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Indoor location based on the signal fusion

Mobile device and base stations for 433 MHz band

Damian Grzechca, Bogusław Biolik
Institute of Electronics
Silesian University of Technology
Gliwice, Poland
Damian.Grzechca@polsl.pl

Lukas Chruszczyk, Jerzy Fiolka
Institute of Electronics
Silesian University of Technology
Gliwice, Poland
Lukas.Chruszczyk@polsl.pl

***Abstract*—The paper presents our work in progress for locating indoor objects based on signal fusion. The location is based on two signals: RSSI (Received Signal Strength Indication) and video camera. This paper presents proposed hardware system, i.e. base station and locating device without video software being under development.**

Keywords-component; RSSI location, signal fusion, mobile electronic device

I. INTRODUCTION

Creation of monitoring systems is required to determine the location of different types of mobile objects. The use of wireless communication can be utilized for location, while maintaining the possibility of movement of objects under consideration. An increasing number of systems and techniques will foster wireless location systems that use these technologies. There are two elements in wireless locating systems: measurements systems and signal transmitter enabling location. Measurement system often acts as a data processing unit (control unit), which on the basis of the received information determines position of the localized object. Because of functions of these components and the relationships between them the wireless location systems can be divided into four groups [1]: remote positioning, self-positioning, indirect remote positioning and indirect self-positioning. Fundamental two concepts are remote positioning systems and auto-location. The first one has a mobile transmitter and one or more measuring systems with known location receives the signal. The data is then sent to the control unit which determines the location of the transmitter. For auto-location systems, measurements and calculations are determined by the locating device on the basis of the signals emitted by transmitters. The transmitters positions are fixed and known. Providing the ability to transmit the measurements leads to the following concepts: indirect remote positioning and indirect auto-positioning. When a device sends information obtained through the auto-positioning system to a stationary receiver, we are dealing with a system of indirect remote location. For indirect auto-positioning, data transmission (position) is send to mobile objects. The choice of the location system concept depends primarily on the amount and nature of the localized objects.

The information needed to locate the objects is based on the measurements. Among the most commonly used methods there can be distinguished: the angle of signal arrival (Angle of Arrival – AOA), received signal strength (RSSI) and propagation time which can be determined as follows: the signal arrival time (Time of Arrival – TOA), time difference of signal arrival (Time difference of arrival–TDOA), response time (Round Trip Time of Flight–RTOF) [1].

When measuring the angle of the arrived signal, there must be examined the difference in phase (angle) between the signals of up to a fixed receiver position. It requires the use of directional antennas, antennas dynamically changing direction or arrays of antennas.

The phenomenon of attenuation occurring in propagation environment is utilized for received signal strength method. RSSI measurement compares known values of signal emitted by the transmitter to the signal attenuation. It allows calculating the distance between two objects. Simplified formula is following:

$$P_R = \frac{P_T}{r^n} \qquad (1)$$

where:
P_R – Power of received signal
P_T – power of transmitted signal
n – constant depending on propagation environment
r – distance between transmitter and receiver.

It is assumed that the attenuation decrease with the square of distance. So, the signal transmitted in a free space corresponds to n=2. Propagation in a real environment differs significantly from the propagation in free space because of the noise, reflection, diffraction, interference, and the unpredictable path of beam. It is impossible to accurately determine damping constant depending on the distance. In practice, more complex patterns are used (or propagation models) for propagation medium. This method is often used because many commercially available receivers have the ability to read the relevant register of RSSI.

II. POSITIONING SYSTEM DEVICES

Now, let us focus on the system fusion. Classic monitoring systems are based on the single operator observing many objects – this is too tiring for the operator. If some of the workers may be present in the restricted area, e.g. inside airport terminal there are many zones where different status is required in order to have permit for accessing or staying. Nowadays, the security guard just observes the halls and has to decide whether to take precautions (in case of infringement of the protected area). In order to have more information about the people (objects in general) we propose the system which combines the information from monitoring system with our portable devices. Due to secure reason the wireless system should operate in license band however for early stage purpose we decided to use one of ISM bandwidth, namely 433 MHz band.

A. Tranceivers

The most important parameter is radio link range which depends on receiver sensitivity, data rate, frequency, antenna and environment. Careful selection of the transceiver allows for maximization the area of location. For that purpose, we have evaluated a number of ICs and only 4 of them are listed in tab. 1. Based on tab. 1 we decided to use cc1000 for prototype electronic device.

TABLE I. PARAMETERS OF CHOSEN TRANCEIVERS [2,3,4,5]

Manufacturer	Texas Instruments	Texas Instruments	Hope Microelectronics	Hope Microelectronics
Model	CC1000	CC1100	RFM12B	RFM22B
Operating frequency [MHz]	300 ÷ 1000	300 ÷ 348, 400 ÷ 464, 800 ÷ 928	430.24 ÷ 439.75, 860.48 ÷ 879.51, 900.72 ÷ 929.27	413 ÷ 453, 848 ÷ 888, 901 ÷ 929
Transfer speed [kbit/s]	76.8	500	115.2	256
Max. power [dBm]	+10	+10	+5	+20
Sensitivity [dBm]	-114	-111	-100	-121
Range [m]	> 2000	> 1000	> 300	> 800
Current consumption [mA] Tx/Rx	9.3 / 26.7	16.5 / 28.9	13 / 24	18.5 / 85

Communication between cc1000 transceiver and microcontroller is done with lines: PALE, PCLK, PDATA, DCLK, DIO. First three are used to configure the system and the other two for data transmission. The ability to read the RSSI value ensures RSSI pin. CHP_OUT pin is an output charge pump or an indicator of the PLL.

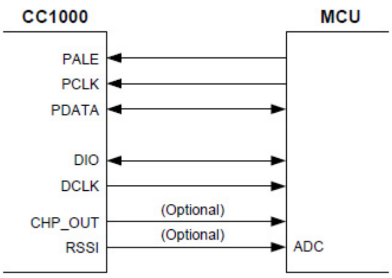

Figure 1. Connection of the cc1000 tranceiver with microcontroler.

The cc1000 transmission uses logic implementation. For NRZ (Non-Return to Zero) or Manchester coding, line DCLK provides clock signal and DIO is input output data. Clock signal should be connected to microcontroller which allows generation of external interrupts. In transmitting mode individual bits on DIO lines are read on the rising edge of DCLK signal. While in receive mode bits on DIO lines are drawn on the falling edge of DCLK signal. For UART mode, data are transmitted with two separate lines. Data entry is line DIO, DCLK, in turn, serves as a line output. DATA_FORMAT enables the type of encryption which belongs to register MODEM0.

Wireless transmission is carried out with the following settings: frequency: 433.507 MHz (Europe ISM), FSK modulation, 64 kHz band separation, 0.6 kbps baud rate, Manchester coding and transmit power 10 dBm [6,7,8].

B. Microcontroler unit

During the first stage of our work we made research towards optimal microcontroller. The AVRs under consideration are gathered in tab. 2.

Base station is equipped with ATmega32A microcontroller. This is a variation of the popular ATmega32 microcontroller with reduced power consumption and a wide range of power supply voltages. 32 kB of program memory allows implementing complex algorithms of the system and support for multiple locations of mobile devices with a single base station as well. Available input/output lines allows connection with cc1000 and PC computer.

Mobile unit is equipped with ATiny4313 microcontroller. This unit has very low power consumption and a wide range of power supply voltages. 4K of program memory is enough for simple data processing. Available IO terminals offer easy connection with cc1000.

TABLE II. PARAMETERS OF AVR UNDER CONSIDERATION

Microcontroler	ATmega8	ATmega32	ATmega32A	ATtiny2313	ATtiny4313
Flash memory (Flash) [kB]	8	32	32	2	4
Data memory (EEPROM) [kB]	0.5	1	1	0.125	0.25
Data memory (SRAM) [kB]	1	2	2	0.125	0.25
No of pins	28/32	40/44	40/44	20	20
IO pins	23	32	32	18	18
Interfeces SPI	yes	Yes	Yes	Yes	Yes
Interfece USART	Yes	Yes	Yes	Yes	Yes
Ext. interrupts	Yes	Yes	Yes	Yes	Yes
ADC converter	Yes	Yes	Yes	No	No
Int. oscillator	Yes	Yes	Yes	Yes	Yes
Current consumption [mA]	11/15	12/15	7.5/15	-/6	3.9/7
Supply voltage [V]	4.5÷5.5	4.5÷5.5	2.7÷5.5	2.7÷5.5	1.8÷5.5

C. Base station for acquiring signals

Schematic for base station has been presented in fig. 2. There are many important tests which have to be validated before final prototype. One of them is current consumption of mobile device. The following values have been measured:

Transceiver cc1000 consumes: 26.7 mA (transmission), 9.3 mA (reception), the ATtiny4313 microcontroller requires 7 mA.

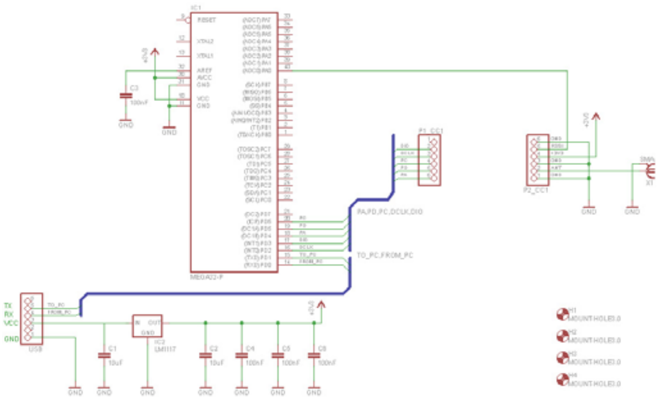

Figure 2. Schematic for base station.

D. Mobile unit

Schematic for mobile unit is presented in fig. 3.

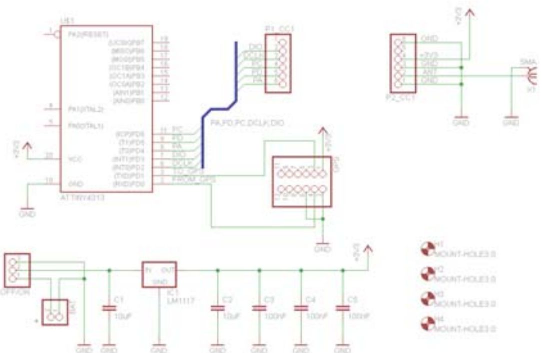

Figure 3. Schematic for mobile unit.

III. PC SOFTWARE

The end-user will be able to manage the process of localization based on RSSI value. The position of an object will is placed on the map and the operator can prove its presence with the video camera. The most important is automatic identification of objects because each has got a unique ID number. The software is under development and the communication with base station is performed with USB or Ethernet. The early stage software screen is presented in fig. 4. Temporary covers for mobile unit and base station are presented in fig. 5. As it can be seen the mobile unit is equipped with USART interface so it can be connected to other devices. There is planned to be attached biometric sensor in order to identify people. On the other hand, the system can be applied for outdoor positioning based on GPS signal (many modules have UART interface already).

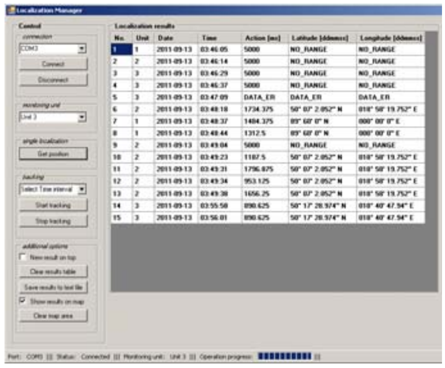

Figure 4. Software for communication with device.

Figure 5. Portable device and a base station.

IV. COMMUNICATION FRAME FORMAT

During the early stage we propose a simple communication frame format of constant number of bytes. Command frame from the PC to the Base Station (BS) contains BS address (there can be more than one BS in our system), mobile unit address, and command.

Address BS (1B)	Address UAI (1B)	Command (1B)

In response to the command frame, the base station sends request to UAI or sends back a specific frame (command not supported yet). Request frame is transmitted from the base station to a particular mobile device (preamble has been set to 16 bytes). All chosen base stations send a frame to a particular mobile device. The device store a base station address and RSSI index for all base stations (max. 12) and then sends data back to the base station.

Response frame from the mobile unit consists of max. 24 bytes (BS1 address, RSS1, BS2 address, RSS2, BS3 address, RSS3,…).

V. SYSTEM PARAMETERS

Currently, the system is under the test and the following parameters has been measured:

- Outdoor/Indoor max. distance from BS is 300m/150m
- Location time is about 1s
- Accuracy not less than 4m (depends on environment and algorithm)
- Work on battery time 7h30min (response every 1s)

- Weight 278g

VI. Conclusions

Our system is under construction and the most time consuming work is still before us. However, first milestone has been presented in this paper, which describes a construction of portable device and a system of base stations. Based on the RSSI index and image processing (video camera) the system will localize and identify objects in the supervised area. First results indicate very low accuracy of RSSI index but we have built only three base stations. We believe that more stations together with image analysis give us reasonable results in a short time.

Acknowledgment (Heading 5)

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