SARape: Miniaturized Synthetic Aperture Radar for UAV’s

The airborne monitoring of civilian and military scenes using unmanned aircraft is becoming increasingly important. Here, the dimensions and mass of the imaging sensor system play a decisive role.

The SARape project (Synthetic Aperture Radar for all weather penetrating UAV Application) focused on the development of a miniaturized SAR system which is optimized for utilization in a UAV (Unmanned Aerial Vehicle) with a low loading capacity. This not only requires a compact and light radar sensor but also a corresponding signal processing and telemetry unit. Another focal point of the project was the development of an efficient and robust SAR processor that is capable of producing fully focused, high resolution images in real-time in spite of the unstable flight conditions in small unmanned aircraft. The concepts of the individual components are largely known, but the combination and utilization of these components in a miniature drone is completely new. In this context, particular reference can be made to the high bandwidth and the very good resolution which have yet to be rivaled in the UAV area.

The project resulted in the creation of a highly developed SAR system which meets all modern civilian and military requirements. The real-time capability of the system opens up a broad range of applications and the radar’s output power of 100 mW is sufficient for a range of several hundred meters. Thanks to the utilization of a high transmit frequency of 94 GHz, the sensor is also suitable for the detection of small-scale objects and a very high resolution of 15 cm x 15 cm can be achieved when used in combination with modern FMCW generation with a high bandwidth (up to 1 GHz) and small antennas. A further advantage of millimeter waves is their reduced susceptibility to image errors caused by multi-path propagation. SARape was developed as a two-channel receiver which allows polarimetric and interferometric measurements. The good signal-to-noise ratio of the receiver guarantees optimal image contrast. To ensure a sufficient bandwidth for the data transmission, the signal is digitalized on board in the preprocessor and converted into baseband. In this way, the two signal channels and the navigation data can be transmitted parallel and the complexity of the data evaluation process can be reduced. The digital data transmission takes place in 2.4 GHz band (WLAN) with a transmit power of approximately 1 watt, thus eliminating the need for special approval procedures.

The combination of the developed SAR processor and a high-precision inertial system (IMU) paves the way for real-time imaging. An extensive database for potential unmanned platforms - which allows the selection of the best possible UAV for a range of scenarios - was also created within the framework of the project.

The SARape consortium, which comprises five partners from four European countries (Germany, Poland, Hungary and Cyprus), was formed under the auspices of the European Defense Agency (EDA). Each partner brings a core competence to the consortium. In its role as consortium leader, FHR is responsible for project management. Moreover, the system concept and the radar front-end were developed in Wachtberg, where the overall SARape system was also integrated and tested. Fraunhofer IAF was responsible for the design and production of the HF components required for the front-end. The preprocessor for signal processing and conversion came from Hungary (Pro Patria Electronics) and the telemetry unit for digital data transmission was developed in Cyprus (University of Cyprus). The Technical University of Warsaw assumed responsibility for the development of the real-time SAR processor and was also responsible for data recording and analysis. A further consortium partner from Hungary (Slot Consulting) handled the programming of the UAV database and media management.
The capabilities of SARape were impressively demonstrated during test measurements and within the framework of a system presentation for invited guests from industry and the Ministry of Defense. A real-time evaluation of the signals and the creation of a "SAR video" was possible up to a distance of 4.5 km between the transmitter and the receiver. The ultra-light aircraft "Dolphin", which is owned by the institute, was used for the measurement flights in September and October (see Fig. 1).

Fig. 2 shows the integrated SARape system (radar front-end, IMU and preprocessor) with overall dimensions of approx. 8 cm x 35 cm x 15 cm (H x W x D). Figure 3 demonstrates the high resolution using a SAR image of the FHR premises. Figure 4, outlines the main subsystems of SARape as well as the participation of each partner in the project.
Fig. 3 SARape high resolution image

Fig. 4 SARape system subsystems and partner participation
Fig. 5. Phased-locked Oscillator unit manufactured by ENAL
Fig. 6. Photograph of internal configuration of telemetry unit as manufactured by ENAL.

Fig. 7 Completed Telemetry Receiver, Transmitter and receive antenna unit.