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MSU ANTENNA PATTERN DATA

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ABSTRACT

The Microwave Sounding Unit (MSU) antenna pattern data for nine MSU Flight Models (FMs) have been successfully rescued from 22-year old 7-track and 9-track magnetic tapes and cartridges. These antenna pattern data were unpacked into user-friendly ASCII format, and are potentially useful for making antenna pattern corrections to MSU antenna temperatures in retrieving the true brightness temperatures. We also properly interpreted the contents of the data and show how to convert the measured antenna signal amplitude in volts into relative antenna power in dB with proper normalization. It is found that the data are of high quality with a 60-dB drop in the co-polarized antenna patterns from the central peak value to its side-lobe regions at scan angles beyond 30°. The unpacked antenna pattern data produced in this study provide a useful database for data users to correct the antenna side-lobe contribution to MSU measurements. All of the data are available to the scientific community on a single CD-ROM.

1. INTRODUCTION

The MSU antenna pattern data were measured by the Jet Propulsion Laboratory (JPL), the instrument contractor, in 1976-1983 when the TIROS-N and NOAA-6 through NOAA -14 MSU flight models (FM) were built. The data were stored on 158 7-track or 9-track magnetic tapes, 148 of which were delivered to NOAA/NESDIS. The contents of the original data on the 148 tapes (TIR1 - TIR148) were copied to 83 IBM-3480 magnetic cartridges (with density 38000 BPI) in the early 1990's. The other data tapes, which remained at JPL, were only recently transferred to NOAA at our request. So far, these data have neither been processed nor applied to make the antenna pattern corrections to the MSU data. The first MSU was launched on TIROS-N in October 1978 and the last one on NOAA-14 was put in space in December 1994. More than 22 years of MSU data will be accumulated by the time when the NOAA-14 MSU ceases to operate. This 22-year accumulation of the MSU data (by 2000) provides a unique long-term data base to construct time series for use in climate trending studies. Since the determination of global climatic warming or cooling trends is extremely important for setting business and public policy, the time series constructed from the accumulated MSU data have been subject to much scrutiny and some criticism. Recent temperature-retrieval study [1] using data from the NOAA-15 Advanced Microwave Sounding Unit-A (AMSU-A) shows that the accuracy of the temperature retrieval is improved if the AMSU-A antenna pattern corrections [2] are applied. Similarly, the MSU antenna pattern data will have the same potential to make the MSU data more reliable for the detection of climate trends. However, there are neither documents describing the data contents nor good bookkeeping records for easy identification of the individual data sets with appropriate MSU flight models. Also, there is a high possibility these antenna pattern data might be permanently lost due to both deterioration of the storage media and the retirement of scientists who have knowledge of the MSU instruments.

This study was undertaken to rescue these MSU antenna pattern data from 22-year old magnetic tapes and cartridges. The task was performed as follows: (1) Locate the data tapes and cartridges, (2) copy data from cartridges and tapes to computer disks, (3) unpack the data, (4) identify the individual data sets with appropriate MSU flight models, (5) understand and decipher the data contents, and (6) develop an algorithm for converting the measured antenna pattern in amplitudes (in volts) into antenna power (in dB) with proper normalization. The individual steps are described in the following sections. The unpacked data filenames corresponding to individual MSU FMs are given in Appendix A.

2. DESCRIPTION of MSU

The MSU on the NOAA Polar-Orbiting Environmental Satellites (POES) is a four-channel Dicke radiometer consisting of two scanning reflector antenna systems, A1 and A2, each of which provides two channels. The A1 provides Channels 1 and 2 whereas A2 gives Channels 3 and 4. The MSU antenna system has a nominal beam width of 7.5^{o} at the half-power points and covers a crosstrack scan of ±47.4° (to beam centers) from the nadir direction with 11 Earth-view positions, each separated by 9.47^{o}. Beam positions 1 and 11 are the extreme scan positions of the Earth views, while beam position 6 is at the nadir direction. Onboard blackbody and cold space calibrations are performed once every 25.6 seconds for each scan line. The main MSU characteristics are given in Table 1. Detailed functional description of the MSU system can be found elsewhere [3] and only a brief summary is given here.

Table 1. Main MSU Characteristics

Characteristics	Channel			
	1	2	3	4
Frequency (GHz)	50.30	53.74	54.96	57.95
RF bandwidth (MHZ)	220	220	220	220
NEΔT (K)	0.3	0.3	0.3	0.3
Resolution at nadir (km)	105	105	105	105
Number of Earth views	11	11	11	11
Scan width from nadir	±47.4°	±47.4°	±47.4°	±47.4°
Antenna beamwidth	7.5°	7.5°	7.5°	7.5°
Antenna beam efficiency	>90%	>90%	>90%	>90%
Polarization at Nadir	V	H	V	H
Integration time (second)	1.84	1.84	1.84	1.84

Microwave energy received by each antenna is separated into vertical and horizontal polarization components by an orthomode transducer. Each of the four signals (from two antenna systems) is then fed to one of the MSU channels. Each channel is identical except for the operating frequency. The incoming signal is connected to a Dicke switch, which switches between a microwave load at instrument temperature and the incoming signal. This modulated switch output signal is passed through an isolator and then mixed in a low noise balanced mixer with a local oscillator (LO) signal to produce an IF frequency with a pass band of 10-110 MHz. The signal is further amplified in the post IF and video amplifiers and then demodulated by the phase detector. The final signal amplification takes place in the integrator and dc amplifier. This output signal is digitized by a 12-bit analog-to-digital (A/D) convertor, stored and then sent to the ground station together with other spacecraft data.

3. DESCRIPTION OF MSU ANTENNA PATTERN DATA

The MSU antenna pattern data were measured at JPL in 1976-1983 when the MSU flight models were built. The data were measured at each channel frequency with scan angle from 0^o to $\pm 90^o$. At each of the four channel frequencies, the measured antenna pattern data consists of the following components,

- Eight plane cuts: At each frequency, antenna pattern data were measured at eight plane cut angles corresponding to 0.0^o, 22.5^o, 45.0^o, 67.5^o, 90.0^o, 112.5^o, 135.5^o, and 157.5^o, respectively.

- Angular range and scan steps: The scan angle extends from 0^o to $\pm 90^o$ from the antenna boresight with 0.5^o steps. But within the central beam region, i.e. $\pm 5^o$, the data were measured at 0.02^o steps. This is required for accurate determination of the antenna beamwidths and peak position.

- Four scan positions: Antenna pattern data were measured at the three Earth viewing positions, 1, 6, and 11, respectively. In addition, data were also taken at the cold-space viewing position (i.e., beam position 12).

- Two polarizations: Both co- and cross-polarized data measured at each cut.

Each cut of antenna pattern data has a Header line which has a four-digit Header Code, "**ABCD**". Each of the letter representation is defined in Table 2. The listing in Table 2 gives the standard set of measurements for each MSU flight models. Actual data files may have more data than the standard set. These additional data were taken for various purposes in testing the antenna system and should not be used to make antenna pattern corrections.

Table 2. Keys to the four-digit Header Code, ABCD, for the standard set of measurements of MSU antenna pattern data.

A: Channel frequency and polarizations	**B: Antenna scan position**
1 50.30 GHz and co-polarization 6 50.30 GHz and cross-polarization 2 53.74 GHz and co-polarization 7 53.74 GHz and cross-polarization 3 54.96 GHz and co-polarization 8 54.96 GHz and cross-polarization 4 57.95 GHz and co-polarization 9 57.95 GHz and cross-polarization	0 scan position 1 5 scan position 6 (Nadir) 4 scan position 11 6 scan position 12 (Space view)
C: Cut angles	**D: Frequency offset (for bandwidth tests)**
0 0.0^o 1 22.5^o 2 45.0^o 3 67.5^o 4 90.0^o 5 112.5^o 6 135.0^o 7 157.5^o	0 Nominal frequency as given by "A" above * 1 +0.2 GHz from "A" 2 -0.2 GHz from "A" * Prior to 3/1/83 only, the number '9' was used for this case

A sample of the MSU antenna pattern data is shown in Table 3. Each Header line contains a four-digit Header code, for example, 2600, which should be interpreted according to the codes given in Table 2. In this case, it means that the antenna data are for Channel 2, co-polarization, at the scan position 12, cut angle 0^o, and the frequency offset is 0. The Header line also lists the day and time when the data were taken, the number of data samples, and the angular increment, respectively. The data contents in individual columns in Table 3 are identified as follows [4],

- Column 1: Scan angles θ in degrees measured from the antenna boresight.

- Column 2: Voltage amplitudes of the field signal measurements (in volts) normalized to 100