E-CLIC AIS-Antenna System

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Prototype

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EUROPEAN UNION
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Programme

Content

1.0 Executive Summary

Within the scope of the project E-CLIC at the Jade University in Wilhelmshaven a receiving System was to be built up in the Lab for Communication Technology and Digital Technology for the AIS (Automatic Identification system). The received data were to be made available to other research institutions or industrial partners by the broadband net.

Pursuing such an arrangement is obvious the regarding topography situation of the college on the North Sea coast. Other facilities in the interior can participate in the results. To achieve a very ample reception range a high-capacity antenna system was developed especially for this application and was then built up.

The prototype is described in the following.

2.0 Antenna design

2.1 Guidelines

To achieve the needed range the aerial gain should amount to at least 11 dBD. The wind load of the antenna and thus the mechanical expenditure should be held as low as possible. All antennas should be mounted on a tower with maximal length of 6 m. Concerning the prior listed demands the inhomogeneous Yagi-Uda antennas are most suitable in the optimized form by Günter Hoch (1). The antenna can be optimized for a narrow frequency response. The chosen design guarantees a good weather independency of the antenna parameters.

The aimed antenna gain of 11 dBD with an angle of aperture of about 110 degrees cannot be realized with a single Yagi-Uda antenna only (see 1). There is a possibility of a stacking system of two antennas (coverage gain) with its overlapping link to the active surfaces. Furthermore the reception range is split in two sectors (cutting the opening angle in half). Using this, the system should be realizable. The mechanical length of an antenna must not exceed 1,50 m (incl. bracket) for economic reasons. Electric optimizations can be also found for e.g. 1,50-1,70m. The semi-finished products (20x20mm Alu profiles) are available at a reasonable price for poles with a length of 6m. Thus four antennas can be built up without off cuts. The foot-point-resistance should amount to 50 ohms.

2.2 Antenna Simulation

The antenna was developed with the software tool “Antenna Optimizer” (AO) by Brian Beezley.
It is software for the analysis and optimization of Yagi-Uda antennas with a small bandwidth. The starting point was a 5 elements antenna by Hoch fed by a folded dipole. A compromise was searched between sufficient side lobe reduction and optimum gain with 50 ohms impedance. The forward to backward relation was not relevant because a certain receipt is not undesirable in the direction of the inland. The 5 element aerial is 1.35 m (0.73 λ) long and can be mounted on 1,50 m of boom with a mast bracket

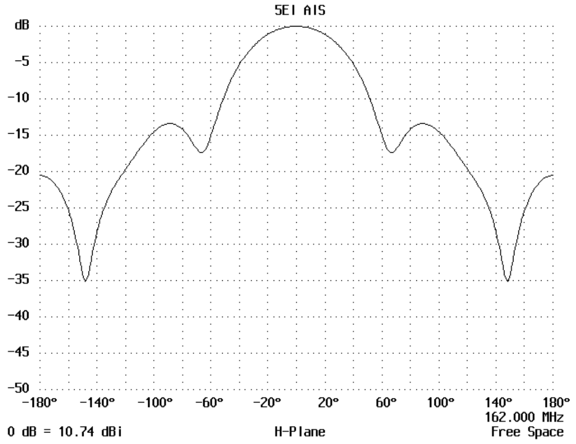
2.3 Simulation results single aerial

The simulation results are a starting point for the stacked system and are shown in the following. Table 1 shows the simulation results for the design frequency (162 MHz) and relevant antenna data with a divergence of plus/minus two MHz.

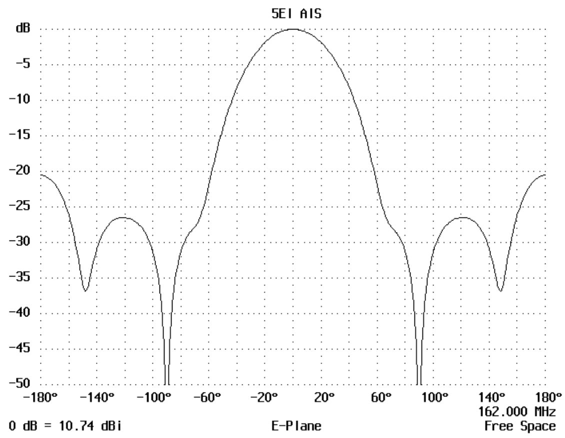
Frequenz (MHz)	**162,0 MHz**	**160,0 MHz**	**164,0 MHz**
Gain (dBD)	8,6	8,4	8,4
forward/backward Ratio (dB)	20,5	22,4	15,0
-3dB opening angle H-Plan (Degree)	+- 31,5	-	-
-3dB opening angle E-Plan (Degree)	+-25,0	-	-
Impedance (Ω)	43,9+j3,2	33,2+j3,3	22,9-j15,3

Table 1 Antenna Data Single 5 element Antenna

The pictures 2 and 3 show the simulated 5 element antenna diagrams in the H- and E-Plane. They refer to a vertically polarized single antenna.

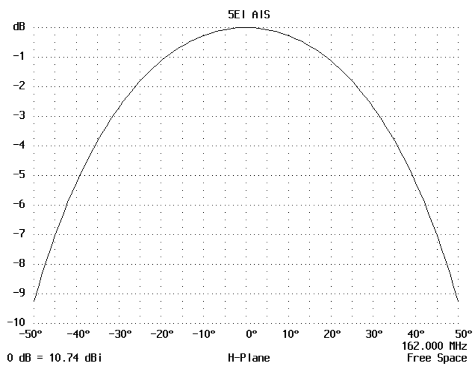


Picture 2 - Single 5 element Antenna H-Plane



Picture 3 - Single 5 element Antenna E-Plane

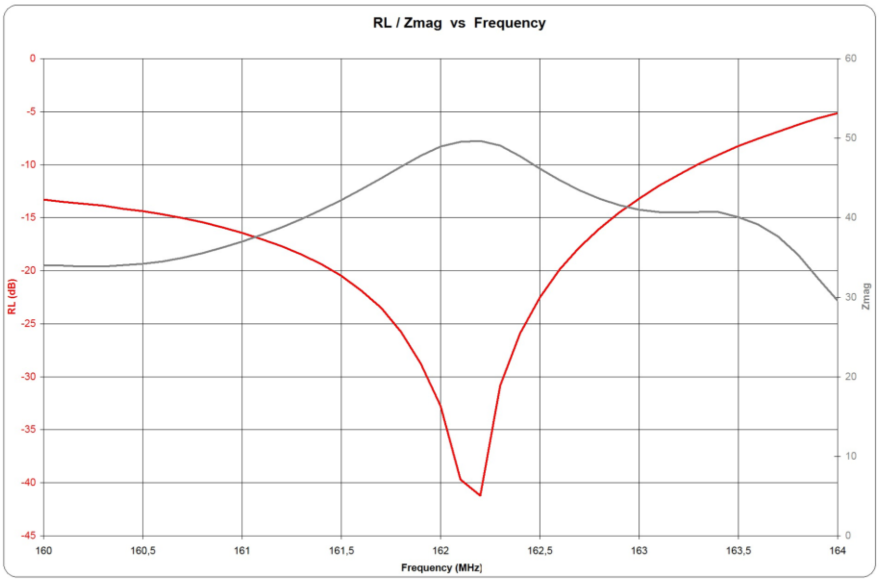
Picture 4 shows the H-Plane diagram with a higher resolution with a-3dB aperture angle of + - 31.5 degrees. This is of interest for the stacking calculation with a vertical



Picture 4 -3db Opening Angle in an H-Plane

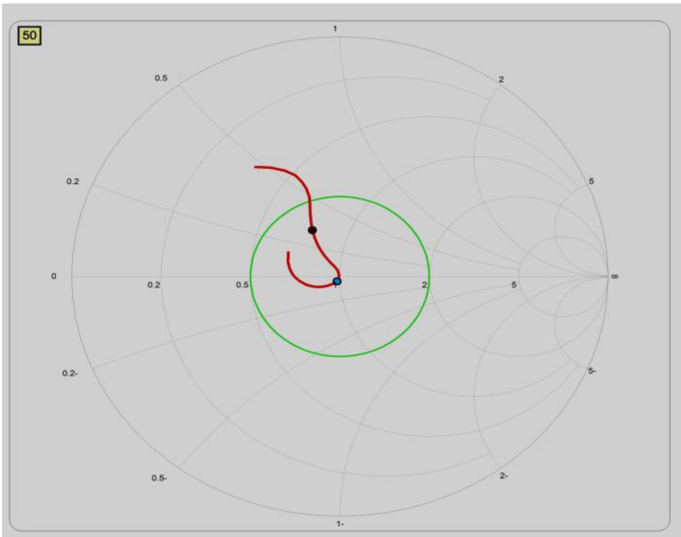
2.4 Matching measurements

After the simulation the antenna with a folding dipole and a 4:1 balun (λ/2 loop) from 50 Ω coaxial cable was installed. The loss of the loop is below 0,1 dB. The following pictures show the results of the matching measurements at the feed point of these antennas. All four antennas exhibit the same behavior. The pictures 5 and 6 show the impedance in a frequency range of 160 to 164 MHz. The antenna has a nearly pure real impedance at the design frequency. Precisely: Z = 49 Ω - j 2 Ω and therefore a return loss (RL) of 33dB. The optimum frequency was chosen a little higher in the simulation to compensate for the influence of rain or ice.



Picture 6 –Return Loss (RL) and Z vs. Frequency

The picture 7 shows the matching from 160 MHz to 164 MHz in a Smith Chart. The blue marker visualizes the frequency of 162 MHz, violet is 163 MHz and the green circle shows a SWR from 2.0 .



Picture 7 - Matching in Smith Chart

3.0 Stacking the Antennas

3.1 Stacking distance

Two Antennas are to be arranged vertically as a Yagi group. A compromise has to be found with this "stacking" between gain and side lope suppression**.** Mr. Hoch´s Formula [1] delivers a good approximation as a first step and was the starting point for the simulation.

$$D = \lambda/(2*\sin(\alpha/2)) \qquad [1]$$

D = optimized distance (~+2.8dB)

λ = Wavelength λ @ 162 MHz = 1,85m

α= -3dB opening angle

With the values from Table 1:

D = 1,85m / (2*sin (31,5°)) -> D = 1,77m

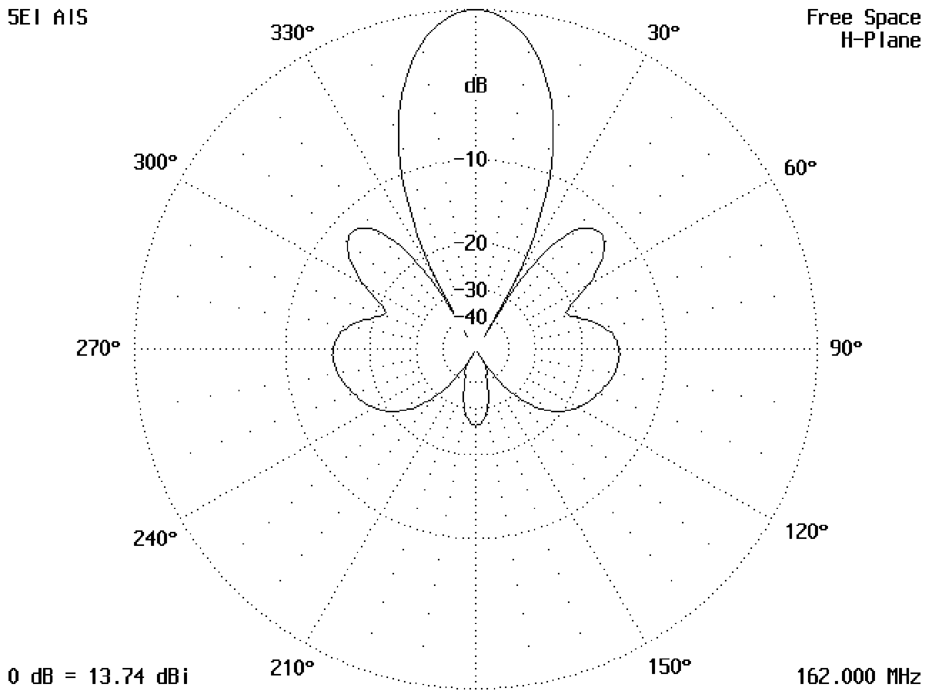
3.2 Simulation results group aerial (2 x 5El.)

A simulation with YO points in Table 2 are shown for a stacking distance of D = 1.80 m which gave the following results:

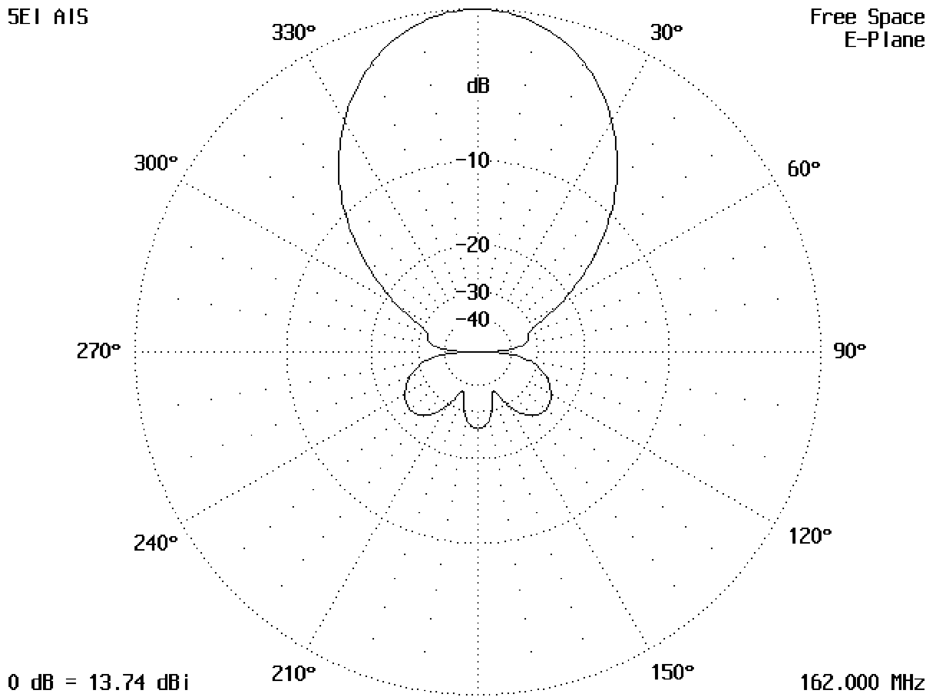
	f (MHz) 162.000
Gain (dBD)	11,6
forward/backward Ratio (dBD)	26
-3dB opening angle H (Degree)	+-14
1.side lobe H suppression (dB) / (Degree)	-12 / 46
2.side lobe H suppression (dB) / (Degree)	-15 / 92
-3dB opening angle E (Degree)	+-25
1.side lobe E suppression (dB) / (Degree)	-32 / 75
2.side lobe E suppression (dB) / (Degree)	-23 / 130
Impedance (Ω)	43,9+j3,2

Table 2 - Data of the Group Antenna (2 x 5El.)

The pictures 8 and 9 show the aerial H-and E-Plane diagrams in a polar coordinate system. The benchmark figures are also indicated in table 2.



Picture 8 - H-Plane Diagram of the Group Antenna (2 x 5El.)



Picture 9 - E-Plane Diagram of the Group Antenna (2 x 5El.)

3.3 Interconnection of the Antennas

Both aerials are connected by the same length coax cable (RG213-MIL-C-17F) to a 3 dB coupler for adding the signals. The lines are 1.83 m long with a loss of a=0,2dB @ 162 MHz. Picture 10 shows the used components.

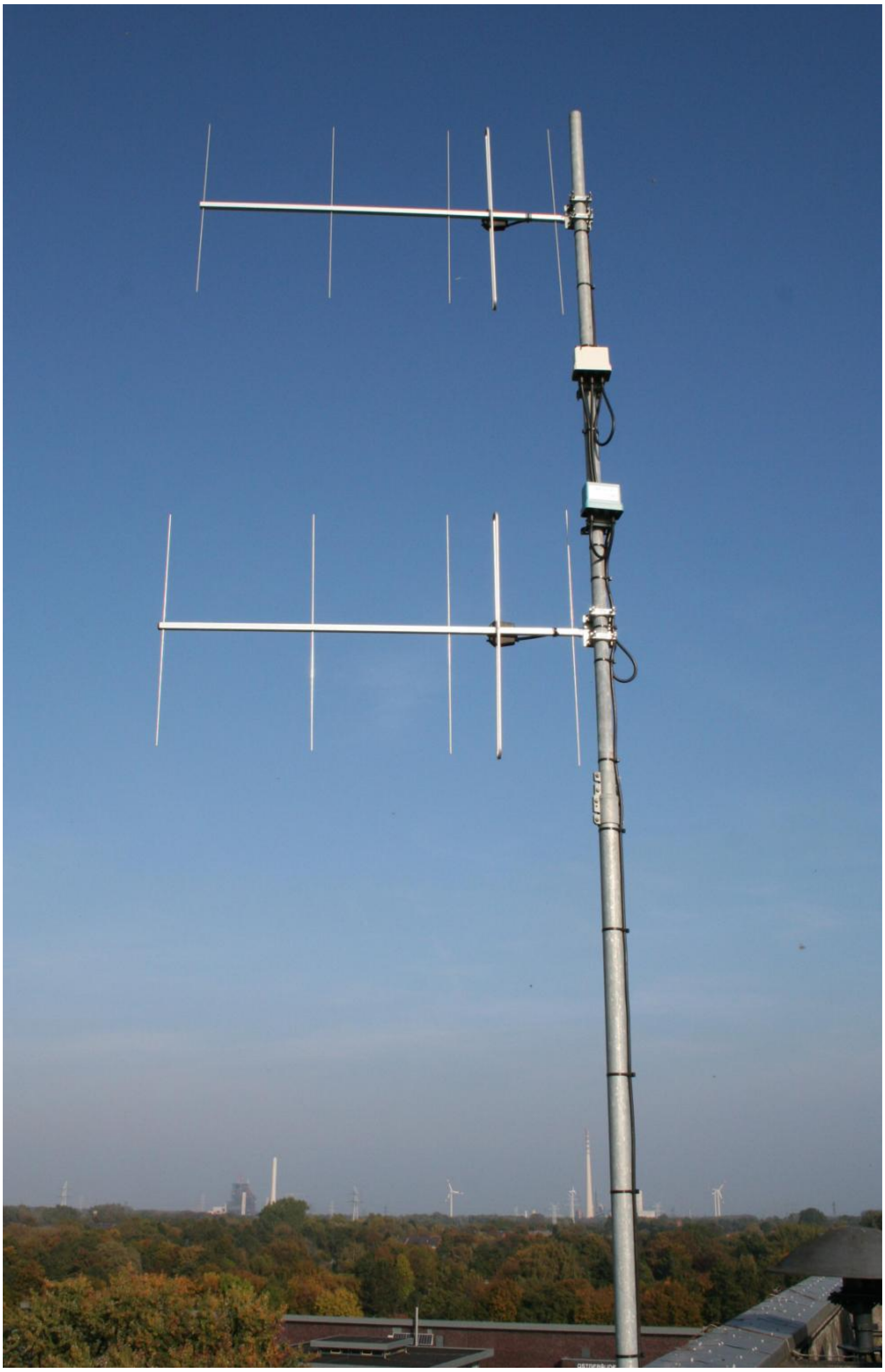
The 3dB coupler is made up of a 75 Ω Teflon cable (RG187). The input impedance of 50 Ω is transformed upwards by a λ/4 transformer to 100 Ω and then is switched in parallel. A loss of a=0,1dB @162 MHz was measured. Therefore the total losses for balun, coupling line and coupler are approx. 0.4 dB. With a simulated gain of 11.6 dB minus the interconnection losses with a system gain of approx. 11dB can be achieved.

Picture 10- Components to the Interconnection

4.0 Results and Preview

In the meantime a rotary antenna system is installed on the main building of the Jade University.
By remote control the arrangement is very flexible. Therefore the aerial can be adapted easily to the respective receipt requirements. Signals from opposite of the coastline can also captured, for example from inland ships.

Picture 11 shows the test set-up of the Yagi group antenna prototype in the antenna test field of the Jade University in Wilhelmshaven with an assembly height of approx. 25 m about the ground level.



Picture 11 - Test Set-up of the Yagi Group Prototype

Literature list:

(1) Hoch, Günther: Wirkungsweise und optimale Dimensionierung von Yagi-Antennen UKW Berichte 1977 Heft 1 S.27ff