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Project No. A–2904

ADVANCED MICROWAVE MOISTURE SOUNDER (AMMS) FOR WB–57F CCOPE MISSION

J. A. Gagliano and J. J. McSheehy

Prepared for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Under

Contract NAS5–26528

October 1981

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

GTEES

1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

AMMS, developed by Georgia Tech under previous contracts NAS5-23710 and NAS5-26220, was flown on the WB-57F Cooperative Convective Precipitation Experiment (CCOPE) in May/June 1981. AMMS data was collected at three bands on either side of the 183.3 GHz water vapor line at ± 2.25, ± 5.00, and ± 8.75 GHz. Data were also collected simultaneously at a single low-loss atmospheric window channel near 94 GHz. The AMMS scanner imaged the scene below the WB-57F over an angular range of ± 45° about nadir with beam-

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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

widths of 2 degree and 1 degree for the 94 GHz and 183 GHz sensors, respectively. The radiometer system operated under control of the onboard microcomputer used to: store radiometric data on the AMMS flight recorder, operate the stepper motor driven scanner, and collect pertinent housekeeping data for the system. A portable ground support system was used following each CCOPE flight to provide quick-look data analysis. Georgia Tech delivered CCOPE flight logs and tape of the AMMS data to NASA.

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Foreword

This final report was prepared by the Electromagnetics Laboratory of the Engineering Experiment Station, Georgia Institute of Technology under Contract NAS5-26528. The contract was initiated by the Applications Directorate of NASA Goddard Space Flight Center, (GSFC), Greenbelt, Maryland. The contract was administered by J. Larry King of the Earth Observations Systems Division.

Final report authors are J.A. Gagliano and J.J. McSheehy. The period of performance was 3 April 1981 to 31 October 1981. The Appendix A contains copies of the monthly technical progress reports furnished to NASA/GSFC during the duration of the program. Appendix B is a copy of a recent paper, describing the AMMS CCOPE mission results, entitled "Moisture Sounding at Millimeter Wavelengths (94/183 GHz) at High Altitudes." This paper was presented in August 1981 at the SPIE 25th Annual International Technical Symposium and Exhibit in San Diego, CA.

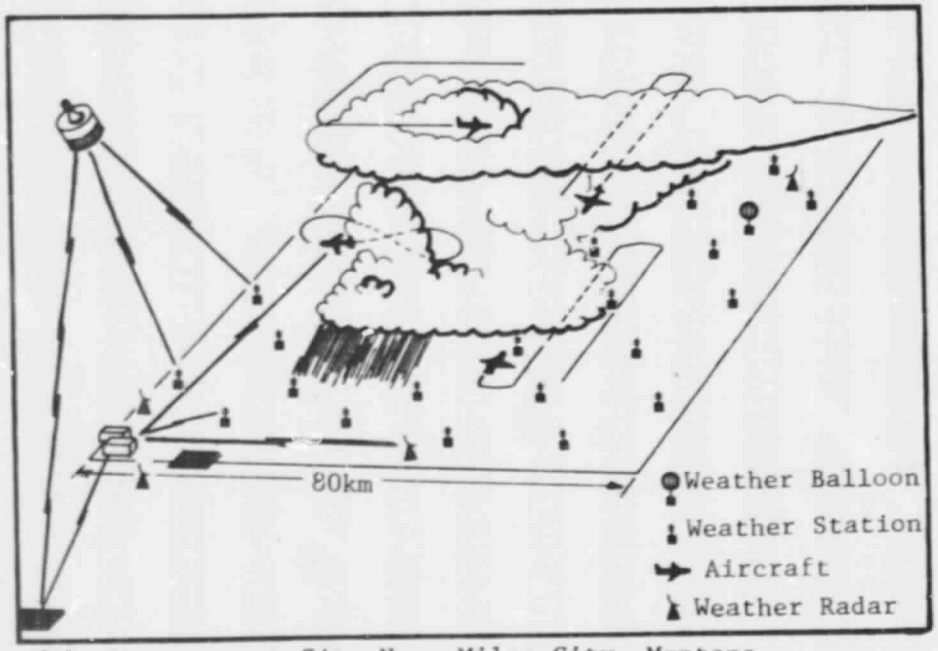
The views and conclusions in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of NASA/GSFC or the U.S. Government.

We would like to acknowledge the valuable contribution to the successful completion of this project by Tom Wilheit, Bob Curran, Chuck Mason, and Jack Pownell of NASA/GSFC; and the following Georgia Tech personnel: Don Gallentine, Ron Forsythe, Stan Halpern, Avery Davis, and John Diller.

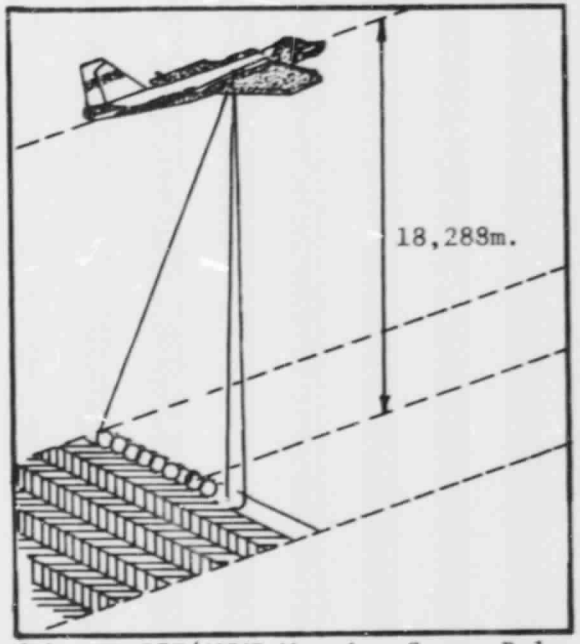
1.0 Introduction

The Advanced Microwave Moisture Sounder (AMMS), developed by Georgia Tech, was successfully flown on NASA's high altitude WB-57F aircraft during the CCOPE (Cooperative Convective Precipitation Experiment) Mission in June 1981. CCOPE was conducted near Miles City, Montana and its main objectives were to study the life cycles of summer convective clouds and storms and to learn how natural processes interact to produce storms. Figure 1 depicts the measurement site over Miles City and shows the AMMS/WB-57F scanning the scene below. A typical WB-57F data flight during CCOPE involved the aircraft flying above a storm at 18 km altitude within a 150 km radius circle near Miles City. At the same time other aircraft would fly in and around the storm. Other operating systems included ground based weather radar, weather balloons, and a satellite-linked network of 125 ground stations.

AMMS performed measurements near the 183.3 GHz water vapor line with three data channels and simultaneously collected data at a single window channel at 94 GHz to measure surface emissivity variations over land. The instrument operated under microcomputer control throughout each flight and collected data continuously from aircraft take-off to landing. A portable ground support system was used following each CCOPE flight to provide quick-look analysis of the data. Table 1 is a summary of AMMS/WB-57F missions performed over the past 2 years ending with the June 1981 CCOPE mission.



(a) Measurement Site Near Miles City, Montana



(b) WB-57F/AMMS Mapping Scene Below

Figure 1. CCOPE Mission with WB-57F/AMMS Performing Measurements

Table 1. Advanced Microwave Moisture Sounder (AMMS)/WB-57F Mission Schedule Summary

Mission	Location	Month/Year
SESAME*	Southwest U.S.	June 1979
Florida Thunder-Storm	Florida	Sept. 1979
Stratiform Precipita-tion	Central and Southern U.S.	Feb. 1980
Severe Storm	South Florida	Aug. 1980
CCOPE**	Montana	May/June 1981

*Severe Environmental Storms and Mesoscale Experiment

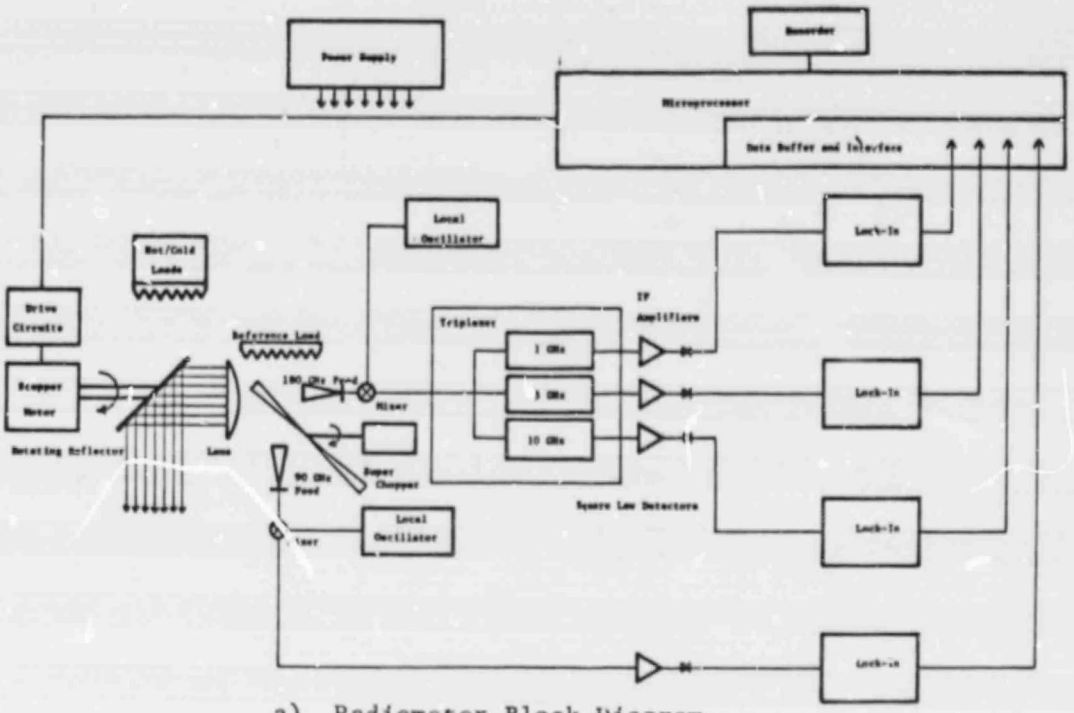
**Cooperative Convective Precipitation Experiment

2.0 AMMS System Description

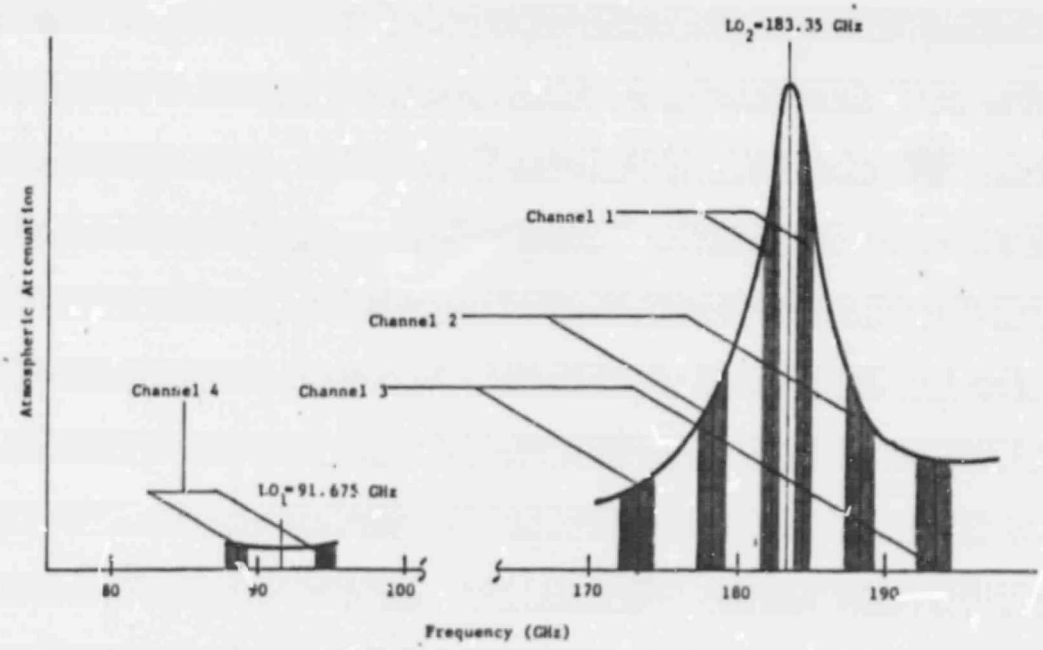
The AMMS 94 GHz channel serves as a low-loss atmospheric window channel and as a background temperature monitor for correction of the 183 GHz water vapor channels. The three 183 GHz channels consist of bands on either side of the 183.3 GHz water vapor line at ± 2.25, ± 5.00, and ± 8.75 GHz. The AMMS block diagram and frequency channel allocation are shown in Figure 2. The AMMS scanner images the scene below the aircraft over an angular range of $\pm 45^{0}$ about nadir. The angular beamwidths for the 94 GHz and 183 GHz sensors are 2 degrees and 1 degree, respectively. The onboard AMMS microcomputer sets the scan period, controls the calibration period, samples the four data channels, and digitizes the data for storage on the flight recorder. Table 2 provides a summary of key parameters for the 94/183 GHz imaging radiometer and ground support system. The ground support system is a portable microcomputer based unit used to provide quick-look data analysis after each flight.

The AMMS RF package is shown in Figure 3 with the external hot and cold calibration loads attached. The rotating reflector operates under microprocessor control and, after a selectable number of mapping cycles (six for the previous WB-57F flights), rotates 360^{0} to reflect each calibration load into the AMMS antenna lens viewing port. A key component developed for the AMMS RF front-end is the 183 GHz subharmonic balanced mixer (pumped at 91.65 GHz) which uses antiparallel mounted Schottky-barrier diodes. Reference is made to the semi-annual status report "Research In Millimeter Wave Techniques" (NASA Grant No. NSG-5012), report period 15 January - 15 July 1981, for further detail on the subharmonic mixer program which supported the CCOPE flights.

Figures 4 and 5 are the AMMS digital package (with dual cartridge flight recorder) and the AMMS ground support system, respectively. Following each data flight the cartridge was removed from the flight recorder and inserted in the ground support recorder, where quick-look data analysis programs were performed.



a) Radiometer Block Diagram.



b) Radiometer Channel Allocation.

Figure 2. WB-57F 94/183 GHz Radiometer Block Diagram and Channel Allocation.

Table 2

Key Parameters of the 94/183 GHz WB-57F AMMS

Parameters	Remarks
AIRBORNE SYSTEM	
Dual Frequency 94/183 GHz Front-end	Solid state, low noise wide band
Multichannel System	3 channels @ 183 GHz, 1 channel @ 94 GHz
Subharmonic Balanced Mixer	183 GHz (Pumped at 91.65 GHz)
Single-ended Mixer and LO Injection Cavity	94.0 GHz
Antenna	5 inch lens aperture (1^0 and 2^0 HPBW)
Precision External Calibration	Effective black body ($\epsilon > 0.999$)
Super Chopper Beam Combining	Essentially Lossless Operation
Beam Scanner (Moving Mirror)	Microprocessor Control (Nominal 6 scans/1 calibration)
Data Recording (4 Radiometric Channels)	Microprocessor Control (Full 6 hour capability)
GROUND SUPPORT SYSTEM	
Data Display	Real time to 2X real time images (4 channels)
Data Flight History	Flight log printout
Data Storage	Airborne cartridge to 9 track tape
Software Support	Custom design on flight-to-flight basis

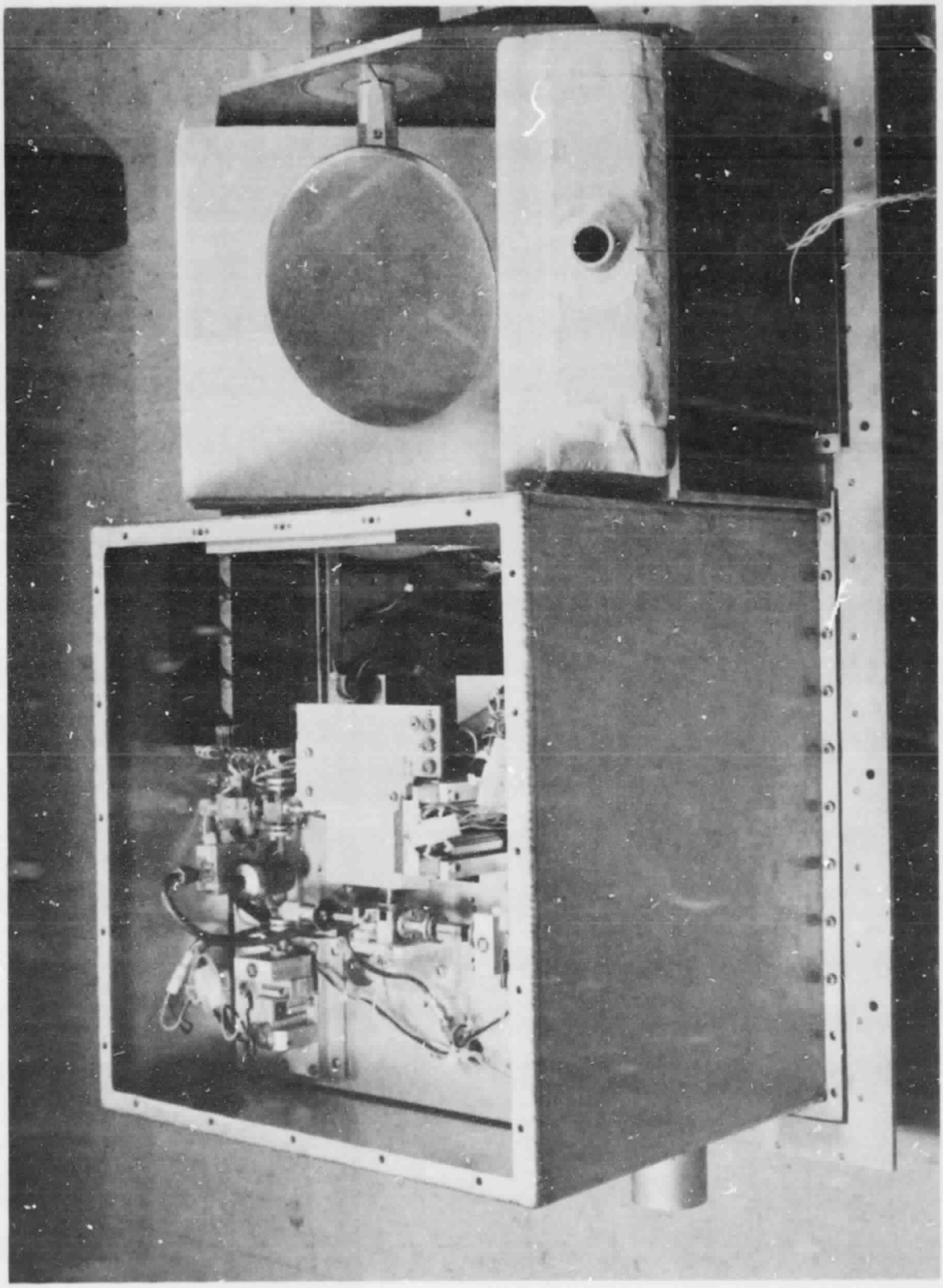


Figure 3. AMMS RF Package Showing Front-End Components, Scanner, and Calibration Loads

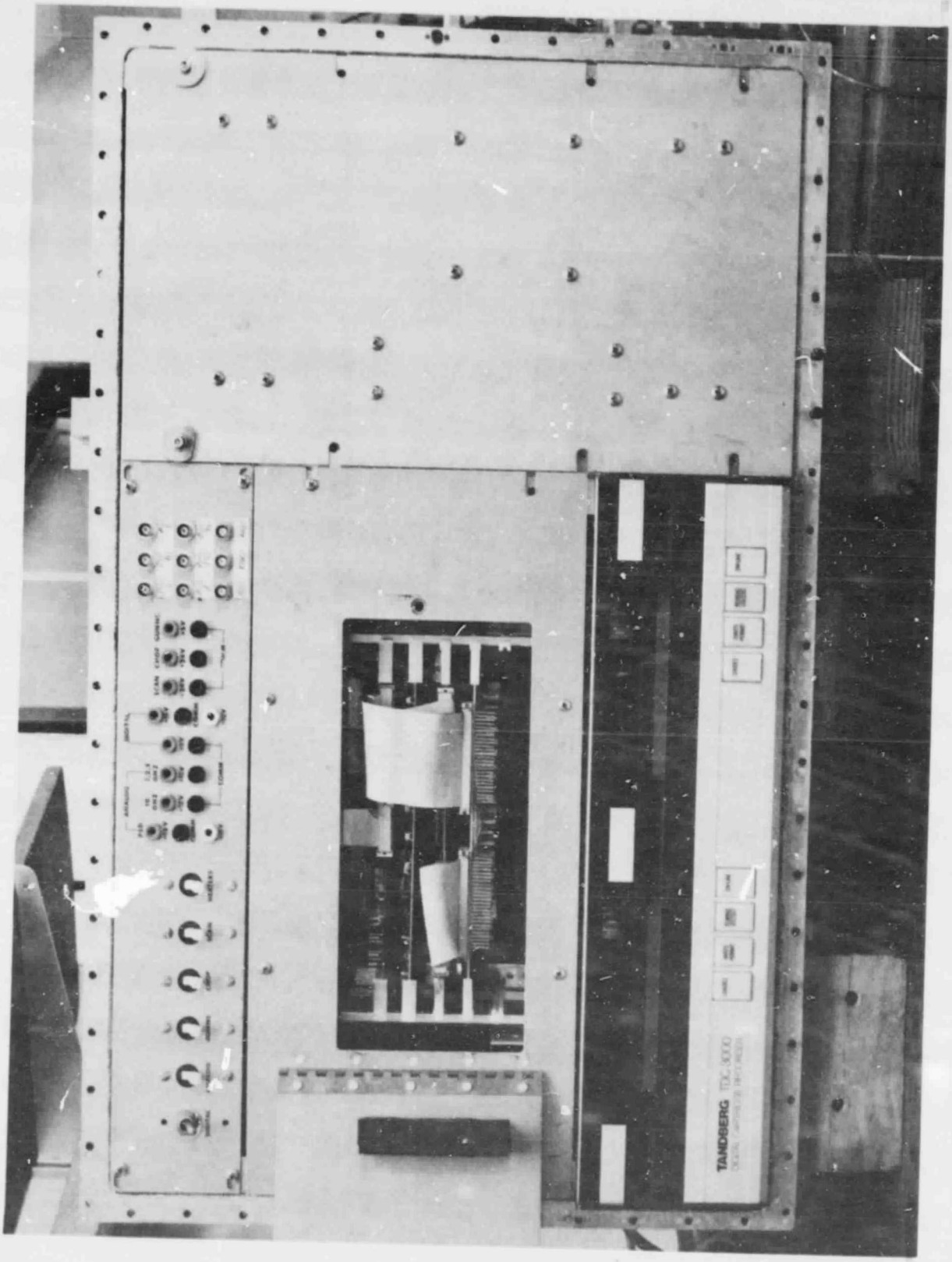


Figure 4. AMMS Digital Package with Flight Recorder

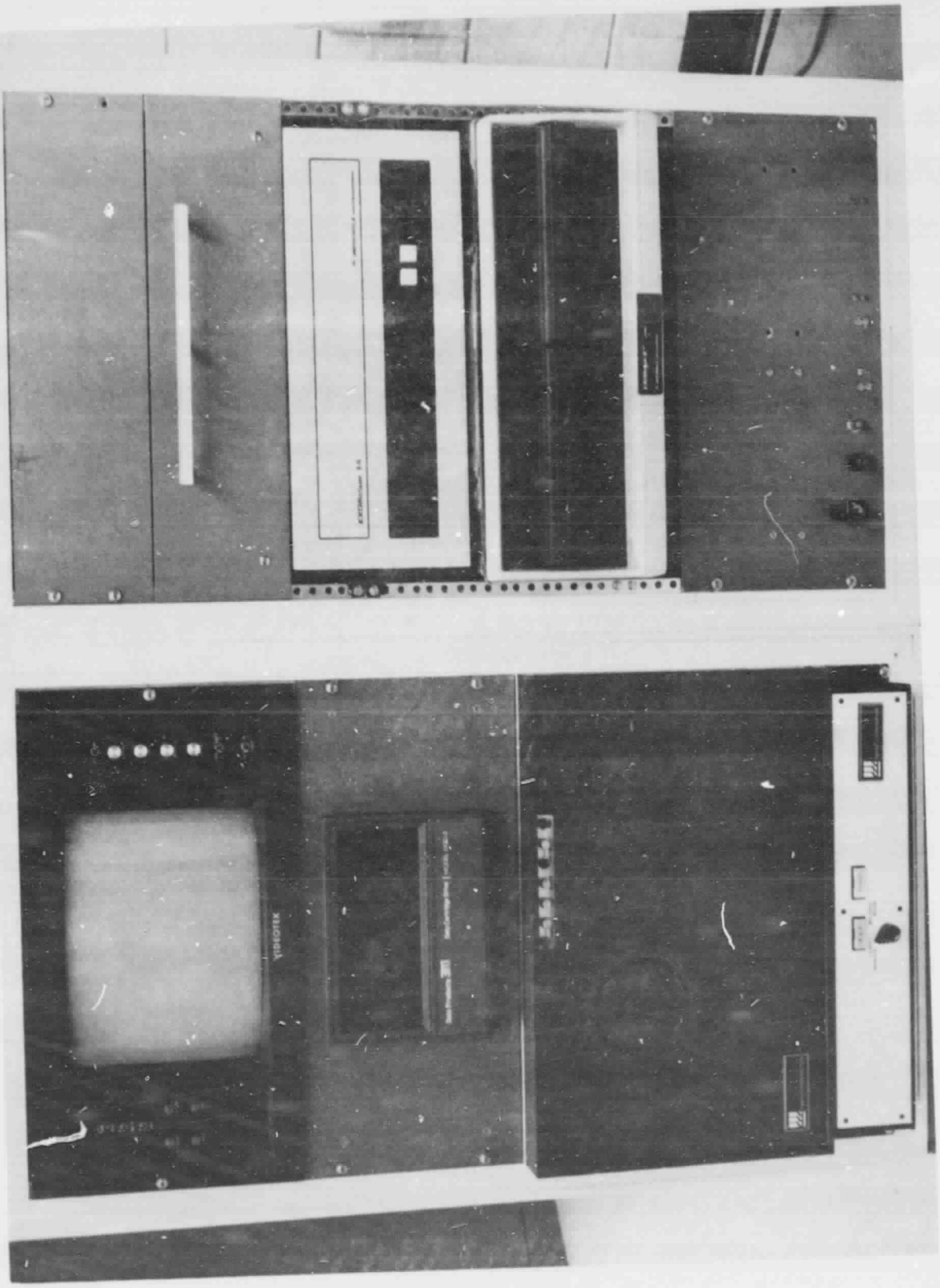


Figure 5. AMMS Ground Support System

3.0 CCOPE Data Quick-Look Analysis Summary

AMMS data collected onboard the WB-57F during the CCOPE mission was analyzed in the field following each data flight. Figure 6 is a four channel radiometric image generated from the flight cartridge for one of the six CCOPE data flights, i.e. CCOPE 2 on 31 May 1981. The aircraft flight time for this image begins at 2013z and ends at 2023z. The time interval of 2017z to 2021z corresponds to a storm cell below the aircraft which was flying at an altitude near 60,000 feet.

The corresponding flight log and history over the same 10 minute time interval for CCOPE 2 are shown in Figures 7 and 8 respectively. The flight log provides data information such as the maximum (MAX) and minimum (MIX) radiometric temperature recorded for each six scan (approximately eighteen seconds) sequence on each data channel. For instance, MA2 = 228K and MI2 = 137K at 2019z correspond to the 94 GHz maximum and minimum brightness temperatures, respectively. The AMMS flight history (Figure 8) provides information on component operating temperatures in degrees centigrade such as: Dicke Reference load (RF), 183 GHz Gunn diode oscillator (GN8), and 183 GHz subharmonic mixer (MX8). The temperature resolution (DELTX) for each of the four data channels is provided. The temperature resolution calculations are based on ten calibration samples each for the hot and cold calibration loads.

Figure 9 is a graph of brightness temperatures for each AMMS data channel versus flight time for the same interval. The time periods 2013z to 2017z and 2021z to 2023z correspond to scenes with relatively clear air and low clouds. The decrease in brightness temperatures on all four channels occurs between 2017z and 2021z. This event represents the detection of a storm cell and is primarily due to resonant backscattering of the 3K cosmic background by particles within the storm cell.

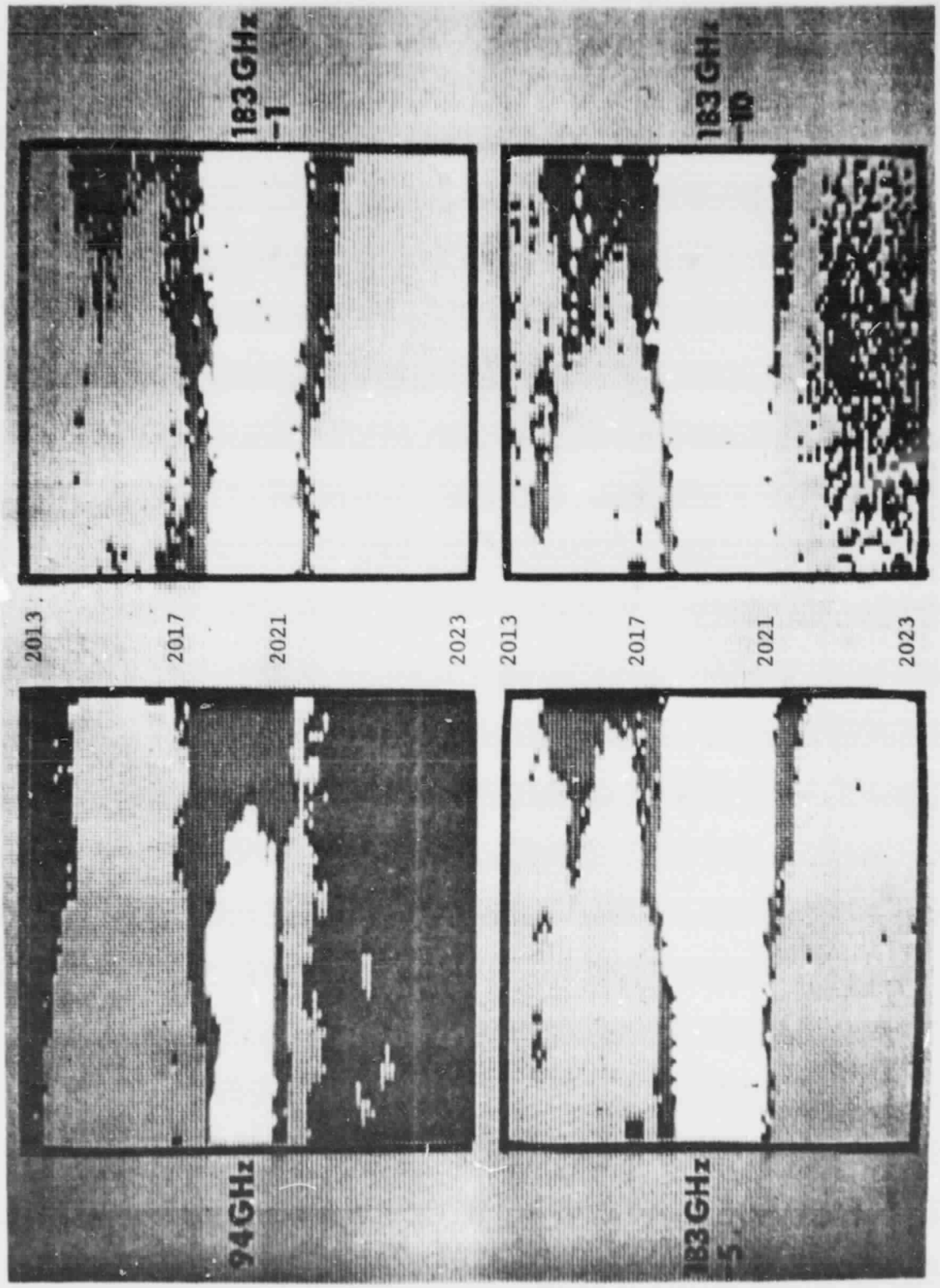


Figure 6. AMMS Radiometric Images (4 Channels) From CCOPE 2 (5/31/81).

PAGE: 4 FLIGHT: CCOPE 2 DAY: 151 DATE: 5/31/81

TK	BLK	TIME	IRIG	CD	MT	RF	G2	G1	GS	G0	MA2	MI2	MA1	MI1	MA5	MI5	MA0	MI0
0	300	0:56	20: 5	-17	57	28	-45	-117	-59	-76	296	282	260	244	271	251	279	258
0	302	0:56	20: 6	-17	57	28	-45	-115	-59	-77	296	278	262	244	270	252	281	258
0	304	0:56	20: 6	-17	57	28	-44	-112	-59	-76	289	265	261	249	268	253	278	255
0	306	0:57	20: 6	-17	57	28	-45	-117	-60	-76	292	265	262	241	269	240	276	245
0	308	0:57	20: 7	-18	57	28	-45	-118	-59	-75	281	216	258	191	268	184	272	178
0	310	0:57	20: 7	-17	57	28	-45	-118	-61	-74	269	150	257	155	263	147	264	138
0	312	0:58	20: 8	-17	57	28	-45	-117	-62	-78	274	160	260	160	269	147	272	137
0	314	0:58	20: 8	-17	57	28	-44	-115	-61	-75	274	241	260	226	266	225	277	224
0	316	0:59	20: 8	-17	57	28	-44	-117	-61	-77	274	228	255	216	263	216	270	212
0	318	0:59	20: 9	-17	57	28	-45	-117	-59	-75	274	252	256	242	262	248	268	245
0	320	0:59	20: 9	-17	57	28	-45	-118	-62	-78	278	232	259	209	266	188	269	174
0	322	1: 0	20: 9	-17	57	28	-45	-124	-61	-81	277	252	256	236	266	239	274	223
0	324	1: 0	20:10	-17	57	28	-45	-118	-61	-79	278	253	261	241	269	240	275	235
0	326	1: 0	20:10	-17	57	28	-45	-122	-60	-77	278	254	262	241	271	245	276	241
0	328	1: 1	20:10	-17	57	28	-45	-118	-60	-76	281	261	265	246	271	246	277	247
0	330	1: 1	20:11	-17	57	29	-44	-122	-62	-76	284	265	262	242	271	249	280	243
0	332	1: 2	20:11	-17	57	28	-45	-119	-63	-79	282	267	258	238	265	240	277	242
0	334	1: 2	20:12	-17	57	28	-45	-120	-62	-76	277	209	249	199	254	184	259	170
0	336	1: 2	20:12	-17	57	28	-44	-120	-65	-75	282	252	256	224	262	212	269	203
0	338	1: 3	20:12	-17	57	28	-45	-118	-63	-76	282	268	258	242	262	240	271	247
0	340	1: 3	20:13	-17	57	28	-45	-117	-62	-75	284	263	259	233	268	236	275	233
0	342	1: 3	20:13	-16	57	28	-44	-119	-64	-79	287	270	260	241	265	241	278	241
0	344	1: 4	20:13	-17	57	28	-45	-120	-62	-78	287	270	259	231	267	242	277	241
0	346	1: 4	20:14	-17	57	28	-44	-122	-65	-76	287	274	260	239	265	244	275	255
0	348	1: 4	20:14	-17	57	27	-44	-123	-63	-76	285	269	258	238	267	247	274	250
0	350	1: 5	20:15	-17	57	28	-44	-125	-62	-77	283	270	255	234	264	239	271	240
0	352	1: 5	20:15	-17	57	28	-44	-125	-65	-76	283	236	259	219	267	208	277	205
0	354	1: 6	20:15	-17	57	28	-45	-124	-65	-80	285	268	261	244	268	243	279	243
0	356	1: 6	20:16	-16	58	27	-44	-122	-64	-80	288	269	263	245	270	248	277	250
0	358	1: 6	20:16	-17	57	27	-45	-122	-65	-78	281	266	261	244	268	246	274	251
0	360	1: 7	20:16	-17	57	27	-45	-122	-65	-78	281	251	258	235	266	231	271	222
0	362	1: 7	20:17	-17	57	28	-45	-130	-65	-80	272	248	253	224	262	220	264	201
0	364	1: 7	20:17	-17	57	27	-44	-124	-66	-78	266	248	255	224	260	214	262	199
0	366	1: 8	20:18	-17	58	28	-44	-124	-67	-80	267	236	256	226	264	221	263	204
0	368	1: 8	20:18	-17	58	27	-44	-130	-65	-79	271	237	255	225	266	215	267	201
0	370	1: 9	20:18	-17	58	28	-45	-123	-67	-79	267	175	240	183	242	168	246	155
0	372	1: 9	20:19	-17	57	28	-44	-129	-67	-77	231	143	206	160	196	148	194	140
0	374	1: 9	20:19	-17	58	27	-44	-122	-66	-79	228	137	210	163	198	145	186	130
0	376	1:10	20:19	-17	58	28	-44	-128	-66	-82	263	207	219	166	218	158	214	145
0	378	1:10	20:20	-17	58	28	-45	-130	-69	-81	270	258	244	205	248	203	253	200
0	380	1:10	20:20	-17	58	28	-45	-130	-68	-78	284	260	255	203	263	203	269	206
0	382	1:11	20:21	-17	58	28	-44	-128	-67	-82	291	267	261	226	271	228	279	226
0	384	1:11	20:21	-17	57	28	-44	-128	-68	-75	293	264	261	244	268	252	281	253
0	386	1:12	20:21	-17	58	28	-45	-128	-67	-76	296	267	264	248	269	253	280	257
0	388	1:12	20:22	-16	58	27	-44	-136	-68	-78	297	285	260	243	270	253	280	260
0	390	1:12	20:22	-16	58	28	-45	-130	-69	-83	295	277	263	245	271	251	281	259
0	392	1:13	20:22	-16	58	28	-44	-132	-67	-80	296	282	262	245	270	253	279	259
0	394	1:13	20:23	-17	58	28	-44	-129	-69	-75	296	280	263	245	268	253	281	262
0	396	1:13	20:23	-16	58	27	-44	-132	-67	-81	297	287	263	240	271	255	281	261
0	398	1:14	20:24	-16	58	28	-44	-131	-67	-78	297	287	263	240	273	252	280	260

Figure 7. AMMS Flight Log From CCOPE 2 (5/31/81)

PAGE: 4 FLIGHT: CCOPE 2 DAY: 151 DATE: 5/31/81

TK	BLK	TIME	IRIGB	CD	HT	RF	GN9	GN8	MX9	MX8	DIG	94B	DELT2	DELT1	DELT5	DELT0
0	300	0:56	20: 5:46	-17	57	28	23	22	19	19	20	0.59	0.73	1.88	2.71	2.94
0	302	0:56	20: 6: 8	-17	57	28	23	22	19	19	20	0.61	0.70	2.92	1.83	2.68
0	304	0:56	20: 6:31	-17	57	28	23	22	19	19	20	0.59	0.90	2.43	2.70	3.89
0	306	0:57	20: 6:53	-17	57	28	23	22	19	19	20	0.59	1.01	2.78	1.88	2.89
0	308	0:57	20: 7:16	-18	57	28	23	22	19	19	20	0.60	1.01	2.12	2.41	3.23
0	310	0:57	20: 7:38	-17	57	28	23	22	19	20	20	0.59	0.98	2.99	2.65	2.98
0	312	0:58	20: 8: 1	-17	57	28	23	22	19	19	20	0.60	0.82	2.49	2.90	2.23
0	314	0:58	20: 8:23	-17	57	28	23	22	19	19	20	0.59	1.06	2.02	2.33	2.50
0	316	0:59	20: 8:46	-17	57	28	23	22	19	19	20	0.59	1.11	2.37	2.00	2.71
0	318	0:59	20: 9: 8	-17	57	28	23	22	19	19	20	0.60	1.10	2.49	1.76	3.79
0	320	0:59	20: 9:29	-17	57	28	23	22	19	19	20	0.59	0.86	2.05	2.12	3.23
0	322	1: 0	20: 9:52	-17	57	28	23	22	19	20	20	0.59	0.94	2.44	1.63	3.18
0	324	1: 0	20:10:14	-17	57	28	23	22	19	19	21	0.59	1.05	2.63	2.30	3.00
0	326	1: 0	20:10:37	-17	57	28	23	22	19	19	20	0.60	0.92	3.11	2.20	2.74
0	328	1: 1	20:10:59	-17	57	28	23	22	19	19	20	0.60	0.89	2.27	2.44	2.54
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0	332	1: 2	20:11:44	-17	57	28	23	22	19	19	20	0.60	1.13	1.52	2.31	2.50
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0	346	1: 4	20:14:20	-17	57	28	23	22	19	19	20	0.59	0.92	2.27	2.76	2.93
0	348	1: 4	20:14:43	-17	57	27	23	22	19	19	20	0.59	0.78	2.23	1.82	2.98
0	350	1: 5	20:15: 5	-17	57	28	23	22	19	19	20	0.60	0.74	2.34	2.58	3.31
0	352	1: 5	20:15:28	-17	57	28	23	22	19	19	20	0.60	0.92	2.35	2.75	3.82
0	354	1: 6	20:15:50	-17	57	28	23	22	19	19	20	0.59	1.29	2.62	2.58	3.79
0	356	1: 6	20:16:13	-16	58	27	23	22	19	19	20	0.60	0.97	2.50	2.74	3.46
0	358	1: 6	20:16:35	-17	57	27	23	22	19	19	20	0.59	0.69	2.18	1.62	3.22
0	360	1: 7	20:16:56	-17	57	27	23	22	19	19	20	0.60	0.97	2.16	2.11	3.61
0	362	1: 7	20:17:19	-17	57	28	23	22	19	19	20	0.60	0.68	3.43	2.95	2.42
0	364	1: 7	20:17:41	-17	57	27	23	22	19	19	20	0.60	0.87	2.73	2.03	3.10
0	366	1: 8	20:18: 4	-17	58	28	23	22	19	19	20	0.60	0.98	2.61	3.19	3.26
0	368	1: 8	20:18:26	-17	58	27	23	22	19	19	20	0.60	0.99	2.58	2.69	2.52
0	370	1: 9	20:18:49	-17	58	28	23	22	19	19	21	0.60	0.85	2.73	2.89	3.22
0	372	1: 9	20:19:11	-17	57	28	23	22	19	19	22	0.60	0.84	1.91	2.30	4.07
0	374	1: 9	20:19:34	-17	58	27	23	22	19	19	21	0.60	0.97	2.42	3.70	2.86
0	376	1:10	20:19:56	-17	58	28	23	22	19	19	21	0.60	0.83	2.76	3.13	2.69
0	378	1:10	20:20:19	-17	58	28	23	22	19	19	21	0.60	0.76	3.12	3.10	4.36
0	380	1:10	20:20:40	-17	58	28	23	22	19	19	21	0.59	1.18	2.63	2.40	3.64
0	382	1:11	20:21: 2	-17	58	28	23	22	19	19	21	0.60	0.82	2.91	2.07	2.87
0	384	1:11	20:21:25	-17	57	28	23	22	19	19	21	0.60	1.01	3.10	3.16	2.19
0	386	1:12	20:21:47	-17	58	28	23	22	19	19	21	0.60	0.87	3.49	2.96	2.94
0	388	1:12	20:22:10	-16	58	27	23	22	19	19	21	0.60	0.82	2.30	2.42	3.24
0	390	1:12	20:22:32	-16	58	28	23	22	19	19	21	0.60	0.97	2.15	3.21	3.99
0	392	1:13	20:22:55	-16	58	28	23	22	19	19	21	0.60	0.73	2.76	1.76	2.76
0	394	1:13	20:23:17	-17	58	28	23	22	19	19	21	0.60	0.83	2.55	2.11	3.56
0	396	1:13	20:23:40	-16	58	27	23	22	19	19	21	0.60	0.91	3.10	2.60	3.57
0	398	1:14	20:24: 2	-16	58	28	23	22	19	19	21	0.60	0.96	2.23	3.50	3.97

Figure 8. AMMS Flight History From CCOPE 2 (5/31/81)

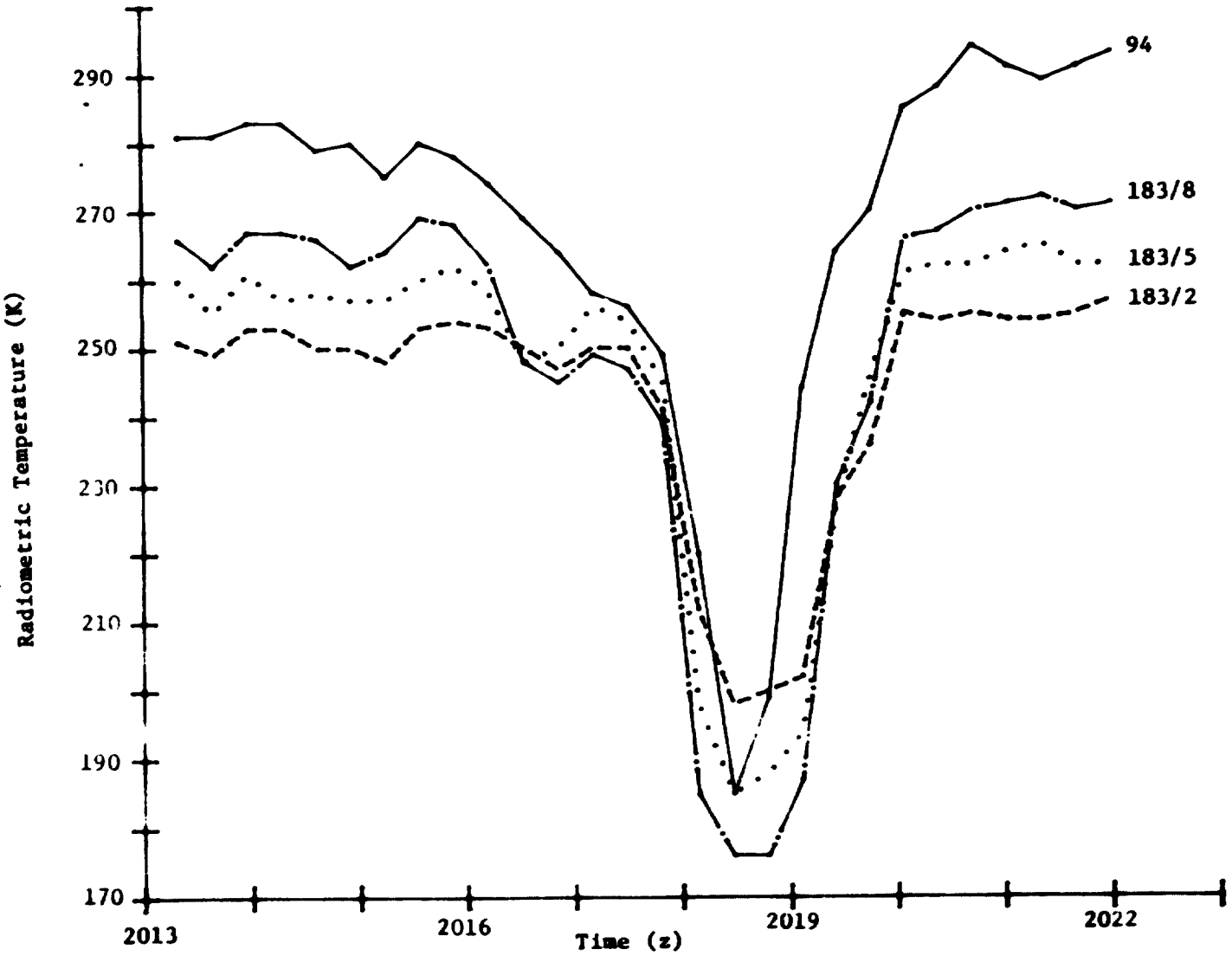

Figure 9. AMMS Brightness Temperatures (Four Channels) versus Aircraft Time.

4.0 Conclusion

In addition to quick-look analysis programs leading to flight logs and computer compatible tapes, Georgia Tech has developed programs for enhanced data analysis using the Eclipse computer system available on campus. Programs developed utilize the image processing software and high resolution COMPTAL display to produce pseudo-color and black and white images with full temperature resolution. The use of non-linear color transfer functions enhances desired temperature ranges to highlight certain weather phenomena, such as a rain cell. Other similar efforts have been performed at Georgia Tech in order to enhance analysis of the AMMS data collected onboard the aircraft.

It is expected that data gathered by AMMS on the WB-57F atmospheric 1979-1981 missions will be used in future high altitude measurement programs such as NASA's earth resources aircraft ER-2. Data gathered from high altitude aircraft programs will eventually be used in the implementation of satellite sensors to collect weather data such as: the measurement of the water content of clouds, the rate at which rain is falling, the detection and observation of developing weather patterns, and the monitoring of severe weather such as thunderstorms and hurricanes.

APPENDIX A

Monthly Progress Report

Monthly Progress Management Report No. 1

Report Period

1 April Through 30 April 1981

Report Prepared

May 8, 1981

"Advanced Microwave Moisture Sounder (AMMS)"
May/June 1981 WB-57 CCOPE mission

J.A. Gagliano

Contract NAS5-26528
(A-2904)

Prepared For

The National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The existing time code demodulator board has been repaired in preparation for the upcoming WB-57F flights. A cold solder connection on the board's supply voltage pin was found and repaired. A back-up time code board from Datum, Inc. was received and tested successfully.

A succesful temperature test of the AMMS was performed during this period. The system was tested over a time period of approximately 4 hours to an ambient temperature of -30°C during which the AMMS cold load reached -14°C. Table 1 provides a log of a portion of the temperature cycle beginning at time 13:12 which is about 3 hours - 45 minutes into the test. This table covers a 15 minute time frame. Observe the stability of the four system gains (G2, G1, G5, G0) which represent in °K/volt the 94 GHz, 183/5 GHz and 183/10 GHz channels, respectively. The radiometer was very reliable throughout the entire test with no problems occuring.

A sky calibration test was performed on the AMMS at Georgia Tech during this period. Table 2 provides a log of a portion of the sky run over a 15 minute time frame. For this test the scanner viewed the sky $\pm 45^{\circ}$ about zenith. Observe the minimum radiometric temperatures (MI2, MI1, MI5, MI0) for the 94 GHz, 183/1 GHz, 183/5 GHz, and 183/10 GHz, respectively. For example at time 16:59, block 122, the sky temperature measured from a minimum of 58°K on the 94 GHz channel to a maximum of 281°K on the 183/1 GHz channel. Table 3 provides a complete pixel printout at time 16:59 of all four channels over six consecutive scans with the average (AVG) pixel temperature for the scans as shown. The zenith position printout is near pixel (PIX) 25 on each channel. PIX 1 and PIX 50 represent -45° and $+45^{\circ}$ positions on the scanner. This test was run in order to have a record of the AMMS sky calibration before the system is shipped to GSFC.

Problems Encountered During This Period

At NASA's direction, the spare 10 GHz IF amplifier was not ordered in case more critical tasks develop in support of the upcoming WB-57F CCOPE mission.

Conclusion

Atmospheric data collected by AMMS from the high altitude WB-57F aircraft will be used in the future in the implementation of satellite weather sensors. Considerable data at lower frequencies such as 19.35 GHz has been obtained from the Nimbus 5 satellite using an Electrically Scanned Microwave Radiometer (ESMR).[8] For this application ESMR images proved useful in determining the extent, structure, and intensity of rainfall. This data has been used to determine, over oceans, the location of frontal rain, rain/snow boundaries, and tropical storm structures. In the future, a satellite weather sensor for the 183 GHz water vapor line (humidity) and the 118 GHz oxygen line (temperature) could aid in the collection of weather data. Future satellite based sensors, when placed in geosynchronous orbit, will allow the continuous observation of rapidly changing phenomena such as severe storms. For instance, a 183 GHz radiometer collecting data from geosynchronous orbit using a 4.4 meter antenna could provide nadir earth surface resolution of about 20 km. Such a sensor would provide excellent mesoscale meteorology data.

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Table 1

AMMS Temperature Cycle Log (15 minute test run)

PAGE: 11 FLIGHT: C DATE: 125 DATE:

TR	BLK	TIME	IR:C	CO	HT	HF	C2	C1	C3	C0	MA2	MI2	MA1	MI1	MA0	MI0
0	486	1:21	18:12	-14	97	27	-43	-54	-44	-41	298	178	299	174	300	178	300	178
0	488	1:21	18:13	-14	97	27	-43	-55	-45	-41	297	179	299	174	301	170	300	177
0	490	1:21	18:13	-14	97	27	-44	-53	-44	-42	299	176	299	173	299	171	299	175
0	492	1:22	18:13	-14	97	27	-44	-54	-44	-43	298	176	298	169	300	174	301	168
0	494	1:22	18:14	-14	97	27	-44	-53	-45	-42	298	178	299	174	301	169	300	181
0	496	1:22	18:14	-14	97	27	-44	-54	-45	-42	297	176	300	172	300	170	301	178
0	498	1:23	18:14	-14	97	27	-43	-55	-43	-41	297	176	299	168	302	178	302	179
0	500	1:23	18:15	-14	97	27	-43	-54	-44	-42	297	178	299	170	300	173	302	174
0	502	1:23	18:15	-14	97	27	-44	-54	-45	- 2	305	178	307	172	306	175	306	176
0	504	1:24	18:15	-14	97	27	-43	-53	-44	-41	305	179	303	171	307	179	301	177
0	506	1:24	18:16	-14	97	27	-44	-52	-44	-41	305	175	304	172	305	177	304	180
0	508	1:24	18:16	-14	97	27	-44	-54	-45	- 1	305	180	304	167	308	175	306	183
0	510	1:25	18:16	-14	97	27	-44	-54	-44	-42	304	178	304	170	304	178	310	175
0	512	1:25	18:17	-14	97	27	-44	-52	-45	-42	306	176	306	180	309	176	311	180
0	514	1:25	18:17	-14	97	27	-43	-54	-44	-42	304	181	305	173	304	175	306	181
0	516	1:26	18:17	-14	97	27	-44	-54	-44	-42	303	181	305	175	308	177	305	181
0	518	1:26	18:18	-14	97	27	-44	-53	-44	-43	302	181	302	180	300	185	302	181
0	520	1:26	18:18	-14	97	27	-44	-54	-44	-41	303	185	303	178	303	180	308	184
0	522	1:27	18:18	-14	97	27	-43	-55	-44	-42	299	185	299	178	302	185	301	188
0	524	1:27	18:19	-14	97	27	-43	-55	-44	-41	305	184	303	180	305	186	307	186
0	526	1:27	18:19	-14	97	27	-43	-54	-44	-42	299	186	301	176	301	183	302	184
0	528	1:28	18:19	-14	97	28	-44	-54	-43	-41	303	183	304	179	305	184	307	191
0	530	1:28	18:20	-14	97	28	-45	-55	-42	-41	303	182	305	184	304	186	306	189
0	532	1:28	18:20	-14	97	28	-44	-55	-43	-42	305	186	307	184	307	185	308	187
0	534	1:29	18:20	-13	97	28	-44	-55	-43	-42	304	186	306	182	304	188	308	184
0	536	1:29	18:21	-13	97	28	-44	-55	-42	-43	299	187	300	180	302	187	302	186
0	538	1:29	18:21	-13	97	28	-43	-56	-42	-43	298	188	299	178	301	186	303	188
0	540	1:30	18:21	-13	97	28	-45	-56	-42	-42	299	189	301	179	302	190	303	191
0	542	1:30	18:22	-13	97	28	-44	-56	-41	-43	299	186	300	179	301	188	304	188
0	544	1:30	18:22	-13	97	28	-45	-56	-41	-42	298	184	302	182	301	187	302	189
0	546	1:31	18:22	-13	97	28	-44	-57	-40	-44	298	187	301	179	300	189	302	187
0	548	1:31	18:23	-13	97	28	-45	-56	-41	-43	299	186	304	184	301	189	302	192
0	550	1:31	18:23	-13	97	28	-45	-56	-39	-44	299	187	299	181	300	196	301	187
0	552	1:32	18:23	-1	97	28	-46	-58	-40	-45	298	185	300	178	301	190	304	184
0	554	1:32	18:24	-13	97	28	-45	-58	-41	-43	305	186	306	180	308	186	306	190
0	556	1:32	18:24	-12	97	28	-45	-56	-41	-44	299	189	301	185	300	185	303	192
0	558	1:33	18:24	-12	97	28	-45	-55	-40	-44	300	187	302	184	300	186	303	188
0	560	1:33	18:25	-12	97	28	-45	-58	-41	-44	301	185	302	179	305	182	302	187
0	562	1:33	18:25	-12	97	28	-45	-55	-40	-44	298	186	299	183	301	183	303	188
0	564	1:34	18:25	-12	97	28	-46	-58	-39	-45	300	186	299	177	302	187	302	187
0	566	1:34	18:26	-12	97	28	-45	-56	-39	-45	298	185	300	180	300	192	300	188
0	568	1:34	18:26	-12	97	28	-46	-57	-39	-45	299	186	301	182	300	187	304	192
0	570	1:35	18:26	-12	98	28	-46	-57	-39	-45	300	186	304	186	302	186	303	186
0	572	1:35	18:27	-10	98	28	-46	-56	-37	-46	299	187	301	185	301	191	303	189
0	574	1:35	18:27	-10	98	28	-45	-55	-38	-46	299	188	303	175	301	187	303	186
0	576	1:36	18:27	-10	98	28	-45	-58	-38	-46	305	188	303	182	306	188	307	187
0	578	1:36	18:28	-9	98	28	-46	-59	-36	-46	300	186	303	181	303	183	300	187
0	580	1:36	18:28	-9	98	28	-46	-58	-37	-45	299	185	300	177	302	189	302	186
0	582	1:37	18:28	-9	98	28	-47	-58	-38	-45	298	186	302	178	303	191	303	190
0	584	1:37	18:29	-8	98	28	-45	-58	-38	-47	300	188	301	180	304	184	303	188

Table 2

AMMS Sky Calibration Test (15 minute data run)

PAGE: 2 FLIGHT: DAY: 3 DATE:

TK	SLK	TIME	IRIG	CD	HT	RF	G2	G1	G5	G0	MA2	MI2	MA1	MI1	MA5	MI5	MA0	MI0	
0	100	0:16	16:56	23	52	30	-57	-42	-65	-104	318	59	318	284	316	277	321	218	Note 1
0	102	0:17	16:56	23	52	30	-57	-41	-62	-93	80	59	297	282	297	277	269	227	
0	104	0:17	16:56	23	53	30	-57	-41	-65	-100	81	56	296	281	295	276	267	223	
0	106	0:17	16:57	23	53	30	-57	-38	-70	-98	84	61	297	283	291	272	266	224	
0	108	0:18	16:57	23	53	31	-58	-40	-68	-97	78	56	295	282	296	275	266	220	
0	110	0:18	16:57	23	53	31	-58	-37	-68	-104	79	57	296	283	296	277	267	223	
0	112	0:18	16:58	23	53	31	-58	-38	-66	-103	110	56	297	285	297	277	271	221	
0	114	0:19	16:58	23	54	31	-60	-39	-68	-101	72	50	295	282	296	274	267	225	
0	116	0:19	16:58	23	54	31	-56	-39	-68	-106	86	64	296	282	292	276	269	219	
0	118	0:19	16:59	23	54	31	-61	-37	-66	-112	69	46	297	282	296	277	267	216	
0	120	0:19	16:59	23	54	31	-59	-41	-71	-96	77	54	295	281	294	274	273	228	
0	122	0:20	16:59	23	54	31	-58	-38	-65	-104	81	58	297	281	296	277	269	224	
0	124	0:20	17: 0	23	54	31	-58	-38	-77	-106	84	59	296	282	292	271	267	221	
0	126	0:20	17: 0	23	54	31	-58	-40	-69	-106	83	59	295	282	296	276	278	225	
0	128	0:21	17: 0	23	55	31	-58	-36	-65	-104	81	58	300	284	295	276	270	224	
0	130	0:21	17: 1	23	55	31	-57	-38	-74	-108	86	61	296	282	293	269	269	222	
0	132	0:21	17: 1	23	55	31	-59	-37	-72	-116	80	55	299	283	296	276	271	214	
0	134	0:22	17: 1	23	55	31	-57	-38	-72	-113	87	62	297	283	293	274	271	217	
0	136	0:22	17: 2	23	55	31	-58	-42	-72	-110	81	58	294	279	293	273	276	222	
0	138	0:22	17: 2	23	55	31	-59	-40	-74	-128	81	56	295	283	295	272	268	209	
0	140	0:23	17: 2	23	56	31	-58	-42	-79	-126	84	56	296	281	296	273	270	209	
0	142	0:23	17: 3	24	56	31	-57	-43	-78	-109	88	62	297	280	299	274	278	226	
0	144	0:23	17: 3	24	56	31	-56	-42	-77	-119	90	65	296	282	295	272	273	215	
0	146	0:24	17: 3	24	56	31	-62	-39	-74	-131	71	41	299	283	296	274	270	212	
0	148	0:24	17: 4	24	56	31	-59	-40	-73	-127	83	55	295	282	295	275	270	205	
0	150	0:24	17: 4	24	56	31	-59	-39	-74	-132	89	54	297	283	296	271	269	206	
0	152	0:25	17: 4	24	56	31	-56	-38	-76	-128	93	65	299	282	297	271	267	207	
0	154	0:25	17: 5	24	56	31	-56	-38	-74	-111	94	65	296	281	295	272	279	219	
0	156	0:25	17: 5	24	57	31	-61	-37	-69	-118	73	45	296	282	297	276	270	216	
0	158	0:26	17: 5	24	57	31	-58	-42	-68	-140	85	60	297	279	297	276	273	199	
0	160	0:26	17: 6	24	57	32	-60	-39	-73	-125	80	51	296	282	296	272	273	208	
0	162	0:26	17: 6	24	57	32	-59	-40	-67	-136	83	56	295	281	298	276	271	199	
0	164	0:27	17: 6	24	57	32	-58	-41	-75	-115	86	61	297	282	294	271	278	223	
0	166	0:27	17: 7	24	57	32	-62	-38	-73	-122	70	43	299	285	295	274	275	222	
0	168	0:27	17: 7	24	57	32	-59	-40	-74	-135	80	56	299	282	296	273	270	212	
0	170	0:28	17: 7	24	57	32	-60	-39	-77	-129	78	53	299	282	296	271	269	211	
0	172	0:28	17: 8	24	58	32	-61	-39	-79	-129	78	51	298	280	294	270	274	221	
0	174	0:28	17: 8	24	58	32	-58	-41	-78	-141	87	61	298	283	297	272	266	211	
0	176	0:29	17: 8	24	58	32	-60	-42	-84	-131	77	53	298	281	296	271	273	220	
0	178	0:29	17: 9	24	58	32	-58	-41	-78	-145	88	63	297	282	296	276	273	213	
0	180	0:29	17: 9	24	58	32	-60	-40	-81	-147	79	54	299	283	301	275	266	215	
0	182	0:30	17: 9	25	58	32	-61	-45	-83	-132	76	53	296	281	295	274	275	227	
0	184	0:30	17:10	25	58	32	-61	-46	-83	-146	78	54	298	281	295	270	270	220	
0	186	0:30	17:10	25	58	32	-60	-46	-94	-155	82	56	299	282	295	271	265	210	
0	188	0:31	17:10	25	58	32	-61	-47	-88	-154	77	54	298	282	295	276	272	222	
0	190	0:31	17:11	25	59	32	-59	-48	-95	-151	270	60	308	283	310	278	314	225	Note 2
0	192	0:31	17:11	25	59	32	-61	-49	-91	-164	293	55	312	282	310	279	312	219	Note 2
0	194	0:32	17:11	25	59	32	-59	-52	-95	-158	300	59	312	274	316	270	315	222	Note 2
0	196	0:32	17:12	25	59	32	-60	-56	-88	-169	299	57	321	275	314	277	320	225	Note 2
0	198	0:32	17:12	25	59	32	-59	-57	-102	-148	86	62	299	277	302	272	284	290	

Note 1. Absorber inserted in front of antenna during this data block.

Note 2. Sky view of +45° scan angle obstructed by vehicle.

Table 3a

AMMS Pixel Temperature Printout (94 GHz and 183/1 GHz Channels)

PIXEL TEMPS

	94 GHZ							183/1 GHZ						
PIX	1	2	3	4	5	6	AV6	1	2	3	4	5	6	AV6
1	80	79	79	80	81	80	80	292	290	292	290	296	291	292
2	74	77	78	75	76	79	77	288	292	291	297	293	291	292
3	74	76	75	77	75	75	75	293	291	295	293	291	291	292
4	73	75	71	73	73	74	73	293	293	295	292	291	293	293
5	71	71	73	73	71	73	72	290	291	292	289	293	288	290
6	71	70	72	73	73	72	72	290	291	292	291	293	288	291
7	69	70	69	69	71	70	70	289	291	290	287	292	290	290
8	71	68	69	68	69	67	69	289	292	292	290	291	293	291
9	66	67	67	69	69	68	68	287	292	288	292	288	290	290
10	68	67	67	68	66	68	67	289	294	288	287	289	290	290
11	65	68	68	67	66	66	67	291	292	296	293	290	288	292
12	65	66	64	65	66	66	66	291	287	291	290	288	289	289
13	65	65	65	66	66	66	65	290	288	289	288	287	288	288
14	62	66	67	64	65	65	65	293	289	287	287	289	287	289
15	65	65	62	63	63	62	63	293	288	292	287	289	284	289
16	64	64	63	61	62	64	63	282	292	291	291	287	290	289
17	63	63	62	67	62	61	63	289	290	288	290	290	289	289
18	64	64	63	63	63	62	63	287	292	291	290	291	286	290
19	60	62	65	63	62	63	63	288	287	291	287	289	289	289
20	63	61	62	63	62	59	62	288	289	286	289	287	285	288
21	64	61	61	62	61	62	62	291	288	289	288	288	291	289
22	62	63	61	62	62	61	62	291	287	285	284	287	290	287
23	62	61	61	61	62	62	61	286	294	288	289	286	291	289
24	59	60	61	63	60	62	61	289	289	290	290	288	290	289
25	61	61	62	58	61	62	61	289	291	285	287	292	287	289
26	60	61	61	62	61	61	61	287	290	289	287	291	291	289
27	61	62	61	61	59	63	61	287	282	289	285	286	288	286
28	59	58	61	61	58	60	59	286	287	289	281	286	289	286
29	60	60	60	58	62	59	60	289	287	286	288	290	290	288
30	63	61	62	58	60	60	61	292	288	289	288	287	286	289
31	61	61	59	60	60	60	60	289	289	291	291	289	287	289
32	59	61	60	60	60	58	60	288	288	286	289	285	286	287
33	60	59	58	61	58	60	59	291	286	287	290	294	286	289
34	61	59	61	59	60	61	60	289	289	287	289	286	289	288
35	60	61	61	62	63	62	62	289	290	290	289	289	290	289
36	64	64	62	63	62	60	63	293	290	292	285	286	288	289
37	62	61	65	64	64	63	63	291	293	288	288	288	291	290
38	63	63	64	64	63	62	63	287	285	291	292	290	294	290
39	65	65	65	65	64	64	65	292	285	291	290	291	288	290
40	64	66	64	65	66	64	65	288	291	288	288	290	286	288
41	66	65	64	66	63	66	65	290	292	295	292	287	289	291
42	66	66	69	67	67	69	67	288	288	290	291	289	285	289
43	67	69	68	67	67	67	67	290	285	287	289	287	289	288
44	69	64	67	66	67	68	67	292	292	291	287	292	291	291
45	67	68	69	69	66	67	68	294	291	289	289	291	289	290
46	69	69	70	71	68	66	69	289	289	291	293	292	290	290
47	72	70	70	70	69	68	70	286	292	287	291	291	292	290
48	72	71	72	73	74	72	72	290	292	292	292	293	293	292
49	74	72	72	72	72	70	72	292	290	290	288	290	291	290
50	78	75	73	74	73	75	75	290	288	293	292	291	292	291

Table 3b

AMMS Pixel Temperature Printout (183/5 GHz and 183/10 GHz Channels)

	183±5 GHz							183±10 GHz						
PIX	1	2	3	4	5	6	AVG	1	2	3	4	5	6	AVG
1	294	293	294	294	291	292	293	262	263	263	267	263	262	263
2	287	293	293	296	294	292	293	263	267	264	263	269	263	265
3	291	292	293	296	291	289	292	258	264	264	263	258	261	260
4	292	293	291	288	294	290	292	258	267	260	256	260	259	259
5	293	291	292	290	293	290	291	260	259	256	256	248	258	256
6	292	292	289	292	288	290	290	249	253	259	251	251	255	253
7	285	291	289	289	287	286	288	253	251	256	250	253	250	252
8	285	288	288	292	291	290	289	248	246	251	250	249	253	249
9	287	289	288	288	290	288	288	243	249	250	249	250	249	249
10	287	289	288	288	287	290	288	248	245	247	247	244	241	245
11	289	288	287	286	289	286	288	237	248	250	254	251	241	247
12	289	289	289	288	287	287	288	246	247	249	238	252	238	245
13	287	288	287	290	287	287	288	242	246	241	243	246	245	244
14	281	287	286	291	283	288	286	243	246	239	240	243	243	242
15	289	286	289	288	283	288	287	241	236	234	241	248	230	239
16	284	291	284	289	285	287	287	234	234	243	239	232	241	237
17	285	288	287	281	286	286	285	238	235	241	235	243	247	240
18	286	284	287	280	287	290	286	237	234	234	236	240	235	236
19	283	288	289	284	289	282	286	235	245	239	242	236	235	239
20	286	285	286	287	285	286	286	237	241	242	234	235	243	239
21	285	287	282	284	286	287	285	236	234	234	232	235	231	234
22	286	281	288	285	281	285	284	238	235	231	240	232	233	235
23	284	282	286	285	284	282	284	240	236	236	237	238	237	237
24	283	282	283	284	286	284	284	229	228	233	234	233	230	231
25	282	282	285	280	279	282	282	226	231	230	227	233	235	230
26	286	285	285	287	285	279	284	236	230	232	238	225	234	232
27	284	288	284	282	288	289	286	232	228	224	232	234	225	229
28	277	282	285	280	283	287	282	236	230	230	230	233	231	232
29	283	284	282	286	286	281	284	230	233	235	232	230	227	231
30	284	280	286	286	279	286	283	232	235	234	236	226	234	233
31	282	288	284	281	284	286	284	225	238	234	228	235	231	232
32	284	282	287	286	283	283	284	228	228	231	232	232	229	230
33	283	286	285	286	282	283	284	225	232	233	235	230	236	232
34	286	285	289	286	286	283	286	228	233	232	240	239	235	235
35	284	286	287	285	283	286	285	237	232	237	238	232	236	235
36	282	283	284	289	290	283	285	236	242	235	239	245	242	240
37	286	287	287	292	288	288	288	237	233	237	239	236	236	236
38	283	285	290	286	284	281	285	239	238	247	234	244	244	241
39	284	291	287	287	286	285	287	243	242	245	243	245	243	244
40	287	285	283	284	286	286	285	244	249	251	240	241	242	245
41	285	288	287	288	284	288	287	245	240	240	242	239	242	241
42	290	285	285	292	281	285	286	242	250	248	249	245	250	247
43	290	290	287	289	288	287	288	250	252	242	248	242	247	247
44	288	284	289	291	289	288	288	241	245	246	247	246	255	246
45	289	286	290	290	287	289	288	248	249	248	243	253	244	247
46	286	292	286	291	288	286	288	257	245	253	255	257	257	254
47	289	291	288	286	289	286	288	255	261	247	254	252	254	254
48	285	290	289	293	294	295	291	253	253	258	254	259	253	255
49	293	289	290	291	290	290	290	260	251	260	248	259	266	257
50	288	290	293	290	292	287	290	258	260	259	257	266	259	260

Monthly Progress Management Report No. 2

Report Period

1 May through 31 May 1981

Report Prepared

1 June 1981

"Advanced Microwave Moisture Sounder (AMMS)"
May/June 1981 WB-57 CCOPE Mission

J.A. Gagliano

Contract NAS5-26528
(A-2904)

Prepared For

The National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The flight software to generate a nine-scan followed by a single-stare mode for the AMMS scanner was developed during this period. In addition the software was modified to increase the integration time to approximately 60 msec when operating the AMMS in the "integrate and dump" mode.

Integration of the AMMS on the WB-57F pallet at NASA/GSFC was completed during this period. Georgia Tech personnel were available at GSFC during system integration tests in mid May.

Georgia Tech personnel began field support of the AMMS during the CCOPE mission in Fargo, North Dakota. Final tests of the AMMS under aircraft power were successfully completed prior to the engineering test flight in late May.

Problems Encountered During This Period

No problems occurred during this time period.

Work to be Performed During the Next Period

Georgia Tech personnel will continue to support the CCOPE mission with 5 data flights scheduled in June 1981. Following the mission the AMMS will be packed for return shipment to NASA/GSFC via truck, and then to Georgia Tech via air freight.

Monthly Progress Management Report No. 3

Report Period

June 1 through June 30, 1981

Report prepared

July 20, 1981

"Advanced Microwave Moisture Sounder (AMMS)"
May/June 1981 WB-57 CCOPE Mission

J.A. Gagliano

Contract NAS5-26528
(A-2904)

Prepared For

The National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The WB-57F CCOPE mission was completed on June 11, 1981 following six data flights and one engineering flight using the Georgia Tech AMMS system. Data was collected at 94/183 GHz using the AMMS on all the CCOPE flights. The AMMS system performed very well throughout the mission and was used to gather severe storm data and high altitude humidity sounding data over Montana during CCOPE.

A complete set of AMMS/CCOPE flight logs were given to the NASA/GSFC scientific investigator at the end of the mission. Computer compatible tapes of CCOPE data from the engineering flight and the first four data flights were given to the scientific investigator.

The AMMS system, ground support system, and associated test equipment were returned to Georgia Tech under NASA/GSFC direction following the CCOPE mission. Georgia Tech personnel performed post-flight evaluation of the AMMS and generated quick-look images of the flight data for report purposes.

Problems Encountered During This Period

The 183 GHz subharmonic mixer was replaced with a back-up unit following the third CCOPE data flight. The back-up mixer performed reliably throughout the remaining flights with all three 183 GHz IF channels collecting data.

The AMMS ground support system was damaged during the air shipment from GSFC-Greenbelt, Maryland to Atlanta, Georgia. Preliminary investigations by Georgia Tech personnel revealed damage to the Videotek display monitor, Digi-Data reel-to-reel tape recorder, and Tandberg cartridge recorder. All of these items are part of the AMMS ground support system which was government furnished equipment for this

contract. The Georgia Tech contracting officer for this contract was notified of the above damaged equipment for purposes of resolving the issues pertaining to the repair of said items.

Work to be Performed During the Next Period

Work will begin on the final technical report for project A-2904. Georgia Tech will assist as required in accessing the extent of damage to the AMMS ground support equipment. This will include coordination of repair estimates by pertinent vendors for purposes of notifying the sponsor prior to any repair being performed.

The last two data flights from CCOPE still need to be transferred from cartridge to reel-reel tape for delivery to NASA. The Digi-Data tape recorder, damaged in the return shipment from GSFC to Georgia Tech, is required for this data tape transfer and needs to be returned to the vendor for repair.

Monthly P:ogress Management Report No. 4

Report Period

July 1 through July 31, 1981

Report Prepared

August 11, 1981

"Advanced Microwave Moisture Sounder (AMMS)"
May/June 1981 WB-57 CCOPE Mission

J.A. GAgliano

Contract NAS5-26528
(A-2904)

Prepared For

The National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Prepared By

Engineering Experiment Station
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Work Performed During This Period

Work continued on the evaluation of damage to the AMMS ground support equipment incurred during the return shipment to Georgia Tech from NASA/GSFC. An inspection report from Delta airline was submitted to NASA with a description of damages to the equipment.

The last two data flights from the CCOPE mission were transferred from flight cartridges to a computer compatible reel-reel tape with 1600BPI storage capacity. The reel-reel tape recorder used for this transfer was a Georgia Tech owned replacement unit for the damaged GFE recorder.

Problems Encountered During This Period

Georgia Tech is awaiting official work from NASA regarding the repair to the AMMS GSE. Transfer of flight data to 800BPI reel-reel tapes is delayed until the Digi-Data reel-reel tape recorder can be repaired.

Work to be Performed During the Next Period

Work will continue on the final technical report required for the project.

Monthly Progress Management Report No. 5

Report Period

August 1 through August 31, 1981

Report Prepared

September 2, 1981

"Advanced Microwave Moisture Sounder (AMMS)
May/June 1981 WB-57 CCOPE Mission

J.A. Gagliano

Contract NAS5-26528
(A-2904)

Prepared For

The National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Prepared By

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Work Performed During This Period

Information was provided to sponsor regarding GFE items damaged during return shipment from NASA/GSFC. Modification #3 to the contract was received, allowing return shipment of damaged items to vendors for repair estimates. Items returned are as follows:

1) Reel-reel tape recorder (Digi-Data Corp.);
2) Video Tek color monitor (Video Tek Inc.);
3) Tandberg TDC 3000 recorder (Innovative Data Techniques) (S/N 50306)

Problems Encountered During This Period

None to report at this time

Work To Be Performed During Next Period

Georgia Tech will send documentation to the sponsor describing AMMS packaging for possible future use on the ER-2 aircraft. A meeting, scheduled in mid-September with Lockheed personnel from Palmdale, CA, will be held at GSFC to review the status of all sensors under consideration for future ER-2 flights. The AMMS documentation will be available at this meeting.

Monthly Progress Management Report No. 6

Report Period

September 1 through September 30, 1981

Report Prepared

October 1, 1981

"Advanced Microwave Moisture Sounder (AMMS)"
May/June 1981 WB-57 CCOPE Mission

J.A. Gagliano

Contract NAS5-26528
(A-2904)

Prepared For

The National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Prepared By

Engineering Experiment Station
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Work Performed During This Period

Vendor information was received regarding repair to the damaged GFE used in the AMMS ground support system for CCOPE. A summary of repair work required is as follows:

1) Digi-Data Corporation (reel-reel tape recorder) recommends replacing the multi-pin interconnect cable between the transport and the formatter and repairing the bent cabinet frame which supports the transport;
2) Video Tek Incorporation (color monitor) says that the printed cracked circuit board can be repaired rather than replaced at a nominal cost;
3) Innovative Data Techniques (dual cartridge recorder) indicated that the tape rewind problem can be easily corrected, but also recommends that the capstan motor and record head be replaced due to excessive wear.

Problems Encountered During This Period

None to report at this time

Work To Be Performed During Next Period

The final technical report will be completed during the next period.

APPENDIX B

"Moisture Sounding at Millimeter Wavelengths (94/183 GHz) at High Altitudes"

Moisture Sounding at Millimeter Wavelengths (94/183 GHz) at High Altitudes

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Abstract

A moisture sounding radiometer at millimeter wavelengths has been developed for high altitude measurements onboard NASA's WB-57F aircraft. Three channels about the 183.3 GHz water vapor line permit measurement of the atmospheric water vapor profile. A single window channel at 94 GHz provides correction for clouds over the ocean and for surface emissivity variations over land. The instrument is an imaging radiometer operating under microprocessor control throughout each data flight. The system is contained within two packages integrated into the WB-57F pallet. A ground support system was used to perform a quick-look analysis of the data collected immediately following each flight.

Introduction

A millimeter wave radiometer operating at 94 GHz (single channel) and 183 GHz (three channels) has been developed for use onboard the NASA WB-57F high altitude aircraft. During the past 2 years the radiometer has been used to collect data from an altitude of about 18 km over severe storm regions throughout the United States. (See Table 1.) Data flights using the 94/183 GHz scanning radiometer onboard the WB-57F were initiated in June 1979 with Project SESAME (Severe Environmental Storms and Mesoscale Experiment) and most recently in June 1981 with Project CCOPE (Cooperative Convective Precipitation Experiment).

Table 1. Advanced Microwave Moisture Sounder (AMMS)/ WB-57F Mission Schedule Summary

Mission	Location	Month/Year
SESAME*	Southwest U.S.	June 1979
Florida Thunder-storm	Florida	Sept. 1979
Stratiform Precipita-tion	Central and Southern U.S.	Feb. 1980
Severe Storm	South Florida	Aug. 1980
CCOPE**	Montana	May/June 1981

*Severe Environmental Storms and Mesoscale Experiment

**Cooperative Convective Precipitation Experiment

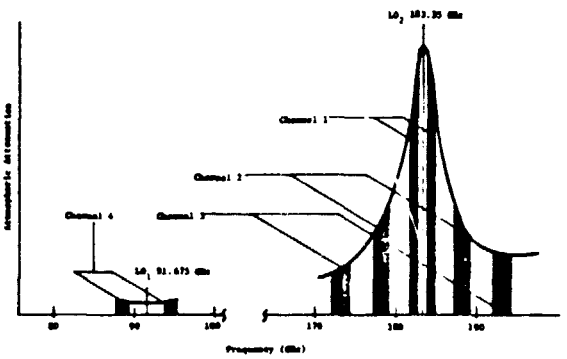


Figure 1. 94/183 GHz Dual Frequency Radiometer Channel Allocation.

Figure 1 shows the relationship of the radiometer channels to the water vapor line at 183.3 GHz. The three channels (±2.25, ±5.00 and ±8.75 GHz from line center) permit measurement of the atmospheric water vapor profile. The window channel, centered at 94 GHz permits correction for clouds over the ocean and for surface emissivity variations over land. Although typical brightness temperatures observed are in the 240 to 280K range, brightness temperatures below 200K have been observed in convective rain with the AMMS instrument[1,2] and with a nonscanning predecessor instrument that was flown into Tropical Storm Cora on the NASA Convair 990 aircraft.[3,4] These low brightness temperatures are interpreted as scattering of the 3K cosmic background into the radiometer by ice particles with dimensions greater than a few hundred microns. Such ice particles are common in

convective precipitation. The degree to which this scattering is observed in the various 183 GHz channels also gives information on the height to which ice is thrown in the storm. In Tropical Storm Cora ice was thrown to at least 8 km altitude. The February 1980 mission demonstrates that these low brightness temperatures are not commonly observed in stratiform precipitation except for occasional embedded convection.

AMMS System Description

The Advanced Microwave Moisture Sounder (AMMS) is an imaging radiometer developed by the Georgia Institute of Technology under contract to NASA Goddard Space Flight Center.[5,6] Figure 2 is a system block diagram of the AMMS airborne 94/183 GHz radiometer as configured for the WB-57F aircraft. The imaged scene is reflected into the antenna unit by the rotating reflector and is chopped at approximately 350 Hz using a beam combining "super chopper". On every sixth mapping cycle the scanner rotates 360 degrees and reflects a hot and a cold calibration load into the antenna lens viewing port. The 94 GHz and 183 GHz channels each have a separate feedhorn behind the lens. The beam combining chopper determines which horn is viewing the mapped scene or the temperature controlled Dicke reference load. Figure 3 depicts the super chopper design implemented to view the scene alternately between the 94 GHz feed and the 183 GHz feed. The 94 GHz signal is down-converted to a 2.32 GHz IF. The 183 GHz signal is down-converted using a X2 subharmonic mixer to intermediate frequencies at 1.5 to 3.0, 4.0 to 6.0, and 7.5 to 10.0 GHz. The three channels are triplexed, amplified, filtered and then square law detected. The detector outputs go to video amplifiers with bandpass responses centered at the chopping frequency. The video amplifier outputs are synchronously detected using phase sensitive detectors. The output of the phase sensitive detector is either a two pole low pass active filter with a selectable integration time or an integrator whose output is proportional to the time integral of the phase sensitive detector output. The integrator output is periodically sampled and dumped under microprocessor control at a rate determined by the scanning period of the imaging radiometer. The microcomputer also digitizes the outputs of the phase sensitive detectors, and controls the storage of data from all four channels onto the dual cartridge flight recorder. The microprocessor also checks for proper operation of the system and, if a fault is detected, it is corrected by reloading and restarting the operating program.

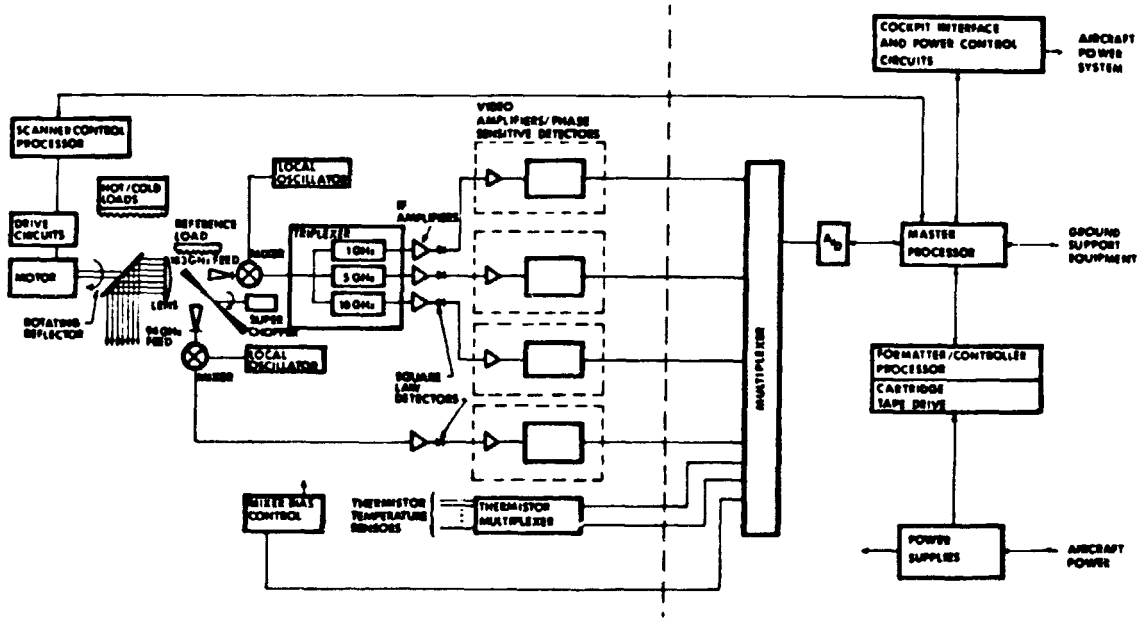
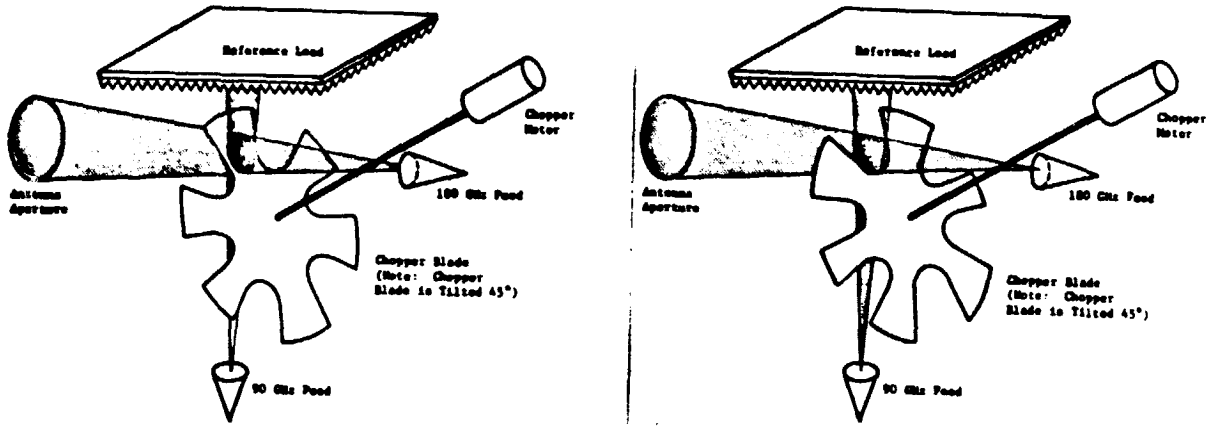


Figure 2. WB-57F 94/183 GHz Radiometer Block Diagram.



a) Super Chopper Concept - Shown Reflecting to Antenna at 94 GHz and Reflecting Into Reference Load at 183 GHz.

b) Super-Chopper - Shown Transmitting to Reference Load at 94 GHz and Transmitting to Antenna at 183 GHz.

Figure 3. 94/183 GHz Radiometer Super-Chopper Concept.

The radiometer's beam scanner is designed to image the scene below the aircraft over an angle of ±45 degrees in a 3 second period. The angular beamwidths for the 94 GHz and 183 GHz sensors are 2 degrees and 1 degree, respectively. The radiometer's scan period is controlled by one of the AMMS microcomputers. The same controller is used to perform precise periodic calibrations of the radiometer during flight. The key parameters for the airborne system are summarized in Table 2. A key component used in the AMMS front-end is the subharmonic balanced mixer developed for the 183 GHz system using antiparallel mounted Schottky-barrier diodes.[7] Figure 4 is a photograph showing the subharmonic mixer assembled in the 183 GHz RF front-end flown on the WB-57F during the CCOPE mission.

Table 2. Key Parameters of the AMMS System

Parameters	Remarks
Dual Frequency Front-End	Solid state, low noise, wide band
Multichannel System	183 GHz (3 channels), 94 GHz (1 channel)
Subharmonic Balanced Mixer	183 GHz (Pumped at 91.65 GHz)
Single-ended Mixer/ LO Injection Cavity	94.0 GHz
Antenna	5 inch lens aperture
Precision Calibration Loads	Effective black body
Dicke Chopper Beam Combining	Essentially Lossless Operation
Beam Scanner (Moving Mirror)	Microcomputer Control
Data Recording	Microcomputer Control

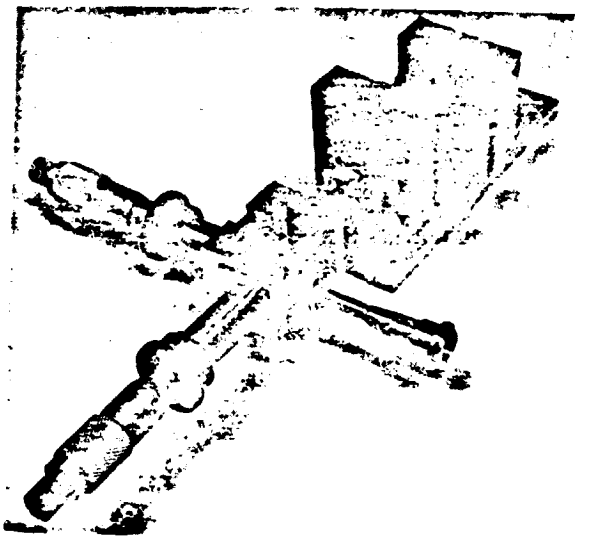


Figure 4. Assembled 183 GHz RF Front-End Using the Subharmonic Mixer.

The AMMS radiometer airborne system is contained within two packages integrated into the WB-57F universal pallet. The AMMS front-end package contains the RF, IF, and video components which are mounted on a temperature controlled common baseplate. Figure 5 is a photograph of the front-end package with the beam scanner (rotating reflector) and calibration loads as shown. An opening in the WB-57F pallet allows the scanner to view the scene below the aircraft. The second AMMS package contains the digital system including the

multiplexed analog-to-digital converter, system power supplies, the microcomputer, and the dual cartridge flight recorder. Figure 6 is a photograph of the digital package which is pressurized to withstand 10 psi differential in order to meet the environmental requirements of the flight recorder.

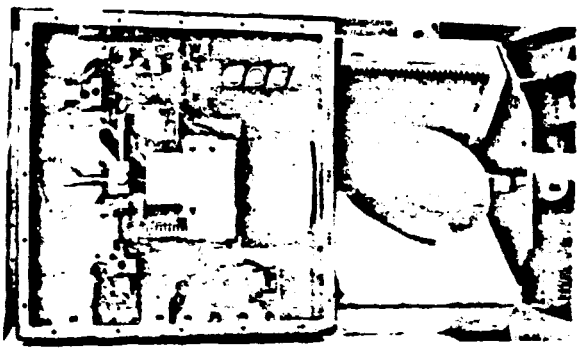


Figure 5. AMMS RF Package Showing Major RF Components.

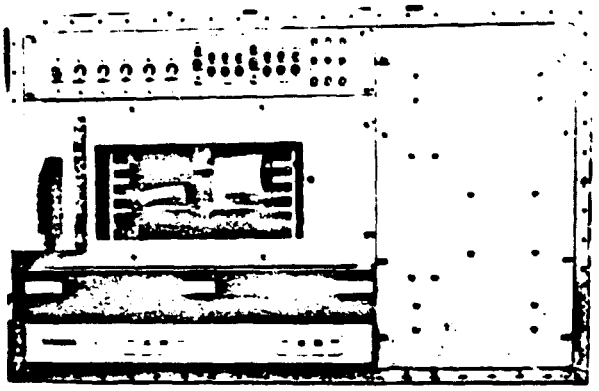


Figure 6. AMMS Digital Package with Dual Cartridge Recorder.

Following each WB-57F flight the AMMS data are examined using the portable ground support system provided in the field. Key parameters for the ground support system are summarized in Table 3. This system is used to perform any necessary flight software modifications to the AMMS. Figure 7 is a photograph of the ground support system showing the ground based microcomputer, the color monitor display, the ground support cartridge recorder, and the reel-reel tape recorder with controller. Functions provided by the ground support system include radiometric images of the 94 GHz and 183 GHz data channels (see Figure 8), hard copy printout of the AMMS flight log (see Table 4), and cartridge to reel-reel tape transfer of the flight data for future analysis by NASA.

Table 3. AMMS Ground Support System Features

Parameters	Remarks
Data Display	Real time to 2X real time images (4 channels)
Data Flight History	Flight log printout
Data Storage	Airborne cartridge to 9 track tape
Software Support	Custom design for each data flight
Data Tape Initialization	Modify operating system software

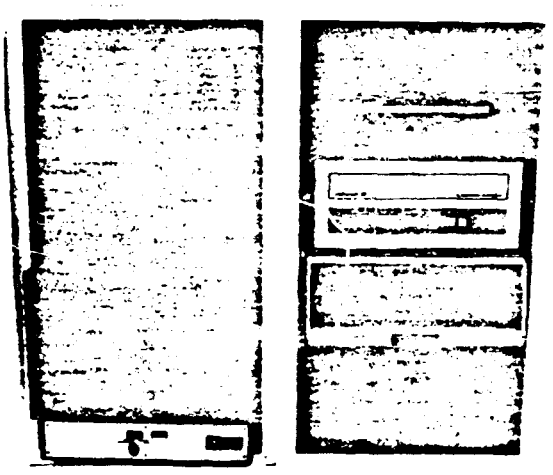
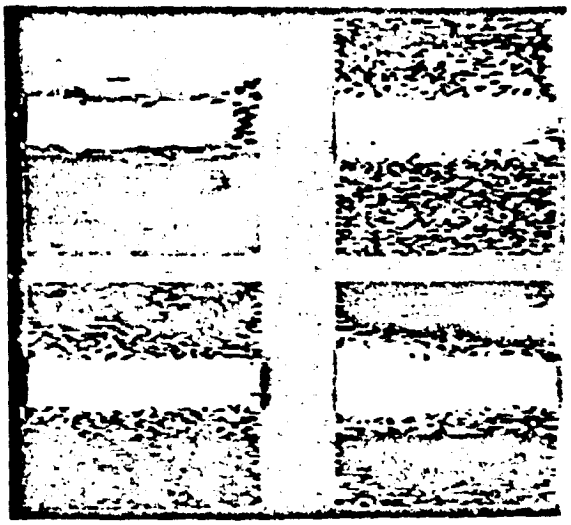


Figure 7. AMMS Ground Support System.



Note:

Lighter regions shown in each of the four channels correspond to brightness temperatures below 210K. Each region is approximately 36 km across by 15 km long.

Figure 8. 94/183 GHz Scanning Radiometer Imaged Data Display.

Table 4. AMMS/WB-57F Severe Storms Flight: Face 3; Day: 244; Date: 08/31/80

BLK	TIME	IRIG	CLD	HOT	REF	G2	G1	G5	G0	MA2	MI2	MA1	MI1	MA5	MI5	MA0	MI0
438	1:13	18:41	2	62	29	-71	-84	-157	-76	266	244	305	240	313	205	302	253
440	1:13	18:41	2	62	29	-68	-93	-135	-71	269	247	291	218	315	240	299	256
442	1:13	18:41	3	62	29	-68	-98	-179	-70	274	247	285	198	302	166	300	210
444	1:14	18:42	2	62	29	-70	-84	-140	-76	282	225	274	182	297	173	286	157
446	1:14	18:42	2	62	29	-70	-98	-222	-74	271	119	222	116	212	16	238	110
448	1:14	18:42	2	62	29	-69	-91	-194	-86	255	108	225	105	175	22	152	59
450	1:15	18:43	2	62	29	-68	-79	-141	-67	256	120	232	134	223	99	200	109
452	1:15	18:43	2	62	29	-67	-141	-126	-74	295	179	264	56	293	166	281	119
454	1:15	18:43	2	62	29	-69	-96	-154	-80	296	247	292	208	317	208	287	204

The hard copy flight log printout provides information such as aircraft time (IRIG), calibration loads (CLD and HOT) physical temperatures, Dicke reference (REF) load physical temperature, radiometer data channels system gains (G2, G1, G5, and G0) in degrees Kelvin per volt, the maximum radiometric temperature (MA) observed for each data channel during six scans, and the minimum radiometric temperature (MI) observed for each data channel. Table 4 represents a portion of the AMMS flight 3 (8/31/80) log designated FACE (Florida Area Cumulus Experiment) from the Severe Storms mission. This partial flight log printout covers three minutes of data taken beginning about one and one-quarter hours after aircraft takeoff. Note at time IRIG 1842 that minimum radiometric temperatures were observed on all four radiometric channels at the time during which the WB-57F was crossing the west coastline of Florida near Naples Park. Each flight log is generated immediately following the day's flight and is used to correlate the AMMS data with the WB-57F backseat operator's log on visual observations. Figure 8 is a four channel radiometric image taken from the WB-57F/AMMS 8/31/80 data flight. Beginning with the upper left image and going clockwise the four channels shown are 94 GHz, 183 (2.25) GHz, 183 (8.75) GHz, and 183 (5.00) GHz respectively. This imaged data corresponds to the flight time printout data provided in Table 4.

Since the radiometer scans +45 degrees about nadir, a ground swath of 36 km is mapped when the WB-57F is at 18 km altitude. The ground support video monitor generates 50 pixels for each line scan which results in about 0.72 km beam cell diameter on the earth's surface. Each data image shown in Figure 8 above represents about six minutes of data collected by the radiometer. At an aircraft ground speed of 400 knots, the total distance covered by the WB-57F is about 74 km for each channel.