The design of Deimos: a microwave radiometer with channels at 23.8GHz and 50.3GHz for the UK Met. Research Flight C-130 aircraft.

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***Abstract*—**
Details of the design of Deimos will be presented. It is an airborne total-power radiometer with a two channel superheterodyne receiver, coupled onto a common axis, which is scanned between various downward views and two onboard black body calibration targets, over a three second period.

I. INTRODUCTION

Since 1989, the Microwave Airborne Radiometer Scanning System ("MARSS") instrument has been used on the UK Met. Office, C-130 Hercules aircraft to obtain a diverse range of passive radiometric measurements at 89GHz and 157GHz. These have validated the radiative transfer models, which will be used for assimilating Advanced Microwave Sounding Unit (AMSU-B) radiances into the UK Met. Office operational numerical weather prediction model. Following the success of MARSS, a new radiometer "Deimos" has been installed on the aircraft to extend the spectrum of microwave observations to the window channels of AMSU-A, centred at 23.8GHz and 50.3GHz. The design of Deimos described in this report is mostly based on that of MARSS.

Like MARSS, Deimos has all the advantages of the C-130 platform, providing long endurance flights, over an altitude envelope from 18m to 10km and an extensive array of supporting measurements of meteorological variables. Accommodation was provided by the installation of a general purpose aperture in the underside of the aircraft, shown in Fig. 1. This measures 458x406mm and is situated in a bay of depth 381mm, accessed through a floor hatch in the cargo hold. The front end (receiver and antenna scanning and calibration systems) of the instrument on which this paper concentrates is designed to fit within these constraints.

Data from Deimos will be used to study sea, land and ice surfaces, liquid and ice clouds, precipitation, as well as atmospheric absorption in the wings of the 22GHz water vapour line and the 60GHz oxygen complex. These measurements will be used to improve and validate the radiative transfer models at AMSU-A frequencies. Deimos may also be used to provide a validation for AMSU-A, once it has been launched on the US meteorological polar platform, NOAA-K, in 1996 as part of the ATOVS (Advanced TIROS Operational Vertical Sounder) payload.

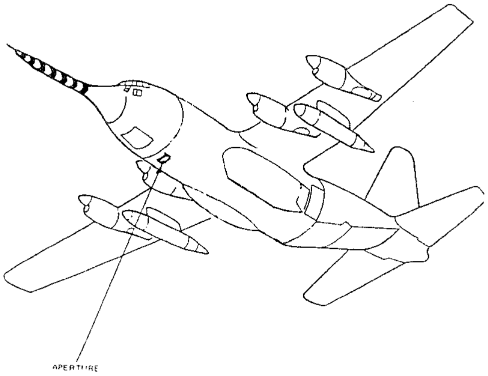

Fig. 1. Deimos Accommodation on MRF C-130

II. DESIGN

The original intention when designing Deimos was to match the radiometric performance of AMSU-A Channels 1 and 3, whilst sharing the same antenna footprints as MARSS. However, limitations imposed by the aircraft resources, restricted instrument to view downwards from nadir to 40° forward. Fig. 2 shows schematically the layout of the design.

II.1 PRESSURE PLATE

The front end of Deimos is divided into two halves by the pressure surface of the aircraft. This pressure plate is structured with a raised box section with a PTFE hyperbolic lens mounted in one wall to transmit radiation from the outside world into the receiver, mounted horizontally, adjacent to this. The unit containing the antenna scanning and calibration mechanism is fitted into the box section. This allows access from the underside of the aircraft for ease of servicing, without the need to break the pressure surface.

This method allows the receiver to be maintained in a stable thermal environment during aircraft ascents and descents, whilst allowing the calibration mechanism to include losses over the entire system and allow the cold calibration target to be sunk to the aircraft sink.

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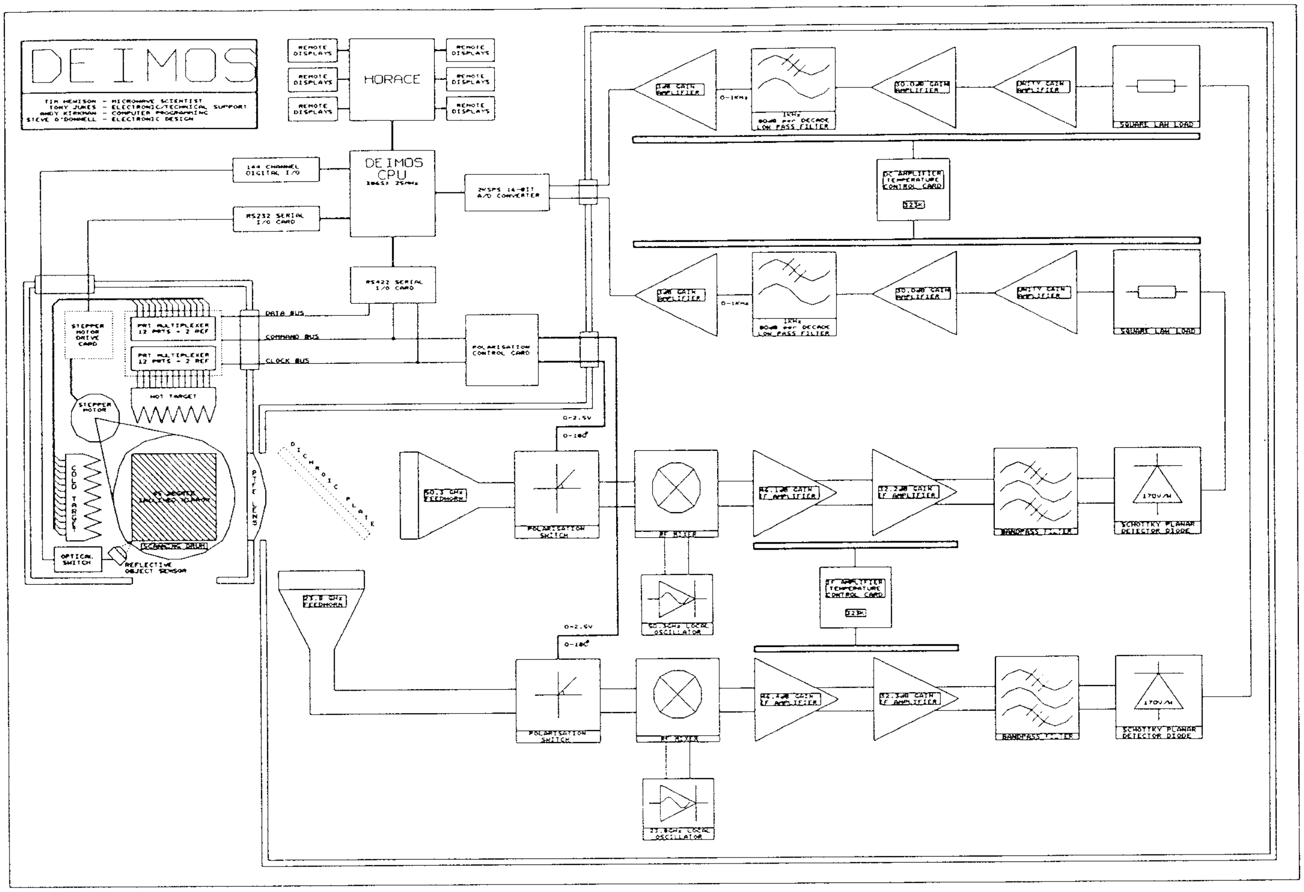

II.2 SCANNER

Upwelling microwave radiation from various directions is reflected into the receiver by a planar mirror housed within a rotating drum. The temperature of this mirror is sensed and it is heated when necessary to prevent condensation of water or ice on its surface, as this would reduce the system's sensitivity. The drum consists of a cylinder of aluminium alloy, open at one end to allow incident radiation to be transmitted along its axis and through the lens in the wall of the pressure plate. The curved window of "TPX" (Polymethyl Pentane) is included in the wall of the drum. As this material has a low loss tangent at microwave frequencies, it transmits only radiation from the desired angles into the receiver, whilst the metallic surface of the drum screens any stray radiation.

Deimos is calibrated continuously in flight as the scanning drum rotates, with a three second period, exposing the receiver to the onboard calibration targets, between various downward views. The drum is driven by a stepper motor via a timing pulley and its position is sensed by an opto switch. This provides a two point end-to-end calibration from which the system noise temperature and gain can be deduced assuming linear behaviour of the receiver.

The targets used are assumed to behave as black bodies. They both comprise of a 114mm diameter array of aluminium pyramids 40mm high, 10mm square base, which are coated with 1mm of Ferroflow absorber by UK Met Office (RSI). The targets cover the beams of the lower frequency channel to its -29dB power contour. Any incident radiation will undergo many reflections within the structure of the target, suffering some loss each time. These targets were found to have worst-case specular reflectivity of less than -40dB above 20GHz. This implies a minimal calibration error due to exposure by radiation of a contrasting temperature.

The hot target is maintained at a constant +65°C by a foil heater mounted on its base, and insulated to maintain a uniform temperature across its surface. A copper heatsink straps the cold target to the aircraft skin, cooling it to -20°C. Each target is close-coupled to the drum by a reflective shroud, which is insulated in the case of the hot target.

II.3 RECEIVER

Incoming radiation is divided by a "DiChroic Plate", a metal plate, perforated with holes on a hexagonal lattice of carefully selected dimensions. This allows high frequencies to be transmitted into one corrugated feedhorn for the 50.3GHz channel, whilst reflecting lower frequencies into the 23.8GHz feedhorn. The layout of the instrument's quasi-optic elements was planned by projecting the 20dB power contour of the Gaussian beams from the beamwaists in the feedhorns' mouths, through the DiChroic Plate onto the lens and re-focussing them to secondary beamwaists in the scanner. From here, the beams expand to their asymptotic limit, defining the beamwidth of each channel.

Radiation is transmitted by circular waveguide from the horns into polarisation switches. These select the transmitted polarisation by Faraday rotation in the Ferrite cores, depending on the current driven through their surrounding coils. This element of Deimos' design allows each channel to rapidly switch between two orthogonal polarisations, which are integrated consecutively for each view (including the calibrations).

Circular to rectangular waveguide transitions pass only the selected polarisation into the mixers. These planar balanced beam-lead GaAs devices mix the broadband incoming (RF) radiation with that of a reference source supplied from GUNN diode Local Oscillators(LOs). This produces intermediate frequency (IF) bands, representing the difference between the input RFs and the LOs.

The power of the intermediate frequencies is only the thermal level equivalent to the antenna temperature plus the noise temperature of the mixer. Bipolar IF amplifiers boost this power by approximately 75dB before it can be detected by subsequent electronics. However, the gain of these amplifiers is highly temperature dependent and any changes over one calibration period would be misinterpreted as changes in antenna temperature. The amplifiers are mounted on a plate, whose temperature is monitored and actively controlled to $<0.015^\circ/3$s, maintaining a gain stability of <0.0002dB.

Bandpass filters are then used to match the passband characteristics of AMSU-A channels 1 and 3, shown in Table 1. These also act to de-sensitise the receiver from reflections of any leaked LO signal.

Planar doped barrier diodes are used as square law detectors to convert the power in the IF spectrum to a voltage level, known as a video signal. Video amplifiers, which are also actively thermally controlled, boost this signal and apply anti-alias filtering before it is sampled at 2kHz by 16 bit analogue-digital converters in the external electronics. These samples are then averaged to provide 50ms integrations for each view under control of the 80486 33MHz computer. This CPU also controls the scanning motor, heaters and thermometry and transmits data to a centralised Data Recording System, for display and logging.

III. CONCLUSIONS

A new radiometer, Deimos, has been designed and manufactured by the UK Met. Office for use on the Met. Research Flight C-130 aircraft to study sea, land and ice surfaces, liquid and ice clouds, precipitation, as well as atmospheric absorption in the wings of the 22GHz water vapour line and the 60GHz oxygen complex. Its first flown scientifically on the MACSI (Microwave Airborne Campaign over Snow and Ice) detachment, based at Oulu, Finland during the spring of 1995, without the polarisation switching. Deimos' performance parameters are summarised in Table 1.

Table 1. Deimos Performance Parameters

AMSU-A Channel	1	3	
Centre Frequency	23.800	50.300	GHz
Frequency Stability	±10	±10	MHz
IF Bandwidth 3dB	8-135	8-90	MHz
40dB Cutoff Freq	154	102	MHz
Scan Period	3.0	3.0	s
Integration Period	50	50	ms
View Angles	+40,+30,	+40,+30,	°
Forward from Nadir	+20,+10,0	+20,+10,0	°
Beamwidth FWHM	10	10	°
Receiver Temp., Trec	580	860	K
Sensitivity, NEΔT	0.35	0.46	K