KA-BAND APPLICATIONS FOR REMOTE SENSING FROM SPACE

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ABSTRACT

The escalation in using higher frequency band of electromagnetic spectrum have proceeded along with the exploitation of data collected from space platforms for new applications.

Recent technological developments, mainly spun-off from the telecommunications field, have shown that feasibility could exist within the next decade (2010-2020), in defining, designing and developing remote sensing techniques and related instruments for both for Earth Observation and interplanetary explorations.

This paper will describe the Thales Alenia Space Italia experience in this field.

1. INTRODUCTION

The effectiveness of ka-band has been demonstrated in the recent years for airborne Radars, where extensive use has been done in Unmanned Aerial Vehicle (UAV) mainly.

Technological issues up now days have prevented the use of ka-band for space applications, even if many experimental instruments in the same frequency band have been exercised for telecommunications.

The domain of microwave remote sensing from space has been based on lower frequency bands. For instance, X-band instruments on Cosmo-Sky-Med from Italy and the German TerraSAR-X satellite are in orbit and produce high resolution images. Few C-bands SAR are in orbit (e.g. ENVISAT, RADARSAT) and in progress, such as GMES Sentinel-1. Multi-frequency band instruments are under study in Europe e.g. X/ku-band (CoRe-H2O), in ESA Earth Explorer mission.

In the recent years, various spaceborne ka-band concepts have been proposed, especially for conventional and wide swath interferometric applications. Due to its short wavelength ka-band could allow reasonable baseline lengths for interferometry from a single platform which would be difficult to achieve at lower frequency radar bands. For interferometric applications the electrical baseline is directly proportional to the frequency of use for a given mechanical length, thus the ka-band allows reasonable baselines from a single platform difficult to achieve at lower radar bands. The main features of a ka-band is radar interferometry which fit well in civil security application which are key for cartography, the generation of Digital Elevation Models (DEM) and the monitoring of disaster such as earthquakes, floods, industrial accidents and humanitarian crises. Potential applications related to science and environment issues include the monitoring of snow layer thickness and accurate height measurements over vegetation, since at ka-band the signal reflection occurs mostly at the top of the snow or tree canopy.

Thales Alenia Space has recently proposed the adoption of AltiKa as a new class of radar altimeter allowing the compatibility with microsatellite. The selected frequency (35.75 GHz) avoids the need for a second frequency to correct the ionosphere delay. NASA’s Jet Propulsion Laboratory (JPL) is involved in the definition of ka-SAR interferometer for Glacier and Land Ice Surface Topography (GLISTIN) based on Digital Beam Forming techniques for mapping the surface topography of glaciers and ice sheets. In the following they are summarized main pro’s and con’s in using ka-band.

According to the ITU regulations 500 MHz of bandwidth is available in ka-band allowing very high resolution imaging down to sub-meters or multi-looking instruments with reduced resolution but higher radiometric accuracy. Ka-band frequency allows to reduce the antenna dimension, which is an important issue with respect to cost and accommodation aspects. The achievable antenna gain at ka-band is proportional higher compared to longer wavelength for same mechanical area and can be used for recovering signal to noise loss. Considerable advantages which came from high-frequency are related to the scattering proprieties, because of this shorter wavelength, the signal reflection takes place closer to the surface for volume scatterers; in addition the backscatter coefficient is significantly higher at this frequency and allows to increase the accuracy of height measurements. It is possible to verify that the backscattering coefficient appears to be less dependent from incidence angle at high frequencies with respect to lower ones. On the other hand, these appealing features need to be traded against some limits that are peculiar to this range of frequencies.

Main concern is about propagation effects which reflect in higher attenuation and phase disturbances [3]. The instrument sensitivity (Noise Equivalent Sigma Zero) is a crucial point in the definition of ka-band instruments, due to the small wavelength, which could impact on the definition of satellite orbit lower than the orbits chosen for X-band or C-band radar. Due to the lower antenna dimension, the PRF to be used, will limit the swath dimension pushing to envisage and to apply wide swath acquisition techniques.

Whereas propagations constraints ka-band waves propagation (it is the case of many interplanetary missions) can be neglected, advantages of this band are evident and cons have a minor impact in the instrument definition.

Thales Alenia Space Italia, for interplanetary mission, is developing an Approaching & Landing Radar for the ExoMars mission; whereas for Earth observation ESA is performing studies to develop new radars for interferometric applications.
2. INTERPLANETARY MISSION

Thales Alenia Space Italia is currently involved in the B phase of ExoMars mission in order to design and develop the ka-band Approaching & Landing Radar (ALR) towards the Mars’ surface within the first Flagship mission foreseen by the Aurora Programme; the current European Space Exploration Programme [5].

The objective of the 2016 mission is to demonstrate European capability to land a surface package on Mars. The ALR will be part of the descent module and it shall provide two information: altitude and velocity vector for guidance in descending phase from 3 km height down to surface.

The ALR is a pulsed CW radar, based on the transmission of a narrow un-modulated pulse and the reception of the corresponding echo scattered from the terrain. The temporal characteristics of the received echo (time delay and shape) are exploited in order to retrieve slant range distance, while the complex correlation of received echo (time delay and shape) are exploited in order to retrieve Doppler component. For this reason, the ALR design foresees a unique transmitting chain and a unique receiving chain, connected through a switch matrix to four antennas: one dedicated to range measurement, the other three antennas used to perform velocity measurements. A pictorial view of the measurement configuration is reported in Figure1.

**Figure 1 - ALR measurement configuration.**

The antenna beam dedicated to range measurement is characterized by its own observation parameters (persistence time, PRF) and radar waveform parameters (pulse width).

The selection of different parameters relevant to range and Doppler frequency estimation comes from the constraints about the non-ambiguity, since a unique selected PRF value cannot meet both requirements on range and velocity ambiguity intervals.

Size and mass considerations have suggested using high frequencies (i.e. short wavelengths) in order to use smaller microwave components and to limit the antenna size needed to get the desired beam width.

On the performance side, the main arguments that have been taken into account are:

- the model selected to represent Mars’ surface behaviour -the Hagfor model- at ka-band frequencies provides a small range of variation for σ₀ and also an higher absolute level almost independent by observation angle;

- the selected approach to velocity measurement - the Doppler shift of the radar backscattered signal due to EDL module moving respect to the Martian surface- is a linear function of the carrier frequencies and the ka-band has demonstrated to guarantee the requested velocity measurement resolution and accuracy;

- the requested narrow antenna beam at ka-frequencies provides the requested narrow beam in order to increase antenna gain and to improve measurement accuracy.

The ALR preliminary mass budget is of about 12 kg and the DC power budget is of 35 W.

3. EARTH OBSERVATION

Thales Alenia Space Italia replied to the Invitation to Tender “Study into Ka-band SAR”, requested by ESA, to study the feasibility in using ka-band for Earth Observation applications. The high achievable resolution in this range of frequency makes this study appealing for several applications [2]. On the contrary, because of the high satellite orbit (i.e. 500-800 Km), the high power required for this application push for improvement of the current available technologies. The ka-band is characterised by a small penetration, thus its principal use will be the generation of DEM to trace surface motion and flows. In particular this application will be useful for disaster monitoring and earthquakes.

The potentials of Differential SAR Interferometry for such applications have been proven since the very initial studies, demonstrating the feasibility of monitoring deformations and motions with high accuracy. Another area of interest will be the Oil spill detection, in particular the identification and separation of the dark areas correspondent to oil slicks on the sea surface is being carried out using SAR data as operational programs exist for the systematic detection of oil slicks in the sea. In fact, oil dampens capillary surface waves and thus reduces the backscatter value. Oil spills can be detected when the wind is strong enough to create those capillary waves to be dampened and weak enough not to destroy this effect for the surface turbulence. The use of ka-band will reduce the minimum wind speed necessary for the observations.

Finally, there is a very wide literature on ship detection and classification, by exploiting different ideas and methodology. Methods for ship detection are based on detection of the ship itself, detection of the ship wake, detection of ship motion by ATI (Along Track Interferometry). Some methods could work in the ka system proposed, like the use of XTI (Across Track Interferometry) to discriminate ship from sea surface, or the use of hybrid ATI+XTI approaches.

The choice of the ka-band is mandatory to have the bandwidth necessary for the resolution and to keep the interferometric baseline at a reasonable size, therefore ka-band allows to improve the interferometric techniques.

In order to obtain both high interferometric performance and wide coverage, different techniques can be considered, in particular two different operative modes appear to be the best choice: Toggle mode and TOPS mode.
The TOPS mode is a technique which performs a steering of the antenna in the azimuth direction in the opposite direction with respect to the Spotlight mode [4]. The toggle mode exploits the use of two different antennas to cover a wide swath with a high resolution, whereas the TOPS mode (defined by the Politecnico of Milan, Italy) allows to implement the Interferometric technique for wide areas although at a lower resolution. Both of these modes could take benefits from the use of DPCA (Displace Phase Center Antenna), in fact the DPCA is a technique through which the antenna is split into two different parts, this allows to reduce the PRF value but with an improvement of the complexity of the receiving antennas. The studied system design implies to consider, at least, two antennas separated by a baseline, with a steering capability both in azimuth and elevation directions (especially for the TOPS technique).

The agility requested for the beams naturally drives to consider active antennas, on the other hand considerations on transmission modules efficiency and cost aspects suggest to study also the possibility to use a passive antenna concept.

### 4. TECHNOLOGICAL ASPECTS

One of the key aspects of these new systems is the link budget. This reflects in the RF Power times Antenna area product. In case of reflector antenna, limits are on size of structures capable of meeting the surface tolerance and tight pointing accuracies requested and it implies that the solution cannot be ever increasing reflector diameters.

In addition, ka-band waveguide component losses are greater than at lower frequency band driving system designers to put the power amplifiers as close as possible to the feed to minimize the output power level required from the amplifier, and thus its cost.

Technological answer is articulated. For TWTA [1] available RF power is in the order of $50 \div 100$ W. In the case of SSPA among two approaches the “discrete” one which envisages for discrete dice mounted on a ceramic substrate on which DC and RF routing is implemented, and the “MMIC (MilliMetre Integrated Circuit)” one in which all main functions are implemented in MMIC form and then combined through a ceramic substrate whose function is mainly to connect the different blocks, the second is preferred. Available amplification is based on Pseudo-morphic High Electron Mobility Transistors (PHEMT) technology i.e. a FET in which the conductive channel is based, nowadays, on GaAs (Gallium Arsenide); depending on development processes ($0.25, 0.15$ gate length) RF available power is in the order 1 W per MMIC. The next future see as prime actor GaN (Gallium Nitride) HEMT for which better results are expected: 4 W(possibly) per MMIC.

Similar technological processes show that LNA (Low Noise Amplification) could reach $1.5$ dB noise figure.