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EurAAP WG GSM Antenna Model Validation

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***Abstract*—The European Association on Antennas and Propagation Software Working Group has found significant discrepancy between computer model and measurement of the RangeStar Ultima™ "World GSM" antenna. This work shows good agreement between our model and the Working Group model as well as with our measurement. It briefly explores several possible sources of error in the Working Group measurements.**

***Keywords*—antenna benchmarking, antenna measurements**

I. Introduction

The European Association on Antennas and Propagation (EurAAP) Software Working Group (WG) has had continuing interest in a GSM antenna geometry, beginning in 2008 when software benchmarking efforts for this antenna showed major discrepancy between six computer modeling suites and experimental measurement [1]. Subsequent studies of the GSM antenna showed improvement in the agreement of simulations [2]. A recent report [3] showed close agreement between computer models at all labs, and close agreement among measurements at all labs; however, the model and measurements results were in significant disparity. This prompted the WG to call for participation [3] to resolve the discrepancy. This work shows good agreement between model and measurement, and explores several possible sources of error in the WG measurements.

II. Methodology

Guy Vandenbosch of the WG furnished the solid model which was used to model and fabricate the antenna (see Fig. 1). The antenna model was imported to Ansys HFSS version 2019R3; first order elements and the direct solver were used. Models were fed by a coaxial waveport at the extremity of a 40.82 mm length of coaxial transmission line included in the model provided by the WG; the internal geometry of the line and connector were meshed and solved. All s-parameters were normalized to 50 Ω. All conductors were modeled as smooth copper ($\sigma = 58$ MS/m) 35 µm thick. The substrate was modeled as Dk = 4.4, and tan(δ) = 0.02 and 1.57 mm thick. Solder mask was optionally modeled as Dk = 4.5 and tan(δ) = 0.029 and 50.8 µm thick. The geometry was located at the center of a 30 x 30 x 30 cm airbox with radiation boundary (vis a vi PML) on its faces. Adaptive pass convergence at 1.5 GHz required three consecutive passes with $|\Delta S| < 0.002$.

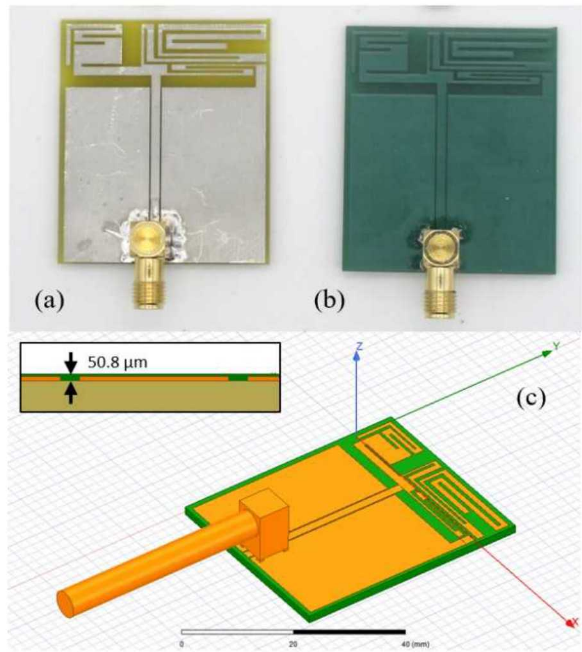

Figure 1. As-fabricated PCBs (a) without solder mask, (b) with solder mask (c) computer model (inset shows cross section of CPW transmission line with modeled 50.8um thick solder mask).

Cabled reflection coefficient measurements were made in an anechoic chamber using an Agilent N5222A VNA with a full 1-port calibration at the end of the SMA measurement cable. Initially, no ferrites were used on the cable. The right-angle SMA connector used for measurement was TE Connectivity 3-1478978-1, as suggested by the WG. Both boards were fabricated by Advanced Circuits (Aurora, CO, USA) on 1.57 mm FR-4 with 35 µm copper. As a potential discrepancy between what was previously modeled and measured by the WG, the antenna was modeled and fabricated both with and without solder mask. The PCB metal finish for the former is HAL and tin plate for the latter.

III. Results

Very good agreement between modeled and measured reflection coefficient is seen in Fig. 2. The differences may be quantified by the vector difference in reflection coefficients at each frequency, $\Gamma_{\text{meas}} - \Gamma_{\text{model}}$; the magntidue of this vector is plotted in Fig. 3. We see that even the noticeable discrepancy

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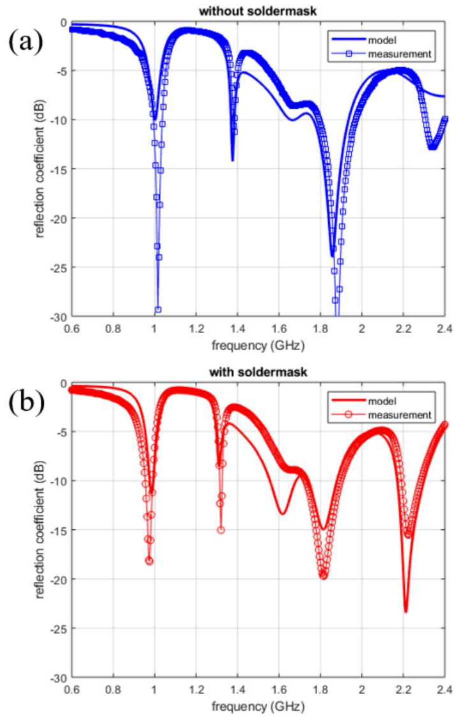

Figure 2. Comparison between model and measurement for (a) PCB without solder mask and (b) PCB with solder mask.

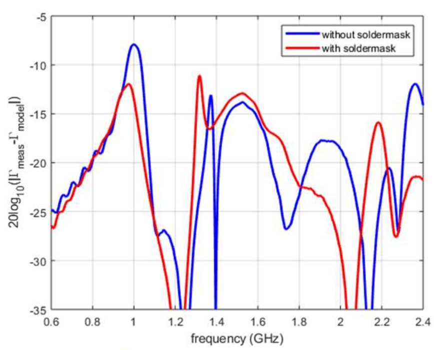

Figure 3. The vector difference in reflection coefficients of the model and the measurement, expressed in dB.

near 1.6 GHz in Fig. 2corresponds to a only a modest vector difference (less than -12dB). Moreover, the average value of the vector difference from 0.6-2.4 GHz is only 0.117 (-18.6 dB) for the case without solder mask and 0.107 (-19.4 dB) for the case with. Considering the simplifying assumptions made in the model regarding substrate Dk, homogeneity and isotropy, solder mask Dk and profile, conductor roughness and metallography, connector internal geometry and truncation of the cable, the agreement with measurement is very good.

Because our model and measurement results appear to agree with model results published by the WG (compare to Fig. 4 of [3]), and multiple measurements from different WG institutions agree with each other, but *not with any model results*, we postulate that a systematic error exists in WG measurement setup that is not captured in WG models.

At present, we cannot identify the difference between our

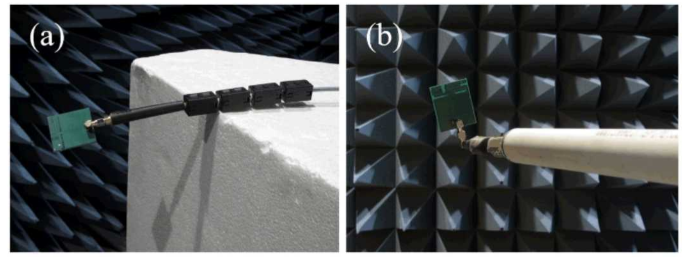

Figure 4. (a) Cable with ferrites (and "-y" cable orientation), (b) cable (with SMA elbow and no ferrites) in "+z" orientation

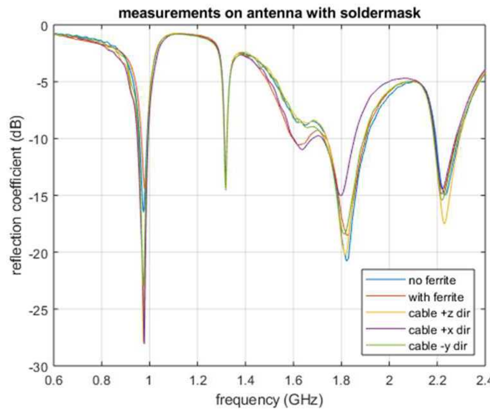

Figure 5. Measurements with and without ferrites and with the cable in various orientations (with reference to Fig. 1(c) coordinate system) showed no significant measurement change. This data is for the antenna with solder mask.

measurement and those of the WG. As is seen in Fig. 2, the solder mask causes only a small perturbation to the antenna input impedance. In addition, we saw no significant change with four Laird HFA150066-0A2 ferrite beads (rated for "256 Ω" at 1 GHz) on the cable near the antenna as seen in Fig. 4(a); results are plotted in Fig. 5. We also characterized the antenna PCB in serveral orientations with respect to the measurement cable, as shown in Fig. 4(b). This too, was found to have no substantial effect, as seen in Fig. 5.

IV. Conclusions

The EurAAP Software WG benchmark GSM model and measurement were replicated. In contrast to prior reports by the WG, good agreement between model and measurement was found. Because there is good agreement between multiple WG measurements, we postulate that a systematic error exists in the WG measurements that is not captured in WG models. We do not yet know the difference between our measurement and that of the WG.

References

[1] G. A. E. Vandenbosch, R. Gillard, and M. Sabbadini, "The Antenna Software Initiatve (ASI): ACE results and EurAAP continuation," *IEEE Antennas Propag. Mag.,* vol.51, no. 3, pp. 85-92, June 2009.

[2] G. A. E. Vandenbosch, F. Mioc, M. Saporetti, and L. Foged, "Bridging the simulations-measurements gap: State-of-the-art," *IEEE Antennas Propag. Mag.,* vol. 58, no. 6, pp. 12-24, Dec. 2016.

[3] G. A. E. Vandenbosch, "Modeling and Design Tools for Small Antennas: State of the Art and Future Perspectives," *IEEE Antennas Propag. Mag.,* vol. 60, no. 4, pp. 18-20, Aug. 2018.