AIRBORNE P-BAND SIGNAL OF OPPORTUNITY (SOOP) DEMONSTRATOR INSTRUMENT; STATUS UPDATE

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1. INTRODUCTION

Root zone soil moisture (RZSM) is not directly measured by any current satellite instrument, despite its importance as a key link between surface hydrology and deeper processes. Presently, model assimilation of surface measurements or indirect estimates using other methods must be used to estimate this value.

Signals of Opportunity (SoOp) methods, exploiting reflected P- and S-band communication satellite signals, have many of the benefits of both active and passive microwave remote sensing. Reutilization of active transmitters, with forward-scattering geometry, presents a strong reflected signal even at orbital altitudes. Radiometry is advantageous as it measures emissivity which is directly related to dielectric constant and sensitive to water content of soil. Synthetic aperture radar (SAR) is used in P-band (400 MHz) for soil moisture and biomass, but faces issues in obtaining permission to transmit due to spectrum regulations, particularly over North America and Europe [4]-[6]. A primary advantage of SAR is excellent spatial resolution. Signals-of-Opportunity (SoOp) reflectometry provides a good compromise between radiometry and SAR by providing adequate sensitivity and spatial resolution for RZSM measurements without issues of spectrum access. Further, a SoOp instrument would not be limited to operating in only a few protected frequencies and is also expected to have less susceptibility to radio-frequency interference (RFI). Although advantageous if available, SoOp techniques do not require the ability to demodulate or decode the communication signals. The SoOp instrument is “receive only” and therefore requires much less electrical power than a SAR and is more similar to a radiometer in architecture. These unique features of SoOp circumvent past obstacles to a spaceborne P-band remote sensing mission and have the potential to enable new RZSM measurements that are not possible with present technology.

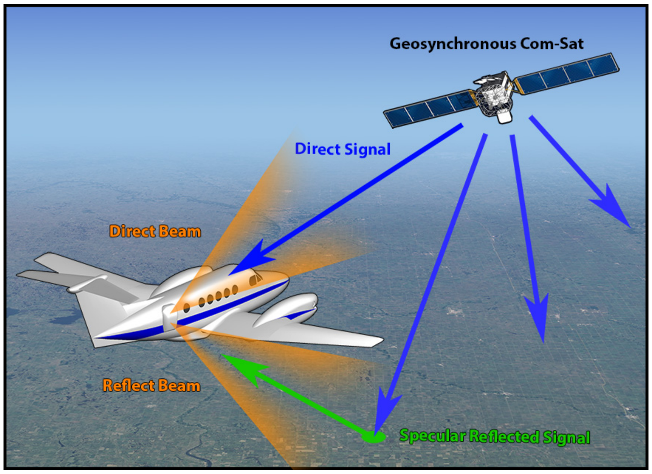

Fig. 1. Airborne P-band SoOp-AD reflectometer shown fields-of-view of the space-viewing and earth-viewing antennas aboard the aircraft. The signal-of-opportunity is represented by the rays originating from the geostationary satellite.

2. APPROACH

We are developing a SoOp reflectometer airborne demonstrator (SoOp-AD) operating at 250 MHz to take advantage of existing communication satellite sources as shown in Fig. 1. As the wavelength at 250MHz (120 cm) is 5 times longer than L-Band, the penetration depth (*1/e*) can be obtained from dielectric model depth equation and is computed to be 7 times deeper than L-Band [7]. Only P-band can reach a penetration depth of multiple decimeters, allowing sensitivity to RZSM. From Kirchoff's Law of thermal radiation, the sensing theory of the reflectometer is hypothesized to be more akin to the radiometer, which measures emissivity, as opposed to the SAR, which measures backscatter. The forward reflection coefficient is highly dependent upon soil moisture, as shown in Fig. 2. A specular reflection is assumed in order to improve resolution beyond that provided by the antenna pattern. We expect specular reflection at the long P-band wavelengths for most regions of interest to RZSM sensing. According to the Rayleigh criterion ($\sigma_x \approx \lambda/(8\cos\theta)$) specular reflection is expected from surfaces with height standard deviation $\sigma_z < 30$ cm, which is not a stringent requirement. Thus, surface resolution for the P-band measurement will thus be set by the first Fresnel zone; 870 m for an orbiting receiver at 400 km altitude and 75 m for an airborne receiver at 3 km. This assumes a mid-latitude receiver, with an incidence angle of $\theta=40^{o}$. Link budgets for specular reflected signals with available integration times likely provide sufficient SNR to adequately measure soil moisture to sensitivity comparable to SMAP. Analyses were performed to evaluate sensitivity vs. error sources such as aircraft attitude, aircraft altitude, antenna pattern uncertainty, terrain height variation, direct-signal leakage into the Earth-view antenna, receiver gain and offset uncertainty, and RFI.

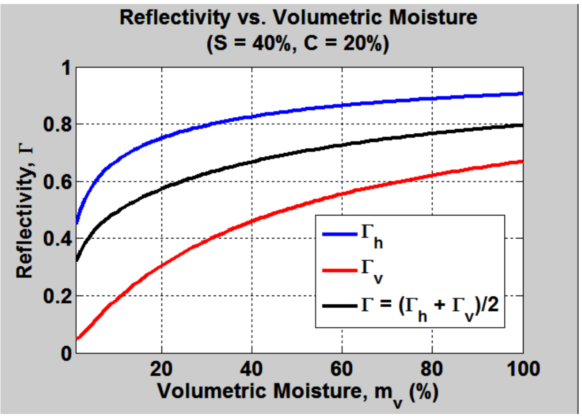

Fig. 2. Reflectivity vs soil moisture. The Fresnel coefficients were computed for an infinite half-space of soil with 40% sand and 20% clay composition. The average of the two polarizations is representative of the reflection coefficient for circular polarization.

3. CONCLUSION

The instrument is currently under development with science flights planned aboard a Beechcraft Super King Air B200 aircraft. The flights will include NASA's SLAP L-Band radar and radiometer to provide coincident measurements. The instrument comprises two dual-polarization antennas (one each for sky and Earth views), a four-channel RF receiver with internal calibration network, and a digital receiver to correlated signal pairs. Brass boards of the P-band receivers have been fabricated and have been used to monitor P-Band satellite transmissions to develop spectrum population statistics and survey unwanted RFI. These results have led to requirements for channel processing and RFI mitigation in both the RF and digital portions of the system. The instrument will store complex correlation coefficients for all pairs of elements formed by the two dual-polarization antennas. These coefficients will be averaged in ground processing to reduce noise prior to estimating reflectivity and retrieving soil moisture. A "Smart Antenna" approach will be used in ground processing to steer an antenna pattern null towards the unwanted reflected signal as seen by the sky-view antenna. The background and status of the SoOp-AD instrument will be discussed along with sources of error and mitigation strategies.

ACKNOWLEDGMENTS

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