AIRBORNE REMOTE OBSERVATIONS OF L-BAND RADIO FREQUENCY INTERFERENCE AND IMPLICATIONS FOR SATELLITE MISSIONS

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1. INTRODUCTION

Passive remote sensing of the Earth's surface and atmosphere from space has significant importance in operational and research environmental studies, in particular for the scientific understanding, monitoring and prediction of climate change and its impacts. Passive remote sensing requires the measurement of naturally occurring radiations, usually of very low power levels, which contain essential information on the physical process under investigation. As such, these sensed radio frequency bands are a unique natural resource enabling space borne passive sensing of the atmosphere and the Earth's surface that deserves adequate allocation to the Earth Exploration Satellite Service and absolute protection from interference. Unfortunately, radio frequency interference (RFI) is an increasing problem for Earth remote sensing, particularly for passive observations of natural emissions. Because these natural signals tend to be very weak, even low levels of interference received by a passive sensor may degrade the fidelity of scientific data. The characteristics of RFI (low-level interference and radar-pulse noise) are not well known because there has been no systematic surveillance, spectrum inventory or mapping of RFI. While conducting a flight experiment over central Tennessee in May 2010, RFI, a concern for any instrument operating in the passive L band frequency, was observed across 16 subbands between 1402-1427 MHz. Such a survey provides rare characterization data from which to further develop mitigation technologies as well as to identify bandwidths to avoid in future sensor formulation.

2. AIRBORNE RADIOMETER DESCRIPTION

The Marshall Airborne Polarimetric Imaging Radiometer (MAPIR) is a dual beam, dual angle polarimetric, scanning L band passive microwave radiometer system developed to support algorithm development and validation efforts in support of hydrological missions. MAPIR observes naturally-emitted radiation from the ground primarily for remote sensing of land surface brightness temperature from which soil moisture can be retrieved. MAPIR consists of an electronically steered phased array antenna comprised of 81 receiving patch elements and associated electronics to provide the required beam steering capability (Fig. 1). The antenna

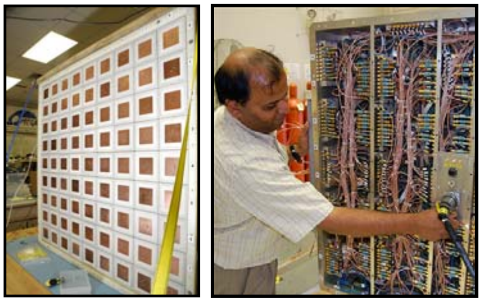

Fig. 1. MAPIR antenna showing the front and back side and electronic control components for each antenna element.

Fig. 2. MAPIR enclosed in fairings beneath a Piper Navajo.

produces two independent beams that can be individually scanned to any user-defined scan angle. The antenna is connected to four microwave radiometers and a spectrum analyzer. Two radiometers operate over a narrow band (science band) between 1400-1425 MHz. Two other radiometers operate over a wider bandwidth (1350-1450 MHz) and are used for Radio Frequency interference (RFI) surveillance. The outputs of the four radiometers are routed to the digital backend module that digitizes and filters the signal into 16 well isolated spectral sub-bands [1] and computes the first four statistical moments in each sub-band from which the radio brightness temperature and kurtosis (a statistical measure indicative of RFI, [1]) can be computed in post-processing. RFI is assumed to be of anthropogenic origin and of non-Gaussian distribution unlike naturally occurring emissions that are typically Gaussian. The amplitude domain approach to RFI detection exploits this signal distinction which is expressed in the higher statistical moments.

MAPIR can operate in two user-selectable modes: Single-Beam Dual (simultaneous) Polarization and Dual (simultaneous) Beam Single Polarization. In the first mode, both beams of the antenna are directed to scan at the same angle, but the radiometers are observing orthogonal polarizations (horizontal and vertical) at the same time. In the second mode, the two antenna beams can be directed to different azimuth and/or angles and the radiometers observe the same polarization at the same time. The instrument is capable of electronic beam steering to one-degree of resolution from 0-40 degrees in elevation and 0-360 degrees azimuth in both beams. MAPIR precision is 0.01K and brightness temperature accuracy is 5 degrees K over a 10 ms integration interval, but is capable of achieving 0.5K sensitivity over a 1 second integration interval. MAPIR has achieved successful flight heritage on the NASA P-3B in the fall of 2008 and was also integrated into a much smaller Piper Navajo to further demonstrate performance. MAPIR integration into the Navajo required building an adapter structure to interface the antenna to the belly of the aircraft with custom fairings to surround the antenna (Fig. 2).

3. FLIGHT EXPERIMENTS

A series of five flights were conducted between May 18 and 26, 2010 on a Piper Navajo aircraft operated by the University of Tennessee Space Institute in Tullahoma, Tennessee. During several of these flights, the aircraft was deployed to a NOAA Climate Reference Network station at Crossville, TN 65 nmi from the base of operation at Tullahoma TN or to the CHESS instrument tower at Oak Ridge National Laboratory 100 nmi from Tullahoma. At each of these destinations, a prescribed pattern of four intersection flight lines was flown at six different altitudes between approximately 2100 and 8500 ft. AMSL. During transit to and from these destinations and while at higher altitudes over station, MAPIR was operated in conical, dual beam scan mode. At lower altitudes, it was operated in nadir, single beam mode. In dual beam mode, MAPIR makes a scene (ground) observation every 60 ms and steps in 20 degree increments of azimuth.

4. RFI OBSERVATIONS

Radio frequency interference at L-band was observed at all times during the flights and comprises approximately one percent of all observations. It occurs in both horizontal and vertical polarizations in nearly equal proportions and was spatially distributed uniformly along a flight transect with no particular bias toward any location (Fig. 3). Although RFI occurs in all 16 subbands, it is usually limited to less than 5 subbands for each observation in which it occurs (Fig 3). However, RFI spreads across slightly more subbands at horizontal polarization compared to vertical polarization. Further analysis is required to determine if this observation is statistically significant. When we plot the actual footprints of the observations in which RFI occurred, it appears that it is fairly uniformly

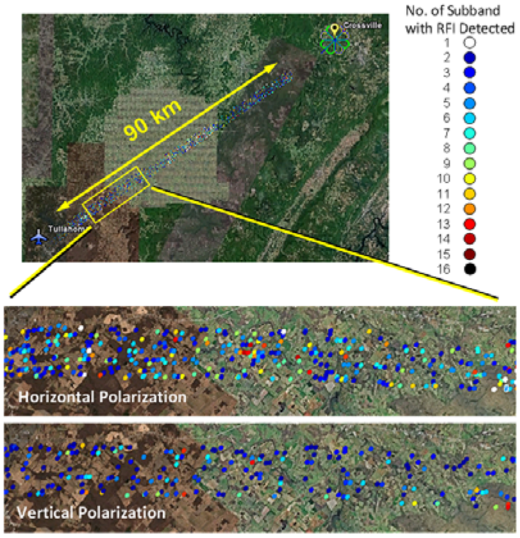

Fig. 3. RFI observed along transect between Crossville and Tullahoma, TN. Affected observations are mapped to the ground and colored according to the number of subbands affected.

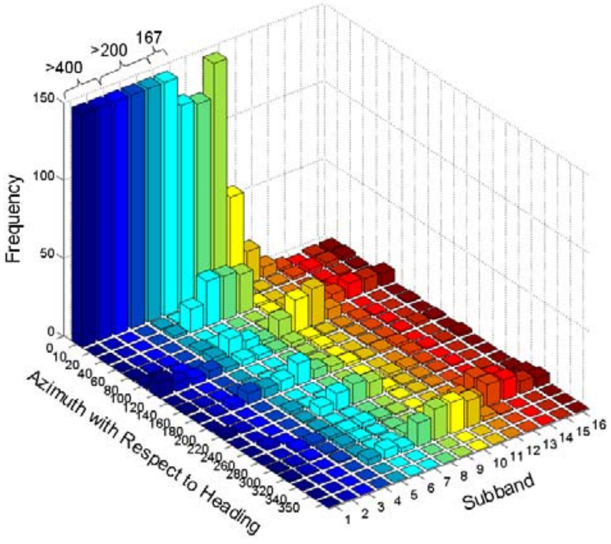

Fig. 4. Frequency histograms of RFI across subbands as a function of scan azimuth (elevation angle = 40°). Subband 1 center frequency is 1401.7 MHz; 16 is 1424.6 MHz

distributed across a scan. However, on one transect in which we were in route back to Tullahoma, data showed a much higher occurrence of RFI in lower frequency subbands at 10 degree azimuth with respect to our heading (Fig 4.). RFI at nadir scan mode was analyzed at the NOAA CRN station at Crossville, TN (Fig. 5). These data show RFI distributed across all subbands somewhat uniformly independent of altitude. However, at lower altitude, it appears that there is a slightly higher frequency at vertical polarization compared to horizontal.

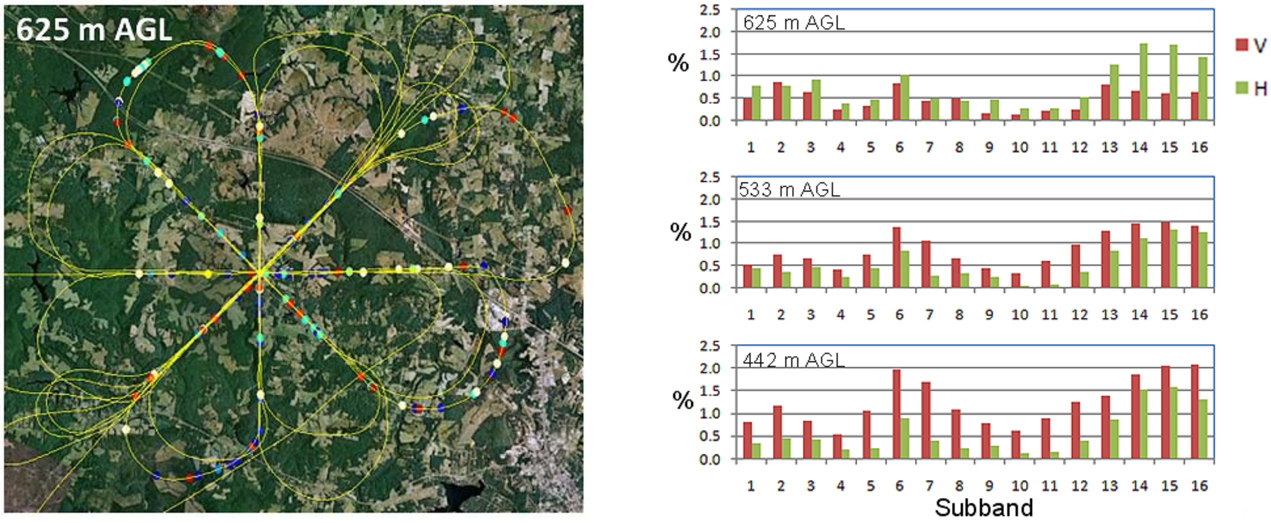

Fig. 5. RFI distribution across subbands observed at three different altitudes along the intersecting transects at the NOAA CRN station at Crossville, TN. MAPIR in nadir scan mode. Color scale from Fig. 3 applies.

5. SUMMARY

Radio frequency interference (low-level interference and radar-pulse noise) is an increasing problem for Earth remote sensing, particularly for passive observations of natural emissions because of their very weak signals. Consequently, these observations are greatly affected by even low levels of interference. Although the L-band frequency between 1400 and 1427 MHz is supposed to be free from transmission, clearly it is not. While conducting a flight experiment over central Tennessee in May 2010, L-band RFI was observed. In this paper, we characterize the nature of the RFI observed both spatially and spectrally in hopes of shedding insight as to what future satellite missions should expect to encounter. Such a survey provides rare characterization data from which to further develop mitigation technologies where time permits for future missions as well as to identify bandwidths to avoid in future sensor formulation.

6. REFERENCE

[1] Ruf, C. S., S. M. Gross and S. Misra, 2006. RFI detection and mitigation for microwave radiometry with an agile digital detector, Geoscience and Remote Sensing, IEEE Transactions on, 44(3), 694-706.