Anomalous propagation: Examination of ducting conditions and anaprop events in SW-Germany

Malte Neuper (malte.neuper@kit.edu) and Jan Handwerker (jan.handwerker@kit.edu)

Anomalous propagation (Anaprop) of electromagnetic rays

- In the atmosphere propagation described by refractivity N:
  \[ N = (n - 1) \cdot 10^9 = 77.6 \cdot \frac{P}{T} + 3.732 \cdot 10^4 \cdot \frac{e}{T^2} \]
  where p: total atmospheric pressure (hPa), T: Temperature (K) and e: water vapor partial pressure (hPa) (Bean and Dutton, 1968)

- bending of the radar beam by decrease of p, increase of T and decrease of e with height
- dry warm air over wet cold air

For practical purpose use of a modified refractivity M:

\[ M = N + \frac{h \cdot 10^6}{R} \]

where h: height above ground and \( R \) earth's radius

- ducting conditions described by decrease of M, profile of M, resp. (Turton et al., 1988) with:
  - duct height H [m]
  - duct thickness D [m]
  - duct strength DM [M-units]
  - Trapping Layer TL

Calculation of the propagation

- From Fermat's principle, the optical way of the beam has to be minimal
- Nonlinear second-order ordinary differential equation (Hartree et al., 1946):
  \[ \frac{ds}{dt} = \left( \frac{1}{n} \frac{dn}{ds} \right)^{1/2} \left( \frac{R_s + R_h}{R} \right)^{1/2} \]

where n is the index of refractivity, s the arc element on the earth's sfc, R: refractivity, Rs: earth's radius

Boundary conditions:

- \( h(s = 0) = h_0 \)
- \( \frac{dh}{ds} (s = 0) = R_s + R_h \tan \varepsilon \)

- Meteorological interpretation:
  - In summer often persistent high pressure systems with temperature- and humidity inversions at the surface present.
  - From october to december also frequent presence of persistant low level inversions.

00 and 12 UTC difference

- Except of the "duct-poor" february march, duct thickness is larger at 00 UTC (night) than at 12 UTC (day)
- Beam stays "longer" in the ducting layer and thus can be bended longer.
- Product of duct strength and duct thickness show - consistent with experience - that stronger ducting is to be anticipated during the night.
- High values of the product for october and december at both times show the persistant inversions during these months, which are also difficult to break during the day.

Case study (19.07.2006)

- Marked blocking anticyclone present over Central Europe with large scale subsidence and warm subtropic air (maximum temperatures of the day over 30°C)
- During the night - besides an elevated subsidence inversion – formation of a marked radiation inversion

Vertical profiles:

- Anaprop echoes possible for lower elevations, especially from the side lobes.

References:
- KIT – University of the State of Baden-Wuerttemberg and National Research Center of the Helmholtz Association