Towards a polarimetric C-band aircraft SAR in The Netherlands

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Abstract:

In The Netherlands a digital SLAR system (X-band) is used since many years in the radar remote sensing research. This system supports research programs in which also other equipment is used, for instance a multiband airborne scatterometer.

Based on our experience in radar remote sensing a polarimetric C-band aircraft SAR is designed, to be realised in the 1990's. The system is of a novel design, using a phased array antenna with solid state amplifiers.

The dataprocessing for this system requires the development of software tools, that take geometric and radiometric corrections into account, as well as the calibration.

1. Introduction.

In the mid seventies radar experiments using a short range scatterometer were started in The Netherlands, mainly for the determination of radarsignatures of agricultural crops. This work was performed at X-band (λ=3 cm) and later on also at 36 GHz (λ=8 mm) [1]. The measurements were taken during a number of growing seasons to gain more insight in the variations from year to year. This led to work in the area of modeling and crop classification. It was soon recognized that calibration of the data taken at different times and under varying incidence angles is very important but also quite difficult to achieve.

The work described above was carried out by a number of institutes, each one covering a specific discipline. This multidisciplinary cooperation was organized through the ROVE team (Radar Observation on VEgetation). Nowadays the Netherlands Remote Sensing Board takes care of sponsoring this ROVE work.

The insight that was gained with this program led to the use of a digital and calibrated X-band SLAR system. Among others the multitemporal crop classification could be demonstrated with this system [2]. It is discussed in more detail in chapter 2.

In the 1980's it was realised that the work had to be extended to more and also lower frequencies and to other areas of interest. These idea's led to the design and the use of the DUTSCAT multiband airborne scatterometer, which is discussed in chapter 3.

The next step will be the development of an airborne polarimetric SAR system in the C-band, called Pharus (Phased array universal SAR). The choice of the parameters for this system are based on the experience we gained with the previous programs. The frequency was chosen to be the same as will be used on the ERS-1 satellite. At present only a first design exists, necessary to raise the funds. We hope to realize the final system by 1993. More details about the Pharus project are given in chapter 4.

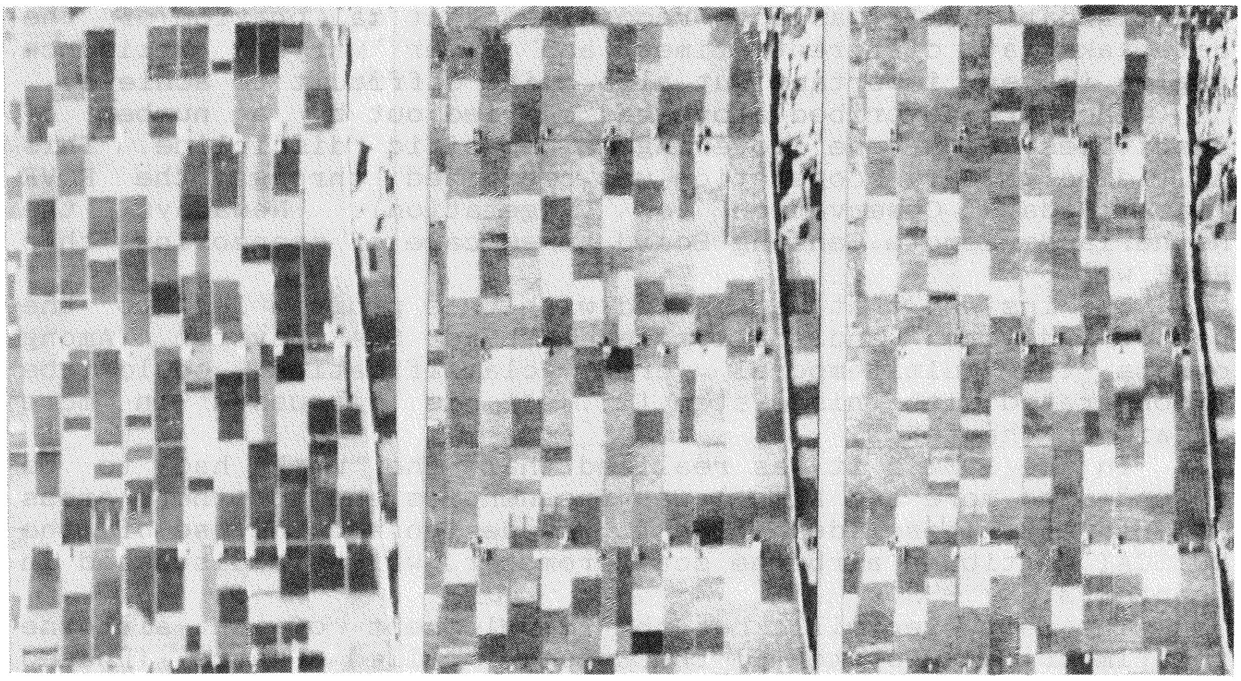
2.SLAR experiments.

For many years the radar remote sensing research in The Netherlands has been using a digital X-band SLAR system to demonstrate various possibilities of radar. Some properties of this system are given in table 1.

frequency	: 9.4 GHz (X-band)
transmitted power	: 25 kW
pulselength	: 50 / 250 ns (7.5 / 37.5 m)
polarisation	: HH
antenna beamwidth	: 10 mrad (.6 $^{\circ}$) twoway
P.R.F.	: 200 Hz
recording	: 4096 * 8 bit sampling @ 50 MHz (3 m)
internal delay line calibration	

Table 1: Specification of SLAR system parameters

By using an internal delay line calibration the system is capable of delivering calibrated images. The geometric and radiometric distortions in the captured data are corrected off line with a computer. This process makes use of the simultaneously recorded aircraft attitude and position parameters, that are delivered by an inertial navigation system. After correction and resampling images of high quality become available [3]. A high image quality is often desirable, for instance in the case of multitemporal crop classification.



07/05/80 11/07/80 12/08/80

Figure 1: X-band SLAR flights over a testarea in the Flevo-polder. Image dimensions: 3.7x6.2 km. Altitude 660 m.

Although the discrimination between various agricultural crop types in one radar image sometimes is difficult, the task can be facilitated by combining several images, taken under different incidence angles or at different times in the growing season. To enable a prosperous identification it is necessary that the images can be overlayed on to each other and that the reflection coefficients (grey values) may be compared between images. If these conditions are met, then useful results may be expected. In figure 1 a set of images from the SLAR are shown, taken in the Flevopolder in The Netherlands at 3 different times. Using a multitemporal classification procedure we were able to correctly classify over 90 % of this area [2,4].

3.Multiband Airborne scatterometer experiments.

Detailed radar signature studies and modeling work require tools to measure backscatter coefficients as a function of frequency, incidence angle and polarisation. The DUTSCAT multiband airborne scatterometer, designed and built by the Delft University of Technology is such a tool, capable of acquiring data at 6 frequencies ranging from 1 - 18 GHz.

In the past a groundbased scatterometer program was carried out in The Netherlands. The datasets that came out can now be extended by the use of this new tool. These datasets form the basis for the knowledge that is necessary to evaluate new applications in the field of remote sensing.

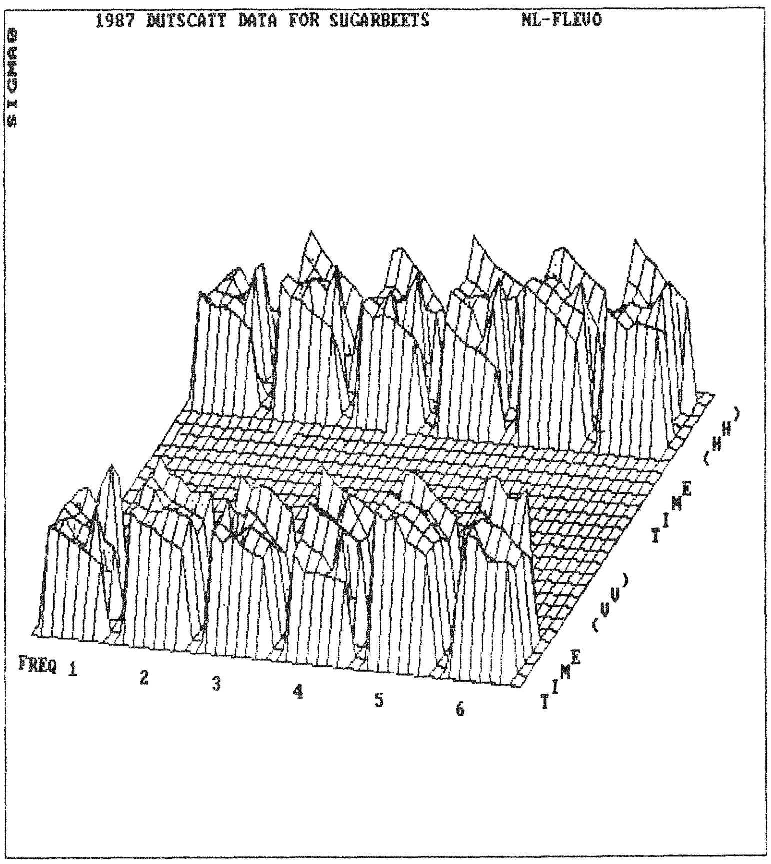


Figure 2: example of the DUTSCAT scatterometerdata captured during the Agriscatt 87 campaign.

Figure 2 shows a 3 dimensional plot of the data that was captured with the DUTSCAT during the 1987 AGRISCATT campaign over a testarea in the Flevopolder. The plot shows the backscatter for sugarbeets in twelve blocks. The upper 6 blocks are the HH polarised measurements, the lower ones VV. Every block along the X-axis shows the data for a certain frequency. Within a block the incidence angle is plotted along the X-axis and time along the Y-axis.

Apart from studying the behaviour of targets as a function of frequency or incidence angle, we can also study the polarisation dependence, which becomes of growing importance as the interest in polarimetry increases. In the near future the DUTSCAT will be fitted with a possibility to measure two like polarisations and their phase difference simultaneously, which enables a thorough preparation for the polarimetric SAR system.

4. Plans for a polarimetric SAR.

A few years ago three institutes in The Netherlands developed a plan to design and build a polarimetric C-band aircraft SAR system of a novel design, meant as a replacement for our current SLAR system. These institutes are the Physics and Electronics Laboratory TNO in The Hague, the National Aerospace Laboratory NLR in Amsterdam and the Microwave Laboratory of the Delft University of Technology. This work was done under contract of the National Remote Sensing Board.

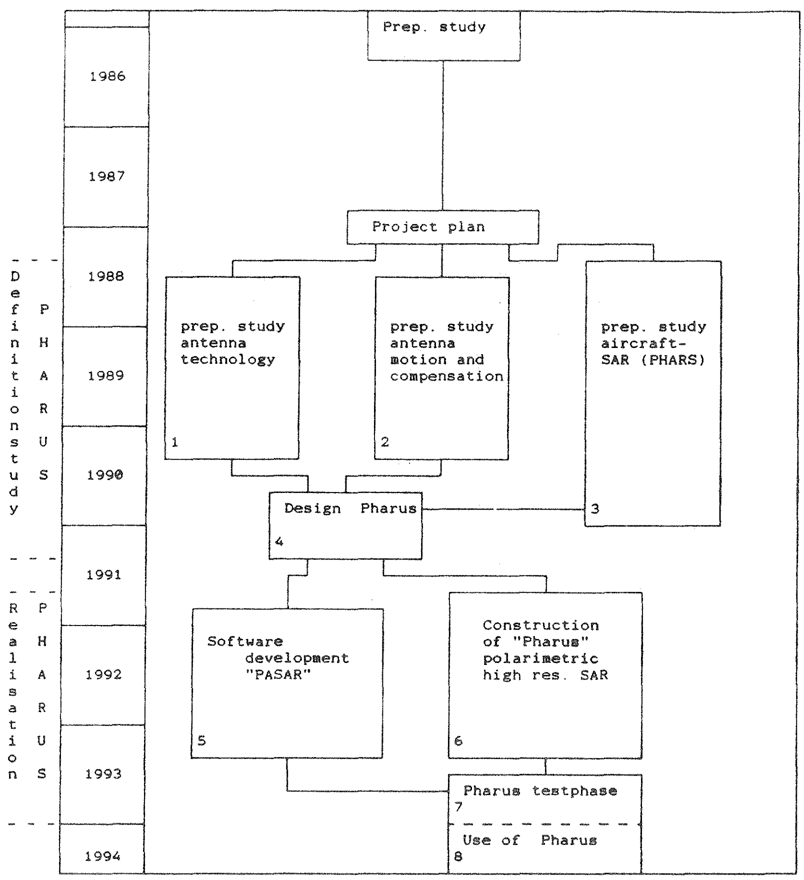


Figure 3: Block diagram of the PHARUS project.

We are presently in the process of fund raising, which sofar took considerably more time than was anticipated in the beginning.

The plans for a SAR are based on the experience that was built up with the previously described programs. The choice for C-band was based on the development of the ESA ERS satellite program [5]. Figure 3 shows a block diagram of the PHARUS project (PHARUS stands for Phased Array Universal SAR).

The projectteam is currently waiting for a GO on the first three preparatory studies. These studies are considered essential for a proper design of the PHARUS. The system will have an active array antenna, reason why a preparatory study on antenna technology is included. Especially the problems of decoupling between the different polarisations and the integrated antenna design (including power and low noise amplifiers) will be studied. The antenna motion and compensation study is necessary to build up the experience with corrections of aircraft or rather antenna movements. In the third preparatory study a SAR testbed will be realised in the aircraft that will also carry the PHARUS. The testbed is necessary to study general problems of aircraft SAR and to study the coherent integration processes which in the end determine the sensitivity of the system. Finally the testbed can be used to determine the antenna motions from the radarsignal (via autofocus techniques). The results will be compared with motion measurements taken from other sensors, like gyro's and accelerometers. This forms an important input for the final choice on a motion compensation system.

In table 2 some key parameters of the PHARS SAR testbed are given. It should be considered as a very simple SAR system with a limited range. There are separate patch antenna's for transmission and reception. These antenna's are fixed to the aircraft. The beam can be steered in coarse steps of 3.5°

-frequency	: 5.3 GHz (C-band)
-antenna's	: two 7-element patch antenna's beamwidth 12 * 24 degr, HH pol. coarse step beamsteering (3.5°)
-transmitted power	: 70 - 140 Watt peak by 7 transistors
-PRF	: 3500 Hz
-pulsewidth	: 32 ns (4.8 m) after compression 12.8 µs before compression
-digitisation	: 2048 samples I and Q, 8 bits @ 40 MHz
-range	: 6 - 13.7 km
-azimuth presumming	: 16 x
-aircraft	: Swaeringen Metro; used at an altitude of 6 km, and a speed of 100 m/s

Table 2: Properties of the SAR testbed to be realised in the preparatory study on aircraft SAR PHARS.

to compensate for the average driftangle. The beamwidth of the antenna is wide enough to eliminate the influence of aircraft yaw. Each element of the array antenna is equipped with its own transistor power amplifier of 10 - 20 Watts.

The use of distributed power generation with transistors instead of central TWT (traveling wave tube) power generation will yield a much smaller than usual peak power in both the

PHARS testbed and the final PHARUS system. The sensitivity of the system relies on the use of a high PRF (3500 Hz) and a large pulse compression ratio of 400. In the PHARUS system the peak power will be increased to approximately 2 kW.

The digital data that remains after the azimuth presumming with a factor of 16 will be recorded on a high density tape recording system. This system is also used for the SLAR and the DUTSCAT. Apart from the azimuth presumming there is no on board processing for the testbed. By getting down as much data as possible, very flexible experiments are enabled with the system at the cost of long processing times. This is not a major disadvantage since the amount of data that will be gathered with the testbed is small anyway.

The aircraft that is used in the project is a Swaeringen Metro II, a twin engine business plane, owned by NLR and in use as a laboratory aircraft. It will fly the PHARS and the PHARUS at an altitude of 6000 meter with a speed of approximately 100 m/s.

The experience that is built up in the preparatory studies will be used in the design phase of the PHARUS. After the design is completed the system will be realised. At the same time a flexible software package for SAR processing, called PASAR (Preprocessing of Airborne SAR data) will be developed. We hope to make use of the experience that was built up with the processing software for the present SLAR system.

It is still to early to give detailed specifications for the PHARUS system. They will be fixed during the design phase. The plans are heading for a polarimetric SAR with user selectable values for resolution (3 - 10 meter), swath (near range, far range or wide swath with reduced resolution), polarisations. The frequency will most probably be the same as used for the PHARS: C-band (5.3 GHz).

If the plans can be carried out following the current time schedule, then the final system should be ready by 1994.

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