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Comparison of Wireless Data Communication System (WDCS) Antenna in Between MRT Kajang Line and MRT Putrajaya Line

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Abstract: Wireless technologies have been widely developed in the last years and now are ready to meet the increasing demands of communication services for control and operation. Establishing solid communications between a fast-moving train and the trackside is one of the most difficult challenges in modern rolling stock systems. The use of wireless technologies in train-to-ground applications is common for bi- and Omni-directional antenna communications, and it is important to choose the best wireless antenna technology for each rail system. Currently, these antenna efficiency and performance for the existing wireless data communication system (WDCS) in the MRT for both lines is still not fully adequate. After extensive research and discussion to determine the root of the problem, it is clear that the issue is most likely caused by the WDCS antenna's inefficiency. Thus, this study focus on to investigate the characteristic of antenna types involves in railway industry and develop a simulation model between Omni-directional and Bi-directional antenna. Next, the comparison of Omni-directional and Bi-directional antenna performance for WDCS in MRT Kajang Line and MRT Putrajaya Line were also explored. The antenna parameter to determine antenna performance such as antenna gain, antenna efficiency, directivity, aperture efficiency, return loss and beamwidth will be taken into measure. The simulation for both types of antenna were develop by using Scout tool software to illustrate the two antennas more precisely and in greater detail. Additionally, coverage measurements between individual antennas along the MRT lines are checked using hardware tools such as test gear equipment. According to the study's findings, bi-directional antennas perform better than Omni-directional antennas and are closer to MRT requirements for an antenna that can deliver complete track coverage along the SSP Line with a consistent minimum signal-to-noise ratio higher than 18 dB, achieve train to ground and ground to train mobility for wireless applications installed in the

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electric trains moving at up to 100 km/h, and achieve capacity performance of 25 Mbps bandwidth at the lowest for each Network Access Point (NAP) and 8 Mbps bandwidth at the lowest for each train. Overall, this comparison shows in more detail that Bi-directional antenna is better to be used as research material for the future.

Keywords: Wireless Communication System, Omni-Directional, Bi-Directional, Antenna, MRT

1. Introduction

Wireless technologies have been widely developed in the last years and now are ready to meet the increasing demands of communication services for control and operation. Railway, subway, airplane, and other transportation systems have drawn an increasing interest on the use of wireless communications services to improve performance and reliability [1]. Mass Rapid Transit (MRT) is one of the best test cases for the analysis of wireless data communication system (WDCS) links and specification of the general requirements for train control and supervision. One of the most important goals of a communication system is to maximize signal transmission and reception efficiency.

An impedance match between the antenna and transmitter is required for optimal power transmission (or receiver). The design of a matching network system between the source (transmitter or receiver) and the load (antenna) for optimum power transmission is a fundamental challenge. An ideal antenna network system is a crucial component of a wireless communication system [2]. These ideas are fundamental to our research and will be developed further in the body of this project. What can be deduced from past conversations with MRT communication specialists is that the existing WDCS system in the MRT for both lines is still not fully adequate. This was confirmed when the Rapid Rail company's operator brought up the problem of WDCS during their weekly meetings with the MRT telecommunications division engineers. The operator indicated that during a test track session, during which they tested the running train on the trackside, they discovered an intermittent issue with the WDCS system not being able to catch or "handshake" at the appropriate moment. They also supplied a report on the problem, proving that it existed. As a result, after extensive research and discussion to determine the root of the problem, it is clear that the issue is most likely caused by the WDCS antenna's inefficiency.

As a result, this study will look at which sort of antenna is best for overcoming or reducing the problem. This project also includes a comparison of the WDCS system for the Kajang Line MRT and the Putrajaya Line MRT to further investigate this topic. The objectives of this report can be summarized as follows: to investigate the characteristic of antenna types involves in railway industry, to develop a simulation model between Omni-directional and Bi-directional antenna, and to compare the performance of Omni-directional and Bi-directional antenna base on the range, frequency and location.

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The issue regarding the loss of sight (LoS) signal for WDCS antenna between the electric trains for this study was referred to the Project for Mass Rapid Transit (MRT) in Malaysia. The issue was investigated from various locations, especially on the trackside at MRT to identify the problem and make some useful comparison for the WDCS antenna. The investigation of various existing project was also been studied in order to improve railway safety, and prevent the public from unwanted incidents from occurring. This study will have a comparison between two major types of WDCS antenna which are Omni-directional antenna and Bi-Directional antenna and also an extra type of antenna from MRT Singapore to further expand the view regarding WDCS antenna. This study also determine and analyze the collection of data from the simulation that will be done throughout this study. This analysis will focus on the comparison between the antennas to have the most suitable antenna for future use.

2. Materials and Methodology

In this chapter, the explanation about the method employed throughout this project is explained. It includes preliminary study, the calculation, measurement and the development of the design. The proposed designs was the combination of both antenna for Omni-directional and Bi-directional antenna into one system. The project is divided in several steps. It was started by studying the suitable antenna for the project. The related journals, paper and books on both antenna are referred.

Antenna coverage measurement and performance are done by using Scout tools or Test gear. Moreover, the selected previous works were chosen and validated. Then the combination design is proposed. Some of the parameter is done in order to get the best antenna performance. A combined directional beam and omnidirectional antenna comprises a unitary structure having a plurality of antennas being configured and oriented to achieve both directional beam coverage and omnidirectional beam coverage. For this project, two RF antennas are tested on site using appropriate tools.

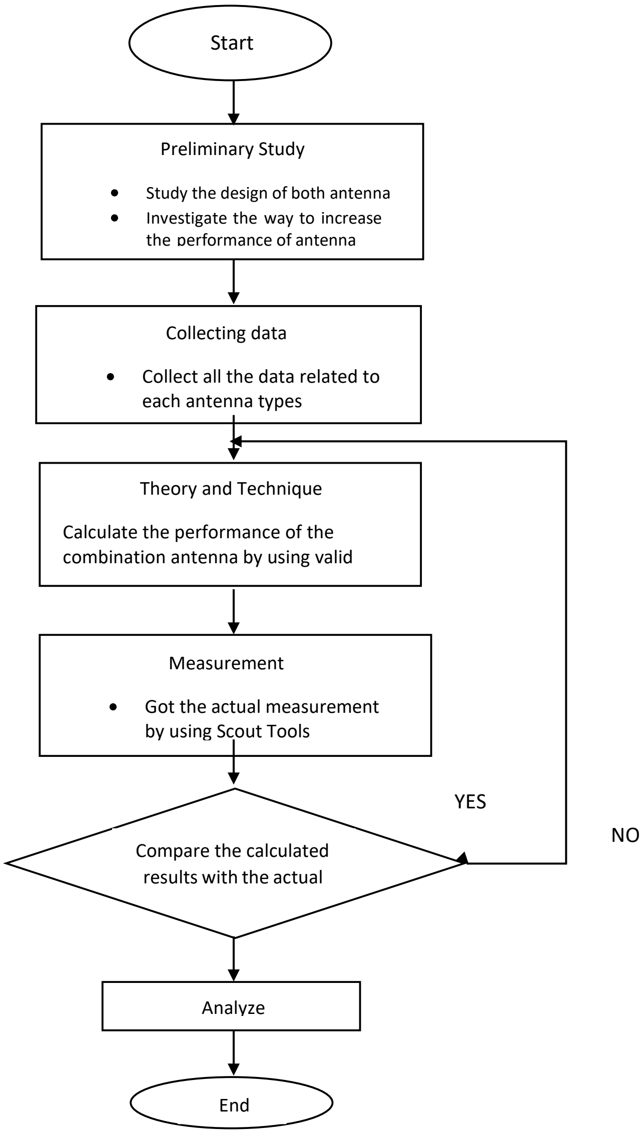

Figure 1: Methodology Flow Chart

2.1 Antenna Testing

For testing our antennas, the use of Scout tools equipment have been utilised. The equipment for all the tools were studied and then used to determine S_{11} (insertion loss), transmitting power, received power etc. We first found out insertion loss parameter of each antenna using network analyser. Then we determined the receiving power of antennas using one as a transmitter and the other as a receiver.

2.2 S_{11} Parameter

The insertion loss of antennas is provided by S_{11} . Insertion loss is proportionate to the antenna's input power divided by its reflectance ratio. In general, antennas transmit effectively for a specific frequency range. At these frequencies, the radiated power ought to be almost equal to the input power, which implies that the reflected power ought to be minimal. So a smooth line across the frequency scale with a significant dip in the working frequency range would be predicted for the plot of S_{11} for an antenna.

2.3 Power Measurement Arrangement

For power measurement we made an arrangement where one of the antennas was made a transmitter and the antenna, a receiver. Here, the bi-directional antenna served as our receiver while the Omni-directional antenna served as our transmitter. As shown in the diagram, we continuously sent a signal of varying frequency and strength from the signal generator to the sending antenna, and we used a coaxial cable to link the bi-directional antenna to the spectrum analyzer on the receiving end. We determined the frequency and strength of the received signal at the receiver end. When a 2.4 GHz signal with a power level of 10 dBm was supplied, we discovered that a signal with a lower power level at the same frequency also existed (near -30 dBm received). Even after doing our testing, we switched the arrangement, using a slotted waveguide antenna as the receiver and a bidirectional antenna as the transmitter. In this instance, power received at the same frequency and power level was somewhat lower, at almost -35 dBm. The following figures show the values that the signal generator and receiver (spectrum analyzer) for the first scenario displayed.

Figure 2: Signal Generator Display

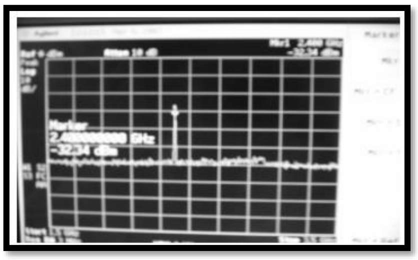

Figure 3: Spectrum Analyzer Display

2.4 Radio Frequency (RF) Inspection

For this simulation, I and the SY206 team (Comms) from MMC GAMUDA and SECHO must conduct operations on site in order to obtain radio frequency results along the track side designated for this project. We created this activity to ensure that each point along the track has a frequency range that is greater than -86dB, as defined in the agreed-upon standards. At the same time, we must go from antenna to antenna while recording the radio frequency signal. For this project, numerous locations along the trackside for the Kajang Line and Putrajaya Line were considered to provide a more detailed comparison.

3. Results and Discussion

One of the experiments for RF course required to obtain the s11 curve of a microstrip fed patch antenna. This antenna was stimulated, so that the reader will have not only the s11 curve of the antenna, but also its radiation patterns and other parameters such as its directivity, which will help them understand the working of the patch better. The dimensions of the patch and a figure of the meshed patch are given below.

Permittivity of substrate = 3.2

Height of substrate = 0.762 mm

Length of ground plane = 51.0 mm

Width of ground plane = 51.0 mm

Length of the patch = 15.0 mm

Width of the patch = 20.685 mm

Frequency = 5 GHz

Width of microstrip = 1.836 mm

Length of microstrip = 30.45 mm

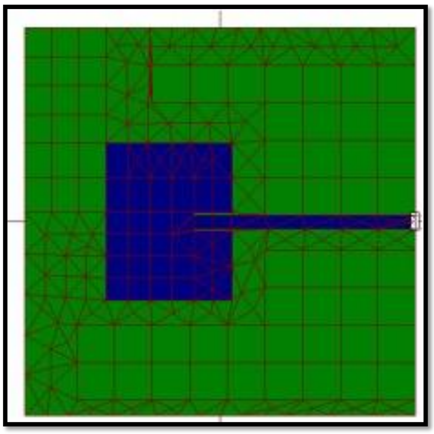

Figure 4: Meshed Patch

These are the simulation findings.

3.1 True 3D Pattern (Omni-directional)

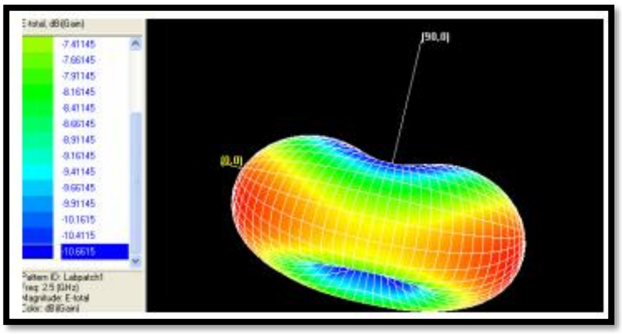

Figure 5: True 3D Radiation Pattern of Omni-directional antenna

3.2 True 3D Pattern (Bi-directional)

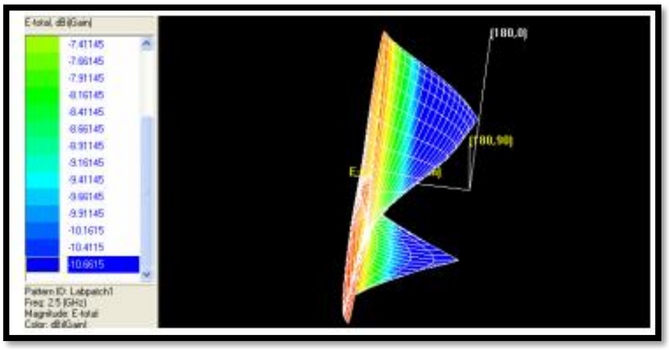

Figure 6: Mapped 3D Radiation Pattern of Bi-directional antenna

3.3 2D Polar Plot

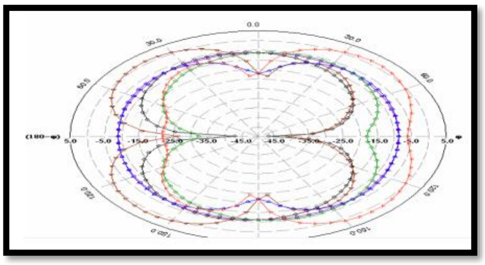

Figure 7: Polar plot for the antenna for three values of φ at f=2.5 GHz and 3.4 Frequency Properties

Table 1: Parameters for the 5 GHz antenna

Frequency	3.5 (GHz)
Incident Power	0.01 (W)
Input Power	0.00520864 (W)
Radiated Power	0.00185641 (W)
Average Radiated Power	0.000147728 (W/s)

Radiation Efficiency	35.6409%
Antenna Efficiency	18.5641%
Conjugate Match Efficiency	17.8205%
Total Field Properties	
Gain	-3.03168 dBi
Directivity	4.28158 dBi
Maximum	at (40, 220) deg.
3dB Beam Width	(56.8323, 183.477) deg
Conjugate Match Gain	-3.20923 dBi

3.5 Return Loss Curve

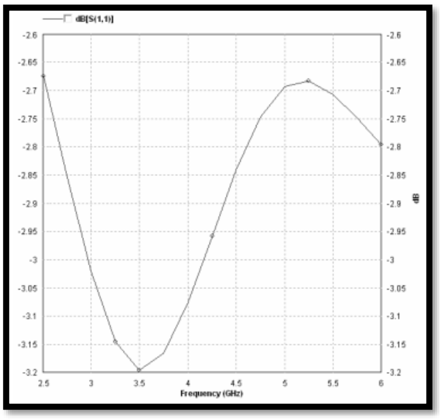

Figure 8: RL curve for the antenna

It can be seen from the return loss curve that the antenna resonates at 3.5 GHz. However, this value differs from the expected value of 5.0 GHz. Reasons for the deviation could be that we didn't have all the dimensions of the patch, and data on type of material used for metal and dielectric. Since, we had to manually measure some dimensions, this is a cause for the errors.

4. Conclusion

As for the conclusion, it can be determined from the comparison between omnidirectional and bidirectional antennae that both have advantages. However, it can be guaranteed that the Bi-directional antenna is the ideal design for use in railway applications and satisfies all standards established for the use of wireless data connection. The decision to integrate the two antennas into a single system for this project was made after it was discovered that doing so could increase antenna efficiency but involved a significant amount of work and expense. The study also discovered that certain features of the combined efficiency of the antenna, such as bandwidth, frequency range, and others, will also be decreased. Upon the conclusion of our project we made the following assessment of our work: The overall working of antennas was understood. The major parameters (such as Return Loss curves, Radiation Patterns, Directivity and Beamwidth) that affect design and applications were studied and their implications understood.

Acknowledgement

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References

[1] Wan Mohd Azri Wan Mohd Yunus. (2014). Final Design Specification for Wireless Data Communication System (WDCS) (CONTRACT-SBK-S-07). APEX COMMUNICATION SDN BHD - LG CNS CONSORTIUM.

[2] SAPURA EVD CONSORTIUM. (2019, May). Final Design of Wireless Data Communication System (WDCS) (contract SSP-SY-206). Jagjeet Singh (WDCS Design Team Lead).

[3] Future strategic plan analysis for integrating distributed renewable generation to smart grid through wireless sensor network: Malaysia prospect. (2016, January 17). ScienceDirect.com | Science, health and medical journals, full text articlesandbooks. https://www.sciencedirect.com/science/article/pii /S1364032115009909

[4] Wireless communications in smart rail transportation systems. (2017, December 5). Publishing Open Access research journals & papers | Hindawi. https://www.hindawi.com/journals/wcmc/2017/6802027/.

[5] Combination antennas. (2021, July 30). PCTEL. https://www.pctel.com /products/antenna-products/combination-antennas/?producttype=53& technologies=75

[6] Alex. (n.d.). The difference between directional and omni-directional antennas. Experts in Networks, WiFi, IT Infrastructure & Comms | NetXL. https://www.netxl.com/blog/networking/directional-or-omni-directional-antennas/

[7] Cost reduction and channel capacity enhancement of MIMO system using antenna selection techniques | Kumar | International Journal of electronics and telecommunications. International Journal of Electronics and Telecommunications.https://ijet.pl/index.php/ijet/article/view/10.24425-ijet. 2019.126300

[8] Omni antenna vs. directional antenna. (n.d.). Cisco. https://www.cisco.com /c/en/us/support/docs/wireless-mobility/wireless-lan-wlan/82068-omni-vs-direct.html

[9] Omnidirectional antenna. (n.d.). ScienceDirect.com | Science, health and medical journals, full text articles and books. https://www.sciencedirect.com /topics/computer-science/omnidirectional-antenna

[10] (n.d.). PowerTrunk - P25 and TETRA Land Mobile Radio. https://www.power trunk.com/docs/Pros_and_Cons_of_P25_vs_TETRA.pdf

[11] Railway. (2021, September 20). WCWL Communications | Inspired To Make It Better. https://wcwl.com.my/railways/

[12] Research and design of data communication subsystem of urban rail transit CBTC system. (2021, January 27). SpringerLink. https://link.springer.com/ article/10.1007/s13198-021-01055-5