



Developing a AIS Antenna System

Autor: Heinz-H. Blikslager

Case Study



Investing in the future by working together for a sustainable and competitive region



Developing a AIS Antenna System

Content

1.0 Executive Summary

1.1 The E-CLIC Project Team “AIS Antenna System”

2.0 Antenna Choice

2.1 Pre-Considerations

3.0 Antenna Design

3.1 Guidelines

3.2 Antenna Simulation

3.3 Antenna Measurements

3.4 Stacking of the Antennas

4.0 Interconnection of the Antennas

5.0 Results and Preview

1.0 Executive Summary

Within the scope of the project E-CLIC at the Jade University in Wilhelmshaven a receiving System should be built up in the lab for communication technology and digital technology for the AIS (Automatic Identification system). The received data should be made available to other research establishments or industrial partners by the broadband net.

AIS is a procedure to increase the security and the simplification of the fleet management within the maritime transport. Static and dynamic data is sent from the ships by a high frequency transmitting and receiving System (transponder). The static data holds following: IMO number, ship name, call sign and MMSI number. Dynamic data is used for e.g., ship position (LAT, LON), Course over the Ground (COG), Speed over the Ground (SOG), Heading (HDG) or course change of rate. For the transponder transmissions two radio canals are booked in the VHF sea radio area (canal A: 161,975 MHz, canal B:162,025 MHz). The transmissions are received by other ships or land stations and are evaluated. Depending on the type ship so-called Class A or Class B are prescribed to the transponder. In the sports navigation only pure receipt devices are used for cost reasons.

In the lab for communication technology and digital technology data should be first received via the AIS with a customary receiver and later with self-developed Software Defined Radio (SDR). The pursuing of such an arrangement is offered by the topography situation of the college on the North Sea coast. Other facilities in the interior can participate in the results. To achieve a very big reception range a high-capacity antenna system was developed especially for this use and was then built up. Such a development is suited especially well to train students to this topic.

1.1 The AIS Antenna System E-CLIC Project Team

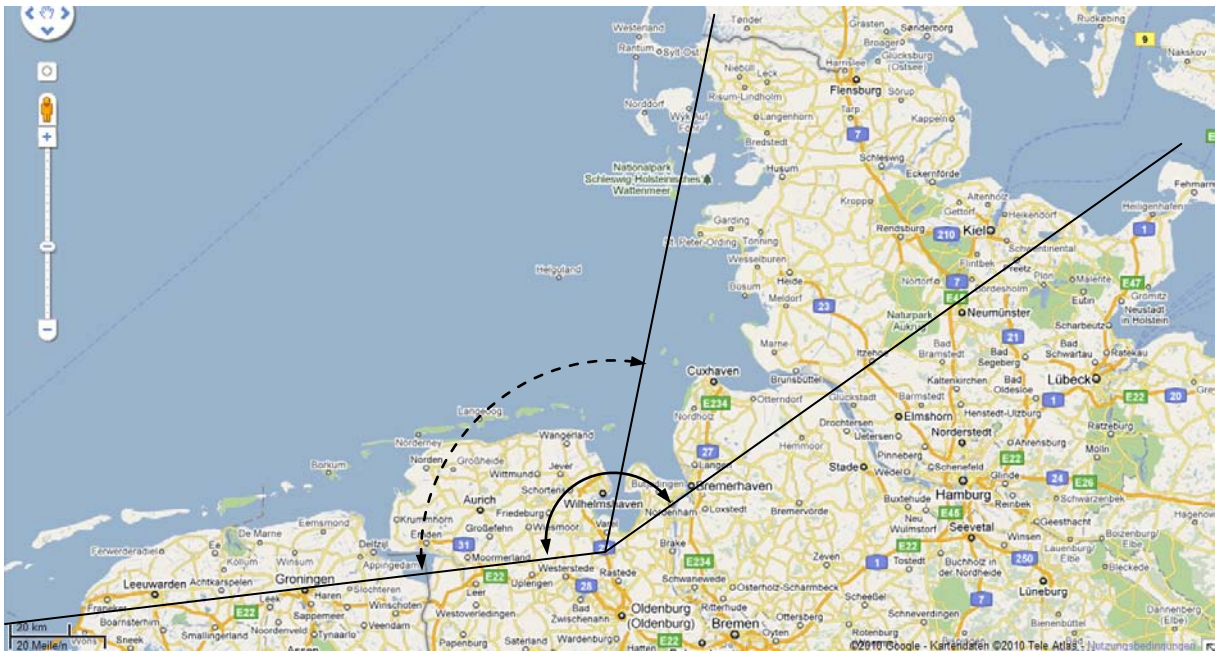
The AIS antenna project was offered to a four headed student group as a study work in form of a project. The members of the team were Florian Ellermann, Bastian Huber, Sebastian Koldemeyer and Heinz- H. Blikslager (lecturer). The students were integrated first by an introduction lecture with the special theoretical bases. Afterwards a Yagi-Uda antenna was developed and optimized by simulation software. The so designed antenna was built up by the task force mechanically and was measured and installed on the antenna test field on the college campus.

Thus not only the theoretical but also the manual abilities of the students could be developed. The results of the works are shown in the following.

2.0 Antenna Choice

2.1 Pre-Considerations

The AIS information is radiated with a vertical polarization. As a reference antenna a commercially made Dipole-antenna was installed with an omni-directional diagram and a gain of approx. 0dBD. Because of the topographic situation of the University the reception to the inland doesn't have to be covered for the primary receipt of ships on the North Sea. Therefore a greater coverage can be achieved by the use of a directional beaming Antenna. To grasp the North Sea, an antenna opening angle (-3dB) of approx. 110 degrees (Picture1 -->). makes sense. Should the north Baltic canal also be grasped the area would have to be expanded to approx. 150 degrees (Picture1 →).



Picture 1 Possible reception ranges

Source:Google Maps

To achieve the needed range the aerial gain should amount to at least 11 dBD. The wind load of the antenna and with it also the mechanical expenditure should be held as low as possible. All antennas should be mounted on a Tower with maximal length of 6 m.

2.2 Choice of Suitable Antennas

- Stacked Dipole Lines

The demanded opening angles can be realized with the given antenna gain using dipole lines. However, the mechanical expenditure becomes too big.

- Yagi-Uda Antenna

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 upward design guarantees a good weather independency of the antenna parameters. This antenna interpretation is also often used by radio amateurs for earth-moon-earth (EME) communications.

3.0 Antenna Design

3.1 Guidelines

The aimed antenna Gain of 11 dBD with an opening angle of about 110 degrees cannot be realized with only a single Yagi-Uda antenna (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). Through 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 6 m poles. With it four antennas can be built up without scrap. The foot-point-resistance should amount to 50 ohms.

3.2 Antenna Simulation

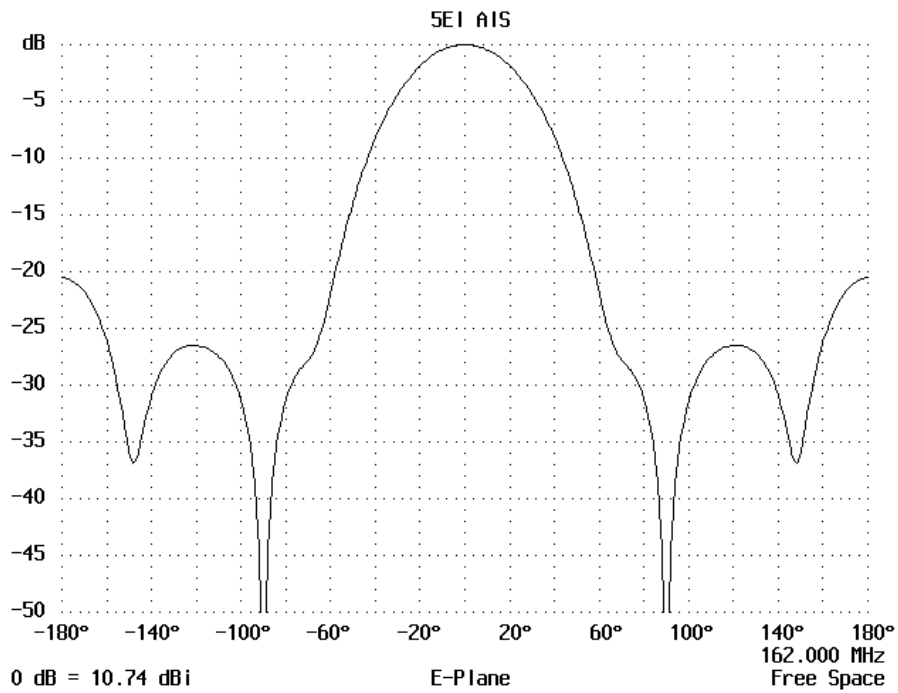
The antenna was developed with the software tool “Antenna Optimizer” (AO) by Brian Beezley. It is software for the analysis and optimization of Yagi-Uda antennas with a small bandwidth. The starting point was a 5 elements antenna by Hoch with feed by a folded dipole. A compromise was searched concerning enough 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 owns in length of 1.35 m (0.73λ) and can be mounted with mast bracket on 1,50 m of boom. 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.

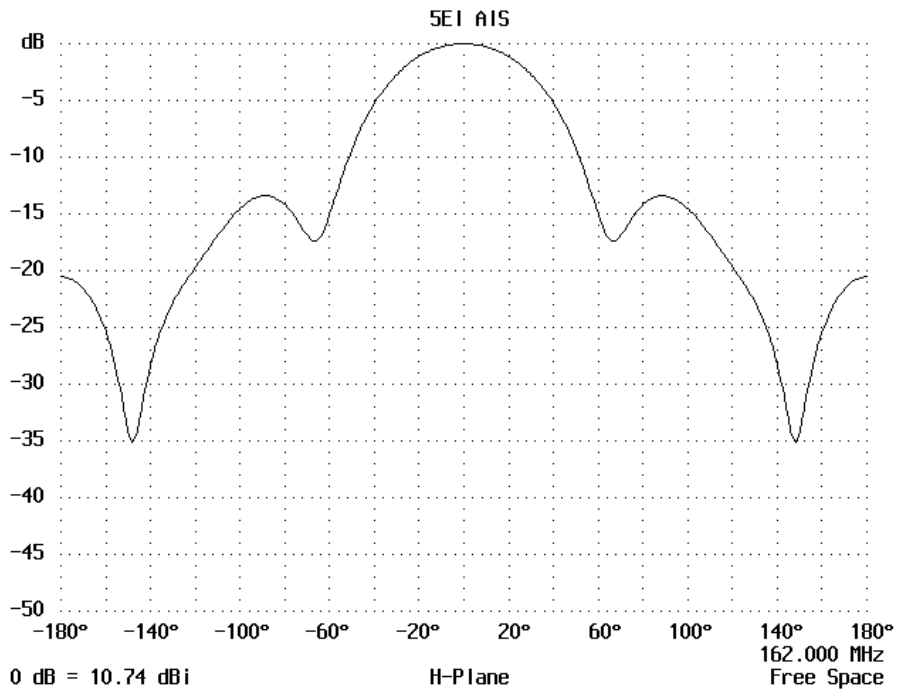
	f (MHz) 162.000	f (MHz) 160.000	f (MHz) 164.000
Gain (dBD)	8,6	8,4	8,4
forward/backward Ratio (dB)	20,5	22,4	15,0
-3dB opening angle H-Plan(Degree)	+31,5	-	-
-3dB opening angle. E-Plan (Degree)	+25,0	-	-
Impedance Ω	43,9+j3,2	33,2+j3,3	22,9-j15,3

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.

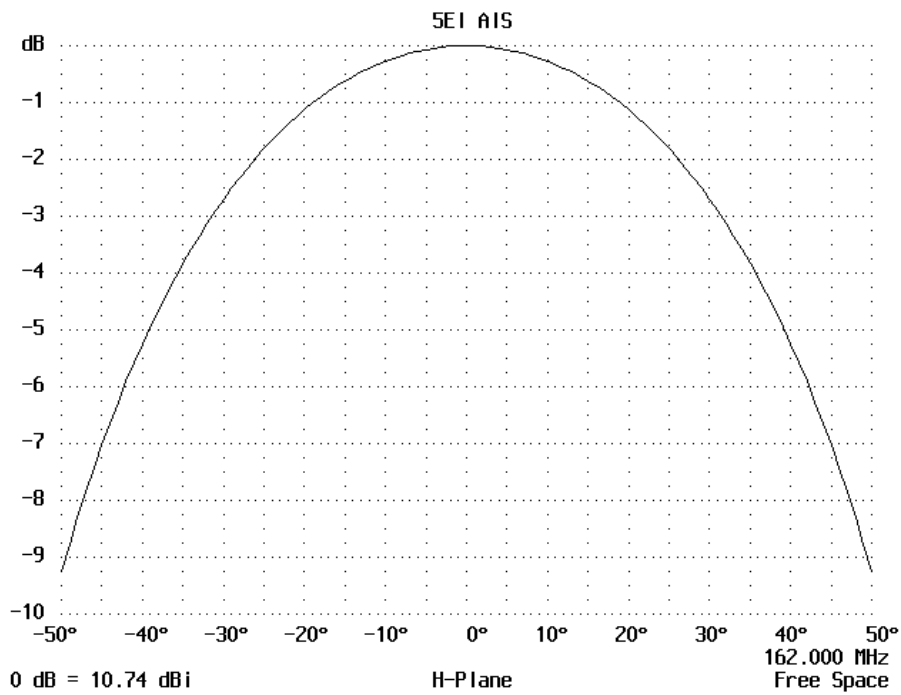


Picture 2 - Single 5 element Antenna E-Plane



Picture 3 -Single 5 element Antenna H-Plane

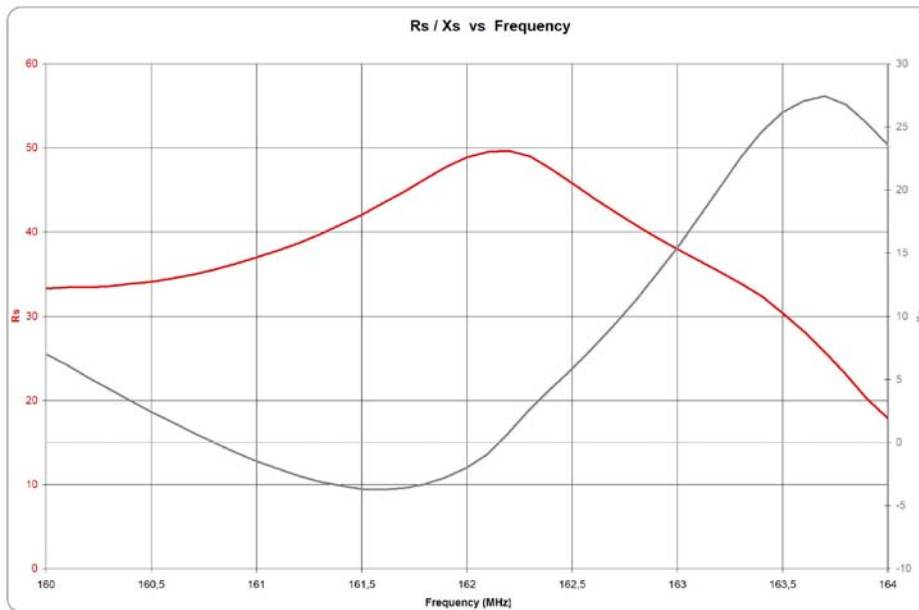
Picture 4 shows a H-Plane diagram with a higher resolution with a ± 3 dB opening angle from ± 31.5 degrees. This is of interest for the stacking calculation with a vertical arrangement



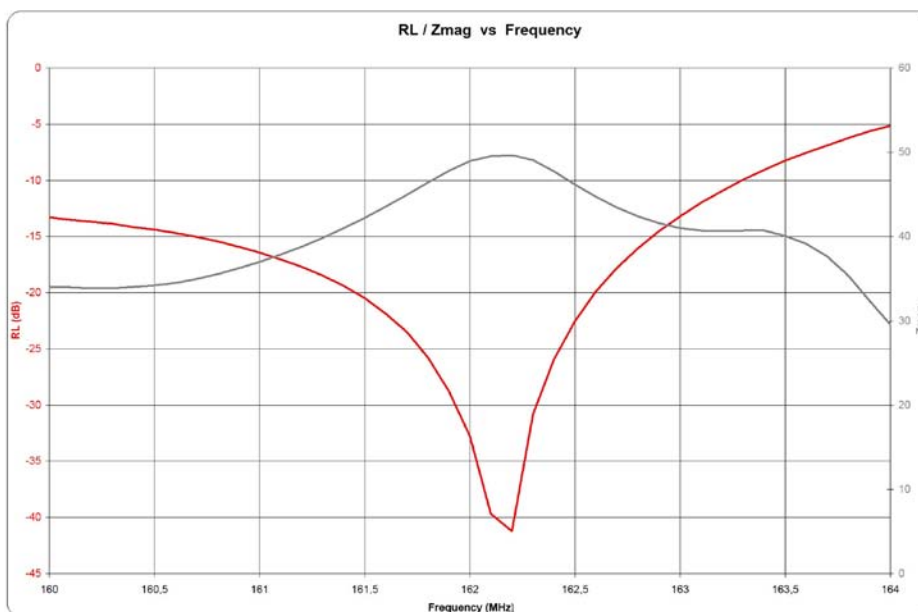
Picture 4 -3db Opening Angle in an H-Plane

3.3 Antenna Measurements

After the simulation the antenna (Picture 8 aerial prototyp) with a folding dipole and a 4:1 balun ($\lambda/2$ 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 adaptation measurements at the feed point of the so built up antennas. All four antennas show the same behavior. The pictures 5 and 6 show the impedance in a frequency response of 160 to 164 MHz. The antenna owns an almost real part impedance value to the design frequency. Precisely: $Z = 49 \Omega - j 2 \Omega$ and therefore a return loss (RL) of 33dB. The optimum frequency was chosen a little higher in the simulation to counteract those disgruntlements by rain or ice.

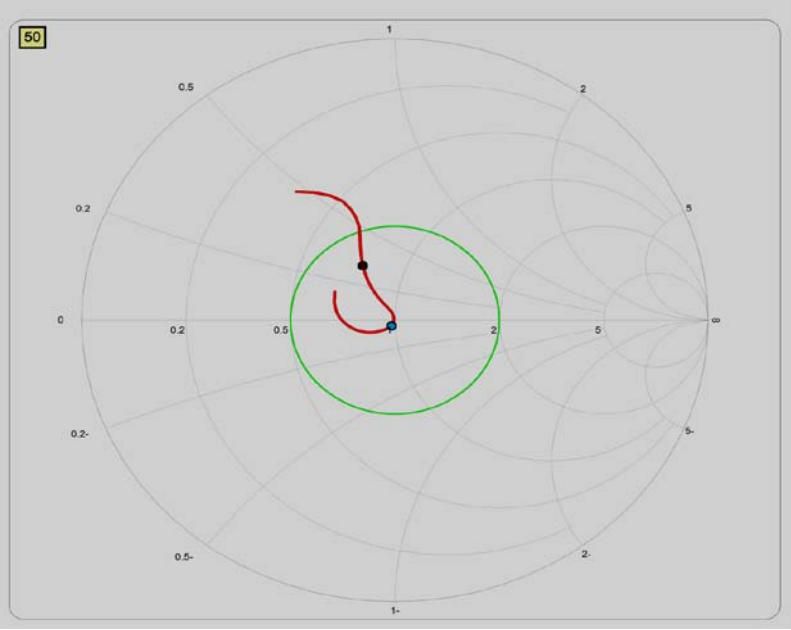


Picture 5 –R and X vs.Frequency



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 160 MHz, violet is 163 MHz and the green circle shows a SWR from 2.0.



Picture 7 - Matching in Smith Chart



Picture 8 - Student Jan Budroweit with the Antenna Prototype

3.4 Stacking of the Antennas

Two Antennas should be arranged to one another (vertically) as a Yagi group. A compromise should be found with this "stacking" between gain and side lobe suppression. Mr. Hoch (1) delivers formally [1] a good first step and was the starting point for the simulation.

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

D = optimized distance (~+2.8dB)

λ = Wavelength $\lambda @ 162 \text{ MHz} = 1,85\text{m}$

α = -3dB opening angle

With the values from Table 1:

$$D = 1,85\text{m} / (2 * \sin (31,5^\circ))$$

$$D = 1,77\text{m}$$

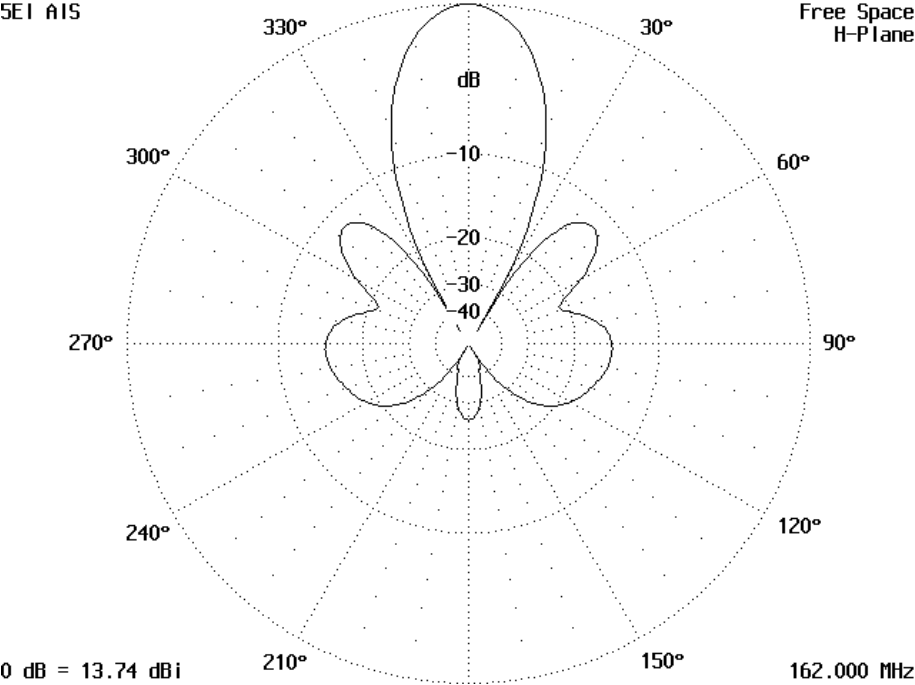
A simulation with YO points in Table 2 are shown for a stacking distance of D = 1.80 m which lead to the following results:

	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

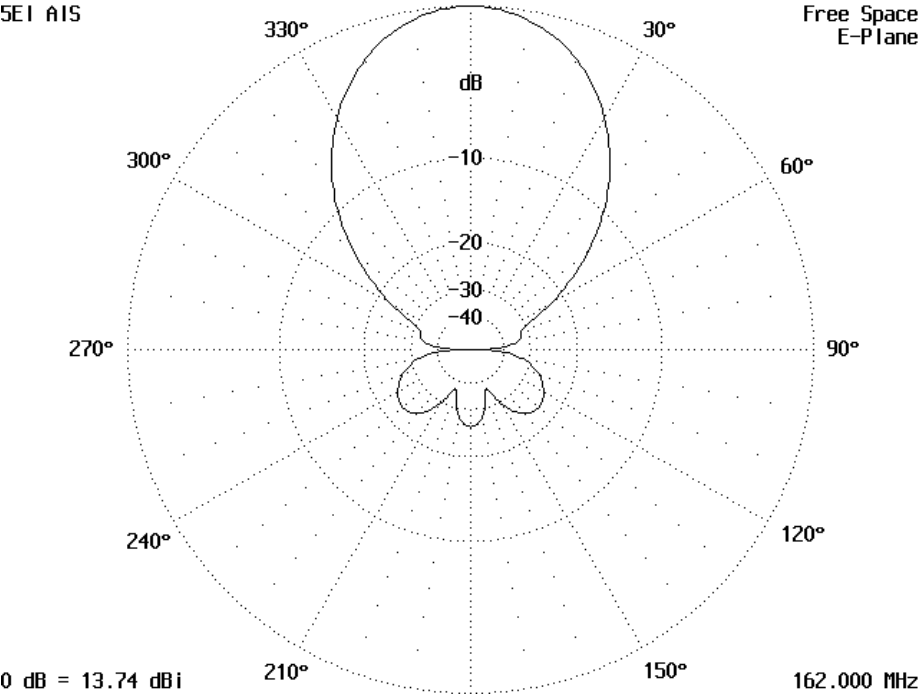
Table 2 - Data of the Group Antenna (2 x 5El.)

The pictures 9 and 10 show the aerial H-and E-Plane diagrams in a polar coordinate system. The benchmark figures are also indicated in table 2.

With a gain of 2.9 dB compared with the single antenna (see table 1) and a clean beaming diagram, the antenna can be installed accordingly.



Picture 9 - H-Plane Diagram of the Group Antenna (2 x 5EI.)



Picture 10 - E-Plane Diagram of the Group Antenna (2 x 5EI.)

With a simulated gain of +2.9 dB compared with the single antenna and a clean beaming diagram, the aerial can be implemented accordingly. Under the consideration of interconnection losses the aimed gain of 11 dB should be reached accordingly.

4.0 Interconnection of the Antennas

Both aerials are led with the same length Coax cable (RG213-MIL-C-17F) to the addition of the signals on a 3 dB coupler. The lines are 1.83 m long and show a measured damping of $a=0,2\text{dB}$ @ 162 MHz.

Picture 11 shows the used components.

The 3dB coupler is made up of a $75\ \Omega$ Teflon cable (RG187). The input impedance of $50\ \Omega$ is highly transformed by a $\lambda/4$ transformer on $100\ \Omega$ and then is switched in parallel. A damping of $a=0,1\text{dB}$ @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 less, the interconnection losses can be achieved with a whole system gain of approx. 11dB.

Directly after the coupler a low noise FET preamplifier with a noise figure of $\text{NF}=0.8\ \text{dB}$ and a gain of 20dB is placed. Therefore a good Signal / Noise (S/N) ratio is guaranteed with a cable distance of 50 m.



Picture 11- Components to the Interconnection



Picture 12 - Test Set-up of the Yagi Group Prototype

Picture 12 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.

5.0 Results and Preview

In the meantime, the first system on the building of the Jade University is installed and aimed toward the northwest direction of the North Sea. With a representation the received AIS signals are displayed in a Google-Earth map (Picture 13), so the antenna diagram stands out. The map shows the reception range with slightly above-average propagation terms on VHF. It can be detected on average by 180 to 270 ships and base stations. Compared with the omni directional antenna it was, as already expected to register a clear reach increase. The received data will transfer to different facilities for research purposes by broadband internet. In the course of the E-CLIC project the second antenna group (see 2.1) should be installed shortly. Other plans pass to extend the arrangement by an antenna rotor. Then the users would be able, when required, to adjust the antenna on the broadband network from the distance. As a new receiving station a SDR (Software Defined Radio) is a proprietary development within the scope of the project E-CLIC according to the treatment.



Picture 13 - Received AIS Objects

Source: Google Earth

Literature list:

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