Radiometric features of land surfaces at 37GHz

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Abstract

Microwave emission from the Earth's surface was found to be sensitive to land characteristics on both local and global scales. In particular, microwave sensors have shown a high sensitivity to certain features of the soil, as well as those of snow and vegetation, which are of great interest in hydrology, meteorology, climatology and - although to a lesser extent - in agriculture as well.

The main parameters influencing microwave emission, and the most important targets of remote sensing of land are soil moisture, vegetation cover, plant water content, snow water equivalent and depth.
Theoretical studies and field experiments, carried out by several research groups in order to relate microwave emission from land to physical parameters of soil, snow-pack and vegetation, have revealed different sensitivities of microwave sensors to these land parameters depending on observation parameters (frequency, polarization, incidence angle).

The IFAC Microwave Remote Sensing Group has a long-time experience in investigating natural surfaces by using ground based and airborne microwave radiometers in a frequency range between 1.4 and 37 GHz. The research led to determining the radiometric behavior of the basic types of land surfaces and to establishing empirical or semi-empirical rules for classification of land surface and estimation of geophysical parameter corroborated by model analyses.

Emission at millimeter-waves is characterized by lower penetration depth inside the observed bodies with respect to the lower frequencies, but the use of sensors operating in this frequency range allows higher ground resolution (or lower antenna sizes), which is a significant advantage from space. Emission from bare soil is essentially determined by the surface characteristics of this medium (moisture and roughness), while radiation from vegetation and snow is emitted by volumetric processes. For example, experimental studies interpreted with a radiative transfer model demonstrated that the optical depth of agricultural crops in the cm and mm wavelength range increases with frequency and is related to the Plant Water Content (PWC) by a nonlinear relationship which shows saturation as the density of vegetation material (in general a sparse low density medium) increases toward the conditions of dense medium. The trend of brightness temperature as a function of PWC shows a maximum at cm wavelengths, denoting prevailing of absorption for low values of PWC and of scattering at the higher values. Instead, in the mm range scattering prevails and emission decreases as soon as the vegetation material increases.

A typical dense medium (with density higher than 10%) is represented by terrestrial snow. For dry snow, emission at 37 GHz regards a snow layer of several decimeters depending on snow density and grain size and is much higher at lower frequencies. Thus, the use of a dual frequency system such as the one available in several satellite sensors (19 and 37 GHz) makes it possible estimating snow depth. If snow becomes wet the loss factor increases dramatically and radiation is emitted by a very thin surface layer even at the lower frequencies, so that the estimate of snow water content seems to be practically impossible.

Significant studies for discriminating land surfaces and estimating quantitative parameters with microwave passive sensors from space have been conducted using satellite data from SMMR, SSM/I, AMSR-E, and more recently, from AMSR2.

For example, data, obtained on different global areas from SSM/I and AMSR-E pointed out a rather flat behavior of the brightness temperature (Tb) spectra from X- to Ka-bands on evergreen forests throughout the whole year, with different levels of brightness only due to surface temperature variations; whereas, on tundra, the spectral trend slightly increases in summertime and sharply decreases in winter.

From these results we realized that, although bare and vegetated soils generally show different values of Tb, a single-frequency, single-polarization observation is generally of little use for investigating the biophysical characteristics of a surface. More information can be obtained by combining brightness temperatures measured at two frequencies and polarizations and by adding information taken in the thermal infrared band. Simultaneous observations at X- and Ka-bands in V and H polarizations can be useful in separating different land surfaces and identifying their moisture conditions.

In particular, the polarization index (PI, i.e., the difference between the vertical and horizontal components of Tb divided by their sum) was found to be dependent on vegetation biomass and independent of crop type, so that it could be related to the plant water content and the leaf area index.

Measurements carried out by means of the 37-GHz channel of SMMR, SSM/I and AMSR-E, confirmed on a worldwide scale the usefulness of polarization index in monitoring vegetation cover and that of frequency difference for detecting snow cover.

In parallel to the experimental investigations, the development of physical and semi-empirical models, made it possible to perform sensitivity analyses to evaluate the potential of the present and future instrumental configurations (frequency, polarization, incidence angle) in estimating land parameters. Emission from soil can be simulated by using semi-empirical approaches or analytical models based on surface scattering. In case of a sparse low dense medium such

978-1-4673-5225-3/14/$31.00 ©2014 IEEE

as vegetation the conventional Radiative Transfer Theory has been frequently and successfully used in various approximate versions to reproduce emission from agricultural crops and forests, whereas, for a dense medium such as snow, coherent effects cannot be disregarded ad more sophisticated approaches such as the one of the Quasi Crystalline - Dense Medium Radiative Transfer Model (QCA-DMRT) need to be addressed.