Comparison of Measured Galactic Background Radiation at L-Band with Model

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Abstract—Radiation from the celestial sky in the spectral window at 1.413 GHz is strong and an accurate accounting of this background radiation is needed for calibration and retrieval algorithms. Modern radio astronomy measurements in this window have been converted into a brightness temperature map of the celestial sky at L-band suitable for such applications. This paper presents a comparison of the background predicted by this map with the measurements of several modern L-band remote sensing radiometers.

Keywords-Galactic background, microwave radiometery; remote sensing;

I. INTRODUCTION

The spectral window at 1.400-1.427 GHz (L-band) is important for measuring parameters such as soil moisture and ocean salinity that are needed for understanding the hydrological cycle, ocean circulation and energy exchange between the atmosphere and surface. At this frequency, radiation from galactic sources is sufficiently strong that it is necessary to include it during calibration (e.g. looking at cold sky) and necessary to make corrections in retrieval algorithms for the down-welling radiation that is reflected from the surface and detected by the sensor. The ability to do this will be important for L-band sensors planned for launch into space in the near future such as Aquarius (sea surface salinity), Hydros (soil moisture) and SMOS (soil moisture and ocean salinity). This background radiation is particularly important in the case of remote sensing of sea surface salinity which requires high radiometric accuracy. In this paper a comparison is presented of the predictions of a model using data from recent radio astronomy measurements at 1.4 GHz with the measurements of several modern remote sensing radiometers. The model used to predict the down welling radiation is that developed by Le Vine and Abraham [1].

The source of background radiation at 1.4 GHz is line emission from neutral hydrogen and broad-band (continuum) emission primarily from thermal and synchrotron sources. Recent measurements of this radiation by radio astronomers using modern instruments have been converted into an equivalent thermal source suitable for use in passive remote sensing applications [1,2]. Figure 1 shows an example map from Le Vine and Abraham (2004) for a radiometer with a bandwidth of 20 MHz and an antenna with a Gaussian beam with a half-power beam width (FWHM) of 10 degrees. The signal measured by the radiometer is obtained by tracing the locus of the bore-sight ray of the antenna on this map (see Appendices A-C in [1]). The solid line in Figure 1 is and example for sensor in polar orbit with the radiometer looking across track at an inclination angle of 30 degrees. Figure 2 shows the actual values measured by the radiometer around the orbit. To compare with measurements made from the surface of the earth, an additional term must be added to account for down-welling emission from the atmosphere. The approximation $1.9 \sec(\theta)$ K where θ is the inclination angle has been used here [3].

II. COMPARISON WITH MEASURMENTS

A. Comparison with PALS

Figure 3 shows a comparison with measurements made with the PALS radiometer developed at NASA's Jet Propulsion Laboratory. This is a passive and active (radiometer and radar) instrument that includes as one of its modes a dual polarized radiometer at L-band [4]. The L-band channel employs a large conical horn antenna with an aperture of 1 meter and an estimated half-power beam width of about 13.5 degrees. The radiometer bandwidth is 20 MHz. PALS is an aircraft instrument, however, during testing on the ground in September, 2001, the radiometer was pointed at the sky (zenith) and allowed to collect data over night.

Figure 3 shows the data recorded on the evenings of September 21-23 [5]. The peaks (0600 and 2100 hours) correspond to the passing overhead of the galactic plane, and the gap in the data corresponds to day-light hours during which data was not recorded. The lower panel in Figure 3

shows a comparison with the signal predicted by the model (bold line). During calibration a value of 5.5 K was assumed for the brightness temperature at the coldest point during the night (about 0200 hours): 2.7 K from the cosmic background, 1.9 K from the atmosphere, and 0.9K for the galactic background (which was chosen from Le Vine and Abraham [1]). Clearly the shape and amplitude of the measurements and predictions are in good agreement. The absence of a bias is a consequence of the value assumed for the galactic background and would not have been zero if a value other than that predicted by the model had been used. Notice the difference between the measurements at the two polarizations. This is not predicted by the model which assumes un-polarized radiation from the sky.

B. The LEWIS Radiometer

Figure 4 shows a comparison with measurements of the LEWIS radiometer developed at the Centre d'Etudes de la Biosphere (CESBIO). This is a dual polarized, L-band radiometer designed for field work to study remote sensing of soil moisture [6]. It employs a Potter horn about 1.1 m in diameter. The antenna has a FWHM of about 13.6 degrees and the radiometer has an effective bandwidth of 20 MHz [7]. The data shown in Figure 4 was collected while looking north at an elevation angle of 60 degrees during validation of this radiometer on August 2, 2002. The fine line is data collected at horizontal polarization and the solid curve is the prediction of the model.

C. The EMIRAD Radiometer

EMIRAD is a polarimetric L-Band radiometer developed at the Technical University of Denmark to look for effects of wind and wave direction on the brightness temperature of the ocean at L-band [8,9]. The antenna is a horn with an aperture of 0.9 x 0.9 m and length of 2 m and a theoretical beam width (FWHM) of about 12 degrees. Experiments have been conducted aboard a Danish Air Force C-130 aircraft in which the radiometer is flown in circles about a fixed point on the surface with an incidence angle of about 45 degrees.

Figure 5 shows data at vertical polarization from circles flown in October, 2003 over the North Sea at about 55.68° N Latitude and 4.70° W Longitude when the wind speed at the surface was about 10 m/s. The top curve is the model prediction and the lower curve is the EMIRAD data (an average of 16 circles). The model calculations assume a specular surface (no roughness) and have been arbitrarily shifted by adding a constant to fit on the same plot as the data. The good correspondence between measured and predicted shape is to be expected because at incidence angles in this range (40-50 degrees), the dependence on wind speed (i.e. roughness) at vertical polarization is small [10,11,12]. Hence, it is not surprising that the surface should behave specularly. At horizontal polarization the dependence on wind speed is strong and a more fluctuating (noise-like) signal is observed.

III. CONCLUSIONS

To first order the model of Le Vine and Abraham [1] for the galactic background radiation is consistent with the observations. The agreement is very good if small changes in the level (bias) of the radiometer measurements are permitted. The data reinforce the need at L-band to make accurate corrections for the background radiation.

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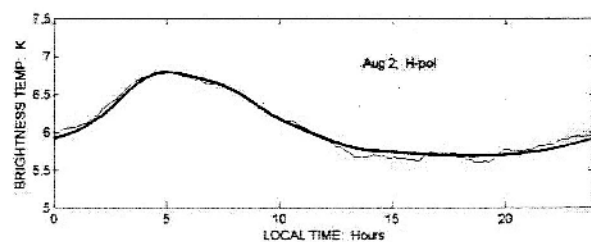
Figure 4. Comparison of LEWIS data at horizontal polarization recorded on August 2, 2002 with model prediction (bold line). The antenna pointed north at 60° elevation. An offset of 0.13K has been added to the data.
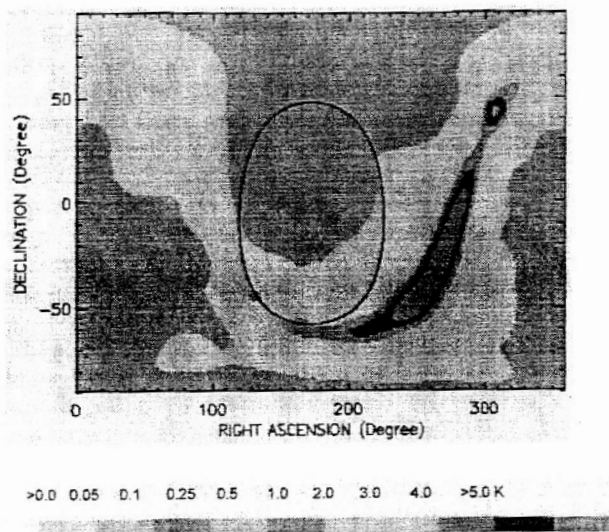
2

Figure 1. Background radiation smoothed with a Gaussian beam with 10° beam width (FWHM). The solid line is the locus of the boresight ray when the antenna is on a spacecraft in a circular, polar orbit with inclination of 95° and looking cross-track at an incidence angle of 30°.
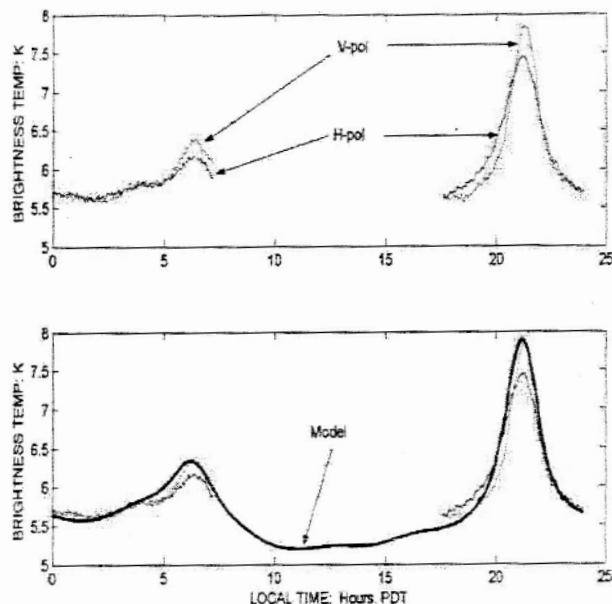

Figure 3. Comparison of the PALS data with predictions of the model [1]. At the top is shown the average of the PALS data collected on Sept. 21-23, 2001. The bottom panel shows the same data plotted with the model predictions (bold line).
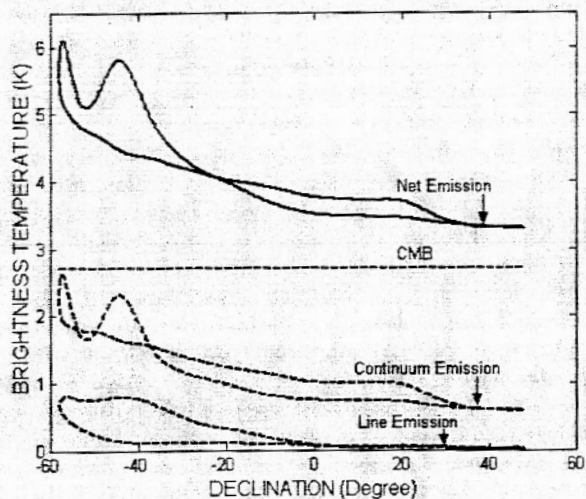

Figure 2: The values of brightness temperature around the oval locus shown in Figure 1. Each of the individual component is shown together with total. The peaks correspond to crossings of the galactic plane.
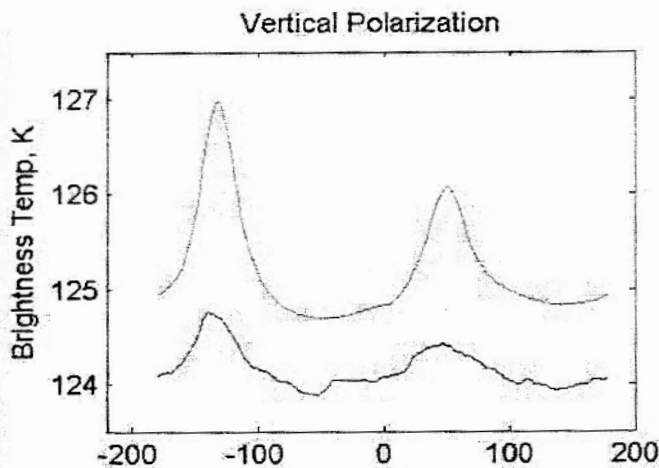
Vertical Polarization

Figure 5: Comparison of the EMIRAD measurements (bottom curve) with prediction for during the LOSAC experiments in October, 2003. The abscissa is angle (azimuth) during the circular flights. The upper curve is the predicted background radiation. The scales are the same for both but an offset has been added to the model prediction so that both can be plotted on the same scale.