# Operational Challenges of the Multibeam Radar Sensor BIRALES for Space Surveillance

**Giuseppe Pupillo[(1)], Germano Bianchi[(1)], Andrea Mattana[(1)], Giovanni Naldi[(1)], Claudio Bortolotti[(1)], Mauro Roma[(1)], Marco Schiaffino[(1)], Federico Perini[(1)], Luca Lama[(1)], Matteo Losacco[(2)], Mauro Massari[(2)], Pierluigi Di Lizia[(2)], Alessio Magro[(3)], Denis Cutajar[(3)], Josef Borg[(3)] and Fabio Monaci[(4)]**

[(1)] INAF -Istituto di Radioastronomia, Via Gobetti 101 – 40129 Bologna (Italy)
[(2)] Dept. of Aerospace Science and Technology, Politecnico di Milano, Via G. La Masa 34, 20156 Milano (Italy)
[(3)] Institute of Space Sciences and Astronomy (ISSA), University of Malta, (Malta)
[(4)] Italian Air Force (ITAF), Viale dell'Università 4, 00185, Roma (Italy)

## ABSTRACT

Space debris population is growing and it is recognized as one of the main threats for satellites orbiting around Earth. Therefore, monitoring the space debris environment has become a key issue in the context of all space activities.

The Italian multibeam BIstatic RAdar for LEo Survey (BIRALES) sensor has been developed in the frame of the European Space Surveillance and Tracking (SST) Support Framework. In this work, we present the novelties of this sensor and we give an assessment of the BIRALES performance as resulting from recent observation campaigns.

The transmitting part of BIRALES is located in Sardinia (Italy) and it consists of a 7 m in diameter fully steerable dish equipped with a UHF transmitter able to radiate continuous wave and chirped signals at the same time. The BIRALES receiving part is composed of a fraction of the large Northern Cross radio telescope array located at Medicina (near Bologna, Italy). Currently, BIRALES uses 8 among the 64 parabolic cylindrical reflectors of the North-South arm of the Northern Cross. The cylinders are steerable in elevation only along the local meridian and they are equipped with 4 receiver each. From the 32 raw signals, a dedicated pipeline generates 24 independent beams (multi-beam) covering the BIRALES instantaneous field-of-view (FoV) and performs a real-time detection/measurement of the echo in each beam. Each detected target (space debris, satellite, etc.) passing inside the array FoV produces a given beam illumination sequence. Consequently, together with the classical bistatic range and Doppler shift measurements, we can estimate the object angular path inside the sensor FoV during the passage. The angular path estimation is hindered by the complex gain pattern of the antenna, which feature several lobes for each beam whose gain depends on the sensor elevation. Therefore, a suitable algorithm for track reconstruction has been implemented to solve the resulting ambiguities.

After track reconstruction, the estimated angular path is coupled with the measured slant range and Doppler shift profiles to perform an initial orbit determination (IOD). The availability of such a plethora of information offers the possibility of performing IOD with a single passage of an object inside the sensor FoV.

This work describes the challenges faced during BIRALES sensor setup and operation. The results obtained during recent observation campaigns will be presented, focusing on both measurements validation and IOD performance in tracking and survey mode. Finally, the performance of the sensor in terms of observation capabilities is illustrated.