IMAGING CAPABILITIES OF ULTRA-WIDEBAND RADAR SYSTEM WITH SMALL RECEIVING ARRAY ANTENNA

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Abstract

This work presents the results of simulation and measurement to visualize of hidden scenes with the help of the experimental portable ultra-wideband (UWB) radar that operates with nanosecond pulses in the 0.5-3.0 GHz equivalent band (-10 dB PSD) by using two receiver channels. Some results are presented and discussed on detection and tracking of moving objects that are inside rooms and observable through walls. Also, a number of issues related to hardware and software implementation are in focus of this study including the direction-of-arriving problem in a baseband antenna array with small separation between two receivers.

Problem Formulation

Imaging for objects hidden in opaque media is important for many applications in science, engineering, defense, law enforcement, and medicine, etc. A particular group of such problems is solvable in the UWB EM spectrum of 0.1-10 GHz wide for such materials like soil, rock, brick, concrete, snow, ice, fresh water, wood, biological tissues, etc. The most known implementation of this technology is ground penetrating radar [1]. We present other type of UWB radar (UWBR) for detecting and imaging objects behind walls in typical buildings [2]. The current UWBR system has two identical receiver channels related to two array elements used to localize spatial position of objects and present them as a bright spot on the radar image.

The UWBR system architecture and several standpoint views of the prototype are shown in Figure 1. The system includes 3 packaged modules of the same overall size, i.e. two receivers, at the left and right, and one transmitter, at the centre. Each module contains antenna, RF and control electronics. All the modules have the same antennas based on novel patented antenna geometry [3] that provides some superior features compared to other UWB antenna solutions. The transmitter provides 60 Volt peak-to-peak output pulses with the 1 MHz pulse repetition rate. The receivers operate in a stroboscopic mode with down-converting to the audio frequency band that enables next easier signal digitizing, e.g. with the help of a standard Windows-compatible sound card. The receiver-recorded signals, viz. scan signals, are updated at the 100 Hz rate, viz. 100 images per second that is compared to modern high-quality computer and TV displays.

Object Position Finding with Receiver Standpoints of a Small Separation

The scene images, Figure 2, are generated for a given horizontal radar field-of-view bounded with the min and max distance, and angular extent. The max distance can be set up to 10 m and angular in the angular sector up to 150 degree. The range and resolution characteristics define the number of "pixels", i.e. spatial point to which the system needs to be focused. The number of the pixels identifies the overall computational cost to form a scene image. For illustration, the signal in two receivers and focused image of a scene (a person behind a wall) are shown in Figure 3 where the target is presented as a bright marked spot. There are many practical difficulties to obtain well-focused scene images. This issue is discussed in the following.

Naive Image Focusing Algorithm
As a simplest focusing algorithm, the UWBR scene image is formed at each pixel through: (1) equalizing the delay in the receiver channels; (2) computing the correlation between the equalized signals. Because such a typical scene is affected by multiple scattering events, the background scattered signals are first remembered and then subtracted from the current scattering pattern. Thus, the system operates in a change detector mode with tracking only for dynamical objects over scenes while ignoring all stationary events there. However, this system has a small interferometer base measured between centers of the receiver antennas, viz. 21 cm. This constraint is dictated by some requirements, e.g. the system might be used as a handheld sensor. The small base causes some difficulties to form a focused image.

Enhanced Image Focusing Algorithm
The UWBR images can be further improved at the next level of processing algorithms based on a number of short-base sensing/imaging techniques with the help of Gabor transform, low-base tomography, etc. but at the cost of extra computational resources required to perform such an additional signal processing job. The similar problem seems is resolved in the human acoustic physics. A human can inherently localize sound sources with parameters compared to what is required for the UWB sensor. For example, in the acoustic band around 1.5 kHz; the free-space wavelength is 20 cm that is comparable to the ear separation of an adult human head. Using the above and other processing techniques enables solving the discussed challenging problem of object localization with a simple 2-element sensor operating with small inter-sensor separation that will be reported in the full version of this work.

References:

1. Daniel D., *Ground Penetrating Radar*, IEEE Publishing, 2004.
2. Sostanovsky D. L. , Boryssenko A. O., An Experimental UWB Module-Based Sensing and Communication System, *Proceedings of Ultra Wideband and Ultra Short Impulse Signals Workshop*, Sevastopol, Ukraine, 2004, pp. 231-233.
3. Sostanovsky D.L, Boryssenko A.O, *Patent UA 65488 A*, Submitted November 28, 2003, Published March 3, 2004, *Bulletin #3*.

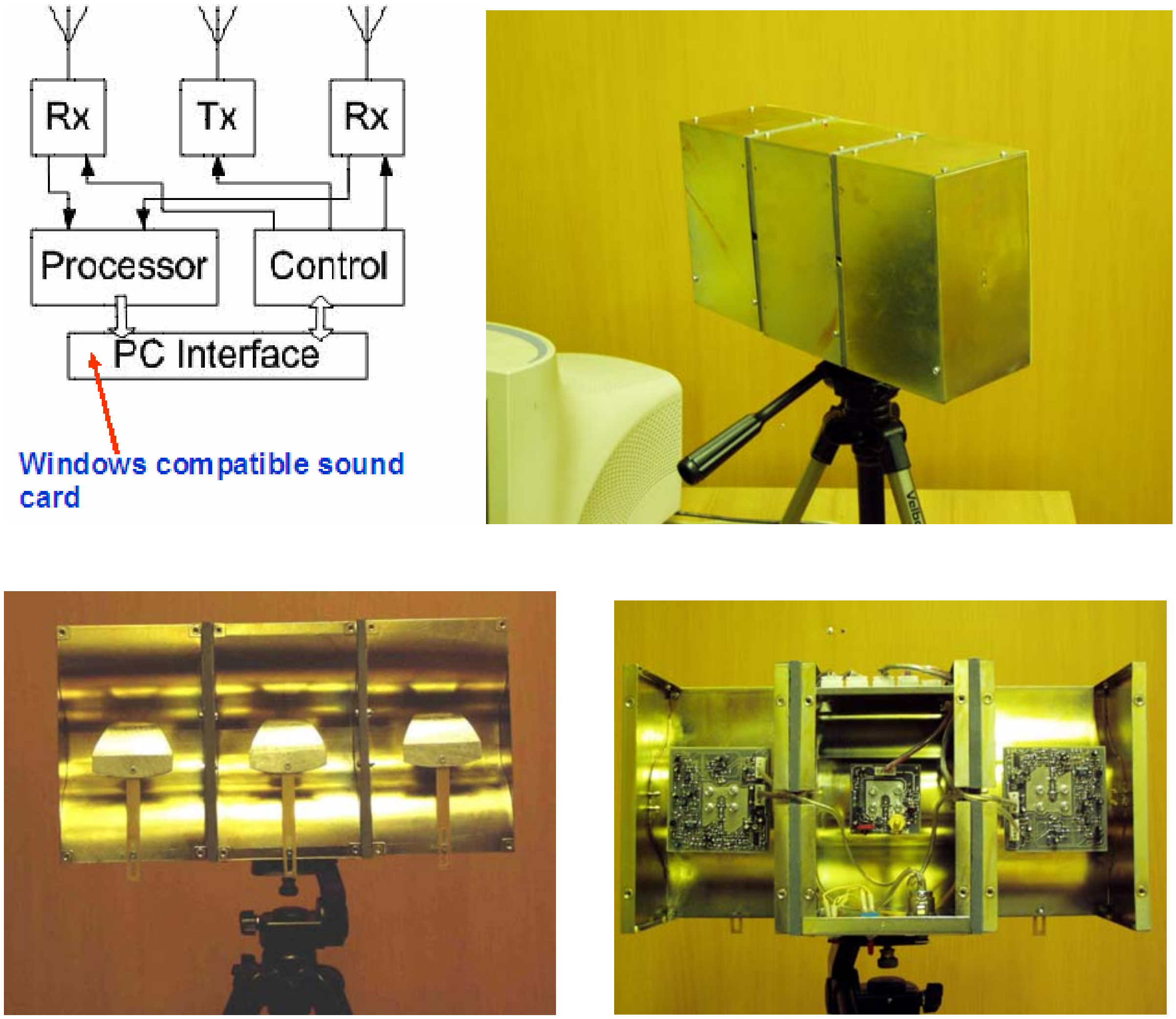

Figure 1. UWBR block-schema (top left), picture assembled system (top right), aperture side view (bottom left) and backside view (bottom left).

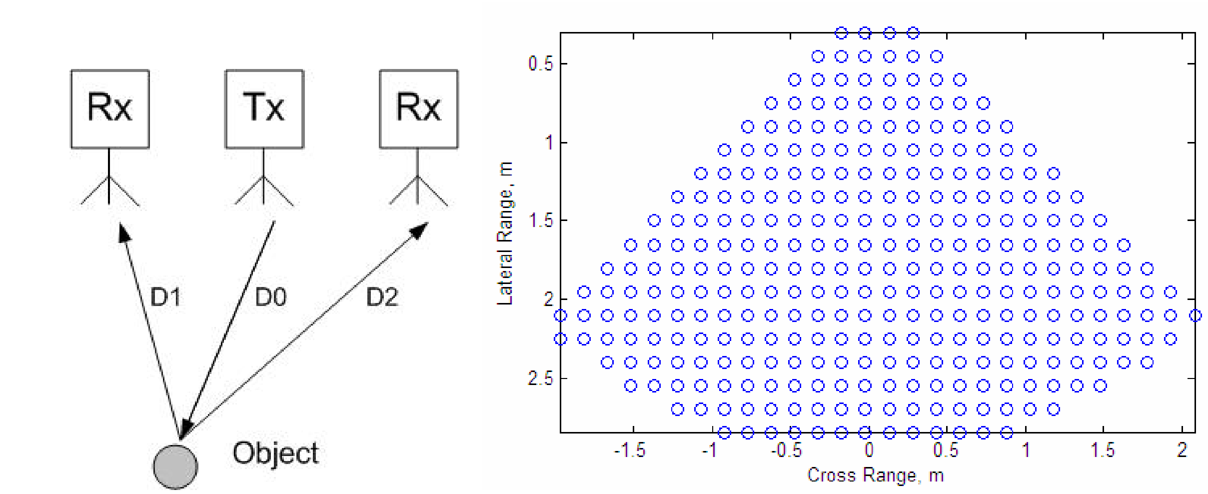

Figure 2. Radar scene for array imaging (left) and numerical map of pixels (right).

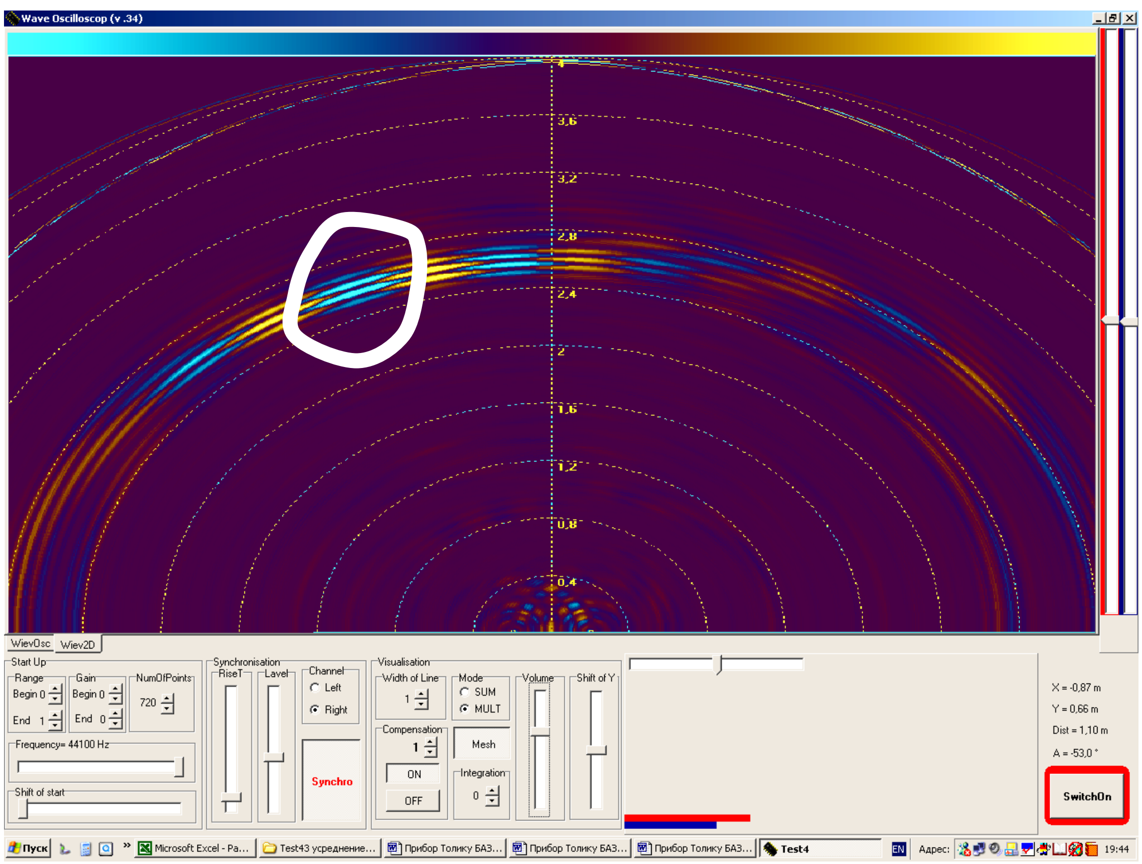

Figure 3. Channel signals (top) and focused image (bottom) with marked target.