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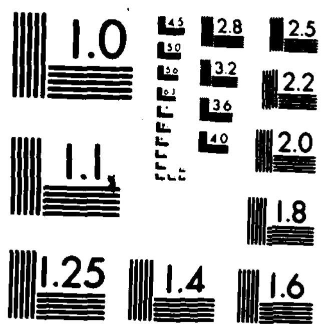

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CSC/TM-81/6078

AN EVALUATION OF SEASAT/SCANNING MULTICHANNEL MICROWAVE RADIOMETER (SMMR) SENSOR DATA RECORD TAPES (SDR)

Prepared for

NAVAL RESEARCH LABORATORY

By

COMPUTER SCIENCES CORPORATION

Under

Contract N00173-80-C-0265

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DISTRIBUTION UNLIMITED

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ABSTRACT

During the implementation of a SEASAT Antenna Temperature Algorithm (ATA) for the Scanning Multichannel Microwave Radiometer (SMMR) experiment on the CDC 3800 at the Naval Research Laboratory (NRL), a detailed comparison of sensor data record (SDR) tapes supplied by the Fleet Numerical Weather Center (FNWC) and the Jet Propulsion Laboratory (JPL) was made for a selected data set. This document describes the discrepancies found between the tapes from the two sources.

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SECTION 1 - INTRODUCTION

A decision was made by the Space Sensing Applications Branch of the Naval Research Laboratory (NRL) to develop an in-house capability to process selected SEASAT Scanning Multichannel Microwave Radiometer (SMMR) observations from the processing of the Sensor Data Record (SDR) stage through to the estimation of geophysical parameters. The Computer Sciences Corporation (CSC) was given the responsibility for the calibration process which is the required first phase of this effort. This calibration involves the derivation of antenna temperatures (T_As) from SDR telemetry data.

The calibration algorithm implemented at NRL was basically the algorithm developed at the Jet Propulsion Laboratory (JPL) and adopted and modified by the Naval Environmental Prediction Facility (NEPRF) to process SDR tapes produced at the Fleet Numerical Weather Center (FNWC). During implementation of this algorithm on the NRL computer both the calibration equation and the algorithm were still being refined, and CSC continued to obtain updates of the calibration constants from JPL and of the algorithm from NEPRF. As the updates became available they were incorporated into the NRL algorithm. Details of the NRL algorithm were presented in a CSC report to NRL in March 1980 (Reference 1).

While the calibration algorithm was being validated at NRL, erratic T_As were discovered when the SDR tapes from FNWC were used. Good results were obtained with SDR tapes from JPL for the same time period. A difference in algorithms was eliminated as a possible source of error by a detailed comparison with the most recent version of the JPL calibration algorithm. The only significant difference concerns the handling of input data which is necessary because arrangement of data on the SDRs are somewhat different. Otherwise, the calibration algorithms are the same.

A comparison of the contents of the SDR tapes from FNWC and JPL for the same time period revealed a number of significant discrepancies which explained the large differences in calculated antenna temperatures. The most significant among these discrepancies is the housekeeping temperatures information. Other discrepancies involve the location data and calibration data. These results will be shown in detail in this paper.

This report is organized as follows: Section 2 contains a brief description of the SMMR SDR tape from FNWC and JPL. In Section 3, detailed comparisons of the SDR data are presented. A summary of the study and suggestions for the future production of SMMR SDR tapes are contained in Section 4.

SECTION 2 - DATA DESCRIPTION

Since the data processing involved in the making of SDR tapes is the same for all satellite scans, a comparison using a small data set is sufficient to reveal the basic differences between the FNWC and JPL SDR tapes. Two successive scans of SMMR data were examined in detail from each of the SDR tapes. These were taken from orbit number 1292 corresponding to September 25, 1978. This is one of the days when the GOASEX experiment was in progress.

The latest version of the FNWC SDR tapes were collected together with relevant information concerning them (Reference 2). Listings of part of the calibration program, miscellaneous written descriptions and manuals (References 4 and 5), and two tapes were received from JPL. One of the tapes contained SDR data for orbit 1292. The other contained T_A and brightness temperature (T_B) for a small portion of orbit 1292. The latter tape served as the benchmark for validating the CSC calibration algorithm.

There are three major portions to the SDR data. They are the Initialization Records, the Telemetry Data, and the Location Data. Thirty pairs of latitudes and longitudes are contained in the location data for each scan, fifteen to each half scan (References 1, 5, and 6). Figure 2-1 depicts the location data for the two FNWC scans (Day 265: 18:15:53.785 and 18:15:57.881) as dotted curves and the location data for the two JPL scans (Day 265: 18:15:55.993 and 18:16:0.089) as solid curves.

The most essential data for the calibration process included in telemetry are the digital counts for each observation and the means and standard deviations of the normal and cold calibration counts. Energies at five frequencies, two polarizations each, i.e., vertical and horizontal, are

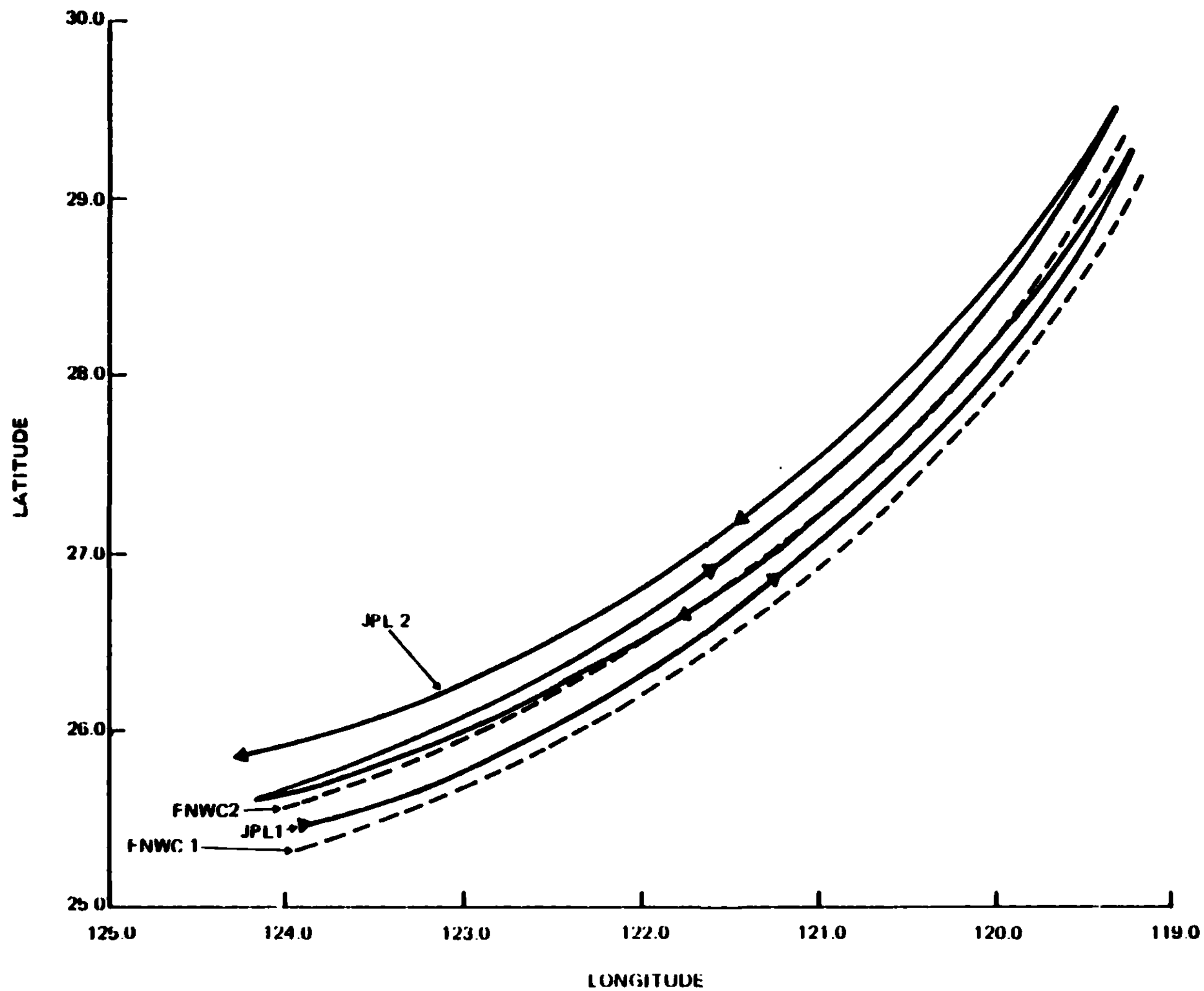

Figure 2-1. Comparison of Two Scans from JPL and FNWC SDR Location Data

measured by the SMMR instrument. The frequencies are 37, 21, 18, 10.7, and 6.6 GHz. The digital counts and the derived T_As for the first 10 data points of each half scan, frequency and polarization, are listed in Table 2-1 for the FNWC and the JPL scans under examination. The calibration information is presented in Table 2-2.

Included in the initialization records are the housekeeping temperatures which are the temperatures of different elements in the SMMR instrument. These are important inputs to the calibration calculations. Housekeeping temperatures are defined in the initialization records and are updated in the telemetry data. For the scans examined, the housekeeping temperatures remained constant for each of the two successive scans. They are presented in Table 2-3.

Table 2-1. Samples of Telemetry and Antenna Temperatures

	FNWC1 18:15:53.785		JPL1 18:15:55.993		FNWC2 18:15:57.881		JPL2 18:16:0.089	
	CNTS	TA	CNTS	TA	CNTS	TA	CNTS	TA
Sample (10) from first half scene 37H	2102	297.7	2102	142.2	2094	295.9	2094	141.0
	2102	297.7	2102	142.2	2095	296.1	2095	141.2
	2093	295.7	2093	141.0	2096	296.4	2096	141.3
	2095	296.1	2095	141.2	2106	298.7	2106	142.7
	2085	293.8	2085	139.9	2083	293.4	2083	139.5
	2083	293.4	2083	139.6	2094	295.9	2094	141.0
	2075	291.5	2075	138.5	2093	295.7	2093	140.9
	2078	292.2	2078	138.9	2090	295.0	2090	140.5
	2078	292.2	2078	138.9	2083	293.4	2083	139.5
	2062	288.5	2062	136.8	2086	294.1	2086	140.0
Sample (10) from second half scene 37H	2071	290.6	2081	139.3	2081	292.9	2088	140.2
	2079	292.5	2077	138.8	2077	292.0	2076	138.6
	2062	288.5	2077	138.8	2077	292.0	2072	138.1
	2063	288.8	2075	138.5	2075	291.5	2057	136.0
	2058	287.6	2077	138.8	2077	292.0	2075	138.5
	2063	288.8	2075	138.5	2075	291.5	2066	137.3
	2064	289.0	2070	137.8	2070	290.4	2071	137.9
	2065	289.2	2065	137.2	2065	289.2	2060	136.4
	2044	284.4	2056	136.0	2056	287.2	2058	136.2
	2057	287.4	2056	136.0	2056	287.2	2056	135.9
Sample from first half scene 37V	2315	266.7	2315	180.8	2309	265.8	2309	179.8
	2312	266.2	2312	180.4	2310	266.0	2310	179.9
	2292	262.8	2292	178.0	2332	269.7	2332	182.6
	2316	266.9	2316	180.9	2323	268.2	2323	181.5
	2308	265.5	2308	180.0	2329	269.2	2329	182.2
	2320	267.6	2320	181.4	2322	268.0	2322	181.4
	2329	269.1	2329	182.5	2319	267.5	2319	181.0
	2319	267.4	2319	181.3	2323	268.2	2323	181.5
	2352	272.9	2352	185.4	2326	268.7	2326	181.9
	2337	270.4	2337	183.5	2353	273.2	2353	185.2

Table 2-1. Samples of Telemetry and Antenna Temperatures (Continued)

	FNWC1 18:15:53.785		JPL1 18:15:55.993		FNWC2 18:15:57.881		JPL2 18:16:0.089	
	CNTS	TA	CNTS	TA	CNTS	TA	CNTS	TA
Sample (10) from second half scene 37V	2271	259.3	2274	175.8	2274	259.5	2295	178.0
	2268	258.8	2311	180.3	2311	266.2	2276	175.7
	2302	264.5	2301	179.1	2301	264.5	2288	177.2
	2294	263.2	2283	176.9	2283	261.5	2293	177.8
	2293	263.0	2279	176.4	2279	260.8	2303	179.0
	2280	260.8	2293	178.1	2293	263.2	2302	178.9
	2288	262.2	2294	178.2	2294	263.3	2304	179.2
	2300	264.2	2322	181.7	2322	268.0	2296	178.2
	2307	265.4	2300	179.0	2300	264.3	2317	180.8
	2306	265.2	2305	179.6	2305	265.2	2295	178.0
Sample (10) from 21H	1916	136.4	1916	134.9	1923	137.3	1923	136.3
	1907	135.3	1907	133.7	1930	138.2	1930	137.2
	1914	136.2	1914	134.6	1924	137.5	1924	136.4
	1910	135.7	1910	134.1	1914	136.2	1914	135.2
	1903	134.8	1903	133.2	1906	135.2	1906	134.2
	1891	133.3	1891	131.7	1887	132.8	1887	131.8
	1872	130.8	1872	129.3	1881	132.0	1881	131.0
	1857	128.9	1857	127.4	1871	130.7	1871	129.8
	1839	126.7	1839	125.2	1853	128.4	1853	127.5
	1834	126.0	1834	124.6	1850	128.1	1850	127.2
Sample (10) from 21V	2099	168.3	2117	165.4	2117	170.5	2106	164.6
	2095	167.8	2097	163.0	2097	168.0	2108	164.9
	2107	169.3	2108	164.4	2108	169.4	2105	164.5
	2112	169.9	2133	167.4	2133	172.4	2127	167.2
	2121	171.0	2125	166.4	2125	171.4	2125	166.9
	2134	172.6	2131	167.1	2131	172.2	2131	167.6
	2130	172.1	2156	170.1	2156	175.2	2149	169.8
	-0-	-88.18	2148	169.2	-0-	-88.1	2159	171.0
	2157	175.4	2145	168.8	2145	173.9	2172	172.6
	2157	175.4	2158	170.4	2158	175.5	2159	171.0

Table 2-1. Samples of Telemetry and Antenna Temperatures (Continued)

	FNWC1 18:15:53.785		JPL1 18:15:55.993		FNWC2 18:15:57.881		JPL2 18:16:0.089	
	CNTS	TA	CNTS	TA	CNTS	TA	CNTS	TA
Sample (10) from 18H	1817	111.0	1817	109.3	1824	111.9	1824	110.0
	1808	109.7	1808	108.1	1817	110.9	1817	109.0
	1796	108.0	1796	106.6	1800	108.6	1800	106.8
	1792	107.5	1792	106.0	1793	107.6	1793	105.8
	1781	105.9	1781	104.6	1793	107.6	1793	105.8
	1781	105.9	1781	104.6	1769	104.2	1769	102.7
	1765	103.7	1765	102.4	1760	103.0	1760	101.5
	1764	103.6	1764	102.3	1761	103.1	1761	101.6
	1756	102.5	1756	101.3	1768	104.1	1768	102.5
	-0-	-142.2	1737	98.7	-0-	-142.2	1757	101.1
Sample (10) from 18V	2089	145.1	2096	146.1	2096	146.0	2093	145.4
	2104	147.2	2085	144.6	2085	144.5	2103	147.4
	2117	149.0	2116	148.7	2116	148.8	2121	149.1
	2108	147.7	2117	148.9	2117	149.0	2116	148.5
	2124	150.0	2121	149.4	2121	149.5	2120	149.0
	2132	151.1	2132	150.9	2132	151.1	2145	152.3
	2133	151.2	2136	151.4	2136	151.6	2144	152.2
	2141	152.3	2156	154.0	2156	154.4	2140	151.6
	2160	155.0	2133	151.0	2133	151.2	2153	153.4
	2145	152.9	2152	153.5	2152	153.8	2148	152.7
Sample (10) from 10.7H	1732	105.6	1732	97.5	1743	107.1	1743	98.8
	1725	104.7	1725	96.6	1734	105.9	1734	97.7
	-0-	-123.5	1719	95.9	-0-	-123.5	1721	96.0
	1716	103.5	1716	95.5	1716	103.5	1716	95.3
	1710	102.7	1710	94.7	1704	101.9	1704	93.8
	1691	100.2	1691	92.2	1701	101.5	1701	93.4
	1693	100.5	1693	92.5	1699	101.3	1699	93.1
	1699	101.2	1699	93.3	1689	99.9	1689	91.8
	1687	99.7	1687	91.7	1689	99.9	1689	91.8
	1676	98.2	1676	90.3	1694	100.6	1694	92.5

Table 2-1. Samples of Telemetry and Antenna Temperatures (Continued)

	FNWC1 18:15:53.785		JPL1 18:15:55.993		FNWC2 18:15:57.881		JPL2 18:16:0.089	
	CNTS	TA	CNTS	TA	CNTS	TA	CNTS	TA
Sample (10) from 10.7V	1997	142.8	2000	135.4	2000	143.2	1991	134.2
	2009	144.4	2000	135.4	2000	143.2	2011	136.7
	2006	144.0	2009	136.6	2009	144.4	2016	137.4
	2028	146.9	2028	139.0	2028	146.9	2021	138.0
	2032	147.4	2041	140.7	2041	148.6	2039	140.3
	2045	149.1	2042	140.8	2042	148.7	2044	140.9
	2046	149.2	2054	142.3	2054	150.3	2054	142.2
	2058	150.8	2060	143.1	2060	151.4	2061	143.1
	2067	152.0	2074	144.9	2074	152.9	2066	143.7
	2074	152.9	2069	144.2	2069	152.2	2077	145.1
Samples (10) from 6.6H	1696	109.9	1696	97.9	1705	111.0	1705	99.0
	1689	109.0	1689	97.0	1693	109.5	1693	97.5
	1677	107.5	1677	95.5	1671	106.6	1671	94.7
	1663	105.6	1663	93.8	1663	106.2	1668	94.3
	1663	105.6	1663	93.8	1652	104.2	1652	92.3
	1647	103.6	1647	91.7	1646	103.4	1646	91.6
	1651	104.1	1651	92.2	1641	102.8	1641	90.9
	1650	104.0	1650	92.1	1652	104.2	1652	92.3
	1654	104.5	1654	92.6	1655	104.6	1655	92.7
	1665	105.9	1665	94.0	1657	104.8	1657	92.9
Samples (10) from 6.6V	1929	146.2	1924	132.9	1924	145.5	1931	133.8
	1942	147.8	1941	134.9	1941	147.6	1953	136.5
	1954	149.3	1953	136.4	1953	149.1	1964	137.8
	1975	151.9	1985	140.2	1985	153.1	1980	139.7
	2000	155.0	1992	141.1	1992	153.9	1992	141.2
	2001	155.1	2011	143.4	2011	156.3	2002	142.4
	2009	156.1	2004	142.5	2004	155.4	2013	143.7
	2004	155.5	2005	142.6	2005	155.5	2008	143.1
	1984	153.0	1981	139.7	1981	152.6	1973	138.9
	1973	151.6	1960	137.2	1960	150.0	1963	137.7

Table 2-2. Means and Standard Deviations of Normal and Cold Calibration Counts

		MNCAL (CNTS)		SNCAL (CNTS)		MCCAL (CNTS)		SCCAL (CNTS)	
		FNWC	JPL	FNWC	JPL	FNWC	JPL	FNWC	JPL
37V	(Set 2)	3291.3	3286.9	14.3	17.3	1046.0	1042.0	11.2	10.1
37H	(Set 2)	3284.6	3283.9	10.7	10.6	1252.6	1254.9	10.5	11.7
21	(Set 2)	3235.5	3240.5	7.9	14.7	696.5	695.5	8.4	13.8
18	(Set 2)	3270.5	3273.3	7.6	13.3	995.6	996.0	6.5	12.7
10.69	(Set 2)	3295.3	3296.3	8.5	14.0	823.1	820.8	7.1	12.6
6.6	(Set 2)	3309.3	3309.5	7.8	18.8	830.7	832.0	8.2	18.1
37H	(Set 1)	3285.0	3282.0	10.7	14.1	1252.4	1255.5	10.5	12.7
37V	(Set 1)	3292.5	3284.3	13.6	23.0	1046.3	1039.7	11.6	12.9
21	(Set 1)	3234.9	3243.5	8.0	17.7	697.0	701.5	8.5	18.0
18	(Set 1)	3270.4	3272.0	7.8	18.1	995.3	993.0	6.7	17.7
10.69	(Set 1)	3295.3	3296.0	8.5	19.4	823.1	819.0	7.3	17.7
6.6	(Set 1)	3308.9	3316.0	8.0	25.0	830.3	828.0	8.3	25.0

Table 2-3. Housekeeping Temperatures

n \ (°K)	JPL	FNWC
1	299.3	308.0
2	300.5	308.0
3	301.7	308.0
4	301.4	302.2
5	301.0	340.2
6	300.6	434.2
7	301.0	497.2
8	300.5	401.2
9	296.2	273.2
10	300.7	273.2
11	297.9	273.2
12	300.9	273.2
13	298.4	273.2
14	300.7	273.2
15	297.7	273.2
16	300.6	273.2
17	299.6	273.2
18	303.2	273.2
19	300.4	273.2
20	300.9	273.2
21	296.8	273.2
22	300.3	273.2
23	297.5	273.2
24	300.6	273.2
25	295.8	273.2
26	300.4	273.2
27	296.8	273.2
28	297.1	273.2
29	298.0	273.2
30	306.7	273.2

SECTION 3 - COMPARISONS

The location data in Figure 2-1 indicates that some significant differences exist between the JPL and FNWC representations. The JPL location data appears to represent the actual satellite scans. The first half scan starts at the southwest end and the second half scan sweeps back from the northeast end as the satellite moves northward. The location data from the FNWC scan shows a modified representation. Location data from two half scans appear to have been averaged to show one single track. Also, there is a jump in the FNWC location data from one scan to another, instead of a smooth shift as it should be as the satellite moves forward. The FNWC scan also appeared to be somewhat earlier than the JPL scan.

A complete back and forth scan of the SMMR instrument takes 4,096 milliseconds. An examination of the FNWC and JPL scan time tags indicates that they are off by 2,208 milliseconds, which is greater than a half scan by 160 milliseconds.

Further examinations of the telemetry data reveal the cause of the time and location data discrepancies. Observations of the 37H and V channels are taken in both half scans, while for the other frequencies, the two polarizations are taken alternately between two half scans. From Table 2, the telemetry data for the first half scan of both the 37H and V channels are identical for both scans while the second half of the first JPL scan corresponds to the first half of the second FNWC scan. Similarly, for 21, 18, 10.7 and 6.6 GHz channels, the horizontal polarization data for each scan are identical, but the vertical channels of the first JPL scan correspond to those of the second FNWC scan. Together with the time tag difference and the JPL location data, this indicates that a JPL scan starts from the near sub-satellite track end. The first half scan takes observations for the 37H and V, 21H, 18H, 10.7H and 6.6H channels while the second half scan takes observations in 37H and V, 21V, 18V, 10.7V and 6.6V channels. A FNWC scan starts half a scan earlier at the farthest end from the sub-satellite track and takes observations for 37H, V, and the other vertical polarization channels first. It then samples 37H, V, and all other horizontal polarization channels during its second half scan. Outside of this difference in the definition of a scan, the digital counts of the actual observations appear to be identical between the two SDR tapes. However, the 160 millisecond discrepancy between the two sets of data has still not been resolved. To trace its cause, retrieval system and various data processing programs must be examined. Such work is beyond the scope of this study.

Another problem in the FNWC SDR tape is that certain observations are replaced by zeros, such as the eighth element of 21V, the tenth element in 18H and the third element in 10.7H, as can be observed from Table 2-1. Negative T_As would result from these zeros.

A casual glance at the T_As for FNWC and JPL scans in Table 2-1 reveals the great difference between them. Since the digital counts are practically identical, the error can only be explained by discrepancies in the mean calibration counts and the housekeeping temperature (Reference 1). The equation for calibration is as follows:

$$T_A = \frac{C_A - C_N}{C_N - C_C} \quad \frac{T_3\alpha_3 - T_C\alpha_1\alpha_2\alpha_3 - T_1(1-\alpha_1)\alpha_2\alpha_3 - T_2(1-\alpha_2)\alpha_3}{\alpha_5\alpha_7\alpha_9}$$

$$\frac{+T_3 - T_6(1-\alpha_6)\alpha_7\alpha_9 - T_7(1-\alpha_8)\alpha_9 - T_8(1-\alpha_9)}{\alpha_5\alpha_7\alpha_9} \qquad (1)$$

where C_A is the digital count of an observation which is identical for both tapes. T_C, the sky radiation temperature, is kept constant at 2.7°K. The transmission coefficients, the αs, are kept constant and, thus, identical for the processing of both tapes; C_N and C_C are the mean normal and cold calibration counts; and the Ts are housekeeping temperatures. The error in the ratio

$$\frac{C_A - C_N}{C_N - C_C}$$

caused by the differing C_N and C_C values is approximately half of a percent of the T_A value, or about one half degree. This is much less than the discrepancies shown in Table 2-1, which is on the order of a few degrees to around 150 degrees. The only element in the equation that could cause the error in T_A are the housekeeping temperatures. It is found upon examining Table 2-3 that the discrepancies in the housekeeping temperatures between the two tapes are, in fact, sufficient to cause the error in T_A. The error of handling the housekeeping temperature also appears to lie with FNWC because of the unrealistic T_A results produced from its tapes. Once more, it is beyond the scope of this study to trace how such an error is caused. It suffices here to state that the calibration algorithm adopted by CSC/NRL is correct and agrees with the JPL equivalent, and to point out that the housekeeping temperature handling procedure at FNWC needs to be modified.

SECTION 4 - SUMMARY AND SUGGESTIONS

During the installation at NRL of the calibration algorithm for SEASAT SMMR data, it became evident that the FNWC SDR tape in use could be erroneous. In an effort to validate the algorithm, SDR tapes produced at JPL of the same time period as the FNWC tapes were obtained. Listings of tape content of the FNWC and JPL tapes were compared; the calibration algorithms as well as results of the application of these algorithms on both the JPL and FNWC tapes were compared. The significant differences which were discovered are listed below with suggestions for their elimination.

- The housekeeping temperatures on the FNWC tapes appear to be erroneous. The errors in T_A are from a few degrees to over 100 degrees. Without correcting this effect, the whole SDR tape processing is useless. The algorithms which retrieve satellite observations, process the analog to digital conversion, and organize the data according to the SDR format ought to be reexamined and corrected.
- The relatively small difference in the calibration temperature between the FNWC and JPL tapes may cause a one-half degree difference in T_A. The handling of calibration counts should be reexamined.
- The mechanism for setting zeros in the telemetry data to eliminate certain observations in the FNWC SDR tapes should be reevaluated.
- The difference in location data does not directly affect the T_A calculations. It may, however, have some effect in the processing of brightness temperature.

- The definition of the start of a scan does not alter the accuracy of the antenna temperature calculations nor conceivably affect the ensuing processing of SMMR data as long as the convention is reorganized by users of the SDR tape. The 160 millisecond difference between the FNWC and JPL time tags may merit further examination.

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