Comparative Analysis of DMR (Digital Mobile Radio) Tier 3 Performance Based on RSSI Parameters at the Rammang-Rammang Site

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Abstract, The trunking radio system used in the Makassar - Pare-pare region utilizes DMR tier 3, an internationally recognized open standard from ETSI. The Makassar - Pare-Pare railway network is a recent route with certain areas lacking network coverage, posing safety risks for train travel. An analysis of trunking radio signal quality along this route has not been previously conducted. This study analyzes signal quality to compare DMR Tier 3 performance. The approach encompasses theoretical analysis via the link budget method, simulation using radio mobile software, and field measurements employing handheld transceivers (HT). Analysis results reveal an average RSSI calculation of -62.49 dBm, simulation at -62.61 dBm, and field measurement at -76.47 dBm. All RSSI values across 36 measurement points meet ETSI (-113 dBm) and TAIT (-119 dBm) standards. The difference between calculation and simulation is 1.01 dBm, favoring the calculation. The average RSSI difference between simulation and field measurement is 13.86 dBm, favoring the simulation. This research offers insights into DMR Tier 3 performance on the Makassar - Pare-Pare route, with theoretical calculations closely resembling field results. These findings are crucial for enhancing communication between train operators and the control center, ensuring the safety and security of train travel along the Makassar - Pare-Pare region.

Keywords: DMR, Link Budget, Radio Trunking, RSSI

1 Introduction

Trunking Radio System is a radio communication system that utilizes repeaters for one or multiple towers. This system employs more than one frequency and allows users to have dedicated channels, enabling them to communicate in groups with a certain level of privacy [1]. The radio trunking system used along the Makassar-Pare-Pare railway line is a DMR tier 3 trunking radio system, utilizing the TAIT TB9300 series as the radio base station. This radio trunking system uses two frequency channels within the range of 380 MHz to 399.5 MHz. DMR tier 3 was first introduced in the field of railway telecommunications in Indonesia on the Makassar-Pare-Pare route. In this route, there are several areas with inadequate network coverage, posing significant risks to railway safety and security and not aligning with the "Safety Management System" development [2]. The areas with poor network coverage are located between Km 13 and Km 14 on the Makassar-Pare-Pare route, between Mandai Station and Maros Station. The positioning of the base station also affects network quality, as improper placement results in areas with poor signal reception. Additionally, factors such as antenna height, distance between transmitter and receiver, and obstacles also influence

A. Pradipta et al. (eds.), *Proceedings of the 2nd International Conference on Railway and Transportation 2023 (ICORT 2023)*, Advances in Engineering Research 231,
https://doi.org/10.2991/978-94-6463-384-9_16

network quality and coverage areas [3]. Due to the presence of several areas with poor signal coverage, the author conducted research on the performance of DMR (Digital Mobile Radio) Tier 3 at the Rammang-Rammang site. This research employs the link budget calculation method to determine the signal strength received by the receiver, known as RSSI (Receive Signal Strength Indicator). RSSI is a parameter used to assess trunking radio network coverage since it represents the level of signal received by the receiver, serving as a measure of network quality [4]. RSSI measurement involves assessing the power received by a receiver device [5]. The purpose of the link budget calculation is to obtain values for other transmission signal parameters. These parameters are necessary due to obstacles in distance and signal attenuation during transmission [6]. Field condition measurements are conducted using the drive test method utilizing railway facilities. Three methods will be employed in this research: theoretical calculations, simulation using radio mobile software, and field measurements (drive test) using HT. Drive test involves collecting data on signals transmitted by a base station [7]. The data obtained will be analyzed using parameters including EIRP, FSL, and RSSI. Subsequently, a comparison will be made between the results of theoretical calculations, results obtained from the simulation process, and field measurements.

2 Literature Review

2.1 DMR (Digital Mobile Radio)

DMR (Digital Mobile Radio) is an open digital radio standard defined by the European Telecommunications Standards Institute (ETSI) for Private Mobile Radio (PMR) usage. It serves as a low-cost entry-level radio system for commercial and public safety applications. DMR offers a digital solution that replaces analog systems with all the benefits of digital technology. DMR is best suited for covering large areas with low traffic, where simulcast/broadcast operation is most effective [8]. The primary goal of DMR is to develop an affordable digital system with relatively low complexity. DMR provides voice, data, and other additional services. The DMR protocol includes three operating modes:

a. DMR Tier I is used for license-free devices with a maximum RF power of 0.5 watts, suitable for small coverage areas and emergency applications.
b. DMR Tier II was developed for licensed radio systems with advanced features, IP data services, and uses TDMA with two slots on a 12.5 kHz channel.
c. DMR Tier III is used for trunking radio operations in large areas, with support for voice, short messaging, and packet services, including IPv4 and IPv6.

The DMR network architecture is simpler compared to other narrow-band technologies but depends on the tier level. Tier I involves end-user devices without repeaters and only supports direct device-to-device operations using FDMA mode. Tier II can accommodate more users, while Tier III includes full trunking capabilities between sites and interfaces to telephone networks and other types of networks. A Tier III network can consist of a single site or multiple stations with a maximum of 15 sites. To see the DMR architecture, refer to Figure 1 below:

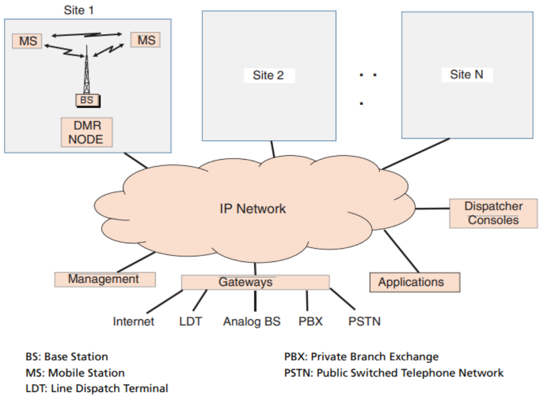

Fig. 1. DMR Architecture

2.2 Link Budget Parameters

Link budget calculation is the process of determining the power gain and losses from the transmitter to the receiver while considering certain parameters [9]. These parameters are necessary due to the presence of distance obstacles and signal attenuation during transmission. In this research, link budget calculation is used to obtain the RSSI (Receive Signal Strength Indicator) value. Some important parameters that need to be calculated accurately to ensure the system functions optimally [10] include:

EIRP (Effective Isotropic Radiated Power)

EIRP is a component calculated in the link budget parameter. EIRP results from combining the transmit power on the antenna with the antenna gain of the transmitter [11] [12]. EIRP can be calculated using the following formula:

$$\text{EIRP} = P_{Tx} - L_{Tx} + G_{Tx} \quad (1)$$

Where :

EIRP : *Effective Isotropic Radiated Power* (dBm)
P_{Tx} : Maximum transmitter power (dB)
L_{Tx} : Loss in the cable or connector at the transmitter (dB)
G_{Tx} : Antenna gain at the transmitter (dB)

FSL (Free Space Loss)

FSL represents the phenomenon of radio wave power reduction as it propagates in free space. This attenuation depends on the signal frequency and the distance between the transmitter and receiver antennas. In this space, no obstacles are allowed because the transmission is Line of Sight (LoS) [12]. To calculate the FSL value, the following equation is used:

$$\text{FSL} = 32{,}45 + 20 \log f + 20 \log d \quad (2)$$

Where:

FSL : Free space loss (dB)
f : Frequency used (MHz)
d : Distance between transmitter and receiver (Km)

Propagation Effects:

Propagation is the process of radio wave propagation from the transmitter antenna to the receiver antenna through the air as the signal transmission medium. Free space propagation occurs when there are no obstacles between the transmitter and receiver. However, if there are obstacles in the propagation path, the signal will experience some attenuation [13].

RSSI (Receive Signal Strength Indicator):

RSSI is a parameter used to measure the coverage of a trunking radio network. Factors affecting the RSSI value include transmitter output power, antenna gain, and signal attenuation during air propagation (path loss) [14]. The RSSI value can be calculated using the following equation:

$$\text{RSSI} = (P_{Tx} - L_{Tx} + G_{Tx}) - \text{Pathloss} + G_{Rx} - L_{Rx} \quad (3)$$

Where:

RSSI : *Receive Signal Strenght Indicator* (dBm)
P_{Tx} : Transmitter antenna power (dBm)
L_{Tx} : Cable loss at the transmitter antenna (dB)
G_{Tx} : Transmitter antenna gain (dBi)
G_{Rx} : Receiver antenna gain (dBi)
L_{Rx} : Cable loss at the receiver antenna (dB)
Pathloss : Total signal loss in propagation (dB)

Receiver Sensitivity

Receiver sensitivity refers to the device's sensitivity on the receiving side and is used as a threshold. Receiver sensitivity reflects how far the receiver can detect and receive transmitted signals [15]. In this research, the receiver sensitivity is -113 dBm, as required by ETSI, and -119 dBm, as required by TAIT.

3 Research Method

The initial step is to survey the location and identify the issues in this research case study, which is the Makassar-Pare-Pare route, and formulate problems based on these issues. Subsequently, a literature review is conducted through the study of previous research data. Next, both primary and secondary data are collected. Primary data is obtained through field measurements, while secondary data is collected from relevant institutions, including base station specifications, antennas, and the frequencies used. Data processing is carried out based on the collected data, which is then simulated using radio mobile software by determining the latitude and longitude coordinates of the transmitter and receiver points. Furthermore, parameters obtained from secondary data, such as the frequency used, antenna height, antenna gain, sensitivity, and transmit power, are inputted. In the data processing process, three methods will be used: theoretical calculations, simulation using radio mobile software, and field measurements (drive test) using HT. The data obtained will be analyzed using parameters including EIRP, FSL, and RSSI. Subsequently, a comparison will be made between the results of theoretical calculations, results obtained from the simulation process, and results from field measurements. Based on this data, an analysis can be conducted to determine whether the performance of the Digital Mobile Radio (DMR) Tier 3 network at Site Rammang-Rammang is satisfactory or not.

4 Results and Discussion

4.1 Theoritical RSSI Calculation

The initial stage in this research is to determine the parameters that affect the RSSI value. Before calculating the RSSI theoretically, it is necessary to establish the parameters that will be input into the calculation. These parameters are obtained from data collected from relevant institutions. The parameters that have been determined are as follows:

Table 1. Parameters Link Budget

Parameter	Value
Mininum Frequency	380 MHz
Maximum Frequency	399.5 MHz
Transmitter Sensitivity	119 dBm
Transmitter Antenna Power	50 W
Receiver Antenna Power	4 W
Losses in Transmitter Antenna Cable	1.137 dB
Losses in Receiver Antenna Cable	0 dB
Transmitter Antenna Height	41 m
Receiver Antenna Height	1.5 m
Transmitter Antenna Gain	11.1 dBi
Receiver Antenna Gain	0 dBi

EIRP Calculation

Results of EIRP Calculation (Effective Isotropic Radiated Power)
The first component to calculate in the RSSI measurement is EIRP (Effective Isotropic Radiated Power). The equation used to calculate EIRP can be expressed using equation (1) as follows:

$$\begin{aligned} \text{EIRP} &= P_{Tx} - L_{Tx} + G_{Tx} \\ &= 47 - 1{,}137 + 11{,}1 \\ &= 56{,}963 \text{ dBm} \end{aligned}$$

Parhloss Calculation

First, the attenuation to be calculated is FSL. In this case study, there are 36 points where RSSI values will be measured, so there are 36 different parameter values of 'd' in the calculation. To obtain the FSL value, you can use equation (2) as follows:

$$\begin{aligned} \text{FSL} &= 32{,}45 + 20 \log f + 20 \log d \\ &= 32{,}45 + 20 \log 399{,}5 + 20 \log d \\ &= 32{,}45 + 52{,}019 + 20 \log d \\ &= 84{,}469 + 20 \log d \end{aligned}$$

The pathloss value represents the total attenuation during transmission, and it can be calculated by combining the total attenuation values of FSL, reflection, diffraction, and scatter. In this case study, based on the International Telecommunication Union Recommendation (ITU-R) P.1406-2 standard, the magnitude of reflection loss in open hill areas is 7 dB.

RSSI Calculation

RSSI is the level of signal strength received by the receiver, and its value must be greater than the receiver device's sensitivity. Receiver sensitivity refers to the level of sensitivity of a device on the receiving end and serves as a threshold to determine whether the signal is reliable or not. After calculating the values of EIRP, FSL, and pathloss, the RSSI value that can be received by the receiver antenna can be calculated using equation (3).

$$\begin{aligned} \text{RSSI} &= (P_{Tx} - L_{Tx} + G_{Tx}) - pathloss + G_{Rx} - L_{Rx} \\ &= (\text{EIRP}) - pathloss + G_{Rx} - L_{Rx} \\ &= 56{,}963 - pathloss + 0 + 0 \\ &= 56{,}963 - pathloss \end{aligned}$$

4.2 Comparison of RSSI

After all the parameters have been entered into the mobile radio software, the next step is to start the simulation in the software using the radio link menu, and the values of EIRP, FSL, Obstruction, and path loss at 36 measurement points will be determined. Figure 2 below shows the mobile radio interface.

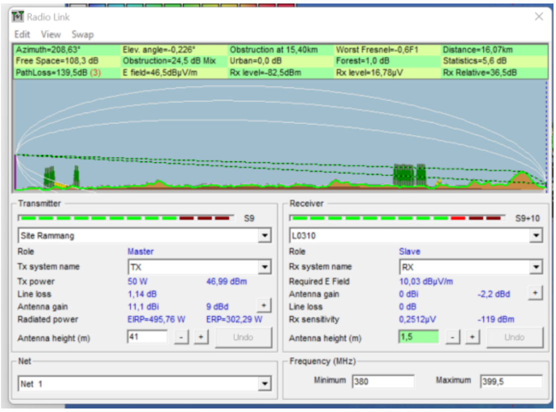

Fig. 2. Radio Mobile Interface

Field measurements are performed by tracking the RSSI values at the specified points. The radio used for testing is the Tait TP 9300 HT. Measurements are taken by tracking the RSSI values at the 36 designated points. After recording the field measurement results, they are then compared with the calculations and simulations from the mobile radio. The comparison results of RSSI calculations, mobile radio simulations, and field measurements are shown in Table 2 below:

Table 2. Comparison of RSSI

No	Location	Theoretical	Simulation	Measurment	No	Location	Theoretical	Simulation	Measurment
1	L0310	-78,65	-82,5	-95,25	19	JL0412B	-66,12	-67,8	-79,75
2	W0311A	-78,57	-84,9	-100,25	20	W0413A	-66,11	-68	-80,75
3	W0311B	-79,17	-86,2	-100,5	21	W0413B	-66,06	-69,6	-80,25
4	JL0312A	-79,78	-86	-101,25	22	X0414	-65,31	-66,5	-79,5

5	ST MAD	-89,50	-92,9	-105,25	23	J0414	-65,50	-65,7	-79
6	JL0312B	-67,94	-63,1	-80,25	24	MJ0414	-63,81	-62,3	-79
7	W0313A	-68,79	-65,7	-79,25	25	ZP0414D	-63,66	-62,4	-74
8	W0313B	-68,60	-67,1	-78,75	26	LINTAS	-62,23	-61,1	-76,25
9	L0314	-68,61	-67,4	-82	27	LINTAS	-60,65	-61,8	-75
10	J0314	-68,69	-71,3	-85,75	28	LINTAS	-58,35	-59,2	-74,75
11	MJ0314	-66,76	-68	-83,25	29	LINTAS	-57,29	-55,5	-71
12	X0410	-67,25	-69,6	-85,5	30	ZP0510A	-53,50	-50,6	-64
13	W0411A	-66,26	-68	-84,25	31	MJ0510	-53,32	-49,3	-63,5
14	W0411B	-66,23	-68,5	-82	32	J0510	-33,88	-32,2	-43,75
15	JL0412A	-66,20	-68,9	-81,25	33	X0510	-32,39	-29,2	-42,5
16	OCC	-66,24	-72,9	-85,25	34	W0511	-27,07	-21,9	-35,75
17	ST MRS	-66,19	-73,5	-88,75	35	JL0512A	-26,00	-22,9	-34,75
18	DEPO	-66,07	-73,7	-88,75	36	ST RMG	-16,83	-17,6	-31,75

Based on Table 2 above, it can be seen that the theoretical link budget calculation results for determining the RSSI values have an average of -62.49 dBm, the average RSSI from simulation is -62.61 dBm, and the average field measurement RSSI is -74.47 dBm. It can be concluded that the RSSI measurements at the 36 measurement points meet the minimum RSSI values required by ETSI, which is -113 dBm, and the minimum required by TAIT, which is -119 dBm. The comparison of RSSI values between theoretical calculations, simulations, and field measurements is shown in Figure 6 below.

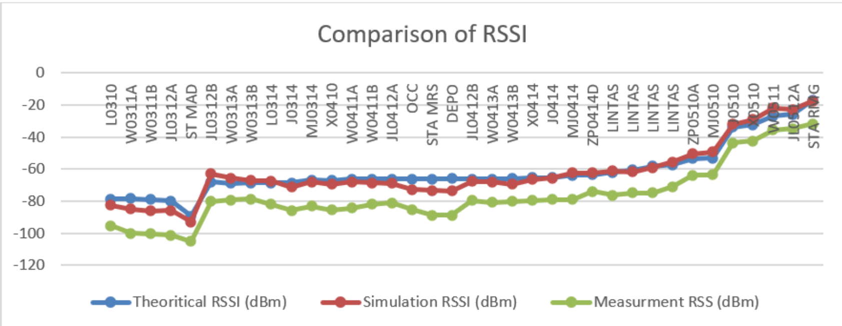

Fig. 3. RSSI Comparison Chart

Based on Figure 3 above, the differences between RSSI in calculations, simulations, and field measurements can be observed. The average difference between RSSI calculations and simulations is 1.01 dBm, with calculations being better. Meanwhile, the average difference between simulation and field measurement RSSI is 13.86 dBm, with simulations being better. The researcher can conclude that the RSSI (Receive Signal Strength Indicator) values are highly dependent on the conditions in the field. It is evident that the field measurement RSSI values are the lowest when compared to the simulated and theoretical RSSI values, as field measurement RSSI values experience a significant amount of attenuation based on real conditions in the field. Field measurements also experience signal attenuation caused by the train's carbody frame or weather-related factors.

5 Conclusion

Theoretical link budget calculations yield an average RSSI of -62.49 dBm, the average RSSI from simulations is -62.61 dBm, and the average field measurement RSSI is -74.47 dBm. It can be concluded that the RSSI measurements at 36 measurement points meet the minimum RSSI values required by both ETSI, which is -113 dBm, and TAIT, which is -119 dBm. There are differences in RSSI values between theoretical calculations, simulations, and field measurements. The average difference between calculations and simulations is 1.01 dBm, with theoretical calculations being more accurate. Furthermore, the average difference between simulation and field measurement RSSI is 13.86 dBm, with simulations being more accurate. This indicates that RSSI values are highly influenced by field conditions and differences in attenuation parameters used. To enhance the performance of DMR Tier 3 at the Rammang-Rammang site, the author has three alternative solutions: first, the addition of a repeater; second, the replacement of antenna types; and third, the addition of transmitter power.

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