Si4x6x TX RF Performance and ETSI Compliance Test Results

1. Introduction

The purpose of this application note is to give a systematic overview of the aspects which have to be taken into account during the design of radio systems in order to maintain compliance with the regulatory requirements of the ETSI EN 300 220-1 standard. The application note provides measurement results and ETSI compliance results for the Si4x6x low current transmitters operating in the sub-GHz frequency bands from 119-1050 MHz. The radios are part of the EZRadioPRO family which includes a complete line of transmitters, receivers, and transceivers; however, this application note focuses on transmitters only. This document does not include results for radiated measurements.

During the measurements the Wireless Development Suite (WDS), an Agilent PXA signal analyzer, and a Rohde & Schwarz Spectrum Analyzer were used. The Wireless Development Suite (WDS) is used to control the radio ICs on the pico boards. The results can be duplicated by using the same configuration (PA power level in CW project mode plus modulation format, DR and deviation in PN9 modulated transmit mode) as in the tests outlined in the following chapters.

2. Relevant Measurements to Comply with ETSI

In this report the rules of the ETSI EN 300 220-1 document are applied. The transmitter tests in the standard distinguish between conducted and radiated measurements and also between narrow band and wide band systems. The required ETSI compliance of the conducted transmitter tests are:

- Frequency error (section 7.1)
- Average power (section 7.2)
- Transient power (section 7.5)
- Adjacent channel power (section 7.6): This clause applies to narrow band systems only.
- Modulation bandwidth (section 7.7): This clause applies to wide band systems only.
- Unwanted emissions in the spurious domain (section 7.8)
- Frequency stability under low voltage conditions (section 7.9)

As was mentioned before, the EZRadioPRO family includes a complete line of transmitters (Si406x), receivers (Si436x) and transceivers (Si446x). The different boards offer various enhanced parameters and features including frequency coverage from 119 to 1050 MHz and output power up to +27 dBm.

The different Tx variants serve the following output power levels with the best efficiency:

- Si4x60 is 10 mW (10 dBm)
- Si4x61 is 25 mW (14 dBm)
- Si4x63 is 500 mW (27 dBm) (with external PA)

This application note contains only the investigation of those RF pico boards which are required by the standard. The table below summarizes which pico board is recommended for which frequency band.

Table 1. Recommended Boards for Each Frequency Band

Frequency Band	Max Output Power	Channel Spacing	Recommended TX Board	Recommended TRX Board
169.400 MHz to 169.475 MHz	500 mW	≤50 kHz		4463-PSQ27F169 4460-PCE27E169S
169.400 MHz to 169.475 MHz	500 mW	≤50 kHz		4463-PSQ27F169 4460-PCE27E169S
169.475 MHz to 169.4875 MHz	10 mW	12,5 kHz	4063-PSQ20B169	4463-PSQ20C169SE
169.5875 MHz to 169.6000 MHz	10 mW	12,5 kHz	4063-PSQ20B169	4463-PSQ20C169SE
433.050 MHz to 434.790 MHz	10 mW	No requirement	4060-PCE10B434	4460-PCE10D434
433.050 MHz to 434.790 MHz	1 mW (see Note1)	No requirement	4060-PCE10B434	4460-PCE10D434
434.040 MHz to 434.790 MHz	10 mW	≤25 kHz	4060-PCE10B434	4460-PCE10D434
863 MHz to 870 MHz Modulation bandwidth up to 300 kHz is allowed	25 mW (see Note 2)	≤100 kHz		4461-PCE14D868
863 MHz to 870 MHz	25 mW	No requirement		4461-PCE14D868
863 MHz to 870 MHz	25 mW	≤100 kHz		4461-PCE14D868
864.800 MHz to 865 MHz	10 mW	50 kHz	4060-PCE10B868	
868 MHz to 868.600 MHz	25 mW	No requirement		4461-PCE14D868
868.600 MHz to 868.700 MHz	10 mW	25 kHz The whole stated frequency band may be used as 1 wideband channel for high speed data transmission	4060-PCE10B868	
868.700 MHz to 869.200 MHz	25 mW	No requirement		4461-PCE14D868
869.200 MHz to 869.250 MHz	10 mW	25 kHz	4060-PCE10B868	4463-PCE20C868SE
869.250 MHz to 869.300 MHz	10 mW	25 kHz	4060-PCE10B868	4463-PCE20C868SE
869.300 MHz to 869.400 MHz	10 mW	25 kHz	4060-PCE10B868	4463-PCE20C868SE
869.400 MHz to 869.650 MHz	500 mW	≤25 kHz The whole stated frequency band may be used as 1 wideband channel for high speed data transmission		4463-PCE27F868
869.650 MHz to 869.700 MHz	25 mW	25 kHz		4461-PCE14D868
869.700 MHz to 870.000 MHz	25 mW	No requirement		4461-PCE14D868
869.700 MHz to 870 MHz	5 mW	No requirement	4060-PCE10B868	

Notes:
1. For bandwidth greater than 250 kHz the power density is limited to -13 dBm/ 10 kHz.
2. Power density is limited to –4.5 dBm/100 kHz.

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3. TX Measurements

3.1. Frequency Error

Frequency error is the difference under normal (and extreme) conditions between the measured, unmodulated carrier frequency and the nominal frequency as stated by the manufacturer. According to the definition the frequency error shall be measured with an unmodulated carrier. The frequency error basically depends on the crystal accuracy. A typical value is 20 ppm; so the ± 100 ppm ETSI limit for non-channelized devices is usually satisfied without any difficulty. For channelized systems with ≤ 25 kHz channels spacing the frequency error specification is more stringent (see table below). However, a 20 ppm XO accuracy is still adequate with the exception of boards, whose frequency bands are between 500 MHz and 1000 MHz. In such applications it is not enough to use the typical accuracy value. According to the standard, the limit is ±14 ppm at these frequency bands. The frequency error limit in ppm if the frequency error is given in kHz can be calculated as follows:

$$\text{XO accuracy [ppm]} = \frac{\text{Offset [kHz]} \times 1000}{\text{Cf [MHz]}}$$

Table 2. Frequency Error Limit for Channel Spacing ≤ 25 kHz

Frequency Band	137 MHz to 300 MHz	>300 MHz to 500 MHz	>500 MHz to 1000 MHz
Frequency (MHz)	169	434	868
Frequency Error Limit (kHz)	± 10	± 12	± 12.5
Frequency Error Limit (ppm)	± 59.17	± 27.65	± 14.4

3.2. Average Power

This section refers only to equipment with a permanent external antenna connector. The average power is the average or mean power delivered to the artificial antenna during one radio frequency cycle in the absence of modulation. Pico board output power levels may have to be adjusted to get the maximum allowed power level in the targeted frequency band. These power level settings are indicated in the table below.

Table 3. Output Powers and Current Consumption to All the Measured Cards

Boards	Pa Power Level (hex)	Output Power (dbm)	Current Consumption (mA)
4463-PSQ27F169	0x7F	26	485
4460-PCE27E169S	0x02	27	487
4063-PSQ20B169	0x2F	10.17	30
4460-PCE10D434	0x1D	9.95	17.33
4460-PCE10D434	0x06	–0.50	11.9
4461-PCE14D868	0x26	13.99	26.78
4060-PCE10B868	0x1D	10.02	19.11
4463-PCE27F868	0x48	26.96	522.18

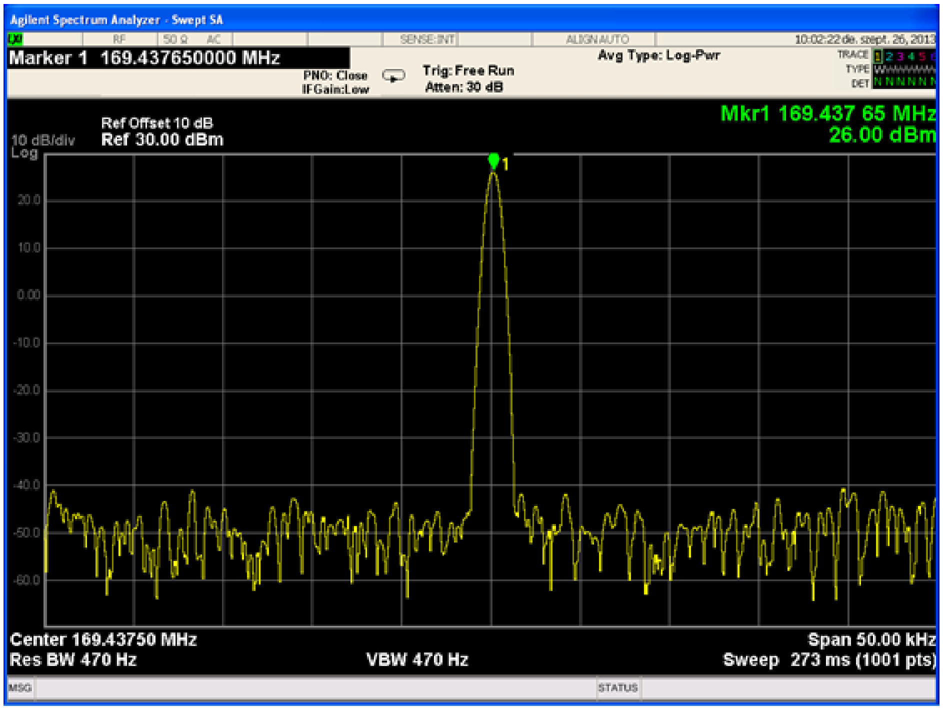


Figure 1. Average Power on 4463-PSQ27F169

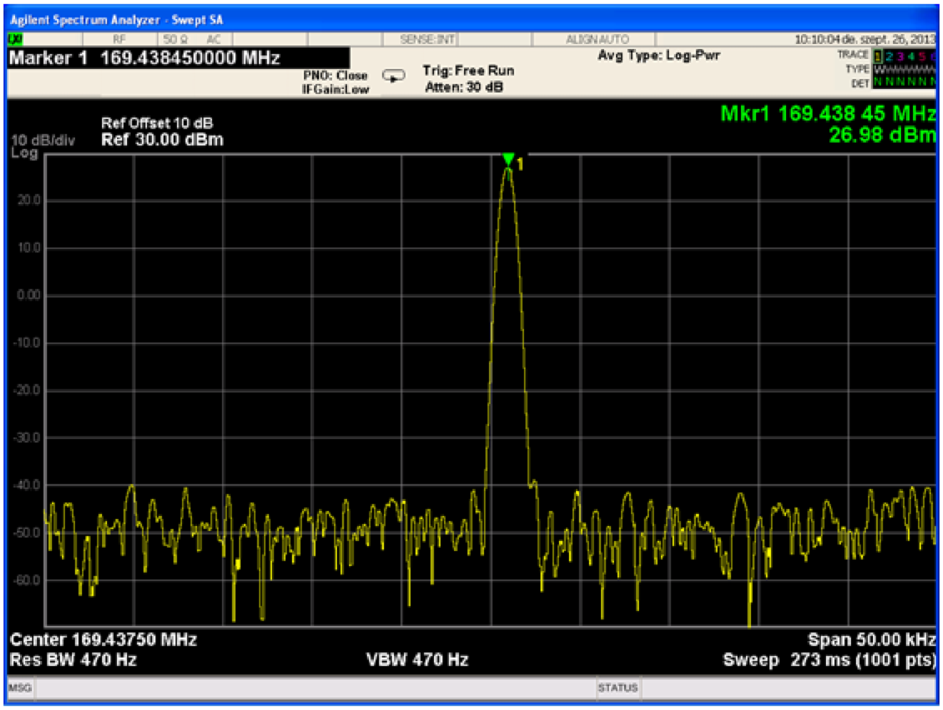


Figure 2. Average Power on 4460_PCE27E169S

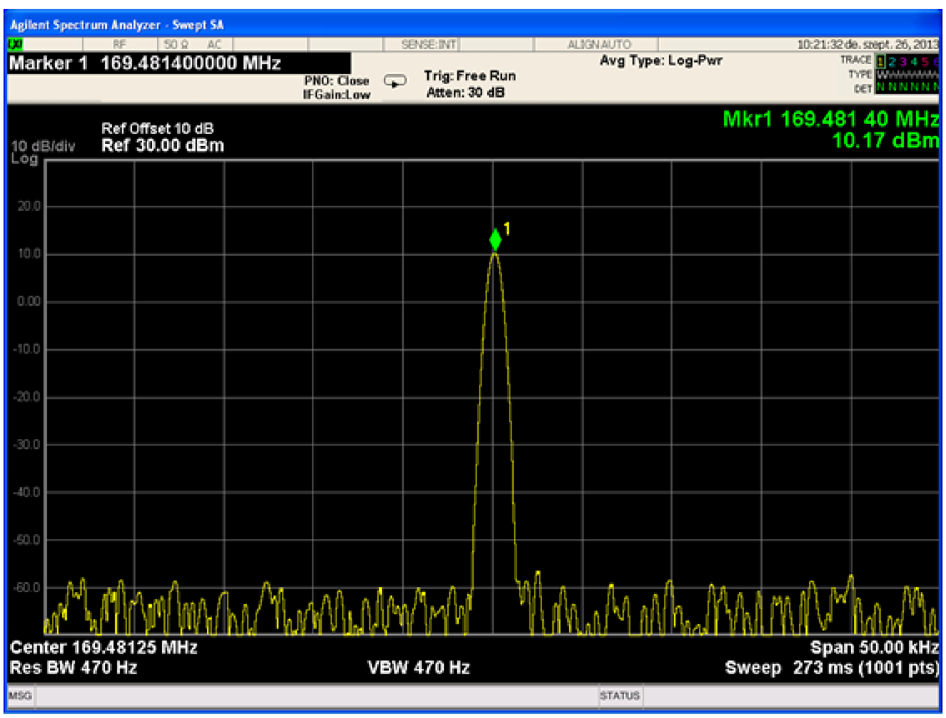


Figure 3. Average Power on 4063-PSQ20B169

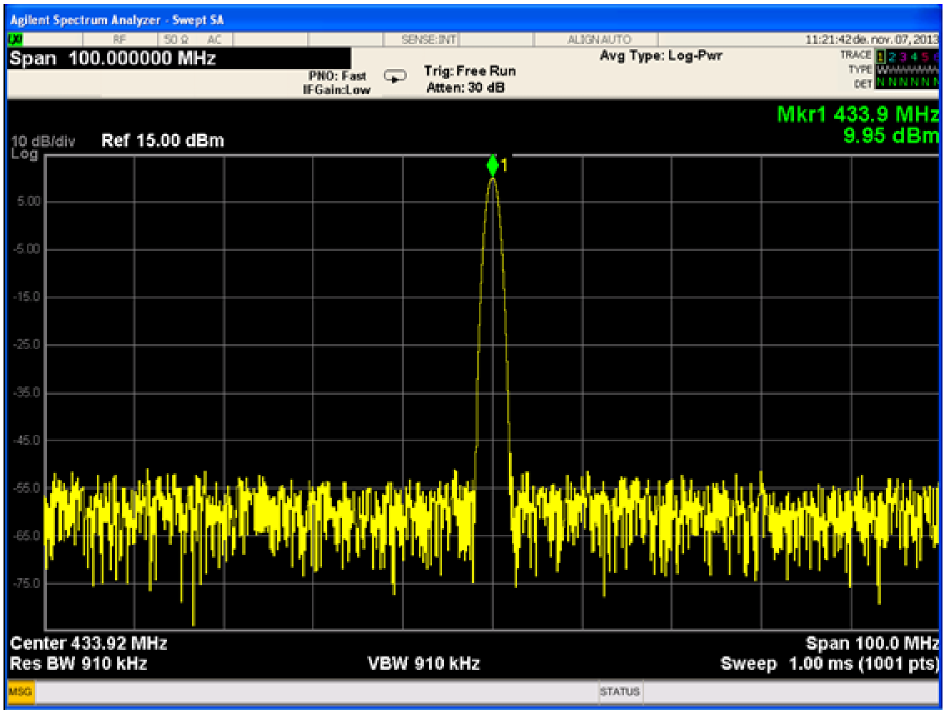


Figure 4. Average Power on 4460_PCE10D434

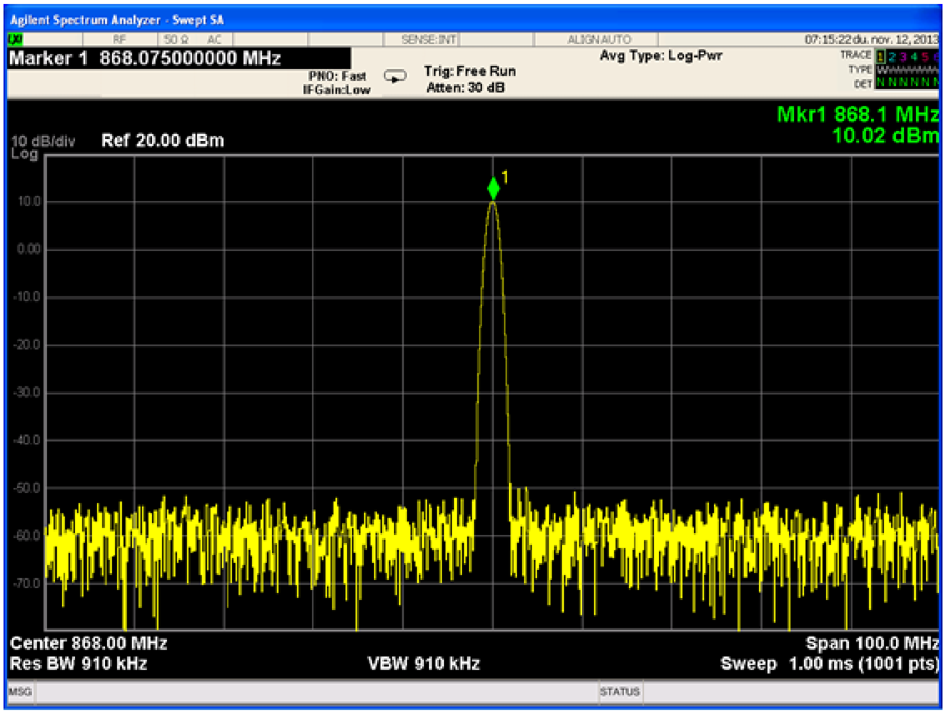


Figure 5. Average Power on 4060_PCE10B868

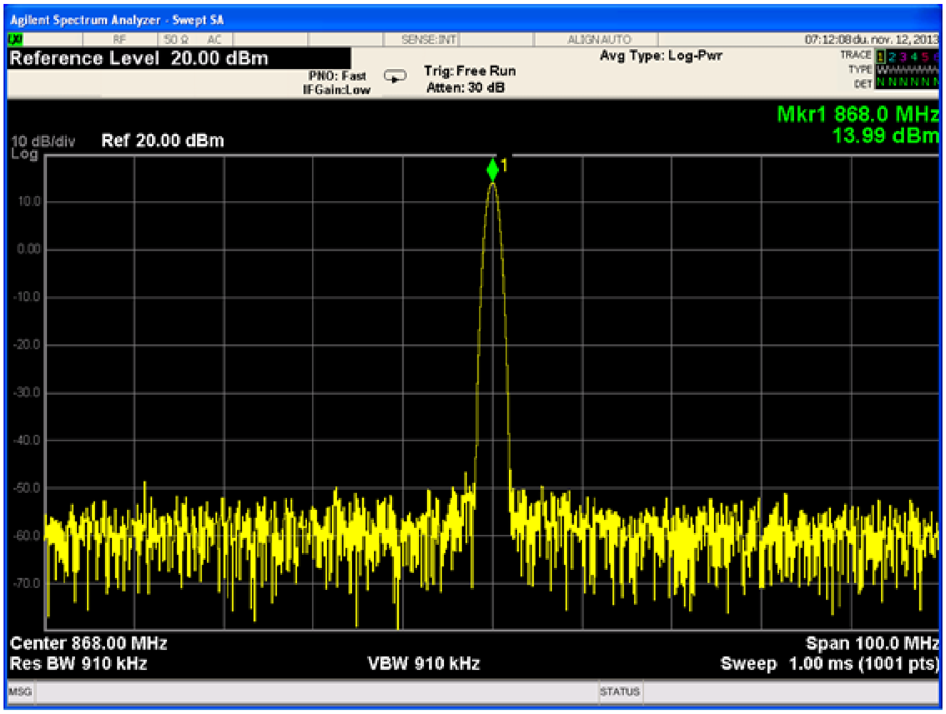


Figure 6. Average Power on 4461_PCE14D868

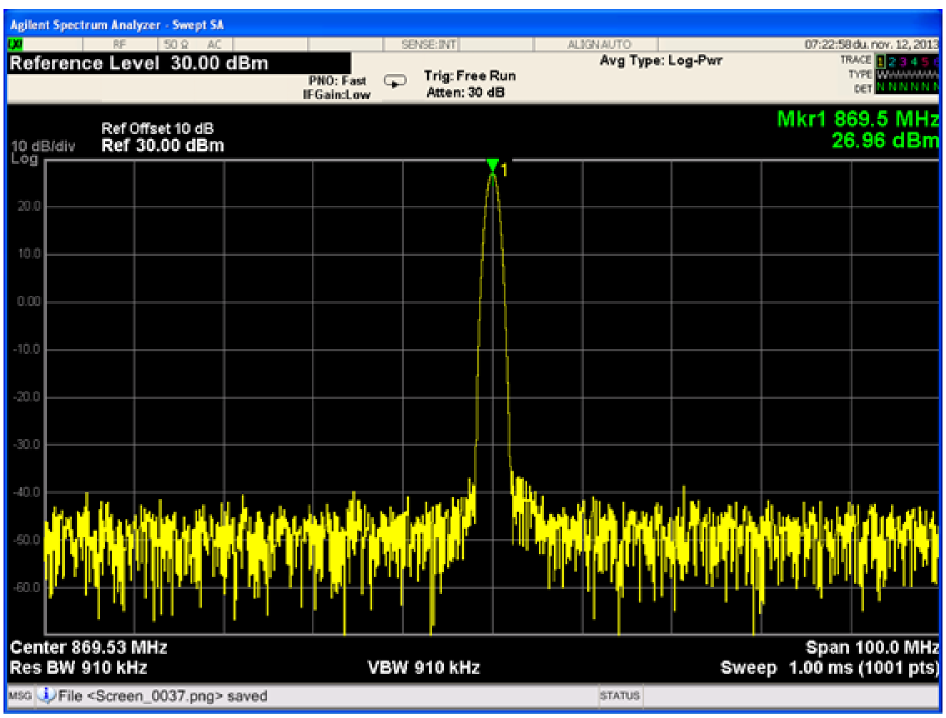


Figure 7. Average Power on 4463_PCE27F868

3.3. Transient Power

Transient power is the power falling into adjacent spectrum due to switching the transmitter on and off during normal operation.

The modulation test signal shall be applied at the transmitter. For constant envelope modulation schemes, it is not required to apply modulation.

Method of the measurement:

1. The measured receiver shall use a QUASI-PEAK DETECTOR defined in CISPR 16-1-1.
2. RBW should be 120 kHz.
3. Special narrowband and wideband settings:
   a. For narrowband equipment (channel spacing < 25 kHz), the center frequency of the measuring receiver shall be set 60 kHz above the beginning of the upper adjacent channel and 60 kHz below the beginning of the lower adjacent channel.
   b. For wideband devices, the initial offset shall be 100 kHz from the modulation bandwidth edge.
4. The measurement step 1 shall be repeated within the spectrum mask every 120 kHz from the primarily adjusted point to both sides of the wanted frequencies, until either it is clearly ascertained that no power increases or limit exceeding appear, or until the frequency offset to the wanted frequency exceeds 2 MHz.
5. The measurement shall be done on both sides of the carrier.
6. The measurement shall be done in ZERO-SPAN mode.
7. The transmitter shall be turned on and off at least 5 times in 60 seconds.
8. The power level should be recorded at least for a period of 60 seconds.
9. If the resulting power level is above the spurious limit (see section 4.5 or section 7.8 of the ETSI document), then the measurement shall be repeated with continuous transmission, and the transient level in Step 6 shall not exceed this power level by more than 3 dB. This is the so-called Step 2 of this measurement according to ETSI.

As measurement method Step 2 is more generic and unconditional, only this one has been performed.

Below spectrum analyzer traces show the static (flat) and transient (changing in level) power vs. time curves in each frequency band.

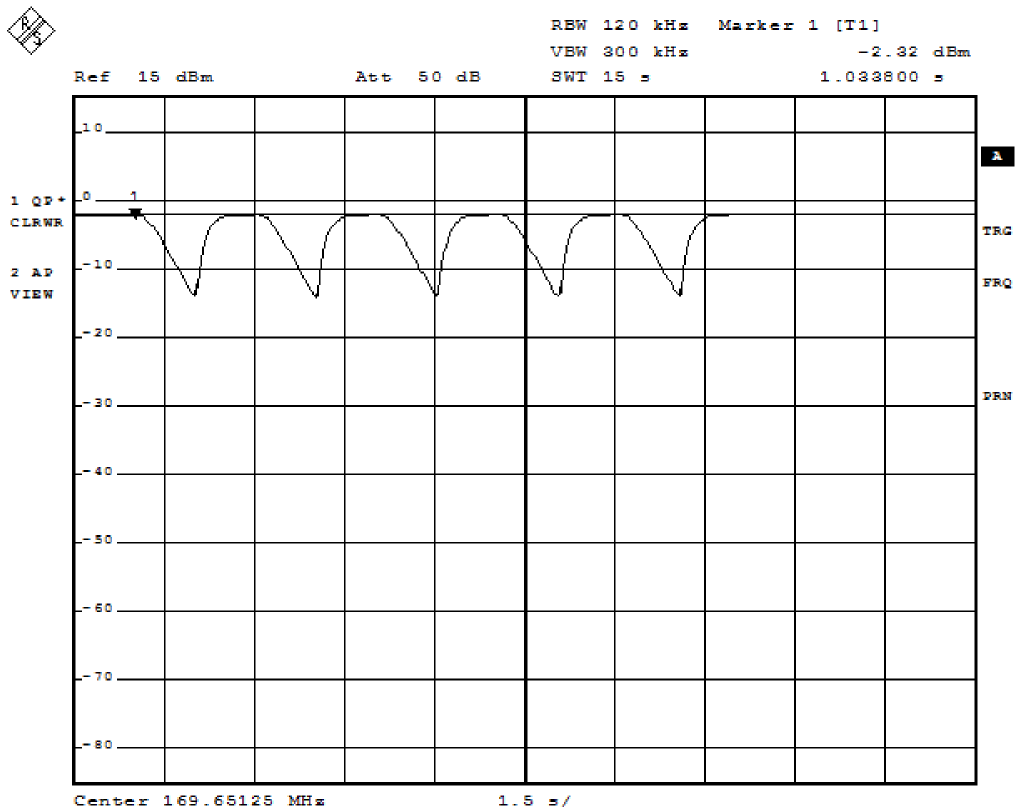


Figure 8. Transient Power on 4063_PSQ20B169+85 kHz Offset

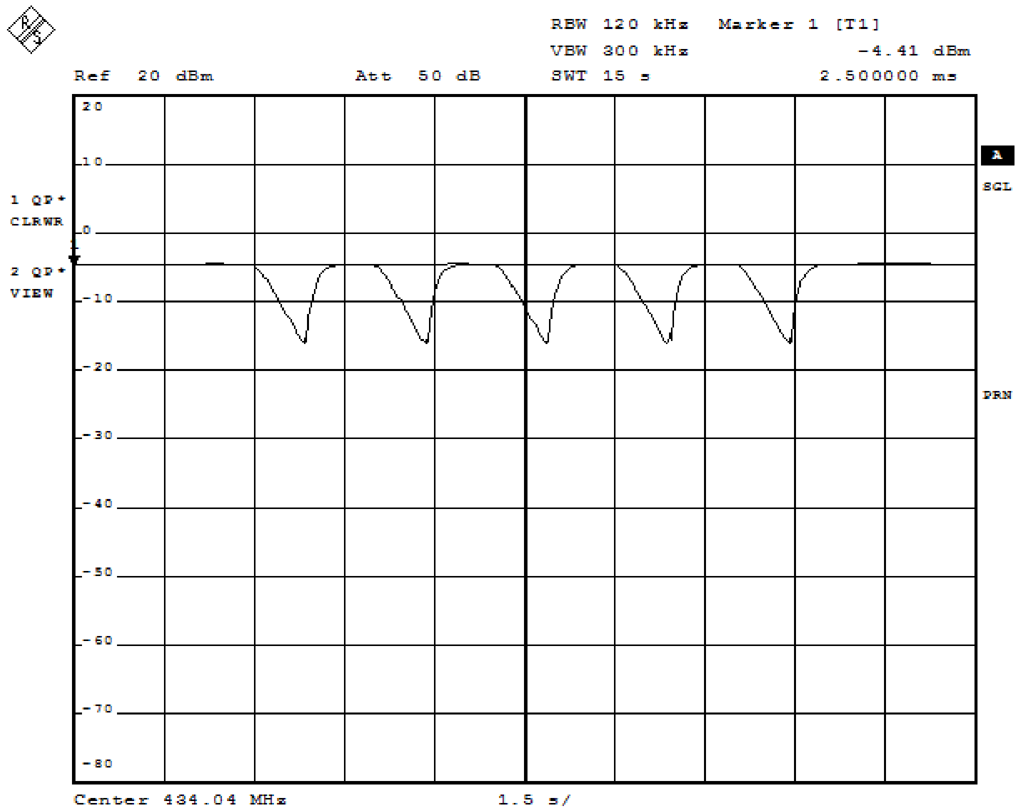


Figure 9. Transient Power on 4460_PCE10D434+120 kHz Offset

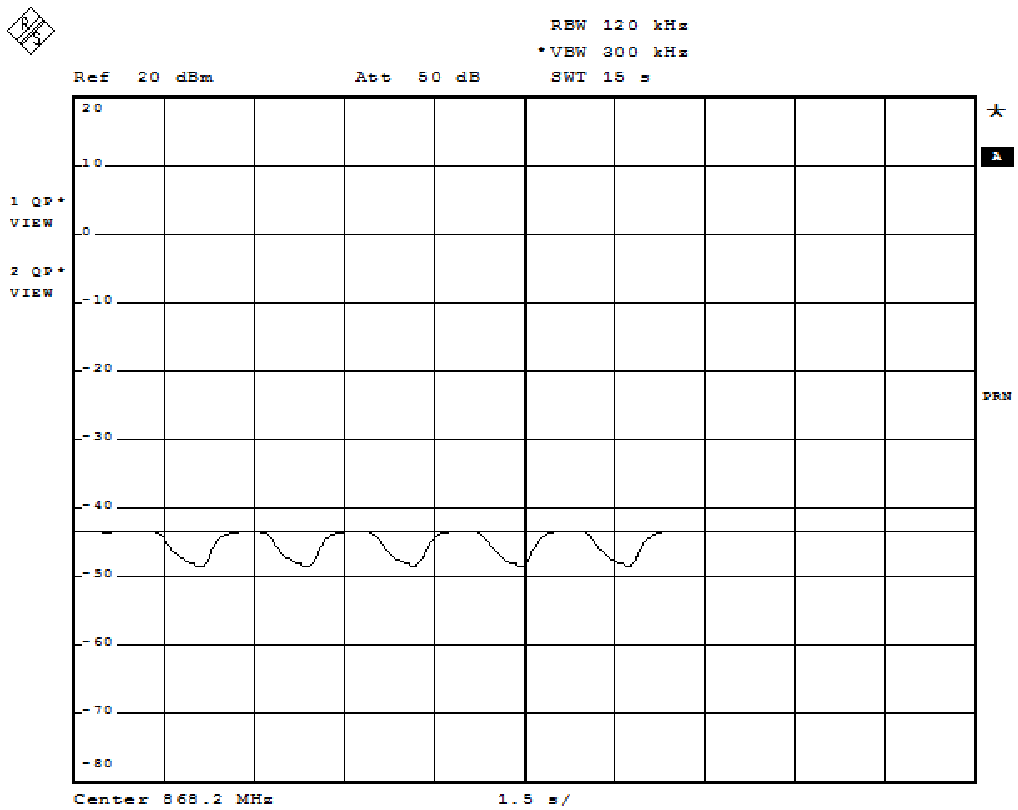


Figure 10. Transient Power on 4060_PCE10B868+200 kHz Offset

As can be seen from the screenshots (and also confirmed by all the other measurements), all the boards comply with the standard.

3.4. Adjacent Channel Power

This section applies to narrow band systems only. The amount of the RF signal power emitted into the adjacent channel is measured. For the measurements a normal spectrum analyzer can be used. The integration bandwidth must be set to 8.5 kHz for a channel spacing of 12.5 kHz and 16 kHz for a channel spacing of 25 kHz.

According to ETSI the narrow band systems are divided into two groups. In the first group, if the channel separation is smaller than 20 kHz, then the ACP limit is –20 dBm in an integrated bandwidth of 8.5 kHz. In the second group, if the channel separation is higher than or equal to 20 kHz, then the limit is –37 dBm in an integrated bandwidth of 16 kHz.

For various modulation formats (2GFSK, 4GFSK) and modulation indices (0.5, 1, 2) the maximum symbol rate has been determined at which the ACP requirement is still met.

At 2GFSK the modulation index (H) can be calculated as:

$$H = \frac{2 \times \text{deviation}}{\text{data rate [kbps]}}$$

At 4GFSK this translates to the following equation:

$$H = \frac{2 \times \text{outer deviation}}{\text{symbol rate[ksps]}}$$

Note: In WDS for a given 4(G)FSK modulation format, the deviation entry requires the inner deviation point which is one-third of the outer one. The measurement results are presented in all frequency bands with tables, that contain all the measured max symbol rate and ACP complemented with screenshots (for 2GFSK modulation with a modulation index of 1).

3.4.1. 169 MHz

Table 4. The 4063_PSQ20B169 Board. ACP with 12.5 kHz channel spacing, Frequency: 169, 48125 MHz, PA Power Level: 0x0C, Output Power: 10 dBm

Modulation	H	Max Symbol Rate (ksps)	ACP (dBm)
2 GFSK	1	8	–21.08
2 GFSK	0.5	13.2	–20.83
2 GFSK	2	5.3	–20.69
4 GFSK	1	8.4	–21.1
4 GFSK	0.5	13.2	–20.05
4 GFSK	2	5.1	–23.79

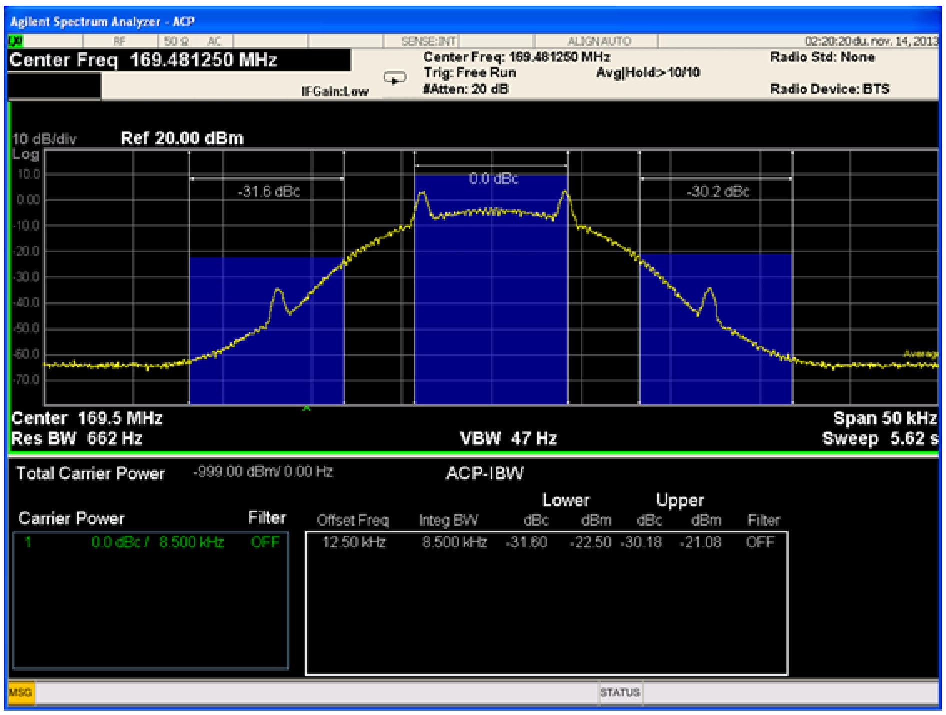


Figure 11. 4063_PSQ20B169 Board ACP with 12.5 kHz Channel Spacing, H=1, Data Rate=8 kbps

Table 5. The 4460_PCE27E169S Board. ACP with 12.5 kHz channel spacing, Frequency: 169.4375 MHz, Output Power: 27 dBm

Modulation	H	Max Symbol rate (ksps)	ACP (dBm)
2GFSK	1	5.2	–20.98
2GFSK	0.5	6.8	–23.2
2GFSK	2	3.8	–20.01
4GFSK	1	5.4	–22.59
4GFSK	0.5	7.44	–20.43
4GFSK	2	3.99	–20.68

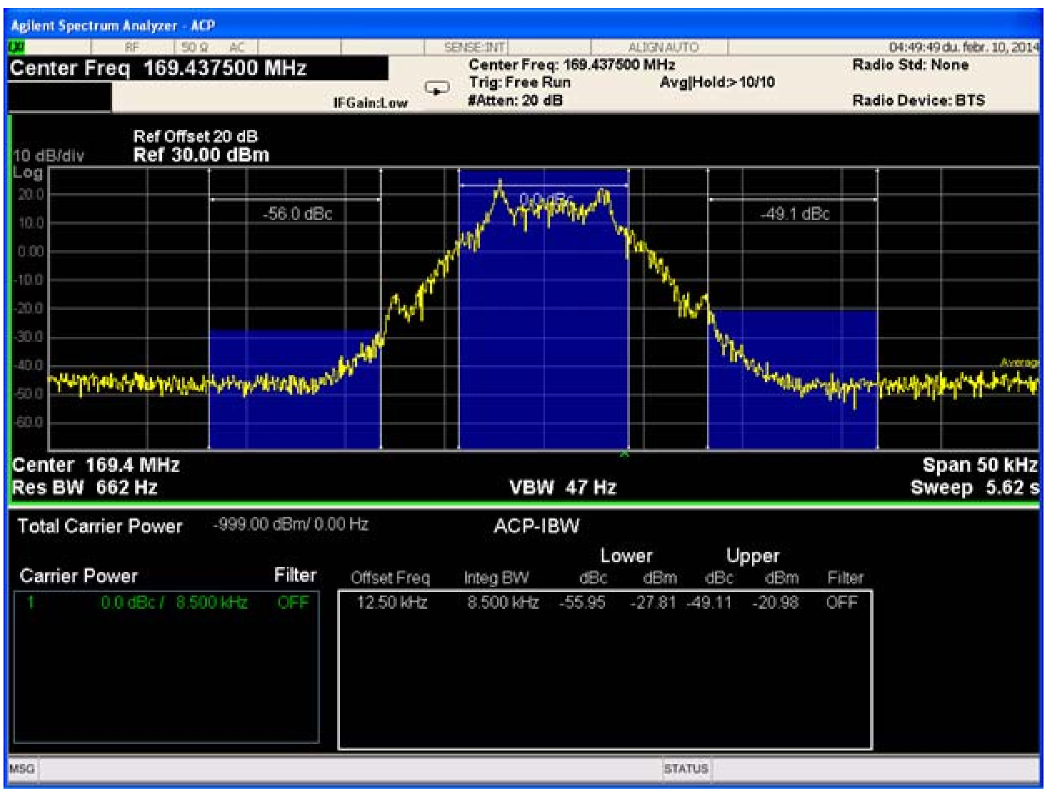


Figure 12. 4460_PCE27E169S Board ACP with 12.5 kHz Channel Spacing, H=1, Data Rate=5.2 kbps

3.4.2. 434 MHz

Table 6. 4460_PCE10D434 board. ACP with 25 kHz channel spacing. Frequency: 433.92 MHz, PA Power Level: 0x06, Output Power: 0 dBm

Modulation	H	Max Symbol Rate (ksps)	ACP (dBm)
2GFSK	1	14.6	–38.04
2GFSK	0.5	18	–38.64
2GFSK	2	9.8	–37.7
4GFSK	1	15	–38
4GFSK	0.5	21.6	–37.65
4GFSK	2	9.9	–37.95

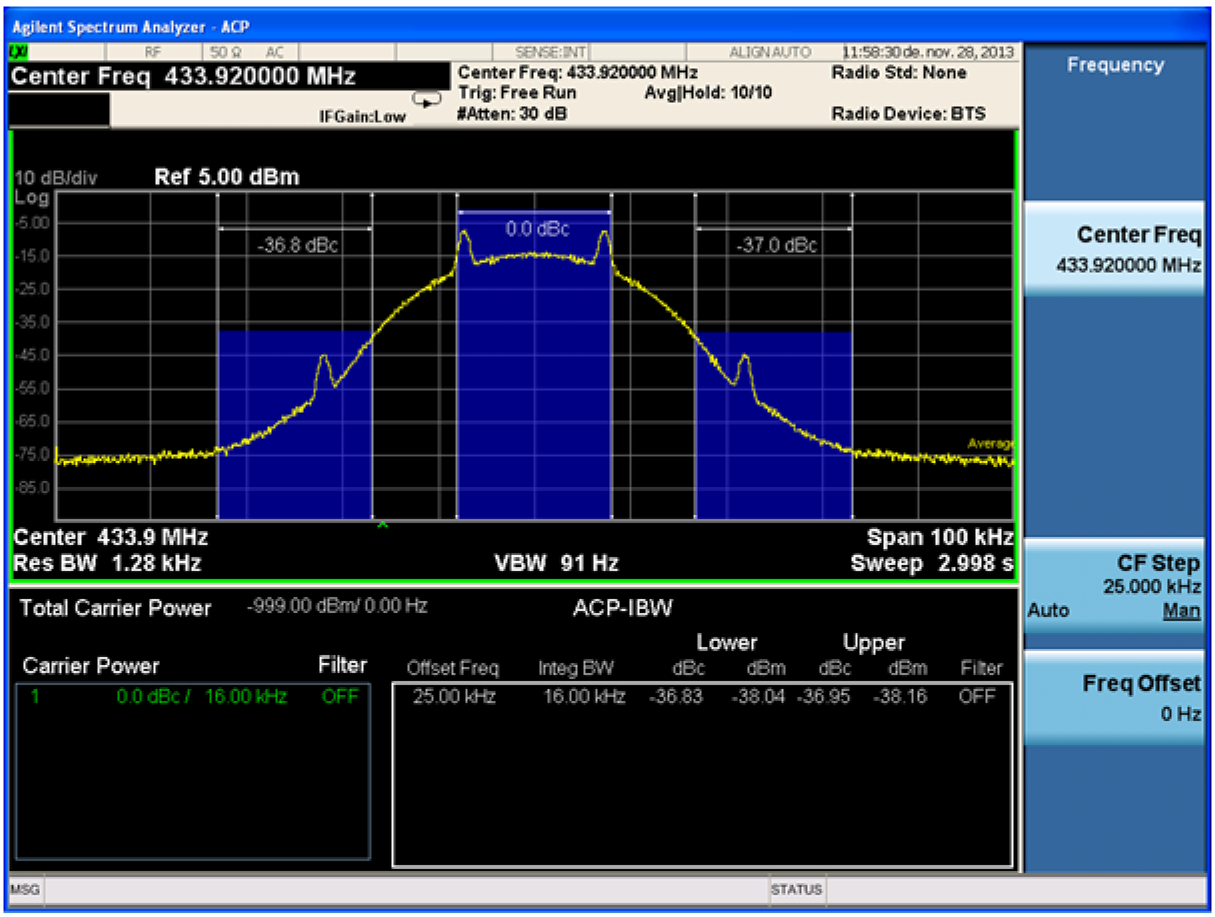


Figure 13. 4460_PCE10D434 Board. ACP with 25 kHz Channel Spacing, Frequency: 433.92 MHz, Power Level: 0x06, Output Power: 0 dBm, H=1, Data Rate=14.6 kbps

Table 7. 4460_PCE10D434 board. ACP with 25 kHz channel spacing. Frequency: 433.92 MHz, Power Level: 0x1D, Output Power: 10 dBm

Modulation	H	Max Symbol Rate (ksps)	ACP (dBm)
2GFSK	1	11	–39.41
2GFSK	0.5	15.2	–37.62
2GFSK	2	8.2	–37.13
4GFSK	1	12	–38.42
4GFSK	0.5	15.6	–37.95
4GFSK	2	8.4	–38

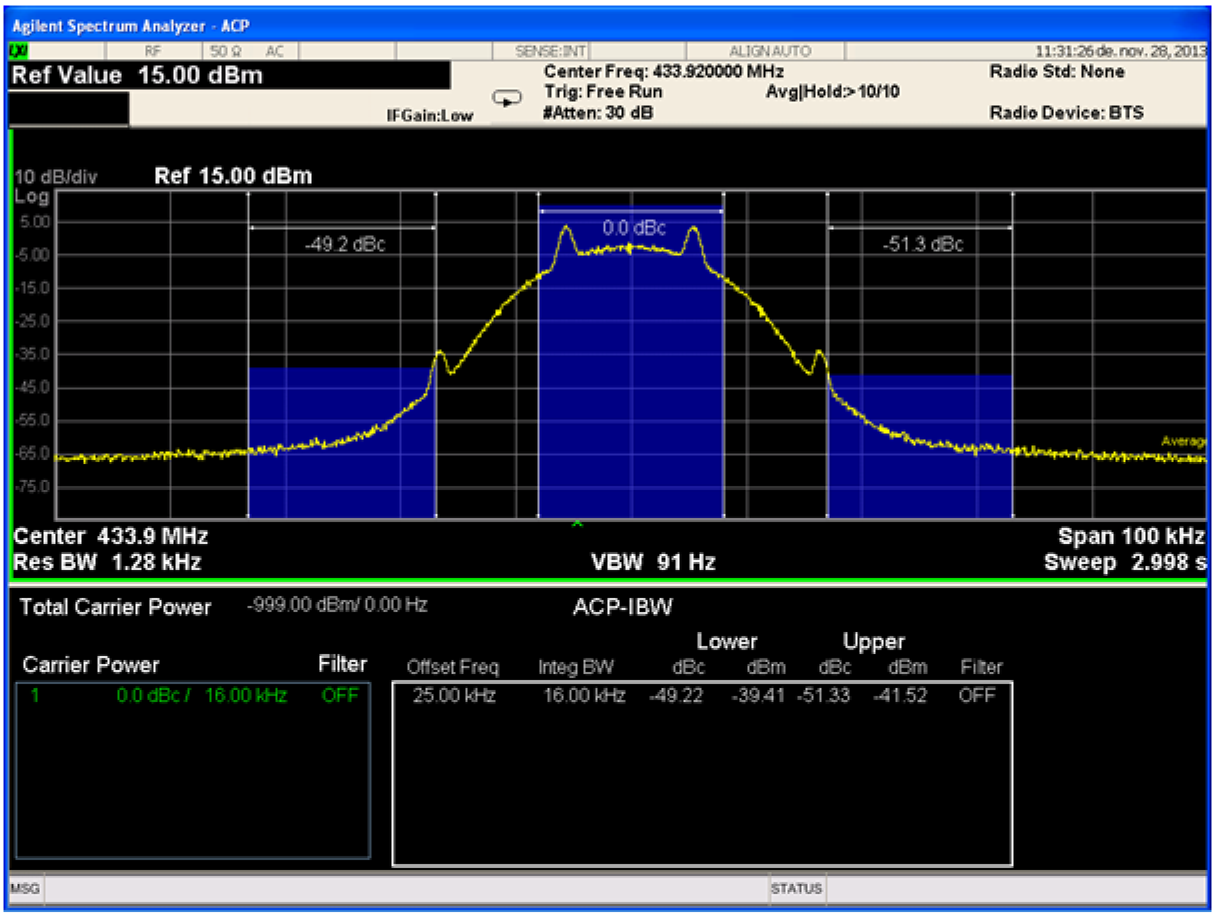


Figure 14. 4460_PCE10D434 Board ACP with 25 kHz Channel Spacing, Frequency: 433.92 MHz, Output Power: 10 dBm, H=1, Data Rate=11 kbps

3.4.3. 868 MHz

Table 8. 4461_PCE14D868 board. ACP with 25 kHz channel spacing. Frequency: 869.675 MHz, PA Power Level: 0x26, Output Power: 14 dBm

Modulation	H	Max Symbol Rate (ksps)	ACP (dBm)
2GFSK	1	10.4	–39.05
2GFSK	0.5	14	–38.58
2GFSK	2	7.6	–37.41
4GFSK	1	10.8	–39.48
4GFSK	0.5	14.4	–39.48
4GFSK	2	7.8	–37.9

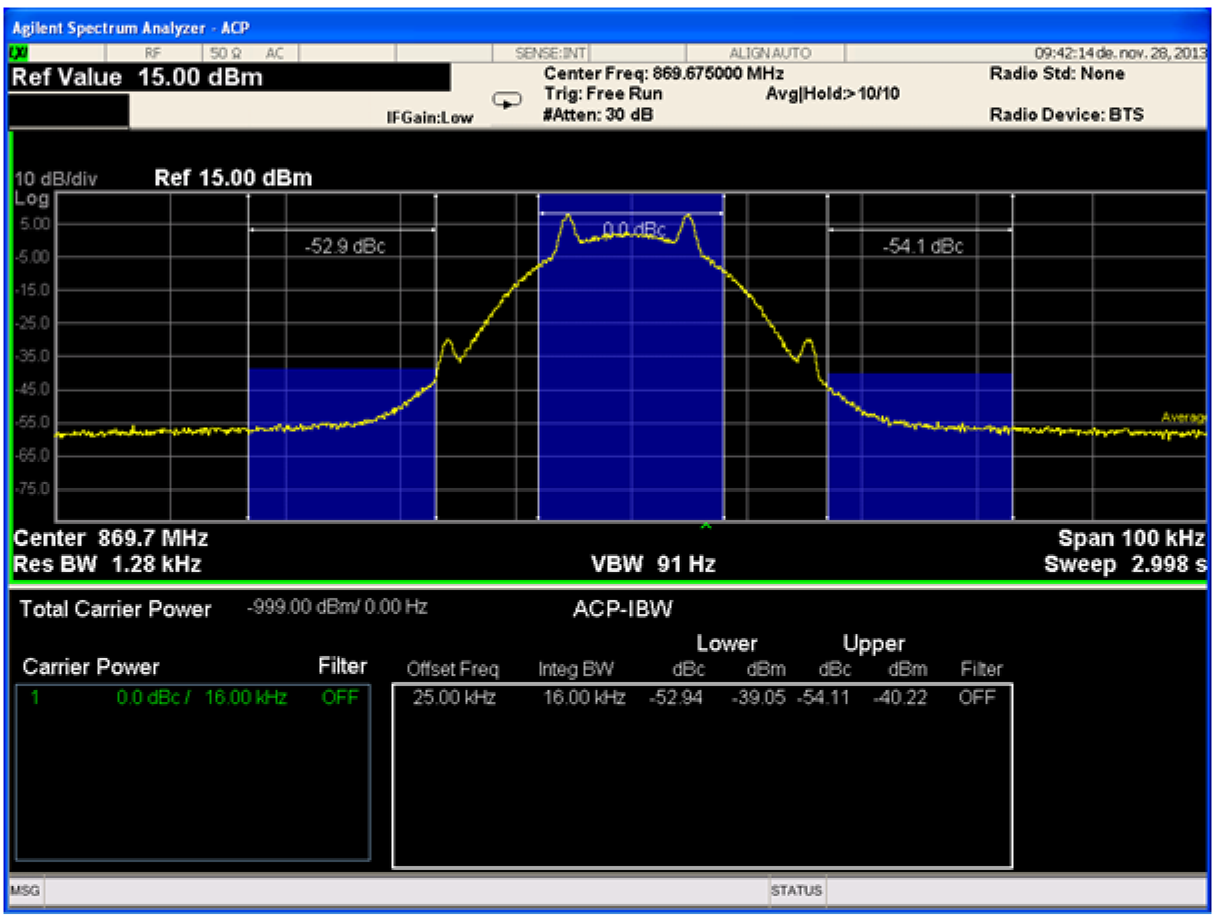


Figure 15. 4461_PCE14D868 Board ACP with 25 kHz Channel Spacing, Frequency: 869.75 MHz, PA Power Level: 0x26, Output Power: 14 dBm, H=1, Data Rate=10.4 kbps

Table 9. 4060_PCE10B868 Board ACP with 25 kHz Channel Spacing, Frequency: 869.2125 MHz, Power Level: 0x1D, Output Power: 10 dBm

Modulation	H	Max Symbol Rate (ksps)	ACP (dBm)
2GFSK	1	10.8	–39.59
2GFSK	0.5	15	–37.03
2GFSK	2	8	–37.38
4GFSK	1	11.7	–38.08
4GFSK	0.5	15.6	–37.8
4GFSK	2	8.25	–37.54

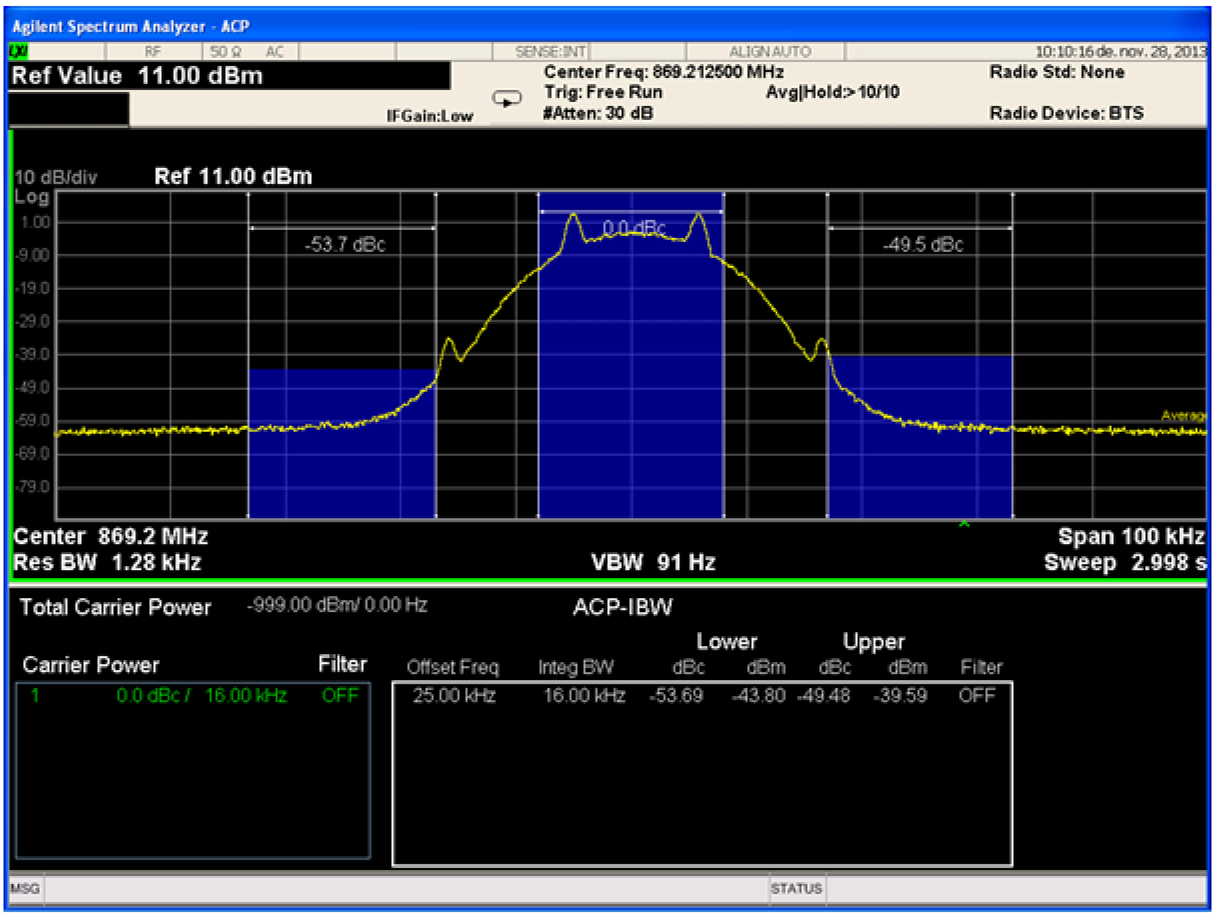


Figure 16. 4060_PCE10B868 Board ACP with 25 kHz Channel Spacing, Frequency: 869.2125 MHz, Output Power: 10 dBm, H=1, Data Rate=10, 8 kbps

Table 10. 4463_PCE27F868 board. ACP with 12.5 kHz channel spacing. Frequency: 869.525 MHz, Output Power: 27 dBm

Modulation	H	Max Symbol Rate (ksps)	ACP (dBm)
2GFSK	1	5.3	–21.1
2GFSK	0.5	7.2	–20.7
2GFSK	2	3.8	–22.91
4GFSK	1	5.7	–21.25
4GFSK	0.5	7.2	–24
4GFSK	2	3.9	–22.5

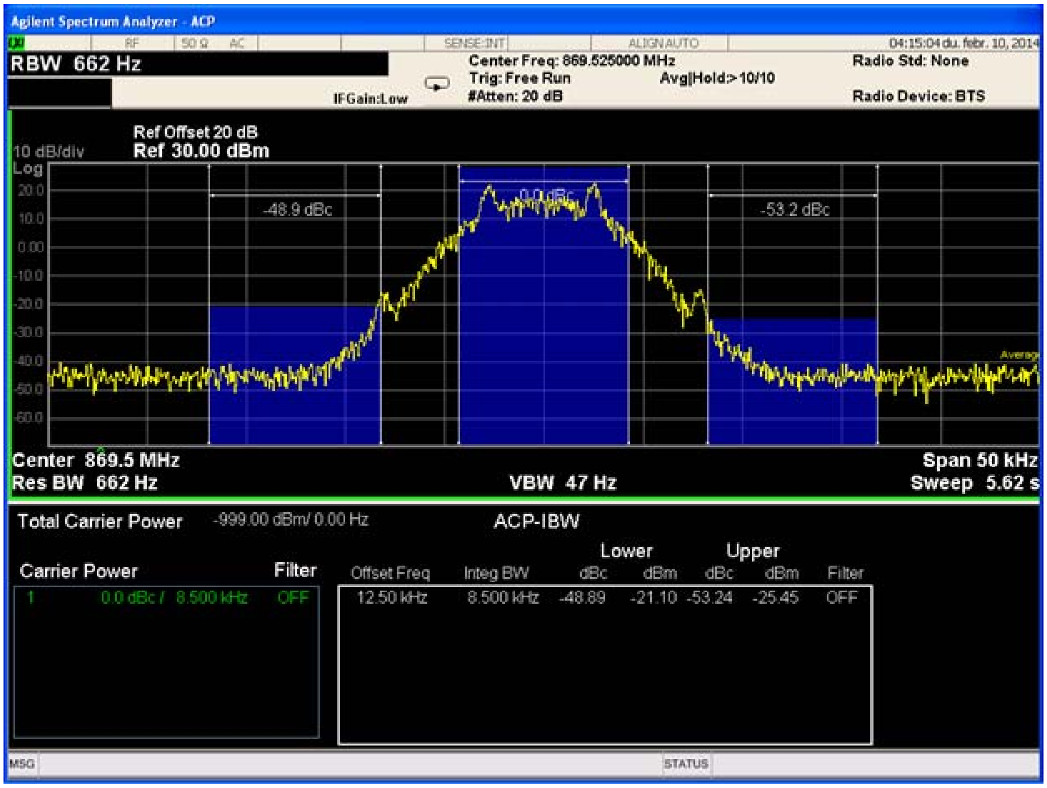
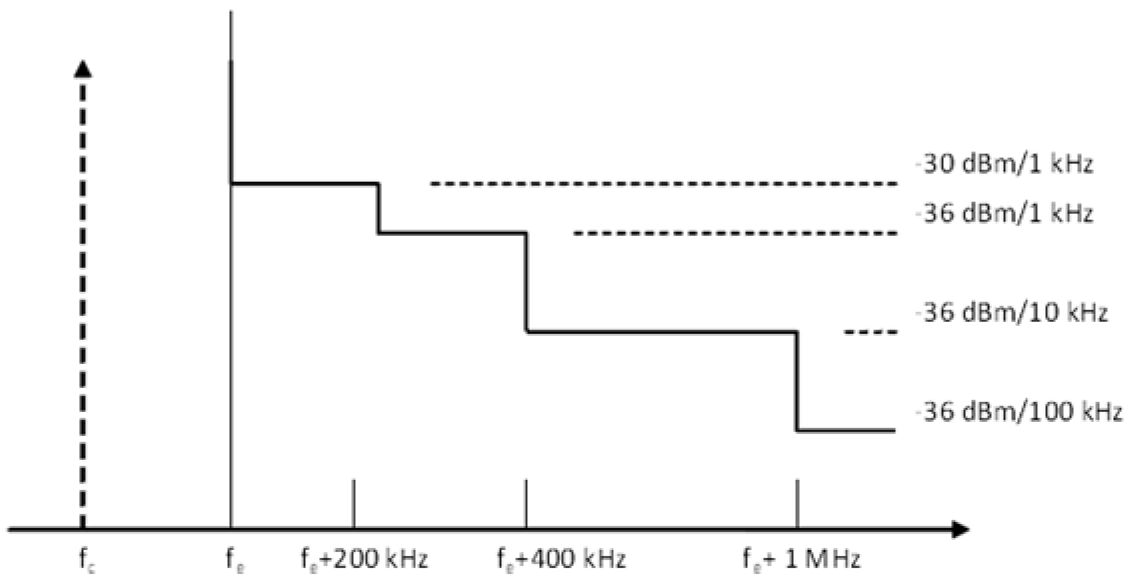


Figure 17. 4463_PCE27F868 Board ACP with 12, 5 kHz Channel Spacing, Frequency: 869.525 MHz, Output Power: 27 dBm, H=1, Data Rate=5.3 kbps

3.5. Modulation Bandwidth

The range of modulation bandwidth is measured on wideband systems instead of the adjacent channel power. The range of modulation bandwidth includes all associated side bands above the appropriate emissions level (ETSI EN 300 220-1 V2.4.1, subclause 7.8) and the frequency error or drift under extreme test conditions. The frequency drift in extreme test conditions primarily depends on the crystal quality, which is not included in this report. The modulation bandwidth is defined as the difference between the two frequencies at which the power envelope reaches the spurious emission limit of –36 dBm/1 kHz. The range of modulation bandwidth is measured with spectrum analyzer. As averaging is allowed on constant envelope modulation formats, the measurement was made in trace average mode with RMS power detector.

The ETSI spectral mask which the radio must comply with at the sub-band edges is demonstrated in Figure 17. There are only two limit thresholds, and the bandwidth of integration is varied at the different offset regions. This can be observed in the spectral mask measurements as well, where the limit lines mark the –30 and –36 dBm levels. As the RBW changes according to the ETSI spectrum mask, the measured phase noise level also jumps abruptly.



NOTE:

- f_c is the emission center frequency.
- f_e is the sub-band edge frequency.
- Only the upper half of the emission is shown. The lower half is a mirror image.

Figure 18. ETSI Spectral Mask Measurement Limits at the Sub-Band Edges

For various modulation formats (2GFSK, 4GFSK) and modulation indices (0.5, 1, 2) the maximum symbol rate has been determined at which the MBW requirement is still met.

At 2GFSK the modulation index (H) can be calculated as:

$$H = \frac{2 \times \text{deviation}}{\text{data rate [kbps]}}$$

At 4GFSK this translates to the following equation:

$$H = \frac{2 \times \text{outer deviation}}{\text{symbol rate [ksps]}}$$

The measurements results are presented in all frequency bands with tables that contain all the measured max symbol rates and margins to the spectrum mask limit complemented with screenshots (for 2GFSK modulation with a modulation index of 1).

Modulation indices 1 and 2 have discrete spectral components at an offset of the deviation (and its harmonics); these discrete components are prone to violating the emission mask. At modulation index 0.5 the discrete components are suppressed, therefore a higher DR can be achieved with them at any given power level and channel bandwidth. This trend can be observed on all of the measurement results in the following sections. The downside of spectral efficiency is ~2 dB sensitivity degradation at the Rx side.

3.5.1. 169 MHz

3.5.1.1. 4463_PSQ27F169

Table 11. 4463_PSQ27F169 Board MBW Mask Margin with 50 kHz Channel, Frequency: 169.4375 MHz, Output Power: 26 dBm

Modulation	H	Max Symbol Rate (ksps)	∆Lim (dB)
2GFSK	1	13.4	–4.57
2GFSK	0.5	18.4	–4.4
2GFSK	2	10	–0.54
4GFSK	1	13.8	–6.2
4GFSK	0.5	20.4	–0.04
4GFSK	2	10.5	–1.62

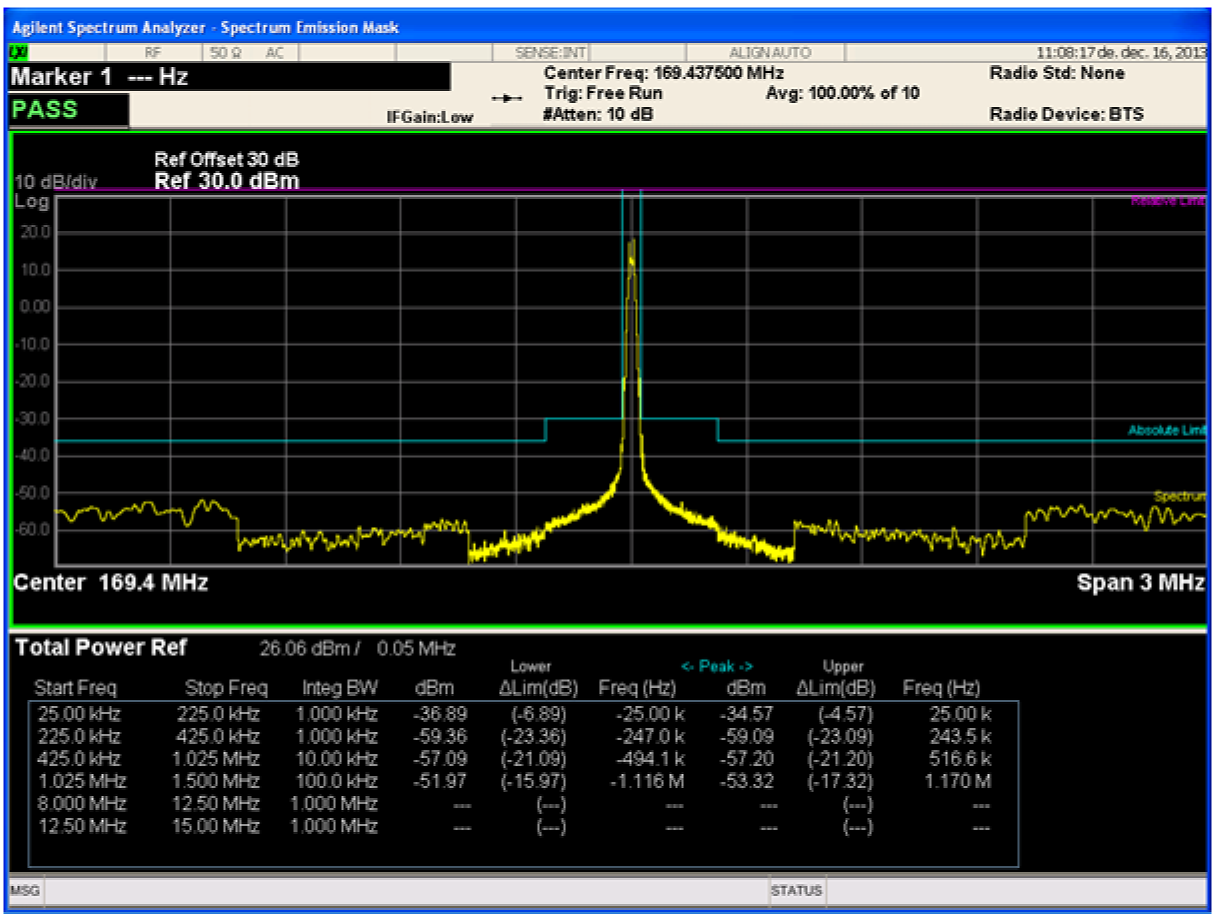


Figure 19. 4463_PSQ27F169 Board MBW Mask Margin with 50 kHz Channel, Frequency: 169, 4375 MHz, Output Power: 26 dBm, H=1, Data Rate=13.4 kbps

3.5.1.2. 4460_PCE27E169S

Table 12. 4460_PCE27E169S Board MBW Mask Margin with 50 kHz Channel, Frequency: 169.4375 MHz, Output Power: 26.98 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	14	–0.82
2GFSK	0.5	17.6	–4.07
2GFSK	2	9.8	–1.88
4GFSK	1	15	–1.81
4GFSK	0.5	19.2	–3.99
4GFSK	2	10.2	–0.97

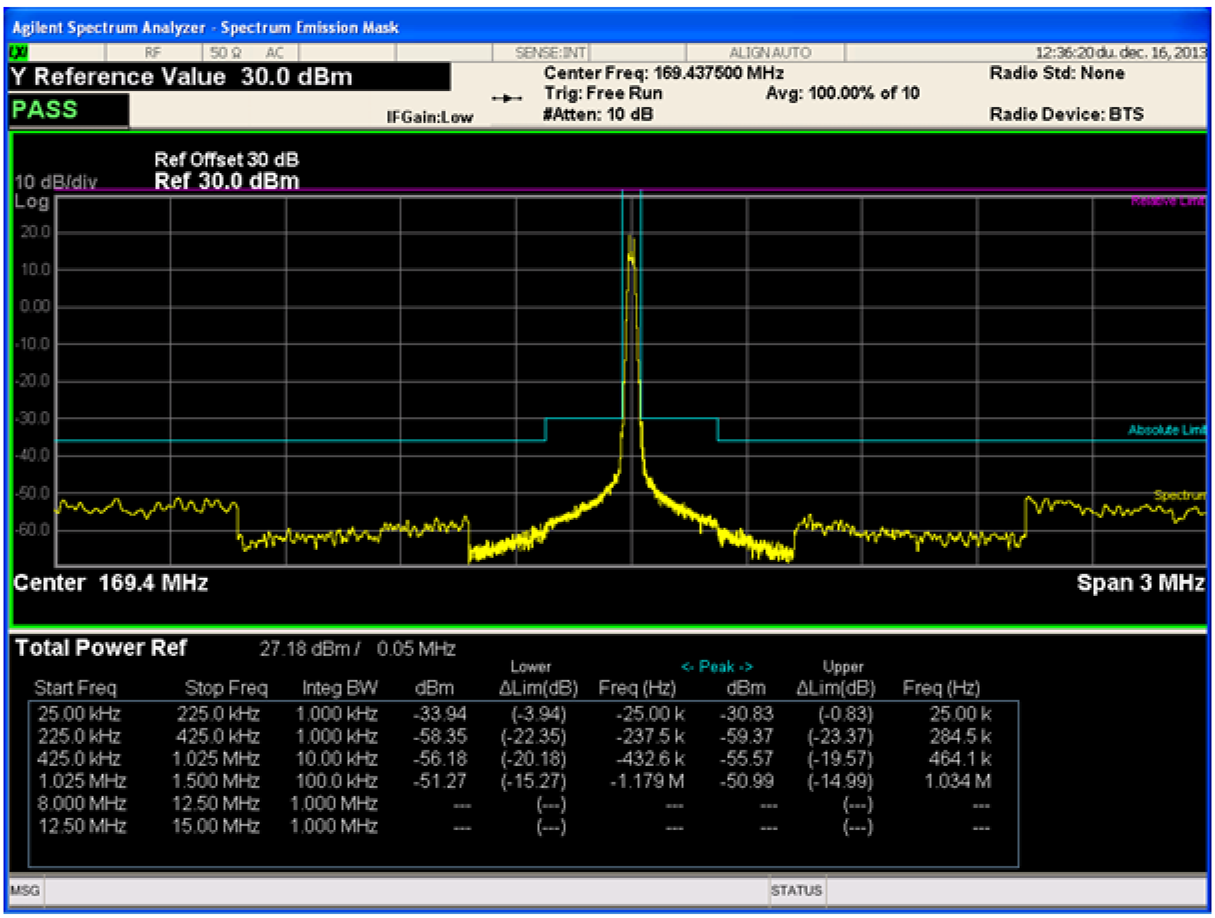


Figure 20. 4460_PCE27E169S Board MBW Mask Margin with 50 kHz Channel, Frequency: 169.4375 MHz, Output Power: 27 dBm, H=1, Data Rate=14 kbps

3.5.2. 434 MHz

3.5.2.1. 4460_PCE10D434

Table 13. 4460_PCE10D434 Board MBW Mask Margin with 100 kHz Channel, Frequency: 433.92 MHz, Output Power: 10 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	34	–1.79
2GFSK	0.5	52	–0.7
2GFSK	2	24.5	–4
4GFSK	1	42	–0.79
4GFSK	0.5	64	–0.68
4GFSK	2	28	–1.14

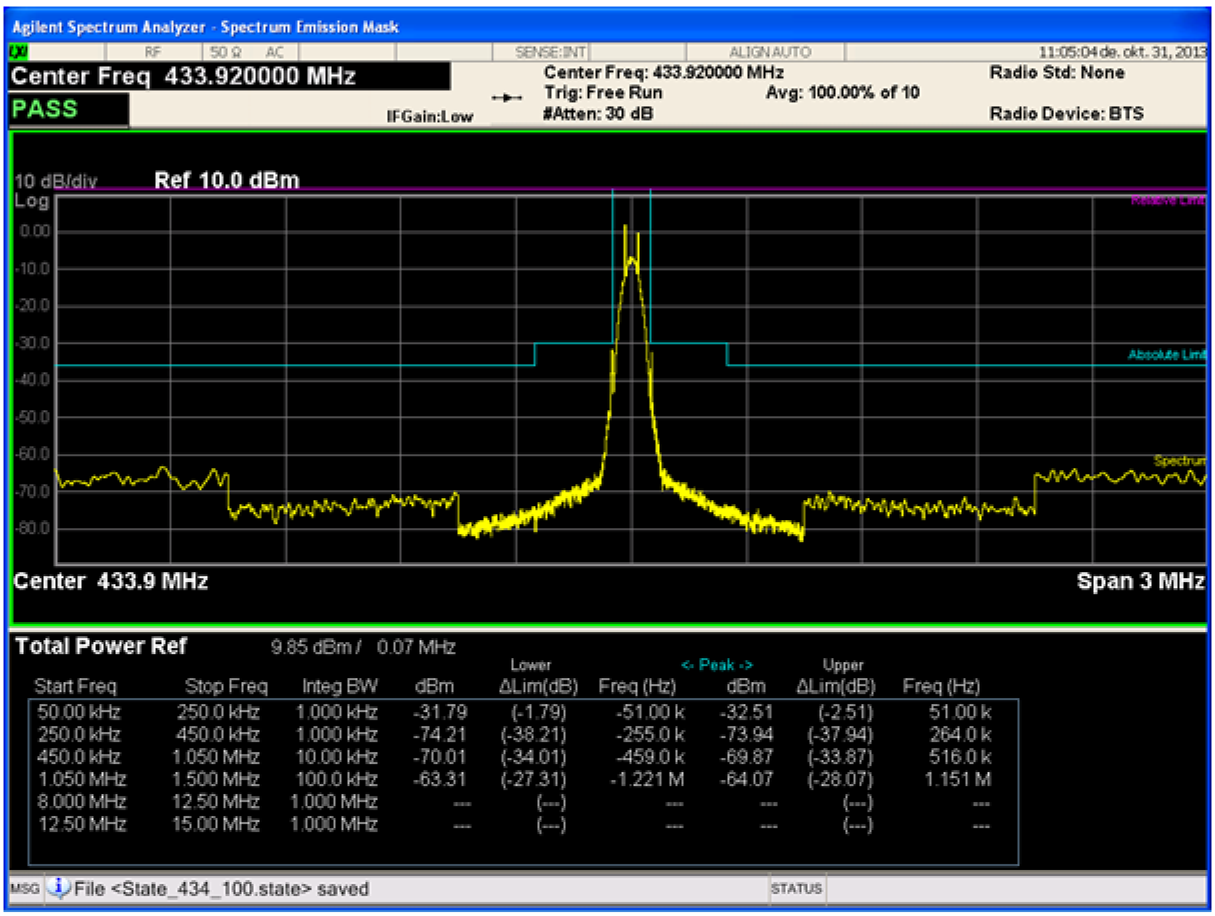


Figure 21. 4460_PCE10D434 Board MBW Mask Margin with 100 kHz Channel, Frequency: 433.92 MHz, Output Power: 10 dBm, H=1, Data Rate=34 kbps

Table 14. 4460_PCE10D434 Board MBW Mask Margin with 435 kHz Channel, Frequency: 433.92 MHz, Output Power: 10 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	208	–0.26
2GFSK	0.5	354	–0.61
2GFSK	2	108	–5.36
4GFSK	1	207	–1, 1
4GFSK	0.5	318	–1.43
4GFSK	2	123	–0.29

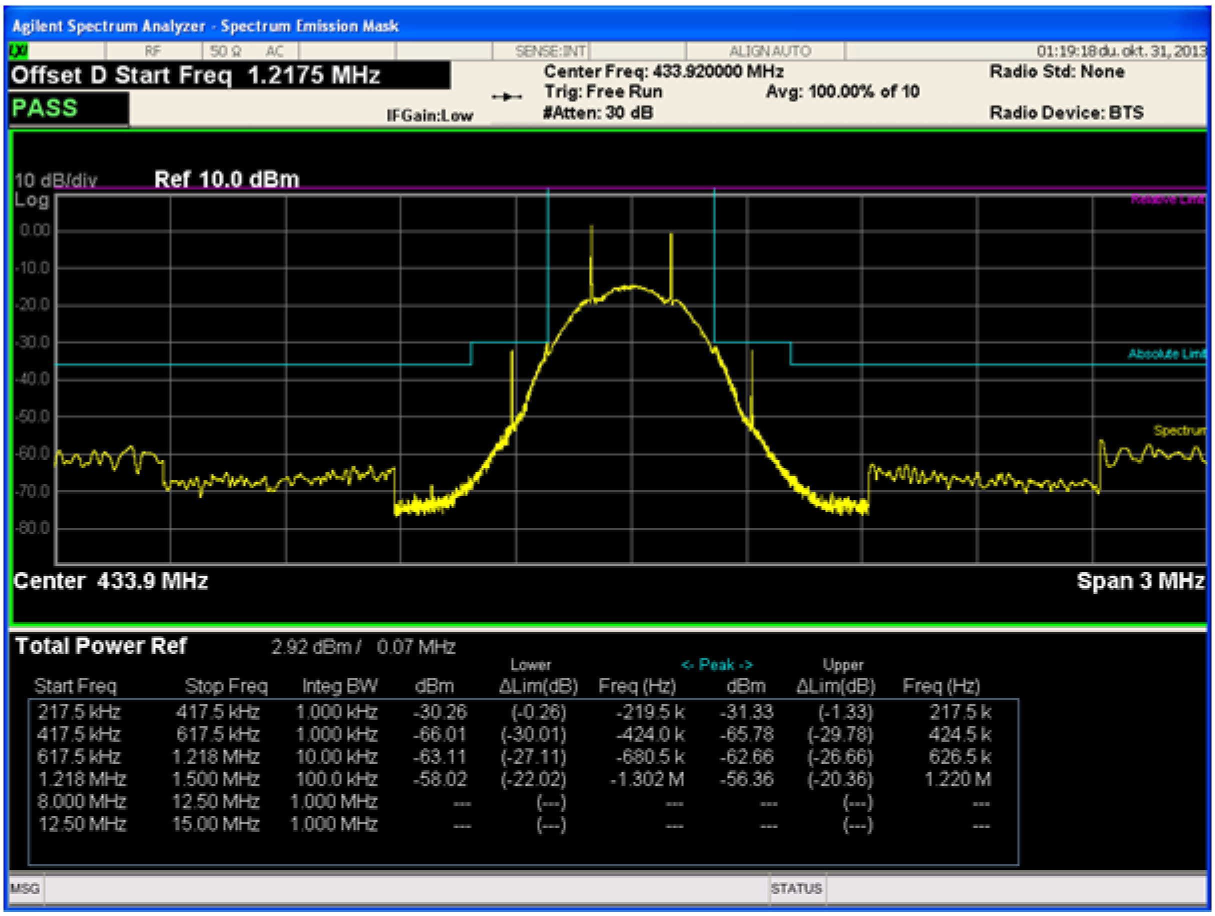


Figure 22. 4460_PCE10D434 Board MBW Mask Margin with 435 kHz Channel, Frequency: 433.92 MHz, Output Power: 10 dBm, H=1, Data Rate=208 kbps

3.5.2.2. Power Spectral Density

As can be seen from Table 1, there is an extra requirement in the frequency band from 433.050 MHz to 434.790 MHz with 1 mW max output power: For bandwidths greater than 250 kHz the power density is limited to –13 dBm/ 10 kHz.

Method of measurement:

At any given modulation conditions, the max output power was measured, where the power spectral density specification is still fulfilled. As on top of the PSD specification the modulation bandwidth spectral emission mask has to also pass, as a second step at the result of the previous measurement (at the minimum max output power over data rate), the max data rate was searched for, which still fulfills the limit of the modulation bandwidth. It is conceivable that the modulation bandwidth spectrum emission mask will put a tighter limit on the DR than the PSD specification. The channel spacing at the MBW mask measurement has been chosen to be 435 kHz as four such high speed channels can be fit into the frequency band.

Table 15. Step 1: Max PSD Restricted Output Power

Modulation	H	Symbol Rate (ksps)	PA Power Level	PSD Driven Max Output Power (dBm)
2GFSK	0.5	100	3	–6.40
2GFSK	0.5	200	5	–2.13
2GFSK	0.5	250	5	–2.13
2GFSK	0.5	500	5	–2.13
2GFSK	1	100	3	–6.40
2GFSK	1	200	3	–6.40
2GFSK	1	250	3	–6.40
2GFSK	1	500	3	–6.40
2GFSK	2	100	3	–6.40
2GFSK	2	200	3	–6.40
2GFSK	2	250	3	–6.40
2GFSK	2	500	3	–6.40
4GFSK	0.5	100	2	–9.93
4GFSK	0.5	200	3	–6.40
4GFSK	0.5	250	3	–6.40
4GFSK	1	100	4	–4.07
4GFSK	1	200	5	–2.13
4GFSK	1	250	5	–2.13

Table 15. Step 1: Max PSD Restricted Output Power (Continued)

Modulation	H	Symbol Rate (ksps)	PA Power Level	PSD Driven Max Output Power (dBm)
4GFSK	2	100	6	–0.59
4GFSK	2	200	8	1.59
4GFSK	2	250	8	1.59

Table 16. Step 2: Max MBW Restricted DR

Modulation	H	PA Power Level	PSD Driven Min Max Output Power (dBm)	MBW Mask Driven Max DR (ksps)
2GFSK	0.5	3	–6.40	500
2GFSK	1	3	–6.40	430
2GFSK	2	3	–6.40	185
4GFSK	0.5	2	–9.93	500
4GFSK	1	4	–4.07	312
4GFSK	2	6	–0.59	165

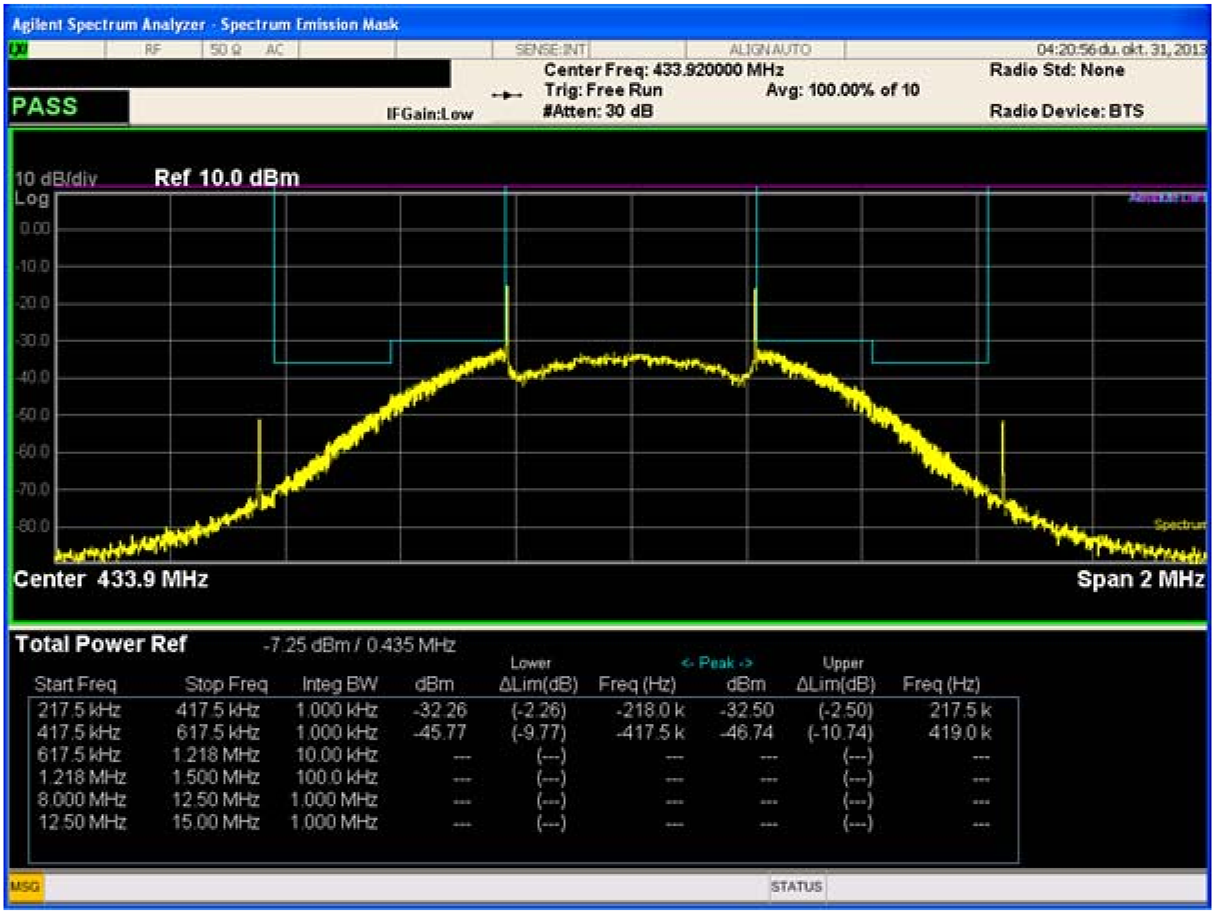


Figure 23. 4460_PCE10D434 Board MBW Mask Margin with 435 kHz Channel, Frequency: 433.92 MHz, PA Power Level: 0x03, H=1, Data Rate=430 kbps, Output Power=–6.4 dBm

At modulation indices 1 and 2 the discrete spectral components are prone to violating the spectrum emission mask, therefore the maximum output power is more limited by the MBW specification. For example, while at 2GFSK H=1 at –6.4 dBm the PSD specification is met in the whole DR range from 100 kbps to 500 kbps, the MBW spectrum emission mask only allows a maximum data rate of 430 kbps. At modulation index 0.5 where the discrete spectral components are suppressed the PSD specification is the stricter limiting factor.

3.5.3. 868 MHz

3.5.3.1. 4060_PCE10B868

Table 17. 4460_PCE10B868 Board MBW Mask Margin with 50 kHz Channel, Frequency: 868 MHz, Output Power: 10 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	19	–0.9
2GFSK	0.5	23.2	–1.29
2GFSK	2	11.7	–2.2
4GFSK	1	19.2	–0.98
4GFSK	0.5	24	–2.05
4GFSK	2	12.6	–0.61

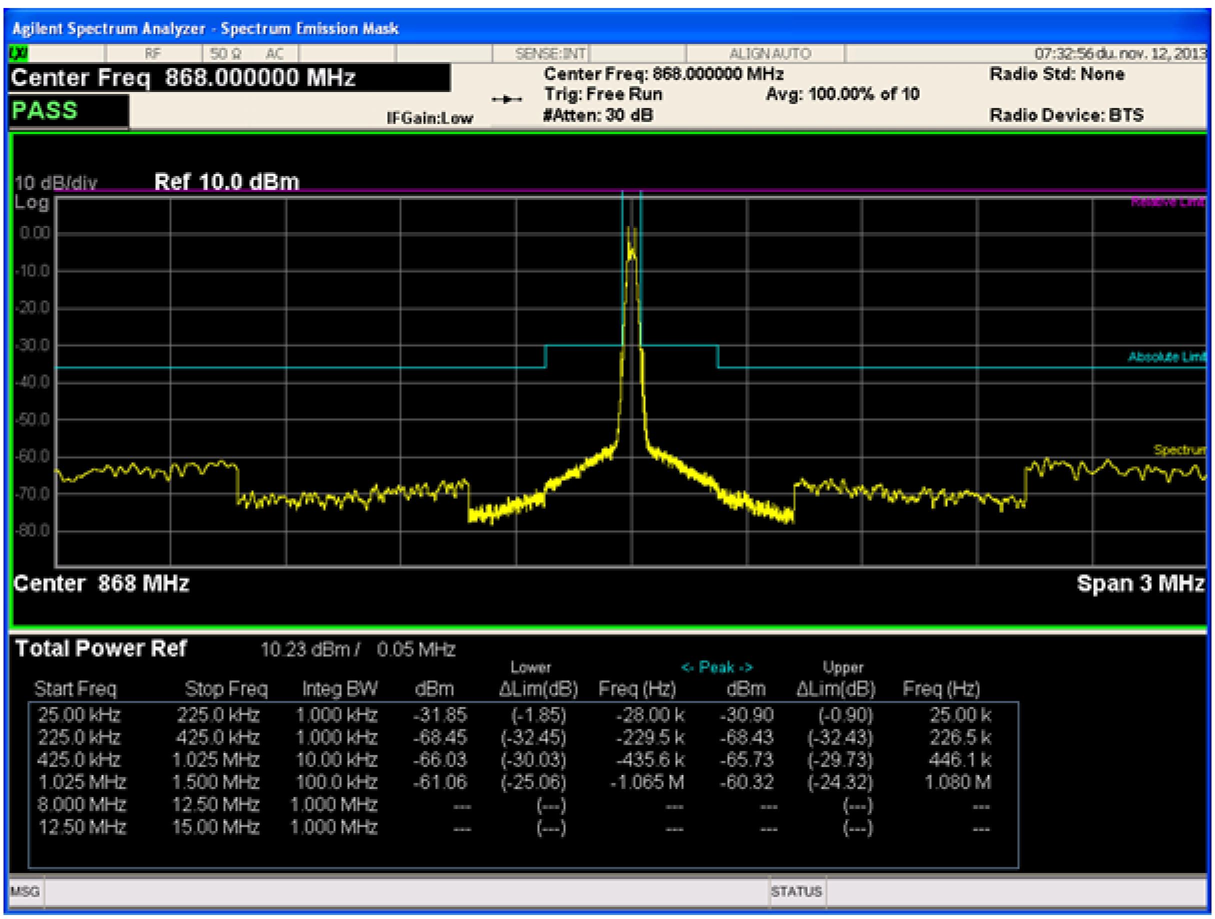


Figure 24. 4060_PCE10B868 Board MBW Mask Margin with 50 kHz Channel, Frequency: 868 MHz, Output Power: 10 dBm, H=1, Data Rate=19 kbps

Table 18. 4060_PCE10B868 Board MBW Mask Margin with 100 kHz Channel, Frequency: 868 MHz, Output Power: 10 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	36	–0.18
2GFSK	0.5	48	–1.44
2GFSK	2	24.2	–2.89
4GFSK	1	39.6	–0.94
4GFSK	0.5	50.4	–0.12
4GFSK	2	27	–0.1

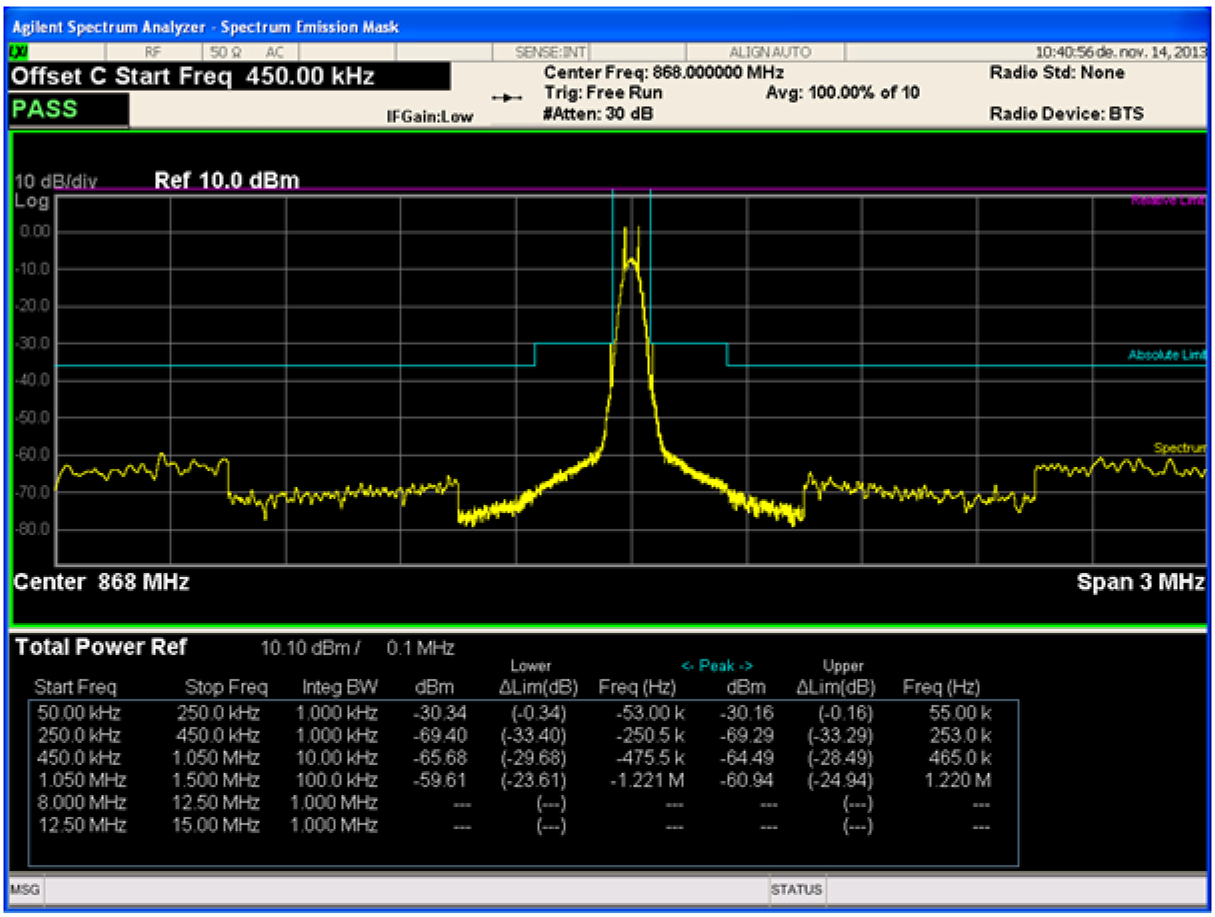


Figure 25. 4060_PCE10B868 Board MBW Mask Margin with 100 kHz Channel, Frequency: 868 MHz, Output Power: 10 dBm, H=1, Data Rate=36 kbps

3.5.3.2. 4461_PCE14D868

Table 19. 4461_PCE14DB868 Board MBW Mask Margin with 100 kHz Channel, Frequency: 868 MHz, Output Power: 14 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	32.6	–4.06
2GFSK	0.5	45	–2.13
2GFSK	2	24	–4.85
4GFSK	1	37.2	–1.18
4GFSK	0.5	48	–0.63
4GFSK	2	24	–3.85

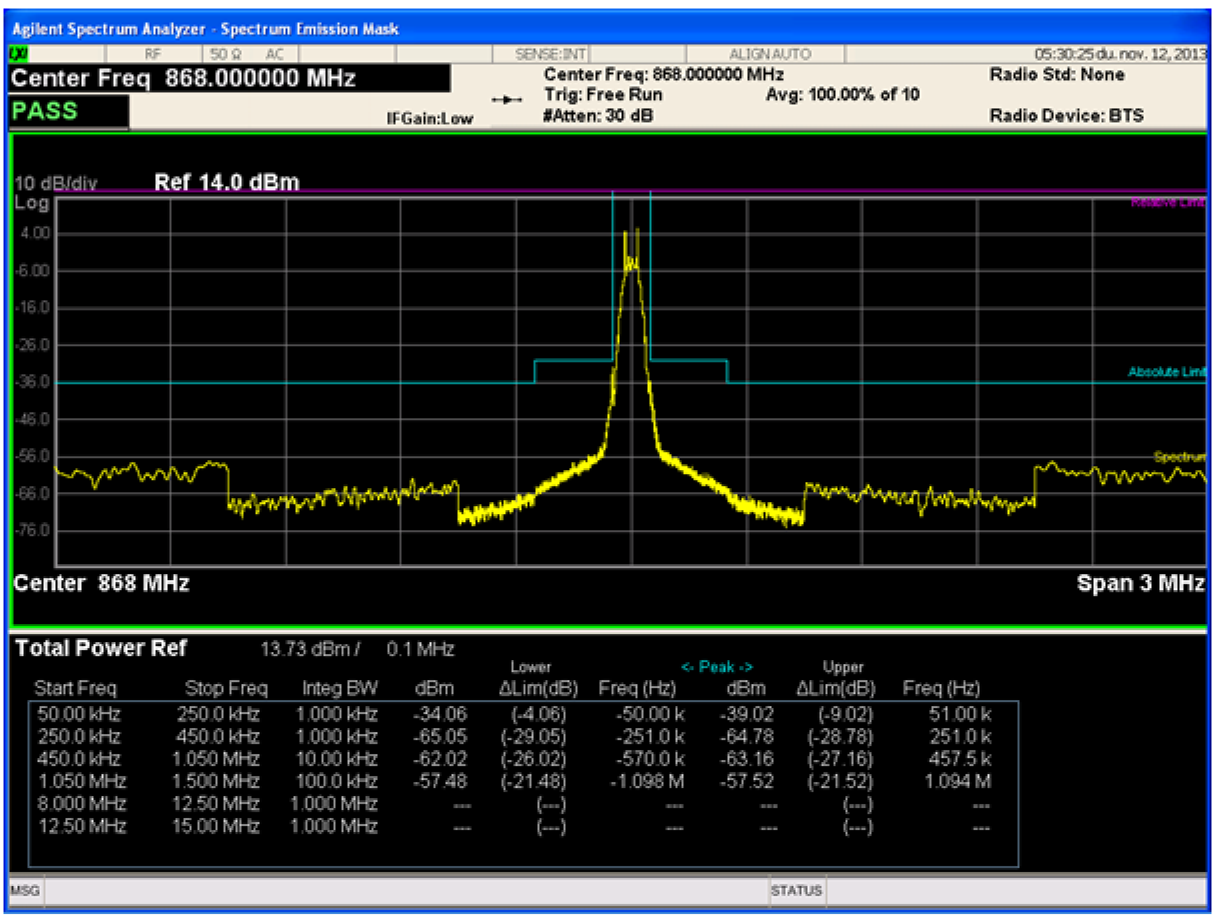


Figure 26. 4461_PCE14D868 Board MBW Mask Margin with 100 kHz Channel, Frequency: 868 kHz, PA Power Level: 0x26, Output Power: 14 dBm, H=1, Data Rate=32.6 kbps

Table 20. 4461_PCE14D868 Board MBW Mask Margin with 300 kHz Channel, Frequency: 868 MHz, PA Power Level: 0x26, Output Power: 14 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	99	–10.61
2GFSK	0.5	154	–0.46
2GFSK	2	74	–1.95
4GFSK	1	114	–1.92
4GFSK	0.5	186	–0.85
4GFSK	2	75	–0.3

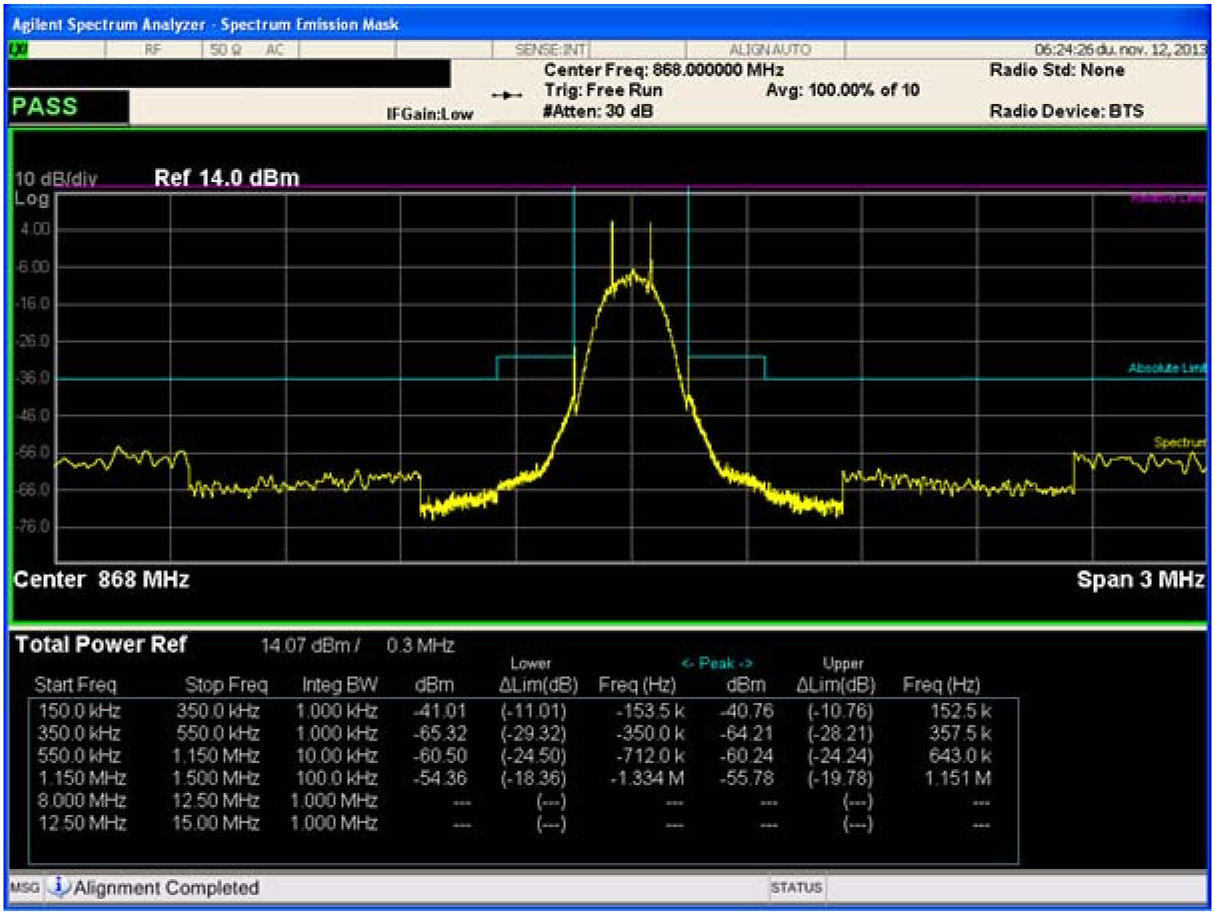


Figure 27. 4461_PCE14D868 Board MBW Mask Margin with 300 kHz Channel, Frequency: 868 MHz, PA Power Level: 0x26, Output Power: 14 dBm, H=1, Data Rate=99 kbps

3.5.3.3. 4463_PCE27F868

Table 21. 4463_PCE27FB868 Board MBW Mask Margin with 250 kHz Channel, Frequency: 869.525 MHz, Output Power: 27 dBm

Modulation	H	Max Symbol Rate (ksps)	ΔLim (dB)
2GFSK	1	72	–0.58
2GFSK	0.5	100	–0.72
2GFSK	2	48	–1.19
4GFSK	1	74.4	–0.83
4GFSK	0.5	103.2	–1.49
4GFSK	2	50.1	–1.73

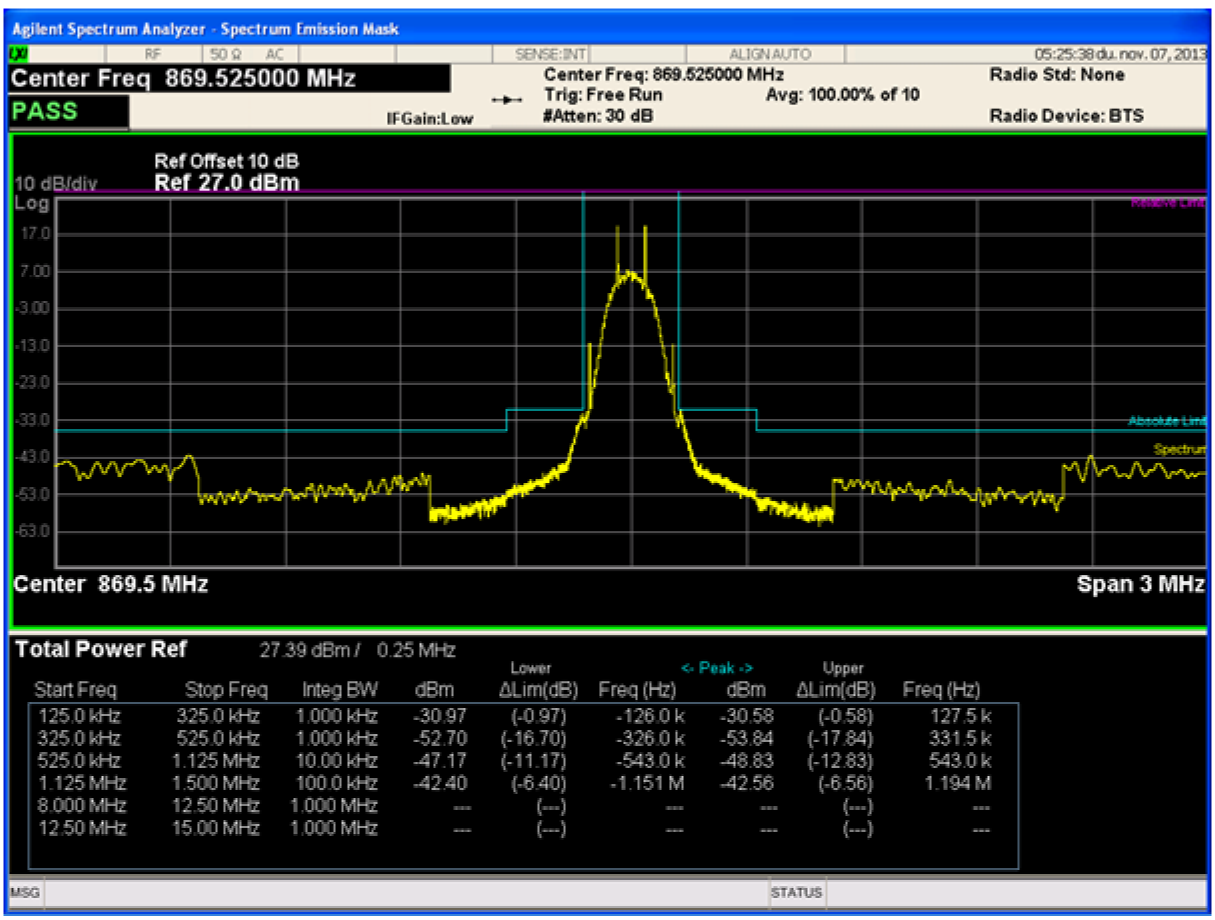


Figure 28. 4463_PCE27F868 Board MBW Mask Margin with 250 kHz Channel, Frequency: 869.525 MHz, Output Power: 27 dBm, H=1, Data Rate=72 kbps

3.5.3.4. Power Spectral Density

As can be seen from Table 1, there is an extra requirement at the frequency band from 863 MHz to 870 MHz with 25 mW max output power: Power spectral density is limited to –4.5 dBm/100 kHz.

Method of the measurement:

At any given modulation condition, the max output power was measured, where the power spectral density specification is still fulfilled.

Table 22. 4461_PCE14F868 Max PSD Driven Output Power

Modulation	H	DR (ksps)	PA Power Level	PSD Driven Max Output Power (dBm)
2GFSK	0.5	100	4	–5.88
2GFSK	0.5	200	5	–3.68
2GFSK	0.5	250	6	–1.9
2GFSK	1	100	5	–3.68
2GFSK	1	200	7	–0.45
2GFSK	1	250	7	–0.45
2GFSK	2	100	6	–1.9
2GFSK	2	200	7	–0.45
2GFSK	2	250	8	0.84
4GFSK	0.5	100	4	–5.88
4GFSK	0.5	200	5	–3.68
4GFSK	0.5	250	5	–3.68
4GFSK	1	100	5	–3.68
4GFSK	1	200	6	–1.9
4GFSK	1	250	6	–1.9
4GFSK	2	100	6	–1.9
4GFSK	2	200	8	0.84
4GFSK	2	250	9	1.93

Note: At lower PA power level codes, the power steps are quite coarse. That is the reason that at some modulation formats (i.e., 2GFSK H=0.5 100 kbps) the overall output power remains below the PSD limit. One code higher PA power level would have violated the limit at these cases.

Note: If only a subset of the frequency band is used, the PSD specification is relaxed in the following way:

Band Start (MHz)	Band Stop (MHz)	PSD Spec (dBm/100 kHz)
865	868	6.2
865	870	–0.8

These relaxations allow for the implementation of high speed channels at relatively high output power levels (~10 dBm) in the band. Maximum output power limits and MBW spectral emission mask elaborations are not included in this section. However, the general statement in section 3.5.2.2 holds here too.

3.6. Unwanted Emissions in the Spurious Domain

Spurious emissions are unwanted emissions in the spurious domain and are emissions at frequencies other than those of the wanted carrier frequency and its sidebands associated with normal test modulations.

In the case of adjacent frequency bands where a device simultaneously meets the requirements of each band in all respects apart from operating frequency, the frequency bands shall be treated as one single band.

The allowed emissions in the spurious domain are shown in Figure 29. A critical restriction is the –54 dBm limit below 862 MHz.

There are two different measurements presented on each pico board and power level. One of them is measuring the harmonics and the other one is measuring the reference spurs (the spurs that appear at an offset of the reference frequency from the center frequency).

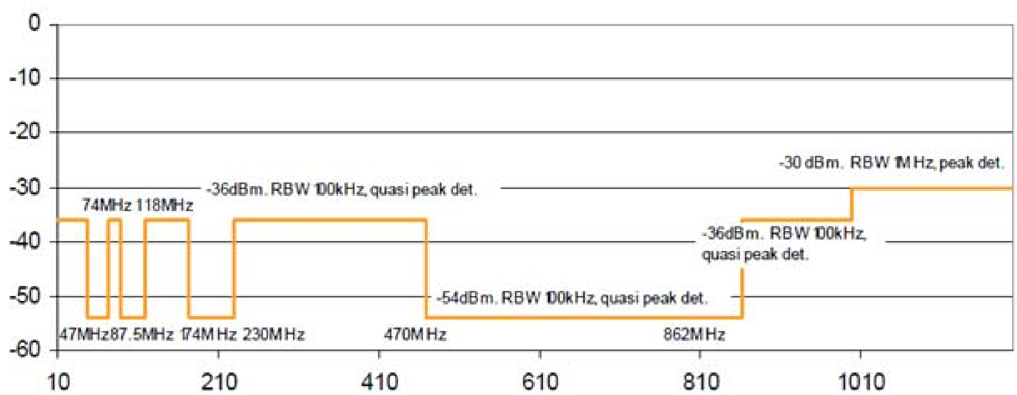


Figure 29. ETSI Spurious Radiation Limits

3.6.1. 169 MHz

3.6.1.1. 4063_PSQ20B169

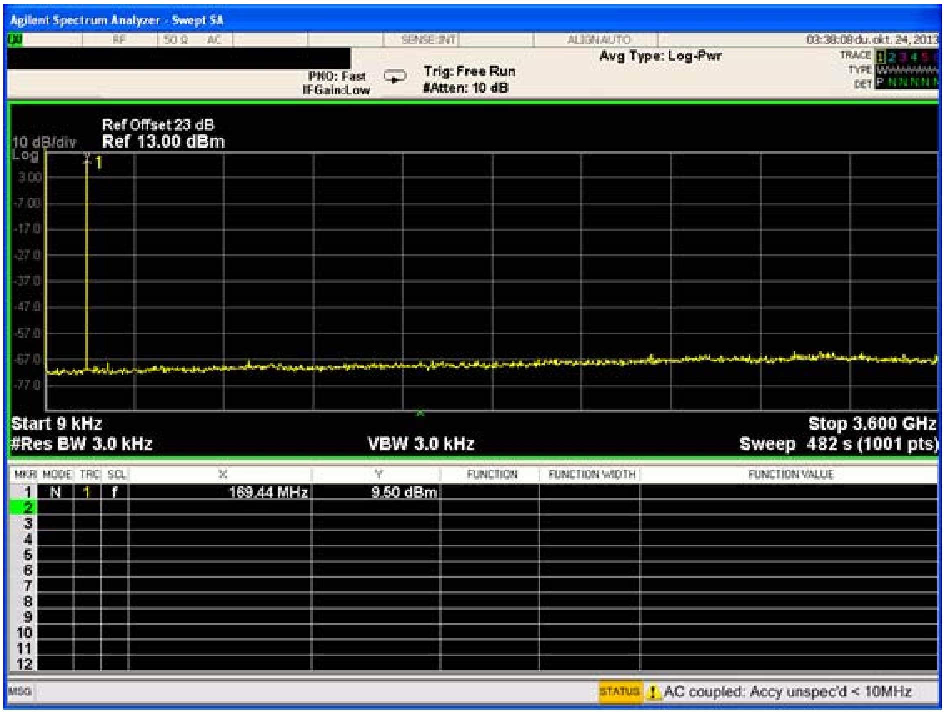


Figure 30. 4063_PSQ20B169 Board Output Power: 10 dBm

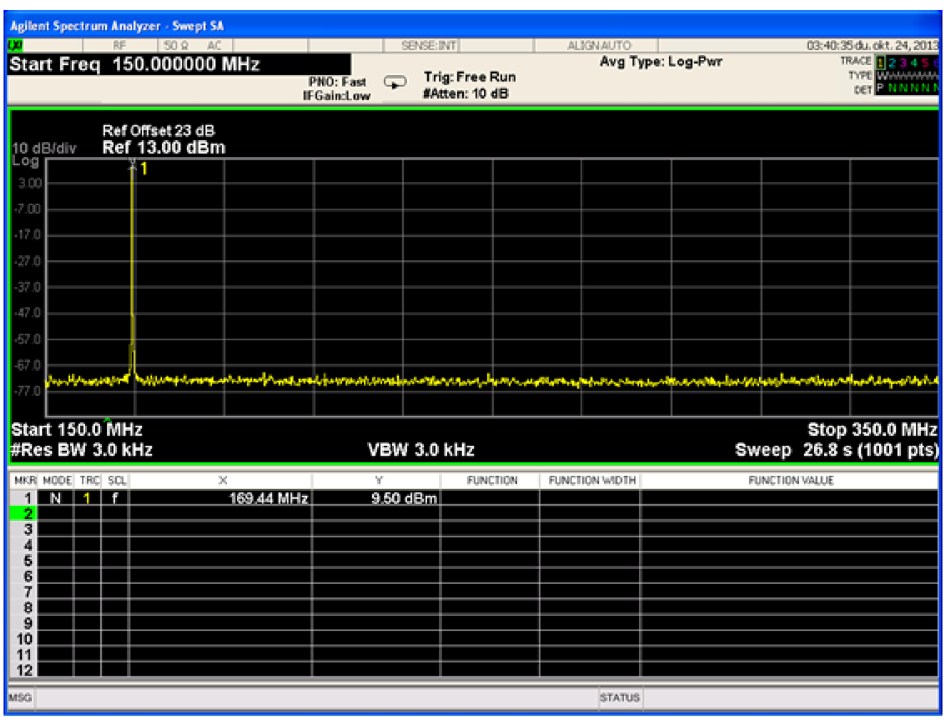


Figure 31. 4063_PSQ20B169 Board Output Power: 10 dBm

As can be seen from the figures, this board meets the required standard.

3.6.1.2. 4460_PCE27E169S

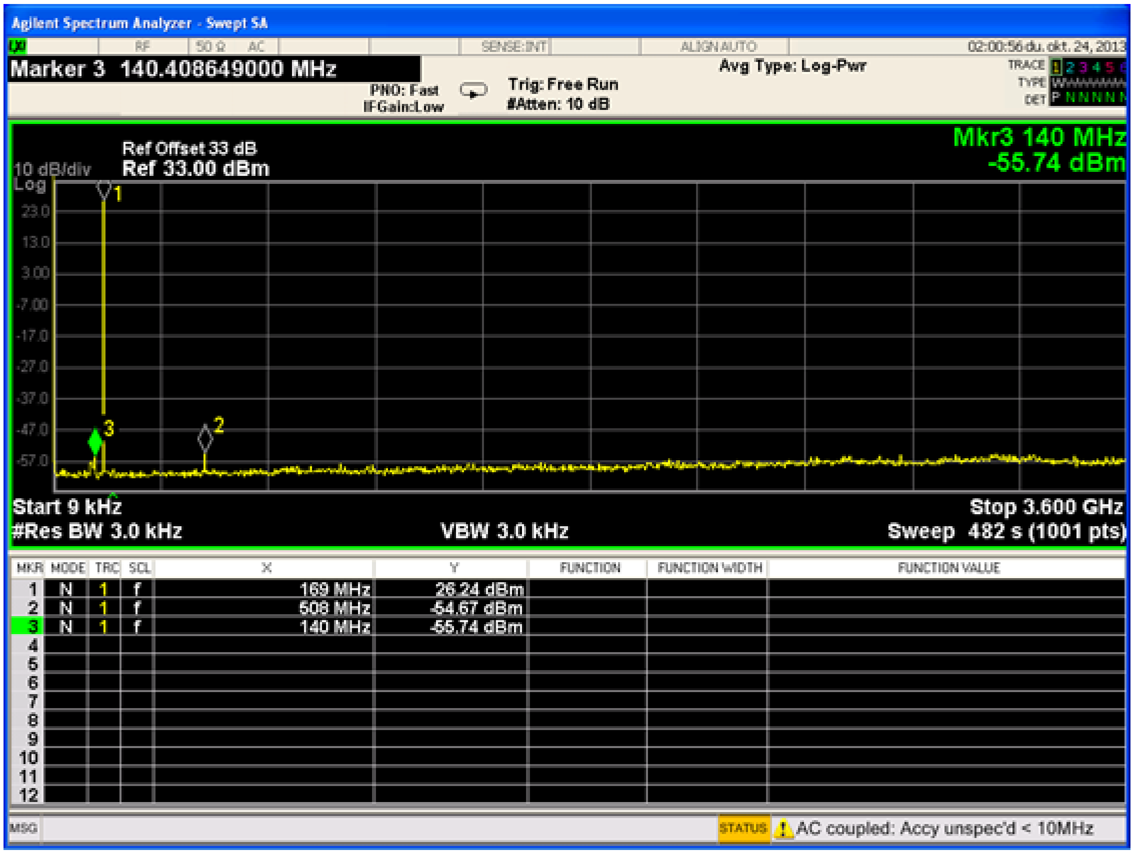


Figure 32. 4460_PCE27E169S Board Output Power: 27 dBm

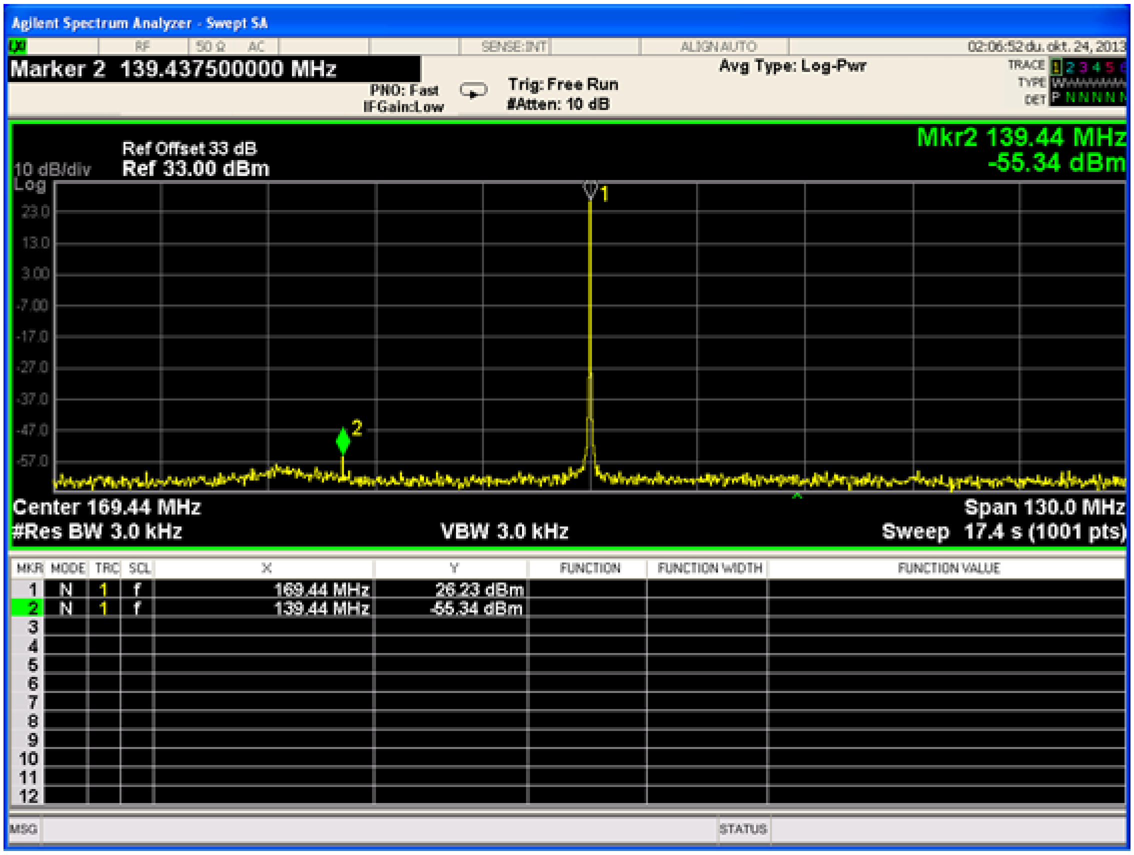


Figure 33. 4460_PCE27E169S Board Output Power: 27 dBm

As can be seen from the figures, this board meets the required standard.

3.6.1.3. 4463_PSQ27F169

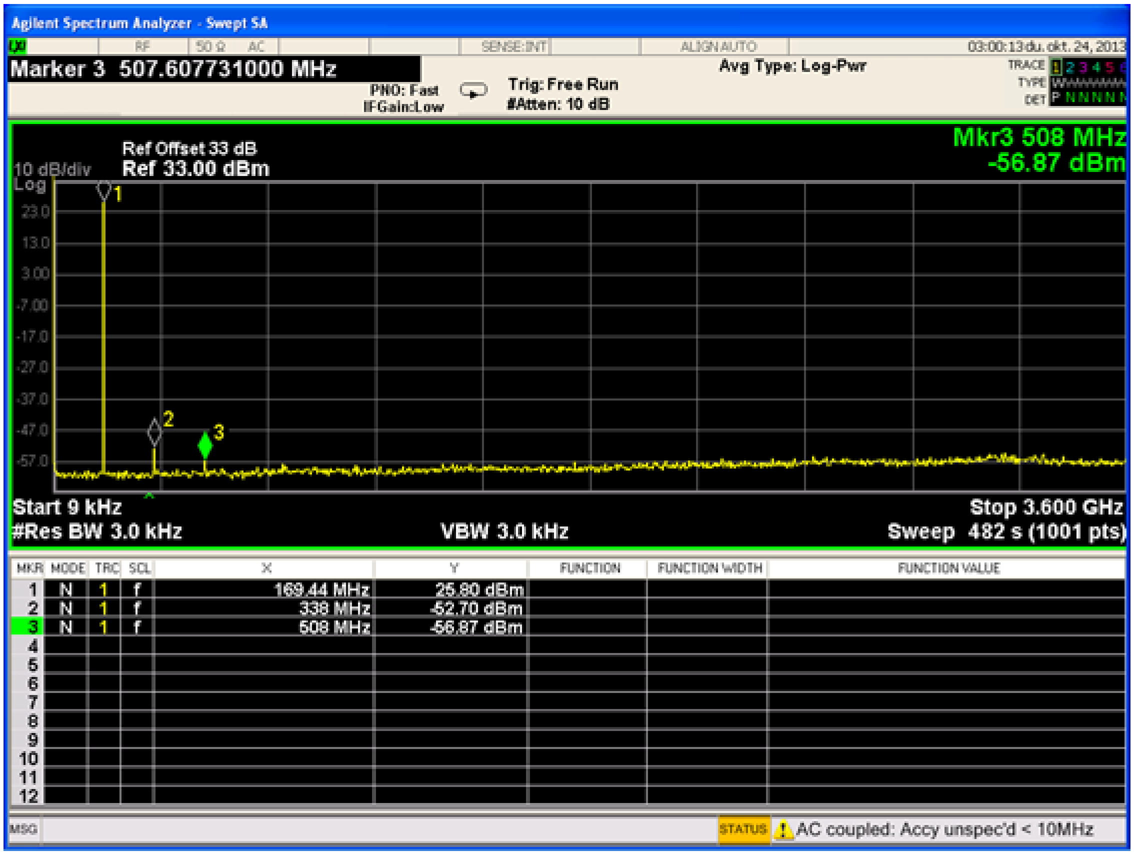


Figure 34. 4463_PSQ27F169 Board Output Power: 27 dBm

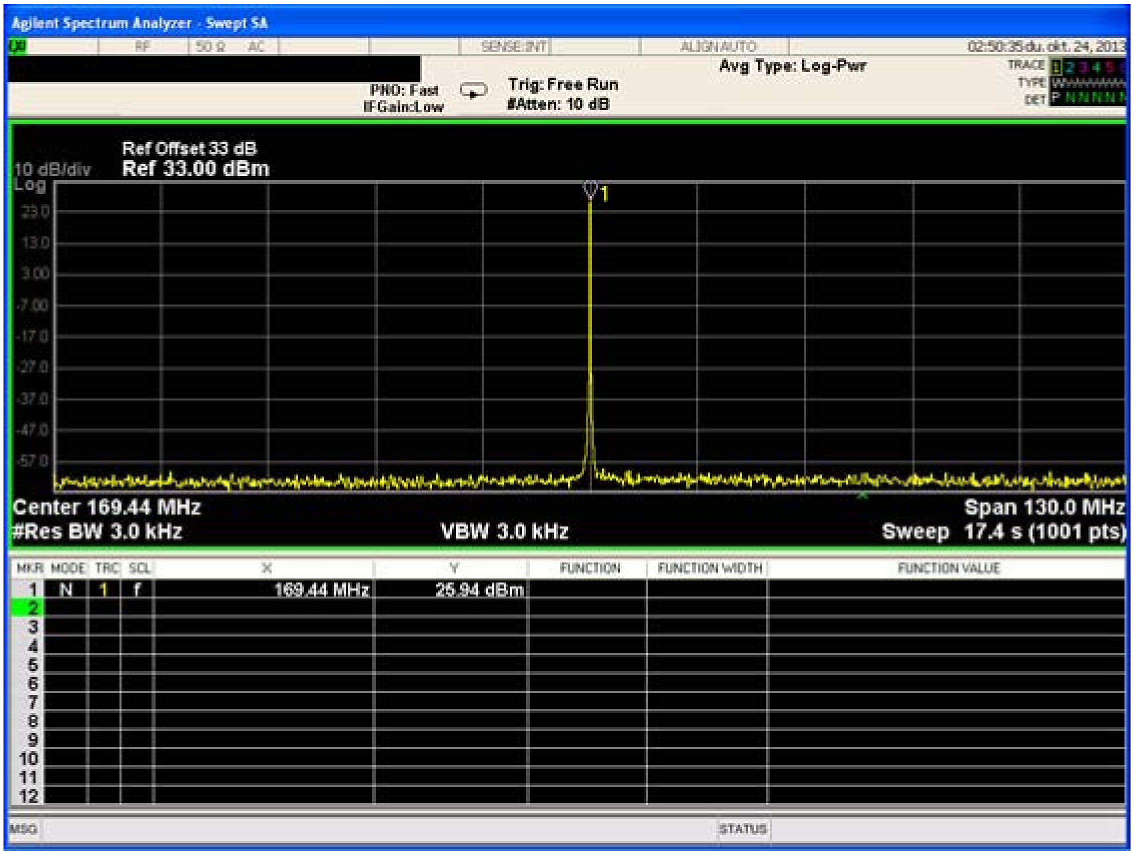


Figure 35. 4463_PSQ27F169 Board Output Power: 27 dBm

As can be seen from the figures, this board meets the required standard.

3.6.2. 434 MHz

3.6.2.1. 4460_PCE10D434

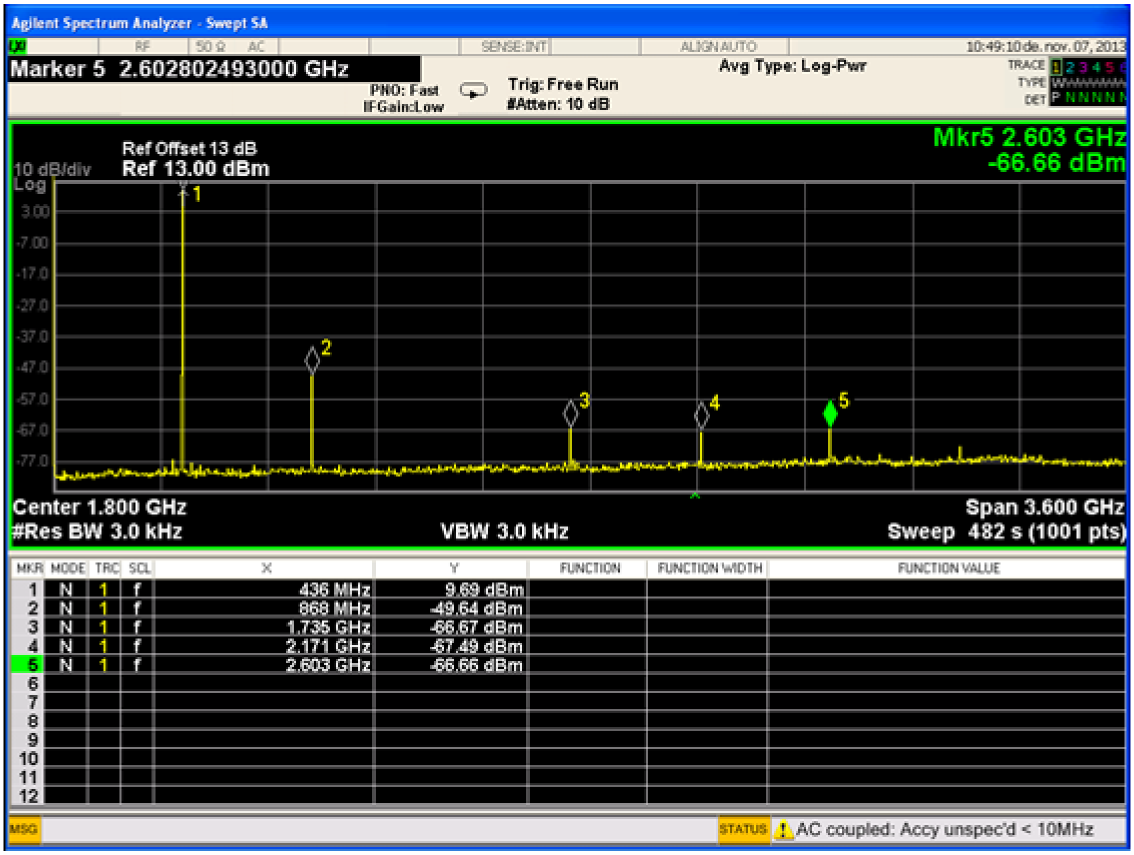


Figure 36. 4460_PCE10D434 Board Output Power: 10 dBm

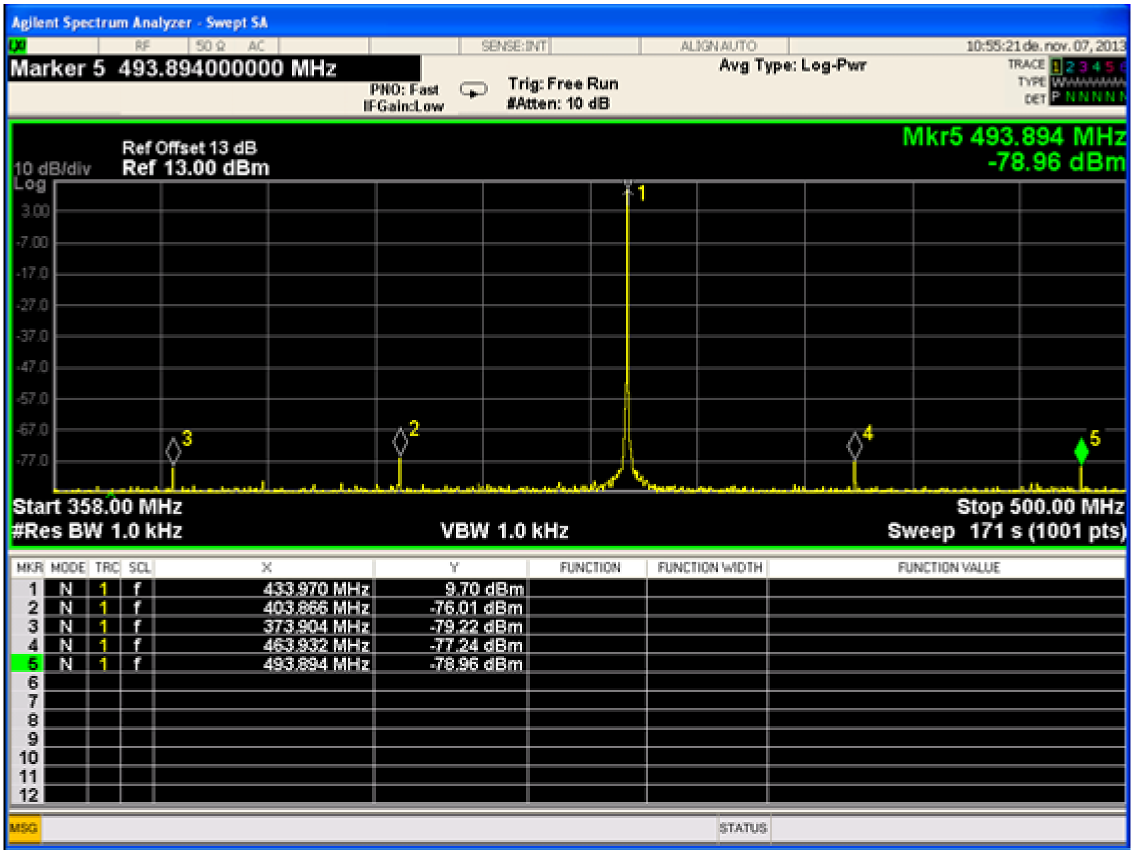


Figure 37. 4460_PCE10D434 Board Output Power: 10 dBm

As can be seen from the figures, this board meets the required standard.

3.6.3. 868 MHz

3.6.3.1. 4060_PCE10B868

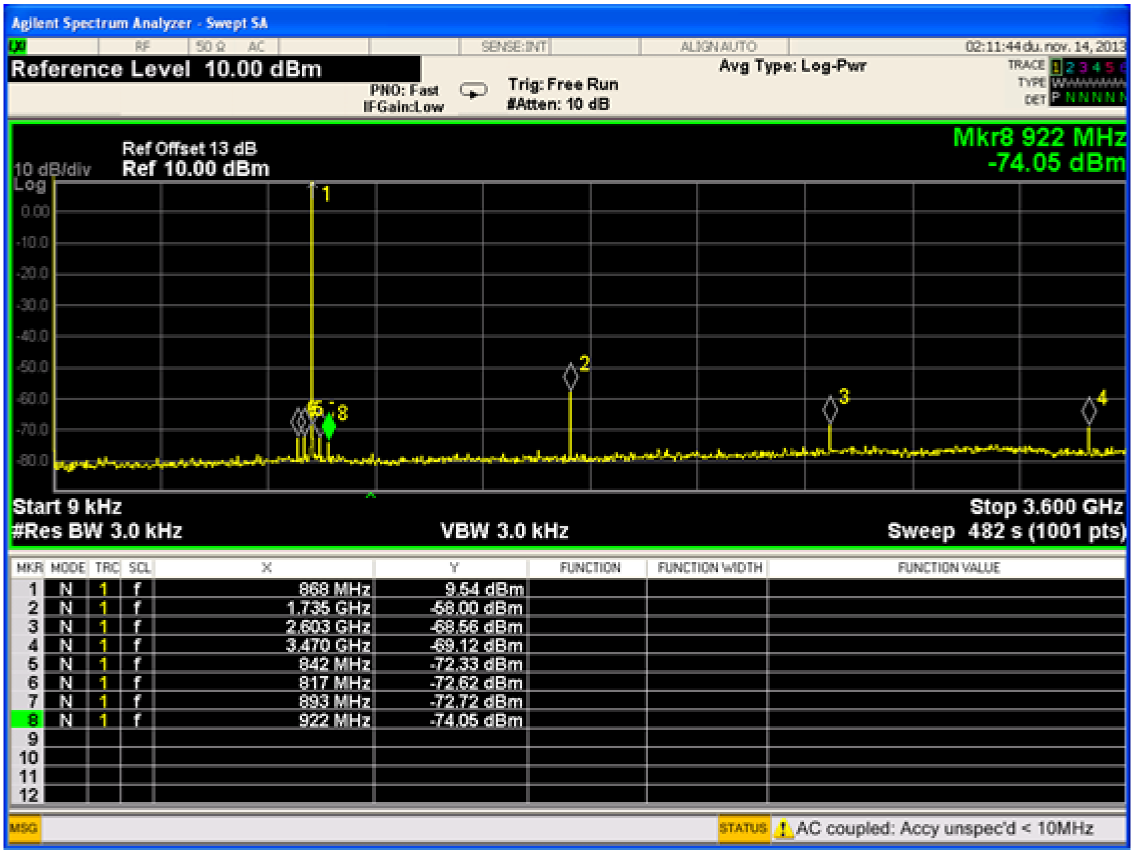


Figure 38. 4060_PCE10B868 Board Output Power: 10 dBm

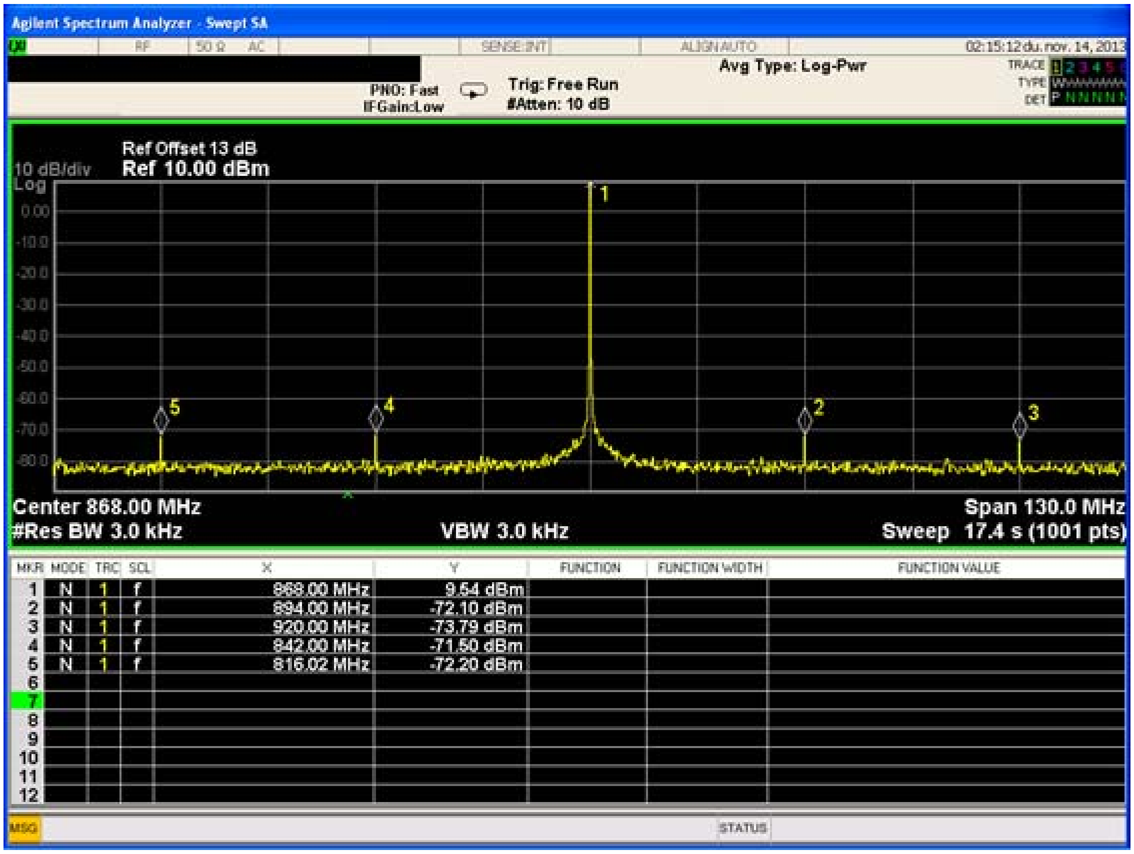


Figure 39. 4060_PCE10B868 Board Output Power: 10 dBm

As can be seen from the figures, this board meets the required standard.

3.6.3.2. 4461_PCE14D868

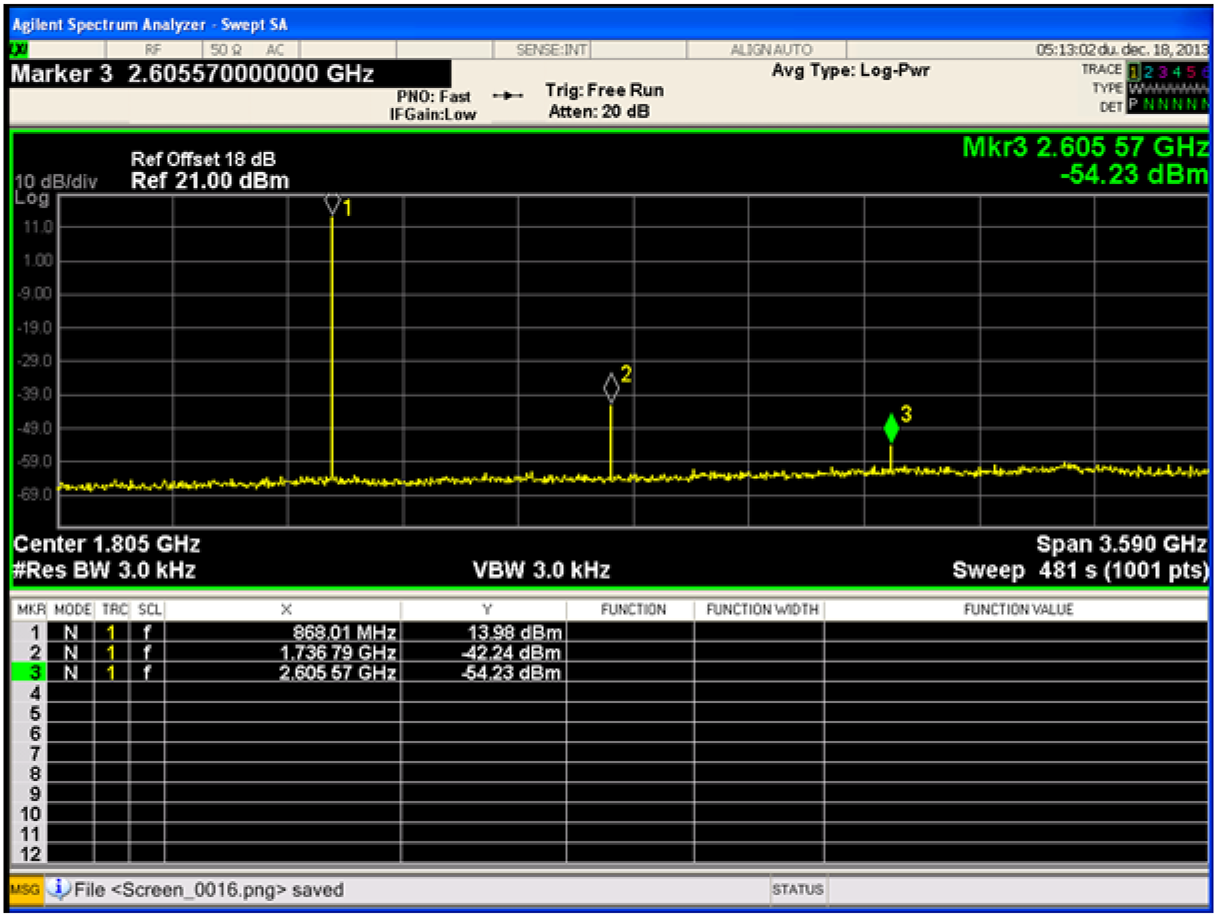


Figure 40. 4461_PCE14D868 Board Output Power: 14 dBm

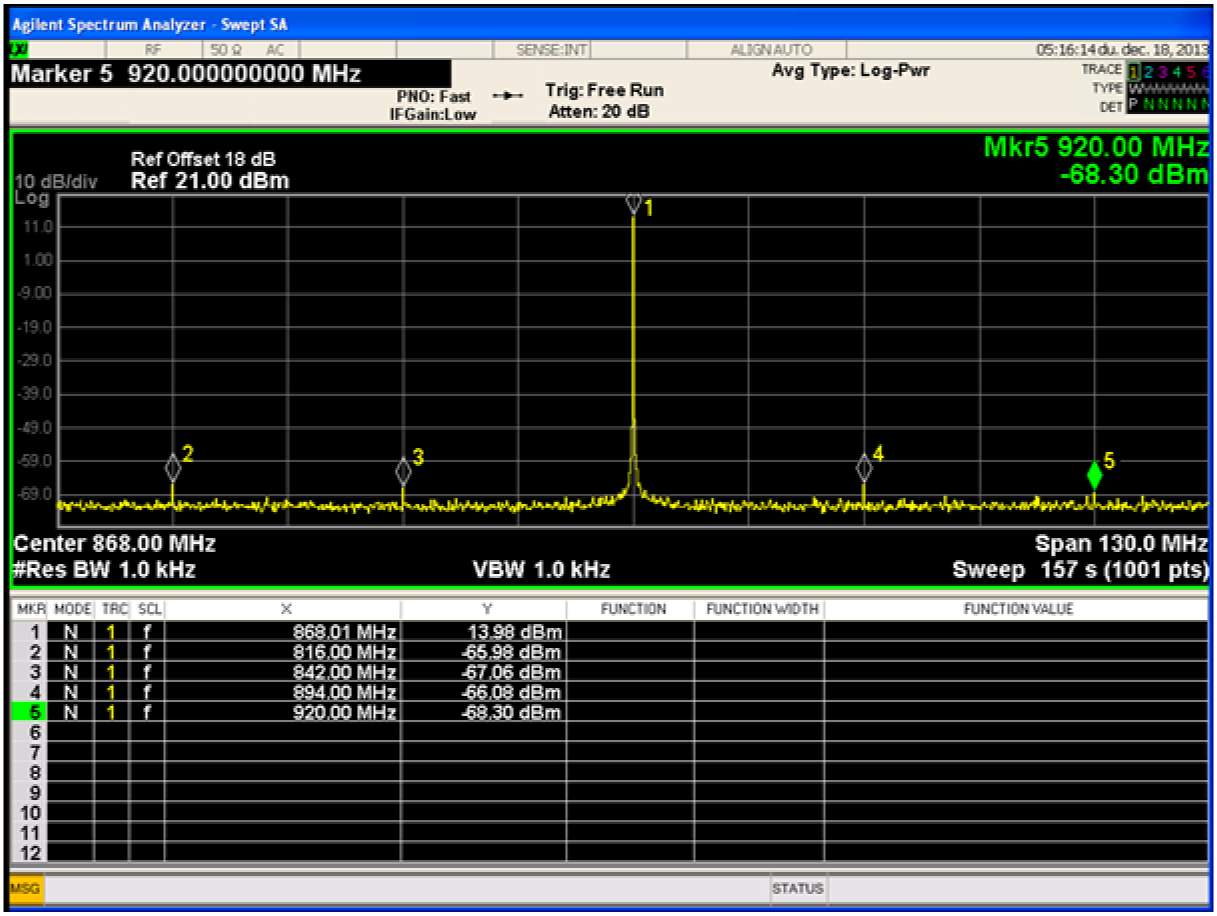


Figure 41. 4461_PCE14D868 Board Output Power: 14 dBm

As can be seen from the figures, this board meets the required standard.

3.6.3.3. 4463_PCE27F868

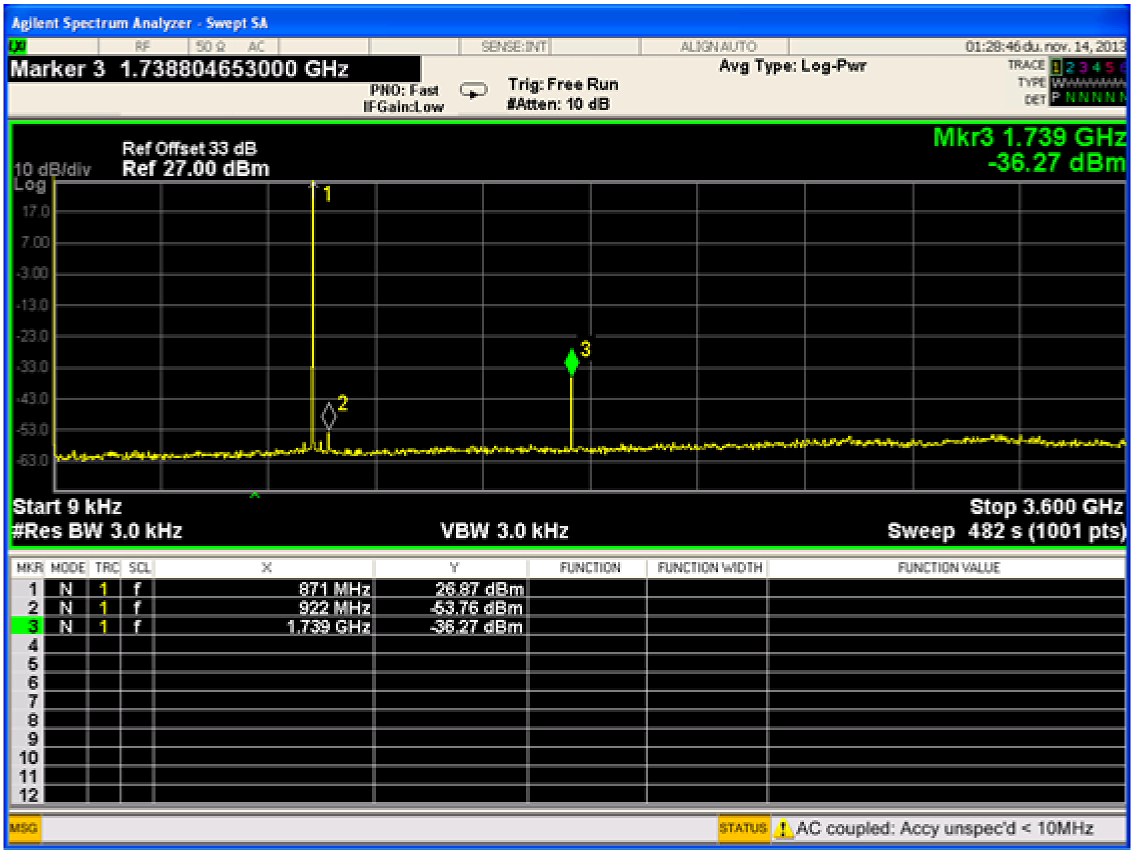


Figure 42. 4463_PCE27F868 Board Output Power: 27 dBm

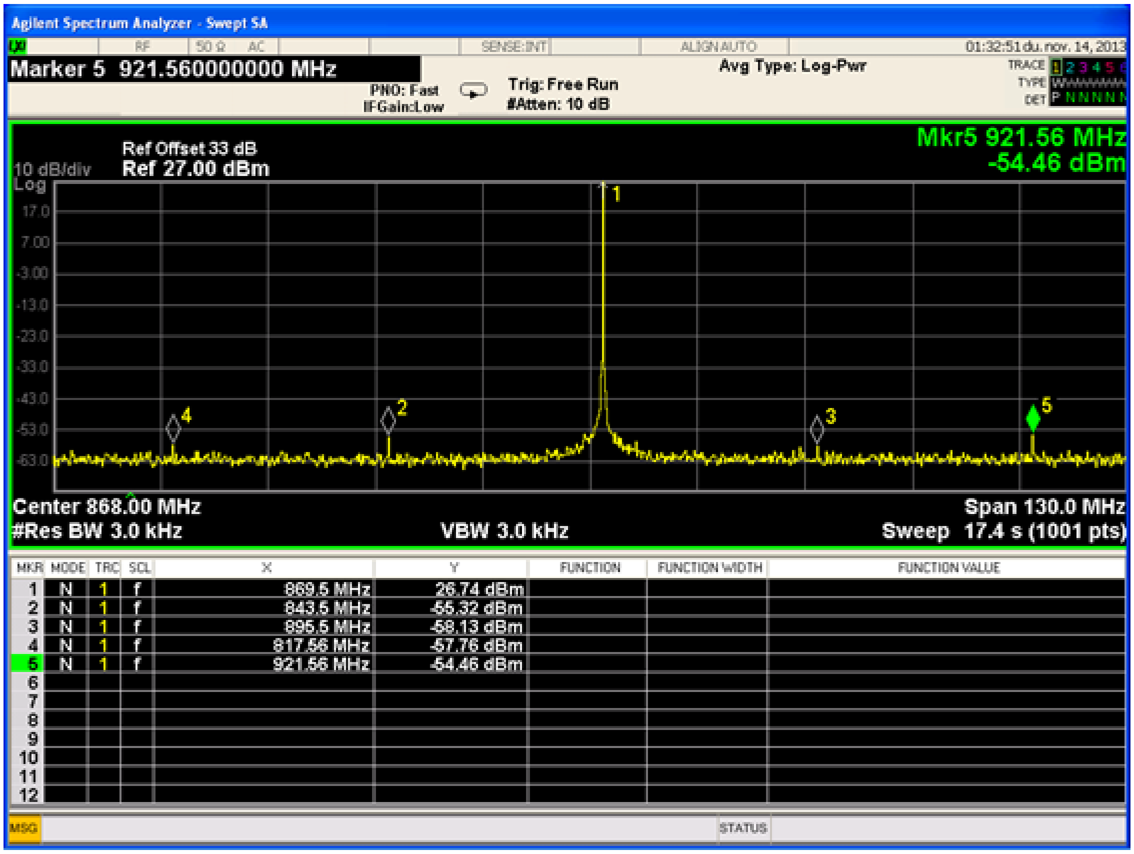


Figure 43. 4463_PCE27F868 Board Output Power: 27 dBm

As can be seen from the figures, this board meets the required standard.

3.6.3.4. 4463_PCE20C868SE

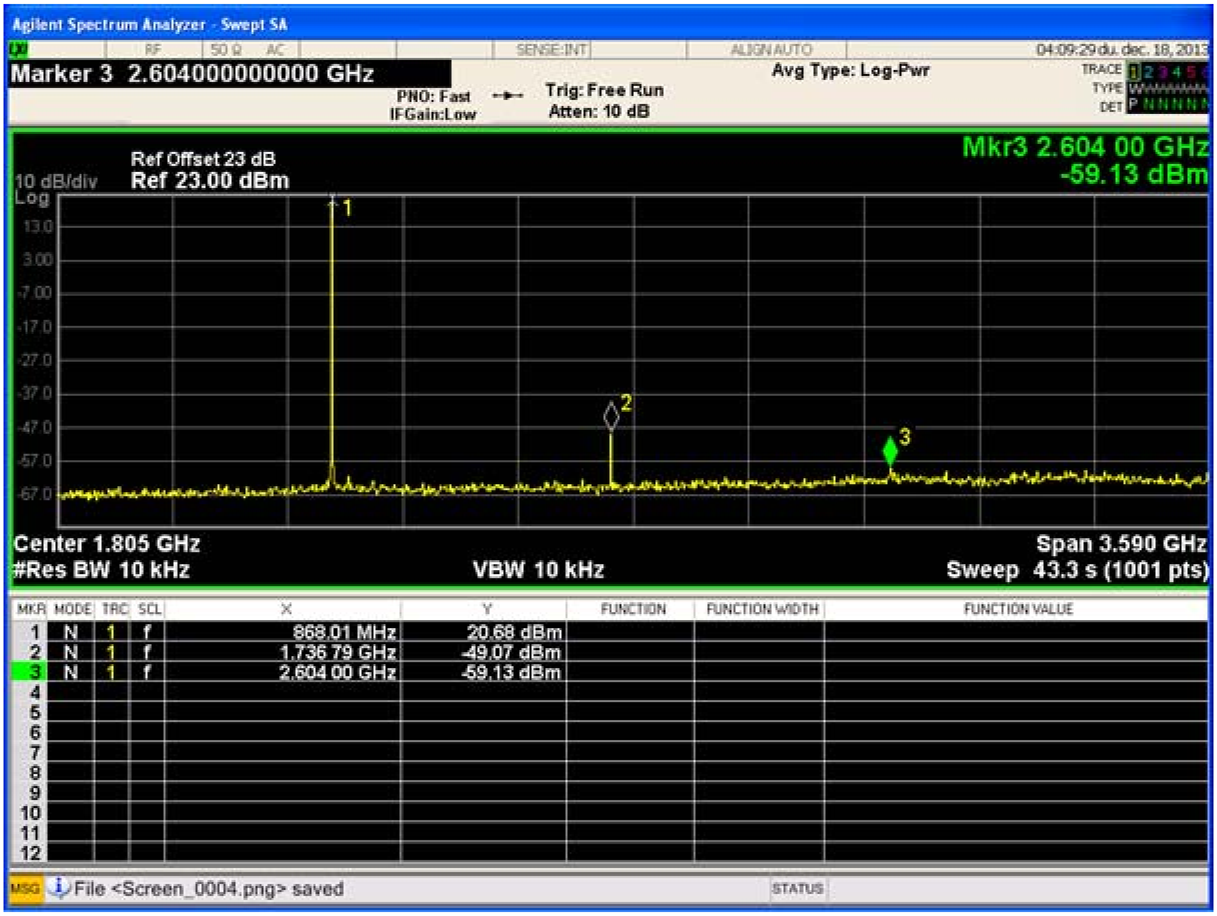


Figure 44. 4463_PCE20C868SE Board Output Power: 20 dBm

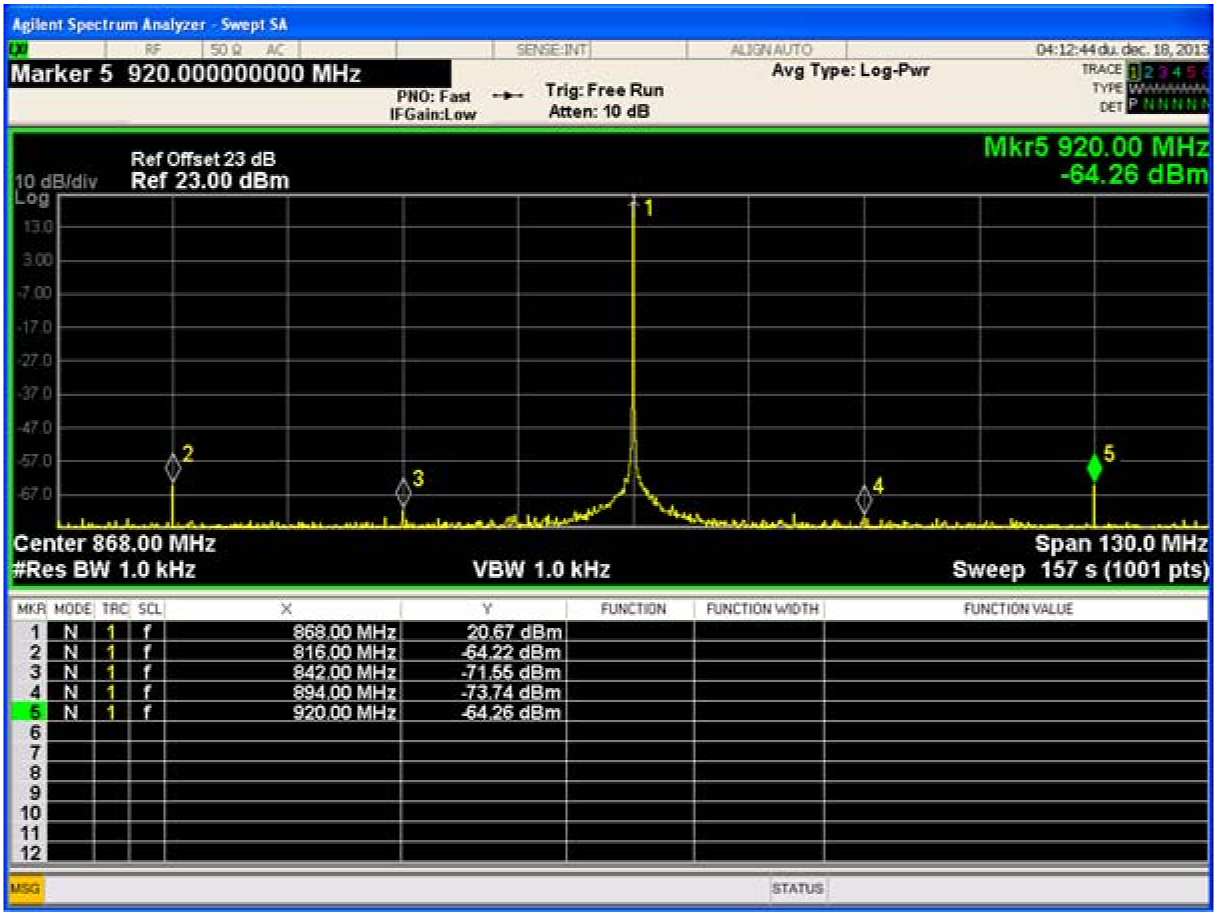


Figure 45. 4463_PCE20C868SE Board Output Power: 20 dBm

This is the only pico board for the 863-870 MHz band equipped with a TCXO. The primary goal of the TCXO is to provide superior reference accuracy for narrowband (≤ 25 KHz bandwidth). Such narrowband applications can transmit at a maximum of 500 mW (27 dBm) output power in sub-band 869, 4 MHz –869, 65 MHz. Note that even if the output power is boosted by 7 dBs to reach the 27 dBm maximum allowed output power in the aforementioned sub-band, the spurious levels will still remain compliant with the standard.

Note that on revision B1B an additional register write is necessary on top of the API property writes to achieve the measured spurious levels.

POKE ‘xosc_cfg’ 0A

For further details on this operation, refer to section 6 in AN785.

3.7. Frequency Stability Under Low Voltage Conditions

The frequency stability under low voltage conditions is the ability of the equipment to remain on channel, for channelized equipment, or within the assigned operating frequency band, for non-channelized equipment, when the battery voltage falls below the lower extreme voltage level.

Stable operation is guaranteed in a specified range of voltage (1.8 V –3.6 V). To avoid any malfunctioning, the use of the Low Battery Detector (LBD) is recommended to monitor the power supply and beacon for action if the battery voltage drops below 1.8 V.

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