MODELLING AND ANALYSIS OF ATMOSPHERIC EFFECTS ON KA-BAND SINGLE PASS INSAR PERFORMANCE

Michael Ludwig, Salvatore D'Addio

Electrical Engineering Department, RF Payload and Systems Division
European Space Agency
Noordwijk, The Netherlands
{Michael Ludwig | Salvatore.DAddio}@esa.int

1. INTRODUCTION

Ka-band has so far not been used for spaceborne SAR but the value of Ka-band SAR imagery has been proven in various airborne demonstrators and instruments. For Earth observation purposes from space Ka-band is currently on the roadmap for altimetry [1]. This paper investigates the feasibility of Ka-band SAR interferometry and describe a conceptual instrument design based on a set of assumed requirements. The effects of the atmosphere and in particular rain on the performance Ka-band SAR interferometry has been studied. The scan-on-receive technique applied on the Ka-band interferometer mitigates to certain extend rain effects, whilst at same time improving the power efficiency of the instrument.
The results this study based on adequate modeling of the instrument and the atmosphere are presented in the paper.

2. ADVANTAGE OF KA-BAND SAR INTERFEROMETRY

The wavelength of Ka-band is short compared to the more conventional frequency bands used for spaceborne radar.
As a result Ka-band allows reasonable baselines for interferometry from a single platform which would be difficult to achieve at lower radar bands for which at least two satellites would be needed.
The shorter wavelength causes the signal reflection to take place closer to the surface for volume scatterers. This can be exploited for accurate height measurement with the help of single pass SAR interferometry.
The major disadvantage of Ka-band compared to lower bands is higher attenuation in the propagation path in particular under rain conditions. However, the backscatter coefficient is on average significantly higher due to the increased surface roughness in relation to the short wavelength, which compensates partially the higher loss. The utilisation of narrow beams inherent with high gain antennas as used in scan-on receive -systems can mitigate the rain effects further. As a result of the investigations presented here, spaceborne Ka-band SAR interferometry is possible also under moderate rain conditions.

The main features of a Ka-band SAR interferometry fit well in civil security application and 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. Additional height information is of great advantage.
Potential applications related to science and environment issues include the monitoring of snow layer thickness and accurate height measurements over vegetation, which could provide important inputs into estimating the biomass of the Earth. The major advantage of Ka-band in this context is that the signal reflection occurs mostly at the top of the snow and the tree canopy as well leading to a good total height measurement.

3. INTERFEROMETRIC INSTRUMENT CONCEPT

For the interferometric baseline of the instrument, a length of 12m is considered, which represents a good compromise from the electrical and mechanical points of view for space applications. At the very end of the boom receive only front-ends are installed utilising high gain antennas with fast beam scanning capability. The scan on receive technique is used in the current design to improve the gain of the antenna system, which in turn allows the transmit power to be reduced. This technique requires steering of the receive beam to that position on ground where the running transmit pulse is located at that instant [2]. This is illustrated in Fig. 2.

Parameter	Value
Orbit	500km
Inc.& baseline	30 deg
Tx Antenna	2.0 m x 0.35m
Rx Antennas	Dish Ø 2.25 m
Tx power	470 W avg.
Res az x el	1m x 1m
Swath width	20km (3dB)
NESZ	<-15 dB
Baseline length	12 m
Post Spacing	12m x 12 m

Table 1, Parameter for Interferometer

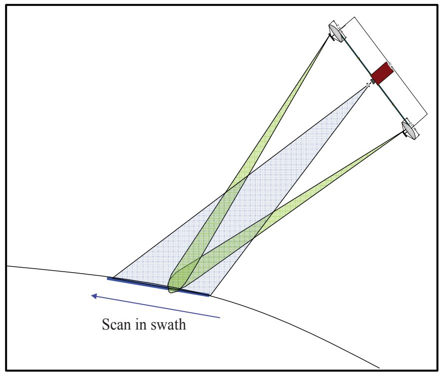

Fig. 2, Flight Geometry

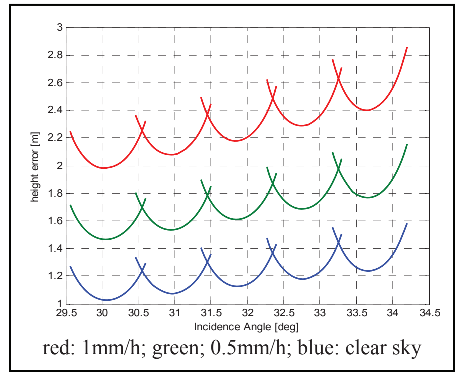

Fig. 1, Rel. Height Errors & Rainfall Rates

4. SINGLE PASS INTERFEROMETRIC PERFORMANCE

The performance of the Ka-band interferometer is preliminary analysed, assuming data acquisition in stripmap mode. Just as a reference, the relative and absolute vertical accuracy is calculated and compared with respect to the HRTI DEM specification. Table 1 summarizes main instrument, mission and processing parameters adopted in the performance analysis.
Generally speaking, the overall InSAR height error is a complex combination of geometrical parameters, instrument parameters, scene characteristics and posting (ground resolution) [3].
In more detail; the height error contributors for a single-pass InSAR can be identified in interferometric phase error and noise and estimation inaccuracy of the observation geometry.
The first error contribution affects the so-called relative height accuracy, since it is independent from pixel to pixel in the scene. The second error contribution affects both the relative as well as the absolute accuracy. In the paper the impact of these errors on the height accuracy will be analysed in detail. In addition, due to the criticality of the atmospheric effects on the performance of Ka-band SAR, it is important to include the impact of the rain on the interferometric phase noise.
Generally speaking, atmospheric effects can affect the interferometric phase in two ways:

- Increased phase noise which does not modify the expected interferometric phase. This is principally due to additional attenuation of the useful signal passing trough the rain and clouds, which in turn affects the SNR and then increases the thermal noise decorrelation and backscatter contribution from rain and clouds
- Phase shift, which then modifies the expected phase in the interferogram. This is principally due to path delay differences between the two interferometric paths and backscatter contribution from rain and clouds

It can easily be demonstrated that the additional phase noise degradation due to rain can be accounted for in the classical coherence figure-of-merit, by simply substituting the decorrelation due to SNR with the decorrelation due to the signal-to-noise-clutter ratio S/(N+C).
However, this modification of the coherence does not take into account eventual interferometric phase shifts due to atmospheric effect, which will need further addressing.
Fig. 1 shows the DEM height error for clear sky and two different rainfall rates. The height error has been calculated by assuming an additional phase noise of 1° in order to take into account the electrical phase stability of the instrument. It can be noticed that the height performance of the Ka-band interferometer is well within the HRTI-3 specification of 2m for a ground posting of 12m x 12m. High resolution performance can still be met with low rainfall rates about 1-2 mm/h.

5. OUTLOOK FOR THE FULL PAPER

The full paper will discuss in more detail the effects of rain on Ka-band interferometry. In particular the modelling used for the presented figure on height error vs. rainfall rates (Fig. 1) in this abstract will be discussed in detail.
The instrument concept will be described in more depth including issues related to phase stability and antenna co-alignment.

6. REFERENCES

[1] Phalippou L.; Caubet E.: "A Ka-Band Altimeter for Future Altimetry Mission", *IGARSS 1999*, Hamburg, 1999
[2] Süss, M.; Grafmüller B.; Zahn R.: "A Novel High Resolution, Wide Swath SAR System", *IGARSS 2001*, Sydney, 2001
[3] Hanssen R.F., *Radar Interferometry*, Kluwer Academic Publisher, 2001