ESTIMATING THE RETRIEVAL PERFORMANCE OF PASSIVE REMOTE SENSING UNDER ALTERNATE SPECTRUM SHARING SCENARIOS

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ABSTRACT

Methods for promoting flexible use of the radio frequency spectrum in microwave radiometry are examined in order to assess the potential for future spectrum sharing paradigms. Results are shown that suggest that geophysical product retrieval performance can be maintained under a variety of channel frequencies and bandwidths.

***Index Terms*—** microwave radiometry, radio frequency interference

1. INTRODUCTION

Earth-observing microwave radiometers provide a variety of valuable measurements of Earth's atmosphere, land surface, oceans, and cryosphere [1]. Achieving accurate measurements of Earth's brightness temperatures requires "protected" or "clean" portions of the radio spectrum within which transmissions from other users of the spectrum are absent or limited to remain below observable power levels [2]. This has been achieved in the past through "static" spectrum regulatory processes that allocated particular frequencies to the "Earth Exploration Satellite Service-passive" (EESS-passive) services on either a primary or secondary basis as shown notionally in the upper plot of Figure 1. Primary allocations prohibit other users from transmitting powers above very low levels, while secondary allocations recommend operation on a 'non-interference basis' for other users [3]. These allocations have resulted in the majority of past satellite radiometry missions using channels at least in part within the existing primary and/or secondary allocations. However, the needs for additional access to the spectrum has motivated many past missions to operate "opportunistically" outside these allocations, under the assumption that interference would remain tolerable due to a limited spatial distribution of existing emitters [1]-[4].

While such approaches have been at least partially successful in the past, the continuing demand for access to the radio spectrum by a variety of applications motivates renewed examination of methods for spectrum co-existence between both active and passive users that can simultaneously meet the application needs of both parties. One potential method for improve spectrum sharing involves

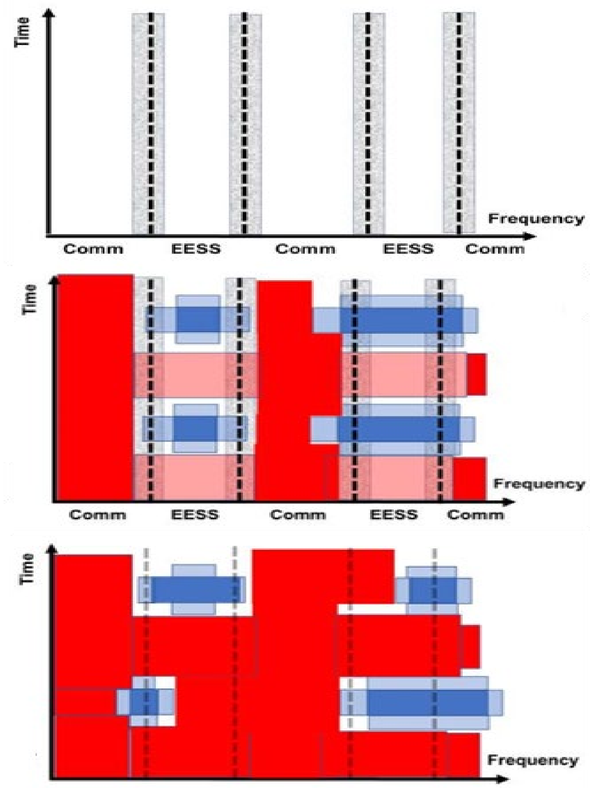

Figure 1: (upper) Existing static frequency allocation for active ("Comm") and passive ("EESS") users (middle) Potential "dynamic" sharing paradigm (lower) Flexible frequency use in a dynamic sharing paradigm

a "dynamic" sharing strategy (as indicated in the middle plot of Figure 1) in which the spectrum of interest to an EESS user may be accessed by other users during the time in which an EESS observation is not performed [1], [5]-[6]. While such strategies are under investigation, additional potential gains in spectrum sharing may become available if more flexible selection of particular frequency channels by microwave radiometers is considered as illustrated in the lower plot of Figure 1. In this figure, radiometer spectrum use occurs during the time of an "overpass" in frequency channels that may vary between access requests. Before examining potential means for implementing this access scheme, the retrieval performance that could be achieved under varying spectrum access levels must first be quantified. An initial examination of this concept is reported in this paper.

2. CHARACTERIZING RETRIEVAL PERFORMANCE

The science products observed by spaceborne microwave radiometers include the sea surface temperature (SST), integrated water vapor content of the atmosphere (IWV), ocean wind speed (WS), and others. Retrieval of these products is performed using brightness temperatures measured in multiple frequency channels combined with a radiative transfer model that relates thermal emissions to the geophysical products of interest. The required models and retrieval algorithms have developed over many years, and have been further refined through empirical studies with past instruments (e.g. [7-8]). It is noted that the latter depend on the availability of existing datasets at a given frequency, making the use of physically-based radiative transfer and emission models desirable for investigations of frequency use outside those previously applied. Due to the heritage retrieval algorithms developed by past missions using particular frequency bands, the use of alternate frequency bands may appear to pose a challenge for eventual operational adoption. However, the potential advantages of spectrum sharing motivate the consideration of the more flexible approach proposed.

A key component to be modeled is the retrieval performance expected as the channel set and channel bandwidths used for a particular retrieval are varied. It is noted that the errors associated with a particular retrieval are governed in part by the sensitivity of the thermal emission in a particular frequency to the geophysical property of interest and in part by the uncertainty of a particular brightness temperature measurement, which itself is impacted by the time-bandwidth product available in a particular measurement.

3. EXAMPLE RESULTS

As an example, Figure 2 illustrates horizontally-polarized brightness temperatures at 18.7 and 23.8 GHz as a function of IWV content and wind speed for SST 290K and observation angle 55 degrees using the semi-empirical model of [8]. The greater impact of IWV content at 23.8 GHz is evident, as well as the influence of wind speed which serves as a "nuisance" parameter in attempting to retrieve IWV alone.

Based on this model's predictions of brightness temperatures in both vertical (V) and horizontal (H) polarization at 6.8, 10.7, 18.7, 23.8, and 36.5 GHz for a wide range of IWV, WS, and SST values, a linear regression was performed (as in [7]) that determined the linear coefficients to be applied to the ten brightness temperatures observed (i.e. two polarizations in five frequency channels) to obtain a specific science product. It is noted that the linear regression described is only one of many algorithms for retrieving geophysical information; it is applied in this example due to

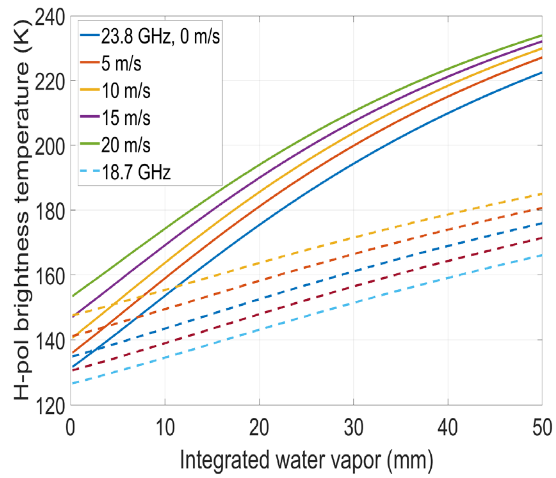

Figure 2: Predicted horizontally polarized brightness temperatures versus integrated water vapor content and ocean wind speed at 23.8 and 18.7 GHz for SST 290K and observation angle 55 degrees

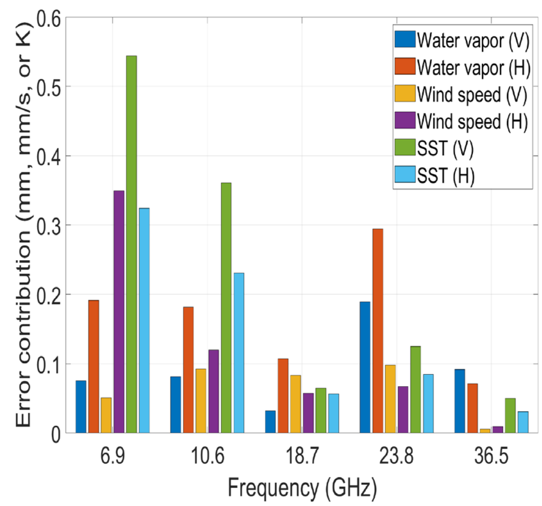

Figure 3: Regression coefficients determined for each of ten brightness temperature measurements (five frequencies in two polarizations) to obtain the IWV, WS, or SST retrieval products

the direct mapping it allows between brightness temperature uncertainties and retrieval product errors.

Figure 3 illustrates the resulting regression coefficients as a bar chart, and shows the varying weights applied to specific frequency channels in estimating particular products (for example, note the larger coefficient values at 23.8 GHz for estimating IWV). If the uncertainty of each brightness temperature is estimated at 1 K, the values shown for each bar represent the error contribution to the final product, with the final error determined as a root-mean-square combination of the errors shown.

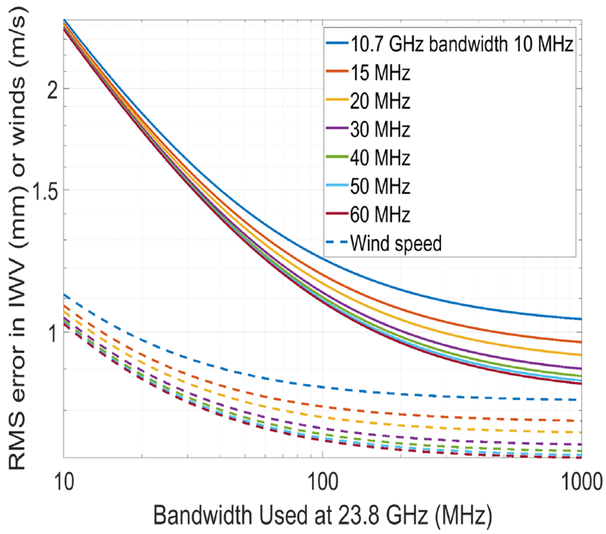

Figure 4: Predicted retrieval errors in IWV (solid) or WS (dashed) as a function of the 23.8 GHz and 10.7 GHz channel bandwidths used

Because the uncertainty in brightness temperature measurements is inversely proportional to the square root of the time bandwidth product used in the observation, the relative contributions of each bar in Figure 3 will vary as differing bandwidths are allocated for each channel. An illustration of these relationships is provided in Figure 4, which examines the retrieval error in IWV and/or WS as a function of the observation bandwidth at 23.8 and 10.65 GHz.

The multiple curves that result show the tradeoffs that are possible; for example, an IWV error of 1 mm can be achieved using a bandwidth combination of 60/200 MHz at 10.65 and 23.8 GHz, respectively, or equivalently using a combination of 15/400 MHz. Similar results are obtained for WS retrievals (dashed curves). These results suggest the potential for future more flexible sharing of the radio spectrum while retaining or improving the retrieval performance of current approaches.

Additional studies of EESS geophysical sensing performance as a function of the spectrum available in specific channels as well as the specific center frequency used will be reported in the conference presentation.

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