DESIGN AND VALIDATION OF A GENERAL PURPOSE NEAR-FIELD ANTENNA MEASUREMENT FACILITY FOR THE ROYAL NETHERLANDS NAVY

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ABSTRACT

This paper describes a new multi-purpose planar & cylindrical near-field antenna test facility installed at the Royal Netherlands Navy (RNN). In this paper an overview is given of the initial list of requirements that was generated and the process of selecting the best type of measurement facility to address these. A description of the facility is given and an outline of the accuracy of the planar/cylindrical near-field scanner is presented. The paper contains details of the extensive validation program and measured data demonstrating the performance of the system.

Keywords: Near-field, General purpose antenna facility, Cylindrical near-field.

1. INTRODUCTION

In this paper a new multi-purpose planar & cylindrical near-field antenna test facility installed at the Royal Netherlands Navy, is described. This antenna test facility was designed and built for the evaluation of all operational microwave antennas currently used in the Royal Netherlands Navy. In this paper an overview is given of the initial list of requirements that was generated and the process of selecting the best type of measurement facility to address these (i.e. outdoor far-field, compact range or near-field). Complicating factors like the wide frequency range (.5 to 40 GHz) and the wide range of antenna dimensions (from 10 cm circular apertures to 8m rectangular array apertures) are addressed. Dealing with high radiated power levels from phased array radar antennas was also considered and this is described from both a shielding and absorber point of view. A description of the facility is given and an outline of the accuracy of the planar/cylindrical near-field scanner (built by NSI) is presented. The paper contains details of the extensive validation program and measured data demonstrating the performance of the system will be presented. For the latter purpose a reference antenna supplied by the European Space Agency was used, as well as other operational antennas. Lessons learnt during the validation exercise, especially in the field of accuracy enhancements with a laser-system and in the comparison between planar and cylindrical data will be presented.

Section 2 contains an overview of the original requirement that drove the procurement of the facility. In Section 3 a description of the system tradeoffs is presented. The near-field system achieved specifications are described in Section 4 and validation tests are described and results presented in Section 5.

2. ROYAL NETHERLANDS NAVY REQUIREMENT

The Netherlands Navy has a wide range of microwave antennas in use on their fleet. The applications vary and include low-frequency long-range search radar antennas, high-frequency tracking radar antennas, EW-antennas and antennas for satellite communications. The operational antennas are refurbished regularly and this process requires the removal of the unit from the platform every 5 to 6 years of service. This service is provided by the SEWACO-Establishment, where all parts are inspected, repaired and finally tested before it is reinstalled. The final testing of antennas was for years limited to checking the mechanical dimensions and alignment and only when a serious problem was detected were the antenna patterns measured. In these cases the antennas were sent to an outdoor range which is located more than 160km away from the maintenance facility. These restrictive conditions and a continuous increase in the complexity and performance of systems lead to the formulation of a need for an indoor test facility as part of the Navy maintenance facility. In order to address the wide range of antennas and also the range of parameters of interest for the Navy the following technical requirements were compiled:

Frequency Range:	1GHz to 35GHz
Typical antenna gain:	7dBi to > 40dBi
Antenna aperture size:	10cm to 8m
Antenna weight:	1kg to almost 10000kg
Max Radiated Power:	Several kilowatts
Side lobe-level:	-50dB

The objective was also set to test and evaluate the antennas during their operational lifecycle to ensure continued performance. The facility would therefore play a very active role in scheduled maintenance tasks and not only serve as a one time evaluation tool. It was also decided that the test facility should be located in a new building co-located with all the workshops for radar, fire-control and EW-systems. (The advantage here was that the design of a new building was not finalized at that time so that it could be customized for some of the requirements for an antenna test site.)

3. SYSTEM TRADEOFFS

The initial objective of the Navy was to design an outdoor far-field test range. This would have been in line with the historical approach and appeared to be a low risk option. The disadvantage of this approach was the limited available real estate and the growing number of buildings that would have impeded measurement accuracy. A growing concern for external radar interference and security aspects also detracted from an outdoor facility and eventually lead to the decision to opt for an indoor system.

This decision ruled out a far-field approach and therefore a compact range or near-field test facility had to be considered. In order to gain as much information about these as possible a number of facilities were visited and valuable information was obtained in this way. It was concluded that the main advantage of a compact range is the that it provides a real-time antenna response. The disadvantages are the size of the reflector(s) and the requirement for high power absorber on all the walls of the chamber (for high power testing). Initial calculations pointed out that for the Navy applications a reflector with a diameter of at least 15m would have been required, which in turn would have dictated a chamber with total absorber area of about 3000m². These facts indicated that the compact range would have exceeded the available budget by far.

Considering planar near-field measurements the advantage of having the AUT stationary was obvious. No positioner was required and the required space was small enough so that it could be incorporated in an existing building with less absorber and only limited areas covered with high power absorber. The disadvantages, however, are that no real-time data can be measured and far-field data can only be calculated after completion of a complete near-field scan. The angular limitation of a planar near-field facility should also be noted. A combination planar/cylindrical near-field range overcomes this problem though.

This information indicated that a near-field system best met the requirements of the Royal Netherlands Navy and could be built on the most cost-effective base. The decision was made to continue the procurement for a near-field test facility for antenna measurements and an order was placed for a shielded anechoic chamber and a separate order was placed for a complete near-field test-system, including scanner, azimuth-positioner, RF-equipment and a control- and processing system. The contract for the building was extended with specific requirements for foundation, cooling system, power and a hoisting system.

4. SYSTEM DESCRIPTION

4.1. SHIELDED ANECHOIC CHAMBER DESCRIPTION & SPECIFICATION

The shielded anechoic chamber built by EEMC for RNN consists of a free-standing steel structure to which wall panels were mounted. These panels are a foam-filled metal sandwich construction (refrigeration panels were used) to ensure a complete metallic enclosure around the near-field test system. Main dimensions of the chamber are 14m(l) x 11m(w) x 9.5m(h) and it has two 7m high automatic access doors as shown in Figure 1. A separate shielded Control Room is located along one of the side-walls. Points of special interest are the large doors for the AUT's, the moving ceiling (visible in Figure 2) for access of the hoisting system and the in- and outlets for the cooling system. The chamber was constructed in such a way that a shielding of at least 40dB could be obtained for frequencies between 1 GHz and 40 GHz. The cooling system was designed to assure a stable temperature without large stratification over the scanner height even under high transmit power conditions. The inside of the shielded room is covered with absorber to prevent reflections from the walls. Special attention was given to new designed high power absorber in an area on the back wall. These absorbers are air-cooled and capable to withstand power levels more than 1.5 W/cm² (about 10W/sq.in). Delivery of the absorber and measurement of the shielding and reflectivity performance was done by Emerson & Cumming, a subcontractor from EEMC.

4.2. NEAR-FIELD FACILITY DESCRIPTION & SPECIFICATION

The near-field measurement facility built by NSI for RNN is a planar and cylindrical combination range. The planar scanner and azimuth positioner are located on a solid T-shaped foundation, 1.5m thick, laid on a separate sand-layer isolated from the rest of the building to suppress vibrations. The planar scanner (depicted in Figure 3) has a total probe travel of 9m(x) x 6.4m(y) and has a planarity of better than 25µm rms. The scanner also allows an additional 2m movement of the tower into a corner “pocket” of the chamber to hide the structure in cases where the chamber is to be used for EMC type measurements. The scanner has a structure monitoring laser feedback system that allows regular checking of the mechanical integrity and active position feedback for the probe carriage. The scanner is also fitted with high power absorber to measure active antennas operating at full radiated power. The azimuth positioner is mounted on a heavy duty linear slide which allows adjustment of the AUT to probe separation distance and also is used as transportation facility of antennas into the chamber (the crane does not reach the full depth of the chamber).

The RF system is based on a dual source HP8530 system with remote mixers and allows operation up to 40 GHz. It has a pulse capability allowing pulsed RF measurement and is reconfigurable for AUT receive or AUT transmit. A pin-diode switch matrix allows measurement of four ports on the antenna simultaneously. The scanner, RF equipment and laser equipment is controlled by NSI software.

The facility has proven performance specifications that allow gain to be measured with an uncertainty of 0.25dB, -45dB side lobes with an uncertainty of 3dB, -30dB cross-polarization levels with an uncertainty of 3dB and boresight accuracy to within 0.02 degrees uncertainty. These performance figures were verified using a number of different antenna types operating in different frequency bands.

5. VALIDATION TEST RESULTS

Validation of the RNN planar/cylindrical near-field facility consisted of three separate tests. The first (Antenna #1) was the testing of a Navy dual band (X & Ka-band) tracking antenna for which far-field radiation pattern data was available. The second (Antenna #2) was the testing of an ESA/ESTEC X-band (VAST12) offset reflector antenna (shown mounted in the chamber in Figure 4) for which comparative spherical near-field test data was available. The third (Antenna #3) was an L-band Navy linear array (shown mounted in the chamber in Figure 5) which was chosen to evaluate the low frequency performance of the facility. The philosophy of the validation exercise was to measure a host of antennas in different configurations in both planar and cylindrical modes and different frequency bands and to perform more than one inter-range comparison to improve confidence in the facility performance.

For Antenna #1 (the dual band tracking antenna) the three ports on the unit were measured simultaneously during a single planar near-field scan. From this data sum and difference patterns were extracted and compared to far-field pattern data. Measurements were performed for the antenna in different configurations in both frequency bands and a NIST 18 term error budget [1] was compiled based on these tests.

For Antenna #2 radiation patterns were measured for the antenna mounted upright, 90 degrees rotated and 10 degrees offset in azimuth in planar near-field mode. The radiation patterns were also measured in cylindrical near-field mode. This data was compared to radiation pattern data obtained from spherical near-field results obtained at another test facility. Measurements were performed for multiple AUT to probe separation distances in order to ensure acceptable levels of reflection from the probe structure. RF leakage tests and scan aperture truncation tests were performed. In order to check chamber reflection levels multiple AUT down range locations were again used for testing, while keeping the probe to AUT separation distance fixed. For this frequency band 18-term error budgets were compiled for antenna gain, -45 dB side lobe level, -30 dB cross-polarization levels, beamwidth and boresight error. In Figure 6 comparative radiation pattern data is shown for Antenna #2 as obtained in the RNN facility. The patterns shown are for the AUT mounted in the normal fashion and rotated in azimuth by 20 degrees.

6. CONCLUSION

We have described in this paper what the requirements were for an antenna test facility for the Royal Netherlands Navy. The typical systems tradeoffs that were performed have been described and the fact that a planar/cylindrical near-field test facility was chosen to overcome the fundamental angular limitation of a planar near-field facility was pointed out. The facility characteristics were presented and the validation process described. Overall it can be stated that the facility is a general purpose test site allowing a wide range of antennas to be tested and the extensive validation program has allowed detailed characterization of errors. Inter-range comparison data wil be presented to demonstrate the successful operation of the facility.

REFERENCES

[1] A C Newell, ”Error Analysis Techniques for Planar Near-Field Measurements”, IEEE Trans. Antennas & Propagation, Vol. 36, No. 6, pp 754-767, June 1988.

8. FIGURES

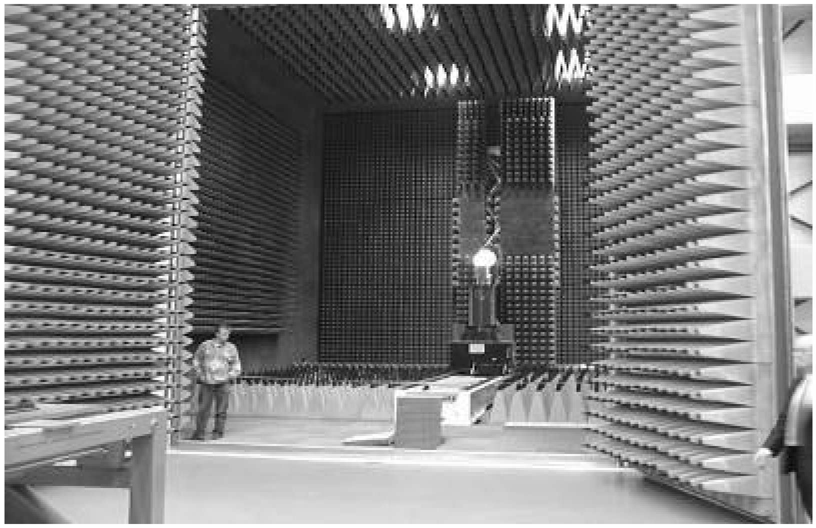

Figure 1 A view of the Dutch Navy facility with the 7m automatic access doors open.

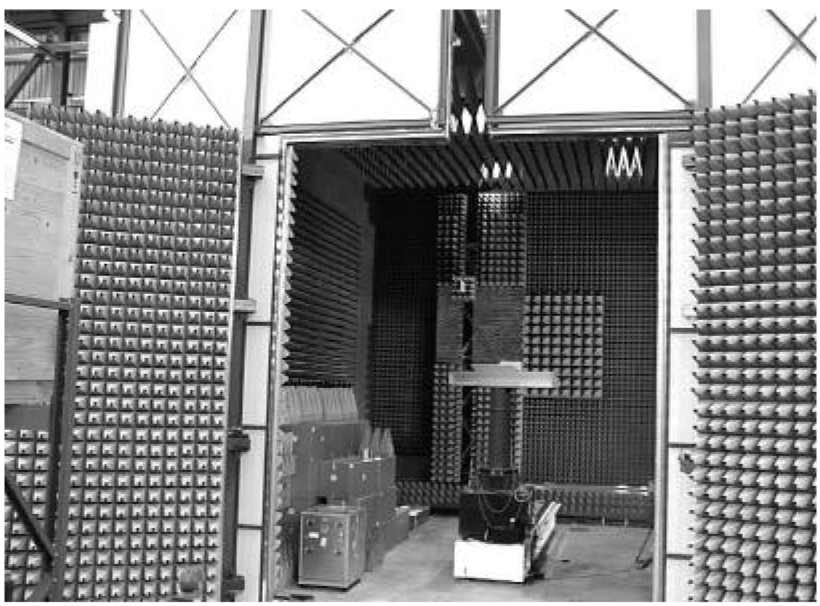

Figure 2 The chamber slotted ceiling allowing crane access is shown.

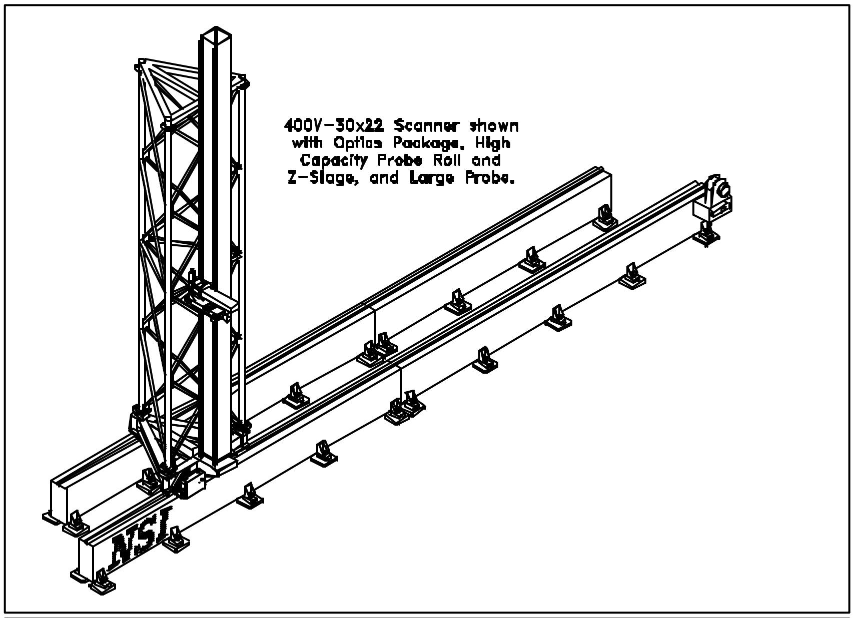

Figure 3 A drawing of the 9m x 6.4m planar scanner.

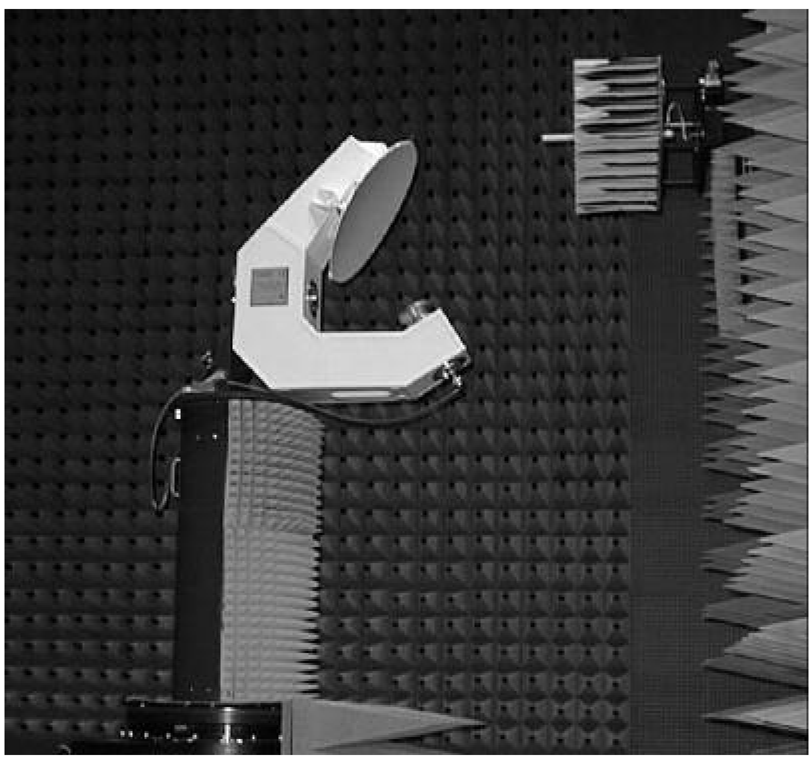

Figure 4 The ESA/ESTEC Vast12 antenna (used for chamber validation) is shown mounted in the chamber. Note the high power probe absorber.

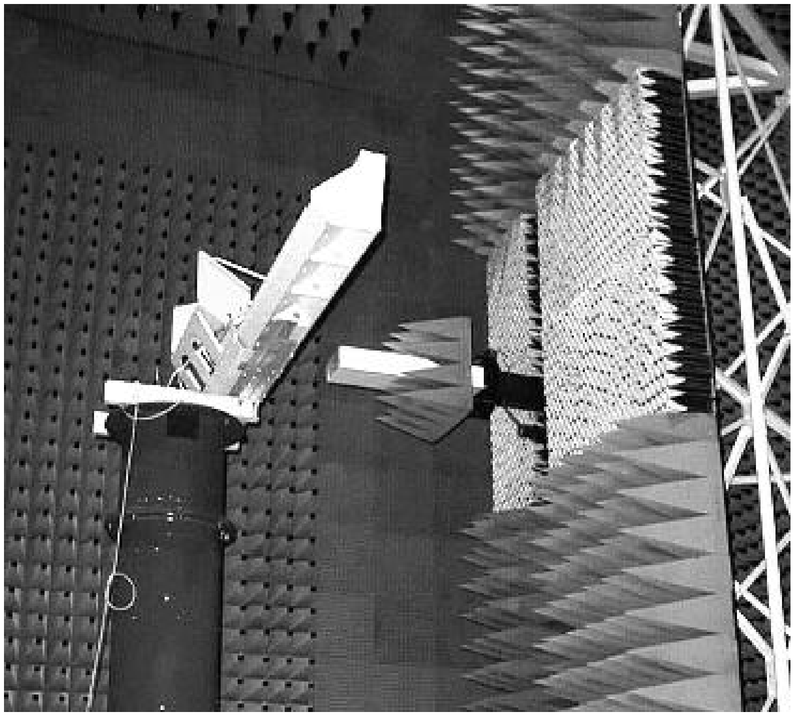

Figure 5 The linear array (Antenna #3) shown mounted in the RNN chamber.

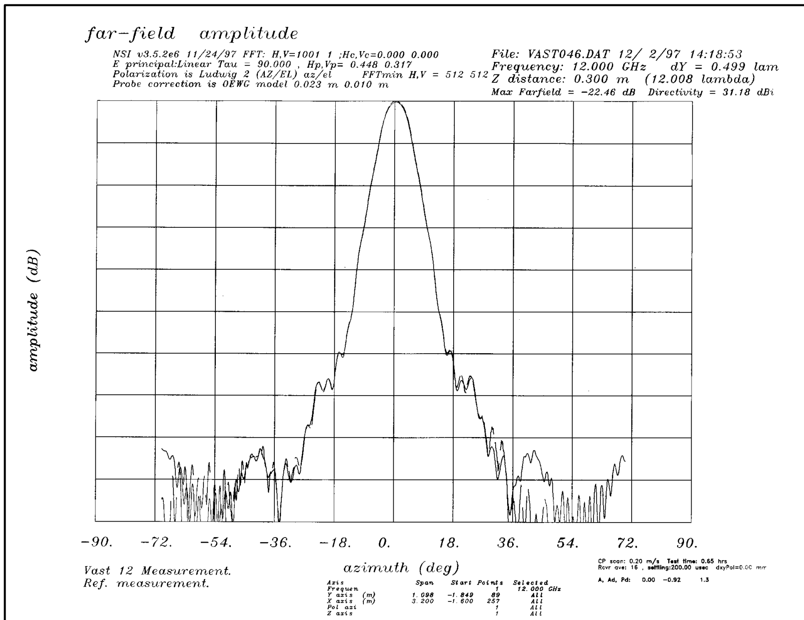

Figure 6 Far-field azimuth reference pattern and pattern for the AUT #2 offset by -20 degrees in azimuth are shown superimposed as part of the system validation testing. (The offset pattern is shown shifted back to 0 here for comparison purposes.)