13A.6 MICROWAVE SCATTERING OBSERVED IN CONVECTIVE CELLS DURING CAMEX-4

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1. BACKGROUND

The High Altitude MMIC Sounding Radiometer – HAMSR – was built by the Jet Propulsion Laboratory (JPL) to demonstrate and validate new miniature technology and advanced design concepts. It is the world's first atmospheric sounder to use receivers based on monolithic microwave integrated circuits (MMICs). It implements dual-band temperature sounding, which results in greater retrieval accuracy as well as a broader measurement scope. HAMSR is the first aircraft microwave sounder with both temperature and humidity sounding capabilities in a single package. Due to miniaturization, this instrument can be accommodated on even small platforms, such as unmanned aerial vehicles (UAVs).

HAMSR is one of the first complete instrument developments coming out of the Instrument Incubator Program (IIP), launched by NASA's Earth Science Technology Office (ESTO) in 1998. From a start in January 1999, HAMSR was essentially completed in early 2000 as a laboratory instrument suitable for ground based applications. It was subsequently upgraded for deployment on NASA's high altitude ER-2 aircraft. The first test flights were successfully carried out in July 2001, and HAMSR then participated in the fourth Convection and Moisture Experiment (CAMEX-4) in Florida during August and September of 2001. HAMSR will be used in the future as a testbed to validate new technology as well as to support scientific missions.

2. INSTRUMENT AND MEASUREMENTS

HAMSR is a passive microwave radiometer, which measures the thermal radiation emitted from the atmosphere and the surface below. It has three receivers, which detect part of this emission in three spectral bands. Each receiver is attached to a spectrometer – a filter bank, which essentially tunes the receiver to a number of narrow spectral channels simultaneously. This allows portions of the spectrum of the radiation to be determined.

HAMSR has 25 spectral channels in those three bands, between 50 and 190 GHz. Fig. 1 shows the atmospheric spectrum in this region. Band I has 10 channels near the 118-GHz Oxygen line and Band II has 8 channels in the 50-70 GHz Oxygen complex. Both are used for temperature sounding. Band III has 7 channels near the 183-GHz water vapor line and is used for water vapor sounding. The characteristics of these channels are listed in Table 1.

Fig. 2 shows the resulting weighting functions in a standard atmosphere. Bands I and II have nearly identical weighting functions and are therefore essentially redundant. Thus, although Band I was not operational during CAMEX-4, full sounding functionality was nevertheless achieved.

For CAMEX-4 HAMSR was installed in the forward compartment of the right wing pod of the NASA ER-2. Thermal radiation from the atmosphere enters through a window in the bottom of the pod into two closely spaced apertures. Each illuminates a scan mirror, which reflects the incoming radiation into the receivers. The mirrors are mounted at a 45° angle on a common scan axis, and by rotating them around this axis the atmosphere below is scanned in a direction perpendicular to the scan axis – which lies in the flight direction. The instantaneous field of view (IFOV) is a cone with an angle of 5.7°. The scan mirrors are programmed to rotate at a constant speed, with one full rotation every 1.1 seconds, and the data acquisition system is programmed to integrate the received signals in 9 ms time slices. During such a sampling period the "beams" move about 3°, i.e. about half of the IFOV. On the ground at nadir the IFOV projects to a circle with a diameter of about 2 km when the instrument is at the normal ER-2 flight altitude of 20 km, and the spacing between adjacent samples is about 1 km. As the mirrors scan away from nadir, the "footprints" projected on the ground become elliptical and grow in size. The result is a "scan line" swath, which for CAMEX-4 was about 40 km wide on the ground. This is illustrated in Fig. 3. With an air speed of 0.21 km/s - the cruising speed of the ER-2, the spacing between adjacent scan lines in the direction of flight is about 1/4 km.

The radiometric sensitivity of HAMSR ranges from 0.2 to 0.4 K, depending on channel, and absolute calibration accuracy is better than 0.5 K. Retrieval accuracy depends on atmospheric conditions and is around 2 K for temperature profiles, with a vertical resolution of about 2-3 km. For water vapor profiles it is around 15-20%, with a vertical resolution of 3-4 km. Liquid water profiles can be derived with an accuracy of 40% and a vertical resolution of 4 km. We expect to make significant improvements in the measurement accuracy – absolute radiometric accuracy as well as retrieval accuracy – over time.

A number of tropical convective systems – large and small – were studied during CAMEX-4. The HAMSR observations exhibited often very large brightness temperature depression over intense convective cells, particularly in the most transparent water vapor channels. This depression could reach 100-150 K. Examples will be shown for the case of the hurricane Erin, shown in Fig. 4, which also illustrates the ER-2 flight track.

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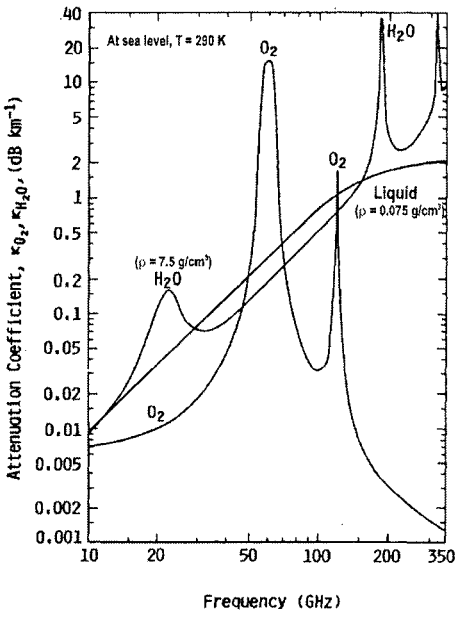

Fig. 1. Microwave absorption spectrum

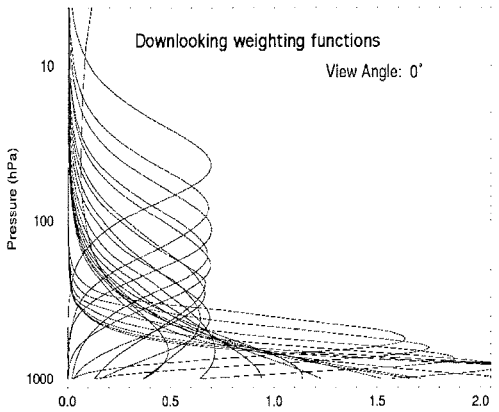

Fig. 2. Weighting functions at nadir

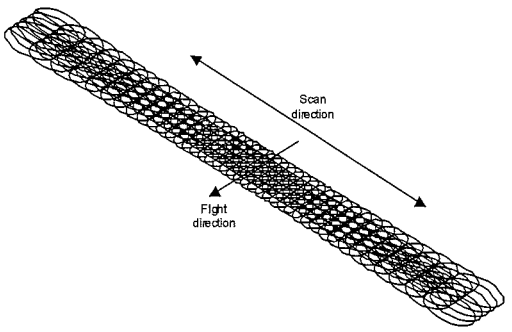

Fig. 3. Scan pattern – ground swath

Table 1. HAMSR spectral properties

Ch #	Center freq. [GHz]	Offset [GHz]	Bandwidth [MHz]	Wt-func. Peak [mb or mm]
I-1	118.75	-5.500	1500	Sfc/[30 mm]
I-2	"	-3.500	1000	Surface
I-3	"	-2.550	500	Surface
I-4	"	-2.050	500	1000 mb
I-5	"	-1.600	400	750 mb
I-6	"	-1.200	400	400 mb
I-7	"	±0.800	2x400	250 mb
I-8	"	±0.450	2x300	150 mb
I-9	"	±0.235	2x130	80 mb
I-10	"	±0.120	2x100	40 mb
II-1	50.30	0	180	Sfc/[100 mm]
II-2	51.76	0	400	Surface
II-3	52.80	0	400	1000 mb
II-4	53.596	±0.115	2x170	750 mb
II-5	54.40	0	400	400 mb
II-6	54.94	0	400	250 mb
II-7	55.50	0	330	150 mb
II-8	56.02 & 56.67	0	270 & 330	90 mb
III-1	183.31	-17.0	4000	[11 mm]
III-2	"	±10.0	2x3000	[6.8 mm]
III-3	"	±7.0	2x2000	[4.2 mm]
III-4	"	±4.5	2x2000	[2.4 mm]
III-5	"	±3.0	2x1000	[1.2 mm]
III-6	"	±1.8	2x1000	[0.6 mm]
III-7	"	±1.0	2x500	[0.3 mm]

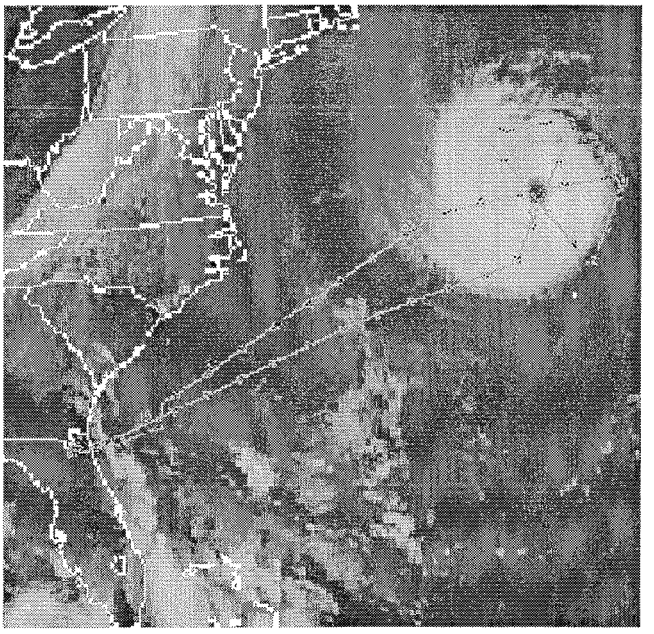

Fig. 4. Hurricane Erin – September 10, 2001