Development and Construction of an AIS Receiving Equipment in SDR Technology Using the Broadband Net

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Case Study

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Content

Development and Construction of an AIS (Automatic Identification system) Receiving Equipment in SDR (Software Defined Radio) Technology Using the Broadband Net

1. Executive Summary

Within the scope of the E-CLIC project a system in hardware and software was developed for receiving AIS (Automatic Identification system) transmissions of ships. Aerials and receiving equipment in the new SDR (software Defined Radio) technology were developed and built up using FPGAs (Field Programmable gate Arrays).

1.1 Partner involved

German Aerospace Center (DLR), Institute of Space Systems in Bremen

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2. The E-CLIC AIS receiving equipment in SDR technology

For many years the Lab of Communication Technology and Digital Technology at the Jade University in Wilhelmshaven has experiences in the development of hard- and software components in the area of communications engineering. Beside the research and development among other things in projects promoted by the EC, the technology transfer is also capitalized in this area. Thus in 2002 Prof. Dr. Werner Pohl and Mr. Heinz-Hinrich Blikslager were awarded a price for successful cooperation between industry and universities by the German Federal Land of Lower Saxony. In 2010 a cooperative agreement was signed between the laboratory at the Jade University and the Institute of Space Systems of the German Aerospace Center (DLR) in Bremen.

Also in the current project E-CLIC modern digital technology is connected with communication.

Within the scope of the project E-CLIC a receiving System should be built up 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 are sent from the ships by a high frequency transmitting and receiving System (transponder). The static data encompass the following: IMO number, ship name, call sign and MMSI number. Dynamic data are used for e.g. ship position (LAT, LON), Course over Ground (COG), Speed over Ground (SOG), Heading (HDG) or rate of course change. Two radio channels are scheduled in the VHF sea radio area (channel A: 161.975MHz, Channel B: 162.025

MHz for the transponder transmissions. The transmissions are received by other ships or land stations and are evaluated.

The data should be received via the AIS with a self-developed Software Defined Radio (SDR). Pursuing such an arrangement is facilitated by the topographic situation of the University on the North Sea coast. Other facilities in the interior can participate in the results. To achieve a very large reception range a high-capacity antenna system was developed especially for this purpose and was then built up. Such a development is especially suited to train students on this topic.

The DLR in Bremen works on sililar subjects in the field of development of satellite systems. The AIS data received in Wilhelmshaven are transferred to the DLR to Bremen over the broadband net. Thus the project partner can evaluate constantly updated raw data and process them. In this manner important information is gained for the draught of a satellite system.

In the E-CLIC project a complete radio receiving system was developed and built up, from the aerial arrangement up to the data recording or transmission. The radio reception technology was developed in the new SDR (software Defined Radio) technology. With these kinds of receivers radio signals are converted into digital signals directly after the aerial entrance. This kind of approach is possible only nowadays. The lab has over 20 years experience with the application of FGPAs (Field Programmable Gate Arrays) and their application in the communication technology. These high speed and highly integrated digital devices permit the construction of a SDR with minimum analog electronic devices. This new technology is especially well suited for the application in satellites.

The receiving system and the additional hardware is usable over the broadband net. Thus the students can use the complex hardware on the campus area (WLAN) or at home. One of the topics in E- CLIC was not only the solution of the technical problems but also an early inclusion of the students in these works.

Thus some parts were offered to bachelor students of the information technology and communication technology as a study project or for a diploma or bachelor thesis.

After a theoretical introduction by the lecturer the subjects were elaborated in the team. Afterwards these students could deepen their acquired knowledge in their bachelor thesis in the lab or in industry with the cooperation partners. All together six students gained experiences in the area of AIS and SDR in the project team and other six by their diploma or bachelor thesis. . Because of the high economic importance and technical actuality the students are in a good position when they apply for a job after finishing their studies.

In the course of the project an enlargement of the arrangement was considered as to the receiving of ADSB in aviation. A project team made first experiences using of an existing 3m dish aerial.

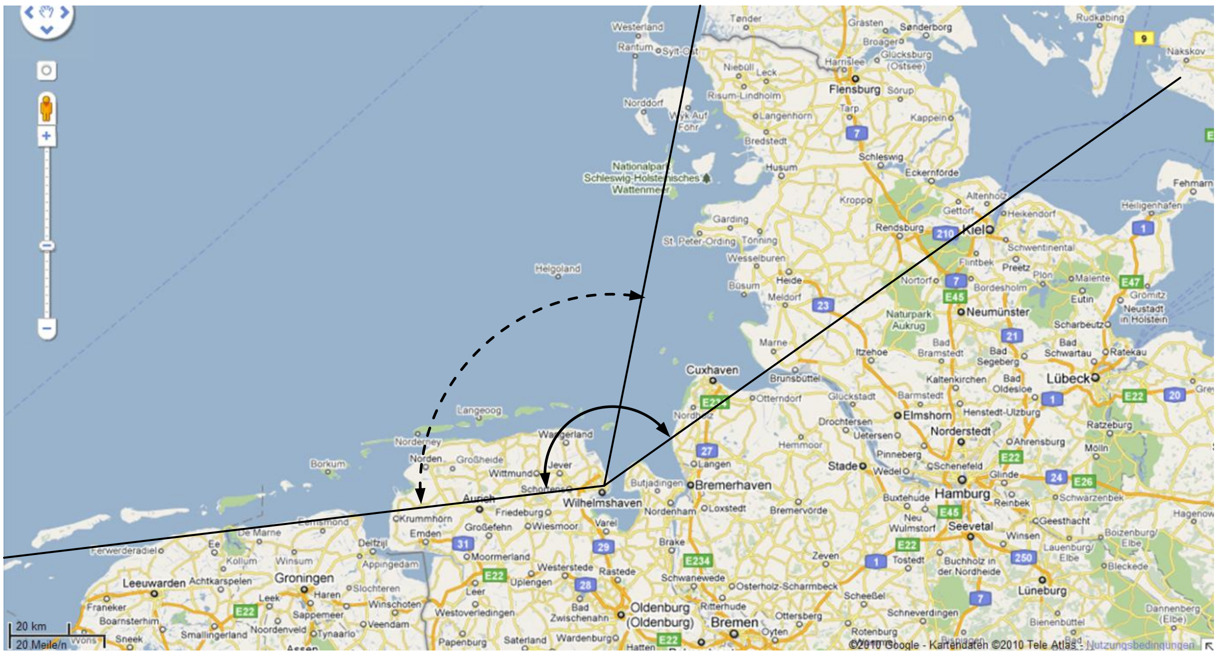
The technical problem formulations were split into the following areas and worked on as project works or final projects in the diploma or master thesis:

1.) The E-CLIC AIS Antenna System
2.) The E -CLIC AIS Display
3.) The E -CLIC AIS Evaluation Software
4.) The E-CLC AIS SDR Receiver

3. The E-CLIC AIS Antenna System

The AIS antenna project was offered to a group of four students as a student research project. The members of the team were Florian Ellermann, Bastian Huber, Sebastian Koldemeyer and Heinz- H. Blikslager (lecturer). The students first took part in an introduction lecture covering relevant theoretical topics. Afterwards a Yagi-Uda antenna was developed and optimized by simulation software. The 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 cultivated.

The following considerations formed the basis of the aerial development. The AIS information is radiated in vertical polarization. As a reference antenna a commercial dipole-antenna was installed with an omni-directional diagram and a gain of approx. 0dBD. Because of the topographic situation of the University the inland doesn´t have to be covered for reception. The main objective is the reception of ships on the North Sea. Therefore a greater coverage can be achieved using a directional beaming Antenna. To grasp the North Sea, an antenna opening angle (-3dB) of approx. 110 degrees (Picture 1◄ - ►) makes sense. Should the Nordostseekanal (canal between the North and Baltic Sea) also be grasped the area would have to be expanded to approx. 150 degrees (Picture1 ◄—►).



Picture 1 : Possible reception ranges   Source:Google Maps

Picture 2: Test Set-up of the Yagi Group Prototype

To achieve the necessary range the aerial gain should amount to at least 11 dBD. The wind load of the antenna and thus also the mechanical dimensions should be held as low as possible. All antennas should be mounted on a tower with maximal length of 6 m. 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 . 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 into two sectors (cutting the opening angle in half). Thus the system should be realizable. The assembly height amounts to approx. 25 m. Picture 2 shows the first experimental set-up.

In this manner a very efficient aerial system was created supporting the SDR developments. In the meantime, the aerials can also be turned in other preferential directions by a rotor . The number the receivable AIS objects, like ships or base stations, depends on the radio propagation conditions in the VHF area. With this arrangement about 200 to 350 objects at a distance from 80 to 150 km can normally be captured. On good VHF conditions longer distances are clearly possible.

The results of the work have flowed into the following publications:

- E-CLIC Case Study: ”Developing an AIS Antenna System“
- E-CLIC Prototype : “E-CLIC AIS-Antenna System”

4. The E -CLIC AIS Display

One of the first working points in this project was worked on by Mr. Martin Stolper (Picture 3) in his Bachelor Thesis. To the display the AIS data with field measurements a handy, PC independent system should be developed suitable for outdoor applications. On this occasion an 8 bit microcontroller with RISC architecture from Atmel should be use. Mr Stolper extended the scope of operations, so that the prototype (picture 4) is also suitable for the application on sports boats.

To localize the own position the device contains an integrated GPS receiver. The display receives data from a standardized interface (serial, NMEA0183) and displays the positions of the AIS objects relative to its own location. The image resembles an arrangement with "radar rings". The range can be zoomed in an area from 2 to 20 sea miles. In addition, data of the individual objects can be displayed selectively as AIS information. An external GPS source can also be connected.

Picture 3: Martin Stolper in the Lab

Picture 4: AIS-Display Prototype

Technical data of the prototype:

- Operating Voltage 12 V to 24 V DC

- Power consumption <2 W, Standby <0.5 W

- Water protection IP64

- Internal GPS RX (or external GPS RX)

- Interfaces: serial, NMEA0183

- Up to 255 objects

- 2 to 20 sea miles adjustable

- Sensor for temperature and air humidity

- Lighting

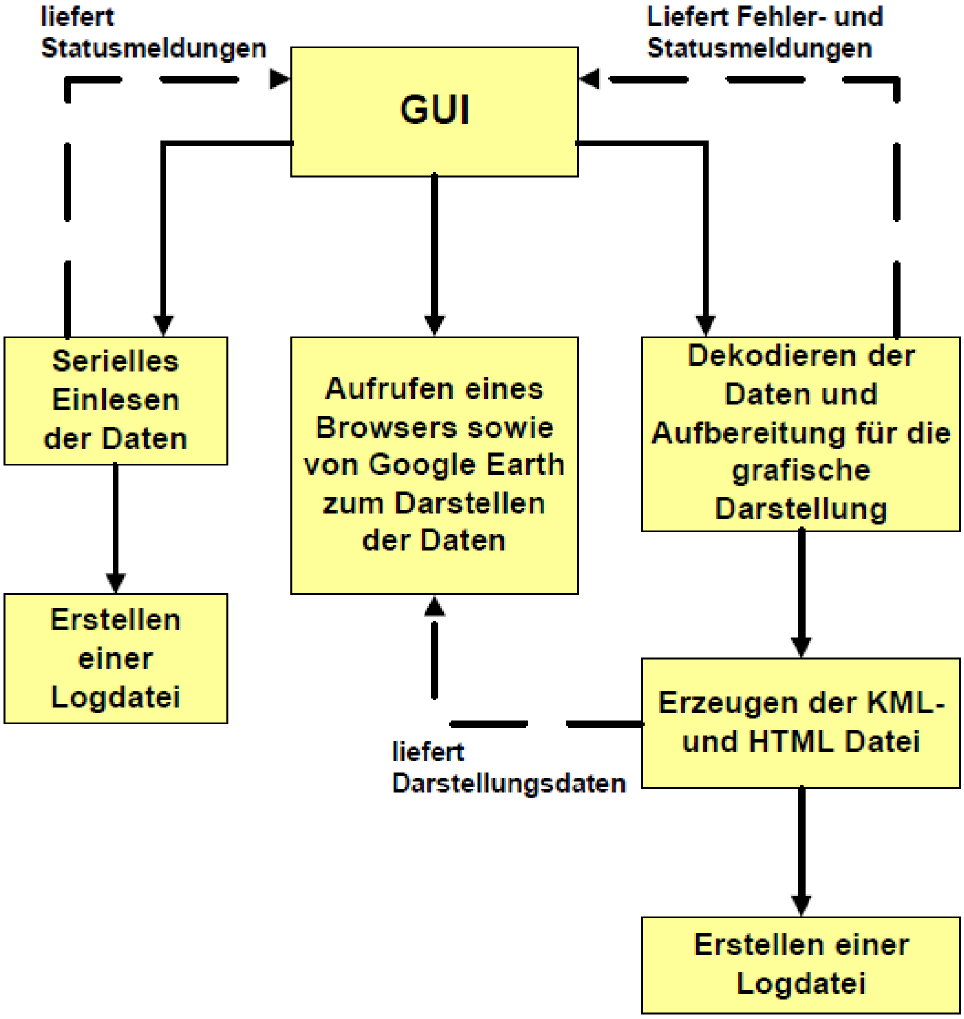
The results are summarized in the following documentation:

- E-CLIC Prototype: “E -CLIC AIS Display”

5. The E -CLIC AIS Evaluation Software

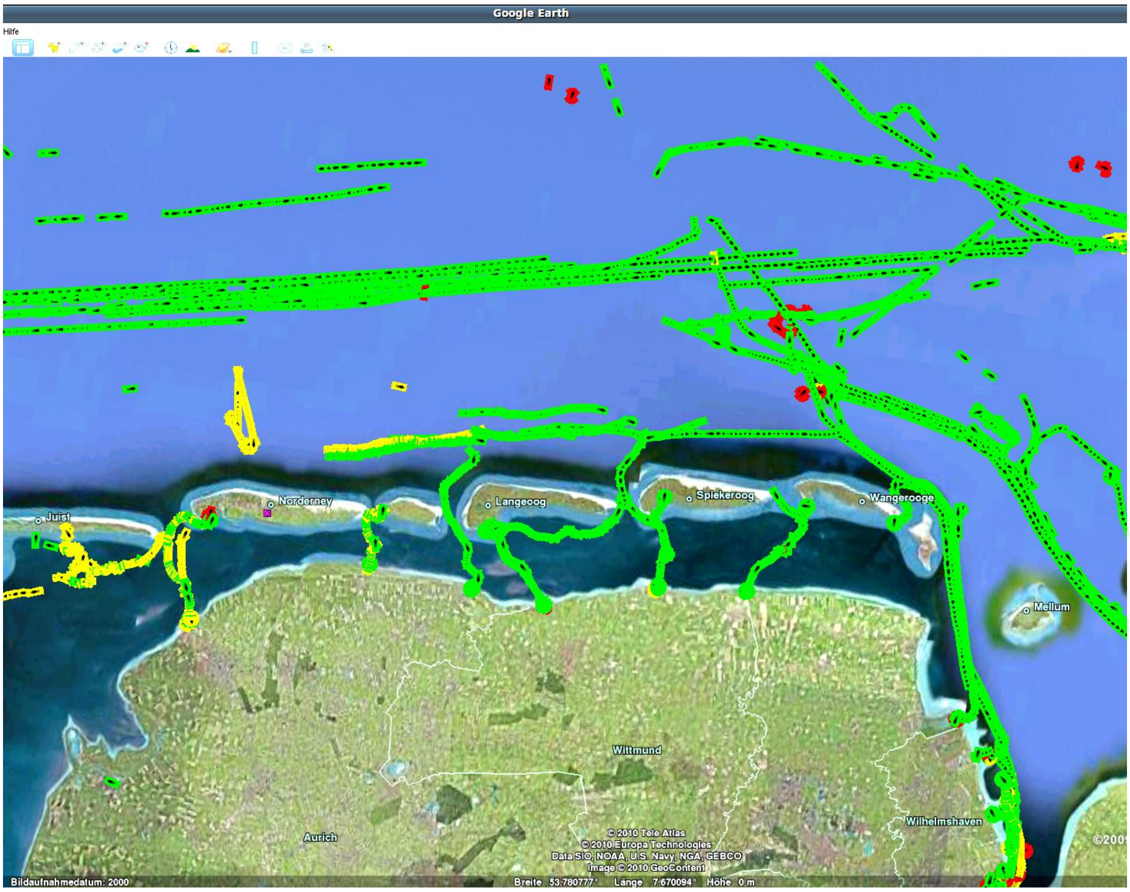
In the course of the E-CLIC project a software concept was developed by Mr. Stephan Reinsch within the scope of his Diploma Thesis. Among others it comprises the interpretation and storage of AIS data. Afterwards the software was tested in the lab. The software evaluates the NMEA-0183 Information of an AIS receiver. The software draught should be made available to a grat number of users, like the project partners or students. Therefore a version with open source software was favored by us. As an operating system Ubunto was chosen under a Unix/Linux environment. Programming was carried out in the language "Python", Google Earth was chosen for a graphic map representation.

The received NMEA data are decoded by the E-CLIC Evaluation Software and as a HTML table or graphically as KML files in the Google Earth Overlay. Picture 5 shows the software modules.



Picture 5: Modules of the Evaluation Software

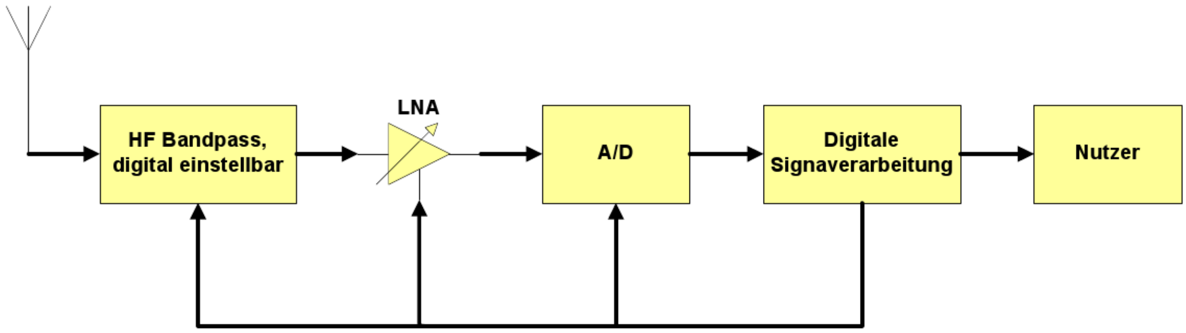
The KML data recorded for a longer period can be analyzed like shown in picture 6 . The "tracks" of the individual ships on the East Frisian North Sea coast become well visible.



Picture 6: Representations of a KML log file in Google Earth

6. The E-CLC AIS SDR Receiver

At the moment a revolutionary advancement of the receiver's technology takes place in the area of the radio communication, possibly comparable to photography, when some years ago the digital camera replaced the classical roll film in a very short time. This new technology is called SDR (Software Defined Radio). Present receiving equipment, for example, for the AIS receiving or the car radio, are built up almost completely analog. Other devices, as for example for the terrestrial digital television reception (DVB-T) or over satellite (DVB-S), use digital signal processing only partially. With SDR, the analog signal caught from the air is converted into a digital one directly after the antenna by means of an analog-to-digital converter (ADC). Before the small analog signal must be prefiltered and amplified by a low-noise amplifier (LNA). In picture 7 such a receiver is shown in a simple block diagram.



Picture 7: SDR Receiver

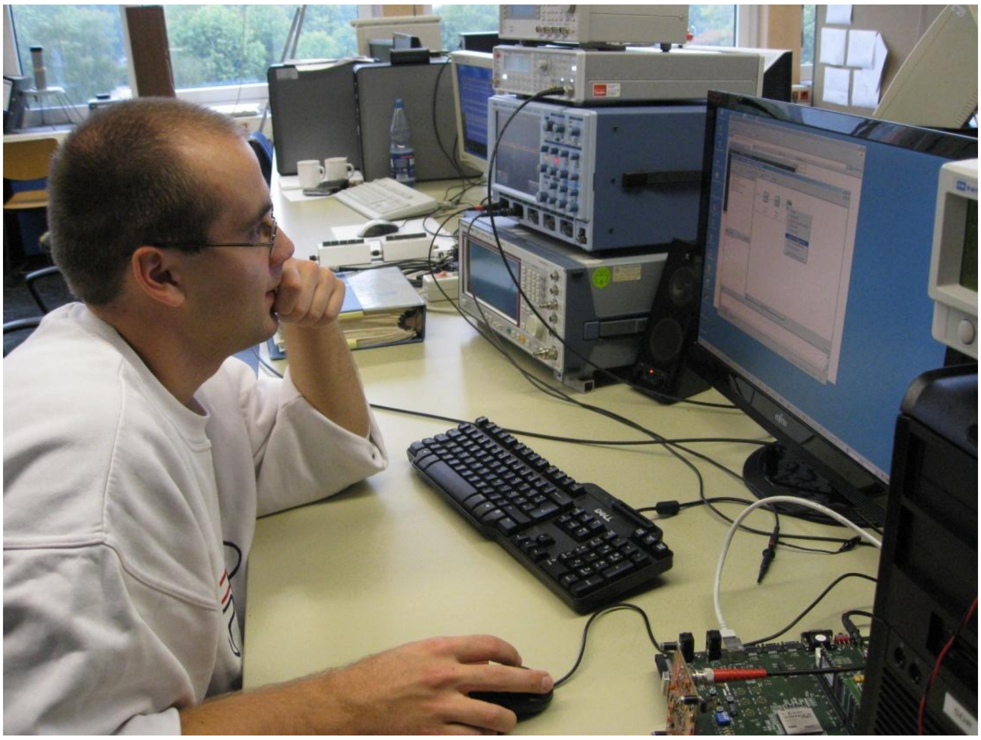
This technical concept became feasible recently with defensible technical expenditure and costs. Inexpensive ADC which can convert high-frequency signals of some hundred MHz are available. Processing can also be made today with high-speed FPGAs (Field-Programmable Gate Arrays). Therefore such a system of the AIS receiving at 162MHz was built up in the project E-CLIC.

Within an analog system the signals are mixed, filtered and demodulated. The filters are often very costly, realized in hardware and usable for one application only. With the software based receivers they are by definition realized in software and their parameters can be changed easily. A system can be adapted for different uses by program modification. Now almost ideal filters are possible.

Therefore such a system is suited particularly for satellites. System changes are hardly possible here with customary configurations. With the SDR a new configuration or software for the satellite can be uploaded on radio transmitter. A disadvantage of this concept is still the higher current consumption. Therefore the cooperation with the DLR is also in the field of SDR.

First a Board with the chip ADC AFE8201 from Texas Instruments was developed as a base for other investigations. Criterion for the choice of this IC (Integrated Circuit) was the fact that the lab already had very good experiences with this IC for an SDR application at 20 MHz. This time, however, an AIS Receiver with undersampling should be examined with a substantially higher frequency. At the same time a feasibility study should originate to be used by the Institute of Space Systems of the German Aerospace Center (DLR) in Bremen.

A part of these works is the Bachelor Thesis of Mr. Karsten Schubert with the subject: „Design and Implementation of a SDR Software Defines Radio)-based Receiving Module using FPGA-based Filter- and Demodulation Algorithms". This excellent work was awarded a prize by the VDE Region Northwest (Association of German Engineers). Mr Schubert (Picture 8) could make use of his experiences gained within the scope of his work during a balloon mission of the DLR in Kiruna (Sweden).



Picture 8: E-CLIC SDR developing place with Mr. Karsten Schubert

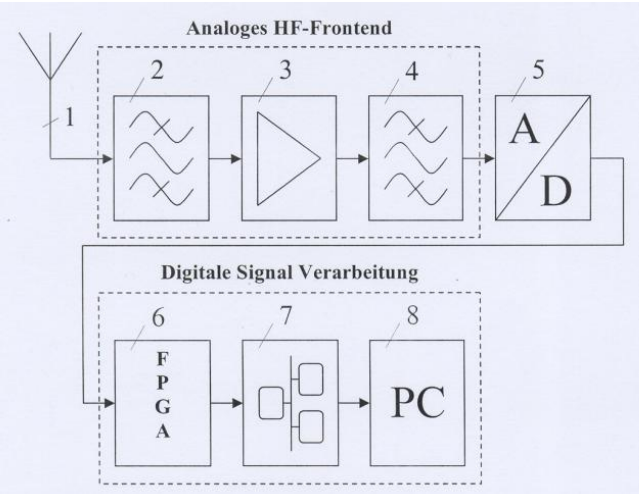
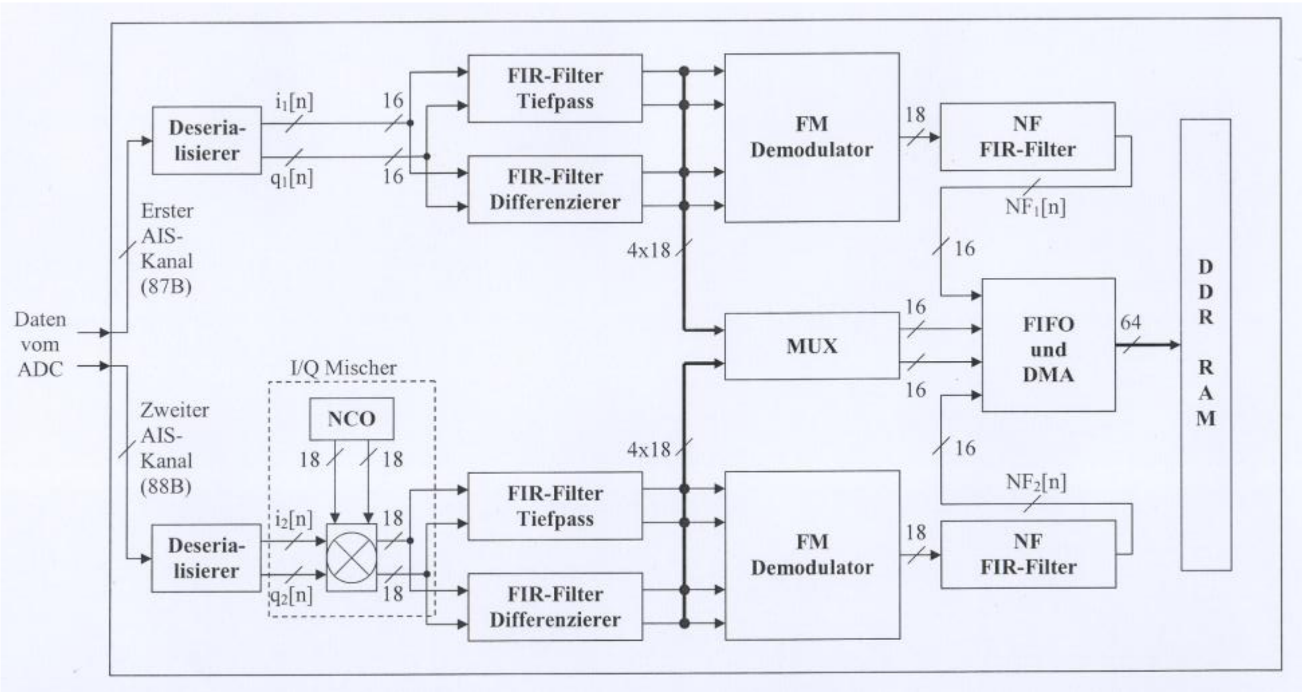


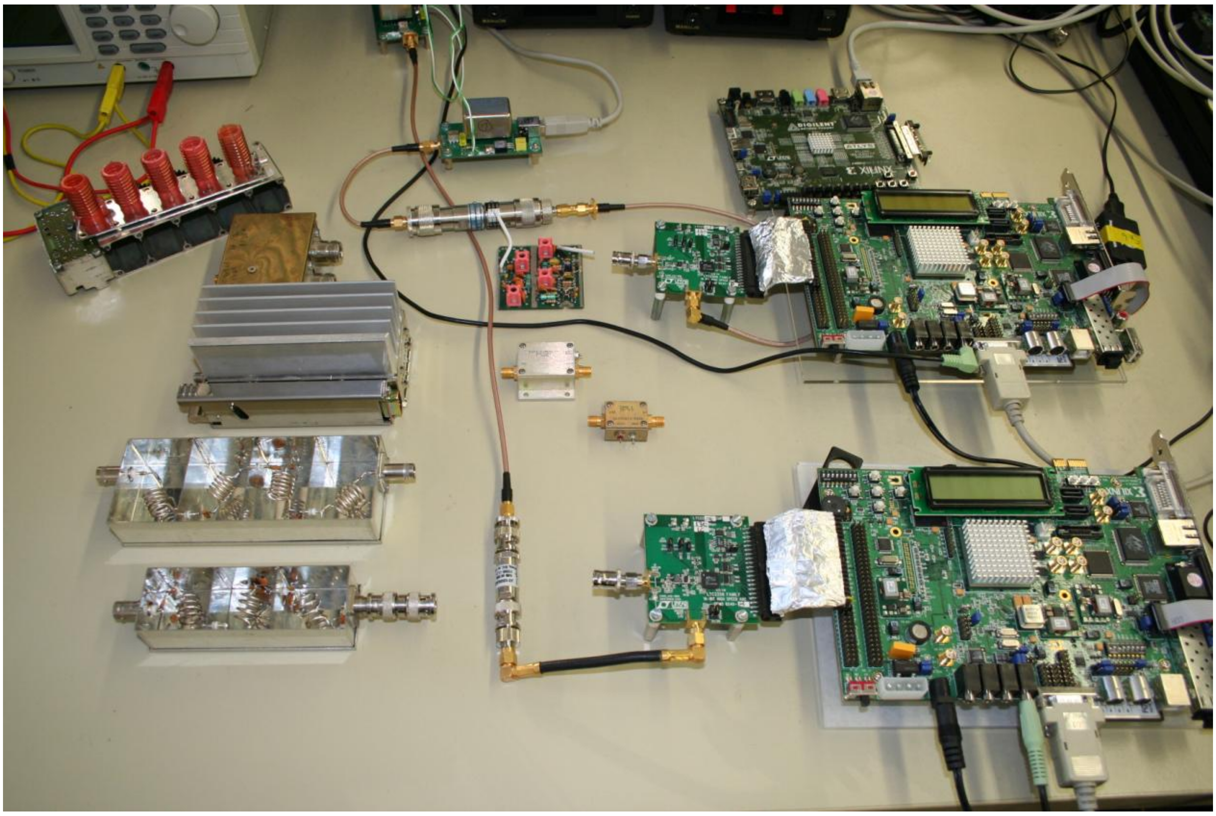
Bild9: SDR prototype arrangement

1	AIS receiving antenna	5	TI AFE8201 12 bit ADC, pursued with 50 MSPS
2	Helix Filter	6	XILINX ® VIRTEX ™ II PER FPGA
3	LNA	7	Fast Ethernet Interface
4	Helix Filter	8	Desktop PC

The following Picture 10 shows the logical functions in the FPGA.



Picture10: FPGA Functions



Picture 11: SDR developing place with components

7. Results and Preview

With the system described above AIS signals can be received and demodulated. A spectrum analyzer function was integrated by means of a fast Fourier transform (FFT) in the high-frequency area and also in the audio area of the AIS Signal. With an additional HF frontend this construction is suitable for FM Broadcast receiving.
In this case FM stereo reception with variable changeover between mono and stereo was programmed. A spectral representation of the stereo multiplex signal is possible. Other experiments were carried out on short wave with single sideband and Digital Radio Mondial (DRM) - transmissions.
Based on this prototype the arrangement on an even more efficient analog to digital converter (Linear Technology LTC 2208-16) and the Xilinx Virtex-5 FPGA family is planned.

At the moment the students Lukas Fink and Sebastian Hinrichsen are involved in the developments in their final project. In a modular construction of hard- and software components the SDR concept is used for AIS, FM broadcasting (Frequency Modulation), aircraft radio VHF (Amplitude Modulation) see Picture 11.

Therefore an efficient, multifunctional platform was developed in the E-CLIC project which can be used for a variety of other applications.
Now the project is even more adaptable over the broadband net by students, project partners or for the application in lectures.