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mm-Wave Experimental Scanning System to Determine the Complete Field by Near-to-Near Field and Near-to-Far Field Transformation

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Abstract

A novel measurement system and a 3D field reconstruction method with near-to-near field and near-to-far field forward transformation are described for wireless transmitters operating at frequencies from 6 – 110 GHz. Measurements are taken as close as λ/6 and the reconstructed 3D field distributions are compared against simulated results. The uncertainty in the measurement plane is better than 1.4 dB. The uncertainty budget at arbitrary observation points will be developed and validated by simulations and far-field measurement systems.

1. Measurement System

We have developed a mm-wave measurement system consisting of a high precision robot and a diode-loaded pseudo-vector probe (EUmmW-probe) operating at frequencies between 750 MHz – 110 GHz that determines the magnitude and polarization ellipse of the electric (E-) field at each measurement location (Figure 1). The pseudo vector probe design has the advantage that (i) it includes an outstanding amplitude precision, (ii) can be built small and non-perturbing, and (iii) field distortions by the probe body can be largely compensated.

2. Phase Reconstruction

Based on the measurements of field magnitude and polarization ellipse on two planes, a plane-to-plane algorithm was developed, which allows reconstruction of the phase on measurement planes as close as λ/6 [Pfeifer et al., 2018]. The closest measurement distance is 2 mm whereas the field can be accurately reconstructed as close as λ/5.

3. Near-to-Near-Field and Near-to-Far-Field Forward Transformation

Based on field magnitude and reconstructed phase, it is possible to compute the equivalent surface current density distribution on this plane. Provided that the measurement plane is large enough to cover the relevant field emitted by the source, the total field can be computed on arbitrary observation points in the half-space away from the measurement plane. This is achieved by evaluating the surface current integrals with the free-space Green's function at the observation points of interest. We are currently working on accelerating the computations and determining the upper bound of uncertainty as a function of distance. This technique will allow to determine the maximum power density anywhere in space, the radiation pattern of the source and projection of the Poynting vector on any phantom surface, e.g., SAM head.

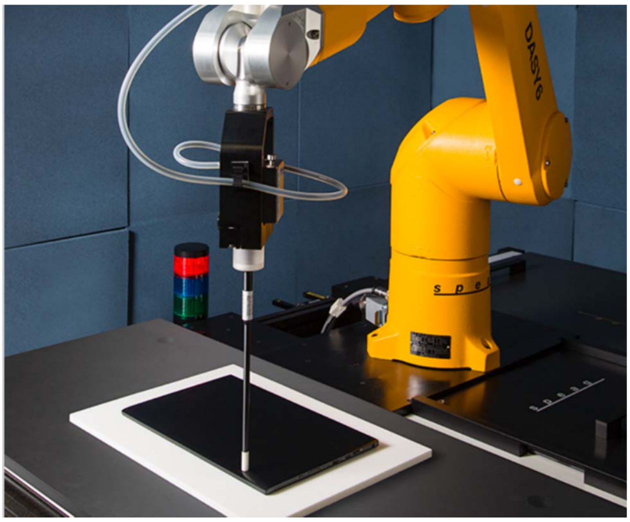

Figure 1. Power density measurement system using a pseudo-vector probe.

4. Results

The method was applied to field data (simulations and measurements) of a cavity-fed dipole array operating at 30 GHz (see [IEC TR, 2018] for antenna details). The two measurement planes were placed at 2 mm and 4.5 mm distance from the antenna plane. To evaluate the sensitivity of forward transformation with respect to measurement

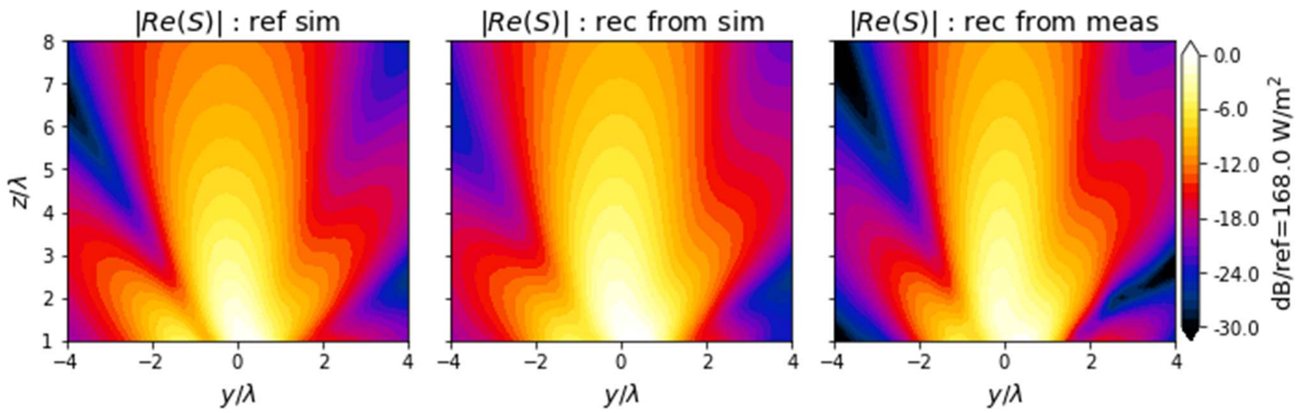

Figure 2. Near field reconstruction of |Re(S)| (dB) from a measurement plane at λ/5. Left: reference simulation. Center: reconstruction from simulation (emulated measurements). Right: reconstruction from measurements

imperfections such as noise, measurement data were emulated by extracting E-field polarization ellipses from the Finite-Difference Time-Domain (FDTD) simulation; for the reference fields the FDTD results including full phase information were used. In a second evaluation, the forward transformation was applied to the measurement data. The resulting near-field on a vertical plane (for a distance from λ – 8λ) is shown in Figure 2; the resulting far-field in Figure 3. These results indicate that it is feasible to reconstruct the complete field in the half-space above the first measurement plane (at λ/5).

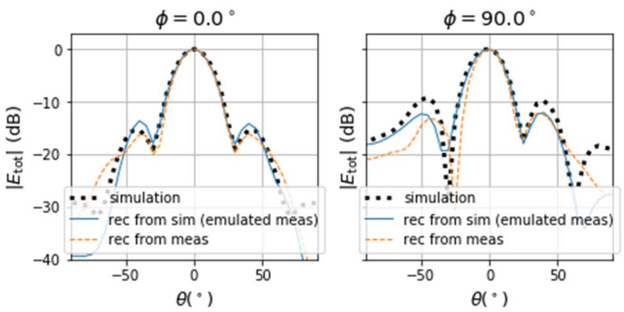

Figure 3. Far-field reconstruction from a measurement plane at λ/5.

5. Conclusions

A novel measurement system and a complete field reconstruction method with near-to-near and near-to-far field transformation have been developed for wireless devices transmitting at frequencies from 6 – 110 GHz. Measurements are taken at λ/5 distance from the antenna and the complete field distributions (near and far field) are compared against simulated results. The precision in the measurement plane is better than 1.4 dB and preliminary results indicate that the complete field can be reconstructed with similar accuracy. As a next step, we will determine a comprehensive uncertainty budget in arbitrary observation points that shall be validated by simulations and far-field measurement systems.

6. References

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