PERFORMANCE SIMULATOR FOR A WIND SCATTEROMETER

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ABSTRACT

Towards the middle of the decade, Europe will launch the next generation of its Earth Resources Satellites, ERS 1. One Sensor, the Wind Scatterometer will be used to measure the wind vectors over the oceans. This paper describes the computer performance simulation which will be used to optimise the sensor design. System geometry, propagation path and receiver processing modelling on a desk-top computer provides an interactive tool for rapidly investigating design changes.
Program description is non-mathematical and includes copies of selected outputs for clarification.

1. INTRODUCTION

It is the field of Oceanography, in particular the monitoring of wind-generated waves, which has stimulated the need for satellite-borne scatterometry.
At microwave frequencies, the rippled ocean surface appears like a reflection grating, hence the radar backscattering coefficient (σ^o) provides a mechanism to measure the surface wind conditions. The nature of this dependence means a number of σ^o measurements is required, hence the need for multiple beams in the sensor. Extensive analysis has led to the recommended beam configurations, as shown in Fig. 1:

- dual beam, dual polarisation, resolution cell segmentation by doppler filtering (Ref. Fig. 2)
- three beam single polarisation, cell segmentation by range gating.

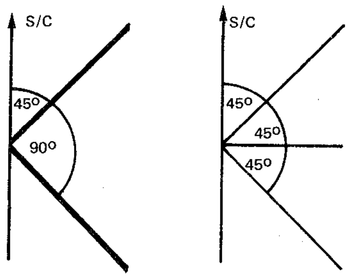

Fig. 1: Recommended Beam Configurations for the Wind Scatterometer

For both system concepts, a Performance Simulator has been developed partly on behalf of the European Space Agency (ESA) and partly under contract from the German Ministry of Research and Technology (BMFT). The main aims of the simulators are:

- to determine optimised system design parameters
- to estimate sensor performance to compare both system design concepts.

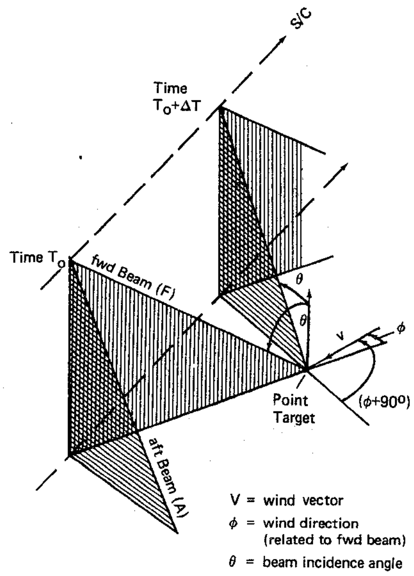

Fig. 2: Geometry for 2 beams with 90° separation

2. IMPLEMENTATION OF THE PERFORMANCE SIMULATOR

The Scatterometer Performance Simulator is a software program, written in the BASIC language. The HP85A, a desk-top computer from Hewlett Packard, has been selected for implementation due to its availability at various sites in Europe where Scatterometer system design is investigated.

2.1 Description of Selected Computer Facility

The HP85A is a complete computer system including a central processor and all necessary peripherals (CRT-display, magnetic tape cartridge and a printer) in a single package. The read/write memory is expandable to 32768 bytes (30,7 K user-available). The CRT-display provides 16 lines of 32 characters each, plus full graphics capability. Mass storage of programs and data is handled by a standard DC-100 tape cartridge, offering 200 Kbytes of on-line storage. The built-in thermal printer will print 32 character lines at 2 lines per sec.. A copy of the graphics display is generated with a single key-stroke.

2.2 Software Structure

For each Scatterometer design concept, a comprehensive, self-consistant Performance Simulator has been deve-

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loped. Due to memory size restrictions of the HP85A, each software package is subdivided in 3 parts, organized in separate files, which are "chained" together. For reasons of program flexibility, each part is composed of sections (subroutines), each having a specific objective. A section consists of:

- Parameter input table
- Computation
- Several specific outputs

An Exit-Routine is implemented for rapid access to earlier sections or system shutdown, with the possibility of future continuation at current or previous sections.

3. CAPABILITIES OF THE SIMULATOR (DOPPLER FILTERING VERSION)

The parts of the simulation program, as written for the Doppler Filtering Technique, are comprised of the following sections:

Part 1: System Definition
Swath Definition
Isodop Overview
FOV Definition
Specific IFOV/TFOV
Timing Definition
Filter Profile (Thru Cell)
Filter Profile (Thru Orbit)

Part 2: Antenna Pattern
Weather Conditions
(Effective IFOV Contour)

Part 3: Link Budget
(Signal Simulation)

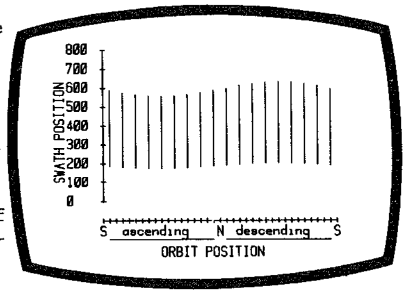
In order to illustrate the capabilities of the Performance Simulator, the following summary of inputs, calculations and outputs is given step-by-step for the sections. Those sections shown bracketed above have not been realised fully at the time of writing, hence descriptions are given for these cases.

3.1 Part 1

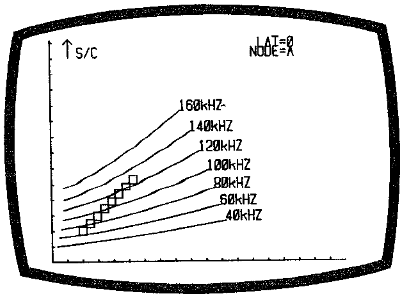
System Definition: major system parameter of transmit frequency and parameters to specify the orbit (height and inclination) are input. This is currently assumed to be circular although implementation of an eliptical orbit (with additional input parameters) is being performed.

Swath Definition: the target band of ocean surface running alongside the spacecraft subtrack is defined by inputting cell-size, number of cells and the minimum beam incidence angle. The latter parameter is important since the reflection model (dependence of the backscattering coefficient (σ^o) on changing wind conditions) is valid for a limited range of incidence angle.

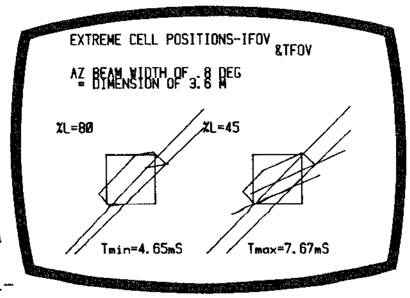
A constant PRF is assumed during the orbit, and also firing continuously via the forward beam at a resolution cell before switching to the aft beam. This quantised inter-cell timing combined with the variation through the orbit of cell-motion during the re-illumination time, leads to a distortion of the ideal swath. This effect is shown as a graphical output. It is a direct result of the need for successful re-sampling of σ^o-values of the resolution cell by both beams.



Isodop Overview: an illustration of the position of isodoppler lines for a specific spacecraft orbit position is obtained by specifying the latter in terms of node and latitude. The output is a vertical projection of the isodop pattern around the correctly positioned resolution cells. It shows whether Doppler Filtering is really feasible for the far cells since the isodops must cut the beam lines at sufficient angles in order to segment the target area adequately.



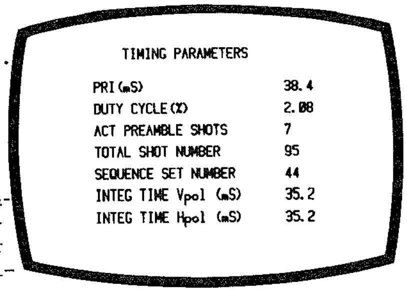
FOV (Field of View) Definitions: user entry of azimuth beamwidth and isodop separation defines the ocean patch for σ^o measurement, i.e. Instantaneous Field of View (IFOV). The isodop spacing is defined as a percentage of the cell diagonal in the beam direction, with the facility to vary it across the swath to compensate for the changing isodop gradient. This is a direct result of the need to limit the IFOV to the neighbourhood of the resolution cell. Continuously firing by each beam leads to the accumulation of largely-overlapped IFOV's to form a TFOV (Total Field of View) of shape defined by the variation of isodops during the measurement period. The driving force here is to maintain an approximately constant IFOV area since gain-stepping may be used to position the receiver dynamic range window for a TFOV-Set of returns. This is achieved here by maintaining the isodop separation constant and tracking the isodops across the beamdirection during the measurement period. The resultant output shows the IFOV, TFOV and resolution cell at the nearest and farthest edge of the swath with some timing information used later to calculate the intra-cell-timing.



A further output of this section shows the variation of IFOV area across the swath.

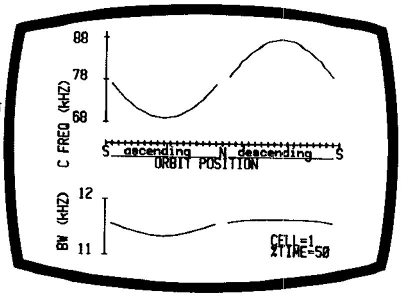
Specific IFOV/TFOV: actual IFOV and TFOV characteristics are shown for a specific orbit position and cell index.

Timing Definition: the intra-cell timing is considered here. User entry of pulse length and the polarisation firing sequence within the TFOV-set of shots, enables the timing parameters to be calculated. Noise subtraction from the returned radar echoes constrains the PRI since the measurement of the noise power needs an interval of twice the pulse length. This value combined with the maximum two-way propagation time sets a lower bound on the PRI. The integration time of each polarisation set is calculated to be used later in the link budget calculation.



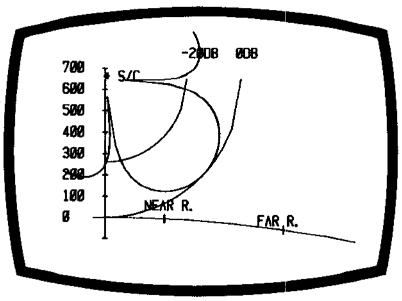
Filter Profile (Thru Cell): tracking the isodops across the beam direction results in this trend of the filter during the measurement period, for a specified orbit position and cell index.

Filter Profile (Thru Orbit): swath distortion through the orbit, due to earth surface speed varying with latitude, necessitates correlated isodop-tuning. User entry of cell index and instant during its measurement period defines an example case for plotting this trend of isodop tuning through the orbit. It is shown as centre frequency and bandwidth variation, and provides useful information for doppler-cell-filter design.



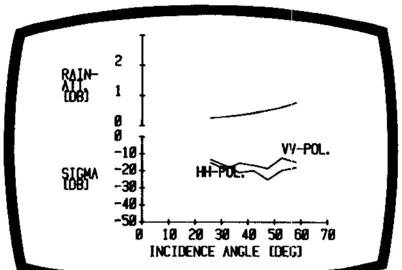
3.2 Part 2

Antenna Pattern: this section allows the definition of the elevation pattern of the antenna, either as a simple $sinc^2$ function or manually by data points input. Its effect in the scatterometer system is further defined by an efficiency factor and boresight pointing direction. The gain pattern is then computed and a side-view displayed to the user. Continuation of this section gives another output showing the antenna's effectiveness across the swath: the two-way antenna gain alone and also combined with the trend of IFOV area and slant range. Finally a summary table of the main antenna characteristics is given.



MAIN ANTENNA CHARACTERISTICS	
3-DB BEAMWIDTH [DEG]	33
BORESIGHT ANGLE [DEG]	47
ANTENNA LENGTH [M]	.088
ANTENNA EFFICIENCY [%]	50
MAXIMUM GAIN [DB]	27.91
1. SIDELOBE LEVEL [DB]	-13.2
GAIN AT min(25.9DEG)	22.367
GAIN AT max(58.1DEG)	27.788

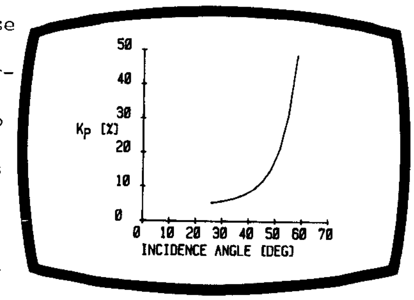
Weather Conditions: the user may arrange a rain-rate profile across the swath which the program uses to calculate rain-rate attenuation using a frequency-dependant model and adds a value for atmospheric attenuation, correcting both for path length variation through the atmosphere. Similarly wind-speed and direction profiles are entered here to define a σ^0-variation across the swath. These profiles are summarised in a graphical output.



Effective IFOV Contour: this section is currently being developed for inclusion in the simulator. Since the Scatterometer is effectively a pulse radar, the returned pulses from the ocean surface have a relatively wide spectrum hence points slightly outside the IFOV also contribute to the measured σ^0-value. Thus the IFOV boundary is not sharp, and this section is aimed at illustrating the effective target area by showing contours of points having equal return power contribution. Selecting isodop separation must then be made more carefully, particularly when strongly asymmetric σ^0 variations are being considered.

3.3 Part 3

Link Budget: in this section the program selects previously-input or calculated data as required for link calculations. Further receiver specification by losses, noise figure, average transmit power etc. allows signal-to-noise calculations to be performed. As an overall performance criteria, the Fischer Kp parameter has been chosen (Ref. 1). This is the predicted normalised standard deviation of the σ^0-values, as calculated from the signal-to-noise ratio, doppler-cell-filter bandwidth and the measurement integration time. It is shown graphically as a function of incidence angle.



Signal Simulation: This section is also still to be implemented in the simulator program but is described here. The receiver losses, as entered in the Link Budget section, consist of hardware and processing losses. The latter are currently only estimated without regard to cell position in the swath. It is the aim of this section to calculate these losses more precisely, by the following technique to compute the signal-to-noise ratio. The received signal power across the entire swath is obtained by summation of normalised returned pulses. Utilisation of its maximum value enables the ADC (Analogue-to-Digital Converter) saturation level to be defined, hence giving the variation of saturation noise across the swath and a value for quantisation noise. Thermal noise is computed via system noise temperature and overall doppler bandwidth. Integration over the range specific to a cell doppler bandwidth allows the determination of a better signal-to-noise ratio and hence, via the Fischer equation, a more accurate prediction of the Kp value for this cell.

4. SUMMARY

In conclusion it must be said that past use of the Performance Simulators has already proved their value as rapid and comprehensive design tools. Further utilisation is expected to enable the optimum sensor concept to be chosen, at which time a specific hardware simulator will be created at Dornier. This will be based on a main-frame computer and will enable the Scatterometer system equipment components to be specified in terms of required performance, and the effects of any degradations investigated.

5. REFERENCES

1. Robert E. Fischer, Standard Deviation of Scatterometer Measurements from Space, *IEEE Transactions on Geoscience Electronics*, Vol.GE-10, No.2, April 1972