Application Note

Dynamic Range Optimization Method for Obtaining Accurate EVM Values

~Signal Analyzer MS2850A Measurement Example~

Contents

1 Introduction

This application note explains methods for measuring the EVM of wideband signals more accurately.

2 Predominant Cause of EVM

At EVM measurement of OFDM signals, the results can be degraded by the following issues with the measuring instrument performance.
• SNR (Signal to Noise Ratio)
• Distortion
• Phase Noise

Since the phase noise performance is unique to each instrument, it cannot be adjusted. However, the SNR and distortion can be optimized by adjusting measuring instrument settings. Generally, the dynamic range is best at the point where the measuring instrument distortion components and noise floor are at the same level, which is when the EVM performance is best. However, since the integrated power of the noise increases in proportion to the signal bandwidth, the measuring instrument relative dynamic range decreases as the signal band becomes wider.

3 Relationship between Signal Bandwidth and SNR

At a same signal Tx power, the power density drops as the signal band becomes wider.
For example, Table 1 lists the power density, SNR, and EVM due to the SNR when outputting signals under the following conditions for five signal patterns: CW, W-CDMA, LTE (20 MHz BW), Verizon 5G (V5G, 1 Carrier), and Verizon 5G (V5G, 8 Carriers).

• Average Output Level: –10 dBm
• Average Noise Density: –140 dBm/Hz

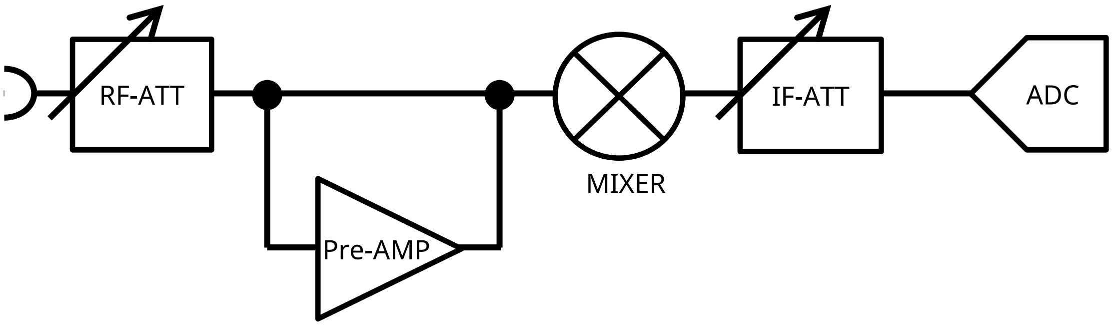
Table 1 Relationship between SNR and Each Communication Method

Communications Method	Tx Bandwidth*1 [MHz]	Power Density [dBm/Hz]	SNR [dB]	EVM due to SNR [%]
CW	-	–10	130.0	-
W-CDMA	3.84	–75.8	64.2	0.06%
LTE	18	–82.5	57.5	0.13%
V5G (1 Carrier)	90	–89.5	50.5	0.30%
V5G (8 Carriers)	720	–98.6	41.4	0.85%

*1: Bandwidth determined by number of available subcarriers

For example, when the target EVM value is <1% (= 40 dB), with a W-CDMA signal, the width of the 1% area is 64.2 dB – 40 dB ≒ 24 dB, whereas for a V5G (1 Carrier) signal, the area of <1% is narrower at 10.5 dB. Moreover, for a V5G (8 Carriers) signal, the 1% area is just 1.4 dB. Clearly, the settings for obtaining the optimum SNR for the V5G signal are much more difficult in comparison to the W-CDMA signal.

4 Signal Analyzer MS2850A Simplified Block Diagram



The MS2850A has three kinds of level adjustment mechanisms: a RF attenuator (RF-ATT), an IF attenuator (IF-ATT), and a Preamplifier (Pre-AMP), each of which plays the following roles.

- RF-ATT: Located at RF stage, it adjusts power input to Mixer and Preamplifier. It is effective when Mixer and Preamplifier have distortion.
- IF-ATT: Located at IF stage, it adjusts power of input to Analog Digital Converter (ADC). It is effective when the ADC overflows.
- Pre-AMP: Amplifies weak signals and improves Noise Figure (NF) of overall system. It is effective when wanting to lower the noise floor.

Unlike the RF-ATT and Pre-AMP, which the user can set arbitrarily, the IF-ATT cannot be set by the user. The IF-ATT is set according to the following equations.

■ At Pre-AMP = OFF

IF-ATT [dB] = Reference Level – RF-ATT + 10; when, 0 dB ≤ IF-ATT ≤ 10dB, 1 dB Step

■ At Pre-AMP = ON

IF-ATT [dB] = Reference Level – RF-ATT + 30; when, 0 dB ≤ IF-ATT ≤ 10 dB, 1 dB Step

For example, at Pre-AMP = OFF, when Reference Level = –3 dBm and RF-ATT = 4 dB, IF-ATT [dB] = –3 – 4 +10 = 3 dB.

5 Signal Analyzer MS2850A SNR Optimization Method

5.1 Measurement Precautions at Pre-AMP = OFF

Table 2 lists the MS2850A design ADC overflow levels. The “Level Over” message is displayed on-screen when the ADC overflows. Since accurate measurement is impossible while “Level Over” is displayed, be sure to measure only when “Level Over” is not displayed.

MS2850A ADC Overflow Level Target Value at RF-ATT = 0 dB, IF-ATT = 0 dB (Signal Analyzer Mode)

Table 2 ADC Overflow Levels at Each Condition

SPAN	≤31.25 MHz	≤31.25 MHz	≥50 MHz	≥50 MHz
Pre-AMP	Off	On	Off	On
Overflow Level Target Value*2, 3	–7 dBm	–27 dBm	0 dBm	–20 dBm

*2: Design value but not guaranteed value; *3: At CW signal input

For example, the following describes the case when inputting a modulation signal with an average power of –4 dBm and a crest ratio of 14 dB to the MS2850A.

The peak power of the above signal is +10 dBm (= –4 dBm + 14 dB). As shown in Table 2, since the MS2850A is designed to have overflow level target value of 0 dBm when the MS2850A is in Signal Analyzer mode with a SPAN setting of ≥50 MHz and RF-ATT/IF-ATT = 0 dB, the total of the inserted RF-ATT and IF-ATT must be greater than 10 dB (10 dBm – 10 dB = 0 dBm) to prevent ADC overflow. However, when inserting a higher-than-required ATT, it is better to set the minimum required ATT value because the drop in signal level results in degraded SNR. Moreover, overflow may occur sometimes even when inserting the required ATT since the ADC overflow level is a set value. In this case, take countermeasures by changing the Reference Level and increasing the IF-ATT, etc.

Table 3 lists the settings to prevent ADC overflow taking the above into consideration.

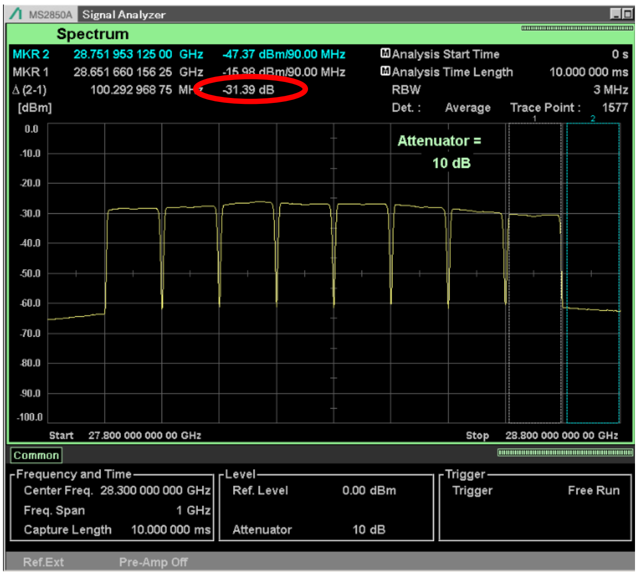
Table 3 RF-ATT and IF-ATT Combinations

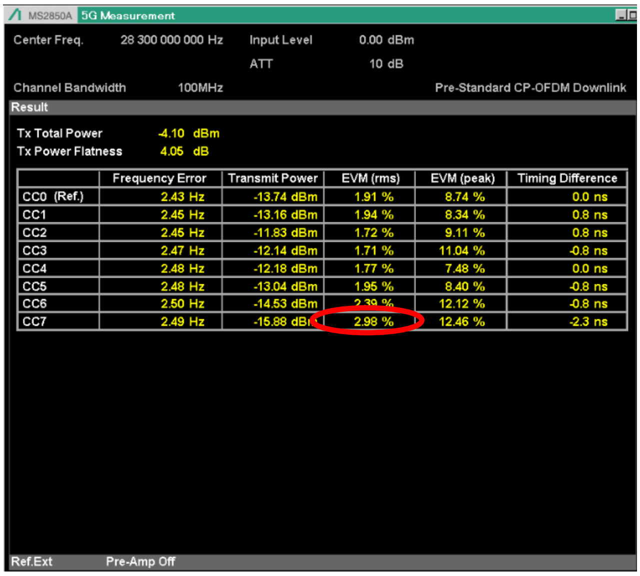
Ref. Level	0 dBm	0 dBm	0 dBm	0 dBm	0 dBm	0 dBm
RF-ATT	10 dB	8 dB	6 dB	4 dB	2 dB	0 dB
IF-ATT*4	0 dB	2 dB	4 dB	6 dB	8 dB	10 dB

*4: IF-ATT is determined by the Reference Level and RF-ATT, and cannot be set by the user.

The following explains some actual examples of settings from Table 3 to assess whether the dynamic range is optimum or not.

RF-ATT = 10 dB, IF-ATT = 0 dB





RF-ATT = 0 dB, IF-ATT = 10 dB

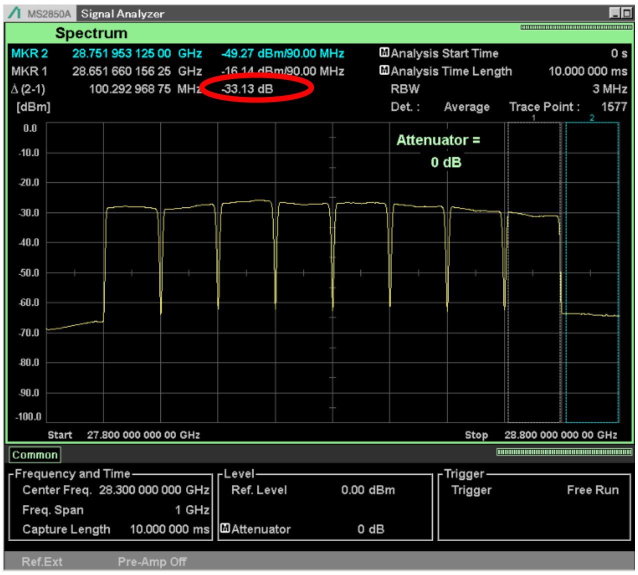


Table 4 SNR and EVM Measurement Results at Each ATT Setting

	SNR (CC7)	EVM (CC7)
RF-ATT = 10 dB, IF-ATT = 0 dB	–31.39 dB	2.98%
RF-ATT = 4 dB, IF-ATT = 6 dB	–33.11 dB	2.36%
RF-ATT = 0 dB, IF-ATT = 10 dB	–33.13 dB	2.35%

Table 4 shows that the SNR and EVM are both improved as the RF-ATT value becomes smaller and the IF-ATT value becomes larger. Generally, the NF of the front end has a large impact on the NF of the overall system. Consequently, inserting a 10 dB IF-ATT improves the NF of the overall system more than inserting a 10 dB RF-ATT. As a result, the EVM is improved by the better SNR. However, setting RF-ATT = 0 dB degrades the VSWR due to the effects of the Mixer and Pre-AMP and we recommend setting RF-ATT = 4 dB due to the possibility of degraded level accuracy and frequency response.

5.2 Measurement Precautions at Pre-AMP = ON (Example of SNR Predominance)

This section investigates the case at lower signal levels than described in section 5.1. For example, at input of a modulation signal with an average signal level of –19 dBm and a crest ratio of 14 dB.

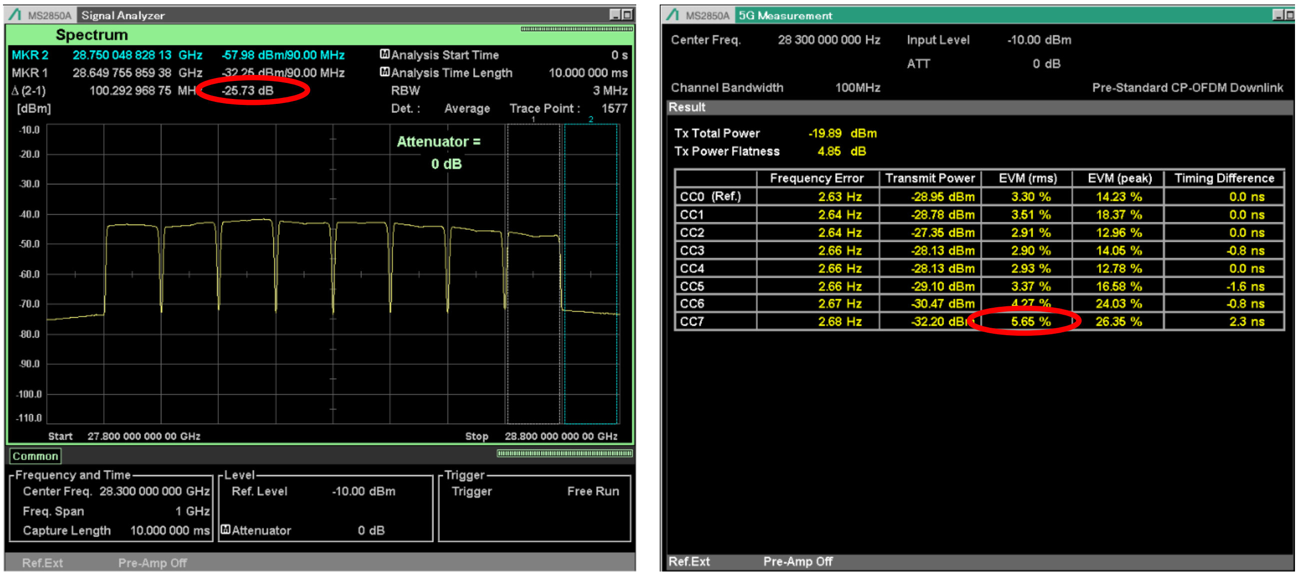
In the case of the above-described signal, the peak power is –5 dBm (= –19 dBm + 14 dB).

As described in section 5.1, when the MS2850A is in Signal Analyzer Mode with a SPAN setting of ≥50 Hz, RF-ATT/IF-ATT = 0 dB, the design is such that the ADC overflows at the 0dBm target.

Consequently, measurement is possible without ADC overflow when Reference Level = –10 dBm, RF-ATT = 0 dB (IF-ATT = 0 dB). However, lowering the average signal level by –20 dBm has an impact on the noise floor and degrades the SNR. Additionally, when RF-ATT = 4 dB, since the NF of the overall system becomes 4 dB worse, the SNR is also degraded by 4 dB.

The following figures show the measurement results under these conditions.

RF-ATT = 0 dB, IF-ATT = 0 dB



RF-ATT = 4 dB, IF-ATT = 0 dB

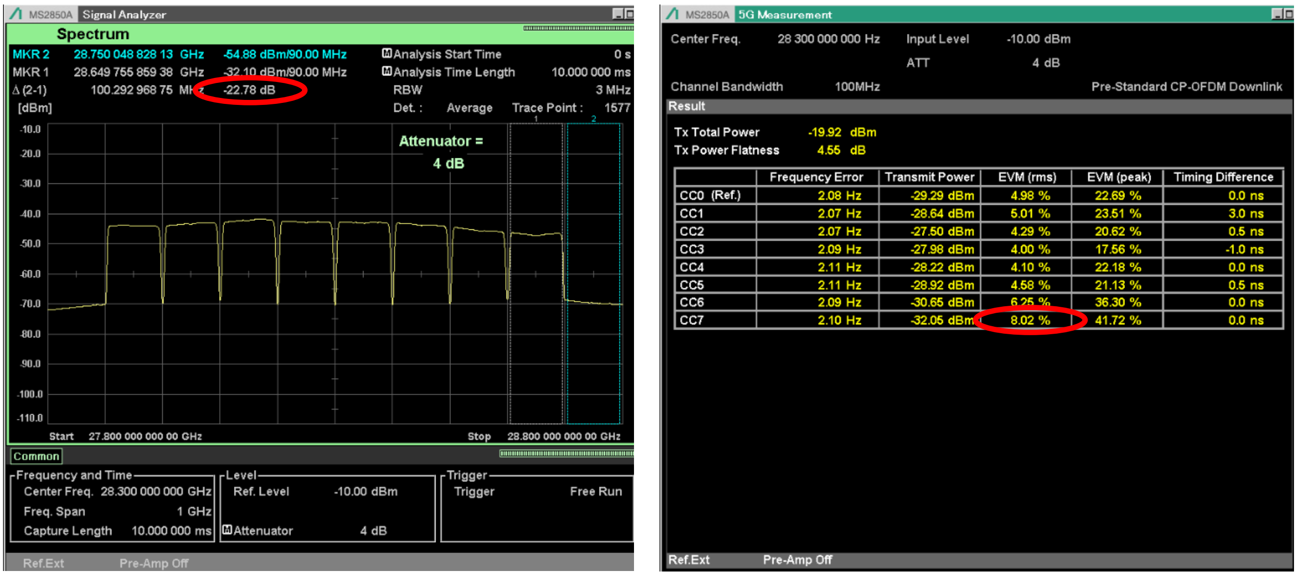


Table 5 SNR and EVM Measurement Results at each ATT Setting

	SNR (CC7)	EVM (CC7)
RF-ATT = 0 dB, IF-ATT = 0 dB	–25.73 dB	5.65%
RF-ATT = 4 dB, IF-ATT = 0 dB	–22.78 dB	8.02%

When the SNR is degraded by the noise-floor effect as the signal level decreases, setting Pre-AMP = ON can improve the SNR. Since the Pre-AMP is located immediately downstream of the RF-ATT, setting it to ON improves the NF of the entire system and lowers the noise floor.

As shown in Table 2, the MS2850A is designed so that the ADC overflows at –19 dBm when Pre-AMP = On. Consequently, as considered in section 5.1, the total of RF-ATT and IF-ATT must be at least 15 dB (–5dBm –(–20dBm)).

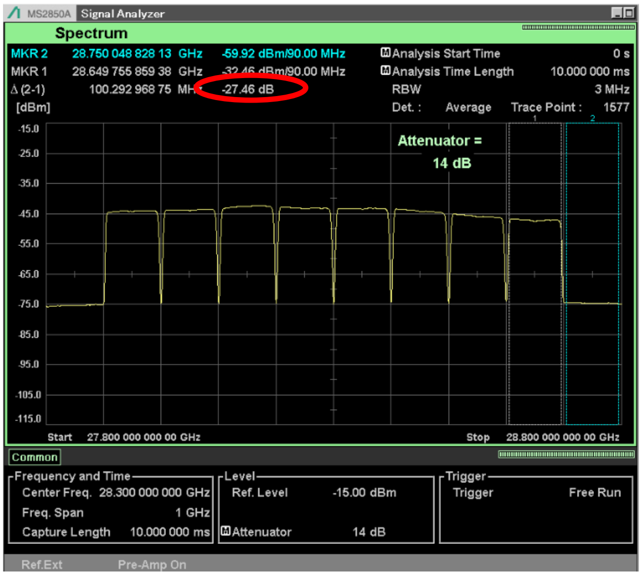
Table 6 Example of RF-ATT and IF-ATT Combinations

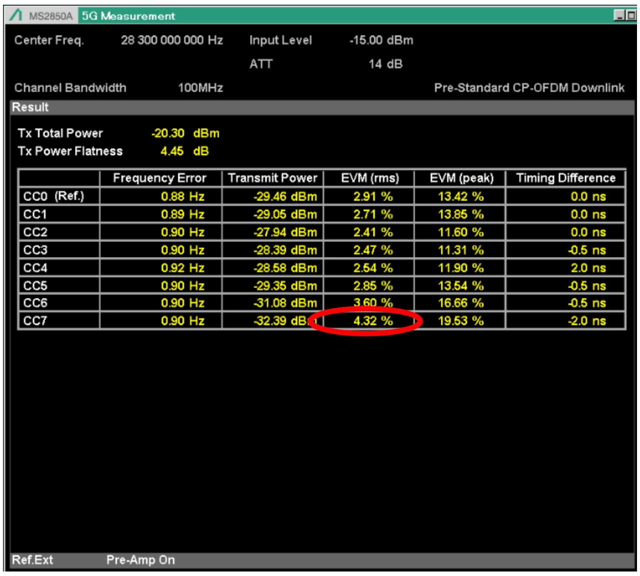
Ref. Level	−15 dBm	−15 dBm	−15 dBm	−15 dBm	−15 dBm
RF-ATT	14 dB	12 dB	10 dB	8 dB	6 dB
IF-ATT*5	1 dB	3 dB	5 dB	7 dB	9 dB

*5: IF-ATT[dB] = Reference Level – RF-ATT + 30; when, 0 dB ≤ IF-ATT ≤ 10 dB, 1 dB Step

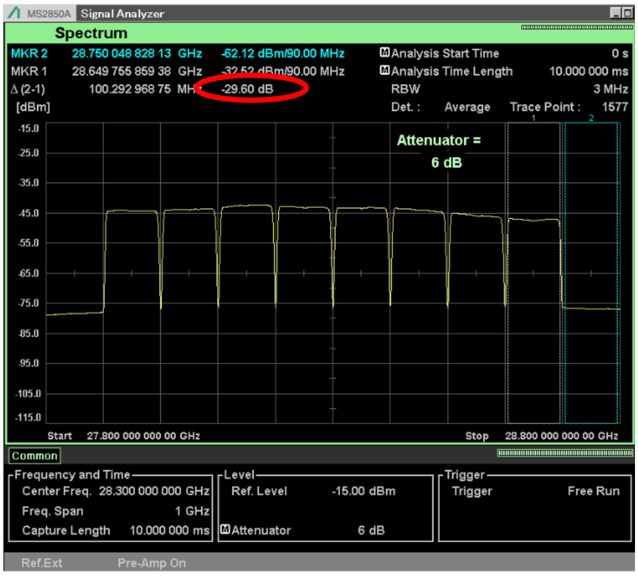
Some actual measurement results are shown below.

RF-ATT = 14 dB, IF-ATT = 1 dB





RF-ATT = 6 dB, IF-ATT = 9 dB



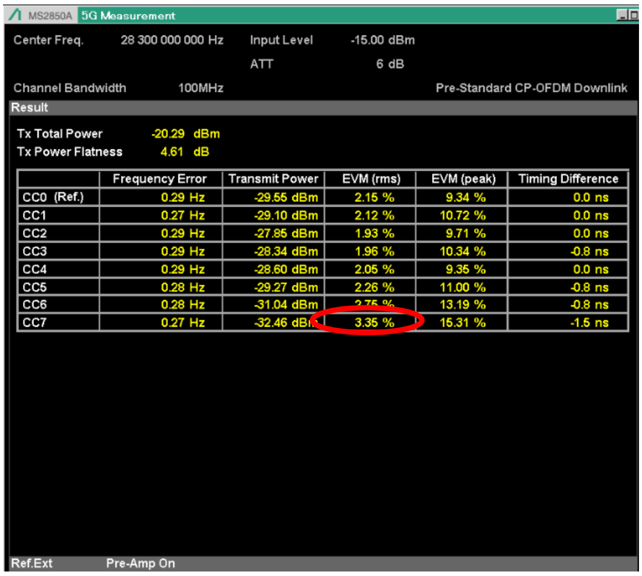


Table 7 SNR and EVM Measurement Results at Each ATT Setting

	SNR (CC7)	EVM (CC7)
RF-ATT = 14 dB, IF-ATT = 1 dB	−27.46 dB	4.32%
RF-ATT = 10 dB, IF-ATT = 5 dB	−28.88 dB	3.68%
RF-ATT = 6 dB, IF-ATT = 9 dB	−29.60 dB	3.35%

As shown above, setting Pre-AMP from OFF to ON improves the SNR and the EVM improves from 5.65% to 3.35%. Also, like the case in section 5.1, when IF-ATT is larger than RF-ATT, the overall system NF is improved and the EVM becomes better.

5.3 Measurement Precautions at Pre-AMP = ON (Example of Distortion Predominance)

This section shows the measurement results for a Single Carrier signal with an average signal level of –19 dBm and a crest ratio of 14 dB, as in section 5.2.

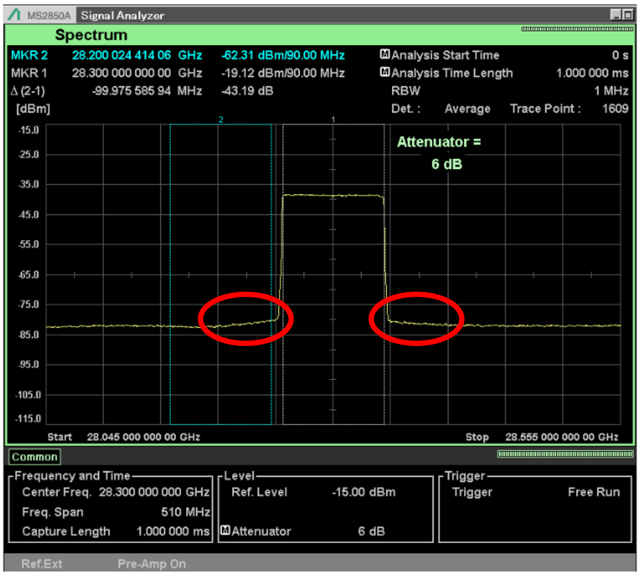
Table 8 SNR and EVM Measurement Results at Each ATT Setting

	SNR	EVM
RF-ATT = 14 dB, IF-ATT = 1 dB	41.51 dB	1.07%
RF-ATT = 10 dB, IF-ATT = 5 dB	43.00 dB	1.02%
RF-ATT = 6 dB, IF-ATT = 9 dB	43.19 dB	1.14%

Although the SNR and EVM show an improvement trend when RF-ATT is smaller and IF-ATT is larger with Pre-AMP = OFF or Pre-AMP = ON and 8 Carrier, the EVM optimum conditions are different at Pre-AMP = ON and Single Carrier as shown in Table 8. This is explained in section 2 and is due to the effect of measuring-instrument distortion. At the same output level, a Single Carrier signal has a power density of 8 times compared to an 8 Carrier signal. EVM deteriorates as the effect of Pre-AMP distortion increases. The waveforms at RF-ATT = 6 dB and 10 dB are shown below where the red ovals clearly indicate the Pre-AMP signal distortion when RF-ATT = 6 dB.

The Pre-AMP distortion characteristics change with frequency, bandwidth, and crest ratio, and since there is individual variation with each product, the RF-ATT should be adjusted while observing the waveform.

ATT = 6 dB

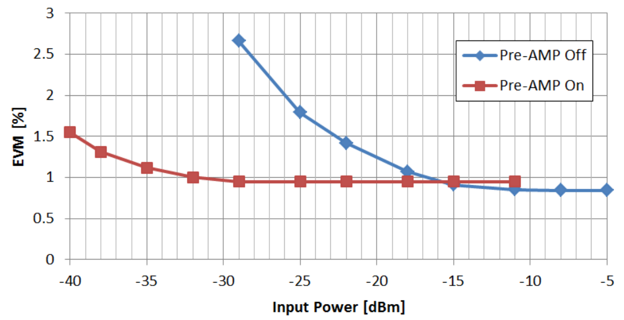


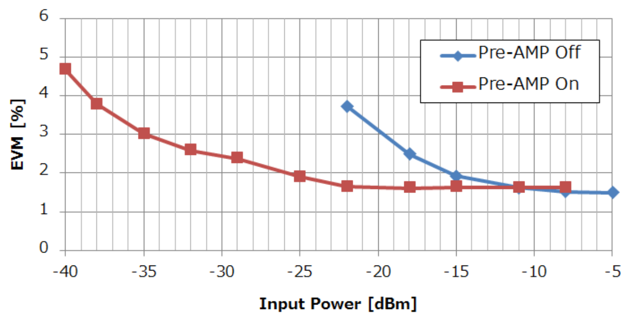
ATT = 10 dB

6 Input Level vs. EVM Measurement Result

So far, we have explained the measurement method for obtaining the optimum EVM value, but this chapter presents some actual EVM measurement results when the dynamic range is optimized at each input level.

Measurement Frequency: 28.3 GHz
Waveform: V5G (1 carrier), V5G (8 carrier)





From these results, the best measurements are obtained when the Input power is low and Pre-AMP = On. Additionally, the Input power threshold at measurement with Pre-Amp = On rather than Pre-Amp = Off is about –16 dBm for 1 carrier, and about –11 dBm for 8 carriers. As explained in Table 1, the power density is higher for 1 carrier than for 8 carriers and since there is little effect from the measuring instrument noise floor, there is hardly any degradation of the EVM even at Pre-AMP = Off. On the other hand, with 8 carriers, the power density is lower than at 1 carrier and the effect of the noise floor becomes more dominant than the measuring instrument distortion. Consequently, the EVM is improved even when the Input power is high as a result of setting Pre-AMP = On.
Generally, the measuring instrument Pre-AMP causes degraded distortion, but power density drops as signal bandwidth becomes wider and the S/N can be improved without degraded distortion even at high Input power. In other words, it may be necessary to change the threshold by setting the Pre-AMP On/Off, depending on the input signal bandwidth and crest ratio.
*6 The measurement results for the 8-carrier signal are the mean of each EVM value for CC0 to CC7.
*7 Since the level corresponding to the EVM value is different for each product, it must be checked Individually.

7 Summary

This application note explains the best methods for measuring the EVM of wideband signals; more accurate EVM measurements can be obtained by measuring in accordance with the following notes.

- SNR optimization is difficult with wideband modulation signals and requires severe adjustment.
- An ATT must be inserted to prevent the modulation waveform peak power exceeding the ADC overflow level.
- When the SNR effect is greater than the distortion effect, inserting a larger IF-ATT improves the SNR, but we recommend inserting an RF-ATT of about 4 dB due to the degraded VSWR.
- In particular, since EVM is degraded by the effect of distortion when Pre-AMP = On, it is necessary to adjust the ATT while observing the waveform.

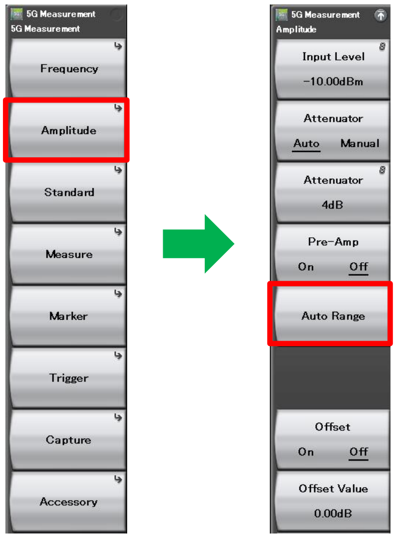
*The measurement results in this Application Note are actual measured values; they are not guaranteed values.

Appendix Auto Range Function

The Auto Range function has been added to the 5G Standard Measurement Software MX285051A from software version 12.01.00. Using this function eliminates complex calculations and supports EVM value optimization. However, to obtain the best value, follow the adjustment procedure described in this Application Note. In particular, adjustment is required at Pre-AMP = On due to the effects of frequency, input level, number of carriers, etc., on EVM measurement results.

In addition, the Auto Range function can be executed using the following procedure.

Select Amplitude → Press Auto Range



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Printed in Japan 公知 2017-11 MG No. MS2850A-E-F-1-(1.00)