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Calibration specification for spectrum analyzer

频谱分析仪校准规范

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Calibration specification for spectrum analyzer

1 Scope

This specification applies to the calibration of a spectrum analyzer in the frequency range from 3 Hz ~ 50 GHz.

2 Normative references

This specification refers to the following documents:

JJF 1071-2010 The rules for drafting national calibration specification

For the dated documents, only the versions with the dates indicated are applicable to this specification; for the undated documents, only the latest version (including all the amendments) are applicable to this specification.

3 Overview

Spectrum analyzer is a super-heterodyne receiver with display device. It consists of preselector, scanning local oscillator, mixer, middle amplifier, filter, detector, amplifier and display. It is mainly used for spectrum analysis, AND can also be used for the measurement of frequency, level, gain, attenuation, analog modulation and digital modulation, and distortion jitter, which is and indispensable instrument in communication, radio, television, radar, aerospace, and other technology areas.

4 Metrological characteristics

4.1 Reference frequency

Frequency nominal value: 10 MHz;

Frequency accuracy: $1 \times 10^{-5} \sim 1 \times 10^{-10}$.

4.2 Calibration signal level

Level range: -30 dBm ~ 0 dBm;

4.16 Input frequency response

Frequency range: 3 Hz ~ 50 GHz;

Frequency response: ± 0.2 dB ~ ± 5 dB.

4.17 Second harmonic distortion

Frequency range: 10 MHz ~ 25 GHz.

4.18 Third-order intermodulation distortion

Frequency range: 10 MHz ~ 50 GHz.

4.19 Gain compression

Frequency range: 10 MHz ~ 50 GHz.

4.20 Input voltage standing wave ratio

Frequency range: 10 MHz ~ 50 GHz;

Input voltage standing wave ratio: 1.02 ~ 3.

4.21 Power bandwidth

3dB bandwidth range: 1 Hz ~ 10 MHz;

The maximum allowable error: ± 0.02 dB ~ ± 0.50 dB.

Note: The above lists the measurement range and technical parameter requirements of each calibration parameter of the spectrum analyzer; during calibration, it shall follow the technical parameter requirements as listed in the technical specifications of the spectrum analyzer under calibration.

5 Calibration conditions

5.1 Environmental conditions

5.1.1 Ambient temperature: (23 ± 5) °C.

5.1.2 Relative humidity of the environment: ≤ 80%.

5.1.3 Power supply voltage and frequency: (220 ± 11) V, (50 ± 1) Hz.

5.1.4 There is no mechanical vibration or electromagnetic field disturbance that affects the normal operation of the calibration system.

6.5.4 TURN on the spectrum analyzer peak marker and TURN on the incremental marker.

6.5.5 SET the signal source output frequency to 600 MHz; PERFORM the peak search; READ out the frequency difference Δ and RECORD it in Table A.4 Measurement value in Appendix A. Then the relative error of sweep width can be calculated in accordance with the equation (3).

$$\delta=\frac{\Delta-0.8\times S_n}{0.8\times S_n}\times 100\% \tag{3}$$

Where:

S_n - The nominal value of the swept width of the calibrated spectrum analyzer;

Δ - Relative error of sweep width.

RECORD it in the relative error table of Table A.4 in Appendix A.

6.5.6 In accordance with Table A.4 of Appendix A, SET it to other sweep widths, and REPEAT the steps from 6.5.2 to 6.5.5.

6.6 Resolution bandwidth

6.6.1 Method I

6.6.1.1 3 dB Resolution bandwidth

6.6.1.1.1 The device connection is shown in Figure 4.

6.6.1.1.2 SET the center frequency of the calibrated spectrum analyzer at the calibration signal frequency, the output level at -21 dBm.

6.6.1.1.3 SET the center frequency of the calibrated spectrum analyzer to its calibration signal frequency, reference level at -20 dBm, vertical scale at 1 dB/div, resolution bandwidth at 100 Hz, sweep width at 300 Hz, AND video bandwidth and scan time at automatic mode.

6.6.1.1.4 ADJUST the signal source output level to -24 dBm, TURN on the spectrum analyzer peak marker, and then TURN on the incremental marker. ADJUST the signal source output level to -21 dBm.

6.6.1.1.5 Fine TUNE the signal source frequency so that the marker increment level fall to the reading zero from the left and right of the signal peak, respectively, READ out the signal source frequency $f_{\text{left (-3 dB)}}$ and $f_{\text{right (-3 dB)}}$. RECORD them in the corresponding table of Table A.5.1 in Appendix A.

6.6.2.2 Calibration of 60 dB bandwidth

6.6.2.2.1 SET the signal source output frequency based on the calibration signal frequency of the spectrum analyzer, AND the output level at - 1 dBm.

6.6.2.2.2 SET the center frequency of the calibrated spectrum analyzer at its calibration signal frequency, the reference level at 0 dBm, the attenuation 10 dB, the resolution bandwidth at 100 Hz, the sweep width at about 20 times of the resolution bandwidth, the vertical scale at 10 dB/div, the video bandwidth at 10 Hz, AND scan time at automatic mode.

6.6.2.2.3 TURN on the single sweep function, and TURN on the spectrum analyzer peak marker and incremental marker. If the calibrated spectrum analyzer has the "ndB down" function, SET ndB to 60 dB and PERFORM this function to measure 60 dB resolution bandwidth $RBW_{m(60dB)}$; If the calibrated spectrum analyzer has no "ndB down" function, ADJUST the spectrum analyzer knob to place the incremental marker on the left sideband of the waveform with the level increment reading at (-60 ± 0.5) dB; SET the incremental marker to the common marker; TURN on the incremental marker; ADJUST the spectrum analyzer knob to place the incremental marker on the right sideband of the waveform with the level increment reading at (0 ± 0.5) dB. READ out the absolute frequency value of this incremental marker, which is the 60 dB resolution bandwidth $RBW_{m(3dB)}$; RECORD it in the corresponding table of Table A.5.2 in Appendix A.

6.6.2.2.4 USE the equation (7) to calculate the selectivity S; RECORD it in Table A.5.2 Selectivity in Appendix A.

6.6.2.2.5 On the other resolution bandwidth in Table A.5.2 of Appendix A, REPEAT the steps from 6.6.2.2.2 to 6.6.2.2.4.

6.7 Noise sideband

6.7.1 Instrument connections are shown in Figure 5.

6.7.2 SET the signal source frequency at 1 GHz AND the output level at 0 dBm.

6.7.3 SET the spectrum analyzer center frequency at 1 GHz, the input attenuation at 10 dB, the reference level at 0 dBm, the vertical scale display at 10 dB/div, the sweep width at 10 kHz, the resolution bandwidth RBW less than or equal to 10 Hz, AND the rest at automatic mode.

6.7.4 TURN on the spectrum analyzer peak marker; then TURN on the incremental marker; respectively MOVE the center frequency to the frequency deviation ± 100 Hz; SET the sweep width at 0 Hz; READ out the minimum absolute value of the incremental marker level of the two frequency deviations

6.11.3 SET the center frequency of the calibrated spectrum analyzer at its calibration signal frequency, the input attenuator at 10 dB, the vertical display scale at 1 dB/div, the reference level at -60 dBm, the resolution bandwidth at 1 kHz, the sweep width at 500 Hz, AND the video bandwidth, scan time, etc. at automatic mode.

6.11.4 SET the signal source output frequency at the calibration signal frequency of the spectrum analyzer, AND the output level at 8 dBm; ADJUST the level to make the display peak value of the signal on the spectrum analyzer at about -62 dBm (it may be set at 1 ~ 2 grids below the reference level).

6.11.5 TURN on the peak marker on the spectrum analyzer; SET the average number of times at 10; READ out the peak level L; TURN on the incremental marker.

6.11.6 SET the attenuation value of the standard attenuator at 80 dB, the spectrum analyzer attenuation value at 0 dB, AND the reference level of the spectrum analyzer at -70 dBm.

6.11.7 READ out the marker increment value ΔL_m at this time, AND the amount of change of the attenuator ΔA = 80 - 70 = 10 dB.

6.11.8 Then the input attenuator conversion effect can be calculated in accordance with the equation (13), AND the calculation result is recorded in Table A.10 Input attenuator conversion effect in Appendix A.

$$\Delta = \Delta L_{\mathrm{m}} - \Delta A \tag{13}$$

6.11.9 In accordance with the Table A.10 of Appendix A, SET the attenuation value A of the standard attenuator, the spectrum analyzer attenuation set point, AND the spectrum analyzer reference level; REPEAT the steps 6.11.2 ~ 6.11.8.

6.12 Resolution bandwidth conversion effect

6.12.1 The device connection is the same as Figure 5.

6.12.2 SET the signal source frequency at the spectrum analyzer calibration signal frequency, AND the level at -20 dBm.

6.12.3 SET the center frequency of the calibrated spectrum analyzer at its calibration signal frequency, the reference level at -15 dBm, the input attenuator at 10 dB, the resolution bandwidth at 30 kHz, the sweep width at appropriate value (can be set to S/RBW = 5 ~ 10), AND video bandwidth and scan time at automatic mode.

6.15.2 SET the spectrum analyzer center frequency f_s at 2 GHz, the sweep width at 1 MHz, the resolution bandwidth at 3 kHz, the video bandwidth at 100 Hz, the input attenuation at 10 dB, AND the reference level at -10 dBm.

6.15.3 SET the signal source frequency at f_s and ADJUST the output level to make it display on the power meter at -30 dBm. From the spectrum analyzer, READ out the signal peak level L_s; RECORD the L_s value in the appropriate table of Table A.14 in Appendix A.

6.15.4 ADJUST the signal source frequency to $f_1 = f_s + 2f_{IF1}$ (when the local oscillation frequency is higher than the signal frequency) or $f_1 = f_s - 2f_{IF1}$ (when the local oscillation signal is lower than the signal frequency); USE the methods in 6.15.3 to adjust the power meter level display to -30 dBm, where f_{IF1} is the first intermediate frequency of the spectrum analyzer. RECORD the f_1 value in the corresponding table of Table A.14 in Appendix A.

6.15.5 From the calibrated spectrum analyzer, READ out the center frequency point level L_1. USE the equation (15) to calculate the image response a_c; RECORD the calculation results in Table A.14 Image response in Appendix A.

$$a_c = L_1 - L_s \tag{15}$$

6.15.6 In accordance with Table A.14 of Appendix A, SET different frequency points; REPEAT the steps 6.15.2 ~ 6.15.5.

6.16 Scan time

6.16.1 CONNECT the function generator output end to the AM input end of the signal source; CONNECT the RF output of the signal source to the RF input of the calibrated spectrum analyzer, as shown in Figure 9.

6.16.2 SET the signal source at the “external AM” mode, the output frequency at the calibration signal frequency of the spectrum analyzer, AND the output level at -21dBm. AND the function generator outputs 500 Hz triangular wave.

6.16.3 SET the center frequency of the spectrum analyzer at its calibration signal frequency, the reference level at -20 dBm, the sweep width at 0 Hz, the scan time T_n = 20 ms, the resolution bandwidth and video bandwidth greater than the function generator frequency, AND the vertical scale at linear mode; USE video to trigger it.

6.17.3 SET the signal source output frequency at the calibration signal frequency of the spectrum analyzer; SET the output level of the signal source so that the peak value of the spectrum analyzer cursor is -10 dBm OR the calibration signal level of the spectrum analyzer; AND this level value is nominal value.

6.17.4 From the power meter, READ out the measured level; RECORD it in Table A.16 Measurement values in Appendix A. SUBTRACT the nominal level value from the measured level to obtain the absolute amplitude indication error; RECORD it in Table A.16 Indication error in Appendix A.

6.18 Input frequency response

6.18.1 The device connection is shown in Figure 3.

6.18.2 SELECT the calibration signal frequency of the spectrum analyzer as the reference frequency point; SET the center frequency of the calibrated spectrum analyzer at the calibrated signal frequency; RECORD it in Table A.17 Calibration signal frequency in Appendix A. SET the spectrum analyzer input attenuation at 10 dB, the reference level at -5 dBm, the vertical display scale at 1 dB/ iv, the sweep width at 100 kHz, the resolution bandwidth at 1 kHz, AND the rest at automatic mode.

6.18.3 SET the signal source frequency to the spectrum analyzer calibration signal frequency AND the output level at -4 dBm; fine TUNE the output level of the signal source, so that the spectrum analyzer peak marker reading at -10 dBm; RECORD it in Table A.17 L_{SA} table in Appendix A; USE this value as L_{SAR}.

6.18.4 USE the power meter to measure the signal level; RECORD it in Table A.17 L_{PM} table in Appendix A; USE this value as L_{PMR}.

6.18.5 In accordance with Table A.17 of Appendix A, CHANGE the the center frequency setting of the signal source and spectrum analyzer; RECORD the peak marker reading of the spectrum analyzer in Table A.17 L_{SA} table in Appendix A; RECORD the power meter reading in Table A.17 L_{PM} table in Appendix A.

6.18.6 USE the equation (18) to calculate the input frequency response FR of each frequency point. RECORD the calculation results in Table 17 Frequency response in Appendix A.

$$FR = (L_{SA} - L_{PM}) - (L_{SAR} - L_{PMR}) \tag{18}$$

6.23.3 SET the center frequency of the spectrum analyzer at 1 GHz, the reference level at 0 dBm, the sweep width at 1 MHz, AND the resolution bandwidth, video bandwidth, and scan time at automatic mode.

6.23.4 TURN on the frequency counter function; in accordance with Table A.22 of Appendix A, SET the frequency resolution; RECORD the peak marker frequency in Table A.22 Measurement value in Appendix A.

6.23.5 In accordance with Table A.22 of Appendix A, SET different center frequencies; REPEAT the steps of 6.23.4.

6.24 Power bandwidth

6.24.1 Definition of power bandwidth

The term “power bandwidth” refers to the resolution bandwidth when measuring the noise marker, band power marker, channel power, and ACP (adjacent channel power).

6.24.2 Power bandwidth calibration method

6.24.2.1 TURN on the internal calibration source of the spectrum analyzer.

6.24.2.2 SET the center frequency of the spectrum analyzer at the internal calibration source frequency, AND the reference level at the internal reference source output level plus 1 dB; CONDUCT measurement at different resolution bandwidths.

6.24.2.3 SET the sweep width at 3 times of the resolution bandwidth. TURN on the marker pair function. INCLUDE the displayed waveform signal in the marker pair; READ out the power value; RECORD it in Table A.23 Measurement value in Appendix A. USE this measurement result to minus the power value as read out through the peak marker to obtain the power bandwidth indication error; RECORD it in the Table A.23 indication error table of Appendix A.

6.24.2.4 In accordance with Table A.23 of Appendix A, SET different resolution bandwidths; REPEAT the steps of 6.24.2.3.

7 Presentation of calibration results

After calibration, ISSUE a calibration certificate. The calibration certificate consists of cover and calibration data. The cover shall use a unified format as determined by the calibration organization, AND the calibration data shall be filled in accordance with the data form listed in the appendix based on the

Table A.4 Sweep width

Nominal value S_n	Measured value	Lower limit	Frequency accuracy	Upper limit
100 Hz				
1 kHz				
10 kHz				
1 MHz				
10 MHz				
100 MHz				
1 GHz				
10 GHz				
26 GHz				
40 GHz				
50 GHz				

Table A.5 Resolution bandwidth and its selectivity

Table A.5.1 3dB bandwidth

Nominal value RBW_n	f_{left} (-3 dB)	f_{right} (-3 dB)	Measured value RBW_m(-3dB)	Lower limit	Relative error	Upper limit
1 Hz						
3 Hz						
10 Hz						
30 Hz						
100 Hz						
300 Hz						

Table A.5.1 (continued)

Nominal value RBW_n	f_{left} (-3 dB)	f_{right} (-3 dB)	Measured value RBW_m (-3 dB)	Lower limit	Relative error	Upper limit
1 kHz						
3 kHz						
10 kHz						
100 kHz						
300 kHz						
1 MHz						
2 MHz						
3 MHz						
4 MHz						
5 MHz						
6 MHz						
7 MHz						
8 MHz						

	3	3				
	4	4				
	5	5				
	6	6				
	7	7				
	8	8				
	9	9				

Table A.8.1 (continued)

Vertical scale	Attenuation dB	dB number to reference level	Measured value dB	Lower limit	Indication error dB	Upper limit
10 dB/div	0	0	/	/	0 (reference)	/
	10	10				
	20	20				
	30	30				
	40	40				
	50	50				
	60	60				
	70	70				
	80	80				

Table A.8.2 Linear scale

Attenuation A dB	V_n mV	Measured value mV	Lower limit	Relative error	Upper limit
4					
8					
12					
16					
20					

Table A.9 Reference level

Vertical scale	Attenuation dB	Measured value dB	Lower limit	Indication error dB	Upper limit
- 10	20	/	/	0 (reference)	/
0	10				
10	0				
- 20	30				
- 30	40				
- 40	50				
- 50	60				
- 60	70				
- 70	80				

Table A.10 Input attenuator conversion effect

Attenuator attenuation dB	Input attenuator dB	Spectrum analyser reference level dB	Lower limit	Input attenuator conversion effect dB	Upper limit
70	10	- 60	/	0 (reference)	/
80	0	- 70			

Table C.1 10 MHz reference frequency measurement results

Number of measurement	1	2	3	4	5
Measurement results (MHz)	9. 999 999 8	9. 999 999 8	9. 999 999 7	9. 999 999 8	9. 999 999 8
Number of measurement	6	7	8	9	10
Measurement results (MHz)	9. 999 999 8	9. 999 999 8	9. 999 999 7	9. 999 999 8	9. 999 999 8

C.1.2.2 Frequency meter reference frequency

The frequency accuracy of the frequency reference crystal is 5 × 10^{-9}, that is, the extension uncertainty is 5 × 10^{-9}. Based on the uniform distribution, $k=\sqrt{3}$, AND the relative standard uncertainty component introduced by the frequency reference is u_{2rel} = 2.9 × 10^{-9}.

C.1.2.3 Frequency meter resolution

When using the frequency meter to measure the reference frequency of 10 MHz signal, the resolution is 0.01 Hz, the introduced relative quantization error is ± 5 × 10^{-10}, based on uniform distribution, $k=\sqrt{3}$, AND the relative standard uncertainty component as introduced by the frequency meter u_{3rel} = 2.9 x 10^{-10}.

C.1.2.4 Data rounding off

Since the measurement of the reference frequency only takes the 0.1 Hz place, the relative quantization error as introduced by the data rounding off is ± 5 × 10^{-9}, based on the uniform distribution, $k=\sqrt{3}$, AND the relative standard uncertainty component as introduced by data rounding off u_{4rel} = 2.9 x 10^{-9}.

C.1.3 Relative standard uncertainty component collection table

Table C.2 Relative standard uncertainty component collection table

Uncertainty source	Uncertainty type	Symbol	Value
Measurement repeatability	Class A	u_{1rel}	4.2 × 10^{-9}
Frequency meter reference frequency	Class B	u_{2rel}	2.9 × 10^{-9}
Frequency meter resolution	Class C	u_{3rel}	2.9 × 10^{-10}
Data rounding off	Class D	u_{4rel}	2.9 × 10^{-9}

C.1.4 Calculation of synthesis relative standard uncertainty

C.2.4 Calculation of synthesis standard uncertainty

Since the introduced uncertainty components are independent of each other, the synthesis standard uncertainty is:

$$u_c = \sqrt{u_1^2 + u_2^2 + u_3^2 + u_4^2} = 0.07\ \mathrm{dB}$$

C.2.5 Calculation of extension uncertainty

TAKE k = 2, the extension uncertainty is:

$$U = 0.14\ \mathrm{dB}$$

C.3 Noise sideband measurement uncertainty

C.3.1 Uncertainty sources and mathematical models

As known from 6.7, the uncertainty sources include measurement repeatability, signal source phase noise, level difference readings, and noise floor of the spectrum analyzer, so it may establish the uncertainty evaluation mathematical model as shown in equation (C.3).

$$\mathcal{L}(f) = \Delta L - 10\log RBW + \Delta\mathcal{L}_1 + \Delta\mathcal{L}_2 + \Delta\mathcal{L}_3 \tag{C.3}$$

Where:

ΔL - Level difference between the level deviated from carrier frequency f AND the carrier frequency;

$\Delta\mathcal{L}_1$ - Error introduced by measurement repeatability;

$\Delta\mathcal{L}_2$ - Error introduced by signal source phase noise;

$\Delta\mathcal{L}_3$ - Error introduced by noise floor of the spectrum analyzer.

C.3.2 Evaluation of standard uncertainty components

C.3.2.1 Repeatability measurement

MEASURE the level difference between the level deviated from 100 kHz frequency deviation and the carrier frequency, AND the results of 10 measurements are shown in Table C.5. USE the Bessel equation of class A evaluation method for calculation, to obtain the standard uncertainty component as introduced by measurement repeatability is u_1 = 0.75 dB.

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