Identifying and eliminating interference in mobile networks

Peter Busch
Segment Manager, Mobile Network Testing
Version 15

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Agenda

- Sources of interference
- Impact of interference on network performance
- Identifying, locating and eliminating external interference
- Overview of test tools and methodologies
- Summary

Sources of Interference

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Sources of interference

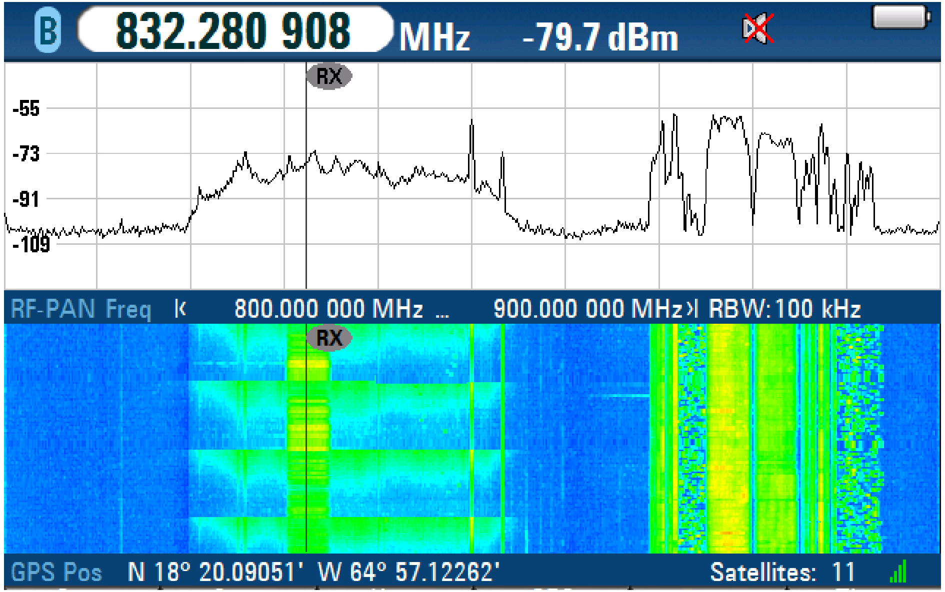
- The types and sources of interference are very frequency-dependent.
- Lower frequencies tend to propagate and penetrate better than higher frequencies.
- For many cellular networks, common interferers tend to be:
  - Harmonics / intermod products
  - Spurious emissions from electronic devices
  - Wrong-region devices
  - Intentional or malicious interference
  - …….
- Note however there are many geography-specific interference types, e.g. from cable or broadcast television.

Repeaters / Bi Directional Amplifier(BDA)

- Mobile repeaters or bidirectional amplifiers (BDAs) can be used to extend cellular coverage in buildings or in fringe areas.
- May also be installed on boats.
- The main interference issues are the retransmission of unwanted signals at the input of the BDA as well as malfunctioning BDAs.
- Difficult to troubleshoot but a very common source of interference in the cellular bands.
- Unlicensed use illegal in the UK.

Bi Directional Amplifier(BDA) Spectral Characteristics

- A broad increase in the noise floor over several tens of megahertz is a typical sign of an oscillating BDA.
- BDAs can pick up noise, harmonics, spurs, intermodulation products, etc. inside a building, then amplify and repeat them at the tower.



Typical spectral pattern created by malfunctioning BDA. Note (from waterfall) that automatic gain control was also malfunctioning.

Bi Directional Amplifier (BDA) Physical Characteristics

- The best starting point is looking for donor antennas (usually small yagis or omnis).
- Indoor antennas are usually ceiling-mount omnis.

Wrong-region devices

- Spectrum allocations vary from country to country
- Interference can be caused by devices using frequencies allocated in a different country / region

- For example, cruise and cargo ships may have systems that disrupt cellular services upon entering different regions.

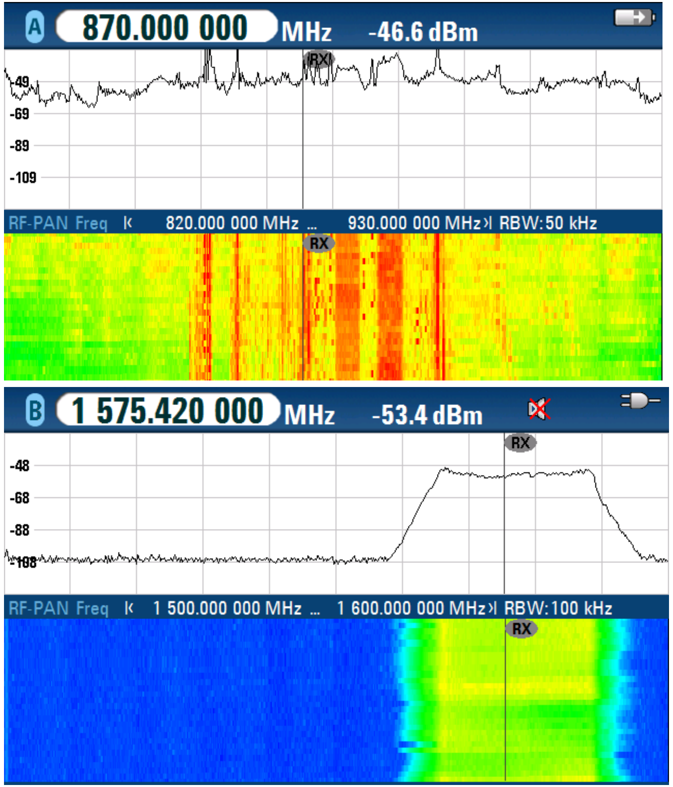
- Common wrong-region devices:
  - Wireless phone systems DECT
  - Baby monitors
  - Microphones

Deliberate interference / jammers

- Deliberate interference may be narrow-band (e.g. talking on a public safety frequency) or broad-band (jamming).
- Pirate or unlicensed ("free band") operations can also cause issues to licensed users.
- Sources may be mobile.
- Although most businesses and individuals are very cooperative in resolving interference, deliberate interferers will usually deny or conceal their activities.

HOT: Portable Cell Phone Jammer 3G/4G/WIFI/GPS/LOJACK
8 Powerful Antennas + band control switch

Spectral characteristics of jammers



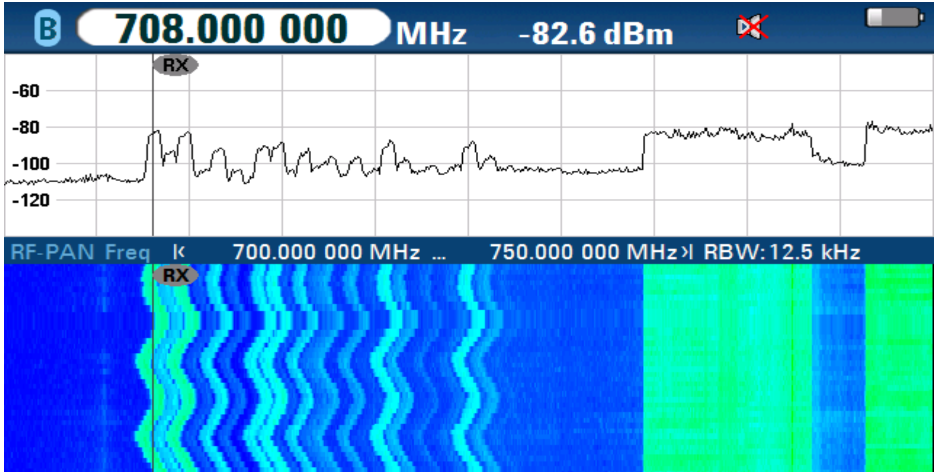
- Jammers are typically easy to identify and locate: strong, broad, always-on signal.
- Some increase the noise floor well outside of their nominal operating range.
- Jammers may generate very strong harmonics outside of their nominal operating range.
- Common commercial cellular jammer targets are cellular, GPS, WiFi, and car remotes.

Wireless microphones

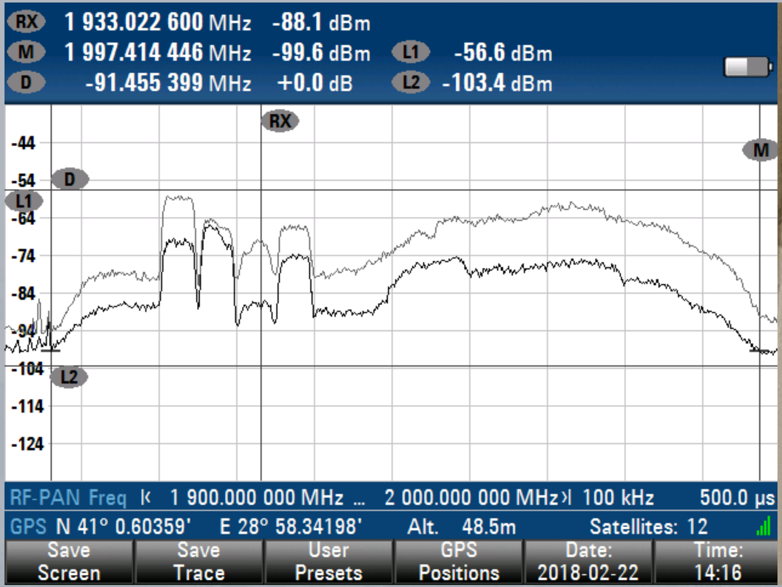
- Often used by clubs, organizations, schools, churches, etc.
- Coming temporarily into town by bands brining their equipment from abroad
- Problems result from operation outside of permitted frequencies
- Typically narrow-band, FM modulated signals. May be very powerful transmitters for their size.
- An excellent way to track down wireless microphones is using audio demodulation / recording.

Spurious emissions from electronic devices

- Almost all electronic devices emit radio frequency energy at various frequencies.
- Interference is caused when high level *spurious emissions* (or their harmonics) fall into cellular bands.
- Spurs can be narrowband or wideband, possibly frequency-unstable.
- Common sources of spurs:
  - Amplifiers of any kind
  - Lighting and displays (screens)
  - Consumer electronics
  - Industrial equipment



Impact of interference on network performance



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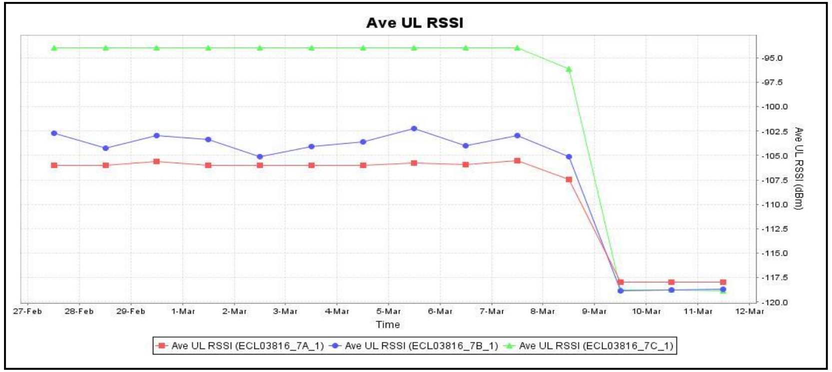
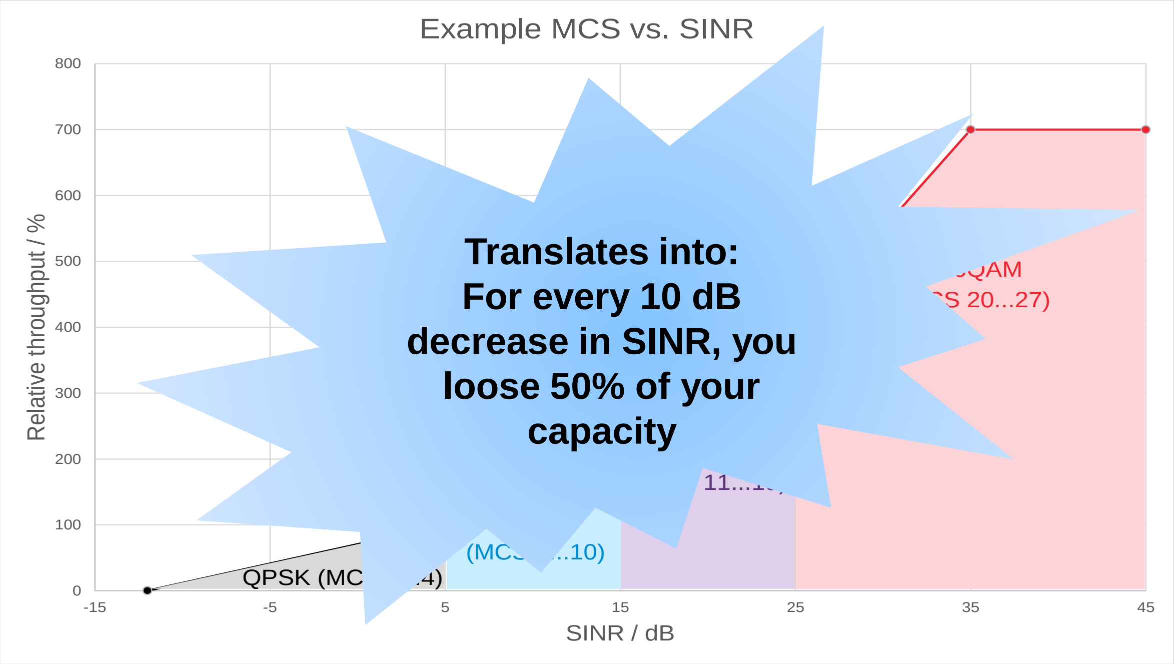
Impact of interference on network performance

- Network performance can be categorized on two levels:
  - RF level : SNR, Ec/Io, RSSI, RSRP, etc.
  - Subscriber level : Throughput, call drops, voice/video quality, etc.
- Interference is an RF level issue, but affects the subscriber quality of experience.
- Important therefore to test at **both** the RF level and the subscriber level.
- Generally speaking, you need a combination of tools to test at both levels.



Impact of interference on network capacity



It is not easy to quantify the impact of interference towards the capacity of a network, because it's depending on so many parameter. Here just a general graph with MCS areas:

The graph is a simplified real-world example for EPA5, 2x2MIMO and HARQ.
The MCS-SINR relation depends on the specific Base Station vendors' algorithms, performance and scheduler implementation, as well as on the channel fading profile etc.

MCS: Modulation and Coding scheme
SINR: Signal to Interference and Noise Ratio

Identifying, locating and eliminating external interference

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Steps in interference hunting

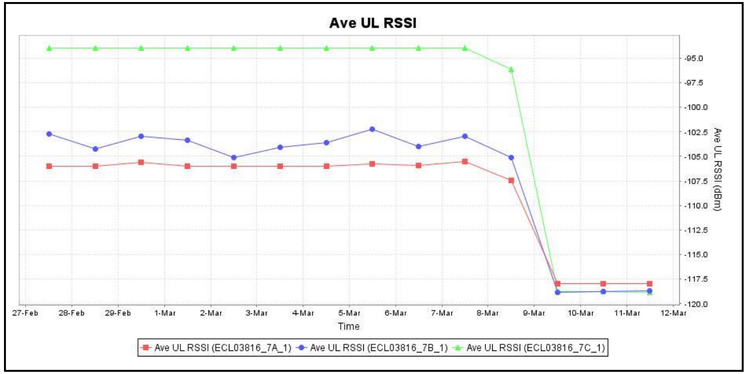
- **Detecting interference**
  - For network operators, usually things like high RSSI, call drops, poor throughput, etc.
- **Reconfirm/Identifying interference**
  - At site, make sure you see the interferer.
- **Determining general location of interferer**
  - Attempt to narrow down location to ~100 meters
  - Often involves driving/walking the entire affected area.
- **Determining specific location of interferer**
  - Done on foot
  - Handheld antennas
  - Need to locate specific device generating RF

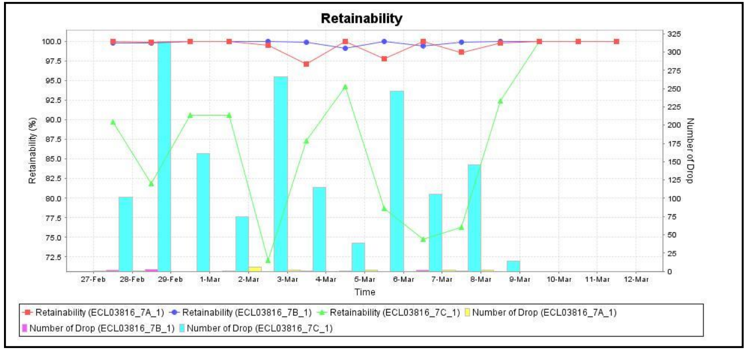
Detecting Interference

- For cellular network operators, interference issues are almost always found in the uplink

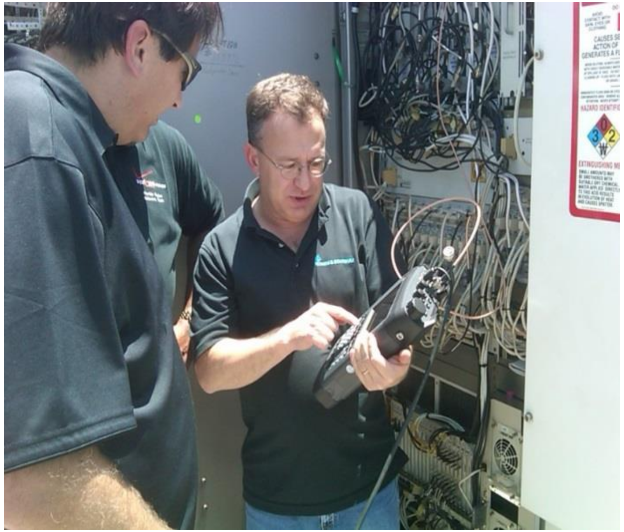
- First indications of interference normally come from the base station statistics themselves

- Usually one sector is affected more than the others. Multiple sectors from multiple base stations may be affected by a single source of interference.





Reconfirm/Identifying Interference

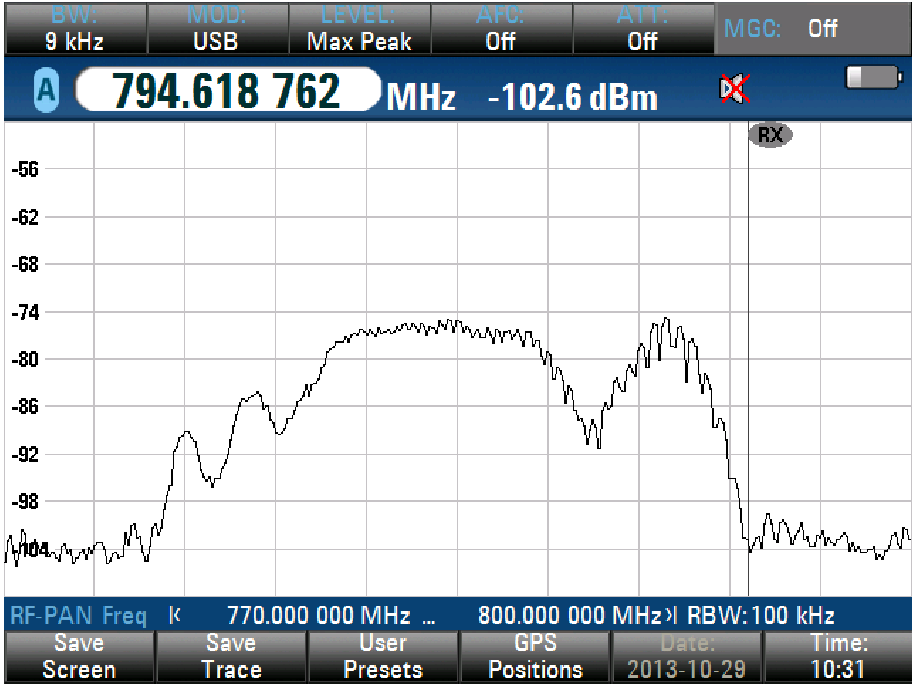


- Analyzing an interfering signal can provide important clues about its source. The most common analysis methods include :
  - Spectral analysis
  - Waterfall analysis
  - Persistence Histogram
  - Pattern analysis

- Many common interference sources can be easily identified by their spectral characteristics.
- Important to know what your spectrum and common interferers normally “look like”.

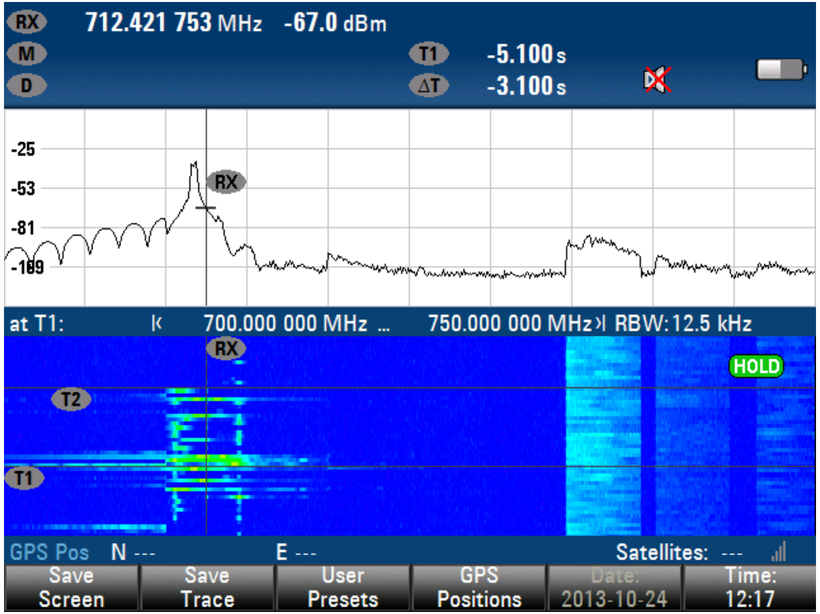
Reconfirm/Identifying Interference: Spectral analysis

- Many interferers have a distinctive spectral “shape” that helps to identify them.
- For example: leaking cable television signals can be identified by the regularly-spaced, identical-width channels.
- Locating the interferer is greatly simplified, if you know (roughly) what you are looking for.
- Many providers build their own “library” of well-known interferers and their spectral characteristics.



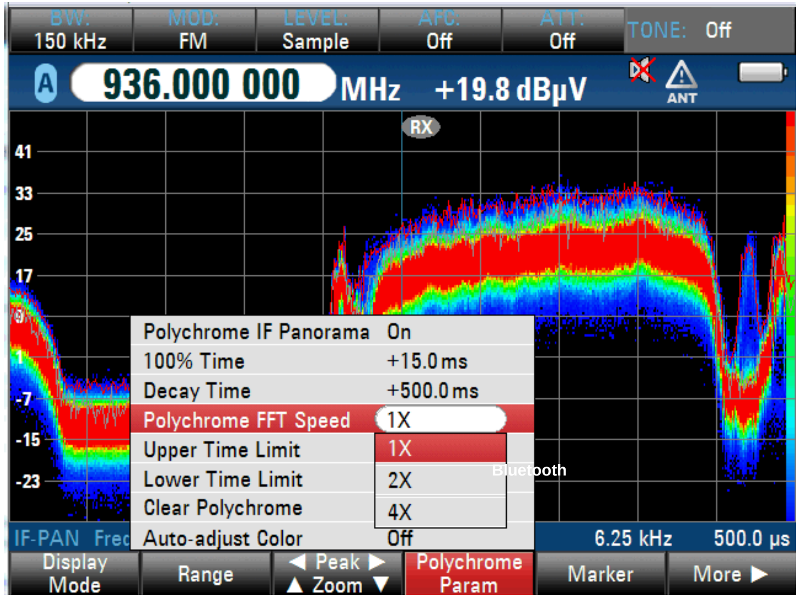
Reconfirm/Identifying Interference: Waterfall analysis

- A waterfall (or spectrogram) display shows frequency, time, and level information (as color)
- Extremely useful in analyzing signal behavior over time or for locating short duration signals.
- Can reveal the presence of interferers underneath desired signals.
- Waterfall intensity can also be helpful in locating an oscillating / drifting signal.
- Recommendation : always use spectrum and waterfall together during interference hunting.



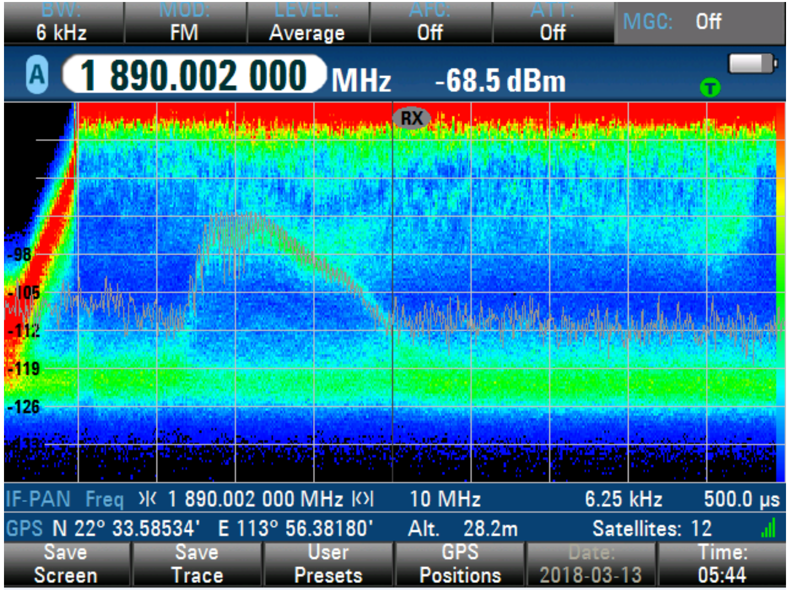
Reconfirm/Identifying Interference: Persistence Histogram

- What exactly is polychrome spectrum display?
  - Persistence Histogram (statistical function that uses several measured levels as basis)
  - Processes level-frequency pairs over time
  - Color indicates relative occupancy over time (How “often” that signal is measured) or signal duration

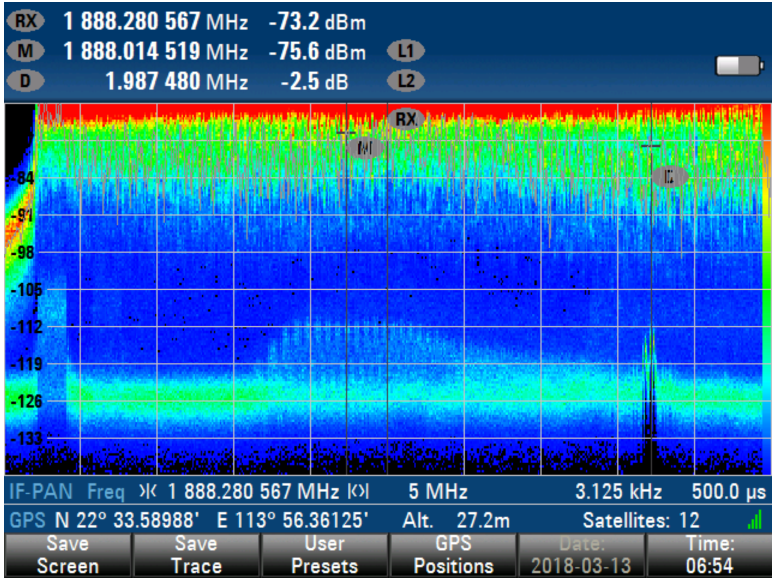


Reconfirm/Identifying Interference
Visualizing the interferer TDD LTE

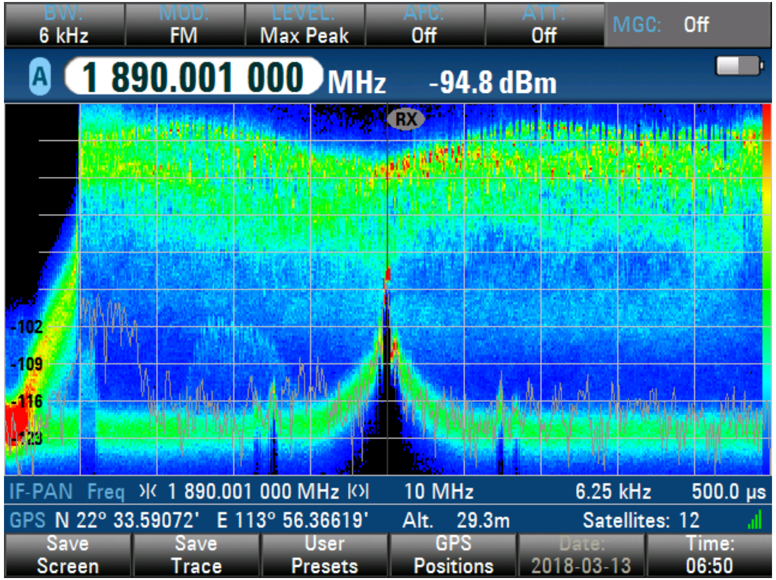
- LTE TDD signal, the Polychrome feature of the MNT100 was used to detect and visualize the external interferer.
- A 100% time of 15 ms was chosen due to the overlaying LTE signal.
- Width, level, and general spectral shape of the suspected external interferer was clearly visible using polychrome.



Reconfirm/Identifying Interference
Visualizing the interferer TDD LTE



Suspected interferer less visible



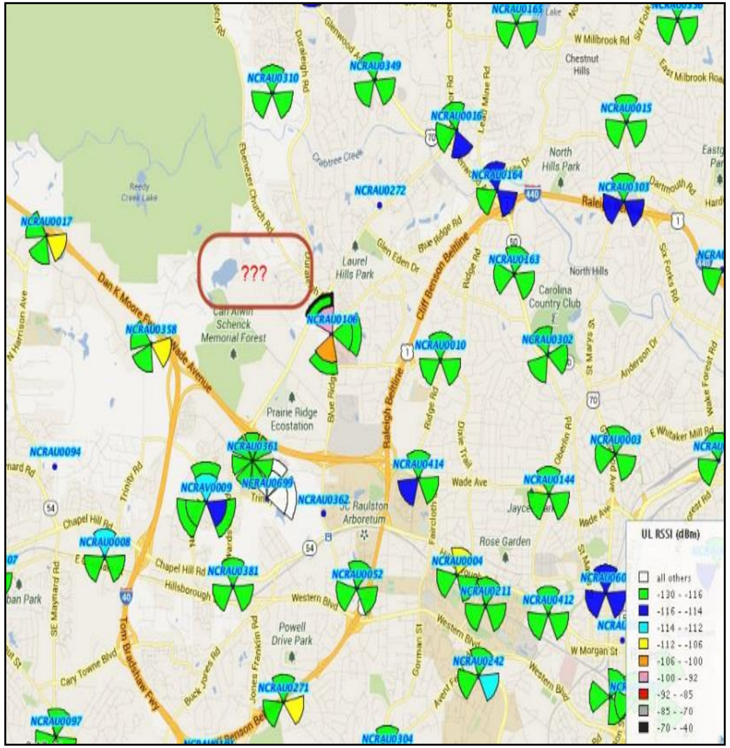
Large CW-type signal seen in later stage of hunt

Reconfirm/Identifying Interference: Pattern analysis

- Important questions to ask in analyzing interference patterns:
  - When does the interference occur?
  - Is the interference constant or intermittent?
  - Does the interference coincide with any other (physical or spectral) events?
  - Does the interferer affect multiple locations in a given sequence?
- In many cases, base station statistics can provide useful information.
- Trying to find interference when it is not “on” is not productive.

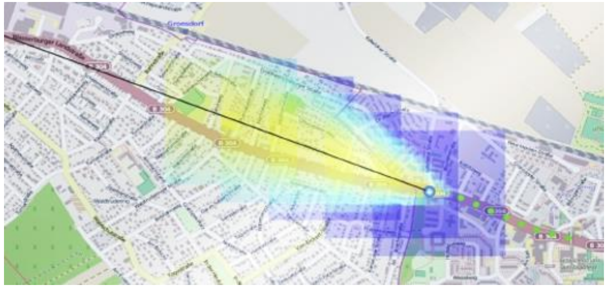
Identifying the general location

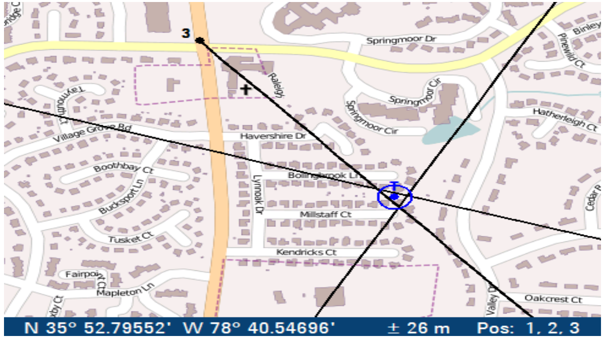
- The first indications of interference normally come from the base station statistics themselves.
- Usually one sector is affected more than the others. Multiple sectors from multiple base stations may be affected by a single source of interference.
- Note that base station statistics can only provide location with a sector-level resolution at best – where is the interferer within that sector?



Driving around

- In most cases, the interferer CANNOT be seen on the ground at the base station.
- One typically has to drive (or walk) the sector(s) / affected area to try to narrow down the location of interfering signal.
- In the driving phase we use things such as:
  - RF “heat maps”
  - Manual and automatic bearings
  - Network performance statistics.
- Typically we want to get within about 100 meters of the interferer.





Walking around

- The next step is to locate the exact source of the interference.
- Handheld antennas are used to sweep or scan. Level information in the form of spectrum amplitude, waterfall intensity, or tone output can be used to determine position.
- Ultimately, the only way to determine if a device is the source of interference is to power it off and examine base station statistics (subscriber-level vs. RF-level)

Overview of test tools and methodologies

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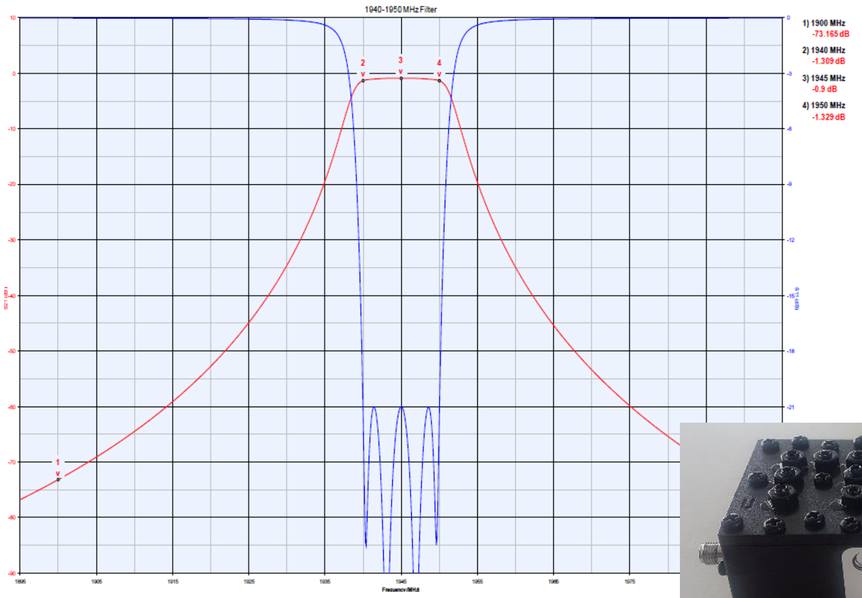
Table of content

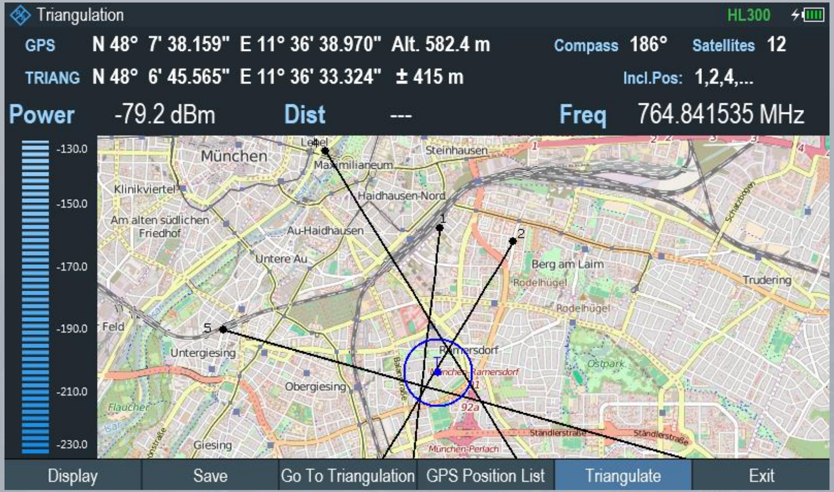
- Uplink Filter
- Directional Antenna HE400/Yagi
- Spectrum Analyser FPH/FSH
- Interference Receiver MNT100
- TDD LTE/5G NR Interference Hunting
- Scanner TSMA/E with Romes
- Mobile Locator DDF007

Uplink Filter (External Filter)

- In most outdoor situation additional external Filter needed.
  (For both Spectrum Analyzer and Interference Receiver)

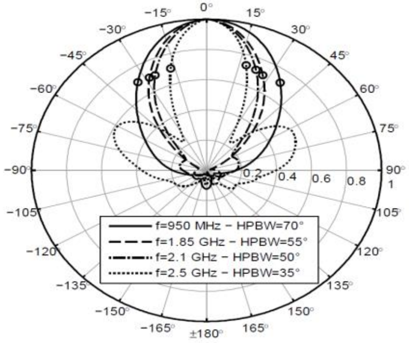


Directional Antenna (HE400)



Directional Antenna R&S®HE400

- Automatic module and polarization recognition
- Low Noise Amplifier (powered by R&S® FSH/FPH or PR100)
- Easy and comfortable handling (trigger button, arm rest etc.)
- Automatic field strength display based on detected antenna module and stored k-factor tables in R&S® FSH/FPH or PR100
- Exact positioning system with GPS and GLONASS support
- Highly accurate bearing information in cellular bands due to delta mode function (R&S®HE400CEL)



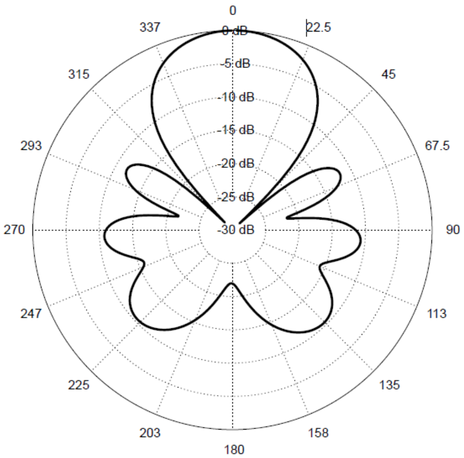
Typical field pattern of cellular module in the H plane in sum mode.

Yagi Antennas R&S®HA-Z900 / -Z1900

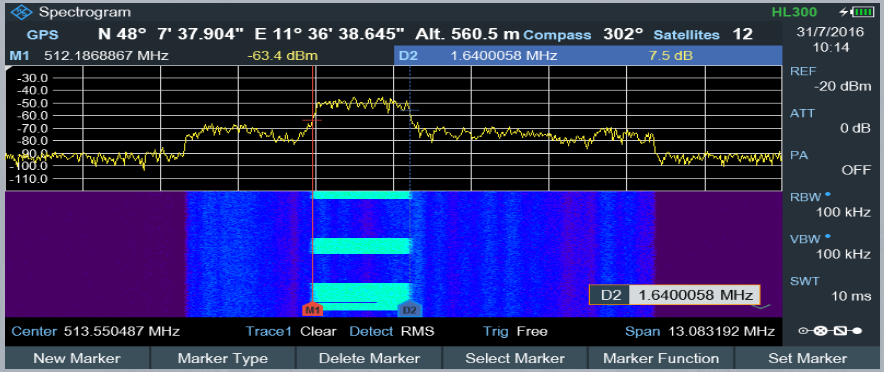
- The R&S®HA-Z900 and -Z1900 are directional Yagi antennas.
- They are easy to handle and designed as a (passive) receiving element in regulated frequency bands.

Table 1-1: Specifications of the R&S®HA-Z900 Yagi antenna

Frequency range	824 MHz - 960 MHz
Gain	11.5 dBi (typ.)
Impedance	50 Ω
VSWR	< 2.5:1
Input	0 V DC, < 22 dBm RF
Connector type	N (f)
Operating temperature range	-10°C to +55°C
Storage temperature range	-40°C to 70°C
Dimensions (W x H x D)	757 mm x 186 mm x 37 mm
Weight	0.4 kg
Mechanical resistance	EN 60068-2-6, EN 60068-2-64, MIL-STD-810E
Climatic loading	MIL-STD-810G



Spectrum Analyzer FPH/FSH



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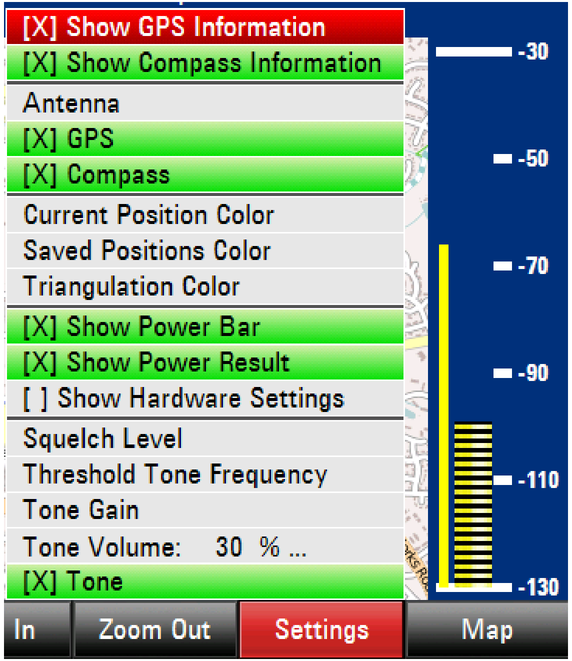
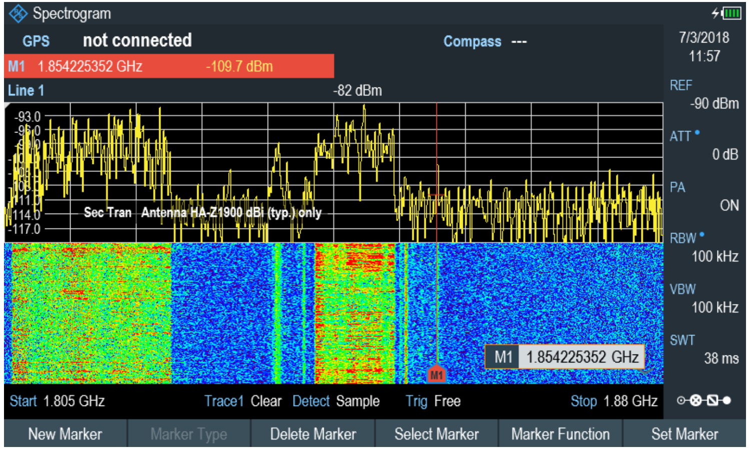
Tone Function

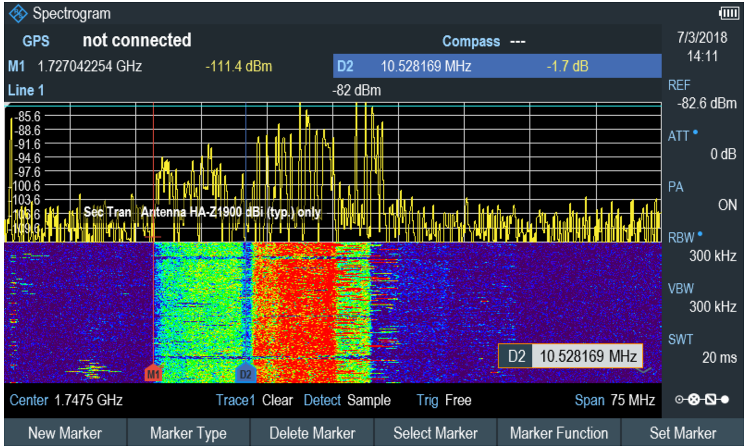
- The Tone function outputs an audible tone whose level varies according to the received signal strength level.
- The current receive level (dashed line) and squelch level (solid line) are displayed in the power bar.
- Tone can be used both for obtaining bearings as well as for sweeping an area to determine the precise location of an interferer.



Spectrogram

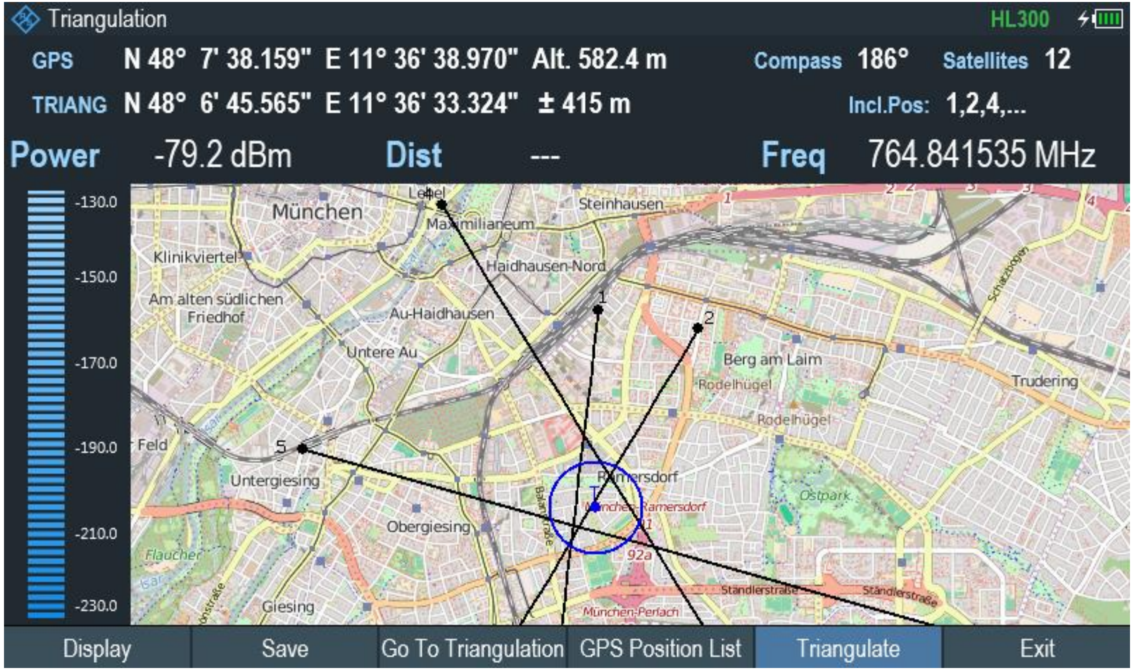
- Spectrograms display amplitude vs. frequency over time. Amplitude is indicated by the color of the spectrogram display.
- Spectrogram reference, range, and other parameters can be specified
- Extremely useful in interference hunting – allows the observation of a signal’s behavior over time.



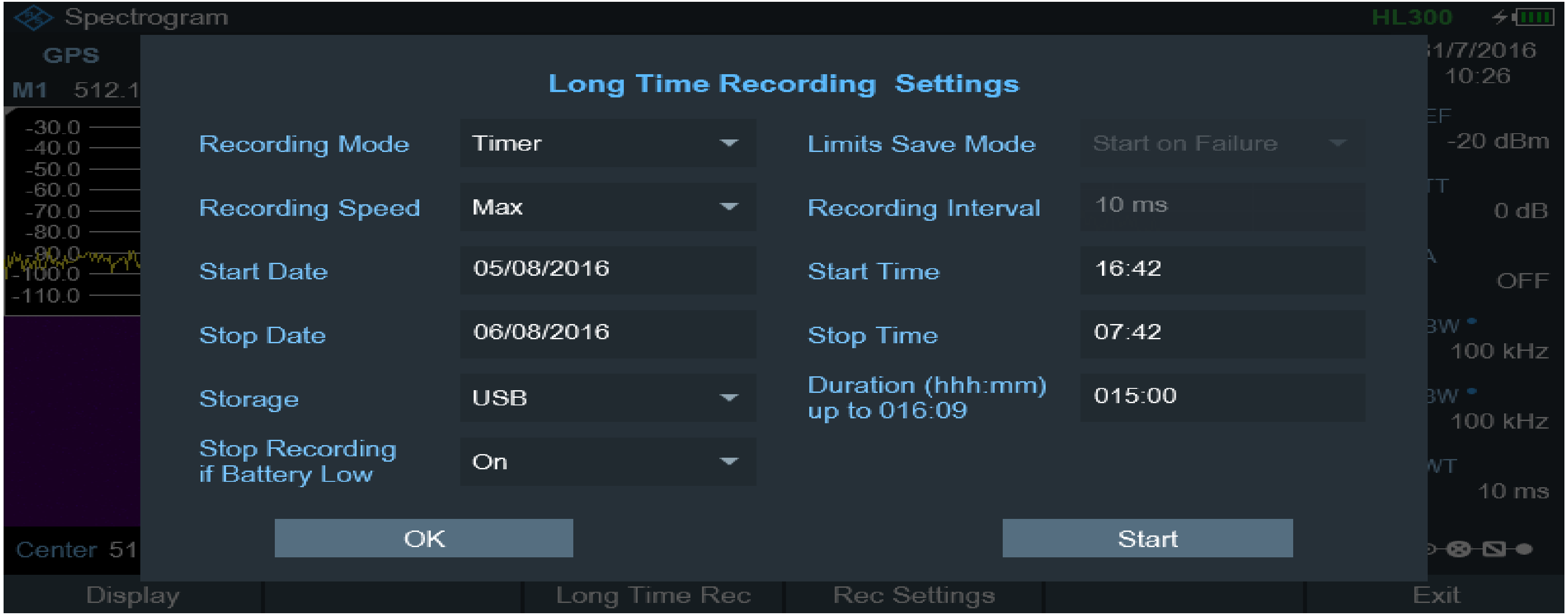


Saving Positions, Azimuth and Triangulation

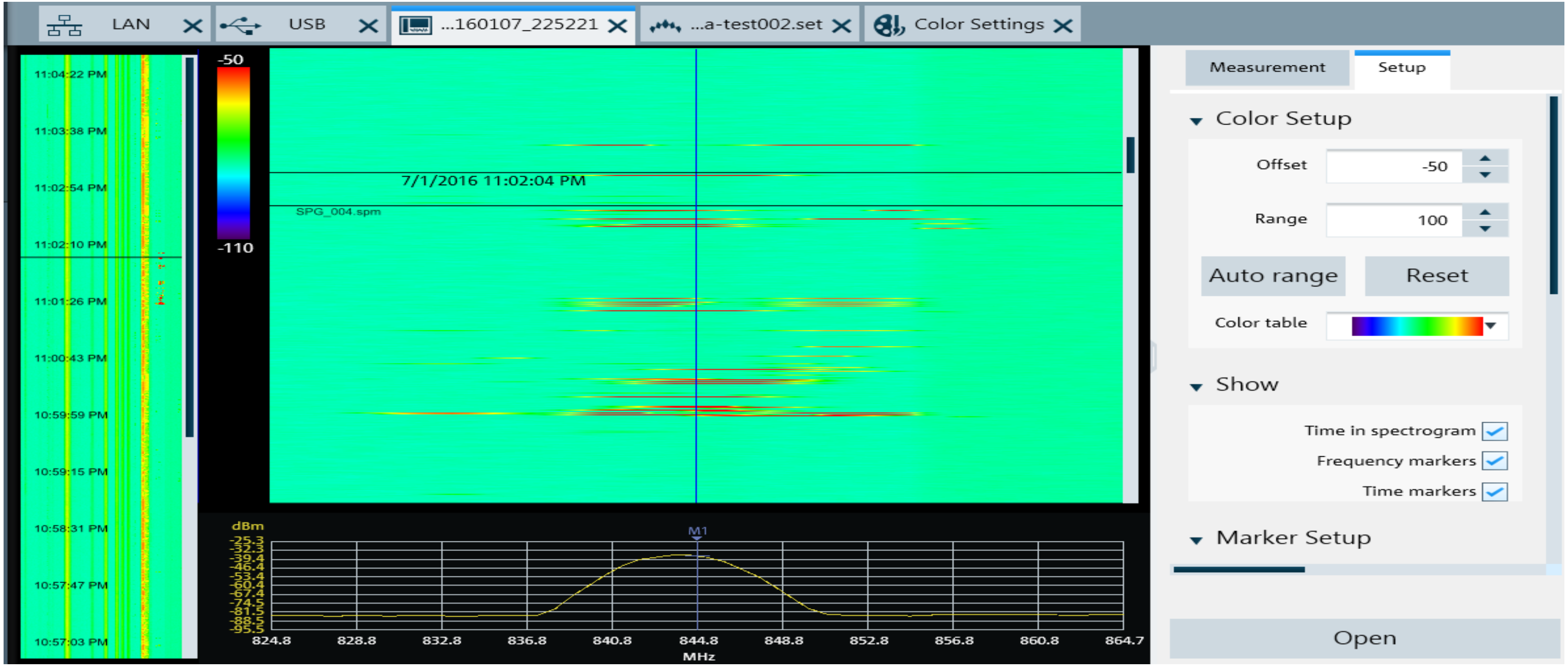
- The azimuth (or bearing) is the direction in which the antenna is currently pointed
- The power bar and power result can help determine the direction of maximum receive power (i.e. bearings towards the transmitter)
- The Triangulate function computes the triangulation point for the selected bearings.



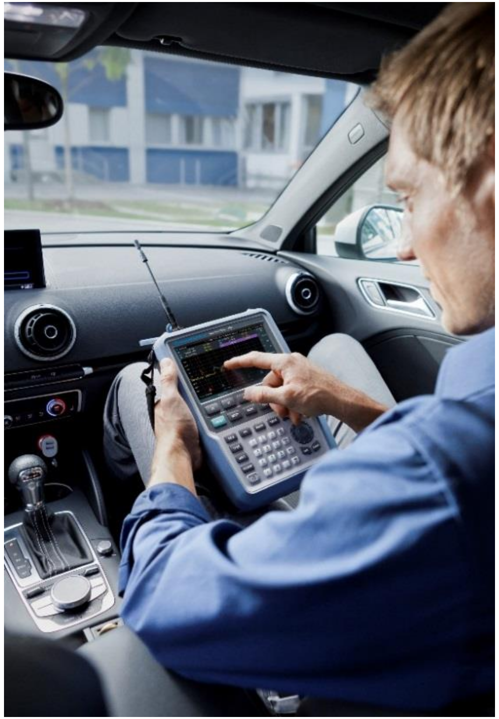
Long Time Recording

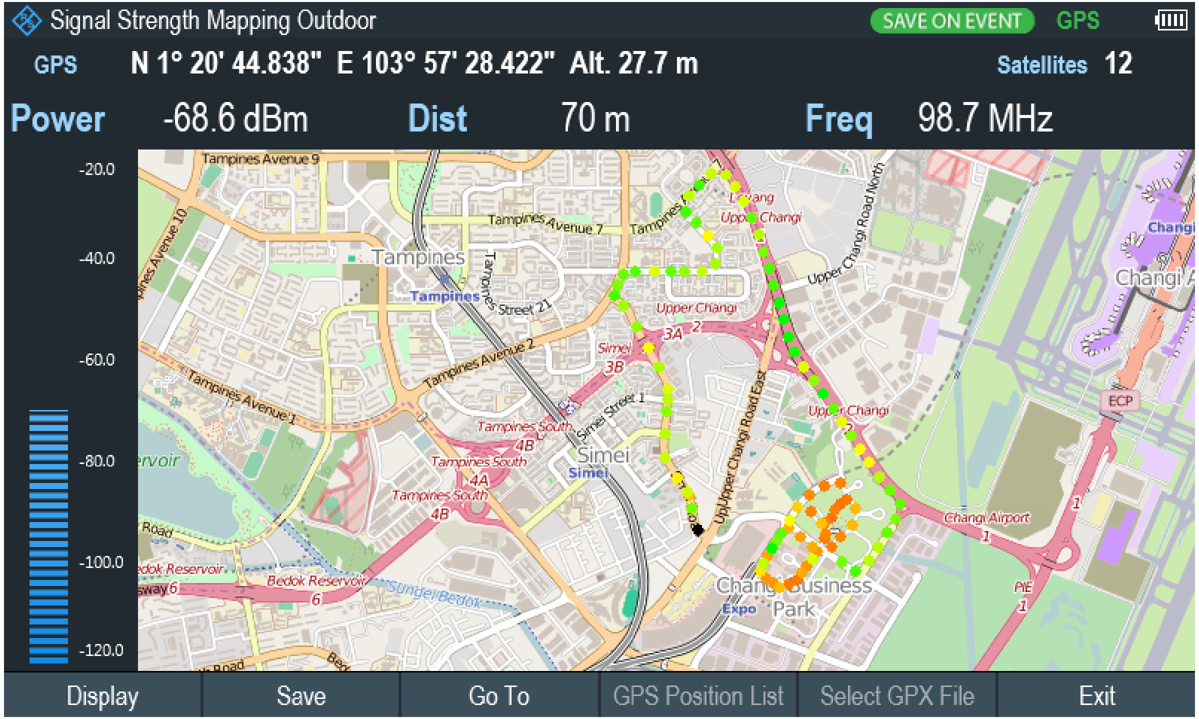


Long Time Recording (Analyses via Instrument View)

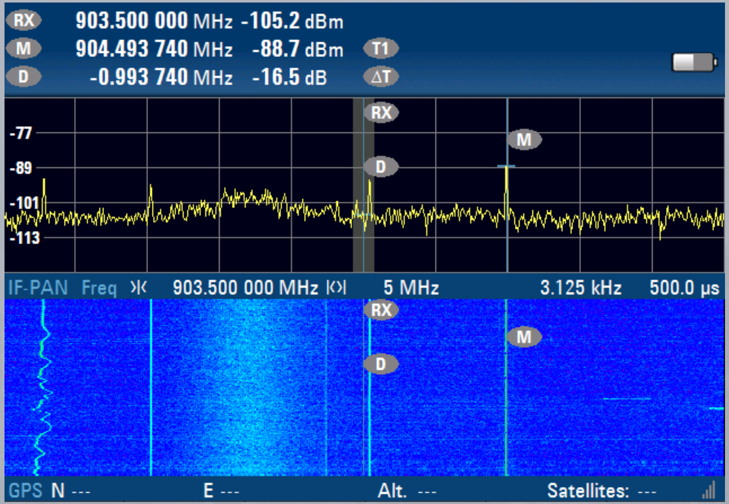


Signal Strength Mapping (FPH-K16)





Interference Receiver MNT100



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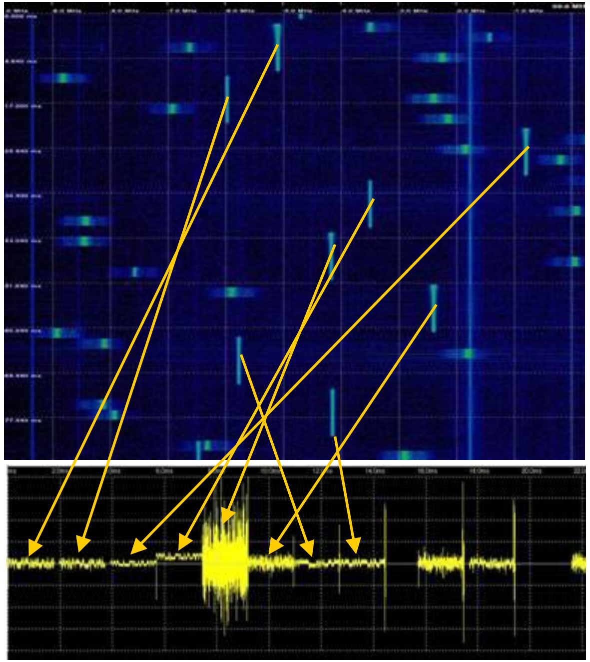
Speed vs. accuracy

- Biggest difference is speed.

- Spectrum analyzers are (relatively) slow, but highly accurate over a wide frequency range.

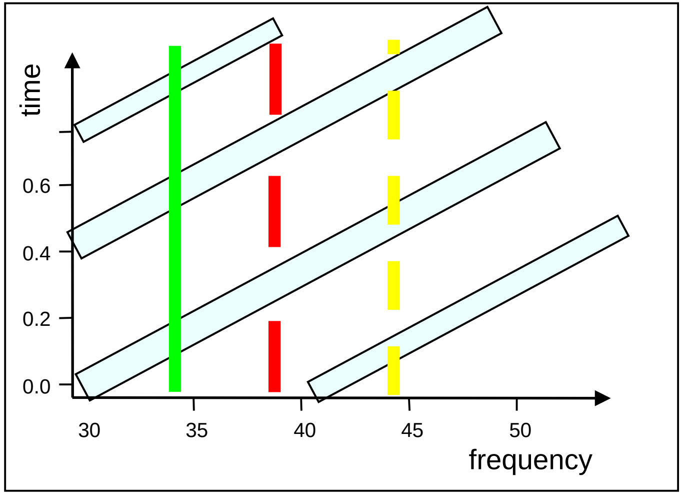
- Monitoring receivers are less accurate, but are very fast (real-time) and gap-free. POI within the demodulation bandwidth is 100%.

- Short duration (low POI) signals
  - Digital data
  - Frequency hoppers
  - Radar pulses
  - Noise sources
  - Clandestine transmitters

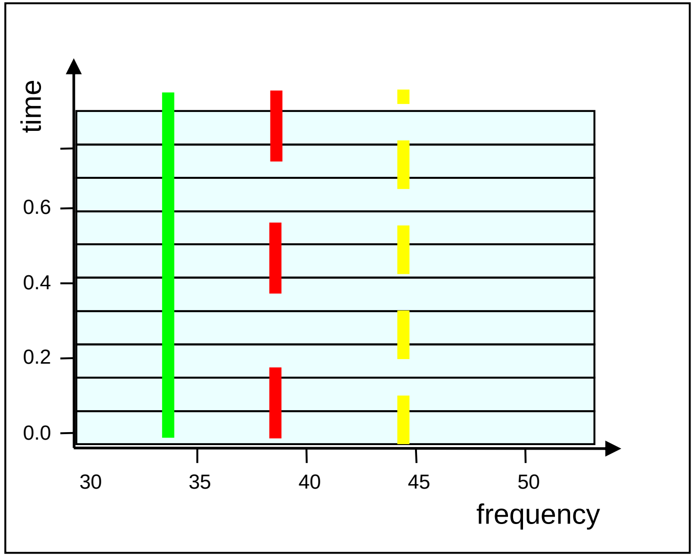


Reassembly of a frequency-agile signal

Monitoring short duration signals



Spectrum analyzer
(swept / heterodyne principle)



Monitoring receiver
(FFT based)

Best sensitivity with acceptable speed

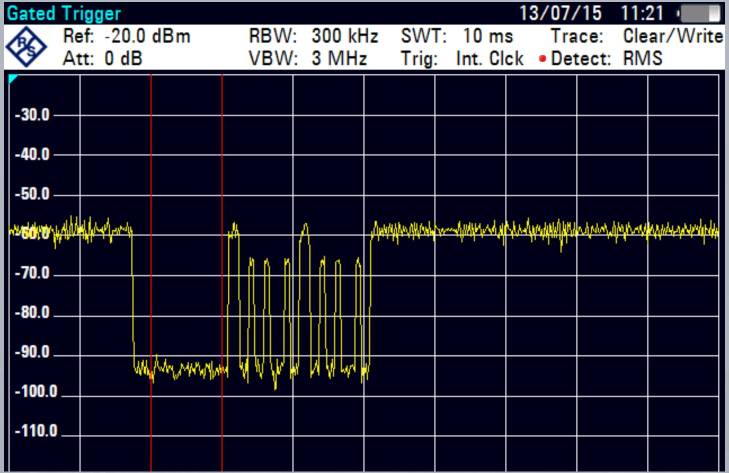
(from Data sheet MNT100) DANL (1 Hz)= -157 dBm
Spectrum Analyzer reaches this with Pre Amp on

Calculation:
DANL (RBW) = DANL (1 Hz) * 10 x log(RBW [Hz] / 1 Hz)

MNT100 uses standard 6,25 kHz RBW (standard in FFM mode: Span 10 MHz)
DANL 6,25 kHz: -157 dBm + 38 dB = **-119 dBm**

For **Spectrum Analyzer** to have acceptable speed used RBW 100 kHz
DANL 100 kHz: -157 dBm + 50 dB = **-107 dBm**

TDD LTE/5G NR Interference Hunting



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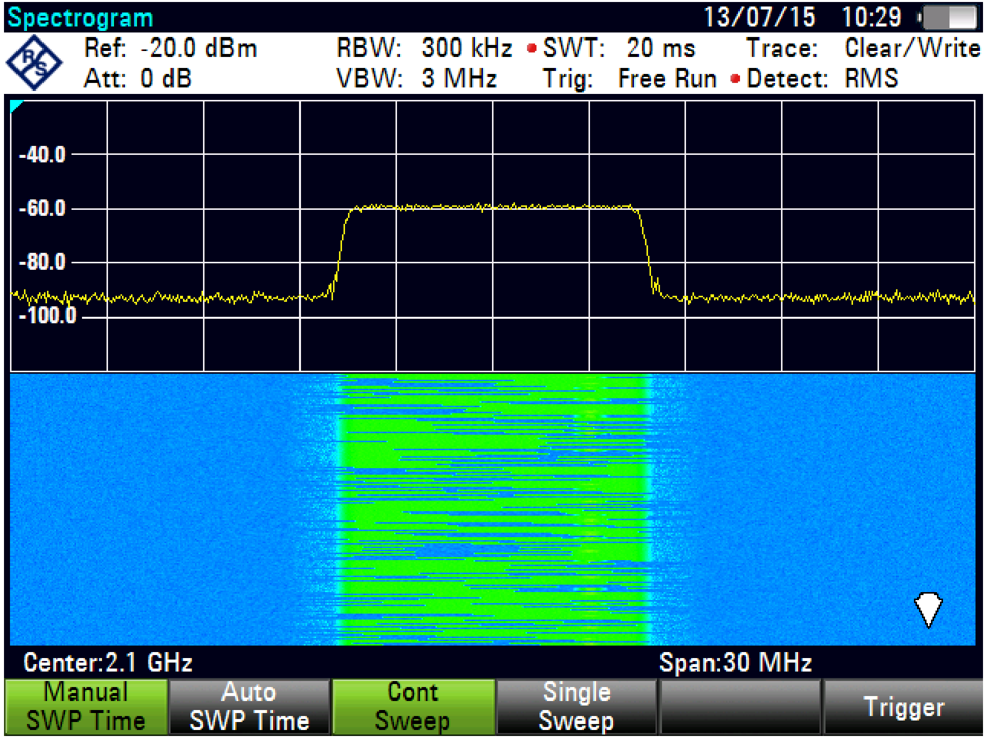
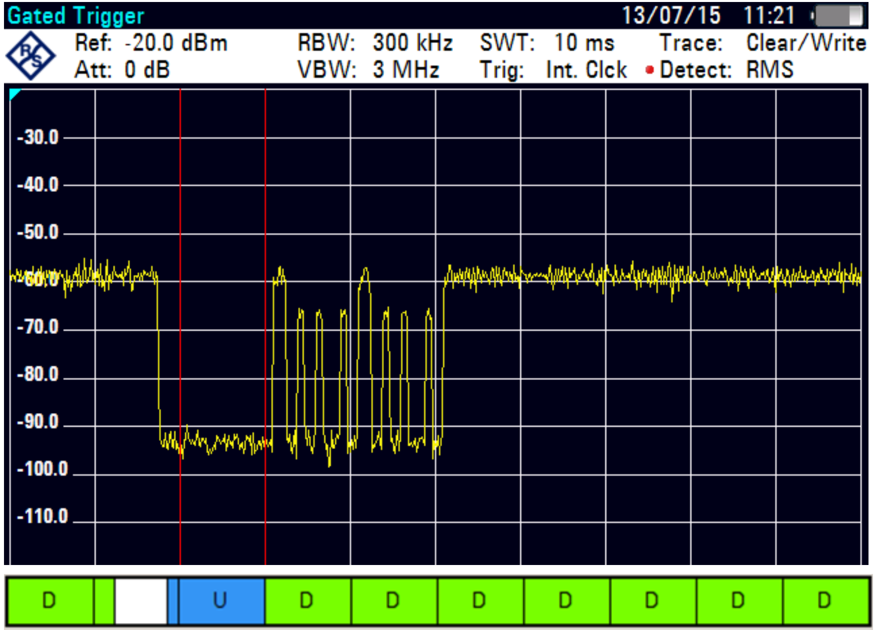
TDD with interferer present (non triggered)

- This is an example of a TDD LTE signal in “normal” (free run) operating mode.
- Downlink frames dominate the spectrum display (no uplink traffic is present in this example).
- Without triggering, it is extremely difficult to see even a strong interferer within the TDD band.
- Having properly configured our Gate Settings, we now enable Gated Trigger



Determining time slot allocations

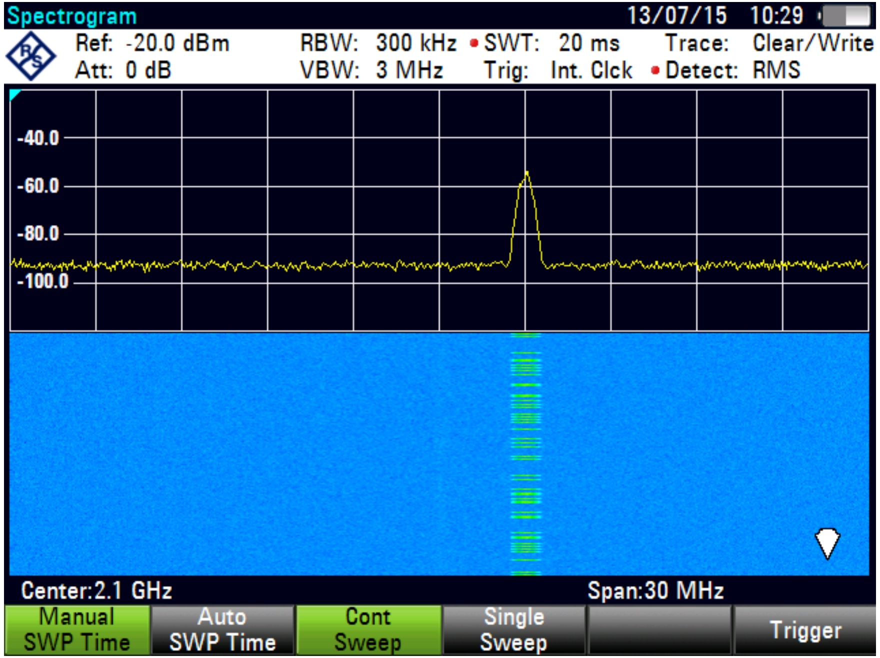
- Zero span screen is used to determine the location of one or more (depending on TDD configuration) uplink timeslots
- Gate delay and gate length are shown as two vertical red lines in the zero span display – gate delay and gate length, will be set to mask uplink only.



TDD with interferer present (triggered)

- With Gated Trigger enabled, the downlink frames are suppressed and we can clearly see a strong (~ -55 dBm) periodic interferer in both the spectrum and waterfall displays.

- All standard FSH functions can now be used with the Gated Trigger enabled.



Nice TDD LTE Video from a customer in the US

Gated trigger feature on Rohde & Schwarz FSH

Liam ONeill

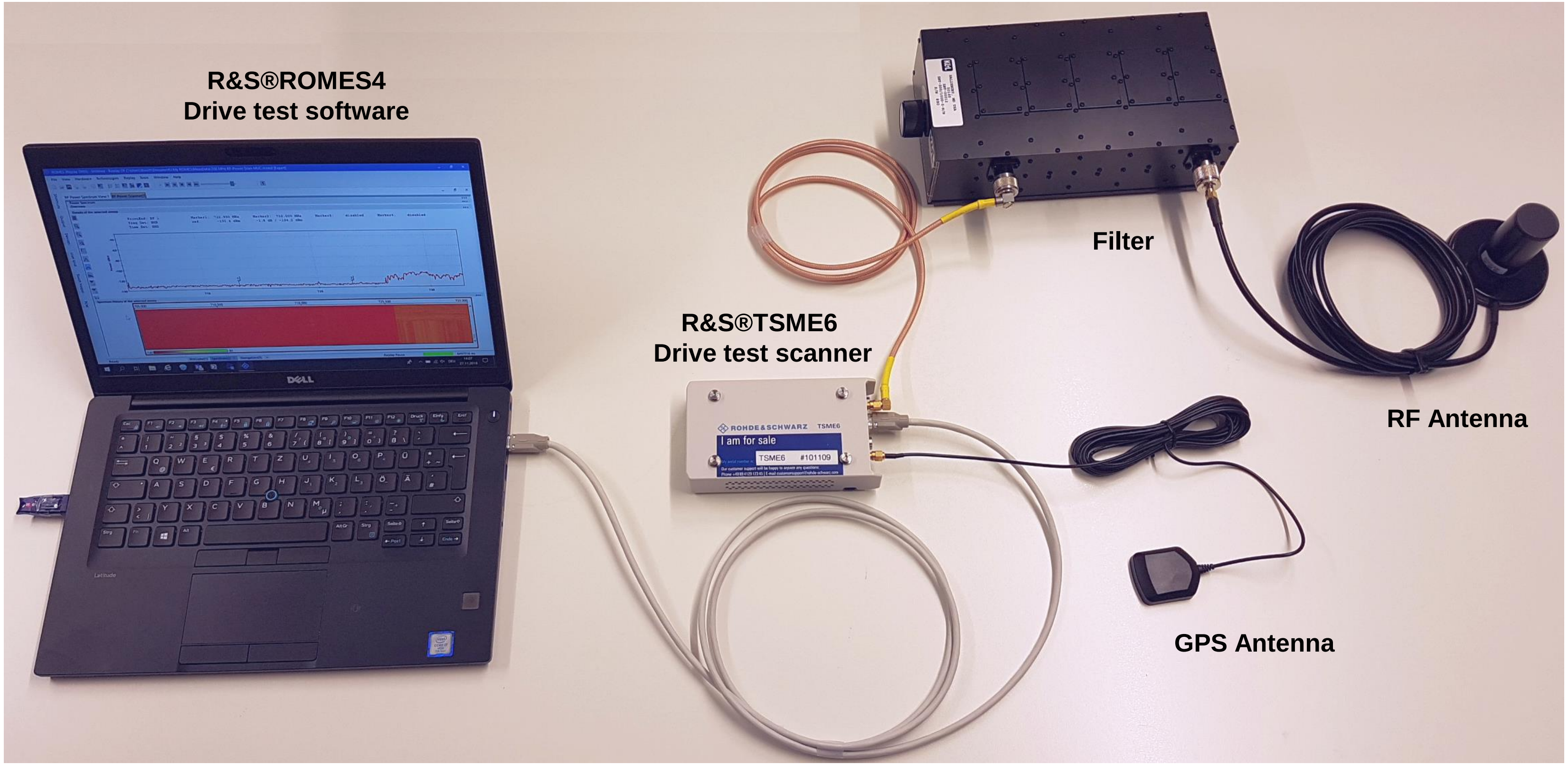
vor 10 Monaten • 304 Aufrufe

The Gated Trigger feature allows the spectrum analyzer to look at uplink only domain in TDD LTE and ignore the downlink domain ...

https://www.youtube.com/watch?v=wvL1cX4F9Uc

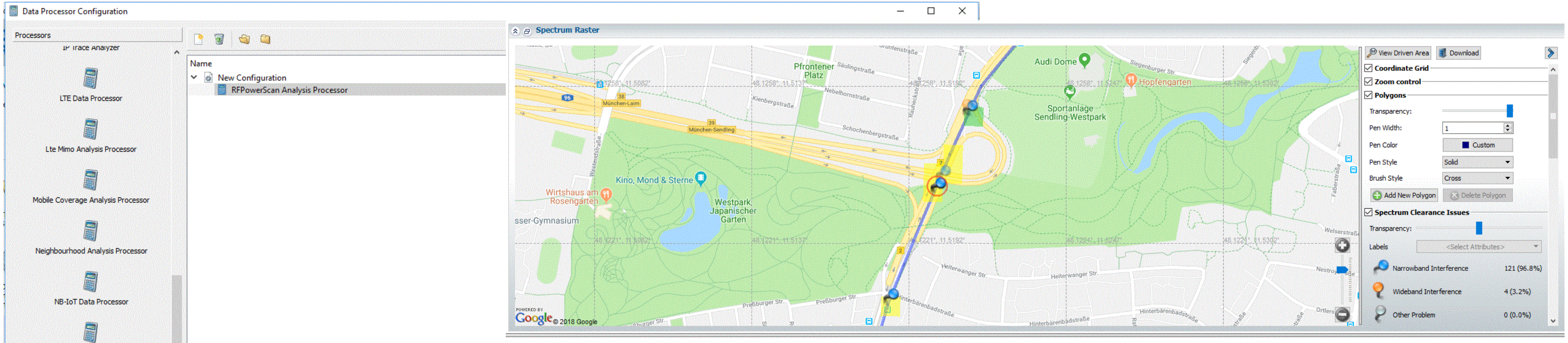
Scanner TSMA/E with Romes. Spectrum clearance

Spectrum clearance system



Measurements while driving

Post-processing back in the office with Network Problem Analyzer

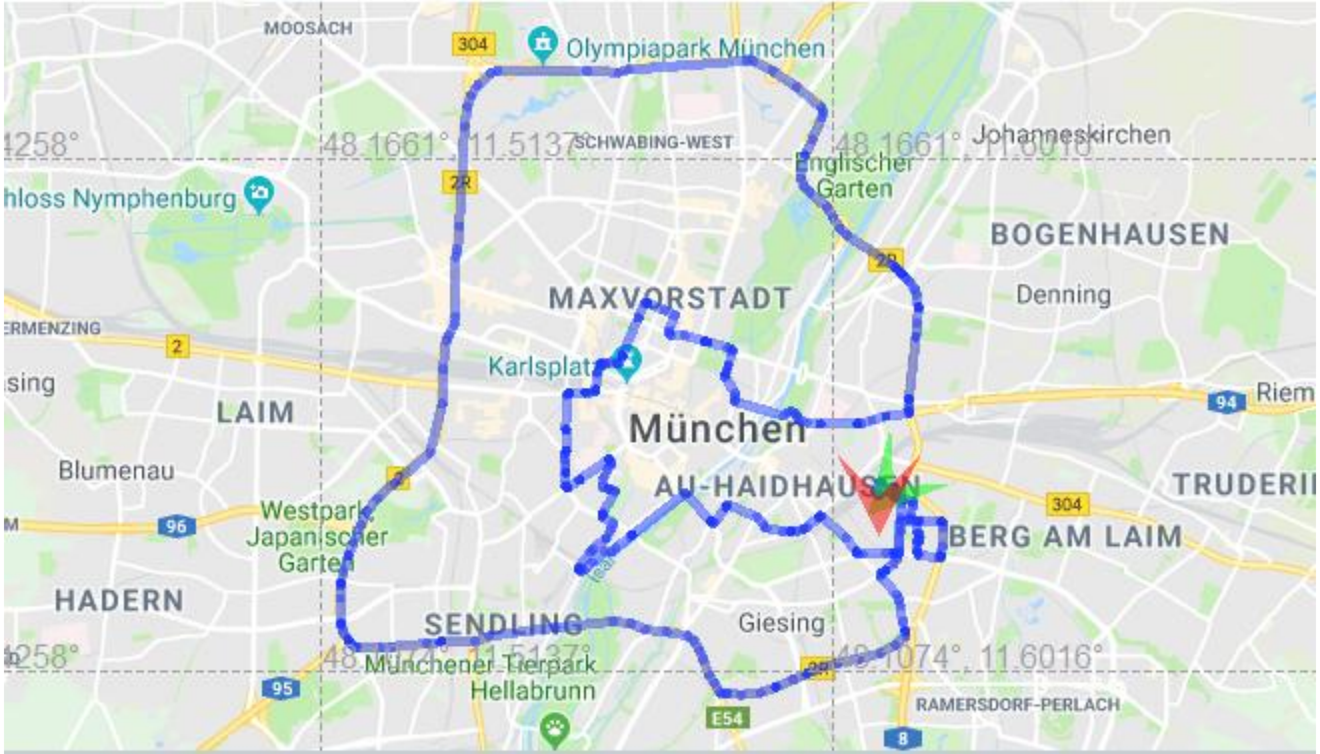


Spectrum Analysis - Issue List

Start Time	End Time	Latitude	Longitude	Title	Description	Frequency	Bandwidth	Peak Power	Duration
10:07:12.720	10:08:37.100	48.1285	11.612	Narrowband Interference	Peak power detected -106.26 dBm at a frequency of 728.23 MHz. Frequency range is from 728.17 MHz to 728.55 MHz.	728.234 MHz	0.385 MHz	-106.3 dBm	84.38 s
10:07:13.163	10:08:35.200	48.1285	11.6121	Narrowband Interference	Peak power detected -108.19 dBm at a frequency of 731.41 MHz. Frequency range is from 731.36 MHz to 731.52 MHz.	731.409 MHz	0.110 MHz	-108.2 dBm	82.04 s
10:07:23.997	10:08:59.899	48.1285	11.6121	Narrowband Interference	Peak power detected -106.61 dBm at a frequency of 729.47 MHz. Frequency range is from 729.33 MHz to 729.71 MHz.	729.472 MHz	0.220 MHz	-106.6 dBm	95.90 s
10:07:30.420	10:08:59.899	48.1285	11.612	Narrowband Interference	Peak power detected -106.51 dBm at a frequency of 730.79 MHz. Frequency range is from 729.82 MHz to 731.63 MHz.	730.793 MHz	0.715 MHz	-106.5 dBm	89.48 s
10:08:25.401	10:09:00.099	48.1285	11.6121	Narrowband Interference	Peak power detected -104.88 dBm at a frequency of 727.73 MHz. Frequency range is from 726.19 MHz to 729.22 MHz.	727.734 MHz	1.375 MHz	-104.9 dBm	34.70 s
10:08:35.600	10:08:35.803	48.1285	11.612	Narrowband Interference	Peak power detected -105.57 dBm at a frequency of 727.58 MHz. Frequency range is from 726.63 MHz to 728.06 MHz.	727.585 MHz	1.430 MHz	-105.6 dBm	0.20 s
10:08:35.600	10:08:37.100	48.1285	11.612	Narrowband Interference	Peak power detected -106.55 dBm at a frequency of 728.98 MHz. Frequency range is from 728.66 MHz to 729.16 MHz.	728.984 MHz	0.495 MHz	-106.5 dBm	1.50 s
10:08:35.803	10:08:37.100	48.1285	11.612	Narrowband Interference	Peak power detected -108.53 dBm at a frequency of 729.52 MHz. Frequency range is from 729.49 MHz to 729.60 MHz.	729.517 MHz	0.110 MHz	-108.5 dBm	1.30 s
10:08:51.700	10:08:59.899	48.1285	11.612	Narrowband Interference	Peak power detected -108.03 dBm at a frequency of 731.86 MHz. Frequency range is from 731.80 MHz to 732.02 MHz.	731.864 MHz	0.110 MHz	-108.0 dBm	8.20 s
10:08:51.700	10:08:59.499	48.1285	11.612	Narrowband Interference	Peak power detected -106.68 dBm at a frequency of 732.69 MHz. Frequency range is from 732.51 MHz to 732.90 MHz.	732.689 MHz	0.165 MHz	-106.7 dBm	7.80 s
10:08:51.700	10:08:59.899	48.1285	11.612	Narrowband Interference	Peak power detected -107.14 dBm at a frequency of 732.15 MHz. Frequency range is from 732.08 MHz to 732.24 MHz.	732.152 MHz	0.110 MHz	-107.1 dBm	8.20 s
10:08:51.900	10:08:59.099	48.1285	11.612	Narrowband Interference	Peak power detected -109.23 dBm at a frequency of 732.33 MHz. Frequency range is from 732.29 MHz to 732.35 MHz.	732.328 MHz	0.055 MHz	-109.2 dBm	7.20 s
10:08:55.599	10:10:46.702	48.1276	11.6121	Narrowband Interference	Peak power detected -101.58 dBm at a frequency of 729.68 MHz. Frequency range is from 726.19 MHz to 732.96 MHz.	729.676 MHz	6.710 MHz	-101.6 dBm	111.10 s
10:09:10.597	10:31:46.620	48.1208	11.5185	Narrowband Interference	Peak power detected -102.46 dBm at a frequency of 713.90 MHz. Frequency range is from 710.35 MHz to 714.75 MHz.	713.897 MHz	4.400 MHz	-102.5 dBm	1356.02 s
10:09:30.195	10:32:11.019	48.1234	11.5201	Narrowband Interference	Peak power detected -104.98 dBm at a frequency of 724.48 MHz. Frequency range is from 724.43 MHz to 725.31 MHz.	724.478 MHz	0.880 MHz	-105.0 dBm	1360.82 s
10:09:39.395	10:32:13.418	48.1237	11.5203	Narrowband Interference	Peak power detected -104.18 dBm at a frequency of 718.09 MHz. Frequency range is from 717.50 MHz to 718.99 MHz.	718.091 MHz	1.375 MHz	-104.2 dBm	1354.02 s
10:13:05.304	10:15:50.104	48.1102	11.6118	Narrowband Interference	Peak power detected -103.43 dBm at a frequency of 729.34 MHz. Frequency range is from 726.41 MHz to 732.90 MHz.	729.336 MHz	4.620 MHz	-103.4 dBm	164.80 s

Spectrum clearance real field measurements results at 700 MHz

Driven area: downtown Munich



R&S®ROMES4 (automated identification via post processing)

Spectrum Analysis - Issue List

Latitude	Longitude	Title	Description	Frequency	Bandwidth
48.123	11.5671	Wideband Interference	Peak power detected -94.54 dBm at a frequency of 714.66 MHz. Frequency range is from 714.42 MHz to 714.70 MHz.	714.660 MHz	0.275 MHz
48.1521	11.6147	Wideband Interference	Peak power detected -95.79 dBm at a frequency of 729.83 MHz. Frequency range is from 726.19 MHz to 732.96 MHz.	729.832 MHz	6.765 MHz
48.1451	11.5798	Narrowband Interference	Peak power detected -97.23 dBm at a frequency of 714.69 MHz. Frequency range is from 714.64 MHz to 714.70 MHz.	714.695 MHz	0.055 MHz
48.1228	11.6038	Wideband Interference	Peak power … ge is from 726.19 MHz to 732.96 MHz.	729.470 MHz	6.765 MHz
48.168	11.5382	Narrowband Interference	Peak power … ge is from 726.19 MHz to 732.96 MHz.	729.513 MHz	6.765 MHz
48.1761	11.5591	Narrowband Interference	Peak power … ge is from 726.19 MHz to 732.96 MHz.	729.350 MHz	6.765 MHz
48.1252	11.5213	Wideband Interference	Peak power … ge is from 722.12 MHz to 732.96 MHz.	728.882 MHz	10.835 MHz
48.1273	11.6125	Narrowband Interference	Peak power … nge is from 726.19 MHz to 732.96 MHz.	729.607 MHz	6.765 MHz
48.1397	11.5345	Narrowband Interference	Peak power … nge is from 726.19 MHz to 732.96 MHz.	729.523 MHz	5.060 MHz
48.1093	11.5791	Narrowband Interference	Peak power … nge is from 726.19 MHz to 732.96 MHz.	729.431 MHz	6.545 MHz
48.1224	11.6165	Narrowband Interference	Peak power detected -101.13 dBm at a frequency of 731.20 MHz. Frequency range is from 731.09 MHz to 731.30 MHz.	731.201 MHz	0.220 MHz
48.1276	11.6121	Narrowband Interference	Peak power detected -101.58 dBm at a frequency of 729.68 MHz. Frequency range is from 726.19 MHz to 732.96	729.676 MHz	6.710 MHz

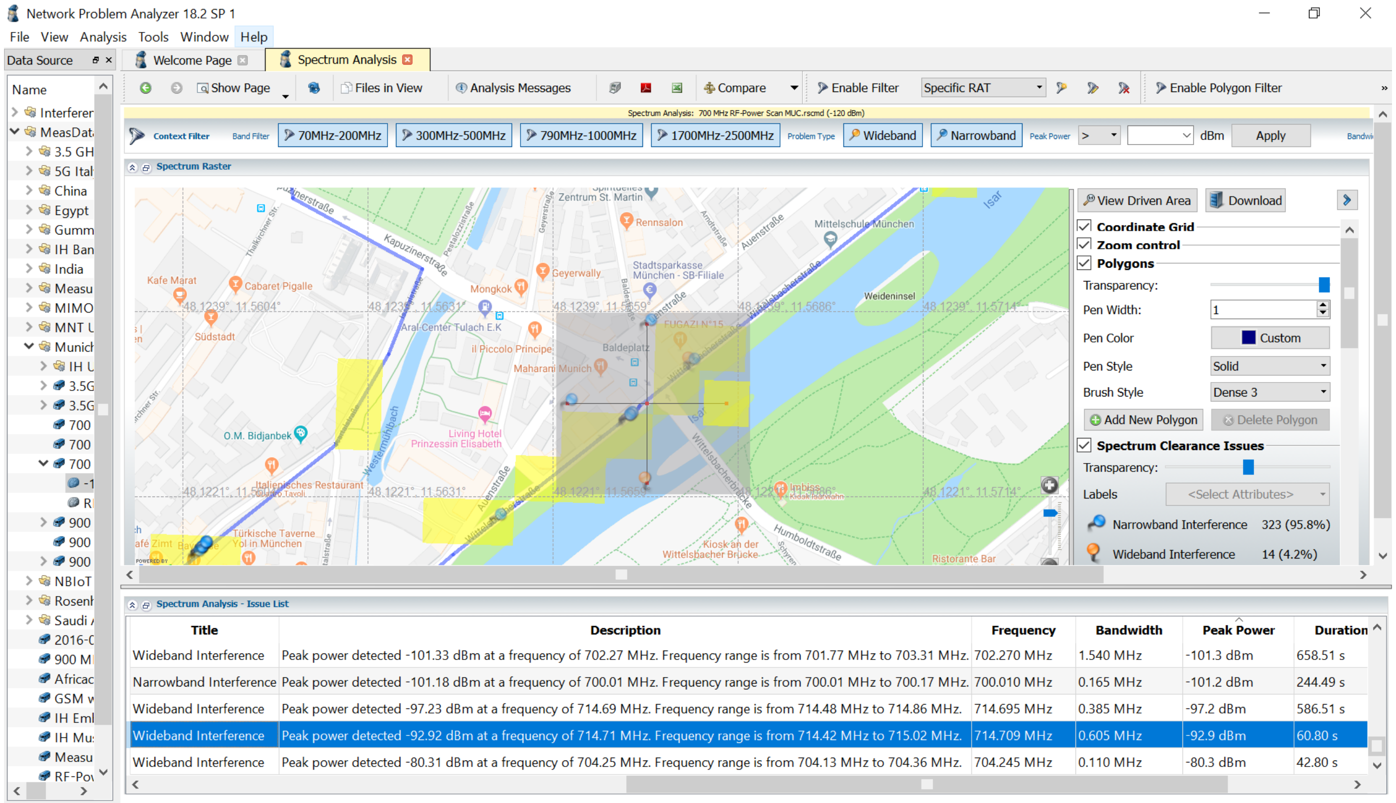
Spectrum Clearance Issues

Transparency:

Labels <Select Attributes>

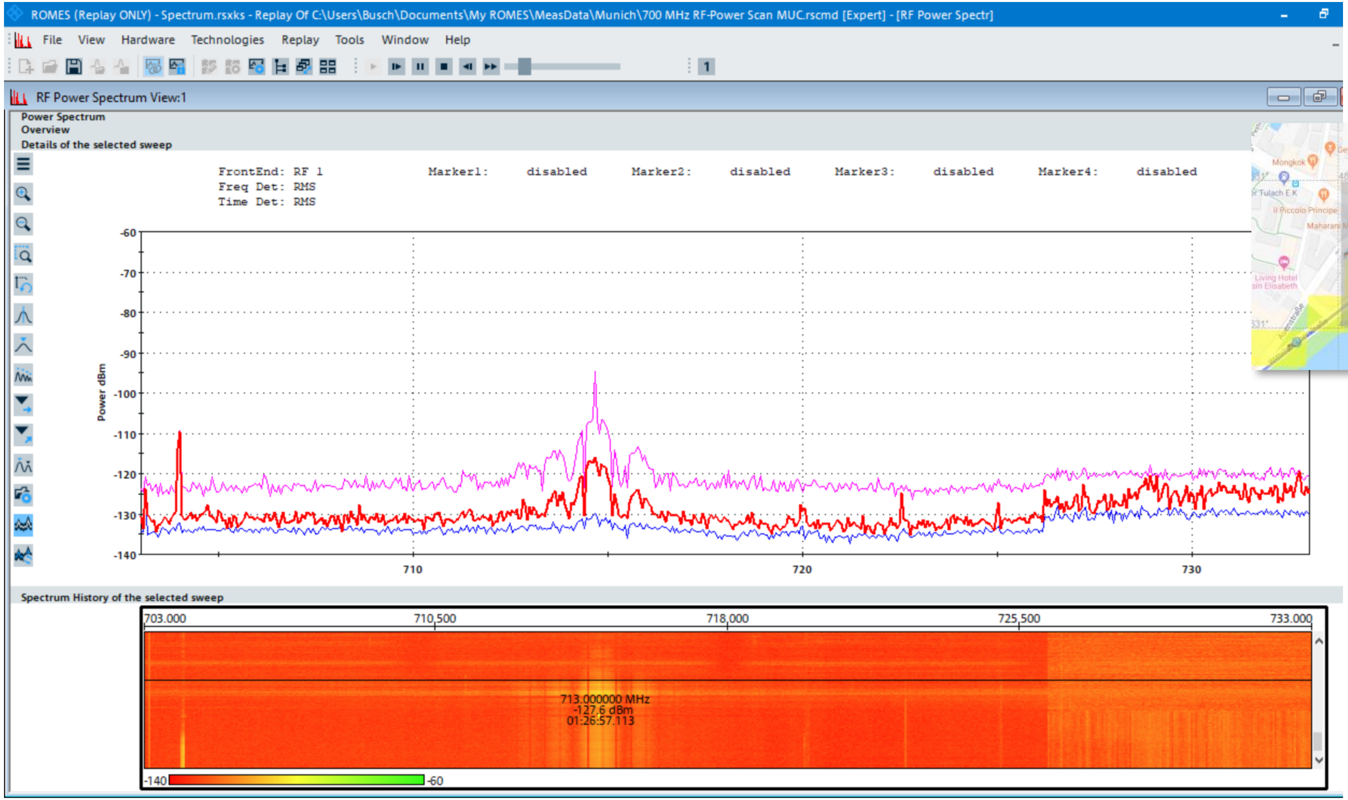
Narrowband Interference	323 (95.8%)
Wideband Interference	14 (4.2%)
Other Problem	0 (0.0%)
Other	0 (0.0%)

R&S®NPA (automated identification via post processing)

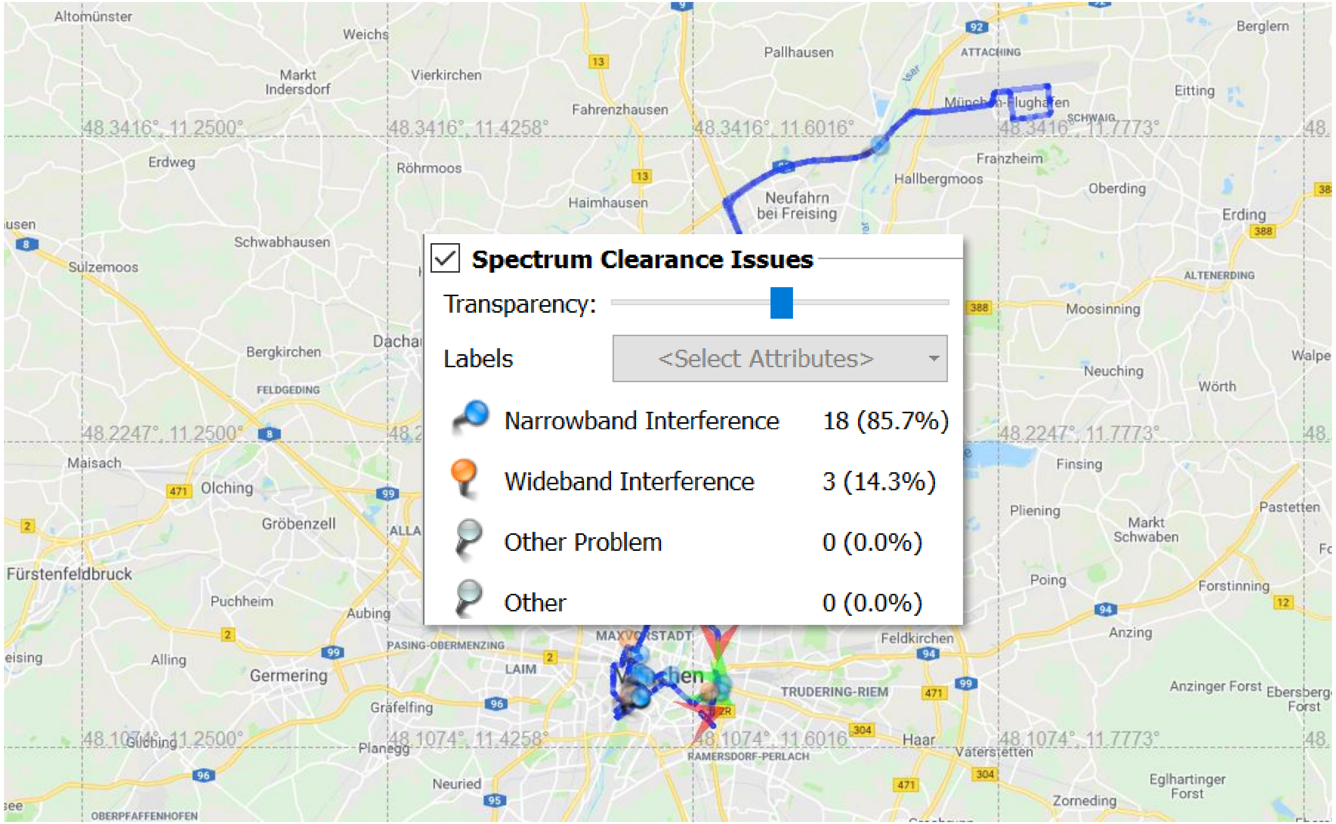


Title	Description	Frequency	Bandwidth	Peak Power	Duration
Wideband Interference	Peak power detected -101.33 dBm at a frequency of 702.27 MHz. Frequency range is from 701.77 MHz to 703.31 MHz.	702.270 MHz	1.540 MHz	-101.3 dBm	658.51 s
Narrowband Interference	Peak power detected -101.18 dBm at a frequency of 700.01 MHz. Frequency range is from 700.01 MHz to 700.17 MHz.	700.010 MHz	0.165 MHz	-101.2 dBm	244.49 s
Wideband Interference	Peak power detected -97.23 dBm at a frequency of 714.69 MHz. Frequency range is from 714.48 MHz to 714.86 MHz.	714.695 MHz	0.385 MHz	-97.2 dBm	586.51 s
Wideband Interference	Peak power detected -92.92 dBm at a frequency of 714.71 MHz. Frequency range is from 714.42 MHz to 715.02 MHz.	714.709 MHz	0.605 MHz	-92.9 dBm	60.80 s
Wideband Interference	Peak power detected -80.31 dBm at a frequency of 704.25 MHz. Frequency range is from 704.13 MHz to 704.36 MHz.	704.245 MHz	0.110 MHz	-80.3 dBm	42.80 s

Real field measurements results at 700 MHz



Real field measurements results at 3500 MHz



Summary

ROHDE&SCHWARZ
Mobile Network Testing

Summary

- There are many different sources of interference in cellular networks; they are pervasive, increasing and particularly effect LTE.
- Interference can be measured at RF-level or the subscriber-level.
- Interference dramatically impacts network performance therefore interference hunting is becoming essential
- Identifying and locating interference can be partially automated using scanning receivers and direction finders
- Analyzing an interfering signal using spectral analysis, waterfall analysis, pattern analysis and content analysis can provide important clues about its source.
- New developments in mobile networks require the use of new solutions for resolving interference.

Q&A / Discussion