IoT Enabled Vacant Parking Slot Detection System Using Inkjet-printed RFID Tags

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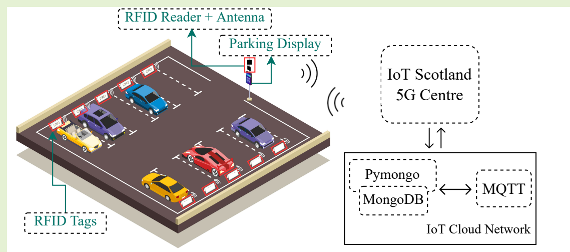
***Abstract*—It is challenging for motorists to manually search for a parking slot in a crowded parking area. Conventional methods for locating vacant or occupied space are regarded as inefficient and unreliable. In this work, an IoT-enabled vacant parking slot detection system is developed and tested using low-cost inkjet printed passive Ultra-High-Frequency (UHF) RFID tags. The working principle of the proposed system is to analyze the back-scattered signals strength from the tags at the receiver side for vehicle presence/absence detection in the parking slots. First of all, We propose a low-cost passive tag optimized to work in UHF RFID-band pasted on plastic material display for parking slots. The data collected by RFID reader from the tags is sent over Message Queuing Telemetry Transport (MQTT) protocol via Scotland 5G-network to MongoDB database using Python module Pymongo for decision making and display of vacant parking slots to the motorists. Python based web-app extracts data from the database and shows it on a web-app display using EJS for each slot. Experimental observations conducted at parking slots in the presence of vehicles indicate a drastic reduction in Received-Signal- Strength-Index (RSSI) value at the receiver end, which implies that RSSI signal drop can be utilized for the detection of vehicle presence in the parking slot. The suggested approach aims to facilitate the economical and effective location of available parking slots. The Test results for the proposed system are recorded and presented, demonstrating its significant performance and showing great accuracy for the tested scenarios.**



***Index Terms*—IoT, Smart Parking System, UHF RFID Tag, 5G cloud, Internet of things, Smart Parking Slot Availability Detection, Radio Frequency Identification.**

I. Introduction

THE increasing use of vehicles in cities due to economic and population growth has made it challenging for motorists to find free parking slots. Today, we witness growing demands and pressure on parking areas as a result of which there are issues like traffic congestion, parking illegally, parking brawls, etc. to name a few. There is often a tendency to park as near as possible to the destination to avoid wastage time in searching for free parking slots. But there might be inadequate capacity or a motorist may find out that there are no vacant slots after entering a parking zone. These situations reflect the immense demand for smart parking systems which can detect and display the availability of vacant slots in a particular parking zone/area [1]. Radio Frequency Identification (RFID) technology has been proven cost-effective and successful in a variety of domains. Its applications extend from supply chain [2], traffic signage inventory management [3], in health care [4], [5], wildlife research [6], smart agriculture [7], smart homes [8], vehicle localization and tracking [9], [10], to its evolution in logistics field and other industry 4.0 applications [11], [12]. RFID technology can be an effective and adequate solution for smart parking systems since it has been employed in various disciplines to identify and detect objects. The proposed solution in this work is able to detect the presence or absence of a tagged object in a particular area by exploiting the back-scattered radiation and Received-Signal-Strength-Index (RSSI) properties of the tag [13]. Besides its applications in asset tracking, etoll collection, supply chain, and smart homes, etc., we have tested its use in the vacant parking slot availability detection, which is solely based on low-cost RFID technology employing RFID tags and readers.

Industries have long used contactless sensing technologies, but the evolution of the Internet of Things (IoT) has advanced

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the growth of these technologies to a whole new level [14]. IoT systems use a number of sensing technologies to function and transmit various types of intelligence and information. It collects the data and shares it with a network of connected devices. All this collection of information enables the devices to autonomously function, helping to make the entire ecosystem smarter every day. Devices are becoming smarter and more useful with the use of a communication network and a set of contact-less sensing technologies [15]. Considering the fact that all measured data is gathered recorded and can be evaluated, it is evident that IoT will grow even more intelligent in the future. Despite significant development in the field, there is still not a single set of rules for spectrum regulations that are followed everywhere. For RFID operations, each country has designated its own restricted frequency spectrum [16]. The regulated bandwidth for RFID activities in various countries is shown in Table. I.

A technological-based extensive comparative analysis of different smart parking systems is presented in [1]. The study concludes that besides using multiple approaches, IoT will work as the backbone of future smart systems. The study also discusses several smart parking sensors and how they may be used in various situations. Furthermore, the report gives a detailed assessment of the pros and cons of various types of smart parking systems. Many studies are conducted on "smart parking," with an investigation on system infrastructure and its implementation. A slotted RFID antenna for intelligent vehicle parking systems is proposed in [17], with a return loss of -20 dB and a gain of 5 dBi. The antenna is designed to work in a variety of road and environmental conditions. The design process is thoroughly explained, beginning with an examination of the effects of various antenna modifications and parametric variations in order to comprehend its operating principle. However, compared to passive RFID tags, the proposed antenna in this work is neither flexible nor low-cost, and has larger dimensions of $320\times180\times20\ mm^3$. In [18], a smart vehicle parking system is implemented using Arduino Uno board for vehicle parking, Node-MCU for wireless transmission of data to the internet using IoT module, and infrared sensors. However, besides using sensors, this system authenticates the vehicle at the parking gate using the RFID tag on the vehicle and after successful authentication looks for a suitable vacant slot from the database record. In such a system, the motorists need to book the free slot in advance or else have to search for a free slot before heading towards such parking areas. In [19], the authors presented an intelligent pre-booking parking system that uses IoT over WiFi by combining a smartphone app with IR sensors, RFID, and an Arduino. Although the study's findings offer a promising solution for vehicle authentication with RFID tags but transpired as inefficient for vehicle slot detection.

Usually, the deployment of RFID and readers in different types of parking lots vary depending on the specific system being used and the layout of the parking lot. However, generally, there are three types of parking lots: bay, parallel, and angled. A bay parking lot is characterized by designated parking spaces, called bays, with vehicles parked perpendicular to the row. This type of parking lot is typically found in commercial or urban areas and often has a higher parking capacity than parallel or angled parking lots. Contrary, parallel parking lots typically have a single row of parking spaces, with vehicles parked parallel to the row. This type of parking lot is typically found in residential or suburban areas and often has a lower parking capacity than bay or angled parking lots. Whereas, angled parking lots typically have multiple rows of parking spaces, with vehicles parked at an angle to the rows. Vehicles park in these spaces by driving into them at an angle, with the front of the vehicle facing the row of parked vehicles. This type of parking lot is typically found in commercial or urban areas and often has a higher parking capacity than parallel parking lots, but a lower capacity than bay parking lots. RFID readers can effectively be placed at the entrance/exit of these parking lots or if the parking has a roof covering, the RFID can be hung from the roof facing towards the row in such a manner to cover more space for detection. The area covered by the reader depends upon the model and specifications of the reader being used. The deployment rules of RFID and readers are nearly similar for all parking lots but dependent upon the layout of the parking lots, since bay parking has a higher capacity than the others, it would require comparatively fewer RFID readers to cover more area. The RFID tags need to be placed at the end spot of the parking row in all three types. The height for placing the tags can be chosen accordingly. An on-site experiment before deployment is always recommended for each parking to achieve efficient results since the surroundings are not similar for every parking. In this work, we experimented with choosing a bay parking layout since it has more parking capacity than the rest.

Our proposed system is greatly taking advantage of the IoT concepts, its block diagram is shown in Fig. 1. We have designed a low-cost IoT-enabled vacant parking slot detection system using low-cost inkjet printed passive RFID tags without involving any other kind of expensive parking sensors for detecting the presence of vehicles in parking slots. Since the tags are fabricated using silver conductive ink using inkjet printing technology, making the system is cost-effective. The designed RFID tag antenna in this work is optimized for use in ETSI upper band and FCC band, allocated for use of RFID operations. The read range of optimized tags is about 13.5 meters as tested using the Tagformance® Pro Unit from Voyantic. Impinj R-700 RAIN RFID reader is used for on-site testing of the proposed system to read the tags installed in the parking slots using a back-scatter mechanism. This system uses MQTT network protocol to share the data over the IoT cloud using the MongoDB database via the Python module Pymongo. The reader reads the vacant parking slots and recorded data is transmitted over MQTT broker (which the Impinj readers support directly) via the Scotland "5G network" to the database. From the database, the results are displayed using an in-house-built dashboard for displaying the occupied and vacant slots in a parking slot. The experimental results demonstrate that in the proximity of vehicles, there is a significant drop in the RSSI value at the receiver end, which shows that RSSI signal drop can be used for the detection of free and occupied parking slots. This proof of presence concept can be further progressed and implemented in larger

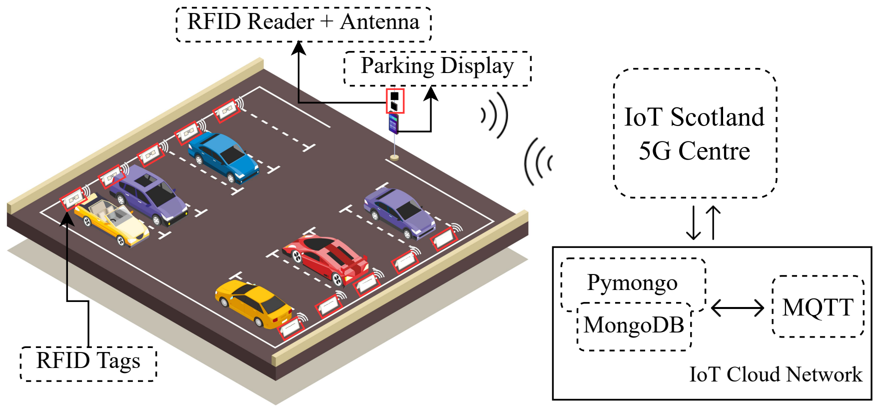

Fig. 1. Block diagram of the proposed IoT-enabled vacant Parking Slot Detection System Using Inkjet-printed RFID Tags.

TABLE I
RFID FREQUENCY BAND ALLOCATION FOR VARIOUS REGIONS AROUND THE WORLD [16].

Region	RFID Frequency Band
Global Band	860-960MHz
ETSI/EU (European Telecommunications Standards Institute)	865-868MHz 915-921MHz
China	840-845MHz 920-925MHz
FCC/US (Federal Communications Commission)	902-928MHz
Asia (most regions)	865-868MHz
Japan	915-928MHz
Australia	920-926MHz
Rest of the world	ETSI / FCC

parking areas/spaces and different kinds of vehicles in the future.

The rest of the paper is arranged as follows. To help put the results in context, RFID tag antenna design and electromagnetic simulation results are presented in II. The concept and implementation of IoT-enabled vacant parking slot detection system is described in III, where RFID Tagformance® test setup for lab and obtained results are shared in III-A, while RFID-based vacant slot detection system deployment along with test results for IoT integration using MQTT network protocol is presented in III-B. The work is concluded in IV.

II. RFID TAG ANTENNA DESIGN AND ELECTROMAGNETIC SIMULATION RESULTS

The physical layer of RFID system involves a tag, reader, reader-antenna, and other peripheral devices. The tag is composed of three main parts i.e. a microchip, an antenna, and a substrate that holds components together. For our application, we utilize the Higgs EC microchip from Alien technologies. We have used Poly Ethylene Terephthalate (PET) as a substrate with ε_r 2.8 and a height of 0.05 mm. The designed antenna is optimized to operate in the US/FCC 902-928 MHz and ETSI/EU upper band 915-921 MHz. Antenna design defines the RF performance of the tag such as the expected reading distance of the application, usable read angles, the material on

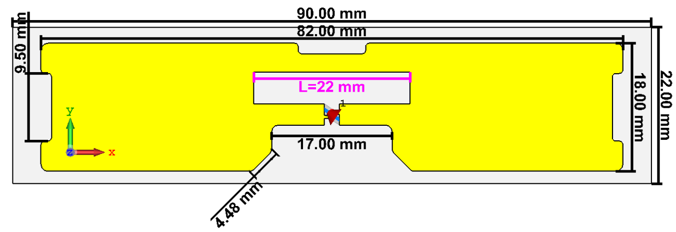

Fig. 2. Simulation model: Geometry of optimized RFID tag antenna with dimensions.

which the tag will work, and other performance optimization. The microchip and selected standard pose some limitations to the performance. The first guess for the design can be created through antenna simulation tools and hence simulation models are first constructed using the Electromagnetic (EM) antenna design tools and their performance is analyzed before prototyping. The EM tool we used for antenna design is Computer Simulation Software (CST) microwave studio suite. The simulation model is shown in Fig. 2.

All stages of the RFID tag design process are important to understand, from studying microchip functionalities and selecting materials for tags, to design verification, tag selection, and documenting tag performance. The basic design process is shown in Fig. 3. Each design step is discussed as follows:

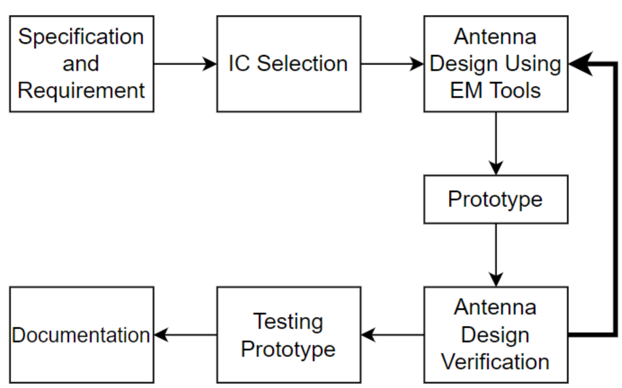

Fig. 3. UHF RFID Tag: Iterative Design Process from Specification Evaluation to Documentation.

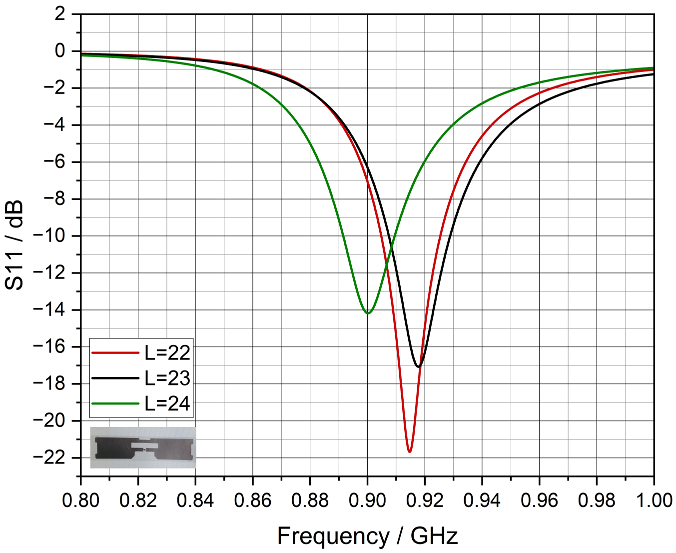

Fig. 4. S11 - Reflection coefficient of the proposed optimized RFID tag.

- The design process starts with gathering requirements and defining the RFID tag specification. The requirements include elements about performance such as read ranges, quality, data content, and physical appearance. For our system, we needed a tag with at least 3-5 meters of read range, compact in size, flexible material, and low cost.
- Microchip/Integrated Circuits (IC) selection is based partly on performance requirements and partly on data content requirements. We used Higgs EC IC in our design. The operating conditions and electrical characteristics of the chip are presented in Table. III. The impedance of the chip at 915 MHz is calculated to be 13–$j183$ Ω.
- The antenna is the tag's major proportion and is linked to the tag's IC. The geometry of our design shows a fat structured dipole with a T-shaped slot in the mid and some slots at the sides in order to conjugate match the antenna impedance with that of the microchip. The size of the antenna is 82×18 mm^2. It is printed on PET substrate 90×22 mm^2, with silver conductive ink using inkjet printing technology. An adhesive layer is added in order to attach it to the surface easily. The length L on the main T-slot is optimized to 22 mm in order to tune the antenna at 915 MHz. The return loss (S11) at $L = 22$, $L = 23$ and $L = 24$ is shown in Fig. 4.

It is imperative to precisely match the antenna impedance with that of the chip for optimal power transfer since the antenna perceives the microchip as a load. The chip's electrical characteristics are defined by the manufacturer and can not be changed, so we need to design our antenna around the impedance of the chip. The chip impedance can be calculated manually using the lumped model equations as given in [13], [20], [21]. The complex chip impedance can be expressed as:

$$Z_{ch} = R_{ch} + jX_{ch} \tag{1}$$

Where, R_{ch} is chip resistance and X_{ch} is chip reactance. To simplify the equations, for resistor-capacitor parallel circuit

TABLE II
EXCEL FORMULA TO CALCULATE CHIP IMPEDANCE.

	A	B	C
1	f_c	Input Central Frequency	MHz
2	Rp	Input Chip Resistance	
3	Cp	Input Chip Capacitance	pF
4	Zr	=B2	
5	Zc	=INT(1/(2*3.14*B1*10ˆ(-6)*B3))	=”-j”&B5
6			
7	Zrˆ2+Zcˆ2	=B4*B4+B5*B5	
8		=B4*B5*B5	=B4*B4*B5
9	Z_{ch} :	=ROUND((B8/B7),1)&”-j”&ROUND((C8/B7),1)	

TABLE III
OPERATING CONDITIONS AND ELECTRICAL CHARACTERISTICS OF HIGGS EC IC [22].

Symbol	Parameter	Min/Max	Units
Operating Conditions			
T_A	Operating Temperature	$-50 + 80$	$°C$
f_{in}	Operating Frequency	840 to 960	MHz
Electrical Characteristics			
S_R	Sensitivity during Read	-20	dBm
S_W	Sensitivity during Write	-14.8	dBm
R_p	Equivalent input parallel resistance	2500	Ω
C_p	Equivalent input parallel Capacitance	0.95	pF
D_{ret}	Data Retention	50	Years

X_{ch} is given (2) and R_{ch} can be calculated as (3):

$$X_{ch} = 1/(\omega Cp) \tag{2}$$

$$R_{ch} = \frac{Rp}{1 + (Rp \times \omega Cp)^2} \tag{3}$$

Where the angular frequency ω is given as (4):

$$\omega = 2 * \pi * f_c \tag{4}$$

In (4), $\pi = 3.14$ and f_c is the resonance frequency of the designed antenna. The related theory concepts for all the given equations in this work can be studied in detail from [13]. In order to make the calculation process time-saving and accurate, We have formulated the same equations into a Microsoft excel sheet to calculate the impedance of the chip with values from the supplier datasheet. The formula is given in Table. II. Using provided values of $f_c = 915MHz$, $C_p = 0.95pF$, and $R_p = 2500\Omega$, the chip impedance calculated using the excel formula is: $Z_{ch} = 13.3 - j183$. For maximum power transfer we need to conjugate match the antenna impedance with the given chip impedance. The optimized antenna shows good matching with a return loss of -21.6 dB, 1.94 dBi gain, and a radiation efficiency of 96%. The omnidirectional far-field pattern at 915 MHz, along with the measured radiation pattern using tagformance pro device and radiation efficiency is shown in Fig. 5.

III. IoT ENABLED VACANT PARKING SLOT DETECTION SYSTEM

The combination of RFID and IoT mechanism is used in this work to take benefit of both technologies for smart vacant parking slot detection system. Many other parking slot detection systems are proposed in literature but those

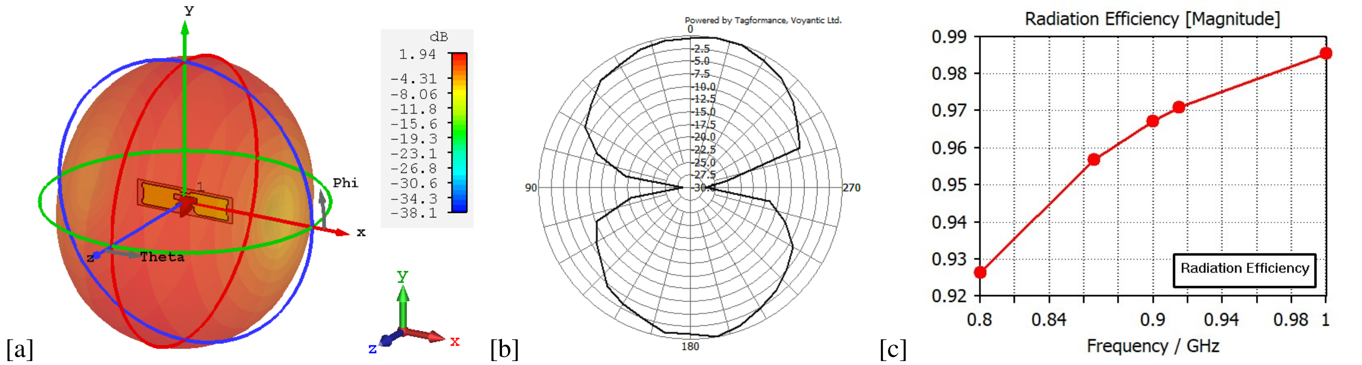

Fig. 5. Far-Field results of RFID tag antenna (a) 3D view of radiation pattern at 915 MHz showing a gain of 1.94dBi, (b) polar plot of measured radiation pattern using Voyantic Tagformance Pro unit, and (c) radiation efficiency of the optimized RFID tag at $800 - 1000$ MHz.

systems are mostly utilizing either active tags or other motion and proximity detection sensors [19], [23]–[26]. In order to make the system cost-efficient, we have used inkjet-printed passive UHF RFID tags and no expensive sensor for vehicle detection is considered in our system. The idea is to put RFID tags on fixed plastic mounts in front of each parking slot and sense/record the RSSI value from each tag using RFID reader installed in the parking lane. Since the designed RFID tag gets detuned in the presence of metallic bodies, thus by analyzing back-scattered radio waves from each tag, the proximity of vehicles is estimated. The communication distance between the reader and RFID depends on the specific RFID system being used, the materials, and the layout of the parking lot. Generally, RFID systems can communicate at distances ranging from a few centimeters to several meters, but the effective communication distance will be affected by the surrounding environment, such as the presence of metal, water, and other obstacles. It is always recommended to conduct experiments on-site to determine the communication distance in different types of parking layouts.

The optimized RFID tag antenna prototype measurements, its utilization, and testing in the proposed parking slot detection system is given in the following sections III-A,III-B.

A. RFID Tag Antenna Prototype Measurements: Tagformance® Pro Unit Test Setup and Results

To validate the simulation results of the fabricated RFID tag antenna, Tagformance® Pro device is used. This device is a complete industrial measurement solution for evaluating different important performance parameters of RFID tags including back-scattered signal strength, read range, orientation sensitivity, transmit and receive power levels, radiation pattern, and other associated parameters. The setup for measurements is shown in Fig. 6.

The Tagformance device consists of Tag Designer Suite (TDS) software, tagformance unit with UHF circulator, a foam spacer and a linearly polarised RFID reader antenna with a gain of 6 dBi. TDS software has multiple gain settings for the reader antenna. We have measured the read range of the antenna under test at 6 dBi, 9 dBi, and 11 dBi gain of the reader antenna. The read range of the antenna in free space and for plastic surface using a 6dBi gain for the reader antenna is presented in Fig. 7. The read ranges measured using a reader antenna with transmit power of 30 dBm and a gain of 9 dBi and 11 dBi is 16.5 m and 21.8 m respectively. The measured radiation pattern is shown in Fig. 5b, while the transmit power and back-scattered signal power levels of the passive tag is provided in Fig. 8.

B. Vacant Parking Slot Detection System: Test Setup and Results

In order to detect a vacant slot in a parking lane, the RFID tags are pasted on fixed plastic mounts in front of each parking slot. The parking slot is numbered 1-10 and similarly, the RFID tags are written with the associated information of the parking slot as parking slot PS01, PS01 up to PS10. The test setup is shown in Fig. 9. The RFID Impinj R-700 reader is used to read the passive RFID tags. The RFID reader installed in the parking lane records the RSSI value from each tag and sends it over the IoT cloud using MQTT protocol where the decision-making algorithm is applied to the data and the availability of slots is decided and displayed to the users. Since the designed RFID tag gets detuned in the presence of metallic bodies, thus by analyzing back-scattered radio waves from each tag, the proximity of vehicles is estimated.

Since passive RFID takes advantage of the back-scatter mechanism, recording the change in the back-scatter signal strength due to vehicle presence in the slot will help detect

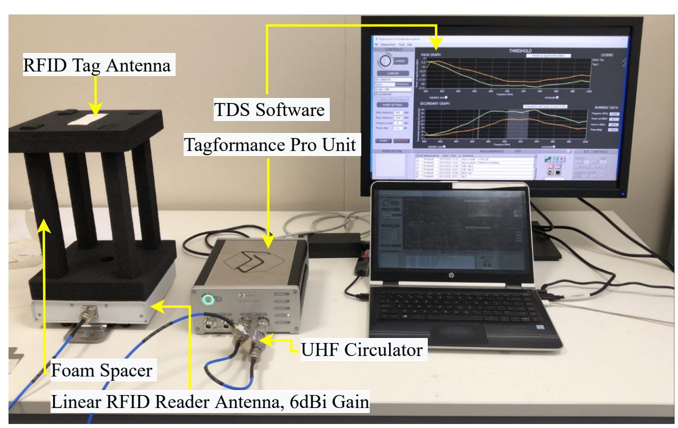

Fig. 6. Experimental setup using Tagformance Pro device.

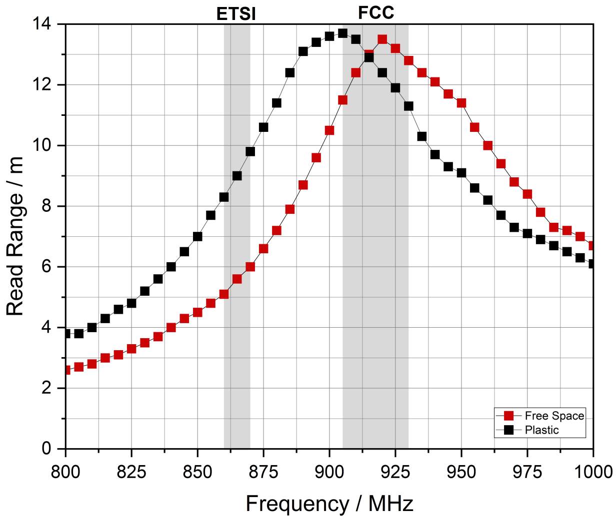

Fig. 7. Read Range of optimized RFID tag antenna in free space and on the plastic surface.

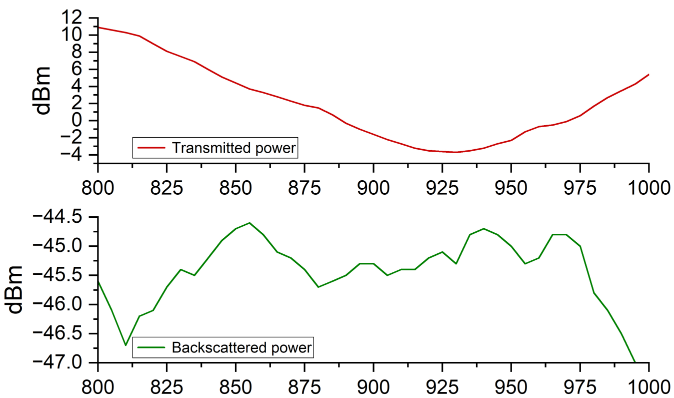

Fig. 8. Analysed transmit power and back-scattered signal at 800-1000 MHz.

slot availability in the lane. This simple mechanism of back-scatter theory has helped us develop a low-cost parking slot detection system using solely RFID tags and readers.

RFID reader reads all the tags and data is sent over the Scotland 5G network using a MQTT broker. The Python script then responds to each message sent while listening to the same MQTT broker. The tag ID number will be extracted from the Electronic Product Code (EPC) value sent once the data has been loaded into a database. From here, it determines whether the system recognizes that tag ID by searching for it in the database, and if it does, it updates the database with the new value and treats any missing tags as occupied. The tags get detected as missing due to de-tuning in the presence of metal (vehicle) in front of it. Python-based web app retrieves data for each available parking spot from the MongoDB database and displays it on a web app display using Embedded JavaScript Templating (EJS) for each parking slot. The display is installed at the entrance of the parking area. For the display, we have developed a complete in-house built web-app dashboard using embedded JavaScript and python, where motorists can see the available parking slots in real time for the exact slot which is available.

Fig. 10 shows the results of the implemented system. We have tested different cases and the slot availability results for each are presented. The green boxes in the display show the vacant slots while the red boxes indicate the occupied slots in the parking zone. As shown in Fig. 10, for case A, the only vacant parking slots in the lane are slot 1 and slot 4 which are successfully being identified by the system and displayed on the dashboard. The remaining slots numbered 6 to 10 were completely occupied during the testing period so we only experimented and showed variation results for slots 1 to 5. In the case of C, slots 1 and 4 are available for parking while the rest are occupied. In the case of D, we parked the vehicle halfway and since the tags were not completely detuned by its presence the same slot 4 is still shown as available. When the same vehicle was parked completely as in case E, slot 4 is shown as occupied. The RSSI level we recorded while performing the experiment was an average of -20dbm to -23dbm in absence of vehicle in the slot which was in direct line of sight. In densely populated scenario, the RSSI was around -40dbm. When the slot was occupied by the vehicle, the RSSI average level was -50dbm to -58dbm. So the threshold value set for filtering the display of parking status was around -45dbm. The threshold of -45dbm or weaker signals shows the slot is occupied. This experiment's findings support the feasibility of incorporating RFID technology into the system.

Generally, if multiple readers are deployed in a parking lot and an RFID tag is accessed by multiple readers, each reader will generate the RSSI of the RFID. To detect the parking space status in this case, an algorithm can be used to process the RSSI values from particular tags. This algorithm can take into account factors such as the distance between the readers and the RFID, the orientation of the readers, and the strength of the RSSI signals to determine the parking space status. To avoid this kind of interference in a multi-reader environment, the RFID tags are written with specific numbers/names for each parking slot. Since the tag is fixed and not mobile, each reader can be programmed to only process signals from particular tags. For example, say reader 1 which is able to cover slot1 to slot6 for instance, can be allocated and programmed to only process these particular tags installed at some particular slots. This reader will only accept and process signals from the selected tags (slots) and it will automatically reject the signals from other tags even if strong enough for it. We can block/unblock tags on the reader end which can help in this scenario of fixed tags installed at parking slots. So, the reader can be programmed to only read the particular tags and display results for vacant/occupied slots on the basis of the associated tags only and filter out the rest.

There are not only vehicles parked in the parking lot, but also pedestrians, moving vehicles, obstacles, and other interferences. These factors can affect the RSSI at reader end. Pedestrians, moving vehicles, and other obstacles can cause physical obstructions that can block or reflect the RFID signal, reducing the RSSI. This can make it more difficult for some of the RFID readers to detect the tag, and can lead to errors or missed detections in case if the obstruction that is completely blocking the tag stays for longer durations. But since in the parking, the vehicles are not staying too long in

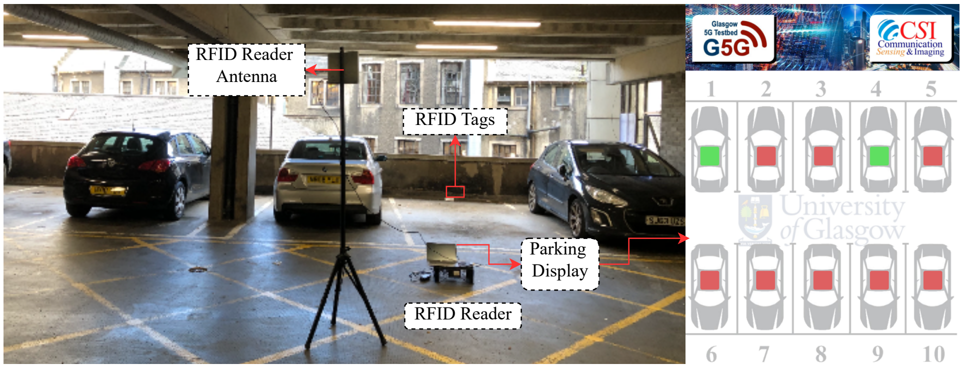

Fig. 9. Experimental test setup for proposed parking slot detection system using RFID technology. (Parking Venue: University of Glasgow, UK.)

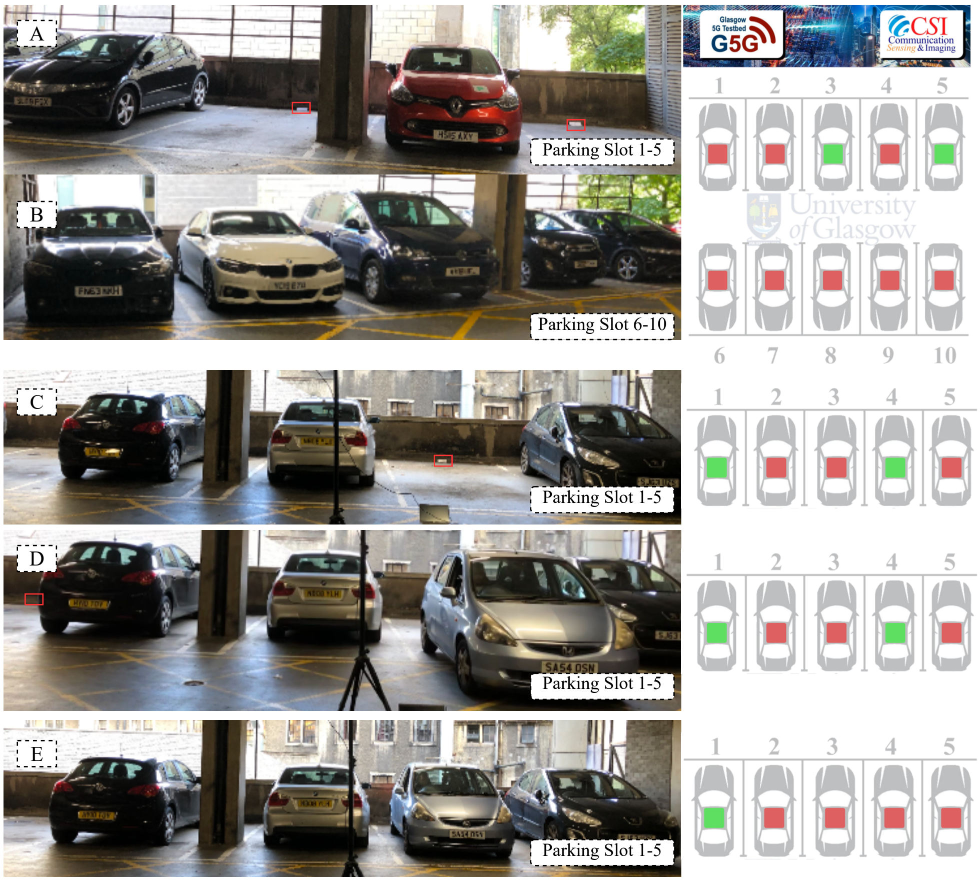

Fig. 10. Dashboard display results for showing vacant parking slots in the parking zone.

front of other slots and will move out/in eventually if they intend to leave/enter the adjacent slots. Depending upon the type of RFID reader used, some of these are good enough to detect even weaker signals (RSSI) from the surroundings and can provide better results. Provided the tag is not permanently blocked by any material, in worst cases. To minimize these interferences, RFID systems often employ techniques such as filtering, modulation, and error correction. For example, RFID readers can be equipped with filters that can reduce the effects of different types of interference. Additionally, RFID tags and readers uses modulation techniques that can help to reduce the effects of interference on the signal. It's worth noting that, in practice, the specific interferences that affect the RSSI will depend on the RFID technology being used.

The proposed system is a cost-effective and low-power communication solution for slot availability detection in smart parking systems. If the vehicle is also tagged with RFID tags, the payment, and advance booking features can be added to the system using relevant decision-making algorithms, however, it was not the focus of this research. With the appropriate selection of RFID readers that offer higher area coverage, the suggested concept in this study can be further extended to larger locations and larger parking spaces. The LoRaWAN technology can also be considered in combination with the RFID readers to connect nodes wirelessly with the internet or central database. The aesthetic perception of the display mounts, on which the RFID tags are attached/pasted, might be taken into consideration after the model has been validated and if developing for larger settings.

IV. Conclusion

The proposed low-cost, low-power IoT-enabled smart parking slot detection system using inkjet printed UHF passive tags and RFID reader is successfully deployed and verified with test results. To detect the availability of free slots, this system takes advantage of the back-scattered communication and the received signal strength of passive RFID tags. No additional sensors such as proximity, ultrasonic, or other motion sensors are employed in this work. This system provides information about vacant parking slots and updates the motorists through the dashboard display in real time. The RFID tags used in the system are designed and optimized to work in both RFID-regulated bands of FCC and ETSI. The recorded signal strength received from the passive tags through the RFID reader is transmitted using the Scotland 5G server over the IoT cloud using MQTT protocol. The decision-making algorithm to display the free slots is processed in the MongoDB database via the Python module Pymongo and the results are shown on the display installed on the entrance using an in-house built dashboard. The motorists can find information about the exact free slots and can park their vehicles with ease. This system can be further extended with more features such as advance booking and parking fee deduction, real-time free slot availability updates to subscribed users via messages, and adding detailed maps of the parking area, etc.

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