

Electromagnetic Exposure from Wireless Devices as Function of Distance

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Abstract

A measurement study has been conducted to understand the relationship between user exposure and distance of the wireless device to the body. This topic is pressing given the recent proposal of the European Committee for Electrotechnical Standardization (CENELEC) to perform Specific Absorption Rate (SAR) testing at 0 mm distance to the body for body-worn test conditions. Based on the two main interaction mechanisms of the coupling of the incident fields with tissue simulating media [1, 2], a monotonic increase of the induced fields with reduced distance is expected. However, early research has already shown that proximity of the user may detune the transmitter structure. This may result in a higher SAR at distances greater than 0 mm to the body. This topic deserves a thorough and comprehensive study so that a standardized testing procedure can be proposed that is both conservative and easy to implement with minimal impact on test time. The results of this study are regularly presented to relevant standards bodies.

1 Introduction

A formal objection to standard EN 50566 [3] was raised in 2020 that the standard is inconsistent with the EU Radio Equipment Directive [4] that it “shall also take into account the reasonably foreseeable conditions”. In the objection, it was proposed that it should be mandatory to test body-worn conditions with the device directly against the body (i.e., at a distance of 0 mm to the body phantom). CENELEC Technical Committee 106X responded by organizing consultations with regulators, wireless device manufacturers, academics, and others. The result of this was a two-pronged solution: a) adoption of mandatory testing at $d = 0$ mm in CENELEC EN 50566; b) detailed study to be conducted by members of the International Electrotechnical Commission (IEC) Technical Committee 106 (TC106) on the issue, leading to a robust, scientifically justified solution.

During the consultations, the authors presented a preliminary study that showed that the maximum SAR is not necessarily at a $d = 0$ mm. There are some cases where the SAR does not monotonically increase with decreasing distance, due to interactions between the device under test (DUT) and the body. While this study indicated that the maximum SAR can occur at non-zero distances to the

body, the prevalence of the effect was not known due to the small scale of the study.

This study is a much larger measurement campaign involving a sample of 4G-enabled commercially available wireless devices at $d = 0$ mm to 10 mm with high resolution. The size of the study will help IEC TC106 to determine the prevalence of the non-monotonic behavior, which will allow IEC TC106 to derive a testing procedure that is conservative and has minimal impact on test time. This work is also of interest for the measurement of absorbed power density at frequencies above 6 GHz [5].

2 Methods

SAR measurements were performed using a DASY8^{3D} system (Schmid & Partner Engineering AG, Switzerland), as shown in Figure 1. The system uses a robot to pick up and position the DUT at any orientation and distance next to a cSAR3D flat phantom. Using the robot enables repeatable positioning at precise orientations and distances with a fine positioning repeatability (< 0.02 mm). cSAR3D (Schmid & Partner Engineering AG, Switzerland) is a vector - measurement based system that uses an array of E - field sensors to measure the peak spatial - average SAR in less than a second.

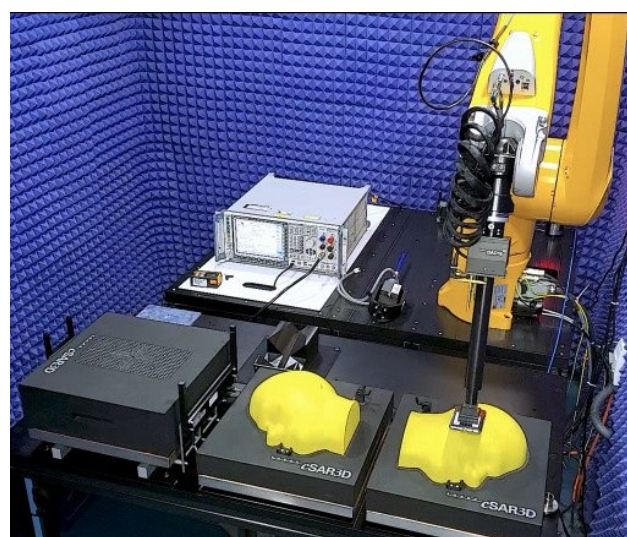


Figure 1. Measurement setup for the study using DASY8^{3D}. The flat phantom of cSAR3D (left) is used for the measurements.

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Twelve devices (see Table 1) were purchased that are available on the US market, so that the authors can review the publicly available SAR test reports containing detailed information about the transmit technologies used. The study was conducted so that exposure control techniques disabled during the tests. This allows the SAR vs distance characteristic to be observed purely as a function of antenna distance to the body. The exposure control techniques (see Table 1) include antenna selection diversity ('Ant.': switching from one antenna to another to improve the communication link), dynamic power control ('Pwr.': adjusting the output power over time to ensure that the time-averaged exposure is within the exposure limit), and proximity sensors ('Prox.': detection of the presence of the user to lower the output power or turn on dynamic power control) that are located at the antenna (labelled 'Ant.' in Table 1) or on the left or right edges of the device where the fingers are gripping the device (labelled 'Gr.').

DUT	LTE Bands	Exposure Control				Tests
		Ant.	Pwr.	Prox. (Ant.)	Prox. (Gr.)	
1	9					2745
2	12					3538
3	22		Y			7259
4	18		Y	Y	Y	5429
5	22					7137
6	10					3294
7	24	Y	Y	Y		5368
8	17		Y	Y		5307
9	25	Y	Y	Y	Y	6161
10	9					3294
11	8	Y	Y	Y	Y	2379
12	8	Y	Y	Y	Y	2379
Total						54290

Table 1. Characteristics of the DUTs used in this study.

For each DUT and for each tested LTE band, all six faces of the DUT were positioned facing the flat phantom at several distances. The chosen distances are $d = 0 - 5$ mm in steps of $\Delta d = 0.1$ mm, and $d = 5 - 10$ mm with $\Delta d = 0.5$ mm. The six faces are the front and back sides, and the left, right, top, and bottom edges. All available 4G LTE (Long-Term Evolution) [6] bands were measured. Over 54,000 measurements were conducted. There are some combinations of LTE band and DUT face where the SAR level was below the noise threshold, so these are not included.

This is a blind study (DUTs are referred to as DUT1, DUT2, etc.) so that the absolute SAR values can be shown without implying that a specific device exceeds the safety limits. Indeed, the measurements are conducted at some distances and edges of the DUT that do not comply with current regulatory requirements, so no assertions of non-compliance can be made.

3 Discussion

All 12 DUTs have been measured, and analysis of the results will be presented. Non-monotonic behavior of the SAR vs distance curve was observed in a minority of all cases (combination of LTE band and DUT face), meaning that the SAR is most often highest at a $d = 0$ mm. However, non-monotonic behavior was observed in all of the devices for at least one configuration of LTE band and DUT face, and in some of these cases, the highest SAR for non-monotonic behavior was significant with respect to the overall maximum SAR for that device.

The prevalence of non-monotonic SAR behavior was observed in some cases to be caused by changes in the SAR pattern that indicate that capacitive coupling of the antenna to the flat phantom is dominating at smaller distances. In other cases, an increase in antenna impedance mismatch reduces the output power, resulting in lower SAR.

The use of proximity sensors significantly affects the findings. Six of the 12 DUTs make use of at least one proximity sensor. The measurements are reported with proximity sensors disabled, which was typically achieved by measuring at a lower output power so that the proximity sensor is turned off, then scaling the results to the maximum power level. However, when the proximity sensor is considered, it was observed that the triggering of the proximity sensor resulted in additional cases where the SAR at $d = 0$ mm is not the highest SAR.

To validate the measurements, the measured results using the array system (cSAR3D) were compared against the results using a scanning system (DASY8). The scanning system is accepted by regulators worldwide and is considered to be the benchmark for measurement accuracy. However, the array system is used for this study as the scanning is very time consuming, making it practically impossible to conduct so many measurements in a reasonable amount of time. For measurements of all DUTs at two distances ($d = 0$ mm and 10 mm) the differences are within the combined standard uncertainty of the two systems.

4 Conclusions

The results support that testing at $d = 0$ mm distance to the body represents the highest SAR in a significant majority of cases, but it does not guarantee a conservative result in all cases. Non-monotonic behavior of the SAR vs distance characteristic was observed in all of the 12 devices tested for at least one combination of LTE band and DUT face. This non-monotonic behavior may result in an underestimation of the reported SAR, and this is further complicated by the implementation of proximity sensors. Other interpretations with respect to compliance are being studied. All results are shared with IEC TC106 for the purpose of developing a consensus approach.

References

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