K-BAND RADIO FREQUENCY INTERFERENCE SURVEY OF SOUTHEASTERN MICHIGAN

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1. INTRODUCTION

The Radio frequency Interference Survey of Earth (RISE) is a new type of instrument used to survey and characterize the presence of Radio Frequency Interference (RFI). It consists of a combined microwave radiometer and kurtosis spectrometer with broad frequency coverage and high temporal and spectral resolution. A K-Band airborne version of the instrument has been built and flown across southeast Michigan. Evidence of RFI has been identified at C-band and at X-band by the Advanced Microwave Scanning Radiometer (AMSR-E) ((*e.g.* Li *et al*., 2004) as well as WindSat. Additionally, AMSR-E has shown that K-band measurements are susceptible to RFI which are believed to be generated by both ground-based sources as well as signals from geostationary telecommunication satellites reflected off of the earth's surface (*e.g.* Li *et al*., 2004; Li *et al*., 2006). In particular, observed RFI centered at 18.7 GHz by AMSR-E and WindSat has significantly increased in 2008-2009 from 2005-2006 measurements. The RISE aircraft mission, operating over 18.7-19.3 GHz, will evaluate the K-band RFI environment in order to assess the optimal passband.

2. INSTRUMENT

The RISE spectrometer, built in collaboration with the Danish Technical University, is a total-power radiometer with a stepped local oscillator (LO) and a digital back-end. A block diagram of the spectrometer is shown in Fig. 1. The spectrometer operates from 18.7 to 19.3 GHz with a spectral resolution of 3.28MHz and a 200 ms integration time. The initial signal is fed to the radiometer through a horn antenna followed by the calibration switch, which alternates from the antenna to the warm load or the cold FET. The warm and cold loads track the stability of the radiometer and serve as calibration points for the raw second moment antenna counts. The horn antenna has a beamwidth of 20° giving it a spatial resolution of approximately 1 km at an altitude of 8500 ft (typical altitude for RISE flight).

The RISE digital back-end consists of an ADC followed by a Xilinix FPGA. Digital subbanding occurs in the FPGA over 16 subbands. The FGPA measures higher order moments including the second moment, which is proportional to power, and the fourth moment which are used to compute the kurtosis of the signal. The kurtosis (K) of a signal is defined by the fourth central moment divided by the square of the second central moment (*e.g.* Ruf et al., 2006):

$$K = \frac{m_4}{m_2^2} \tag{1}$$

where $m_n = \langle (v - \langle v \rangle)^n \rangle$ with v defined by as the predetected voltage.

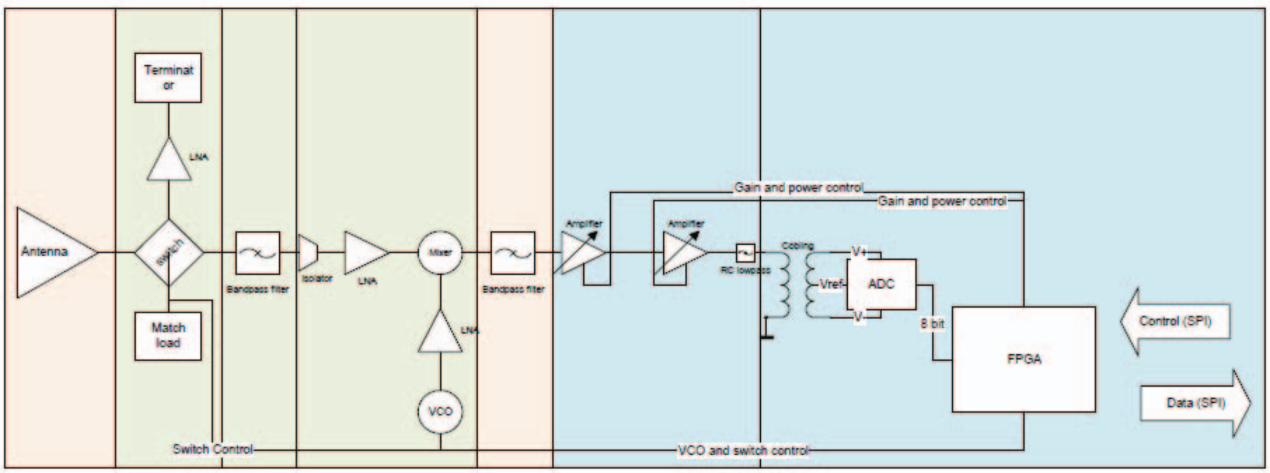


Figure 1: RISE functional block diagram

Internal radiometer noise and natural thermal emission sources from the Earth and sky generate Gaussian distributed predetected voltage. In the presence of man-made source such as RFI, the distribution will no longer be normal. Based on the deviation of the kurtosis ratio from an ideal value of 3 it is possible to detect RFI and characterize it as pulsed-type and continuous-wave (*e.g.* DeRoo et al., 2007).

3. FLIGHT CAMPAIGN

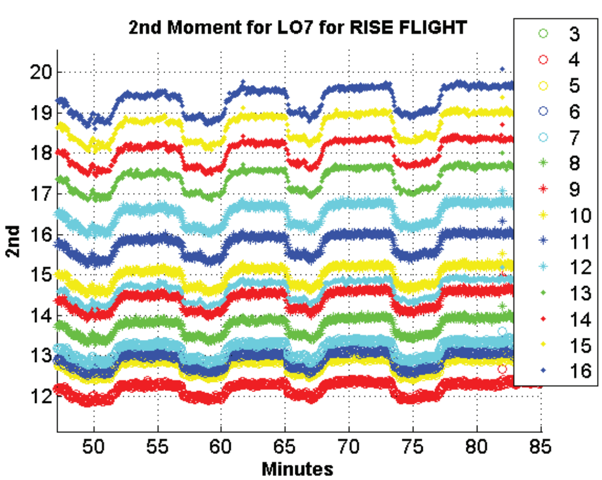
The RISE aircraft mission specifically targeted RFI due to telecommunication satellites operating at K-band. The incidence angle of the antenna was adjusted to view specular reflection from the DirecTV satellite located in Geosynchronous orbit with a sub-satellite point at around 100 degrees West longitude. Given the latitude and longitude of the RISE flights and the curvature of the Earth, the required incidence angle is approximately 52 degrees with the antenna pointing 23 degrees aft when the plane is flying due East.

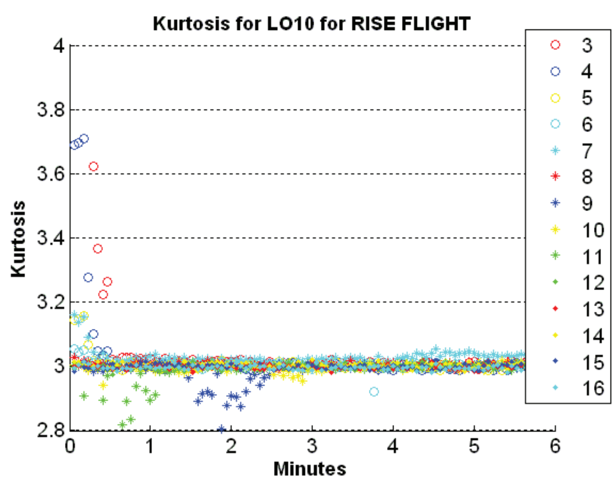
The RISE aircraft mission flew November 6th, 2009 on a Cessna 172 over Southeastern Michigan and along the Northern coast of Lake Huron (Fig. 2). Water crossings over Lake St. Clair and Lake Huron were used for brightness temperature (TB) calibration. Additional landmarks were selected for their diversity in surface topography.

Figure 2: RISE flight track

4. DATA ANALYSIS

Water crossings during the flight were noted to verify the geolocation of the antenna footprint. As seen in Fig. 3a, the water crossings are sharply defined as a marked decrease in 2[nd] moment counts. RFI was observed over the Ann Arbor airport, the RFI beacon, Flint, MI and at lower levels over the western coast of Lake Huron. The Ann Arbor airport shows the highest range of pulsed RFI (Figure 5a) where kurtosis is above 3 in the first two minutes of the flight. The beacon clearly shows the CW generated signal, where the kurtosis is below 3 as also seen in Figure 5a. Over different LO frequencies, the kurtosis varies as seen in Figure 5b and 5c. Future work for this survey will be critical in characterizing RFI generated from the reflection of geostationary satellites as well as identifying additional ground-based sources. The digitally filtered subbands will aid in future analysis in isolating specific frequencies where RFI occurs.





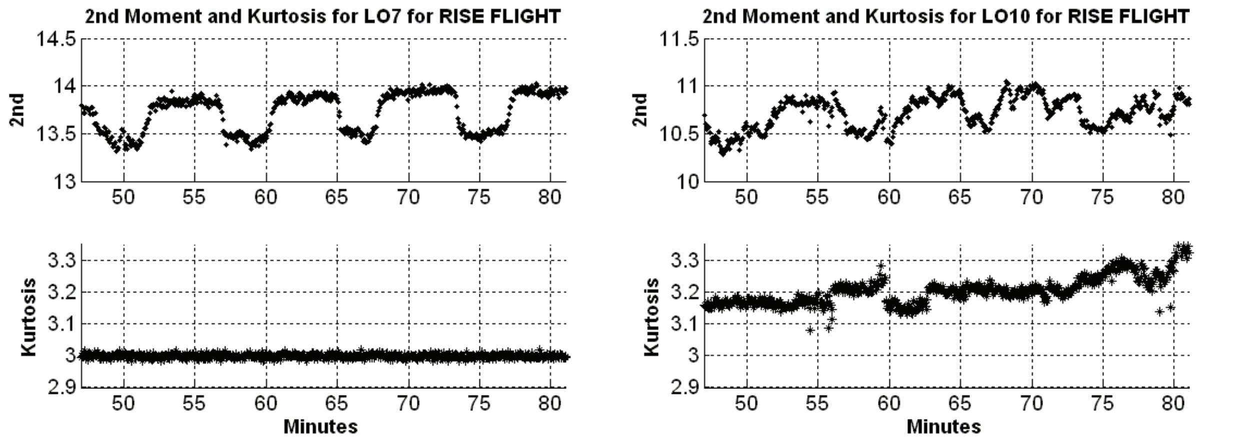


Figure 3: a) RISE raw 2nd moment time series over water crossings for all subbands b) LO 10 kurtosis during the initial minutes of the RISE flight b) LO 7 raw second moment and kurtosis (subband 8) over 45-80 minutes after take-off c) LO 10 raw second moment and kurtosis (subband 8) over 45-80 minutes after take-off

5. REFERENCES

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