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Specific absorption rate (SAR) measurement procedure for long term evolution (LTE) devices

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International Electrotechnical Commission

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CONTENTS

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SPECIFIC ABSORPTION RATE (SAR) MEASUREMENT PROCEDURE FOR LONG TERM EVOLUTION (LTE) DEVICES

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
106/377/PAS	106/385/RVD

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INTRODUCTION

LTE technology shows an added complexity over previously available radio schemes and in order to configure and test LTE devices, many signal parameters have to be taken into account. The combinations of parameters in a given frequency band can result in hundreds of LTE Modes and SAR test configurations. The main purpose of this protocol is to support the demonstration of DUT compliance with applicable exposure limits based on a reasonable number of SAR evaluations.

SPECIFIC ABSORPTION RATE (SAR) MEASUREMENT PROCEDURE FOR LONG TERM EVOLUTION (LTE) DEVICES

1 Scope

This Publicly Available Specification (PAS) applies to measurement procedures of Specific Absorption Rate (SAR) generated by devices with LTE (Long Term Evolution) technology specified by 3rd Generation Partnership Project (3GPP), Rel. 8 and 9 [1] where the devices are intended to be used with the radiating part in close proximity to the human head and body. This document supports both FDD and TDD modes. The objective of this document is to define the number of test conditions with respect to basic radio frequency aspects, i.e. channel bandwidths, number and offset of allocated resource blocks (RB), modulation, and maximum power reduction (MPR) for IEC 62209-1 and IEC 62209-2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62209-1:2016, *Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Part 1: Devices used next to the ear (Frequency range of 300 MHz to 6 GHz)*

IEC 62209-2, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)*

ETSI TR 121 905, *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Vocabulary for 3GPP Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ETSI TR 121 905 and the following apply.

3.1
LTE Mode
specific operational characteristics of the DUT

Note 1 to entry: LTE Mode is the combination of channel frequency, channel bandwidth, modulation, number of resource blocks, the offset of the resource blocks within the bandwidth, and the MPR.

3.2
Device Position
orientation and position of the DUT with respect to the phantom

3.3
Test Condition
Test Condition refers to the combination of both the LTE Mode and Device Position

4 Symbols and abbreviated terms

For the measurement procedures specified in this document, the symbols and abbreviated terms of IEC 62209-1 and IEC 62209-2 shall apply.

5 Protocol for SAR assessment

5.1 General LTE SAR testing considerations

LTE technology shows an added complexity over previously available radio schemes. In order to configure and test LTE devices, many signal parameters have to be taken into account: frequency band, channel bandwidth (from 1.4 MHz to 20 MHz), modulation (QPSK and 16-QAM), number of resource blocks allocated, offset of the resource blocks within the channel bandwidth as well as MPR. The combinations of parameters in a given frequency band can result in hundreds of LTE Modes and SAR test configurations. In order to address this a specific protocol is necessary for SAR assessment of LTE devices. The main purpose of this protocol is to support demonstration of DUT compliance with applicable limits based on a reasonable number of SAR evaluations.

For a given LTE Mode and Device Position (Test Condition), the peak spatial-average SAR is related to the maximum RF output power. As a consequence, RF conducted power measurements can be used to quickly identify high SAR LTE Mode. SAR and RF conducted power are however not directly proportional because:

i) RF conducted power is measured with a 50 Ohms load impedance;

ii) the antenna impedance of a DUT is generally not 50 Ohms and varies over frequency;

iii) the antenna impedance can be affected by Device Position and phantom coupling conditions.

Because of this, a single SAR measurement using the LTE Mode with the highest measured maximum conducted output power in a frequency band may not be sufficient to demonstrate compliance unless the SAR value is significantly lower than the applicable compliance limit. In the following, the required Test Conditions are established by applying the protocol in 5.2.

The LTE Test Conditions are measured according to the SAR measurement protocols in IEC 62209-1 for devices used next to the ear and in IEC 62209-2 for hand-held and body-mounted devices. This document only specifies the procedures to identify the LTE Test Conditions that will most likely result in SAR levels closest to the highest and conservative SAR result obtained from an up-scaling procedure.

For the above reasons, studies on the relationship between RF conducted power and SAR were conducted by MT1 using handsets operating in Band 1, 4 and 17. The results in Annex A show that:

- QPSK modulation with 1 RB allocation generally produces the highest peak spatial-average SAR – MPR does not apply in this case.
- Peak spatial-average SAR has good correlation with the measured RF conducted output power. The relationship deviates from proportionality by less than 25 % (k = 2).
- For LTE Modes with maximum conducted power lower than 85 % of P_{max}, where P_{max} is the highest measured maximum RF conducted output power across all LTE Modes in the frequency band, it is highly unlikely that highest SAR results would be expected.

5.1.1 Description of LTE Mode selection

Conducted power shall be measured for the largest channel bandwidth supported by the LTE Modes in each frequency band, using QPSK modulation with 1 RB allocation. The required test channels shall be determined by 6.2.5 of IEC 62209-1:2016. If the number of required channels is 1, the 1 RB shall be allocated at offset = centre; if the number of required channels is 3, the 1 RB shall be allocated at offset = 0, centre, and max within the channel bandwidth. If the number of required channels is 5, the 1 RB shall be allocated at offset = 0, centre, centre, centre and max within the channel bandwidth, respectively, for channels from lowest to highest.

Other LTE Modes besides “QPSK modulation with 1 RB allocation” shall also be measured for the different channel bandwidth configurations using the modulations and RB allocations described in Table C.1 (without MPR) and C.2 (with MPR), which are specified by 3GPP for conformance testing. Conducted maximum output power shall be measured using the following test channel and RB offset configurations.

- When MPR does not apply, the configurations in Table C.1 are measured for the low and middle channels with RB offset = 0 and RB offset = max for the high channel.
- When MPR applies, the configurations in Table C.2 are measured
  - for the low channel with RB offset = max,
  - for middle channel with RB offset = 0 and max,
  - for high channel with RB offset = 0.

For “QPSK modulation with 1 RB allocation” in smaller channel bandwidth configurations, when the same RB offset has already been measured in the highest channel bandwidth, such RB offset configurations may be omitted. These correspond to RBs allocated next to the channel edges; for example, offset = 0 for the low channel and max for the high channel for 5 MHz, 10 MHz, 15 MHz channel bandwidths in Band 1 may be omitted.

The conducted maximum output power measurements are illustrated in Figure 1 for 5 MHz, 10 MHz, 15 MHz, and 20 MHz channel bandwidths in Band 1 (1 920 MHz to 1 980 MHz) and 5 MHz and 10 MHz channel bandwidths in Band 17 (704 MHz to 716 MHz). The orange and blue colour RBs correspond to test configurations that are specified by 3GPP for conformance testing. The red colour RBs are the additional configurations required for QPSK and 1 RB allocation in the largest channel bandwidth configuration, not specified for 3GPP conformance testing. The low, middle and high channels are determined according to the IEC 62209-1 requirements. Annex E lists the LTE Modes to be tested in Band 3, 7 and 20.

NOTE Conducted power testing for additional LTE Modes is allowed, when the results form a superset of above requirements (e.g. conducted power testing according to FCC requirements). When such a conducted power superset is reported, all results shall be taken into account in following SAR test procedures.

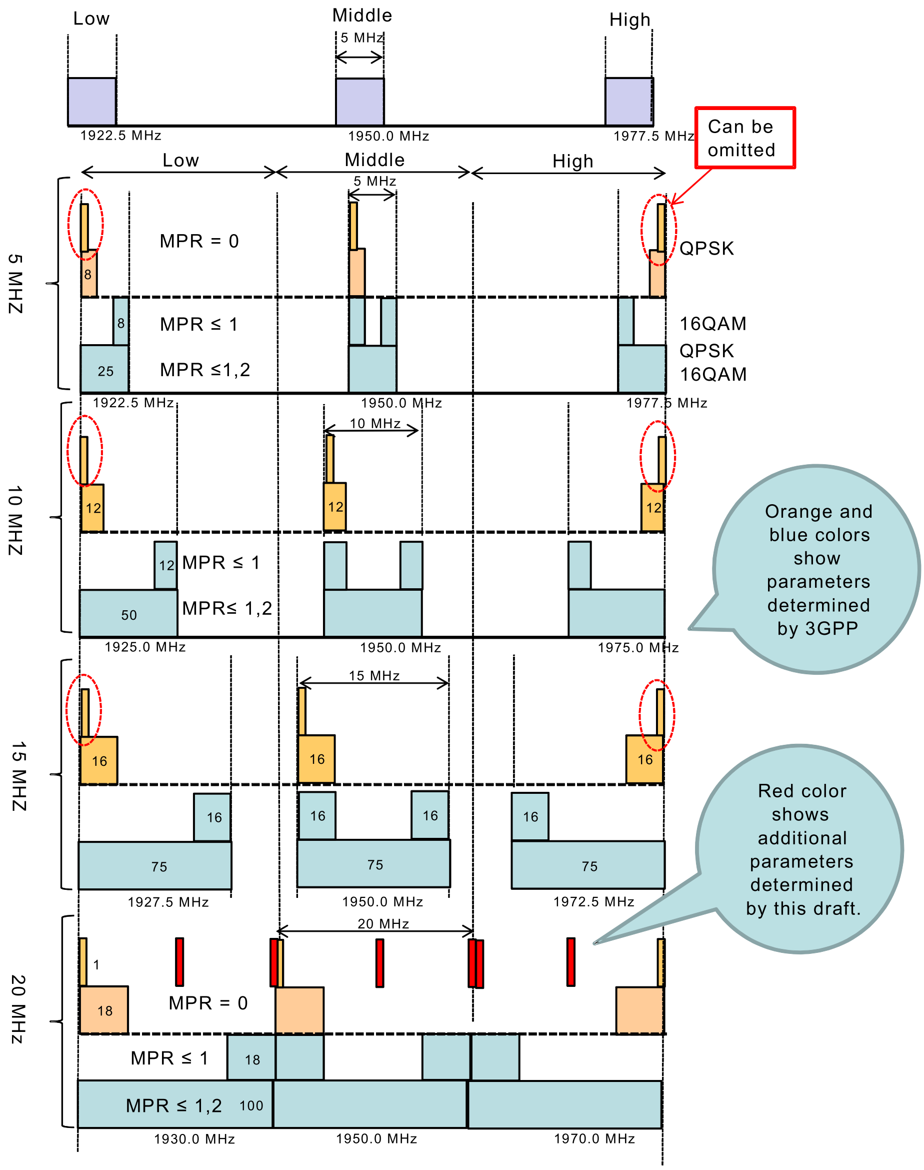

Figure 1a – Band 1 (1 920 MHz to 1 980 MHz)

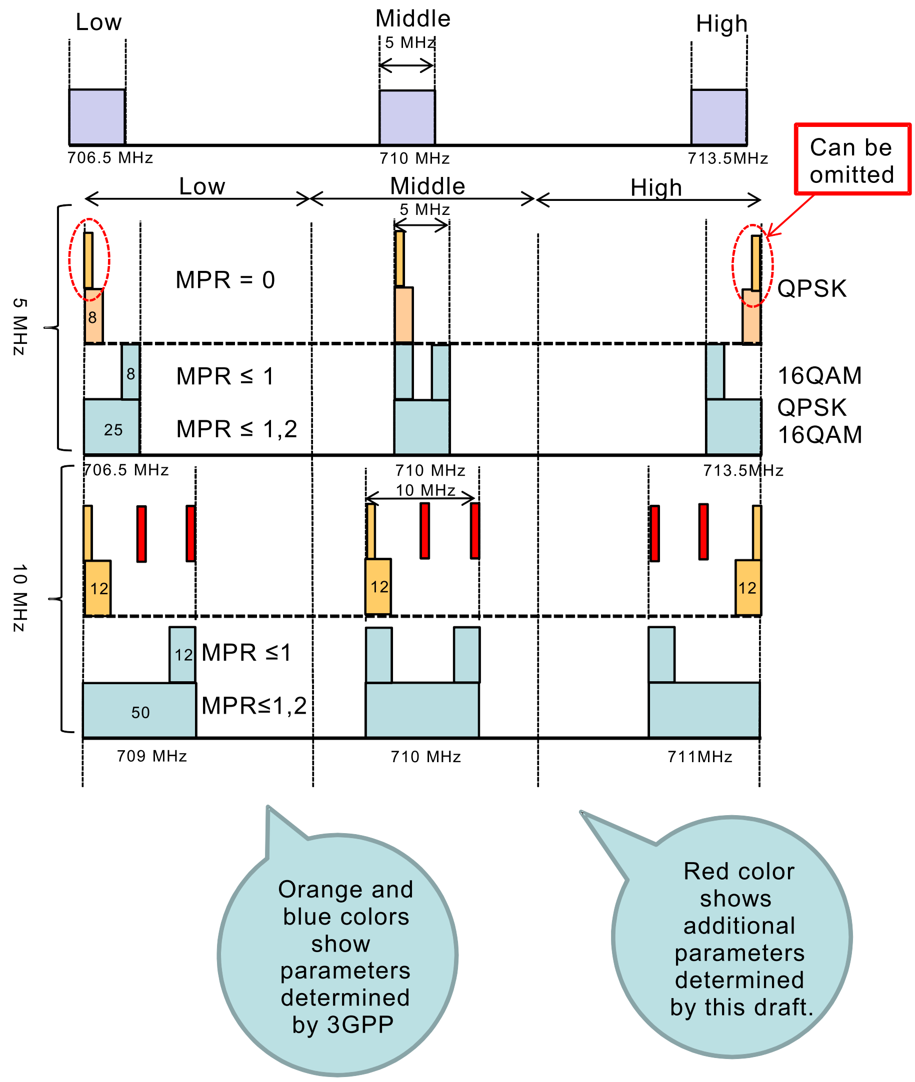

Figure 1b – Band 17 (700 MHz)

Figure 1 – Use of conducted power for LTE Mode selection

5.2 Power and SAR Measurement Protocol

The method described in IEC 62209-1 and IEC 62209-2 for the SAR measurement protocol requires tests to be performed first at the channel that is closest to the center of the transmit frequency band for each transmit antenna for all device test positions, all use configurations and all operating modes. Secondly for the condition providing highest peak spatial-average SAR determined in above, perform all tests at all other test frequency channels, e.g. lowest and highest channels. Finally, the largest peak spatial-average SAR value is determined from all of the previously tested configurations. The following protocol is exactly the same in principle except that it commences with the LTE Mode with the highest conducted power rather than the center of the transmit frequency band.

Step 1: RF conducted power measurement

RF conducted power measurement shall be performed for all LTE Modes described in the previous section, where $P(m)$ are the measured power for the m LTE Modes. The measurement protocol for RF conducted output power is described in Annex D.

The LTE Mode with the highest measured maximum conducted output power in each frequency band is identified as P_{max}.

The subset of LTE Modes in a frequency band with measured power greater than or equal to 85 % of P_{max} is identified as S.

Step 2: SAR measurement for the LTE Mode generating maximum RF conducted power (P_{max}) and Device Position causing maximum SAR

SAR measurement shall be performed for all Device Positions for the LTE Mode with maximum RF conducted power (P_{max}) to determine the Device Position with the highest peak spatial-average SAR, identified as SAR_{STEP2}.

Three approaches can be applied to determine the highest peak spatial-average SAR in step 3:

Approach 1 (AP1): Select the SAR measurement at Device Position causing maximum SAR for Step 2

For the test position with the highest peak spatial-average SAR_{STEP2}, multiply by 1.35 to yield the scaled highest peak spatial-average SAR, identified as AP1 SAR_{STEP3}. The factor of 1.35 is based on the k=2 value of the ratio between SAR and conducted power (α) determined from Equation (A.1) and the two studies given in Annex A.

Approach 1 is fast method yielding a conservative estimate of the maximum SAR of the device. If maximum SAR result obtained using this approach are above the SAR limit, Approach 2 can be used to obtain more accurate maximum SAR result.

Approach 2 (AP2): SAR measurement at Device Position causing maximum SAR for LTE Modes included in subset *S*

For the test position with the highest peak spatial-average SAR_{STEP2} determined in Step 2, perform SAR measurements in this test position for the other LTE Modes included in the subset S. The highest peak spatial-average SAR is identified as AP2 SAR_{STEP3}.

Approach 2 is the more accurate method, but requires testing of the LTE Modes in each Subset S.

Approach 3 (AP3): Limited SAR measurements at Device Position causing maximum SAR for LTE Modes included in subset *S*

For the test position with the highest peak spatial-average SAR_{STEP2} determined in Step 2, perform SAR measurements in this test position for another LTE Mode having the highest conducted power among all the untested LTE Modes included in the subset S. Multiply the new measured peak spatial-average SAR by 1.35 to yield the new scaled peak spatial-average SAR, identified as AP3 SAR_{SCALED}. If AP3 SAR_{SCALED} is not below the SAR limit repeat SAR measurement for the next LTE Mode as described above in this step, otherwise select the highest value among all the measured peak spatial-average SAR results and the last scaled value AP3 SAR_{SCALED} and identify it as AP3 SAR_{STEP3}.

AP1 SAR_{STEP3}, AP2 SAR_{STEP3} or AP3 SAR_{STEP3} shall be reported as maximum SAR for the LTE frequency band.

NOTE When assessing simultaneous multi-transmission SAR (e.g. LTE+WLAN), the maximum LTE SAR value for each test position obtained using the above approaches AP1, AP2 or AP3, or combination of those, shall be applied according to the simultaneous transmission SAR procedures in IEC 62209-1 or IEC 62209-2 for this assessment.

6 Uncertainty estimation

As the protocol described here is exactly the same in principle as that contained in both IEC 62209-1 and IEC 62209-2 except it commences with the LTE Mode with the highest conducted power rather than the center of the transmit frequency band, there is no change to the uncertainty estimation for the peak spatial-average SAR.

The uncertainty estimation should be performed as outlined in IEC 62209-1 and IEC 62209-2.

7 Measurement report

The maximum conducted power measurement results shall be included in the SAR report to identify the LTE Modes that required SAR measurement according to the protocol in this document. The SAR measurement results shall be reported according to requirements of IEC 62209-1 and IEC 62209-2.

Annex A
(informative)

Supporting information

The relationship between RF conducted power and peak spatial-average SAR is investigated using the following equation, where *m* defines a given LTE Mode in a frequency band:

$$\mathrm{SAR}(m) = \alpha(m)P(m) \quad \text{(A.1)}$$

The peak spatial-average SAR is proportional to RF conducted power *P.* However due to antenna mismatch, phantom coupling and other conditions, the ratio between SAR and conducted power (α) is expected to vary among the LTE Modes (*m*). In order to evaluate the deviation of α among LTE Modes, two independent studies were conducted.

Study 1:

This study is fully described in [2], [3] and [4]. This study was performed according to the protocol in IEC 62209-1 and therefore refers to low, middle and high channels. The protocol to commence SAR testing with the LTE Mode with the highest RF conducted power was recommended after the results of this study and Study 2 were combined. The following is a summary of the test configurations:

- Device type and characteristics: Smartphones.
- Frequency and channels tested: Band 1 (1 920 MHz to 1 980 MHz); Low, Middle, and High channel.
- Phantoms and test positions: SAM and Flat.
- Conducted power measurement configurations: Figure A.1.

  NOTE Green colour bars mean measurements were not conducted for these conditions because these are the same as those of 20 MHz bandwidth (largest channel bandwidth used in device).

- Number of DUTs: 4 different devices from 3 different manufacturers.
- Number of measurements: 42 for both conducted power and SAR.

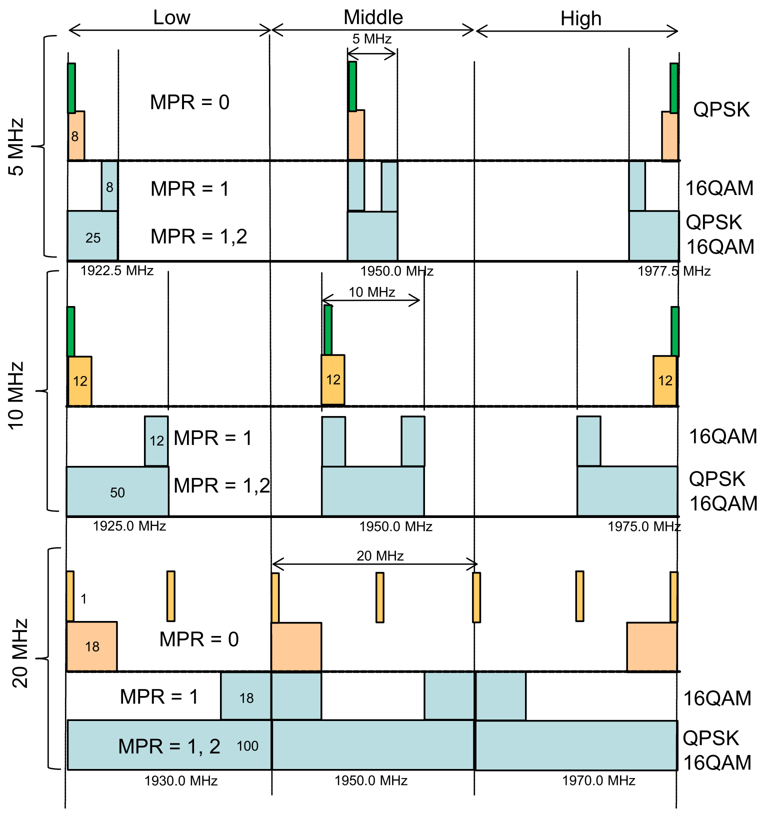

Figure A.1 – Low, Middle, and High channel at 2 GHz band (Band 1)

The results are summarized in the following.

- Deviations: Coefficient of variation (CV) of α is less than 11.5 % (Table A.1).
- RF conducted power is highest without MPR for the devices, which also result in the highest SAR.
- The deviation of α for SAM is slightly larger than that of Flat phantom. This may be due to DUT placement uncertainty.

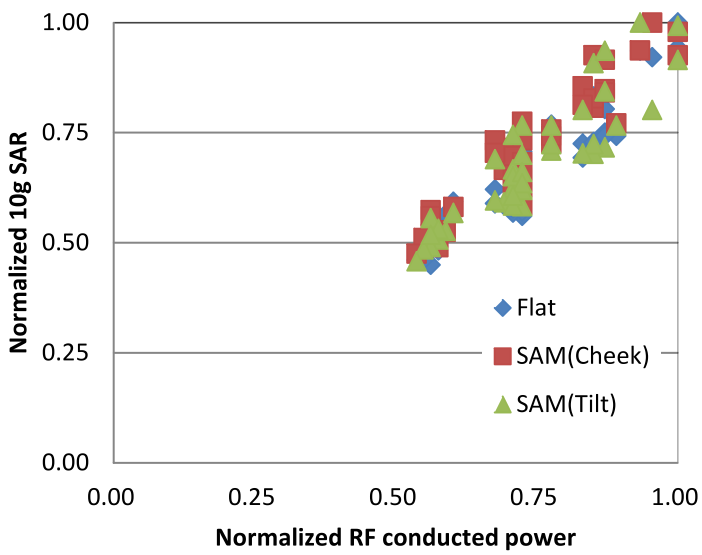

Figure A.2 – RF conducted power vs. 10g SAR

Table A.1 – CV of α

SAR	1g	10g
Flat	7.9 %	7.9 %
SAM (Cheek)	9.9 %	9.4 %
SAM (Tilt)	11.4 %	10.9 %

NOTE CV stands for coefficient of variation which is the standard deviation divided by the average value.

Study 2:

This study is fully described in [5].

- **2 DUTs**
- **Positions:** body rear 10 mm, left SAM side cheek / tilt, right SAM side cheek / tilt
- **Bands:** LTE FDD band 4, LTE FDD band 17
- **Channels:**

  Band 4: 19975 (1712.5 MHz), 20000 (1715 MHz), 20025 (1717.5 MHz), 20050 (1720 MHz), 20175 (1732.5 MHz), 20300 (1745 MHz), 20325 (1747.5 MHz), 20350 (1750 MHz), 20375 (1752.5 MHz)

  Band 17: 23755 (706.5 MHz), 23780 (709 MHz), 23790 (710 MHz), 23800 (711 MHz), 23825 (713.5 MHz), 23825 (713.5 MHz).
- **Bandwidths:**

  Band 4: 5 MHz, 10 MHz, 15 MHz, 20 MHz

  Band 17: 5 MHz, 10 MHz
- **RB sizes:**

  Band 4: 1, 12, 25, 36, 50, 75, 100

  Band 17: 1, 12, 25, 50
- **RB offsets:**

  Band 4: 0, 6, 12, 13, 18, 24, 25, 36, 39, 49, 50, 74, 99

  Band 17: 0, 6, 12, 24, 25, 49
- **Modulations:** QPSK, 16-QAM
- **Number of measurements:** 2510. A summary of the measurements including LTE Modes, conducted power measurements, Device Positions and Test Conditions can be found in [5].

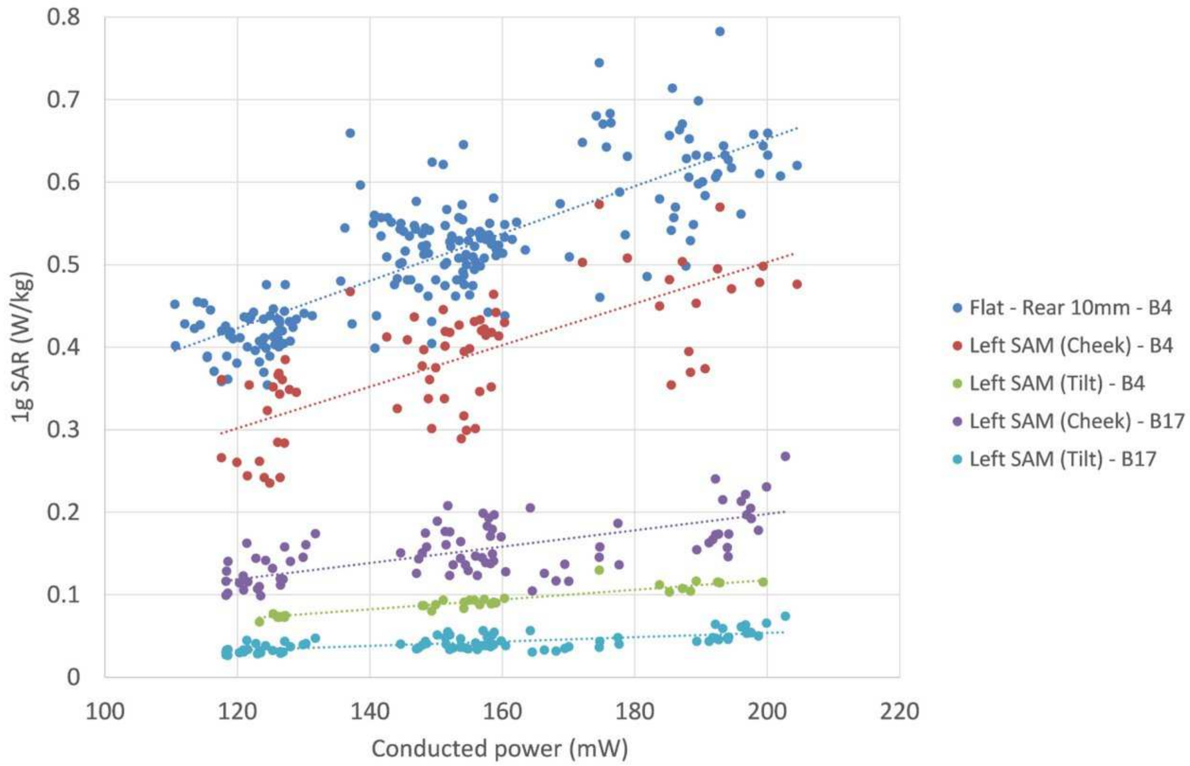

Figure A.3 – 1g SAR as a function of RF conducted power in various test conditions (dashed lines indicate y=a*x linear regressions)

Table A.2 – Maximum CV of α found in Study 2

SAR	1g
Flat	12.9 %
SAM (Cheek)	17.1 %
SAM (Tilt)	16.8 %

Justifications of relative standard deviations

The probability density function of the ratio of two normal random variables was derived by Hinkley in [6]. Assuming the peak spatial-average SAR for a given LTE Mode *m* is a random normal variable with a maximum of 15 % relative standard deviation (30 % *k*=2 uncertainty) and the conducted power *P*(*m*) is a random normal variable with a maximum 5 % relative standard deviation, then $\alpha(m)$ follows a distribution as defined by Hinkley such that:

- If SAR(*m*) and *P*(*m*) are uncorrelated then the 95 % confidence interval of $\alpha(m)$ is about 31 % large or +/-15.5 % around average.
- If SAR(*m*) and *P*(*m*) correlate with a coefficient of more than 0.9 then the 95 % confidence interval of $\alpha(m)$ is about 22 % large or +/-11 % around average.

In other words, for the above assumption, the *k*=2 uncertainty on $\alpha(m)$ determination for a given LTE Mode *m* can be as high as 15.5 %. In addition, $\alpha(m)$ varies with the mode *m*, so that CV of α across modes is likely to be higher than 8 %.

To investigate the CV that can be expected, 100 samples of $\alpha(m)$ were artificially generated as the output of a ratio of two uncorrelated normal random variables SAR(m) and $P(m)$ with respective relative standard deviation of 15 % and 5 %. For a mode $m1$, SAR($m1$) was chosen with a mean value of 0.66 W/kg and a mean conducted power $P(m1)$ of 137 mW. For a mode $m2$, the average of SAR($m2$) and $P(m2)$ were chosen respectively equal to 0.66 W/kg and 124.5 mW. As a matter of fact, $\alpha(m1)$ and $\alpha(m2)$ were logically found to exhibit an average relative difference over the 100 realizations of about 10 %. However, the maximum relative difference on a specific set of realizations of $\alpha(m1)$ and $\alpha(m2)$ was observed to be as high as 54 %. This approach is however conservative as, when comparing SAR values across LTE Modes in a given position, the whole uncertainty budget of the measurement system is not explored. In addition, averaging the uncertainty contributions across a variety of modes decreases the overall observed dispersion of α.

Annex B
(informative)

Maximum Power Reduction (MPR)

Table B.1 – Maximum Power Reduction (MPR) for Power Class 3

Modulation	**Channel bandwidth / Transmission bandwidth configuration** [RB]						**MPR** (dB)
	1.4 MHz	**3.0** MHz	**5** MHz	**10** MHz	**15** MHz	**20** MHz	
QPSK	> 5	> 4	> 8	> 12	> 16	> 18	≤ 1
16 QAM	≤ 5	≤ 4	≤ 8	≤ 12	≤ 16	≤ 18	≤ 1
16 QAM	> 5	> 4	> 8	> 12	> 16	> 18	≤ 2

Annex C
(informative)

Power test conditions

Table C.1 – Test Configuration Table without MPR

Ch. B.W. [MHz]	**Modulation**	**RB**
1.4	QPSK	1
1.4	QPSK	5
3	QPSK	1
3	QPSK	4
5	QPSK	1
5	QPSK	8
10	QPSK	1
10	QPSK	12
15	QPSK	1
15	QPSK	16
20	QPSK	1
20	QPSK	18

Table C.2 – Test Configuration Table with MPR

Ch. B.W. [MHz]	**Modulation**	**RB**
1.4	QPSK	6
1.4	16QAM	5
1.4	16QAM	6
3	QPSK	15
3	16QAM	4
3	16QAM	15
5	QPSK	25
5	16QAM	8
5	16QAM	25
10	QPSK	50
10	16QAM	12
10	16QAM	50
15	QPSK	75
15	16QAM	16
15	16QAM	75
20	QPSK	100
20	16QAM	18
20	16QAM	100

Annex D
(normative)

RF Conducted Output Power Measurement

As explained in Clause 5.1, RF conducted output power measurements are used to identify Test Conditions that are unlikely to produce the highest SAR values for the LTE Modes in a frequency band. It is hence essential to define guidelines for ensuring repeatable and precise RF conducted power measurements for LTE devices. Studies conducted by MT1 committee [Derat et al.; Newbury 2013] showed that the results of such measurements can be affected by e.g. (i) the presence / absence of device charger, (ii) the number of data frames (10 ms for LTE) used for RMS power averaging.

Hence, the following guidelines shall be applied to measure conducted output power:

- Device amplifier output shall be cabled to the measurement instrument (power meter, base station input, etc.) and cable shall not move during assessment of conducted power for a given frequency band.
- Device shall be operated on battery and no charger shall be connected to the device. Battery shall have at least 60 % charge for all power measurements.
- The same subframe allocation shall be used for power measurements of all LTE Modes in a given frequency channel. As an example, measurements for all LTE Modes in band 17 could be carried out with the following scheme: only subframe #0 is actively transmitting in each data frame with the remaining 9 subframes inactive.
- Measured RF conducted output power shall be averaged over at least 20 frames.

Conducted power measurements shall be documented and measurement uncertainty shall be taken into account. For a given frequency channel and a given LTE Mode m, $U(P(m))$ denotes the relative standard deviation of conducted power measurements of mode m obtained over at least 5 repeated measurements. The relative standard deviation is the standard deviation divided by the average $\overline{P}(m)$ across the 5 measurements.

In this document, including Clause 5.2 for the SAR test protocol:

- Conducted output power $P(m)$ for a given LTE Mode m at a defined frequency channel shall be understood as $\overline{P}(m)$.
- Maximum output conducted power across the m LTE Modes shall be understood as $\max_{m=1:M}\left\{\overline{P}(m)_{\max}\right\}$.
- $U(P,k=2)$ denotes the k=2 uncertainty of conducted power assessment defined as $\max_{m=1:M}\left\{2U\left(P(m)\right)\right\}$.
- For the sake of simplicity, the core text simply refers to $P(m)$ and $P_{\max}$.

Annex E
(informative)

RF Conducted LTE Modes to be tested for Band 3, 7 and 20

Table E.1 – Band 3 (1 710 MHz to 1 785 MHz)

Band	Channel Bandwith [MHz]	Channel N.	Modulation	RB Number	RB Offset
3	20	19300	QPSK	1	0
3	20	19300	QPSK	1	49
3	20	19300	QPSK	1	99
3	20	19300	QPSK	18	0
3	20	19300	QPSK	100	0
3	20	19300	16QAM	18	82
3	20	19300	16QAM	100	0
3	20	19575	QPSK	1	0
3	20	19575	QPSK	1	49
3	20	19575	QPSK	1	99
3	20	19575	QPSK	18	0
3	20	19575	QPSK	100	0
3	20	19575	16QAM	18	0
3	20	19575	16QAM	18	82
3	20	19575	16QAM	100	0
3	20	19850	QPSK	1	0
3	20	19850	QPSK	1	49
3	20	19850	QPSK	1	99
3	20	19850	QPSK	18	82
3	20	19850	QPSK	100	0
3	20	19850	16QAM	18	0
3	20	19850	16QAM	100	0
3	15	19275	QPSK	16	0
3	15	19275	QPSK	75	0
3	15	19275	16QAM	16	59
3	15	19275	16QAM	75	0
3	15	19575	QPSK	1	0
3	15	19575	QPSK	16	0
3	15	19575	QPSK	75	0
3	15	19575	16QAM	16	0
3	15	19575	16QAM	16	59
3	15	19575	16QAM	75	0

Band	**Channel Bandwith** [MHz]	**Channel N.**	**Modulation**	**RB Number**	**RB Offset**
3	15	19875	QPSK	16	59
3	15	19875	QPSK	75	0
3	15	19875	16QAM	16	0
3	15	19875	16QAM	75	0
3	10	19250	QPSK	12	0
3	10	19250	QPSK	50	0
3	10	19250	16QAM	12	38
3	10	19250	16QAM	50	0
3	10	19575	QPSK	1	0
3	10	19575	QPSK	12	0
3	10	19575	QPSK	50	0
3	10	19575	16QAM	12	0
3	10	19575	16QAM	12	38
3	10	19575	16QAM	50	0
3	10	19900	QPSK	12	38
3	10	19900	QPSK	50	0
3	10	19900	16QAM	12	0
3	10	19900	16QAM	50	0
3	5	19225	QPSK	8	0
3	5	19225	QPSK	25	0
3	5	19225	16QAM	8	17
3	5	19225	16QAM	25	0
3	5	19575	QPSK	1	0
3	5	19575	QPSK	8	0
3	5	19575	QPSK	25	0
3	5	19575	16QAM	8	0
3	5	19575	16QAM	8	17
3	5	19575	16QAM	25	0
3	5	19925	QPSK	8	17
3	5	19925	QPSK	25	0
3	5	19925	16QAM	8	0
3	5	19925	16QAM	25	0
3	3	19215	QPSK	4	0
3	3	19215	QPSK	15	0
3	3	19215	16QAM	4	11

Band	Channel Bandwith [MHz]	Channel N.	Modulation	RB Number	RB Offset
3	3	19215	16QAM	15	0
3	3	19575	QPSK	1	0
3	3	19575	QPSK	4	0
3	3	19575	QPSK	15	0
3	3	19575	16QAM	4	0
3	3	19575	16QAM	4	11
3	3	19575	16QAM	15	0
3	3	19935	QPSK	4	11
3	3	19935	QPSK	15	0
3	3	19935	16QAM	4	0
3	3	19935	16QAM	15	0
3	1.4	19207	QPSK	5	0
3	1.4	19207	QPSK	6	0
3	1.4	19207	16QAM	5	1
3	1.4	19207	16QAM	6	0
3	1.4	19575	QPSK	1	0
3	1.4	19575	QPSK	5	0
3	1.4	19575	QPSK	6	0
3	1.4	19575	16QAM	5	0
3	1.4	19575	16QAM	5	1
3	1.4	19575	16QAM	6	0
3	1.4	19943	QPSK	5	1
3	1.4	19943	QPSK	6	0
3	1.4	19943	16QAM	5	0
3	1.4	19943	16QAM	6	0

Table E.2 – Band 7 (2 500 MHz to 2 570 MHz)

Band	Channel Bandwith [MHz]	Channel N.	Modulation	RB Number	RB Offset
7	20	20850	QPSK	1	0
7	20	20850	QPSK	1	49
7	20	20850	QPSK	1	99
7	20	20850	QPSK	18	0
7	20	20850	QPSK	100	0
7	20	20850	16QAM	18	82
7	20	20850	16QAM	100	0
7	20	21100	QPSK	1	0
7	20	21100	QPSK	1	49
7	20	21100	QPSK	1	99
7	20	21100	QPSK	18	0
7	20	21100	QPSK	100	0
7	20	21100	16QAM	18	0
7	20	21100	16QAM	18	82
7	20	21100	16QAM	100	0
7	20	21350	QPSK	1	0
7	20	21350	QPSK	1	49
7	20	21350	QPSK	1	99
7	20	21350	QPSK	18	82
7	20	21350	QPSK	100	0
7	20	21350	16QAM	18	0
7	20	21350	16QAM	100	0
7	15	20825	QPSK	16	0
7	15	20825	QPSK	75	0
7	15	20825	16QAM	16	59
7	15	20825	16QAM	75	0
7	15	21100	QPSK	1	0
7	15	21100	QPSK	16	0
7	15	21100	QPSK	75	0
7	15	21100	16QAM	16	0
7	15	21100	16QAM	16	59
7	15	21100	16QAM	75	0
7	15	21375	QPSK	16	0
7	15	21375	QPSK	75	0
7	15	21375	16QAM	16	0

Band	**Channel Bandwith** [MHz]	**Channel N.**	**Modulation**	**RB Number**	**RB Offset**
7	15	21375	16QAM	75	0
7	10	20800	QPSK	12	0
7	10	20800	QPSK	50	0
7	10	20800	16QAM	12	38
7	10	20800	16QAM	50	0
7	10	21100	QPSK	1	0
7	10	21100	QPSK	12	0
7	10	21100	QPSK	50	0
7	10	21100	16QAM	12	0
7	10	21100	16QAM	12	38
7	10	21100	16QAM	50	0
7	10	21400	QPSK	12	38
7	10	21400	QPSK	50	0
7	10	21400	16QAM	12	0
7	10	21400	16QAM	50	0
7	5	20775	QPSK	8	0
7	5	20775	QPSK	25	0
7	5	20775	16QAM	8	17
7	5	20775	16QAM	25	0
7	5	21100	QPSK	1	0
7	5	21100	QPSK	8	0
7	5	21100	QPSK	25	0
7	5	21100	16QAM	8	0
7	5	21100	16QAM	8	17
7	5	21100	16QAM	25	0
7	5	21425	QPSK	8	17
7	5	21425	QPSK	25	0
7	5	21425	16QAM	8	0
7	5	21425	16QAM	25	0

Table E.3 – Band 20 (832 MHz to 862 MHz)

Band	**Channel Bandwith** [MHz]	**Channel N.**	**Modulation**	**RB Number**	**RB Offset**
20	20	24250	QPSK	1	0
20	20	24250	QPSK	1	49
20	20	24250	QPSK	1	99
20	20	24250	QPSK	18	0
20	20	24250	QPSK	100	0
20	20	24250	16QAM	18	82
20	20	24250	16QAM	100	0
20	20	24300	QPSK	1	0
20	20	24300	QPSK	1	49
20	20	24300	QPSK	1	99
20	20	24300	QPSK	18	0
20	20	24300	QPSK	100	0
20	20	24300	16QAM	18	0
20	20	24300	16QAM	18	82
20	20	24300	16QAM	100	0
20	20	24350	QPSK	1	0
20	20	24350	QPSK	1	49
20	20	24350	QPSK	1	99
20	20	24350	QPSK	18	82
20	20	24350	QPSK	100	0
20	20	24350	16QAM	18	0
20	20	24350	16QAM	100	0
20	15	24225	QPSK	16	0
20	15	24225	QPSK	75	0
20	15	24225	16QAM	16	59
20	15	24225	16QAM	75	0
20	15	24300	QPSK	1	0
20	15	24300	QPSK	16	0
20	15	24300	QPSK	75	0
20	15	24300	16QAM	16	0
20	15	24300	16QAM	16	59
20	15	24300	16QAM	75	0
20	15	24375	QPSK	16	59
20	15	24375	QPSK	75	0
20	15	24375	16QAM	16	0

Band	Channel Bandwith [MHz]	Channel N.	Modulation	RB Number	RB Offset
20	15	24375	16QAM	75	0
20	10	24200	QPSK	12	0
20	10	24200	QPSK	50	0
20	10	24200	16QAM	12	38
20	10	24200	16QAM	50	0
20	10	24300	QPSK	1	0
20	10	24300	QPSK	12	0
20	10	24300	QPSK	50	0
20	10	24300	16QAM	12	0
20	10	24300	16QAM	12	38
20	10	24300	16QAM	50	0
20	10	24400	QPSK	12	38
20	10	24400	QPSK	50	0
20	10	24400	16QAM	12	0
20	10	24400	16QAM	50	0
20	5	24175	QPSK	8	0
20	5	24175	QPSK	25	0
20	5	24175	16QAM	8	17
20	5	24175	16QAM	25	0
20	5	24300	QPSK	1	0
20	5	24300	QPSK	8	0
20	5	24300	QPSK	25	0
20	5	24300	16QAM	8	0
20	5	24300	16QAM	8	17
20	5	24300	16QAM	25	0
					0
20	5	24425	QPSK	8	17
20	5	24425	QPSK	25	0
20	5	24425	16QAM	8	0
20	5	24425	16QAM	25	0

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