Development of high cost performance signal analyzer MS2830A -044/045

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[Summary] We have developed a middle-price-range signal analyzer supporting 26.5 GHz and 43 GHz with a world-class wide dynamic range at 40 GHz (displayed average noise level of –144 dBm/Hz and TOI of +13 dBm) for the micro and millimeter wavebands.

1 Introduction

Signal and spectrum analyzers have a wide range of applications, such as Tx and device performance tests, etc., in the markets for manufacturing and maintenance of wireless equipment, starting with mobile terminals, as well as in device manufacturing. However, as communications systems have become increasingly digital, wideband, and high-density in recent years, there has been increasing need for a low-cost yet high basic performance spectrum analyzer supporting new functions, such as wideband signal analysis and wide dynamic range.

To meet these needs, in February 2010, we commercialized the MS2830A Signal Analyzer with excellent cost-performance, wide dynamic range and wideband performance.

The MS2830A lineup until now includes options -040/041/043 supporting maximum frequencies of 3.6/6/13.5 GHz, respectively.

With the recent increase in wireless applications, there has been a growing trend towards applications using the millimeter waveband, which is relatively wide and has more open frequencies than other bands. For example, due to the increasing volume of communications in microwave links and satellite communications, etc., even higher frequency and wider band modulation signals are tending to be used. Moreover, the ITU-R SM.329-10 guideline indicates tests of spurious in the millimeter waveband, requiring a dynamic range of at least –60 dBc/MHz from the carrier wave (at 50 W Tx power). However, conventional millimeter spectrum analyzers cannot perform wideband modulation signal analysis due to bandwidth limitations at the preselector inserted in the stage before the microwave band mixer. Additionally, at spurious measurement, sufficient dynamic range cannot be assured due to displayed average noise level limits.

Figure 1 Front view of MS2830A-045 Signal Analyzer

To solve these problems, we developed the MS2830A-044/045 option covering the millimeter wave frequency band up to 43 GHz using coaxial input and supporting wide bandwidth modulation analysis of 31.25 MHz max. coupled with a low noise level (DANL: –144 dBm at 40 GHz). Both the MS2830A-044 (covering up to 26.5 GHz) and MS2830A-045 (up to 43 GHz) are high cost-performance signal analyzers and this article describes the development concepts, design features and main performance. Figure 1 shows the front view of the MS2830A-045.

2 Development Concept

We developed the MS2830A-044/045 as a signal analyzer with the functions and performance to support future millimeter wave applications as follows:

(1) Low-cost design to invigorate the MS2830A platform

Manufacturers need lower-cost micro and millimeter measuring instruments. Our aim was to develop a low-cost analyzer based on the MS2830A by making use of low-cost components for the current LOCAL oscillator, LOCAL signal generator circuits, etc., while extending the frequency analysis range to 43 GHz by adding the minimum required number of components.

(2) High dynamic range for millimeter wave band

We re-examined the harmonic mixing method in the conventional millimeter waveband down converter and achieved a high dynamic range by suppressing mixer losses in the high-frequency band up to 43 GHz using a fundamental mixer and sub-harmonic mixer as well as by lowering the displayed average noise level. Additionally, we used a low-noise preamp supporting frequencies up to 43 GHz.

(3) Support for millimeter waveband modulation frequencies

We used the 31.25 MHz bandwidth modulation analysis function from the conventional MS2830A in the MS2830A-044/045 to support millimeter band modulation analysis by arranging a system bypassing the preselector.

(4) Low-power-consumption YTF driver circuit

In a micro/millimeter waveband spectrum analyzer, since the YTF driver circuit at the preselector consumes a large amount of power and generates a lot of heat, it is difficult to miniaturize. We re-examined the YTF driver from the ground up and designed a new driver circuit with low power consumption.

3 Circuit Structure

Figure 2 shows the MS2830A-044/045 block diagram. The part in the dashed-line rectangle is the newly developed front-end. In the MS2830A-044 version covering up to 26.5 GHz, the attenuator and YTF are the same as in the MS2692A, while in the MS2830A-045 covering up to 43 GHz, the front connectors and attenuator are the same as used in the MG3694C Signal Generator, both designs helping to cut costs. We developed a new down converter and 2nd Converter as common components for the MS2830A-044/045. The down converter is the key component to achieve good dynamic range. The 2nd Converter has the control circuits of the front-end components starting with the down converter and YTF, the circuit of the local signal and the circuit to convert the 2nd IF signal. Ad-

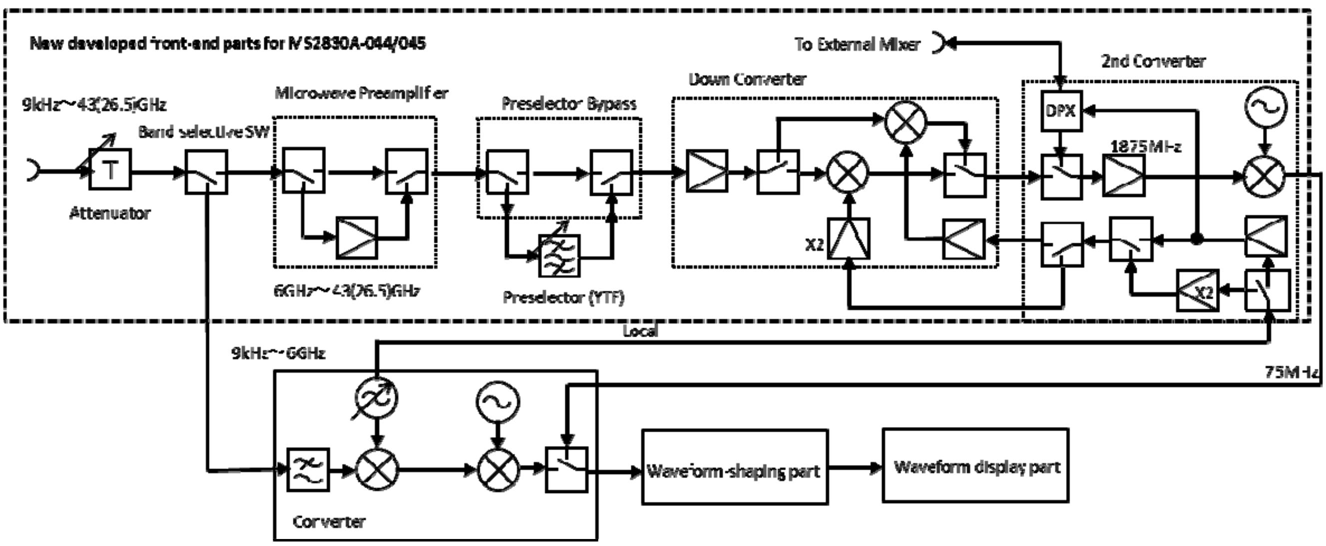

Figure 2 MS2830A-044/045 Block diagram

ditionally, we developed a microwave preamp (MS2830A-068) option supporting 43 GHz, as well as a microwave preselector bypass (MS2830A-067) option for bypassing the YTF to support millimeter waveband signal analysis. Moreover, we designed the MS2830A-044/045 with no additional option to support frequencies up to 325 GHz by combined use with an external mixer. This approach to maximize use of existing parts has helped keep development costs down while not compromising on new development of parts to improve performance.

4 Design Features

4.1 Band Switching

The MS2830A-044/045 has a low-frequency band up-converting the IF signal for avoiding spurious, and a high-frequency band passing via the preselector. These two paths can be switched. The switch requires low-loss so as not to degrade the noise floor characteristics, as well as high isolation to reduce level fluctuations caused by reflections from the preselector. A PIN-diode switch is added to the 5GHz cutoff frequency diplexer to assure high isolation in this equipment.

We designed an instrument as lumped parameter circuit covering the millimeter band with an upper limit of 43GHz offering good performance even at 6-GHz band switching as small as size.

4.2 Microwave Band Preamp

Without a preamp option, the noise floor performance of the standard MS2830A-044/045 at 40 GHz is 13 dB better than the MS2668C previous spectrum analyzers. However, to achieve a lower noise floor, we developed a preamp option supporting frequencies up to 43 GHz. At preamp OFF, the path without an amp is selected and at preamp ON, the path with an amp is selected by the internal PIN diode switches. At amp OFF, the frequency characteristics are flat and the insertion loss is low up to 43 GHz, while at amp ON, the displayed average noise level at 40 GHz is less than –150 dBm/Hz. Figure 3 shows the displayed average noise level characteristics (lower graph) when the MS2830A-068 Microwave Preamp Option is installed in the MS2830A-045.

4.3 Microwave Preselector Bypass

In the MS2830A-044/045 at the frequency band above 6 GHz, generated spurious is filtered out via a preselector using a YIG electromagnetic tuning filter (YTF). However, this preselector can limit the pass band width, and degrade the flatness of the frequency characteristics in the pass band. As a result, it has an adverse impact on modulation analysis. We developed the Microwave Preselector Bypass option in order to solve this problem. This option can select the YTF path or the path bypassing the YTF. This option uses a PIN diode as a switch. Thin-film resistors deposited on substrate are used for the portion that supplies bias to the transmission line instead of a choke coil. These small thin-film resistors achieve the good flat characteristics from low to high frequencies up to 43 GHz.

4.4 Down Converter

In general high-frequency spectrum analyzers with the high-frequency band passing a preselector, down conversion is performed with a harmonic mixer using a limited frequency range of the local oscillator. However, since the mixing order of the harmonic mixer is large, as is the mixer conversion loss, the displayed average noise performance in the spectrum analyzer is degraded. In the MS2830A-044/045, this degradation is suppressed by two mixers. One is a fundamental mixer (the mixing order is 1) covering the measurement frequency range from 6 to 18.4 GHz. The second is a sub-harmonic mixer (the mixing order is 2) from 18.4 to 43 GHz. These mixers are driven by the fundamental signal or the doubled signal of the limited local frequency range. As a result, due these mixers, loss is held to the minimum, and a world-class displayed average noise level of less than –144 dBm/Hz is achieved at 40 GHz. Figure 3 shows the displayed average noise level performance (top graph) of the MS2830A-045.

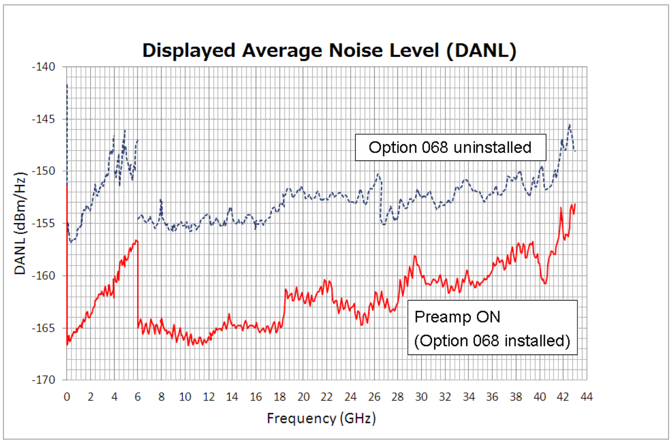

Figure 3 MS2830A-045 Displayed average noise level

4.5 YTF Driver Circuit

In the MS2830A-044/045, the frequency band above 6 GHz uses a YTF as a preselector but a conventional YTF driver circuit consumes a lot of power and generates a lot of heat so there is a problem with requiring a large heat sink. The MS2830A-044/045 uses a new drive method to minimize the power consumption, as well as a simplified and smaller heat sink to reduce heat radiation, resulting in overall reduced costs. Conventional YTF driver circuits use a constant-current circuit at a constant voltage and the difference between the power supply voltage and the voltage applied on the YTF tuning coil is dropped at the constant-current circuit. In this method, the product of the difference of voltage and the current through in the tuning coil becomes the loss of the constant-current circuit, causing high power consumption and heat radiation. Unlike the conventional method, in the MS2830A-044/045, the voltage supplied to the constant-current circuit changes both dynamically and continuously, which reduces the loss at the constant-current circuit to a minimum. Figure 4 outlines the block diagram and operation of this YTF driver circuit. Achieving this requires a switching regulator as a high efficiency power supply and, in addition, the power supply circuit must be able to change the output voltage at high speed. We used a digitally controlled switching power supply due to the low cost achieved in recent years resulting from advances in semiconductor technology. There is an A/D converter and DSP in the voltage-control feedback loop of digital switching power supply to flexibly control the output voltage using control software, achieving a power supply circuit with the operational characteristics required for the YTF driver circuit. Using the above-described YTF driver circuit, we were able to minimize the power consumption and heat generation of the MS2830A-044/045, simplify the structure, and cut the costs.

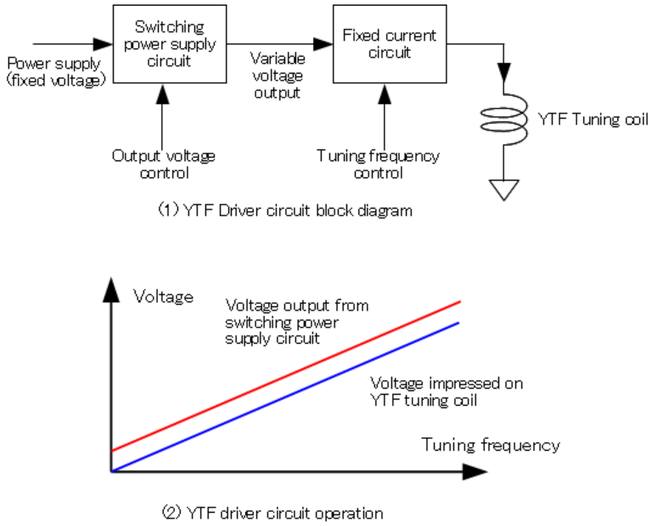

Figure 4 YTF Drive circuit block diagram

4.6 IF Section

To achieve a millimeter wave front end with high dynamic range, we performed a detailed examination of the level diagram for the IF signal path using low noise and low distortion devices. Figure 5 shows the block diagram of the IF section. The 1st IF features a high setting of 1875 MHz to support a wide bandwidth. As a result, it is possible to output a 1-GHz 3-dB band IF signal in the band above 6 GHz (including external mixer) externally.

4.7 External Mixer Support

The MS2830A-044/045 can use an external mixer for spectrum analysis at frequencies above 43 GHz. Connecting an external mixer to the 1stLO port on the front panel supports frequency bands up to 325 GHz. The local frequency range of the MS2830A-044/045 from 6.6 to 9.9 GHz becomes higher than the 4 to 6.9 GHz range of previous spectrum analyzers (MS2668C and MS2687B). As a result, it became possible to lower the harmonic mixing order of the external mixer, and suppress conversion loss.

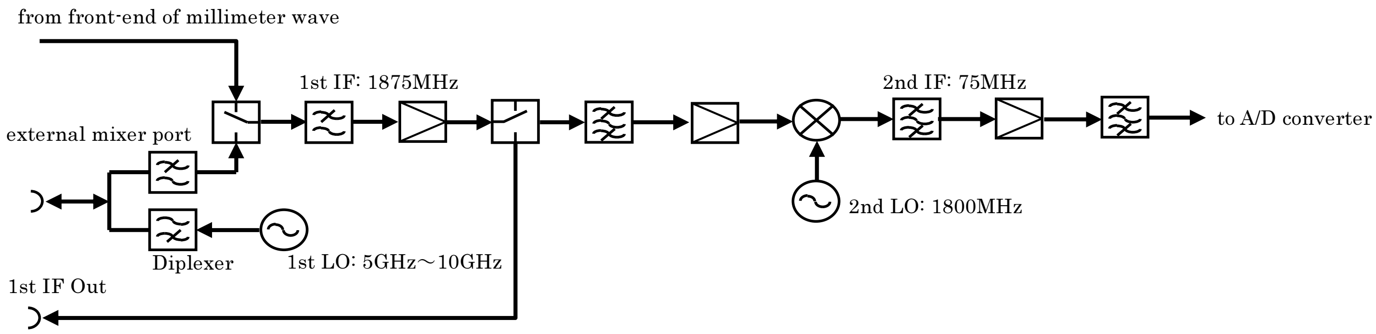

Figure 5 Block diagram of IF circuit

Furthermore, since the IF frequency of the external mixer is set as 1875 MHz, which is a higher setting than other companies' instruments, millimeter wave wideband modulation analysis can be supported using an external mixer; the 1st IF output port on the MS2830A-044/045 back panel can also be used as a down converter for monitoring a bandwidth modulation signal as wide as 1 GHz.

4.8 Software

The MS2830A Signal Analyzer software system manages everything, ranging from setting key parameters to controlling service modules.

Accordingly, combining control of hardware added to support millimeter waveband measurement with these modules supports a variety of MS2830A hardware options. This software configuration minimizes the need for application updates supporting the spectrum analyzer, signal analyzer, and modulation analysis functions added to millimeter waveband measurement. Additionally, the application software can be used as is for any configuration of hardware options. Using this software configuration supports previous spectrum analyzer functions, such as connection of an external mixer, while also supporting signal-analyzer functions such as signal analysis using multi-colored traces, saving digitized data, and replaying traces.

In terms of speed at millimeter waveband measurement, the hardware control speed at frequency switching is about nine times faster than previous instruments (MS2668C). When filtering hysteresis caused by YTF control, using a method for changing the YTF control range according to the sweep span at frequency setting achieves about a six times faster sweep speed than the previous MS2668C for some frequency bands (43 GHz full span), and about a 66 times faster sweep speed for the frequency band.

Measured level correction uses the reference signal oscillator in the MS2830A Signal Analyzer, but since this is inadequate for correcting these millimeter wave frequencies, another method for calculating correction values for current temperatures is supported using a coefficient to correct differences caused by temperature changes from measurement results at normal, high and low temperatures at basic calibration before shipment.

5 Main Specifications

Table 1 summarizes the key specifications of the MS2830A-044/045

6 Summary

We have developed the MS2830A-044/045 Signal Analyzer with high cost-performance and supporting high frequencies, wide dynamic range and wideband modulation to meet the needs of future millimeter waveband markets. This instrument not only replaces the previous Anritsu Microwave Spectrum Analyzer, but also helps cut production costs in the micro and millimeter wave wideband applications markets, such as microwave links, satellite communications, radar, etc.

References

1) K. Narui, T. Oda, N. Shyam, Y. Kishi, and Y. Takahashi, "MS2668C-World's Lightest and Highest-Sensitivity Spectrum Analyzer for Millimeter Frequencies", Anritsu Technical No. 77, pp. 71－78 (1999.4), in Japanese.

2) T. Doi, Y. Yamada, Y. Kishi, N. Watanabe, T. Hanaya, K. Kobayashi, and T. Endo, "Development of MS269xA Signal Analyzer Series for Next-generation Systems", Anritsu Technical, No. 86, pp. 3－12 (March 2008), in Japanese.

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Table 1 MS2830A-044/045 Main Specifications

- Common Main Frame Specifications

Frequency	Frequency Range	9 kHz to 26.5 GHz [MS2830A-044], 9 kHz to 43 GHz [MS2830A-045]
Amplitude	Displayed Average Noise Level	18° to 28°C, Detector: Sample, VBW: 1 Hz (Video average), Input Attenuator: 0 dB Without MS2830A-067/068, Frequency Band Mode: Normal –134 dBm/Hz (100 kHz) –144 dBm/Hz (1 MHz) –153 dBm/Hz (30 MHz ≦ Frequency < 1 GHz) –150 dBm/Hz (1 GHz ≦ Frequency < 2.4GHz) –147 dBm/Hz (2.4 GHz ≦ Frequency ≦ 3.5 GHz) –144 dBm/Hz (3.5 GHz < Frequency ≦ 4 GHz) –144 dBm/Hz (4 GHz < Frequency ≦ 6 GHz) –151 dBm/Hz (6 GHz < Frequency ≦ 13.5 GHz) –149 dBm/Hz (13.5 GHz < Frequency ≦ 18.3 GHz) –146 dBm/Hz (18.3 GHz < Frequency ≦ 26.5 GHz) –146 dBm/Hz (26.5 GHz < Frequency ≦ 34 GHz) –144 dBm/Hz (34 GHz < Frequency ≦ 40 GHz) –140 dBm/Hz (40 GHz < Frequency ≦ 43 GHz) Without MS2830A-067, with MS2830A-068 installed, and with Preamplifier turned off , Frequency Band Mode: Normal –134 dBm/Hz (100 kHz) –144 dBm/Hz (1 MHz) –153 dBm/Hz (30 MHz ≦ Frequency < 1 GHz) –150 dBm/Hz (1 GHz ≦ Frequency < 2.4 GHz) –147 dBm/Hz (2.4 GHz ≦ Frequency ≦ 3.5 GHz) –144 dBm/Hz (3.5 GHz < Frequency ≦ 4 GHz) –144 dBm/Hz (4 GHz < Frequency ≦ 6 GHz) –147 dBm/Hz (6 GHz < Frequency ≦ 13.5 GHz) –145 dBm/Hz (13.5 GHz < Frequency ≦ 18.3 GHz) –141 dBm/Hz (18.3 GHz < Frequency ≦ 26.5 GHz) –141 dBm/Hz (26.5 GHz < Frequency ≦ 34 GHz) –135 dBm/Hz (34 GHz < Frequency ≦ 40 GHz) –132 dBm/Hz (40 GHz < Frequency ≦ 43 GHz) Without MS2830A-067, or with Microwave Preselector Bypass turned off With MS2830A-068 installed, and with Preamplifier turned on, Frequency Band Mode: Normal –147 dBm/Hz (nominal value: 100 kHz) –156 dBm/Hz (1 MHz) –163 dBm/Hz (30 MHz ≦ Frequency < 1 GHz) –161 dBm/Hz (1 GHz ≦ Frequency < 2 GHz) –159 dBm/Hz (2 GHz ≦ Frequency ≦ 3.5 GHz) –155 dBm/Hz (3.5 GHz < Frequency ≦ 4 GHz) –155 dBm/Hz (4 GHz < Frequency ≦ 6 GHz) –160 dBm/Hz (6 GHz < Frequency ≦ 13.5 GHz) –158 dBm/Hz (13.5 GHz < Frequency ≦ 18.3 GHz) –156 dBm/Hz (18.3 GHz < Frequency ≦ 26.5 GHz) –156 dBm/Hz (26.5 GHz < Frequency ≦ 34 GHz) –150 dBm/Hz (34 GHz < Frequency ≦ 40 GHz) –147 dBm/Hz (40 GHz < Frequency ≦ 43 GHz)
	1-dB Gain Compression	Without MS2830A-008/068, or with Preamplifier turned off, Mixer Input Level ≧+3 dBm (300 MHz ≦ Frequency ≦ 4 GHz) ≧–1 dBm (4 GHz < Frequency ≦ 13.5 GHz) ≧–1 dBm (13.5 GHz < Frequency ≦ 26.5 GHz) ≧–1 dBm (nominal value, 26.5 GHz < Frequency ≦ 40 GHz)
Spurious Response	Image Response	8° to 28°C, ≧300 kHz separation Without MS2830A-068, or with Preamplifier turned off, Mixer Input Level: –15 dBm (per waveform) ≦–54 dBc, TOI = +12 dBm (30 MHz ≦ Frequency < 300 MHz) ≦–60 dBc, TOI = +15 dBm (300 MHz ≦ Frequency < 3.5 GHz) ≦–58 dBc, TOI = +14 dBm (3.5 GHz ≦ Frequency ≦ 6 GHz, Frequency Band Mode: Normal) ≦–56 dBc, TOI = +13 dBm (6 GHz < Frequency ≦ 13.5 GHz) ≦–56 dBc, TOI = +13 dBm (13.5 GHz < Frequency ≦ 26.5 GHz) ≦–56 dBc, TOI = +13 dBm (nominal value: 26.5 GHz < Frequency ≦40 GHz)
Measurement Functions		ACP, Channel Power, Occupied Bandwidth, Spurious Emissions, Spectrum Emissions, Mask, Burst Average Power

- Signal Analyzer Functions

Functions	Trace Mode	Spectrum, Power vs Time, Frequency vs Time, Phase vs Time, CCDF, Spectrogram
	Analysis Band-width	Specify from center frequency to captured analysis bandwidth 1 kHz to 10 MHz (1-2.5-5 sequence) (MS2830A-006 installed) 1 kHz to 25 MHz (1-2.5-5 sequence), 31.25 MHz (With MS2830A-005 installed, or with MS2830A-007 installed) *Cannot install MS2830A-005MS2830A-045 installed
	Sampling Rate	Auto-setting dependent on analysis bandwidth 2 kHz to 20 MHz (1-2-5 sequence) (MS2830A-006 installed) 2 kHz to 50 MHz (1-2-5 sequence) (MS2830A-005 installed, or MS2830A-007 installed)
	Capture Time	Sets capture time length Minimum capture time length: 2 μs to 50 ms (determined according to analysis bandwidth) Maximum capture time length: 2 s to 2000 s (determined according to analysis bandwidth) Setting Mode: Auto, Manual
	Digitize Function	Saves captured waveform data to HDD, or outputs to external

- Common Specifications

RF Input	18° to 28°C, Input Attenuator: ≧10 dB MS2830A-044 Connector: N-J (front panel), 50 Ω (nominal value) VSWR: ≤1.2 (nominal, 40 MHz ≤ Frequency ≤ 3 GHz) ≤1.5 (nominal value, 3 GHz < Frequency ≤ 6 GHz) ≤1.6 (nominal value, 6 GHz < Frequency ≤ 13.5 GHz) ≤1.9 (nominal value, 13.5 GHz < Frequency ≤ 26.5 GHz) MS2830A-045 Connector: K-J (front panel), 50 Ω (nominal) VSWR: ≤1.2 (nominal value, 40MHz ≤ Frequency ≤3GHz) ≤1.3 (nominal value, 3 GHz < Frequency ≤ 6 GHz) ≤1.3 (nominal value, 6 GHz < Frequency ≤ 13.5 GHz) ≤1.4 (nominal value, 13.5 GHz < Frequency ≤ 26.5 GHz) ≤1.6 (nominal value, 26.5 GHz < Frequency ≤ 40 GHz) ≤1.6 (reference value, 40 GHz < Frequency ≤ 43 GHz, value including V-K conversion at RF connector)
IF Output	Connector: SMA-J (back panel), 50 Ω (nominal value) Frequency: 1875 MHz Gain: –10 dB (nominal value, Input Attenuator: 0 dB, Input Frequency: 10 GHz)
1st Local Output	Connector: SMA-J (front panel), 50 Ω (nominal value) Frequency: 5 GHz to 10 GHz (LOCAL signal output), 1875 MHz (IF Signal Frequency) Gain: –10 dB (nominal value, Input Attenuator: 0 dB, Input Frequency: 10 GHz)

- Others

External Mixer	Frequency Frequency Range: 26.5 GHz to 325 GHz Frequency Band Composition Band Frequency Range Mixer Harmonic Order [N] Band A 26.5 GHz to 40 GHz 4+ Band Q 33 GHz to 50 GHz 5+ Band U 40 GHz to 60 GHz 6+ Band V 50 GHz to 75 GHz 8+ Band E 60 GHz to 90 GHz 9+ Band W 75 GHz to 110 GHz 11+ Band F 90 GHz to 140 GHz 14+ Band D 110 GHz to 170 GHz 17+ Band G 140 GHz to 220 GHz 22+ Band Y 170 GHz to 260 GHz 26+ Band J 220 GHz to 325 GHz 33+ Amplitude Mixer Conversion Loss Setting Range: 0 to 99.9 dB Maximum Input Level, Average Noise Level, Frequency Response: using external mixer I/O Supported: Only 2-port Mixer LOCAL Frequency: 5 GHz to 10 GHz IF: 1875 MHz

Publicly available