

Annex 8A

**Method for combining the horizontal and vertical antenna patterns
in the land mobile service**

1 The calculation of the 3-D antenna radiation pattern.

The following description outlines how to calculate the 3-D antenna radiation pattern from the following input data of the Tx and Rx antennas:

- the partial horizontal and vertical antenna codes, respectively 9XH and 9XV,
- the azimuth and elevation angles of maximum radiation, respectively 9A, 9B,
- the azimuth and elevation angles of direction in which the resulting attenuation of 3-D antenna radiation pattern has to be calculated (propagation path).

In a first step the two vectors (antenna direction and propagation path) are combined to one vector, represented by horizontal and vertical difference angle (hda, vda) that can be applied to the antenna in its basic position. This is done by plain spherical coordinate transformation. This step takes care of the azimuth and mechanical tilt (elevation) of the antenna.

If the antenna has additional electrical tilt, it can now simply be applied to the resulting vertical difference angle as it is independent of the azimuth.

With the resulting horizontal and vertical difference angle, the values for horizontal and vertical attenuation can be calculated according to the relevant antenna codes.

The generally applied combination method to obtain the 3D-attenuation value is the geometrical sum. Due to reasons described in chapter 2, special cases have to be considered and taken care of to avoid inconsistencies.

2 Combination of the partial horizontal and vertical radiation patterns into resulting 3-D radiation pattern

The resulting 3-D antenna radiation pattern is fully defined only in the two basic horizontal and vertical planes by the *hCode* and the *vCode*. The attenuation in random directions can only be evaluated by either a simple or a sophisticated approximation. The *hCode* and the *vCode* represent two upright cross-sections of resulting 3-D antenna radiation pattern, and therefore their back lobe attenuations have to be equal, as is demonstrated in Fig.2.

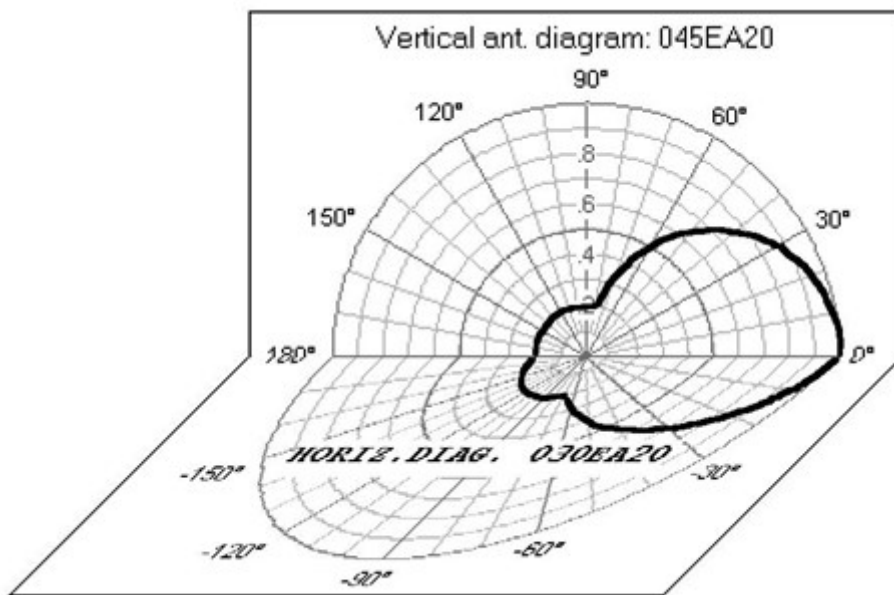


Fig.2.

[The existing reality is that some co-ordination requests contain mathematically incompatible antenna codes, as demonstrated in Fig.3.]

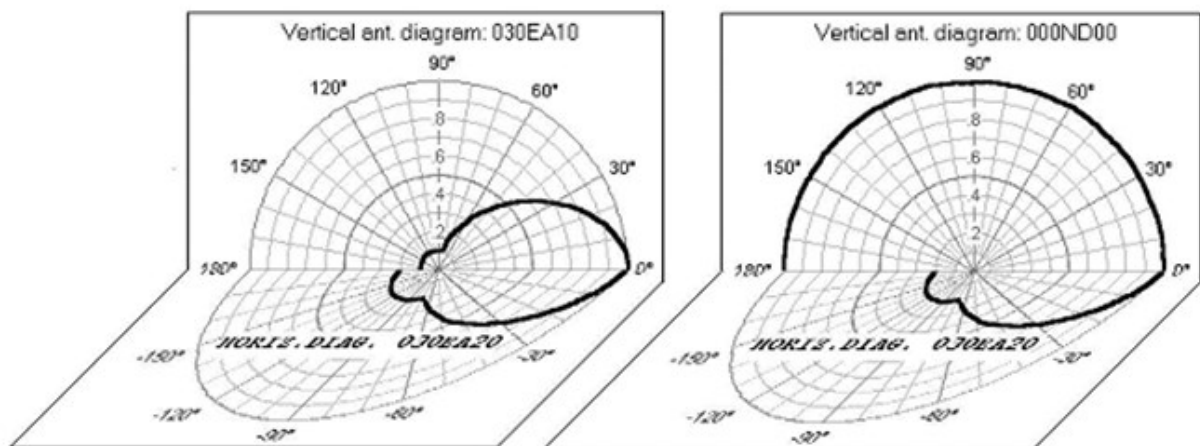


Fig.3.

One of reasons for this is that the applicant of the co-ordination request wants to express the intention that he does not want to claim any restrictions due to the vertical antenna code *000ND00* in conjunction with some directive horizontal antenna code. But this interpretation is nonsense from the mathematical point of view because it causes the ambiguity and the discontinuity of the resulting 3-D radiation pattern, as was demonstrated on Fig.3.

The first step of combining the antenna diagrams is therefore to check whether they are compatible. If they are not compatible, then the vertical antenna diagram is adapted to conjunct the horizontal antenna diagram. The matching of both antenna diagrams together is performed by means of the following smoothing bridge function:

$$A_{VD_back} = A_{VD_back_O} * \text{SQR}(\sin^2 vda + rb * \cos^2 vda) \dots\dots [5]$$

where: A_{VD_back} is the attenuation of the matched vertical antenna back branch
 $A_{VD_back_O}$ is the attenuation of the original (unchanged) vertical antenna back branch
 rb is back attenuation ratio of the original vertical and horizontal antenna diagrams at the angle $vda = \pm 180$ deg.

The smoothing bridge function affects the back branch of the vertical antenna diagram only where it creates a new diagram shape, while its forward branch remains unchanged.

The result of the matching adaptation process is demonstrated in the example given in Fig.4.

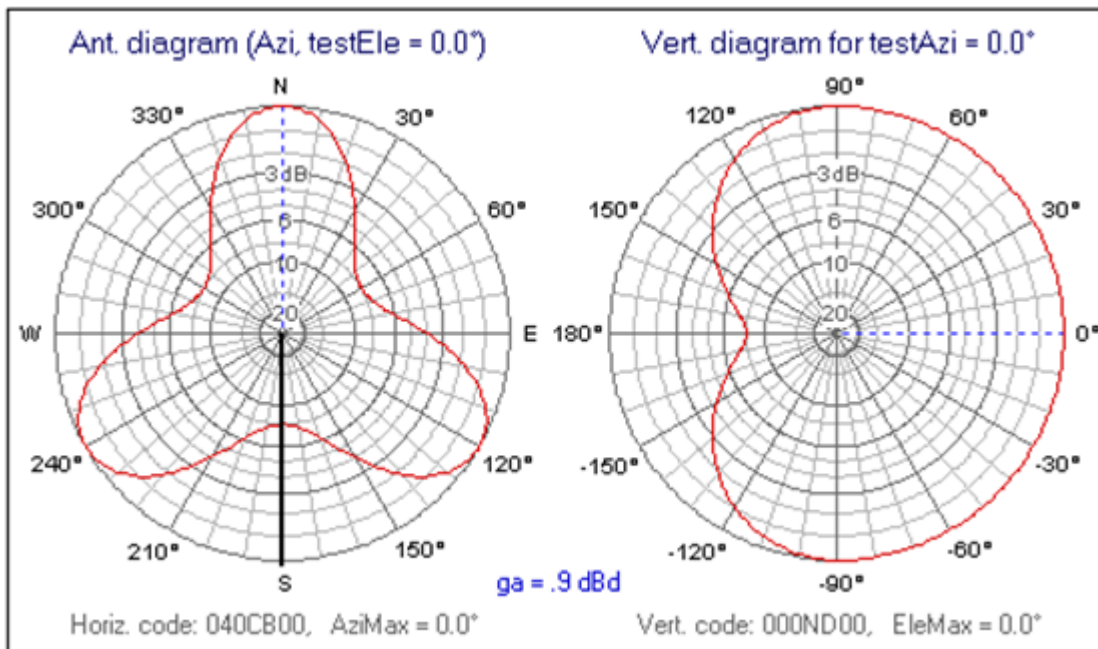


Fig.4.

The back branch of the vertical antenna diagram with vda angle range from $+90$ to ± 180 deg. and from -90 to ± 180 deg. was continuously adapted to the existing back

attenuation of the horizontal diagram for $hda = 180$ deg. The forward branch of the vertical antenna diagram remained omni-directional i.e. it remained unchanged.

In the second step of the combination of the antenna diagrams, the resulting vertical antenna diagram is interpolated over different azimuth angles hda . The vertical antenna diagram consists of a forward and a back branch. The forward branch and the back branch of the vertical antenna diagram are eventually matched. (See Fig. 5)

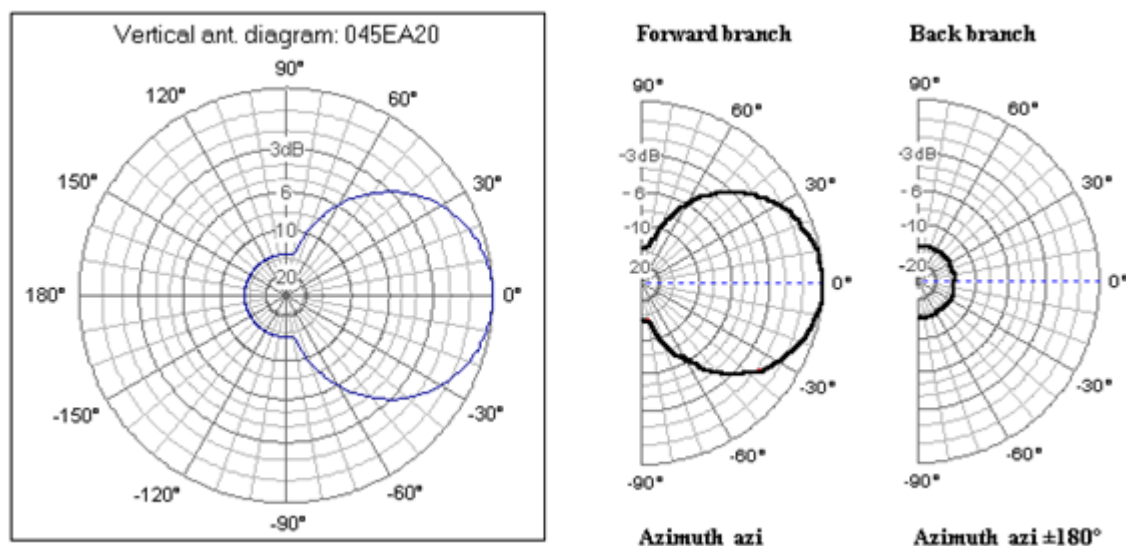


Fig.5.

Two different types of interpolation are used: proportional and linear. The suitability of the interpolation type depends on the horizontal antenna diagram shape.

The proportional interpolation of the source vertical antenna sub-diagrams is used for a directive multiple-lobe or for a one-lobe horizontal antenna diagram. The interpolation weight coefficient w is developed from the attenuation of the horizontal antenna diagram in the mentioned angle of hda and it is described by formula:

$$w = (1 - h) / (1 - hb)$$

where: h is the attenuation of the horizontal antenna diagram in the azimuth hda
 hb is the attenuation of the horizontal antenna diagram in the back direction ($hda = 180$ deg.)

Proportional interpolation assures, for example as given in Fig.4., that the vertical antenna diagrams will be identical in the symmetry hda axes of horizontal antenna diagrams 0, 120, 240 deg. The one-lobe directional horizontal antenna diagram case is shown in Fig.6.

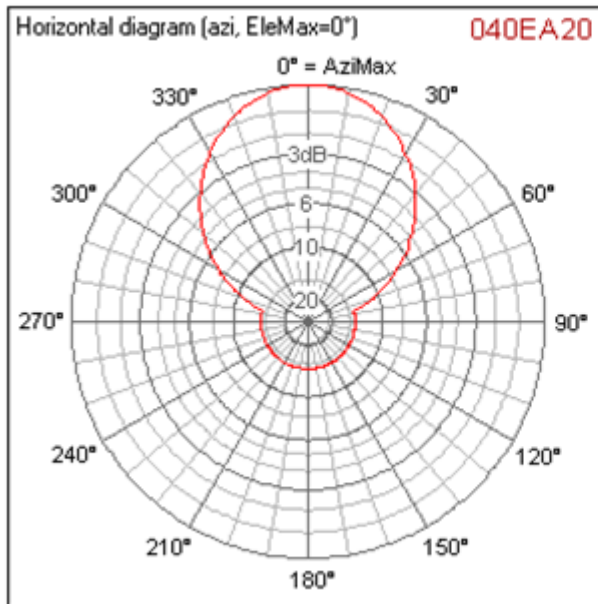


Fig.6.

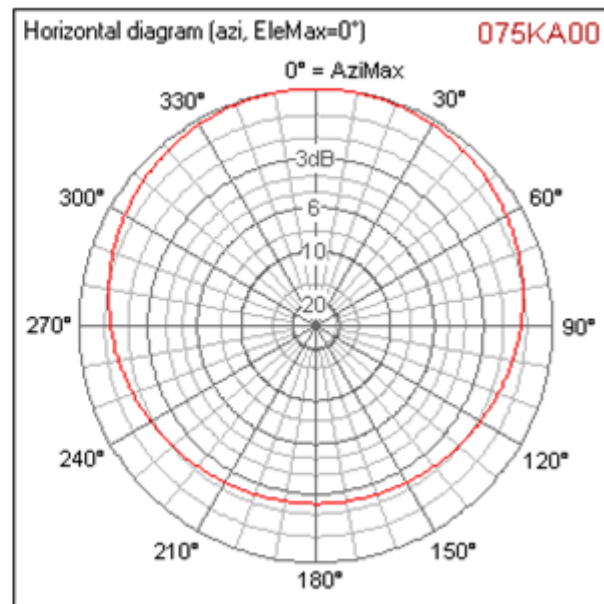


Fig.7.

Proportional interpolation type assures in the case of Fig.6. that the back branches of all vertical antenna diagrams will be identical in the *hda* azimuth range from 80 to 280 deg. due to constant attenuation of the horizontal antenna diagram there.

Linear interpolation is used for slightly directive horizontal antenna diagrams only. An example of typical slightly directive horizontal antenna diagram is given in Fig.7.

The interpolation weight coefficient *w* is developed from the angle interval between the forward azimuth angle and the back azimuth angle of *hda*, and it is described by formula:

$$w = \text{ABS}(hda / 180)$$

The third step of the combination of partial antenna diagrams makes final checking whether the interpolated vertical antenna diagram and the horizontal antenna are compatible altogether in the evaluated azimuth *hda*. The reason for this last checking is demonstrated in Fig.8. If the pre-analyzed antenna diagrams are not compatible in some azimuth, then the partial vertical antenna diagram has to be adapted to the partial horizontal antenna diagram.

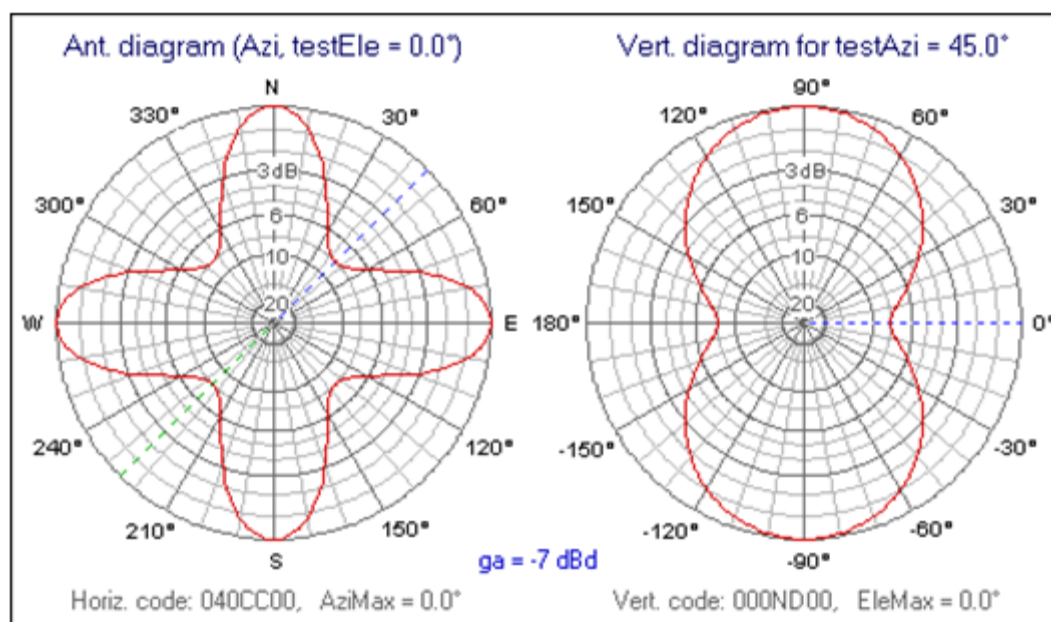


Fig.8.

The demo example, given in Fig.8., describes the case where both partial input antenna diagrams are compatible and both source vertical diagram branches are identical i.e. omni-directional. The pre-calculated omni-directional vertical diagram has to therefore be matched to the horizontal antenna diagram shape in azimuths where the attenuations of partial antenna diagrams are different, for example in the azimuth of $hda = 45$ deg.

The matching of both partial antenna diagrams together is performed by means of a smoothing bridge function analogous to [5] described above.