GPS? Not only to navigate! Territory monitoring using GPS signals reflected from the soil

The monitoring of the territory is important for many applications, including natural hazards monitoring (floods, fires, land and snow slides), traffic and pollution control, agricultural applications and in general to highlight any critical situations.
It can be done through several sensors, such as hygrometers to measure the soil moisture. However, these technologies need a very high number of sensors to be installed and maintained, which is costly and not practical. Therefore, remote sensing techniques are required, such as for instance radar techniques. The radar principle is to transmit an electromagnetic wave and receive the wave after its reflection on a surface: knowing the transmitted signal and analysing the reflected one, some characteristics of the surface itself can be retrieved.

Fig. 1. (a) Sensor prototype mounted on a manned aircraft. (b) Prototype in its carbon fiber case, a black airfoil structure. The sensor is screwed to the down-looking antenna at the bottom side, and to a rectangular black plate (trolley unit), at the top side. The trolley unit allows an easy and quick connection (both mechanical and electrical) of the sensor to the aircraft.

This principle can also be applied exploiting signal sources already existing for other scopes. As instance, the Global Positioning System (GPS), and more in general the Global Navigation Satellite System (GNSS), is made of tents of in-orbit signal transmitter, designed for navigation purposes. A GNSS transmitter (satellite) together with a receiver capable of processing GNSS reflected signals becomes a so called GNSS bistatic radar.

Depending on the power, delay and shape of the reflection some parameters of the surface can be retrieved, such as moisture, height, or roughness. From this, some interesting applications come: water basins and floods detection, soil moisture and vegetation monitoring, altimetry and ocean height measurements, snow and ice thickness estimate. This approach results in a simple, lightweight, low-cost and low-power instrumentation compared to a traditional radar equipment, which is bulky, expensive and requiring high transmitting power. The additional advantage of this technology is being independent from weather conditions and offering a wide coverage.

Fig. 2. Soil moisture estimates.

So far, many instruments based on the GNSS bistatic radar principle have been proposed in the literature. In this paper, we present the development of a new GNSS-based sensor prototype, used to classify lands according to their soil water content. The prototype is small, compact and lightweight enough to be mounted on board of Unmanned Aerial Vehicles (UAVs) and small manned aircraft, as Figure 1 shows. The hardware and software components of the prototype have been specifically designed to overcome the difficulties connected to the weakness and variability of the reflected signal, then mathematical models have been applied to retrieve the soil parameter. The prototype receives and stores both the direct signal from satellites using an up-looking antenna, and the reflected signals from ground with a down-looking antenna.

Figure 2 shows some results from a real in-flight data campaign over the countryside nearby Torino, in Italy. The colored dots are the reflection points of one GPS satellite (PRN 13), while the receiver is moving, on board of the aircraft. The dot color represents the measured moisture: dark blue stands for moisture content index (water surface), while red indicates close-to-zero moisture (dry soil). The dots lying on other areas show different colors according to the measured moisture. It can be clearly seen that the existing humid area close to the greater lake is clearly detected by the instrument.

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