Electromagnetic Sensing of Obstacles for Visually Impaired Users

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Abstract Vision impairment is a physical and sensory disability affecting a large number of subjects around the world. A large part of this subjects is aged 65 or older and their number grows faster than the overall population. In this work, a innovative sensing method, proposed by the research group of the Università Politecnica delle Marche based on EM pulses, is presented together with some experimental results achieved in obstacles detection. The proposed approach accomplishes most of the operative requirements of electronic travel aids for visually impaired subjects and can provide additional information (height form the ground, distance and position of the obstacle) on obstacles respect to the available assistive technologies currently used by subjects affected by visual impairments.

1 Visual Impairment and Assistive Technologies

Blindness and vision impairment (VI) is a physical and sensory disability affecting a large number of subjects around the world. The incidence of severe VI varies between industrialised (0.4 % of the population) and developing countries (>1 % of the population) [9]. Globally the World Health Organization (WHO) estimates 40–45 million of people to be totally blind and up to 314 million to have some kind of visual impairment; the 87 % of them live in the developing countries [10].

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The majority of blind and VI subjects is aged 65 or older; their number grows faster than the overall population and it is estimated that such figures will double by year 2020, making such issue of particular relevance for Europe strategic agenda.

From a social point of view, VI subjects live strong limitations on their social life, in fact the sight reduction or impairment limits the access to the information, the work opportunities and the interactions with other people and the surrounding environment. In particular autonomous mobility for VI subjects can be extremely difficult and in most of the case it requires the use of assistive devices.

The most common way to navigate for VI subjects is the white cane which is a pure mechanical device dedicated to the exploration of the ground in front of the user (about 1.5 m from his/her feet). Static obstacles and holes or steps can be detected by the user handing the cane simply by tactile-force feedback; floor characteristics (hard, soft, etc.) can also be inferred by the sound produced by the cane tip on the ground. This device is light, portable and cheap, but it suffers the limit to only provide information of static obstacles from the ground and a portion of less than 1.5 m in front of the user feet. The presence of trunk or head level obstacles is not detectable and consequently it can cause hits; this representing a major limitation on self-confidence in autonomous mobility for VI subjects, especially if aged.

The last decades have seen the proposal of many assistive technologies aiming to reduce the difficulties of VI subjects in mobility tasks. They typically involve the use of systems able to collect information of the space around the subject to provide orientation information and to warn for obstacle avoidance. Such devices are commonly known as electronic travel aids (ETAs) and are all based on exploring (with different sensing methods) the environment and to transfer the information gathered to the user by other sense (mainly hearing or touch). It is generally agreed that currently no available electronic travel aids (ETA) (commercial system or prototype) incorporates all the required features recommended by the Visually Impaired (VI) community and the International Guidelines to a satisfactory extent [4–6]. Moreover, it is interesting to note that in the literature there is a lack of studies which consider electromagnetic (EM) radiation in the radio frequency or microwave ranges as the physical quantity able to deliver information on obstacle presence for visually impaired users. Recently, the authors have demonstrated the possibility to sense the presence of obstacles in the volume in front of the user by EM pulse transmission [7].

In this work, an innovative sensing approach based on EM pulses is presented together with some tests conducted in real indoor/outdoor premises and achieved by the research group of the Università Politecnica delle Marche.

2 Operative Scenario and Scope

The ETA system proposed in this work has to give information on the presence and the distance of the obstacles eventually in front of the subject, exploring in elevation a region from ground to head level, and in azimuth an area corresponding to the subject's body.

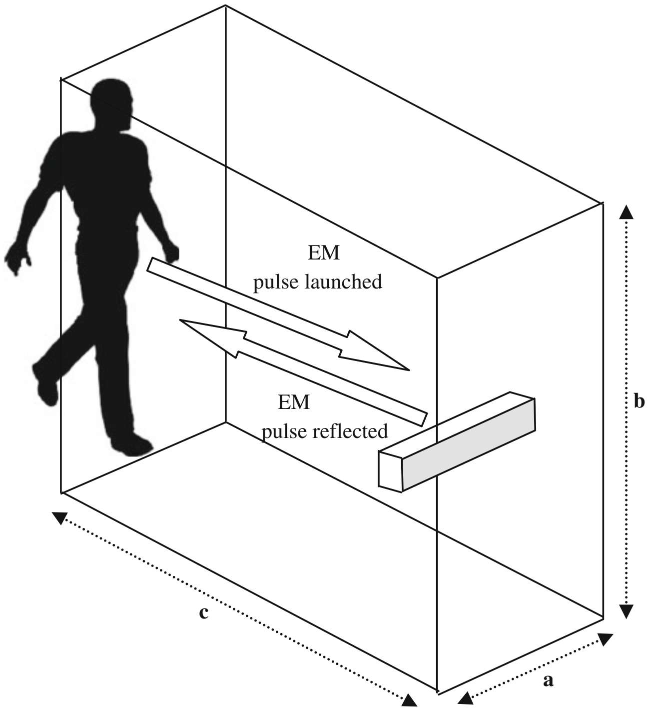


Fig. 1 Volume explored by the proposed system

The minimum distance or range over which this information is needed is a comfortable stopping distance at normal walking speed [4, 6]. The operative scenario explored in this study is represented in Fig. 1, where a = 1.5 m, b = 2 m, c = 3 m. The dimensions selected for the explored volume are a compromise between the necessity, in a real system, to give sufficient information to the user and the need to limit meaningless and multiple alarms thanks to continuous monitoring.

The present study aims to analyze the signal reflected from different types of obstacles placed at a different distance, level and position inside the above mentioned volume. In particular, it will be reported the case of two obstacle: the first obstacle is static (a person standing in front of the system) while the second is a moving obstacle (a person moving toward the system). The tests have been conducted in an outdoor space (parking pool) and in a corridor of the Faculty with standard metallic furniture.

3 The Proposed Solution

The experimental set-up realising the EM obstacle monitoring system is schematized in Fig. 2 and it is described in detail in [7]. The obstacle is illuminated using a helical antenna (matched from 4 to 6 GHz; half power beam of about 35.9° in the plane $\varphi = 0°$ and 36.9° in the plane $\varphi = 90°$).

Fig. 2 Photo of the electromagnetic obstacle detection sensor. The EM portable system (*left*); The system in use (*right*)

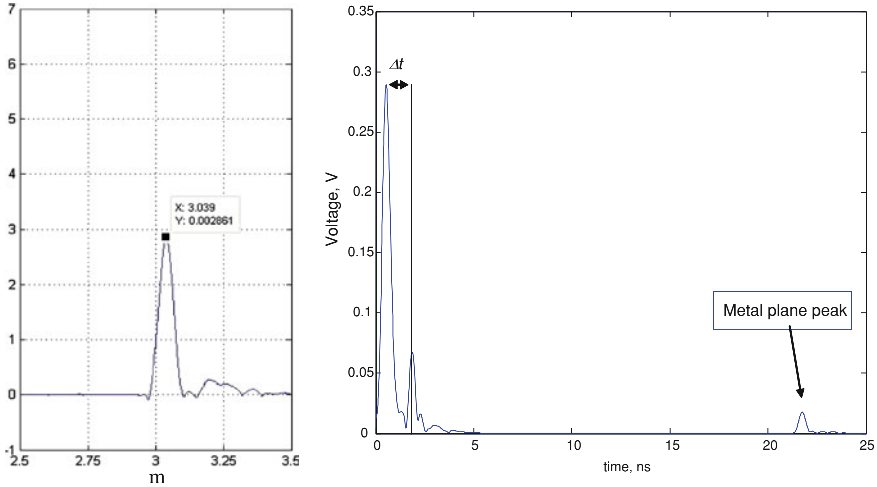


Fig. 3 Time response measured with a plastic plane (50 × 50 cm) placed at 3.04 m (*left*). Time response measured with a metal plane (200 × 200 cm) at 3 m (*right*)

A vectorial network analyzer (VNA) is used to measure the reflection coefficient at the antenna input. VNA provides the time domain response which has a pulse duration 0.4 ns (calculated at 50 % of the pulse amplitude), corresponding to 12 cm spatial resolution. The electromagnetic system is basically set up by a control unit, a Tx/Rx unit, and a radiating element. Each part has to be analysed and properly designed according to the requirements of the scenario. The radiated signal is a short pulse whose echo will be used to extract information of the object.

In Fig. 3, we report the time domain response measured in the case of a 50 × 50 cm plastic plane placed at 3.04 m (left) and of a metal plane (2 × 2 m) at a distance of 3 m (right). In Fig. 3-right, the x-axis is reporting time (ns) in order to appreciate the time scale of the whole phenomenon (the peak corresponding to the obstacle is detected after 21.8 ns for an obstacle at 3 m); the Δt (duration 1.32 ns) is the time interval between the coaxial-waveguide transition and the antenna aperture, during this interval the system is not able to detect the obstacle (it correspond to <28 cm).

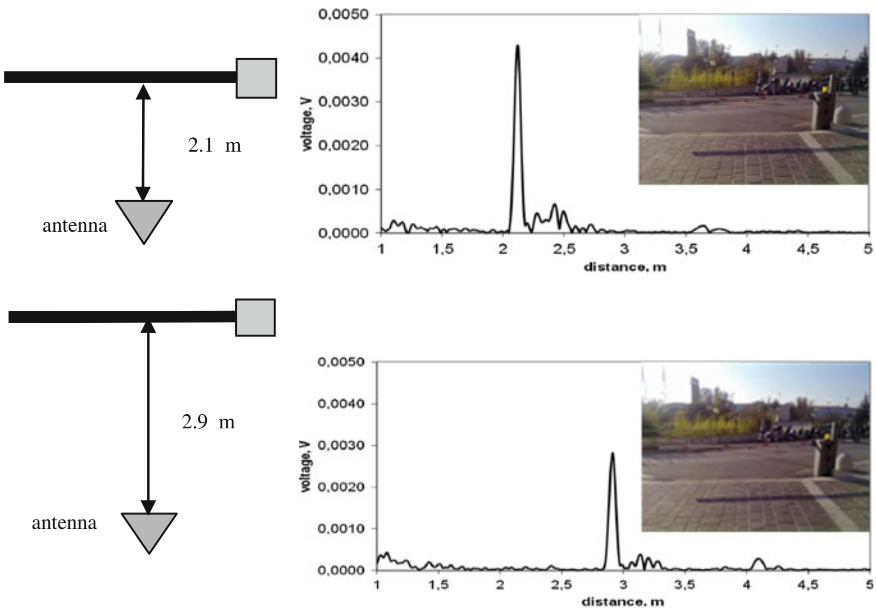


Fig. 4 Obstacle detection and distance measurement for the outdoor scenario

For the figure on the right, two peaks are well evident in the early time response corresponding to the coaxial-waveguide transition of the antenna and to the antenna aperture, they limit the minimum detectable distance to <28 cm.

4 Results

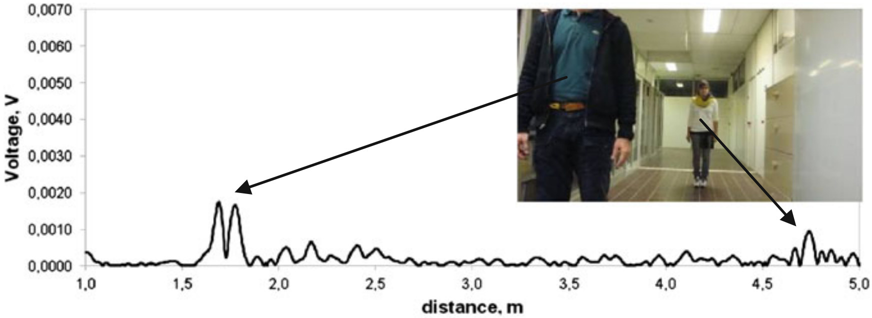
4.1 Outdoor Scenario: Static object

In Fig. 4, an example of an outdoor static obstacle (parking gate bar, height from the ground: 1.1 m)—not detectable by a cane—is reported for two different distances (2.1 and 2.9 m). The obstacle is clearly identified and its distance is determinable.

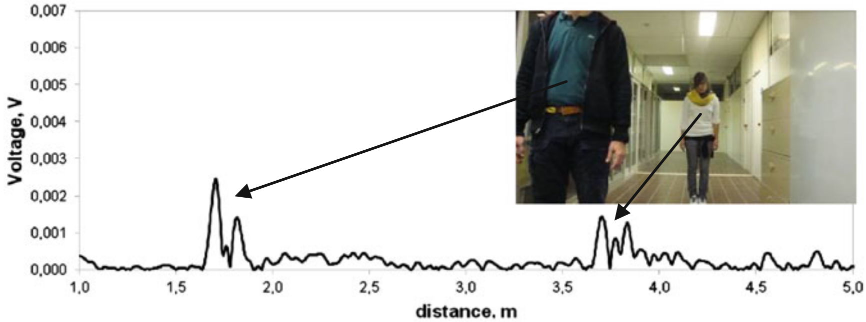
4.2 Indoor Scenario: Static and Dynamic Obstacles

In Fig. 5, it has been simulated a possible indoor scenario with static and dynamic obstacles: a corridor with one person standing on the right and one advancing the system). Signals measured by the proposed system are reported on the same figure on the right; the obstacles presence and their distances are clearly individuated by peaks. A sequence of measurements have been recorded while the subject on the right was moving toward the system.

Distance: 4.70 m



Distance: 3.70 m



Distance: 2.70 m

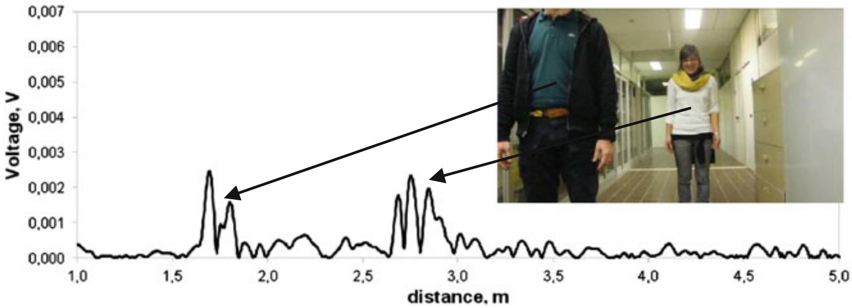
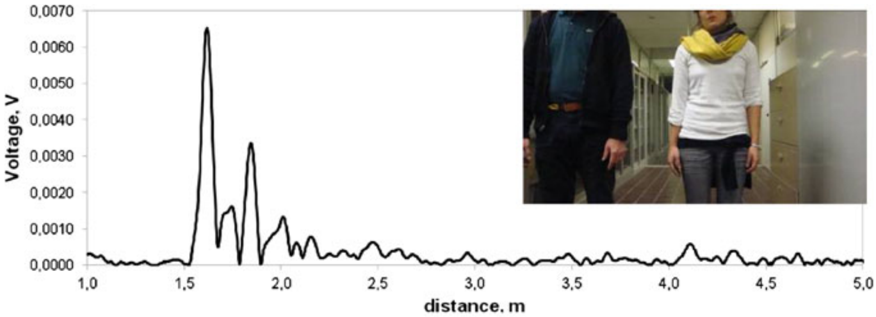


Fig. 5 Obstacle detection and distance measurement for the indoor scenario: test at different distances

Finally a test with a blind user has been operated with a portable version of the system and a specially portable antenna. The test has proved the ability of the user to avoid obstacles randomly placed, to identify in time obstacles at trunk height and to pass through a gate without hits (a video of the tests is available on line at [8]).

Distance: 1.80 m



Distance: 1.20 m

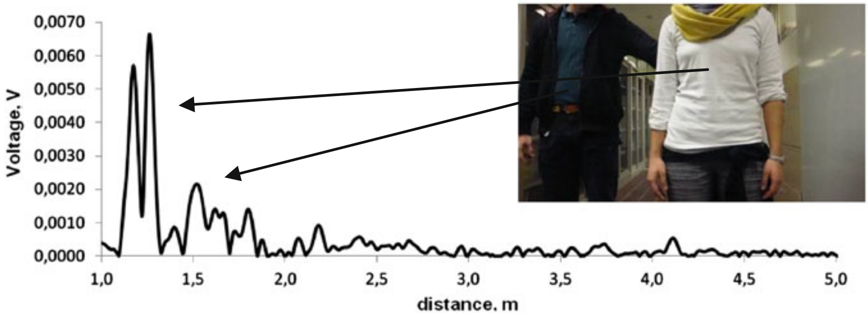


Fig. 5 (continued)

5 Conclusions

The use of EM pulses is suitable technique for obstacle detection in real mobility scenario for VI user. A first important characteristic of the proposed system is that, thanks to the high number of measurements operated per unit of time, the user can stand still or walk at an acceptable speed (<1 m/s). A second aspect is that the system is compatible with the cane and it can be also be mounted on the stick; if it is moved by the user in order to explore the volume of the space in front, (thereby intrinsically performing a space scanning like a real surveillance radar), mechanical motion is far slower than the speed of the EM pulse. Consequently the obstacle appears to be still with respect to the EM system. Therefore, the availability of a reflected pulse, providing the information on the distance of an obstacle, is the simplest and most effective way to inform the VI person.

The electromagnetic technology allows to achieve some advantages with respect to existing ETA systems (in particular the ultrasonic sensors):

- the frequency range allows the miniaturization of the antenna and of the device, more comfortable for the users.
- the possibility to integrate the antenna onto white cane. In particular more than one antenna could be used to detect obstacles at different height (ground, trunk, and head level). Finally a narrow beam in the horizontal plane would allow to determine the direction of the obstacle simply exploring the environment with the oscillatory movement of the cane.
- the penetrability of fabric from the electromagnetic waves, offering a full wearable ETA, improving acceptability and usability.
- the very high quantity of information collected in short time intervals, allowing the detection of moving obstacles whose velocity could be easily sensed.
- the dependence of the scattered field upon dimension and material of the radiated object could be usefully exploited to extract the obstacle characteristics.

It is important to note that future development of the proposed system will aim to improve system reliability and robustness, to design an advanced multi-sensory strategy allowing to optimise the system use and to study proper system-to-user-interface [1–3]. The use of EM sensing for VI subjects mobility is currently patent pending.

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