# A UHF Direction Finding Antenna With Optimised Radar Cross Section

Rainer Mueller*[1], Ralf Lorch[1], and Wolfgang Menzel[2]

[1] EADS ewation GmbH, Ulm, Germany

[2] University of Ulm, Department of Microwave Techniques, Ulm, Germany

## Introduction

A modern state of the art direction finder system consists of several direction finding (DF) antennas and the direction finder itself. The direction finder antenna system is designed for most accurate results, and often is built using a circular antenna array. On the other hand there are well known design rules for radar cross section (RCS) optimisation of different vehicles, planes and ships. Combining these two different fields of research aiming at a new design of a RCS optimised direction finding antenna lead to an increased number of design parameters which have to be considered. In this paper a solution for a fully featured RCS optimised DF antenna design is explained in detail.

## Antenna description

In this work a common UHF DF antenna configuration was chosen: 5 dipoles are positioned on a circle in front of a reflector. Figure 1 shows the prototype of the UHF DF antenna.

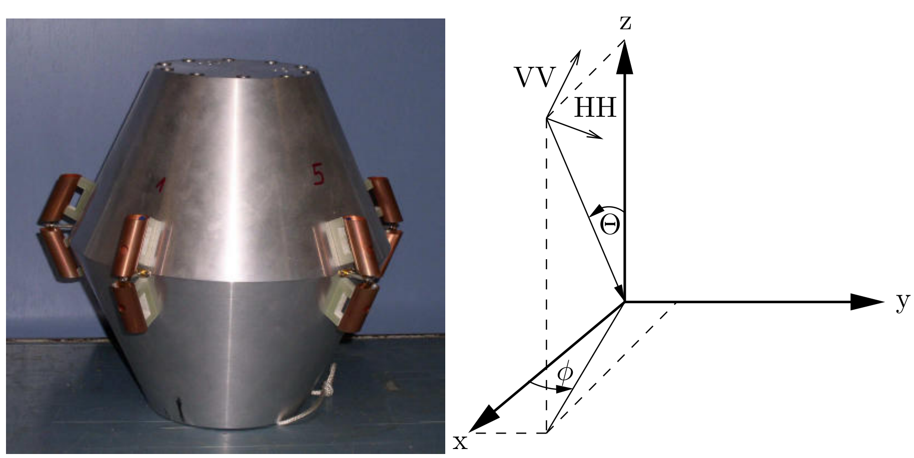


Figure 1: DF-antenna prototype and the used coordinate system.

A beamforming algorithm as proposed in [1] is used to obtain the direction of the incident wave, which can be seen as an interferometric evaluation of the phase of each antenna. The DF functionality should be fulfilled from 800 MHz up to 3 GHz and also the DF sensitivity requirements should be met. To achieve the required low monostatic RCS in the elevation sector $\Theta = 65^\circ \cdots 115^\circ$ and for all azimuth angles, the reflector is bent and formed out of two frustums. Also the dipoles are bent to fit to the reflector.

## DF-Error and DF-Sensitivity

Figure 2 shows the RMS DF-Error and the sensitivity of the prototype DF-Antenna, measured in an anechoic chamber. To obtain the measurement results a commercial 5-channel broadband direction finder was used.

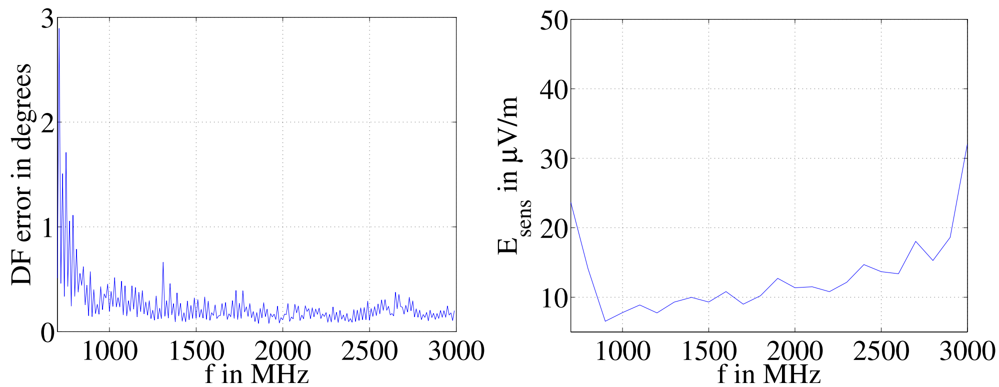


Figure 2: RMS DF-Error (left) and DF sensitivity (right).

The RMS DF-Error per frequency is a figure of merit for noise independent system errors and measured with sufficient S/N ratio. It is defined as

$$DF_{error} = \sqrt{\frac{\sum_{i=1}^{n}(e_i - e_A)^2}{n}} \quad \text{with} \quad e_A = \frac{\sum_{i=1}^{n} e_i}{n} \tag{1}$$

where $e_i$ is the error at the $i$th azimuth angle and $n$ the number of azimuth angles. $e_A$ is the so called A-Error which stems from the misadjustment of the antenna mounting. The DF sensitivity is defined as the E-field strength for which the statistical spread of the bearing is less than 1° using a certain set of DF-parameters such as the integration time bandwidth product $B \cdot T$, the bandwidth and the filtering of the direction finder equipment.

The results shown in figure 2 are comparable to commercially available DF-antennas and show the high performance of the RCS optimised DF-antenna.

## Radar Cross Section

The Radar Cross Section (RCS) $\sigma$ of an object can be defined in the farfield [2] as

$$\sigma = 4\pi R^2 \frac{P_S}{P_I} \tag{2}$$

and is dependent on the angle of incidence of the wave and the angle of scattering and its polarisations. A special case is the monostatic RCS where the incident direction and scattered direction is the same. For the simulation of the monostatic RCS a Methods of Moments simulation tool was used [3]. The measurement was done in an anechoic chamber using a vector network analyser and a broadband antenna horn performing a $s_{11}$ measurement. To obtain only the RCS of the object fourier transformation was used to perform a timegating and therefore a range gating. Moreover the object was mounted with non-metallic strings as depicted in figure 3 to avoid the reflection of a mast. For absolute measurements of the monostatic RCS a calibration object with a known RCS is needed. For this purpose a hollow stainless steel sphere with a diameter of 25 cm was used. The monostatic RCS of a sphere is given in [2]:

$$\sigma_{sphere} = \pi a^2 \quad \text{for} \quad \lambda \ll a \tag{3}$$

Applying equation (3) the used sphere has a RCS of -13.09 dBsm, which was used for calibration.

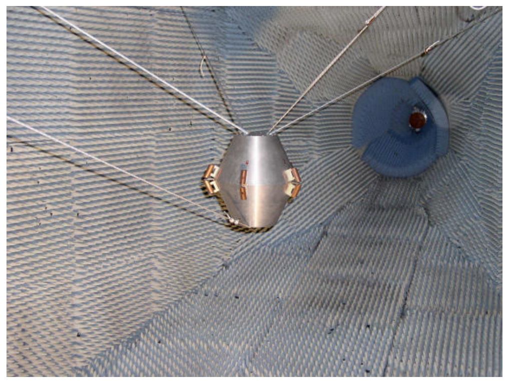

Figure 3: Antenna in anechoic chamber.

The results shown in figures 4 and 5 were normalized with respect to the maximum RCS at 8.5 GHz of a cylinder with the same volume and height as the prototype antenna because standard DF antennas have approximately the shape of a cylinder.

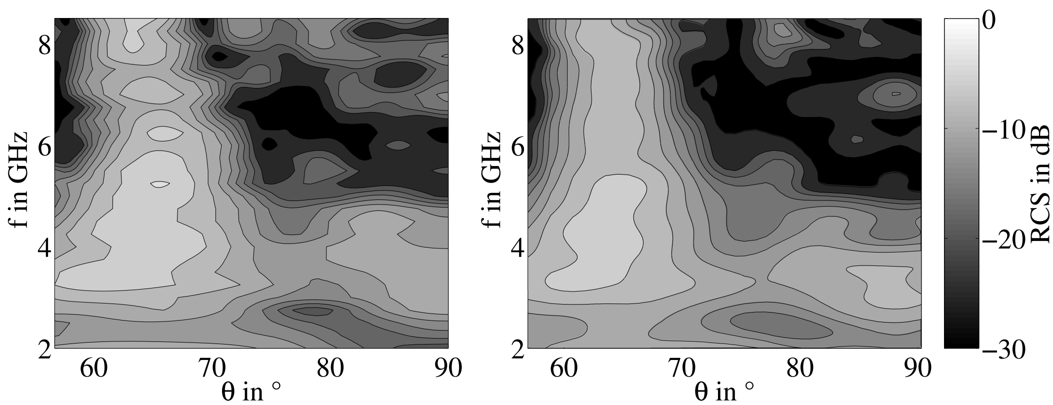


Figure 4: Simulation result (left) and measurement (right) of $\sigma_{VV}$ at $\phi = 180°$.

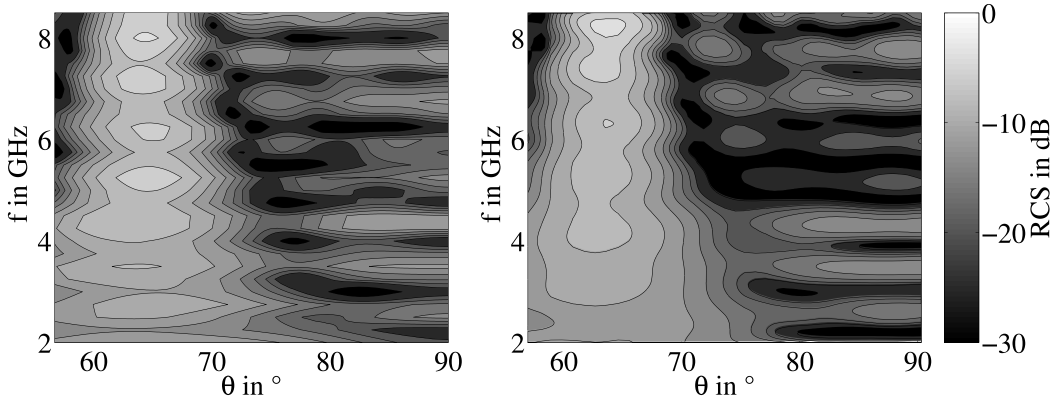


Figure 5: Simulation result (left) and measurement (right) of $\sigma_{HH}$ at $\phi = 180°$.

The results of the simulation and the measurement in figure 4 for vertically polarized transmit and receive signals and in figure 5 for horizontally polarized transmit and receive signals show a good agreement between simulation and measurement. The measurement was also performed for other $\phi$ angles and show the same good results. In the sector of $\Theta = 65° \cdots 115°$ the desired reduction of the RCS compared to a normal cylindrical antenna of about 12 dB for most of the frequencies was achieved. For frequencies around 4 GHz and vertical polarisation the RCS could be reduced by only about 9 dB, which was expected because of the vertical polarised dipoles which are still close to their resonant frequency.

The reduction of the monostatic RCS of 12 dB corresponds to a reduction of radar range $R$ to a half according to the well known radar equation [2].

## Conclusions

The presented results show that the simulation with a modern simulation tool using Methods of Moments agree very well with the measurements of a prototype. Furthermore it is shown that the monostatic RCS of a UHF DF antenna can be successfully reduced without degrading the DF performance.

## References

[1] H. Krim and M. Viberg. Two decades of array signal processing research: the parametric approach. *Signal Processing Magazine, IEEE*, 13(4):67–94, 1996.

[2] M. T. Tuley E. F. Knott, J. F. Shaeffer. *RADAR CROSS SECTION, Its Prediction Measurement and Reduction*. Artech House, Inc., 2003.

[3] U. Jakobus. Latest developments in the method of moments for an efficient solution of complicated and large scale emc problems. *15th International Wroclaw Symposium on Electromagnetic Compatibilty*, pages 221–224, 2000.