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A SCANNING MICROWAVE RADAR & RADIOMETER

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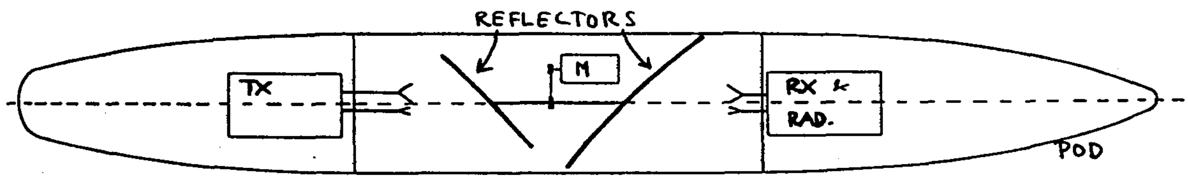

Figure 1: The Instrument in the Pod

System Overview

The Scanning Microwave Radar & Radiometer (SMRR) is a line scanner featuring a combined radar and radiometer system operating around 35 and 94 GHz. The key word is synergism - in this case trying to use both active and passive measurements to obtain information not otherwise available using either one of these alone. This has been done before using separate radars and radiometers, but always hampered by lack of simultaneousness and lack of identical footprints.
The layout of the SMRR is shown in Figure 1. The 2 offset antenna parabolas scan in syncronism, the receiver antenna has the higest gain in order to ensure that footprints are identical for the radar and the radiometer.
The instrument will be flown in a pod under a Gulfstream G3 normally cruising with 240 m/sec at 12500 m (41000 ft), and will thus be able to sense clouds and precipitation from above. In the following it will be assumed that the clouds to be sensed are 10000 m below the aircraft.

The 35 GHz Radiometer

The pod limits the antenna aperture to 45 cm which corresponds to a beamwidth of 0.023 (1.3°), and hence a footprint at 10 km distance of 230 m (288 m at the surface of the Earth). The receiver noise figure is 5 dB and the pre-detection bandwidth is 500 MHz. We require contiguous coverage of the clouds and a 30 % footprint overlap to ensure proper sampling. 20 footprints across track are imaged resulting in a swath of 4600 m. Using a sinusoidal across track scan pattern and the nominal flight conditions the minimum footprint dwell time is found to be 21.3 msec. Again, requiring 30 % overlap for proper sampling this implies a 15 msec sampling interval and integration time in the radiometer. For a total power radiometer we thus calculate a sensitivity $\Delta T=0.34$ K.

The 35 GHz Radar

The transmitter is based on a 46 kW magnetron having a pulse width of 125 nsec and a duty cycle of 0.1%. The corresponding bandwidth is 8 MHz, the range resolution 18.75 m, and the maximum PRF is 8 kHz leading to an unambiguous range of 18.75 km. The simple, brute force transmitter technique is chosen due to the unfavourable sensing situation where very week signals from the clouds must be measured with little time difference to the ground return typically 60 dB stronger. Pulse compression techniques with time sidelobes way below -60 dB is very difficult if not impossible.
The receiver noise figure of 5 dB and the bandwidth of 8 MHz results in a receiver noise level of -100 dBm. The transmitter power of 46 kW equals 77 dBm and the system sensitivity is 177 dB (for S/N=1). Assuming at first for simplicity that equal sized antennas are used for transmission and reception (45 cm aperture corresponds to some 42 dB gain at 35 GHz) the radar equation predicts a round trip loss of $P_R/P_T=6.4 \times 10^{-10} \times \sigma^V$, σ^V being the volume backscattering coefficient. For normal, non-precipitating clouds consisting of water droplets (1g/m^3) $\sigma^V=2.4 \times 10^{-9}$ is a typical value, see (1) and (2). Inserting this figure in the above

expression for the round trip loss results in a value of -178 dB, and the single pulse signal to noise ratio will be close to 1. For a typical ice cloud the situation is quite different as σ^V=1.0 x 10^{-4} is a realistic value, resulting in a round trip loss of -132 dB, hence a single pulse signal to noise ratio of +45 dB.

Signal to noise ratio can be improved by integration of pulses. The dwell time per footprint is 21.3 msec and with a PRF of 8 kHz we find a potential for integrating 170 pulses. Incoherent integration of 170 pulses will give a gain of 16 dB for a non-fluctuating target. However, this is hardly the case for the present distributed target, and the 16 dB can be regarded as an upper limit. If we consider the Swerling cases 1 and 2 (many small scatterers, none dominating) we get integration gains ranging from the 16 dB (Sw. 2: de-correlation from pulse to pulse) to 5 dB (Sw. 2: no de-correlation over integration period). So, de-correlation is an important property. If we move 1/2 antenna aperture a distributed target de-correlates. Since we move at 240 m/sec we get at least 23 independent samples per footprint. Incoherent integration of 23 independent pulses will give an integration gain of 11 dB. Hence, we can expect an integration gain of 11 to 16 dB and for the typical water cloud the resulting signal to noise ratio will be 10 to 15 dB.

In order to obtain the same footprint for the radiometer and the radar measurements it is necessary that the radar antenna beam is wider than the receiver antenna beam. In principle it should be constant over the significant portion of the receiver beam. The price to pay is of course loss in sensitivity according to the loss in transmit antenna gain. Since we do not have superfluous sensitivity at hand a compromise must be made. The SMRR is made with 2 equal sized reflectors and by changing feed horns on the transmitter for potential underillumination of the reflector, different options to be tried in real life is readily at hand.

94 GHz Channel

The noise figure of the receiver is 7 dB, and in the radiometer mode the bandwidth is 1 GHz. The 94 GHz channel will underilluminate the reflectors to obtain a footprint identical to that of the 35 GHz channel.

The radiometer sensitivity is slightly degraded to 0.38 K.

The transmitter is based on a 2.5 kW magnetron having a pulse width of 50 nsec. Compared with the 35 GHz radar we have a change in the round trip loss of -13 dB on the peak power, -4 dB on the bandwidth, -4 dB on the pulse length, and -3 dB on the noise figure. However, we gain on the frequency. The radar equation changes with the wavelength to the second power while σ^V changes with frequency to the fourth power, and the result is a gain of 9 dB. Hence, the total round trip loss is degraded with - 15 dB, and the signal to noise ratio after proper integration will be below 0 dB for typical water clouds. While the 94 GHz channel is not very useful for water clouds, ice clouds will be well imaged.

Sensing of the Earth's Surface

The instrument will also be useful for sensing of the surface of the Earth. The radar equation predicts a round trip loss of P_R/P_T=2.2 x 10^{-11} x σ_o. A typical value for sigma naught is -10 dB for land surfaces, and the resulting round trip loss is -117 dB leading to ample sensitivity.

A special aspect of the high return of the ground compared with the water clouds (typically 60 dB difference) is the possibility of interference. Problems with pulse compression have already been discussed. Antenna sidelobes pointing towards the ground is a potential problem, but not in a nadir looking system. At the swath edges the slant range distance to the ground is 330 m larger than the nadir distance to the ground. Hence the large nadir return in general precludes the measurement of clouds below 330 m.

Sensing of Rain

The instrument will also be very well suited for detailled studies of rain. The sensitivity is ample due to the reflectivity factor being orders of magnitude larger for even moderate rain than for water clouds. The high frequency will suffer from loss passing through the rain, but due to the nadir geometry and the associated short path length this never becomes a problem.

Conclusions

An airborne, imaging cloud sensor has been described. It combines a radar and a radiometer to ensure exact simultaneousness and equal footprints for active and passive measurements. Other cloud radars are around, often featuring a doppler mode, but normally ground based. This radar is an imager providing detailled spatial information.

References

(1) Ulaby, F. T., Moore, R. K., and Fung, A. K.: "Microwave Remote Sensing, Vol.1", Artech House

(2) Sauvageot, H. and Omar, J.: "Radar Reflectivity of Cumulus Clouds", Journal of Atmospheric and Oceanic Technology. June 1987