A Conformal UHF Slot Type Direction Finding Antenna With Optimized Radar Cross Section

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

[1] EADS Deutschland GmbH, Ulm, Germany
[2] University of Ulm, Institute 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 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) optimization of different platforms like vehicles, planes and ships. Combining these two different fields of research aiming at a new design of a RCS optimized direction finding antenna leads to an increased number of design parameters which have to be considered. In [1] and [2] a UHF direction finding antenna with optimized radar cross section has been introduced. To achieve a low radar cross section the structure of the antenna was modified using shaping techniques. In comparison to the antenna design in [1] using five dipoles in front of a shaped reflector, a fully featured DF antenna design consisting of five conformal slot antennas is introduced in detail in this paper. The low radar cross section is achieved by the integration of the slot antennas into the structure of the platform, which is already RCS optimized.

Antenna description

In this work a common UHF DF array configuration was chosen: 5 antenna elements are positioned on a circle. These antenna elements are designed as broadband slot

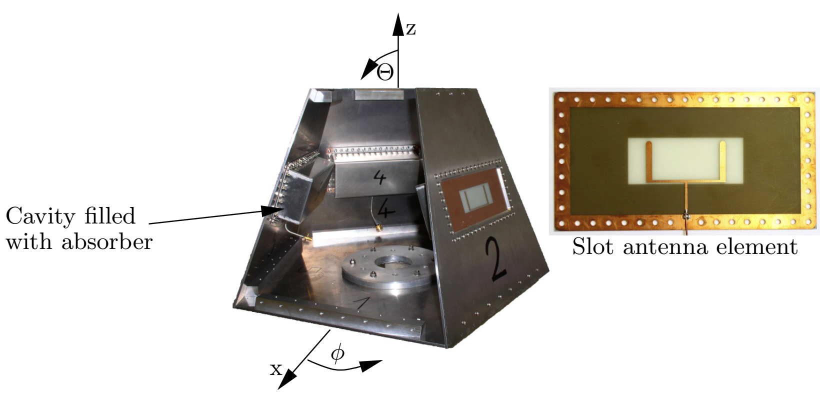

Figure 1: DF antenna prototype (left) and slot antenna element design (right)

antennas (figure 1 right) similar to the design in [3]. The frequency is shifted to the UHF band from 1 GHz up to 3 GHz. Instead of using a coplanar feed, a microstrip line feed is used. The length and width of the microstrip line in the slot determine the input impedance whereas the overall size of the slot sets the frequency range. A detailed description of the slot antenna element design is given in [4]. As example for a typical platform structure with low RCS a pentagonal pyramidal structure as depicted in figure 1 (left) is used. The centers of the antenna elements are positioned on a virtual circle with 30 cm diameter. The sidewalls of the structure are tilted to achieve a low RCS. In order to be able to integrate the slot antenna element into the structure of the platform, a cavity is used, which is partly filled with absorbing material.

A beamforming algorithm as proposed in [5] is used to obtain the direction of the incident wave, which can be seen as an interferometric evaluation of the phase weighted with the amplitude of each antenna. The DF functionality should be fulfilled from 1 GHz up to 3 GHz and also the DF sensitivity requirements should be met.

DF-Error and DF-Sensitivity

Figure 2 shows the RMS DF error and the sensitivity of the prototype DF slot antenna and the DF antenna proposed in [1], measured in an anechoic chamber. To obtain the measurement results a commercial 5-channel broadband direction finder was used. The RMS DF error per frequency is a figure of merit for noise independent

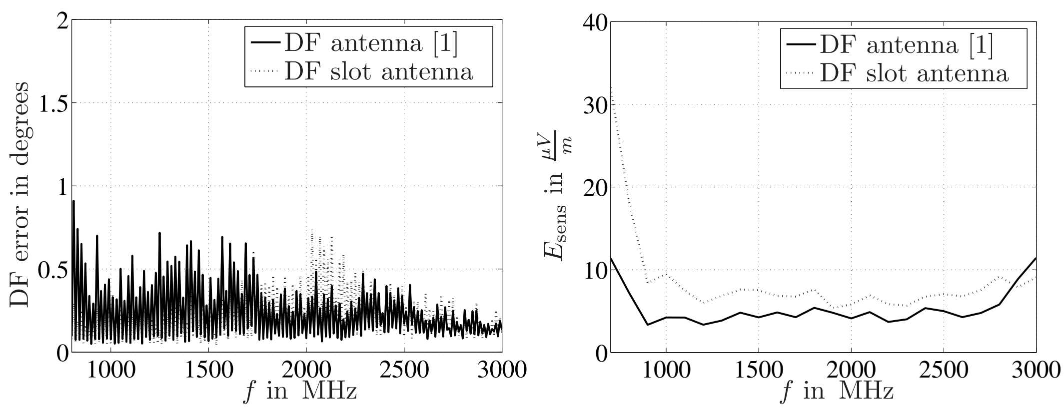

Figure 2: RMS DF-Error (left) and DF sensitivity (right) of the DF slot antenna and the DF antenna proposed in [1].

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 ith 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. In Figure 2 (left) the DF error of the slot antenna and the DF antenna proposed in [1] is shown. It can be seen that the measured DF errors of both antenna designs are in the same range of less than 1 degree over the whole frequency band, which shows the good performance of the DF slot antenna.

The DF sensitivity, which is shown in figure 2 (right), 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. When comparing the two antenna designs, it can be seen that the DF slot antenna is between 1 dB and 4 dB less sensitive for most frequencies than the design in [1]. Since absorbing material is used in the DF slot antenna, this result was expected. Further measured and simulated results can be found in [6].

Radar Cross Section

The Radar Cross Section (RCS) σ of an object is dependent on the frequency, on the angle of incidence of the wave, the angle of scattering and its polarizations. A special case is the monostatic RCS where the incident direction and scattered direction are the same. For the simulation of the monostatic RCS a MLFMM

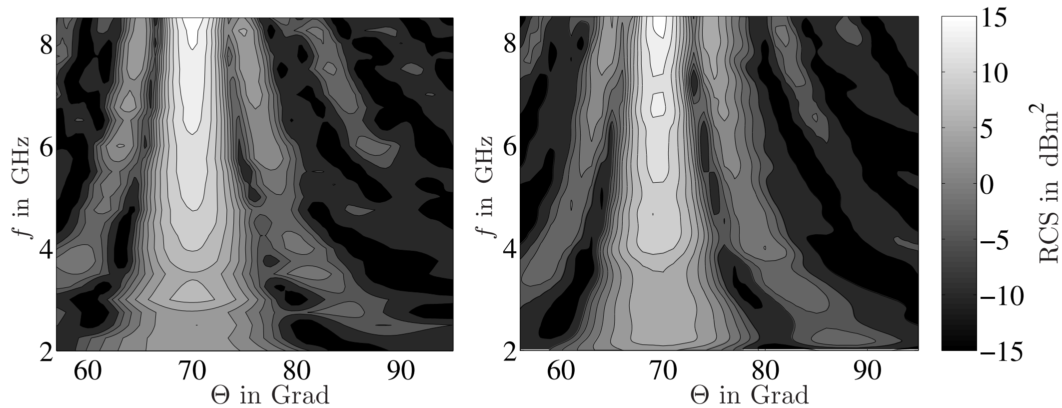

Figure 3: Simulated RCS σ_{hh} (left), measured RCS (right) for $\phi = 0°$

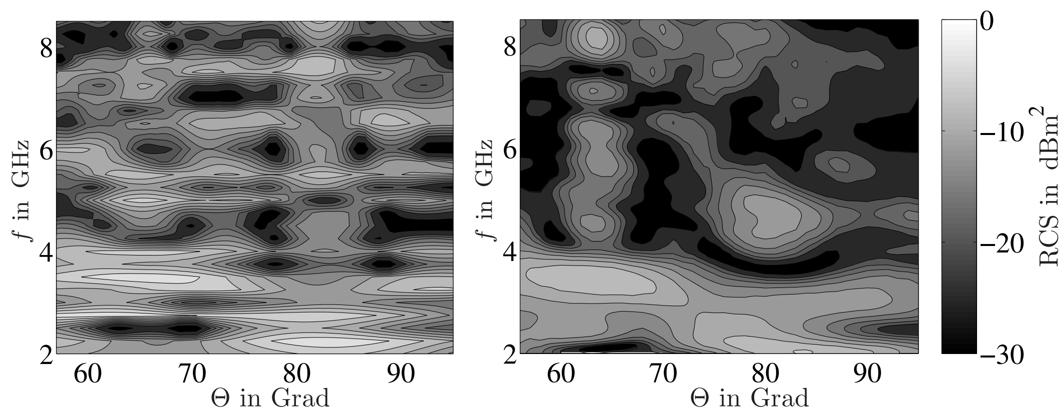

Figure 4: Simulated RCS σ_{hh} (left), measured RCS (right) for $\phi = 36°$.

simulation tool was used [7] without modelling the absorbing material in the cavity. 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 time gating and therefore a range gating. Unlike the mounting with non metallic strings in [1], the object was mounted on a frustrum made out of material which has the permittivity ϵ_r close to air similar to the mounting in [2].

The simulated and measured results in figure 3 for horizontally polarized transmit and receive signals for $\phi = 0°$ agree very well. For $\phi = 36°$ (figure 4) a good agreement of the simulated and measured results is not given. The reason for the difference of the measurement and simulation is the missing absorbing material in the simulation modell. Also note that the absolute value of the RCS for $\phi = 36°$ in figure 4 is 15 dB lower than for $\phi = 0°$, which can be explained by the typical mechanical structure of the DF slot antenna.

Conclusions

The presented UHF DF slot antenna design shows no degradation of the DF error and expected 3 dB (typical) in sensitivity only when compared to the DF antenna design in [1]. This shows that the broadband slot antenna design, introduced in this paper, can be used for conformal direction finding antennas. This conformal DF antennas are integrated into the structure of modern platforms, which have an optimized low radar cross section.

References

[1] R. Mueller, R. Lorch, and W. Menzel. A UHF direction finding antenna with optimised radar cross section. In *IEEE Antennas and Propagation International Symposium*, pages 3255–3258, 2006.

[2] R. Mueller, R. Lorch, and W. Menzel. Extended characterisation of a UHF direction finding antenna with optimised radar cross section. In *INICA 2nd International ITG Conference on Antennas*, pages 210–212, 2007.

[3] R. Chair, A. A. Kishk, and K. F. Lee. Ultrawide-band coplanar waveguide-fed rectangular slot antenna. *IEEE Antennas and Wireless Propagation Letters*, 3:227–229, 2004.

[4] Christian Fuchs. Untersuchung von Schlitzantennen. Master's thesis, Institute of Microwave Techniques, University of Ulm, August 2007.

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

[6] Rainer Mueller. *Untersuchung von Peilantennen mit reduziertem Radarrückstreuquerschnitt*. PhD thesis, Institute of Microwave Techniques, University of Ulm, Germany, 2008.

[7] U. Jakobus and J. van Tonder. Fast multipole acceleration of a mom code for the solution of composed metallic/dielectric scattering problems. In *Advances in Radio Science*, volume 3, pages 189–194, 2005.