Exploring a narrow-band OFDM-Protocol in an ultrasound spectrum

Master thesis, Computer Science or Electrical Engineering, German or English

Background

Indoor positioning is still an unsolved problem in many scenarios. Finding the needed product in a supermarket, getting the right path to the doctor's office in a clinic or navigating workers in a logistics hall are just three real-world examples where a working indoor positioning solution could create a positive impact. Previous research and existing solutions use a wide variation of technologies trying to solve these problems. Besides WiFi and Bluetooth, newer approaches use loudspeakers and microphones enabling an ultrasound-based spectrum to provide an indoor positioning.

One of these approaches is "Koopango", a product of Rostock-based startup DEJ Technology GmbH. Founded in 2016 as a spin-off of the chair for information and communication services (IuK/Prof. Cap), Koopango is using Chirps [1] from 17.5 to 21.5 kHz, which already reached its physical limits. Other methods might have much bigger advantages but did not yet tested on commodity hardware and on a less than 4 kHz band. Because of its advantages on small bands, OFDM might be valuable option.

Goal

The goal of that thesis is to develop a concept and test an OFDM-based prototype for an ultrasound-based indoor positioning solution using commodity hardware (as smartphones for example).

Description

Most of the publications available are on OFDM systems for ultrasound within the magnitude of tens of KHz ([3] and [4]). One can find several papers on the use of OFDM in relatively wide-banded ultrasound medium, but not in the narrow-banded scenario that we are interested. This implies the first research question: What are the pitfalls of using electromagnetic technologies in narrow-banded ultrasound medium (of which OFDM is one example)? In detail this research question covers the following questions to investigate:

1. What are the requirements ultrasound have on commodity hardware(bandwidth, latency, etc.)?
2. Which protocols known from electromagnetic technologies could be applied to an ultrasonic band?
3. How does the adaption affect the protocols characteristics (frame length, error detection, etc.)?
4. How does the adaption affect the protocol's performance (transmission time, throughput, etc.)?

Because OFDM is one possible approach, the thesis is focused first on exploring if and how conventional radio communication protocols and methods can be applied in a narrow-banded ultrasound medium. OFDM will be a specific case study in the thesis secondly.

Therefore, the thesis' practical part includes the customization of this conventional technologies to fit into the limitations of the narrow-banded ultrasound medium. The evaluation of an OFDM-based approach deals then with the detailed research question from above. Therefore the tasks of that thesis are:

1. Collect requirements of ultrasound requirements for indoor positioning on commodity hardware
2. Research electromagnetic technologies and protocols for application in an ultrasonic narrow-band
3. Select and explain one protocol for adaption, imply theoretical impact on it's characteristics
4. Develop a prototype for selected protocol
5. Evaluate prototype regarding the impact in its performance

References

[1] Ens, A., Höflinger, F., Wendeberg, J., Reindl, L. M., & Schindelhauer, C. (2013, October). Indoor positioning using ultrasonic waves with CSS and FSK modulation for narrow band channel. In Int. Conf. on Indoor Positioning and Indoor Navigation 2013 (IPIN'2013). IEEE.

[2] Nee, R. V., & Prasad, R. (2000). OFDM for wireless multimedia communications. Artech House, Inc.

[3] Jiang, W., & Wright, W. M. (2016, September). Indoor wireless communication using airborne ultrasound and OFDM methods. In 2016 IEEE International Ultrasonics Symposium (IUS) (pp. 1-4). IEEE.

[4] Jiang, W., & Wright, W. M. (2017). Indoor airborne ultrasonic wireless communication using OFDM methods. IEEE transactions on ultrasonics, ferroelectrics, and frequency control, 64(9), 1345-1353.