Discussions
on
SAR Measurement Issues

FCC / OET

Laboratory Division

October 2008

TCB Workshop

Topics

- Basic Measurement Issues
  - SAR system & test requirements for current generation transmitters
    - early generation handsets vs. today's products & technologies
  - some labs still seem unfamiliar with the SAR basic methodologies
- PBA Considerations
  - to avoid invalid test results: inquire & resolve test issues before testing
    - HSPA: power & SAR measurement issues
    - Wi-Max: test methodology vs. test configuration problems
    - other new products & technologies have similar concerns
- Technologies & Products with Defined SAR test procedures
  - there are still issues and concerns in applying these procedures correctly
- Other Miscellaneous Concerns
  - test report inconsistencies and lack of explanations
  - not adhering to the required procedures
  - oversights in both generating & reviewing test reports

Basic Measurement Issues

- duty factor & PAR issues are wireless technology specific
- SAR scan region and resolution can be device dependent
- device holder perturbation may vary with DUT dimensions
- test device positioning may depend on phantom & DUT
- SAR and power drifts are different
- Z-axis scans problems can disqualify test results
- tissue recipe, dielectric parameter & dipole problems
- probe calibration & system validation issues
- issues with inconsistent power measurements
- improper measurement uncertainty analyses

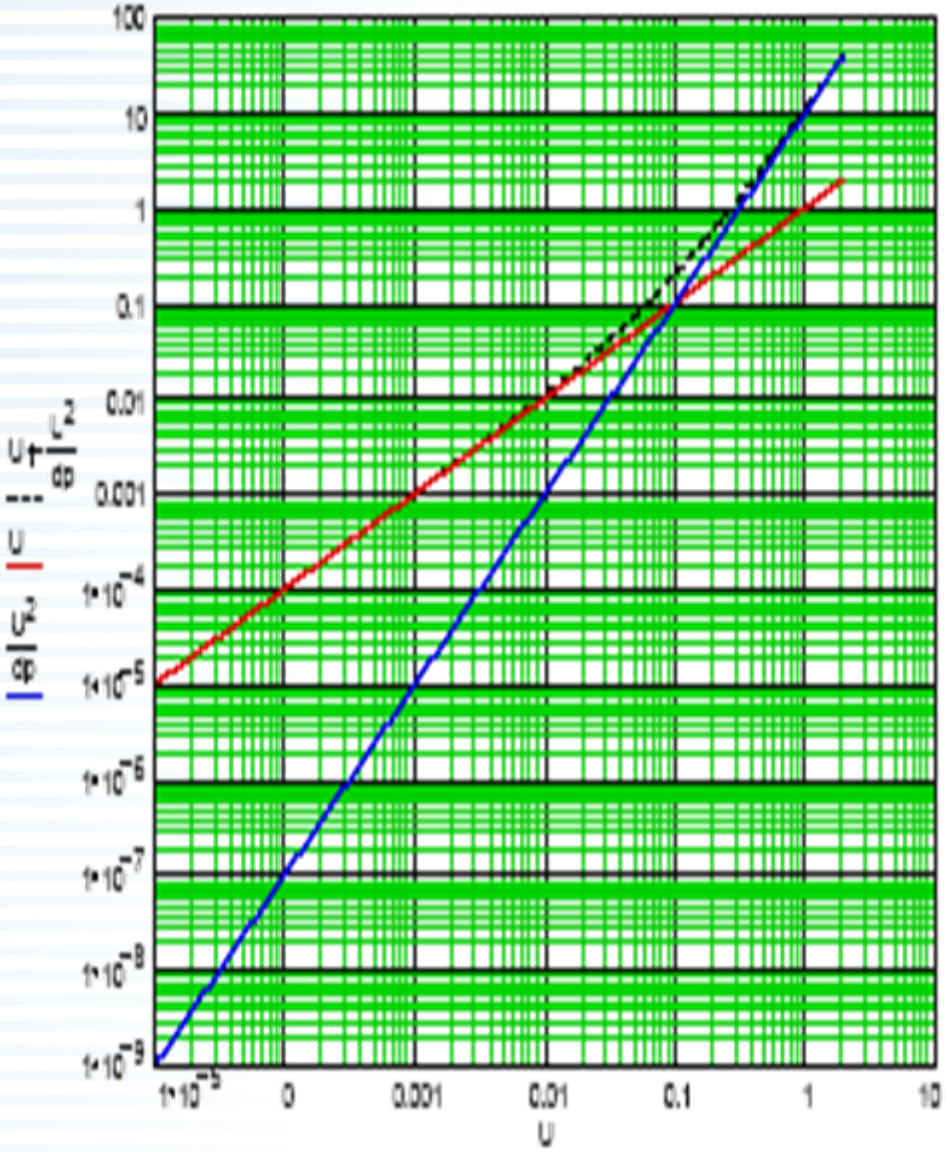
Signal Conversion & Duty Factor

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

For Periodic signals

duty factor = t/T

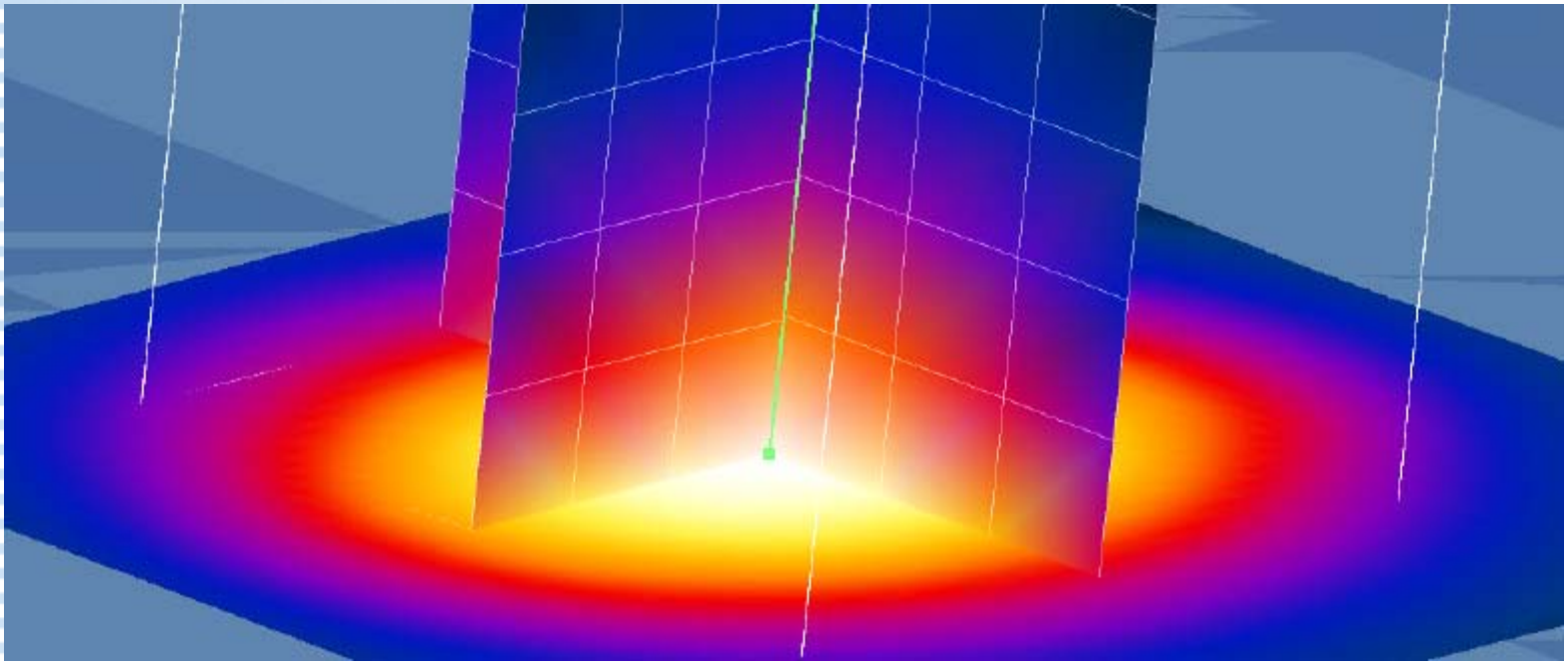
crest factor (*cf*) =√(T/t)



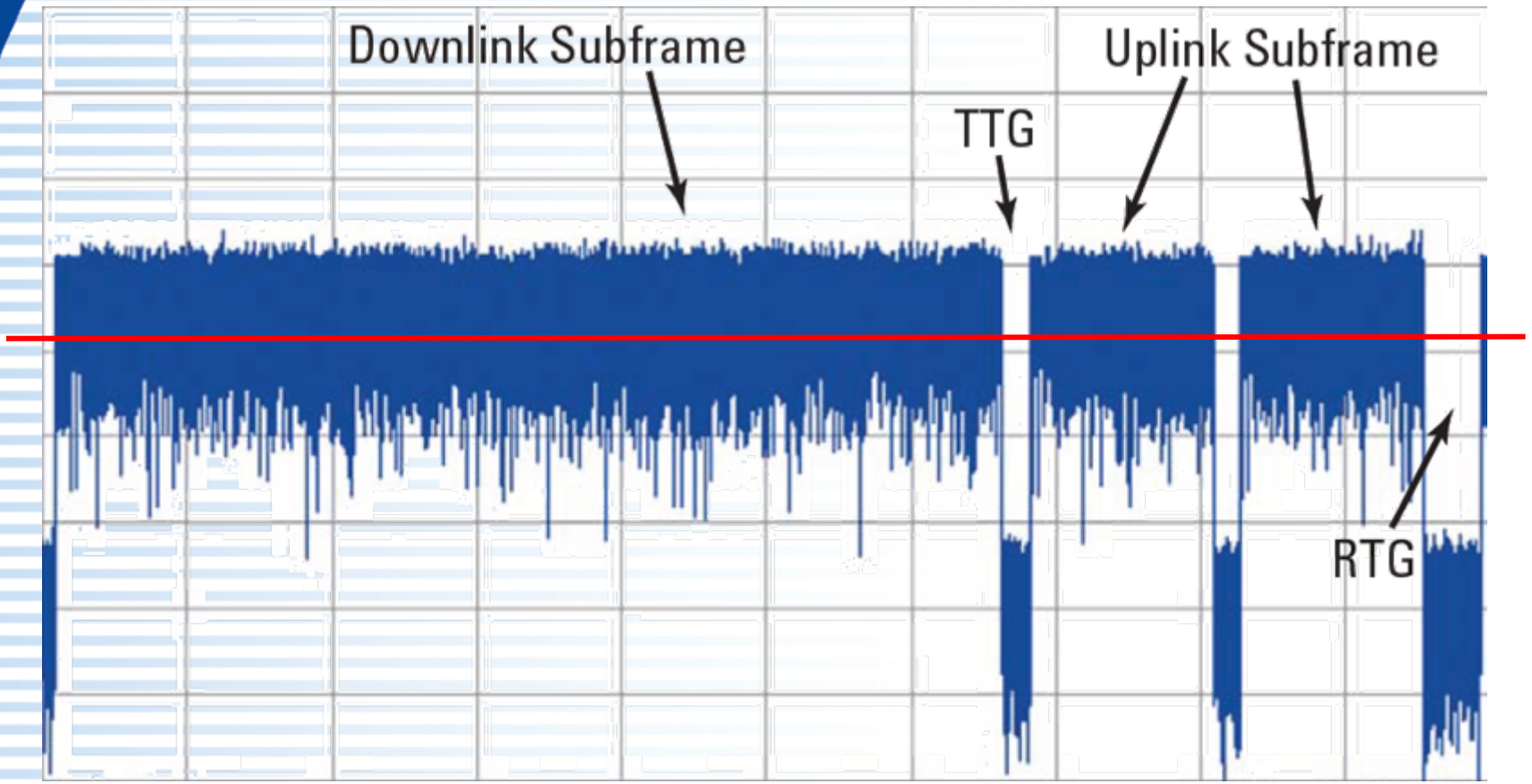
SAR Conversion

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i} \qquad E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2} \qquad SAR = E_{tot}^2 \cdot \frac{\sigma}{\rho \cdot 1'000}$$



PAR & Crest Factor of Non-Periodic Signals



Scan Resolution
&
Device Holder Perturbation

Scan Region & Device Positioning

Measurement Data

Area Scan : 5x5x1

x = 12mm, y = 12mm, z = 4mm

Zoom Scan : 5x5x8

x = 8mm, y = 8mm, z = 4mm

Power Drift-Start : 0.044 W/kg

Power Drift-Finish: 0.083 W/kg

Power Drift (%) : 88.887

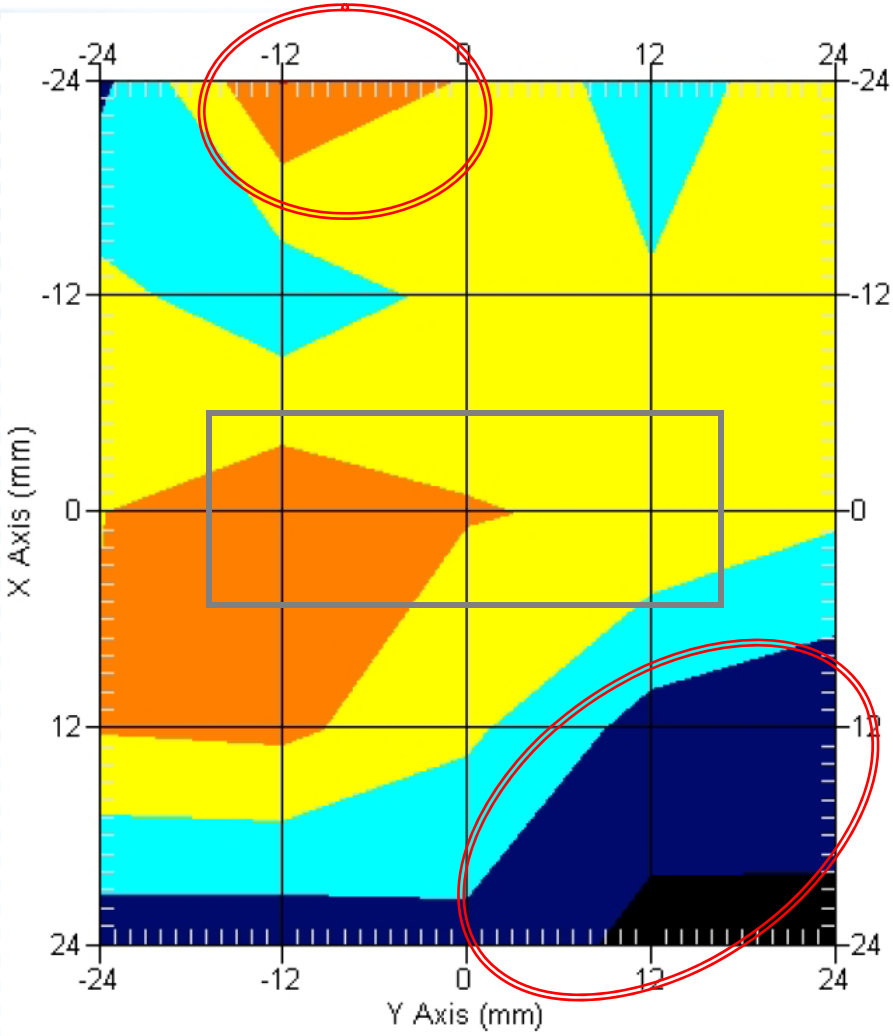
DUT Position : Antenna 180º

1-g SAR: 0.172 W/kg

10-g SAR: 0.073 W/kg

Area Scan Peak: 0.182 W/kg

Zoom Scan Peak: 0.380 W/kg

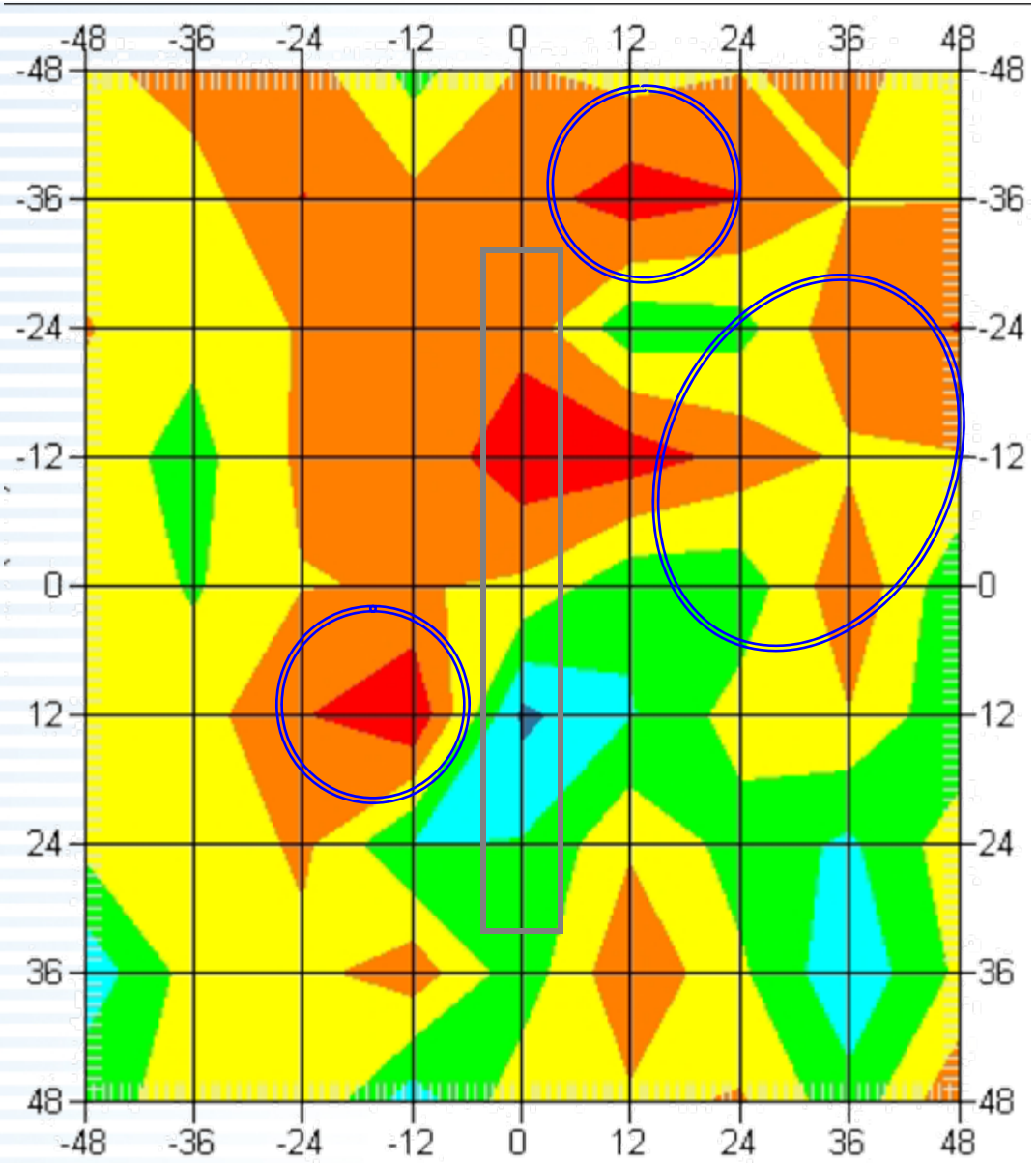


1-g SAR: 0.397 W/kg

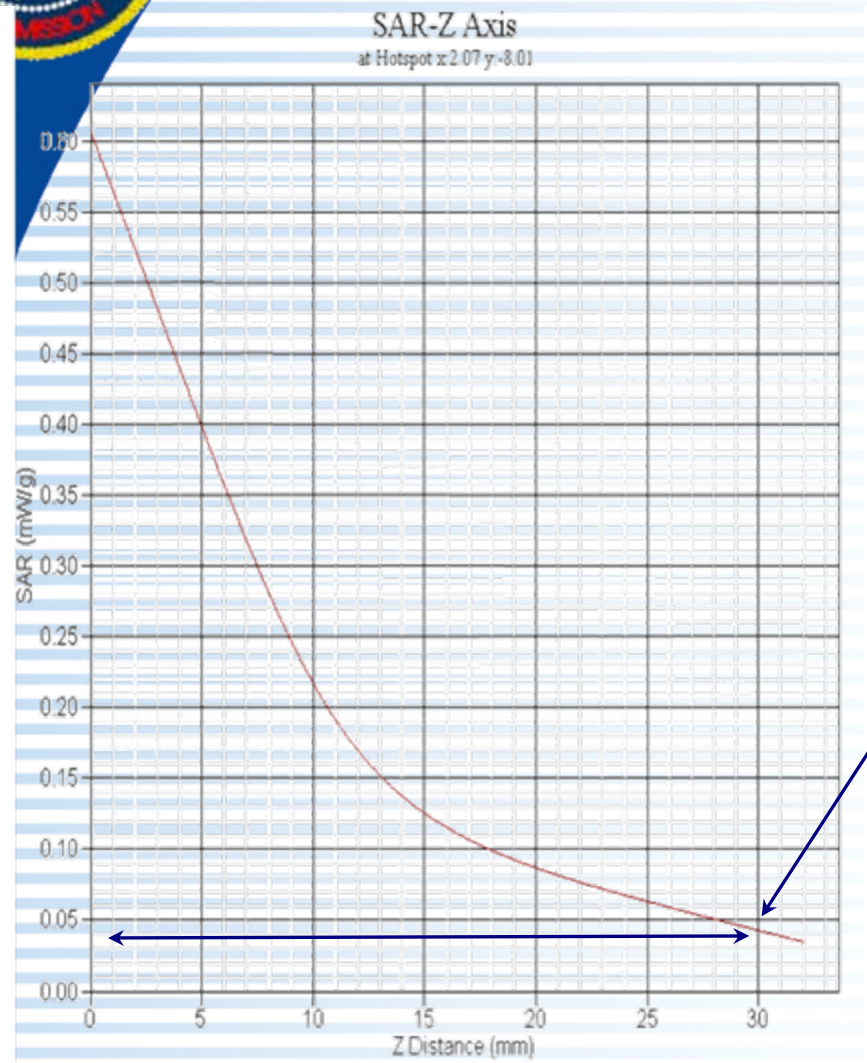
10-g SAR: 0.202 W/kg

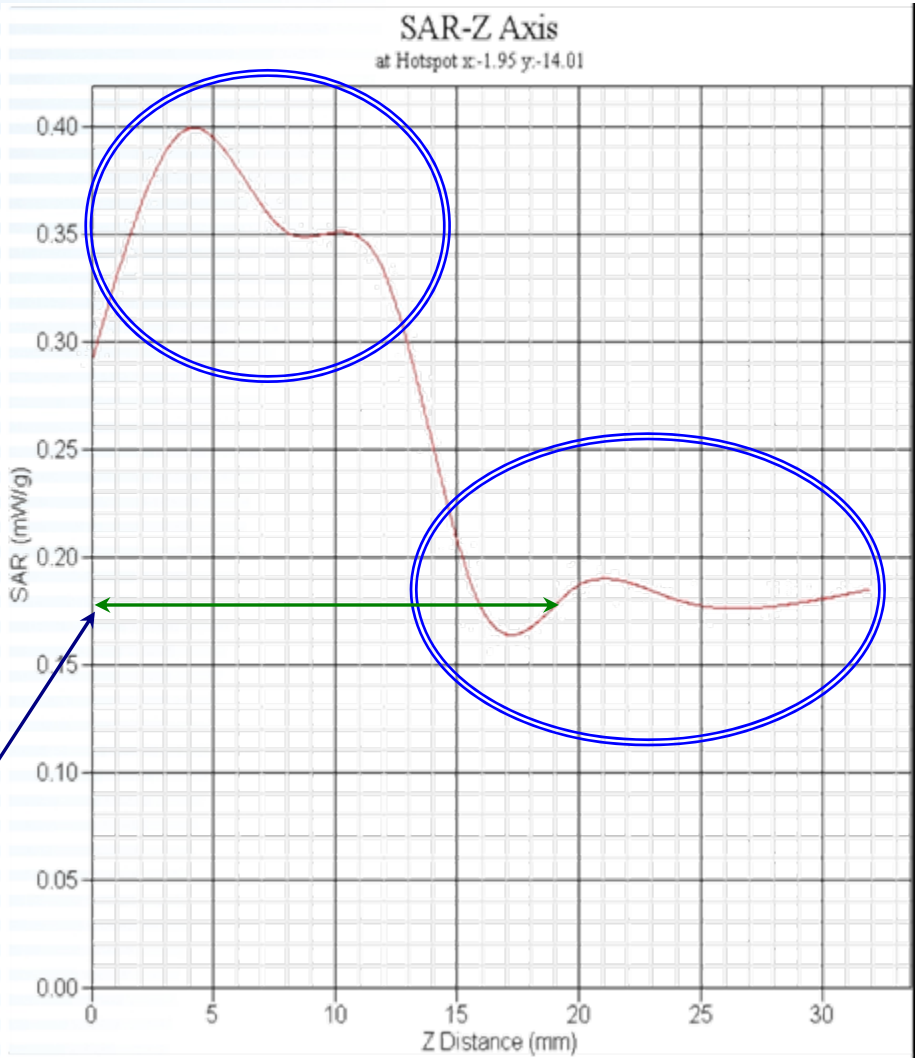
Area Scan Peak: 0.590 W/kg

Zoom Scan Peak: 0.756 W/kg

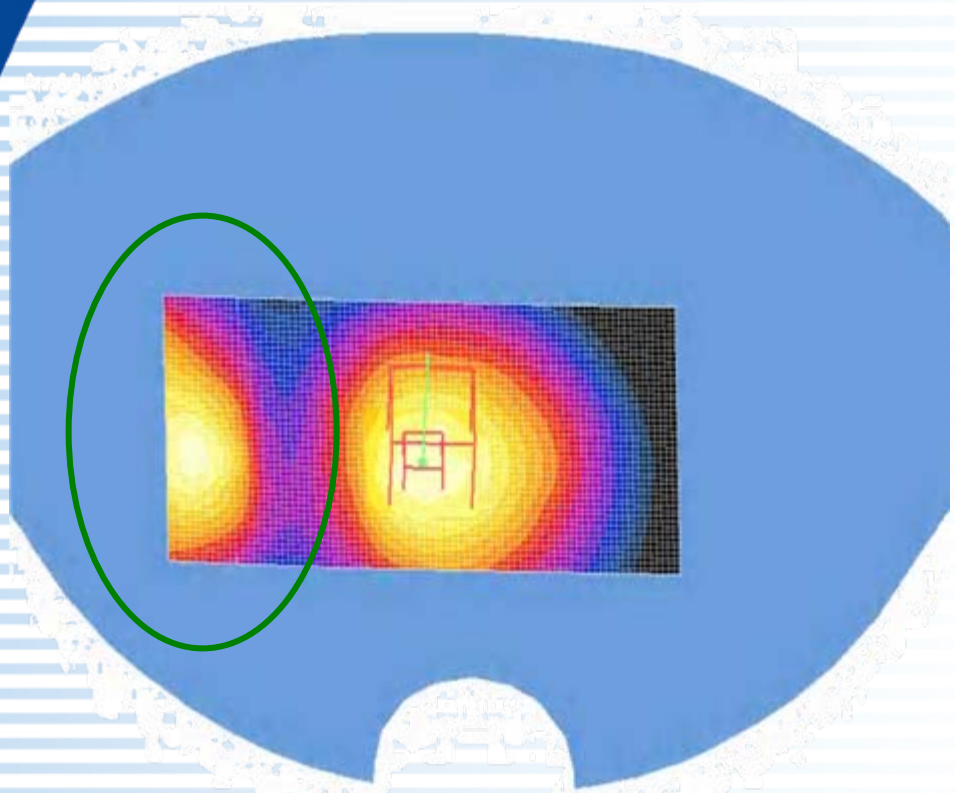


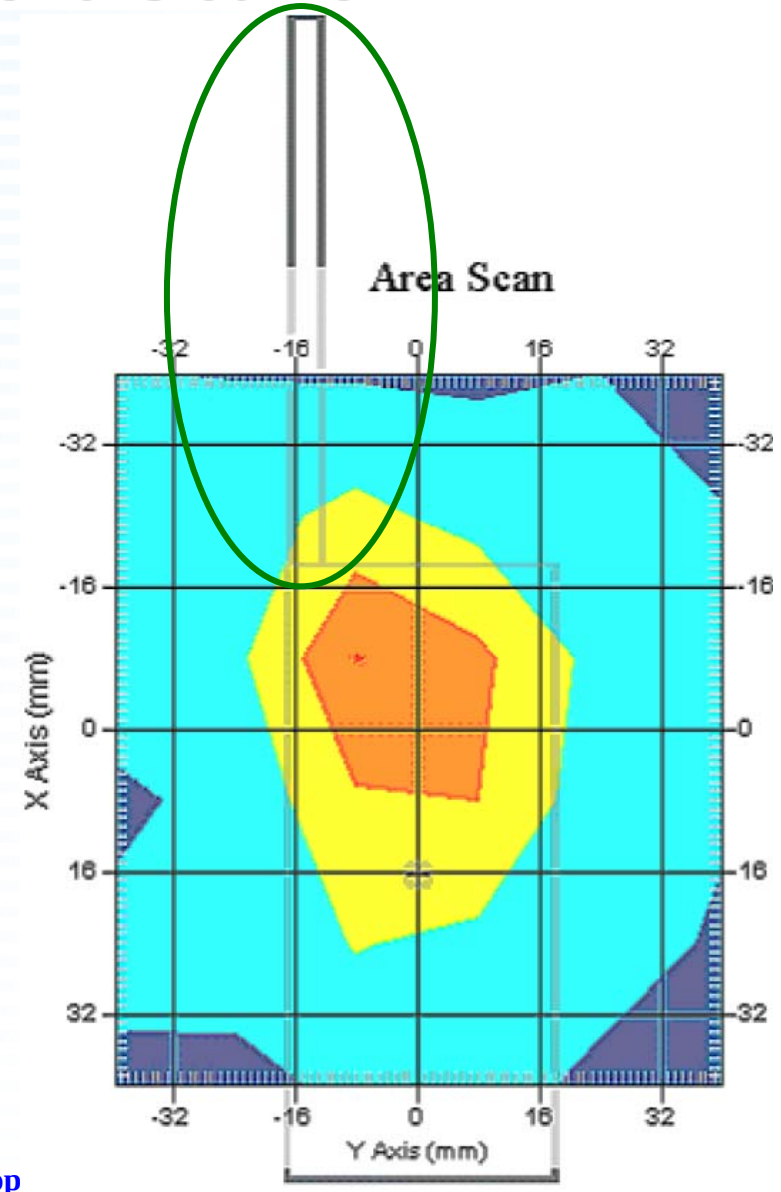
Z-Axis Scans


SAR-Z Axis
at Hotspot x:2.07 y:-8.01
SAR (mW/g)
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
30
Z Distance (mm)


SAR-Z Axis
at Hotspot x:-1.95 y:-14.01
SAR (mW/g)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
30
Z Distance (mm)

Unacceptable Scans





Tissue Recipes

Ingredients		Simulating Tissue	
		835 MHz Muscle	1900 MHz Muscle
Mixing Percentage			
Water		52.40	69.91
Sugar		0.00	29.96
Salt		45.00	0.00
HEC		1.40	0.13
Bactericide		0.10	0.00
DGBE		1.00	0.00
Dielectric Constant	Target	55.20	53.30
Conductivity (S/m)	Target	0.97	1.52

Other Measurement Issues

- listed impossible tissue recipes
- used incorrect target dielectric parameters
- tested incorrect dipoles
- probe calibration used ± 10% tissue parameters
- system validation issues
- measurement uncertainty issues
- inconsistent power measurements

PBA Considerations

- Resolve testing issues before conducting tests
  - incorrect tests can lead to invalid results; therefore, unacceptable
- HSPA
  - confirm SAR exclusion according to power measurements
  - verify MPR implementation according to power measurements
  - address & resolve any SAR & power measurement issues
- Wi-Max
  - matching the test methodology to signal characteristics
    - TDD duty factor vs. OFDM crest factor, frame & gap time
    - normal transmission vs. test conditions
    - test software vs. basestation simulator issues
    - selecting time vs. frequency domain parameters for testing
    - validating the SAR system & measurement requirements

HSPA

Sub-test	β_c	β_d	β_d (SF)	β_c/β_d	β_{hs} (1)	β_{ec}	β_{ed}	β_{ed} (SF)	β_{ed} (codes)	CM (2) (dB)	MPR (dB)	AG (4) Index	E-TFCI
1	11/15 (3)	15/15 (3)	64	11/15 (3)	22/15	209/225	1039/225	4	1	1.0	0.0	20	75
2	6/15	15/15	64	6/15	12/15	12/15	94/75	4	1	3.0	2.0	12	67
3	15/15	9/15	64	15/9	30/15	30/15	β_{ed1}: 47/15 β_{ed2}: 47/15	4	2	2.0	1.0	15	92
4	2/15	15/15	64	2/15	4/15	2/15	56/75	4	1	3.0	2.0	17	71
5	15/15 (4)	15/15 (4)	64	15/15 (4)	30/15	24/15	134/15	4	1	1.0	0.0	21	81

Note 1: Δ_{ACK}, Δ_{NACK} and $\Delta_{CQI} = 8 \Leftrightarrow A_{hs} = \beta_{hs}/\beta_c = 30/15 \Leftrightarrow \beta_{hs} = 30/15 * \beta_c$.

Note 2: CM = 1 for β_c/β_d =12/15, β_{hs}/β_c=24/15. For all other combinations of DPDCH, DPCCH, HS- DPCCH, E-DPDCH and E-DPCCH the MPR is based on the relative CM difference.

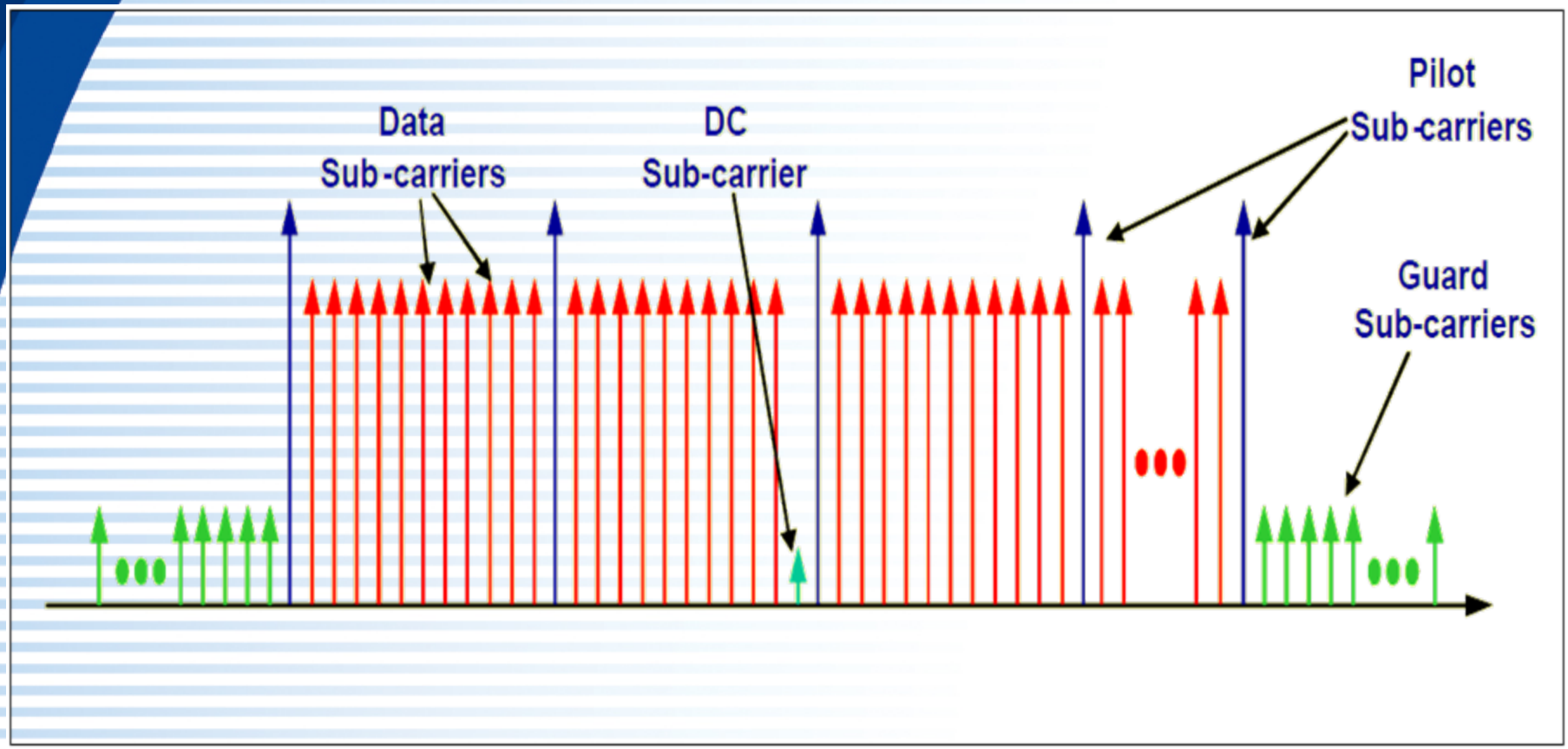
Inner loop power control necessary to maintain the required E-TFCI during the test:

- set the Absolute Grant according to Table C.11.1.3 of TS 34.121-740
- set the UE power to be at least 5dB lower than the Maximum output power
- send power control bits to +1, wait 500 ms; repeat until E-TFCI begins to decrease
- send power control bits to -1 and confirm E-TFCI is equal to target E-TFCI
- measure mean power should be averaged over at least one timeslot
- repeat measurement for different combinations of beta given in Table C.11.1.3

Reported HSPA Power

Modes		HSDPA				HSUPA					WCDMA
Sets		1	2	3	4	1	2	3	4	5	
Band	Channel	Power [dBm]	Power [dBm]	Power [dBm]	Power [dBm]	Power [dBm]	Power [dBm]	Power [dBm]	Power [dBm]	Power [dBm]	Power [dBm]
850	4132	21.04	18.30	17.90	17.20	19.10	20.50	17.80	21.40	19.00	21.80
	4183	20.40	17.80	17.20	17.07	19.10	19.10	15.90	19.80	18.00	20.60
	4233	21.20	18.20	17.70	17.20	18.50	19.20	16.10	19.80	19.00	21.30
1900	9262	21.00	18.00	17.850	17.20	18.80	19.20	17.20	19.80	18.00	21.15
	9400	21.10	18.00	18.20	17.30	19.00	20.10	17.30	20.20	18.30	21.15
	9538	20.00	17.80	17.60	17.00	18.70	19.10	17.10	19.80	15.60	20.08
βc		11	6	15	2	11	6	15	2	15	
βd		15	15	15	15	15	15	15	15	15	
ΔACK, ΔNACK, ΔCQI		8	8	8	8	8	8	8	8	8	
AGV		20	12	15	17	20	12	15	17	21	

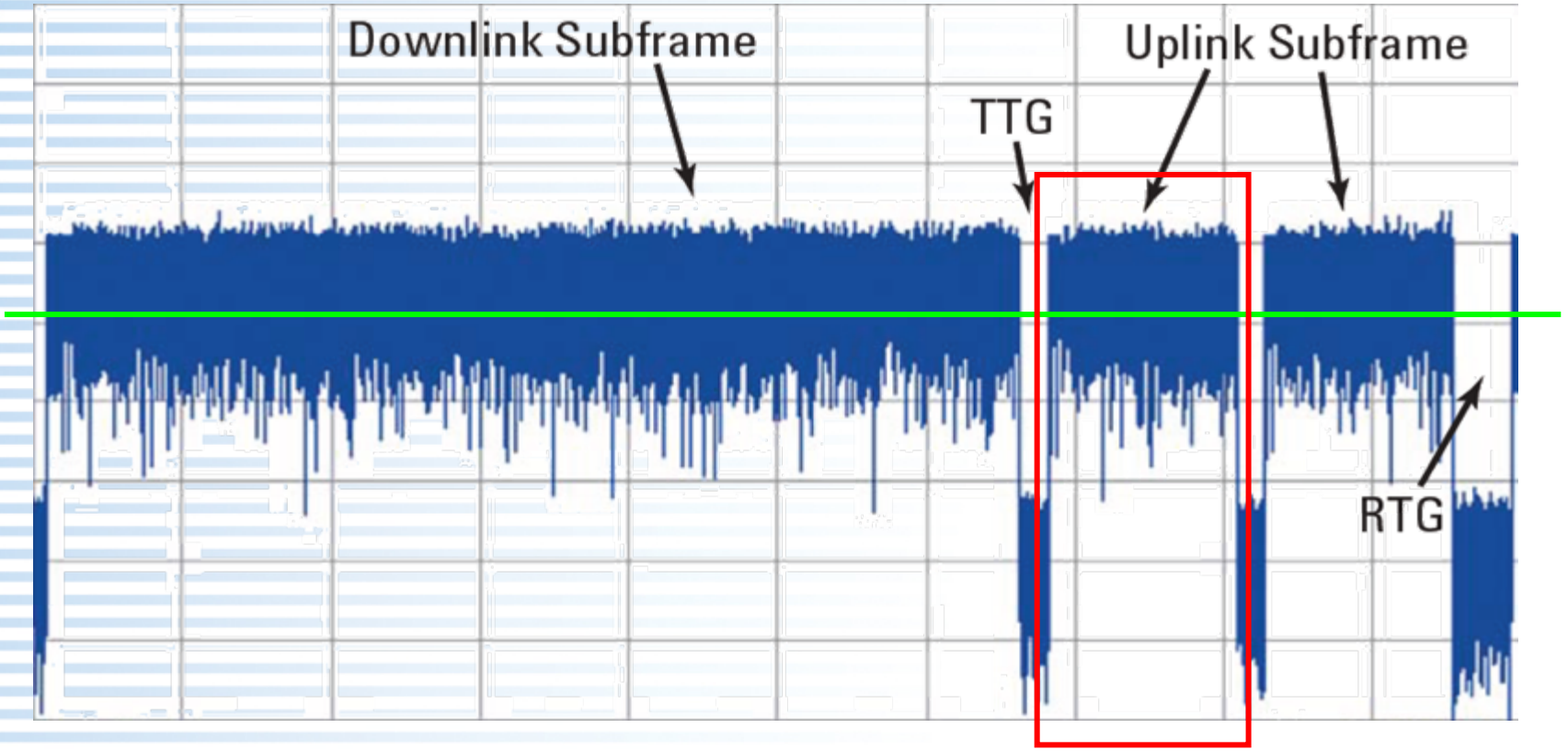
OFDM/OFDMA


Data
Sub-carriers
DC
Sub-carrier
Pilot
Sub-carriers
Guard
Sub-carriers

TDD Frame Structure

test software; test software + signal generator ?

Wi-Max communication test set ?



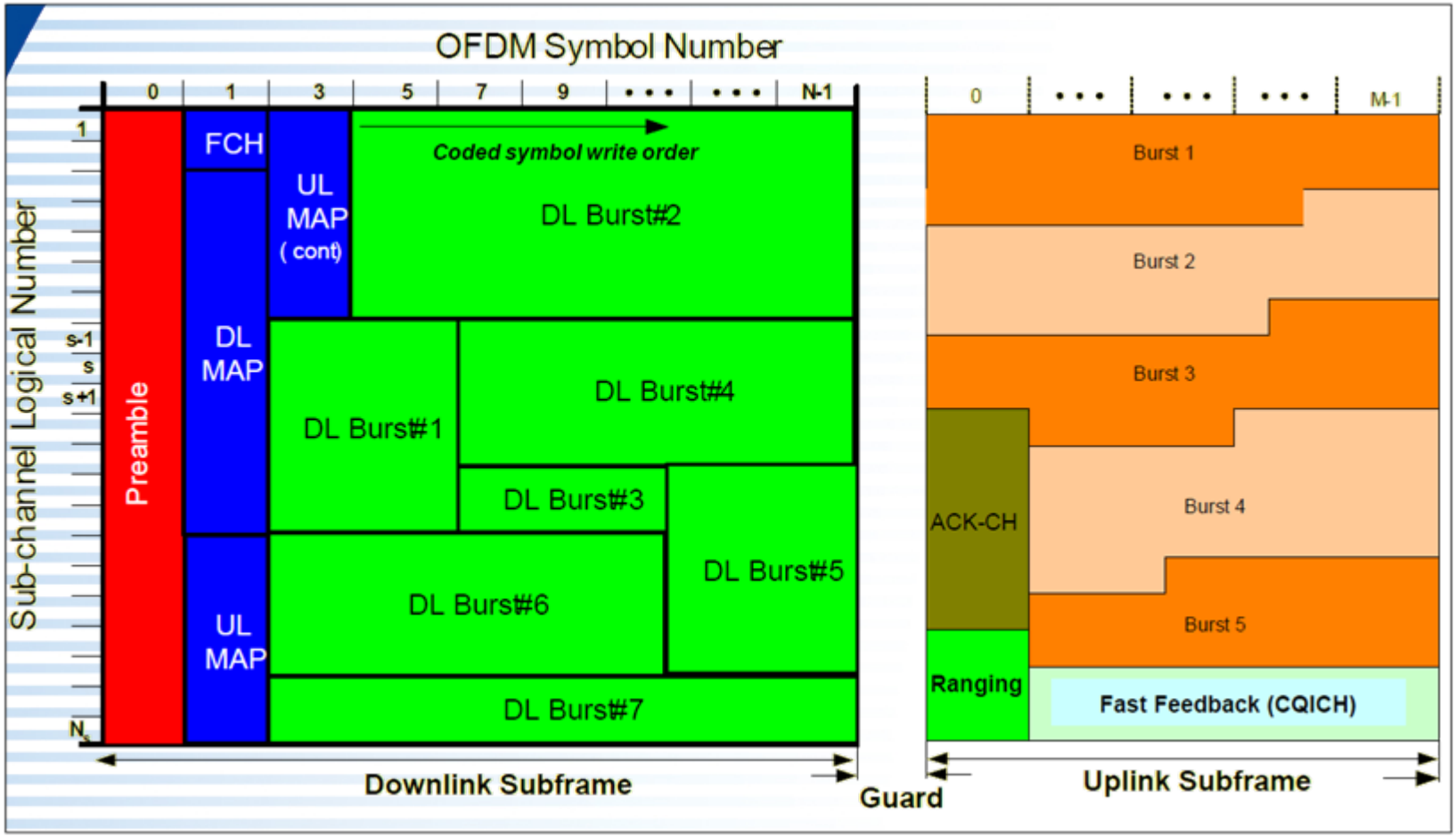
Wi-Max

- SAR test methodology issues
  - TDD: duty factor – OFDM/Burst to frame average
  - OFDM: PAR (crest factor) – within burst
- signal characteristics
  - normal use vs. test conditions
    - determining the maximum TDD duty factor
      - frame structure: burst intervals & gaps
    - evaluating output power & SAR probe issues for PAR
    - setting maximum uplink symbol & sub-carrier allocation
- test limitations
  - software vs. basestation simulator

Time & Frequency Parameters

- frames are divided into UL & DL sub-frames of
  - different zone types (PUSC, FUSC, AMC etc.) & sub-channels
- zones contain bursts
  - a burst is assigned to a dedicated user
  - an OFDM burst may not be the same as a conventional power burst
- smallest logical allocation
  - frequency domain = sub-channel = groups of sub-carriers
  - time domain = symbol ~ guard time & carrier spacing
- sub-channels are group into segments
  - a segment can contain 1 – 6 sub-channels
- 1 slot is the minimum data allocation
  - a slot = 1 sub-channel = 1 – 3 symbols (3 symbols for UL-PUSC)

Wi-Max Frame Structures



Example PUSC

Parameter	Downlink	Uplink	Downlink	Uplink
System Bandwidth	5 MHz		10 MHz	
FFT Size	512		1024	
Null Sub-Carriers	92	104	184	184
Pilot Sub-Carriers	60	136	120	280
Data Sub-Carriers	360	272	720	560
Sub-Channels	15	17	30	35
Symbol Period, T_S	102.9 microseconds			
Frame Duration	5 milliseconds			
OFDM Symbols/Frame	48			
Data OFDM Symbols	44			

Wi-Max PBA Considerations

- device operating parameters
  - channel BW, sub-carrier spacing, operating frequency
  - if TDD – maximum duty factor according to
    - burst average power & frame average power
  - transmission formats
    - normal use vs. test configurations
    - zone types, time & frequency domain resource allocations
- SAR test methodology & parameters
  - probe calibration issues
    - maximum TDD duty factor
    - verify error margin & resolve burst crest factor issues
  - test software vs. test set configurations
    - if TDD – isolate DL signal in the SAR measurement

Technology & Product Test Setup

- measure configurations required by the procedures
  - identify the specific test setup & parameters
- 3G power measurements (HSPA, 1xRTT/EV-DO)
  - identify parameters & ensure numbers make sense
- 802.11a/b/g, laptop, tablets & cellphones
  - KDB procedures may overlap, take all applicable procedures into consideration, including KDB 447498
- KDB 447498 intended for generic configurations
  - modules, simultaneous transmission, hand-held & body SAR, PTT & mobile devices etc.
- resolve all test issues before conducting tests

CDMA 2000
Power Measurements

IS-2000	Channel	SO2 [dBm]	SO2 [dBm]	SO2 [dBm]	SO55 [dBm]	SO55 [dBm]	SO9 [dBm]	SO9 [dBm]	SO55 [dBm]	TDSO SO32 FCH Only [dBm]	TDSO SO32 FCH+SCH [dBm]
	F-RC	RC1	RC3	RC4	RC1	RC3	RC2	RC5	RC2	RC3	RC3
Band	Vocoder Rate	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
Cellular	1013	24.01	24.22	24.18	24.13	24.14	24.16	24.05	24.09	24.16	23.43
	384	23.53	23.65	23.57	23.54	23.62	23.74	23.77	23.61	23.68	22.92
	777	23.40	23.50	23.54	23.42	23.50	23.50	23.44	23.54	23.56	22.91
PCS	25	23.23	23.29	23.25	23.33	23.44	23.18	23.45	23.35	23.36	22.58
	600	23.54	23.54	23.60	23.68	23.78	23.69	23.60	23.59	23.68	22.76
	1175	23.72	23.78	23.80	23.59	23.69	23.59	23.76	23.74	23.74	22.96

EV-DO
Power Measurements

Cellular Band - RTAP				Cellular Band - FTAP			
Channel	f (MHz)	R-Data Pkt Size	Conducted power (dBm) Average	Channel	f (MHz)	R-Data Pkt Size	Conducted power (dBm) Average
384	836.52	9.6	23.87	384	836.52	9.6	23.90
		19.2	23.94			19.2	23.88
		38.4	23.87			38.4	23.89
		76.8	23.93			76.8	23.90
		153.6	23.94			153.6	23.88

PCS Band - RTAP				PCS Band - FTAP			
Channel	f (MHz)	R-Data Pkt Size	Conducted power (dBm) Average	Channel	f (MHz)	R-Data Pkt Size	Conducted power (dBm) Average
600	1880.00	9.6	24.06	600	1880.00	9.6	23.94
		19.2	24.15			19.2	23.93
		38.4	24.14			38.4	23.98
		76.8	24.04			76.8	23.99
		153.6	24.00			153.6	23.97

GSM/GPRS/EDGE
Power & SAR Measurements

Frequency (MHz)	GPRS 1 slot Power (dBm)	GPRS 2 slots Power (dBm)	GPRS 3 slots Power (dBm)	GPRS 4 slots Power (dBm)
824.2	31.8	30.8		
836.6	31.8	30.8		
848.8	31.9	31.1		

Frequency (MHz)	EGPRS 1 slot Power (dBm)	EGPRS 2 slots Power (dBm)	EGPRS 3 slots Power (dBm)	EGPRS 4 slots Power (dBm)
824.2	26.8	26.8	26.8	26.8
836.6	26.9	26.9	26.9	26.9
848.8	27.0	27.0	27.0	27.0

Frequency (MHz)	GPRS 1 slot Power (dBm)	GPRS 2 slots Power (dBm)	GPRS 3 slots Power (dBm)	GPRS 4 slots Power (dBm)
1850.2	28.8	27.9		
1880.0	28.8	27.8		
1909.8	28.7	27.8		

Frequency (MHz)	EGPRS 1 slot Power (dBm)	EGPRS 2 slots Power (dBm)	EGPRS 3 slots Power (dBm)	EGPRS 4 slots Power (dBm)
1850.2	26.1	26.1	26.1	26.1
1880.0	26.0	26.0	26.0	26.0
1909.8	26.0	26.0	26.0	26.0

General Review Concerns

- Test reports
  - check numbers & plots
    - identify DUT & antenna positions and orientations
    - numbers match in all parts of the report
  - info & descriptions are accurate & meaningful
  - attestations are signed and all tests are dated
- Power measurements are consistent in all reports
- Manuals & instructions
  - include actual manuals with proper instructions
  - verify discrepancies
    - especially operating requirements and SAR numbers

Other Concerns

- SAR standards development delays
- resolve test issues before testing
  - for 802.11n & other MIMO configurations
  - for any non-standard products & technologies
  - inquire if PBA is required
- PBA revised to include LTE & 802.20
- acquire the necessary proficiency on related products & technologies to conduct test & review
- ensure numbers & results in test reports have clearly identified supporting info
- look for obvious errors – position, SAR vs. power

Other Questions

- round numbers to 2 significant digits
  - inquire through KDB if special consideration is needed
- test questions should come from grantees & labs
  - provide copy of KDB inquiry to TCB
  - including KDB tracking number in filing
- review questions should come from TCB
  - issues are resolved between TCB & grantee (& its lab)
- PBA requires TCB to review & determine
  - appropriateness of test methodologies & test conditions
  - resolve issues with grantee and determine if TCB can conduct the review without further difficulties