Optimization of bistatic radar configurations for vegetation monitoring

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The potential of SAR in both agricultural and forest applications has been demonstrated in several studies. Major applications include, on one side, desertification control, forestry inventory and deforestation monitoring, and, on the other, pasture and crop monitoring, yield estimates, and irrigation and harvest control. Both their almost all-weather capability and enhanced spatial resolution make imaging radars apt to these tasks, however, in spite of several efforts, classification and monitoring techniques are still limited since, in several cases, variations of plant parameters are observed to produce minor effects on σ^0. Other severe problems stem from the effects of simultaneous variations of several soil and plant parameters, which make it difficult to identify the causes of σ^0 variations. In order to overcome the above mentioned limits, which could prevent operational use of microwave remote sensing, synergy with new data sources has been proposed like, for example the bistatic radar technique. Classification and monitoring potentials can be, in this way, improved with respect to single configuration observations.

Up to now, no bistatic radar campaigns, nor laboratory experiments, having vegetation as the target, have been set up, but the bistatic radar potential has been theoretically analyzed taking advantage of electromagnetic scattering models, like the one developed at Tor Vergata University. This model is based on the radiative transfer theory, and adopts a discrete approach. Vegetation elements, such as trunks or stems, branches and leaves are represented by means of canonical shapes, i.e. cylinders and discs. The bistatic scattering and extinction cross sections of single elements are modelled using the appropriate electromagnetic approximation, and the various contributions are then combined by using the Matrix Doubling technique, that is a multiple scattering algorithm. The soil is described as a homogeneous dielectric half-space characterized by an incoherent bistatic scattering coefficient and also by a coherent scattering coefficient. The same Matrix Doubling algorithm is used to combine vegetation scattering with soil scattering. Finally, the bistatic scattering coefficient, at any angle of observation (defined both in azimuth and in elevation), is computed. To this aim, the Tor Vergata model has been recently improved to take into account the coherent soil component in the specular direction - which is a function of the characteristics of the transmitting and receiving antennas -, and also the downward bistatic scattering of the vegetation canopy which is coherently reflected by the soil in a given observation direction.

Due to the lack of experimental data, validation of the bistatic simulations cannot be achieved by comparison with measurements, so that an indirect approach has been used: according to energy conservation, emissivity can be expressed as the complement of the integral of the bistatic coefficient extended to the upper half space. Therefore, the comparison of both backscattering and emissivity simulations with experimental data can be assumed as a way to infer the validity of the bistatic scattering model. In this work, we present the comparisons performed with multifrequency (L- to C-band) and multipolarization active and passive data collected over agricultural fields. Afterwards, bistatic scattering of the same vegetation canopies observed in several configurations is analyzed as a function of the scattering azimuth and elevation angles, searching for the sensor parameters (i.e., frequency, incidence and scattering angle, polarization) that optimize the sensitivity to the vegetation or soil parameters.

To this aim, the contributions coming from the various vegetation components are studied. Indeed, it will be shown that the effects of vegetation can be enhanced in particular bistatic configurations making retrieval or classification easier. On the other hand, at other bistatic configurations vegetation effects may be minimized, enhancing the properties of the underlying ground. For example, it is well known that the HV backscattering coefficient is smaller than the copolarized backscattering responses. If the scattering plane does not coincide with the incidence plane, the vertical and horizontal polarization planes will also change. In particular, when the plane of scattering becomes orthogonal to the plane of incidence, the relationship between co- and cross-polarized responses may reverse. Since this phenomenon is strong for soil and smoothed for the vegetation, the polarization responses may show different ratios with respect to the monostatic configuration. This property may have a significant impact when evaluating the potential performance of the bistatic radar, especially if simultaneous monostatic and bistatic observations are performed.

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