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Optimization of Head Phantom Size/Weight for Millimeter Wave OTA Tests

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Fifth Generation (5G) networks and devices are currently being released into the market together with ongoing 3rd Generation Partnership Project (3GPP) standardization [1]. With the addition of the mm-wave frequency range 2 (FR2), radiofrequency (RF) conformance and performance must be tested in a radiated, over-the-air (OTA) environment [2]. 3GPP is developing FR2 OTA testing methods, which are currently based on an indirect far-field (IFF) setup using the compact antenna test range (CATR). It has unique features, such as a compact footprint, and supports all types of RF measurements with low measurement uncertainty, while still providing a good dynamic range. The Cellular Telecommunications Industry Association (CTIA) is also working on new mm-wave OTA testing methods and plans to introduce head and hand phantoms to enable testing device performance in realistic usage scenarios. However, it is difficult to adopt full-sized head phantoms in IFF setups because of limitations on the weight of the device under test (DUT) supportable by the positioner and the quiet-zone size provided by the test range for certain implementations. Although, e.g., modern CATR systems can support centered DUT weights of up to 8 kg and have quiet zones of up to 30 cm in diameter [3], there are other implementations with limited DUT load capacities of 2–4 kg. The weight of the full mm-wave specific anthropomorphic mannequin (SAM) head is greater than the load capacity of certain CATR systems. The size of the full head requires the DUT to be positioned offset far from the center of the coordinate system, where it might even lie outside the quiet zone, leading to increased measurement uncertainty. Bringing the DUT to the center coordinates may not be an option, as that could introduce torque not complying with the positioner specifications.

In this study, we used Sim4Life V5.0 (ZMT Zurich MedTech AG) to investigate the feasibility of modifying the full mm-wave SAM head to substantially reduce the size and weight of the phantom to allow positioning the DUT in the center of the quiet zone, while minimizing the impact on OTA performance relative to that of the full head. The OTA performance of antennas in a virtual cellphone placed in the tilted talk position against the full-head phantom was compared to that for head phantoms in which materials on the shadow side were progressively removed until significant differences in OTA performance were observed. In a second step, the effects of making the head hollow were investigated. Four antennas (6, 10, and 90 GHz dipoles, and a 38.5 GHz patch array) were simulated, and the influence of antenna positioning was addressed by placing the antennas at the four corners and edge centers of the virtual cellphone of dimensions 158 mm × 77 mm × 8 mm in multiple orientations. Differences in performance between the full-head phantom and the half-head and hollow half-head phantoms were derived for all standard CTIA OTA performance parameters – e.g., total radiated power (TRP), near-horizon partial radiated power (NHPRP), etc. – plus a new parameter, near opposite partial radiated power (NOPRP), that allows characterization of the power radiated towards the shadow side. These parameters serve to indicate whether the partial-head phantoms qualify as acceptable representations of the full-head phantom.

Our results show that the optimal SAM head for mm-wave measurements is a hollow half-head phantom with a shell thickness of 30 mm and a weight (including the stand) of about 2.5 kg. The peak absolute deviation observed for standard OTA performance parameters is 0.20 dB, and 0.25 dB with NOPRP included. The numerical results were validated experimentally under various test conditions with a Rohde & Schwarz ATS1800C CATR.

References

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