Field Reconstruction and Estimation of the Antenna Support Structure Effect on the Measurement Uncertainty of the BTS1940 Antenna

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***Abstract*—The 3D reconstruction algorithm of DIATOOL is applied to the BTS1940 antenna, recently measured at the DTU-ESA Spherical Near-Field Antenna Test Facility in Denmark. The antenna was measured mounted on the antenna tower through a custom support structure. The purpose of this paper is to investigate the effect of the support structure on the measured field, by reconstructing the currents induced on the support frame with DIATOOL. The field obtained by filtering these currents is presented. Moreover, the spatial resolution obtained by the 3D reconstruction is discussed and compared with the one obtained by traditional microwave holography and by the inverse Fourier transform of the plane wave spectrum with knowledge of the invisible region.**

***Index Terms*— antenna diagnostics; measurements; uncertainty**

I. INTRODUCTION

Accurate and general antenna diagnostics techniques have in recent years attracted the attention of the antenna measurements community. Several algorithms and two commercial software tools were developed in the past years with the purpose of identifying from the radiated measured field the electrical and mechanical errors affecting the performances of the antenna under test. DIATOOL from TICRA is one of the available commercial software tools. One of its key features is its 3D reconstruction algorithm, which, with its higher-order Method of Moments-based implementation, makes it possible to reconstruct field and equivalent surface currents on arbitrary 3D surfaces enclosing the antenna under test [1]-[2]. It is noted that the equivalent currents reconstructed by DIATOOL radiate the measured field outside the reconstruction surface and zero field inside.

An important feature of the 3D reconstruction algorithm of DIATOOL is the ability of identifying and computing the undesired sources of radiation, such as leaking feed lines and antenna support structures, which can affect the performances of the antenna. The support structure may have significant effect on the measured results for non-highly directive antennas having noticeable back radiation. A thorough investigation and quantification of this effect is in practice, however, a difficult and time consuming task, since at least one more measurement with another support structure is necessary; this only happens in a few special cases. The filtering capabilities of DIATOOL allow an alternative way of investigating this problem, obtaining a more accurate measured field [3]. The purpose of this work is to investigate and quantify the effect of the support structure on the measured antenna field of the BTS1940 antenna, recently measured at the DTU-ESA Spherical Near-Field Antenna Test Facility in Denmark.

The BTS1940 antenna is a 1 by 8 dual linearly polarized array of dipoles backed by cylindrical cups, of dimensions 1200 mm by 152 mm by 160 mm, working at 1.71-2.20 GHz. The diameter of each cup is slightly less than a wavelength. The BTS1940 antenna was measured on a full sphere at the DTU-ESA Facility, by mounting it to the antenna tower through a standard mounting frame, as shown in Figure 1. The support structure is a rectangular steel frame with outer dimensions of 190 mm by 190 mm by 285 mm. Ideally, the support structure should not affect the array radiation pattern. In practice, this could never be proven due to the impossibility of measuring the antenna without it.

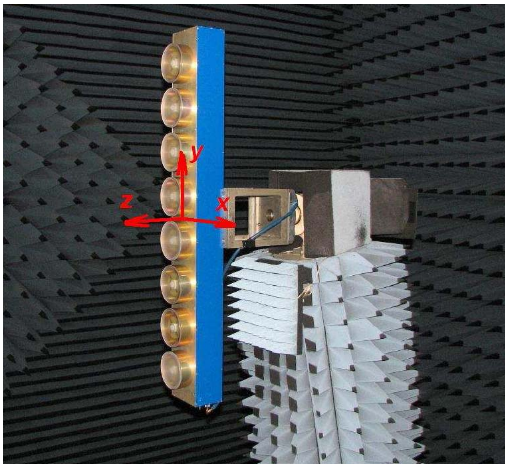

Figure 1. The BTS1940 antenna mounted on the antenna tower through the support frame with the measurement coordinate system highlighted.

II. EFFECT OF THE SUPPORT STRUCTURE

DIATOOL is thus used to reconstruct from the measured field the corresponding equivalent currents located on a closed surface conformal to the array and the support structure, see

Figure 2. It is noted that all eight elements can be clearly distinguished. The field radiated by the reconstructed currents is then compared with the input measured field, and, as expected, excellent agreement is obtained. In particular, the complex difference between the two fields shows an amplitude of around -30 dBi, or lower, over the [0, 130] deg theta domain, see Figure 3, and slightly higher in the backward direction. This difference corresponds to an equivalent error signal (EES) at -45 dB from the pattern peak, which results in ±0.05 dB peak-to-peak (pp) deviation or around 0.02 dB standard deviation (σ). These values agree very well with the expected measurement accuracy.

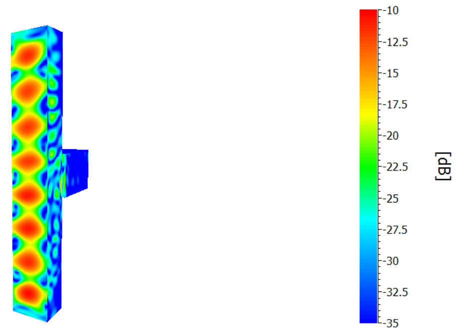

Figure 2. Amplitude of the *y*-component of the equivalent electric currents computed by the 3D reconstruction of DIATOOL, on a closed surface conformal to the array and the support structure.

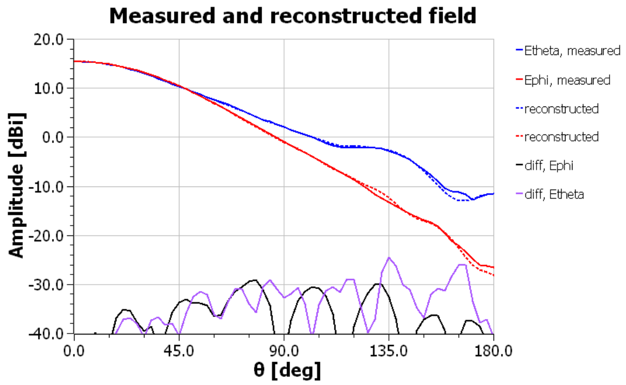

Figure 3. Measured pattern and field radiated by the reconstructed currents, together with their complex difference: phi=0 deg.

To prove that the currents located on the frame do contribute to the measured far-field, the currents reconstruction is repeated by considering as reconstruction surface only the closed box conformal to the array, disregarding the frame. The field obtained by the reconstructed currents is again compared with the input measured field, see Figure 4. It is seen that the complex difference is now about 10 dB higher than in Figure 3, meaning that the field radiated by the reconstructed currents gives a worse match with the input measured field, since the scattering from the support frame is ignored. This is also reported by DIATOOL and means, as we deduced by comparing Figure 4 with Figure 3, that some sources are not enclosed by the reconstruction surface. Within the 3 dB beamwidth the difference field is at the level of about -24 dBi, corresponding to an EES at -39 dB. The peak of the difference field reaches the level of about -21 dBi with the EES being -36 dB. The scattering from the support frame thus contributes with ±0.1 dB pp deviation or 0.03 dB (σ) within the main beam, and with ±0.14 dB pp deviation or 0.05 dB (σ) in the whole sphere.

An alternative approach is to impose the currents located on the frame and computed in Figure 2 as non-radiating. The field from the remaining currents is computed and compared again with the input measured field, see Figure 5. It is seen that the complex difference rises more than 10 dB for theta between 0 deg and 125 deg relative to Figure 3, reaching the value of -18 dBi. This corresponds to an EES at -33 dB, resulting in ±0.2 dB pp deviation of the measured pattern at the pattern peak level or 0.06 dB (σ). For theta between 125 deg and 180 deg the rise is even larger, around 15 dB. This last value can be explained by the fact that by removing the currents on the support frame, a hole is now present in the reconstruction surface, see Figure 6, meaning that the radiation in the back lobe becomes inaccurate.

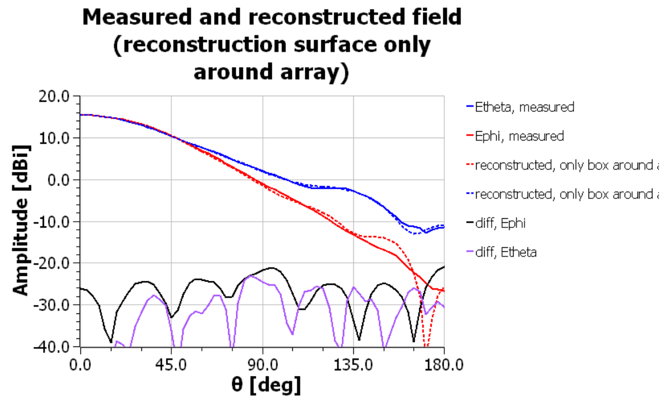

Figure 4. Measured pattern and field radiated by the reconstructed currents, together with their complex difference: phi=0 deg, reconstruction surface does not enclose the frame.

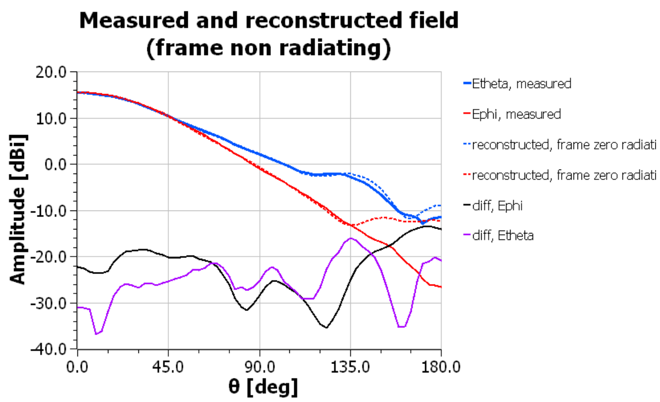

Figure 5. Measured pattern and field radiated by the reconstructed currents, together with their complex difference: phi=0 deg and frame non radiating.

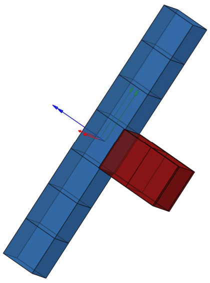

Figure 6. Closed conformal reconstruction surface used in the currents reconstruction of DIATOOL: the currents on the frame are imposed non-radiating and the structure is thus highlighted in red.

III. 3D RECONSTRUCTION VS. MICROWAVE HOLOGRAPHY

Finally, the equivalent currents are computed by traditional microwave holography on a rectangular plane coinciding with the top face of the reconstruction surface of Figure 2. The result is shown in Figure 7, and clearly shows that the eight array elements cannot be resolved. The higher spatial resolution achieved by the 3D reconstruction of DIATOOL in Figure 2 is due to the fact that the 3D reconstruction considers in its formulation the a-priori information that sources are confined inside the reconstruction surface, while microwave holography does not. The reconstruction surface conformal to the antenna becomes a physics-based filter.

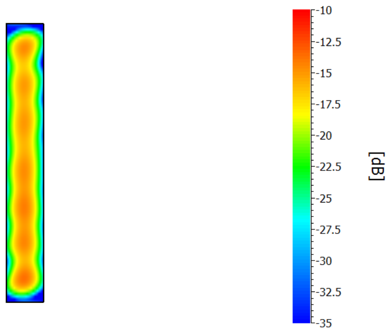

Figure 7. Amplitude of the y-component of the equivalent electric currents reconstructed by traditional microwave holography.

It is at this point interesting to compare the resolution of the 3D reconstruction with the one given by the SWE-to-PWE transformation [4], also implemented in DIATOOL. We know that the SWE of the measured field is affected by noise. The presence of noise implies that the SWE coefficients of the measured field can generally only reconstruct the plane wave spectrum in the visible region. The measured SWE coefficients are generally not accurate enough to reach convergence of the spectrum in the invisible region.The field is then obtained as inverse Fourier transform of the reconstructed plane wave spectrum. When the SWE-to-PWE of DIATOOL is used with the measured SWE as input, the result concides with Figure 7. On the other hand, the currents reconstructed by the 3D reconstruction of DIATOOL provide a field which is noise-free, see Figure 8, where the SWE of the field radiated by the reconstructed currents of Figure 2 is compared with the SWE of the measured field of the AUT. It is seen that the measurement noise floor at -60 dB is removed and substituted by a numerical noise floor at -250 dB.

When the SWE-to-PWE of DIATOOL is used with the noise-free SWE of the reconstructed field as input, i.e. the blue curve of Figure 8, we obtain the results shown in Figure 9. The SWE of the reconstructed field now allows one recovering a large part of the invisible region of the plane wave spectrum. By comparing Figure 9 with Figure 7 we see that with the recovery of the invisible region the resolution has clearly improved. Moreover, by comparing Figure 9 with Figure 2 we observe that the two images coincide. The resolution obtained by the SWE-to-PWE reconstruction (planar reconstruction) of DIATOOL with the recovery of the invisible region of the plane wave spectrum is equivalent to the resolution of the 3D reconstruction. Both are definitely higher than the resolution achieved by traditional microwave holography, where the invisible region of the spectrum is always disregarded.

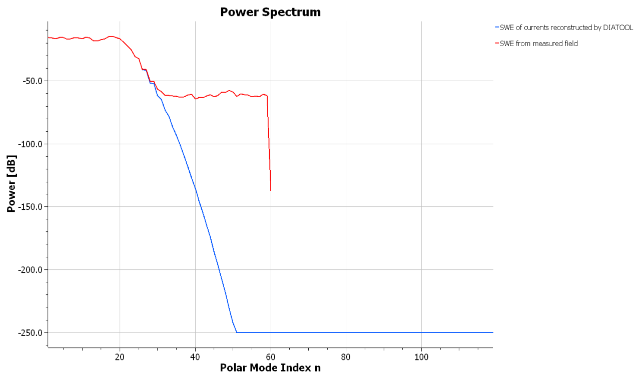

Figure 8. Power spectrum of SWE of the measured field of the BTS1940 antenna, in red, and of the SWE of the field radiated by the reconstructed currents of Figure 2, in blue.

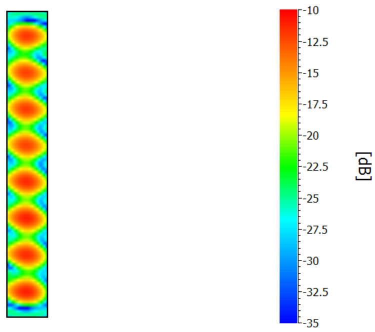

Figure 9. Amplitude of the y-component of the equivalent electric currents reconstructed by the SWE-to-PWE reconstruction of DIATOOL when the invisible region of the plane wave spectrum is recovered.

IV. CONCLUSIONS

Presently available commercial software tools allow a detailed investigation of the equivalent surface currents on arbitrary 3D surface enclosing the antenna under test. An important and useful feature of these software tools is the ability of identifying and filtering the undesired sources of radiation, such as leaking feed lines and support structures.

The 3D reconstruction algorithm of DIATOOL was applied to the BTS1940 antenna with the purpose of investigating and quantifying the effect of the support frame on the measured radiation pattern. The scattering from the support frame can be estimated either in terms of peak-to-peak deviation or the standard deviation, easily applicable in the uncertainty budget calculation. For the BTS1940 antenna the effect of the support frame was found as being between 0.03-0.06 dB (σ) depending on the used approach.

The 3D reconstruction algorithm of DIATOOL provides a spatial resolution in the reconstructed currents which is higher than the one given by traditional microwave holography. All array elements could be resolved by the 3D reconstruction, while this is not the case with microwave holography. This is a general observation and is due to the fact that the 3D reconstruction considers in its formulation the a-priori information that sources are confined inside the reconstruction surface, while microwave holography does not. It was finally shown that the SWE of the field radiated by the equivalent currents reconstructed by the 3D reconstruction is noise-free and allows the recovery of the plane wave spectrum in the invisible region.

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