A noise based transmitter system for the HITCHHIKER project

Simon Reuter, Florian Behner, Holger Nies, Otmar Loffeld
Center for Sensorsystems (ZESS), University of Siegen
hitchhiker@zess.uni-siegen.de

Abstract

The HITCHHIKER project was started in 2009 with the goal to develop a passive high resolution receiver system to perform a series of bistatic experiments using the German TerraSAR-X system as illuminator and demonstrating the feasibility of high resolution bistatic imaging with a stationary receiver. This paper describes valuable extensions augmenting the system to a fully functional bistatic one pass interferometer to acquire high resolution DEMs on the one hand and further integrating a modular and flexible high bandwidth transmitter component with a thermal noise based signal source for waveform generation to upgrade the system to a fully operational active bi- or monostatic (standalone) SAR sensor. A first experimental result with a noise based transmitter and the HITCHHIKER receiver and an outlook on upcoming experiments with this new system in 2012 completes the work.

1 Introduction

The HITCHHIKER project, inspired by the Spanish SABRINA experiment [1], was started in 2009 [2] with the goal to develop a receiver system to perform a series of bistatic experiments with DLR’s spaceborne TerraSAR-X system demonstrating the feasibility of high resolution passive bistatic SAR imaging with a stationary receiver. The high bandwidth of the transmitter and especially its spotlight SAR mode extending the synthetic aperture used by the stationary receiver system promised interesting results [3].

Basically designed as a two channel receiver system, with one channel as a reference channel, capturing the direct illumination signal and triggering the acquisition system from pulse to pulse, the second channel captured the target or scene signal. Based on this hardware setup new processing algorithms were developed and experimentally verified delivering high resolution (1m) SAR images. After performing several multi pass bistatic interferometric experiments using TerraSAR-X it was observed that temporal decorrelation was severe in vegetated or forested areas[4]. Hence the decision was taken to extend the receiver to four receiving channels. The additional receiving channels also allow for receiver side polarimetry which enables us to acquire full polarimetric images in combination with the dual polarimetric imaging mode of the transmitter.

To achieve a high resolution Radar, it is necessary to work with high bandwidth signals, whereas the type of waveform is nearly irrelevant. In the past, the generation of such high bandwidth signals was performed by sweeping the frequency of a sinusoidal waveform generator. This principle leads to deterministic waveforms. The pulse compression is done digitally or in an analogue way.

However, it is not necessary to use deterministic signal waveforms to compress a high bandwidth signal to a very short pulse. Recording the transmitted signal enables to perform a pulse compression digitally and allows to use thermal noise as a high bandwidth signal source. This is shown in [5], [6] and called Noise Radar.

This paper describes a new noise based transmitter system as an extension for the HITCHHIKER project. The bandwidth of the used noise source is in X-band between 8 to 12 GHz. But it is limited to 500 MHz to a center frequency of 9.65 GHz, due to the specifications of the existing HITCHHIKER receiver system. It is planned to extend the bandwidth in the future by replacing the bandpass filters.

In the following sections the extended receiver setup is discussed and the designed transmitter system is presented. The paper concludes with an experimental verification of such a noise based transmitter system as an extension for the HITCHHIKER project and an overview of the experiments planned for 2012.

2 Extended Four Channel Receiver System

In extending the receiver frontend to four channels the already existing two channels had to be reused, also leaving the form factor of the receiver unchanged. In addition to the direct receiving channel, which continues to be used for synchronisation and capturing the reference signal we have three receiving channels that are used for imaging. Two channels are connected to an interferometric pair of antennas while the remaining channel is used with a different polarization for polarimetric acquisition.
3 Transmitter System

To be more flexible in configuration and performance of experiments also in order to achieve standalone capabilities it was further decided to develop and operate an own transmitter system. In conventional Radar systems for SAR imaging the common waveform is deterministic like the linear frequency modulated "Chirp” signal. While this signal is easy to describe it is technologically demanding to generate high bandwidth signals digitally. Encouraged by Lukin’s research and the fact that the receiver system implicitly captures a replica of every transmit pulse, the idea came up to develop a transmitter based on white thermal noise [5]. As the analogue signal is directly generated in the X band, the transmitter system design for the noise waveform is simple and shown as "Noise Waveform" block in figure 2.

To evaluate the system and for a first test, we performed an indoor experiment with the transmitter prototype which is discussed in section 4.

Besides transmitting a noise waveform, the system also is intended to be capable of transmitting the conventional chirp waveform. The chirp waveform is generated by means of a DDS in complex baseband, then upconverted, amplified and transmitted by the same power amplifier stage used for the noise waveform. The DDS is implemented in a "commercial off-the-shelf" integrated circuit and with its sampling rate of 1 GSPS capable of generating chirp waveforms with a bandwidth of up to 800 MHz. The proposed system is shown in figure 2.

As the system is intended for outdoor use it is planned to perform a series of experiments imaging an area of 3-6 km in range. In combination with the HITCHHIKER receiver system the transmitter will be designed to expect a noise equivalent sigma zero of $-42$ dB like in the TerraSAR-X – HITCHHIKER experiments [2].
4 First Experiment

We performed an indoor experiment with a prototype transmitter and the HITCHHIKER receiver. This prototype consists of a thermal noise source in X-band, which is amplified by a 42 dB low noise amplifier. The signal is pulsed to trigger the HITCHHIKER system with the direct channel. The resolution in range direction of about 30 cm depends on the bandwidth of the transmitted signal, which was limited to 500 MHz. Due to the gain of the antennas of 20 dBi the aperture angle is very large. This leads to a high resolution of about 5 cm in cross range direction. The target area of this experiment was the staircase of the ZESS building. We used a rolling cart to move the transmitter and receiver (monostatic case) along the gallery, to be able to perform SAR processing techniques for cross range focusing. The system looked straight down to the stairs. Figure 3 shows a photograph of the target area.

In figure 4 an image of the processed data is shown, focused with a SIFT processor. As a distinctive target a mannequin is used, which is clearly visible in the focused result, due to the high resolution in cross range direction. Furthermore each stair can be discriminated.

5 Conclusion and Outlook

The straightforward design of the presented system leads to a cost effective high bandwidth transmitter suitable for high resolution SAR imaging. Due to the direct channel of the HITCHHIKER system, recording of the transmitted signal is done automatically for pulse compression. The promising results encourage us to carry on the development.

For 2012 we have planned to perform a series of experiments with different configurations on different platforms. The first experiment is again a spaceborne–stationary setup. We plan to acquire a DEM using the interferometric phase at the stationary receiver, which will be the first test of the new interferometric setup. While an interferometric
phase was already acquired in earlier experiments, the generation of an usable DEM failed due to the unknown geometrical relation between the receiving antennas. The illuminating transmitter in this experiment is the TerraSAR-X system.

In a series of monostatic experiments with a truck-mounted sensor we are planning to test the transmitter system and especially the generation of a synthetic aperture using the noise waveform. The expected resolution for these experiments is about 30 cm in range and 5 cm in cross range. The range resolution is planned to be extended later to 7.5 cm by filter replacement and thus an increase of the signal bandwidth to 2 GHz.

Further it is planned to perform bistatic experiments with the sensor system as it was originally designed for the bistatic configuration. This includes the configurations truck–stationary and the airborne–stationary case.

6 Call for proposals

We want to encourage the reader to contact the authors in order to propose new ideas for experiments and applications. Requests for cooperation are also welcome if the reader is interested in working with data acquired with the HITCHHIKER system. Please contact us by email hitchhiker@zess.uni-siegen.de.

References


