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Sources of L-Band RFI Determined from Kurtosis Using the SMAP Radiometer

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Abstract

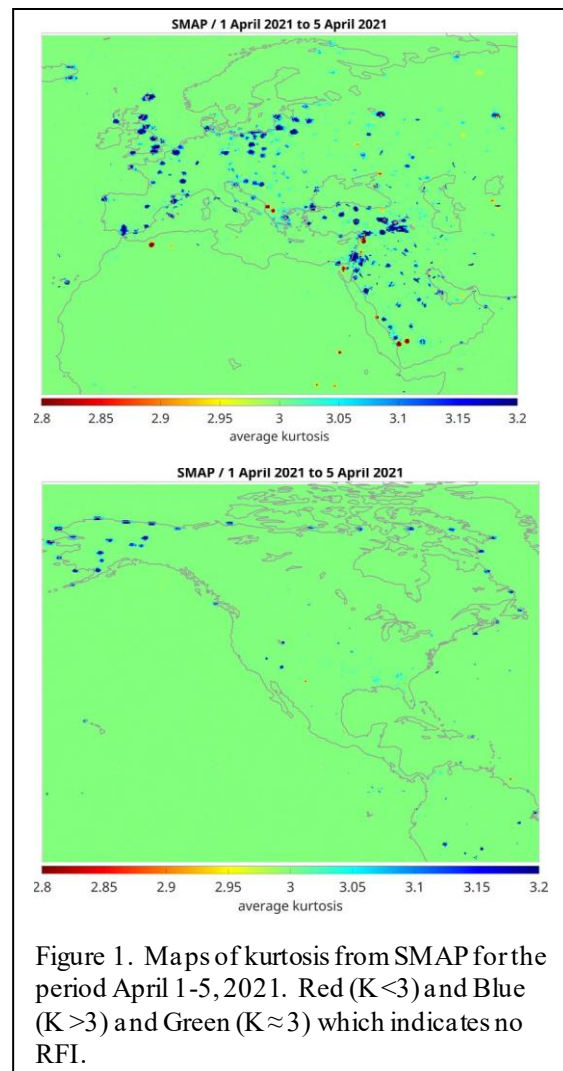
Among the parameters of the signal measured by the SMAP radiometer to identify RFI is kurtosis which indicates the departure of the received signal from a gaussian distribution and therefore helpful in identifying RFI. But the kurtosis has the potential to provide additional information. This manuscript reports results of an investigation examining the connection between the level of kurtosis (K) and the characteristics of the source of the RFI. It is shown, for example, that the level of can be used to distinguish the short pulse, relatively wideband RFI associated with radar from the narrow bandwidth signals associated with faulty consumer electronics.

1 Introduction

Microwave remote sensing in the band 1400–1427 MHz (L-band) protected for passive measurements is important for global monitoring of soil moisture and sea surface salinity, parameters needed for understanding the global water cycle and climate change. Although emission in this band is prohibited, radio frequency interference (RFI) is observed over significant portions of the earth [1,2]. RFI means lost data and degraded science products and modern sensors employ algorithms to detect and remove RFI. But very little is known about the sources of the interference, even though information about the sources and the characteristics of the interference they generate has the potential to lead to improved detection.

The advanced tools for RFI detection system included in the SMAP radiometer [3] provide data to locate the source [4] and tools such as the spectrum and time history that can be used to relate the characteristics of the observed RFI with the characteristics of the source [5,6]. Among the parameters of the signal measured by the SMAP radiometer is kurtosis. Kurtosis measures the departure of the probability distribution (PDF) of a signal from a gaussian distribution. But kurtosis has the potential to provide additional information. Theory shows that the level (whether $K > 3$ or $K < 3$: $K = 3$ indicates a gaussian PDF) depends on the fraction of the radiometer integration cycle occupied by RFI, information which can be used to distinguish the short pulse relatively wideband RFI associated with radar from the narrow bandwidth signals associated with faulty consumer electronics. These conclusions have been verified using the SMAP signal to locate sources and comparing the kurtosis with the spectral

and temporal information provided by the SMAP radiometer.



2 Background

The fundamental datum of the SMAP radiometer is a measurement at L-band (1400 MHz) averaged over an integration time of 0.3 ms and bandwidth of 24 MHz [3]. The radiometer is fully polarimetric with a coherent digital backend (i.e., phase and amplitude are preserved). In addition to the Stokes parameters, the kurtosis and spectrum of the signal are computed. Figure 1 is an example of the kurtosis reported by SMAP. RFI with $K > 3$

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Figure 1 displays a 2x6 grid of plots showing RF-unfiltered V-polarization antenna temperature [K] versus millisecond from beginning of scan for orbit 32986_A / scan 513. The top row shows scans 1-6 and the bottom row shows scans 7-12. Each plot has a y-axis from 0 to 2000 K and an x-axis from 0 to 3600 ms. The plots show varying patterns of signal, including a large peak in scan 6 and scan 12.

Figure 2 is an example of the spectrum provided by SMAP [3]. Each panel in Fig 2 represents the amplitude of the signal as a function of time in one of the frequency channels (each 1.5 MHz wide) starting at the top left with the channel with center frequency at 1401.5 GHz and ending at the bottom right with the channel at center frequency 1422.5 GHz. Each vertical bar represents one spectral measurement, and the spaces are the times set aside for radiometer internal calibration. In this example there is a strong source of RFI centered around 1700 ms which appears in several frequency bands. The RFI is strongest at 1413.5 MHz and 1415.0 MHz where the receiver is saturated.

$$Y = A \text{rect}(t/T) \cos(2\pi f t + \phi) + R \quad (1)$$

for 0.3 ms (as done by SMAP [8]) and then the kurtosis is computed for each 0.3 ms measurement from the PDF of the samples. This can also be done theoretically. Determining the pdf of the discrete samples of a sinusoid in noise was solved by [9] and generalized to include a pulsed sinusoid by [10] (see Eqns 13-14 in [10]). In addition, [10] computed the kurtosis from these samples (Eqn 20 in [10]):

$$K = 3(1 + 2S + S^2/2d)/(1 + S)^2 \quad (2)$$

3 Discussion

However, radar can also have $K < 3$ even when the signal does not saturate the radiometer receiver. An example is a very strong radar observed in China in 2020 [de Matthaeis et al, 2021]. The spectrum of the RFI from this radar was very narrow band, appearing predominately in only one of the SMAP subbands (Fig. 6 in [11]) suggesting a relatively long pulse. The corresponding kurtosis was $K < 3$ (Fig. 7 in [11]) reaching 1.7 during saturation but remaining below 3 when the radiometer was not saturated.

4 Conclusion

Based on a very limited supply of ground truth, a reasonable hypothesis is that strong RFI with $K < 3$ (and not saturated) is likely radar with pulses long compared to the SMAP radiometer integration time and when $K > 3$ the source is likely radar with pulses short compared to the integration time. RFI with $K \approx 3$ is likely a continuous, narrow band source of RFI. Several examples of faulty consumer electronics have recently been found by spectrum management officials given locations reported by SMAP including a surveillance camera in Wisconsin and an amplifier for a TV system in West Virginia. In each case the spectrum was narrow and kurtosis close to 3 [12].

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