Ultra wideband radar for through wall detection from the RADIOTECT project

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The first section of the paper will introduce the philosophy behind the RADIOTECT project, which includes investigation into through wall applications and through clothes imaging for rescue and security applications. The second section of the paper will shortly introduce the project partners. The third section of the paper will concentrate on presenting the latest ultra-wideband prototype through wall system utilising pseudo random codes as a stimulus signal, before going on to describe some of the results with the system.

1.1 Philosophy of the project

The RADIOTECT project is co-funded through the European Commission's "Co-operative Research" scheme in the 6th Framework Programme for Research and Technological Development. The specific technical goals in the project are to develop high resolution radar (with bandwidth up to 5GHz) and ultra high-resolution radar (with bandwidth of 8 GHz or more) for use in a number of application scenarios. Two radar techniques are being advanced in the project: a sub-nano second impulse technique and an ultra-wideband pseudo-random-code technique. This paper will concentrate on the application of the ultra-wideband pseudo-random-code technique as a hand held sensor to see through the walls of buildings or rubble.

1.2 Partners

The Swedish Rescue Services Agency is the central supervisory government authority for the rescue services in Sweden, it has helped develop end user requirements and to plan field tests. MEODAT GmbH is a provider of high frequency technology provider, its main expertise is pseudo-

random code UWB Radar technology. GEOZONDAS Ltd is a also a provider of high frequency technology, but its main expertise is sub-nano second impulse UWB Radar technology. The Engineering Office Klukas Dresden has developed suitable antennas for the imaging techniques. INGMETAL, has identified packaging technologies and manufactured housing for components and systems in the project. The Technical University of Košice, Vrije University Brussels, Technical University of Ilmenau (TUI) and the Technical University of Delft all bring expertise in the area of radars and digital signal processing. Their key tasks are to extract movements from measured data (walking people, breathing people) and to reconstruct the geometrical structure of objects from measured data (the rough interior of a room or the shape of the objects carried at the body). TUI also brings expertise in UWB-system conception and RF-solid state circuit design. Crabbe Consulting Ltd expertise is in project management, the development of end user requirements in liaison between end users and technology developers and the development of exploitation plans.

1.3 Pseudo random code through wall system

We consider through wall sensing from two view points. Firstly, to determine whether people are in a room or building without entering this space due to some dangerous conditions (e.g. fire/smoke/dust or armed persons). Secondly, to detect people trapped beneath rubble as a result of an earthquake or explosion etc.

Electromagnetic waves within the lower GHz-range can penetrate most building materials which allows for the detection of hidden targets. Every body causes electromagnetic wave reflection, which can be registered by the radar receiver. The challenge is (depending on the scenario) to distinguish between wanted (e.g. living persons) and unwanted objects (e.g. rubble, interiors of a room etc).

The detection of people is achieved by using the fact that a living being is always connected with some movements even if it sleeps or is trapped since it must breath. Breathing causes minor variations in the body's shape which can be determined by radar. For the recognition of static objects, radar imaging must be performed which requires some scanning and sophisticated data processing.

The ultra wideband radar used provides reasonable wall or rubble penetration as it operates at a low centre frequency and a good range resolution due to its high bandwidth. A high range resolution is required for radar imaging and the separation of different sources of motion (e.g. several persons in a room or a breathing person and debris moving due to the wind).

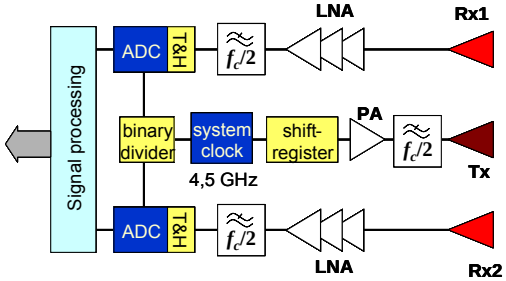

Figure 1 illustrates the basic structure of the ultra-wideband radar. We decided for a minimal structure of one transmit and two receive antennas in order to allow target localization by tri-lateration and easy and safe handling.
The sounding signal is a low voltage (about 0.5 V peak) pseudo random code (M-sequence in our case) which is provided by a digital shift register. It has a low probability of interception due to its random nature. The shift register is clocked by a stable 4.5 GHz source resulting in a sounding signal with reasonable spectral power from DC to about 2 GHz from which either 200 MHz to 2 GHz or .8 ... 2 GHz are exploited depending on the antennas used. The antennas with the higher cut-off frequency are comparatively small for a handy device for security forces. The larger antennas with a lower cut-off frequency are more suitable for rescue operations in connection with e.g. collapsed buildings. Here, the device dimensions are of less importance but operation under moist conditions is more significant.
The received signals are captured by an integrated T&H-circuit which operates in an undersampling approach to disburden the ADC and the signal processing from a data stream which is too large. The sampling control is carried out by a binary divider which leads to a very time stable/jitter free system promoting the detection of very small target movements [1].

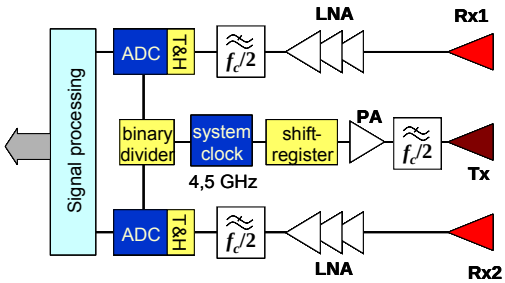

Figure 1: Block schematic of the Through wall radar

1.4 Detection and tracking of moving people behind a wall

The electromagnetic waves which penetrate a wall are scattered by all objects located within the antenna beam. The reflections from large or metallic objects dominate the back scattered signals. Reflections from a human being are comparatively weak and covered by these signals. Since the perturbing objects are however of static nature (i.e. their radar signature does not change with time), it is possible to extract radar data which is caused by human activity e.g. walking. Furthermore, it is possible to localize and track the moving targets by evaluating the different times of flight between the two receive antennas and the target (Figure 2). The exact reconstructed track deviates from the real one. A theoretical estimation also shows these deviations. This is caused by mathematically ill-conditioned problems due to the small distance between the antennas required for device size and handling.

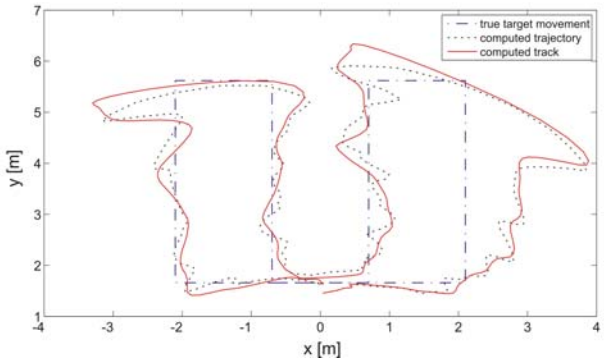

Figure 2: Reconstructed track of a walking person behind a brick wall [2]

1.5 Detection of trapped people

The detection of motionless people (trapped by rubble or handcuffed) is harder for the radar device, since the only criteria to distinguish the target from the surrounding is based on the minor motion of the breast due to breathing. This motion is comparatively small and will therefore cause only weak radar signatures. On the other hand it is a regular motion at a fixed location which permits the application of signal processing techniques which enhance the "breathing" signal from noise [3]. Figure 3 demonstrates an example, where a simulated victim was buried beneath moist soil and rubble. After removing the clutter signals caused by static objects, it was not possible to detect the victim in the radar data since the signals were attenuated by the moist soil. However by tracking the signal processing to the periodicity of the breathing, the victim could be localized. It should also be noted, that by using the wideband radar the victim can be localized and other sources of motion can be excluded which is difficult to achieve by typical narrowband systems.

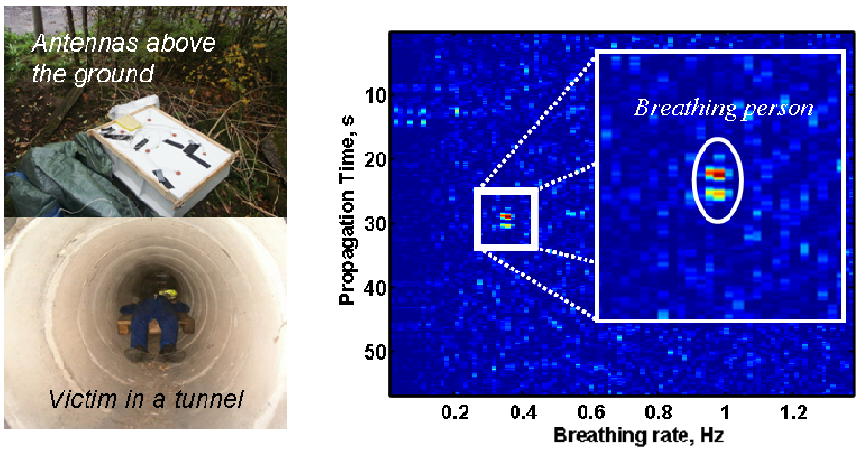

Figure 3: Detection of a buried victim

1.6 References

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