B-1-2 DESIGN OF SPHERICAL NEAR-FIELD TEST FACILITY [*)]

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The ever increasing demands for antenna performance causes correspondingly increasing requirements to the antenna testing. For large antenna structures the near-field test techniques are very attractive and offer higher accuracy than may be obtained by conventional far-field testing. The requirements to the equipment are exacting with respect to the tolerances of acceptable inaccuracies. Thus it is important to be in a position to perform a proper test facility design in which a trade off between the various inaccuracies are carried out.

The principle of the near-field techniques (NFT) is that the near field of the test antenna is probed and the far field is obtained by proper computations. According to the surface over which the near field is probed, the techniques are denoted PNFT, CNFT and SNFT for the planar, the cylindrical and the spherical near-field technique, respectively. During previous studies the SNFT has been selected by the European Space Agency at an experimental NFT facility to be implemented in the Radio Anechoic Chamber at the Technical University of Denmark for satellite antenna testing. Experiments have been carried out with conventional equipment for demonstration of the SNFT; it was found that the critical areas with respect to the obtainable accuracy are the stiffness of the mechanical system and the accuracy and the stability of the receiver (Jensen et al. 1976).

As a tool to get reliable tolerances for the design of the test facility, a computer-program simulator has been found valuable due to the generality and the flexibility. By means of a facility simulator it is possible to generate the theoretical near field of a realistic test antenna, to compute the far field by a near-field to far-field transformation, and to compare this far-field to the theoretical far-field of the test antenna. Thus it is possible to evaluate the accuracy of the applied near-field technique; however of special importance for the design of a test facility, it is further possible to simulate any combination of inaccuracies and tolerances of the complete measurement set-up and of the measurement procedure, and to compare the accuracies of the obtained far fields. In this way any inaccuracies and tolerances may be evaluated directly.

During studies for European Space Agency preliminary facility simulations have been performed. Some of the obtained results are reported in the following (Jensen et al. 1976, Bach et al. 1978).

The mechanical system to be designed is based on an antenna tower (elevation over azimuth) as conventionally applied for far-field testing: The probe is fixed and the test antenna is rotated around two perpendicular axes resulting in a θ-ϕ spherical scan of the field, cf. fig. 1. The facility simulator is based on this type of set-up but may easily be modified to simulate a set-up in which the test antenna is rotated around a vertical axis and the probe is moved around a horizontal axis by a gantry arm or following a circular rail. This type of set-up is especially important for testing of satellite antennas which are not allowed to be rotated with respect to the direction of gravity.

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The most critical mechanical inaccuracies are the intersection (Δy_a) of the axes of rotation in a right-angle (β_a), the aligment of the probe (Δy_p, Δz_p, β_p) and the accuracy of the sample point position ($\Delta\theta$,$\Delta\phi$), cf. fig. 1.

While the mechanical system has to be designed according to the resultant tolerances it was decided to select the receiver as an off-the-shelf component (Scientific-Atlanta, Inc. 1771-I-M three-channel receiver) and to simulate and evaluate the performance on basis of the manufacturers worst-case specifications. A logarithmic mode (60 dB dynamic range) and a linear mode were simulated. The receiver was investigated with respect to amplitude and phase unlinearities, thermal noise, cross talk, aging, temperature drift, measurement delay and measurement response time of which the two last mentioned items caused the most severe inaccuracy.

The measurement delay is caused by the finite measurement period at each sample "point": Since a continuous rotation of the test antenna is assumed, the sampled field value represents the field "after" the desired sample point. The measurement response time, on the other hand, represent a tardiness of the system tending towards the sampled field value represents the field "before" the desired sample point. By a proper calibration it is shown that the two effects partially may cancel each other.

The simulations - so far - have been carried out for two relatively small test antennas. The test antennas are 3-dimensional linear arrays of diameter 2.5 and 3.9 wavelengths and with directivity 10.5 and 21.0 dBi, respectively. The design requirements applied to the near-field test facility are summarized in table 1. The obtained requirements to the mechanical system are summarized in table 2 under the assumption that all inaccuracies contribute with the same amount to each far-field parameter. The consequences of the receiver performance are tabulated in table 3.

It is found that the requirements to the mechanical system are exacting but possible to reach within existing technology. For the receiver it is concluded that performance according to the manufacturers specifications are not accurate enough to fulfill the requirements to the SNFT facility. It will, however, be possible to calibrate for a substantial part of these inaccuracies.

The results are obtained on the basis of preliminary simulations and the stated conclusions shall be taken as guidelines only. Detailed simulations are planned in order to clarify the critical points in the design of a test facility. It is expected that some of the tolerances will be slackened hereby, and that it will be possible to design an SNFT test facility of the desired accuracy from off-the-shelf products.

References

H. Bach, E. Lintz Christensen, J. Hansen, Frank Jensen, F.H. Larsen, O. Sørensen and J. Voldby, 1978,
"Study and development of near-field test methods for antennas",
Final report on ESTEC contract 2955/76, Report R. 194, Electromagnetics Institute, Technical University of Denmark, Lyngby, Denmark, January 1978

Frank Jensen, Flemming Holm Larsen and Knud Pontoppidan, 1976,
"Development of spherical near-field far-field antenna test technique",
TICRA report S-4502, Final report on ESTEC contract 2478/75 AK,
TICRA, Copenhagen, Denmark, November 1976

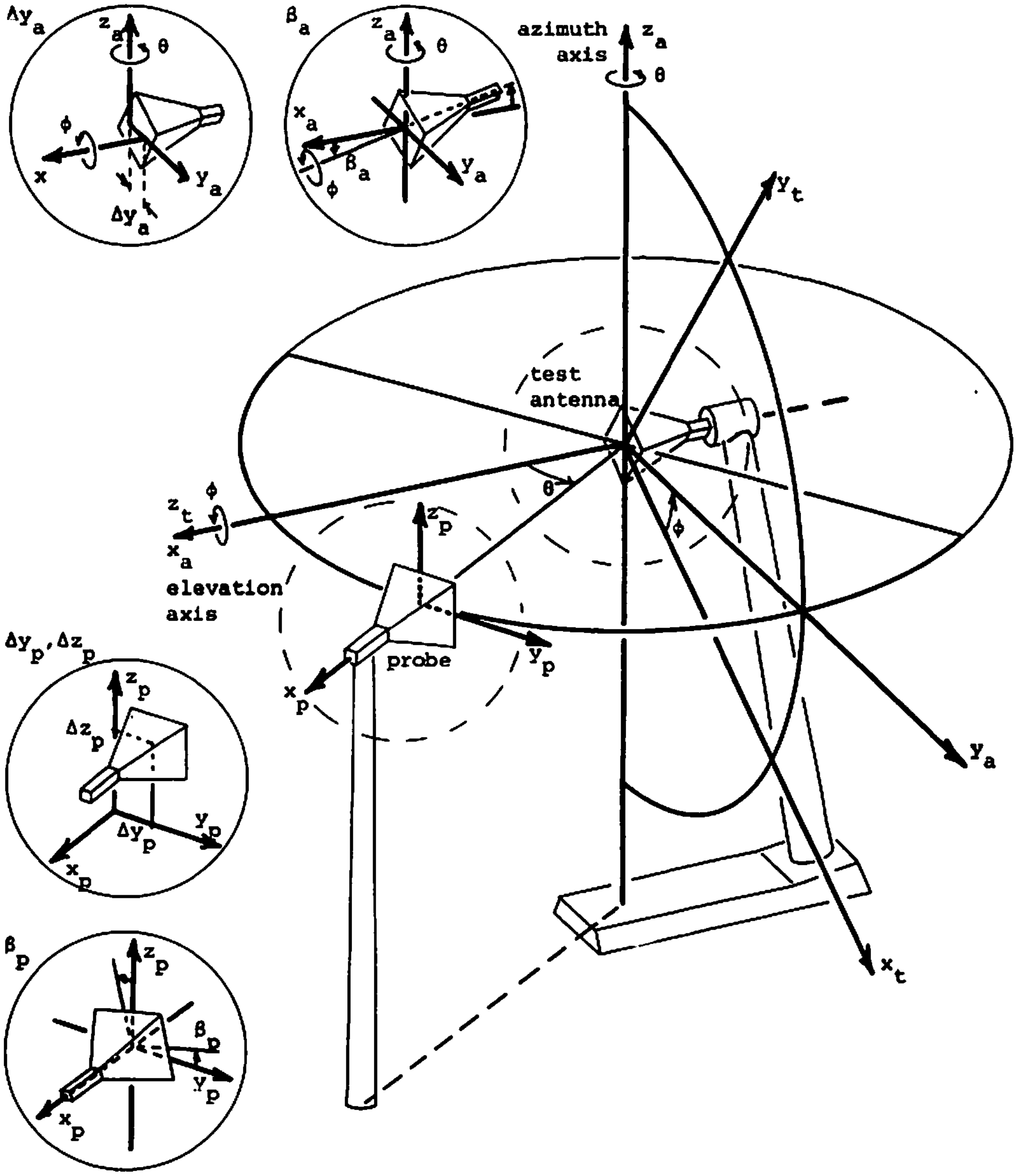

Figure 1. The mechanical measurement system. Simulated measurement inaccuracies are illustrated in the circles:

Δy_a: non-intersecting axes of rotation,
β_a: axes of rotation intersect at an oblique angle,
$\Delta y_p, \Delta z_p$: misplaced probe, correct orientation,
β_p: tilted probe.
Further, inaccuracies $\Delta\theta$ in θ and $\Delta\phi$ in ϕ have been simulated.

Far-field parameter	Design requirements for the test antennas	
	10.5 dB antenna	21.0 dB antenna
Directivity accuracy	±0.5 dB	±0.1 dB
Cross-polarization accuracy at level -7 dB	±0.5 dB	-
-45 dB	-	±2 dB
Side-lobe accuracy at level -20 dB	±0.5 dB	-
-25 dB	-	±0.5 dB

Table 1. Design requirements to performance of test facility.

Accuracy requirements to	Maximum allowable inaccuracy at X-band
Intersection of axes of rotation (Δy_a)	0.04 mm
angle between axes of rotation (β_a)	0.12°
transverse probe position ($\Delta y_p, \Delta z_p$)	0.09 mm
probe tilt (β_p)	0.013°
sample point position ($\Delta\theta, \Delta\phi$)	0.08° at 10° spacing

Table 2. Mechanical specifications to test facility when all inaccuracies are assumed to contribute equally.

Far-field parameter	Total receiver inaccuracies (10 samples per second)	
	logarithmic mode	linear mode
Directivity increase	0.057 dB	0.032 dB
Cross-polarization accuracy at level -7 dB	±0.03 dB	±0.07 dB
-45 dB	±2.4 dB	±6.7 dB
Side-lobe accuracy at level -20 dB	±1.4 dB	±1.7 dB
-25 dB	±2.5 dB	±3.1 dB

Table 3. Far-field inaccuracies caused by the receiver. When compared to table 1 allowance must be made for mechanical and other inaccuracies.