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The Difference between Conventional and Doppler VOR – Some Missing Issues

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Multipath propagation for VHF omnidirectional radio range systems, i. e. the conventional and the Doppler VOR can lead to bearing errors, which are widely discussed in the community, especially in the context of wind turbines. According to numerous publications, the DVOR is supposed to be less sensitive to multipath propagation compared to the conventional VOR. This short contribution addresses some missing aspects regarding the assessment of possible bearing errors, that should be considered for a complete analysis of multipath propagation an associated bearing errors.

Key Words: VHF omnidirectional radio range, bearing error, signal to noise ratio

1. The Assumption of an Omnidirectional Scatterer

When Anderson et al. in 1959 analytically derived bearing errors for a DVOR in [1], they assumed an omnidirectional scatterer of an amplitude 0.1 relative to the direct propagation path. Of course, since numerical tools were not established that time, this was a pragmatic assumption. However, since now numerical tools are available for even calculating the scattering behavior of very large objects, this starting point should be reconsidered essentially from fundamentals of scattering theory. Fig. 1 shows the known bearing errors diagram in azimuth plane for DVOR and CVOR for an omnidirectional scatterer located in the east, i.e. 90°.

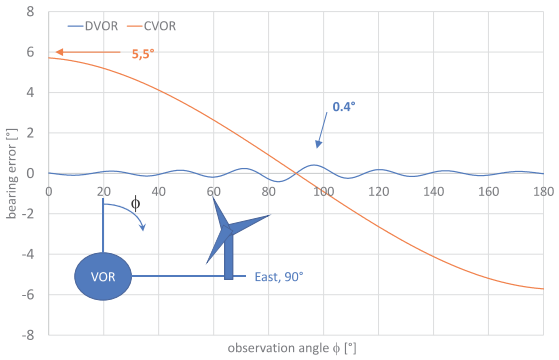

Fig. 1. VOR receiver's sensitivity for an omnidirectional scatterer.

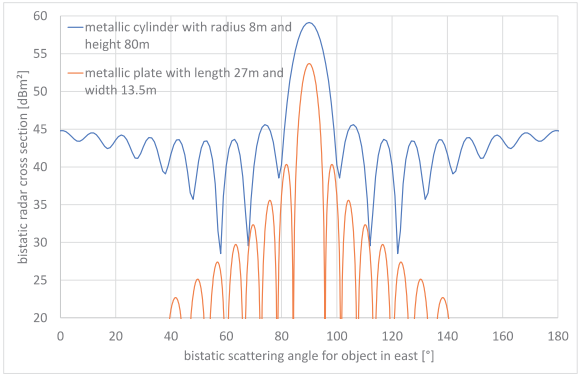

Fig. 2. Bistatic RCS for generic example objects located in the east.

Whereas the largest error for the DVOR is close to the direction of the scatterer itself (located in the east, 90°), the error maximum for the CVOR is in the perpendicular direction, i.e. north. However, considering the scattering behavior of objects, e.g. a cylinder as example for a wind turbine's mast or a metallic plate as shown in Fig.2, their scattering maximum always is in the forward scattering region, close to the DVOR receiver's sensitivity. The difference in the scattering amplitude in those directions is nearly 15 dB for the cylinder and much for the metallic plate and significantly influence the overall bearing error.

2. A Missing SNR Error Analysis

Another crucial simplification with respect to the receivers' bearing error function (Fig.1) is that it refers to the directional signal solely neglecting the reference signal, e.g. the AM for the DVOR. However, any signal with finite signal to noise ratio (SNR), has a corresponding phase uncertainty. In [2] an analytical expression is derived for such uncertainties. For example, a phase uncertainty of 1° within the 95% interval requires a SNR better than 40 dB. If the relative amplitude of a scatterer was 0.01, the maximum bearing error of a CVOR is 0.5°. A SNR less than 40 dB, as could be expected in low altitudes due to the elevation pattern of the VOR would dominate the bearing error overall statistics, regardless the particular VOR type.

3. Flight Studies and Empirical Results

Several flight studies have investigated DVOR and CVOR performances, e.g. [3], [4] reporting negligible influence of wind turbines regardless CVOR and DVOR. Fig. 3 exemplarily shows one flight trajectory away and towards a VOR clearly showing the influence of the SNR as discussed above.

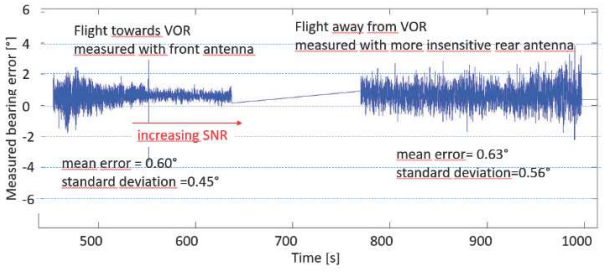

Fig. 3. Bistatic RCS for generic example objects located in the east.

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