MEASUREMENTS OF RADAR GROUND RETURNS

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ABSTRACT

The ground based measurement techniques for the determination of the radar back-scatter of vegetation and soils as used in The Netherlands will be described. Two techniques are employed: one covering a large sample area (> 1000 m^2) but working at low grazing angles only and one (short range) covering a small sample area of about 1 m^2 only, but working at higher grazing angles. They will be compared with the requirements: 1. that all samples investigated must contain sufficient scatterers to give a Rayleigh distribution at the output of the sensor and 2. that the decorrelation time is sufficiently short to obtain an adequate number of uncorrelated samples in one measurement. With both equipments the depression angles between 1^o and 75^o are covered.

Results of measurements will be reported. They include measurements on coniferous trees, selected agricultural crops, grass and bare soils.

The radar return parameter γ as a function of wavelength and polarization is a useful classifier. Within the full dynamic range of γ as met in nature its total variation for vegetation is a 20 dB.

The radar back-scatter coefficient as a function of frequency and polarization seems to be the only possible classifier for vegetation species.

1. INTRODUCTION

1.1 One of the major problems nowadays in airborne remote sensing (RS) is the fact that an unsufficient knowledge of the input end of the observation systems - the physical properties of the air/ground interface - hampers the wide use of the output - the imagery or other data obtained.
By many users of SLAR imagery, for instance, the crucial fact is often overlooked that a SLAR image is a transformation from the microwave part of the electromagnetic spectrum - where the radar observes - to the visual part of the spectrum - where our eye can see. This often leads to requirements or questions from the side of the user which in fact leave out completely the real potentialities of the RS-system under consideration. Many users so overemphasize resolution where other physical attributes of the target under consideration may well be a better classifier. The following physical attributes can so be used to describe analyse or identify an object or target:
- the spatial (shape and size; here resolution is important)
- the spectral properties ("colour")
- polarization effects
- dynamic range and
- the temporal effects (changes in time and place)

The present study was undertaken to investigate the possibilities of using the radar back-scatter coefficient (r.b.c.) as a function of wavelength, polarization and dynamic range as a classifier for vegetation inventory.

1.2 The variation in the r.b.c. for different vegetation types as visible in SLAR imagery by variations in image tone suggests its use as a classifier. Photograph 1 gives an example of such imagery.

It is possible to measure the r.b.c. from the air but we preferred a fixed measuring platform because of
a. the costs otherwise involved
b. the well defined place in space through time and as a consequence

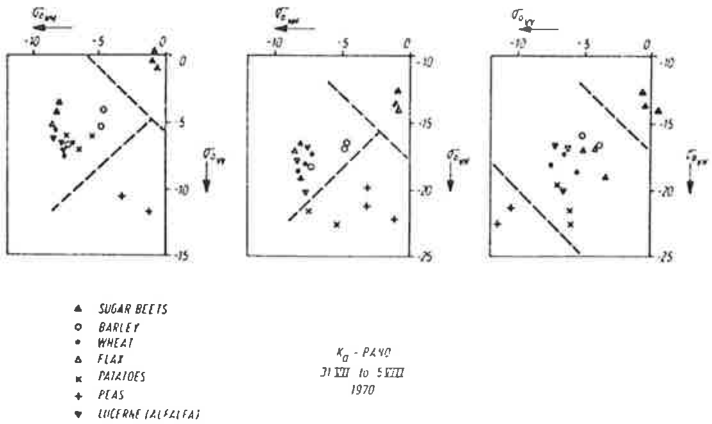


FIGURE 1. CLUSTER PLOTS AT K_a-BAND. Vegetation selection on the variation in radar back-scatter coefficient due to polarization.

2.1.2 THE X-BAND RADAR. MEASURING ACCURACY. The bulk of our measurements was made at X-band. The measuring radar is a non-coherent pulse radar of which the properties are given in Table II.

TABLE II. PROPERTIES OF THE X-BAND MEASURING RADAR

Frequency	9375 MHz
PRF	1000 Hz
Antenna	1.8°, pencil beam
Polarization	HH and VV
Pulselength	0.5 μsec
Gatelength	40 nanosecs.
Output P_t	50 kW
Receiver	logarithmic; dynamic range 50 dB
$P_{rec.min}$	-103 dB
Range variable	from 600 m to 50 km

It is the same radar as used by Sittrop for his sea-clutter measurements reported earlier in this Symposium[2]. This radar is equipped with a logarithmic receiver-amplifier having a dynamic range of 50 dB in which range it is always used. After peak detection in the variable range gate the video signal is boxcarred, filtered (500 Hz) and recorded in analog form on a magnetic tape recorder (in dB's). A measurement is performed by directing the antenna onto the field to be measured and setting the gate at the required range. Data blocks of 100 seconds are then recorded which are later digitized in the Laboratory. Each data block so contains 100.000 cross-section measurements from which distribution, average and standard deviation are determined. The fluctuating or fading spectra are obtained by subtracting the average and determining the frequency content of the fluctuating component of the signal.

The above procedure can give an insight into the accuracy of the values obtained for γ. Knowledge of the number of independent samples is then necessary. To learn this the following procedure in 2 steps is commonly used[3]:

a. The target area illuminated by the radar is of such a size that it contains a sufficiently large collection of independent scatterers so that the envelope of the received signal is a random variable with its amplitude described by a Rayleigh distribution.
b. For a fixed measuring system, working at one frequency, the spacing between independent samples in time is then given by the decorrelation time. This decorrelation time is directly related to the width of the fluctuating spectra.

Figure 2 gives an example of measured results on four different (mature) crops plotted on Rayleigh paper. All four distributions are similar in shape. For wind speeds larger than v = 0.5 m/sec similar distributions are found for all our vegetation measurements, including woods. There is not a perfect fit with a Rayleigh distribution function but this is attributable to small imperfections in sampling and to the finite gatewidth used[4].

So having shown that in these measurements the target can be considered as a Rayleigh scatterer the number of independent measurements can be determined when knowing the decorrelation time. The fluctuation spectra obtained in all our measurements on vegetations

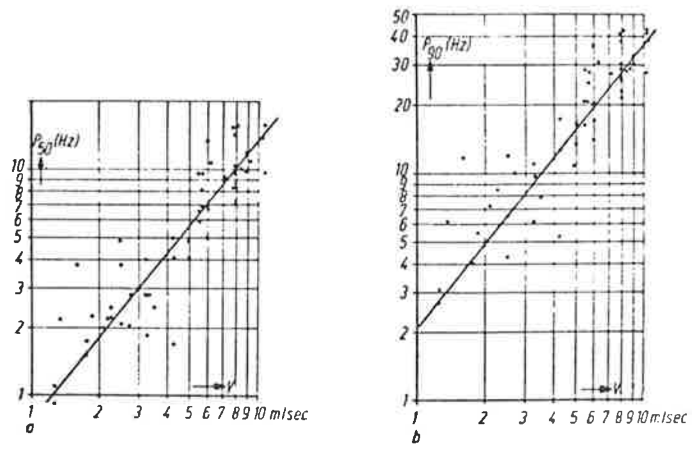


FIGURE 4. WIDTHS Δf OF THE FREQUENCY SPECTRA AS A FUNCTION OF WINDSPEED v.

a: at 3 dB point
b: at 10 dB point

T_i = 0.25 1/Δf (correlation function down to $1/\pi^2 \approx 0.1$).
By taking T_i = 0.37 1/Δf (width at the 1/e level) the vertical axis of figure 4b also gives the number of uncorrelated samples per second as a function of windspeed. A crude rule of thumb can be deduced from it saying that the windspeed in knots approximately gives the number of uncorrelated samples per second for that windspeed and at X-band.

An illustration is found in figure 5, showing only small variations in the mean of 20 second averages for γ for the higher windspeeds and larger variations at the lower windspeeds. Another possibility to obtain independent samples, - a possibility in fact always used in SLAR - is spatial decorrelation. Figure 6 is an example giving results on

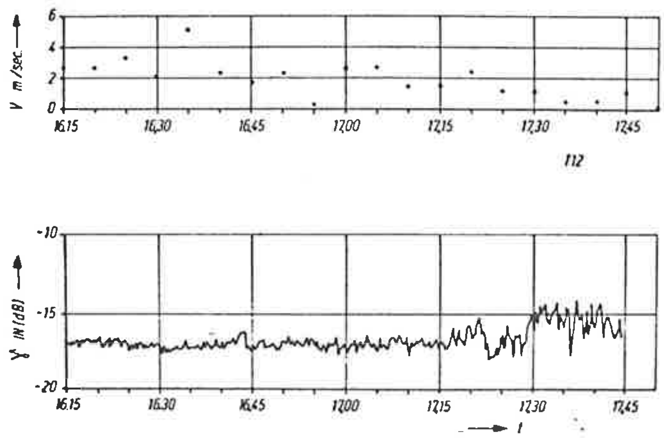


FIGURE 5. LONG TERM FLUCTUATION OF γ AT LOW WINDSPEEDS
20 second averages. Wheat field.
Polarization HH.

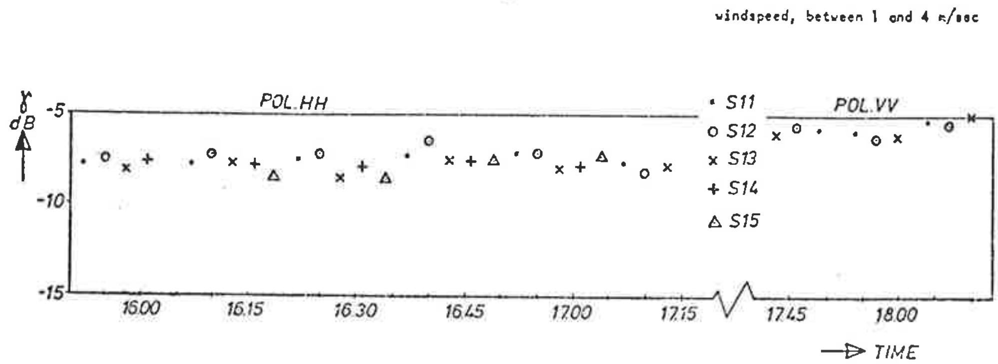


FIGURE 6. MEASUREMENTS ON THE SAME FIELD OF SUGAR BEETS BUT AT 5 DIFFERENT PLACES

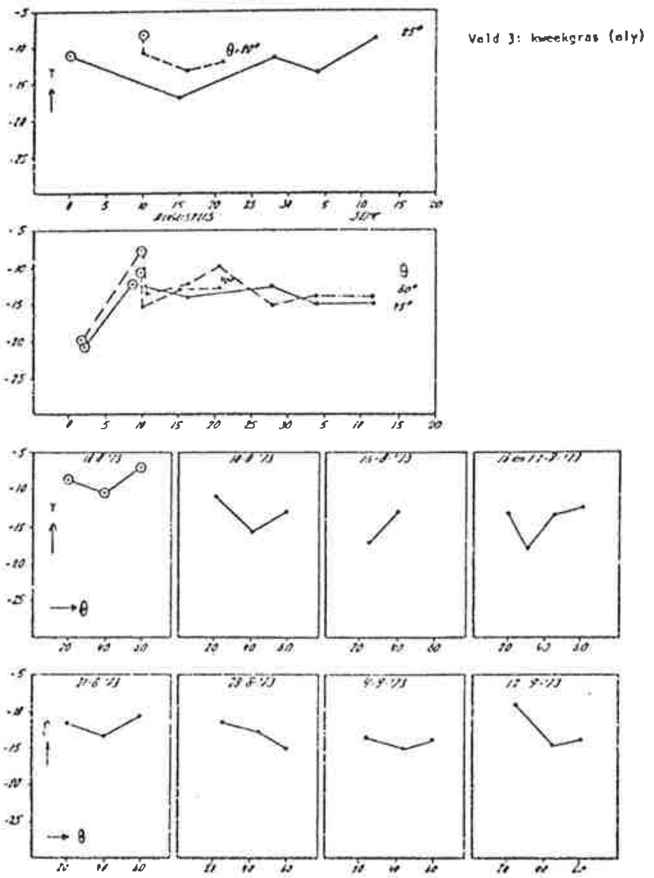


FIGURE 7. MEASURING RESULTS ON FIELD 3, grass. Summer 1973.

2.2.2 THE FM-CW MEASURING SYSTEM. The problems with a sufficient number of independent samples can be solved by using an FM-CW radar with a sufficiently wide frequency sweep. Developments in the Netherlands have now gone also in this direction. The problem of target size remains, although with this type of equipment it could be overcome - at least partially - by looking at a somewhat larger area (a little more than 1 m^2) and by taking more measurements on the same field. For more details of this system see the paper of E.P.W. Attema for this symposium[7].

3. MEASURING RESULTS

Figure 8 gives results on three agricultural crops as measured through a season from

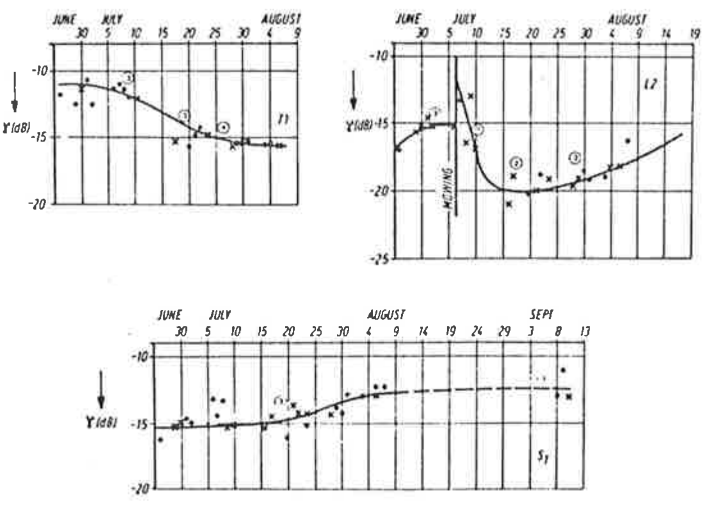


FIGURE 8. VARIATION OF γ THROUGH THE SEASONS

Polarization HH;
T_1 : wheat;
L_2 : lucerne (alfalfa);
S_1 : sugar beets;

1970.

the attenuation of its echo by this canopy was determined for a depression angle of 45°. Figure 10 gives the results.

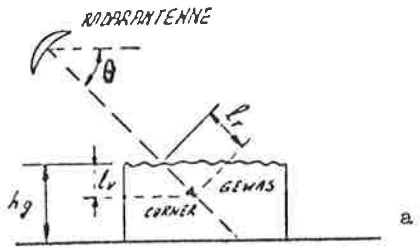
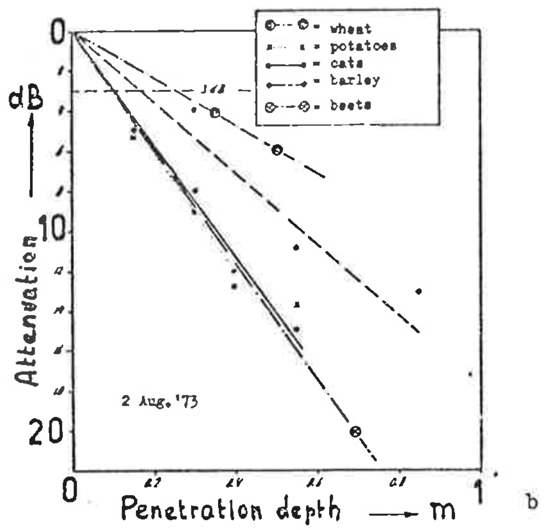


FIGURE 11. MEASUREMENT OF PENETRATION DEPTH
a. set up
b. results



Only a small top layer already halves the influence of the corner reflector showing that the influence of lower layers in the canopy on the value of γ rapidly decreases.

The average value for γ measured for the relatively smooth soil under the vegetations of figure 9 is: $\gamma_{VV} = -19.4$ dB. Different types of soils with varying roughnesses and stubble content were measured from one of the TV-towers (Goes). Values between $\gamma = -15$ dB and $\gamma = -35$ dB were obtained, with the stubble fields at the high end.

We now can give a crude classification of ranges for γ at X-band. Measurements on sea surfaces gave values for γ at X-band between -28 and -12 dB [2, 8]. Below this range and partly covering it we find the bare soils (-35 to -15 dB), where at the high end the vegetation echoes are found (-18 to -8 dB). Above this range lie the echoes of "natural" structures as hedges, dams, rows of trees, edges of woods, etc. (γ = -10 to 0 dB). The echoes of man-made objects grow above γ = 0 dB. Table IV summarizes these data.

TABLE IV. RANGES OF THE RETURN PARAMETER γ

Bare soils	γ = -35 to -15 dB
Sea clutter	γ = -28 to -12 dB
Vegetation	γ = -18 to - 8 dB
"Natural" structures	γ = -10 to 0 dB
Man-made structures	γ > 0 dB

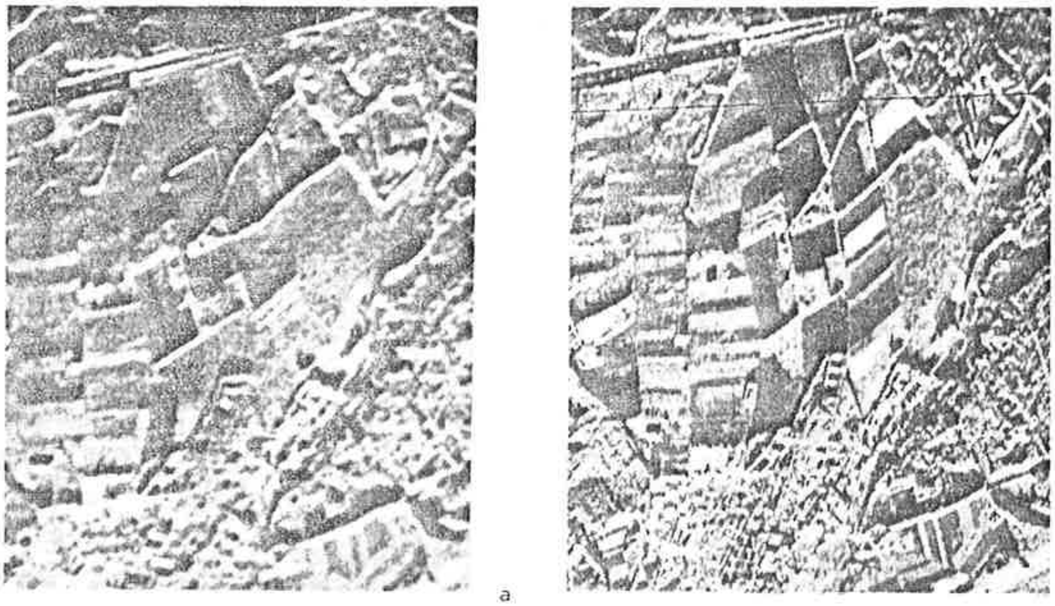
4. DISCUSSION

Table IV shows that the total range of the r.b.c. is fairly large. For specific applications, however, as sea clutter measurements or measurements on vegetation this range reduces. Every application has its own level. For vegetation inventory a range of 20 dB would be sufficient when chosen at the right level. The variation in γ between vegetations is due to a. the morphology of the plant
b. the water content of the canopy above the soil.
As we see it now the morphology determines the place of a specific species within the range of γ for vegetations where the water content of the top layers (amount of leaves and their water content) determines the variation around this level. This last fact suggests the use of the return parameter γ for in-situ biomass determinations since the amount of free water in a specific crop is (through a calibration procedure) indicative for the biomass of that crop.

Further study is needed here and it is clear that for a further clarification of the specific influences of morphology and water content in relation with the botanical properties of the plant a fairly high accuracy (in dB) will be required of the determination of γ.

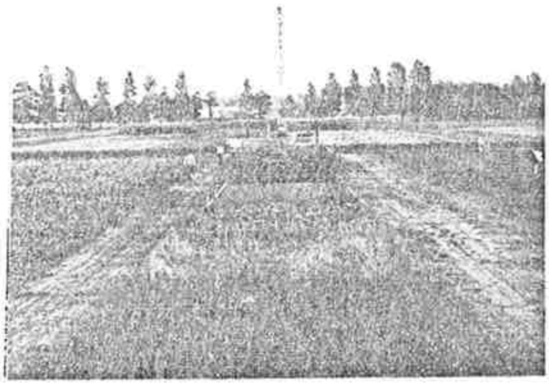
5. CONCLUSION

The radar return parameter γ as a function of wavelength and polarization is a useful classifier. Within the full dynamic range of γ as met in nature, the range for use of γ for vegetation inventory and vegetation measurements is a 20 dB.

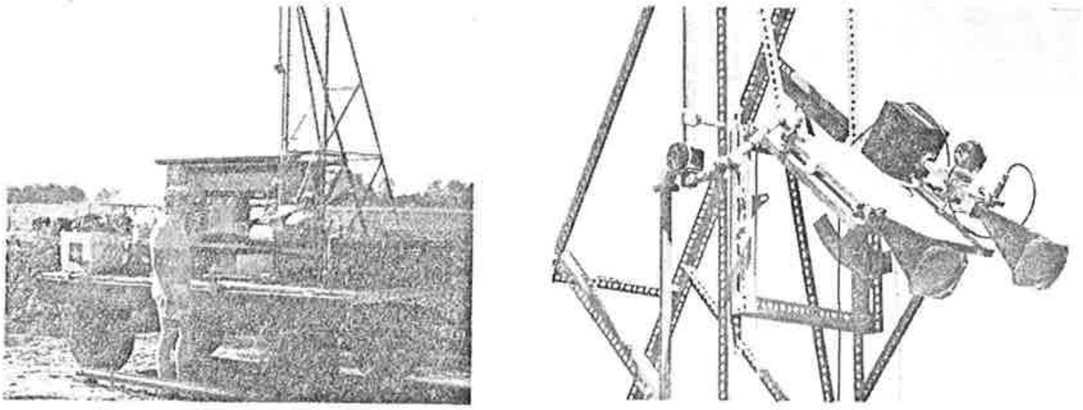


a b

PHOTOGRAPH 1. SLAR IMAGE OF AGRICULTURAL AREA. Ka-band. a. November; b. July.



PHOTOGRAPH 2. OVERVIEW OF TESTFIELDS.
Short range measurements, summer 1974.



PHOTOGRAPH 3. SINGLE FREQUENCY X-BAND SHORT-RANGE REFLECTOMETER 1973.

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PROCEEDINGS

of the

URSI

Commission II

Specialist Meeting on

MICROWAVE SCATTERING AND EMISSION FROM THE EARTH

held at Berne (Switzerland), 23 to 26 September 1974

Edited by E. Schanda
Institute of Applied Physics University of Berne
1974