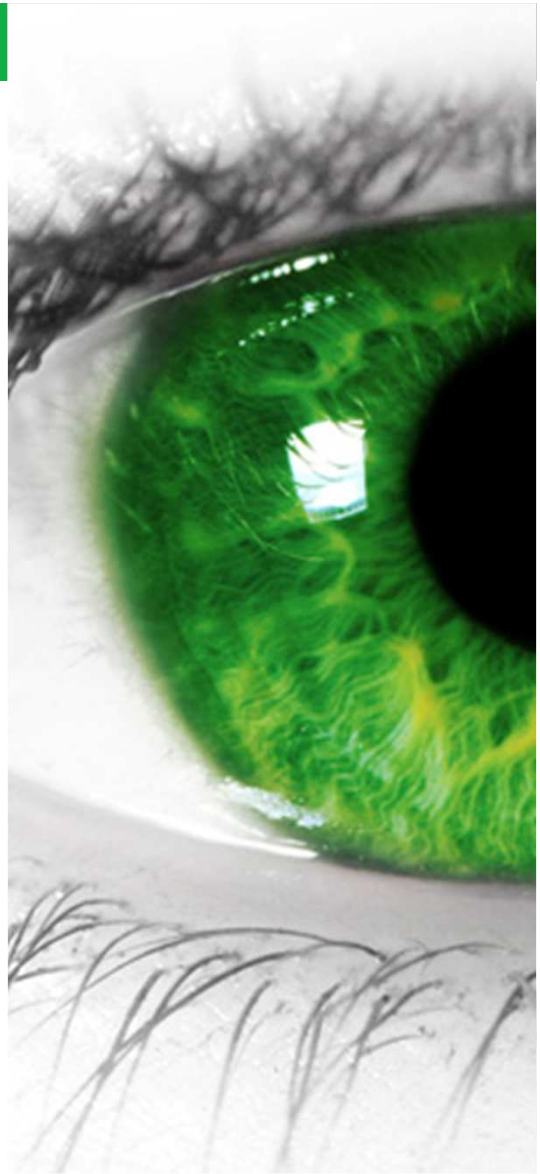
TETRA
Site and coverage acceptance measurements



Ferdinand Gerhardes

Program Manager EDU, Research & Defense
Anritsu GmbH Germany

1st April, 2014

Anritsu envision : ensure

RF 2014 TECHNOLOGY DAYS

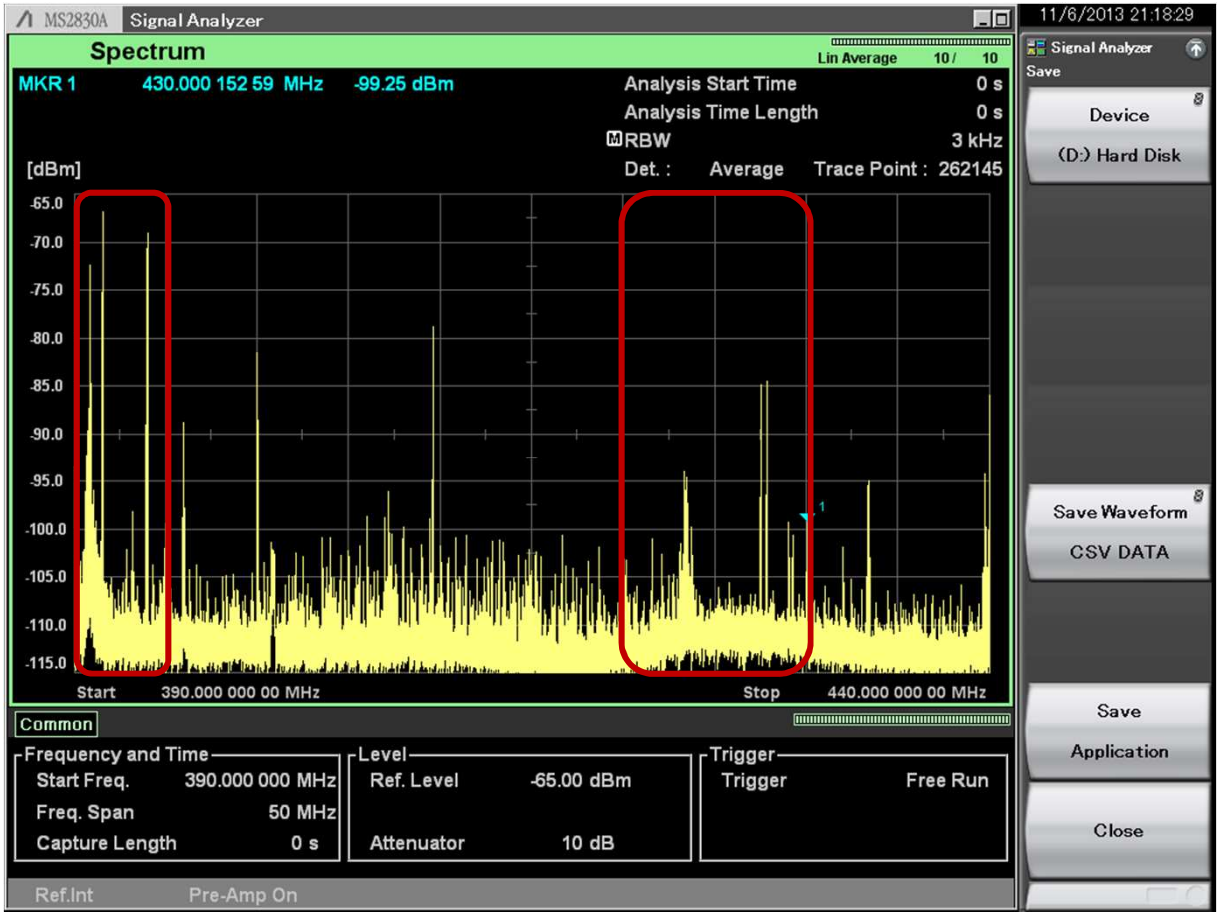
RF Technology Days 2014

Agenda

- Motivation – Interference a common problem in todays crowded spectrum
- S412E multi purpose tool for installation and maintenance
- TETRA Analyzer
- TETRA IQ capture
- TETRA Coverage Mapping
- Tunnel Coverage Mapping
- Horizontal Scan Measurements
- TETRA measurement antennas
- Inline Power Sensor MA24105A
- Emitter bearing and localization MA2700A

Interference the problem in todays densed spectrum

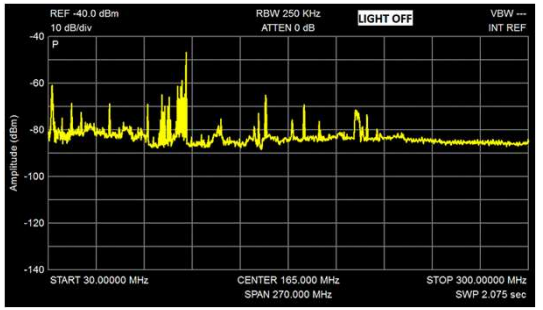
TETRA Spectrum in dense urban Leipzig area



- **TETRA BOS DL**
  - **390 – 395 MHz**
- **TETRA Zivil DL**
  - **420 – 430 MHz**

Interference the problem in todays densed spectrum

Motivation



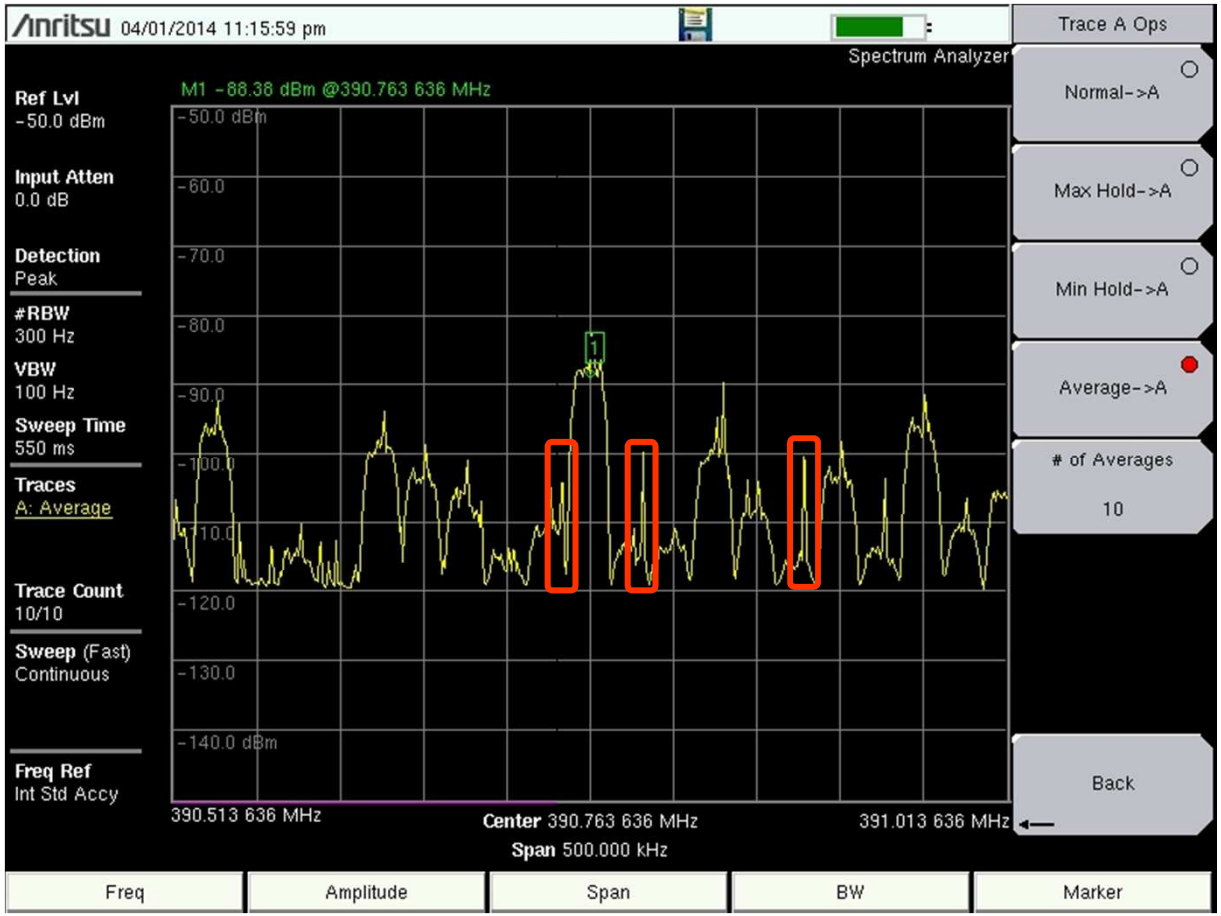
- Interference
  - is annoying and
  - often frustrating,
  - problems are intermittent or
  - when it seems that a problem has been solved, only to have it return later.
- Efforts to correct interference problems are also often complicated by the fact that there are several kinds of interference and each requires a different approach and a different solution.
- Sometimes a "quick fix" will work, more often it does not.

Goal

- Provide timely and equitable access to the radio-frequency spectrum by as many users and for as many uses as possible, with a minimum of interference".
- But what is the best tool to use?

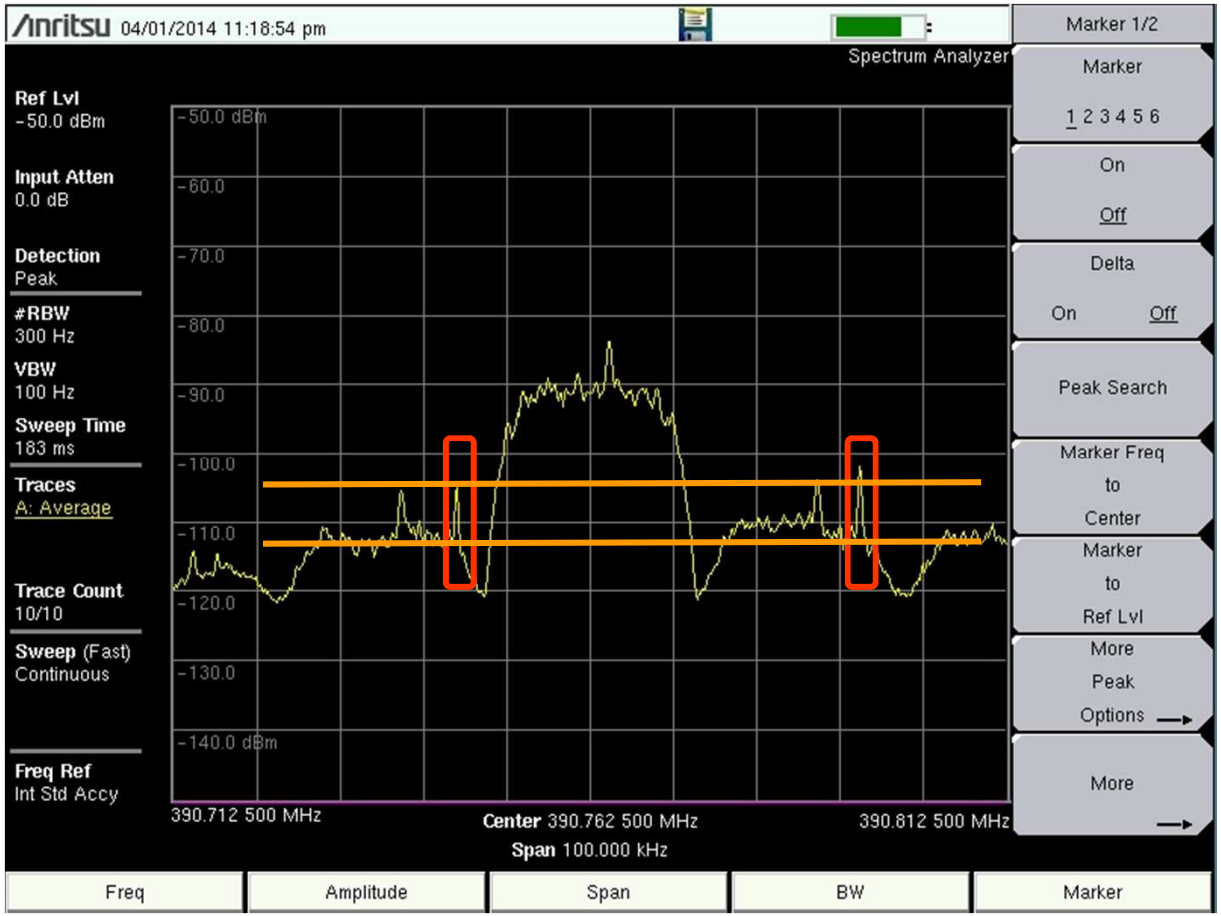
Interference the problem in todays densed spectrum

TETRA Spectrum LEIDEN ytd April, 2'nd



Interference the problem in todays densed spectrum

TETRA Spectrum LEIDEN ytd April, 2'nd



~MS sensitivity -103 dBm

~BTS sensitivity -106/-112 dBm

Interference the problem in todays densed spectrum

TETRA Spectrum Niederkrüch

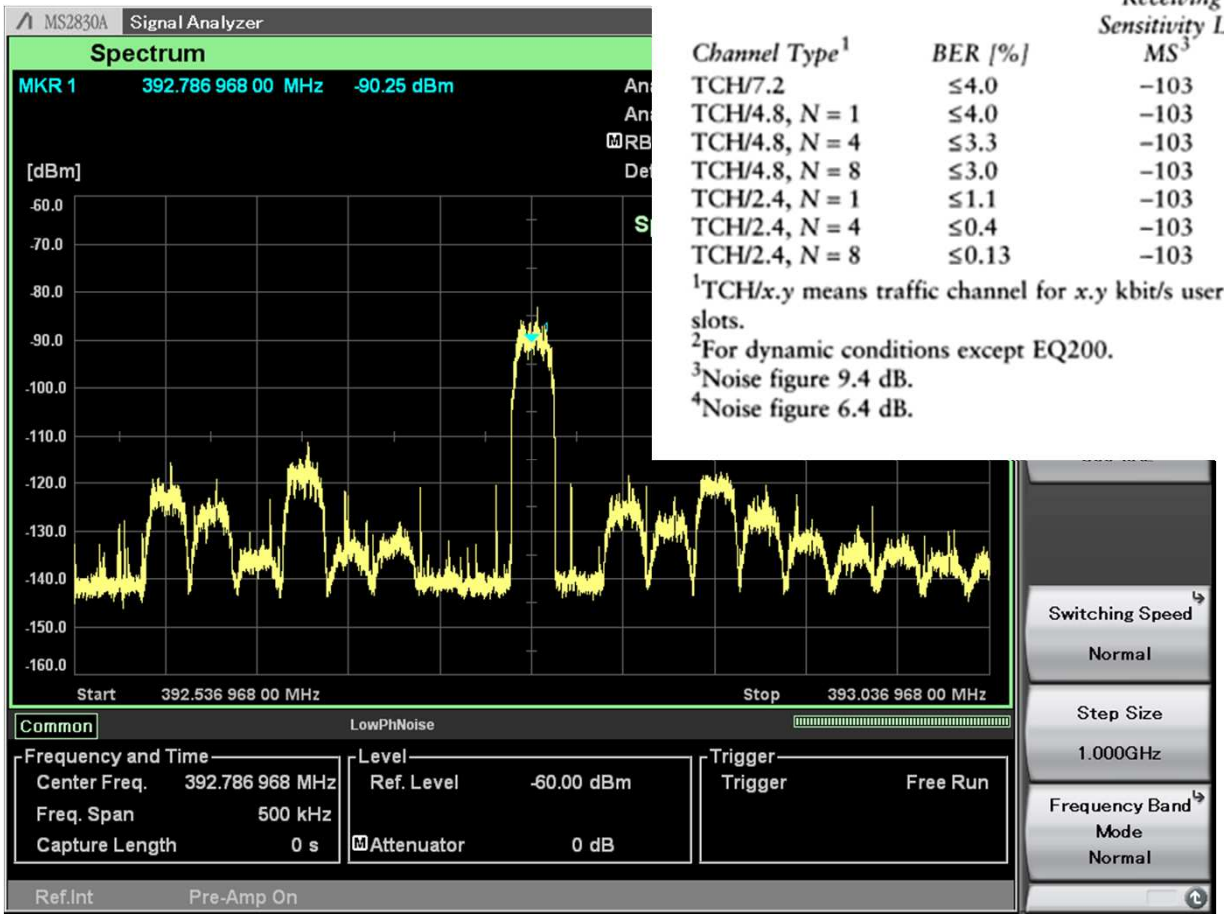


Table 6.4 Dynamic Reference Sensitivity of TETRA Receivers

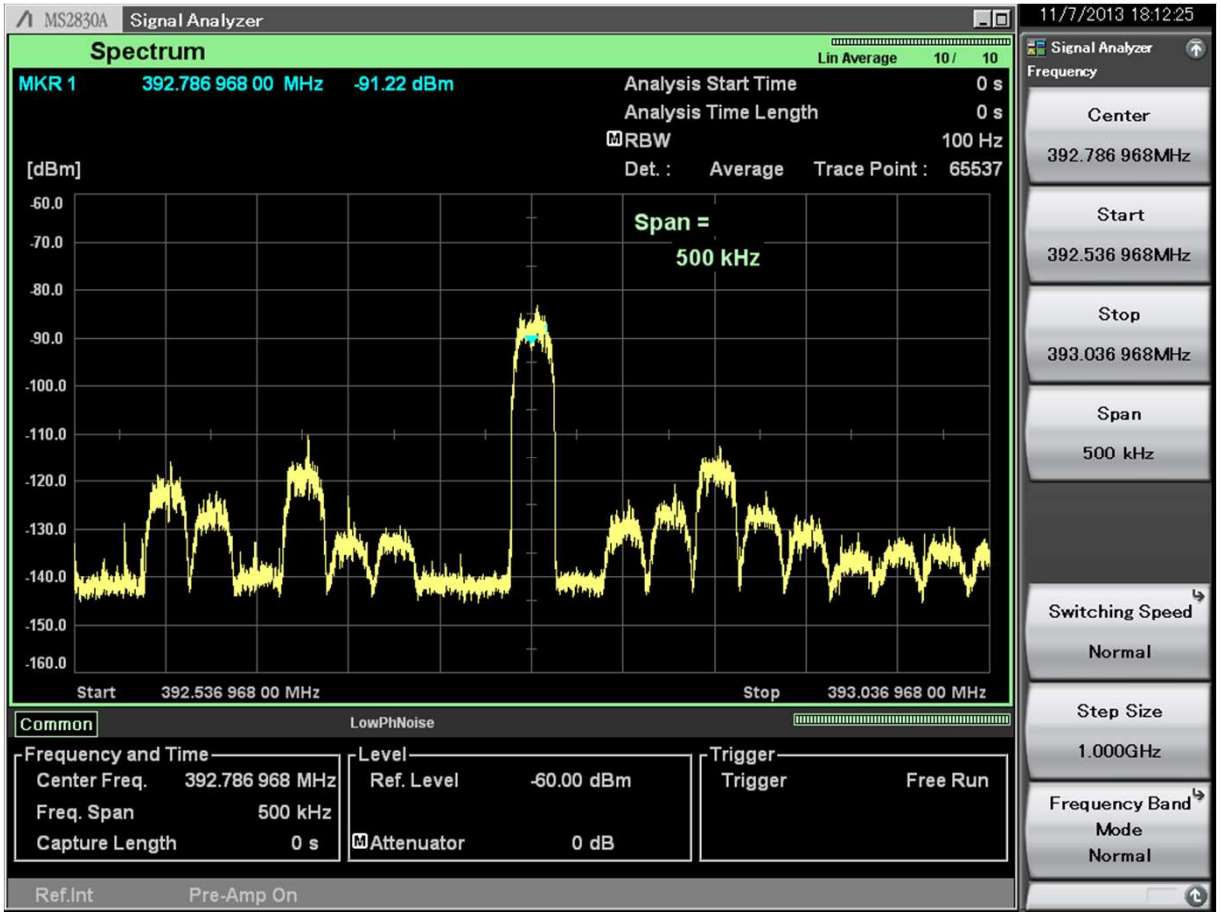
Channel Type[1]	*BER [%]*	*Receiving Reference Sensitivity Level [dBm]*[2] *MS*[3]	*BS*[4]
TCH/7.2	≤4.0	−103	−106
TCH/4.8, $N = 1$	≤4.0	−103	−106
TCH/4.8, $N = 4$	≤3.3	−103	−106
TCH/4.8, $N = 8$	≤3.0	−103	−106
TCH/2.4, $N = 1$	≤1.1	−103	−106
TCH/2.4, $N = 4$	≤0.4	−103	−106
TCH/2.4, $N = 8$	≤0.13	−103	−106

[1]TCH/*x.y* means traffic channel for *x.y* kbit/s user bit rate and N is the number of interleaved time slots.
[2]For dynamic conditions except EQ200.
[3]Noise figure 9.4 dB.
[4]Noise figure 6.4 dB.

http://www.amazon.de/gp/search?index=books&linkCode=qs&keywords=9781580531733

Interference the problem in todays densed spectrum

TETRA Spectrum Niederkrüchten without interference



S412E
General purpose tool for any kind installation, maintenance and interference trouble shooting

LMR Master S412E

Basic model features

- 2-Port Vector Network Analyzer
  - 500 kHz to 1.6 / 6 GHz
  - 100 dB dynamic range
- Spectrum Analyzer
  - 100 kHz to 1.6 / 6 GHz
  - DANL -152 dBm
- CW / VSG Signal Generator
  - 500 kHz to 1.6 / 6 GHz
  - 0 to -130 dBm, 0,1 dB steps
- Power Meter
  - 10 MHz to 1.6 / 6 GHz
  - High Accuracy Power Meter 50 MHz to 6 GHz
  - Inline USB Power Meter 350 MHz to 4 GHz

LMR Master S412E

Option overview

- **Options**
  - 6 GHz Spectrumanalyzer
  - 6 GHz Vektor Netzwerkanalysator
  - Distance Domain for 2-port VNA
  - Vector Voltmeter
  - Testsignalgenerator for NXDN, DMR II, P25, NBFM
  - PSU & High Voltage Bias Tee (SPA, VNA)
  - High Accuracy Power Meter
  - Interference Analyzer
  - Channel Scanner
  - RSSI Coverage Mapping
  - GPS receiver

LMR Master S412E

Signal- and Modulation Analyzer overview

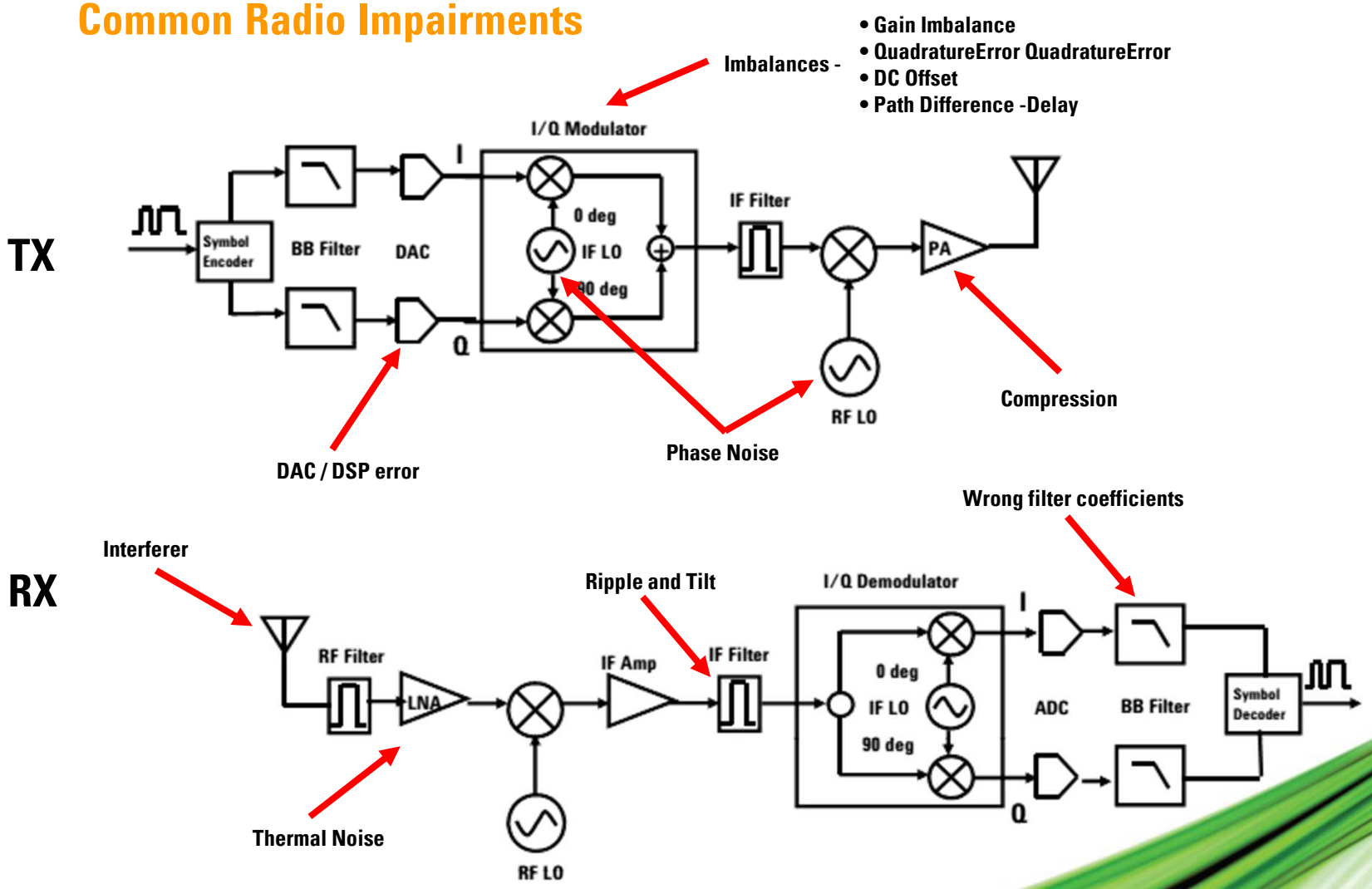
- **Signal- and Modulation Analysis via**
  - **Over-the-Air Measurement Signal Analysis**
  - **Coverage Mapping (RSSI, BER, EVM, MF)**
  - **Over-the-Air Measurement Signal Analysis**
    - **AM/FM/PM Modulation Analyzer with audio listening**
    - **Narrowband FM**
    - **P25/P25 II (*)**
    - **NXDN (*)**
    - **TETRA**
    - **DMR II (*)**
    - **PTC**
    - **LTE 10 MHz**
    - **IEEE 802.16 Fixed / Mobile WiMAX**

(*) BCCH decoding

Typical
TETRA
Modulation Analysis Measurements

Vector Signal Analysis

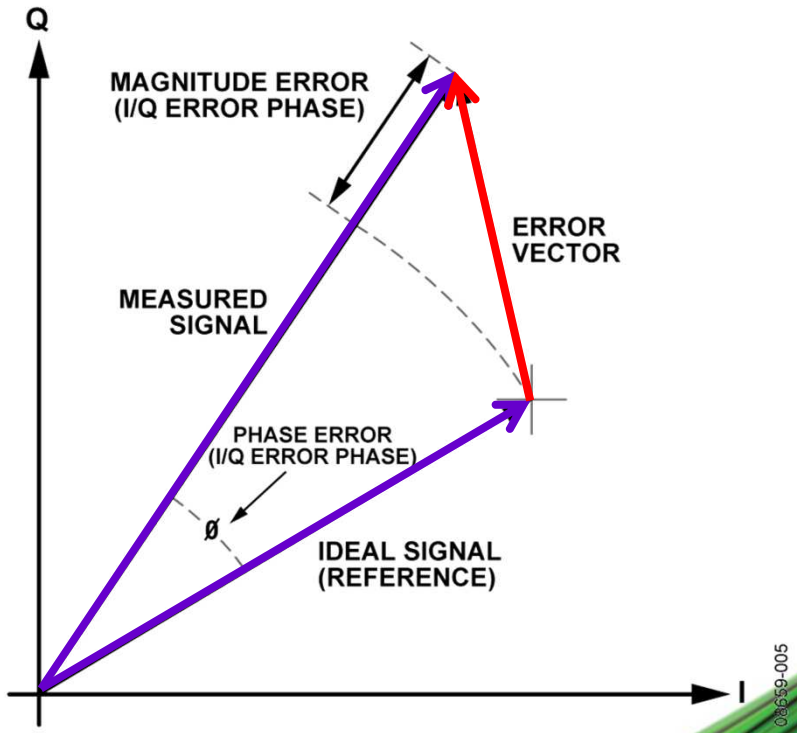
Common Radio Impairments



Vector Signal Analysis

Error Vector Magnitude

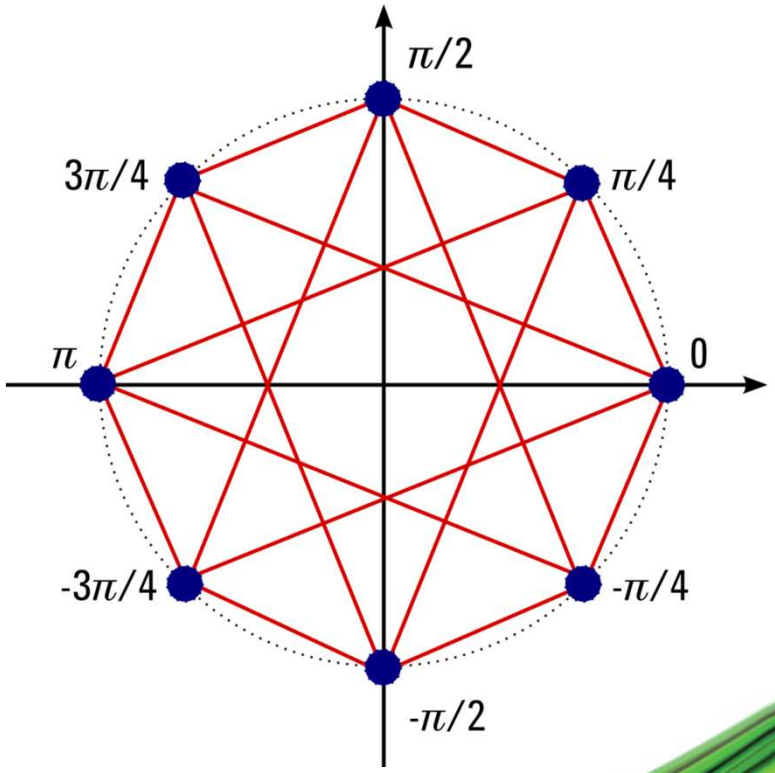
- **Error Vector Magnitude (EVM)**
  - is a measure used to quantify the quality or performance of a modulated signal from a transmitter or receiver.
- **In simple terms, if we consider a constellation diagram**
  - the EVM is the magnitude of the difference between the measured vector and the ideal (reference) vector.



Vector Signal Analysis

Error Vector Magnitude

- Error Vector Magnitude (EVM)
  - is a measure used to quantify the quality or performance of a modulated signal from a transmitter or receiver.
- In simple terms, if we consider a constellation diagram
  - the EVM is the magnitude of the difference between the measured vector and the ideal (reference) vector.
- **EVM is influenced by a number of IQ-parameters**
  - **Phase Error**
  - **Frequency Error**
  - **Magnitude Error**
  - **(Phase)Noise**

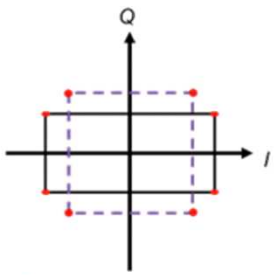


π/4-DQPSK

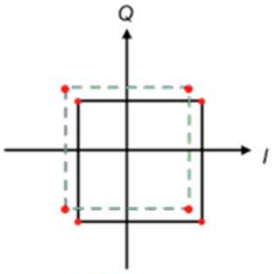
Vector Signal Analysis

Error Vector Magnitude

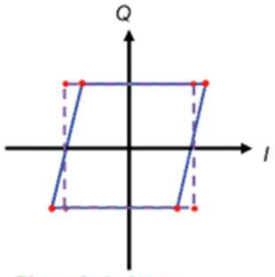
- The constellation plot provides information on the link quality
- Unlike a closed loop BER measurement, EVM provides information about the factors impairing the link that can be used as diagnostic information about the degradations that limit performance



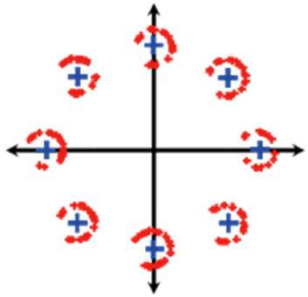
Gain Imbalance

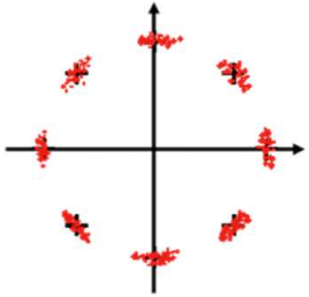


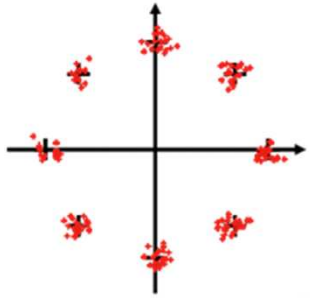
I-Q Offsets



Phase Imbalance


Interference


Phase Noise

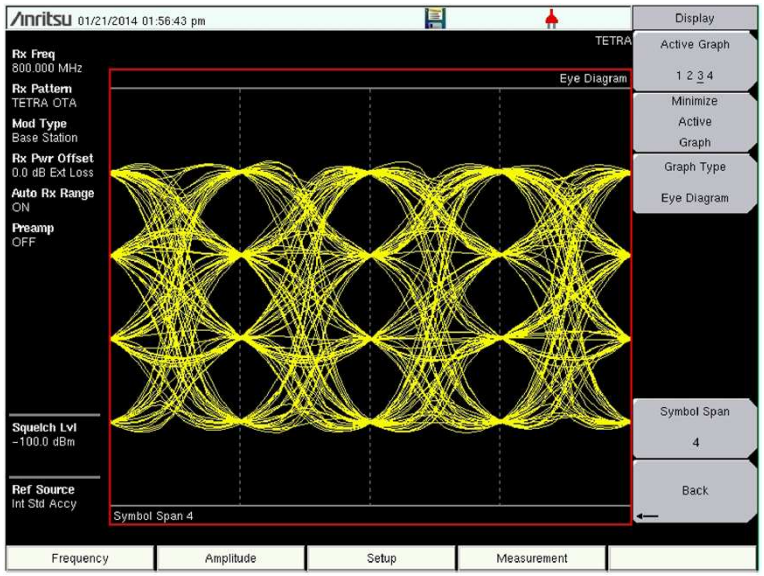

Added Noise

TETRA Analyzer

TETRA Analyzer

Feature description

- The LMR Master TETRA Analyzer and TETRA Coverage Mapping options are intended for over-the-air (OTA) use.
- The TETRA Analyzer
  - provides a method to verify the operation of TETRA repeater and BTSn
  - Ability to display
    - constellation,
    - spectrum,
    - Symbol histogram,
    - eye diagram graphs
  - Summary graph displays numeric values of
    - received power,
    - frequency error,
    - error vector magnitude (EVM),
    - Bit Error Rate (BER),
    - IQ imbalance,
    - phase and magnitude errors
    - symbol rate error



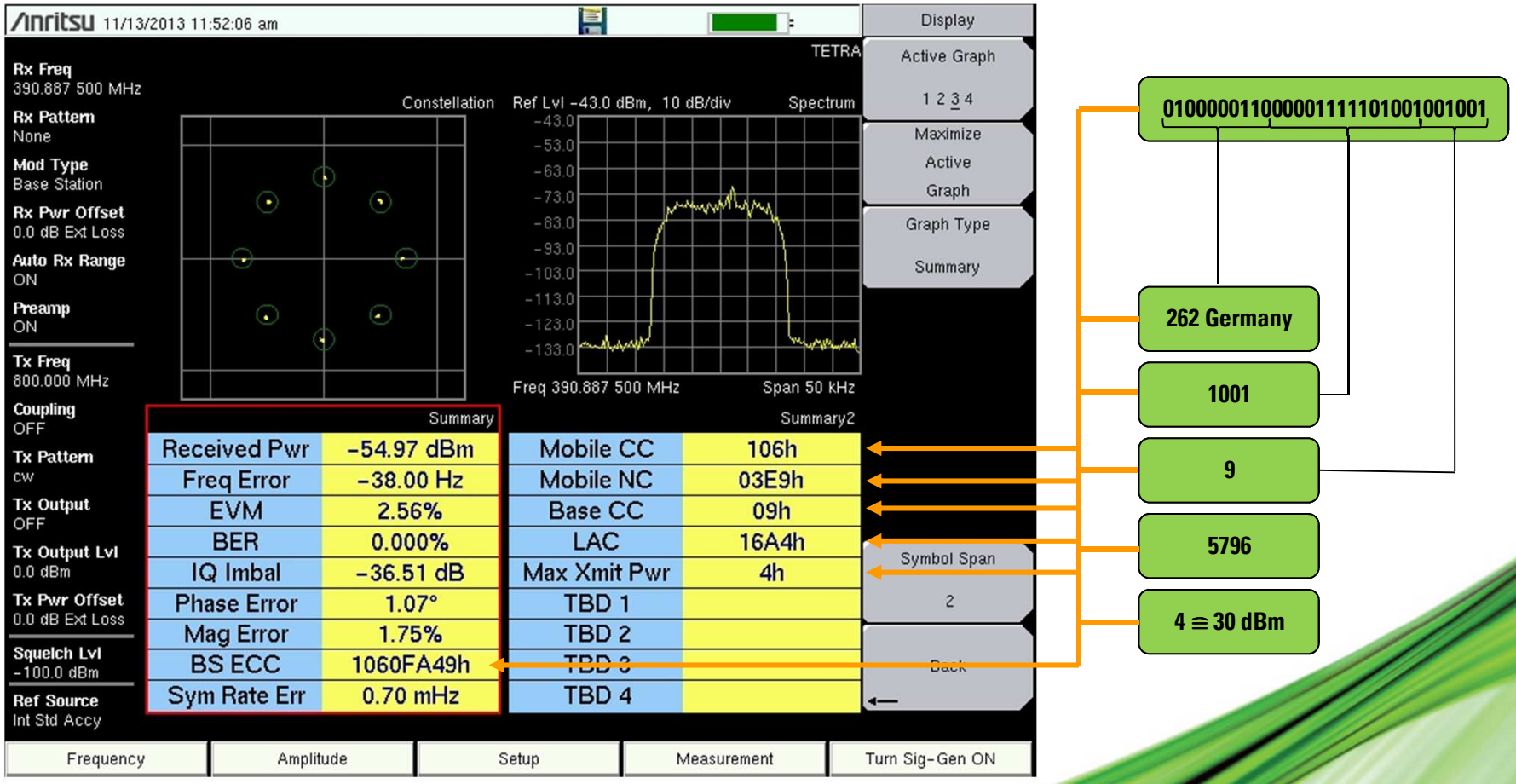
TETRA Analyzer

Definitions acc. to ETSI TS 100 927 V7.8.0 (2003-09)

- **The Mobile Country Code** (MCC) - is a 10 bit three-digit code identifying the country in which the network is set up or a unit is operated; range 0 to 1023
  - 204 Netherlands
  - 206 Belgium
  - 208 France
  - 222 Italy
  - 234 United Kingdom
  - 262 Germany
- **Mobile Network Code** (MNC) - is a 14 bit four-digit code of the TETRA network operator; range 0 to 16383 (1000 to 1100 for Schengen countries)
- **Base Colour Code** (BCC) - is the number of subscriber group in a network; range 0 to 63
- **Location Arae Code** (LAC) - Usually a Location Area consists of multiple BSs, typically managed by a cluster controller (CC). The coverage area of a TETRA network is divided into a number of Location Areas (LAs). An LA may correspond to a single cell or to a group of cells; range 0 to 16383

TETRA Analyzer

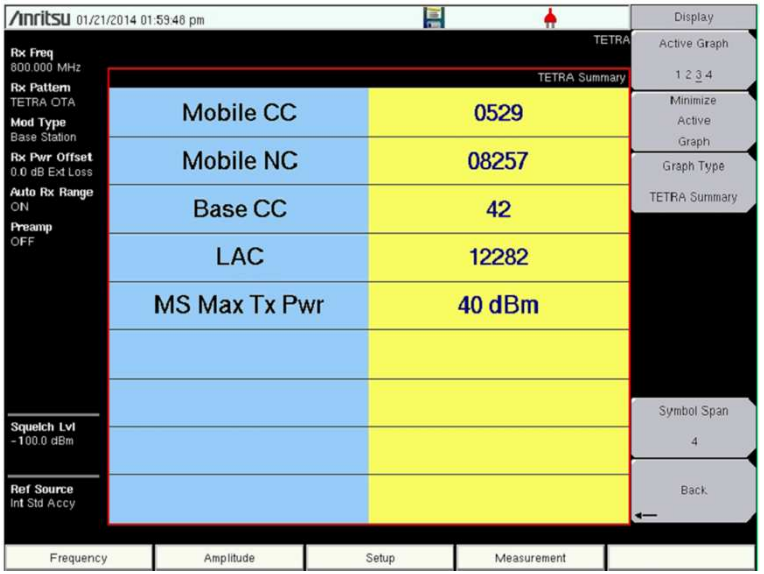
TETRA Analyzer – BS ECC analysis (Hex format readout)



TETRA Analyzer

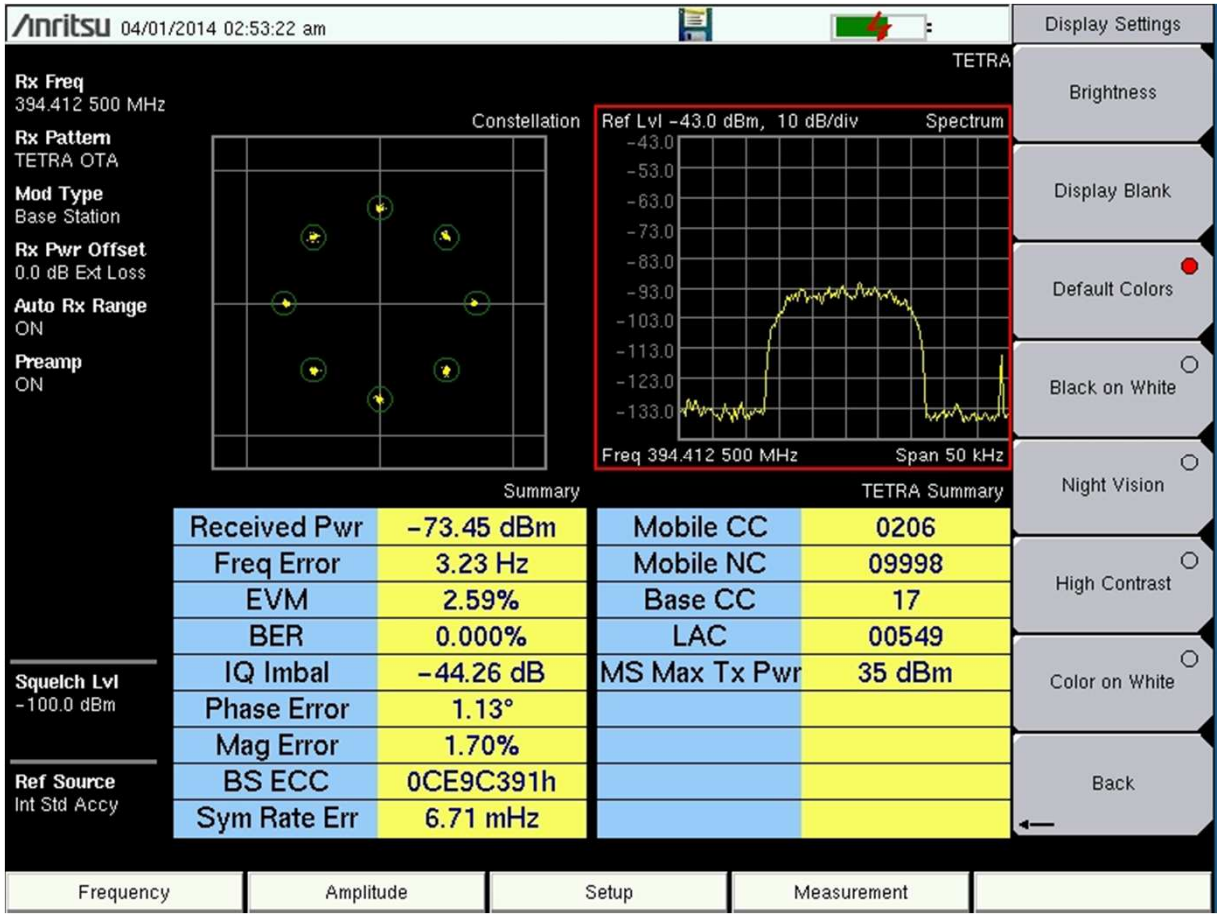
Feature description

- The analyzer also reports the BTS extended color code(BS ECC),
  - mobile color code (MCC),
  - mobile network code (MNC),
  - base color code (BCC),
  - location area code (LAC), and
  - mobile station maximum transmit power (MS Max TX Pwr)
- BER and EVM analyses are obtained by analysis of the TETRA data stream, using a proprietary algorithm.



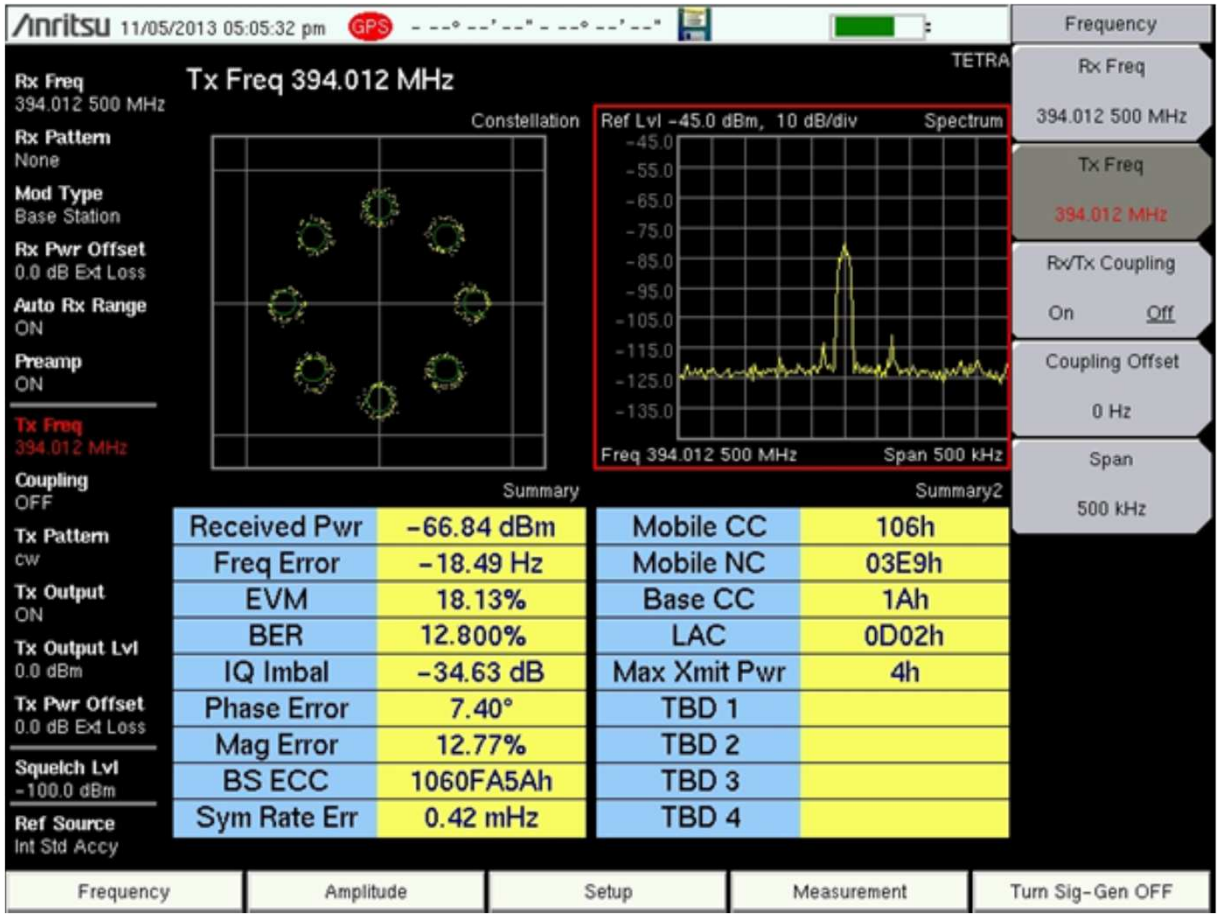
TETRA Analyzer

TETRA Analyzer – BS ECC analysis (decimal format readout)



TETRA Analyzer

TETRA Analyzer – Summary representation (signal not ok)

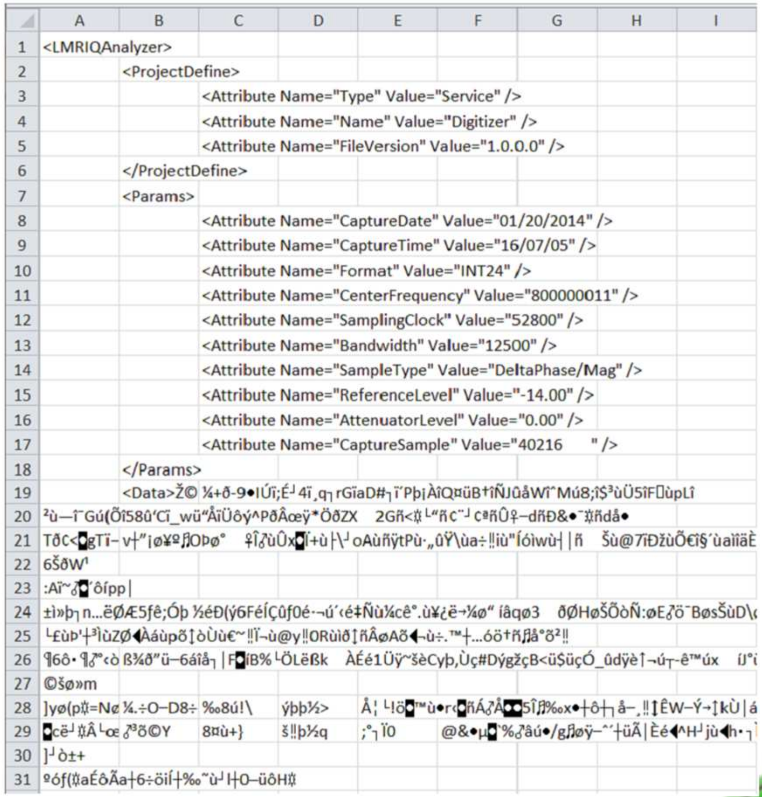


TETRA
IQ-Data Capturing

TETRA IQ capture

Tab delimited data formats

- **The LMR Master can capture and log TETRA IQ data to a USB flash drive**
- **The IQ data is sampled at 4,800 x 11 samples per second.**
- **The saved file has an ASCII header and binary data .The data is written in 24-bit two's complement integer format. Interleaved Delta Phase (I) data then Magnitude (Q) data is captured.**
- **The file is intended for post-processing in MATLAB.**



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    <Attribute Name="Name" Value="Digitizer" />
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  </ProjectDefine>
  <Params>
    <Attribute Name="CaptureDate" Value="01/20/2014" />
    <Attribute Name="CaptureTime" Value="16/07/05" />
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    <Attribute Name="CenterFrequency" Value="800000011" />
    <Attribute Name="SamplingClock" Value="52800" />
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  </Params>
  <Data>
```

TETRA
Coverage Mapping

Motivation for Radio Coverage Mapping

Radio Coverage Mapping was (and still is)

- Expensive
  - Due to measurement receiver hard- and software (e.g. TSWM plus ROMES4)
  - and especially due to the need for licensed map material
- Wasteful with regard to operator training

Nowadays Radio Coverage Mapping can be

- Inexpensive
- And easy / intuitive in operation and handling,
- Can be integrated in general purpose measurement equipment,
- Can be purchased subsequently,

There is a slightly need to budge from historical ideas about radio coverage mapping and its elaborate features.

Motivation for Radio Coverage Mapping

Outdoor Coverage Mapping (GPS assisted)

- The instrument logs data automatically based on either time or distance interval. If no map is available when making the measurements, then you can still save all the data to a KML file and later combine the data file with a map

Indoor Coverage Mapping

- Using a start-walk-stop approach, the instrument provides in-building coverage mapping by overlaying data directly onto the downloaded map. Data is captured at user-defined time intervals or user-defined map locations by tapping the touchscreen.

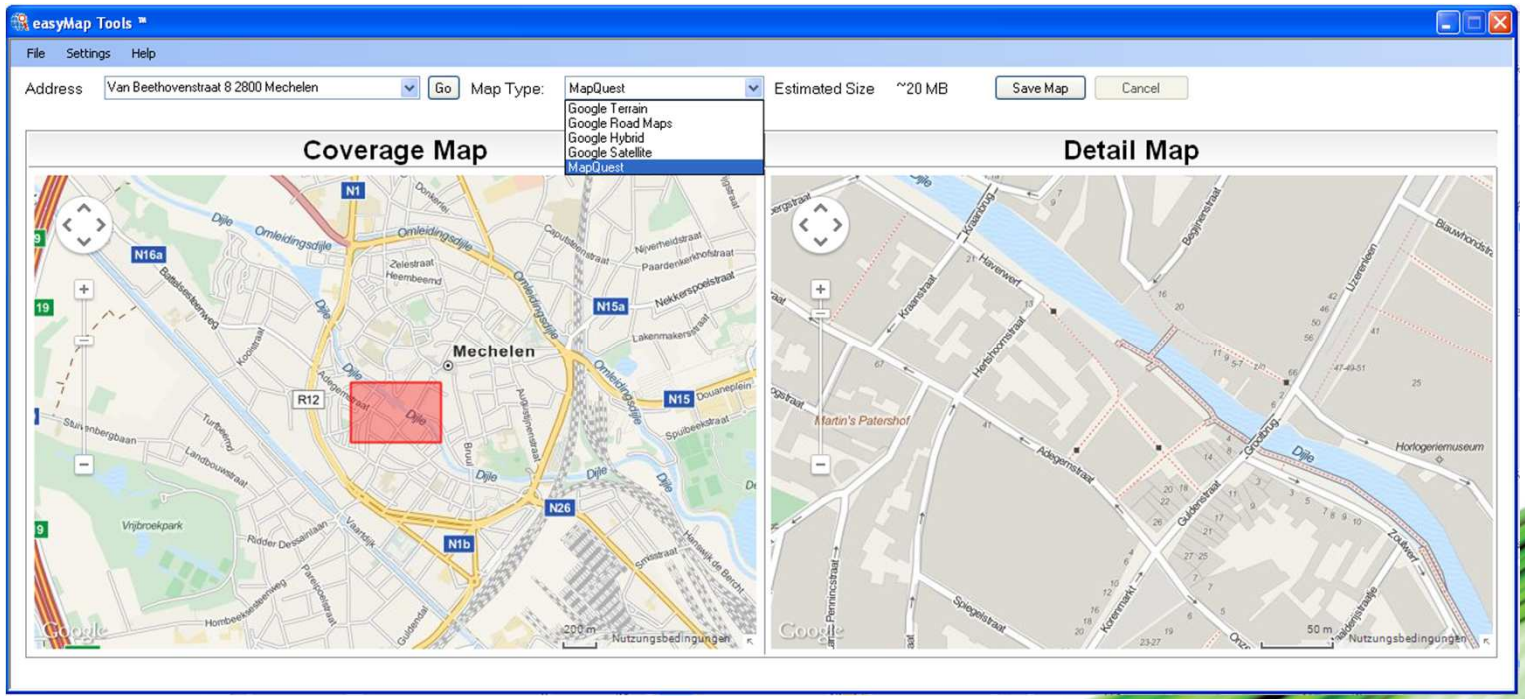
Triggered Coverage Mapping

- Using a trigger event from a speedometer, meter wheel or any other trigger source to perform equidistant measurements.
- Logging up to 4 different RF's (instruments) via external box
- On-Line evaluation done on Laptop / Tablet

TETRA Coverage Mapping

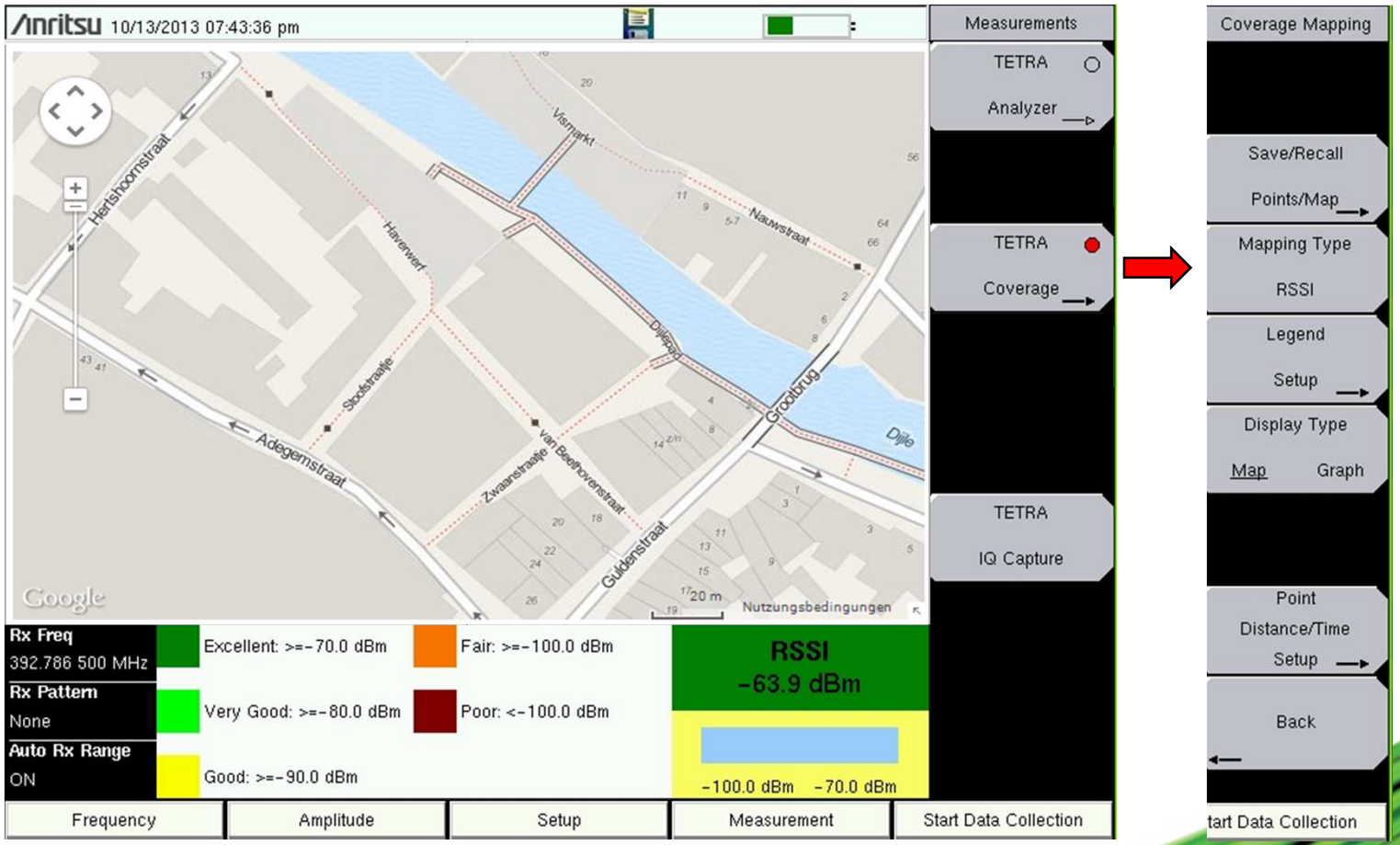
Creating an Outdoor Map File with easyMap Tools

- The easyMap Tools program allows you to create a map from map providers Google and MapQuest.
- Google Maps: Road, Terrain, Satellite, and Hybrid maps.
  MapQuest: OpenStreetMaps.



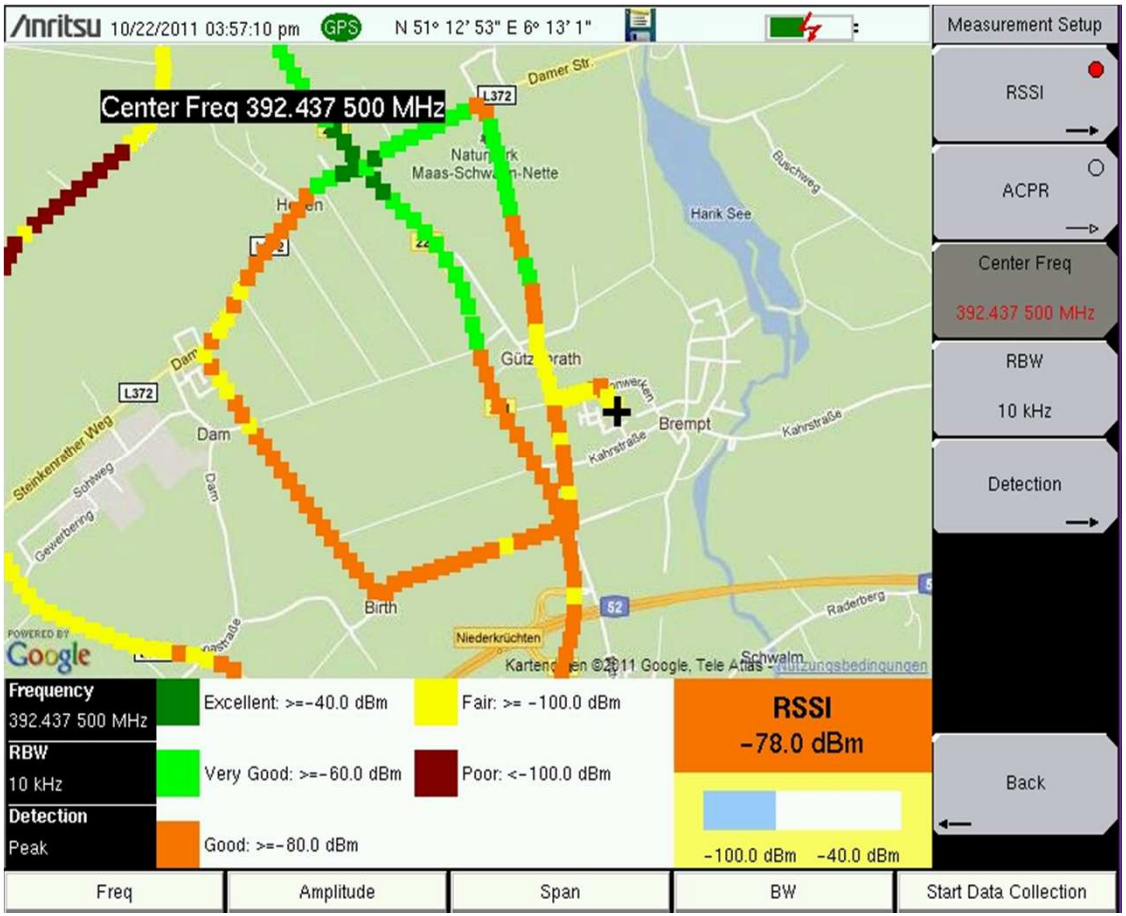
TETRA Coverage Mapping

Coverage Mapping Parameter Setting



TETRA Coverage Mapping

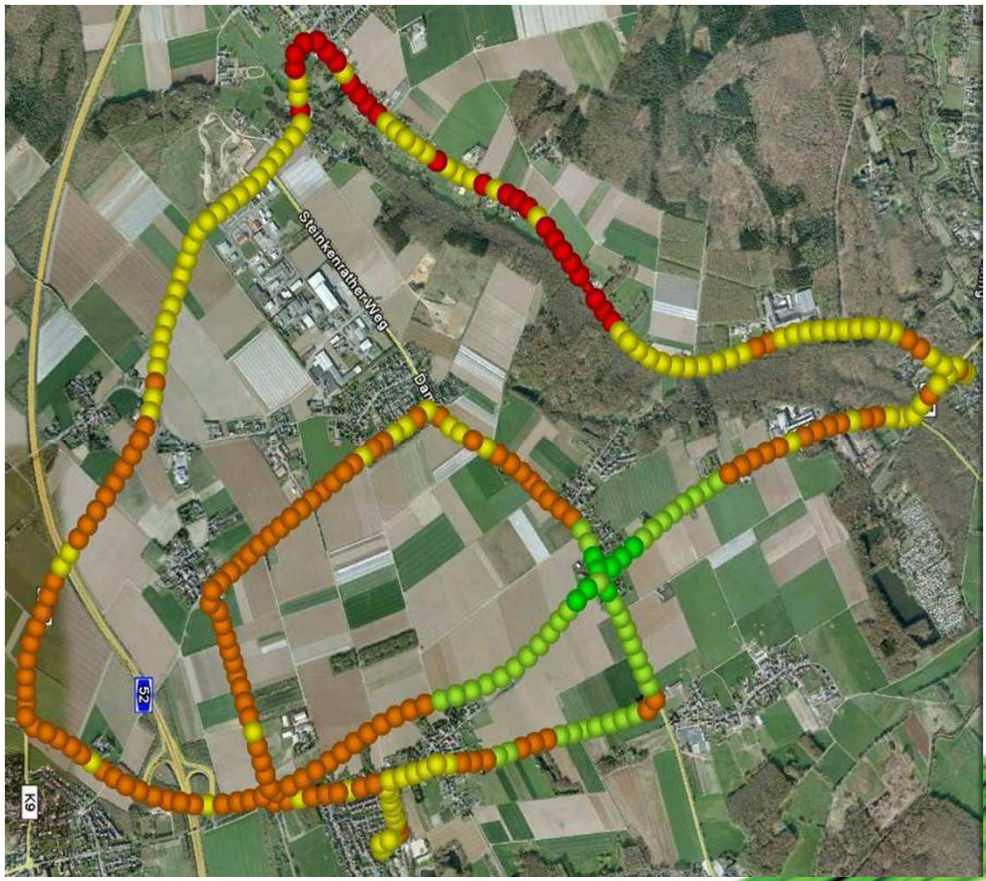
TETRA Coverage Mapping - RSSI mode (instrument view)



TETRA Coverage Mapping

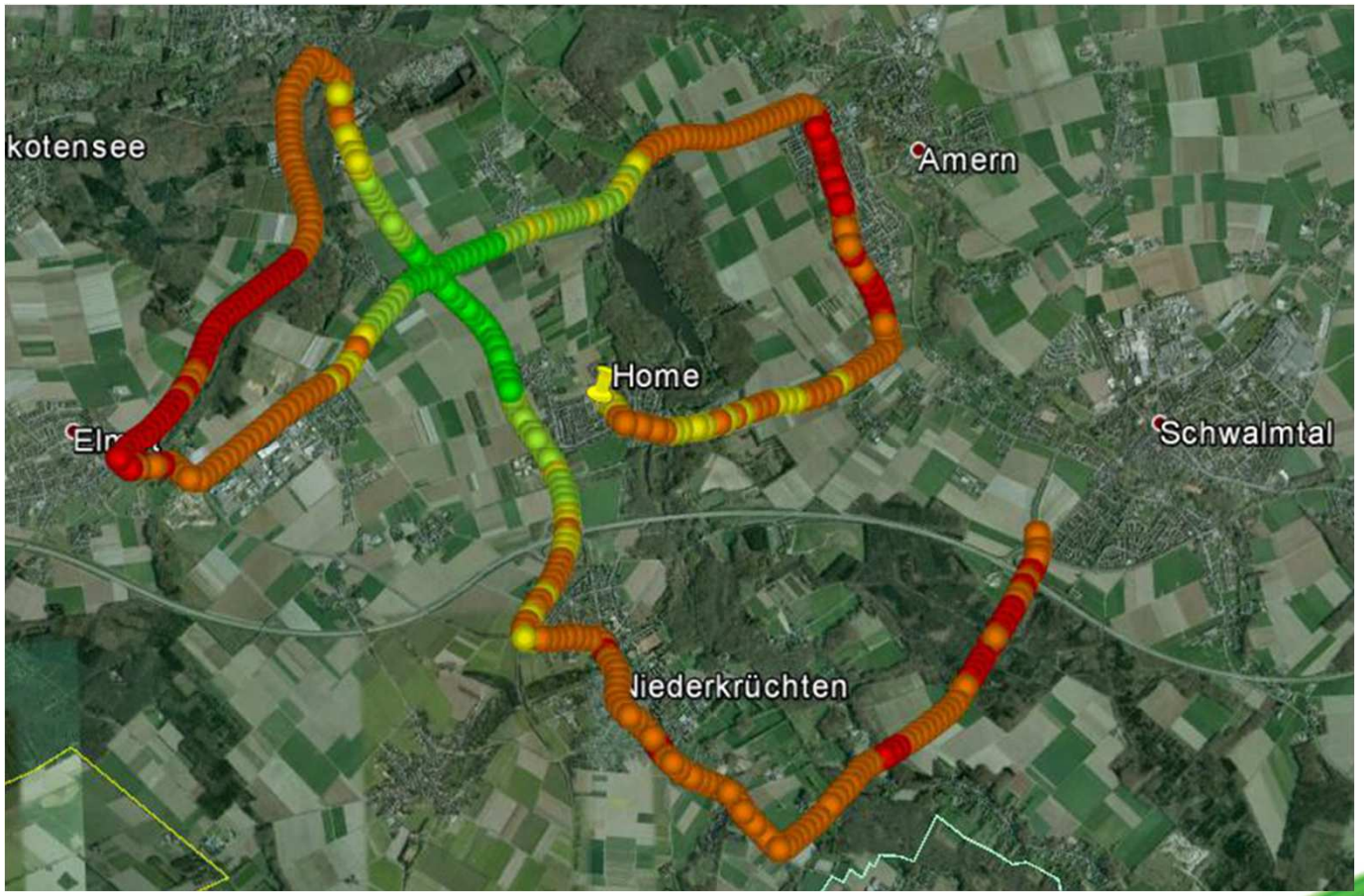
TETRA Coverage Mapping - RSSI mode (post processing)

- Goole Maps KMZ file
- f = 392,4375 MHz
  RSSI measurement
  Zero Span RBW = 1 kHz
- Repeat Distance = 50 m
- Excellent >= -40 dBm
  Very Good >= -60 dBm
  Good >= -80 dBm
  Fair >= -100 dBm
  Poor =< -100 dBm



TETRA Coverage Mapping

TETRA Coverage Mapping - RSSI mode kml-file Google Earth upload



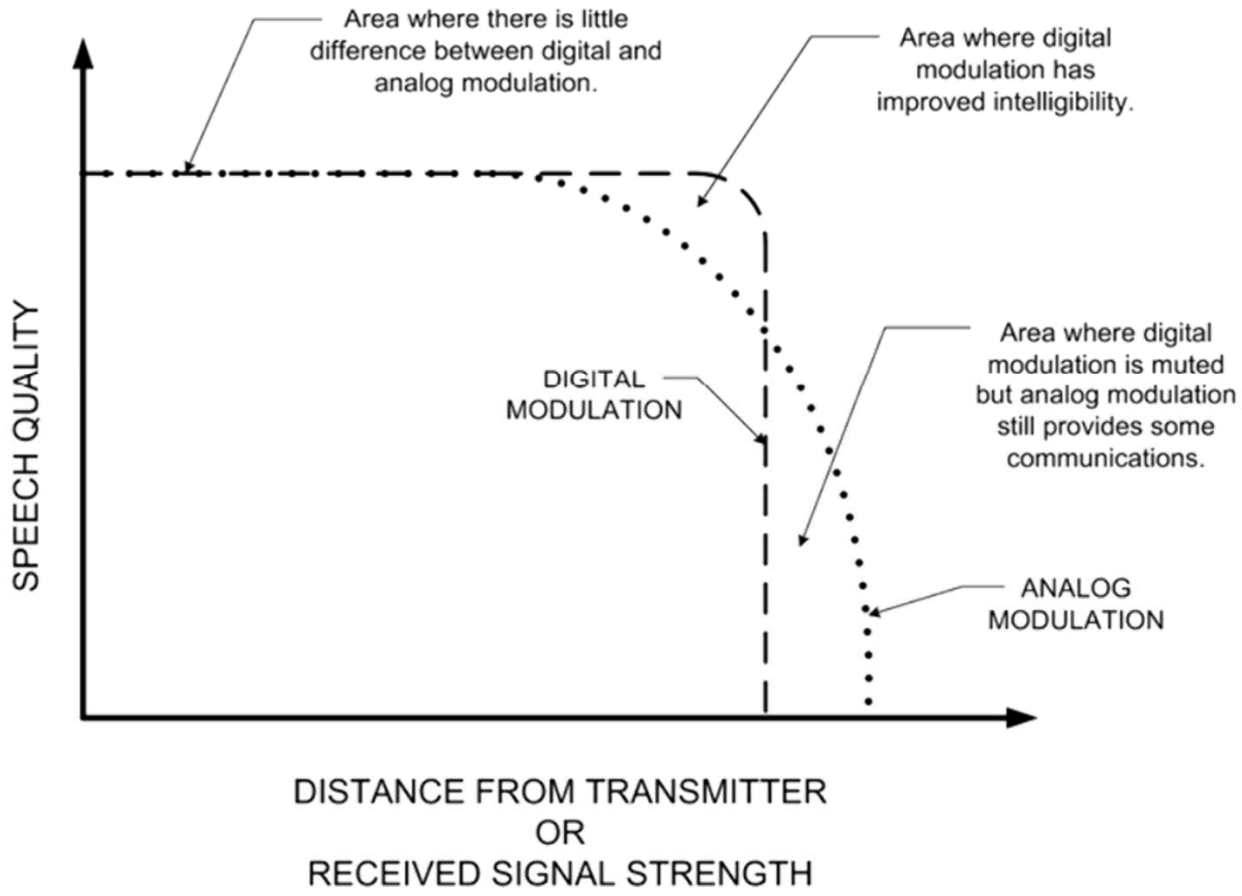
TETRA Coverage Mapping

TETRA service – Analog versus digital communication

- When comparing analog modulation to digital modulation it is critical to recognize that, while there is little difference in performance and audio quality in good signal areas, there is a major difference between analog and digital modulation in poor signal areas.
- Analog modulation degrades slowly with more and more background noise as the signal gets weaker
- Even though it may be difficult to understand a weak signal, with some care a message can be passed
- Digital modulation is perfect until there is not enough signal for the decoder to work properly. When this happens the signal is muted and no communication is possible. There is even no indication that someone is attempting to communicate.
- Another critical concern when comparing analog to digital modulation is that digital encoder can not process audio intelligibly when there is high background noise.

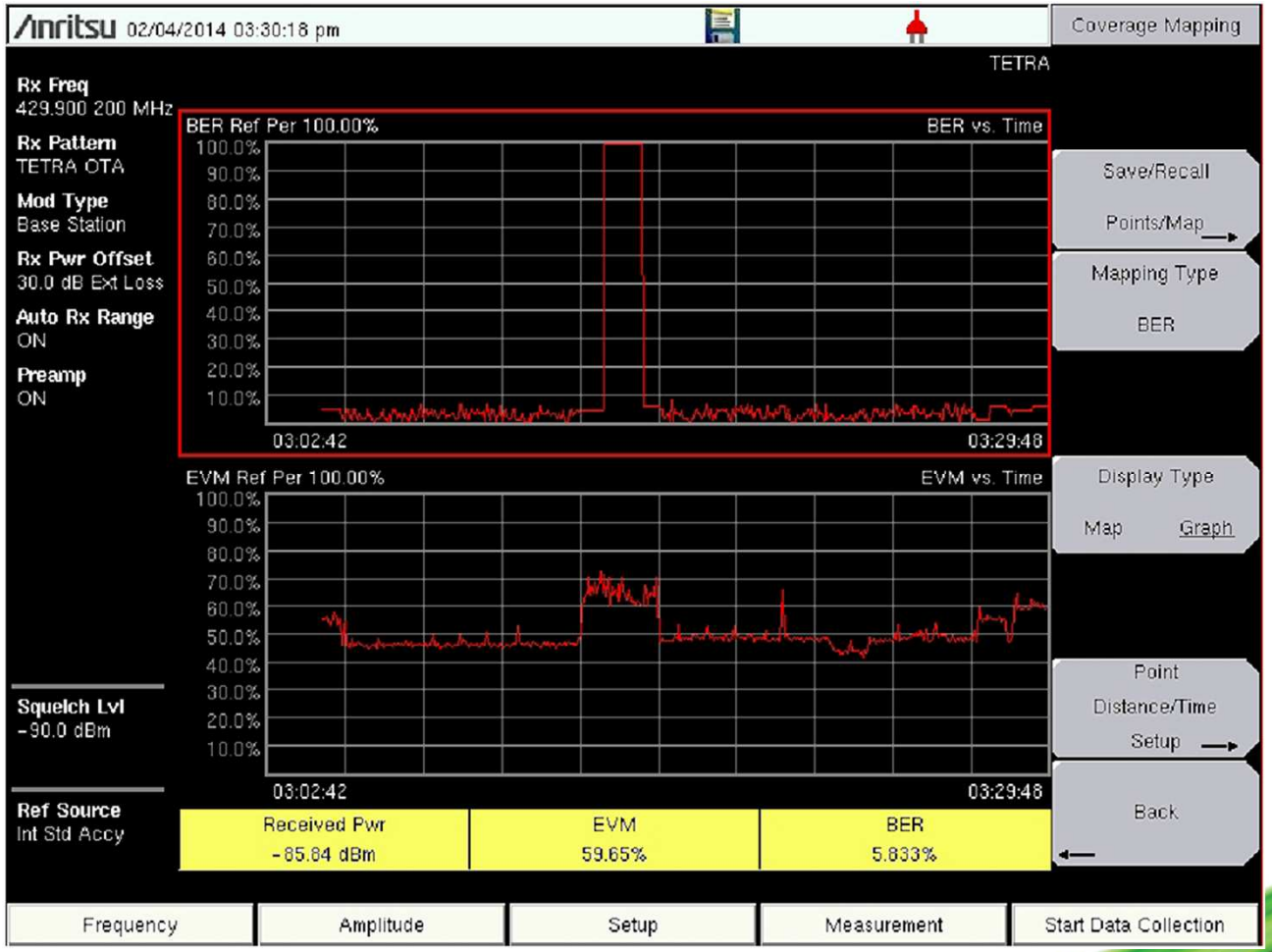
TETRA Coverage Mapping

TETRA service – Analog versus digital communication



TETRA Coverage Mapping

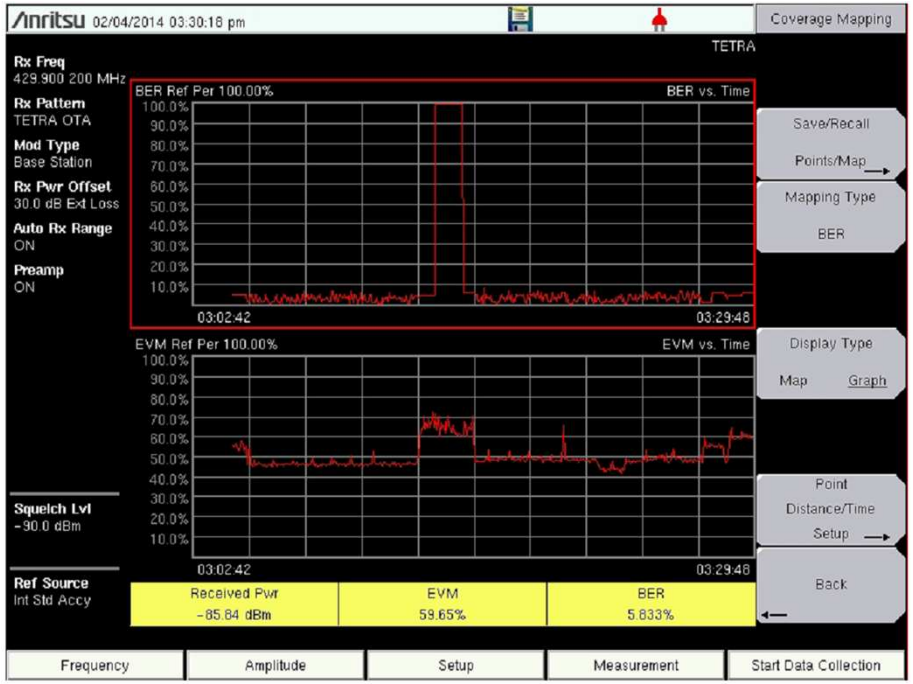
RSSI vs BER, RSSI vs EVM or BER vs EVM



TETRA Coverage Mapping

RSSI vs BER, RSSI vs EVM or BER vs EVM

- EVM is quite high, ~50 %. EVM should be < 5 % for a strong or good signal.
- The BER < 10 % most of the time, but occasionally rises to more than 100 %. For a strong signal, the BER would be well under 5 %.
- BER greater than 100 % is provided to indicate that even though the signal was above the squelch level, it was so poor that the BTS Synchronous Channel could not be decoded.
- This decoding is essential for any receiver analyzing a TETRA downlink signal.



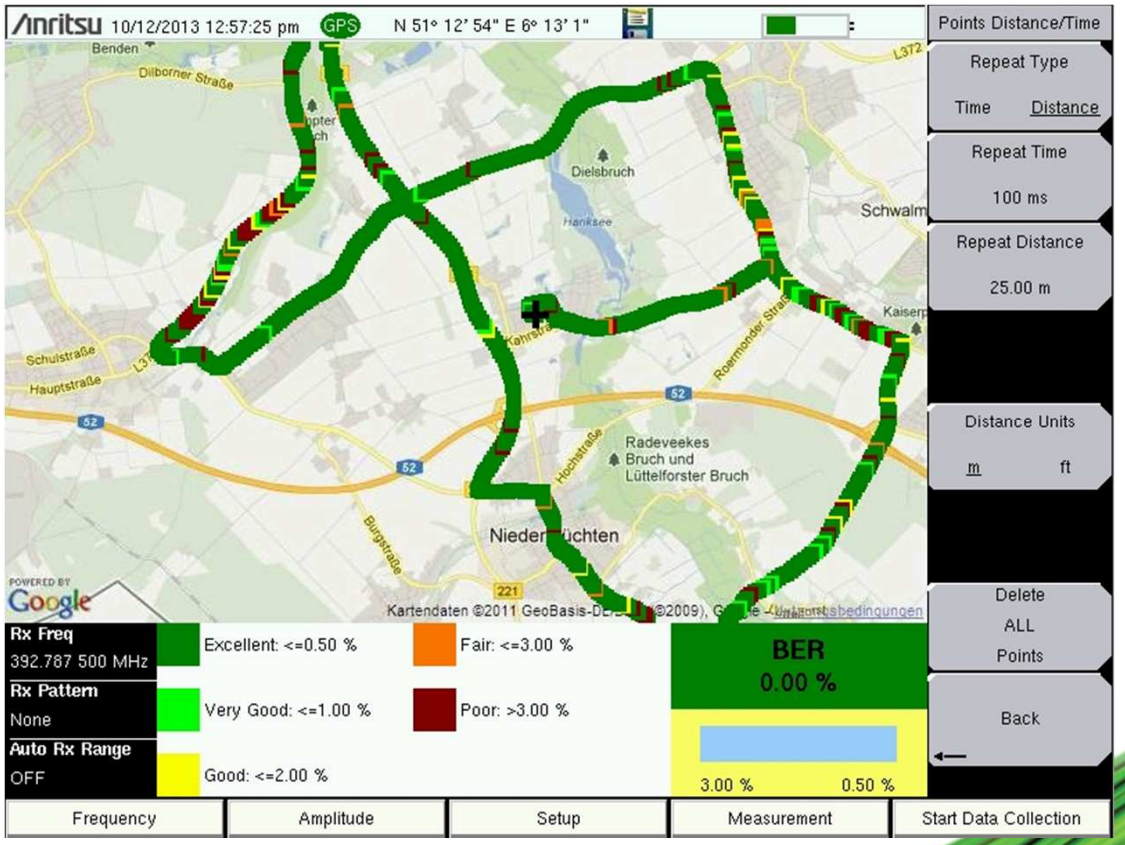
TETRA Coverage Mapping

TETRA Coverage Mapping - RSSI versus BER mapping

TETRA Coverage Mapping

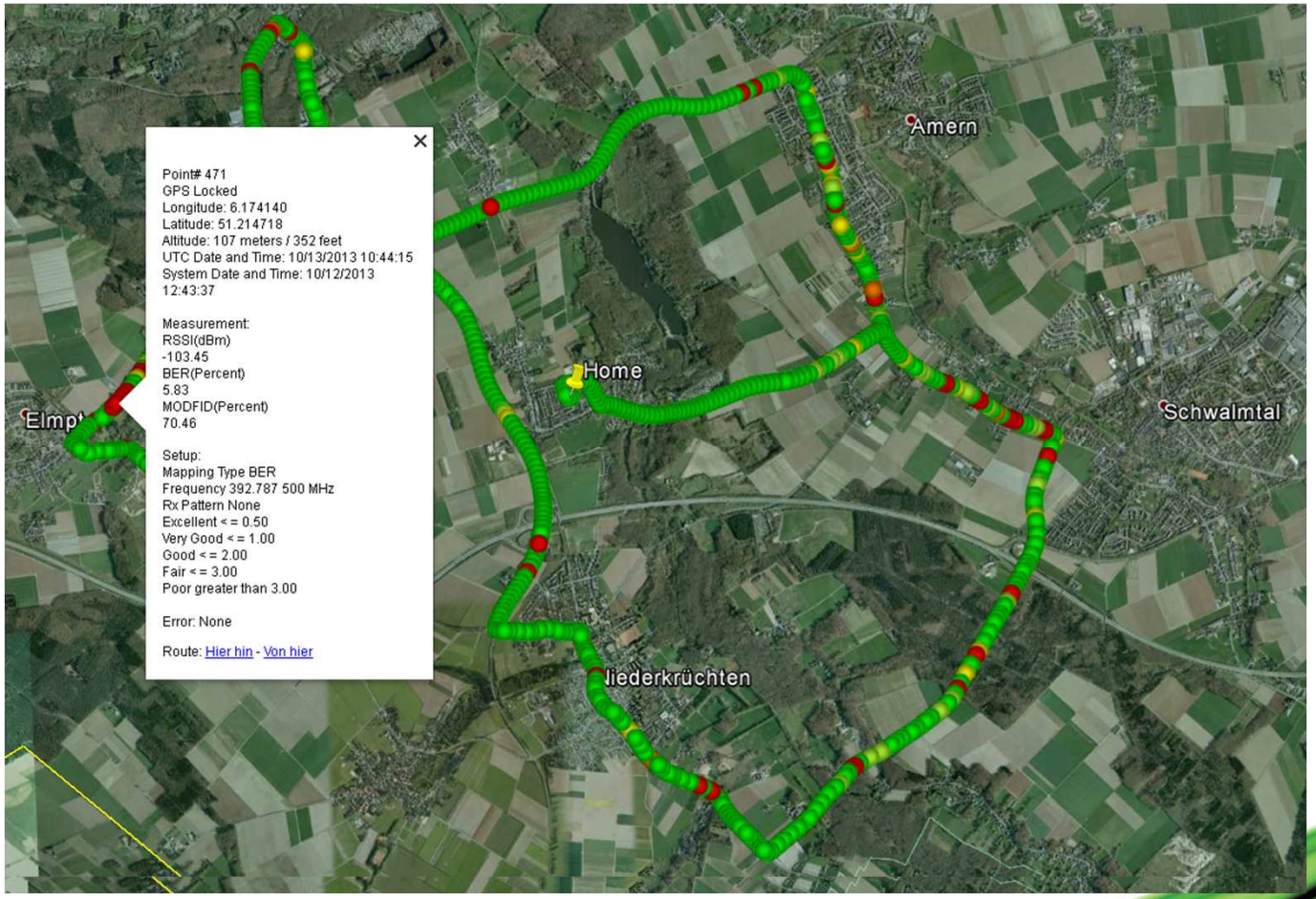
TETRA Coverage Mapping - BER mode

- **BER measurement**
  - **Outdoor and Indoor**
  - **The correct way to characterize a digital modulation format**
- **EVM measurement also possible**
- **RSSI vs BER, RSSI vs EVM or BER vs EVM**



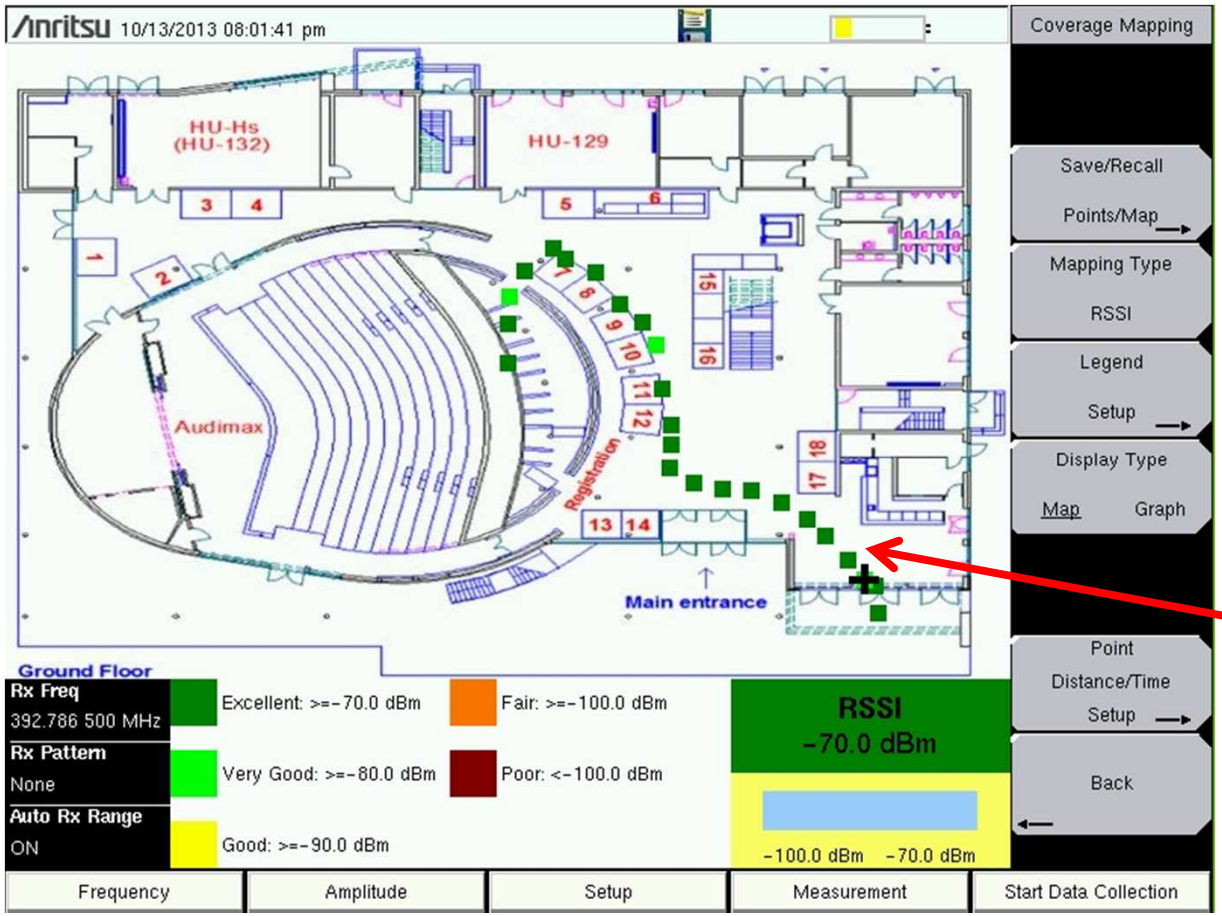
TETRA Coverage Mapping

TETRA Funkversorgung - BER mode Google Earth kml-file upload



TETRA Coverage Mapping

RSSI Indoor Coverage Mapping - start-walk-stop approach

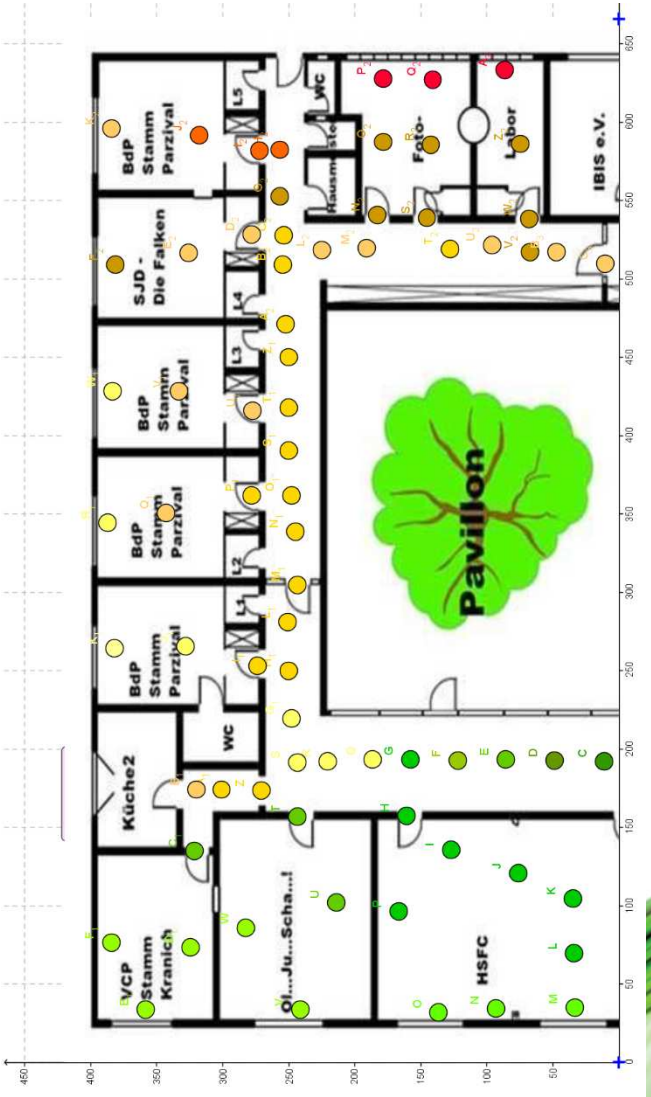


Touch screen

TETRA Coverage Mapping

Indoor Coverage Mapping

- **Indoor map parameters**
  - **Screen size in 666 x 420 px**
  - **Possibility to „sub-tile“ large indoor maps**
  - **Export into CSV-format possible**
  - **Work in progress for „large“ indoor plan handling**



TETRA Coverage Mapping

Indoor Coverage Mapping

Beforehand large indoor floorplan subtiled and later on recombined

TETRA Coverage Mapping

Tab delimited data formats with all relevant information

	A	B	C	D	H	I	J	K	L	M	N
1	<ANRITSU>										
2	FILE_MODE=										
3	MODEL=S412E/10/15/19/25/27/31/431/501/509/521/522/531/532/541/542/546/591/592/721/722										
4	SN=1211049										
5	UNIT_NAME=										
6											
7	DESCR=/card0/usr/ghmt.mtd										
8	DATE=2014-02-27-04-07-49-56				Scale:						
9	BASE_VER=T4.71.5052				Excellent >	0.0 dBm					
10	APP_NAME=SPA				Very Good >	-20.0 dBm					
11	APP_VER=T6.11.5052				Good >	-40.0 dBm					
12	APP_MODE=1				Fair >	-100.0 dBm					
13					Poor less than	-100.0 dBm					
14	# Begin SPA Setup										
15	<APP_SETUP>										
16	VERSION=1										
17											
18	<APP_DATA>										
19	#Pt	GPS Status	Longitude(X)	Latitude(Y)	System Date	System Time	RSSI(dBm)	Frequency	RBW	VBW	Detection
20	Point# 1	GPS Not Locked	333	210	02/27/2014	07:40:27	-98.4	391,687454 MHz	1 kHz	10 Hz	Peak
21	Point# 2	GPS Not Locked	399	237	02/27/2014	07:40:33	-93.1	391,687454 MHz	1 kHz	10 Hz	Peak
22	Point# 3	GPS Not Locked	384	193	02/27/2014	07:40:37	-86.9	391,687454 MHz	1 kHz	10 Hz	Peak
23	Point# 4	GPS Not Locked	355	170	02/27/2014	07:40:40	-88.8	391,687454 MHz	1 kHz	10 Hz	Peak
24	Point# 5	GPS Not Locked	323	160	02/27/2014	07:40:42	-82.4	391,687454 MHz	1 kHz	10 Hz	Peak
25	Point# 6	GPS Not Locked	271	170	02/27/2014	07:40:45	-91.1	391,687454 MHz	1 kHz	10 Hz	Peak
26	Point# 7	GPS Not Locked	240	193	02/27/2014	07:40:47	-89.5	391,687454 MHz	1 kHz	10 Hz	Peak
27	Point# 8	GPS Not Locked	194	178	02/27/2014	07:40:49	-87.0	391,687454 MHz	1 kHz	10 Hz	Peak
28	Point# 9	GPS Not Locked	101	119	02/27/2014	07:40:52	-91.9	391,687454 MHz	1 kHz	10 Hz	Peak
29	Point# 10	GPS Not Locked	146	162	02/27/2014	07:40:56	-88.2	391,687454 MHz	1 kHz	10 Hz	Peak

Tunnel
Coverage Mapping

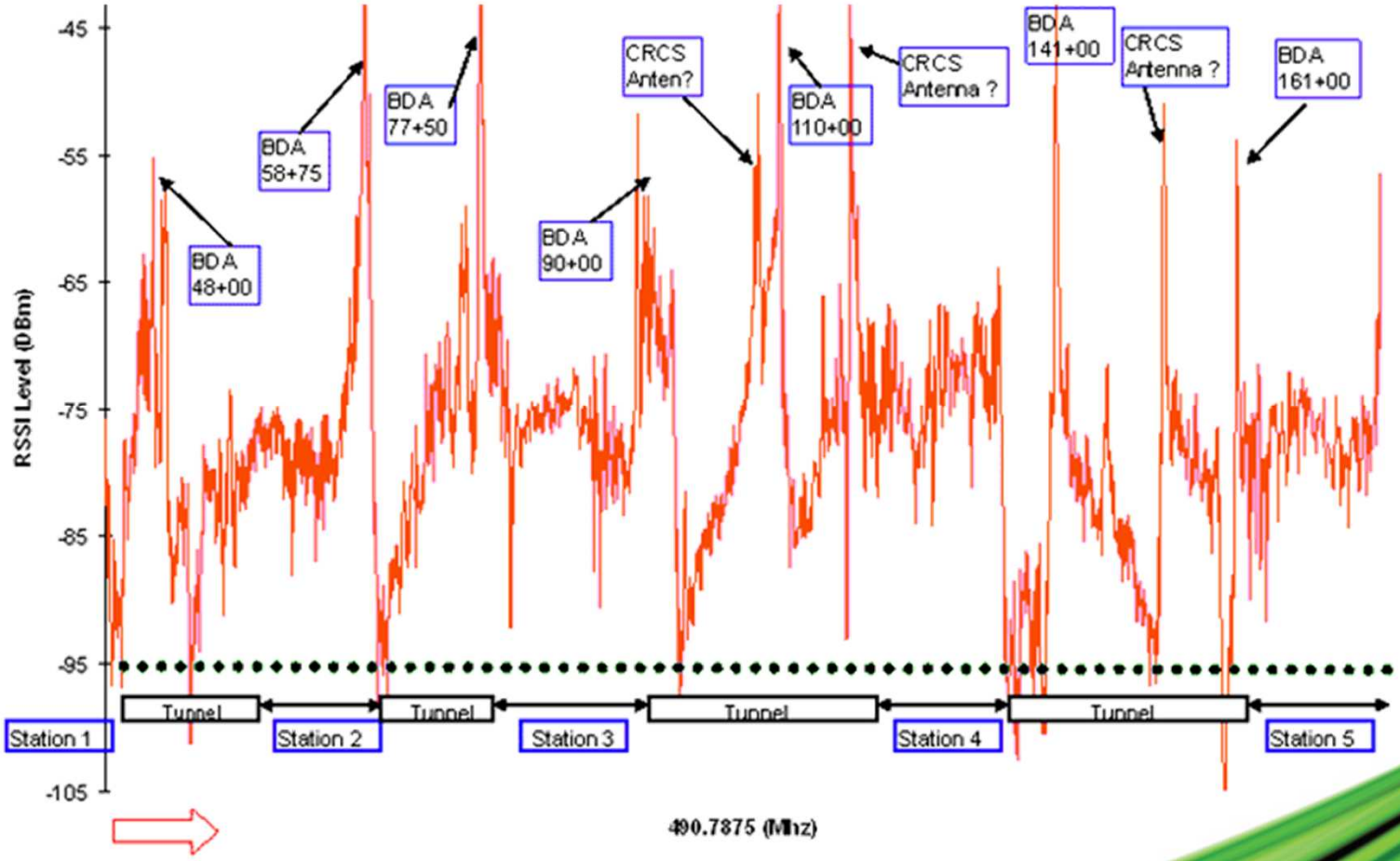
Tunnel Coverage Mapping

Tunnel Radio Coverage for a Metro Transit Systems

- Transit officials are noticing "nulls" in radio coverage spots inside the tunnels
- Would like to verify radio coverage after having deployed a new radio service (e.g. TETRA)
- **Action:**
  Determine and analyze the radio signal strength
- **Result:**
  The analysis will help to identify RF coverage "nulls" or prove radio coverage along rails within the tunnels and stations and allow remedial actions where necessary

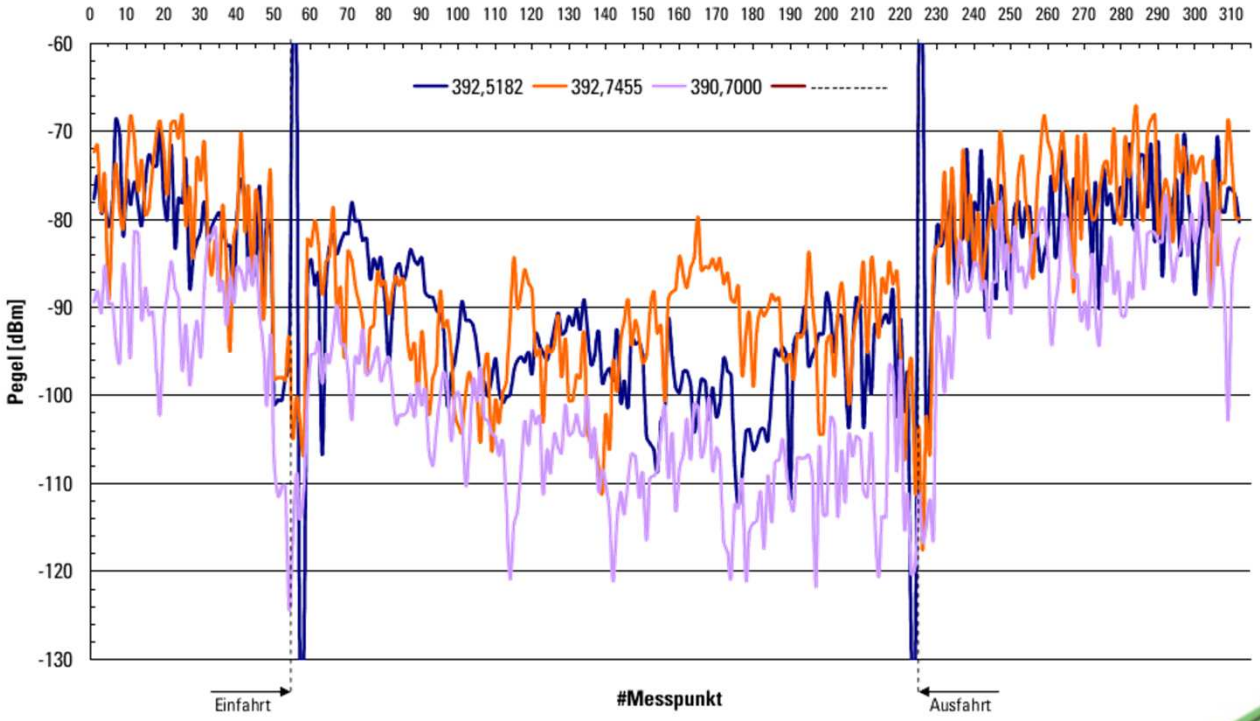
Tunnel Coverage Mapping

Example of tunnel radio coverage for a Metro Transit System



Tunnel Coverage Mapping

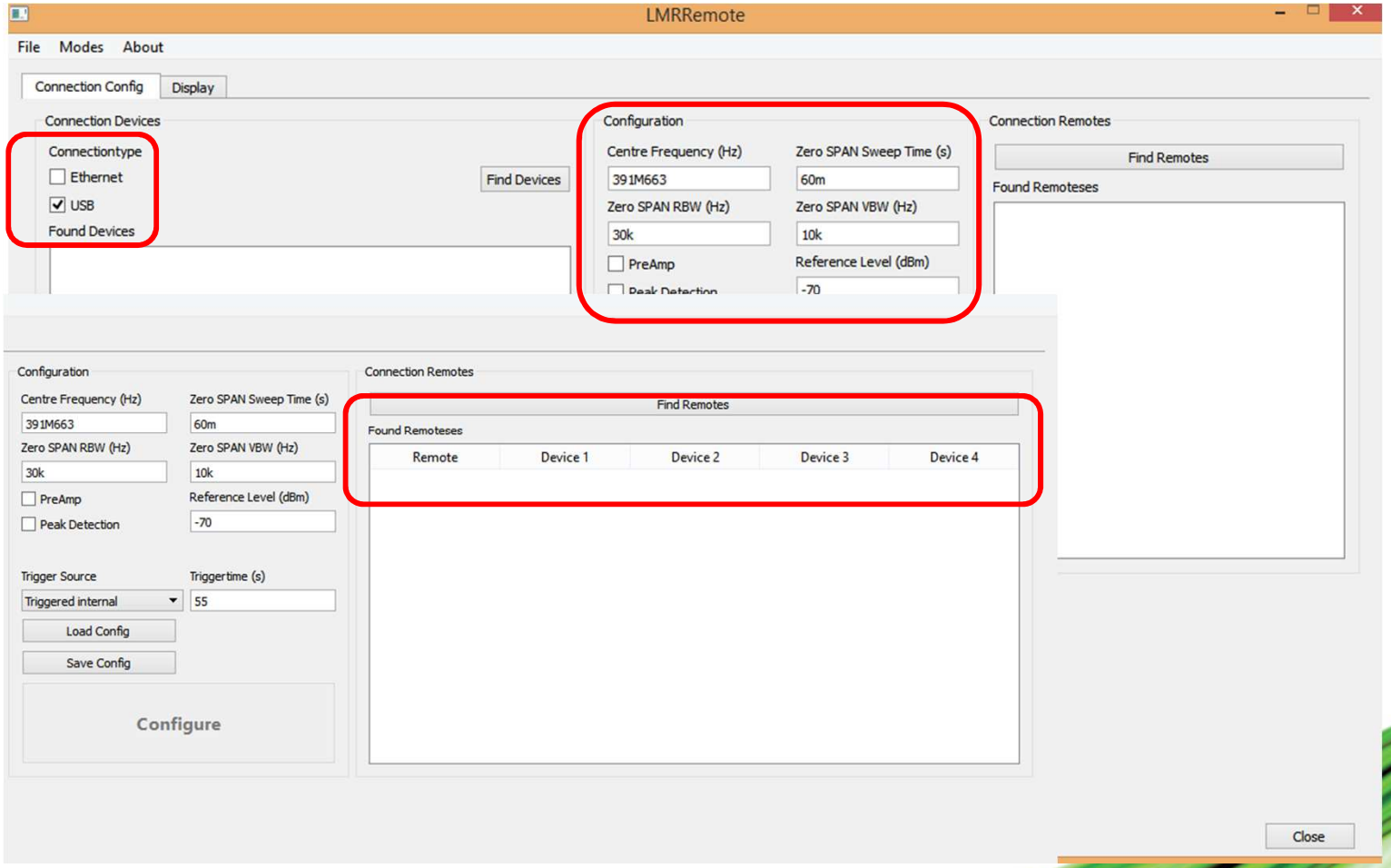
Example of a typical tunnel radio coverage measurement



Where is my position inside the tunnel?

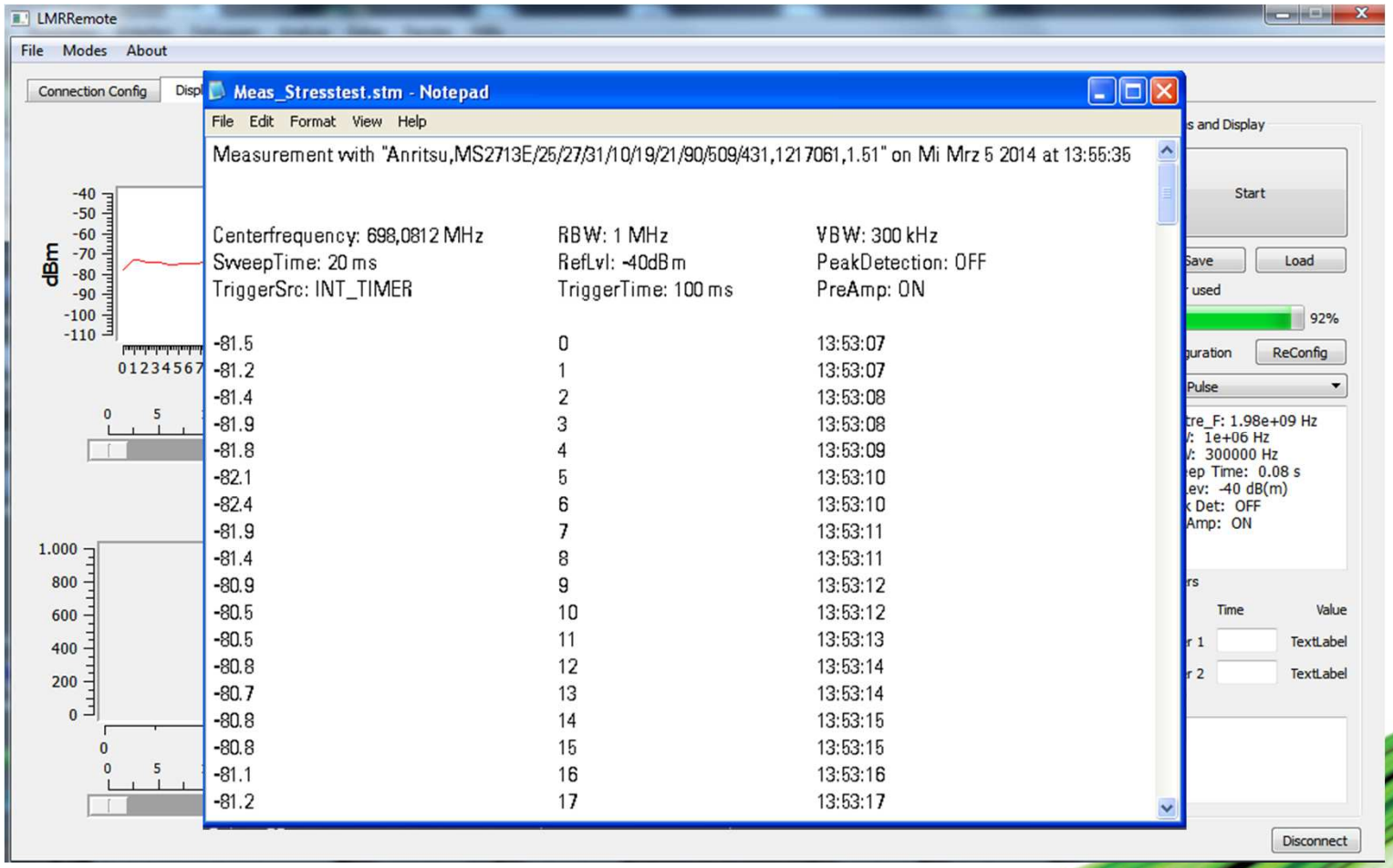
Tunnel Coverage Mapping

Triggered Coverage Mapping (Beta release)



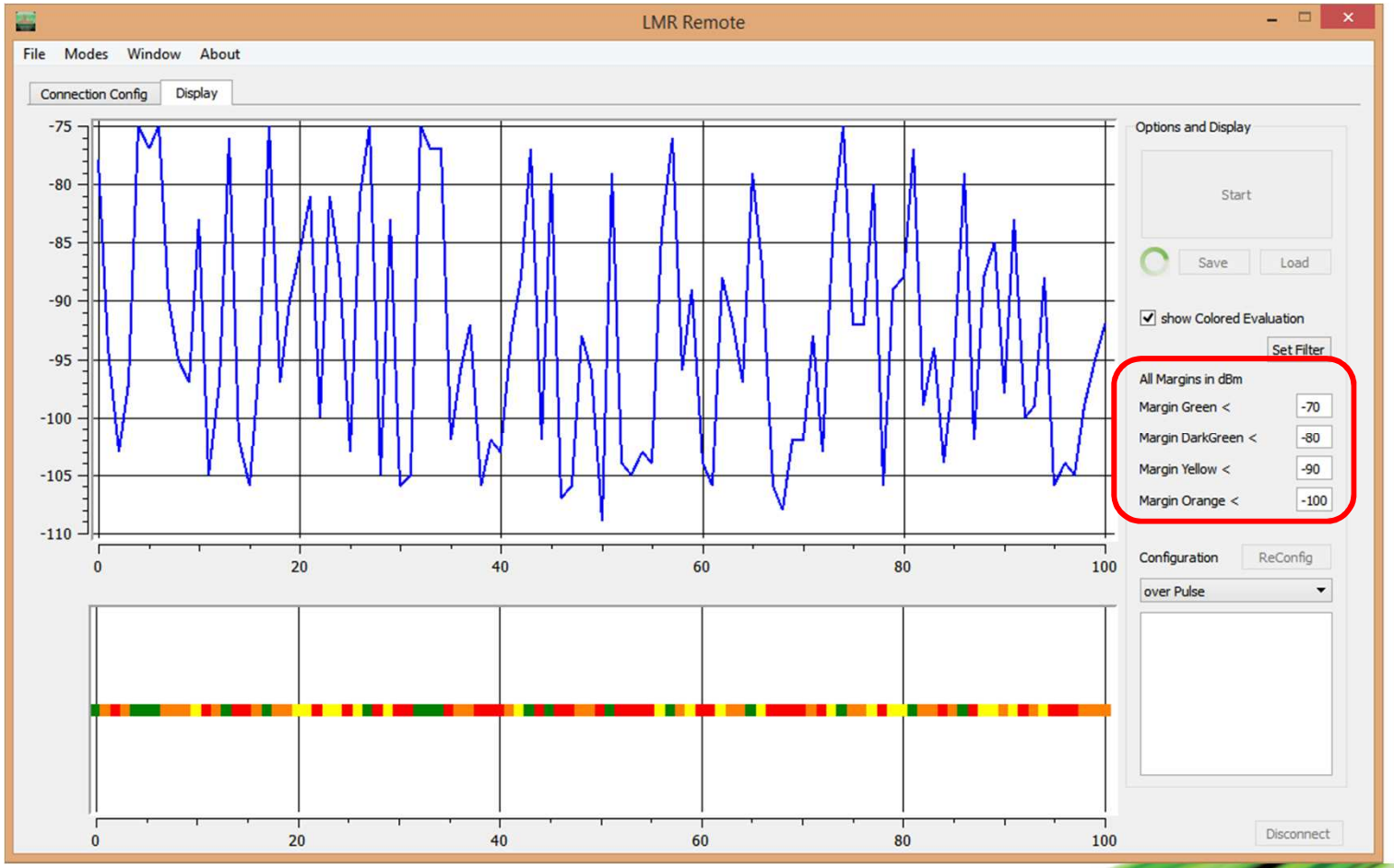
Tunnel Coverage Mapping

Triggered Coverage Mapping (Beta release)



Tunnel Coverage Mapping

Triggered Coverage Mapping (Beta release)



Horizontal Scan Measurements with Channel Scanner

Horizontal Scan Measurements

Problem and Goal

Problem

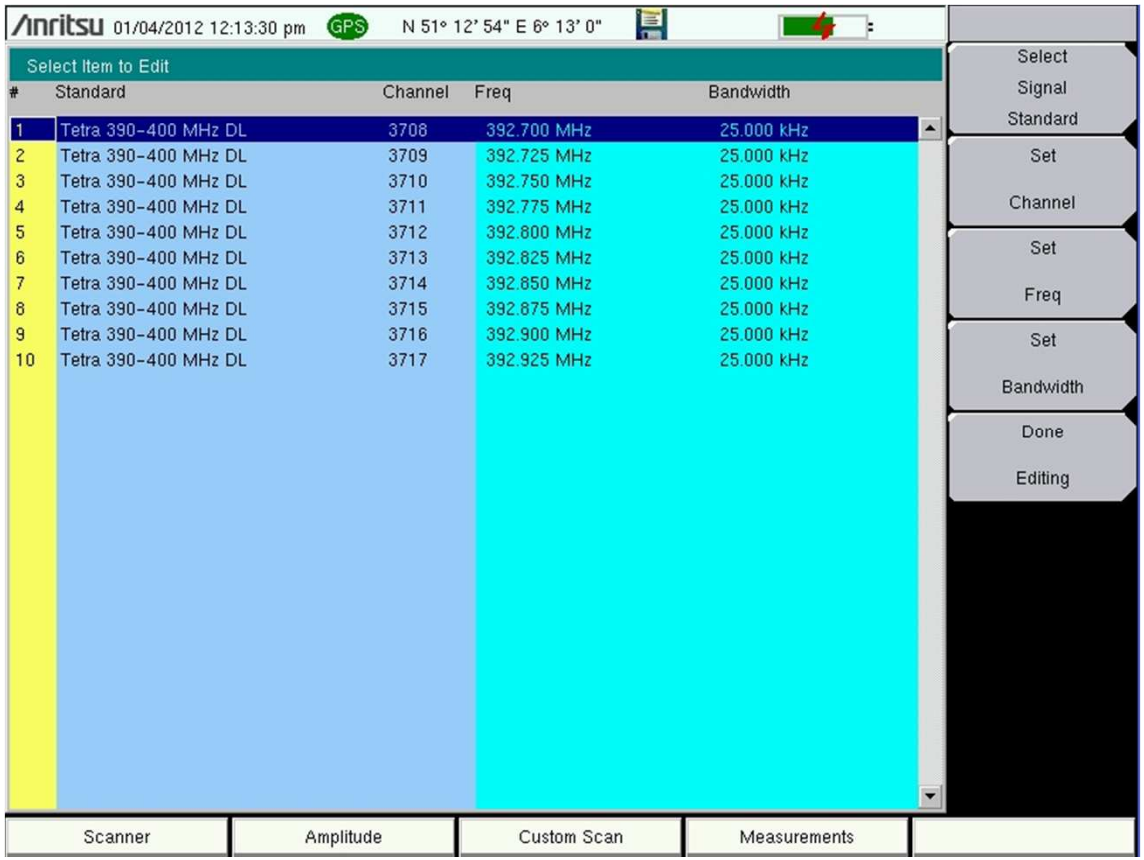
- Get the azimut of several BTSn on different frequencies in order to link a repeater to a BTS

Goal

- Get this information just with one 360° scan
- Measurement shall be GPS referenced
- Use of a directional antenna with high gain, good front-to-back ratio and a quite narrow halfpower beamwidth

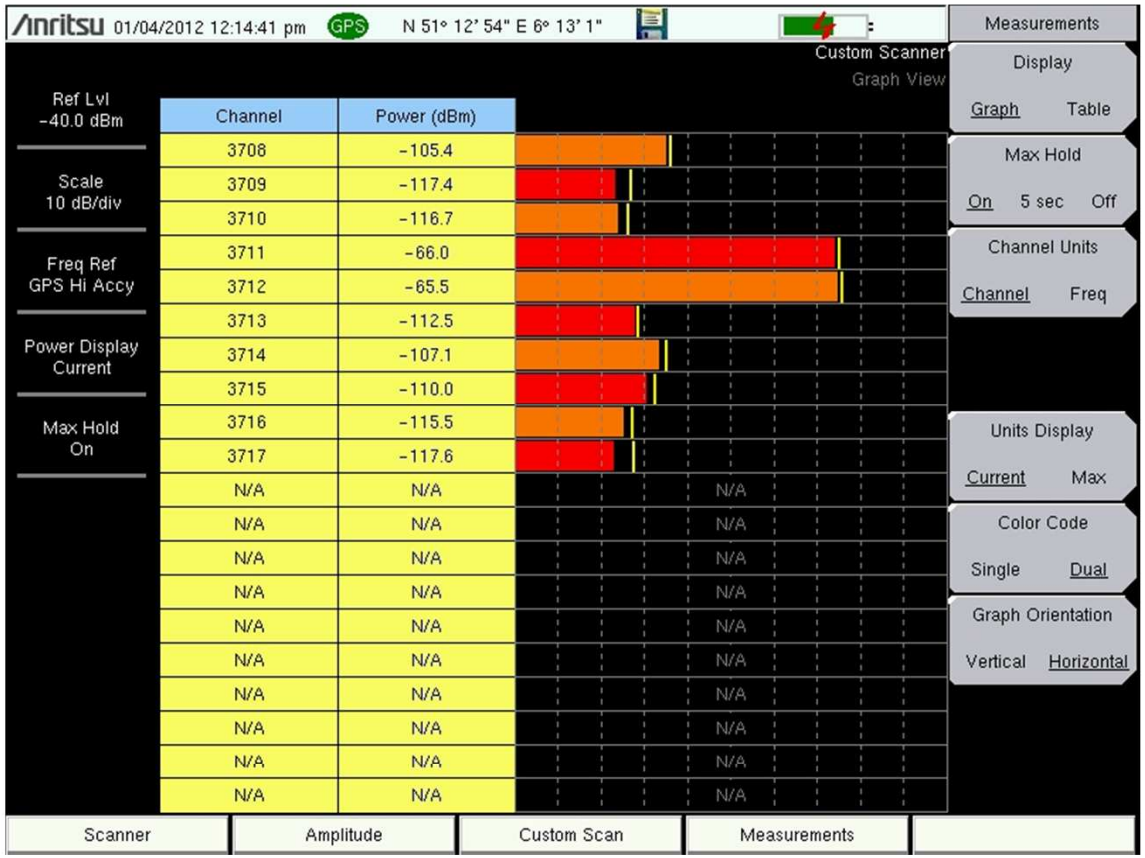
Horizontal Scan Measurements

(TETRA) Channel Scanner – Set of supervision channels



Horizontal Scan Measurements

(TETRA) Channel Scanner – display representation



Horizontal Scan Measurements

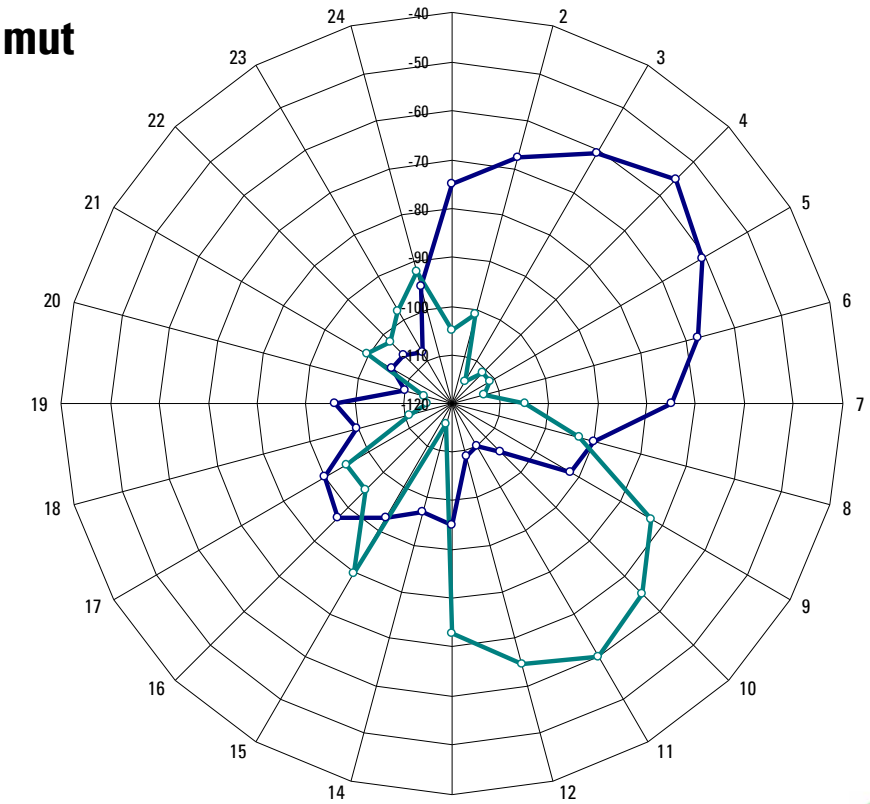
(TETRA) Channel Scanner – Script Master display

- Parallel measurements of up to 20 GPS referenced channels on the instrument display
- Documentation via ScriptMaster Tool
- Spektrum monitoring or spectrum clearing measurements without complicated configurations

Horizontal Scan Measurements

(TETRA) Channel Scanner – Script Master Nutzung

- **Example of serving BTS 'n azimut**
  - **45° and**
  - **150°**



Handheld based emitter location
MA2700A

Handheld Emitter Location

MA2700A

- MA2700A offeres
  - Built-in electronic compass
  - Built-in GPS receiver
  - Built-in preamplifier
  - Trigger for saving vectors
- Easy no-tool attachment of antenna
- Ergonomic design
- Light weight

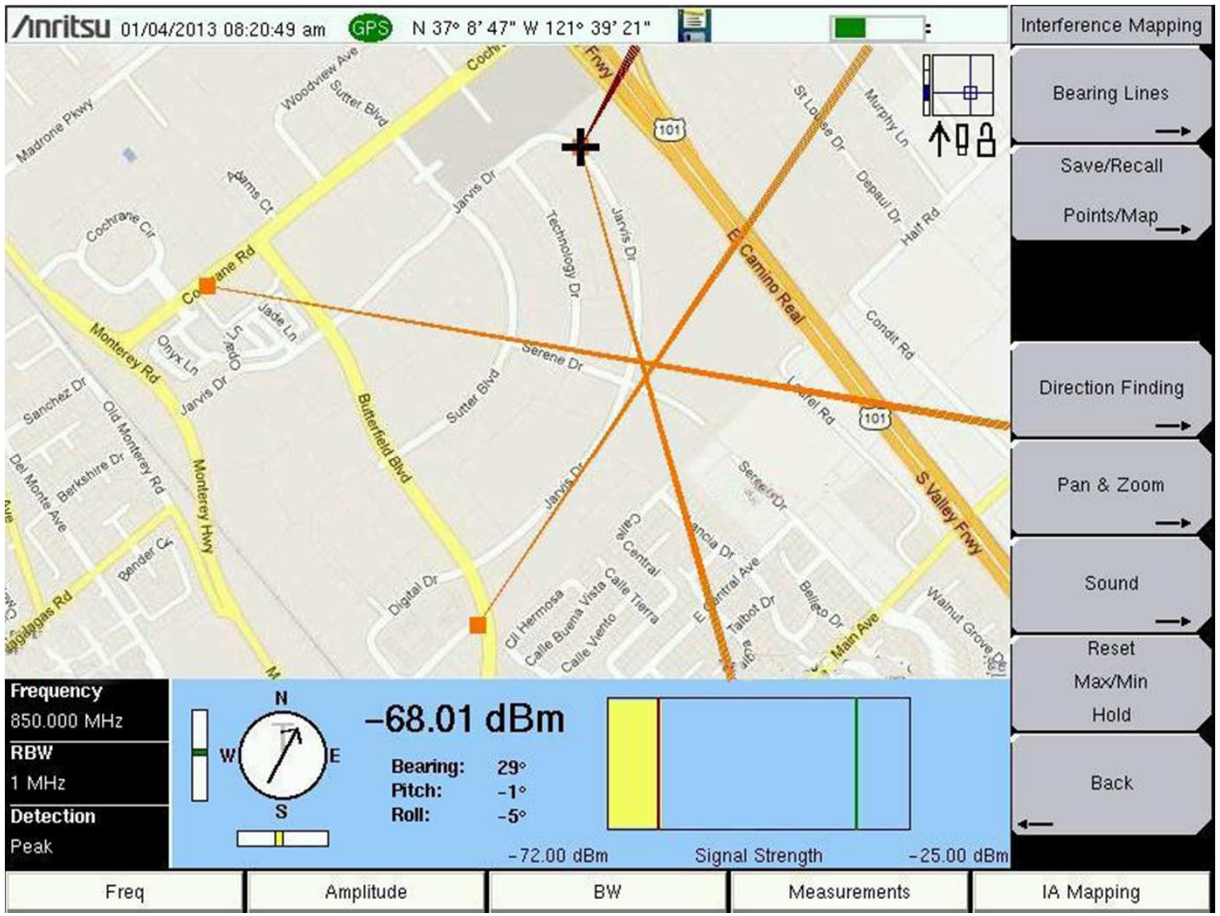
Handheld Emitter Location

MA2700A Specification

Power Consumption	
Preamplifier On	0.6 Watts
Preamplifier Off	0.5 Watts
Preamplifier	
Bandwidth	10 MHz to 6 GHz
Gain	≥ 8 dB: 10 MHz to 2.4 GHz ≥ 5 dB: > 2.4 GHz to 4 GHz ≥ 3dB: > 4 GHz to 6 GHz
Electronic Compass	
Power	Powered from USB
Accuracy	≤ 5°
Interface	USB
GPS Receiver	
Satellites Tracked	12 (maximum)
GPS Locking Time	Cold start: 30 s, typical, with a clear view of the sky Warm start: 2 s, typical, with a clear view of the sky
Position Uncertainty	± 2 meter, typical
Tripod Mount	
	1/4 - 20 UNC x 7 mm
Size and Weight	
Size	303 mm x 220 mm x 70 mm (11.9 in x 8.7 in x 2.76 in)
Weight	< 1 kg (2.2 lb)

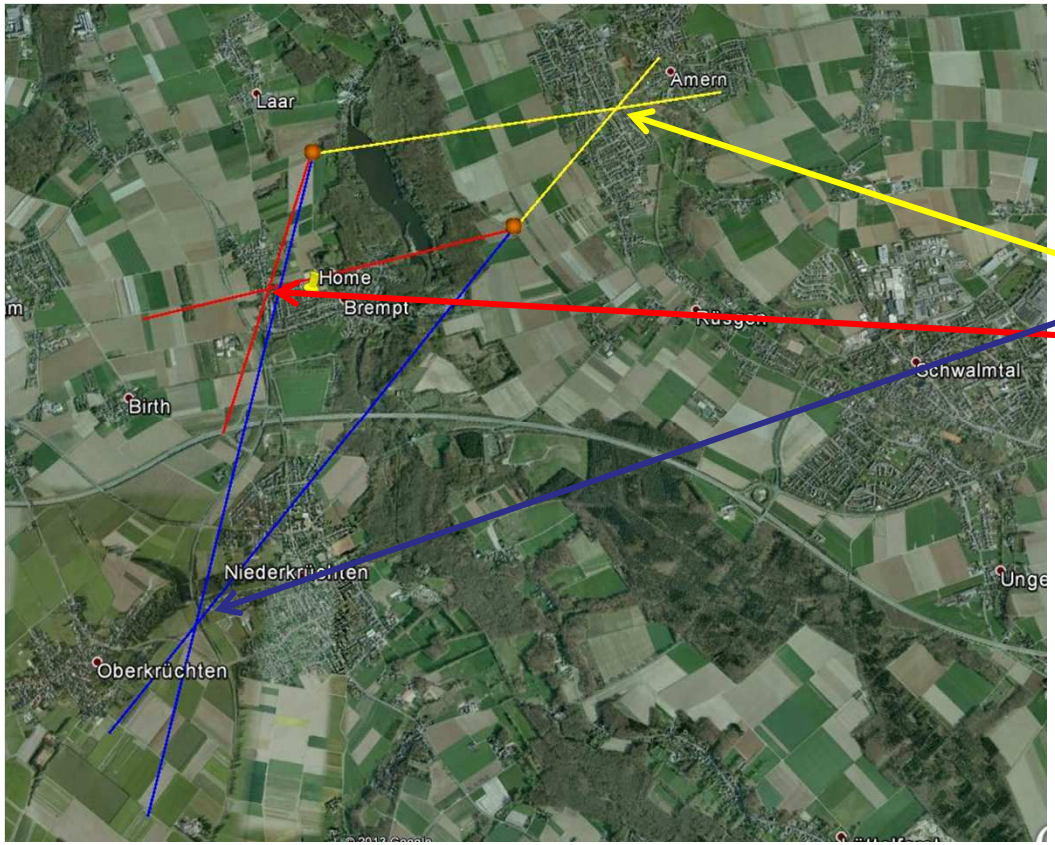
Handheld Emitter Location

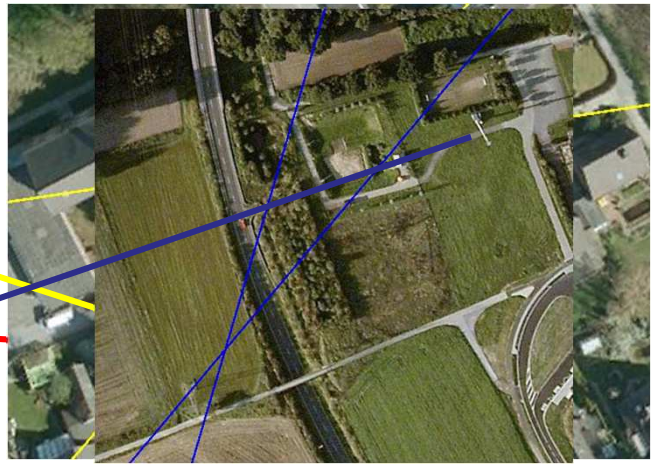
MS2700A – typical results



Handheld Emitter Location

MS2700A – typical results

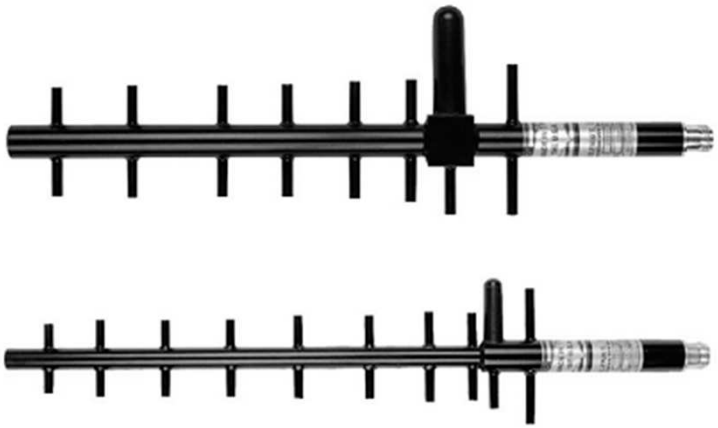




Handheld Emitter Location

Available Antennas

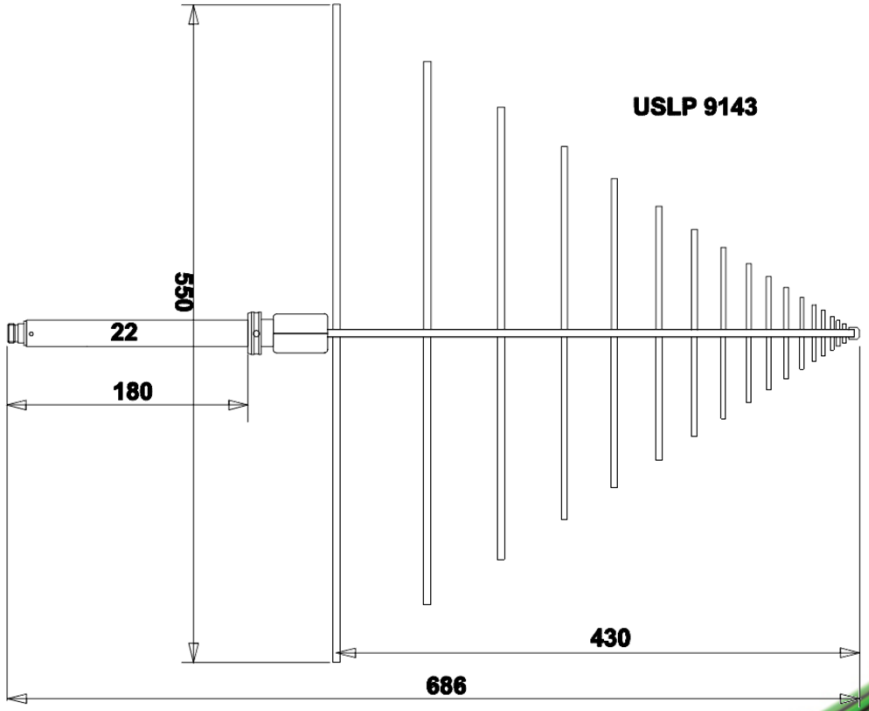
Part Number	Description
2000-1411-R	822 MHz to 900 MHz, N(f), 10 dBd, Yagi
2000-1412-R	885 MHz to 975 MHz, N(f), 10 dBd, Yagi
2000-1413-R	1710 MHz to 1880 MHz, N(f), 10 dBd, Yagi
2000-1414-R	1850 MHz to 1990 MHz, N(f), 9.3 dBd, Yagi
2000-1415-R	2400 MHz to 2500 MHz, N(f), 10 dBd, Yagi
2000-1416-R	1920 MHz to 2170 MHz, N(f), 10 dBd, Yagi
2000-1659-R	698 MHz to 787 MHz, N(f), 8 dBd, Yagi
2000-1660-R	1425 MHz to 1535 MHz, N(f), 12 dBd, Yagi
2000-1727	Monopod



Handheld Emitter Location

Available Antennas

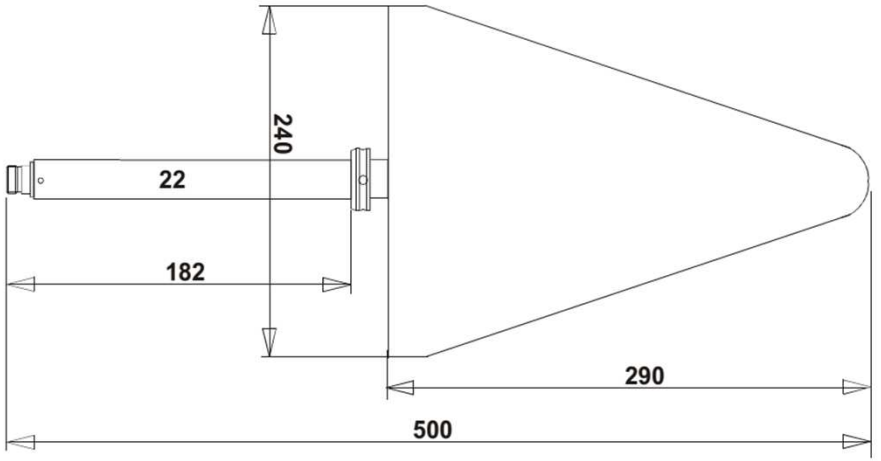
- **300 MHz to 5 GHz (USLP 9143)**
  - **Frequency: (0.25) 0.3 – 5 (7) GHz**
  - **Gain: 4 - 7 dBi typ.**
  - **Antenna factor: 14 - 42 dB/m VSWR typ.: < 1.8**
  - **Weight: 0.8 kg**
  - **Max. Input Power: 100 W**
  - **Connector: N-female**



Handheld Emitter Location

Available Antennas

- **1 to 18 GHz (ESLP 9145)**
  - Nominal Frequency range: 1 - 18 GHz
  - Useable Frequency range: 0.7 - 20 GHz
  - Connector: N(f) Connector
  - Mounting tube: f=22 mm, L=185 mm
  - Isotropic gain: typ. 6 dBi +/- 1.2 dB
  - Antenna Factor: 22 ... 50 dB/m
  - SWR typ.: < 2
  - Max. Input Power: 20 W
  - Half-Power Beamwidth (E-plane): 55° (70° - 40°)
  - Half-Power Beamwidth (H-plane): 85° (130° - 65°)
  - Dimensions: 500 x 240 x 40 mm
  - Weight: 900 g

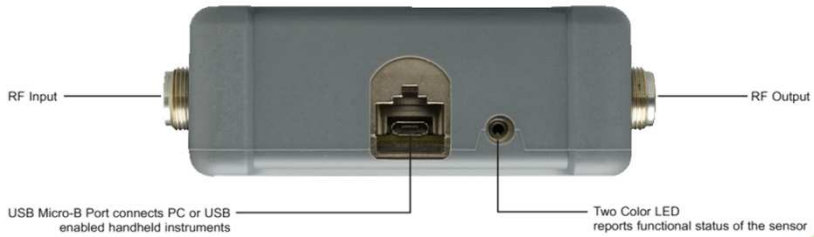


TETRA
BTS power measurements

TETRA BTS Power measurements

MA24105A Inline Peak Power Sensor

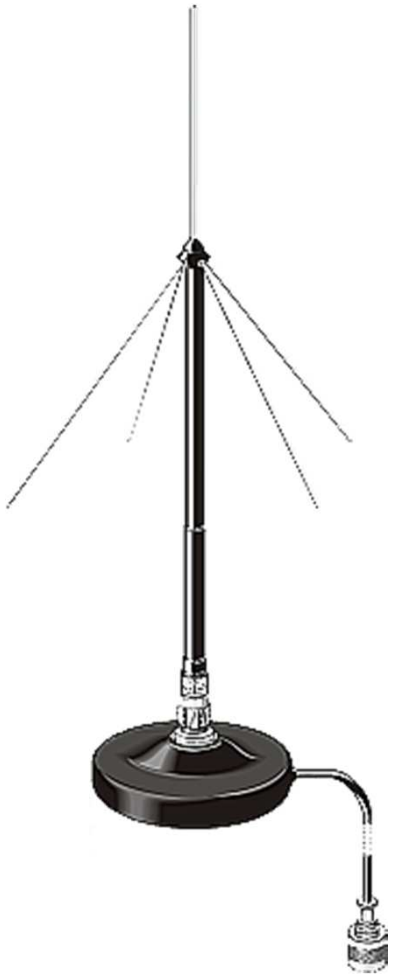
- Power sensor RF range 350 - 4000 MHz
- Dynamic Range +3 to +52 dBm (2 mW to 150 W)
- sensor employs a "dual path" architecture that enables True-RMS measurements like CW, Multi-Tone and digitally modulated signals
- Forward direction path with 4 MHz bandwidth in order to measure PEP power, crest factor, CCDF, and burst average power
- Reverse direction path for reverse power, reflection coefficient, return-loss, and SWR
- Stand alone operation via LAN or USB together with PC / Laptop
- Operation with Option 19 “High accuracy power meter” on LMR Master S412E or other HH units

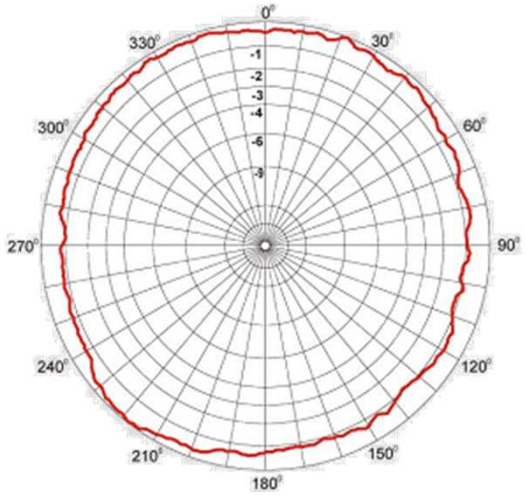


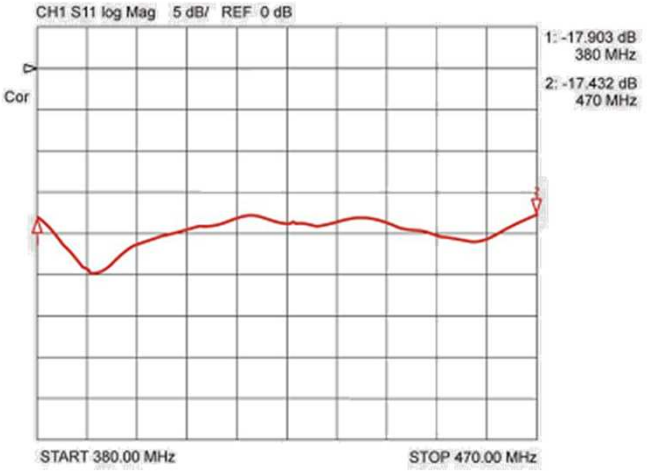
TETRA
Measurement antennas

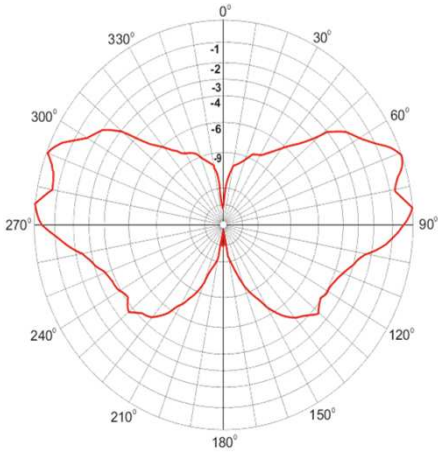
Measurement antennas

Groundplane antenna





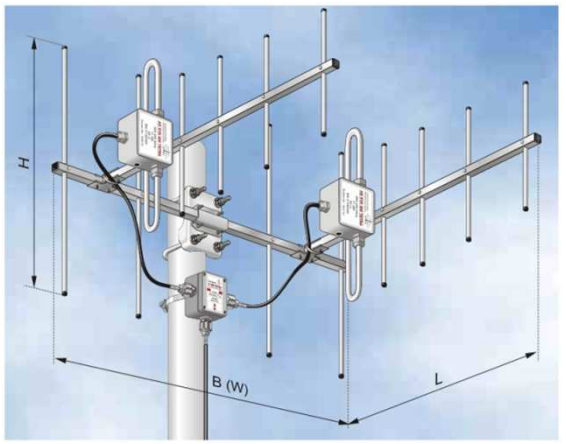


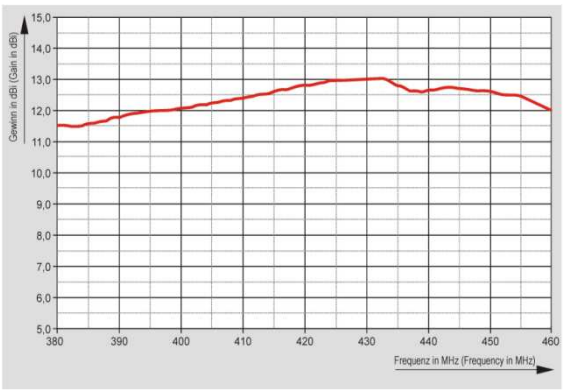


Measurement antennas

Directional antenna

- Horizontal Scan
- Technical specification
  - TETRA RF range
  - Gain = 12 dBi
  - HPBW = 36°
  - F/B > 20 dB






Thank
you
Merci
Gracias
Arigato
bolzïn
Tashakkur
Shukuria
Shukria
Grazie
Biyan
Juspaxar
suksama
Mehrbani
Maake
gozaimashita
atu
Yaqhanyelay
Efcharisto
Dankscheen