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User Interface and RF-Front End Design for Radio Direction Finding-Miniature Unmanned Air Vehicles (RDF-MUAV)

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ABSTRACT

Radio direction finding perform better at high altitude due to greater line of sight coverage. In this paper, the radio direction finding-miniature unmanned air vehicles (RDF-MUAVs) platform able to localize the beacon by accessing the direction of signal and report it back to the ground station immediately, improving search and rescue operations. RDF-MUAV system divided into four major part; RF front end design; RF software design; ground station design; and user interface (UI). This paper focuses on two out of the four major parts, which designing a good UI and RF front end to be integrated into the system. The UI is designed using Linux, Apache, MySQL, PHP (LAMP) architecture in Raspberry Pi platform that can display accurate data obtained from RDF-MUAVs. The UI is based on HTML which is lightweight, modifiable and can be accessed through smartphone, tablets, or personal computer. In the antenna design, phase direction finder method is chosen. The rotation of antenna can be done by moving the UAV to obtain the bearing to the source signal. Proposed type of antenna is Yagi-Uda antenna due to its high gain and relatively small size. The folded dipole is chosen as the driven element of the antenna due to its bandwidth characteristics and directivity. Result shows the function-al bandwidth is 200MHz which can accept electromagnetic waves from 500MHz to 600MHz and 900MHz to 1000MHz. Overall, the design implementations provide a feasible system in search and rescue operation.

Key words : Antenna; Miniature Unmanned Air Vehicle; LAMP server; Radio Direction Finding; Search and Rescue

1. INTRODUCTION

In this modern age and advanced technologies, search and res-cue technology are becoming more advance with the satellites, radar and sonar technology expending and growing up from day to day. Despite all of this technology, there are still a lot of cases that failed to be solved such as the missing of flight MH370 from radar in March 2014. The search operation for this missing flight have been the largest searches operation in aviation history[1]. After more than two years of failed search efforts made by many agencies from many countries, the search activities were stopped on 17 January 2017 by the decision made by government of Malaysia, Australia and Republic of China [1]. This massive search failure indicates that the geolocation technology is still not perfect and need more improvement to pre-vent this tragedy from happening again in the future. One of the researches that aims to improve Search and Rescue system is Radio Direction Finding Miniature Unmanned Air Vehicles (RDFMUAV). Radio Direction Finding (RDF) is a type of radio-location that aims to locate the beacon by several successive measurements that yield the actual angle to the transmitter. In typical Radio Direction finder, the person needs to rotate the equipment around to locate correct direction towards the beacon. As the person moves, the readings must continue to make sure the direction always on the right path. The Miniature Un-manned aerial vehicle (MUAV) can easily move around and pass through the obstacles such as mountains and sea. Using a custom-built Radio Direction Finder, MUAVs can search the beacons efficiently by passing through the obstacles. The RDF-MUAVs platform are able localize the emergency location beacon (ELB) and report it back to the ground station immediately. The paper focusing on the user interface and antenna design of the system.

The paper offers two main contribution. First is a fully functional web-based server using LAMP that can display the accurate data obtained from Radio Direction Finding Miniature Unmanned Air Vehicle (RDF- MUAV) in real time; enable wireless transmission of data in MySQL database to the web server and; provide attractive and responsive user interface to the end user. Second contribution is the antenna design, which propose a high directional and light in weight antenna design using Yagi-Uda antenna for RDF-MUAV system to be implemented in search and rescue process.

The rest of this paper is organized as follows. In section 2, the overall system for RDF-MUAV is represented. RDF-MUAV user interface design is then explained in section 3 followed by antenna and RF-Front End design in section 4. The result of the proposed system is provided in section 5 and being concluded in section 6.

2. OVERALL SYSTEM FOR RDFMUAV

This radio direction finding-miniature unmanned air vehicles contains of four main parts; RF front end design; RF software design; ground station design; and user interface (UI). The unmanned air vehicles that being use is quadcopter which uses four rotors positioned at the ends of a square on the drone body. For the ground station, ArduPilot mission planner is being used. The drones' longitude, latitude, altitude and azimuth value will be obtained from mission planner and will be transferred into database.

The next part is the payload of the drone which is the radio receiver module. The payload use Radio Signal Strength Indication (RSSI) technique to detect the location of the beacon. This technique use principle that the received strength of the signal is inversely proportional to the distance from the UAVs to the beacon[2]. Therefore, the higher the RSSI value, the stronger the signal. Radio receiver module can be separate into two parts; hardware antenna design and the software design. For the antenna design part, the antenna of chosen is yagi-uda antenna. It receives the emergency signal from the beacon and transmit it to the tuner to be observed. The software parts responsible for collecting signal data obtained by the antenna using Software Defined Radio (SDR), analyze the data and convert that value into format that can be transferred into the database system before being displayed on the website. The block diagram of the system is shown in Figure. 1.

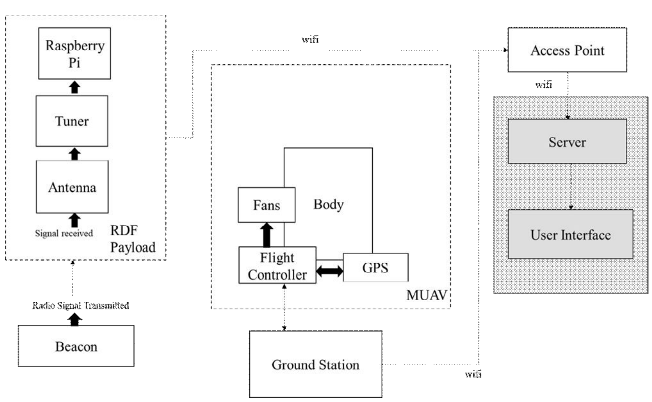


Figure 1 : RDF-MUAV Block Diagram

This paper focuses on RF front end design for custom build RDF antenna and also user interface using LAMP server that can provide real time data from the UAV.

3. RDF-MUAV USER INTERFACE

The interface aims to provide a quality website. A Quality of a website is dependent on many factors such as completeness, look and feel, content, structure, multimedia, usability, navigation and others. It is also related to the reliability, maintainability, security, privacy, personalization, adequacy, and safety[3] as the quality interface design can assist users to achieve maximum performance of the system[4]. The user interface process, as shown in Figure. 2, started by hardware and software setup, including the setup for the Raspberry Pi 3, and installation of all the software needed such as LAMP server, VNC Viewer and phpMyadmin.

The next step is to create a database using MySQL which then will stores all the data from the drone. After the database was created, some random data for timestamp, signal strength, azimuth, latitude, longitude and altitude were generated using Python code to be filled in the database table before getting the actual value from other parts of the system. Creating the website takes turn after creating the database. Next step is synchronizing the database from the MySQL to the website to enable data representation on the website. The website functionality was tested using the random data form the database. The second last process is connecting and collect the real data from other database from other parts of the drone into one database. The data is transferred from one database to another using replication process. The last process is presenting the obtained data on the website to be observed by the user in real time. Finally, Apache web server with the help of MySQL and PHP and others would then able to display the output on the website [5].

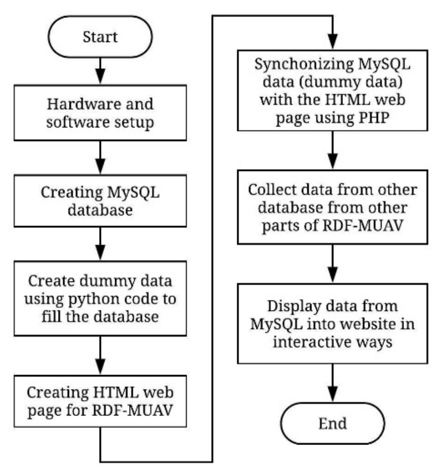


Figure 2 : Workflow of User Interface design

3.1 User Interface System Architecture

The user interface architecture consists of three layers; the database layer, application layer and presentation layer. The system layer is illustrated in Figure. 3.

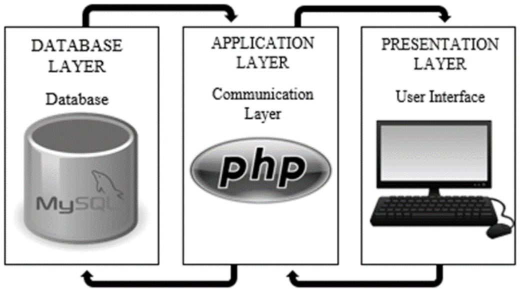


Figure 3 : Web Server Architecture

3.1.1 Database Layer

The database layer comprises of the database storage system and data access layer. Database layer is where all the data are stored. To create this database layer, we use LAMP server which made up of Linux operating system, Apache web server, MySQL database and PHP scripting language.

- *Replicating MySQL Data from Remote Database.*

In MySQL database system "rdfmuav" database was created to store all the data. In this system, all the data from base station and payload are stored in different databases. In order to obtain the data to be use in the web interface, it need to be in one database. The data from payload and base station will be collected by replication process. The replication process consists of two components, which is a master and slave. The database that hold the actual data is called as Master, and the database that willreceive the data is called Slave. MySQL replication is a process that enables data from one MySQL database server (master) to be copied automatically to one or more MySQL database servers (slaves). The replicated data will be stored in "rdfmuav" table that run on the server and the data can be managed using phpMyadmin, a web-based software acts as administrator tools for MySQL. But, since the data is needed from two different database, master with relay slave technique is being used. This technique enable slave of one master to be master to another slave. During replication, a slave server creates several logs that hold the binary log events relayed from the master to it, and record information about the current status and location within the relay log. The system is shown in Figure. 4 below.

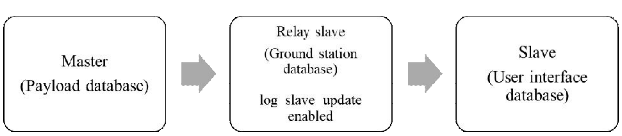


Figure 4 : Master with relay slave technique diagram

3.1.2 Application Layer

Application layer acts as the connector between database layer and presentation layer. It controls the web functionality by performing detailed processing. This layer is also where the access right was specified[6]. This application tier is also the one that writes and reads data into the database tier.To enable interaction between the sites to the database, most of the website use mysql_connect but for [7], it use OCBC connector which requires more overhead to be done.

- *Open Connection to MySQL using PHP*

PHP language is used to obtain data from database layer to be displayed in the presentation layer as shown in Figure. 5.

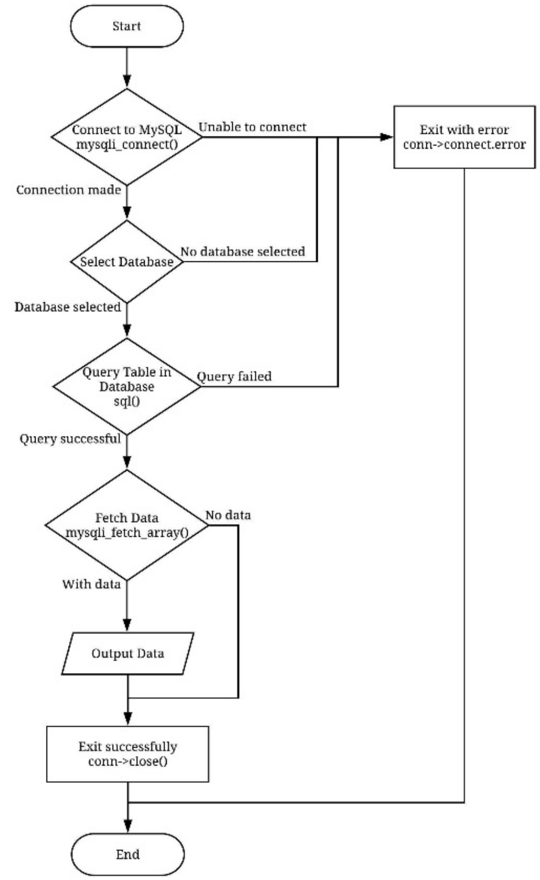


Figure 5 : Database Connection

3.1.3 Presentation Layer

The presentation tier is the front-end layer in the 3-tier system and consists of the user interface. The web is designed using the fundamental way which is by using HTML code with the addition of CSS code to make it responsive and looks good, and PHP and Javacsript to make it more interactive for the user.By designing the website without using any other method like Content Management System, the website can load faster, which in this case, will bring huge advantages since the data from the drone need to be updated as often as possible. This website made up of two web pages.

- *The Web Pages Design*

The main page is basically based on HTML, CSS and PHP code. It displays the information about RDF-MUAV and have button monitoring data which if it is clicked, will directed the user to the next page. The second page is based on PHP code. This page will have the signal strength indicator, a signal versus time graph, data table, a download data button and a back button. PHP code is used to connect the database to the website. With the help of Javascript code, the data can be presented in attractive way. The content of this page will be refreshed or updated every 5 seconds to display only the latest data to the user. The back button will take user back to homepage. Figure. 6 shows the website mapping.

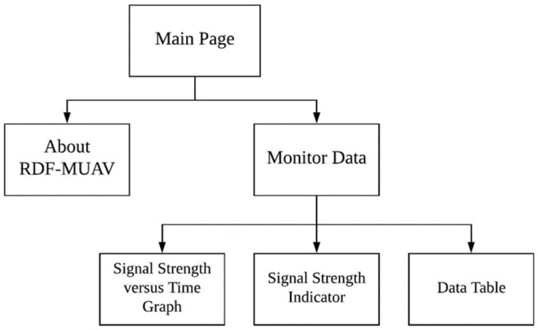


Figure 6 : Website Mapping

The website also can be viewed in mobile phone like native application without installing it to the phone system. It is being done using manifest or "add to home screen" function. It enables the website to be placed in device home screen by selecting the "add to home screen" function in the browser setting and run the web like any other application. To enable the function, a link tag to the webmanifest file need to be included in the head of the index.html file.The signal strength versus time graph and signal strength indicator are represented using Javascript code. For this website, charts from ZingChart.com has be used. ZingChart's flexible data handling allows direct data usage from a database. By using PHP to query a MySQL database, the data can be converted into JavaScript variables to be used in the charts. PHP while loops has been used to loop through data to create JavaScript arrays from the result set. The result of the system will be shown in section 5.

4. ANTENNA AND RF FRONT END DESIGN

Basically, RF front end design mainly focus on part of antenna design and its supporting framework and casing design. Based on Figure 7, the project workflow diagram is clearly showing the working process from the starting point of project until the end.

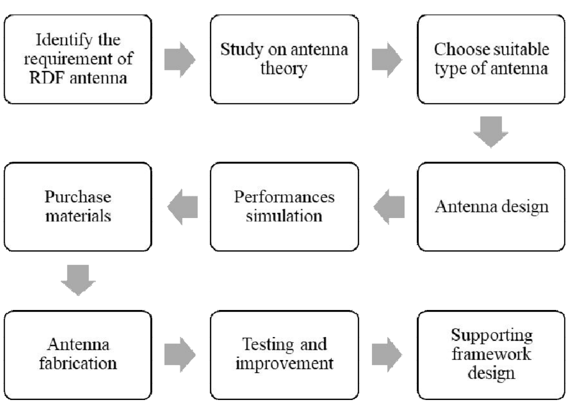


Figure 7 : Workflow of antenna and RF front end design

4.1.1 Different Type of Directional Antennas

Radio direction finder requires directional antenna to localise the direction of source signal. In order to obtain high accuracy of data, the antenna requires high directivity, high gain, high sensitivity and narrow beam width. There are many types of directional antenna including bow tie antenna, yagi-uda antenna, log periodic tooth antenna and helical antenna. The Table 1 shows the comparison of these directional antenna in aspect of gain, directivity, bandwidth and size. The data collected is based on the study of directional antennas[8]–[11]

Table 1 : Comparison Of Different Directional Antenna

Antenna	Gain	Directivity	Bandwidth	Size
Bow tie	Medium	Medium	Wide	Small
Yagi-uda	High	High	Narrow	Medium
Log periodic tooth	High	High	Wide	Large
Helical	High	High	Wide	Large

4.1.2 Antenna Design

The antenna is designed and simulated by simulation software CST suite studio. The design of the antenna is shown in Figure 8. The details of the antenna design are listed at Table 2.,

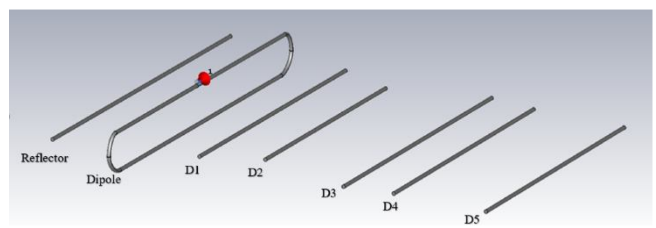


Figure8 : Design of antenna

Table 2 : Details of Antenna

Parameters	Data
Length of Reflector (mm)	167.75
Length of Dipole (mm)	152.37
Length of D1 (mm)	138.80
Length of D2 (mm)	114.54
Length of D3 (mm)	141.88
Length of D4 (mm)	134.57
Length of D5 (mm)	133.59
Diameter of rods (mm)	2.00
Spacing between Reflector and Dipole (mm)	32.63
Spacing between Dipole and D1 (mm)	40.00
Spacing between D1 and D2 (mm)	29.19
Spacing between D2 and D3 (mm)	50.75
Spacing between D3 and D4 (mm)	25.26
Spacing between D4 and D5 (mm)	49.83
Type of dipole	Folded dipole
Material	Steel

4.1.3 Steps for Antenna Fabrication

The steps of fabrication of the antenna are shown as Figure 9.

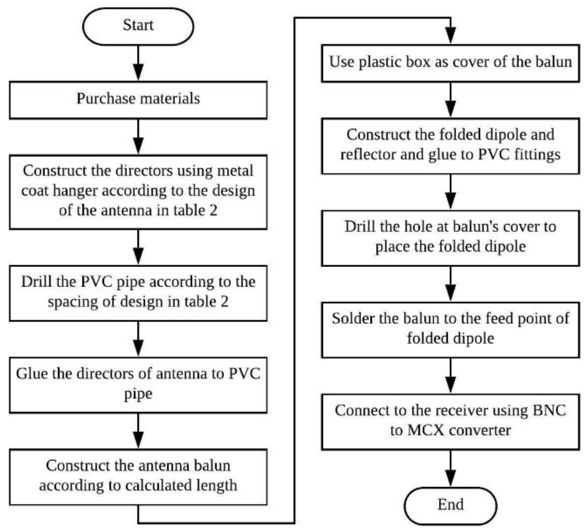


Figure 9 : Steps of fabrication of antenna

4.1.4 Supporting Framework

The Supporting Framework of antenna is required to integrate the RDF system into Miniature UAV. The PVC fitting is suitable to use as supporting framework and the plastic electronic project box use as cover for receiver. Figure 10 shows the design of supporting framework. The screws and nuts are used to fix and hold the supporting framework and casing into miniature UAV.

Figure 10 : Supporting Framework of Antenna

The final integration of RDF-MUAV can be done by connecting the Yagi-Uda antenna into the supporting framework. Figure 11 shows the final integration of the RDF-MUAV.

Figure 11 : Complete structure of RDF-MUAV

5. RESULT AND DISCUSSION

5.1 User Interface

The user interface system is designed to monitor the drone location and signal strength of the emergency beacon in real time. The database table consist six types of data; the time stamp, azimuth, latitude, longitude, altitude and signal strength. The data are replicated from remote databases using Master Slave replication. But, since the data is needed from two different database, master with relay slave technique is being used. The timestamp, azimuth, latitude, longitude and altitude data are originated from the ground station while signal strength is from the payload. The timestamp represents the actual time when the data is collected. The azimuth enable user to know which direction the drone is currently moving. The location of the drone is determined by the latitude and longitude while the height the drone currently flying is determined by the altitude. The signal strength is depending on whether the drone is approaching or away from the emergency beacon. Figure 12. (a) and (b) shows data obtained from ground station and payload.

Timestamp	Azimuth	Altitude	Latitude	Longitude	signalstrength
13/12/18/ 01:22:46	208	6.86	21441500	1027280000	-40.0729
13/12/18/ 01:22:59	207	6.87	21440500	1027280000	-40.0729
13/12/18/ 01:23:10	208	6.9	21440100	1027280000	-40.0729
13/12/18/ 01:23:22	208	6.99	21440000	1027280000	-40.0729
13/12/18/ 01:23:33	208	6.94	21440000	1027280000	-40.0729
13/12/18/ 01:23:44	208	6.97	21440200	1027280000	-40.0729
13/12/18/ 01:23:55	207	6.93	21440500	1027280000	-40.0729
13/12/18/ 01:24:06	207	6.99	21440300	1027280000	-40.0729
13/12/18/ 01:24:18	207	7.02	21440200	1027280000	-40.0729
13/12/18/ 01:24:29	207	7.04	21440300	1027280000	-40.0729
13/12/18/ 01:24:40	207	6.99	21440400	1027280000	-40.0729
13/12/18/ 01:24:51	208	7.03	21440500	1027280000	-40.0729
13/12/18/ 01:25:03	207	7.09	21440400	1027280000	-40.0729
13/12/18/ 01:25:14	207	7.03	21440500	1027280000	-40.0729
13/12/18/ 01:25:25	207	7.03	21440500	1027280000	-40.0729
13/12/18/ 01:25:36	207	7.05	21440200	1027280000	-40.0729

(a) (b)

Figure 12 : (a) Data obtained from ground station (b) Data obtained from payload

The webpage contains three types of data visualization; the signal strength indicator, time versus signal strength graph, and data table. These data presentations aid users to have better experience with the website. The indicator in Figure 13 makes it easy for the user to see the strength of the signal because it provides colorful range depending on the strength

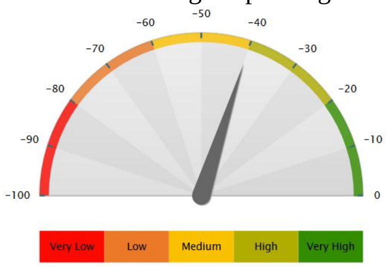


Figure 13 : Signal strength indicator

The graph as shown in Figure 14 below provides user the means to monitor the signal strength value versus time. It helps user to observe the signal strength in real-time. the ten latest data will be presented in this graph.

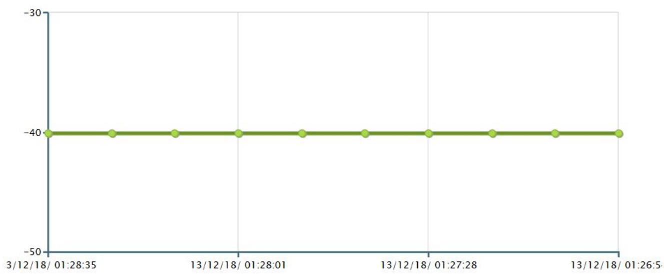


Figure 14 : Time versus signal strength graph

The last data presentation is in table consist of all six types of crucial data in this RDFMUAV system. The table combine all the data collected from base station and payload into one table which all these data then can be downloaded in .csv file to enable user to do further analysis on the data. The table is shown in Figure 15.

TIME STAMP	AZIMUTH	LATITUDE	LONGITUDE	ALTITUDE	SIGNAL STRENGTH
13/12/18/ 01:28:35	208	2.1441	102.728	6.88	-40.0729
13/12/18/ 01:28:24	208	2.14412	102.728	6.9	-40.0729
13/12/18/ 01:28:13	208	2.14413	102.728	6.94	-40.0729
13/12/18/ 01:28:01	208	2.14412	102.728	6.9	-40.0729
13/12/18/ 01:27:50	208	2.14411	102.728	6.91	-40.0729
13/12/18/ 01:27:39	207	2.14412	102.728	6.9	-40.0729
13/12/18/ 01:27:28	208	2.14412	102.728	6.97	-40.0729
13/12/18/ 01:27:17	208	2.14412	102.728	6.91	-40.0729
13/12/18/ 01:27:05	208	2.14412	102.728	6.91	-40.0729
13/12/18/ 01:26:54	207	2.1441	102.728	6.9	-40.0729

Figure 15 : Data table

The website interface is compatible for browsers in personal computers, smartphones and tablet usage. The interface will change its view according to the resolution of the browser in the device used. New data will be updated every five seconds to enable user to get the latest data to keep up with the drone actual situation. Figure 16 and 17 shows the interface for personal computer

Figure 16 : Homepage view in personal computer

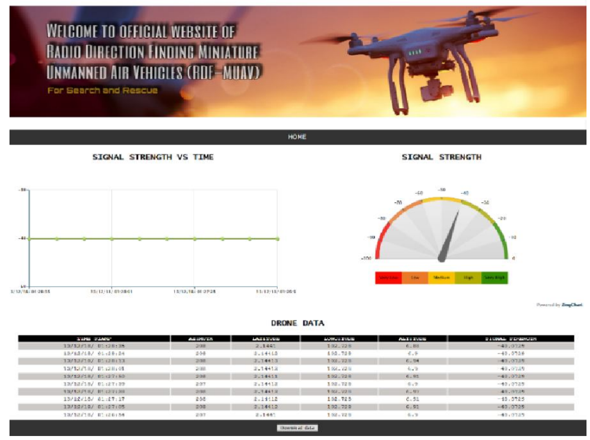
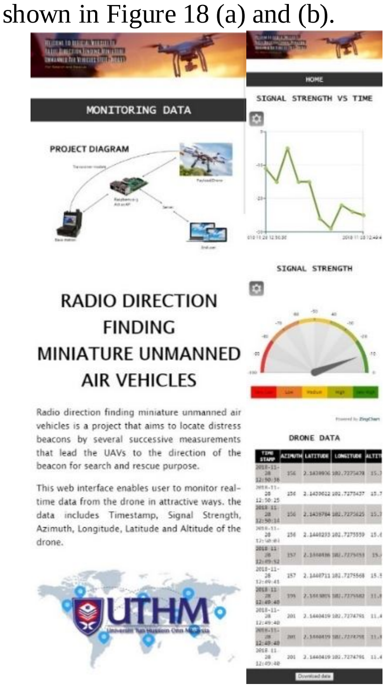


Figure 17 : Monitoring data page view in personal computer

To make it user-friendly, the website also can be viewed as web application in user's smartphone or tablet by adding it to home screen. This function enables the web app run on its own windows, separate from the web browser and also hides standard user interface (UI) elements like URL and bar. The interface is shown in Figure 18 (a) and (b).



(a) (b)

Figure 18 : (a) Homepage view in smartphone (b) Monitoring data page view in smartphone

5.2 RF-Front End

The simulation result based on the design of antenna satisfy the needs of radio direction finding. Firstly, the gain of antenna is equal to 9.98 dBi. This value is acceptable due to the limited size of antenna. This is approximately 10 times of power relative to an isotropic antenna in peak direction. The s-parameter is -13.68 dB for frequency 920MHz. Besides, the VSWR value of this antenna is 1.56, which means this antenna has low mismatch loss. The radiation pattern is shown in Figure 19. The front to back ratio is high and exhibiting a null. Lastly, the functional bandwidth of this antenna is around 70MHz which is from 875MHz until 945MHz. This range of functional bandwidth successfully fulfil the requirement of free frequency that assigned by Malaysian Communications and Multimedia Commission which is from 919MHz until 923MHz. The details of simulation result will be shown in Table 3 below.

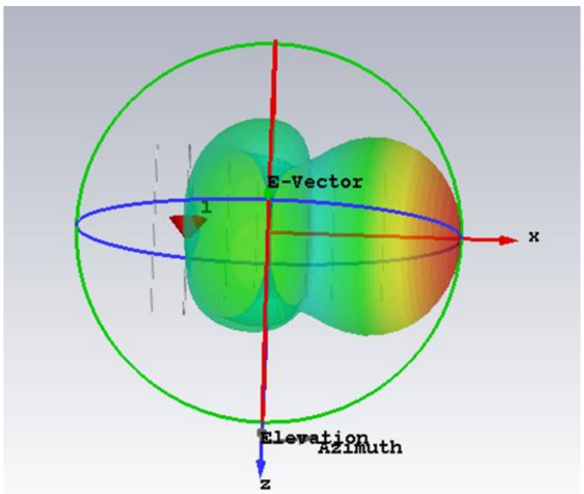
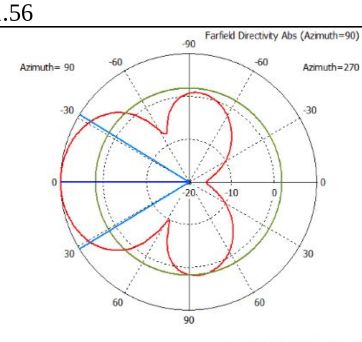
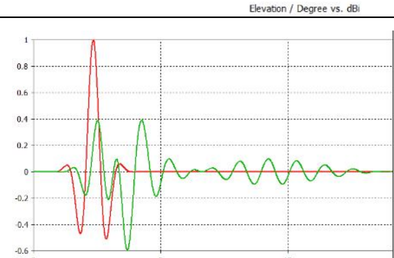


Figure 19 : Radiation Pattern

Table 3 : Details of Simulation Result

Design	Yagi-Uda antenna
Gain (dBi)	9.98
S parameter (Db)	-13.18
VSWR	1.56
Polarization Pattern in 2D	
Port Signals	
Impedance (Ω)	300
Radiation Efficiency (dB)	0.1424
Total Efficiency (dB)	-0.07599
Angular Width 3dB (Deg)	62.8
Total Length (mm)	228.656
Maximum Width (mm)	167.75
Functional Bandwidth (MHz)	875 to 945

The S11 parameter of the Yagi-Uda antenna did measured by using spectrum network analyzer. The Figure 20 shows the graph of S11 parameter versus frequency. As the graph shown, the graph of S11 parameter obtained from simulation result had been compared with the tested result. The simulation result shown in red line whereas the real result shown in black line. The S11 parameter of the real result is similar to the simulation result in term of functional bandwidth. Based on the graph, the real result shows the functional bandwidth of this antenna is around 200MHz which is from 500MHz to 600MHz and 900MHz to 1000MHz

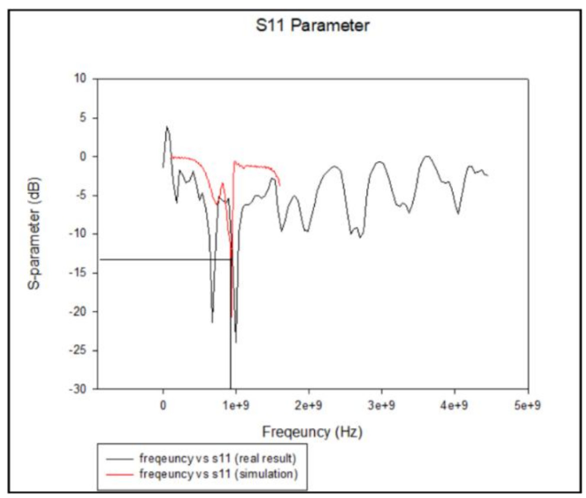
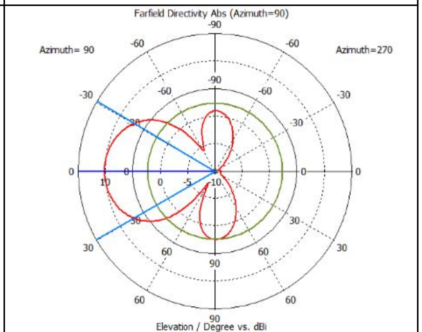


Figure20 : Graph of S11 Parameter Versus Frequency

Since the metal will oxidize, the alternative design of director's a ray does not take out plastic of meat coat hanger. However, the gain of antenna will slightly decrease due to that. To overcome the decrease in gain, an extra one director is added. The Figure 10 shows the antenna with alternative design of director's array. The 7-element Yagi-Uda antenna now became 8-element Yagi-Uda antenna. This design indicates increased in gain up to 10.1dBi. The main lobe degree was becoming 60.3 degree from initially 62.8 degree. The performance of antenna has been improved in expense of the weight of antenna. The Figure 10 shows the prototype of antenna with the alternative director's array design. The simulation result for alternative 8-element Yagi- Uda antenna is shown in Table 4.

Table 4 : Result for 8-Element Yagi-Uda Antenna

Design	8-Element Yagi-Uda antenna
Gain (dBi)	10.1
S parameter (Db)	-13.18
VSWR	1.63
Polarization Pattern in 2D	
Impedance (Ω)	300
Radiation Efficiency (dB)	0.1846
Total Efficiency (dB)	-0.07819
Angular Width 3dB (Deg)	60.3
Total Length (mm)	278.656
Maximum Width (mm)	167.75
Functional Bandwidth (MHz)	900 to 945

The result proved that the fabricated Yagi-Uda antenna able to receive the desired free frequency assign by Malaysian Communications and Multimedia Commission which is from 919MHz to 923MHz. on the RF software design part, Software Defined Radio (SDR) is being used to analyze the obtained data and convert that value into format that can be transferred into the database system before being displayed on the website.

6. CONCLUSION

In this paper, web interface and directional antenna that able to provide accurate bearing measurement and implementation for RDF-MUAV have been presented. The RDF-MUAV website is relevant to be designed because it can give a huge contribution in search and rescue mission. The real time data provided by this website can possibly make a huge impact in someone's life. The system has a number of attractive features, including low-cost, compact, scalable, easy to customize, easy to deploy, and easy to maintain. The Yagi-Uda antenna is fabricated using the materials such as metal coat hanger, PVC pipe, PVC fitting and coaxial cable. Experiment result shows the S11 parameter value is around -13dB with desired frequency 920MHz. It proves that the fabricated antenna is functionable and can receive electro-magnetic waves with wavelength of 0.33m. The website is able to monitor real time location of the drone and also display the signal strength collected by the Yagi-Uda antenna, originated from the emergency beacon in attractive ways. User also are able to access the website using personal computer, smartphone or tablets. The data from the drone can be conveniently downloaded from the website for analysis purpose. The system was successfully designed, implemented and tested.

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