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Position Discrimination of a 2.4 GHz IEEE 802.15.4 RF Mobile Source Inside-Outside a Vehicle

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***Abstract*—Thanks to the recent advancements in the automotive industry, in smart city infrastructure and in electronics miniaturization, low-power wireless sensors are becoming a reference sensing technology connecting the internet of things (IoT) with the conventional world. This study provides an empirical solution to the modern radio location problem of inside-outside position discrimination for a mobile radio frequency (RF) source. The solution is delivered by a detection system that is fully enclosed inside a modern vehicle cabin, whereas the RF ranging is based solely on the received signal strength indicator (RSSI) and the individual sensor's directivity achieved through shielding. The RF detection system is provided through a low-power wireless sensing network as a complete 2.4 GHz IEEE 802.15.4 solution, anticipating the future integration of this technology in the next generation of smartphones. The RSSI fingerprinting database, which is derived from empirical outdoor measurements for a range up to 5 m, delivers a consistent performance inside the highly RF-reflective vehicle cabin by exploiting the sensor position and directivity, focused on the front of each seat to avoid future human interference. Moreover, a theoretical propagation model based on Friis' transmission equation constructed on system parameters shows a high correlation with the RSSI fingerprinting experimental model, supporting the consistency of the empirical model, and demonstrating a similar high inside-outside discrimination. The decision algorithm logics used for inside-outside discrimination illustrate a strong example for sensor group decision based on two spatial thresholds: maximum detection range for outside discrimination and the cabin width for inside discrimination. This study's location system design creates exploitation possibilities beyond the vehicle environment. Various applications that require complete sensor encasement, such as road flushed traffic sensors or underground systems for parking space occupancy detection may benefit from this work's findings.**

***Keywords*—wireless, location, positioning, vehicle**

I. INTRODUCTION

The emblematic presence of the low-power wireless sensor exceeds the internet of things (IoT) context, its presence within home and commercial automation, toys, medical instruments, wearable electronics, and smart city infrastructure confirms its merits as an integral part of life. Its potential and limitations for communication as well as for radio frequency (RF) location-based services (LBS) have generated a vast research legacy focusing on various applications for outside and inside positioning [1].

Since the imminent evolution in the smart car industry, the robustness of the wireless low-power sensors for mobile RF LBS is again under research review. As the smartphone platform wraps, aside its main RF transceiver, a variety of wireless low-power communication services such as Wi-Fi, Near Field Communication (NFC), Bluetooth Low Energy (BLE), and other numerous forthcomings, the association with its owner's position transforms it in a reputable active RFID authentication device. Utilising the smartphone's secondary wireless services for user position tracking is a highly appreciated commercial competence despite introducing various challenges, providing numerous exploitation opportunities for security pass [2], indoor guidance [3], pedestrian detection [4], assessing advertisements effectiveness [5], non-contact ticketing [6], etc.

To implement a non-contact access system, two protection layers need to be considered: physical, through placement of the platform inside a protective compartment or out-of-reach locations, and software, able to deal with possible cyberattacks. Moreover, upon using the smartphone as an authentication device, the mobile phone location requires an accurate position discrimination outside or inside the secured area, determined by a detection system that is completely enclosed within the protected perimeter. The inside-outside position discrimination through exclusive RF presents many challenges if the restricted space of a modern car is considered.

Modern car keys embed functions like Passive Keyless Entry (PKE) or Passive Entry Passive Start (PEPS) and a real effort is concentrated on studying the possibility of migration towards smartphone non-contact access, providing the user with a more powerful interface to the vehicle, and reducing the number of devices to carry. Detecting the mobile phone position over a short range outside and inside the vehicle through services such as BLE or Wi-Fi is a difficult task, since the global 2.4 GHz license-free band delivers via its received signal strength indicator (RSSI) a position accuracy of only 1-2 m [7-11]. Moreover, Wi-Fi implementation [12] requires a subscription while the service is not power economic. Currently, implemented systems based on BLE access require either their original RFID keys presence [13], or pairing with a doorknob touching sensor [14]. Other possible technologies to be integrated next in a smartphone, such as ultra-wide band (UWB) radio, may provide the accuracy necessary to solve the inside-outside position discrimination problem, however, there is a considerable concern that UWB may interfere with the complex sensor system environment deployed in the smart car of tomorrow. The most representative automotive manufacturers have adopted the NFC phone access entry solution [15-20], as it requires a few centimeter proximity from the interrogation point, however the desired PKE or PEPS car key functionality has not been reached.

State-of-the-art research indicates that location accuracy under 1 m via BLE inside a passenger car is possible if additional parameters are added to the RSSI: data transmission time stamping [21, 22], using the door and seat sensors information [23], or for inside detection only the assumption that each seat provides a unique RF signature by making directive sensors through backplane shielding [24].

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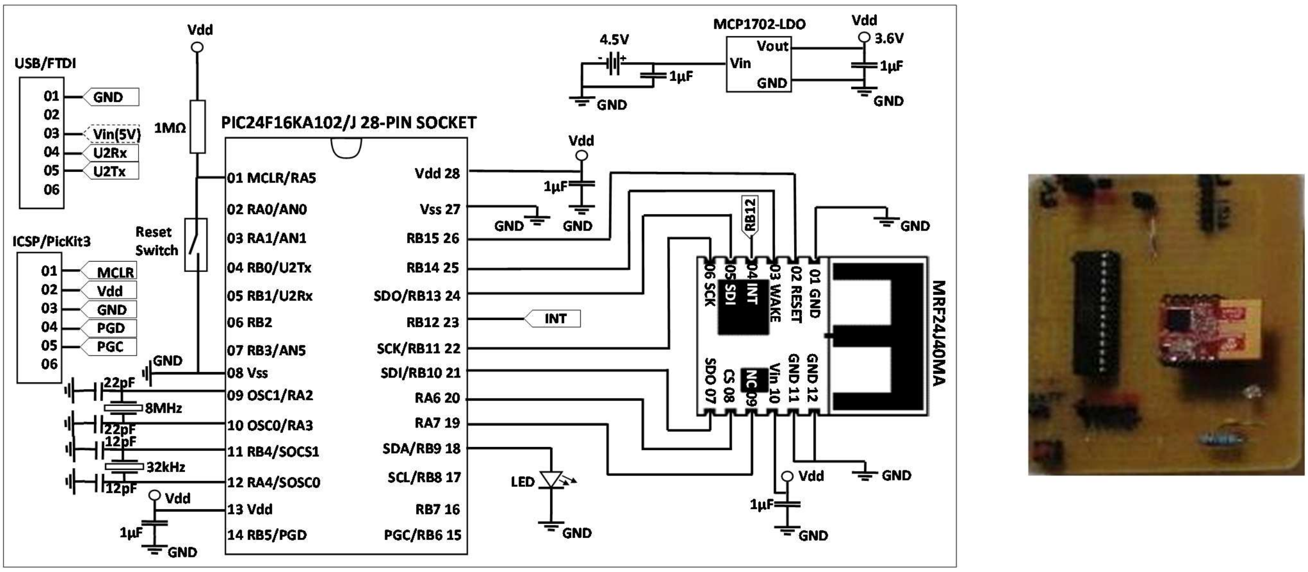


(A) (B)

Figure 1. (A) Electronic schematics of the used RF sensor, (B) top-view of the wireless sensor prototype

This study reports an implementation method for a detection system that is completely enclosed inside a modern vehicle cabin, relevant for a 2.4 GHz low-power wireless sensing network. The detection system can fully discriminate the inside-outside position of a mobile RF source solely relying on RSSI and its wireless sensors' directivity achieved through shielding.

It is of special interest to this study to determine the validity of such proposed solution via empirical experimentation, as a proof-of-functioning prototype provides more relevant integration directions. The overall goal of this work is to illustrate the decision steps converging to the materialization of the RF detection system, as the innovative result may encourage other similar approaches to be used for solving well-acknowledged challenges.

This work's contribution has wide applicability, whereas its proposed solution delivers directly to PKE or PEPS domains, the same approach may be tailored to industrial or commercial areas with a similar context. Moreover, the study's novel direction towards the transformation of an omnidirectional wireless sensor in a directive one, without any antenna alteration or additional connections, may deliver the conceptual support for applications such as road flushed traffic sensors or, buried detectors for parking space occupancy. Finally, as the experimental system is based on the 2.4 GHz IEEE 802.15.4 standard protocol instead of BLE or Wi-Fi, it anticipates the new generation of smartphones' wireless low-power services aimed to offer a direct connectivity to the existing ZigBee networks, used in home and industrial automation, providing a pioneering lead to forthcoming research.

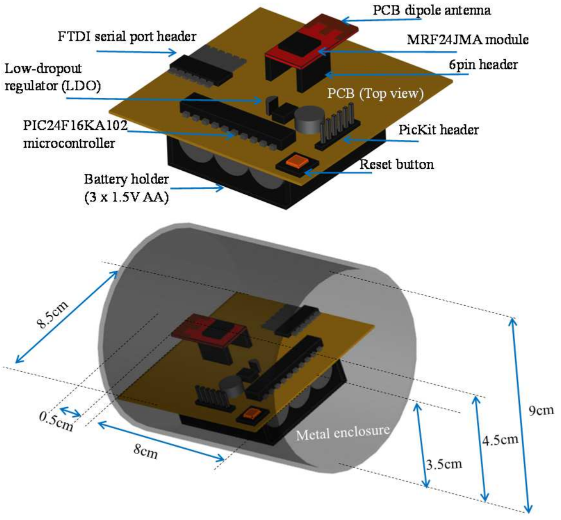
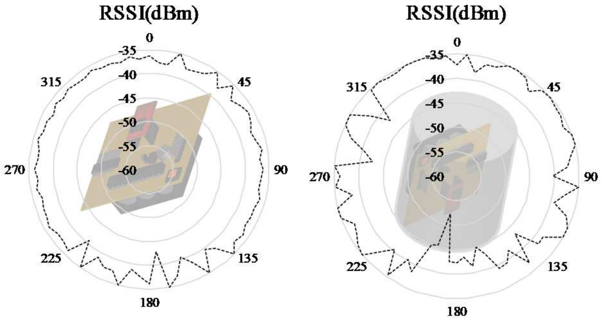


Figure 2. Dimensions and three-dimensional (3D) schematics of the proposed RF sensor based on a MRF24J40 transceiver, outside and inside a cylindrical metal enclosure.

II. METHODOLOGY

The low-power wireless system proposed in this work is composed of Microchip's MRF24J40MA 2.4 GHz transceiver [25] paired with a PIC24F16KA102 microcontroller integrating the eXtreme Low Power (XLP) technology [26]. The sensor offers a direct-programming interface through its In-Circuit Serial Programming (ICSP) connection, whereas the serial port, mediated by a Future Technology Devices International (FTDI) TTL-232x [27] cable, is based on the PIC's second Universal Asynchronous Receiver/Transmitter (UART) interface as presented in Fig. 1. The MRF24J40 transceiver was considered as a good candidate to be tested within this environment as it provides alternatives like MRF24J40-I/MLVAO and MRF24J40T-I/MLVAO that are automotive qualified components used in designs involving vehicle integration. The Low Drop Out (LDO) MCP1702 transforms the incoming voltage delivered by three AA batteries to 3.6 V, extending the overall sensor lifespan by granting a larger direct current (DC) power supply.

After a custom ray tracing (RT) simulation in MATLAB, it was observed that a shielding surface that encloses and separates the initial receiver into two distinct systems for inside and respectively outside detection, may deliver the solution for this study's location problem. The three-dimensional (3D) overall wireless sensor schematics, its enclosure, position and dimensions are shown in Fig. 2. Since



(A) (B)

Figure 3. RSSI radiation pattern for the wireless sensor (A) outside the enclosure and (B) inside the cylindrical cavity. In (A) 0º indicates the MRF24J40 module's PCB antenna location, and in (B) 0º indicates the cylindrical cavity opening.

the sensor circuitry is completely confined within the cylindrical shielding, resembling a circular waveguide or a cylindrical cavity antenna, the wireless transceiver's embedded PCB antenna is placed in close proximity of the cavity's back wall to reduce side-receiving sensitivity towards delivering an increased directivity. Illustrated in Fig. 3 are the radiation patterns in a polar plot obtained by in-plane measurements from 0^0 to 360^0 with a 5^0 step, preserving a 0.5 m distance between transmitter (TX) and receiver (RX) for the omnidirectional sensor (A) and for the directive sensor (B). The units in the plots are dBm instead of dBi, as this measurement is more representative for the RSSI metrics rather than RSS.

A 5 m ranging RSSI fingerprinting data base was constructed by moving an unshielded TX in a straight line with a 0.05 m step towards a shielded RX, both in horizontal (H) polarisation towards the ground plane. To validate the experimental data ranging profile, a theoretical model derived from the deterministic model of Friis' free-space propagation equation, [28, 29] has been created:

$$P_{Rx} = P_{Tx} + G_{Tx} + G_{Rx} - 20\log\left(\frac{4\pi d}{\lambda}\right) \qquad (1)$$

where P_{Rx} is the received power, P_{Tx} is the transmitted power, G_{Tx} is the transmitting antenna gain, G_{Rx} is the receiving antenna gain, d is the measured distance between TX and RX, and λ is the signal wavelength. Acknowledging the presence of a 3 dB ambient noise in the equation (1), the resulting theoretical model is compared against the empirical data in MATLAB, resulting a high correlation of 0.97 (i.e., Pearson's correlation coefficient) between the two models. Both empirical and mathematical models are presented in Fig. 4.

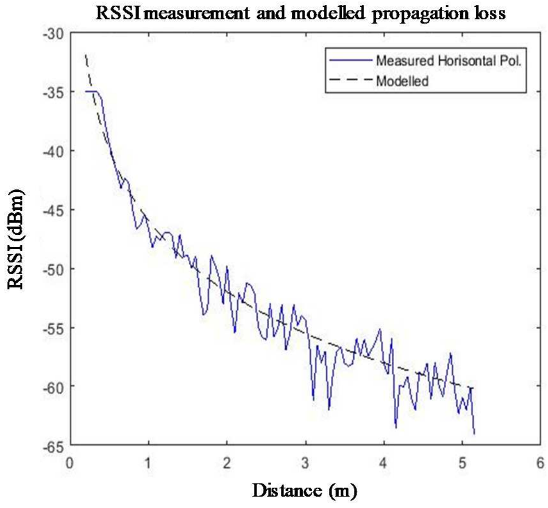


Figure 4. Experimental RSSI ranging-fingerprinting data for horizontal polarisation (solid line) and the theoretical model based on Friis' free-space propagation equation (dashed line).

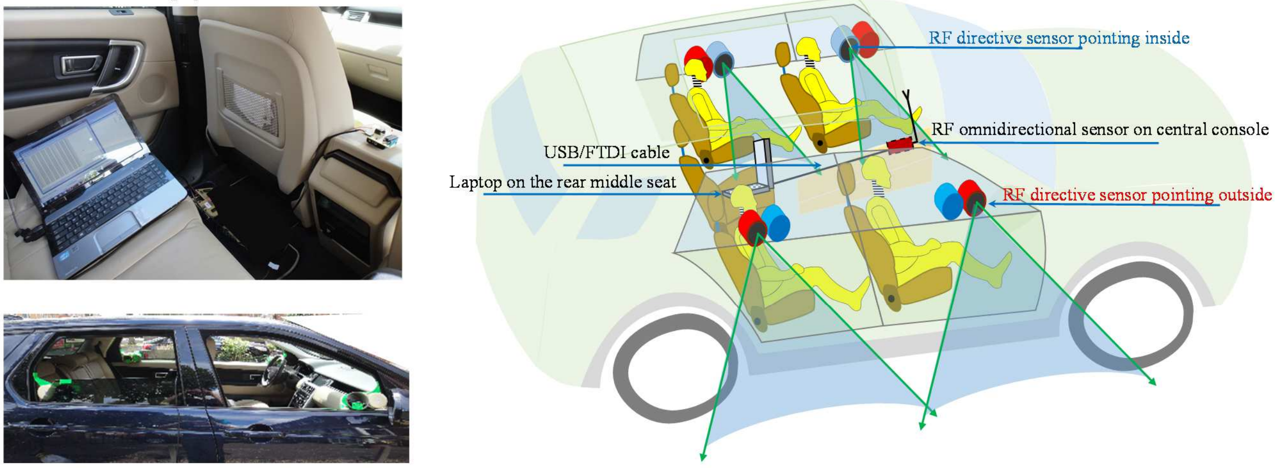
For the assessment of the RF mobile target detection system, eight shielded sensors were assembled and installed with adhesive tape on the front and rear extremities of the side windows of a Discovery Sport car: four oriented towards the cabin's interior and four pointing outside in the opposite direction. The eight wireless sensors were tested in two overall window positions to determine the optimum configuration: high and low. A central omnidirectional wireless sensor, positioned on the car's central console and linked via USB to a data acquisition laptop placed on the central rear seat collected the ranging data from the eight sensors through a time division multiple access (TDMA) algorithm. Fig. 5 illustrates the wireless low-power sensor network position during the mobile target detection experiment.

The setup developed for the RF mobile source test points is presented in Fig. 6. The initial plan was to generate an approximatively homogeneous distribution of the testing points around the vehicle, however the parking area's spatial constraints adding to the vehicle's irregular shape produced three different separations on the measurement axes, independent from the signal's wavelength. The four RF target test points inside the car are symmetrically situated on the front and rear seats. The RF mobile source TX was emulated through an unshielded omnidirectional sensor on a tripod situated at 0.9 m above the ground, equivalent to the possible position for a smartphone carried by an average sized person [30], with the "7-8 head model" of the human body used as area reference representation [31-33] . The TX power was set to 0 dBm, while a ten-byte payload was continuously broadcasted, simulating a common BLE location beacon. Since the proof-of-functioning detection system assesses the setup's viability in solving the inside-outside position discrimination problem, the real-time feature is not implemented: one hundred RSSI readings from each of the eight directive sensors are averaged, delivering one value for each of the RF mobile source test point evaluations. Then, each resulting RSSI value is transformed in a ranging distance estimation based on the RSSI fingerprinting data base.

The decision system employed by this study to discriminate the inside-outside RF mobile source position is presented as follows:

- The directional sensors are divided into two numbered groups: 1 to 4 are oriented inside and 5 to 8 point outside, whereas the omnidirectional central sensor is labelled as 0 since its ranging results are not used.
- The maximum outside detection threshold (T1) is set to 5.2 m (i.e., the RSSI fingerprinting measurement started at 5.2 m and ended at 0.2 m). Therefore, any sensor indicating a value equal to T1 (i.e., a ranging distance equal or higher than 5.2 m) estimates the mobile source position as outside and will generate a "0", equivalent to a "miss" of the car's cabin.
- The RF source is considered inside the vehicle if at least three of the four inside-oriented sensors indicate a predicted distance value smaller than T1, **and** at least one

RF directive sensors high positioned on the side windows



(A) **(B)**

Figure 5. RF target location measurement setup: (A) sensors 1-8 high/low configuration, only showing four sensors, the other four are symmetrically placed on the opposite car windows. The laptop is operated during the measurements from the central rear seat and connected to the RF sensor node placed on the central console. The node from the central console receives the data from all eight sensors wirelessly based on a time division multiple access (TDMA) protocol developed for the tests; (B) Full car illustration of the orientation of the inside (blue) and outside (red) detecting sensors, with their approximate detection domain sketched for the forward facing ones.

sensor estimates a ranging measurement smaller than the maximum vehicle's width of 1.75 m, labelled as threshold two (T2). If this occurs, the algorithm will generate a "1", equivalent to a "hit" of the vehicle's interior.

- The Boolean decision system based on the external threshold T1 and the internal threshold T2 applies a logical OR-relationship between the sensor groups oriented towards the inside and the outside.

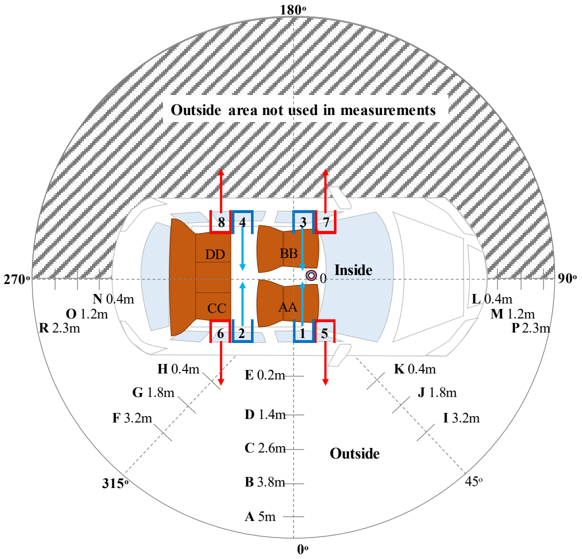


Figure 6. RF target location measurement setup: sensors 1-8 target position A-R (outside) and AA, BB, CC, DD (inside) the car's cabin. As the scenario is symmetrical, only the presented side will be considered in the location tests. The RF source on the tripod is sequentially moved, and the RF sensors placed in the car receive the signal and send their RSSI readings via a TDMA protocol to the node placed on the central console. The results from all sensors are recorded and stored on a laptop for analysis.

III. RESULTS AND DISCUSSION

Following the transformation of the RSSI data in spatial ranging estimations for both low and high sensor setups, and applying the decision steps described in the previous section, the RF source position discrimination results were recorded as shown in Table 1 for the empirical model, and in Table 2 for the theoretical model. The light blue ranging values in Table 1 and 2 display the inside sensors' estimated distances smaller than T2, based on which the algorithm's decision generates a "1", as the target is detected within the cabin's interior. When the target is detected inside, the outside pointing sensors display ranging measurements smaller than or equal to T1 due to RF reflections and parasitic back reception. Nevertheless, the inside sensors consistently detect the mobile target inside the cabin, and applying a logical OR function between the indicated 1 and 0 between the sensor groups, result in a correct inside position estimation. The same results are displayed for both empirical and theoretical models, demonstrating that a short distance ranging system based on RSSI and sensor's directivity produces consistent results. The human presence is known to influence RSSI measurements; however, it is recommended that the internal oriented sensors point towards the empty space in front of the seats, avoiding interference with human occupants of the car. Therefore, the effects are minimised by the short-distance sensing and sensor directivity.

When examining the decision hierarchy, it can be noted that the inside detection group can generate 1 whereas the outside oriented sensors can only produce 0. Therefore, the decision balance for inside-outside RF target discrimination may depend only on the inside pointing sensors. With the next envisaged research step being the estimation of the RF mobile

Table 1. Results for applying the Inside/Outside discrimination decision for the empirical ranging model

Sensor setup	Sensor Direction	Sens. no	Ranging with the empirical model																			
			Outside test points																Inside test points			
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	AA	BB	CC	DD
Low	Sensors In decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
	In	1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	0.85	1.2	2	0.9
	In	2	5.2	5.2	5.2	5.2	4.35	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	2.35	2.15	0.6	1.7
	In	3	5.2	5.2	5.2	4.8	3.2	5.2	5.2	5.2	5.2	4.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	**0.7**	4.2	4.45
	In	4	5.2	5.2	5.2	4.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.9	1.7	0.65	2.25
	Sensors Out decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Out	5	4.35	5	3.3	1.2	4.1	4.2	5.2	1.6	3.35	3.8	4.95	5.2	5.2	5.2	5.2	5.2	5.2	1.75	5.2	4.5	3.15
	Out	6	3.9	4.7	3.1	2.2	3.9	5.2	5.2	5.2	3.3	2.3	3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.25	2.95	0.7
	Out	7	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.6	4.1	5.2	5.2
	Out	8	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.2	5.2
	Total In-Out Decision		Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	In	In	In	In
High	Sensors In decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
	In	1	5.2	5.2	5.2	4.5	3.4	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.95	1.3	3	2.95
	In	2	5.2	5.2	5.2	5.2	4	5.2	5.2	5.2	5.2	5.2	3.25	5.2	5.2	5.2	5.2	5.2	5.2	1.1	1.8	2.4	1.1
	In	3	5.2	5.2	5.2	5.2	4.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.25	5.2	3.05	2.95
	In	4	5.2	5.2	5.2	4.35	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	2.7	2.25	1.45	1.8
	Sensors Out decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Out	5	5.2	5.2	2.8	2.9	1.35	5.2	5.2	5.2	4.25	3.6	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.4	5.2	2.8	2.25
	Out	6	1.75	3.05	1.6	1.4	1.6	4.4	4.9	5.2	2.55	2.4	0.7	5.2	5.2	5.2	5.2	5.2	5.2	3.4	5.2	1.25	4.8
	Out	7	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3	5.2	4.2
	Out	8	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.35	1.7
	Total In-Out Decision		Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	In	In	In	In

source's spatial position, the outside oriented sensor group's function will become equally important.

Another important observation relates to the sensors' high directivity, when the mobile RF source was on the outside test points L, M, N, O, P, R (i.e., in the front and rear of the vehicle), all sensors provided estimations equal to T1, meaning in this context that the target was out of range.

IV. CONCLUSION AND FURTHER WORK

This study has demonstrated a method for the implementation of a detection system completely enclosed inside a modern vehicle cabin, able to solve the inside-outside position discrimination of a mobile RF source, solely relying on its inside detecting sensor network. Combined with the innovative RF sensor design and presented discrimination algorithm, this may deliver new opportunities for commercial LBS using the 2.4 GHz IEEE 802.15.4 low-power protocol. As the proof-of-functioning stage has been successfully assessed by this work, further refinements in sensor size reduction and integration within a secured environment will be subsequently pursued and analysed.

Table 2. Results for applying the Inside/Outside discrimination decision for the theoretical ranging model

Sensor setup	Sensor Direction	Sens. no	Ranging with the theoretical model																			
			Outside test points																Inside test points			
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	AA	BB	CC	DD
Low	Sensors In decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
	In	1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	0.95	1.3	2.3	1.15
	In	2	5.2	5.2	5.2	5.2	4.8	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.95	3	0.6	2.05
	In	3	5.2	5.2	5.2	5.2	3.45	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	0.8	5.2	5.2
	In	4	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.6	2.05	0.7	2.3
	Sensors Out decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Out	5	4.6	5.2	3.6	1.25	4.55	5.2	5.2	1.65	5.2	3.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	2.5	5.2	4.3	5.2
	Out	6	3.5	4.05	3.35	2.05	3.5	5.2	5.2	5.2	3.65	1.9	2.55	5.2	5.2	5.2	5.2	5.2	5.2	5.2	4	2.8	0.8
	Out	7	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	4.25	4.55	5.2	5.2
	Out	8	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.4	5.2
	Total In-Out Decision		Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	In	In	In	In
High	Sensors In decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
	In	1	5.2	5.2	5.2	4.4	4.45	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.85	1.15	2.6	2.8
	In	2	5.2	5.2	5.2	5.2	2.9	5.2	5.2	5.2	5.2	5.2	3.95	5.2	5.2	5.2	5.2	5.2	5.2	1.35	2.45	2.15	1.3
	In	3	5.2	5.2	5.2	5.2	4.55	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.2	5.2	2.75	2.75
	In	4	5.2	5.2	5.2	4.6	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	2.9	2.25	1.2	2.45
	Sensors Out decision		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Out	5	5.2	5.2	3.6	2.35	1.2	5.2	5.2	5.2	5.05	4.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	1.5	5.2	3.6	2.25
	Out	6	2.55	2.7	1.65	1.5	1.65	5.2	3.7	5.2	3.25	2.1	0.85	5.2	5.2	5.2	5.2	5.2	5.2	4.45	5.2	1.2	5.2
	Out	7	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	2.55	5.2	5.2
	Out	8	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	2
	Total In-Out Decision		Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	Out	In	In	In	In

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