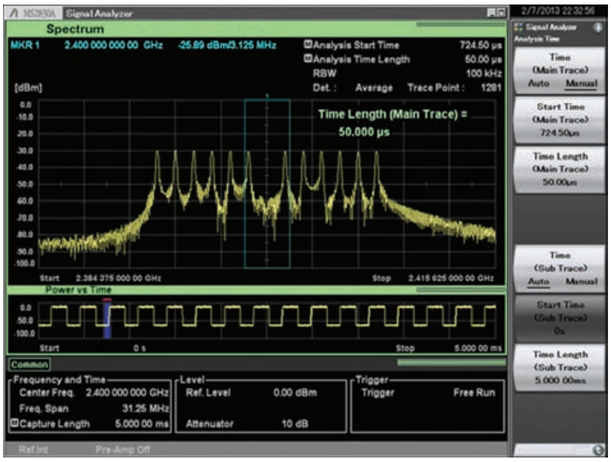


Figure 1.2.1 : Wireless LAN OFDN spectrum

## 2. Spectrums

Electrical signals can be measured in various ways using different types of measuring instrument. The methods can be broadly divided into measurements in the time domain and in the frequency domain, but RF signals are most commonly measured and evaluated in the frequency domain.

### 2.1. Frequency domain and Time domain

Figure 2.1.1 shows a 3D representation of the time, frequency and level of an electrical signal. There are two measurement approaches to capturing and observing this signal in 2D.

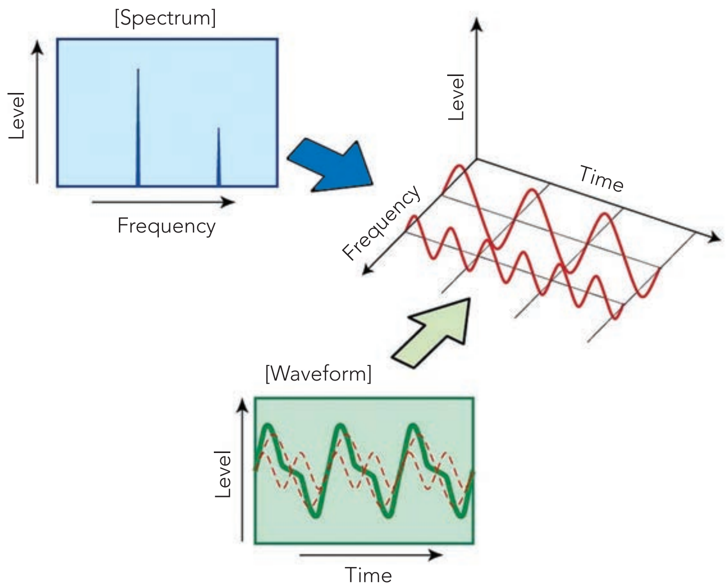



Figure 2.1.1 : Signal observation directions

The first is in the time domain by looking at the signal from the direction of the green arrow in the figure. This is the typical waveform measured using an oscilloscope. The display in the time domain is easy to understand intuitively and is used commonly to evaluate the quality of low-frequency signals and high-speed digital signals.
The second is in the frequency domain looking at the signals from the direction of the blue arrow in the figure. The distribution of the frequency components appear as a “spectrum”.
In this case the x-axis is frequency and the values on the y-axis are not time instants but are instead amplitude or power. A spectrum analyzer typically uses this approach.

Since both 3D waveform and spectrum data are represented as 2D, either the time-axis or frequency-axis data is overlapped and obscured.
For example, Figure 2.1.1 shows the appearance of a waveform containing two sine waves of different frequency.
On the other hand, since the same signal is viewed from two different directions, Fourier transform/Inverse transform can reveal the correspondence between the waveform and spectrum.
Incidentally, the spectrum analyzer is also the main instrument used for measuring RF signals. One reason is that most information included in an RF signal such as a modulated signal used in wireless communications has many slight differences in the frequency domain, making evaluation difficult in the time domain.
For example, Figure 2.1.2 shows a comparison between two signals one with just the 1 GHz carrier wave and the other with added 1 kHz modulation. Viewed in the frequency domain on the spectrum analyzer, it is easy to see the difference between the two, but the waveforms on the oscilloscope show no differences at all.

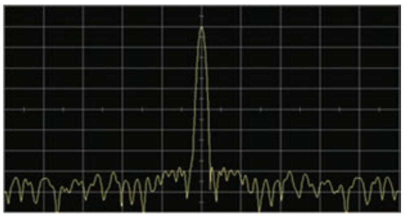
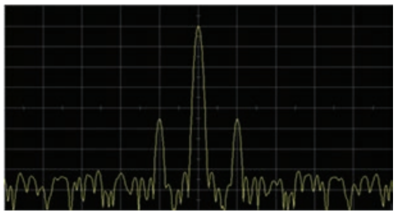
| | **Only Carrier Wave (Modulation: Off)** | **1 kHz Frequency Modulation (FM)** |
|---|---|---|
| Spectrum Analyzer<br>(Frequency domain) |  |  |
| Oscilloscope<br>(Time domain) |  |  |

Figure 2.1.2 : Appearance of 1 GHz RF signal

### 2.2. Time variations in spectrum

In the same way that signals displayed in the time domain obscure information in the frequency domain, signals displayed in the frequency domain include the possibility of losing sight of information in the time domain.

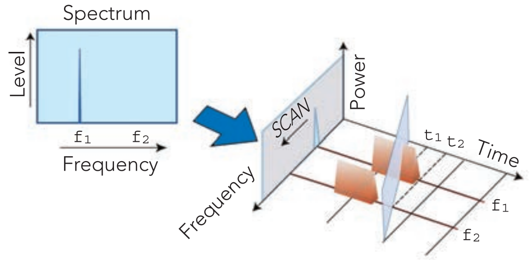



Figure 2.2.1 : Spectrum analyzer response to transient signal

Figure 2.2.1 shows a high-frequency signal changing with time as measured with a sweep spectrum analyzer.
(In these materials, a sweep spectrum analyzer is described simply as a spectrum analyzer.)

The spectrum analyzer measures a spectrum by sweeping the analysis frequencies smoothly from low to high to detect frequencies based on the assumption of measuring a stationary signal that does not change between measurement start and stop. In this above figure, this is equivalent to viewing the angled slice on the times axis from the frequency domain. Consequently, if there are no measured signal frequency components at each sweep frequency time point, nothing is detected and no signal is reflected in the displayed results.
In the above figure, although there is a signal component when the sweep frequency ($f_1$) is at time point ($t_1$), nothing is detected because there are no signal components when the sweep frequency ($f_2$) reaches time point ($t_2$). As a result, it appears as if the spectrum only has the ($f_1$) component.
Although a spectrum analyzer is the most reliable instrument for measuring high-frequency signals, it is clear that it cannot detect signals that change during the sweep time.
In contrast, a digital IF signal analyzer can capture non-regular spectrums.
Since a signal analyzer adds extra functions to a spectrum analyzer, it can capture signal time, frequency, and level (power) changes in three dimensions for multi-dimensional display and analysis.
For example, as shown in Figure 2.2.2, a signal analyzer can be used to observe a signal from different viewpoints, such as observing the spectrum at any time as a spectrogram, or as changes in power over time, or changes viewed from the direction of the power axis (viewed from top of following figure).

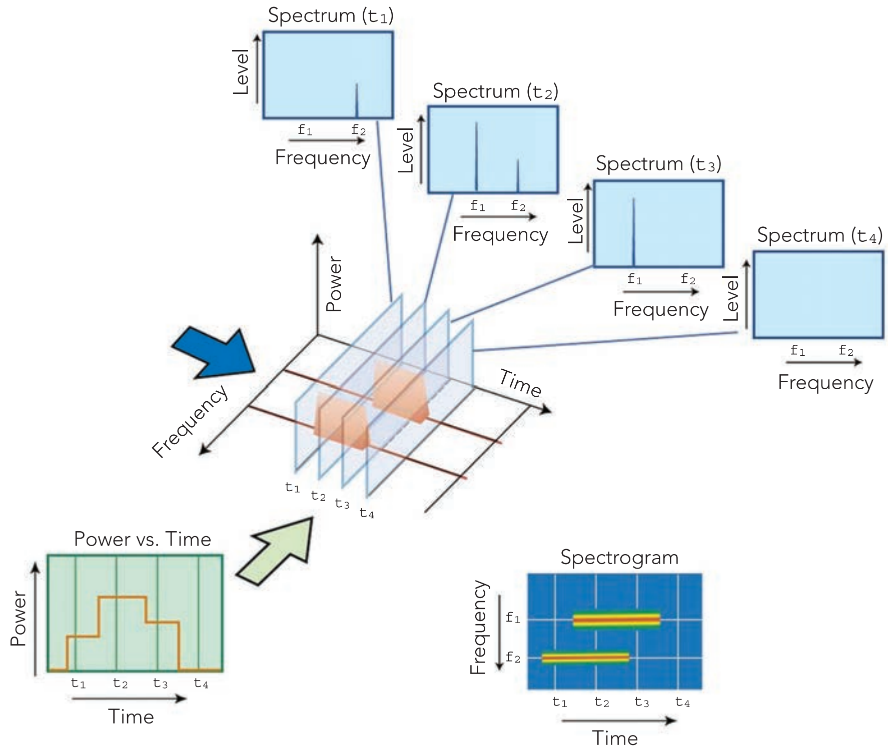



Figure 2.2.2 : Signal analyzer response to transient signal

## 3. Signal analyzer principles and operation

The signal analyzer makes use of high-level digital processing technologies, such as high-speed A/D conversion, FFT processing, digital filters, etc., to capture a spectrum that changes over time, such as for a burst signal, as well as a spectrum with transient variations.

### 3.1. System

To make best use of the signal analyzer functions and performance, it is important to understand how the signal analyzer captures the spectrum.
Figure 3.1.1 shows the signal processing flow and operation principles of a signal analyzer.
Signal analyzers capture the spectrum results using three main processes: frequency conversion, digitization and storage, and conversion to the spectrum.

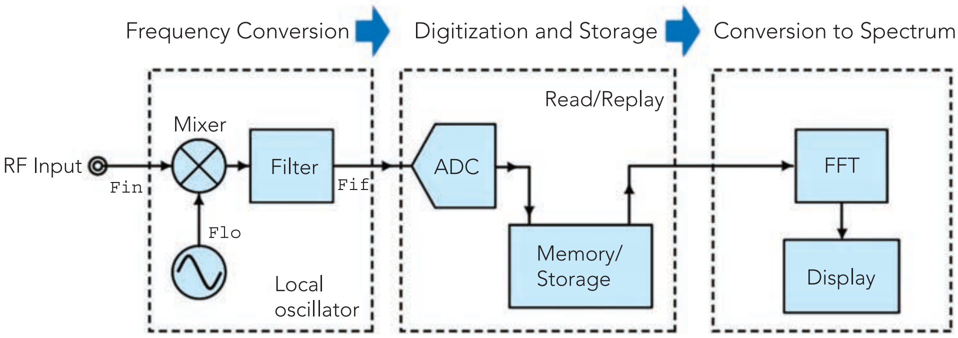



Figure 3.1.1 : Signal analyzer principle and Operation

First, the measurement signal input in a spectrum analyzer is converted to an intermediate frequency (IF) by the frequency conversion section composed of a local oscillator, mixer and bandpass filter.
The intermediate frequency Fif is found from the following equation where Fin is the measured signal frequency and Flo is the local oscillator oscillation frequency.

$$Fif = Fin - Flo \qquad \text{(Eq 3-1)}$$

In a signal analyzer, the value of Flo is fixed during measurement. In addition, the IF has a wide bandwidth corresponding to the measurement bandwidth (frequency span). As a result, the measured signal spectrum is frequency-converted to IF without changing the shape at Fin.
Next, the IF-converted measured signal is converted to digital data using an A/D converter.
In other words, the signal analyzer captures the true form of the measured signal in a fixed time period just by frequency conversion. The digitized time series waveform data is immediately captured to the internal memory and this data can be saved to another hard disk.

Any part or range of the measured signal captured as time-series waveform data can be read immediately and analyzed using digital processing. Deploying digital processing using Fast Fourier Transform (FFT) in the frequency domain captures the spectrum in the read time range.
The data stored in memory or hard disk is the basis of the signal analyzer display. In other words, the signal capture processing that stores the signal as digital data, and the analysis processing that reads the data can be executed independently time wise. Since capture and analysis are batch processed, either offline analysis can be performed in the free time after capture, or the same signal can be analyzed repeatedly using different methods and settings. This is a key feature of signal analyzers that is not supported by sweep-type spectrum analyzers.
For example, the measurement results can be confirmed using saved data by changing to a different RBW at measurement.

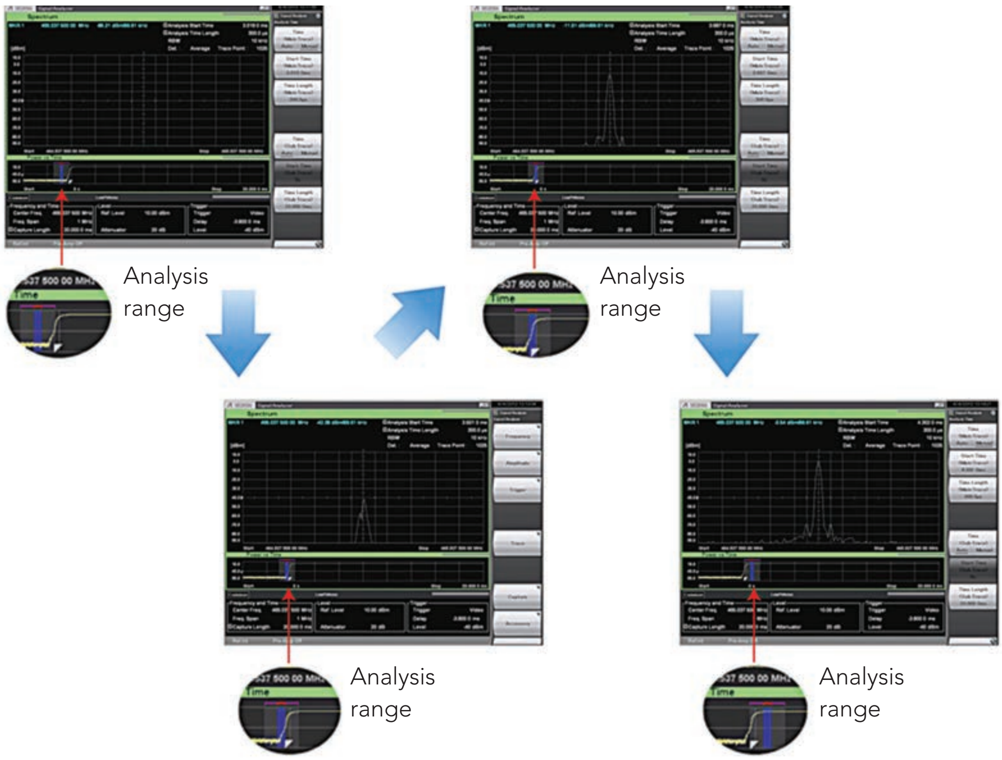



Figure 3.1.2 : Sequential display of wireless signal spectrum display captured in memory

## 3.2. Operation of each part

### Input and frequency conversion

In an actual analyzer, an attenuator (signal attenuator) and preamplifier in the input section assure the correct measured signal level.
At frequency conversion, although it is possible to obtain the IF signal using a single conversion, in measuring instruments, the final IF signal is obtained using multiple frequency conversions rather than a single conversion. In addition, if the frequency of the measured signal is higher than the measured signal frequency, sometimes a frequency converter is used at the input stage. The signal path until frequency conversion is the same in a signal analyzer and spectrum analyzer and the items to consider are the same.
Noise and non-linearity generated in the analog section from input to IF conversion is added to the measured value and is part of an analyzer's basic performance. Consequently, high-level analog circuit technology is essential when handling very small high-frequency signals.
As a result, in the MS2830A for example, a very low displayed average noise level of –150.5 dBm/Hz is assured to permit wide dynamic range measurements.

Signal Analyzer MS2830A specifications
Displayed Average Noise Level (DANL): –150.5 dBm/Hz (Signal analyzer mode, 30 MHz ≤ Frequency < 1 GHz, Pre-amp: Off)

### Local oscillator

The local signal oscillator handles frequency modulation of the measured signal. In a spectrum analyzer, the local oscillator oscillation frequency is swept (changed continuously) at measurement, but in a signal analyzer it oscillates at a fixed frequency during measurement.
In the same way that noise and non-linearity generated in the analog section from input to IF conversion form the basis of an analyzer's basic performance, the signal purity of the local oscillator is directly related to basic performance. For example, if there is even a slight variation in the oscillation frequency, the measured signal will appear to fluctuate at that moment too. Similarly, short-term variations will cause Single Side Band (SSB) phase noise and widespread errors in the spectrum tails. Consequently, the local oscillator section of a signal analyzer incorporates a high-purity oscillator.
Figure 3.2.1 shows an example of signal analyzer SSB phase noise characteristics (MS2830A Option-066).

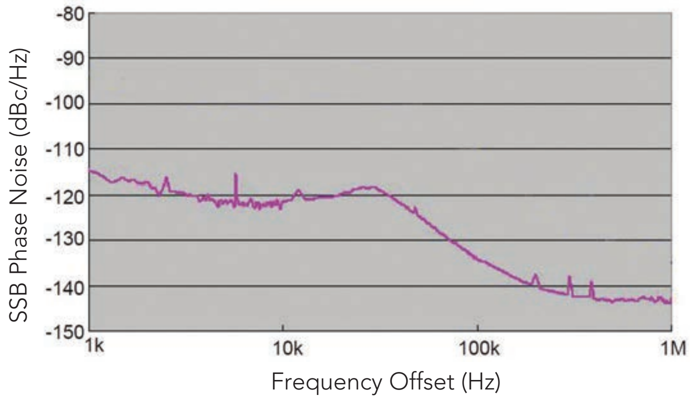



Figure 3.2.1 : MS2830A Option-066 SSB phase noise characteristics

### IF circuit

The IF-converted measured signal is band-limited by the bandpass filter while being simultaneously amplified to the level required for analysis.
The signal analyzer IF requires a frequency bandwidth that is equal to or greater than the analysis frequency width (span). Consequently, the signal analyzer IF circuit is designed to achieve flat characteristics over a wide band of about 30 MHz normally, and sometimes exceeding 100 MHz, depending on the situation.

### A/D converter

The frequency-converted IF (analog) measured signal is converted to a digital (time-series data) signal by the A/D converter.
At A/D conversion, the signal analyzer IF requires high-speed conversion from the wideband signal.
In addition, supporting wide-dynamic-range analysis requires high-resolution A/D conversion.
Consequently, the signal analyzer has a built-in high-speed, high-resolution A/D converter.

### Digital processing

The digitized measured signal is saved to memory. In addition, it can be either saved to internal hard disk or transferred to an external storage device for later loading and replay.

At this time, the read data is converted to the necessary narrow range by FFT and repeated data loading and FFT creates a spectrum series changing with time which is displayed on-screen to give the impression of a spectrum changing dynamically in real time (Figure 3.2.2).

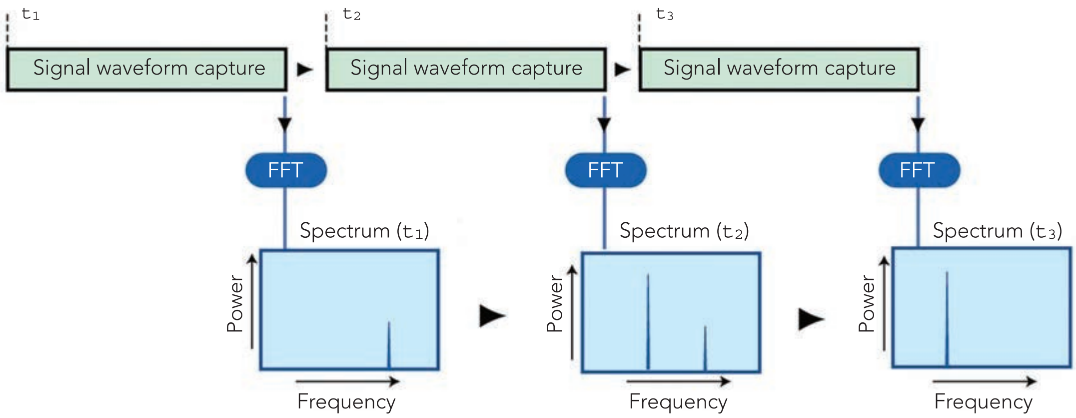



Figure 3.2.2 : Continuous analysis at short cycle

Moreover, as shown in Figure 3.2.3, after saving long-term data, loading the data by slightly shifting the analysis time range and performing FFT makes it possible to sequentially inspect spectrum transitions with time at any point and any speed.

Additionally, besides performing FFT on read data to obtain the spectrum, it is also possible to obtain other information such as changes in power with time by performing processing on read data using other parameters.

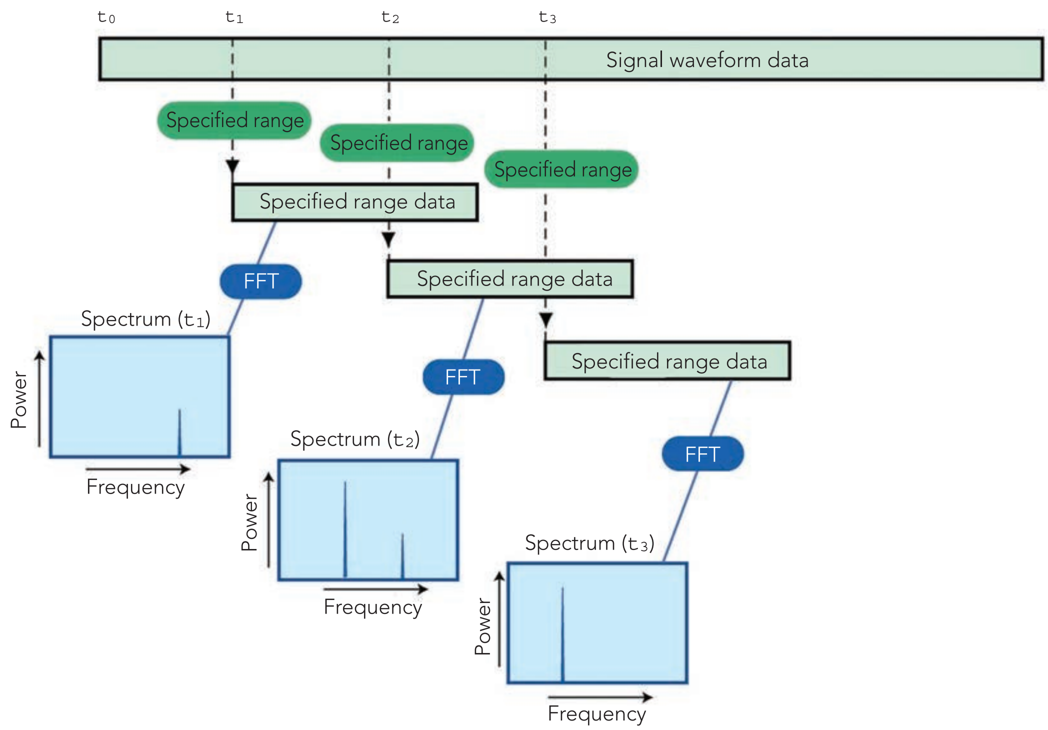



Figure 3.2.3 : Analysis of specific signal range recorded in memory

### 3.3. Sampling rate and sample count

The A/D-converted digital IF signal is resolved into the I-Q components (In-phase/Quadrature-phase) after waveform correction, etc., and is stored in memory following various procedures such as decimation, floating point data processing, etc.
Rather than leaving the data as a time-series waveform (scalar quantity), resolving and saving as I-Q data maintains the signal phase data as a vector quantity, which can assure the flexibility for post-processing, such as digital modulation analysis, etc.
The cumulative time range (capture time) can be saved to memory as data counts (samples) allocated by capture period (sampling rate).
In an actual signal analyzer, the standard memory capacity is 1 Gbyte, supporting a maximum data storage capacity of about 100 Msamples per measurement.
The sampling rate is limited by the frequency span at FFT processing, but in a signal analyzer the sampling rate is selected automatically by setting the analysis frequency span.
Consequently, there is no necessity to be concerned about sampling rate at usage. The max. capture time and max. sample counts are decided at the same time as the sampling rate, but usually rather than capturing the max. sample count, the optimum sample count is set for the measurement conditions.
Table 3.3 lists the sampling rates for the set frequency span and the relationship between the max. capture time and max. sample count.

| Frequency span | Sampling rate | Max. capture time | Max. sample count |
|---|---|---|---|
| 1 kHz | 2 kHz | 2000 s | 4 M |
| 10 kHz | 20 kHz | 2000 s | 40 M |
| 100 kHz | 200 kHz | 500 s | 100 M |
| 1 MHz | 2 MHz | 50 s | 100 M |
| 10 MHz | 20 MHz | 5 s | 100 M |
| 31.25 MHz | 50 MHz | 2 s | 100 M |

Table 3.3 : Frequency span, Sampling rate, Max. capture time and Max. sample count (Extract for MS2830A)

### 3.4. FFT (Fast Fourier Transform)

Any time range of the I-Q data saved in memory can be read.
The read data is FFT processed to generate the spectrum for the relevant time range.
Similarly, processing with other parameters can also generate other signal displays, such as Power vs. Time, etc.
The spectrum obtained by FFT processing is a sequence of amplitude values for discrete frequency points.
In addition, the frequency span obtained by FFT depends on the sampling frequency while the frequency gap is inversely proportional to the number of data points (sample count).
Consequently, the data used for FFT is digitized at the sampling rate that satisfies the frequency span for spectrum display while also assuring a sample count supporting the frequency resolution.
Put another way, the data for FFT must be digitized as the "sampling frequency" and "sample count" that achieves the expected "frequency span (frequency range)" and "resolution" at spectrum display.
Incidentally, in a spectrum analyzer, the frequency resolution is evaluated as the Resolution Bandwidth (RBW); the time required for measurement, or the sweep time, is determined by the RBW and frequency span.
A signal analyzer emulates the usability of a spectrum analyzer and uses the same concept of RBW as a spectrum analyzer to improve the consistency of data measured using a spectrum analyzer.
To start with, the sampling rate and data length required for FFT processing supporting the frequency span and RBW settings are set automatically.
Additionally, the RBW corresponding to the frequency span can be set automatically. At this time, in the same way as a spectrum analyzer, the measurement time increases because the number of calculations increases as the RBW becomes smaller (frequency resolution increases).

| RBW / Span | 1 kHz | 3 kHz | 10 kHz | 30 kHz | 100 kHz |
|---|---|---|---|---|---|
| 31.25 MHz | 262144 | 65536 | 32768 | 8192 | 2048 |
| 10 MHz | 131072 | 32768 | 8192 | 4096 | 2048 |
| 1 MHz | 8192 | 4096 | 2048 | 2048 | 2048 |

MS2830A Spectrum trace marker result: Integration

Table 3.4 : Frequency span, RBW and Data points (Extract)

FFT processes the time range to be analyzed as one period and performs the same continuous repetitions on the signals before and after (the time range).
As a result, a difference in the values near both sides of the analysis time range causes an error in which the spectrum appears to widen, etc. To prevent this, the signal analyzer performs window function processing using a Gaussian window, but this requires there to be data before and after the analysis time range (Figure 3.4.2).

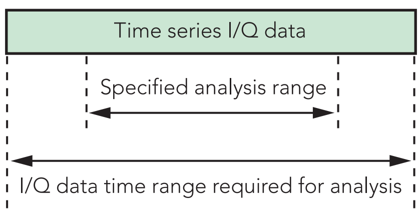



Figure 3.4.2 : Required data range at analysis

As a result, the data length used for the analysis calculations (I-Q data length) becomes longer than the target analysis time (width). This also happens with non-FFT analysis (trace) modes, For example, Power vs. Time plots require data before and after the analysis time length to perform processing for the detection and moving average, and for the spectrogram window function and detection.
The length of the required before and after data differs with the trace type and the marker measurement result read accuracy setting (Marker result). Usually, the minimum data length required to capture the results as quickly as possible is set automatically (Capture time: Auto).
Obviously, analysis can be performed using the maximum memory by setting any time for the captured data length (Capture time: Manual).
In either case, the analysis range and the data range used for calculation are expressed as color bands on the time axis (Figure 3.4.3).


Figure 3.4.3 : Data range display

## 3.5. Traces

The signal analyzer digitizes the signal and then uses FFT to capture the instantaneous spectrum, but a spectrum is not the only method for displaying a changing signal. A signal analyzer also has several trace display methods using captured data to measure and evaluate 3D signals from various viewpoints.

### 3.5.1. Main traces

**Spectrum trace**

The Spectrum trace displays the basic spectrum with frequency on the horizontal axis and power on the vertical axis.

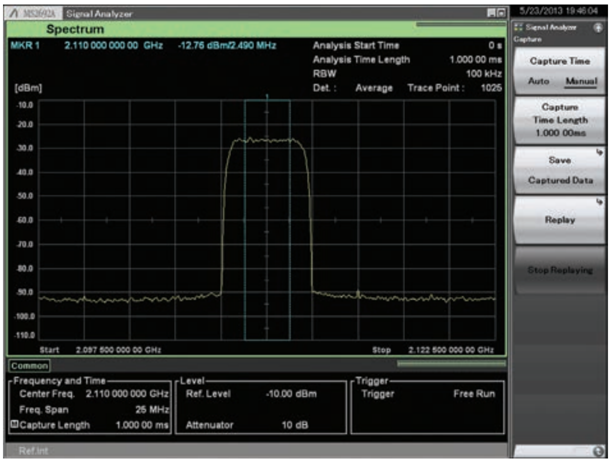



Figure 3.5.1 : Example of spectrum trace
(Spectrum of W-CDMA signal)

**Power vs. Time trace**

The Power vs. Time trace is a method for displaying and observing changes in signal power with time. It is good for understanding signals that switch On/Off with time and amplitude variations.

The horizontal axis is time and the vertical axis is power.


Figure 3.5.2 : Example of Power vs. Time trace
(ARIB T61 Emergency radio burst signal)

**Frequency vs. Time trace**

The Frequency vs. Time trace can be used to grasp signal frequency drift and sudden frequency fluctuations. The horizontal axis is time and the vertical axis is frequency.

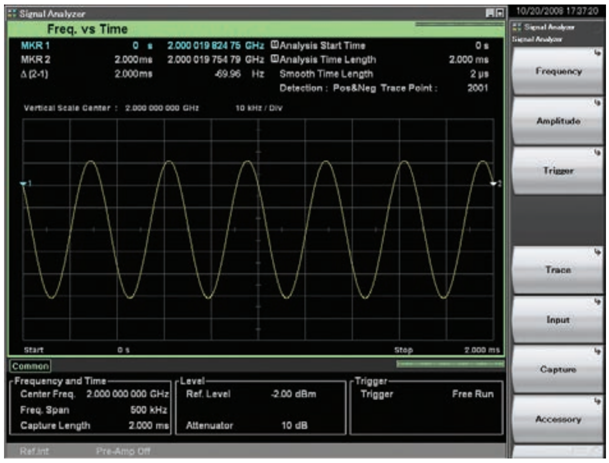



Figure 3.5.3 : Example of frequency vs. time trace
(Frequency deviation of FM waveform)

**Phase vs. Time trace**

The Phase vs. Time trace is good for analysis of signal phase time stability and phase modulation, etc. The horizontal axis is time and the vertical axis is phase.


Figure 3.5.4 : Example of Phase vs. Time trace
(Phase characteristics of 1.9 GHz band unmodulated signal)

**CCDF trace**

The CCDF trace is useful for comparing the digital modulation signal peak and average as well as for confirming the amplitude distribution of non-periodic noise in a signal. The horizontal axis is amplitude and the vertical axis indicates the probability that the signal is at each amplitude. The probability is displayed as CCDF or PDF.

CCDF (Complementary Cumulative Distribution Function):
Cumulative distribution of instantaneous power deviation vs. average power

APD (Amplitude Probability Distribution):
Probability distribution of instantaneous power vs. average power


Figure 3.5.5 : Example of CCDF trace
(CCDF of terrestrial digital TV signal)

**Spectrogram trace**

The Spectrogram trace is the equivalent of looking down from the top of the power axis at the power, frequency and time data represented in 3D (Figure 3.5.7) to get a good overall grasp of the signal spectrum and power changes.
The horizontal axis is time and the vertical axis is frequency. The power level is color-coded.

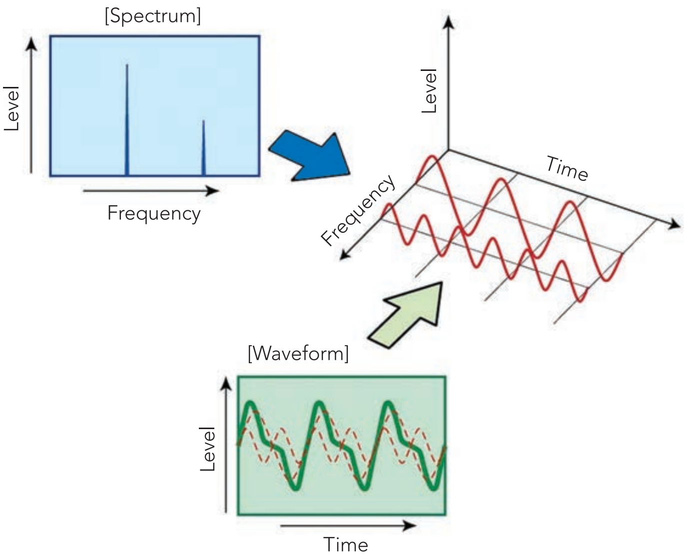



Figure 3.5.7 : Signal observation direction

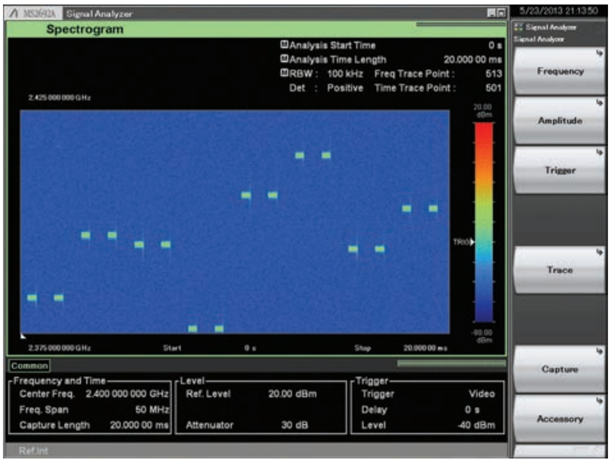



Figure 3.5.6 : Example of Spectrogram trace
(Frequency hopping of *Bluetooth* signal)

### 3.5.2. Sub-traces (Split screen display)

This function displays a sub-trace under the main trace as a supplement to the normal main trace.
The sub-trace can be selected to display either the Power vs. Time or Spectrogram trace with the trace displaying data for any time period. When the sub-trace is displayed, the main trace results are conveniently displayed immediately above for the corresponding point in time. Additionally, setting the analysis range at the sub-trace and slowly shifting the analysis start point slightly using the main dial displays a time-lapse animation of the spectrum on the main trace.


Figure 3.5.8 : Example of split screen display
(Main trace: Spectrum, Sub-trace: Power vs. Time)

## 4. Uses of spectrum analyzer and signal analyzer

The signal analyzer offers added spectrum analyzer functions any of which can be used.
The basic rule is to use a signal analyzer for a changing spectrum and a spectrum analyzer in other cases, but even ignoring this point, understanding the operation principles and operation differences is useful in assuring correct usage.

### 4.1. Structural differences and similarities

Figure 4.1.1 shows the operation principles of the spectrum analyzer.
The measured signal is converted to an intermediate frequency (IF) signal at the mixer and then passed through a narrowband filter. The amplitude of the frequency in the measured signal (`Fin`) is determined by the detector.
Additionally, since the input frequency Fin is composed of `Flo` + `Fif` (local oscillator frequency + intermediate frequency), sweeping (continuously changing) `Flo` makes it possible to obtain the spectrum corresponding to the sweep range. In other words, the frequency width (span) that can be analyzed by a spectrum analyzer is determined by the sweep range of the local oscillator.
In passing, the part of Figure 4.1.1 enclosed by the dotted line (post-IF signal processing and local oscillator control) have been digitized, resulting in much faster measurement speed and higher accuracy.

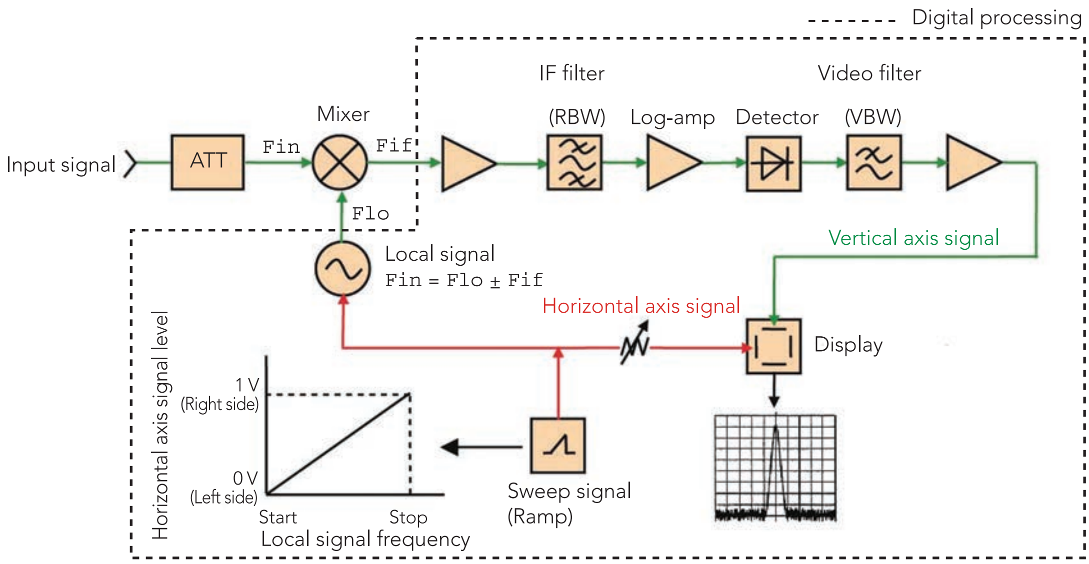


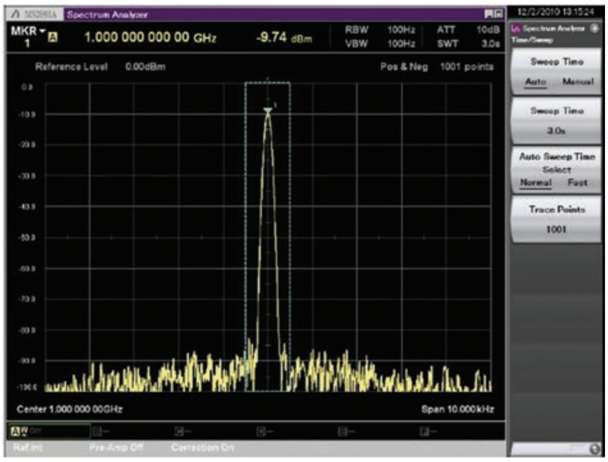

Figure 4.1.1 : Spectrum analyzer operation principle

If we treat the digital part of the spectrum analyzer (part inside dashed line in Figure 4.1.1) as a black box, comparison with the signal analyzer operation principles shows the circuit diagram of both the spectrum analyzer and signal analyzer to be very similar. One reason is because the signal analyzer offers added spectrum analyzer functions. On the other hand, compared to the signal analyzer, which captures the spectrum using FFT, a big difference between the two is that the spectrum analyzer captures the spectrum according to the operating principles in Figure 4.1.1 using filtering and digital log conversion/detection.

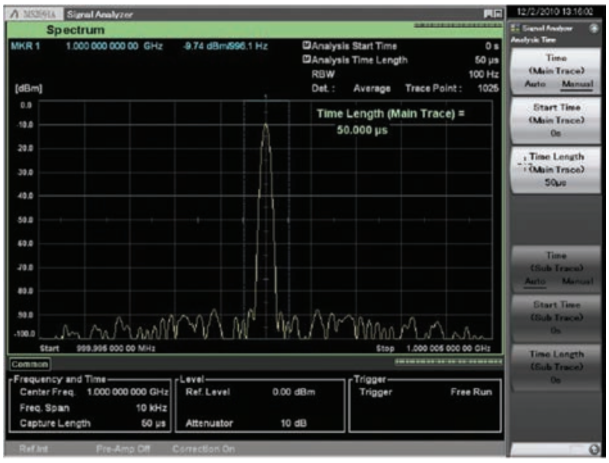
### 4.2. Operation differences

Due to the different principles of spectrum capture, the signal analyzer is ideally suited for capturing irregular signals where the spectrum changes in the short term. This is a key functional difference compared to the spectrum analyzer, which is better for measuring stationary signals with a stable spectrum over time. In addition, the spectrum analyzer and signal analyzer have other differences as a consequence of the differences in the operation principles.
The first difference is the analysis frequency width (span). The spectrum analyzer analysis frequency width (span) is dependent on the local oscillator sweep range; the local oscillator supports sweeping of a wide frequency range exceeding 1 GHz. Conversely, the signal analyzer analysis frequency width (frequency span) is determined by the IF bandwidth. The actual IF bandwidth is several MHz to 100 MHz. As a result, the spectrum analyzer is used to measure spectrums with a wide frequency of more than several 100 MHz.
The second is the time required for measurement. The problem with spectrum analyzer measurement time is the time required for the local oscillator sweep. Consequently, sweep speed (frequency conversion rate) is limited by the frequency resolution (RBW) and a drop in the sweep speed is required to delay the response as resolution increases (RBW becomes narrower).
In comparison, the signal analyzer measurement time depends only on the time to capture and FFT-process the signal and is much shorter than the local oscillator frequency sweep. As a result, when comparing both measurement times for a relatively narrow span, the signal analyzer completes measurement and obtains the measurement in the shortest time. The difference is striking when measurement is repeated, such as when averaging measured values (Figures 4.2.1 and 4.2.2).

Incidentally, the effect of using averaging to decrease randomness in measured results depends on the video filter VBW setting for spectrum analyzers and on the number of measurements used at averaging processing for signal analyzers.

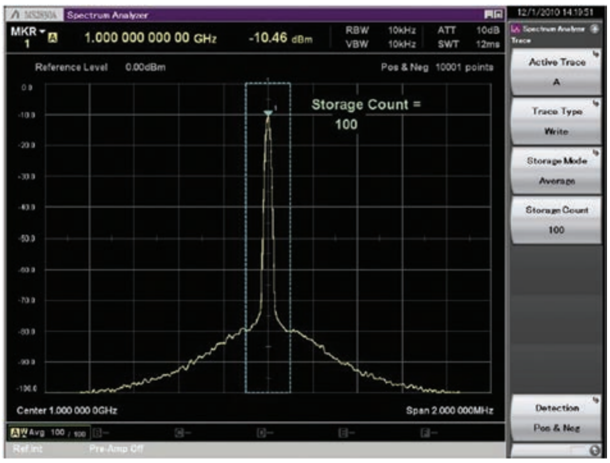



**Spectrum Analyzer**
Measurement time (Sweep time): 3 s
(VBW: 100 Hz)

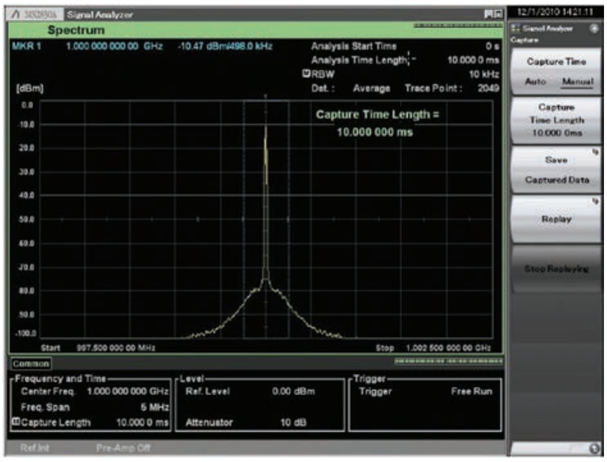



**Signal Analyzer**
Capture time: 50 µs
(Average trace points: 1024)

Figure 4.2.1 : Example of narrowband high resolution measurement (Center frequency: 1 GHz, Span: 10 kHz, RBW: 100 Hz)




**Spectrum Analyzer**
Measurement time: 1.2 s
(Sweep time: 12 ms; Averaging count: 100,
Frequency span: 2 MHz)




**Signal Analyzer**
Capture time: 10 ms
(Analysis time length: 10 ms, Average trace points: 2049,
Frequency span: 5 MHz)

Figure 4.2.2 : Example of Averaging measurement time (Center frequency: 1 GHz, RBW: 10 kHz)

The third is that the spectrum analyzer captures measurement results while the measured signal is connected whereas the signal analyzer uses batch processing so it can perform measurement both in real time and when offline. As a consequence, various analyses can be performed by changing the analysis method and parameters (RBW, time specifications, etc.). In addition, since the signal analyzer can record and save the measured signal to a storage device, such as a hard disk, it is possible to take data recorded on-site back to the laboratory where it can be replayed and analyzed.

## 5. Applications

This section explains how to use the Anritsu MS2830A Signal Analyzer to evaluate and analyze various transitional RF signals.

### 5.1. Radio signals (Transient phenomena at Tx start)

This is an example of measuring transient phenomena of radio transmitters.
The antenna output of a small radio transmitter using the 460-MHz band via a dummy load or attenuator is connected to the signal analyzer, and transient phenomena in the emitted radio signal are measured immediately before and after pressing the press-to-talk switch.
Actually, the signal is captured for 20 ms from immediately before the transmission start to observe the change in the spectrum immediately after transmission starts. (Figures 5.1.1 to 5.1.4 show the transition for a frequency span of 1 MHz and RBW of 10 kHz.)
The sub-trace (lower half) in each figure shows the Power vs. Time for 20 ms; the red and blue time bands in the sub-trace show the spectrum part displayed as the main trace (top half). Although the spectrum rises at the same time as the power rise, in the case of this radio transmitter, the final spectrum distribution has a different shape as the power rises.

Figure 5.1.1 : Spectrum transition immediately after Start-1

Figure 5.1.2 : Spectrum transition immediately after Start-2

Figure 5.1.3 : Spectrum transition immediately after Start-3

Figure 5.1.4 : Spectrum transition immediately after Start-4

Figure 5.1.5 shows the details of the change in power with time with the signal analysis range set to the rise part. It confirms a gentle rise but with a step-shaped form.

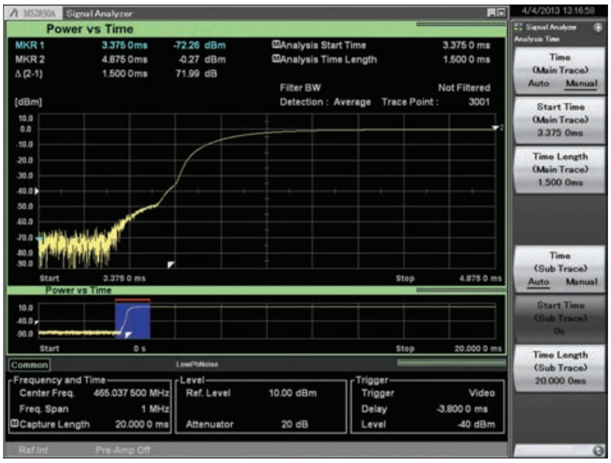



Figure 5.1.5 : Change in power with time (Signal analyzer)

The same type of results are obtained at Power vs. Time measurement using a spectrum analyzer Zero span (fixed frequency and time on horizontal axis). In this case, since the power is measured within the measured frequency, this method can be used to measure the time until a PLL VCO (voltage controlled oscillator) is locked to the relevant frequency. Incidentally, Figure 5.1.6 shows the spectrum analyzer Zero span measurement results. (Note the different horizontal axis scale.)

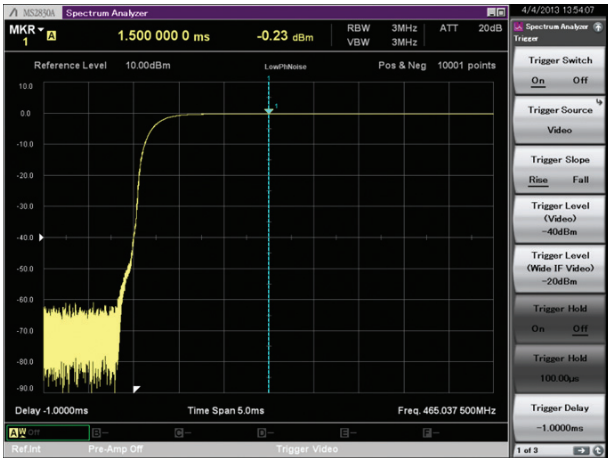



Figure 5.1.6 : Spectrum analyzer measurement results (Zero span)

Figure 5.1.7 shows the same signal, but in this case, it is viewed as a Frequency vs. Time trace.
The small triangle symbol in the figure indicates the signal capture trigger point; in this example the trigger is at the signal rise point so there is a signal to the right of the triangle symbol but no signal to the left.


Figure 5.1.7 : Frequency vs. Time trace

From this trace, we can see that the frequency immediately after the rise has some slight instability but then stabilizes. However, although the part on the left before the rise seems to have a huge frequency variation, this part is a meaningless measurement result, because the frequency is uncertain since there is no signal here.

## 5.2. Chirp signals

This is an example of measurement of a chirp signal used by radar, etc.
This type of signal is switched on and off repeatedly while the frequency is changed in a short time period.
Figure 5.2.1 shows a split screen with the main trace displaying the Frequency vs. Time and the sub-trace displaying Power vs. Time.
In the Frequency vs. Time display, the analysis time length when the signal is on is set to 2 μs.


Figure 5.2.1 : Split screen display of chirp signals
(Main trace: Frequency vs. Time,
Sub-trace: Power vs. Time)

From the Frequency vs. Time trace, we can see that the frequency change is linear over a short time period.
In a Frequency vs. Time trace, the frequency at each time is represented by one point. Since all these points are plotted as one line as shown in the figure, this method is useful for measuring the frequency of a signal where the spectrum changes linearly as shown in this example.
The same state can also be seen on a spectrogram trace, which also displays the simultaneous presence of other signals and spectrum spread.

### 5.3. 2-FSK signals

This is an example of measurement of a digital frequency modulated RF signal.
2-Frequency Shift Keying (2-FSK) is a popular modulation method used by many applications, such as automotive keyless entry (RKE), tire pressure monitoring systems (TPMS), etc. In this method, digital 1 and 0 are allocated to two frequencies ($f_1$ and $f_2$) that the signal shifts between.
Until now, 2-FSK signals have been commonly measured using the Max Hold function of a spectrum analyzer (plots maximum value of each frequency at repeated measurement on trace). However, since the spectrum analyzer Max Hold superimposes the repeated measurements, the spectrum lacks data on transient changes and the repeated measurements also take a long time.
In contrast, the signal analyzer requires capture of only one signal to display a spectrum indicating the instantaneous frequency shifts.
The following shows some figures for comparison.
Figures 5.3.1. to 5.3.5. are the measurement results using a signal analyzer. After capturing the signal for 50 ms, the instantaneous spectrum is displayed for analysis time lengths of 200 μs while changing the start position.
The spectrum shows the two frequency switching states and the spectrum spread during the switch.

Figure 5.3.1 : 2-FSK signal instantaneous Spectrum-1

Figure 5.3.2 : 2-FSK signal instantaneous Spectrum-2

Figure 5.3.3 : 2-FSK signal instantaneous Spectrum-3

Figure 5.3.4 : 2-FSK signal instantaneous Spectrum-4

Similarly, Figure 5.3.5 shows the spectrum when the analysis time is widened to 50 ms.
Since the frequency switches several times during this period, the superimposed spectrum can be viewed.


Figure 5.3.5 : 2-FSK signal spectrum (Signal analyzer)

On the other hand, Figure 5.3.6 shows the measurement results for the same signal using the Max Hold function of a spectrum analyzer.
The measurement requires about 6 s to perform the 100 sweeps each with a sweep time of 60 ms but even with 100 repetitions the entire spectrum cannot be confirmed.
Confirming the same spectrum with a spectrum analyzer requires many more sweep repetitions and a lot more time.

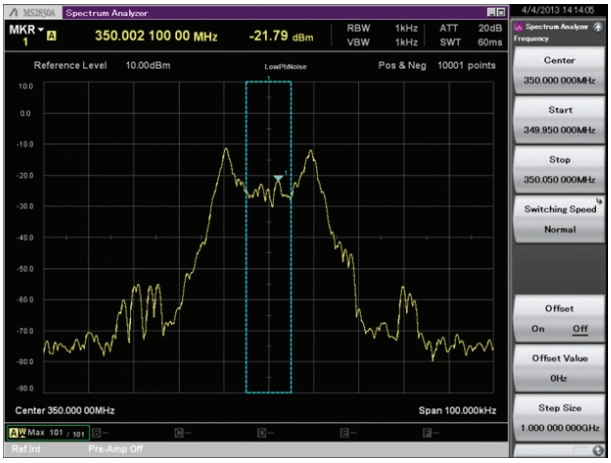



Figure 5.3.6 : 2-FSK signal spectrum (Spectrum analyzer)

## 5.4. Frequency hopping

This is an example of *Bluetooth* signal measurement.
*Bluetooth* is a short-range wireless communications standard used by small communications devices, such as smartphones. It uses the Frequency Hopping Spectrum Spread (FHSS) technology in which the frequency changes randomly during a short time period.
Figure 5.4.1 shows the spectrogram trace for a *Bluetooth* signal of 100 ms duration.

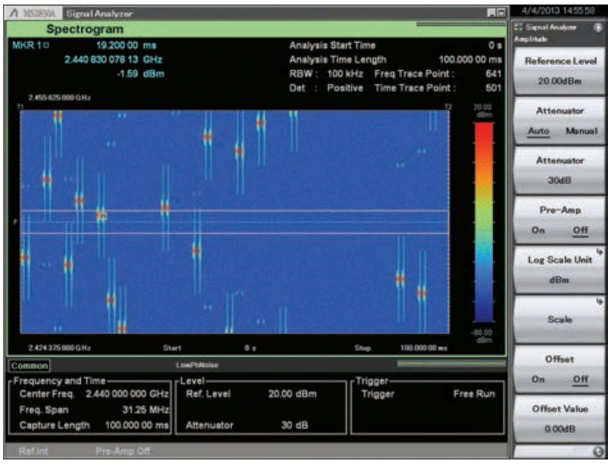


Figure 5.4.1 : *Bluetooth* signal spectrogram trace

Since measurement of the 2.4-GHz band is performed with a resolution bandwidth of 31.25 MHz, only part of the *Bluetooth* signal (about 80 MHz bandwidth) is displayed, but it is easy to confirm at a glance how the *Bluetooth* signal frequency changes successively.
A spectrogram is the best trace to use when wanting to intuitively understand a signal with changing spectrum as a whole.

## 5.5. Noise

This is an example of overall noise analysis using the various signal analyzer/spectrum analyzer functions.
The measurement target is electromagnetic noise generated by a LED light bulb. An EMI probe (small loop antenna in Figure 5.5.1) is placed near the LED light to detect surrounding EMI.

Figure 5.5.1 : Anritsu EMI Probe (MA2601B)

First, a wide frequency band is swept from 9 kHz to 1 GHz using the spectrum analyzer function to detect the noise frequency band (Figure 5.5.2). This is because noise is distributed across a wide frequency range generally.

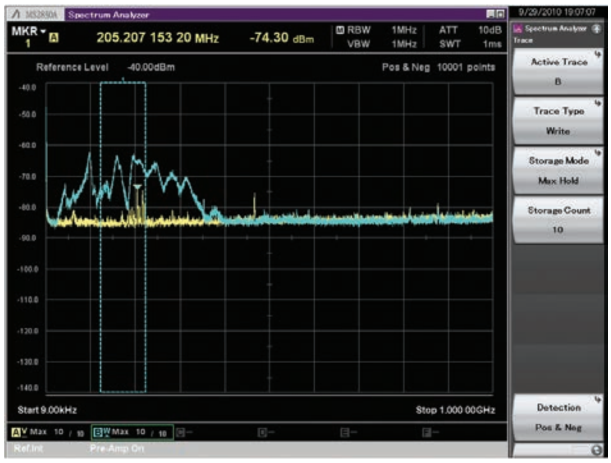
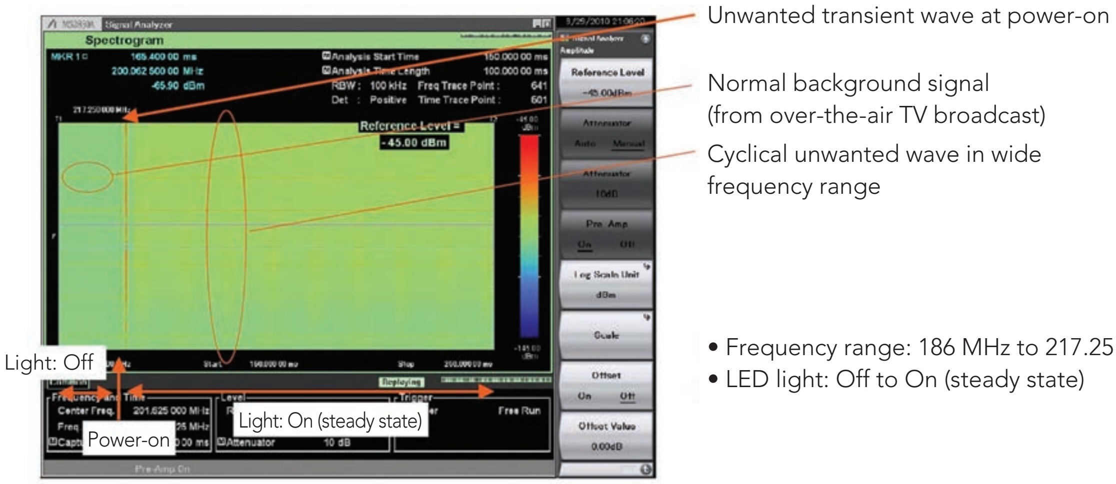



Figure 5.5.2 : Sweep measurement using spectrum analyzer

The yellow trace in the above figure is when the LED light is off. The spectrum seen at this time is coming from some external source, such as a TV broadcast wave. On the other hand, the blue trace in the figure is the spectrum when the LED is on. Noise components can be seen centered around 100 MHz to 300 MHz. Consequently, it is best to set this range as the signal analyzer analysis range.

Figure 5.5.3 shows the entire spectrum trace when the signal analyzer frequency range is set to 186 MHz to 217.25 MHz (analysis bandwidth: 31.5 MHz) with an RBW of 100 kHz and the noise signal is captured for 250 ms including the period before the LED light is lit.




- Frequency range: 186 MHz to 217.25 MHz
- LED light: Off to On (steady state)

Figure 5.5.3 : Noise spectrogram trace

The noise has a wide spectrum and is seen as wide traces in the spectrogram.
Based on this spectrogram, there is large wideband noise generation at power-on that stops, but then wideband noise also reoccurs when the LED light is lit.
Figures 5.5.4 and 5.5.5 compare the instantaneous spectrums of the captured signals for 500 µs at power-off and at power-on, respectively, for the specified frequency. Compared to power-off, the noise at power-on clearly rises by close to 20 dB.

Figure 5.5.4 : Power-off spectrum

Figure 5.5.5 : Instantaneous spectrum at power-on

In addition, Figure 5.5.6 shows the Power vs. Time trace when the LED is lit, confirming that the noise is pulsing periodically.

Figure 5.5.6 : Power vs. Time trace when LED lit

Additionally, for confirmation, Figure 5.5.7 shows the Amplitude Probability Distribution (APD) of the noise as a CCDF/APD trace at the power-on instant. It follows a gentle curve, suggesting a single noise source. If there were multiple noise sources, the curve should be changing.

Figure 5.5.7 : Noise APD

Since the measurements so far indicate the wideband noise is periodic, the signal is captured for a 100-ms period at a center frequency setting of 185 MHz, span of 10 MHz, and RBW of 30 kHz to analyze the noise while the LED is lit (Figure 5.5.8).

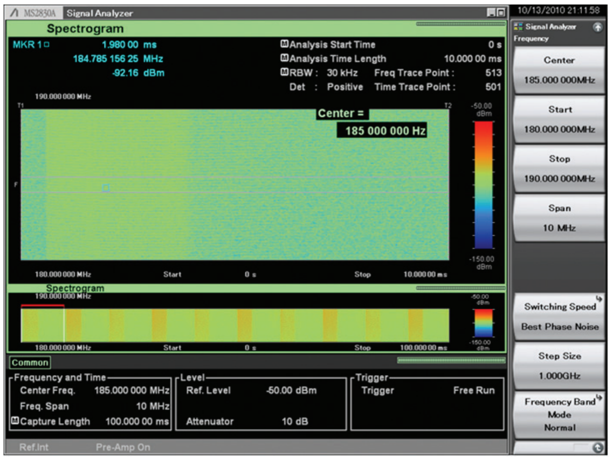


Figure 5.5.8 : Noise when LED lit

Looking at the spectrogram (sub-trace) time scale, the noise appears as bands with an interval of 10 ms. Moreover, at an expanded time range (main trace), the peak noise level duration is about 3 ms, confirming the pulse-type periodic noise. Converting the generation period to frequency gives a value of 100 Hz, or in other words twice the (Japanese) commercial power supply frequency. In addition, based on the pulse period, we can reasonably suggest that the source of the noise is near the power input, such as the LED driver rectifier circuit.
As an aside, since the signal analyzer measurement is fast even at continuous repeated measurements, it is even possible to specify the exact location of a noise source by using a small noise probe as a positional scanner. Moreover, sending the captured noise signal to a signal generator (option) for replay supports noise immunity tests.

## 6. Conclusion

The signal analyzer supports capture of non-periodic high-frequency signals by making good use of its digitization and signal processing functions. Although the signal analyzer internal structure seems much the same as a spectrum analyzer, it has many functional differences and offers a path to precision measurements based on understanding the usage differences of spectrum analyzers and signal analyzers.
Anritsu's MS2830A and MS2690A have built-in signal analyzer functions supporting new measurement needs, including analysis of very transient phenomena and investigation of electromagnetic noise.

Anritsu

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