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Appendix C
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ALGORITHM AND DATA USER MANUAL FOR THE SPECIAL SENSOR MICROWAVE IMAGER/ SOUNDER (SSMIS)

Appendix C: DOPPLER CORRECTION ALGORITHM IN BRIGHTNESS TEMPERATURE COMPUTATION

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TECHNICAL REPORT

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1 Introduction

This appendix describes the software correction for the RF gain and bias changes due to the Doppler shift compensation performed onboard the Special Sensor Microwave Imager/Sounder (SSMIS).

The combination of conical scan and spacecraft nonzero ground velocity cause the RF signals received by the SSMIS to be Doppler shifted. The Doppler shifts, dependent on the scan angle (i.e., beam position), are significant relative to bandwidths of some frequency channels. Thus, in principal the brightness temperature of all channels, but especially narrow-band upper-air channels, must be compensated for the Doppler effect.

The SSMIS sensor compensates for the Doppler shifts in the air-temperature-sounding channels by appropriately adjusting the local-oscillator frequency. However, in addition to compensating for the Doppler shift, this frequency tuning also causes gain changes in the temperature-sounding channels and bias changes in some non-temperature-sounding channels. Initially it was believed that this unwanted effect could be reduced to acceptable levels by hand selection and matching SSMIS receiver components. As this was not possible, it was decided to measure the error (i.e. brightness temperature error due to gain and bias changes) during calibration and modify the GPS to remove the residual error.

Measurements were performed on all channels for all combinations of device mode (i.e., primary or backup PLO), sensor look-direction (i.e., forward or backward relative to the spacecraft flight direction), and instrument temperature. The local oscillator frequency was adjusted for peak Doppler shift (scan center) only. It was found that the temperature errors were significant (of order 0.1K or greater) only for the temperature sounding channels and for channels 15 and 16 on SN04 (~ 0.5K)[1].

A Doppler correction algorithm was implemented in the SDRP module of the SSMIS GPS to correct for the effect of gain and bias changes on observed brightness temperature using the calibration measurement data. It is performed after the SDRP function to convert scene radiometric counts into brightness temperatures, and before the corrections for polarization cross-coupling and feedhorn spillover. The details of this algorithm are given in Section 2.

2 Algorithm Description

The combination of conical scan and spacecraft nonzero ground velocity produce sinusoidal Doppler shifts. The Doppler correction in SDRP is therefore dependent on the scan angle:

$$T_{B,a} = T_{B,b} - \left|\sin(\text{Scan Angle})\right| \cdot \Delta T_{B,Doppler} \cdot \frac{(T_{B,b} + T_R)}{(305 + T_R)}$$

where $T_{B,b}$ and $T_{B,a}$ are the scene brightness temperatures before and after the Doppler correction, respectively; $\Delta T_{B,Doppler}$ is the Doppler-correction coefficient measured during calibration for a

[1] At the time of this document release, no correction coefficients for Channels 15 and 16 were available from the hardware systems engineer(s). Constants are expected to be updated during re-calibration and during the Cal Val phase.

combination of sensor serial number, sensor-look direction, device mode, and instrument temperature; and T_R is the receiver temperature for the channel.

The scene brightness temperatures $T_{B,b}$ and $T_{B,a}$ correspond to a specific combination of channel and scan angle. The beam-center scan angle is dependent on channel number, beam position, and sensor-look direction. That is,

$$\text{Scan Angle} = \phi_{sb} + \phi_{bw} \cdot (BP - 1)$$

where ϕ_{sb} and ϕ_{bw} are the channel-dependent initial scan angle and beamwidth, and BP is the channel-dependent beam position. Table 1 gives the initial scan angle and beamwidth for all channels and sensor-look direction.

Table 1: Channel-Dependent Initial Scan Angles and Beamwidths

Look Direction	ϕ_{sb} (Deg)	ϕ_{bw} (Deg)	Channel No.
Forward	18.4	0.8	8, 9, 10, 11, 17, 18
Forward	18.8	1.6	12, 13, 14, 15, 16
Forward	19.2	2.4	1, 2, 3, 4, 5, 6, 7, 24
Forward	20.4	4.8	19, 20, 21, 22, 23
Backward	198.4	0.8	8, 9, 10, 11, 17, 18
Backward	198.8	1.6	12, 13, 14, 15, 16
Backward	199.2	2.4	1, 2, 3, 4, 5, 6, 7, 24
Backward	200.4	4.8	19, 20, 21, 22, 23

Hardware engineers measured and documented (e.g., Appendix G of Report 11298) the Doppler-correction coefficients ($\Delta T_{B,Doppler}$) during the development of each SSMIS sensor for Channels 1 through 7, and 19 through 24. Measurements were made for instrument temperatures from 0^0 to 40^0 C at 10^0 C increments. The temperatures of the A2 and A4 plates from the digital multiplexed data are used to determine the instrument temperature for each scene. A linear interpolation is then performed between the temperature measurements to determine the appropriate value for $\Delta T_{B,Doppler}$. The device mode corresponds to the redudancy of the phase lock loop oscillator (PLO).

The ratio $\dfrac{(T_{B,b} + T_R)}{(305 + T_R)}$ is applicable only to the channels where the Doppler compensation causes a gain modulation (the temperature sounding channels) and is set to unity for the other channels where the onboard compensation causes a bias change. The numerator is the system noise temperature for the scene of interest, whereas the denominator is the system temperature for the conditions under which the Doppler-correction coefficients were measured (i.e. a target temperature of 305K was used).
Table 2 lists the receiver temperatures measured for SN01.

Table 2: Receiver Temperatures in Kelvins for Channels 1-7, and 19-24

CH 1-5	CH6	CH7	CH 19-20	CH 21	CH 22	CH23	CH 24
733	687	575	733	606	587	583	619

3 Algorithm Implementation

The Doppler correction is implemented in SSMIS SDRP. It has the following features.

1) The Doppler correction is performed on the scene brightness temperatures before the corrections for polarization cross-coupling and feed-horn spillover.
2) The Doppler correction is applicable to all twenty-four channels. The correction coefficients are set to zero for those channels whose measured residual errors are negligible. This feature facilitates Doppler correction in all twenty-four channels, if necessary, after the calibration and validation of each SSMIS sensor in space.
3) The average of the A2 and A4 plate temperatures is the instrument temperature in the selection of Doppler-correction coefficients.
4) A manual ‘software switch’ activates the Doppler correction in SDRP. The switch status (on/off) is indicated in an ASCII input file (frequently referred to as the constants file) to SDRP.
5) A manual ‘software switch’ indicates the sensor look-direction. This switch is located in the constants file to SDRP.
6) All Doppler-correction coefficients for a given sensor serial number are included in the constants file to SDRP. Thus, the coefficients can be updated after the calibration and validation of each SSMIS sensor in space.

4 References

Interface Control Document for DMSP Block 5D-3 (S16-S20) Mission Sensor SSMIS, GenCorp Aerojet Electronics System Division, ICD-88806 Revision A, Azusa, CA, October 13th, 1997.

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Operator’s Manual for the Special Sensor Microwave Imager/Sounder (SSMIS), GenCorp Aerojet Electronics Systems Division, Contract F04701-89-C-0036, Report 9468B, CDRL 029A2, Azusa, CA, July 23rd, 1997.