

Development of Measuring Instrument to Measure and Visualize the Antenna Radiation Patterns as the Teaching Aids for Antenna and Propagation Engineering Practices in Laboratory

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ABSTRACT

The performance of antenna radiation pattern measurement conducted manually possesses some drawbacks and limitations: inefficient, inaccurate, slow process, and expensive. This leads to limit the topics and material in practical work in the laboratory since one cycle of measurement which takes a long time to complete. To overcome this problem, a microcontroller is utilized as the main part of the automatic antenna pattern measurement. Along with other supporting components and devices, the microcontroller can be programmed to set and control the direction and step of the rotator, convert electromagnetic wave signal received by the antenna into DC signal, and send it to PC to be processed by another program to be plotted and displayed as a graph on the monitor. The result of the research shows the efficiency, accuracy, and fast measurement process. Consequently, it will expand and enrich the topics of practical subjects in the laboratory.

Keywords: Antenna radiation pattern, automatic measurement, microcontroller, transceiver radio. E-plane, H-plane.

1. INTRODUCTION

Antenna radiation pattern is one of the most important properties of an antenna; therefore, the understanding of this parameter is a must by telecommunications students. The radiation pattern is three-dimensional. However, for the practical purposes, it is usually measured and plotted in two-dimensional, namely principal planes. The principal planes consist of E-plane (elevation plane) and H-plane (azimuth plane), and the two are orthogonal to one another.

The existing measurement system of the antenna radiation pattern at Telecommunication Laboratory Electrical Department, Bandung State Polytechnic, is still manually performed. This is due to the high cost of commercial equipment to carry out automatic measurements' device.

Manual measurements are slow and give inaccurate results. In the measuring operation, the antenna is rotated circularly step by step to respond all electromagnetic waves surrounding the antenna. The

required steps are as small as possible; but manually, the resolution is typically only 10 degrees. Consequently, there may be missing values of data in between that step, especially when the pattern has a lot of side-lobes. Moreover, the power readings received at the device are often inconsistent, so it is necessary to read several times and calculate the average value [1].

When the measurement is finished and all the data has been recorded, the data is plotted using a spreadsheet. This manual technique requires a long time to complete one cycle of measurement. We need to measure many kinds of antenna radiation patterns and in various antenna positions as well. Besides that, it is also necessary to measure the antenna influenced by various environmental conditions such as the presence of objects in the vicinity.

Another constraint of the antenna radiation pattern measured manually is the high cost of equipment required. The measurement system consists of a generator signal in the transmitter part, a spectrum analyzer, and a rotator in the receiver part. All

equipment is quite large and is not compact. To overcome these problems, a device for measuring radiation patterns and polarization is designed to work automatically.

There are several applications for measuring and visualizing antenna radiation patterns with automated techniques such as [2][3][4][5][6][7]. These studies were carried out by using various methods and applications to produce an effective and efficient measurement system in terms of cost and measurement time. These studies take advantage of the availability of modular sub-systems that are available in the market at relatively low prices. However, some studies still use commercial devices as sub-systems such as network analyzers to transmit and receive data [4] [5] [6]. In [7], the transmitting system uses a signal generator, and the receiving system uses a separate spectrum analyzer. On the other hand, the implementation of practice in the laboratory requires several devices to be used by several groups of students in parallel.

In this study, a radiation pattern and polarization measurement system were designed by using a microcontroller, a package of radio transmitter and receiver modules, motor driver, and other complementary components. These devices are available in the market at relatively low prices. The initial design of this device has been carried out [8]. Although this measurement system works in a narrow frequency range, this system device only requires a low cost to be mass-produced to carry out laboratory practice.

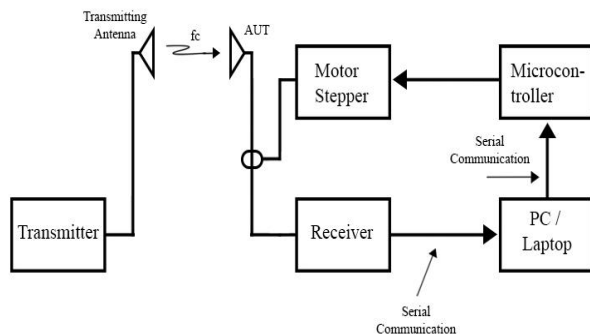


Figure 1 System block diagram

2. SYSTEM DESCRIPTION

The block diagram of the overall system is seen in Figure 1. This measurement system consists of two parts: a data processing system with a computer and a data processing system with a microcontroller. The two systems communicate via serial communication. The computer gives instructions to the microcontroller to run the antenna drive actuator.

The data processing system uses VB .NET language software. This subsystem consists of three program

bodies. First, there is receiving and processing power level data program. This program acts as a liaison between the computer and the radio receiver. Second, there is the antenna radiation pattern visualization program which function is to process all power level data received by the computer into a polar graph. Third, there is a program for communication with the microcontroller to drive the actuator.

The microcontroller system consists of two program bodies. First, the communication program with the PC acts as a liaison between the microcontroller and the PC. Second, the actuator control program functions as a command to drive a stepper motor that is not directly connected to the microcontroller but has a driver in between.

The transmitter and receiver radio are the 3DR (SiK Telemetry Radio) transceiver radio package that works at the center frequency of 433 MHz or 915 MHz [9][10]. Radio transmitter has the function to provide RF waves. The antenna used in the radio transmitter is an omnidirectional antenna or dipole antenna.

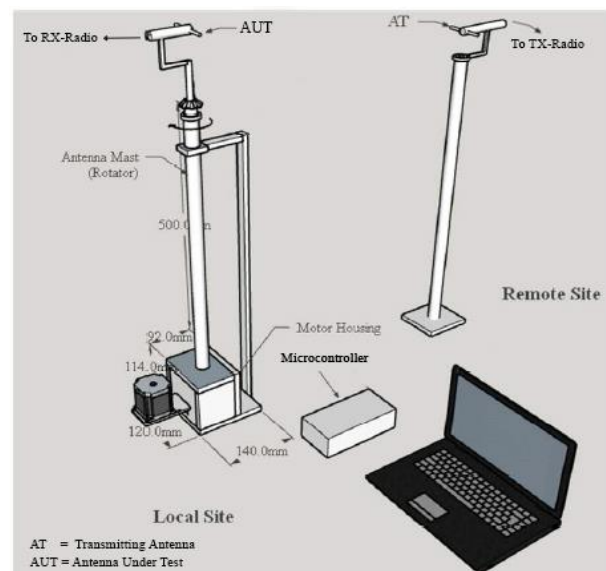


Figure 2 System construction

The radio receiver catches the RF waves through the antenna under test and converts the waves into an RSSI signal (received signal strength indicator). The radio receiver is connected to the PC via serial communication. The application on the PC will give a command to take the input data in the form of RSSI from the 3DR radio receiver. The data is then converted into dBm units and immediately displayed in the application. The application will control the rotation of the motor to drive the stepper motor step by step after successfully receiving the data. The stepper motor program drives the motor rotation every 7.2 degrees or 3.6 degrees. The stepper motor used is NEMA 17 [11].

In addition to being able to be driven continuously in one full rotation for the measurement of radiation patterns, this motor can also be driven step by step or directed in the desired direction. The sampling of radiation pattern data is carried out starting from 0 degrees to 356.4 (or 352.8) degrees with 3.6 (7.2) degrees resolution. The amount of power received by the antenna under test for each position is stored by the application. After all data has been completed, this data is immediately displayed and plotted on the PC screen. In general, the development of this device consists of 3 stages: physical design and manufacturing, motor controller design and realization, and software design and realization.

2.1. Physical design and fabrication

Figure 2 shows the physical construction of the radiation pattern measuring device. The motor stepper is attached to the rotating shaft.

2.2. Motor Controller Design and Realization

This section consists of the following steps: determining the wiring stepper motor, mechanical rotator design, motor control design with microcontroller, design of the angle of rotation of the stepper motor or step, establishing a connection between VB and microcontroller, and realization of motor control VIA (Visual Basic Application).

2.3. Software Realization

The realization of the software is the creation of application software for automatic sampling of antenna radiation pattern measurement data acquisition. Data acquisition software for antenna radiation pattern measurements was programmed by using the Visual Basic 6.0 application. The software consists of the following programs: receive signal strength indicator (RSSI) data retrieval program, stepper motor rotation program, and graph plot program for antenna radiation patterns. These programs consist of several programming sections as follows: Serial Communication Program, Power Level Data Collection Program, Motor Drive and Counter Program, and Interfacing Visual Basic 6.0 with Microsoft Office Excel.

3. RESULT AND DISCUSSION

3.1. Measurement of Dipole Antenna Radiation

Pattern

The measurement of the antenna radiation pattern is carried out in the principal plane: E-plane and H-plane. In measuring the dipole antenna radiation pattern in the

E-plane, the measured antenna (half-wavelength dipole) and the transmitting antenna are parallel to the ground.

The measurement results that appear on the monitor screen are the measured power level and the plot of the power level. Figure 3 is the measured power level data. Figure 4 is a polar plot which is the antenna radiation pattern in the E-plane. The step used in this measurement is 7.2 °.

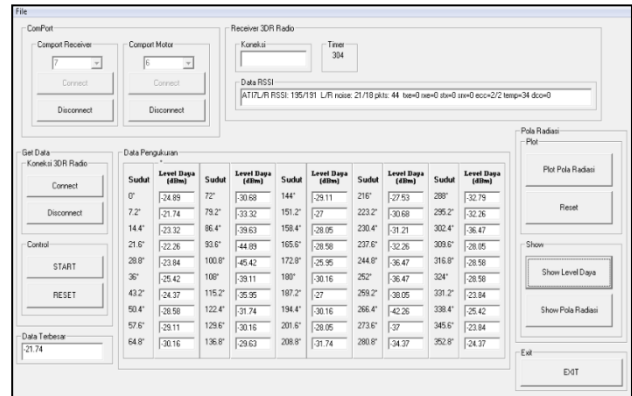


Figure 3 Display of measurement results of the dipole radiation pattern in the elevation plane

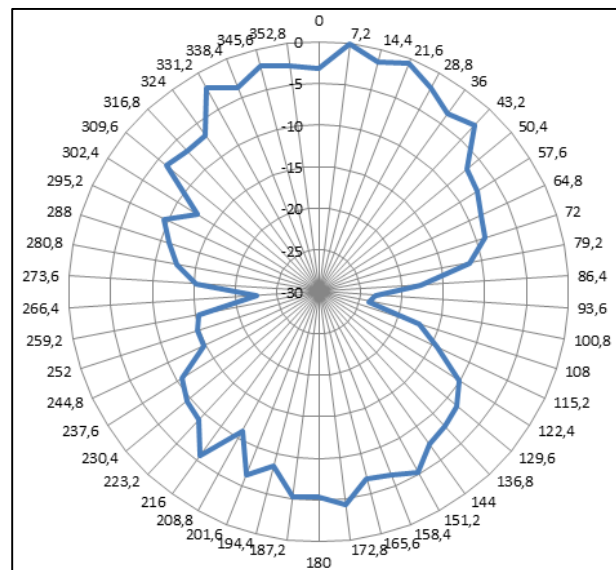


Figure 4 Dipole antenna radiation pattern plot on elevation plane

In measuring the dipole antenna radiation pattern in the H-plane, the measured antenna (half-wavelength dipole) and the transmitting antenna are perpendicular to the ground.

The measurement results that appear on the monitor screen are the measured power level and the plot of the power level. Figure 5 is the measured power level data. Figure 6 is a polar plot which is the antenna radiation pattern in the E-plane. The step used in this measurement is 7.2 °.

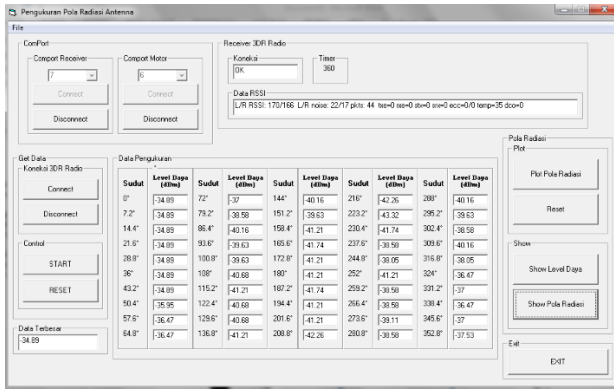


Figure 5 Display of measurement results of the dipole radiation pattern in the azimuth plane

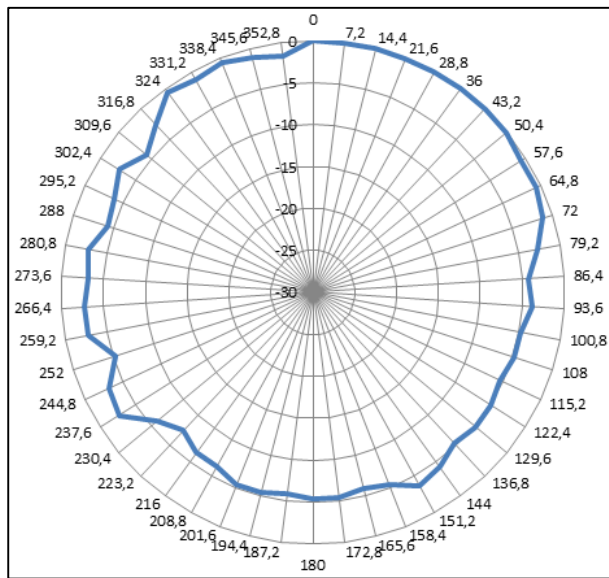


Figure 6 Dipole antenna radiation pattern plot on azimuth plane

The figure of eight and the circle shapes shown in Figure 3 and Figure 5 agrees with the radiation pattern of the half-wave dipole. These figures correspond to the formula of [12]

$$F(\theta, \phi) = \frac{\cos\left(\frac{\pi}{2} \cos \theta\right)}{\sin \theta}$$

$$0 \leq \theta \leq \pi, 0 \leq \phi \leq 2\pi$$

where $F(\theta, \phi)$ is the element pattern of the half-wavelength dipole and in this formula, the dipole element lies parallel on the z-axis. Here, the E-plane can be the x-z plane or y-z plane and the H-plane is the x-y plane.

3.2. Measurement of Yagi Antenna Radiation Pattern

As in the measurement of the radiation pattern of a dipole antenna in the E-plane, the measured antenna (Yagi) and the transmitting antenna (dipole) are parallel to the ground.

Based on the measurement data shown in Figure 7, the radiation pattern plot of the Yagi antenna is displayed as shown in Figure 8 for the elevation plane and Figure 8 for the azimuth plane. From the figures, the shape of the radiation pattern is under the theory, namely unidirectional. Since Yagi antenna has a relatively high gain, they have side lobes and back lobe. For the existence of minor lobes, a smoother resolution of 3.6 degrees is used. The plot of the radiation pattern on the azimuth plane is shown in Figure 9.

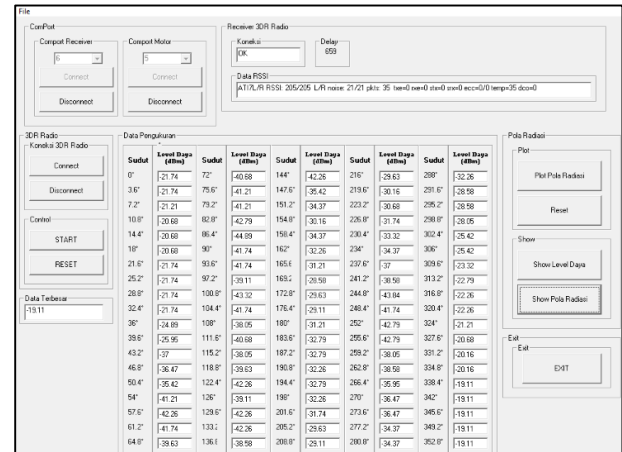


Figure 7 Yagi antenna radiation pattern plot on elevation plane

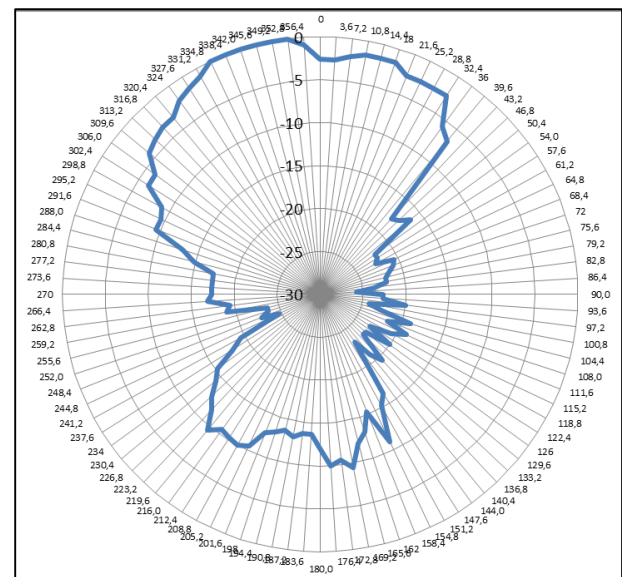


Figure 8 Yagi antenna radiation pattern plot on elevation plane

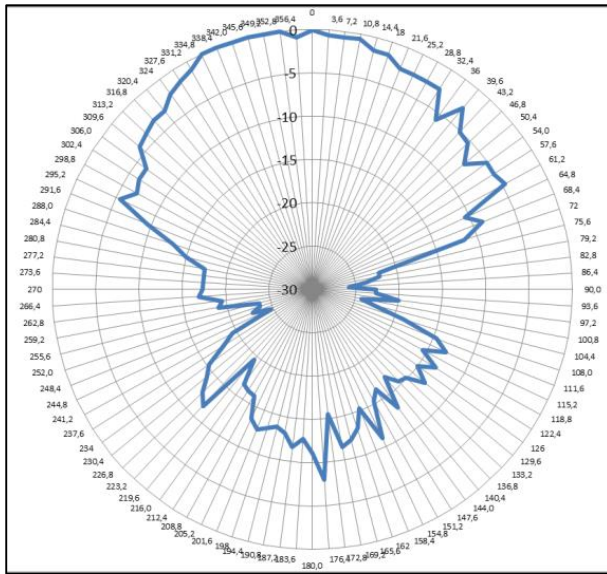


Figure 9 Yagi antenna radiation pattern plot on azimuth plane

4. CONCLUSION

In this research, low-cost measuring equipment to measure and plot antenna radiation patterns has been built. This equipment utilizes an Arduino Uno microcontroller, 3DR Radio Telemetry as the radio transceiver module, and other complementary modular components that are simple to program, cheap in price, and available on the market.

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