Wireless - What you see is not always what you get?

MikroTik User Meeting

Prague 2015

By Ron Touw

LinITX, England

Experience?

- RF Wireless Engineering for UK Government for 25 years.
- Training certifications from companies such as Marconi, Hewlett-Packard, Rohde & Schwarz, Microsoft, Ruckus, Meru.
- User of MikroTik since 2006
- Certified Consultant and Trainer since 2009.
- Member of RoutedWorld.com

Who are LinITX?

- Largest MikroTik Distributor in UK
- Largest number of MikroTik Certified Consultants in a single UK Distributor
- Certified MikroTik Training Centre
- Provide Consultancy and Third Line Support to ISPs and WISPs using MikroTik Routers

What's the Problem?

- Wireless is 'invisible'
- Needs other tools for it to be 'seen'
- Poor CCQ, Low or 'flapping' Data rates, even OFDM error stats only provide limited information - basically "there is a problem"
- We may change a card and the problem is solved
- But WHAT was the problem? We need to:
  - To get the complete picture
  - To fully understand what's "out there"

Solution to the Problem?

- Use a Spectrum Analyser? But which?
  - MikroTik ‘Built in’ - via The Dude?
  - MikroTik ‘Built in’ - via Simple CLI?
- Independent / Calibrated / High Cost? E.g.
  - HP Agilent
  - Rohde & Schwarz

Solution to the Problem?

- Or… Independent / Low Cost, e.g.
  - Metageeks Wi-Spy

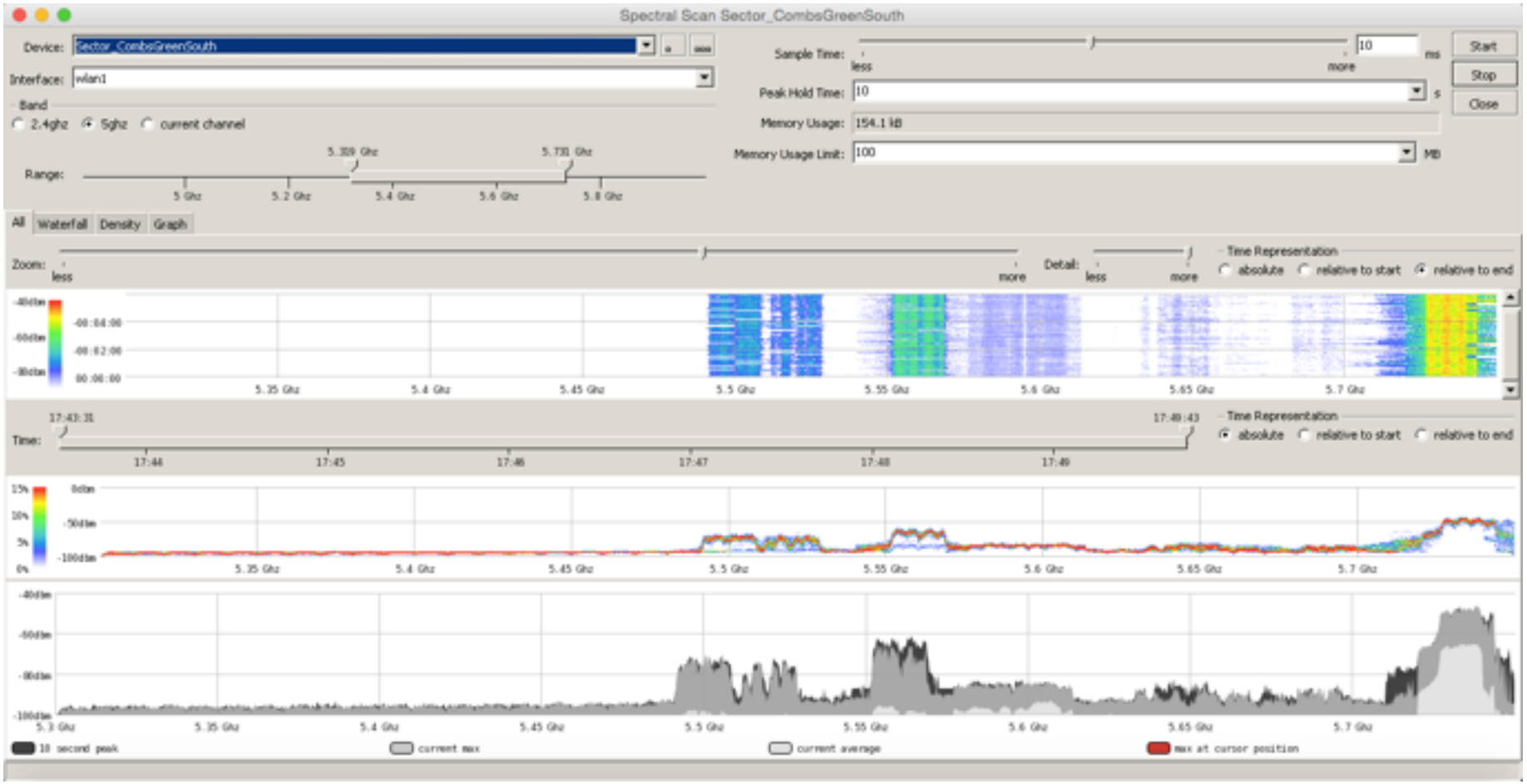
  - Signalhound

  - Aaronia Spectran

MikroTik Tools

- Benefit of using MikroTik ‘built in’ analysers:
  - Low cost - already paid for :)
  - Uses the actual link equipment itself
    - Any analysis will “see” the same as the link itself “sees”.
    - Same antenna, therefore
    - Same beam width / aperture
- Requires install of ‘TheDude’

Spectrum - via TheDude



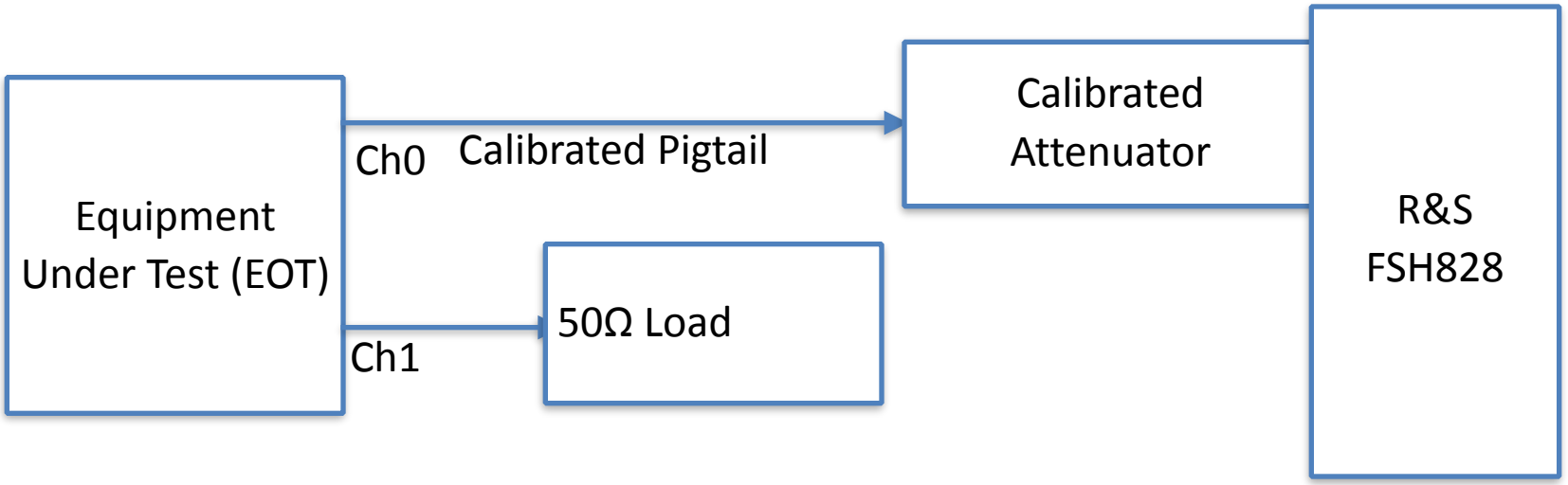
Spectrum Analysers

- Using a Spectrum Analyser is not just about seeing noise or interference on a link
- Also can be used to find what problems **we** are **generating** by using faulty equipment
- Can also be used to demonstrate the difference between “reality” and “theory”
  - Are we only operating on one frequency or are there spurious transmissions?
  - I.e. When we set a power level, is that the real power level we get?

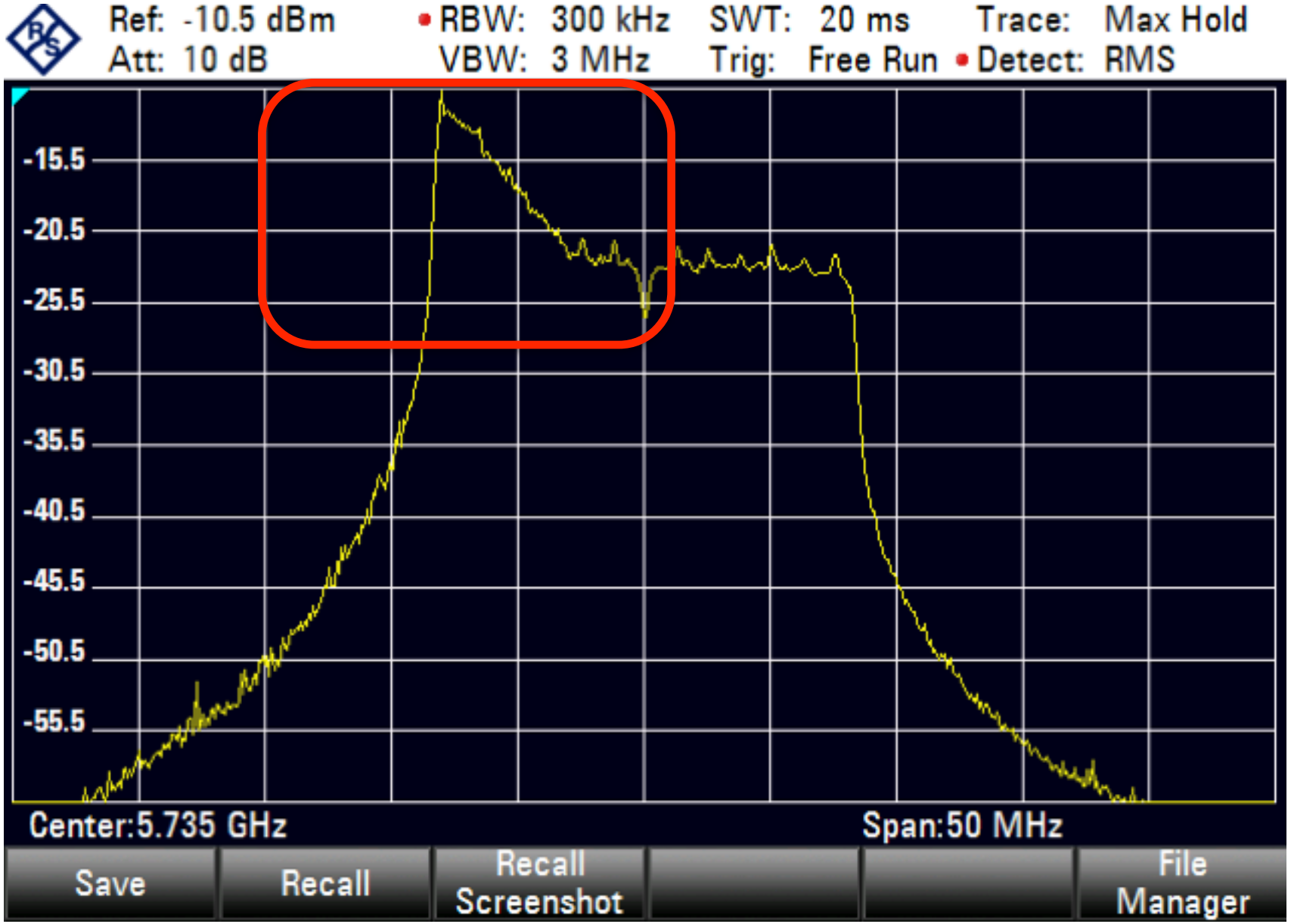
Self Generated problems?

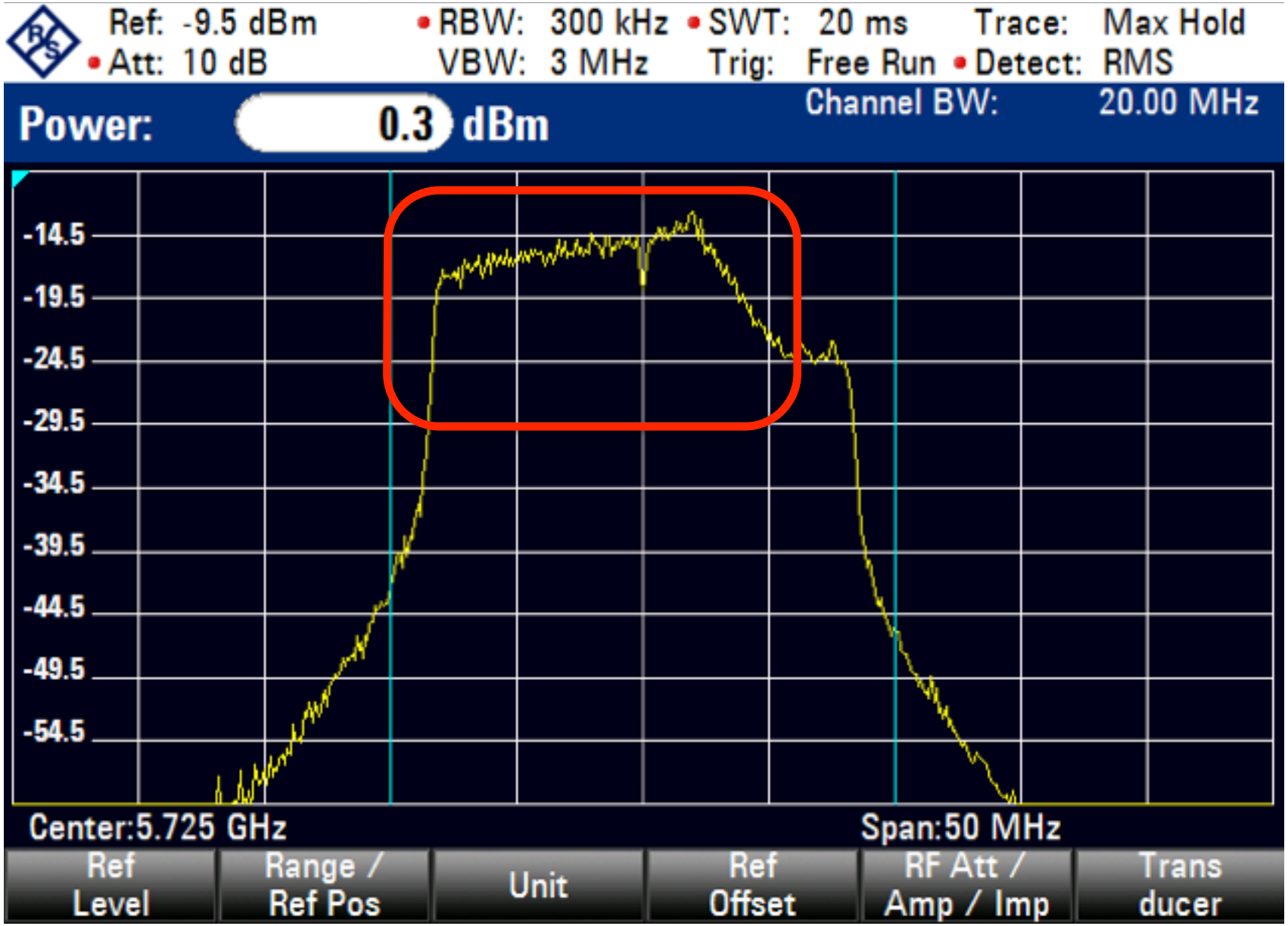
- Transmitter failure is predictable, sadly however what is not predictable is **when!**
- Nor do we know “how” it will fail
- Failure types:
  - No output at all - simple/visible/obvious
  - Lowered output - partially visible/ detectable?
  - Distorted output / spurious - ‘invisible’?
  - Interference or high noise floor?

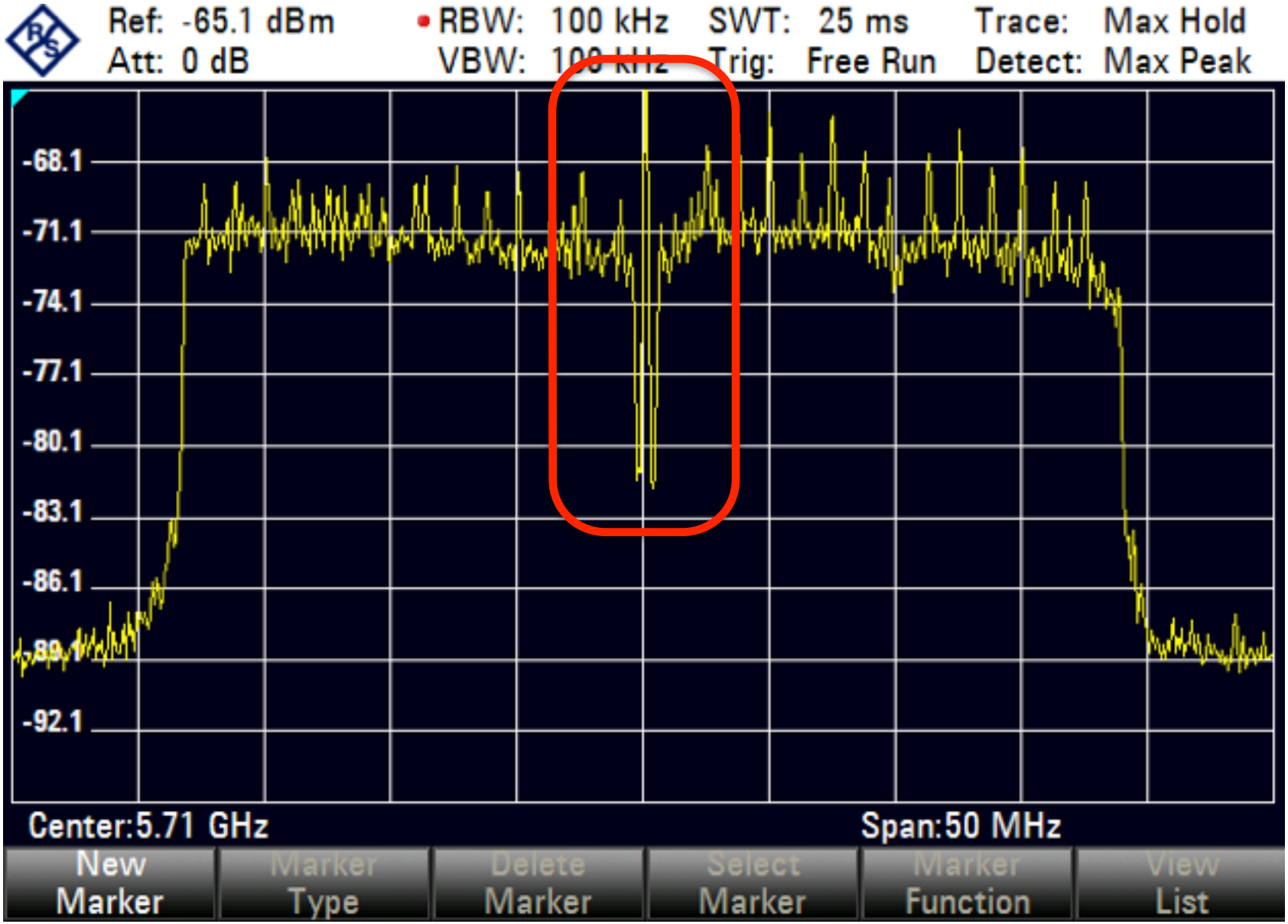
Let's see some Spectrum examples

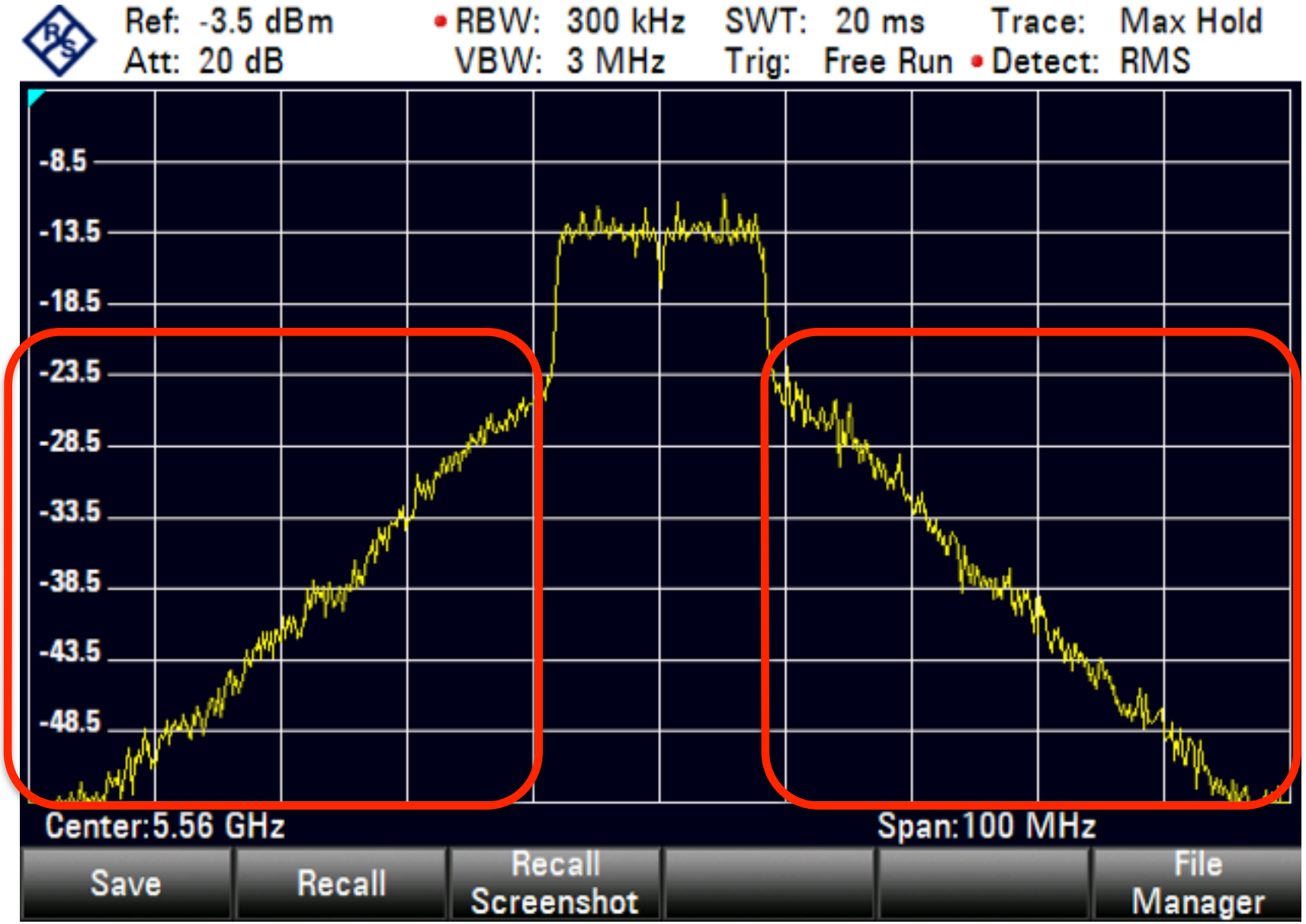


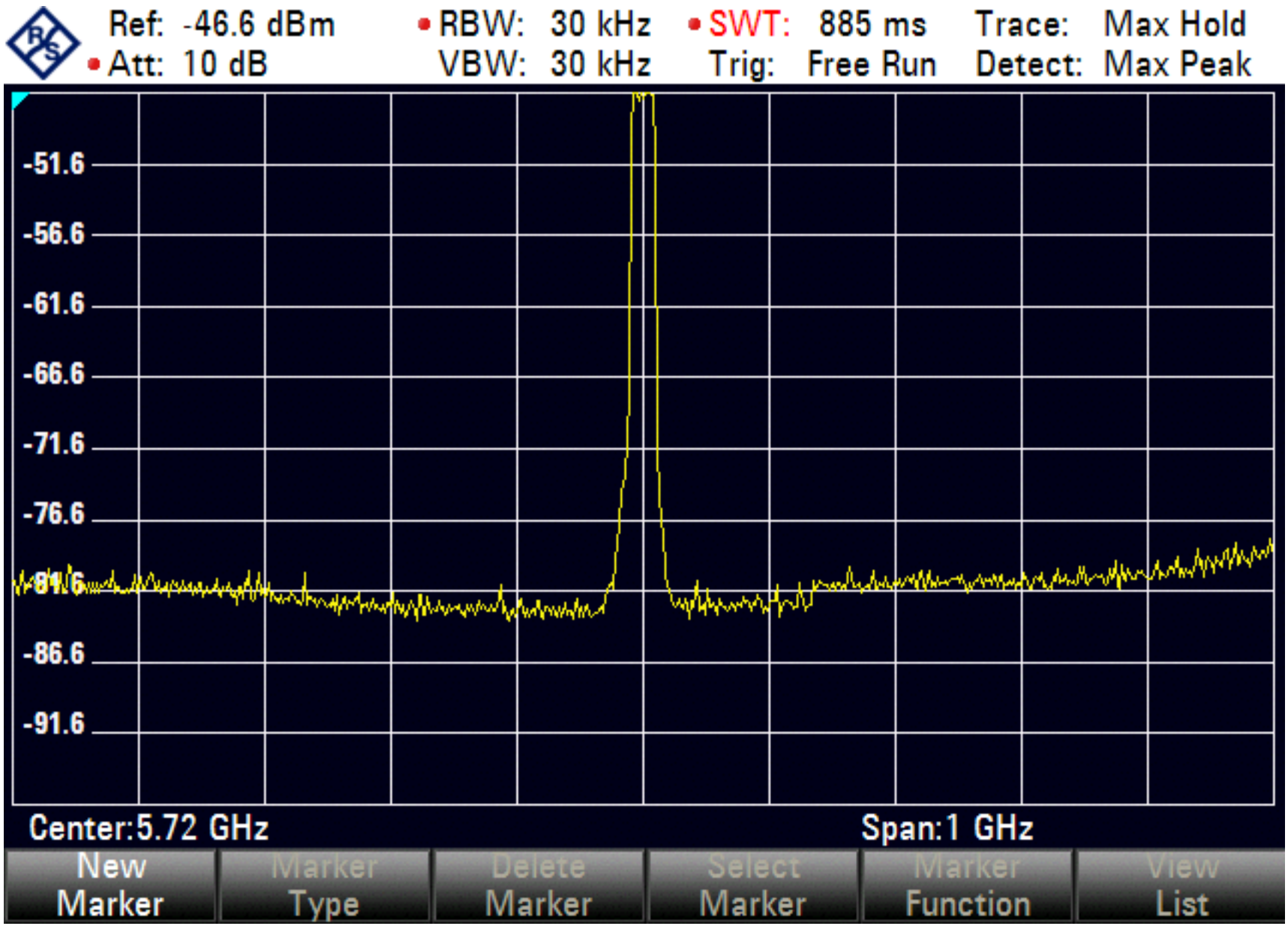
- Testing cards thought to be faulty or have caused suspicions in the past can be very illuminating…

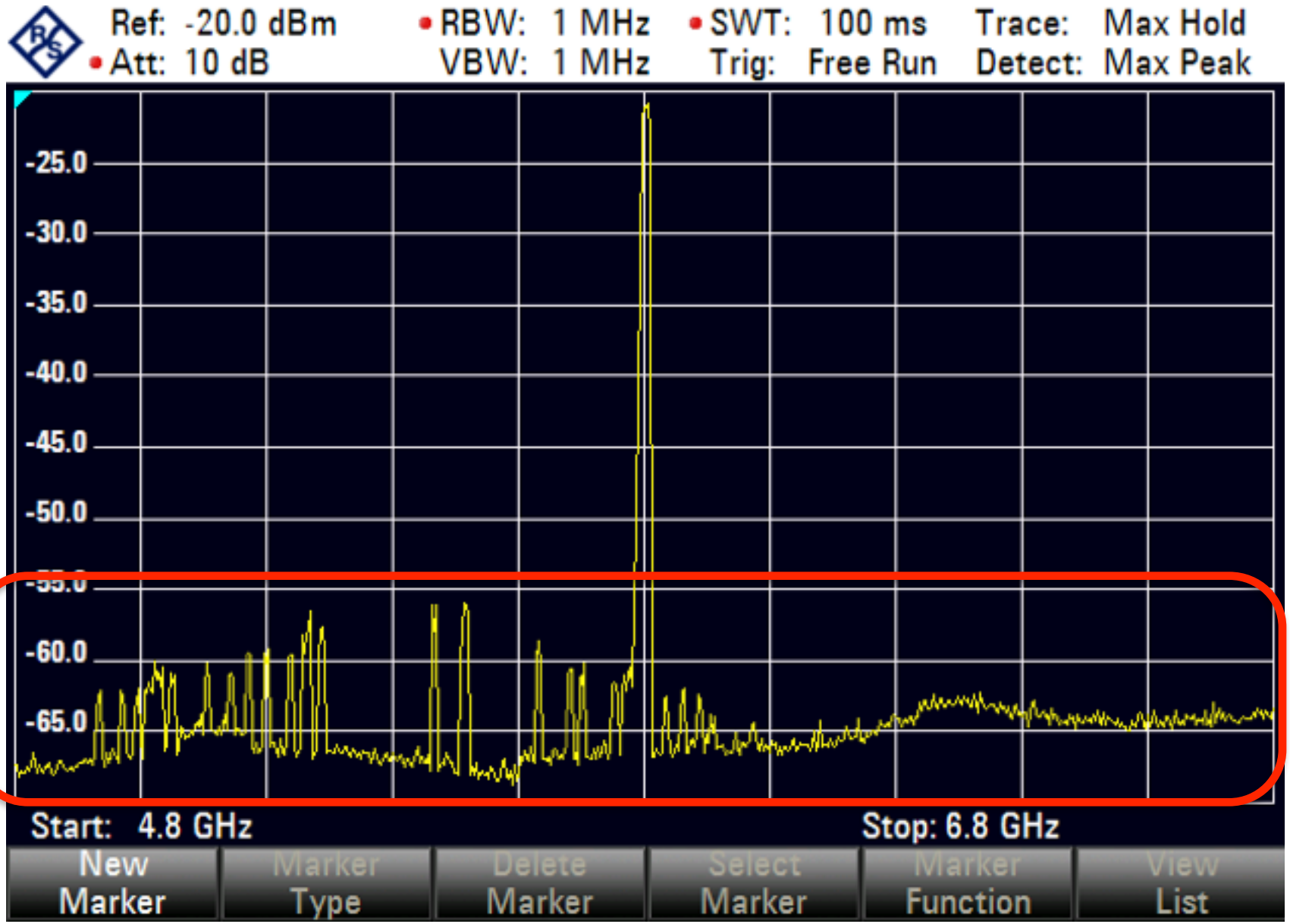

Ref: -10.5 dBm
Att: 10 dB
RBW: 300 kHz
VBW: 3 MHz
SWT: 20 ms
Trig: Free Run
Trace: Max Hold
Detect: RMS
-15.5
-20.5
-25.5
-30.5
-35.5
-40.5
-45.5
-50.5
-55.5
Center:5.735 GHz
Span:50 MHz
Save
Recall
Recall Screenshot
File Manager

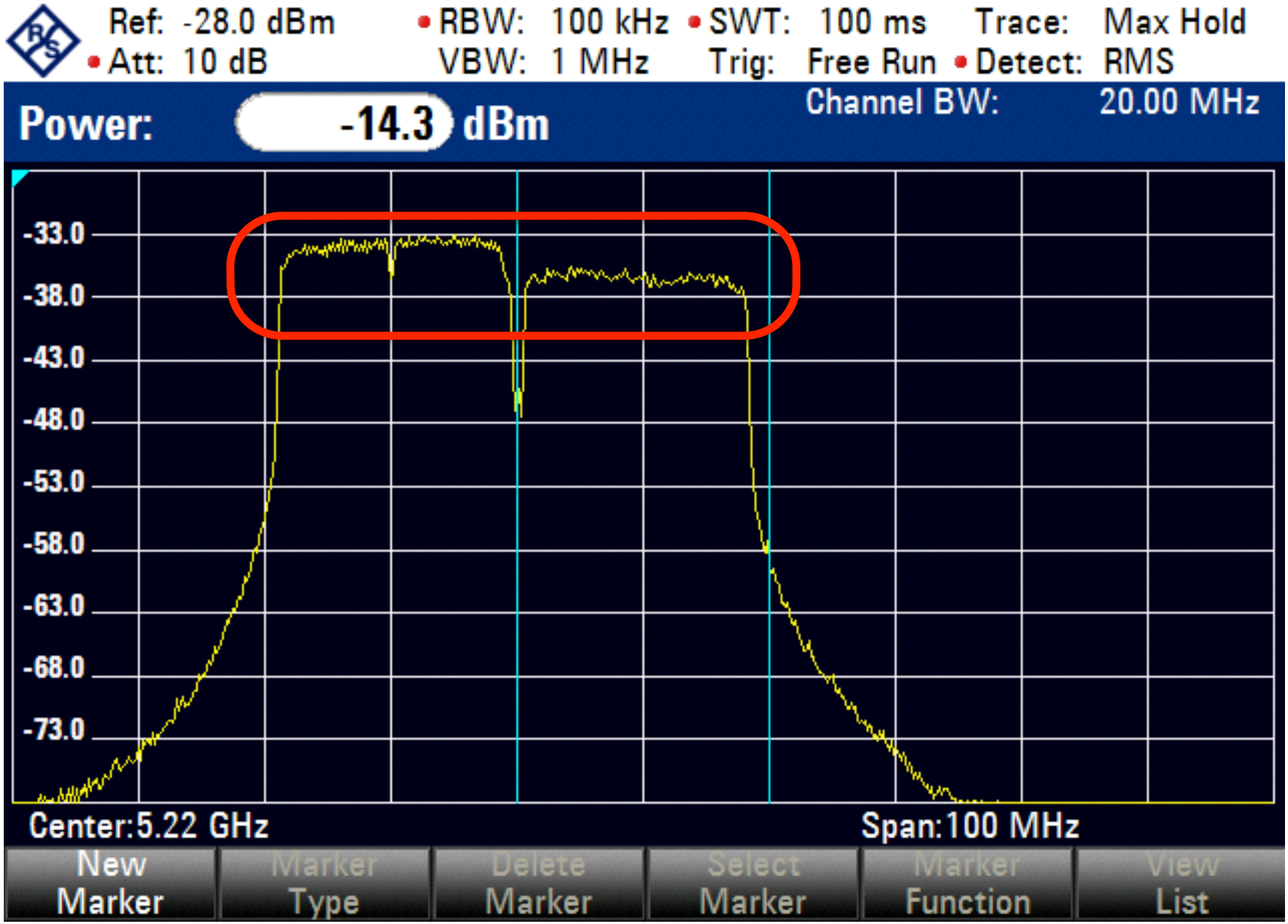

Ref: -9.5 dBm
RBW: 300 kHz
SWT: 20 ms
Trace: Max Hold
Att: 10 dB
VBW: 3 MHz
Trig: Free Run
Detect: RMS
Power: 0.3 dBm
Channel BW: 20.00 MHz
-14.5
-19.5
-24.5
-29.5
-34.5
-39.5
-44.5
-49.5
-54.5
Center:5.725 GHz
Span:50 MHz
Ref Level
Range / Ref Pos
Unit
Ref Offset
RF Att / Amp / Imp
Trans ducer

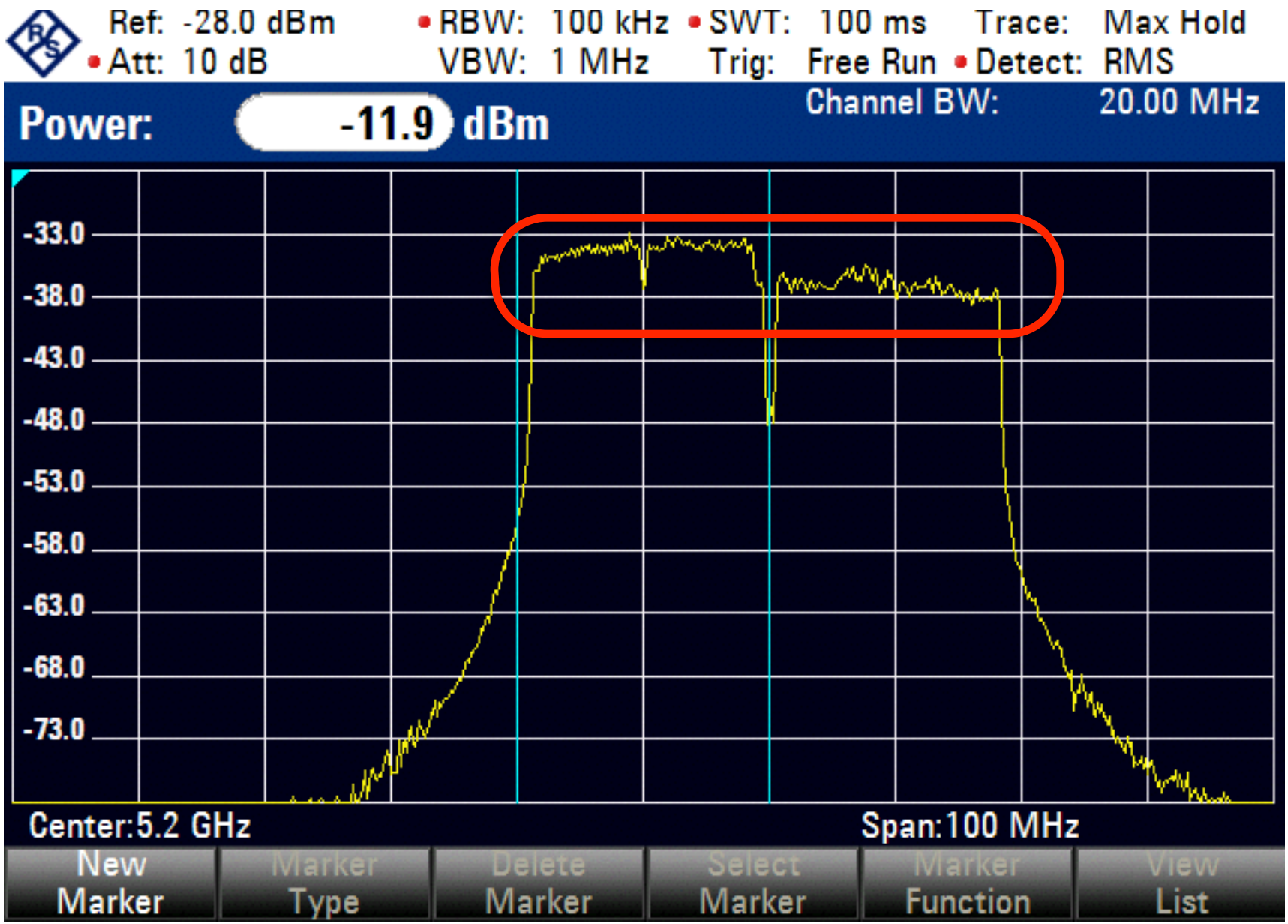

Ref: -65.1 dBm
Att: 0 dB
RBW: 100 kHz
VBW: 100 kHz
SWT: 25 ms
Trig: Free Run
Trace: Max Hold
Detect: Max Peak
-68.1
-71.1
-74.1
-77.1
-80.1
-83.1
-86.1
-89.1
-92.1
Center:5.71 GHz
Span:50 MHz
New Marker
Marker Type
Delete Marker
Select Marker
Marker Function
View List


Ref: -3.5 dBm
Att: 20 dB
RBW: 300 kHz
VBW: 3 MHz
SWT: 20 ms
Trig: Free Run
Trace: Max Hold
Detect: RMS
-8.5
-13.5
-18.5
-23.5
-28.5
-33.5
-38.5
-43.5
-48.5
Center:5.56 GHz
Span:100 MHz
Save
Recall
Recall Screenshot
File Manager


Ref: -46.6 dBm
Att: 10 dB
RBW: 30 kHz
VBW: 30 kHz
SWT: 885 ms
Trig: Free Run
Trace: Max Hold
Detect: Max Peak
-51.6
-56.6
-61.6
-66.6
-71.6
-76.6
-81.6
-86.6
-91.6
Center:5.72 GHz
Span:1 GHz
New Marker
Marker Type
Delete Marker
Select Marker
Marker Function
View List


Ref: -20.0 dBm
Att: 10 dB
RBW: 1 MHz
VBW: 1 MHz
SWT: 100 ms
Trig: Free Run
Trace: Max Hold
Detect: Max Peak
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-60.0
-65.0
Start: 4.8 GHz
Stop: 6.8 GHz
New Marker
Marker Type
Delete Marker
Select Marker
Marker Function
View List


Ref: -28.0 dBm
RBW: 100 kHz
SWT: 100 ms
Trace: Max Hold
Att: 10 dB
VBW: 1 MHz
Trig: Free Run
Detect: RMS
Power: -14.3 dBm
Channel BW: 20.00 MHz
-33.0
-38.0
-43.0
-48.0
-53.0
-58.0
-63.0
-68.0
-73.0
Center:5.22 GHz
Span:100 MHz
New Marker
Marker Type
Delete Marker
Select Marker
Marker Function
View List


Ref: -28.0 dBm
RBW: 100 kHz
SWT: 100 ms
Trace: Max Hold
Att: 10 dB
VBW: 1 MHz
Trig: Free Run
Detect: RMS
Power: -11.9 dBm
Channel BW: 20.00 MHz
-33.0
-38.0
-43.0
-48.0
-53.0
-58.0
-63.0
-68.0
-73.0
Center:5.2 GHz
Span:100 MHz
New Marker
Marker Type
Delete Marker
Select Marker
Marker Function
View List

How about Tx Power?

- How can you know what Tx Power you are generating?
- Do you set the Tx-Power variable and blindly trust that is what you will get?
- What about card errors?
- What about fault conditions?
- Have you read the manufacturer's specifications regarding 'tolerance'?

802.11n/ac Differences

- For 802.11ac chipsets it reports Tx power of ALL chains combined
- For 802.11n chipsets it reports Tx power of each chain
- E.g.
  - 2 chain 802.11n, 27dBm is 27dBm PER Chain, therefore 30dBm total!
  - 2 chain 802.11ac, 27dBm is 27dBm

Datasheets & “Tolerance”

	Data Rate	TX Power		Tolerance
		1 chain	2 chains	
5G HT 20	MCS0/8	18dBm	21dBm	±2dB
	MCS1/9	18dBm	21dBm	±2dB
	MCS2/10	17dBm	20dBm	±2dB
	MCS3/11	17dBm	20dBm	±2dB
	MCS4/12	16dBm	19dBm	±2dB
	MCS5/13	16dBm	19dBm	±2dB
	MCS6/14	15dBm	18dBm	±2dB
	MCS7/15	12dBm	15dBm	±2dB
	Data Rate	TX Power		Tolerance
		1 chain	2 chains	
5G HT 40	MCS0/8	17dBm	20dBm	±2dB
	MCS1/9	17dBm	20dBm	±2dB
	MCS2/10	17dBm	20dBm	±2dB
	MCS3/11	17dBm	20dBm	±2dB
	MCS4/12	16dBm	19dBm	±2dB
	MCS5/13	14dBm	17dBm	±2dB
	MCS6/14	13dBm	16dBm	±2dB
	MCS7/15	9dBm	12dBm	±2dB

Datasheets & “Tolerance”

- Chipset manufacturers such as Intel or Qualcomm Atheros only provide a +/-2dB tolerance (or accuracy) in their data sheets
- Therefore any actual generated output power could be anywhere between +/-2dB from the value set in RouterOS. That’s 4dB of ‘uncertainty’.
- You set “20dBm” but what do you get?
- 18 - 22dBm!

Trusted?

- For testing the unknown or non-obvious problems we need equipment we can trust.
- Trustworthy equipment will be calibrated to a standard or is known to provide accurate trustworthy results.
- That requires the equipment to be calibrated against a ‘Standard’.

Trusted? (“Uncertainty”)

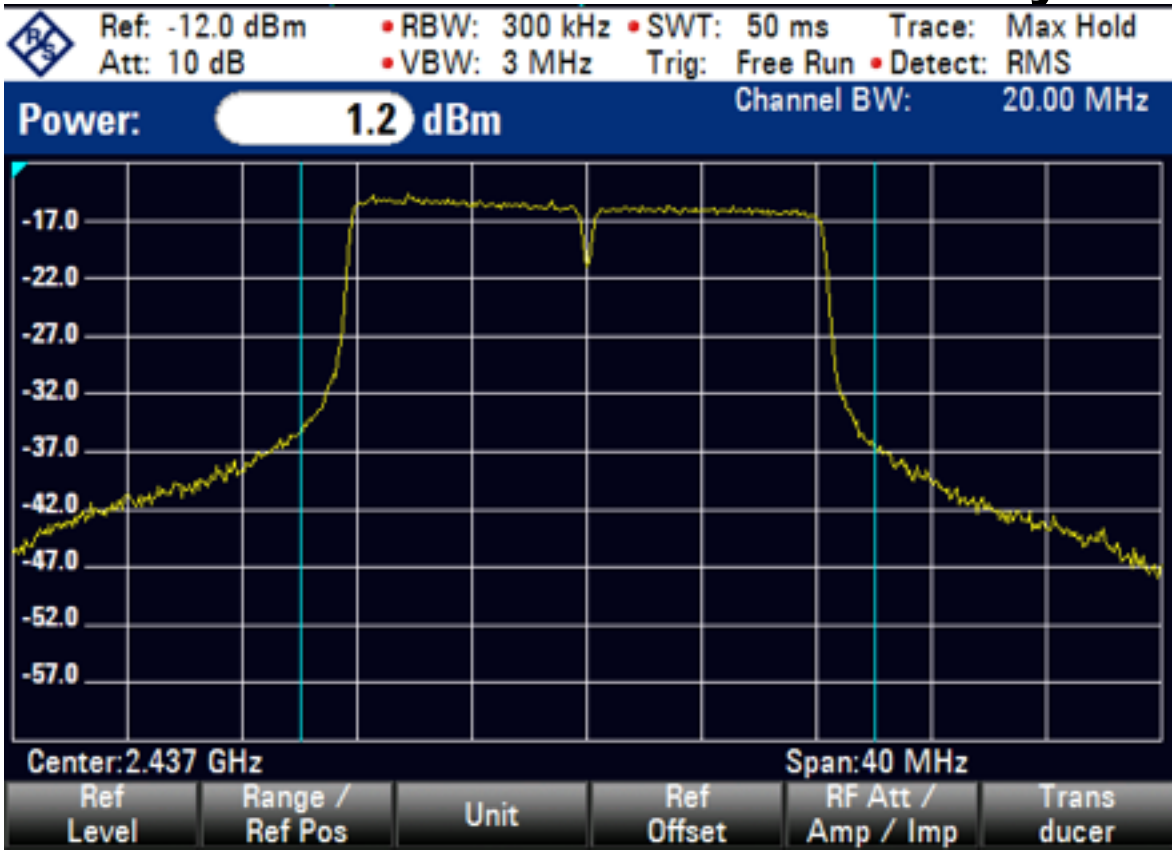
- But, first… A question - which is the more accurate measurement?
  - A - Tx Power = **23.4376** dBm or
  - B - Tx Power = **23.4** dBm?

Measuring Tx Power

- To ensure the measurement is trusted use calibrated equipment
- I use a Rohde and Schwarz FSH-828)

Measurement Method

- FSH828 has a special power measurement function for TDMA and CDMA systems



Accuracy?

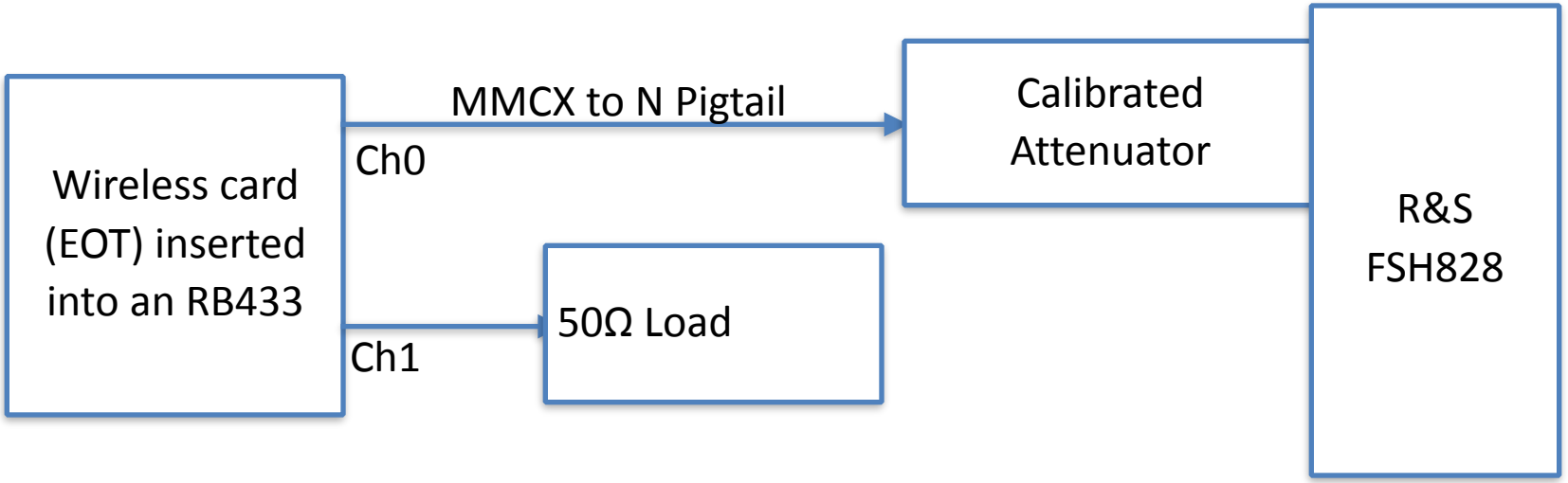
- FSH828 - R&S states in their technical data:

95 % confidence level, +20 °C to +30 °C, SNR > 16 dB, 0 dB to –50 dB below reference level, RF attenuation auto	
10 MHz ≤ f ≤ 3.6 GHz	< 1 dB, typ. 0.5 dB
3.6 GHz < f ≤ 20 GHz	< 1.5 dB, typ. 1 dB

- At 2.4GHz, it is <1 dB, typically 0.5 dB
- At 5GHz, it is <1.5 dB, typically 1 dB

- Therefore anything recorded with a greater accuracy than above, is not valid!

Measurement Method

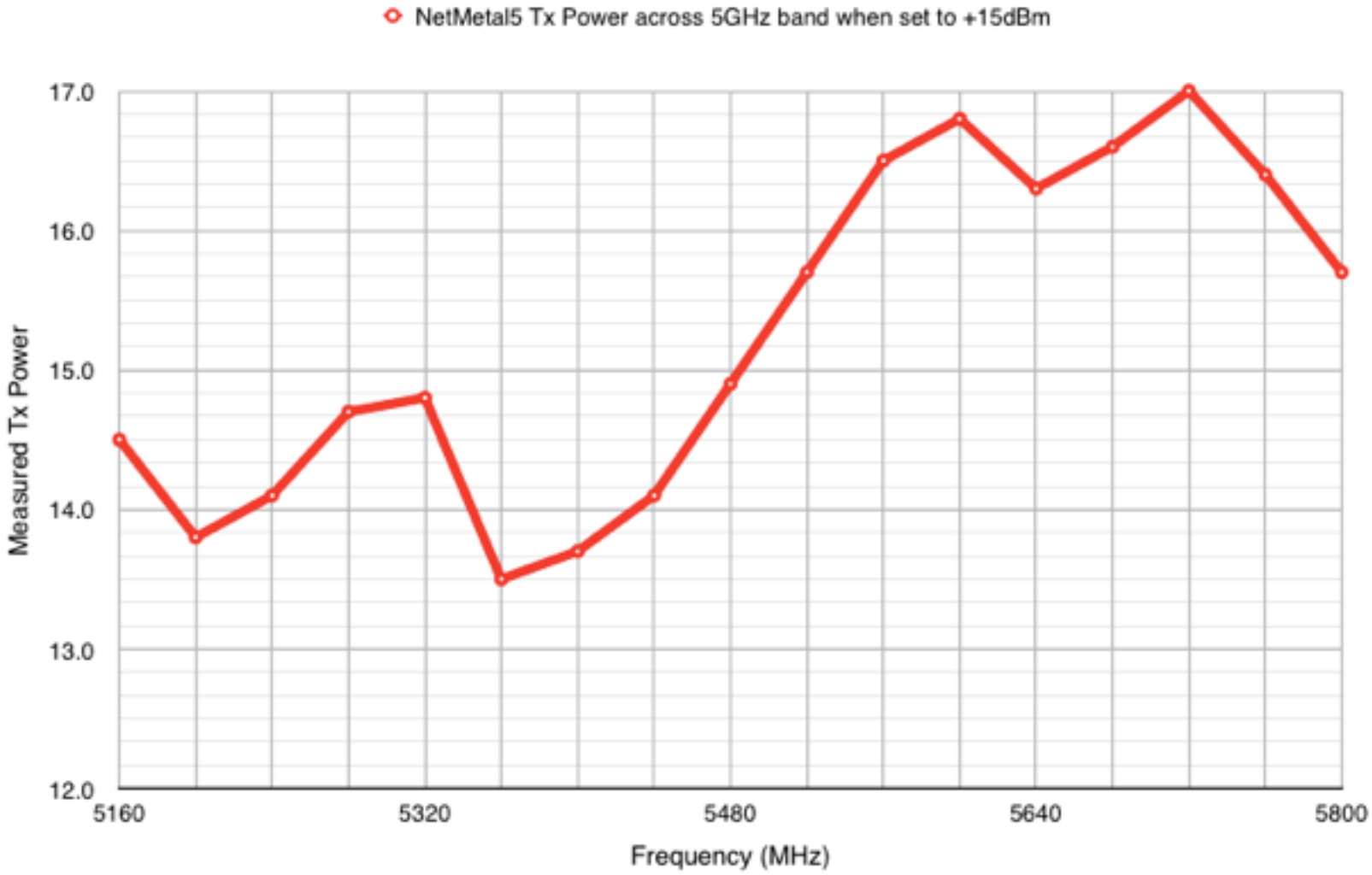


Typical Result across 2.4GHz band for +10dBm

Frequency	RouterOS Tx	Measured Tx	Error
2412 MHz	+10 dBm	+11 dBm	+1dB ✓
2437 MHz	+10 dBm	+11 dBm	+1dB ✓
2462 MHz	+10 dBm	+11 dBm	+1db ✓

- R52Hn running 802.11bg mode, beacons only, RouterOS v6.22, RouterBoot v3.18, wireless package (not wireless-fp)

+15dBm on 5GHz = +/-2dB



Various Tx-Power settings

Frequency	RouterOS Tx	Measured Tx	Error
2437 MHz	+5 dBm	+4.5 dBm	-0.5 dB ✓
2437 MHz	+10 dBm	+11 dBm	+1 dB ✓
2437 MHz	+15 dBm	+16 dBm	+1 db ✓
2437 MHz	+20 dBm	+21.5 dBm	+1.5 db ✓
2437 MHz	+23 dBm	+22.5 dBm	+1.5 dB ✓

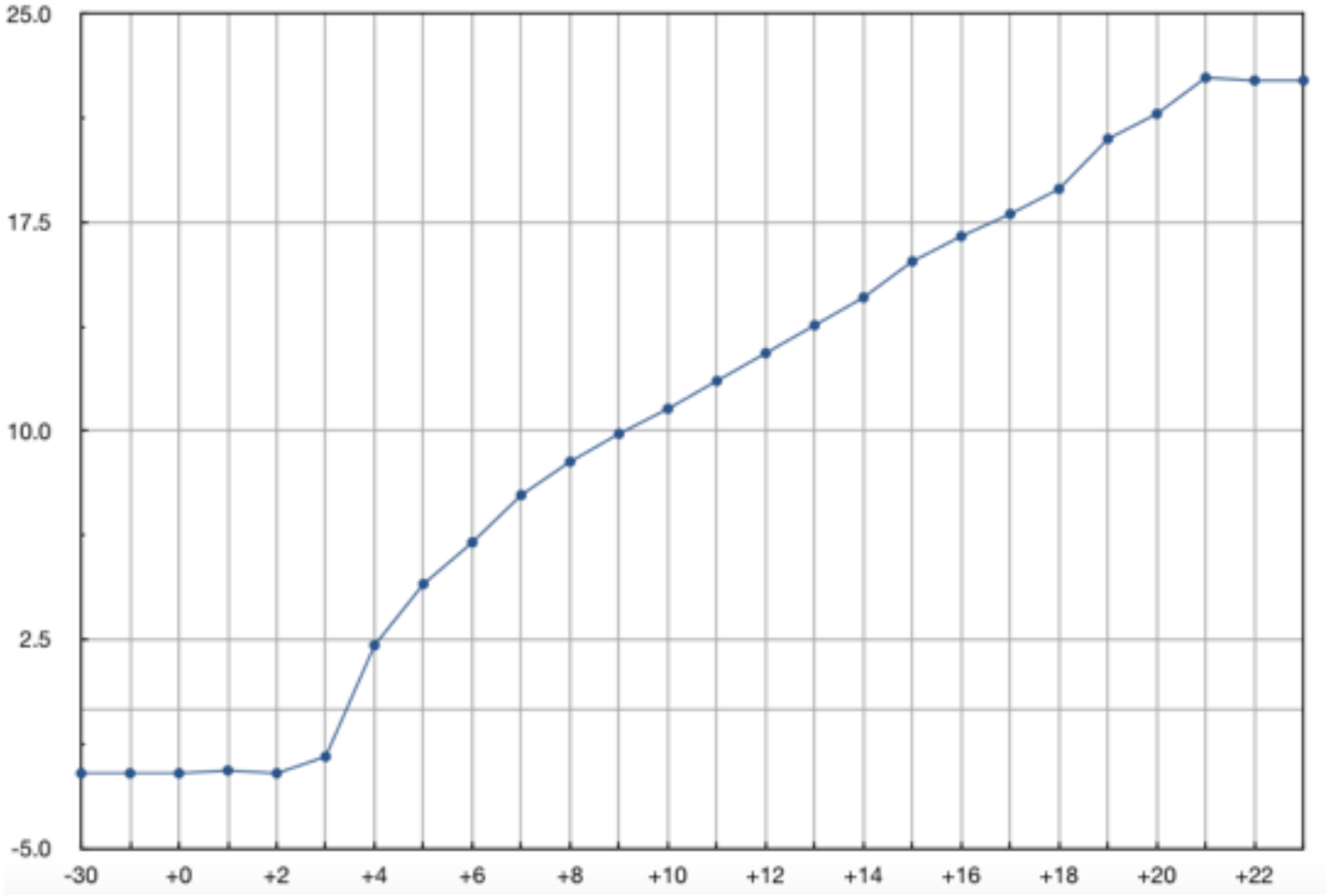
- R52Hn running 802.11bg mode, beacons only, RouterOS v6.22, RouterBoot v3.18, wireless package (not wireless-fp)

Low powers…

Frequency	RouterOS Tx	Measured Tx	Error
2437 MHz	-30 dBm	-2.0 dBm	+ 28.0 dB
2437 MHz	-20 dBm	-2.0 dBm	+ 18.0 dB
2437 MHz	-10 dBm	-2.0 dBm	+ 8.0 dB
2437 MHz	-1 dBm	-2.0 dBm	-1.0 dB
2437 MHz	0 dBm	-2.0 dBm	-2.0 dB
2437 MHz	+1 dBm	-2.0 dBm	-3.0 dB
2437 MHz	+2 dBm	-2.0 dBm	-4.0 dB
2437 MHz	+3 dBm	-1.5 dBm	-4.5 dB
2437 MHz	+4 dBm	+2.0 dBm	-2.0 dB

- R52Hn running 802.11bg mode, beacons only, RouterOS v6.22, RouterBoot v3.18, wireless package (not wireless-fp)

Is this “linear”?



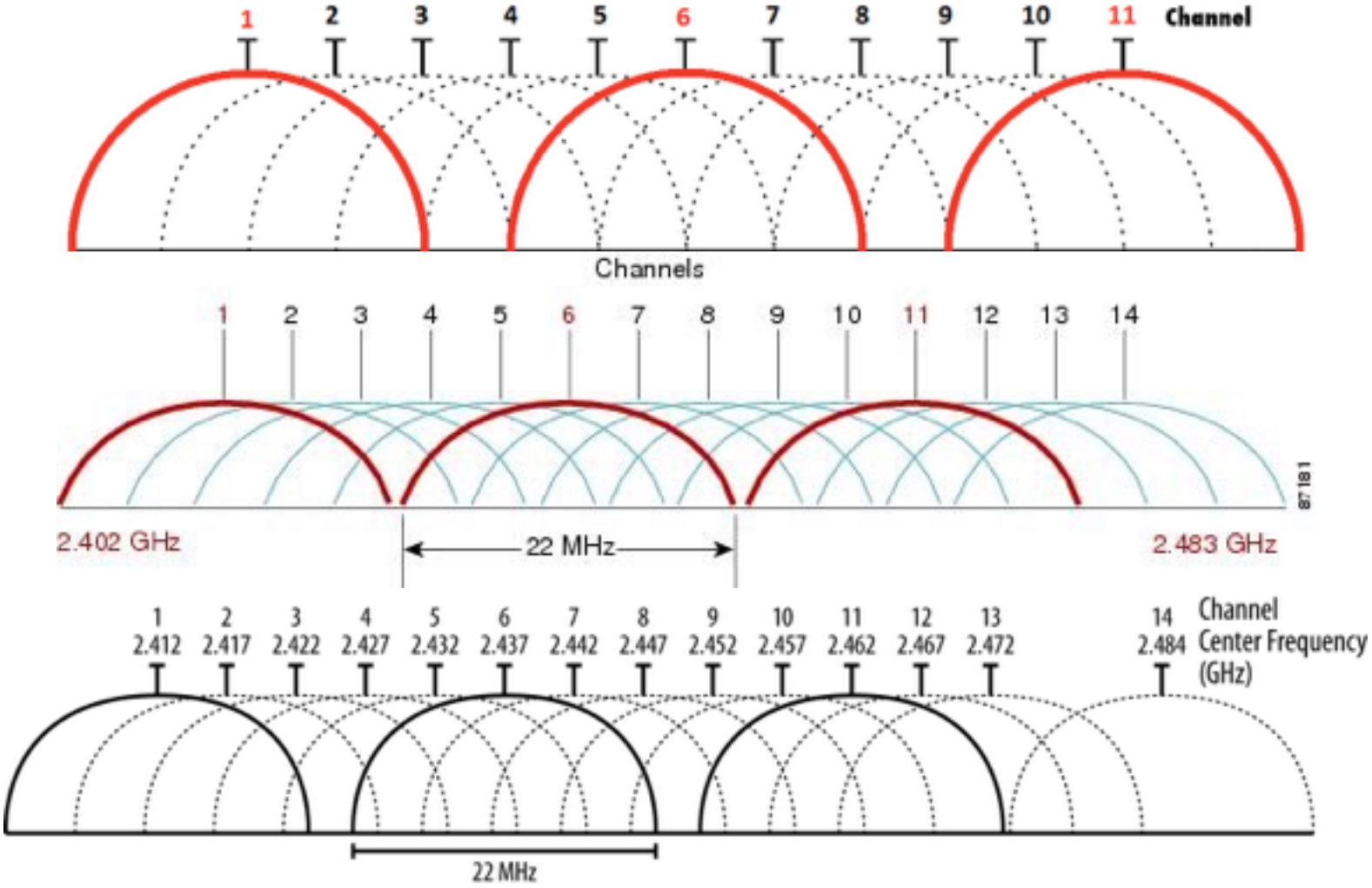
Spectrum Occupancy

- We have seen that although they do not appear to be truly linear, the devices are within the manufacturer's tolerance levels (+/-2dB)
- But - what did you expect for $40-$60?!
- So, if Tx powers are not always what you thought you would get…
- How about the spectrum occupied?

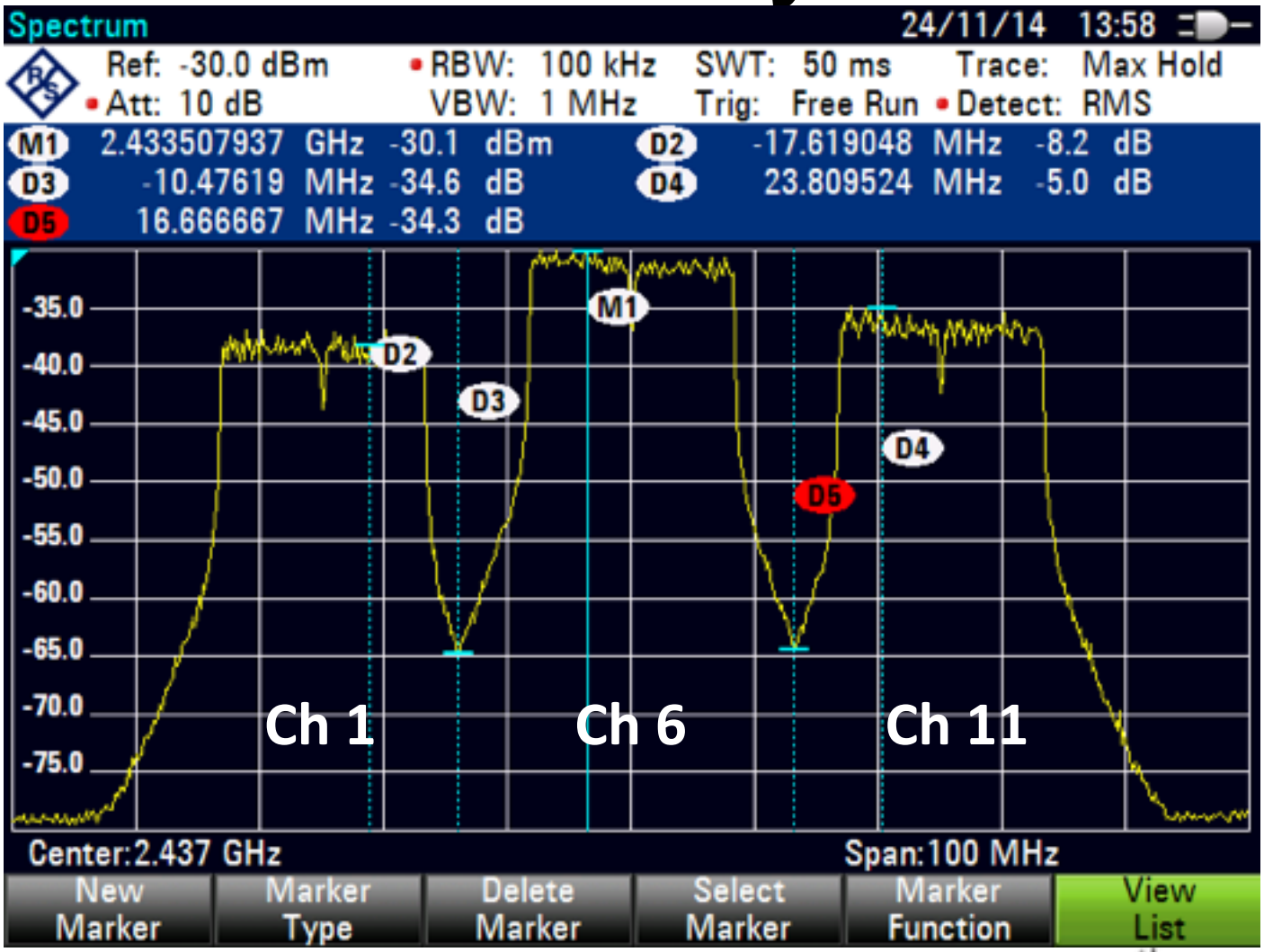
True or False?

- On 2.4GHz, there are three non-overlapping 20MHz channels, 1, 6 and 11.
- When deploying Access Points in a building, one should always use a channel layout using only 1, 6 and 11.
- Co-locating APs on Channels 1,6 and 11 do not interfere with each other

Seen these diagrams?



Reality


Spectrum
24/11/14 13:58
Ref: -30.0 dBm
RBW: 100 kHz
SWT: 50 ms
Trace: Max Hold
Att: 10 dB
VBW: 1 MHz
Trig: Free Run
Detect: RMS
M1 2.433507937 GHz -30.1 dBm
D2 -17.619048 MHz -8.2 dB
D3 -10.47619 MHz -34.6 dB
D4 23.809524 MHz -5.0 dB
D5 16.666667 MHz -34.3 dB
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
M1
D2
D3
D4
D5
Ch 1
Ch 6
Ch 11
Center:2.437 GHz
Span:100 MHz
New Marker
Marker Type
Delete Marker
Select Marker
Marker Function
View List

Non-overlapping?

- Reality is that energy of WiFi signals actually extends further away from centre frequency than you may think
- Co-locating adjacent 20/40M channels on 5GHz also have the same problem
- Separate by at least 20MHz of free spectrum
- E.g. 5500 Upper = 5490-5530, therefore next channel should be on 5560 Upper, not 5540 Upper

How about Pigtail losses?

- Short high quality pigtails between a radio and antenna have minimal loss but it is not the **same** loss across the whole 5GHz band due to resonances in the cable (E.g. +/-1dB)

Need for Accuracy?

- When calculating EiRP for regulatory authorities - how accurate should you be?
- As we have seen, the card maybe +/-2 dB and the pigtail may be +/-1dB and then there is the antenna gain - this may be different at different frequencies too!
- So .. try not to work too hard to calculate the exact dBm power level. It will only be a calculated “guess” :)

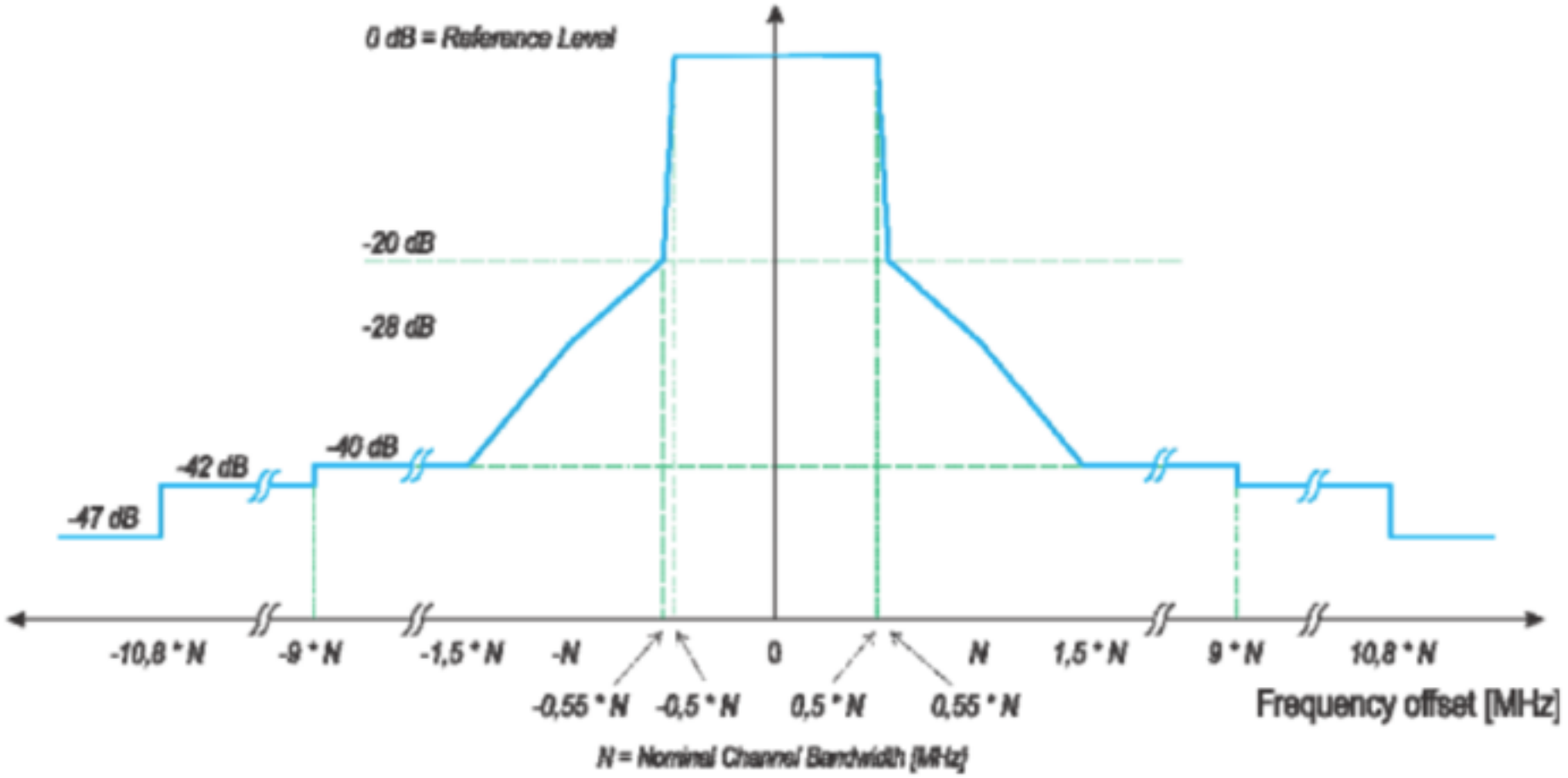
“I need more power!”

- It is not wise to set everything to the maximum power possible for the card.
- Use ‘default’ Tx Power mode, Regulatory settings and input antenna gain figure or set to ‘all-rates-fixed’ and input a reduced power value.

“all-rates-fixed”

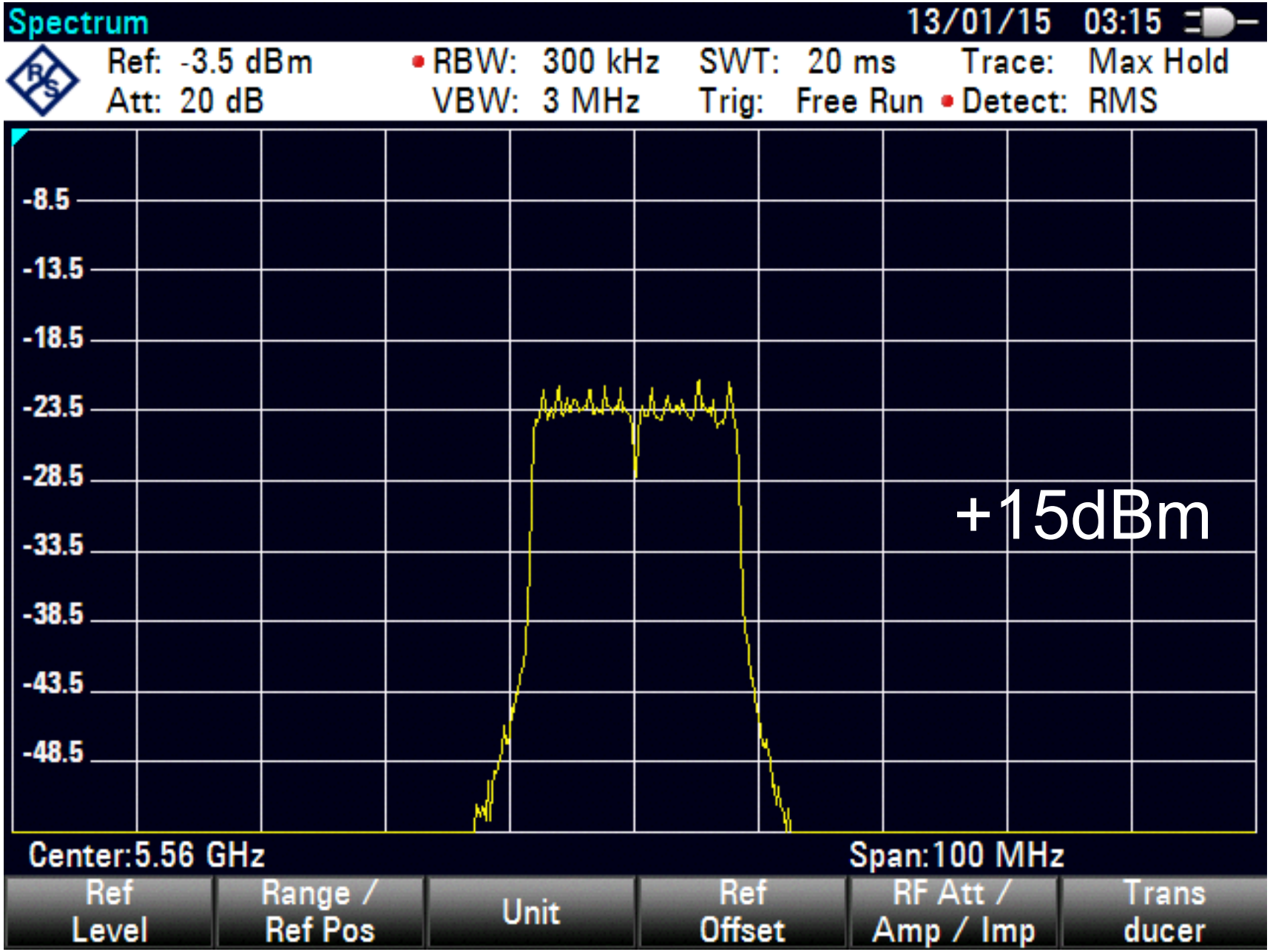
- From Wiki:
  - *“Note that it is not recommended to use 'all-rates-fixed' mode as the wireless card tx-power for the higher data rates is lower…”*
- Meaning = To ensure ETSI Compliance by keeping the spectrum within the regulatory spectral mask, the higher data rates usually have the Tx-Power automatically lowered, but by using ‘all-rates-fixed’ you are overriding this!

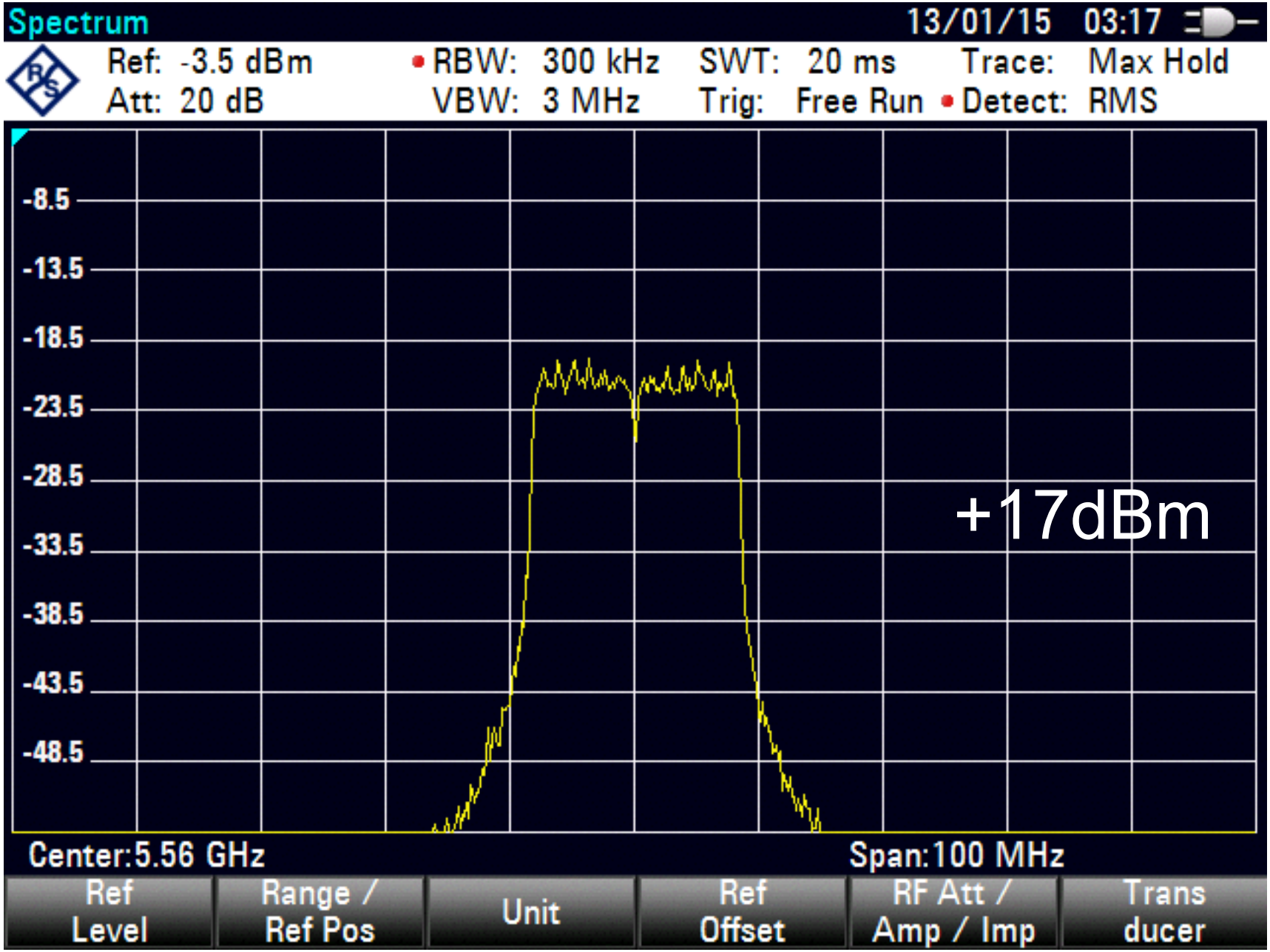
ETSI Spectral Mask

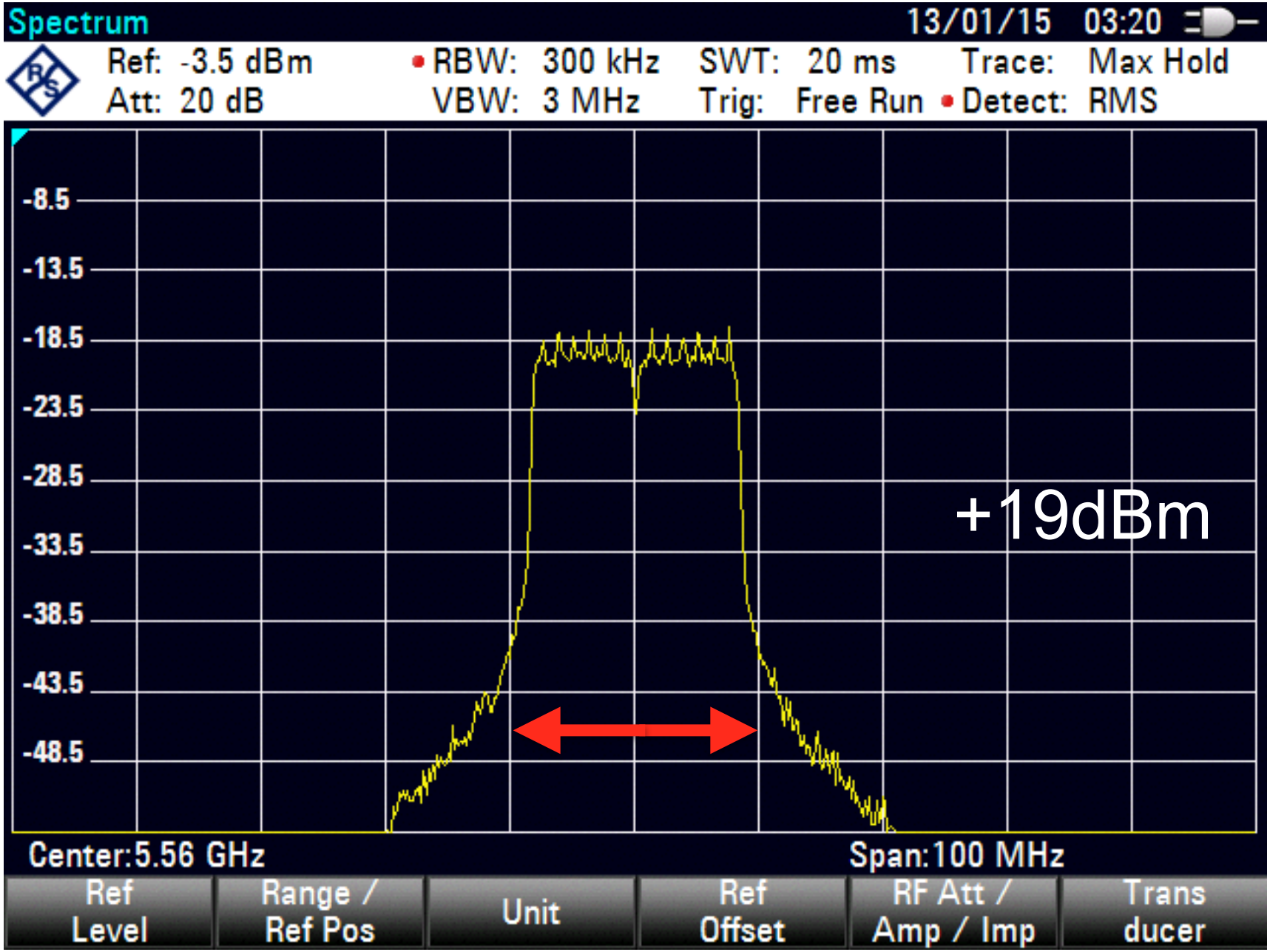


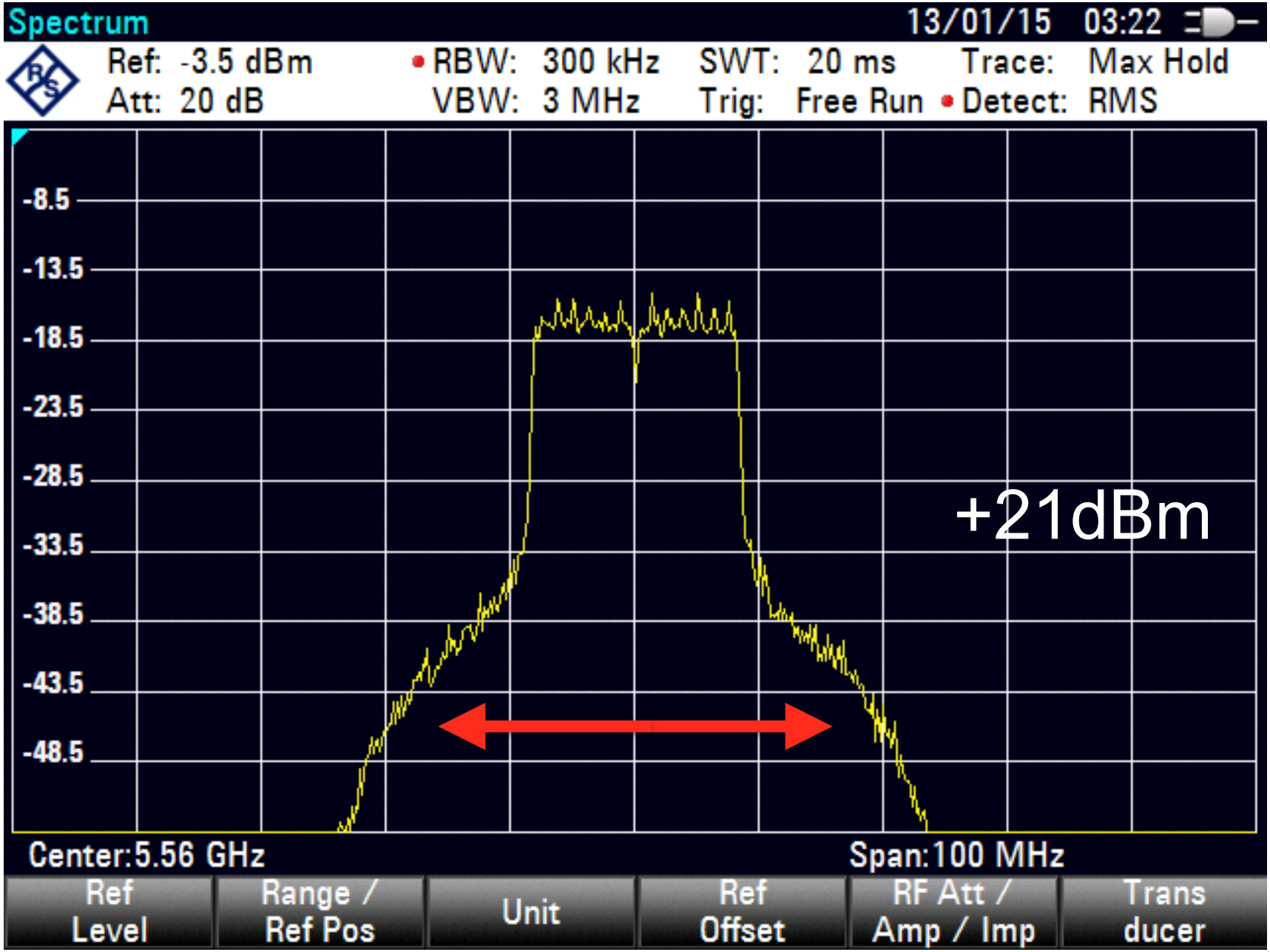
So - what happens?

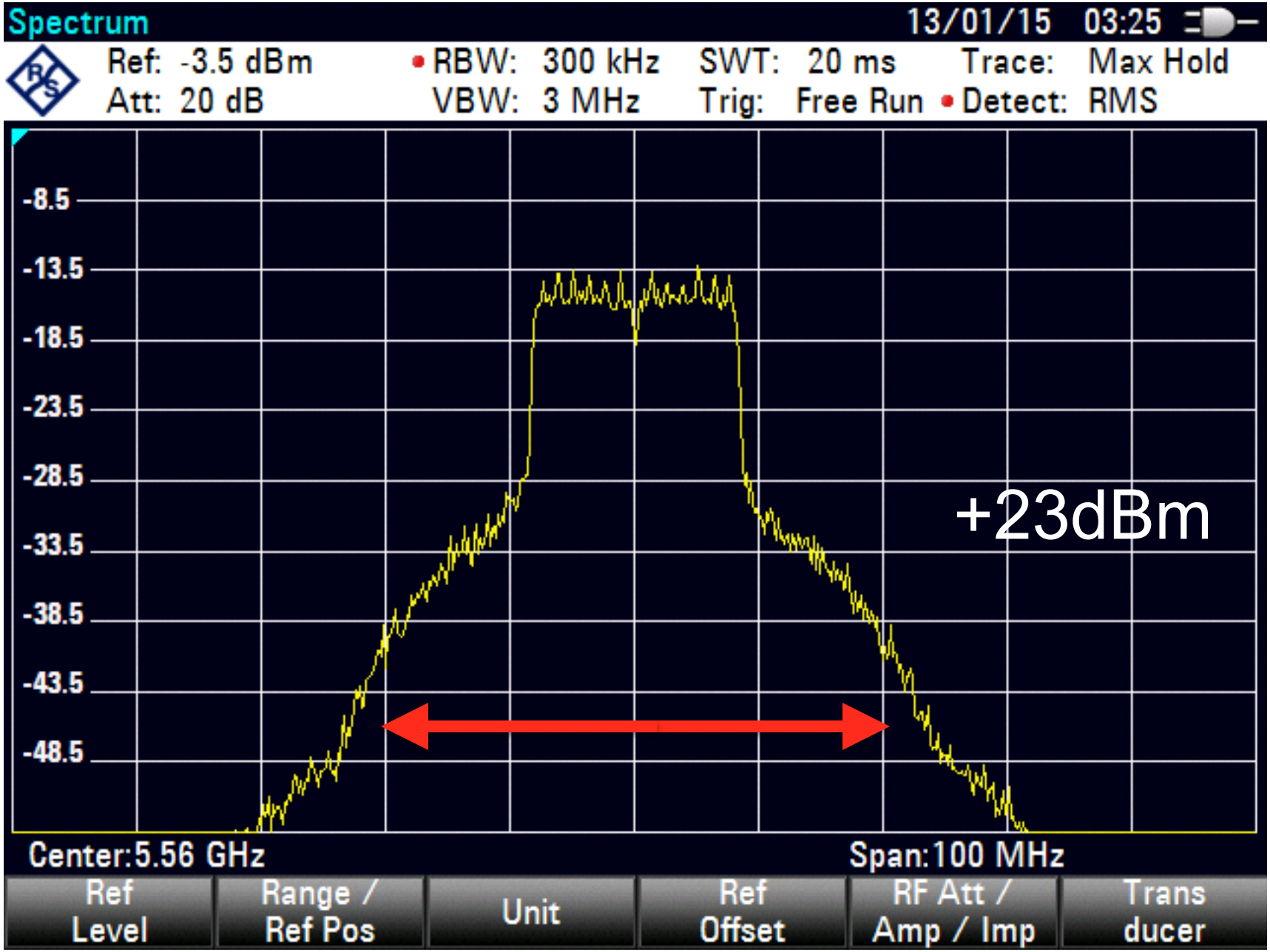
- E.g. Increasing the Tx-Power setting on a R52nM Card by 2dB steps, while leaving the Tx-Power Mode on “all-rates-fixed” instead of ‘default’ (and using ‘antenna gain’ value to reduce power if necessary)


Spectrum
13/01/15 03:15
Ref: -3.5 dBm
Att: 20 dB
RBW: 300 kHz
VBW: 3 MHz
SWT: 20 ms
Trig: Free Run
Trace: Max Hold
Detect: RMS
-8.5
-13.5
-18.5
-23.5
-28.5
-33.5
-38.5
-43.5
-48.5
+15dBm
Center:5.56 GHz
Span:100 MHz
Ref Level
Range / Ref Pos
Unit
Ref Offset
RF Att / Amp / Imp
Trans ducer


Spectrum
13/01/15 03:17
Ref: -3.5 dBm
Att: 20 dB
RBW: 300 kHz
VBW: 3 MHz
SWT: 20 ms
Trig: Free Run
Trace: Max Hold
Detect: RMS
-8.5
-13.5
-18.5
-23.5
-28.5
-33.5
-38.5
-43.5
-48.5
+17dBm
Center:5.56 GHz
Span:100 MHz
Ref Level
Range / Ref Pos
Unit
Ref Offset
RF Att / Amp / Imp
Trans ducer


Spectrum
13/01/15 03:20
Ref: -3.5 dBm
Att: 20 dB
RBW: 300 kHz
VBW: 3 MHz
SWT: 20 ms
Trig: Free Run
Trace: Max Hold
Detect: RMS
-8.5
-13.5
-18.5
-23.5
-28.5
-33.5
-38.5
-43.5
-48.5
+19dBm
Center:5.56 GHz
Span:100 MHz
Ref Level
Range / Ref Pos
Unit
Ref Offset
RF Att / Amp / Imp
Trans ducer


Spectrum
13/01/15 03:22
Ref: -3.5 dBm
RBW: 300 kHz
SWT: 20 ms
Trace: Max Hold
Att: 20 dB
VBW: 3 MHz
Trig: Free Run
Detect: RMS
-8.5
-13.5
-18.5
-23.5
-28.5
-33.5
-38.5
-43.5
-48.5
+21dBm
Center:5.56 GHz
Span:100 MHz
Ref Level
Range / Ref Pos
Unit
Ref Offset
RF Att / Amp / Imp
Trans ducer


Spectrum
13/01/15 03:25
Ref: -3.5 dBm
Att: 20 dB
RBW: 300 kHz
VBW: 3 MHz
SWT: 20 ms
Trig: Free Run
Trace: Max Hold
Detect: RMS
-8.5
-13.5
-18.5
-23.5
-28.5
-33.5
-38.5
-43.5
-48.5
+23dBm
Center:5.56 GHz
Span:100 MHz
Ref Level
Range / Ref Pos
Unit
Ref Offset
RF Att / Amp / Imp
Trans ducer

MTCWE?

- Why not join us for MTCWE training and learn more about MikroTik and Wireless configuration?
- Special discount if you speak with me today :)
- See www.mikrotik.com/training …

- March 30-April 01, Czech Republic, MUM Prague, LinITX (MTCWE), English

Now you see that you do not always get what you wanted!

Thank You.

By Ron Touw
LinITX, England

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