TITLE OF THE RESEARCH ACTIVITY

Microwave RAdars and radiometers for drone-based Hydraulic Monitoring (**MiRAHM**)

STATE OF THE ART

Radars and radiometers are complex microwave apparatuses, historically adopted for remote-sensing and imaging purposes. The firsts (radars) are active sensors used to detect objects of different nature, to measure their distance and relative velocity (by the Doppler effects) and to locate or identify them. The seconds (radiometers) are passive sensors that reveal the microwave black-body radiation of the matter and, through this principle, they are capable to measure, in a contactless way, the (brightness) temperature of objects. Furthermore, since various molecule and atom resonances occur in the microwave range, microwave radiometers can identify specific substances such as the water vapor in the atmosphere. In addition, the long wavelength microwaves can penetrate through cloud cover, haze, dust, and even rain. Finally radiometers are at the heart of radio-telescopes and radioastronomy and the nowaday knowledge of the universe is also based on their discoveries: from the Cosmic Background Radiation (CMB) to the atomic hydrogen in stellar clouds and nebula.

Despite the widespread usage of radar and radiometers in ground and space-based platforms, their potential is not yet fully exploited in drones. The impressive advances of the radio-frequency hardware, mostly due to the progress of silicon microelectronic technologies, allow a new class of ultra-miniaturized radar/radiometer sensors to be conceived. These could be on-board drones to allow a number of exciting applications: monitoring the water level and surface velocity of rivers, early detection of forest fire, pollution monitoring, precision agricolture and many other.

Among these scenarios, the hydraulic monitoring of rivers is of particular relevance since these sensors can be adopted, in a IoT infrastructure, for floods prevention and risk management.The next challenge, indeed, is the extensive monitoring of rivers and, to this purpose, the unit cost of radar (radiometric) sensors should be reduced by one order of magnitude, i.e. from thousand to hundred euro. Since the most expensive item is the antenna, low-cost technologies (like planar technologies) have to be accepted in the sensor design at the expenses of some performance degradation.

The present Ph.D. research aims at exploring these novel possibilities: from the hardware conception of the sensors to their on-field exploitation. It will be carried-out within the National Research project "*IntEractions between hydrodyNamics flows and bioTic communities in fluvial Ecosystems: advancement in dischaRge monitoring and understanding of Processes Relevant for ecosystem sustaInability by the development of novel technologieS with fIeld observatioNs and laboratory testinG*" (ENTERPRISING), funded in 2019 by MIUR.

SHORT DESCRIPTION & OBJECTIVES OF THE RESEARCH ACTIVITY

The primary objective of the present Ph.D. research is to develop, experimentally validate and demonstrate on board drones a miniaturized, multi-mode radar/radiometer sensor equipped with frequency scanning antenna. The two basic ideas are: i) since radars and radiometers share most of the front-end devices and electronics, a multi-mode sensor can be devised in such a way to increase miniaturization; ii) a frequency scanning antenna array can be used in both cases to provide an imaging capability without the complex (and costly) electronic of a phased array.

Along this line there are several open problems, requiring a deep investigation. The major open issues from the radar point of view are: modeling of FMCW radars with frequency scanning antennas; development of leakage cancel circuits in the FMCW mode; noise caused in the Doppler mode by the drone blades and its reduction; data processing in order to reconstruct the image. The major open issues from the radiometer point of view are: modeling of microwave radiometers with frequency

scanning antennas; singal processing of the radiometer data and image reconstruction; new calibration circuitry. Novel and original results are expected for each of the above issues.

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