IEC 62209-3 Vector Probe-Array SAR Measurement

MIC MRA International Workshop 2016

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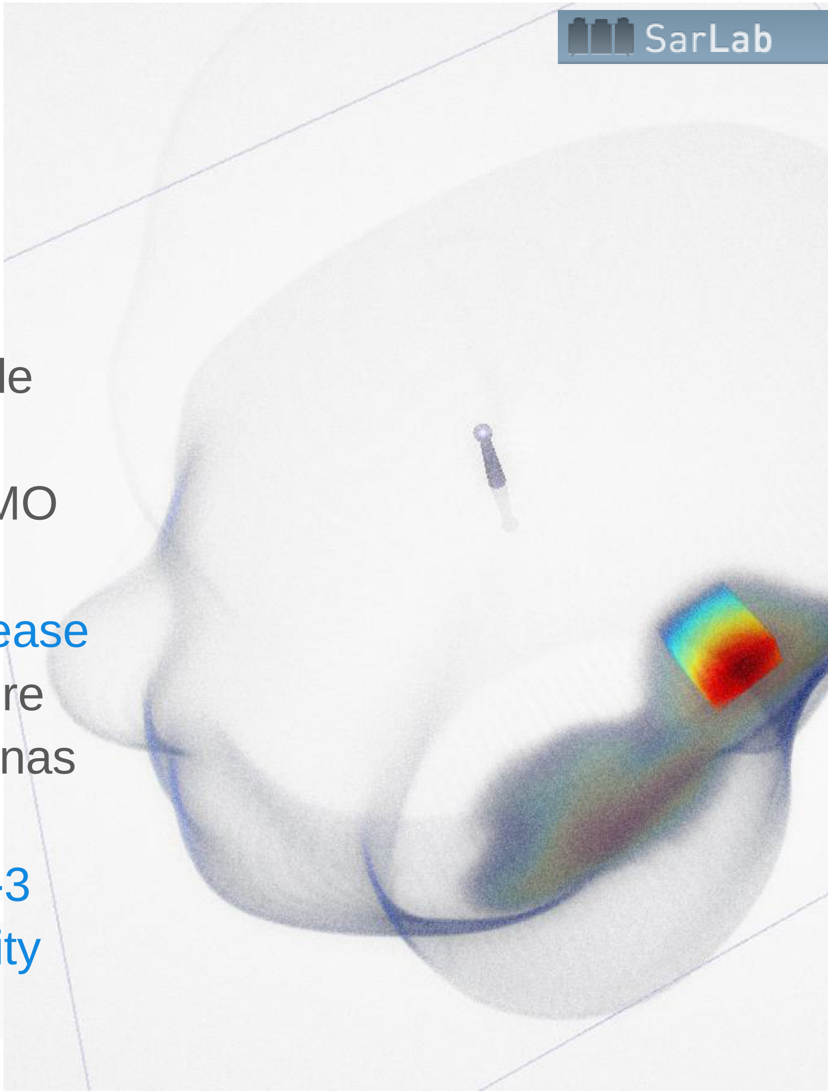
> Introduction

- → Peak spatial-average 1g and 10g Specific Absorption Rate measurement is key to demonstrate conformity of wireless mobile devices with regulatory exposure limits

- → Complexity of wireless technologies: multiple bands, dynamic antenna tuning, AsDiv, P-sensors, simultaneous multi-frequency, MIMO

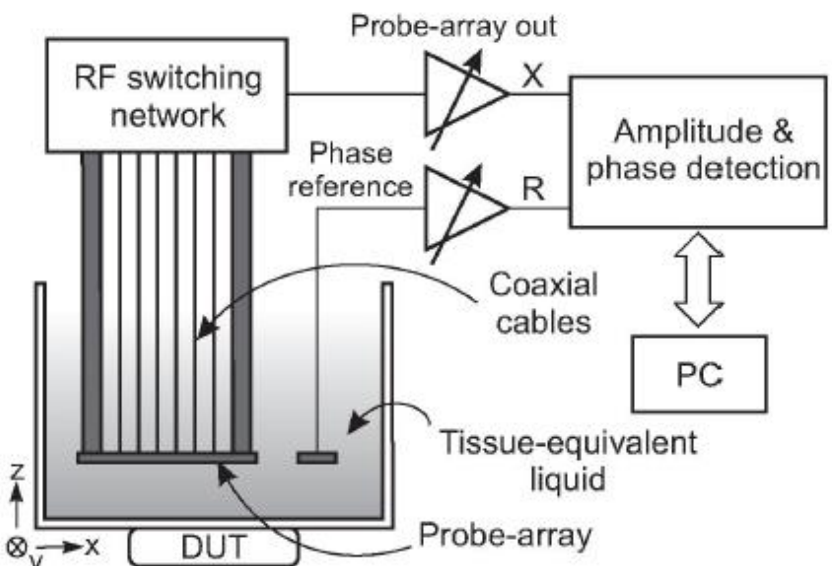
- → 40-fold SAR compliance testing matrix increase in the past 15 years: 5x more bands, 4x more communication systems, 2x as many antennas

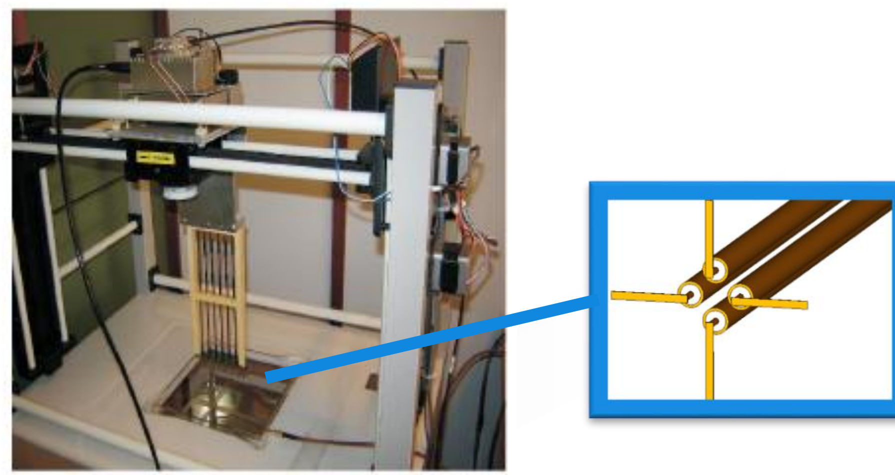
- → Vector-based techniques under IEC 62209-3 offer an approach to solve the test multiplicity issue and respond to new testing needs



> Beginnings of Vector Probes in SAR

- → Vector-Probe array SAR measurement techniques were among the earliest fast SAR approaches introduced [Merckel, PhD Thesis, 2002], [Merckel, Joisel, Bolomey, Proc. AMTA, 2003], [Cozza, Merckel, Bolomey. Proc. IEEE IWAT 2007].





Background of Vector Probe SAR Techniques and IEC 62209-3

- → **Fast and accurate is possible with vector probe-arrays**
- → A 2-D field scan of 2 E or H complex field components tangential to a surface contains enough information to deduce the 6 components of E and H fields in the whole 3-D volume
- → 3-D distribution can be accurately reconstructed using propagation functions (Huygens principle)
- → 3rd field component (normal) is obtained from the 2 other (tangential) components (Gauss law)
- → The reconstruction can be performed using a variety of near-field transformations

Standardizing Vector-Probe SAR
IEC 62209-3 – Current Scope

Current scope:

This International Standard provides specific requirements for dosimetric assessment systems using vector measurement-based systems. Such systems determine the peak spatial SAR by 3D reconstruction within the volume of interest. The systems covered by this standard shall determine the 1g and the 10g averaged SAR values with known uncertainty for any radiating source.

This standard specifies the requirements for the system, calibration, uncertainty assessment and validation methods over a specified volume.

IEC 62209-3 – Current Definitions

3.1 vector probe

probe which measures both the magnitude and phase of an electric or magnetic field.

3.2 scalar probe

probe which measures only the amplitude of the electric and magnetic field.

3.3 vector-measurement based system

system consisting of multiple sensors which together provide information about the amplitude distribution or the amplitude and phase distribution of the electric or magnetic fields over a specified volume.

> Timeline for IEC 62209-3

→ Timeline indicated on IEC website: http://www.iec.ch/dyn/www/f?p=103:23:0::::FSP_ORG_ID,FSP_LANG_ID:1303,25

IEC 62209-3 Ed. 1.0 Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 3: Vector probe systems (Frequency range of 100 MHz to 6 GHz)	106/289/NP 196 kB	2014-05	ANW 2014-05	1CD 2016-02	PT 62209-3	J. Keshvari	2017-01

→ CD expected after the May 2016 meeting.

> Reasons for Delay in the 62209-3 Development

ART-Fi
Advanced Real Time Field Imaging

→ Discussions have been mostly focused on

- Definitions of vector probe and probe-array
- System Verification / Validation
- Uncertainty Estimation – Clause 7

→ Consensus has been achieved in January 2016 on definitions

→ No consensus yet achieved on system verification / validation

→ Uncertainty section has made progress but is now being revised to incorporate comments from NPL

→ Traceability (17025) and uncertainty propagation methods for vector probe and vector probe-array systems are open issues

IEC 62209-3
System Specifications – Clause 5

- → Specific requirements for single vector probe
- → Specific requirements for vector probe-array systems
- → Phantom and material properties specifications are the same as in 62209-1 and 62209-2. Solid tissue-simulating material can be used.

> IEC 62209-3
> Protocol for SAR Assessment – Clause 6

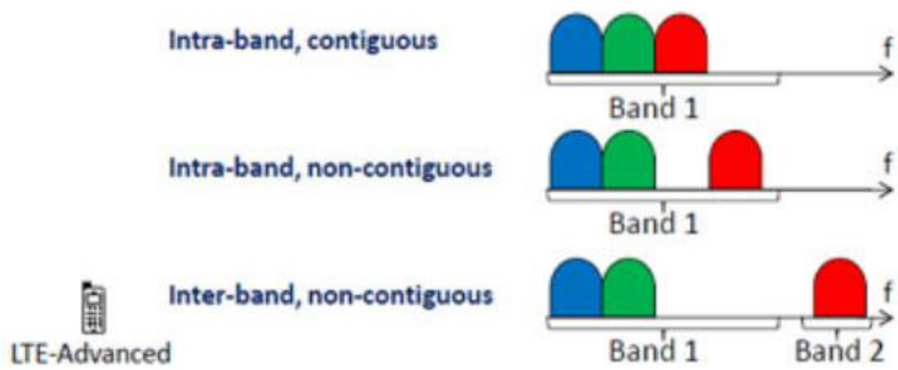
→ Specific requirements for test procedures

- Fewer test points
- Acquisition of only two field components is possible
- Scan over a surface or in volume
- Specific post-processing requirements

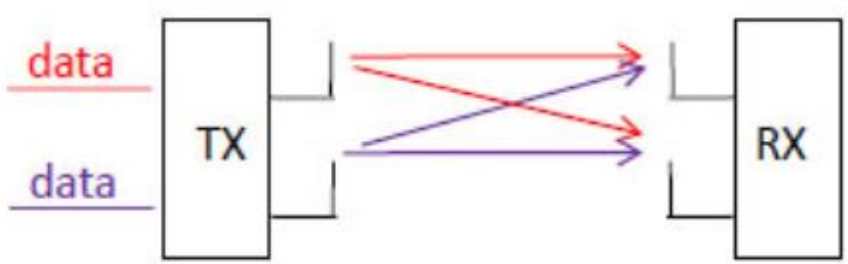
→ New procedures proposed for measurement of simultaneous transmission

- Non-correlated signals: spectral analysis capability introduced
- Correlated signals (MIMO): application of clause 6.5.1 of TR62630 enabled

→ LTE-Advanced (Release 10)



Carrier aggregation



MIMO

[Source: www.3gpp.org]

62209-3 Procedure for Vector-Probe Systems with Frequency Discrimination

a. The DUT is set to transmit simultaneously at frequencies f_1, f_2, f_N… in the considered supported transmission mode.

b. The DUT is positioned to the phantom according to Clause 6.1.5.

c. Measurement system is set to measure SAR at frequency f_1, so that frequency contributions falling within the $f_1 \pm B_a/2$ range are assessed. B_a is the analysis bandwidth of the probe or probe-array readout electronics. The procedure described here supposes B_a is larger than the signal bandwidth B_s.

d. If $f_i \pm B_{si}/2$, for any transmitter i between 2 and N, is contained in the $f_1 \pm B_a/2$ range, then the SAR is measured directly as in the case of single-frequency transmission mode. This is equally applied to the case where more than 2 signal bands fall within B_a.

e. If there is no overlap between $f_i \pm B_{si}/2$, for any index transmitter index i, and $f_1 \pm B_a/2$ range, then measure SAR for the f_1 transmission mode.

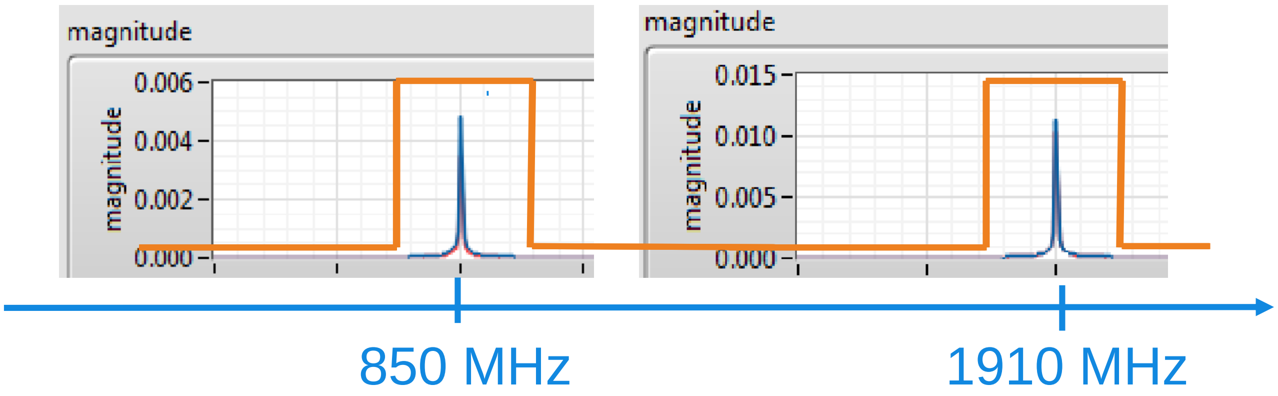
f. If there is overlap between $f_i \pm B_{si}/2$ and $f_1 \pm B_a/2$ range, then (i) reduce the analysis bandwidth to match a bandwidth as small as possible but no lower than B_{s1} and avoid overlap, then apply step g); (ii) enlarge and/or move the analysis bandwidth so that the span from the minimum frequency to the maximum frequency of the two signals falls within the analysis bandwidth, then apply step d).

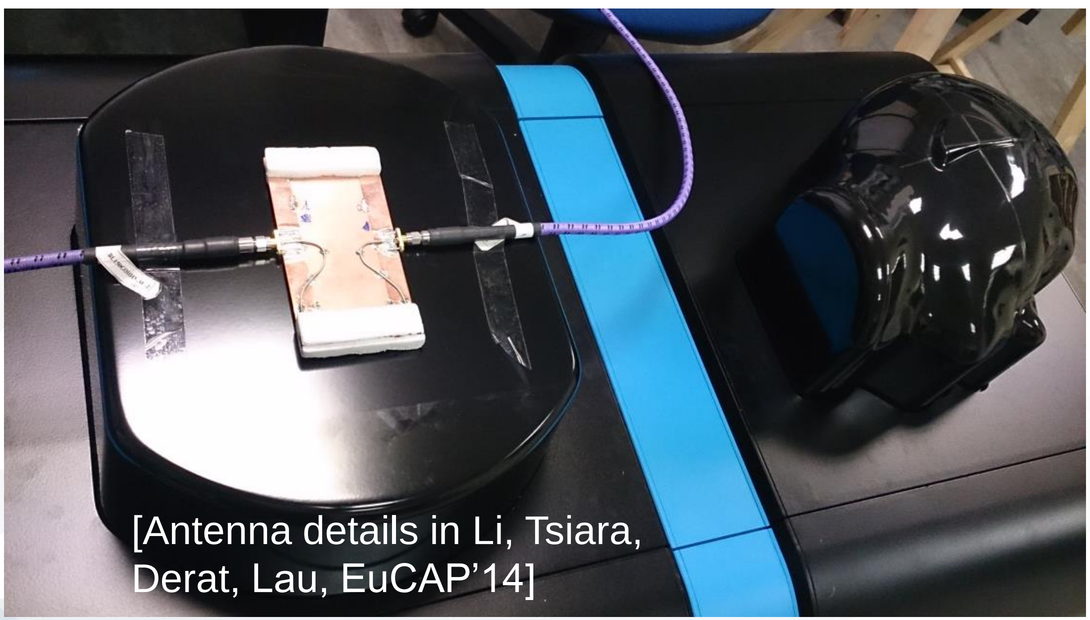
g. Set the measurement system to measure SAR at frequency f_2, so that frequency contributions falling within the $f_2 \pm B_a/2$ range are assessed. Apply step d), e), f) for transmitter 2 as appropriate.

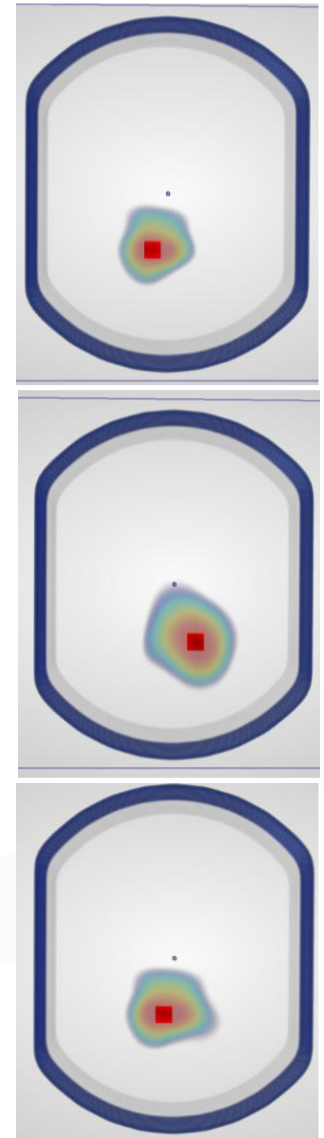
h. Repeat steps d), e), f) and g) for all other transmission modes.

i. Use one of the four alternatives defined in Clause 6.3.2.1 of IEC 62209-1 to obtain the combined SAR.

> Simultaneous Multi-Frequency Assessment







Uplink MIMO – Correlated Simultaneous Transmission

- Uplink MIMO with up to 4 antennas transmitting simultaneously
- Antenna and chipset technologies supporting 4x4 MIMO operation are available
- See e.g. SkyCross Dual iMAT & Qualcomm Snapdragon 820
  - Band 3 and band 7
  - Supports dual-band carrier aggregation of two 20 MHz channels

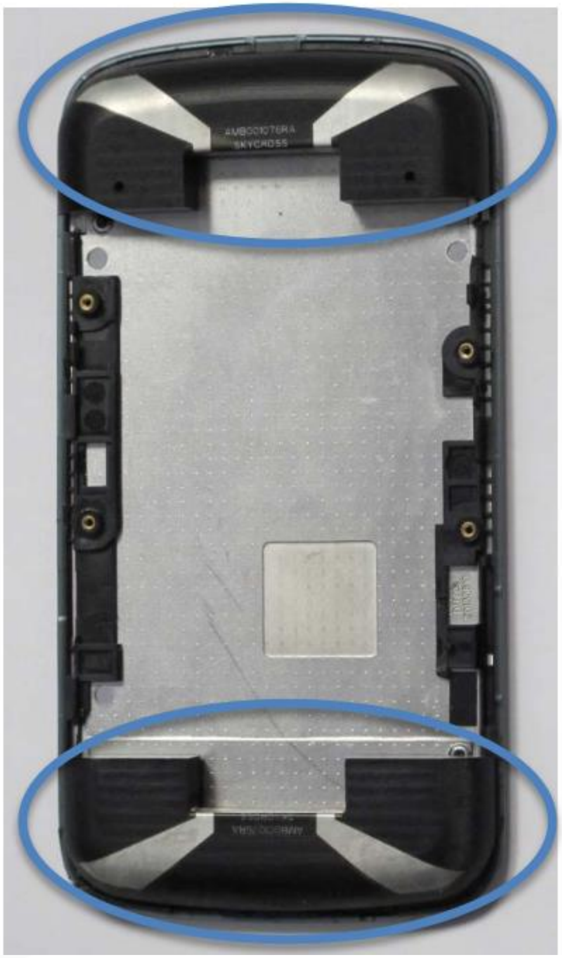


Photo: SkyCross Dual iMAT 4x4 MIMO technology

Uplink MIMO and SAR Testing with Vector-Based Approaches

→ Approach with 62209-3 vector probe or probe array systems (also detailed in IEC TR62630)

- Exploits the fact that the total vector field is a linear combination of the vector fields created by each antenna

$$E_{total} = |E_1|e^{j\varphi_1} + |E_2|e^{j\varphi_2} + \cdots + |E_N|e^{j\varphi_N}$$

- For a wireless device with N antennas, a measurement of N conditions is sufficient to process accurately all possible MIMO conditions.

→ Fast and accurate MIMO SAR is possible with vector probes

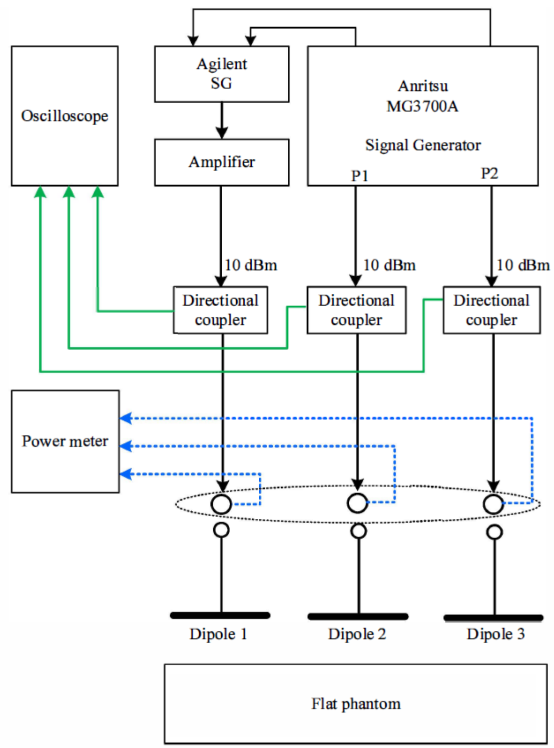
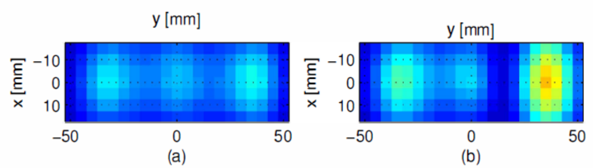


Fig. 1. Measurement scheme



Source: D. T. Le et al, An estimation method for vector probes used in determination SAR of multiple-antenna transmission systems, EMC Tokyo conference 2014.

> IEC 62209-3 – Clause 7 Uncertainty

- → New aspects taken into account wrt 62209-1 and -2: phase measurement, near-field transforms, solid-state systems, arrays
- → Some uncertainty components are coupled
- → Use of reference vector field distributions generated from numerical simulations to evaluate the impact of some tolerances when injected in post-processing algorithms

IEC 62209-3 – Clause 7
List of Uncertainty Components (1/3)

→ Mechanical

- scanning system and probe positioning
- device positioning
- device holder
- phantom shell

→ Material

- tissue-simulating material conductivity and permittivity
- tissue-simulating material temperature
- spatial-variations in tissue-simulating material

IEC 62209-3 – Clause 7
List of Uncertainty Components (2/3)

→ RF signals

- system linearity
- sensitivity limit
- modulation response
- RF ambient conditions
- Measurement system immunity / secondary reception
- amplitude and phase drifts
- amplitude and phase noise
- calibration of the measurement equipment
- readout electronics
- integration time
- response time
- SAR drift

IEC 62209-3 – Clause 7
List of Uncertainty Components (3/3)

→ **Probe or probe array related**

- probe or probe-array isotropy
- sensor mutual coupling

→ **Stray signals**

- boundary effect
- probe or probe-array coupling with DUT
- (RF ambient conditions – reflections)

→ **Acquisition and Post-processing**

- spatial sampling
- truncation and array boundaries
- post-processing uncertainty

FCC Accepting Sensor Array Systems for Diversity Antenna SAR Testing

Diversity Antenna SAR

- When a transmitter uses identical antennas to support transmit diversity, where
  - the diversity antennas are fed by the same set of identical hardware
    - amplifier, tuning and matching etc.
  - the only difference is the antenna locations within the device
  - there is no simultaneous transmission among the diversity antennas
- To reduce testing time for such combinations while maintaining the same number of normally required tests for each frequency band, wireless mode and exposure condition combination
  - either array sensor SAR systems or the area scan estimated 1-g SAR procedures (Motorola fast SAR) in KDB 447498 may be used in conjunction with full SAR
- SAR is measured using one of these methods; do not mix methods

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Courtesy of Kwok Chan, FCC

FCC Accepting Sensor Array Systems for Tuner SAR Testing

5. DYNAMIC ANTENNA TUNING

Some recent generation smart phones may incorporate specific hardware that allows selected antennas to be tuned dynamically during transmission according to actual use conditions to optimize antenna matching. Control mechanisms based open loop, closed loop or combinations of these may be used in conjunction with sensing of certain use condition to determine antenna tuning. Manufacturers may use different hardware, sensing mechanisms or RF operating parameters and algorithms for selected frequency bands and wireless transmission modes of individual phone models. The individual frequency bands may be sub-divided into multiple sub-bands to optimize tuning. The frequency band and sub-bands can be tuned with respect to built-in capacitive and switching components that can support a substantially large number of antenna tuning states. In order to reduce the number of SAR tests required to demonstrate compliance for the numerous tuning states, when applicable, certain SAR screening procedures may be considered to identify the higher SAR conditions that need the full set of normally required SAR measurements and allow SAR test reduction for the lower SAR conditions.

As this type of technology continues to evolve and adapt to various phone designs, the SAR screening procedures are expected to vary with design and implementation, When the tuning hardware is separate from the antenna and does not influence antenna performance, depending on the available tuning states, sensing and control mechanisms etc., fast SAR measurement methods such as those used in sensor array systems, the area scan estimated 1-g SAR procedures in KDB publication 447498 D01 or, in some cases, single point SAR measurements may be considered to determine the test configurations that require full SAR measurement to demonstrate compliance. A KDB inquiry with sufficient details is required to determine the acceptable SAR screening and full SAR measurement requirements to support dynamic antenna tuner SAR test reduction.

Source: FCC KDB 648474 D04

> Conclusion

- → IEC 62209-3 will enable fast and accurate SAR measurements using vector probe-array systems.
- → 62209-3 systems with frequency discrimination capability are the only ones which can provide uplink carrier aggregation SAR in realistic use conditions, as opposed to 62209-1 and -2 systems.
- → 62209-3 systems will simplify uplink MIMO SAR testing.
- → The CD of 62209-3 is targeted for after the May 2016 meeting.
- → Assessment of uncertainty and system validation are the main remaining points to address.
- → Regulators like the US FCC are already moving forward accepting sensor array systems for screening cases, e.g. antenna diversity and dynamic antenna tuner SAR.