AN EXPERIMENTAL UWB MODULE-BASED SENSING AND COMMUNICATION SYSTEM

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Abstract

An experimental UWB system is developed, designed, prototyped and tested to support a number of multitask sensing and telecommunication applications in the 0.1-3.0 GHz band, viz. subsurface radar or GPR, intrusion sensor, "trough-wall seeing" scanner, indoor comm. & geolocation and so on. As such, a set of hardware modules is created that can be combined/assembled in a particular fashion/architecture for each specific mission including functioning with receiving and transmitting arrays (a part of our ongoing R&D efforts). The basic system components involve: (1) transmitter (Tx), (2) receiver (Rx), (4) antennas, (5) control unit, (6) digitizer and comp interface. As well, controlling and processing software is an inherent part of each system to be configured for every definite operational mission.

Keywords: Ultra-wide band, transmitter, receiver, hardware, software, radar, through-wall-seeing, Matlab programming

1. UWB Technology Perspectives & Challenges

UWB technology provides a number of unique operational capabilities in a diverse range of research and applied engineering fields including high-resolution radars, sensors in opaque matter, EMP, EMC, communication, combined wireless and geolocation and so on. At the same time, this technology is pretty challenging for its practical implementation because of its inherent complexity of transient electromagnetics and quiet diversity comparing to traditional narrow band electromagnetic systems. For example, one of the commercial trends is building of UWB short-range systems with sensing, communications and networking opportunities when nonhierarchical nodes would be based on portable battery-fed cheap components.

Ratio Company provides recently several experimental works in this field under cooperation and support of a number of institutions and companies in the United States, Singapore and other countries. The purpose is creating a set of module-based reconfigurable UWB components that enable experimental exploration of this technology for sensing in matter, multipath propagation, short-range data transfer in dense indoor environment and/or combining both the operational modes. To this end, we developed and tested hardware and software means developed in house. Some results of these efforts are reported in this paper and would be discussed with more details in the presentation.

2. Basic Components of UWB Module-Based System

2.1. Antenna

A key system feature is supporting a required pulse shape or/and its spectrum for generated, radiated and received UWB pulsed signals. To this end, the Tx & Rx circuitries and antenna structures are properly co-designed including several found innovative technical solutions that are under patenting now. The antennas can be omnidirectional or directive high-gain ones. Specifically, the invented directive antennas with controllable beams are well-matched in the band. Also, they provide short pulses without ringing and high front-to-back isolation.

One more advanced feature of the antennas is a possibility to operate over the whole band 0.1-3.0 GHz by using just a single antenna instead of a number of changeable antennas in a typical GPR. Before their prototyping and testing all antennas are accurately modeled and optimized through a full-wave electromagnetic simulation tools. Also, the simulator enables simultaneously modeling of electromagnetic system parts, i.e. antennas and nonlinear circuitry, e.g. transmitter. So, the whole Tx-Rx transducer can be properly designed.

2.2. Analog & Digital Electronics

Several Tx schematics solutions are developed, designed and tested. E.g., a recent Tx module on the 2x2 cm PCB supplies with the 60 V peak-to-peak amplitude @ 300 ps rising time pulses and 90% energy efficiency. Much higher generator output voltage and shorter pulses can be provided also. Some of the Tx units are based on SRDs while other solutions implement advanced schematics with low jitter and high (up to 50 MHz and more) pulse repetition rate.

The created Rx units provide down-converting (stroboscopic sampling) necessary in the case of sensor mode to catch preciously transient waveforms. Optionally, the receiver can provide capturing of short pulses under rigid synchronization when the UWB system is employed for communication purposes for data transfer between two standpoints (nodes). Second specific operation mode for communication can be supported that is based on correlation reception for direct converting the received UWB pulses into digital data streams in accordance to an employed signaling schema, e.g. PPM or time-hoping.

Both the Tx & Rx units are controllable through the system synchronization unit that forms clock pulses for both accordingly to a particular system function. The Rx output in stroboscopic mode is digitized through an ADC. For example, we use a PC sound card for this purpose in our subsurface radar prototype design. Such a card is a standard and cheap PC part that enables 116 kHz 2-channel digitizing with 16 bit resolution while a comparable data acquisition card is much expensive.

The data collecting and processing can be completely programmed using, e.g. Matlab. The later is very attractive for fast prototyping of both the UWB software and hardware. In general, system software is necessary for many purposes like controlling, real-time and post-processing, scene visualization for sensors etc. Initially we use Matlab for algorithms' development and code prototyping. Then, if necessary, the compiled fast C/C++ codes can be created as well as making easier the programs using including user-friendly GUI features etc. At the same time, a modern 2 GHz PC provide a nearly real-time operation of UWB systems with Matlab-based software for some applications like GPR with up to hundred scans per second as in commercial GPR systems.

3. UWB THROUGH-WALL CHANGE DETECTOR SYSTEM

As an illustration of our efforts in this field, we present a prototype of UWB through-wall change detector that operates on the base of UWB radar sensor that is configured from the described above components to operate for this particular mission. The presented case is a simplest system with one Tx module and one Rx module that enables detector of changes over scenes behind walls. Adding one and more Rx channels provides possibilities for target tracking as spots moving over the scenes. Some results for this version of through-wall-vision sensor will be included in our presentation.

The general layout for involved components and the whole scene is depicted in Figure 2 a. A number of pictures illustrates two Tx & Rx blocks with antennas, Figure 2c, and those on tripod close to the wall, the control unit with attached signal and control cables, Figure 2d. The sensor antennas, Figure 2 b, are close to the concrete reinforced wall and are disturbed by it. The resulted signal registered by the sensor is shown in Figure 1a. The target, a person moving at the distance about 3 m from the wall are not much visible there before the background removing is not applied. But after that the target appears more clearly, Figure 1 b. Finally, the resulted radar image received during about 1 min data collection session is shown in Figure 3 when that person behind wall was approaching first and then moving off the wall .

In contrast, e.g. to commercial subsurface radar of typical price ≥ 10K$ the price for this system is very low and its considerable part is a computer itself. Also, network configuration for sensors is possible that can support controlling a big operational area.

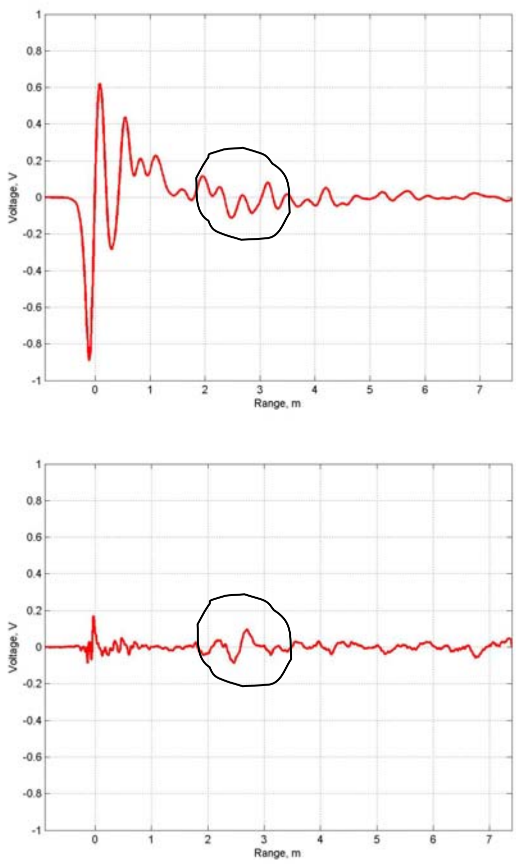
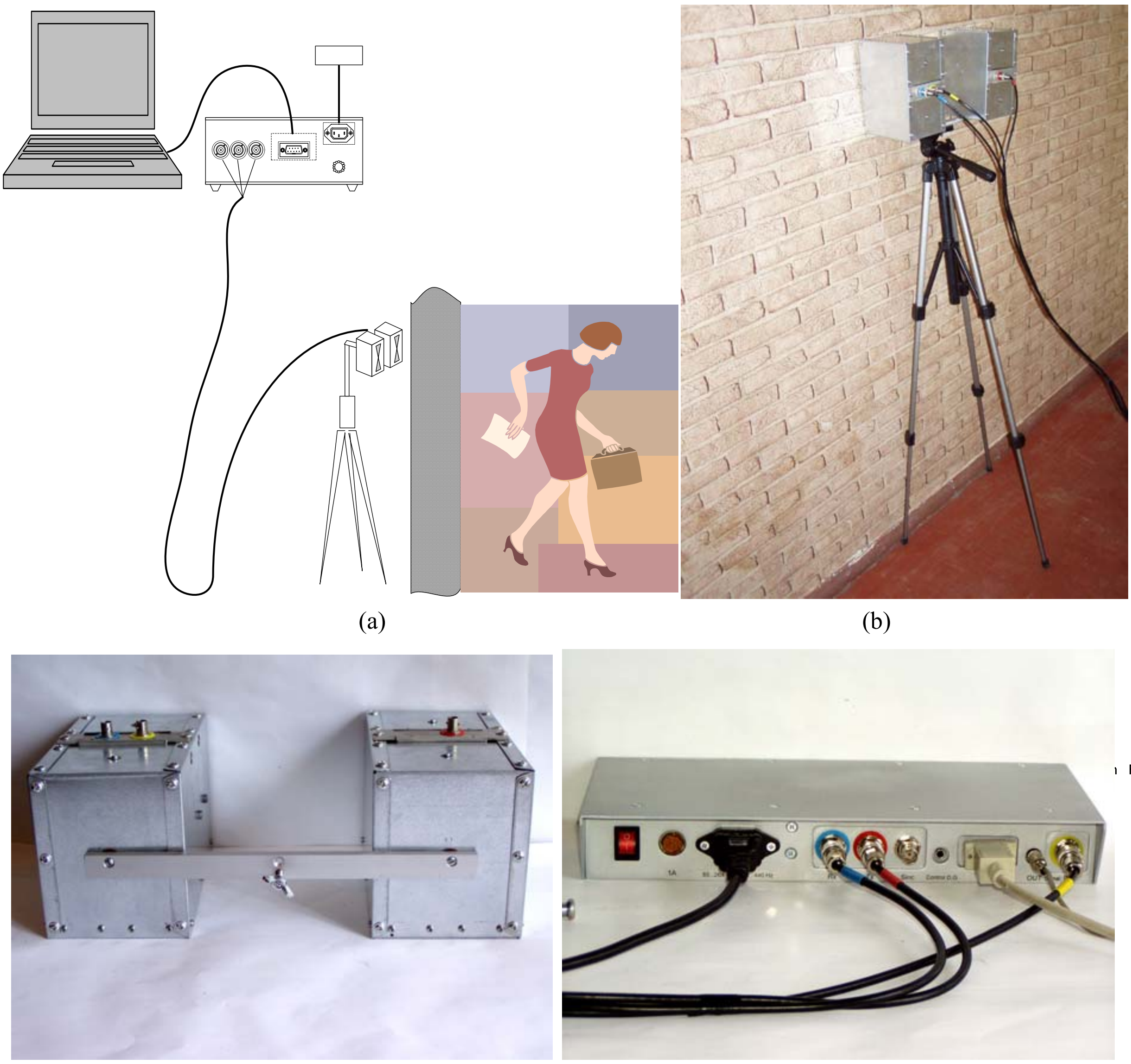


Fig. 1. Radar registered waveforms before (top) and after (bottom) background removing. Target location is circled.



(a) (b)

(c) (d)

Fig. 2. Experimental UWB radar sensor operating in the 'change detector" mode: (a) experiment layout, (b)-(c) antennas' unit, (d) programmable control and interface unit.

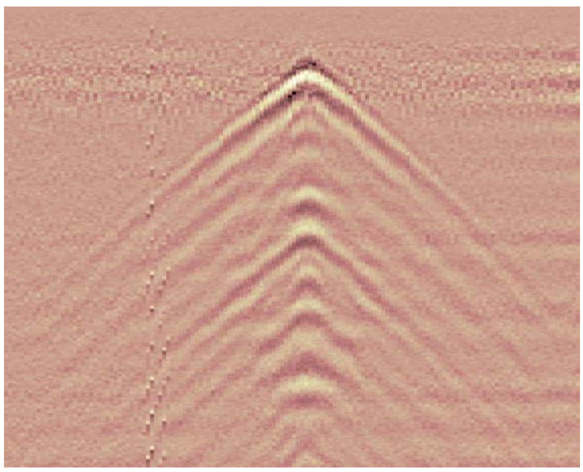


Fig. 3. Radar imaging of somebody moving behind 30-cm thick reinforced wall.

REFERENCES

1. J.D. Taylor, (ed.), *Introduction to Ultra-Wideband Radar Systems*, CRC Press, Boca Raton, 1995.
2. *Radar-Based Through-the-Wall Surveillance System*, www.nlectc.org/techproj /nij_26.html
3. A.O. Boryssenko, *et al*, Inspection of Internal Structure of Walls by Subsurface Radar. *Proceedings of Conference on Ground-Penetrating Radar*, Gold Coast, Australia, 2000, pp. 32-35.
4. E. C. Ifeachor, B. W. Jervis, *Digital Signal Processing: A Practical Approach*, Prentice Hall, 2002.