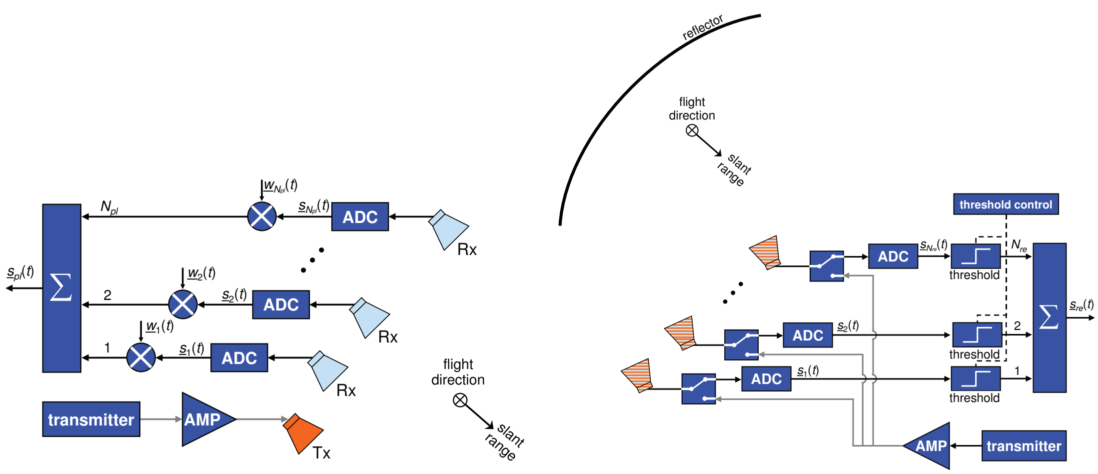
DIGITAL BEAM-FORMING FOR SPACEBORNE REFLECTOR- AND PLANAR-ANTENNA SAR — A SYSTEM PERFORMANCE COMPARISON —

Marwan Younis, Sigurd Huber, Anton Patyuchenko, Federica Bordoni, and Gerhard Krieger

Microwaves and Radar Institute, German Aerospace Centre (DLR)
E-Mail: marwan.younis@dlr.de

1. ABSTRACT

Synthetic aperture radar (SAR), utilizing digital beam-forming, is increasingly being considered for future missions. This is evident both from research activities and space qualified technology demonstrations [1, 2]. These systems will comprise multiple digital channels, where the analog-to-digital converter is moved closer to the antenna. This dispenses the need for analog beam steering and by this the used of transmit/receive modules for phase and amplitude control. One of the reasons for this trend is that state-of-the-art SAR systems can not fulfill the heterogeneous demand on products at the required performance level. The motivation for using Digital Beam-Forming (DBF) techniques is their ability to provide a simultaneous wide swath (coverage) and high resolution [3]. Systems utilizing the various forms of digital beamforming, such as SCan-On-REceive (SCORE) [4] or multiple azimuth receive channels [5] are jointly referred to as SMART, which stands for Smart Multi-Aperture Radar Techniques. In the most general sense SMART sensors allow a relaxation of the system design parameters, by increasing the degrees of freedom. Specifically, for a given geometric resolution SMART yields systems with higher Signal-to-Noise Ratio (SNR) and lower ambiguity-to-signal ratio [6, 7], both being key requirements on SAR systems. Equipped with digital receive channels, SMART sensors do do not require phase and amplitude control of the received signals (beam-forming), this yields an RF hardware free of transmit/receive modules and the complex control and calibration units. Instead, SMART will push the development of on-board digital signal processing capable of handling multiple channels of high data rate.



(a) planar system (b) reflector system

Fig. 1. Schematic architecture of planar and reflector systems showing multiple channels in elevation; some components such as LNAs, mixers, filters etc. are not shown to maintain a clear representation.

An arising topic is the benefit of combining digital beam-forming techniques with new antenna architectures specifically reflector antennas. A deployable reflector is attractive because it requires little space in the launcher while yielding a large aperture in space. Several examples of successful deployment and operation exist for communication satellites. The paper addresses the topic by comparing a planar antenna to a reflector system. The use of SMART in conjunction with two antenna concepts is discussed. On one side a planar array, consisting of a single small transmit antenna and a receive antenna array with multiple sub-apertures in elevation, as shown in Fig. 1(a) is considered. The array is equipped with digital receive channels and on-board digital beamforming is performed on the data. On the other side we consider a reflector antenna with a feed consisting of multiple transmit/receive elements in elevation, shown in Fig. 1(b). Here beam-forming is performed both on transmit and on receive by selecting the active elements of the array. Both systems can provide high resolution and wide coverage, however the implementation and the resulting requirement on system resources are different.

The paper starts by describing the system architectures and design for each of the planar and reflector system, respectively. This is followed by an analyzes and comparison of the system concepts in terms of realization complexity, space suitability, hardware issues, and digital processing requirements. Further elaboration yields the resulting SAR performance of both systems, which is presented together with related requirement on system resources such as average transmit power. By this, the paper considers multiple novel aspects of digital beam-forming SAR system design, which jointly flow into the presented system performance.

2. REFERENCES

[1] Gerhard Krieger, Nicolas Gebert, Marwan Younis, Federica Bordoni, Anton Patyuchenko, and Alberto Moreira, "Advanced concepts for ultra-wide swath SAR imaging," in *Proc. European Conference on Synthetic Aperture Radar EUSAR'08*, Friedrichshafen, Germany, June 2008.

[2] Christian Fischer, Christoph Schaefer, and Christoph Heer, "Technology development for the HRWS (High Resolution Wide Swath) SAR," in *International Radar Symposium IRS'07*, Sept. 2007.

[3] Marwan Younis, Christian Fischer, and Werner Wiesbeck, "Digital beamforming in SAR systems," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 41, no. 7, pp. 1735–1739, July 2003.

[4] Martin Süß, Bernhard Grafmüller, and Rolf Zahn, "A novel high resolution, wide swath SAR," in *Proc. Int. Geoscience and Remote Sensing Symposium IGARSS'01*, 2001, vol. 3, pp. 1013–1015.

[5] Gerhard Krieger, Nicolas Gebert, and Alberto Moreira, "Unambiguous SAR signal reconstruction from non-uniform displaced phase centre sampling," *IEEE Geoscience and Remote Sensing Letters*, vol. 1, no. 4, pp. 260–264, Oct. 2004.

[6] Marwan Younis, Federica Bordoni, Nicolas Gebert, and Gerhard Krieger, "Smart multi-aperture radar techniques for spaceborne remote sensing," in *Proc. Int. Geoscience and Remote Sensing Symposium IGARSS'08*, Boston, MA, USA., July 2008.

[7] Nico Gebert, Gerhard Krieger, and Alberto Moreira, "Digital beamforming on receive: Techniques and optimization strategies for high-resolution wide-swath SAR imaging," *IEEE Transactions on Aerospace and Electronic Systems*, 2009, accepted for publication.