MetaSensing compact, high resolution interferometric SAR sensor for commercial and scientific applications
Adriano Meta, Christian Trampuz, Alex Coccia, MetaSensing, The Netherlands

Abstract
For the first time in the world Frequency Modulated Continuous Wave (FMCW) Synthetic Aperture Radar (SAR) images have been acquired in interferometric mode. The paper reports on the X-band images collected by the new high resolution, compact MetaSensing interferometric SAR sensors in 2009. MetaSensing approach allows cost-effective SAR mapping by employing small, readily available Cessna 172/182 or similar in order to drastically cut the costs of current radar campaigns for scientific and commercial applications. MetaSensing X-band SAR sensor is able to transmit more than 1.4 GHz of bandwidth and its versatile two receiving channels allow along-track and cross-track interferometric acquisitions. A fully polarimetric L-band sensor is in the final test stage and is available from the third quarter of 2010. The new MetaSensing approach is an optimal solution for commercial and scientific application which requires SAR mapping on local areas.

1 Introduction
By combining Frequency Modulated Continuous Wave (FMCW) technology and advanced Synthetic Aperture Radar (SAR) techniques [1], MetaSensing has developed a very high resolution, cost-effective airborne sensors operating at X-band.

High resolution mapping is desirable for homeland security, environmental assessment and infrastructure monitoring, but it has been usually too expensive or of difficult realization.

MetaSensing provides the cost effective mapping solution which meets the needs of scientific institutes and private companies who face daily the increasing demand for accurate monitoring. The mapping technique is based on SAR, a technology for producing imaging employing a radar sensor [2].

Big and expensive sensors and aircrafts are not needed for mapping campaigns using MetaSensing technology. Accurate mapping measurements can be carried out by employing small, readily available and cost effective aircrafts (see Figure 1), cutting the high operational costs of such campaigns. One of the main advantages of MetaSensing sensors is the very low irradiated power, which results in a low power consumption of the whole sensor. This feature is of very importance when considering the possible use of MetaSensing high resolution SAR sensors on board small Unmanned Aerial Vehicles (UAVs).

The reduced operational cost of the airborne mapping radar services directly translates into benefits for commercial and scientific airborne radar mapping applications.

In September 2009, flight campaigns have being organized for cross-track interferometric measurements. This configuration mode allows the generation of geocoded 3D. The paper reports on first radar images and interferograms generated by the MetaSensing sensor.

FMCW SAR interferograms have been generated for the first time in the world using the compact MetaSensing technology.

2 First Results of MetaSensing campaigns
All the images presented in the paper have been processed with a spatial resolution of 40 cm and a pixel spacing of 25 cm. MetaSensing X-band sensor is however able to acquire images with a maximum resolution reaching 15 cm. This high resolution mode is currently under testing.

First campaigns have been performed in April 2009 for testing the 2D mode acquisition. Other campaigns
have been carried out in September 2009 and cross-track interferometric SAR images for 3D applications have been acquired. The flights took place in different areas in The Netherlands and Portugal. A unique data set of repeat pass interferometric data has also been collected.

Along-track interferometric campaigns for maritime applications and polarimetric acquisitions for vegetation monitoring are undergoing. These campaigns will fully validate MetaSensing capability at X-band.

The following figures report about examples of images acquired during the April and September 2009 campaigns. More pictures and updated information can be found at [3].

Figure 2 shows an example of geocoded radar image displayed in the popular Google Earth environment. MetaSensing images are delivered in GeoTIFF format in order to easily integrate them in any standard GIS software.

Figure 3 illustrates post-processing results applied to a single look 2D radar image in order to remove speckle noise (the typical salt and pepper noise in radar images) and to highlight human structures by color coding the direction of arrival of the radar backscatter energy.

Finally, Figure 4 shows first cross-track interferograms for 3D information retrieval. Colors (going from blue through green and yellow to red) indicated the radar interferogram phase, while the intensity of the image is related to the radar backscatter level.

The reported interferograms are the first in the world to be acquired with FMCW SAR technology.

The absence of any phase undulation in the interferograms illustrates the excellent behavior of the MetaSensing X-band radar in terms of phase stability and the high processing accuracy of the proprietary MetaSensing SAR processing chain.

Table I reports the characteristics of the MetaSensing X-band sensor and typical operational data.

### Table I

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Cessna 172, UAVs (or similar)</th>
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<tbody>
<tr>
<td>Frequency</td>
<td>X band (9 – 10.5 GHz)</td>
</tr>
<tr>
<td>Receiving channels</td>
<td>2</td>
</tr>
<tr>
<td>Polarization</td>
<td>VV-VH/HH-HV</td>
</tr>
<tr>
<td>Azimuth resolution</td>
<td>15 cm, single look</td>
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<tr>
<td>Slant range resolution</td>
<td>up to 15 cm</td>
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<tr>
<td>Maximum range</td>
<td>up to 6 km</td>
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<tr>
<td>Look angle</td>
<td>From 20° to 70°</td>
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<tr>
<td>Quantization</td>
<td>16 bits</td>
</tr>
</tbody>
</table>

3 Conclusions and near future implementations

MetaSensing is an innovative remote sensing company offering airborne radar imaging services based on its proprietary compact, high resolution SAR technology.

First results of airborne campaigns have shown high quality results in terms of signal to noise ratio, phase stability, processing accuracy.

Cross-track interferograms for 3D retrieval are a clear example of the capabilities of the MetaSensing sensors and processing chain. A complete geometric accuracy data evaluation is undergoing.

Figure 1. The MetaSensing radar is a compact sensor that it can be mounted on small unmanned aircrafts or on single-engine aircrafts such as the Cessna 172, shown here. It is therefore easy to image any item or area on land at a much lower cost than traditional surveys.

Figure 2. MetaSensing radar images can be directly displayed using standard geographical software such as Google Earth.
Figure 3. A 2D radar picture acquired in The Netherlands. In a) the single look radar image; in b) the multilooked image; in c) a color coded images where colors are related to the direction of scattering. Therefore colors indicate the orientation of the surface toward the aircraft carrying the radar. This image highlights the sensitivity of radar sensors to human structures.
Figure 4. Radar interferograms acquired by MetaSensing X-band sensor. Colors (going from blue through green and yellow to red) indicated the radar interferogram phase, while the intensity of the image is related to the radar backscatter level. Colors can be directly translated into height information. These radar interferograms are the first in the world acquired with FMCW SAR technology.

Along track interferometric flight tests are being performed in order to address maritime applications, like wave speed measurements and underwater topography retrieval.

A fully polarimetric L-band SAR is under testing and is available for the third quarter of 2010. The L-band sensor will allow MetaSensing to complement the current X-band capability in order to cover other applications for vegetation monitoring, like forest mapping, biomass estimation and soil moisture measurements.

MetaSensing sensors and services are an optimal solution for local mapping and scientific campaigns. In fact, MetaSensing can carry SAR campaigns and deliver the acquired data to scientific and commercial institutes enabling several applications with real airborne SAR data.

References

