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# CONCEPT OF DETECTION SYSTEM TO LOCALIZE INSIDE CLOSED AREA BY RADIO TOMOGRAPHIC IMAGING

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***Abstract.*** *System for navigation and localization inside buildings will determine man's location in confined spaces with level of accuracy never yet achieved. System's operation will be mainly based on Bluetooth signals in accordance with the Beacon standard. A worldwide innovation will be the use of Radio Tomographic Imaging (RTI). This technology will enable tracking of moving objects by image reconstruction based on changes of electromagnetic field signal strength (RSS).*

**Keywords**: beacons, bluetooth, location inside buildings, radio tomographic imaging

## KONCEPCJA SYSTEMU DETEKCJI DO LOKALIZACJI WEWNĄTRZ OBSZARÓW ZAMKNIĘTYCH Z WYKORZYSTANIEM TOMOGRAFII RADIOWEJ

***Streszczenie***. *System do nawigacji wewnątrz budynków będzie umożliwiał określenie pozycji człowieka w zamkniętych pomieszczeniach z dużą precyzją. Działanie systemu będzie opierało się na sygnałach Bluetooth zgodnie ze standardem Beacon.. Innowacyjnym rozwiązaniem będzie zastosowanie tomografii radiowej (ang. Radio Tomographic Imaging (RTI)). Wykorzystanie tej technologii umożliwi śledzenie poruszających się obiektów poprzez rekonstrukcję obrazu na podstawie zmian siły sygnału (RSS) pola elektromagnetycznego.*

**Słowa kluczowe**: beacons, bluetooth, lokalizacja wewnątrz budynków, tomografia radiowa

## Introduction

Systems based on tomography and analysis involving the solution of the inverse problem for inaccessible areas are developed over many years [3-9]. In this work it has been presented the idea of creating a hybrid smart navigation and location inside buildings. Real Time Locating Systems is one of the most dynamically developing branches of ICT. They allow the spatial location of the object or person in real time. RLTS systems can be divided into systems operating in open spaces and working inside the buildings. First class system primarily uses technology (Global Positioning System) in combination of cellular systems and its best-known application is the location of persons/vehicles and fleet management. By using reliable and accurate GPS location technology development of systems of this type does not cause trouble. Unlike location systems for open spaces Indoor Positioning Systems cannot use GPS to determine the position inside buildings. For this reason, this issue is the importance of more complex both technically (there is a need to build a dedicated infrastructure) and scientific (the need to use complex algorithms which take into account the phenomenon of propagation inside buildings - multipath) [1, 2, 10].

## 1. System idea

The present system will make it possible to determine the position of man in confined spaces with unprecedented accuracy. This type of solution will be unique in the world. The system will be based largely on signals Bluetooth 4.0 LowEnergy according to the standard Beacon. At the same time intelligent hybrid system will be determined the position, using multiple sources of WiFi signal and data supplied by the sensors found in smartphones (gyroscope, accelerometer, magnetometer). An innovative solution in the world will also use Radio tomographic imaging (RTI) [11,12]. The use of this technology will enable the tracking of moving objects through image reconstruction on the basis of changes in signal strength (RSS) of the electromagnetic field between the transmitter and receiver (frequency WiFi 2.4 GHz). For this purpose, they will be designed and manufactured copyright dedicated devices "Beacon" using communication protocols WiFi and Bluetooth 4.0 LowEnergy. These devices are also equipped with copyright antenna transceiver directional characteristics.

## 2. Beacon

Becons are small wireless devices that use wireless communication (mainly Bluetooth BLE) to communicate with phone or tablet. Despite the fact that the device beacons were launched in 2013 and now has a number of entities created their own transmitters, still they are based on the same template uses to communicate only Bluetooth Smart (also known as BLE - Bluetooth 4.0 Low Energy). This is a method very accurate and quite unreliable. Particular attention should be paid to the innovative design of transceivers and the use of tomography using radio waves with a frequency of 2.4 GHz. The proposed innovation is the hybrid technique location different from the previously used using both signals BLE and WiFi.

Currently, in order to determine the approximate location of the mobile device is measured index values of radio signal strength (RSSI) between the two devices covering the range of operation of the passage of the same. Thanks to the hybrid model combining different interfaces and information from multiple sources. The system will be able to give much more accurate position of the localized object. The use of hybrid location will ensure stability of access to information, the stability of tracking the object and reading the dynamics of movement unprecedented in systems of this type. The client application will not focus exclusively on collecting and displaying properly correlated with the transmitter of information, but also take an active part in creating useful statistics for businesses and analyses. In case of any problems with radio communication application using the built-in accelerometer and gyroscope the mobile device will be able to lead the navigation until to restore and stabilize the connection.

## 3. Radio Tomography Imaging

Radio tomography bases its action on the measurement of the strength of the radio signal between the transmitter and the receiver. In the case where between the transmitter and the receiver an object is measured, signal strength value is changed, the due to reflection, absorption or scattering of electromagnetic waves (Fig. 1 and 2).

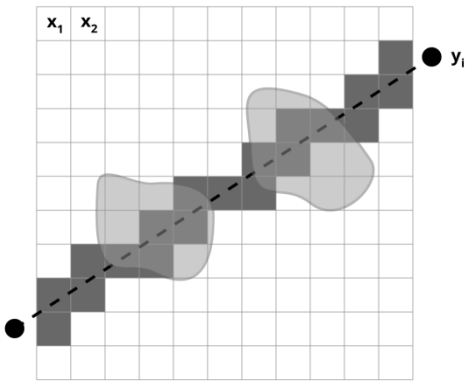


*Fig. 1. Schematic diagram the course of a single wave between the transmitter and receiver*

If K is the total number of transmitters (receivers) is the total number of independent pairs of "electrodes" expressed by the formula:

$$M = \frac{K^2 - K}{2}. \quad (1)$$

The averaged signal strength of the bidirectional link is referred to R-dependent:

- $P_t$ – power transmitter,
- $S_s$ – losses due to static objects,
- $S_m$ – losses due to moving objects,
- $F$ – signal interference narrowband,
- $L_d$ – loss due to different distances between the transmitters,
- $L_a$ – losses due to antenna mismatch,
- $N$ – noise.

Mathematically, the received signal power (in dB) is described as:

$$R = P_t - L_d - L_a - S_s - S_m + F - N. \quad (2)$$

The model of the objects for the radio tomographic imaging, user and device location show Figure 3-8.

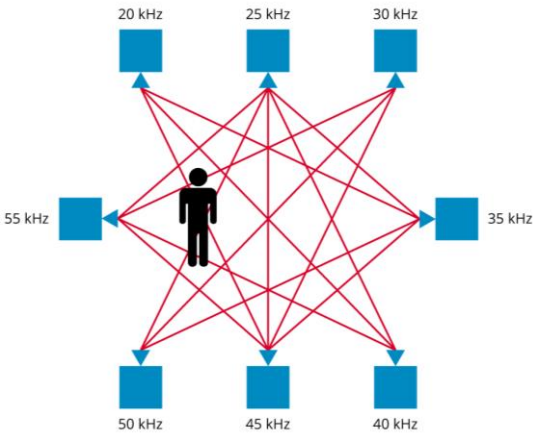


*Fig. 2. The idea of radio tomographic imaging*

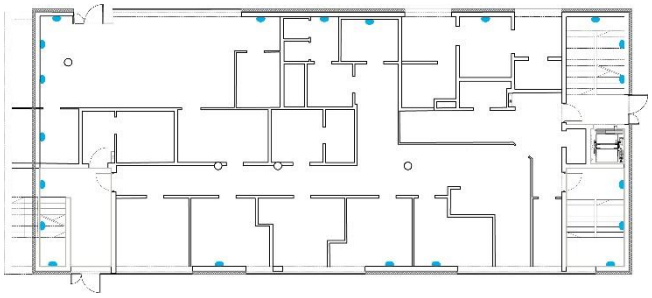

*Fig. 3. Model of the object*

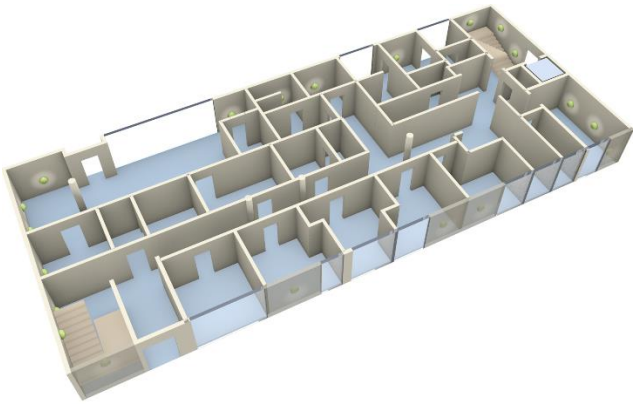

*Fig. 4. Model of the object 3D*

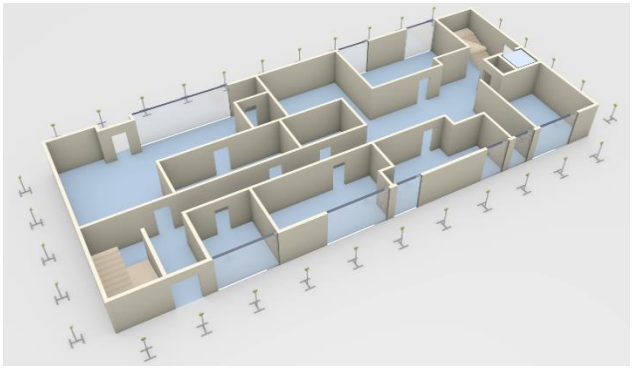

*Fig. 5. Model of the object with sensor on the outside*

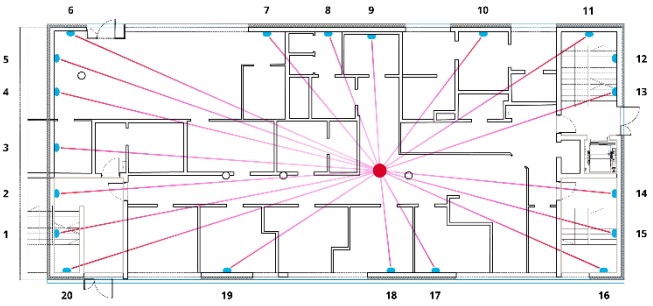


*Fig. 6. Device location*

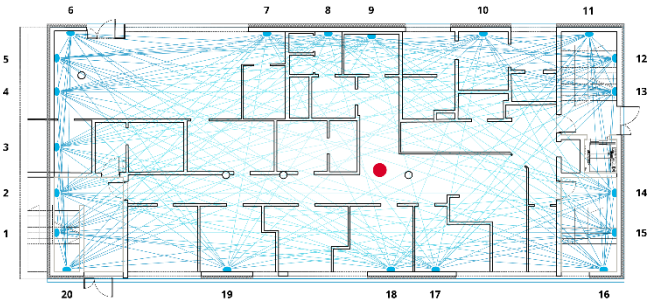


*Fig. 7. User location*

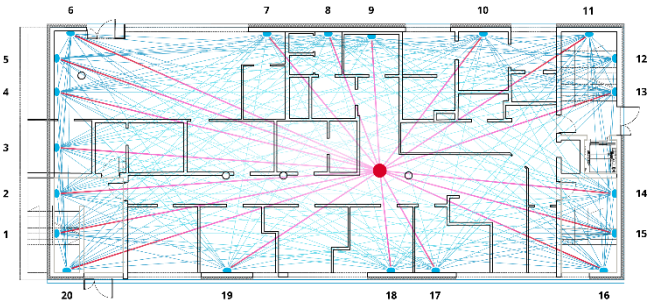


*Fig. 8. User and device location*

## 4. Devices

The project of device for radio location and communicating the phone presents in Figures 9 and 10.

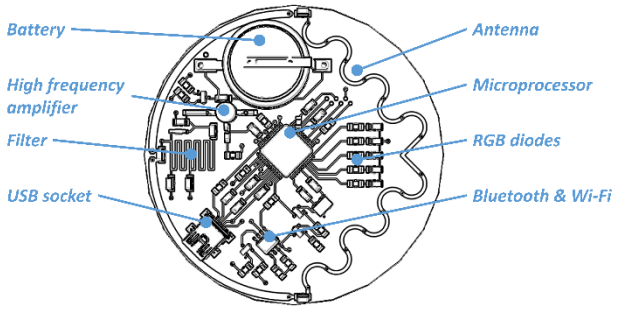


*Fig. 9. A device for radio location*

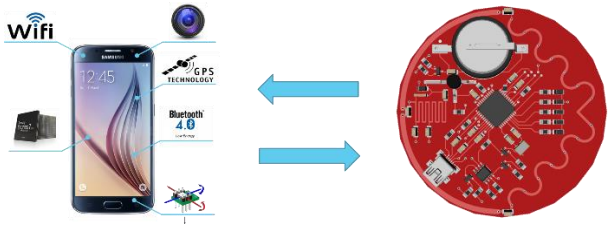


*Fig. 10. Communicating the phone with the device*

## 5. Ultra Wideband

Ultra wideband (UWB) is one of the techniques of radio-based fast sending short pulses. The duration of a single pulse of the order of tens of picoseconds, so the emission spectrum is very broad. UWB technology is developing wireless communication, which is characterized by high data rates (up to 2 Gb / s). UWB operates at a low power level, which eliminates interference from other radio systems and allows you to build devices with low power consumption. The system operates in the GHz range 3,1-10,6 (Mutli-Band OFDM).

Once an electrode is suitable (TX) signal, and then records the signals reflected from objects. If within the area there are people that signals are reflected and weakened. In this case, all of the independent electrodes to operate simultaneously.

Energy dependence of frequency for UWB and Narrowband is presented in Figure 11. Figure 12 shows schematic drawing of diffraction of radio waves UWB measurement sequence.

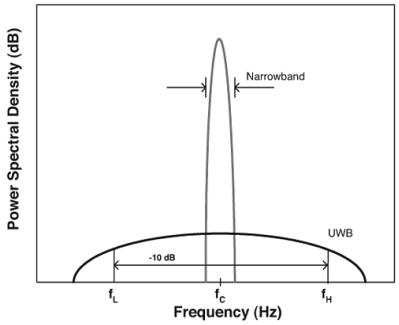


*Fig. 11. Energy dependence of frequency for UWB and Narrowband*

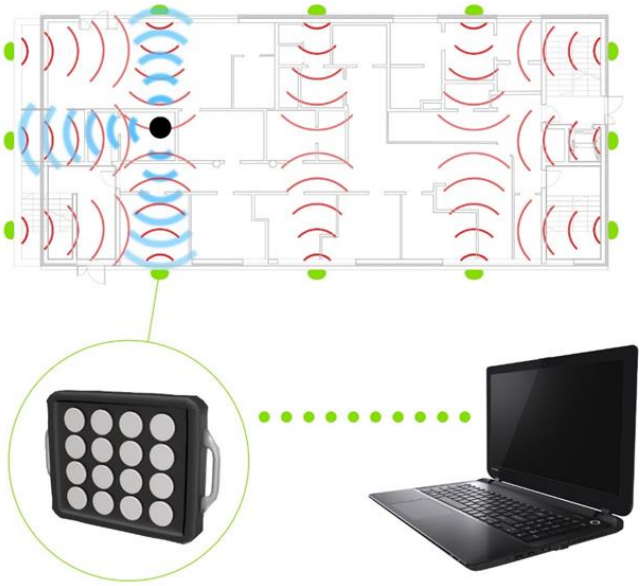

*Fig. 12. Schematic drawing of diffraction of radio waves UWB measurement sequence*

## 6. Image reconstruction in RTI

Using radio tomography for to the presented technology allows tracking of moving objects through image reconstruction on the basis of changes in signal strength (RSS) of the electromagnetic field between the transmitter and receiver (frequency WiFi 2.4 GHz). Through reconstruction of the image and the segmentation you will be able to very precisely determine the location of the human (Fig. 13).

The image reconstruction of the distribution of field lines and numbering of mesh elements are shown in Figure 14 and 15.

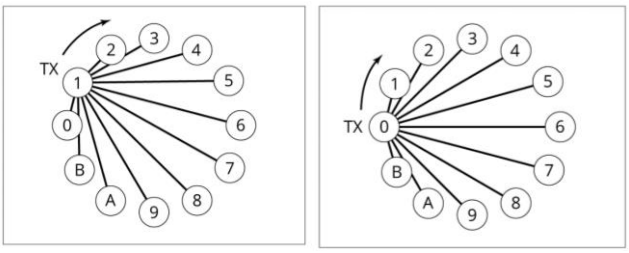


*Fig. 13. The idea of location (signal) in the radio tomography*

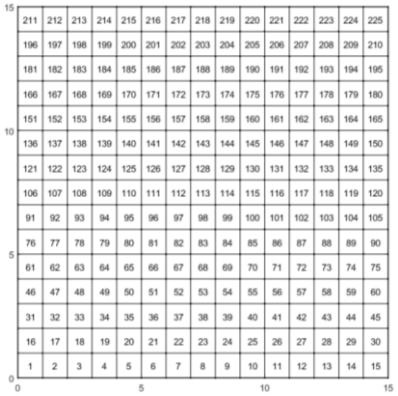


*Fig. 14. Numbering of mesh elements*

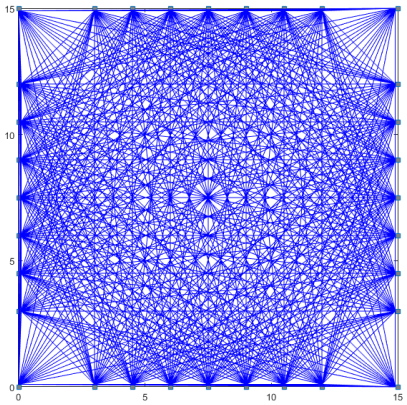


*Fig. 15. Distribution of field lines*

## 7. Conclusion

The concept of navigation system inside the buildings is based on radio tomography possible to determine the user's location using public facilities such as a smartphone, tablet and dedicated modules "Beacon". In contrast to currently used technologies proposed solution will enable you to determine the position with high precision (accuracy of 0.5 – 1.0 meters). The new technology will be based on its effect on communication protocols, such as WiFi and Bluetooth 4.0 LowEnergy. At the same time it will use sensors available in portable devices (gyroscope, accelerometer, magnetic field sensor) as well as the camera, so the system will be reliable in all conditions. Hybrid location inside the building, will be able to determine the position of the human even when density housing.

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