CHAPTER I

INTRODUCTION

1.1 Background

Regulations are made in managing certain matters, in order to control a process and system to towards the expected resul. The existence of technical regulations is a guide for related parties, like regulator, manufacturers, technical consultants, distributors, applicator, and user in distributing and implementing the products. Updating to the technical regulations must always be considered and carried out as long as there are recent developments related to technology and service features. Technical proposals based on literature research and experiments are important to be accommodated in order to create a safe and comfortable situation of implementing technology and services for all parties concerned.

IEEE sets a new standard in the development of wireless local area network (WLAN) technology. The standard is labeled with 802.11ax or high efficiency (HE). By the Wi-Fi Alliance, it is called Wi-Fi 6. One of the advantages of Wi-Fi 6 compared to previous standards is the implementation of 1024-QAM modulation and the orthogonal frequency division multiple access (OFDMA) method so that it is able to produce high throughput and serve multi-user multiple input multiple output (MU-MIMO) both in downlink and uplink. This Wi-Fi 6 standard works on the 1 GHz to 6 GHz spectrum.

The application of high-order modulation up to 1024-QAM on Wi-Fi 6, demands good signal modulation accuracy in order to maintain the quality of data received by users. Error vector magnitude (EVM) is an important parameter and feature in measuring the transmit signal quality of wireless digital communications. Through the measurement of the EVM parameters, it can be determined how many decibels the error rate that occurs in the receiving device are. It is also known that the impact of phase noise and gain imbalance on the system of transmitting devices will also be known.

The current measuring instrument for wireless devices, namely the WLAN tester which can simultaneously act as a traffic generator and spectrum analyzer, has been equipped with the EVM measurement feature. Through a wired connection of a WLAN tester device with an access point (AP) and a remote PC, the results of measurements and observations can be carried out properly and completely. Data processing has been carried out using software

that is embedded and enabled in the WLAN tester. This is an opportunity to simplify the functions and testing procedures of AP devices which in the future will be further enhanced by the application of a higher modulation order than the current 1024-QAM.

Regulation of the Director General of Resources and Equipment of Post and Information Technology no. 5 of 2019 concerning Technical Requirements for Cellular Mobile Telecommunication Equipment and/or Devices has included the EVM test parameter as a measure of transmitter signal quality, which is a transmitter requirement for a 450 MHz long term evolution (LTE) subscriber station [1]. In contrast to the Regulation of the Director General of Resources and Equipment of Post and Information Technology No. 2 of 2019 Regarding Technical Requirements for Wireless Local Area Network Telecommunication Equipment and/or Devices, the EVM conformity requirements have not been stated at all on outdoor and indoor WLAN telecommunication equipment and/or devices [2], but keep applying the standard bit error rate (BER) parameter measurement as a parameter of transmit signal quality test. Because EVM parameters can be converted to produce BER parameter values, it is considered important to include these EVM parameters as technical requirements that need to be met by AP devices.

Daan Weller et al. specifically tested the performance of 1024-QAM modulation technology and OFDMA downlink technology features on Wi-Fi 6 communication systems from 2 different AP manufacturers. These two new technology features are compared to the 256-QAM modulation standard of the previous Wi-Fi 5, and are proven to provide a throughput increase of up to 25% over the previous modulation. The allowable throughput is in accordance with the maximum standard error of the EVM provisions on Wi-Fi 6, where the distance simulation is carried out using the attenuator setting. The simulation was carried out in an anechoic chamber at a bandwidth of 20 MHz using a single spatial stream. The accepted standard EVM value is adjusted to a setting of less than -35 dB for Wi-Fi 6 to maintain throughput up to 70.6 Mbps [3].

Mansoor Dashti Ardakani et al. perform EVM and BER analysis in the 57 GHz – 64 GHz V-band spectra, as an alternative band for the 5G communication backbone capable of achieving high transmission rates with close range. EVM analysis was performed on BPSK, QPSK, 8-PSK, 16-QAM, and 32-QAM modulations. The BER value is obtained through the conversion formula from the EVM measurement results. His research confirms that the EVM conversion to get the BER value is valid and can be carried out for the case of mm-wave channels that apply/limited additive white gaussian noise (AWGN) [4]. EVM calculations are carried out directly using a vector signal analyzer with an EVM percentage accuracy of

up to 13%, and are able to show the quality of the observed wireless communication network reliably and practically.

Huan Li and Wenhua Ye carried out direct measurements of EVM parameters using a vector signal analyzer (VSA). The signal demodulated by VSA is measured by the root mean square EVM value and then the results of the conversion are analyzed into BER [5]. Measurements were made on BPSK, 4-QAM, 16-QAM, and 64-QAM modulations. EVM is considered as the most likely key parameter in describing the closest prediction of the ideal I/Q constellation with the demodulated signal captured by the receiving device. In other words, the EVM_{RMS} quantity is the residual noise and distortion that is still present when compared to the ideal modulated signal. The measurement results show the BER value on a scale of 10^{-6} for the EVM_{RMS} value of -11 dB for BPSK, -13 dB for 4-QAM, -21 dB for 16-QAM, and -27 dB for 64-QAM.

The need for high throughput and involving massive devices and/or devices in a single service range, is met by the application of 1024-QAM or higher order modulation techniques. This encourages the importance of including EVM parameters, as a measure of whether or not the modulation performance of the radiated signal from a telecommunication equipment and/or devices is good. As an accredited test center, the Telkom Test House needs to formulate testing procedures for each WLAN telecommunication equipment and/or devices to be used in Indonesia. Moreover, the current development of WLAN connectivity measuring tools has provided a measurement module for EVM parameters so that it is good for use in testing the technical requirements of each WLAN tool and device that will be marketed in Indonesia.

1.2 Problem Definition

The formulation of the problems observed in this study are:

1. Perdirjen SDPPI Kemenkominfo No. 2 Tahun 2019, concerning about Technical Requirements for WLAN Telecommunication Equipment and/or Devices is not including EVM as a technical parameter, but BER. Meanwhile, the EVM parameter is actually very relevant to the use of 1024-QAM modulation on WiFi 6 and has become a technical requirement for cellular communication base station devices for WCDMA/UMTS and subscriber station devices on 450 MHz LTE technology.

2. Several previous studies have produced a BER of 10^{-6} as an excellent threshold for good signal reception quality, however Perdirjen SDPPI No. 2 of 2019 requires a BER of 10^{-8} as a condition.

1.3 Research Objectives

There will be some analysis will be conducted through the research:

1. It is important to include the EVM parameter as a technical requirement on the transmitter side of the test which is in line with the BER parameter on the receiver side of the test. This is especially true for high-level M-QAM modulation that reaches 1024-QAM on Wi-Fi 6.
2. Determination of BER 10^{-7} as a new provision for the technical requirements of WLAN telecommunication equipment and/or devices that meet the application in Indonesia.

1.4 Scope of Work

Assumptions and problem limitations to support this research are as follows:

1. The type of test carried out is a transmission test for indoor devices. EVM is part of the transmit quality test for the transmitter modulation criteria. The measurement will take the RMS value obtained from the single stream transmission of the AP device to the WLAN tester, which is directly calculated by the software on the measuring instrument.
2. BER is a parameter of the reception function (receiver test) which is voluntary. The BER value will be estimated through the conversion results using a formula from the latest research.
3. Measurements were made on the 802.11ax standard, with several modulation and coding rate schemes (MCS) that support communication with aircraft using previous technologies.
4. Comparisons were made on 2 AP devices of different manufacturers.
5. The EVM calculation is carried out by the WLAN connectivity test set, Anritsu MT8862A, which also functions as a signal generator and spectrum analyzer.

1.5 Hypothesis

EVM is an appropriate test parameter used in measuring the quality of modulation performance on AP devices of WLAN wireless communication systems. The RMS value of the EVM is able to show the percentage deviation between the ideal signal and the signal received by the destination device. In Wi-Fi 6 deployments that use 1024-QM modulation, a good device is one with an error rate of less than 1.8% (or less than -35 dB) on MCS 10 and MCS 11. The higher the modulation level used, the the requirements of the EVM will also be

smaller in order to avoid errors as the space between the constellations of modulated symbols is getting narrower. The ideal BER threshold is achieved with the provision that the EVM decibel is a maximum at the 10^{-6} level, or one single error for every one million bits transmitted.

Through the stages of measuring the EVM value and then comparing it in terms of bandwidth, MCS, and between manufacturers, it is possible to evaluate the range and validity of EVM from AP devices for the application of wireless technology according to the latest data communication needs. It can be a proposed standard procedure by the equipment test center in measuring the technical requirements of WLAN wireless equipment and/or devices.

1.6 Methodology

1. Preparation stage. Theoretical understanding is carried out through literature study of the IEEE 802.11ax standard. The literature studied comes from journal papers, articles, datasheets, as well as video learning media.

2. Measurement of EVM. The transmission test carried out is to test the modulation quality of the transmitted signal. Measurements were carried out in 3 scenarios, namely through comparison of bandwidth, modulation scheme and choice of coding rate, as well as comparing 2 AP devices from different vendors. The final or fourth scenario that is carried out is to carry out a sampling test from the obtained EVM value, to be converted into a BER value as an illustration of the level of error that may occur on the receiving device side with the assumption that the noise model used in the transmission line is AWGN. c

3. The measured EVM value will be compared with the IEEE reference standard. If the value is equal to or less than the reference, the measurement is categorized as successful. If it is more than the reference, it will be re-measured.

4. Displays the measurement table and the graphs associated with it, and then analyzes it to find out the trend it has. The analysis is also elaborated in determining the possible error cause of the radiated signal modulation, based on the resulting constellation graph.

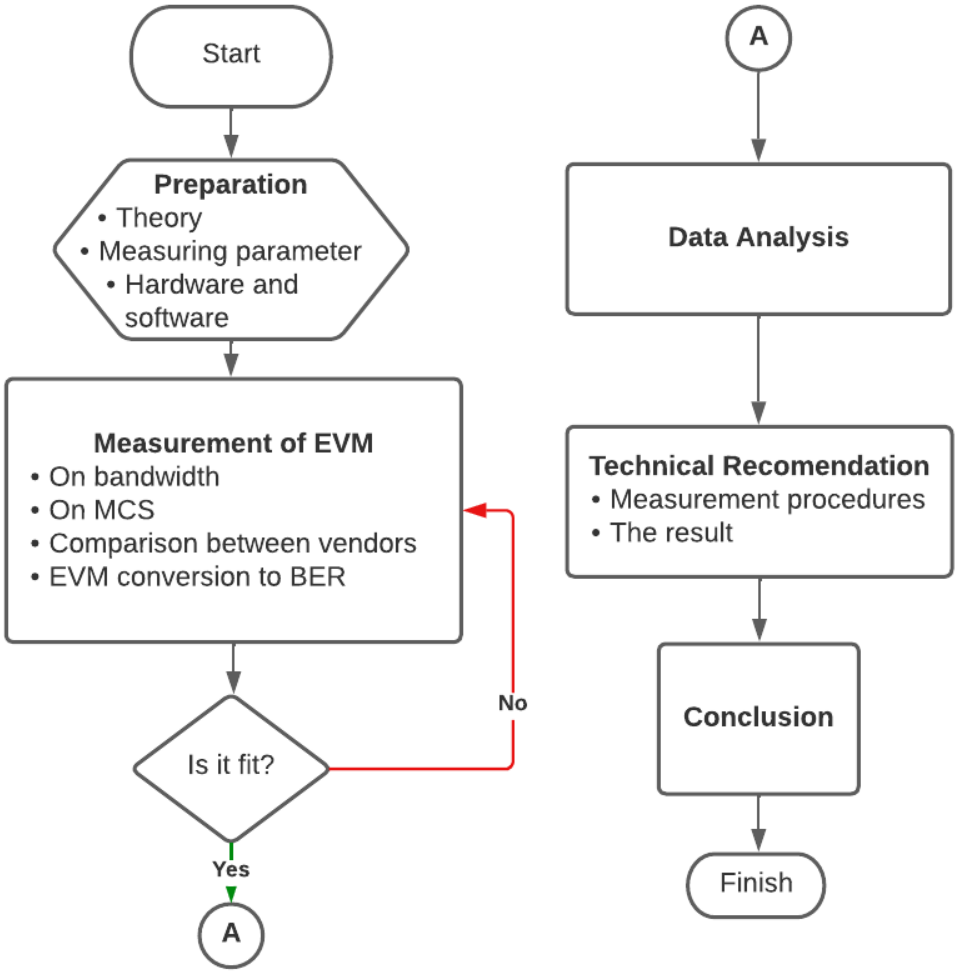

Figure 1.1 Research Methodology

5. Technical recommendations. The measurement steps, which are compiled from several references, will be standardized as standard operating procedures to be submitted as research contributions. Also the results of the EVM measurement and BER conversion will be the proposed value to be considered for the perdirjen regarding the technical requirements of WLAN equipment and/or equipment.

6. Conclusions drawing. The formulation of conclusions is the final stage of the research conducted. In addition to summarizing all the results of the measurements carried out in line with the identification of the problem and the purpose of the research, a message was also conveyed regarding further research that could be continued.

1.7 Research Method

The research methods taken are through:

1. Literatures study. The literatures studied are all scientific sources related to wireless local area network (WLAN), especially the IEEE 802.11ax standard or better known as Wi-Fi 6. The literature can come from articles, posters, journal papers, textbooks, or magazines. The selected literature is also supported through information obtained from learning videos and web seminars.

2. Laboratory measurements. Measurements were made at the Transmission Laboratory, Telkom Test House, which is located in the Telkom Geger Kalong office area, Bandung. Measurements were made using a WLAN tester equipped with the latest series software capable of reading 1024-QAM modulation, and an access point that supports the Wi-Fi 6 service standard.

3. Question and answer discussion with policy makers. Related parties include regulators (Directorate General of SDPPI, Ministry of Communication and Information), manufacturers of access point equipment, and telkom standard testing institutions (STEL). Discussions were held to obtain a complete picture of the regulation of WLAN technical requirements and their development needs.