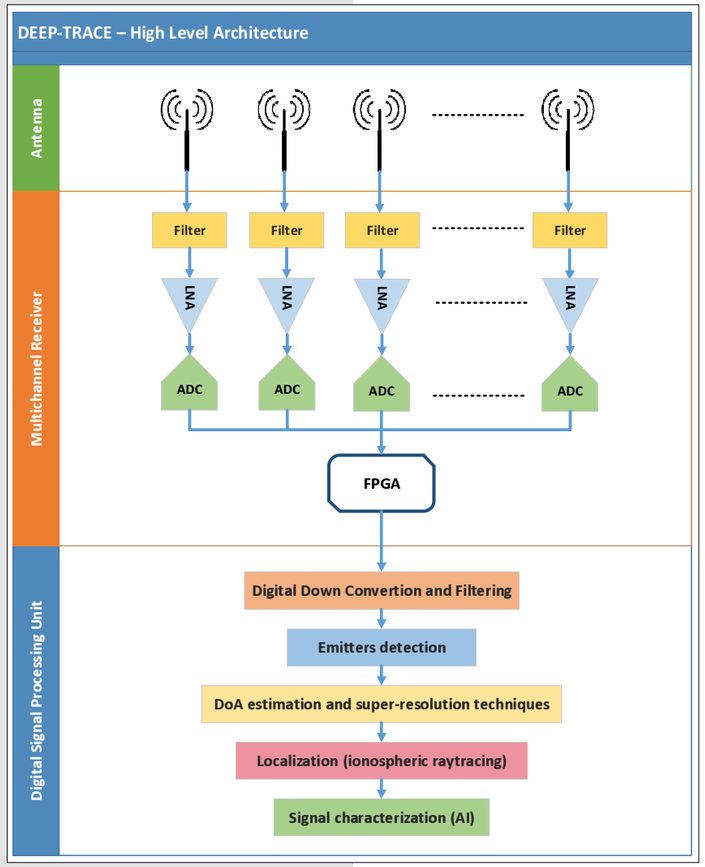
PROJECT DEEP-TRACE

Deployable performing HF radio goniometer compact system for C-ESM applications

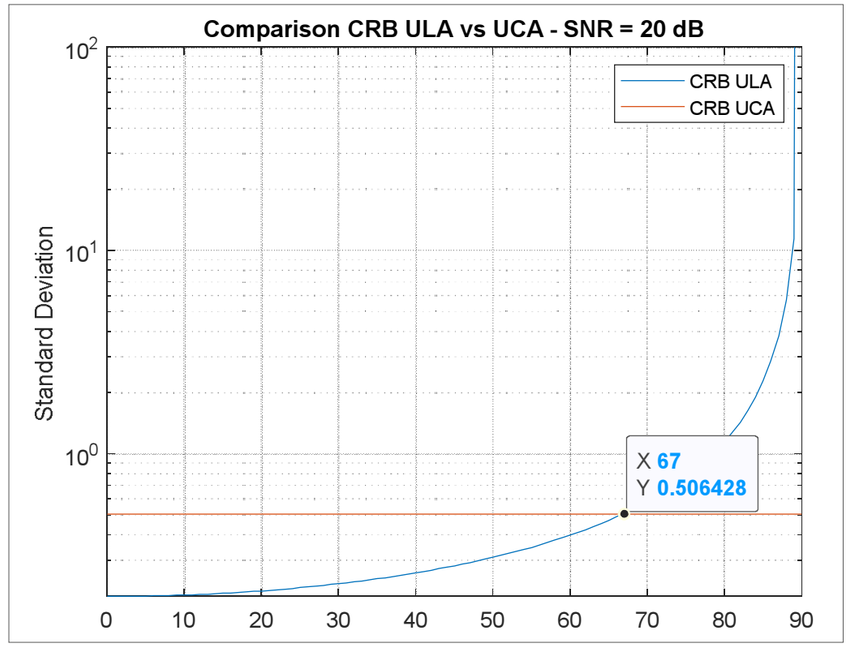
The DEEP-TRACE project aims at realizing a multi-channel system based on an array of compact receiving antennas for receiving, digitizing and analysing HF band signals for C-ESM applications. This configuration is conceived to cope with compactness, easy deployment, modularity and scalability requirements.
The proposed technological solution allows to estimate the direction of arrival (DoA) of the received signals, to characterize the signal through the use of Artificial Intelligence (IA) techniques and to localize the source making use of 3D ionospheric propagation models for the signals transmitted in sky-wave mode. This system could be used individually or in a multi-sensor / multi-platform configuration. This last configuration, appropriately dislocated, will allow the geolocation of the HF source, regardless of the type of propagation (sky-wave or surface-wave).
The main innovative aspects of this proposal are:

1) An accurate miniaturization of the antennas combined with the use of an active and flexible adaptation, able to use the radiating elements in array configuration to be deployed both in the terrestrial environment (urban or not) and naval;
2) Implementation of different DoA estimation techniques even in the presence of a limited number of sensors, and comparison of their performance in terms of mean square error of estimate and robustness to mismatches between design conditions and actual conditions determined by the ionospheric channel;
3) Positioning techniques of the individual receiving nodes in a sensor network configuration. The techniques adopted will optimize the spatial configuration of the nodes in order to minimize the Cramer-Rao limit on the DoA estimate;
4) Localization based on 3D ionospheric propagation models able to reconstruct the e.m. path from the receiver to the transmitter through the ionospheric channel;
5) Artificial Intelligence (IA) for classifying the detected signal (e.g.: type of propagation, continuous / pulsed wave, modulation, etc.).

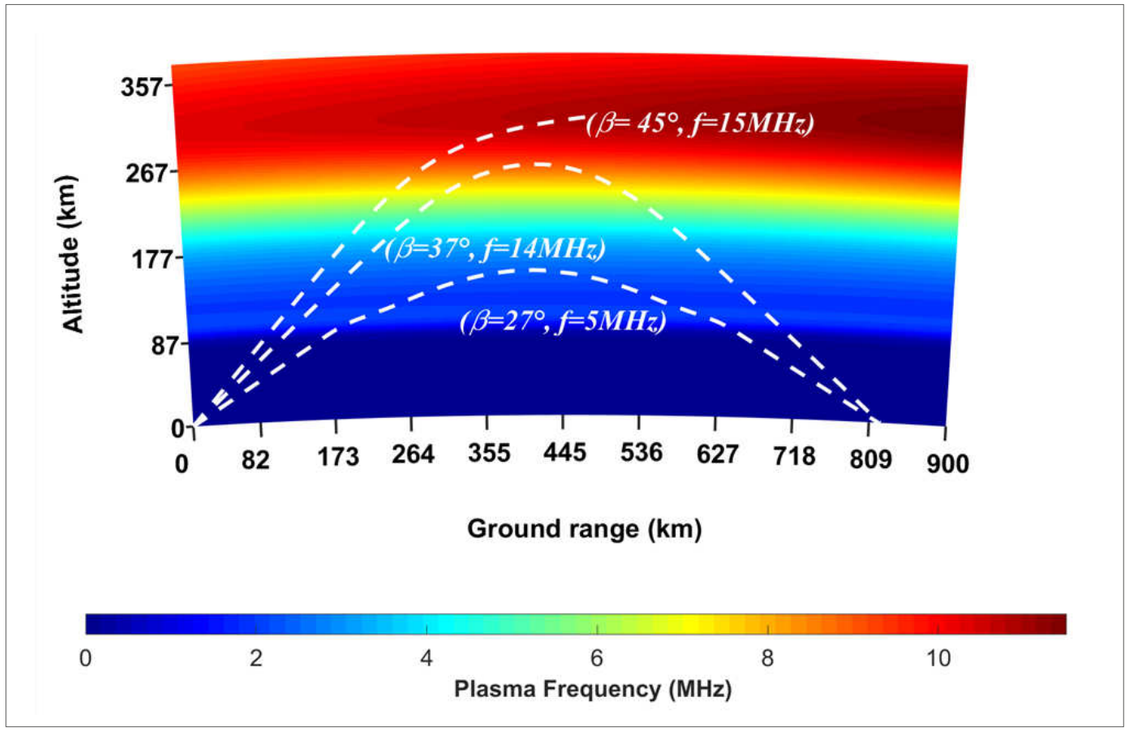
Technical Sheet
Funding institution:
Italian MoD
Project partners
ECHOES s.r.l., FreeSpace s.r.l
Project duration
June 2021 – June 2024
Involved countries
Italy



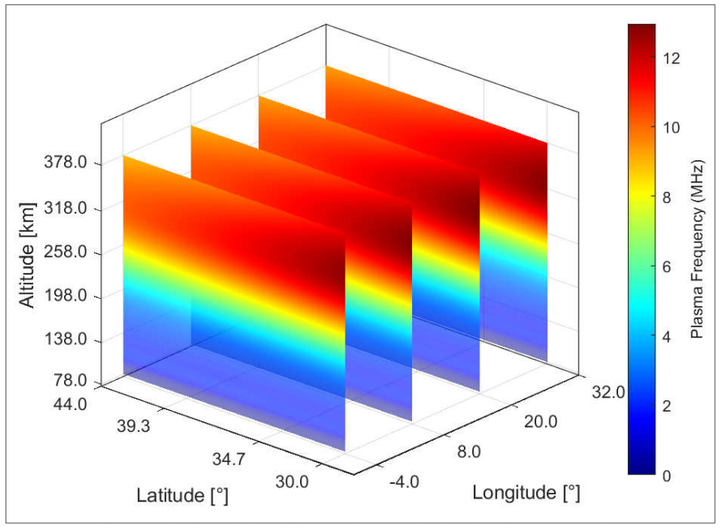
(a) DEEP-TRACE High-level architecture



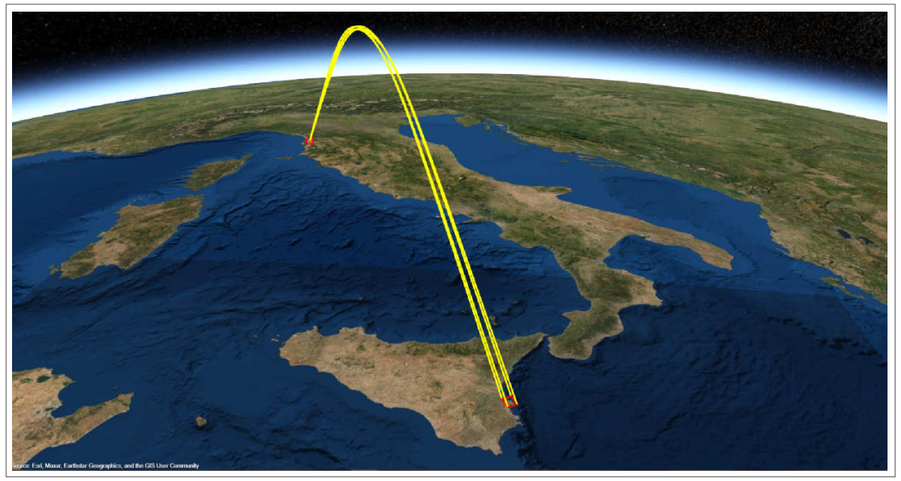
(b) Beamforming performance comparison: Uniform Linear Array (ULA) vs Uniform Circular Array (UCA) (SNR=20 dB)



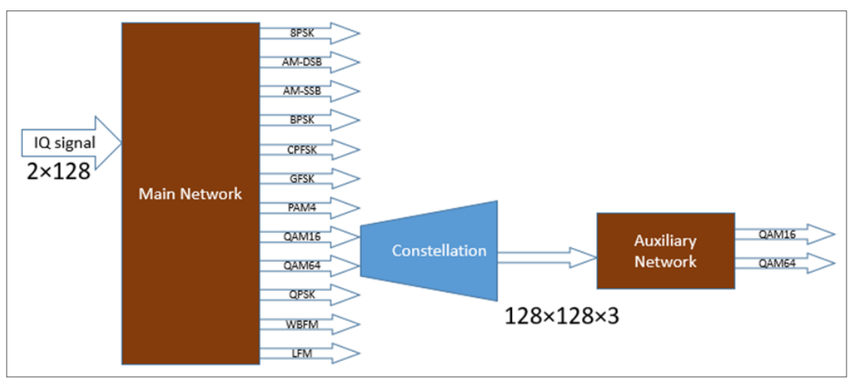
(c) Electron density profile and ray-paths formation related to the reference scenario



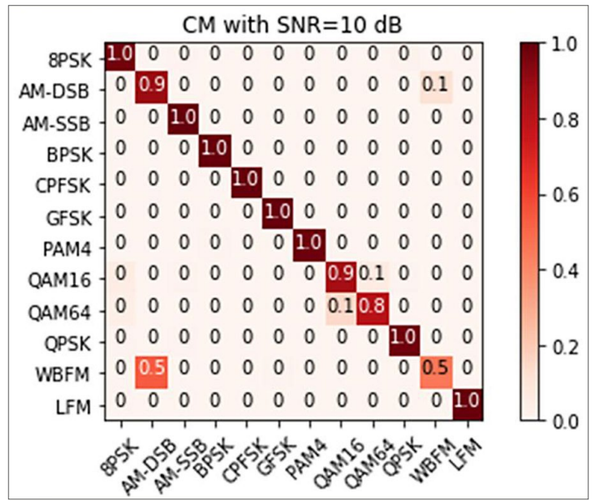
(d) Longitude slices of the 3D Electron density related to the reference scenario



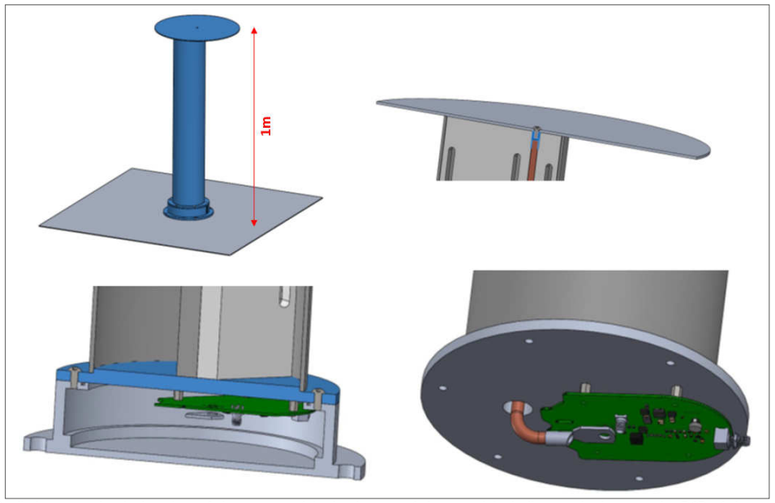
((e) 3D ray tracing outcome for the transmitter localization in the reference scenario



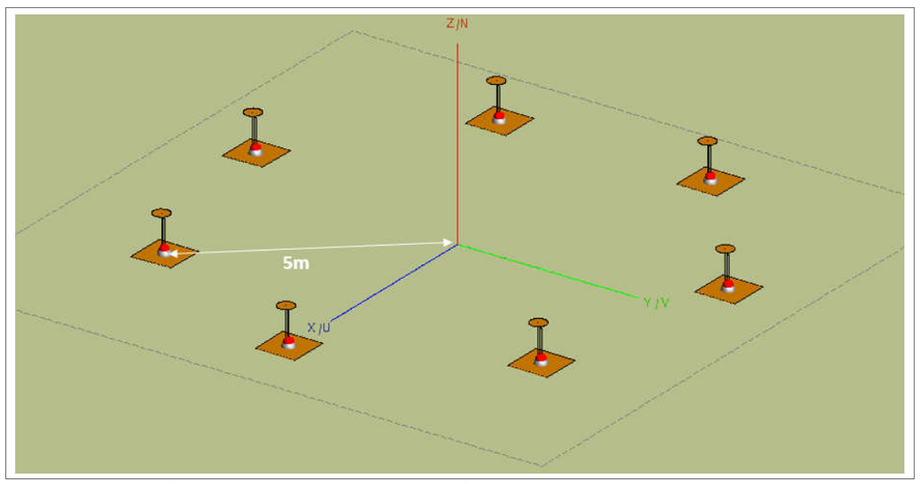
(f) The CNNbased automatic modulation classification architecture. The auxiliary network resolves the ambiguity between the two similar modulations (QAM16, QAM64) to enhance the overall accuracy



(g) The confusion matrix of the proposed automatic modulation classification architecture at SNR=10dB



(h) Preliminary mechanical project of the antenna (single element of the array) including, at the bottom, the PCB of the amplifier performing the matching with the front-end of the receiver. The antenna is very compact having an overall dimension of about 1m



(i) EM model of the circular array for the DOA estimation. The array diameter is about 10m and it can be easily deployed in the operative scenario due to the compact antennas