# Stepped-frequency software-defined ground-based synthetic aperture radar

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## 1. INTRODUCTION

Ground based synthetic aperture radar is a valuable tool for monitoring natural hazards, in particular those phenomena producing ground displacements. Paper[1] presents a successful application of this technique for landslide monitoring and slope movements. Paper[2] studies man-made structures deformations caused by underground mining activity and gravitational slope deformations. Another field of application of the proposed system is through-wall imaging. The majority of the systems presented in the available literature use either custom built hardware or Vector Network Analyzers, which are inflexible and expensive. In response to this, the solution proposed in this paper uses a PC and a low cost USRP N200 platform fitted with a cheap, non-coherent WBX daughterboard. The lack of coherent operation is corrected by means of a minimum number of low-cost, external components consisting of two off-the-shelf RF switches, an Arduino Uno microcontroller board and a fixed RF attenuator. A dedicated software routine measures and corrects the random phase offset between the transmitter and receiver sections of the WBX board before each measurement. The result is a low cost yet flexible software-defined radar system. The SAR focusing algorithm based on paper[3] is very straightforward in order to reduce the learning curve for inexperienced users.

## 2. EXPERIMENTAL SETUP

The proposed hardware consists of a PC and a USRP N200 platform fitted with a WBX RF daughterboard. This configuration provides a full-duplex transceiver. The transmitter and the receiver sections of the system are connected to Vivaldi antennas and a fixed attenuator through a couple of RF switches. The choice for this particular antenna is motivated by its wide-band and ease of fabrication. The switches are controlled by the computer through an Arduino Uno board as depicted in figure 1.

The baseband signal processing is divided between the USRP motherboard, mainly the FPGA module, and the personal computer connected to it, which also serves as the system's human interface device. The most extensive part of the signal processing is performed on the computer and is coded, for simplicity, in LabVIEW. The FPGA uses factory firmware.

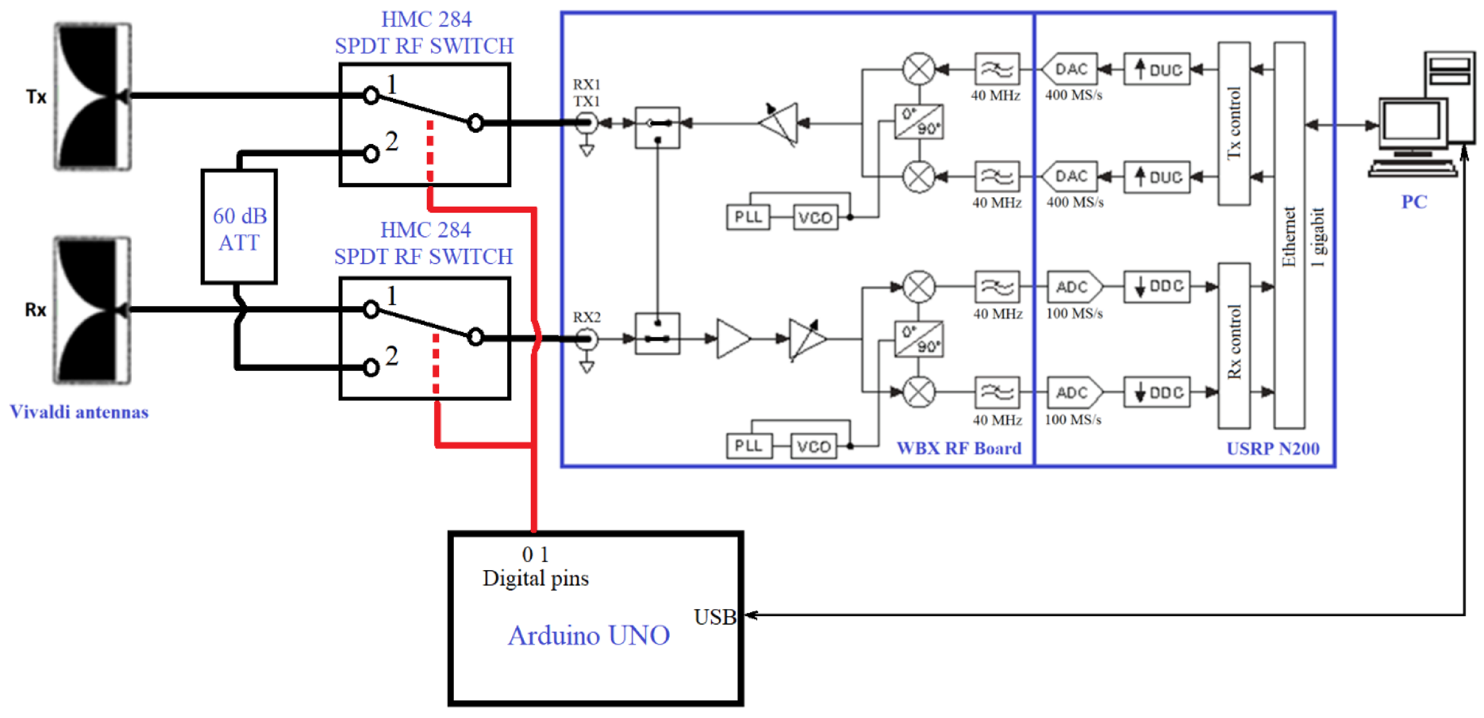


Fig. 1. Experimental setup – block diagram.

## 3. OPERATION

The system implements stepped-frequency radar operation with a bandwidth of 1500 MHz (500 – 2000 MHz) achieving a resolution of 10 cm in air. The proposed system mimics the behavior of Vector Network Analyzers. It works by sweeping its operating frequency over the 1500 MHz frequency band and storing the amplitudes and phases of the scattered waves. These are assembled in a matrix, the so-called raw data matrix, which is processed using an implementation of the backprojection (BP) SAR algorithm to generate the bidimensional focused image.

The main difficulty in implementing radar operation on low-cost, general purpose software-defined radio transceiver platforms stems from the lack of coherence between the transmitter and receiver sections of the device. This translates in a random phase shift between the transmitter and the receiver sections. In order to successfully implement radar operation, it is imperative to correct this fundamental problem. The proposed solution is to continuously measure and subtract this random phase shift from the acquired signal.

The second essential correction is the parasitic antenna coupling. This unwanted effect is corrected by subtracting a previously stored target-less measurement from each scan.

The complete algorithm for the operation of the proposed system is presented in the flowchart in figure 2.

While in operation, the program displays the continuously updated unfocused image computed by means of Inverse Fast Fourier Transform (IFFT). At the same time, the program also stores the acquired data in multiple files, a file for each scan location, in 3 columns format. The first column stores the frequency, the second column the amplitude in dB and the last column the phase in degrees, similar to Vector Network Analyzers. This makes the data available for applying the synthetic aperture algorithm for focusing the data.

If the program cannot find the antenna-coupling correction file named Correction.txt in its directory / Data it automatically creates one using the data obtained in the first scan, which becomes the reference for correcting the antenna coupling from the following scans. The device has to be manually moved from a scan position to the next and the new scan is triggered by clicking the NEXT MEASUREMENT button.

After scanning the entire region of interest, the available data is processed using a MATLAB implementation of the backprojection focusing algorithm. It assembles the acquired files into a matrix, the so-called raw data matrix.

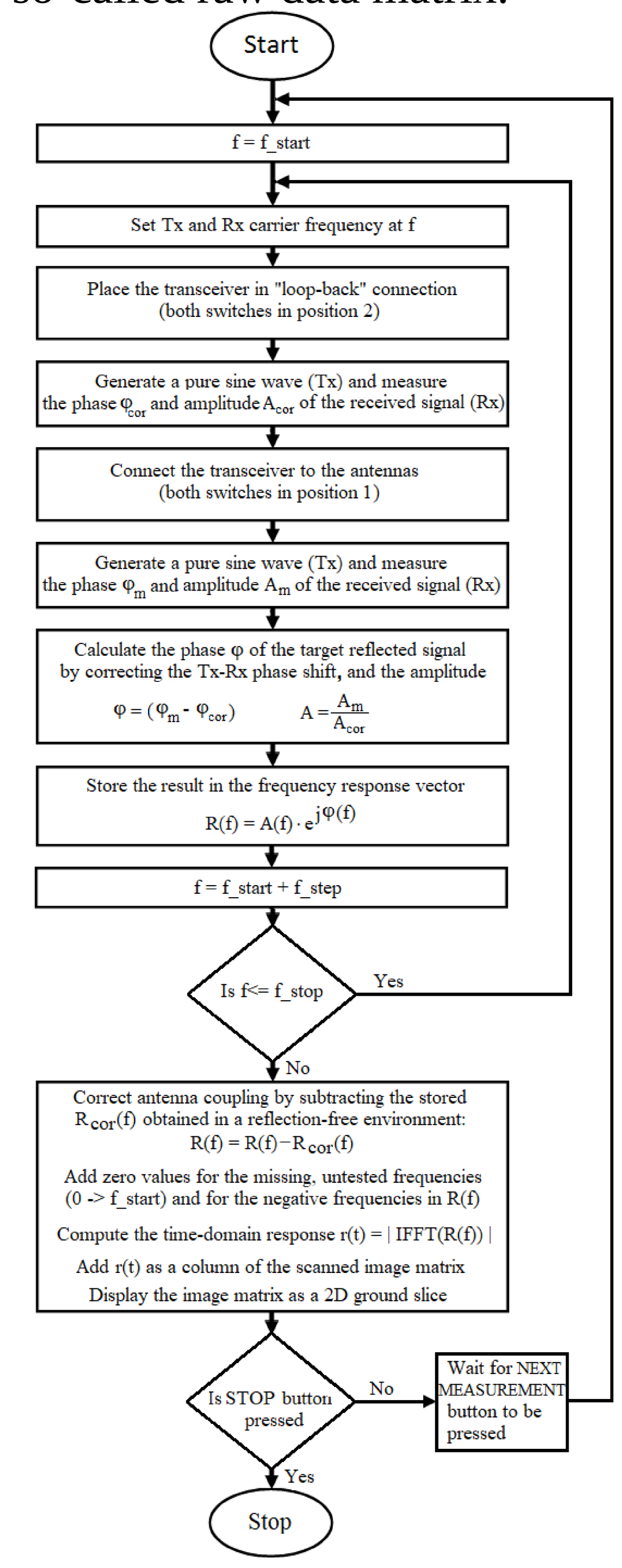


Figure 2. The proposed scanning algorithm.

## 4. RESULTS

The system was tested using the configuration in figure 3. The target was a metal tray 30 cm x 20 cm, situated at a distance of 1 m in front of the radar. The radar was moved on a straight line (a carpentry meter stick) for a length of 135 cm with a step of 3 cm between successive scan points. The resulted image is depicted in figure 3. The range resolution is $\delta_r$= 10 cm and and the focused azimuth resolution is $\delta_a$= 5 cm.

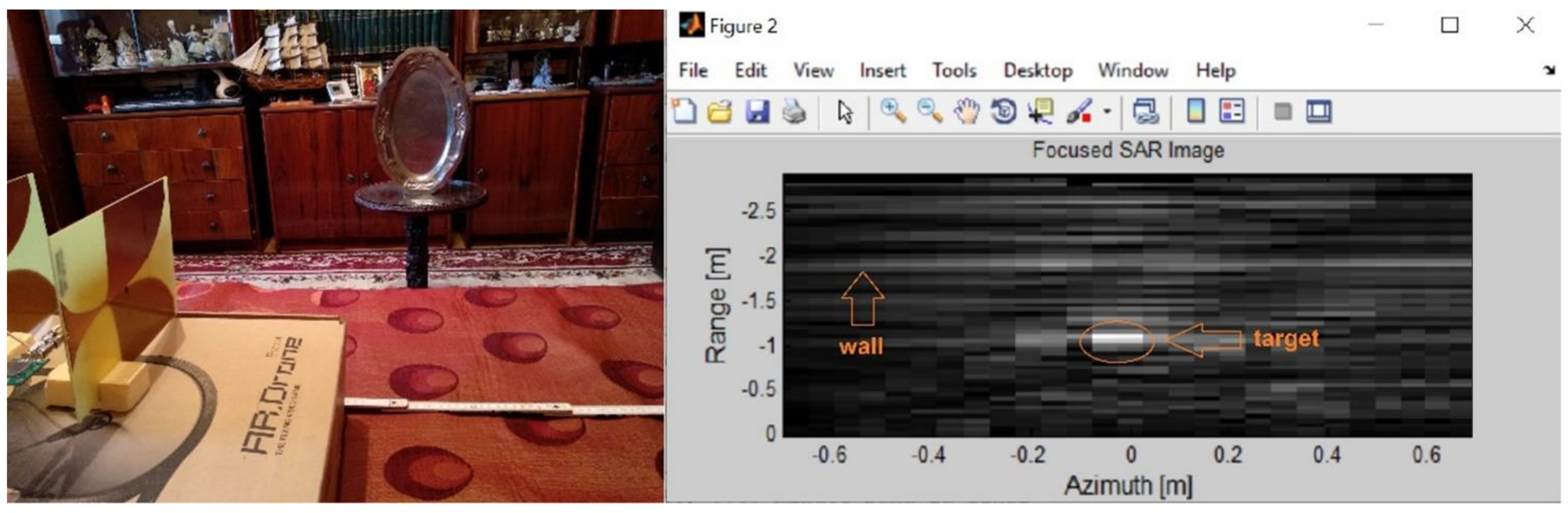


Fig. 3. Experimental results.

## 5. CONCLUSIONS

The system proposed in this paper implements a high-resolution (10 cm in air) ground based synthetic aperture radar (GB-SAR) using a low-cost software-defined radio and a minimum number of external components. The proposed implementation overcomes the instantaneous bandwidth limitation of the software-defined radio by employing frequency sweeping over the entire operating bandwidth of the device and correcting phase shifts and amplification variations. The only disadvantage is the slower scanning speed. The system can be used for through-wall imaging, construction deformation monitoring etc.

## REFERENCES

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