OVERVIEW OF THIRD GENERATION SPACEBORNE X-BAND SYNTHETIC APERTURE RADAR (SAR)

Abstarct

The deployment of advancedSynthetic Aperture Radar (SAR) observationcapabilities from spacerepresents a keyelement for militarysurveillance of borderareas, support in criticallogisticstheatres and the collection of national security intelligence. Modern security and defenceoperationalmodels use the Intelligence, Surveillance and Reconnaissance (ISR) functionasone of the essentialresourcesnecessary to acquire a detailed and accurate situationalpicture, useful for obtainingvaluable information to support decision-making, at a strategiclevel, operational and tactical. SAR satellites are one of the keysolutionscontributing to the implementation of an eŒective ISR capability, helping to enhance the protection of militaryforces and assets in the field.

In thiscontext, itisclearthat the quality of the information provided to the userobviouslydepends on the performance capabilities of the SAR system and, atmost, on those of the instrumentthatconstitutesitsheart. Thispaperpresents a fewengineeringsolutionsthat can be evaluated in the perspective of a next generation of high-performance SAR instruments, in order to push performance beyond the current state of the art, improving the quality of intelligence and reconnaissance information and extendingitsoperationalpurpose in support of nationaldefence and security. In particular, the possibility of overcoming the currentlimits of the resolutionachievable over wide swathwidthsisaddressedasone of the keyobjectives to be pursued for these new generation advanceinstruments. Thispaperdescribes an example of X-band SAR solutionimplementingthiscapability and itsachievable image quality performance. The proposedexamplehas no claim to exhaustivenessbutitisuseful in portending the significantrepercussionsthat the architecturalfeaturespresentedcouldhave for Imagery Intelligence (IMINT) applications.

Instrument Design

The current generation of spaceborne X-band SAR instruments can acquiremicrowave images with medium geometricresolution (~3 m) and medium swathwidth (~30 km) whenoperated in Stripmap. Theseinstrumentsalsoofferacquisitionmodes to optimizeresolution (Spotlight-basedmodes) or swath (ScanSAR-basedmodes), butimprovingone of thesetwoparametersalwayscomesat the expense of the other. On the otherhand, modern remote sensingapplicationsrequireimprovingbothresolution and swathwidth, and complementingthem with significant performance in terms of NoiseEquivalent Sigma Zero (NESZ) and Distributed Target Ambiguity Ratio (2D-DTAR).

Figure 1 reports azimuthresolution vs. swath-width SAR performance of actual Instruments (Cosmo Second Generation and TerraSAR-X) vs. target performance for the third generation ones.

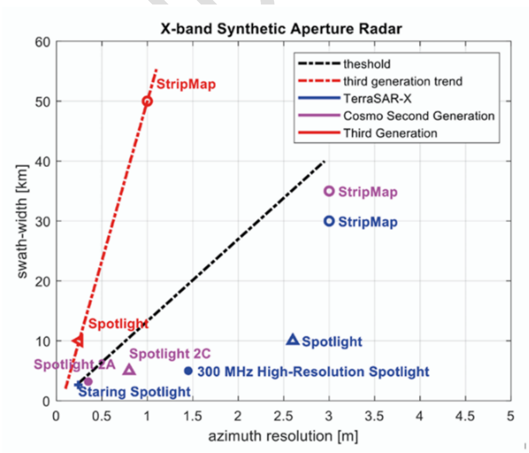

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Figure 1 - X-band SAR Instrumentswath-width vs. azimuthresolution: comparisonbetweenpresent and third generation

High geometricresolution performance over a large area can be achievedby applying innovative radar acquisitiontechniques, suchasScan-On-Receive (SCORE) and Multiple Azimuth Processing (MAP), whichhavebeenproposed in the recentyears in order to overcome the theoreticaltrade-oŒlimitsconstrainingresolution and swathwidth in SAR instrumentsemploying standard acquisitionmodes. For example, by usingthesetechniques the SAR can be designed to meet a tar getresolution of 1 m and a swath of 50 km in StripMap and 10 km in Spotlight, establishing the conditions for exceeding the performance limits of the current generation.

Performance

The considered SAR instrumentisassumed to be equipped with a planar activephased array antenna. In addition, the proposed SAR Instrumentimplements the following innovative acquisitiontechniques:

- Digital Beamforming (DBF) to implement Digital SCOREs, at the purpose of maximising the receive antenna gain and thereforeimproving NESZ and range DTAR.
- AP implementedatdigitallevel in SAR Electronic Sub-system (SES), for improvingazimuth DTAR.

Figure 2 shows an example of values of NESZ achievable in Stripmap by implementing the aforementionedtechniqueswhile Figure 3 shows the relatedcurves of 2D-DTAR. The examplerefers to an accessregioncovering the range of incidenceangles 20÷60 deg. These plots show that a worstvalue of NESZ in the order of -20 dB and 2D-DTAR up to -18 dB are achievable over the consideredaccessregion. The mentioned performance iscomputedat an orbitaltitude of 619 km.

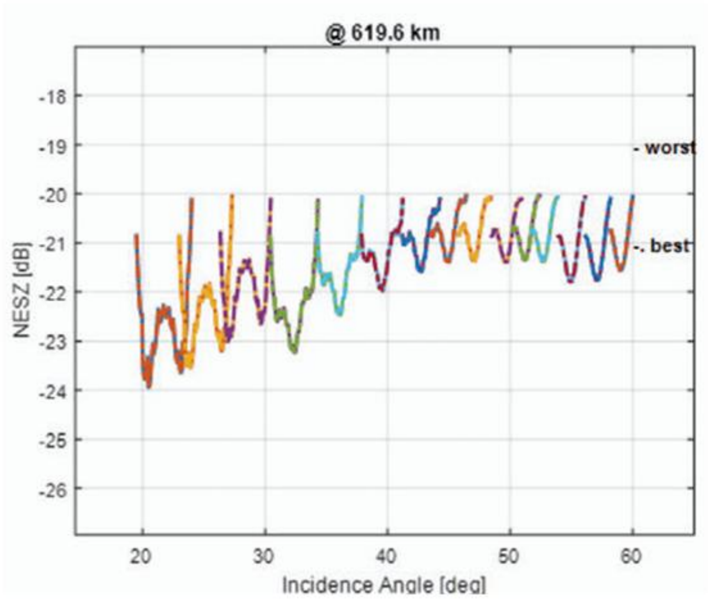

Figure 2: SAR Stripmap NESZ performance

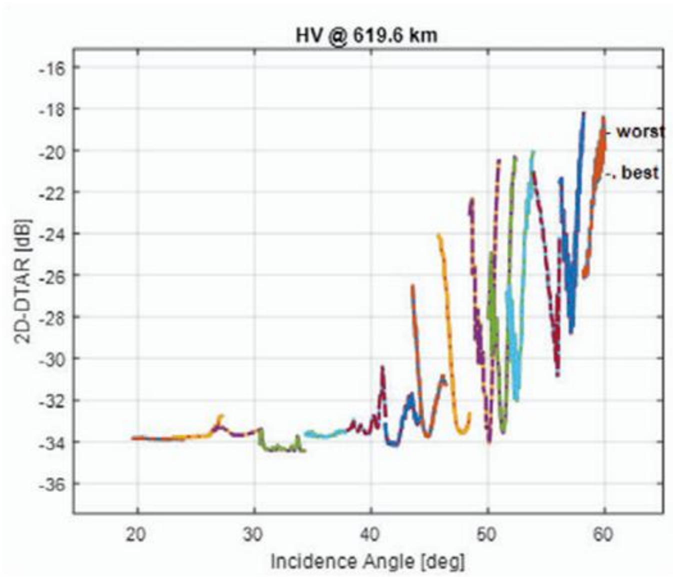

Figure 3: SAR Stripmap 2D-DTAR performance

Instrument Architecture

The functionalarchitecture of the consideredinstrumentisshown in Figure 4. The instrumentconsists of twomain sub-systems: SAR Electronic Sub-system (SES) and SAR Antenna Sub-system (SAS).

Within SES, the digitalunit (DGU) isconceivedas a modular unit, developed tomanage a large number of receiverchannels for supporting the acquisitiontechniques of SCORE and MAP. According to aconsolidatedapproach, thisunit can be split in twoecho-processing layers. A First Stage Processor (FSP) module can implement a first level of processing including: signalsampling, filtering, and decimation, signalcompensation and digitalbeamforming. A Second Stage Processor (SSP) module can be used to complete the processing of the FSP and to perform multi-channelcalibrationalgorithms for supporting DBF at the aim of implementing SCORE and echo data compressionalgorithm (Automatic BAQ developed by TAS-I). SAS requires to be controlled by a dedicated Antenna Controller and Processor module (ACP). ACP can be usedalso to control the internal SAR Instrumentunitsand to communicate with the Platform (P/F). The RF unit (RFU) within SES assures the signalconditioning to adapt the transmitted and receivedsignalsbetween DGU and SAS. In between, a unit (SCSU) isrequired for splitting/combining and switching the signals, and for managingredundancypaths. For eachreceivingpath, RFU implements: signalmatching, filtering, amplification, gain control, and adaptive down-conversionschemesbased on the diŒerentobservationmodes of the instrument. The internalfunctions of SAS can be assumed to be distributedamongfiveassemblies: Radio Frequency, Power, Command and Control, Mechanical, and Thermal assemblies. The electricalfunctionsincluded in the first threeassemblies can in turn be assigned to the following set of units, which are typical of a SAR activephased array antenna: Tile Control Unit (TCU), Tilepower Supply unit (TPSU), Electronic Front-End (EFE), True-time Delay Line (TDL), Radiating Board (RB), BeamForming Network (BFN), and DC Harness.

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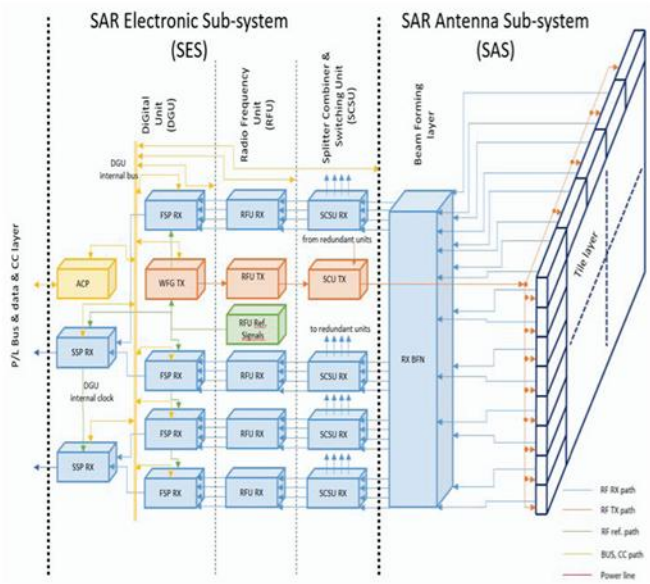

Figure 4: Example of SAR instrumentfunctionalarchitecturecomprisingtwomainsubsystems: SES and SAS.

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