A HF/VHF Direction Finding Antenna With Optimised Radar Cross Section

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Introduction

A modern state of the art direction finder system consists of several direction finding (DF) antennas and the direction finder electronics. In order to achieve most accurate results for all azimuth directions the direction finder antenna system is often 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 leads to an increased number of design parameters which have to be considered. In [1] a UHF direction finding antenna with optimised radar cross section has been introduced. In comparison to the UHF arrangement a different mechanical design has to be used for a HF/VHF direction finding antenna due to the increased dimensions. In this paper a solution for a fully featured RCS optimised DF HF/VHF antenna design is explained in detail and compared to a non RCS optimised state of the art antenna.

Antenna description

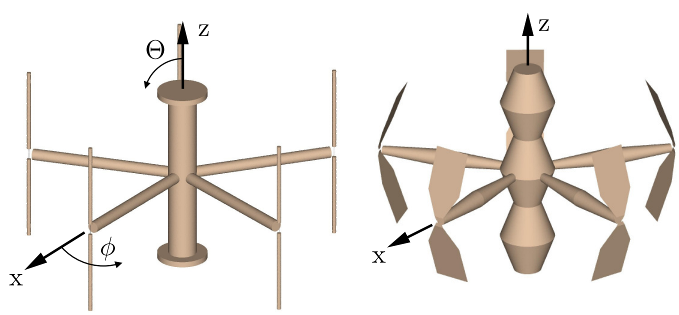

Figure 1: Conventional antenna (left) and RCS optimised design (right).

Both the conventional and the RCS optimised DF antenna consist of five dipoles positioned as a circular array. The dipoles are mounted on a mast with arms. The form of the mast, the arms, and the dipoles of the RCS optimised DF antenna are adapted to meet the low RCS requirements in the elevation sector $\Theta = 72° \cdots 108°$ for all azimuth angles. Figure 1 shows the conventional and the RCS optimised design.
A beamforming algorithm as proposed in [2] is used to obtain the direction of the incident wave, which can be seen as an interferometric evaluation of the phases of

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all dipoles. The DF functionality should be fulfilled from 20 MHz up to 500 MHz and also the DF sensitivity requirements should be met.

DF side lobe interspace and effective height

A measure for the DF functionality is the side lobe interspace (SLI) and the effective height. The SLI is the difference between the main lobe and side lobe, where the main lobe is normalized to one, using the proposed beamforming algorithm. The effective height is defined as

$$h_e = \frac{2V}{E} \tag{1}$$

where E is the electric field strength and V the Voltage at the antenna port.

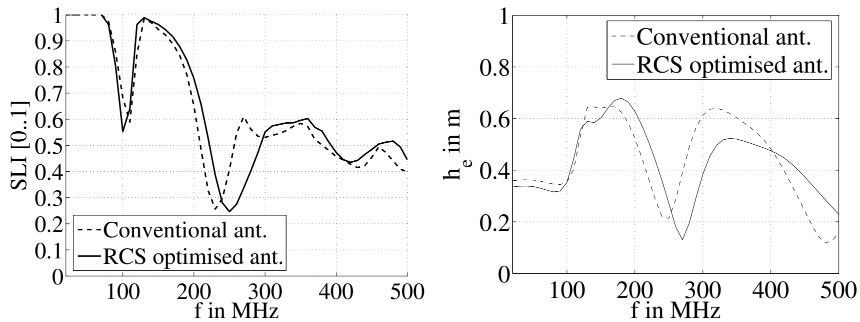

Figure 2: Side lobe interspace (left) and effective height (right).

Figure 2 shows the SLI and the effective height for the conventional antenna and the RCS optimised antenna. It can be seen that around 240 MHz the SLI has a minimum due to the presence of the mast. As shown in figure 2 the results of the SLI and of the effective height are comparable for the conventional and the RCS optimised antenna, which ensures the DF functionality.

Radar Cross Section

The Radar Cross Section (RCS) σ of an object can be defined in the farfield [3] 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 commercially available system, offering a new technique called MLFMM [4] was used to obtain the simulation results. Figure 3 shows the simulation results for the conventional antenna and the RCS optimised design. All RCS results, measurement and simulation, given in this publication are normalised with respect to the maximum of the conventional antenna design. By comparing the conventional antenna to the RCS optimised it can be seen that in the threat sector $\Theta = 72° \cdots 108°$ (corresponds to $\Theta = 72° \cdots 90°$ in fig. 3 due to the symmetry plane $z = 0$) the RCS is

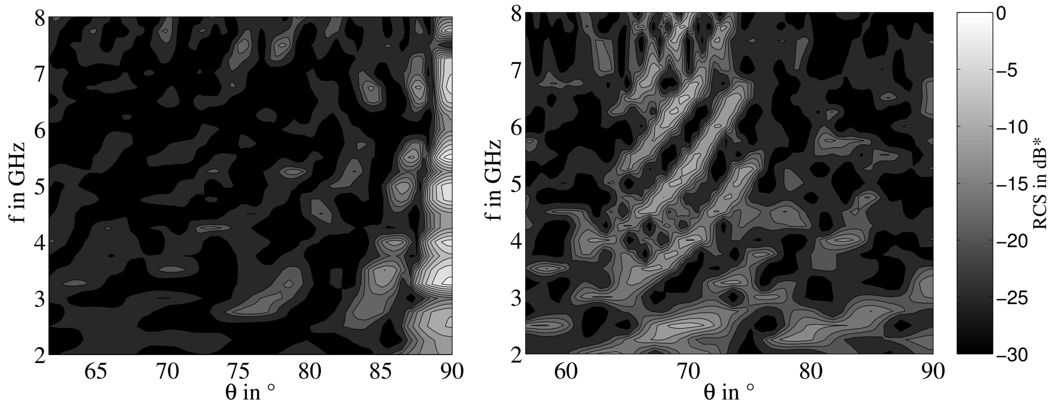

Figure 3: Simulation result of the conventional antenna (left) and the RCS optimised design (right) for σ_{VV} at $\phi = 36°$.

reduced by at least 12 to 15 dB which corresponds to a reduction of radar detection range to at least half according to the common radar equation.

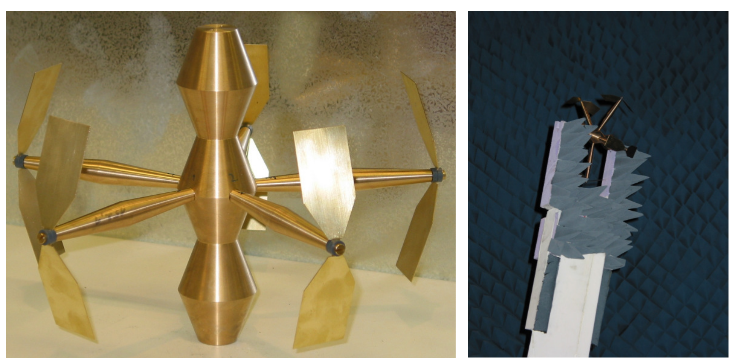

Figure 4: Antenna modell (left) and mounted in the anechoic chamber (right).

The measurement was done in an anechoic chamber using a vector network analyser and a modell (figure 4) of the RCS optimised antenna design. The modell was scaled by the factor $s = 4.5$ in order to meet farfield conditions in a 25 m long chamber. Therefore the frequency was scaled to the range from 9 GHz up to 40 GHz, and the resulting RCS must be scaled by the factor s^2 [3]. Moreover fourier transformation and range gating were performed, and the object was mounted with material which has an ϵ_r close to air as well as specially placed and formed absorbers to obtain only the RCS of the object (figure 4). As calibration a measurement with a hollow stainless steel sphere was performed. When comparing the results of the simulation and the scaled measurement problems like fabrication tolerances, modelling of the dipole feeds, positioning of the object in the anechoic chamber and measurement at high frequencies have to be considered. Also the coarse frequency steps (250 MHz) of the simulation compared to the very fine frequency steps of the measurement have to be taken into account. Nevertheless the results of the simulation and measurement shown in figure 5 for vertically polarized transmit and receive signals agree very

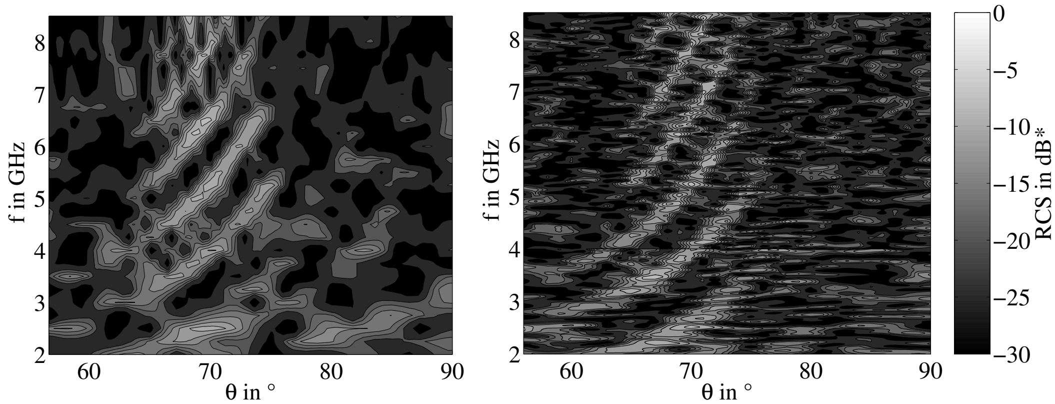

Figure 5: Simulation result (left) and measurement (right) of σ_{VV} at $\phi = 36°$.

well. Other ϕ angles and polarisations were measured and simulated and show the same good agreement between simulation and measurement.

Conclusions

The presented results show the successful RCS optimisation of a HF/VHF antenna without degrading the DF performance. This has been proven with measurements of a scaled modell showing good agreement with previously achieved simulated values.

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