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Application-based Simulation on the Digital Trunking Radio Communication System to Predict the Area Coverage

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ABSTRACT

A radio communication system (RCS) based on digital trunking of the digital mobile radio (DMR) type of Tier-III with any of the brands is installed, consisting of mobile radio devices, portable radio devices, repeater devices, devices antenna, and power supply device. The technical specifications for these types of equipment have been approved by institution-owned. This paper describes a radio communication system infrastructure based on a digital trunking RCS for predicting the area coverage for independent or private use. The research contributions of this study include (a) predicting the signal of area coverage of the repeater and radio devices and (b) observing results of communication performance on the DMR Tier-III Trunking radio communication system. Research methods for achieving research objectives, including five main parameters are required connectivity, the DMR application for predicting radio signal area coverage of the repeater system, and observation of the communication performance. Tuning on the repeater system include five conditions, while on radio equipment includes four conditions. Prediction and observation of the coverage area based on seven parameters as input. The simulation results are in the form of a screenshot with an area coverage of 140.938 kilometers. The observation of communication performance through dummy loads in the form of providing types of artificial condition calls. In general, after the research objectives are obtained, it is expected that the system is well connected.

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1. INTRODUCTION

The radio communication system (RCS) uses air media and radiofrequency as a signal that carries pieces of information of audio and data [1]. According to the International Telecommunication Union, the world is divided into three regions for radio regulation for the management and alignment of the allocation and use of radio spectrum globally [2, 3]. The display of area coverage for three regions according to ITU designation [3, 4] is shown in Fig. 1. Each region with its own set of frequency allocations, which are generally very similar. Concerning the division of regions, according to Resolution 646 (WRC-03), it is highly recommended to use regional harmonic bands with frequency allocation [3-5], namely:

(i) Region-1 at 380 to 470 Megahertz as the frequency range with the band 380 to 385 or 390 to 395 Megahertz is the preferred main alignment band for permanent protection activities in certain countries in region-1;
(ii) Region-2 at 746 to 806 Megahertz, 806 to 869 Megahertz, 940 to 990 Megahertz; and
(iii) Region-3 at 406.1 to 430 Megahertz, 440 to 470 Megahertz, 806 to 824 or 851 to 869 Megahertz, 940 to 990 Megahertz, and 850 to 925 Megahertz.

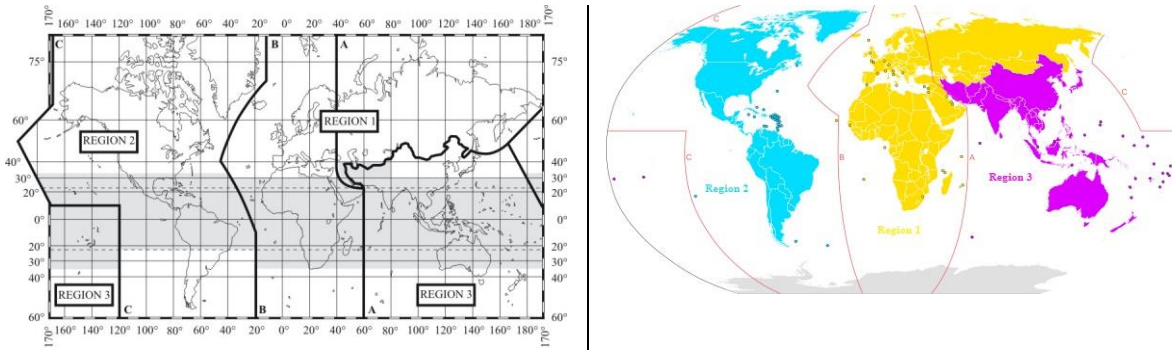

Fig. 1. The display of area coverage for three regions according to ITU designation

Radio equipment for communicating consists of three main parts or basic components, namely the radio set, antenna, and switched-mode power supply [6, 7]. A radio set is a part that functions as a transmitting-end and receiving-end of information in the form of sound waves so that the device of the radio set consists of two parts, i.e., the transmitter and receiver. Thus it becomes one unit with their respective functions and is often called radio transceivers (transmitters and receivers) [8-11]. A radio transceiver is a type of two-way communication, so it can send and receive signals at one operating frequency [12, 13]. The communication method used is full-duplex, where the information signal occurs at the same time and contra direction [14, 15], so if using a half-duplex, where the information signal can occur in two directions alternately [16, 17]. Based on the descriptions of background in this paper, the performance characteristics of a radio communication system based on digital trunking are reviewed in detail in simulations.

In the presence of a transmitter and receiver on the radio for communication, the transceiver operates continuously [13, 18]. Radio transceivers can operate simultaneously, i.e., sending and receiving the radiofrequency waves [1, 19, 20]. The time for sending radio waves (Tx) is different from receiving radio waves (Rx) [21]. The existence of a push to talk (PTT) switch on the transceiver radio is a switch for setting the transceiver radio to the receiver or sender position [13, 22]. For conditions where the PTT switch is "ON," the transceiver radio is transmitting (signal emitting), whereas if the PTT switch is "OFF," the transceiver radio is receiving (signal reception) [13, 23]. In a transceiver system, a Tx transmitter transmits power through the antenna towards its destination, and the signal is emitted in the form of electromagnetic waves [24, 13]. A suitable antenna receives these electromagnetic waves [25, 13]. The received signal is then forwarded to an Rx receiver [13]. The keypad found on each radio device is a telephone number for cell phones and landlines [26].

Digital Mobile Radio or DMR is a digital-based radio communication system standard for voice and data in non-public wireless networks [27-30]. The DMR is a transmission standard based on the "ETSI EN 300 113" standard [31], specifically intended for Mobile or Private Mobile Radio (PMR) based on digital technology [32, 33, 27-30], sometimes called Public Access Mobile Radio (PAMR) users [27-30]. On the other, the European Telecommunications Standards Institute (ETSI) has developed the Terrestrial Trunked Radio (TETRA) [34-37] as a PMR or PAMR to give the possibility for cross-border networks in Europe [27-30]. The effort is to respond to the requirements of commercial services and emergency services, ideally suited for professional and high-performance mobile radio solutions, and offer a high level of investment protection [35-37].

The standard was created for use on channels with a frequency range of 12.5 kHz on a licensed ground mobile frequency [38]. Apart from standardizing the frequency range, it is also intended to comply with the 6.25 kiloHertz frequency range regulations of the Frequency Division Multiple Access (FDMA) [39]. This protocol provides for consumer and low-power commercial applications using a maximum of 500 mW e.r.p (effective radiated power). Digital Mobile Radio is convenient in digital systems when used for voice, data, and other additional purposes [27-30]. All products are manufactured to the DMR specification, currently sold worldwide [5, 27-30]. One of the advantages of using the DMR system is the ETSI standard as an open system standard. As a result, there is ease in integrating DMR products with different brands [27-33].

The coverage of the DMR protocol [29, 35] includes the use of unlicensed systems (such as Tier-I systems), conventional licensed systems (Tier-II systems), and trunking systems (Tier-III systems). The difference between Tier-I, Tier-II, and Tier-III [27-30] is shown in Table 1.

Based on Table 1 can be explained that the DMR was developed by the ETSI in early 2005 [27-30]. The schematic diagram of the transmit and receive process on a trunking system [30] is shown in Fig. 2.

Table 1. Difference between Tier-I, Tier-II, and Tier-III

System	Following are the features of DMR
Tier-I: unlicensed systems	It uses the 446 MegaHertz frequency band in Europe and US. This band is a license-free band.
	ETSI specification defines two-time slots in 12.5 kiloHertz channels as per TDMA structure.
	Devices transmit maximum power of 0.5 watts. It is used for low-power transmission devices.
Tier-II: Conventional licensed systems	It uses a 66 to 960 MegaHertz frequency band.
	This licensed band is used for mobile phones and conventional radio systems.
	Direct replacement for conventional analog radio.
	This mode can use the repeater to extend the radio coverage.
	This mode is used for high-power transmission devices.
Tier-III: trunking systems	It uses a 66 to 960 MegaHertz frequency band.
	It supports both voice and data transmission simultaneously.
	It operates in trunking mode.
	Supports packet data services, including IPv4 and IPv6 formats.
	Supports short messaging services.
	It extends the coverage of the radio to a wide area.
	It replaces an analog radio system with a digital trunked mode.
	Used for a variety of applications such as SCADA, remote monitoring and control, automation, etc.

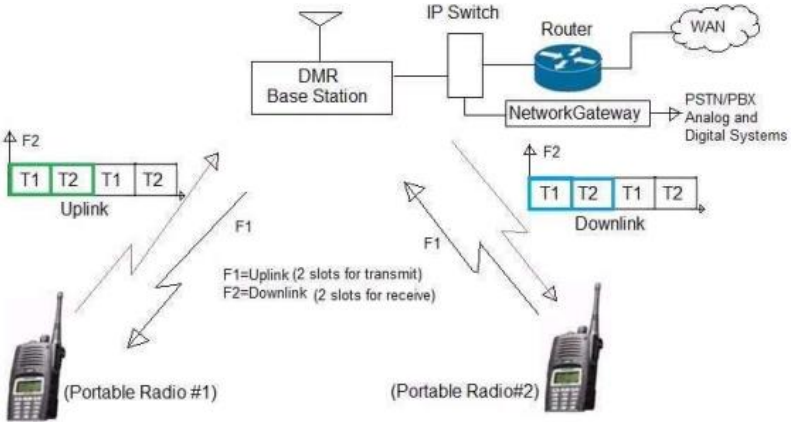

Fig. 2. The schematic diagram of the transmit and receive process on a trunking system

A radio communication system based on digital trunking type DMR Tier-III with any of the brands [30] is installed, consisting of i) mobile radio devices, ii) portable radio devices (as handy talky, HT), iii) repeater devices, iv) devices of antenna and v) device of switched-mode power supply. The technical specifications for these types of equipment have been approved by institution-owned. A schematic diagram of a radio communication system based on DMR Tier-III Trunking for independent use [30] is shown in Fig. 3.

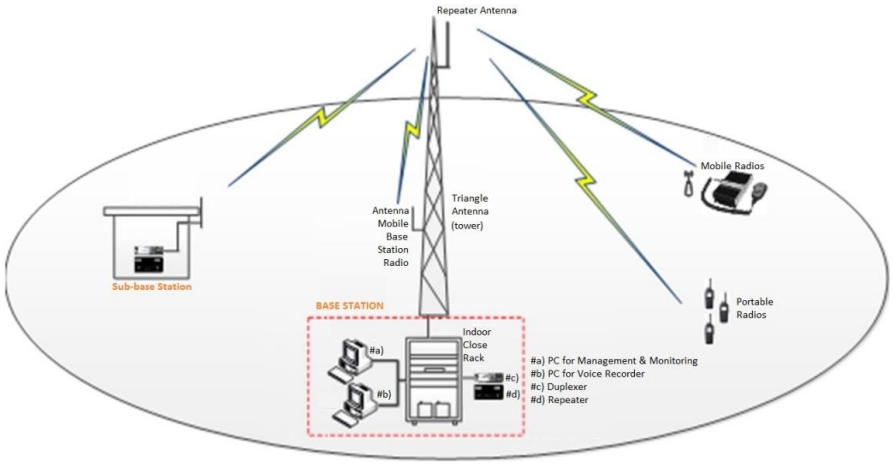

Fig. 3. A schematic diagram of a radio communication system based on DMR Tier-III Trunking for independent use

Based on Fig. 3, it is shown that the DMR Tier-III Trunking radio communication system for independent uses is a necessity. Therefore, the objectives of this simulation are to obtain the settings on the repeater-radio devices and simulation based on the Mobile Radio application. After the research objectives are obtained, it is expected that the acquisition of research contributions to research contributions are (a) for predicting the signal of area coverage of the repeater device and (b) observation results of communication performance on the DMR Tier III Trunking radio communication system.

2. METHOD

The method of research is an algorithm of a researcher for conducting the research that is carried out in the form of stages to achievement and which is guided by the research objectives [40, 16]. In other words, this research method is made in the form of a flow chart, and under steps for achieving each research objective [41, 17], some stages must be carried out sequentially the objectives [40, 41, 16, 17]. The flowchart of the research methods is shown in Fig. 4.

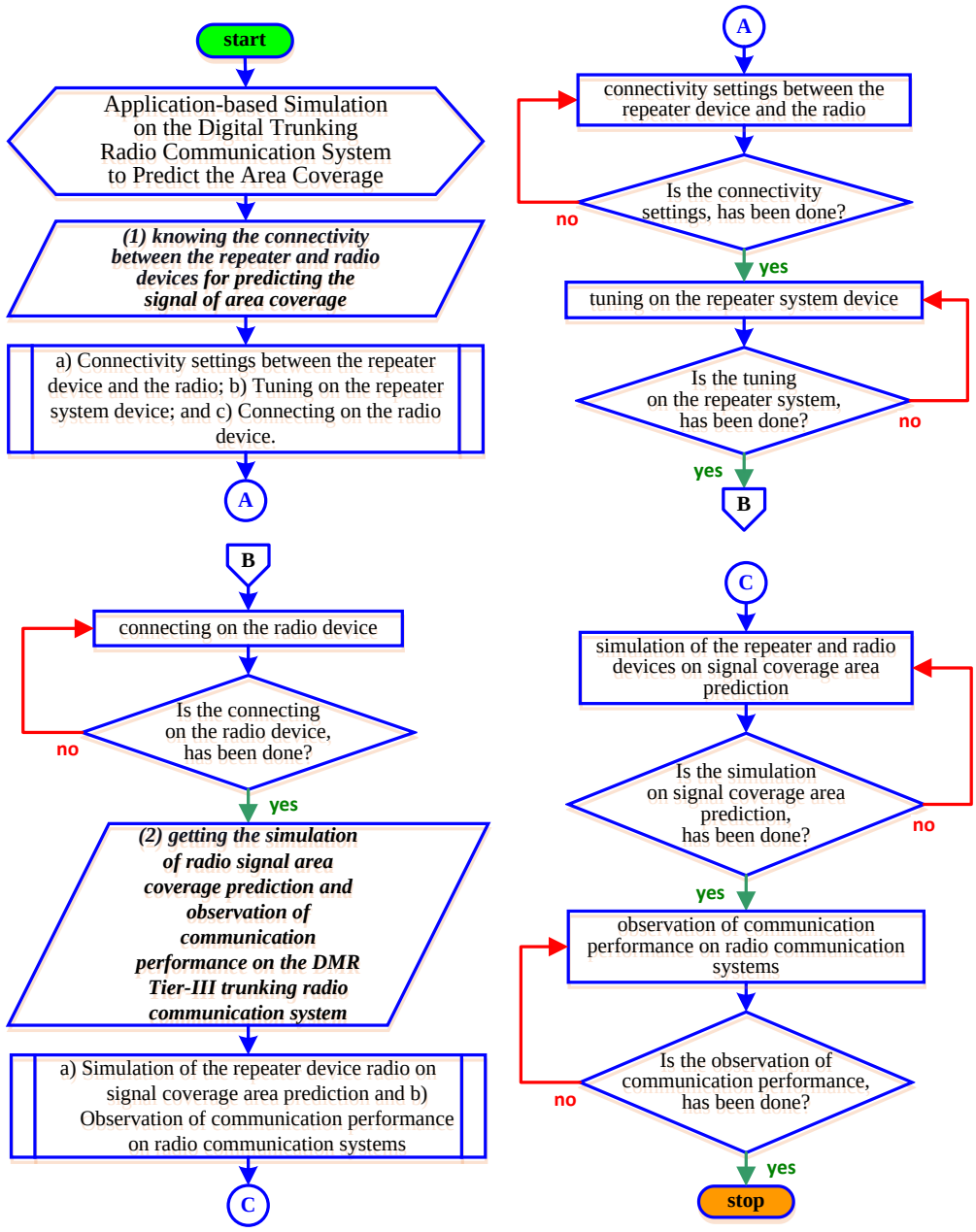

Fig. 4. The flowchart of the research methods

The RCS Tier-III of Simoco equipment installation is carried out in two stages, i.e., the first stage is carried out at the office, and the second stage is carried out at each transmitter station location [42]. For the first installation stage, the installed device is an indoor device or device that will later be installed in the room consisting of a repeater device and power supply and placed in a standard 19-inch indoor close rack with 27 U (800 mm) height. For the second stage, installation in the form of a triangle tower, pulling coaxial cables and installing a lightning protection system that awaits the readiness of the transmitter station area. The arrangement of the devices is mounted in a 19-inch indoor close rack and 27 U (800 mm) high.

The schematic diagram of a radio communication system at a repeater station is shown in Fig. 5. Based on Fig. 5, it can be shown that the schematic in the repeater system will be installed at each site repeater. The power supply is obtained from a rectifier system with an electrical power supply from the State-owned Electricity Company network with a 220-volt ac voltage system. The battery is installed and functions as a backup power supply if the power supply from the State-owned Electricity Company network goes out. The use of batteries with a voltage specification of 12 volts dc 100 Ah (Ampere hour) type maintenance-free consists of 2 pieces arranged in parallel so that the value of the voltage remains at 12 volts dc and there is a large increase in the value of the current that can be supplied. Using a capacity of 2 x 100 Ah, the battery's existence is expected to backup power from the switched-mode power supply for up to 2 hours or more.

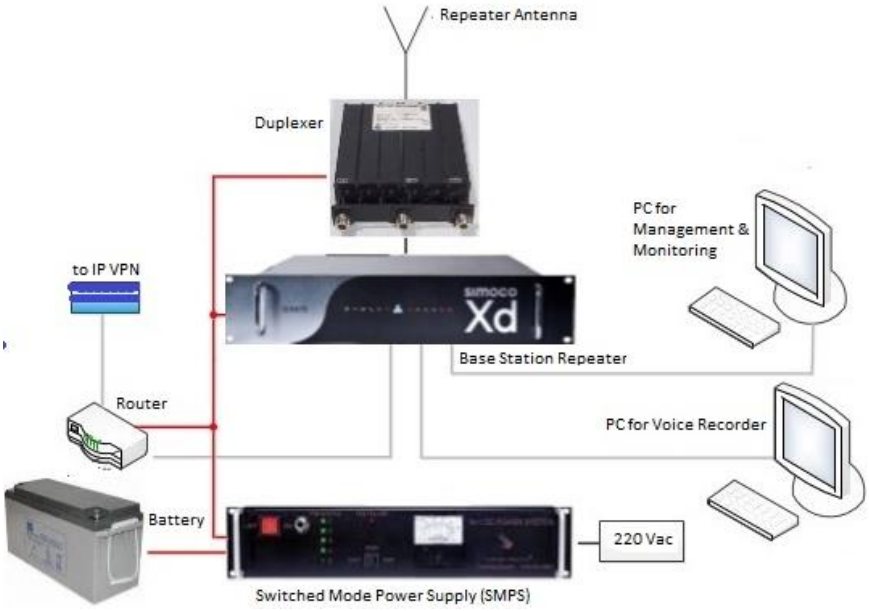

Fig. 5. The schematic diagram of a radio communication system at a repeater station

Implementing the work on the design of radio communication systems based on digital trunking for independent use is carried out. The Trunking-based Radio Communication System (RCS) on Digital Mobile Radio (DMR) [27-30], namely DMR Tier-III Trunking with the Simoco brand [42], is operated on the Ultra High Frequency (UHF) frequency band 410–430 Megahertz. According to the allocation of frequency spectrum use in Indonesia, which is included in region-3 as stipulated by the ITU [5], the system operates in full digital trunking [30]. The use of a radio communication system with full digital trunking aims to obtain a larger number of conversation groups and make conversations between groups not interfere with each other [42].

Requirements for functions and features in the design of radio communication systems design of digital trunking-based radio communication systems for communication facilities. These functions and features include [27-30, 42]:

i) The supplied equipment must be new and in good working order and comply with internationally accepted industry standard safety regulations (ITU, ETSI, Advanced Multiband Excitation/AMBE +2);
ii) The characteristics and performance of the equipment must be following the latest developments or up-to-date on articles, regulations, and recommendations of the DMR or Time Division Multiple Access (TDMA);
iii) Equipped with a certificate of tools and equipment, which is still valid;

iv) Radio communication equipment based on "Digital Technology," i.e., DMR or TDMA;
v) Connected up to HT to HT level with service areas along toll roads, including access roads;
vi) The system can be developed and configured easily according to needs (scalable and flexible);
vii) The system can be integrated with other radio communication systems in the future;
viii) Can be integrated with IP-based telephone systems;
ix) Can be monitored and configured remotely (remote);
x) Equipped with a good security system;
xi) Compatible with digital conventional (Tier II) and digital trunking (Tier-III) systems and capable of interoperability with a minimum of two different brands;
xii) Equipped with a backup power supply with the ability to supply the base station/repeater for at least twenty minutes;
xiii) Voice recording equipment and data storage media based on digital technology;
xiv) Equipped with a special telephone number (hotline);
xv) Guaranteed manufacturer/official license;
xvi) There is a letter of support from the principal/distributor;
xvii) Availability of spare parts and after-sales service in Indonesia;
xviii) Equipped with a Radio Station License or a frequency use permit from the Authority;
xix) Spaces for work up to training and maintenance within the warranty period; and
xx) Has minimal features: (a) There is displayed caller ID, (b) Can be made calls "person to person" and/or "person to group" (private call), (c) Can be made a call into a group (group call), (d) Can be sent a signal, or a distress call (mayday) can be made if the radio user is in an emergency by only pressing 1 (one) button that has been previously set (emergency call), (e) Can be checked discreetly, whether the intended radio is usually contacted or not (radio check), (f) Can be activated and deactivated certain radios (radio disabled/enabled), (g) Can be sent position coordinates in real-time (Global Positioning Satellite, GPS enabled), (h) Can take over the channel with the intersection of the ongoing conversation (transmit interrupted), and (i) Can be recorded radioactivity (radio log).

3. RESULTS AND DISCUSSION

3.1. Settings on the Repeater and Radio Devices

The application display for setting up the repeater system device with the System Digital Management Terminal (SDMT) application. Settings on the repeater and radio devices include (i) connectivity settings between the repeater device and the radio, (ii) tuning on the repeater system device, and (iii) tuning on the radio. The Simoco's repeater system (SDB680 type), the Simoco's mobile radio (SDM630 type), and the Simoco's portable radio (SDP660 type) require settings with some software. For example, tuning for the repeater device requires the SDMT application and the IP Network Configuration Tool (IP Config Tool). In contrast, the Field Personality Programmer (FPP) application is required for radio devices, whether mobile or portable.

1) Connectivity settings between the repeater device and the radio

The existence of connectivity between the repeater device and the radio requires adjustment of five main parameters, namely i) transmitter (Tx) and receiver (Rx) frequencies, ii) user ID, iii) IP address for each site, iv) channel trunking mode, and v) talk group ID. For the SDB680 repeater system device configuration, version 4.1.0.0 of the SDMT application is required, and the Simoco IP Config Tool version 2.3.0 application. The SDMT application functions as a whole repeater system setting in one Virtual Access Control (VAC) is used to change the Internet Protocol (IP) Address of the Simoco SDB680XD device if an IP Address. Therefore, it is different from the default IP Address of the device during the Simoco IP config tool application. In addition, the SDMT application contains several parameters that must be set so that the repeater system can operate optimally.

2) Tuning on the repeater system device

Several parameters must be entered into the Simoco SDB680XD repeater system with the help of the SDMT application, namely a) Tx and Rx frequencies, b) talk group ID, c) user ID, d) power on the Simoco SDB680XD repeater, and e) sys code.

(a) Tx and Rx frequencies

The frequency value at the Ultra High Frequency (UHF) level with a frequency bandwidth of 410–430 Mhz., This frequency is commonly referred to as the carrier frequency used in repeater systems for duplex

mode. Then, it means that the transmitter and receiver frequencies are different. Generally, between the transmitter and receiver frequencies, there is a difference of 5-10 Megahertz. Then, there is no interference. The frequency that has been tuned is assigned a channel ID so that radio devices can recognize it.

(b) Talkgrup ID

Talk-up ID can be analogized to a highway, where the function of talk group ID is to form a talk channel so that every radio device on the same talk group ID can communicate with each other. Talk-up ID is unique, such as a user ID, so that in a repeater system, more than one talk-up ID can be created. Between one talk group ID and another, it is not interfered with when used simultaneously [by Simoco].

(c) User ID

User ID is installed on mobile and portable radio devices and must be registered into the repeater system database system. User ID is unique. Each mobile and portable radio device with a different user ID. User ID functions can help the repeater system recognize the ID of each radio device registered at a repeater site. In addition, the repeater system can serve requests from every radio device that already has a user ID and is registered in the repeater system [by Simoco].

(d) Power on the Simoco SDB680XD repeater

Repeater system power in watts. The maximum repeater system power used in the system is 50 watts. The greater the power used, the other the repeater system service area will be. The repeater system power settings should be considered by the end-user device used. Then, it is for efficiency in using the power supply and safeguards so that the repeater system is more durable in operation.

(e) Syscode

Syscode is a code in hexadecimal numbers used by mobile and portable radio devices to detect the presence of repeaters. The sys code setting on the repeater must be the same as the sys code setting on mobile and portable radio devices. Changing the IP Address on the repeater device can be done by changing the DMR Tier III Settings display. Then, it is done to confirm the Simoco SDB680XD repeater device's IP address and change it as desired. For the SDB680 repeater system device configuration, version 4.1.0.0 of the System Digital Management Terminal (SDMT) application is required, and the Simoco IP Config Tool version 2.3.0 application. The SDMT application functions as a whole repeater system setting in one Virtual Access Control (VAC) is used to change the Internet Protocol (IP) Address of the Simoco SDB680XD device while the Simoco IP config tool application. If an IP Address is different from the default IP Address of the device. The SDMT application contains several parameters that must be set so that the repeater system can operate optimally. An example of the process of changing the IP address of the Simoco SDB680XD repeater device is shown in Fig. 6. Based on Fig. 6, it can be detailed that the Simoco IP Config Tool application is used when the Simoco SDB680XD device is set for the first time.

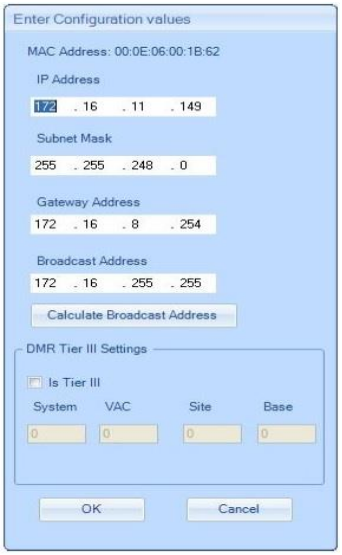

Fig. 6. An example of the process of changing the IP address of the Simoco SDB680XD repeater device

3) Connecting to the radio device

For tuning both mobile and portable radio devices, version 1.10.66 of the Field Personality Programmer (FPP), the application is required. The important thing that must be considered when setting up mobile and portable radio devices for the first time is to ascertain the location of the repeaters of the mobile and portable radios that will be operated later. When tuning mobile and portable radios, several parameters must match between repeaters, mobile radios, and portable radios. Adjustment of four parameters, namely, i) Tx and Rx frequencies, ii) use of sys code, iii) talk up ID, and iv) radio ID. For tuning both mobile and portable radio devices, version 1.10.66 of the Field Personality Programmer (FPP), the application is required. The important thing that must be considered when setting up mobile and portable radio devices for the first time is to ascertain the location of the repeaters of the mobile and portable radios that will be operated later.

(a) Tx and Rx frequencies

It has been explained that the model used is a duplex, which means that the frequency set on the radio device is the opposite of the frequency set in the repeater device. The transmit frequency from the radio device is the receive frequency from the repeater device. The receive frequency from the radio device is the transmit frequency from the repeater device.

(b) Use of sys code

It has been explained that the sys code is a hexadecimal code that must be the same between the repeater device and the radio device. Therefore, the Syscode which has been set on the repeater device is inserted into the radio device.

(c) Talkgroup ID

Talkgroup ID is a channel or channel for communication in one repeater device, and radio equipment can consist of several talk groups to run the trunking principle. Telkgroup is a decimal value formed from several unique digit numbers and is commonly known as talk-up ID [16]. Each radio device can be set with one or more talk group IDs according to the desired communication concept and the end-users needs.

(d) Radio ID

A talk group ID, radio ID, or user ID is a decimal value with a unique number of digits. There is no user ID with the same number on one repeater system. User ID on digital radio is generally made with a combination of a special code, where the repeater and radio devices are used, usually based on the radio device's location, site number, and ID number. Examples of using radio ID are i) User ID 31701 and ii) This User ID can be explained:

X-XX-XX = 3-17-01
3 = is the repeater system number
17 = repeater site number
01 = User ID.

3.2. Simulation for the Coverage Prediction on Mobile Radio Applications and Observation of Communication Performance

In this subsection, two results are described, namely, the simulation of radio signal coverage area prediction for repeater devices based on mobile radio applications and the result of observation of communication performance in radio communication systems.

1) Simulation of the repeater and radio devices on signal coverage area prediction

The existence of Mobile Radio application can be downloaded for free from the Internet. For the use of the Radio Mobile application, there are several parameters as input, namely:

a) Type of area for radio system operation;
b) The type and specifications of the antenna used;
c) Loss arising from the presence of cables and cable connector connections;
d) Coordinate for the installation of a transmitter station or placement of a repeater, longitude, and latitude;
e) The height of the transmitting station or repeater antenna in meters;
f) Radio receiver sensitivity in dB; and
g) Power used in repeaters and radio receivers in watts.

The display of setting some parameters for determining the predicted radio signal coverage area of the repeater device based on the Radio Mobile application is shown in Fig. 7. Based on Fig. 7, it can be explained that the Mobile Radio application is used to simulate the prediction of the radio signal coverage area of the repeater device through the determination of several parameters. The simulation result is in the form of a screenshot on a personal computer monitor screen.

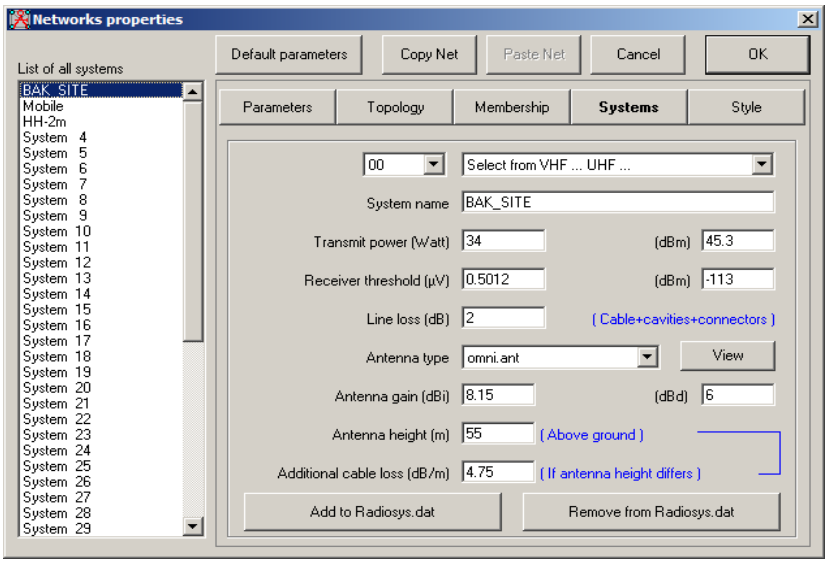

Fig. 7. The display of setting some parameters for determining the predicted radio signal coverage area of the repeater device based on the radio mobile application

2) Observation of communication performance on radio communication systems

After configuring the Simoco SDB680XD repeater device, the Simoco SDM630 mobile radio, and the Simoco SDP660 portable radio with the parameters determined, the communication performance measurement is carried out. The results of the observation of communication performance using the dummy loads in the form of providing types of artificial condition calls are shown in Table 2.

Table 2. The results of the observation of communication performance using the dummy load

No.	Types of Calls	From	To	Observation Results
1	Group Calls 1	Mobile Radio SDM630	Portable Radio SDP660	Connection is good
	Group Calls 2	Portable Radio SDP660	Mobile Radio SDM630	Connection is good
2	Individual Calls	User ID 31701	User ID 31703	Connection is good
3	Emergency Calls	Mobile Radio SDM630	All Radio	Connection is good
		Portable Radio SDP660	All Radio	Connection is good

An example of a display of the simulation results of the prediction coverage area of the radio signal coverage of the repeater equipment for the specific area along 140.938 kilometers is shown in Fig. 8.

4. CONCLUSION

Based on the results and discussions, conclusions were drawn according to each research objective. The tuning and connection settings include (i) tuning the repeater and radio equipment is required three condition settings, (ii) the connection settings between the repeater and radio equipment are carried out on five main parameters, and (iii) tuning on the repeater system equipment is carried out on five main parameters, while on the radio equipment is carried out on four main lines. Observation of the repeater system device predicts radio signal coverage area based on the Mobile Radio application and seven parameters as input. The results of the observation simulation on the prediction of the radio signal coverage area of the repeater system device are in the form of screenshots with the example of the specific area along 140.938 kilometers. The observation of communication performance on the radio communication system through dummy loads in the form of providing types of artificial condition calls so that research contributions can be obtained. In general, it is expected that the system is well connected and performed. Completing conclusion, recommendations for future work related to the measurement of the various purposes and the real conditions to predict the area coverage of the digital trunking radio communication system can be implemented.

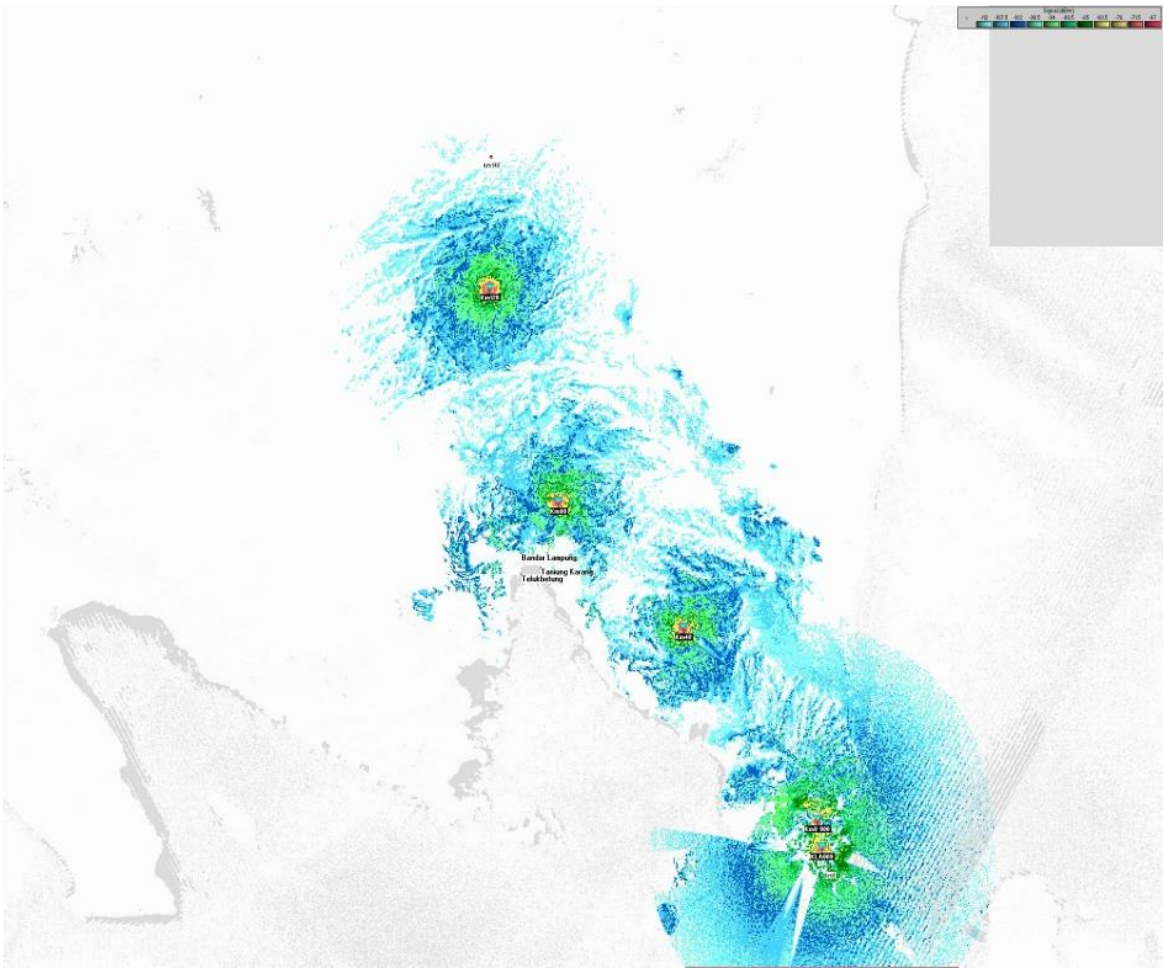

Fig. 8. An example of a display of the simulation results of the prediction coverage area of the radio signal coverage of the repeater equipment for the specific area along 140.938 kilometers

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