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# Wireless Sensor Node with Passive RFID for Indoor Monitoring System

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**ABSTRACT**

This paper discusses the development of an indoor monitoring system based on passive radio frequency identification (RFID) system and Raspberry Pi 3. There are two algorithms designed for this project where the first is to link the RFID module to the Raspberry Pi 3, and the other one is to send the data obtained to a database over wireless network via UDOO Quad as a secondary router. The result is then displayed on a localhost generated using XAMPP. The objective of this project is to realize a monitoring system that incorporates different systems such as Raspberry Pi 3, UDOO Quad, and also RFID module by designing algorithms using Python and C programming language. Plus, the performance of the system is also analyzed using different type of antennas such as the Raspberry Pi 3 Antenna, monopole antenna, and a Yagi Uda antenna in terms of power received versus distance in both line of sight position and non-line of sight position. Finally, antenna that produces the best performance for line-of-sight (LOS) propagation is Yagi Uda antenna while monopole antenna is better when it comes to non-line-of-sight (NLOS) propagation.



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## 1. INTRODUCTION

The wireless monitoring technologies have been playing an important role in today's societies. It can be seen used on wireless navigation system, living assistance system, surveillance system, security system or even as an attendance system in an industrial building. [1] Plus, as the world is getting more technologically advanced every year, the need of real, error-free, and real-time indoor tracking systems are crucially needed more than ever. [2] For example, the old inventory checking system using RFID tags have been modified so that the cheap system can be used as a centralized monitoring of location and movement of people inside a building. It can be helpful in correctional institutions where it is important to track precise location of inmates and also pinpointing the staff during intimidating situations. [3] Moreover, the realization of these applications that is essentially based on location information are gaining more popularity as it is making life easier and more convenient.

Since 1995 the Global Positioning System (GPS) have been playing an important part in outdoor environment localization as it sends precise user location to space and then back to the database on earth. [4] However, every innovation comes with limitations as GPS cannot send signals from inside the building thus, making it inefficient in tracking indoor object. This inanity is due to the weak signals emitted by the GPS and their disability to pass through most building mediums. Hence, since people nowadays prefers to be in the safe space of their own home or in other indoor environment, GPS is not acceptable for indoor tracking and related surveillance routines.

On the contrary, with the wireless technologies that is constantly being improved systems designed based on radio frequency (RF) will definitely be the main localization technique as they could cover larger distance. Systems designed using RF applies the usage of electromagnetic wave transmission which is capable to go through opaque objects such as walls and humans. [1] Plus, radio frequency identification (RFID) also provides read and write option to certain cards and tags thus, personalization of each card is attainable. Finally, it can be used to identify and track multiple users or objects in the system.

Reference papers [1],[5]-[7] gave the essence of various usage of RFID such as detecting moving object, indoor localization, outdoor detection, and resource management during emergency situations. This paper practically introduce the design of the monitoring system that is able to perform in indoor environment where the RFID reader are set in predetermined places so that precise location of user could be tracked and monitored. Finally, the reader is tested with different types of antenna such as the Raspberry Pi 3 antenna, monopole antenna, and a Yagi Uda antenna in terms of power received versus distance in both line of sight position and non-line of sight position to determine the best antenna to work with this system.

## 2. RESEARCH METHOD

In this section, the method for RFID system development and antenna testing is explained and summarized in different parts.

### 2.1. RFID system development

The concept of data transfer for the system that integrates Raspberry Pi 3, UDOO Quad, and RFID module is shown in Figure 1 below. The data obtained from the RFID reader will be translated and processed by Raspberry Pi 3 using the algorithm developed to link the two systems. Next, the data will be sent to a database created using XAMPP through UDOO Quad board that acts as a secondary access point for the system. After the data have been stored in the database, user can monitor the activity on the monitoring centre that will display the location of detected card on the laboratory layout and also the history of activities on the tag history section of the monitoring centre.

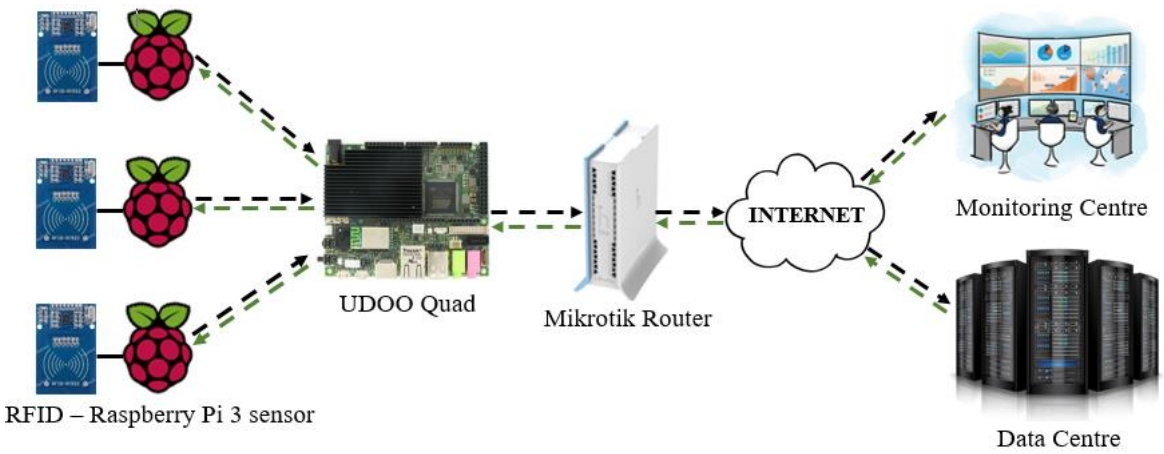



Figure 1. The concept of data transfer of the system from the RFID reader up to the monitoring centre

This method offers a way to observe and evaluate the data collected directly on a monitoring centre. Hence, the system could be described as a monitoring system with passive RFID module installed on a network that could trail the position of the user on a computer system. The algorithms developed for this system is divided into two main parts. The first part as shown in Figure 2 describe the course in developing the wireless connection between the RFID with the Raspberry Pi 3 and to send the data obtained from the RFID to the database.

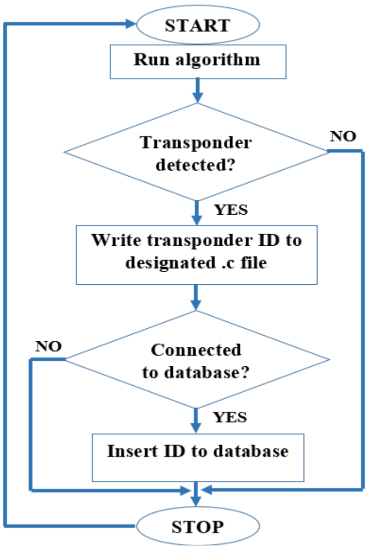



Figure 2. Process flowchart for RFID – Raspberry Pi 3 sensor

On the other hand, Figure 3 shows the process flowchart of the monitoring center after data is sent from the database. A minor set of algorithm is designed to display the collected data on the monitoring center in two forms. The first one is the graphical form where the location of detected tag is highlighted on the laboratory layout designed using Microsoft Visio. Next, a tabulated form where details of detection such as card ID, location, time, and date is displayed in a table form.

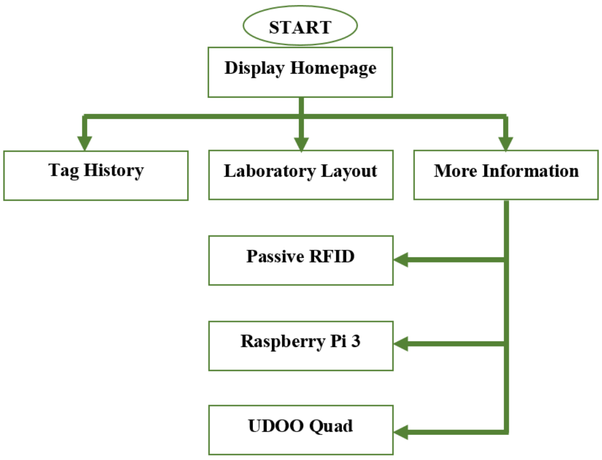
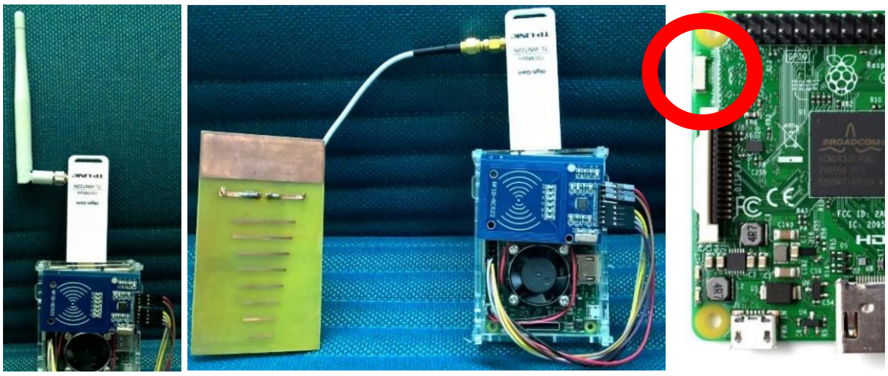



Figure 3. Process flowchart for data display on monitoring center

### 2.2. System testing with various antennas

The performance of the system is analyzed using different type of antennas such as the Raspberry Pi 3 Antenna, monopole antenna, and a Yagi Uda antenna in terms of power received versus distance in both line of sight position and non-line of sight position. Figure 4 shows the antennas used for this test, monopole antenna, Yagi Uda antenna, and Raspberry Pi 3 antenna. Figure 4 a) and b) shows the external antennas connected to the sensor through an adapter while Figure 4 c) shows front section of Raspberry Pi 3 and the chip circled in red is the built in antenna. Eventhough Raspberry Pi 3 is overall better than its previous generation models despite having to draw more power, the antenna is only powerful enough to connect to nearby WiFi network. Next, the difference between the two external antennas is that monopole antenna is a omni directional antenna while Yagi uda antenna is a directional antenna. Directional antenna as the name suggest refers to the signal coverage in a particular direction. The antenna must be aimed in the direction of the router for the best signal quality and strength.



a) b) c)

Figure 4. a) Monopole antenna and b) Yagi Uda antenna c) Raspberry Pi 3 antenna

On the other hand, omni directional antenna are mostly used to create hot spots by broadcasting a signal over a large area in all directions. Unlike directional antennas, omni directional antenna do not need to be pointed at the router since it tranmits signal in 360 degrees. The gain rating or decibel isotropic (dBi) for Yagi Uda antenna is 6.3dBi and the monopole antenna has the gain rating of 4dBi. Before testing the external antennas, the built in antenna as shown in Figure 2 needed to be off or the sensor would have two working antennas and the result obtained would be useless.

To turn off the function of the built-in antenna, the Raspberry Pi 3 board must be turned on, and connected to a monitor or by using Putty, a terminal emulator software that allows remote access to the Pi over the internet. Next, create a configuration script by typing “sudo nano /etc/modprobe.d/raspi-blacklist.conf” as shown in Figure 5. This command will direct the user to an empty script where the user need to type two lines of command “blacklist brcmfmac” and “blacklist brcmutil” as shown in Figure 6. After saving the configuration script, restart the Raspberry Pi 3 using line command “sudo reboot”. Plug the external antenna and presume the testing.

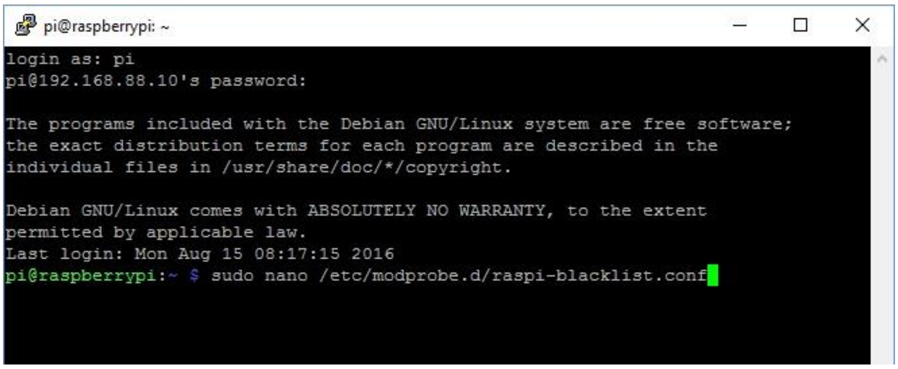



Figure 5. Setting up configuration folder in Raspberry Pi 3 through Putty

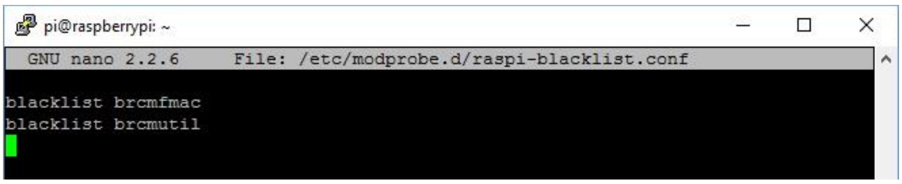



Figure 6. Two lines to turn off the function of the internal antenna

On the other hand, the testing took place on two conditions. The first condition is the line-of-sight propagation, where the distance is set to be 300 meters from the router to the sensor on level field. The second condition is the non-line-of-sight propagation where the placement of the router and sensor is shown in Figure 7 below.

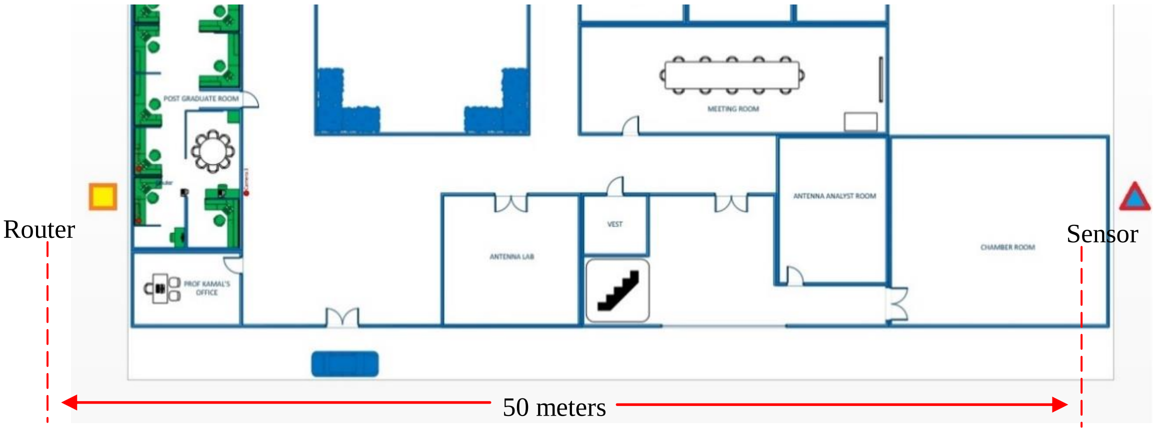



Figure 7. The position of router and sensor outside laboratory

For non-line of sight propagation test, eventhough the distance is set to be 50 meters between the router and the sensor, the signal needs to go through multiple walls and other obstacles inside the rooms since the router and sensor is placed at opposite ends of the laboratory.

## 3. RESULTS AND ANALYSIS

In The results for system development and antenna testing is elaborated in two parts as describe below.

### 3.1. System development

By running the Raspberry Pi 3 on a monitor or by Putty, the user can be notified when the data is read as shown in Figure 8 on the line "Card detected" and also when it is successfully sent to the database by the line "database connection successful". The unique identification number of the card is set to be displayed on the terminal so that the user can distinguish cards and personalization can be done in the future.

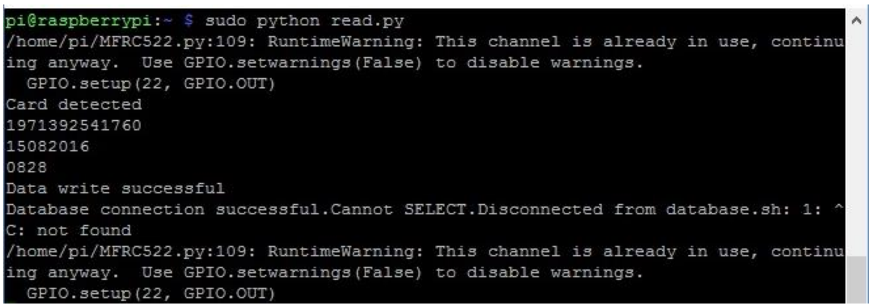



Figure 8. The data have been successfully sent to the database

Figure 9 shows one of the three options available on the localhost where it shows the location of detected tag by circling the location on the layout.

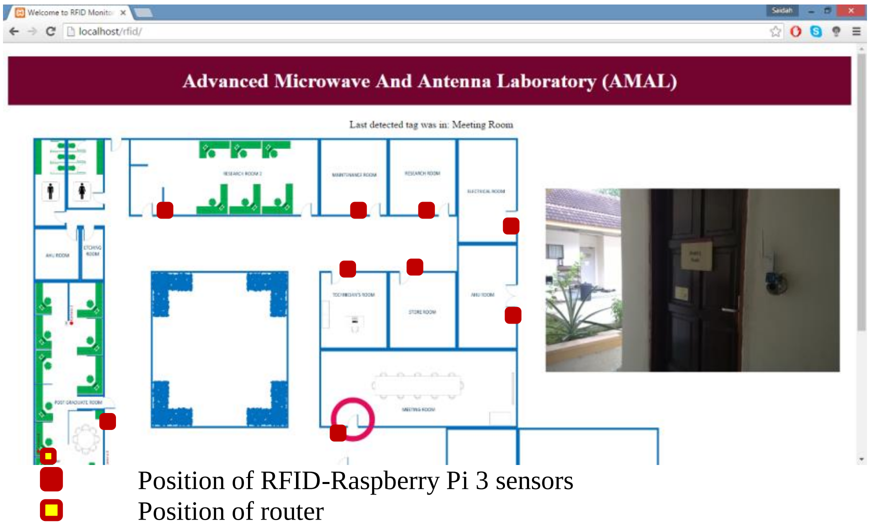



Figure 9. The lab layout where a red circle indicates the location of recent tag detection

### 3.2. Antenna testing

For this RFID system, the data needed to be transferred to the database through the network is small. Hence, even at the lowest signal strength captured, the data is still successfully sent over to the database. On that note, graphs displayed below show the graph of signal strength (dBm) versus distance (m) for each distance an average of 10 seconds of signal strength is plotted.

As shown in Figure 10, Rapberry Pi 3 antenna yields the worst signal strength compared to the other two antennas starting at only -86dBm at 10 meters. Monopole antenna produced the best signal strength at short distances starting at -77dBm at 10 meters whereas Yagi Uda antenna offered a more stable signal strength throughout the non-line of sight (NLOS) test starting at -84dBm at 10 meters despite having lower signal strength than the monopole antenna. The reason why the Yagi Uda antenna seems to yield lower signal strength than the monopole antenna is because it is angled to beam straight to the router, facing directly at a wall and multiple obstacles past the wall such as doors, lab equipments, trees, more walls and office equipments. Eventhough Yagi Uda antenna has higher gain rating than the monopole antenna, this setting caused the signal strength to weaken eventhough the directional antenna is mostly used for NLOS transmissions. On the other hand, the Raspberry Pi built in antenna shows the worst performance of signal strength as it was only designed to connect to a nearby networks. Nonetheless, the data is successfully sent to the database eventhough the signal strength is very low.

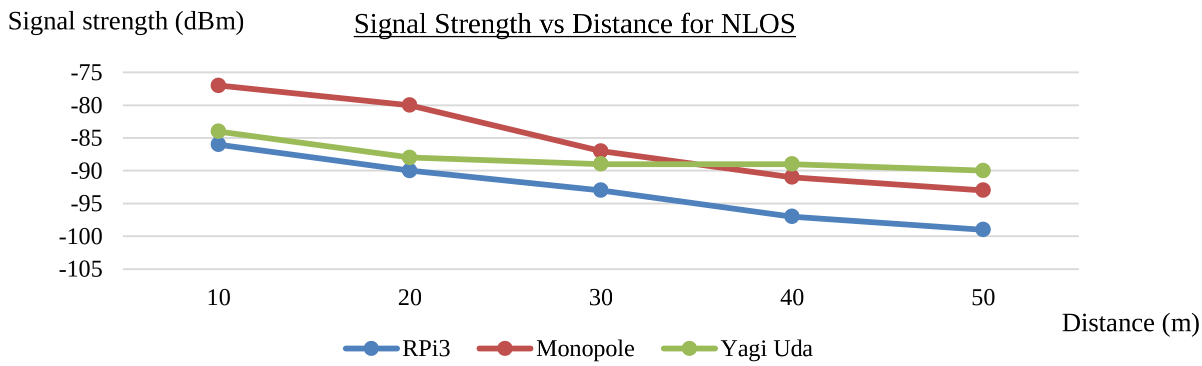



Figure 10. Data of signal strength versus distance in non-line of sight (NLOS) propagation condition

For line of sight propagation test, Yagi Uda yields the best signal strength compared to the monopole antenna and the raspberry Pi 3 antenna as shown in Figure 11. Starting at -65dBm at 50 meters, the directional antenna needed to be pointed precisely at the router or the signal strength will drop. Next, monopole antenna yields a slightly lower signal strength than Yagi Uda antenna starting at -78dBm at 50 meters because the direction of the signal is dispersed rather than focused like the Yagi Uda antenna. Finally, the Raspberry Pi 3 antenna. All of the data sent from the RFID is successfully received by the database.

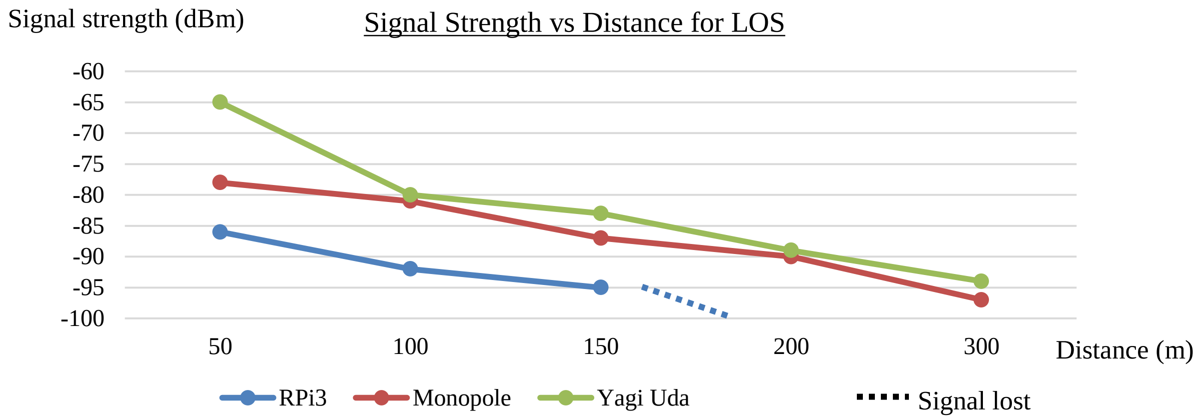



Figure 11. Data of signal strength versus distance in line of sight (LOS) propagation condition

## 4. CONCLUSION

The first algorithm for system development is desgined so that it will display the series of the card's unique ID on the Raspberry Pi 3 terminal when it is presented within the reading range of the reader which is from 0 to 60mm away. Next, the second algorithm is designed to send and save the data received from the Raspberry Pi 3 to the database through UDOO Quad board that was reconfigured to be a secondary access point to further add the distance covered by the network signal. The signal strength of the network was also measured in two different conditions which are the non-line of sight condition and line of sight on level field. For the non-line of sight test, the antenna that produces the highest signal strength is the monopole antenna meanwhile for the line of sight test, Yagi Uda antenna yields the best signal strength. As for the Raspberry Pi 3 antenna, the bad performance on both tests is due to the antenna chip itself as it was not designed to connect to far networks.

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Farid Zubir received his first degree in Electrical Engineering (Telecommunication) from Universiti Teknologi Malaysia in 2008. In 2010, he received his M. Eng. Degree (Communication) from the same university and was awarded Best Postgraduate in the Faculty of Electrical Engineering as well as certified by the University's Senate for Pro-Chancellor Award at the graduation ceremony. He completed his PhD at the University of Birmingham for research into the direct integration of power amplifiers with antennas in microwave transmitters in 2016. His current research interest and specialization are in the area of RF and Microwave technologies including Planar Array Antenna, Dielectric Resonator Antennas (DRAs), Active Integrated Antenna (AIA), Microstrip Reflectarray Antenna (MRA), Electromagnetic Band Gap (EBG), Artificial Magnetic Conductor (AMC), Full-integrated Transmitting Amplifiers, Linear PAs, Doherty PAs and Bias Decoupling Circuits.

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