

REVOLUTIONARY NEW OUTDOOR TESTING WITH A MOBILE AIRBORNE NEARFIELD TEST FACILITY (ANTF)*

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ABSTRACT

This paper will draw the attention to a revolutionary new, extremely mobile and flexible approach on a nearfield test facility concept for outdoor measurements. After addressing the current measurement dilemma, the potential measurement objects are indicated, covering application areas in telecommunication, defense, air traffic management, research and verification of outdoor antenna & RCS test facilities. Further an outlook will be given on the future and urgent necessity on measurements of the radiated performances of outdoor antenna installations.

The presented antenna test facility is based on a remote-controlled and floating platform, enabling probing of electromagnetic fields within relatively large air volumes of up to 100 x 100 x 100 meters. In combination with precise position techniques, accurate measurements of up to 20 GHz are considered to be achievable. The design philosophy and system concept will be explained. The paper concludes with a prediction on the system performance and with a brief realization schedule.

The proposed ANTF concept will allow detailed radiation analyses in unprecedented depth and quality, representing a real breakthrough in characterizing electromagnetic fields in open air test sites (OATS).

Keywords: Nearfield antenna measurements, farfield antenna measurements, mobile antenna & RCS measurement facilities, verification of outdoor antenna & RCS test facilities, open air test sites, OATS, ANTF, CNTF, airborne nearfield test facility, UAV, antenna test, antenna measurements, characterization of electromagnetic fields, radiated performance, outdoor antenna measurements, nearfield scanning, nearfield probing, positioner, scanner, Near-field, Far-field

1. INTRODUCTION

In May 1994 Astrium GmbH, EADS former Dasa / MBB Munich, delivered the so called Cylindrical Nearfield Test Facility (CNTF), which distinguishes from common Antenna Nearfield Test Facilities by its 36m high diamond shaped concrete tower and its outdoor operation for industrial production testing mainly for large Air Traffic Management Radar Antennas. The CNTF, located in open air, allows precise characterization of radiated performances of large reflector and array antennas, since restrictions due to the sizes of anechoic chambers are overcome.

However, even for the CNTF but also for other kinds of outdoor antenna test ranges, such as farfield ranges, one major drawback could not be solved until today prohibiting on-site antenna measurements of the numerous large antenna installations worldwide: The stationary property of those facilities. Figure 1 illustrates the measurement dilemma.

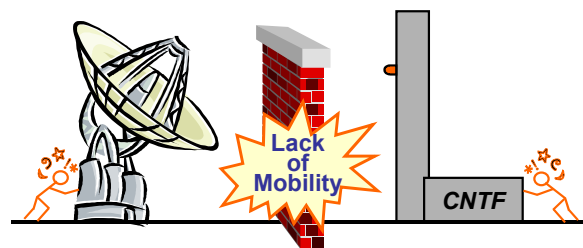


Figure 1 - The Measurement Dilemma

During the recent years engineers of the Astrium Antenna Department in Munich investigated quite intensively on methods to overcome the drawback of stationary antenna measurement facilities. Thanks to the rapid developments of the Unmanned Aerial Vehicles (UAVs) technologies the basic idea of the Airborne Nearfield Test Facility (ANTF) could be derived out of those. The ANTF concept implies a remote-controlled gyroplane serving as an extremely

mobile nearfield scanner performing precise antenna measurements of large stationary RF-installations, such as:

- ATM Radar antennas
- Airport navigation aid antennas
- Aircraft and vehicle Radar and telecommunication antennas
- Coastal Radar antennas
- Ship Radar and telecommunication antennas
- Combat Radar antennas
- Antennas for electromagnetic combat/jamming
- Antennas for intelligence services and signal reconnaissance
- Large RCS objects
- Large scattering objects, e.g. airport buildings
- Radio astronomy antennas
- Satellite groundstation antennas
- Broadcast antennas
- Cellular basestation antenna farms
- Shortwave antennas
- Outdoor antenna & RCS test facilities

The precise knowledge of the radiated performance of an antenna or RF-installation could be quite beneficial over the entire life cycle of the installation, such as during system development, system installation and optimization, system handover and acceptance, system modifications and upgrades. But also due to health, security and economical reasons the periodic verification of the radiated performances of those systems in more quantity and better quality might become crucial in view of the massive increase of spectrum users. Reasons for the degradation of the radiation characteristic could be multifarious, such as: aging, wear, pollution, damage by storm or lightning, destruction by animals, failure due to faulty operation and changes of the surrounding.

Responsible authorities might be forced to rethink their monitoring philosophy of the radiated RF-performances of antenna installations. Currently applied methods of spectrum monitoring are either performed by stationary or mobile facilities addressing all antenna installations which can be reached from the location of a monitoring facility. This allows the derivation of radiated field strengths of the antenna installations for the relevant direction towards the monitoring facility, which means only for one specific azimuth and elevation angle. Radiation measurements towards directions, which are not accessible by the mobile monitoring facilities, e.g. off-road locations or locations above surface, e.g. high-rise office buildings or even airplanes, can not be performed. The use of the ANTF, which is able to completely characterize the radiated RF-performance of

an antenna installation on-site, could significantly help to fill such gaps of information.

A typical measurement configuration is shown in Figure 2 indicating the remote controlled ANTF gyroplane guided by the laser beams of six tracking laser theodolites in front of a large active array antenna and the planar nearfield to be scanned.

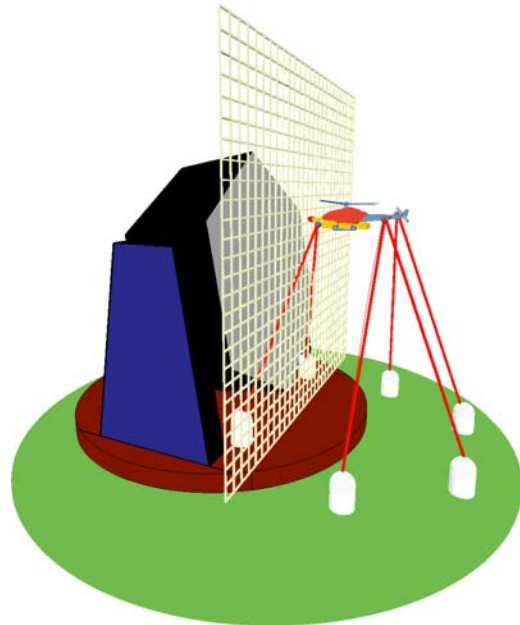


Figure 2 - Typical ANTF Measurement Configuration

2. DESIGN PHILOSOPHY

The driving parameters for the ANTF can be condensed to the following four design goals:

- Mobility
- Flexibility
- Accuracy
- Speed

To ensure, that most of the existing antenna installations can be physically reached by the ANTF, a high degree of mobility is required. The major contribution to the mobility is the system concept itself. Since even large air volumes can be accessed, the amount of required hardware is small compared to conventional and stationary antenna test facilities, where large steel constructions are dominant. Further the system design will ensure, that the ANTF transport containers can be shipped by air cargo and that the transport of the containers for the last meters to the antenna installation can be performed by a two man lift.

As explained in the introduction, a wide range of types of antenna and RF-installations can be addressed with the ANTF, which also requires a high degree on measurement flexibility. The ANTF as a fully developed system should be able to perform the following measurement parameters:

- Nearfield and farfield measurements
- Planar, cylindrical and spherical measurement contours
- Frequency spectrum towards 20 GHz
- Measurement of linear and circular polarization
- Measurement of cross-polarization
- Measurement of receive or transmit modes or both modes at the same time for RCS measurements
- Measurement in continuous, pulsed or chirped signal modes

Further the system needs to be able to operate and to deliver acceptable measurement results at certain wind speeds.

Measurement accuracy for nearfield measurements mainly depends on the position accuracy of the probe when conventional nearfield methods are applied. In case of more advanced nearfield measurement methods the precise knowledge of the measurement positions needs to be known, but the probe does not need accurately to be positioned in respect to the measurement contour and its grid points. To achieve this performance special attention is drawn to the position measurement sensors and the flight control.

Concerning speed there are two areas to be considered:

- The measurement speed of the system, which is directly linked to the maximum flight speed of the gyroplane within the given flight corridor as the scan length of a data collection of large measurement objects at higher frequency could be in the order of several tens of kilometers. To perform measurements within an acceptable time frame the max. flight speed should be in the order of up to 1.0 meter per second.
- Quick system transportation and installation should not be a critical issue because of the few required hardware and its air cargo compatible transport container dimensions.

3. SYSTEM CONCEPT

The ANTF system concept is subdivided into the following three subsystem concepts:

- Positioner Subsystem Concept
- RF-Subsystem Concept
- Measurement Control & Processing Subsystem Concept

The positioner-subsystem is the most characteristic part of the ANTF, consisting of a remote controlled gyroplane serving as probe positioner.

The RF on-board equipment needs to be weight optimized and compliant to flight requirements, whereas the RF ground equipment as well as the measurement control & processing subsystem comply to standard equipment.

Figure 3 shows the hierarchy of the ANTF system concept.

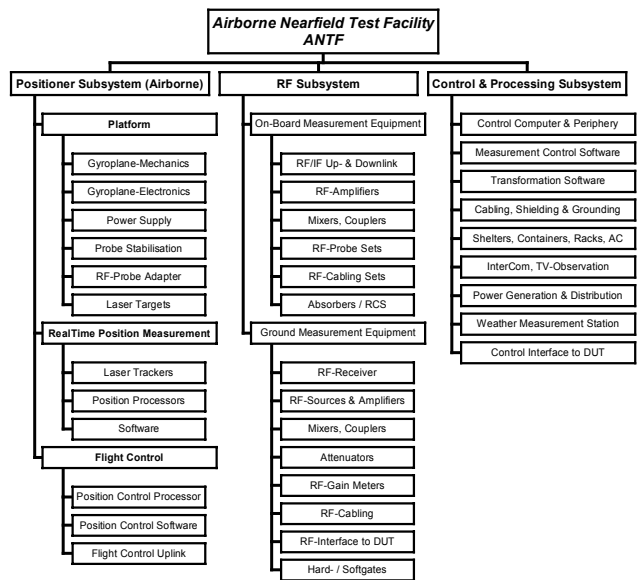


Figure 3 - ANTF-System Hierarchy

3.1 POSITIONER-SUBSYSTEM CONCEPT

The airborne positioner subsystem consists of three items:

- The floating platform
- The real time position measurement equipment
- The flight control equipment

Figure 4 shows a functional diagram of the Positioner Subsystem.

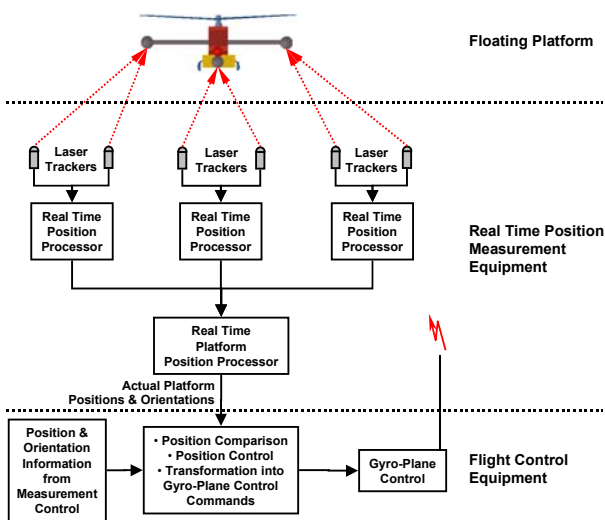


Figure 4 - Functional Diagram of the Positioner Subsystem

The floating platform is equipped with three laser reflectors, which positions are tracked by as a minimum of six laser theodolites. The highly accurate angle information of the laser theodolites will be processed in real time into the six degrees of freedom of the floating platform. This information will be compared with the required position information of the measurement control. The flight position and attitude deviations will be transformed into control parameters of the gyro-plane and executed.

For antenna farfield measurements optionally three GPS / Galileo receivers could be used instead of the three laser reflectors, in case the floating platform might detect the radiation field of the antenna in distances larger than the visibility of the laser beams.

For highly accurate measurement a RF-probe stabilization is foreseen in propagation direction to improve phase accuracy but also in the polarization axis to improve crosspolar purity.

An additional elevation control for the RF-probe is foreseen to allow the probing on spherical measurement contours.

Figure 5 shows the floating platform with the gyroplane, the laser reflectors and the RF-payload with the RF-probe/sensor.

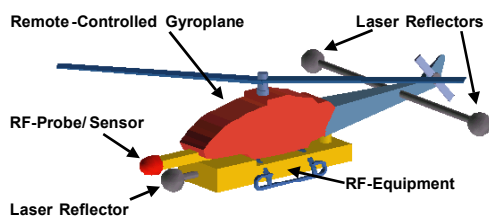


Figure 5 - Illustration of the Floating Platform

The gyroplane will have a payload capacity of about 25 kg, powered by a 21 hp 2 cylinders 250 cm³ engine and has a main rotor with a diameter of about 3,0 meters. The max. flight time of one tank filling is about 1.0 hour.

The real time position measurement equipment consists of three laser reflectors mounted at the floating platform serving as targets for the laser trackers, six automatic laser trackers as a minimum, three real time position processors as a minimum and one real time platform position processor.

In a first step each position of the three laser reflectors are measured by triangulation of at least two laser trackers. In a second step the flight position and attitude of the floating platform is calculated out of the three positions of the laser reflectors and feed into the flight control equipment.

Several back-up laser trackers are available to cover interruptions of line of sight between laser trackers and gyroplane e.g. for cylindrical and spherical measurement contours.

It is intended to develop a dedicated software for optimization of the locations and optimal triangulation angles, taking into account the available number of the laser trackers, line of sight interruptions due to measurement object and other site specific obstructions and the position of the sun. The latter is necessary to avoid that the laser trackers will look into the sun during a data collection flight, which could cause damage to the internal laser tracker sensors.

For farfield measurements the position measurements can optionally be performed by differential GPS/Galileo receivers located at the floating platform. The laser reflectors would then be replaced by the GPS/Galileo receive antennas and the position information transmitted to the ground control, feeding the flight control.

The information of the flight position and attitude of the floating platform will be managed by the flight controller in two ways. First the information will be forwarded to the data collection process to assign each RF-measurement made with the flight position and attitude information of the floating platform, allowing post-processing of the measured data. Second the actual position and orientation information will be compared with the reference position and orientation information generated from the data collection control program.

Deviations will be transformed into gyroplane control parameters and fed into the gyroplane flight control, which closes the control loop to the gyroplane. From take-off to landing the gyroplane will be governed by the RF-measurement control sequence. During the entire data collection a back-up pilot will be ready to override the computer control in case of an unexpected occurrence.

Further the flight control also manages a dynamic assignment of the laser trackers, ensuring permanent and

optimal line of sights for the triangulation measurements to the three laser reflectors.

3.2 RF-SUBSYSTEM CONCEPT

The on-board RF-measurement equipment will be realized as interchangeable units to allow fast configuration changes in terms of frequency measurement range, Rx/Tx or RCS measurement modes and signal modes, such as continuous, pulsed or even chirped wave forms. Pending on the contour and size of measurement plane and pending on the applied nearfield method the RF- and instrumentation control signals will be transferred from and to the ground control by a wireless or the fiber-optic link. The power supply for the RF-instrumentation will be generated through the engine driving the main rotor of the gyroplane. Pending on the applied nearfield measurement method, the required measurement parameters, the required measurement accuracy and type of scan contour the RF-probe/sensor can optionally be positioned and/or stabilized by a dedicated servo-loop.

3.3 MEASUREMENT CONTROL & PROCESSING SUBSYSTEM CONCEPT

The ANTF will be controlled from the ground control station accommodated in a demountable and air-conditioned control cabin with a large window, enabling direct view to the test field. The core equipment will be the control rack, which contains the:

- Real time position processors
- Flight control units
- Displays about gyroplane conditions
- Manual gyroplane control unit
- Displays about laser tracker angle positions and conditions
- Laser tracker joy-sticks
- Control monitors connected to each build-in TV camera in the laser trackers, giving additional surveillance of the floating platform during operation and allowing by joy-stick control the optical alignment between DUT and ANTF
- RF-measurement equipment
- Measurement control computer
- Satellite terminal for data transmissions
- Intercom units
- Displays of the installed wind and temperature sensors
- Reconfigurable control interface unit for the DUT

The ANTF will be design for autonomous operation. Provisions will be made for power generator, workshop, storage and a staff cabin.

4. EXPECTED SYSTEM PERFORMANCES

The expected ANTF performances are summarized below.

DUT size:	up to 100 x 100 x 100 m for nearfield measurements up to several kilometers for farfield measurement
Frequency range:	up to 20 GHz
Measurement accuracies @ 1.5GHz:	
Sidelobes:	±1.0 dB @-30dB SLL
Gain:	±0.3 dB
Cross polarization:	±0.3 dB @-25dB
Beam pointing:	±0.02 °
Polarizations:	Linear and circular
RxTx modes:	Rx, Tx, RCS
Signal modes:	Continuous, pulsed (chirped optional)

Max. wind speed:	10 m/s
Operational temperatures:	-10 to 45 °C

Typ. measurement time:	3.0 hours @1.5GHz; 30x30m planar scan
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Typ. system installation time and alignment:	0.5 day
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5. REALIZATION SCHEDULE

The ANTF is currently in the conceptual phase. From mid to end of 2002 market opportunities, financing and possible partnerships will be investigated in detail. In 2003 the system definition phase is expected and for 2004 the system development is planned, targeting to have the first ANTF operational in 2005.

6. CONCLUSION

The ANTF closes the technological gap in mobile outdoor antenna testing and opens up state-of-the-art antenna measurement technology to a community of antenna operators and public authorities, which until now were excluded from the access to precise knowledge about the radiated performances of their antenna systems. Once this community recognizes the benefits and

possibilities derived out of the unprecedented data quality delivered by the ANTF a major breakthrough in antenna testing would be the result, paving the way to a common antenna measurement standard, allowing a more efficient and meaningful comparison of antenna performances.

“There is no science without measurements,
no quality without testing and
no global market without standards”

(Motto of the Measurement & Testing Activity of the FP6
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