narda Safety Test Solutions®
an L3 Communications Company

SRM User Group 2016

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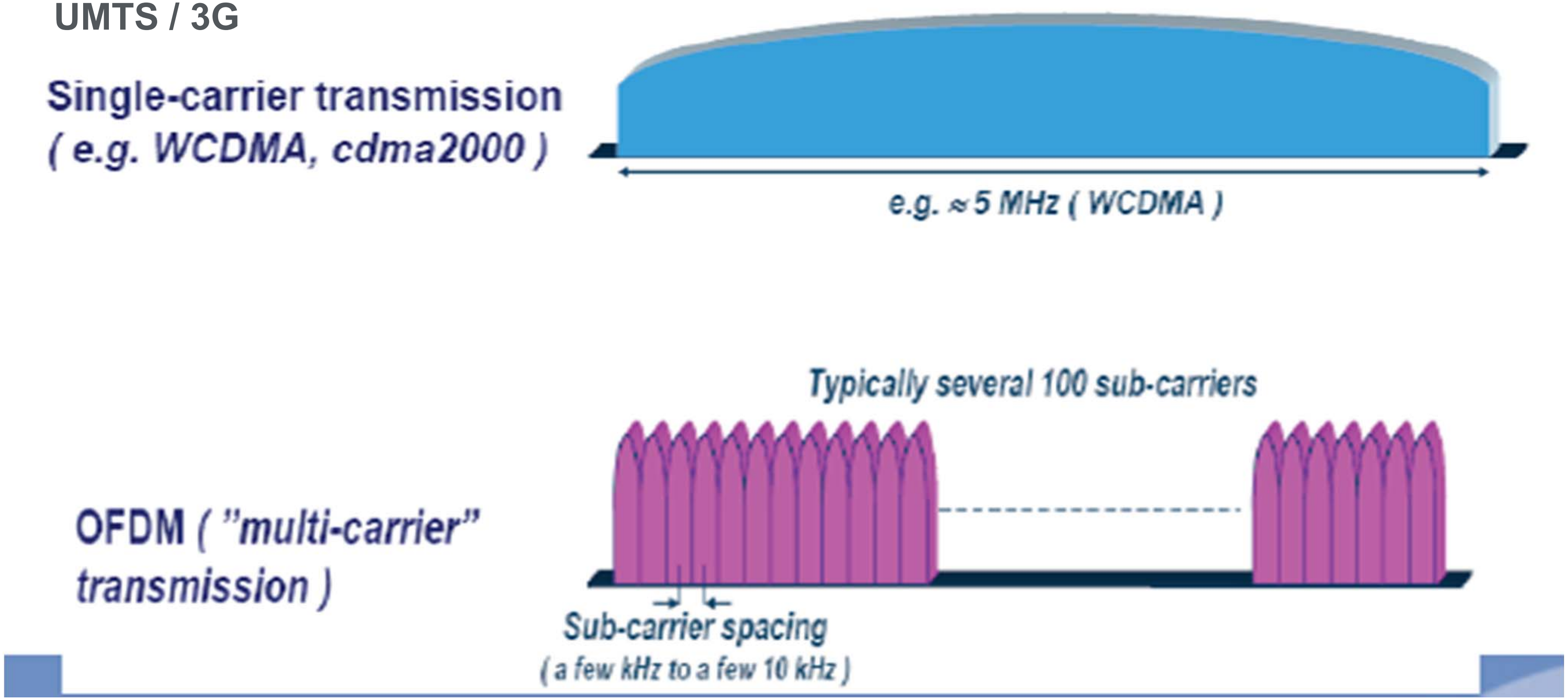
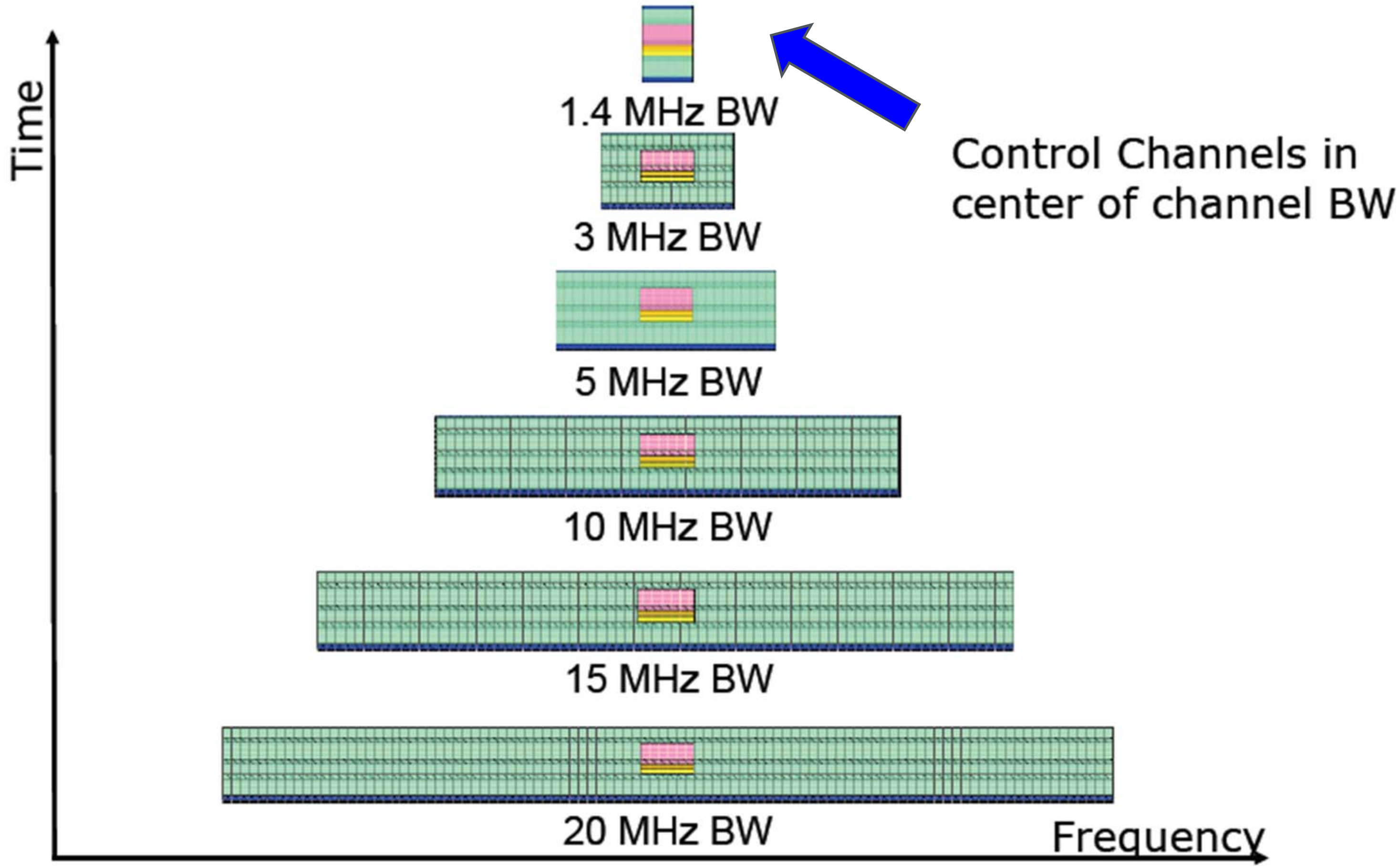
DOWNLINK (DL) Signal Transmission

› **UMTS / 3G**



- › **LTE / 3.9G: Orthogonal Frequency Division Multiplexing (OFDM) @ air interface**
- › **OFDM is a multi-carrier modulation (MCM), i.e. concurrent transmission of multiple sub-carriers with 15 kHz spacing**

› **Channel Bandwidths - CBW**



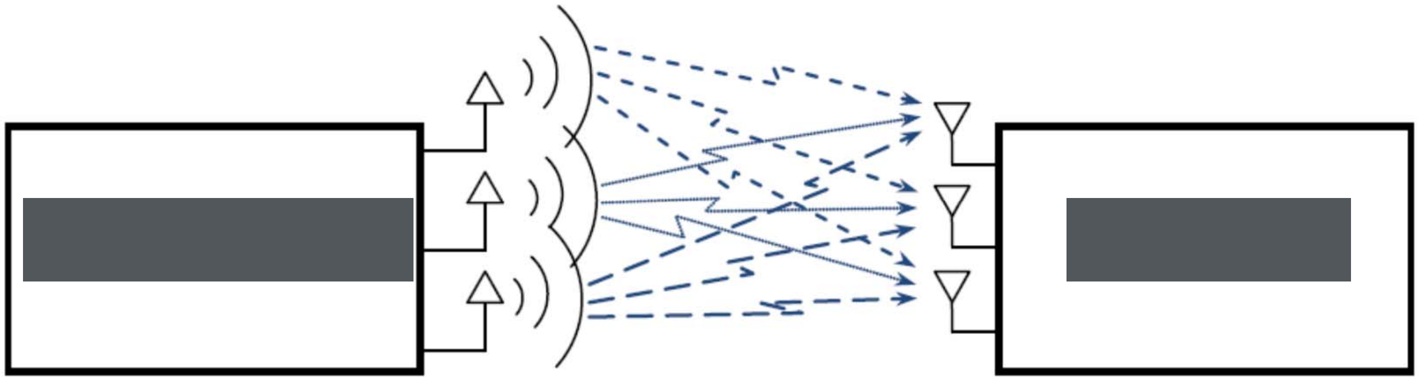
Source: http://www.3gpp.org/LTE

Main Technical Specifications of LTE

- **Downlink Multiple Access**
  OFDMA
- **Multiplexing**
  FDD and TDD with 10 ms frame repetition rate
- **Sub-carrier spacing**
  15 kHz
- **Data Modulation**
  QPSK, 16QAM, 64 QAM
- **Channel Coding**
  Convolution and turbo coding
- **SISO or MIMO *for DL***
  Single Input Single Output antenna OR
  Multiple Input Multiple Output antennas

Space Diversity or Space Multiplexing

- Principle of Multiple Input Multiple Output (MIMO), e.g. 3 x 3

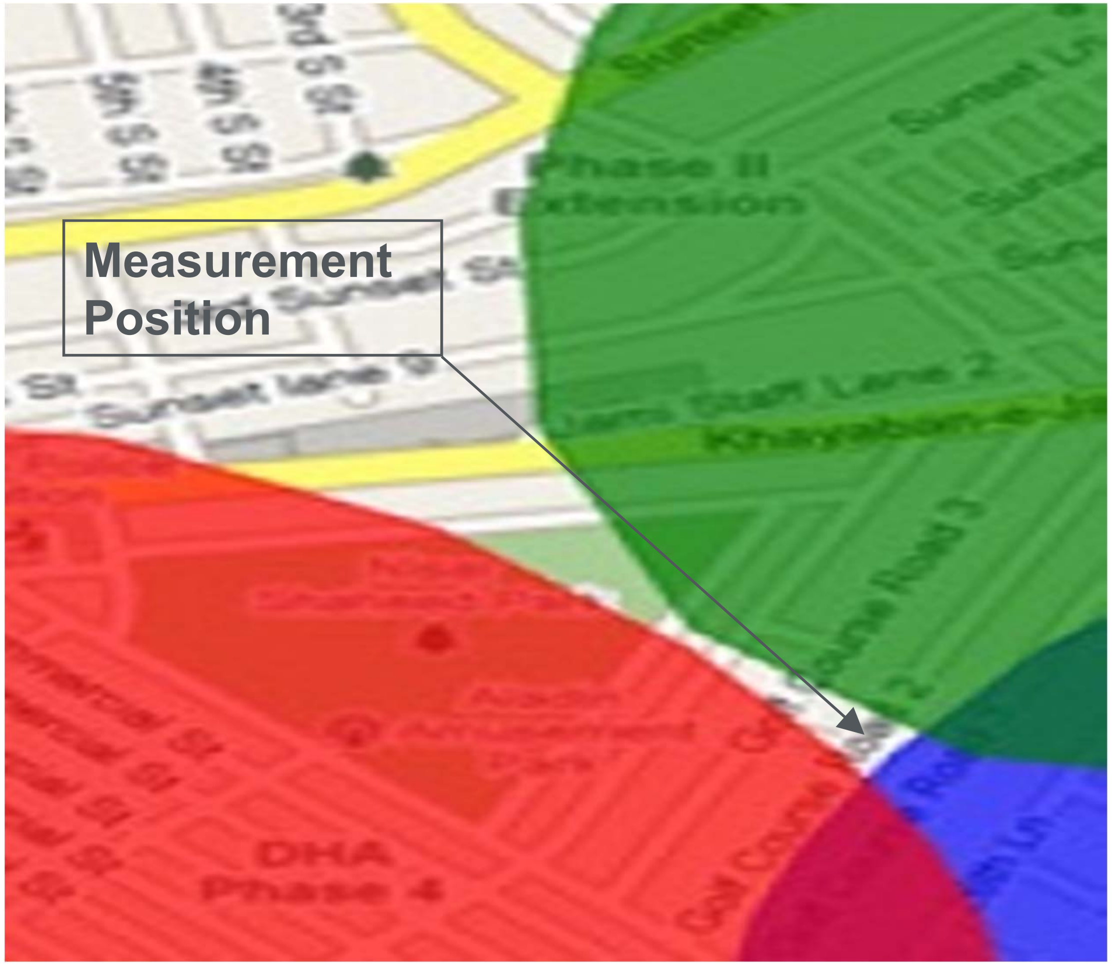


- Space Multiplexing
  - Increase of transmission channel capacity by factor 2 or 4 (here 3, as an example, only)
- Space Diversity
  - Significant signal quality improvement in case of strong and/or fast fading. Phase shift between antenna mitigates multi-path propagation effects created by reflections.
- N.B. : every antenna contributes to EMF Immission
  => thus exact measurement does require individual assessment of fields
  => MIMO offers to have segments (120°) comprising of 1, 2 or 4 antennas
  => individual measurement of signal power from up to 3 x 4 => 12 antennas / group ID

Immission contribution by towers, sectors and antennas

Concurrent Measurement needed

- Multiple Towers: Group ID
- Multiple sectors: Cell IDs
- SISO / MIMO: 1 / 2 / 4 antennas
- Per provider / licensed frequency



Tower A
Cell ID # 1

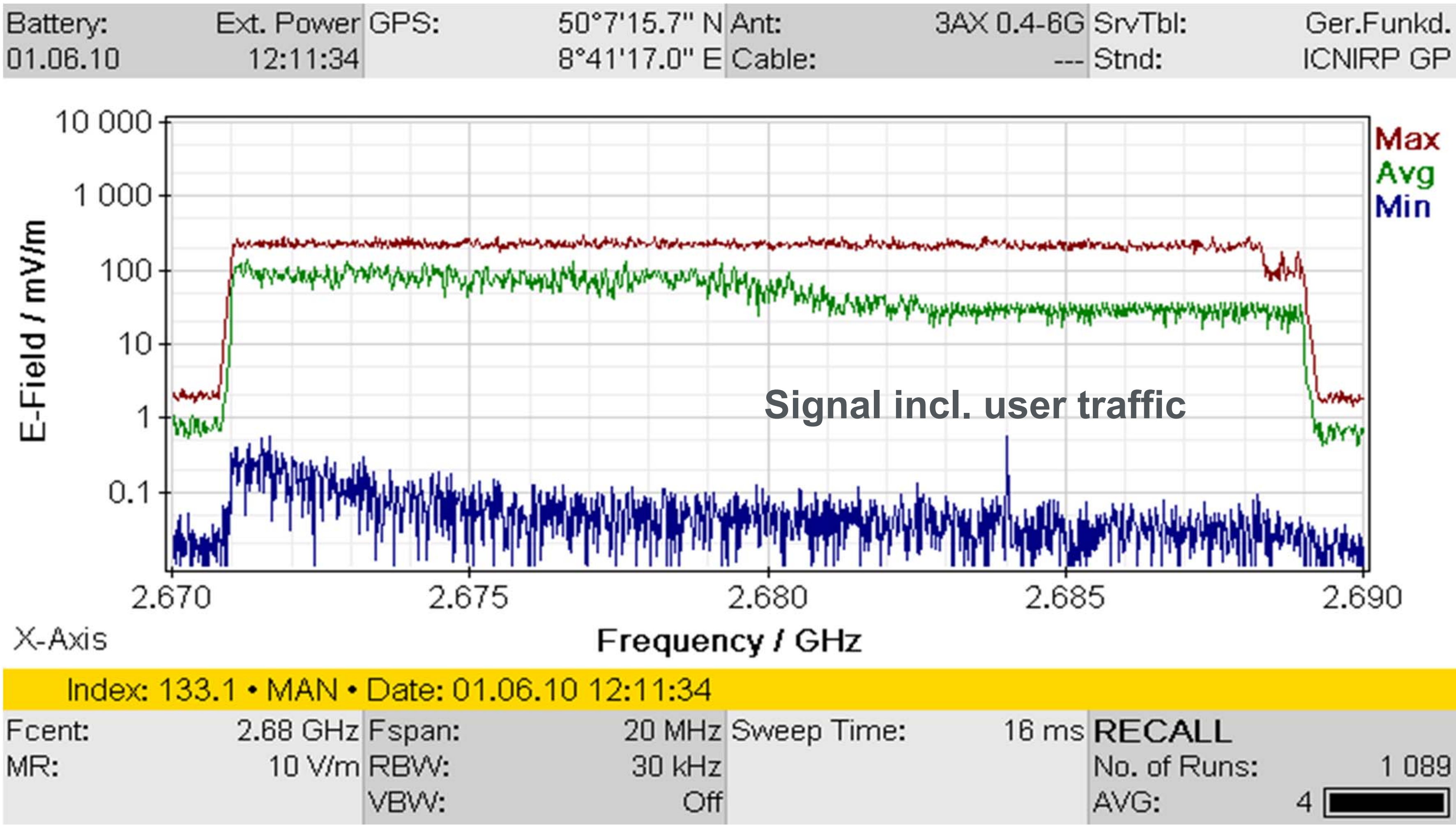
Tower B
Cell ID # 2

Tower C
Cell ID # 3

Glossary LTE Vs 3G Terminology

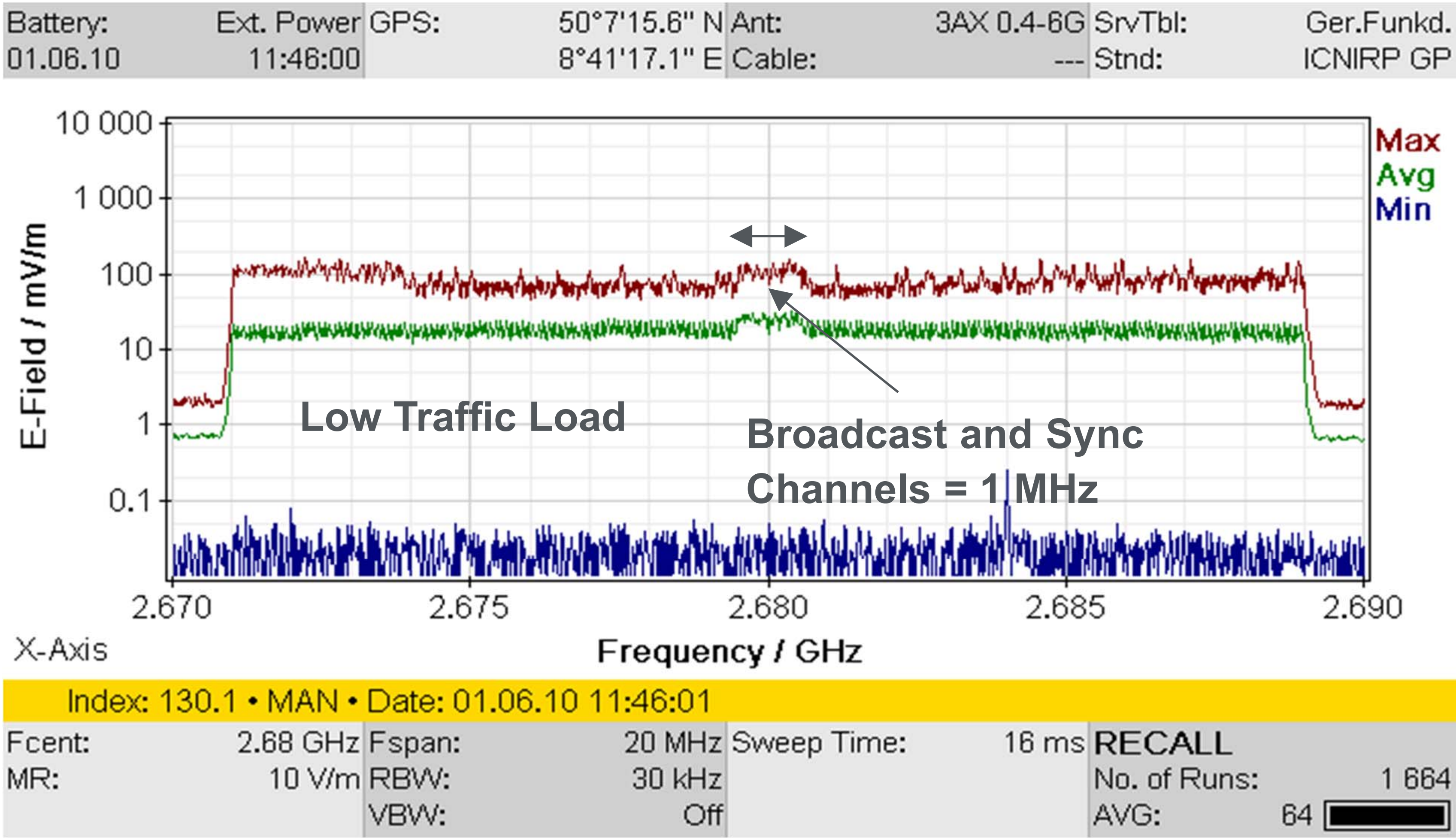
LTE – 3.9G	CDMA	UMTS (W-CDMA)
RS Reference Signal - distributed over whole bandwidth in SISO or MIMO (2/4 antennas) config.	**Pilot**	**CPICH**
P-SS Primary Synchronizing Signals – contains 120° sector information	***Sync***	***P-SCH***
S-SS Secondary Synchronizing Signals - contains group ID (part of Cell ID)	**n.a.**	**S-SCH**
PCFICH Physical Control Format Indicator Channel	**n.a.**	**n.a.**
PBCH Physical Broadcast Channel	***Paging***	***BCCH***
PHICH Physical Hybrid ARQ Indicator Channel	**n.a.**	**n.a.**
PDCCH Physical Downlink Control Channel	***Paging***	***P/S-CCPCH & PICH***
PDSCH Physical Downlink Shared Channel	***Traffic***	***Traffic***

Measuring Complete Band = 20 MHz
- ideally whole spectrum measured with one FFT



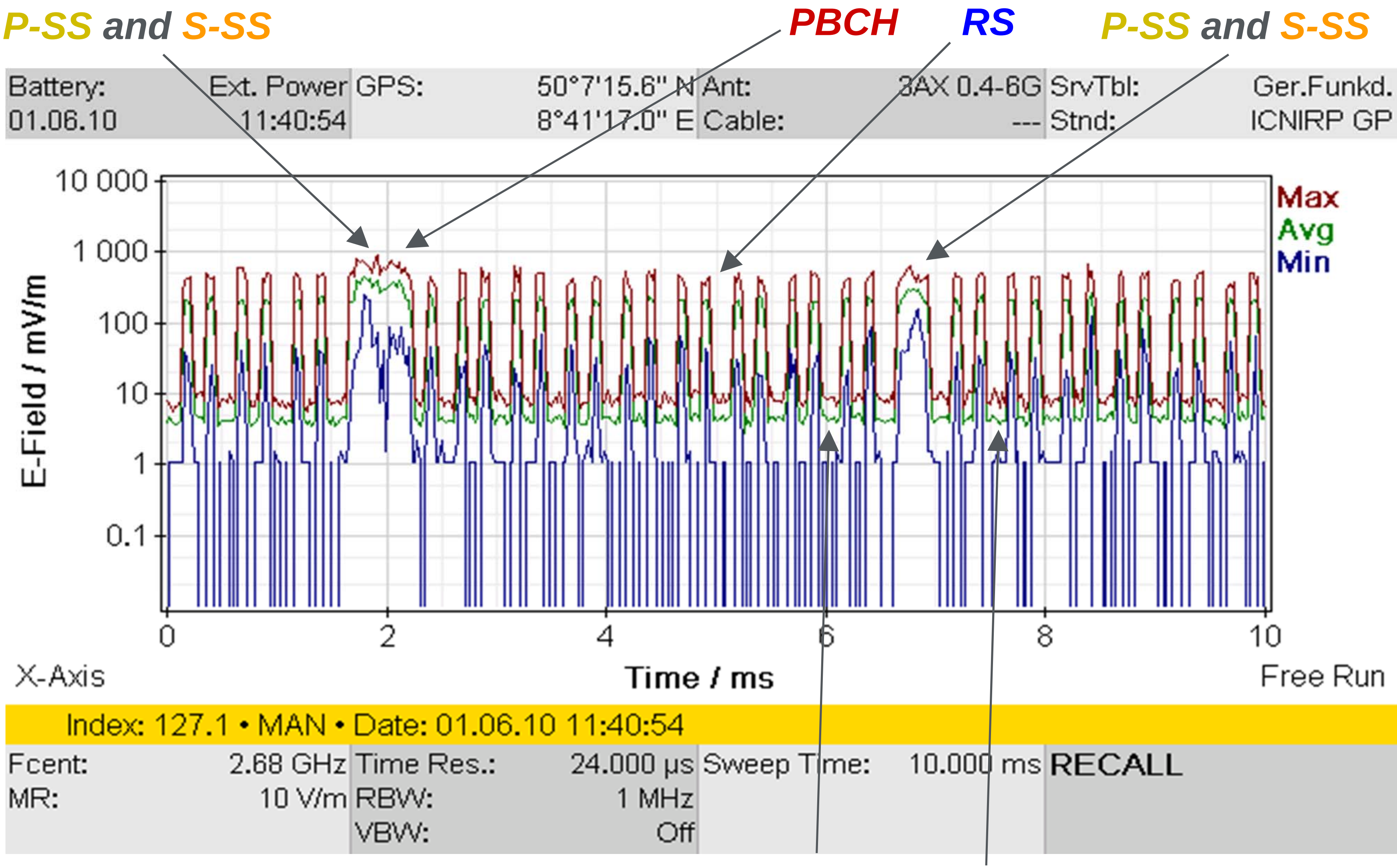
• LTE Station – Trial at City of Frankfurt

LTE Spectrum Measurement – Broadcast & Sync. Channels

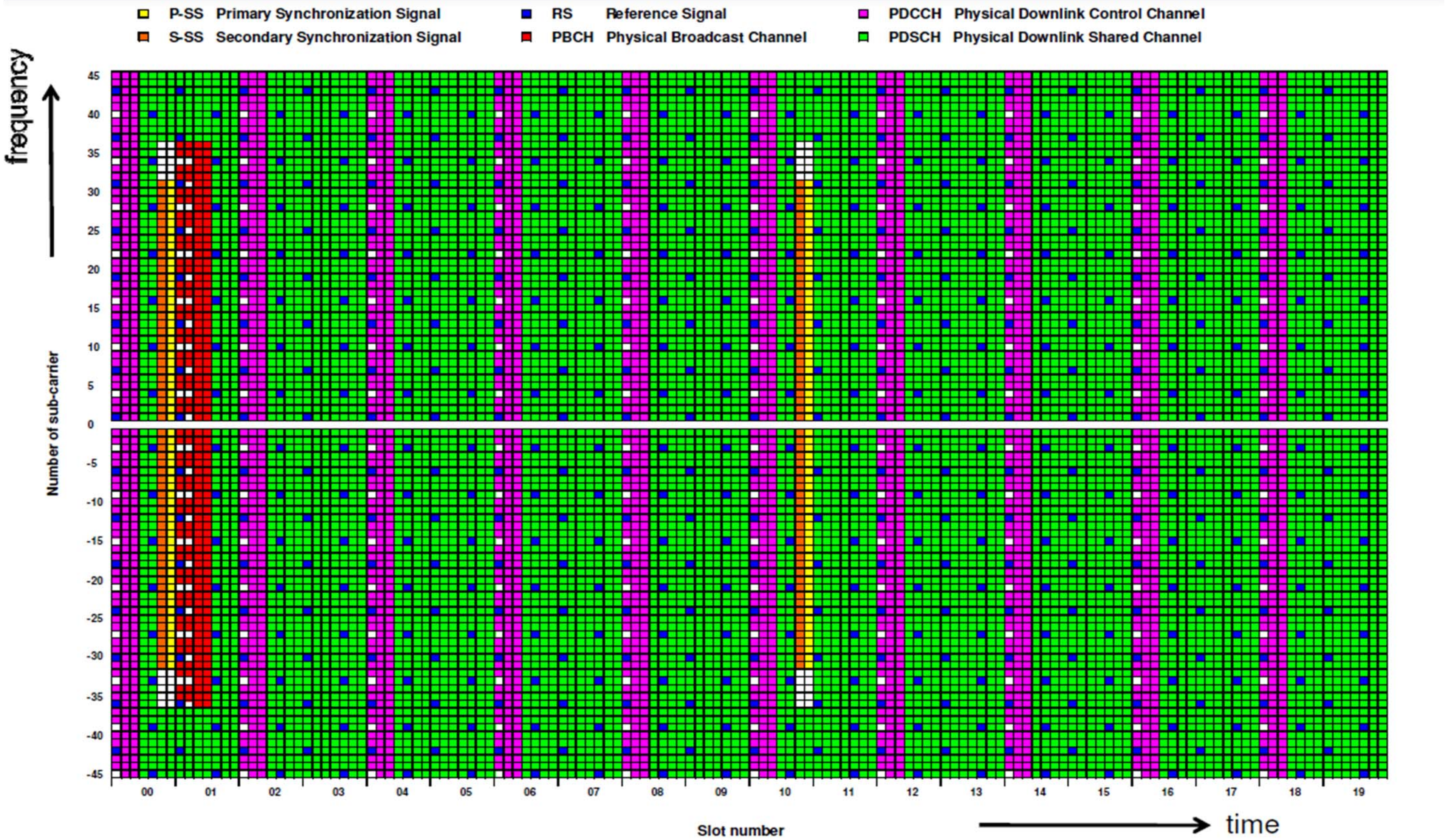


• LTE Station – Trial at City of Frankfurt

LTE Signal in Scope Mode – One Frame



LTE Trial at Frankfurt w/o traffic, i.e. no PDCH, nor PDSCH present


P-SS Primary Synchronization Signal
S-SS Secondary Synchronization Signal
RS Reference Signal
PBCH Physical Broadcast Channel
PDCCH Physical Downlink Control Channel
PDSCH Physical Downlink Shared Channel
frequency
Number of sub-carrier
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
Slot number
time

Characteristics of Resource Grid

- ‘Resources’ are organized in a frequency vs. time domain grid
  - Previous slide shows an extract of resource grid presenting 90 sub-carriers around center frequency : (-) 45 + (+45) x 15 kHz => 1.35 MHz => y-axis
  - One radio frame has length of 10 ms : 20 slots (made up of 7 symbols) with 0.5 ms duration => x-axis
  - Center frequency is blanked-out (white), i.e. no signal present
  - Primary and secondary sync. signals P-SS and S-SS are used to derive group & cell IDs and time sync information
- One ‘resource element’ is represented by
  - one carrier of 15 kHz ‘depth’ and
  - one symbol of 71 µs ‘width’ => x 7 symbols = 1 RE (resource element)
  - several elements are combined to a ’resource blocks’ => e.g. traffic channel

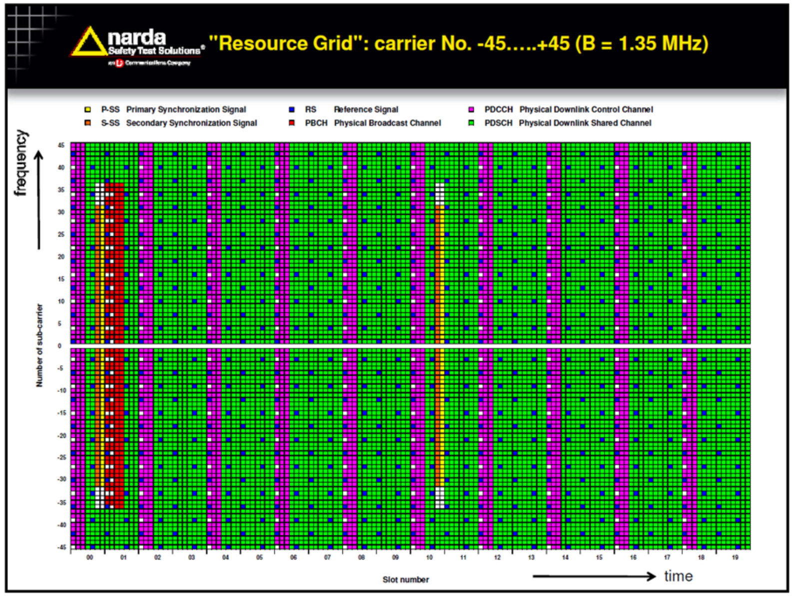
Why to base measurement upon RS ?

- Spatial multiplexing is used for Traffic-Dependent Signals
  PDCH / PDSCH and Ref. Signal RS but not for P-SS and S-SS

- In order to include fading effects being present in total bandwidth it is further not advisable to use Sync. Signals P-SS / S-SS as they do only cover a part (approx. 1 MHz) in the center of total band

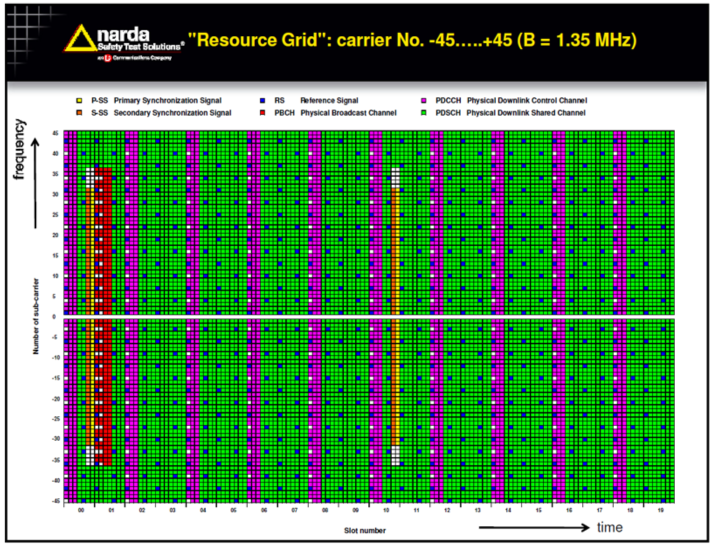
- For faster results,
  measurement bandwidth can be reduced

  This is important for
  spatial sweeping method,
  when fading is then less critical
  => due to spatial / time averaging



Considerations of LTE Analysis

- Center of band contains six resource blocks with two types of signals which are expected to transmit max. power
  - P-SS …. primary sync. signals
  - S-SS … secondary sync. signals
  - PBCH … physical broadcast channel



- Individual Carriers of with 15 kHz spacing
  - P-SS and S-SS signals use center 62 carriers
  - PBCH uses center 72 carriers

- Sync. signals or PBCH are noise-like bursts of
  - 2 symbol intervals (142.7 μs)
  - or 4 symbol intervals (285.4 μs)
  - Sync. signals pulse occurs twice within a 10 ms frame
  - PBCH occurs only one time always immediately after 1st sync. signal pulse

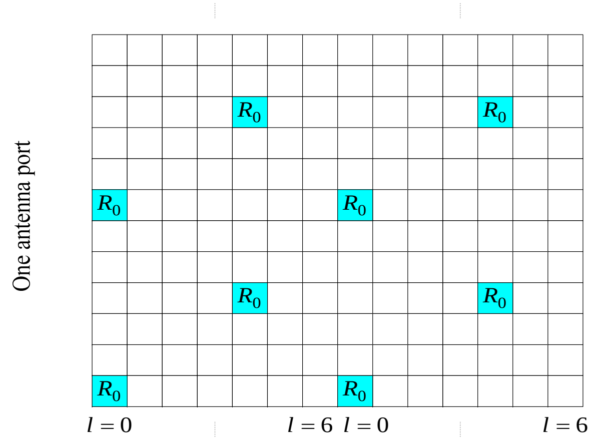
- RS signals are distributed over whole frame (time Vs frequency) and are typically transmitting max. power in SISO or MIMO configuration
  => ideal for extrapolation to total power and offering minimal effect from fading on measurement uncertainty when decoding whole bandwidth (CBW)

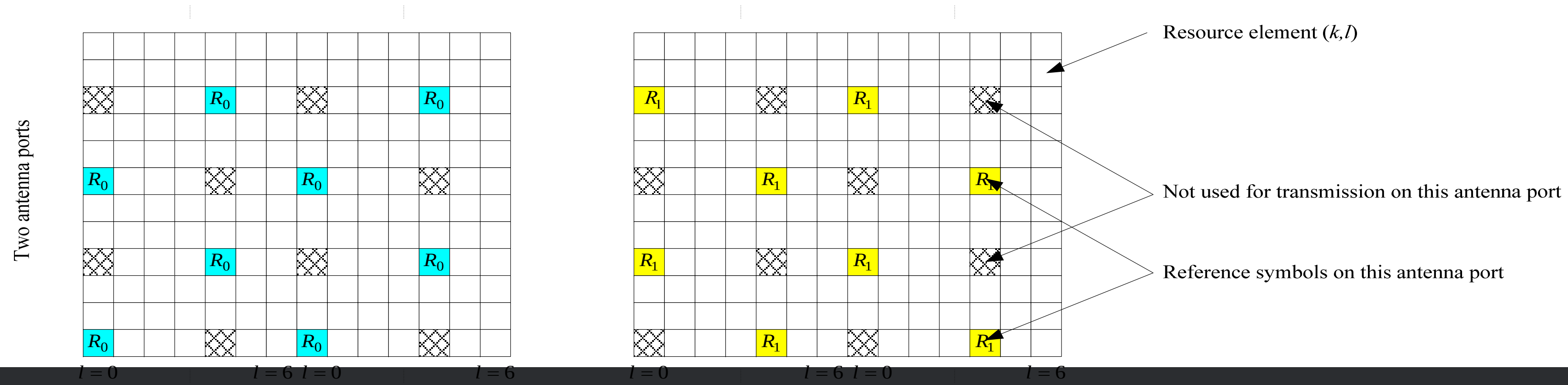
DL Mapping of signals with 1 antenna port

- **Reference signals (RS) are equally distributed over whole grid - their power level is known**

DL Mapping of signals with 2 (4) antenna ports

- **Same position of RS (frequency vs. time) is not reused – all RSx are interleaved**
- **Typically use of co- and cross-polarized (+/- 45°) antenna elements**
- **Only reference signals RS & traffic signals (PDCCH / PDSCH) are transmitted by all antennas & over whole band => ideal for testing !**





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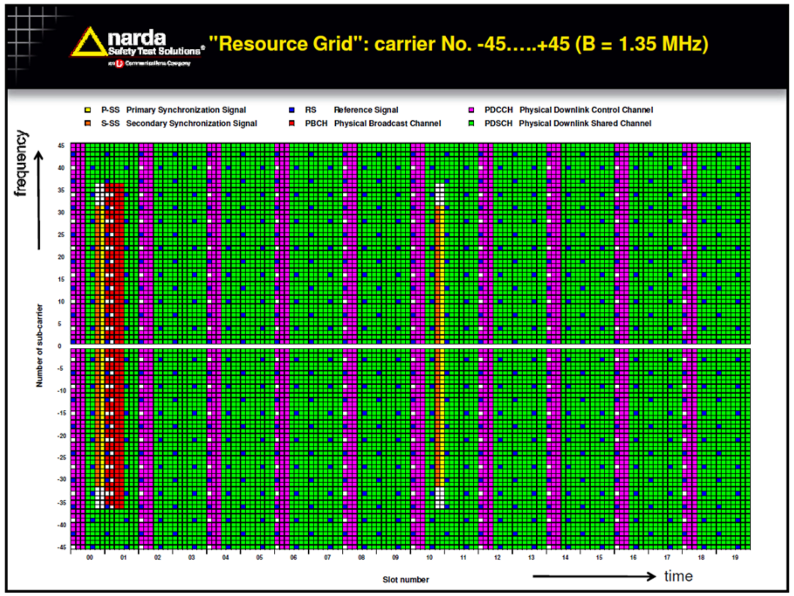


Further steps of LTE result processing

- Automatic calculation of ‘Total RS Power’, i.e. sum of all Cells

- Worst case extrapolation by using average power of respective resource elements (P-SS, S-SS, RS) multiplied
by number of used carriers (Extrapolation Factor to be entered)

  => according to table on next page

- Finally an extrapolation factor for ‘fine-tuning’ may be applied
- based on operator input (system set-up / power ratio) and/or as per regulator requirement (margins)

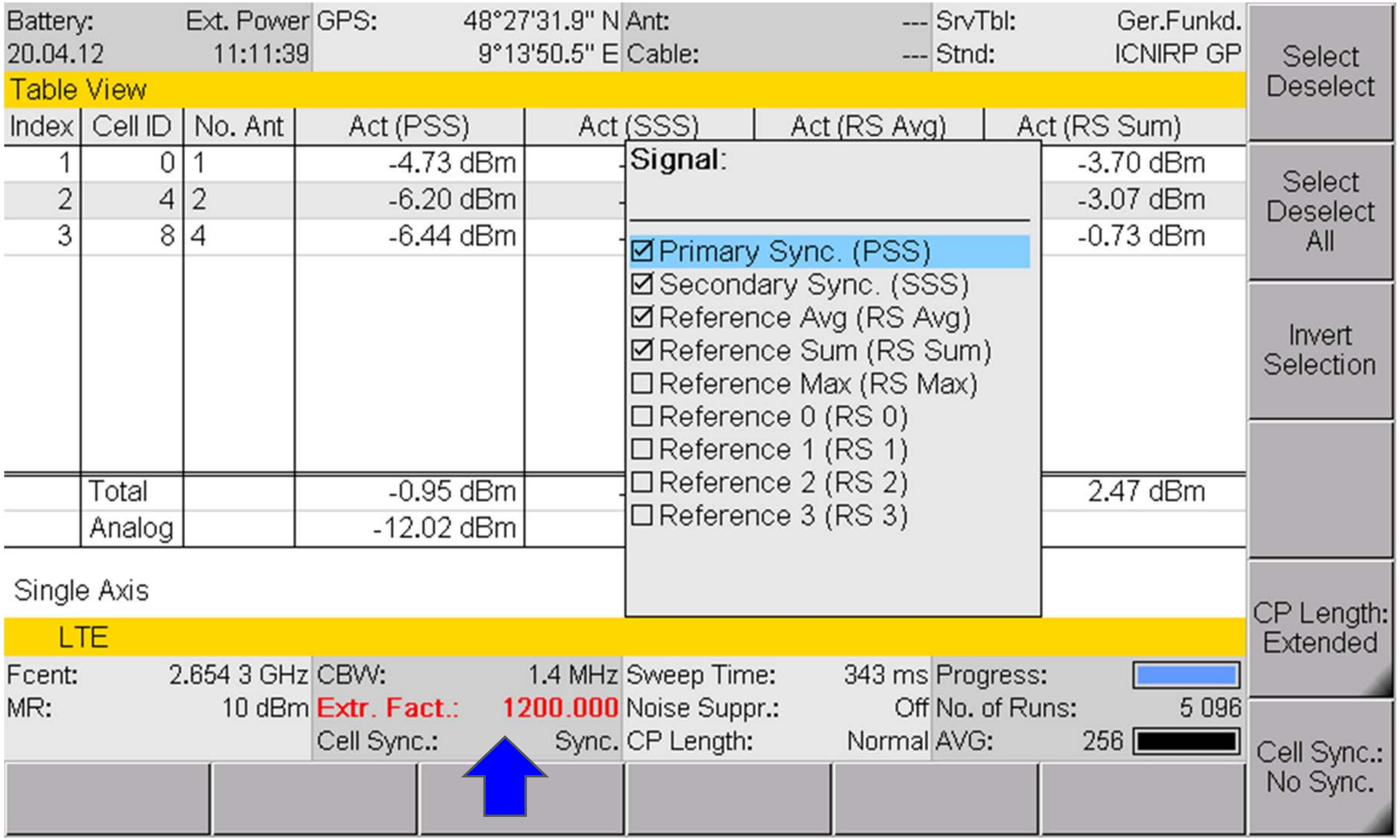
  This will take care of situations if future increase of transmit power of LTE station is foreseeable or to allow for a ‘safety cushion’

Extrapolation factor mainly based on Transmission Bandwidth (TBW)

Channel Bandwidth *in MHz*	Carriers *n*	TBW (in kHz) *n x 15 kHz*
1.4	72	1.080
3	180	2.700
5	300	4.500
10	600	9.000
15	900	13.500
20	1200	18.000

N.B.: Operators may arrange 20M or 10M bands by splitting into 2 x 10M or 2 x 5 M, respectively

LTE Demodulation - Parameter Selection



LTE Demodulation – MIMO (x 1 to x 4)

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Battery:	Ext. Power	GPS:	48°27'31.7" N	Ant:	---	SrvTbl:	Ger.Funkd.
20.04.12	10:51:01		9°13'48.2" E	Cable:	---	Stnd:	ICNIRP GP

Table View

Index	Cell ID	No. Ant	Act (RS 0)	Act (RS 1)	Act (RS 2)	Act (RS 3)
1	0	1	-3.64 dBm	-999.00 dBm	-999.00 dBm	-999.00 dBm
2	4	2	-5.43 dBm	-5.11 dBm	-999.00 dBm	-999.00 dBm
3	8	4	-7.55 dBm	-7.22 dBm	-6.25 dBm	-5.94 dBm
	Total		-0.49 dBm	-3.03 dBm	-6.25 dBm	-5.94 dBm
	Analog		-11.63 dBm			

Single Axis

LTE

Fcent:	2.654 3 GHz	CBW:	1.4 MHz	Sweep Time:	257 ms	Progress:	
MR:	10 dBm	Extr. Fact.:	1200.000	Noise Suppr.:	Off	No. of Runs:	HOLD
		Cell Sync.:	Sync.	CP Length:	Normal	AVG:	256

LTE Demodulation - Signals

- For PSS, SSS, RS 0, RS 1, RS 2, and RS 3 average power per resource element of all resource elements belonging to signal are displayed
- 'RS Avg' displays average power of all detected antennas (RS 0 up to RS 3)
- 'RS Sum' displays total power of all detected antennas (RS 0 to RS 3)
- 'RS Max' displays power of strongest detected antenna (RS 0 to RS 4)

Fast LTE Demodulation – Measured in center of band, only

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Battery:	Ext. Power	GPS:	48°27'31.1" N	Ant:	---	SrvTbl:	Ger.Funkd.
20.04.12	10:49:30		9°13'47.2" E	Cable:	---	Stnd:	ICNIRP GP

Table View

Index	Cell ID	No. Ant	Act (PSS)	Act (SSS)	Act (RS Avg)	Act (RS Sum)
1	0	1	-3.77 dBm	-3.68 dBm	-3.63 dBm	-3.63 dBm
2	4	2	-5.30 dBm	-5.50 dBm	-5.06 dBm	-2.05 dBm
3	8	4	-6.37 dBm	-7.49 dBm	-6.27 dBm	-0.25 dBm
	Total		-0.24 dBm	-0.52 dBm	-0.08 dBm	3.01 dBm
	Analog		-11.57 dBm			

Single Axis

LTE

Fcent:	2.654 3 GHz	CBW:	1.4 MHz	Sweep Time:	254 ms	Progress:	
MR:	10 dBm	Extr. Fact.:	1200.000	Noise Suppr.:	Off	No. of Runs:	HOLD
		Cell Sync.:	Sync.	CP Length:	Normal	AVG:	256

Precise LTE Demodulation – measured with full CBW

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Battery:	Ext. Power	GPS:	48°27'31.6" N	Ant:	---	SrvTbl:	Ger.Funkd.
20.04.12	10:46:52		9°13'50.2" E	Cable:	---	Stnd:	ICNIRP GP

Table View

Index	Cell ID	No. Ant	Act (RS Avg)	Max (RS Avg)	Avg (RS Avg)	Min (RS Avg)
1	0	1	-3.06 dBm	-3.01 dBm	-3.17 dBm	-3.49 dBm
2	4	2	-4.43 dBm	-4.36 dBm	-4.50 dBm	-4.70 dBm
3	8	4	-5.81 dBm	-5.76 dBm	-5.92 dBm	-6.32 dBm
	Total		0.48 dBm	0.51 dBm	0.38 dBm	0.29 dBm
	Analog		-0.02 dBm	0.00 dBm	-0.01 dBm	-0.02 dBm

Single Axis

LTE

Fcent:	2.654 3 GHz	CBW:	20 MHz	Sweep Time:	2.443 s	Progress:	
MR:	10 dBm	Extr. Fact.:	1200.000	Noise Suppr.:	Off	No. of Runs:	HOLD
		Cell Sync.:	Sync.	CP Length:	Normal	AVG:	256

Trade-Off : Test speed vs. MU

- **Fastest measurement by selecting CBW = 1.4 MHz**

  E.g. for spatial averaging, pendulum method, max. search

  => typically ca. 250 ms

- **Most precise measurement by selecting whole CBW of LTE Signal**

  - Single spot / position measurement
  - Provides precise results / best measurement uncertainty (MU) - even in presence of strong selective fading effects

  => typically ca. 2,5 sec

Reliable EMF Immission Tests based on high-performance OFDM Demodulation

- **Individual assessment of EMF exposure from individual towers, segments and even antennas by calculation and extrapolation of signal strength based on decoding of individual resource elements : RSx, P-SS and S-SS**

- ***20 MHz demodulation (CBW) bandwidth – prerequisite of assessing total LTE signal for improved accuracy in the presence of selective fading***

- **Display of calculated total average field strength based on individual power measurement from all antennas of multiple cells (towers and antenna arrays) – averaged or summed values**

- **METAS (CH) and CENELEC (EU) recently published initial drafts of recommended test procedures and calculations being in line with presented method**

Measuring LTE

Facts of LTE:

- In the center 6 resource blocks there are two types of signals which will **probably** be transmitted with maximum power:
  - primary and secondary synchronization signals
  - PBCH (physical broadcast channel)
- Used carriers of a system with a carrier spacing of 15 kHz
  - synchronization signals use the central 62 carriers
  - PBCH uses the central 72 carriers.
- The synchronization signals or the PBCH are noise-like bursts with a total duration of
  - 2 symbol interval (142.7 µs)
  - or 4 symbol intervals (285.4 µs)
- The synchronization signals pulse occurs twice within a 10 ms frame, the PBCH occurs only one time.
- The PBCH pulse occurs always immediately after the synchronization signals pulse.

Assumptions

Assumptions:

The resource blocks of the following signals are transmitted with the highest or equal power compared to any other resource block:

1. primary and secondary synchronization signals
2. PBCH
3. Both the primary and secondary synchronization signals and the PBCH

If one the assumptions can be verified by the operators of the LTE-Systems the following procedure can be used. Assumption 2 will most likely be verified.

Measure LTE (Preliminary)

If you want to measure LTE in Level Recorder set SRM-3006 up as following:

- RBW = 800 kHz
  (broadest RBW to attenuate any spectrum of traffic dependent signals)
- VBW = 1.25 kHz for single axis and assumption 2 or
  VBW = 1.6 kHz for three axis and assumption 2
  (best compromise between settling time and reduction of fluctuations due to noise like structure of the signal)
- Center Frequency of LTE Signal
- Detector: Peak

Extrapolation of worst case scenario:
Extrapolation

$$Pmax = \frac{Ppmax * Fc * TBW}{NBW}$$

Pmax = Maximum transmitted Power

Ppmax = Measured Peak Power

Fc = correction Factor (depending on settings)

Correction factor for SRM-3006 three axis measurement: 0.925
Correction factor for SRM-3006 single axis measurement: 0.875

TBW = Transmission Bandwidth of LTE signal

NBW = Noise Bandwidth from measurement device

*= 0.96 * RBW (for SRM-3006 in Scope Mode / Level Recorder)*

Note:

- The worst-case power is based on the assumption that all available resource blocks are transmitted with the same power as the measured resource blocks. This will often not be true. However, in such cases the assumed knowledge about the relationship between the measured signals and the full traffic power can be used for extrapolation.
- An additional correction must be applied to extrapolate the worst-case emission if the synchronization signals or the PBCH were not transmitted at their maximum power.

Measurement Uncertainty

Measurement Uncertainty of the procedure

(to be added to the normal measurement uncertainty)

for three axis measurement: 0.42 / -0.47 dB

for single axis measurement: 0.34 / -0.37 dB

There are other possible measurement procedures, but there are less accurate.

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

DRAFT
EN 50492
prAA

September 2012

ICS 17.220.20; 33.070.01

English version

Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations

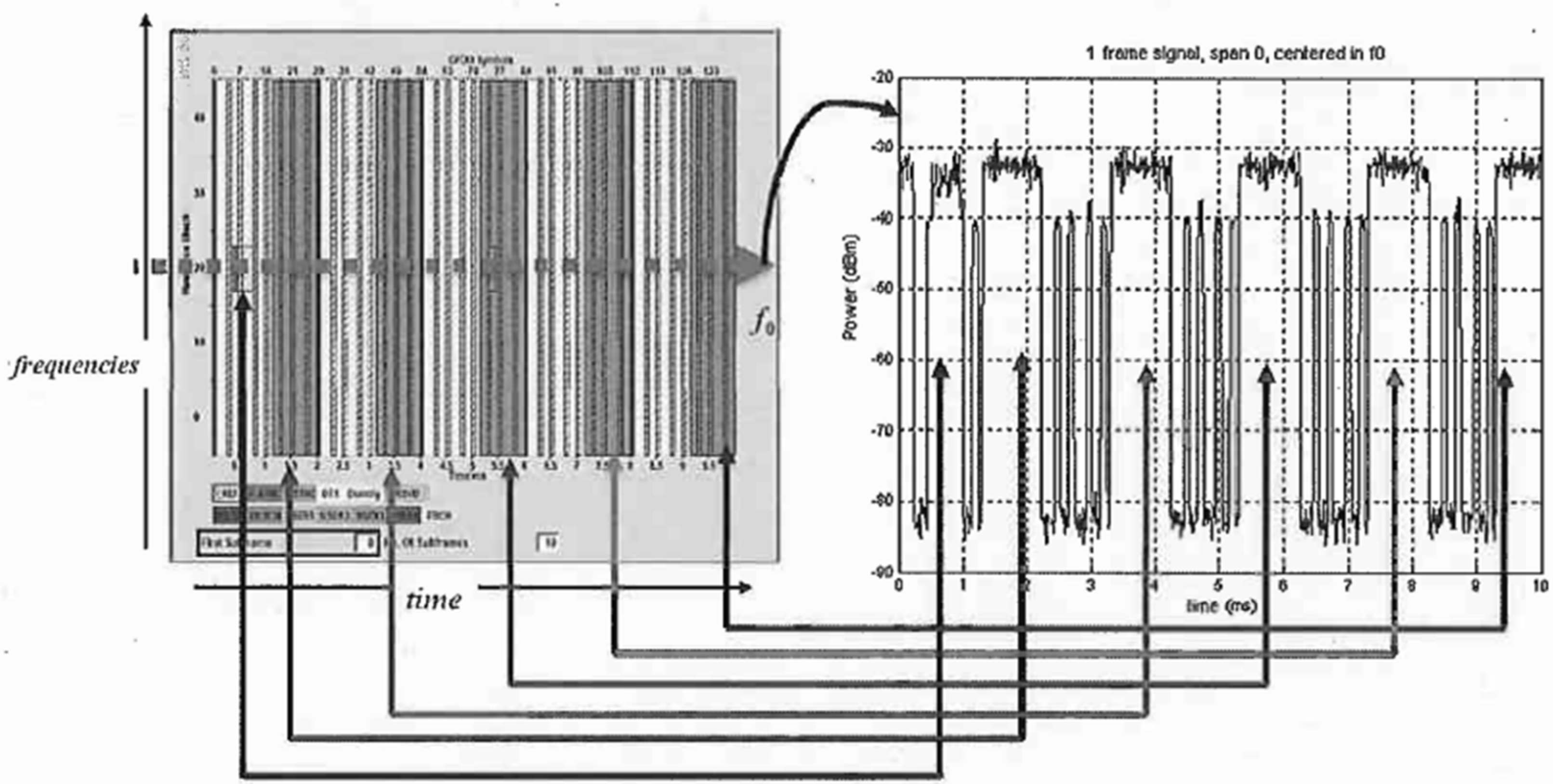

Figure L.3 – LTE spectrum: ***PBCH*** **power higher than** ***RS*** **power**

5.4 Using measurement routines

Main Menu • Measurement Routines

Measurement routines are automated sequences of setups. They are particularly useful for the following applications:

- for eliminating errors when performing repetitive measurement tasks
- for ensuring compliance with company regulations for sequences / procedures
- as a guide for semi-skilled staff.

NOTE: When you have saved setups on the device, you can create measurement routines only with the aid of the PC software on a PC. These routines must then be uploaded to the device. You can only display and start the measurement routines on the device itself.

6.12 Changing operating mode and keeping the same parameters

You can switch directly from one operating mode to another without opening the main menu. Certain measurement parameters are kept the same when you do this, depending on the target operating mode (see table below).

Table 26: Parameters retained when changing operating mode

Target operating mode	Parameters retained
Safety Eval	• none
Spectrum	• Fcent (= (Fmin + Fmax) / 2) • Fspan (= Fmax - Fmin) [1)]
Level Recorder Scope	• Fcent (= (Fmin + Fmax) / 2) • RBW (= Fmax - Fmin)
UMTS LTE	• Fcent (= (Fmin + Fmax) / 2)

1) Safety Eval only, otherwise Fspan = RBW

To change operating mode directly:

⇒ Press the **Extras** softkey, then select the desired operating mode from the navigation bar on the right.

NOTE: The RBW values set in the service tables have no function when parameters are retained as these RBW values are only used in Safety Evaluation mode.

Interference and Direction Analyzer IDA 2
Selective Radiation Meter SRM-3006

Technical Note TN109

Transferring parameters from stored measurement results

IDA 2 and SRM-3006 provide several convenient ways to store measurement parameters

6.5 Setting the video bandwidth (VBW)

Direction Finding
Spectrum
Level Meter
Time Domain (Scope)
I/Q Analyzer

The video filter can smooth signals and reduce flutuations. It results in RMS averaging with an integration time that is affected by the VBW. The selection of the video filter bandwidth (VBW) is relative to the RBW / CBW setting:

- Spectrum mode: VBW = RBW/10 … RBW/1000 or **Off**
- Other operating modes: VBW = CBW/1 … CBW/10000 or **Off**

To set the video bandwidth:

1. Press the **BW** softkey, followed by the **VBW** softkey.
   ↳ The **Select Video Bandwidth (VBW)** entry box opens.
2. Use the rotary control to select the desired setting and press the **OK** key.
   ↳ The selected value is applied. The selected **VBW** is shown in the lower status bar.

NOTE: The smaller the VBW, the longer the measurement time (Sweep Time) in Spectrum mode. The measurement time in other operating modes is unaffected.

The effective integration time for forming the RMS value can be defined as follows:

$$T = 1 / (\pi \times VBW) \quad \text{or} \quad T \approx 0.32 / VBW$$