Motion Sensing Behind Walls and Obstacles Using Radio Waves

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Changes in radio wave propagation may be used to sense movement. A concept for sensing the movement of people or objects hidden behind walls or objects was rapidly prototyped and tested with the aid of a flexible SDR platform combined with a MISO antenna system. Tests successfully demonstrated the feasibility of using radio waves to sense the motion of persons or objects hidden behind walls or obstacles.

Alterations of wave transmission have been used for decades to detect objects and movements. This is the basic principle of radar. The results presented in a recent paper by MIT[1] demonstrate that narrowband transmission in the 2.4 GHz ISM band (i.e., WiFi) can be used to detect the movement of people and their relative locations behind walls without their having to carry any active or passive RF identification devices. The concept relies on the use of two transmitters and one receiver behind the wall (opposite to the person whose motion we wish to detect). The transmitters operate jointly so that, in the absence of movement, the signal at the receive antenna is nulled. However, in case of movement, the differential signal from the transmitters seen at the receive antenna does not cancel; enabling movement to be detected. This has been verified at CSEM using a software defined radio (SDR) platform.

The first objective of the project was to reproduce the results of the behind walls sensing system proposed by MIT[2] and assess the potential to develop a solution that can be built with low-power CSEM technology. The second objective was to setup a versatile platform for rapid prototyping of ideas and algorithms for RF sensing based on a SDR platform, in our case, the well-known Universal Software Radio Peripheral (USRP), and to learn how to use the open source software "GNU Radio". The ability to perform the necessary signal processing in a compact and efficient way is a key challenge.

The idea behind of motion sensing through walls and opaque obstacles is similar to that of radar or sonar imaging. The RF signal is transmitted towards the obstacle in question, where part of the RF signal penetrates the obstacle, reflects off of the moving object on the other side and returns to the receiver. The received signal contains information about what is hidden behind the obstacle. Losses may be large though and indeed the major problem with detection through walls and behind obstacles is that the received signal is very weak compared to the signal reflected off of the wall or obstacle.

The solution relies on the ability to cancel the strong signal components reflected off of the wall, or obstacle, leaving the weak signal reflected off the target person or object behind the wall (or obstacle). For this purpose, a type of Multiple Input Multiple Output (MIMO) antenna system known as a Multiple Input Single Output (MISO) antenna is used to cancel or null the signal from obstacle reflection. In this case, the MISO test system consisted of two transmit antennas and one directive receive antenna pointed towards the wall or obstacle. The antennas were connected to the USRP device and the PC with installed SDR platform for controlling, data acquisition and processing. The test setup is illustrated in Figure 1.

In order to demonstrate the feasibility, two SDR platforms were tested: 1) commercially available MATLAB/SIMULINK software and 2) open-source GNU radio. A block diagram of the nulling algorithm is presented in Figure 2. In addition to the fact that the GNU radio platform is an open source software, it also demonstrated better flexibility compared to that of SIMULINK.

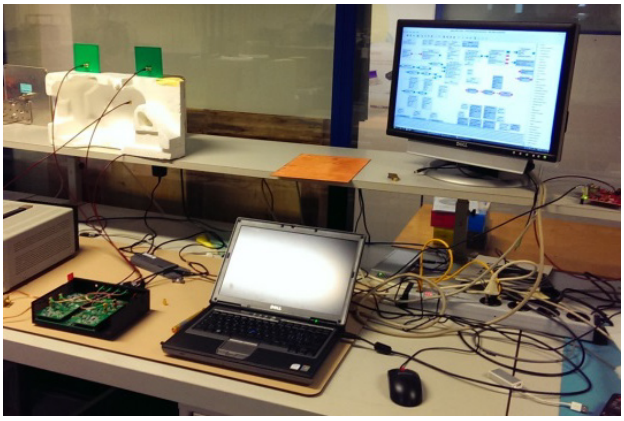

Figure 1: Setup for test and demonstration of motion sensing behind obstacles using and SDR platform and MIMO principles.

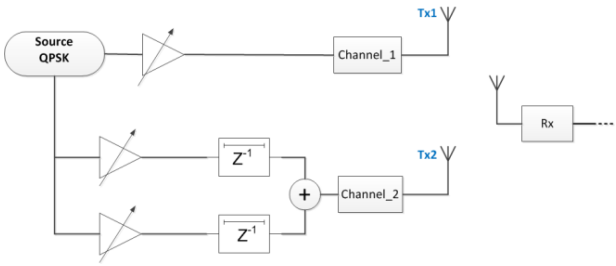

Figure 2: Functional block diagram of the nulling algorithm implemented in GNU Radio.

Using the test platform, we demonstrated the ability to detect hidden persons or objects moving behind walls. The results are promising. In principle, the sensing system could be implemented in commercial WiFi base stations (e.g. WiFi base stations using OFDM signals in the 2.4 GHz ISM band) equipped with multiple antennas without the need for additional hardware. Additionally, the SDR platform proved to be a very useful tool for rapid prototyping and experimentation with different algorithms (i.e., before implementing them in optimized hardware). However, before the results can be exploited, improvements are required including: new hardware with increased operational bandwidth and better channel isolation (in order to avoid crosstalk), as well as, calibration and recognition mechanisms for different RF transparent obstacles.

[1] web.mit.edu

[2] A. Fadel, “See through walls with WiFi”, Proc. ACM Special Interest Group on Data Communication (SIGCOMM), (2013)