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ON THE USE OF DISTRIBUTED TARGETS FOR THE CALIBRATION OF IMAGERY FROM THE EUROPEAN SAR 580 CAMPAIGN.

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Abstract

In 1981 ESA (European Space Agency) organized a large measurement campaign in Europe to stimulate the interest in radar, especially SAR. The Canadian SAR 580 system visited testsites during a 1 month period. Imagery was acquired in X, C and L band. Since several experiments called for calibrated measurement values, a calibration program was added, consisting of flights over calibration sites in the U.K. and Germany. On these sites corner reflectors were set up. The results of this calibration will be presented to all participants.

One of the testsites in The Netherlands was located in the Flevopolder, an agricultural area. During the growing season and especially during the SAR-580 flights scatterometer measurements were made here. The Dutch digital SLAR system operated at the same time. The knowledge on the radarsignature of crops can be used to calibrate the SAR 580 images, like it has been done for the Dutch digital SLAR system. Unfortunately the quality of the SAR 580 data was too bad to enable this calibration and to compare the data with our SLAR system and scatterometer. Nevertheless the method is worthwile to be reported.

Keywords: SAR, radar, calibration, image correction.

Introduction

In 1981 the European Space Agency (ESA) organized a large measurement campaign in Europe to stimulate the interest in radar, especially Synthetic Aperture Radar (SAR). Many projects were submitted, each one of them requiring its own test area. Experiments could take place over sea or over land. The Canadian SAR 580 system, that was made available for this campaign, acquired data in the X, L and C band (2 out of 3 wavelengths at a time), with a choice of polarizations. The data was recorded both optically and digitally. The latter being the most important for basic projects that needed quantitative information on the radar backscatter coefficients.

Several experiments were submitted by research groups in The Netherlands. This paper will deal with the experiences on testsite NL-2, situated in the Flevopolder, an agricultural area. This experiment was defined and carried out by the ROVE team, a working group in which the following institutes participate:

CABO, Centre for Agro Biological Research, Wageningen
Agricultural University, Wageningen
Delft University of Technology, Microwave department
National Aerospace Laboratory NLR, Amsterdam
Physics Laboratory TNO, The Hague.

At the beginning of this project we had two goals in mind for the experiment at testsite NL-2:

- To calibrate the SAR-580 system using distributed targets,
- to compare the SAR data with other sources, i.e. the Dutch digital SLAR system (Side Looking Airborne Radar) and a ground based X-band scatterometer.

The SLAR system operates in the X-band and made underflights during the passes of the SAR-580. The system is further described in ref. 1.

The ground based X-band scatterometer has been used for a number of years already to determine the radar signature of several croptypes. These measurements take place on a testfarm at special testfields. This work is reported in ref. 2.

During the period of SAR-580 passes these measurements were carried out many times. Also during the remainder of the growing season some measurements were taken, to facilitate a comparison with the results of experiments in former years.

The test area was visited twice by the SAR-580, on June 18 and on July 3, 1981. Although this is rather early in the growing season for our purpose and these dates are close to each other, it should be possible to reach the goals.

First it will be shown how one can calibrate the radar data using distributed targets. The method will be demonstrated on SLAR data. Finally the application to the SAR-580 data will be shown.

Processing of the radar data

Figure 1 shows an example of the SAR-580 imagery from our test area. The image is recorded in X-band, horizontal polarization. The data is available in digital form, on a Computer Compatible Tape (CCT). At near range and at far range the received power decreases. In between a bright area can be seen. The variation in brightness in the image is caused by a number of effects. The radar formula can be used to explain this:

$$P_R = \frac{P_T\, G^2(\theta)\, \lambda^2\, \sigma}{(4\pi)^3\, R^4} \qquad (1)$$

with P_R = received power
P_T = transmitted power
G = antenna gain
R = distance to reflecting object
λ = radar wavelength
σ = radar cross section
θ = grazing angle

The distance to the target and the antenna gain at the incidence angle under consideration are the most important factors. Furthermore the radar cross section, which varies with the

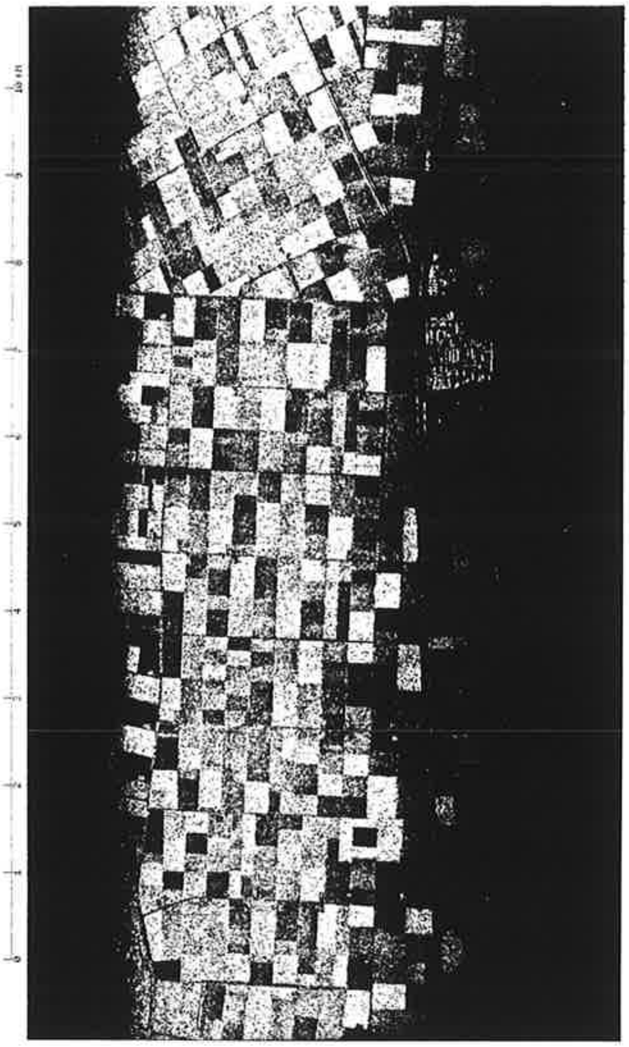

Figure 1: X-band HH pol. SAR-580 image of test area NL-2 in The Netherlands (Flevo polder), processed by DFVLR.

incidence angle influences the brightness. Since we have to deal with distributed targets rather than point targets, the use of the radar backscatter coefficient has to be introduced:

$$\sigma = A.\sigma_0 = A_i.\gamma \qquad (2)$$

with A = illuminated area
A_i = cross section of illuminating beam

This relation between the backscatter coefficients σ_0 and γ is illustrated in figure 2.

Now: $$\gamma = \sigma/A\sin\theta \qquad (3)$$

For the illuminated area A we may write:

$$A = \beta\, R\, \frac{c\tau}{2} \frac{1}{\cos\theta} \qquad (4)$$

with β = antenna beamwidth
$c\tau/2$ = radar pulselength

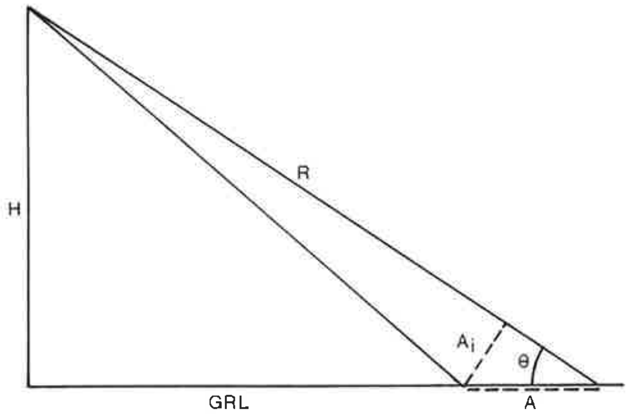

Figure 2: the SLAR recording situation.

If we now substitute (4) in (3) and remove all the constant values from the equation, we have:

$$\gamma \sim \frac{R^3 \cos\theta}{G^2(\theta)\sin\theta} P_R \qquad (5)$$

Equation (5) gives us the relation between the backscatter coefficient, the antenna gain and the received power. The image files that contain the received power per pixel (or rather the amplitude) can now be corrected for the influence of the range, the grazing angle and the (angle dependent) antenna gain. As a result the pixel values are converted to backscatter coefficients. The antenna gain must be known to be able to calculate the corrections.

Determining the antenna gain function

The antenna gain function is often one of the most uncertain factors in the correction process of radar data. The reason for this is that the antenna gain function of the antenna mounted under the aircraft in the presence of obstacles will differ from the gain function in free space. Thus the antenna measurements in free space can not be used.

A well known method to calibrate a radar system makes use of point targets. Several error sources contribute to the final result. First we have to deal with pointing errors and multipath effect. Secondly, the result that is obtained through the use of a point target will differ in general from the one that is obtained for distributed targets. In fact, our radar system does not measure only the point target. The antenna diagram in azimuth for the incidence angle (range gate) under consideration is convoluted with all the backscattering components in the area of interest. As a result the antenna gain function as measured by distributed targets, thus integrated over all azimuth angles, may differ from the one obtained by the measurement of point targets, which gives us essentially non integrated values. Integration in azimuth direction for the point target method may lead to the same result if the background around the point target gives sufficiently low backscatter and the point target itself has a constant radar cross section over a wide range of azimuth angles.

In this project an attempt was made to use distributed targets as a calibration object. The test area, which is situated in the Flevopolder, is favorable for agricultural application. The fertile, homogeneous soils with sufficient water content ensure a good crop coverage of the area. The most important crop types that are grown in this area are sugarbeet, potatoe and wheat. Because of our ground based scatterometer projects which have been carried out for several years, we have a lot of information on the radar signature of these crops. Figure 3 gives the time dependence of the backscatter coefficient and figure 4 the variation as a function of grazing angle.

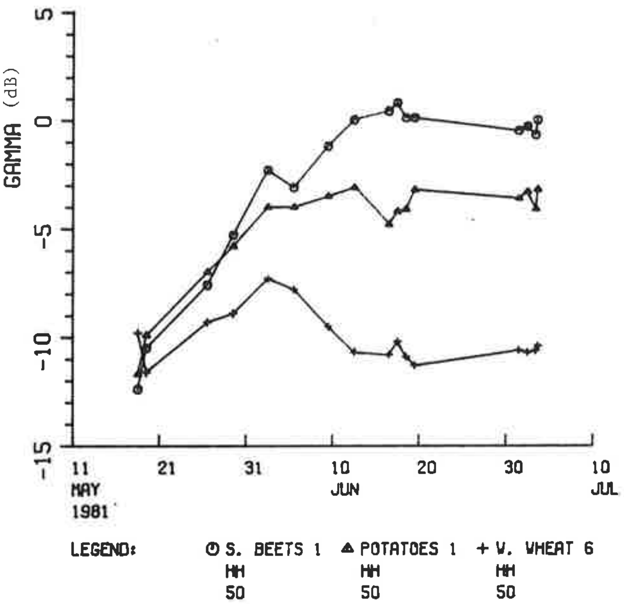

Figure 3: Time dependence of the radar backscatter coefficient for several croptypes at X-band, HH polarization, 50 degrees grazing angle.

Especially for sugarbeet we found very little dependence on both incidence angle and time. Furthermore the backscatter coefficient, which is in the order of 0 dB, is quite high for this croptype compared with other crops. Once the crop covers the ground completely, the backscatter coefficient is very stable, also if we compare the measurements of several years.

The antenna gain function can now be determined from the image files, if only the pixels corresponding to the sugarbeet fields are taken into account, assuming a sufficient availability of such pixels at all incidence angles of interest. Since on the average the backscatter coefficient must be constant, we can determine the gain function $G(\theta)$.

In our test area the determination of the antenna gain function by using all the available pixels instead of sugarbeet fields only, gives almost the same result. In general this is not necessarily through, since the result depends on the characteristics of the area. Nevertheless it enables an evaluation of the method more quickly (but less accurate).

Results

SLAR

The method as described in the previous chapter was first applied to SLAR data. The results are published in ref. 3 and also partly in these proceedings[4]. Figure 5 shows some antenna gain functions that were derived from our SLAR data during several flights. The agreement between the curves is good, although for small grazing angles (large distances) the points are a little more scattered, presumably due to the receiver noise.

In figure 6 a corrected SLAR image is shown. Equation (5) was used here, together with the antenna gain function from figure 5. The variation of the greylevel in range direction has become very small. This type of images have been used for several applications, among them crop classification[5].

SAR-580

The procedure followed for the SLAR images was also used for the SAR-580 data. Figure 7 gives the corrected image of figure 1 and figure 8 shows the antenna gain function. The area in the middle of figure 8 appears to be saturated. The contrast between the fields is small in this area compared with the rest of the image. The appearance of several bright spots in the area (for instance near the small town) can be explained by the SAR imaging process, which still does its job even though the radar system is saturated. As a result a point target can still be imaged very brightly, whereas distributed targets, that are hardly affected by the SAR process are saturated on a virtually lower power level.

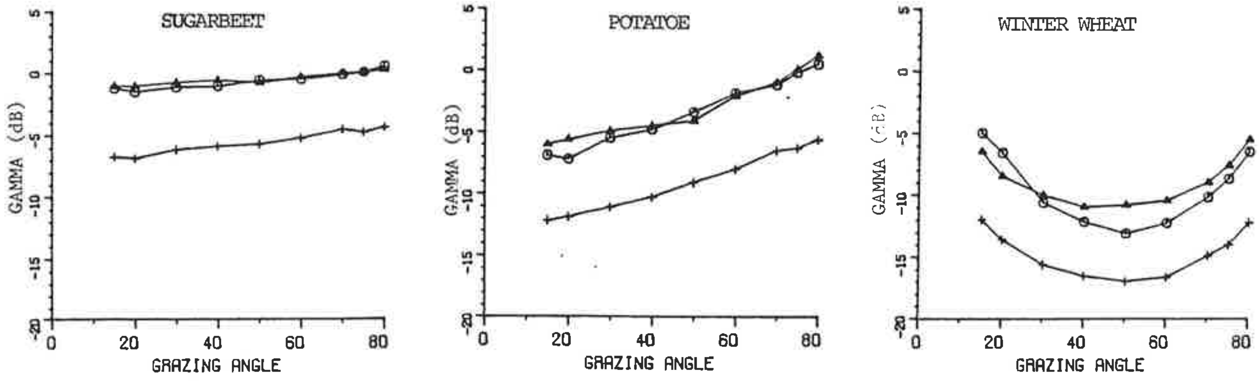

Figure 4: Radar backscatter coefficient versus grazing angle for several croptypes at X-band (date: July 3, 1981) O=VV ▲=HH +=HV

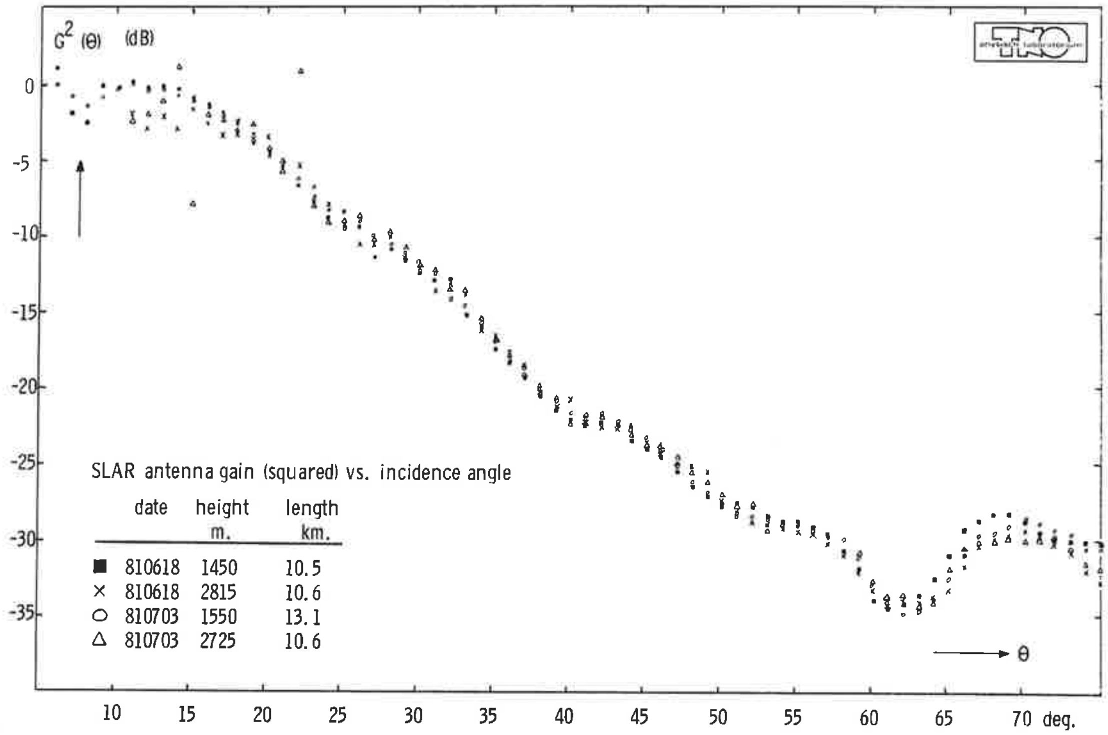

Figure 5: Antenna gain functions for the Dutch digital SLAR system, derived from several flights.

Figure 6: Example of a fully corrected SLAR image (10 x 13 km, NL-2 testarea).

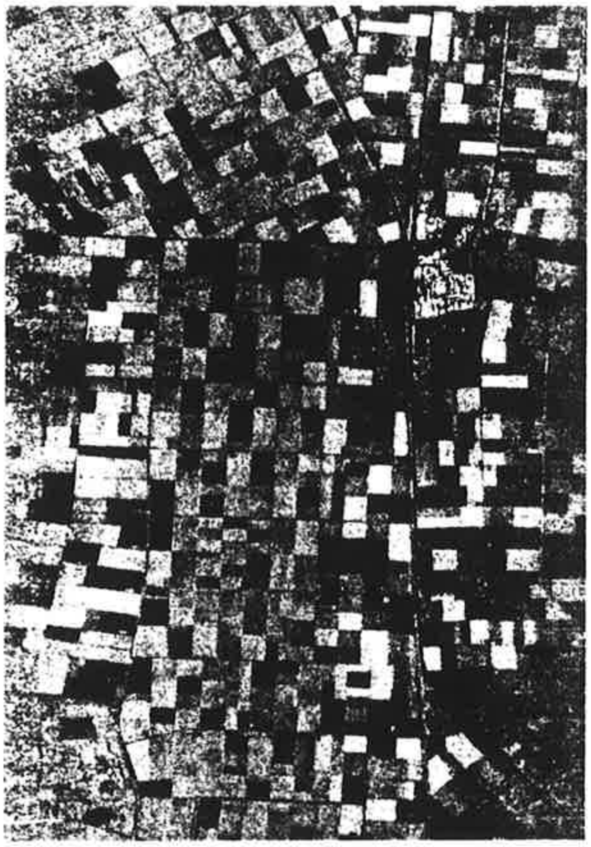

Figure 7: Resulting SAR-580 image for the NL-2 testarea after correction, June 18, 1981, X-band.

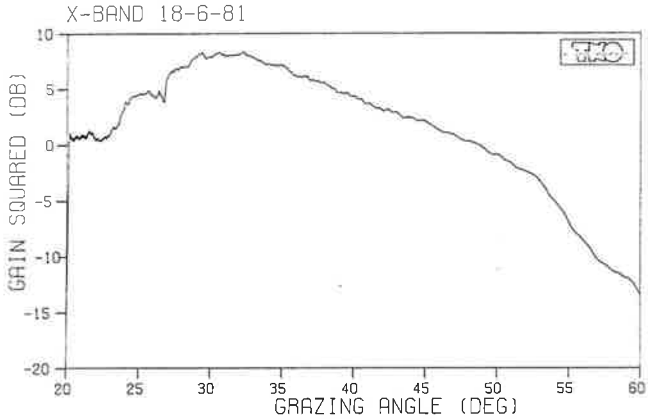

Figure 8: Antenna gain function for the SAR-580 system derived from one flight on June 18, 1981.

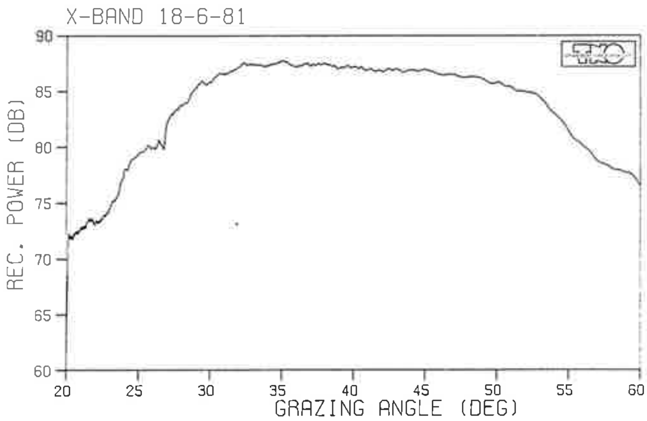

Figure 9: Average received power level versus grazing angle for the SAR-580 system on June 18, 1981 (X-band, NL-?).

As a further illustration of the saturation problem, figure 9 gives the average received power as a function of the grazing angle. The curve shows a rather flat part in the middle. This unrealistic shape can also be explained from the saturation effect. To investigate how serious the image is affected the contrast between certain croptypes is compared with ground based measurements in table 1. For sugarbeet relative backscatter coefficients are given as well.

grazing angle	sugarbeet		sugarbeet minus wheat		sugarbeet minus potatoe	
degrees	SAR	ground based	SAR	ground based	SAR	ground based
70	0	0	8	10	1.5	2.5
60	0	0	9	11	1.5	3.5
50	-1.5	0	5.5	11	1	4
40	-2.5	0	3.5	10	0.5	5
30	0.5	0	6.5	10	5	6
20	-0.5	-1.5	5	8.5	4.5	5.5

Table 1: Some relative backscatter coefficients in dB for X-band, SAR-580, date: 18/6/81. Comparison with ground based measurements.

From this table it is clear that the contrast decreases in the range of appr. 30 - 50 degrees. This change in contrast can also be seen in the original image (fig. 1), indicating that it is not a processing artefact of the algorithm applied here. The same effect is present in a second image we have of the area, flown at July 3. Some images of other sites of the SAR-580 campaign also show this effect, which is probably caused by a wrong gain setting on the radar system.

Apart from X-band imagery, we have images in the C-band of the test area. This system was used operationally for the time ever in the European SAR-580 experiment. Excessive noise in the images and the lack of a "cal sig" generator made these data less valuable. Therefore it is not further discussed here.

Conclusions

In this paper a method is outlined for the determination of antenna gain functions of radar systems. Once this function is known, a further calibration of the radar data can be undertaken, given the radar system is sufficiently stable and the data are of good quality.

The calibration method using distributed targets proved to be useful in the case of the Dutch digital SLAR system. The same method applied to the SAR-580 data revealed poor data quality which is probably caused by saturation of the radar system. In addition the slant range correction of the delivered imagery is questionable. This problem -not further discussed here- has an impact on the radiometric corrections and -accuracy. As a result the proposed goals of the SAR-580 project on the Dutch testsite could not be reached.

Imagery of other testsites should be checked for this phenomenon, since the Dutch testsite is not the only one in the SAR-580 project that suffered from this saturation. A few other examples of the effect are already known to the author. Data suffering from this problem may easily lead to wrong conclusions if the effect is not recognized.

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