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Design and Construction of A Grid Antenna to Enhance Global System for Mobile Communications 900 Mhz Signal Reception

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Abstract— **Human life is inseparable from the interaction between humans as social beings and technology as the medium used by humans. The capabilities of technology have addressed various human challenges for interacting with each other, where limitations of distance, time, and space are no longer barriers to human desire for communication. The Global System for Mobile communication (GSM) is a cellular communication technology applied to mobile communication, especially mobile phones, thus providing conveniences as a medium for information delivery. However, in remote or rural areas far from the Base Transceiver Station (BTS), the signal coverage is poor. This will disrupt communication such as short message service (SMS), telephone calls, internet access, and other forms of communication. An antenna is a device used to transmit or receive electromagnetic waves. Reception using an antenna will amplify the signal acquisition according to the antenna's capabilities. GSM (Global System for Mobile Communications) service providers, with their limited network coverage, create a significant need for signal acquisition enhancement. The Grid antenna is one of the options for signal acquisition enhancement. The Grid antenna has two main components: the driven element, which is a dipole, and a reflector that serves to reflect the signal transmission. This Final Project is designed, realized, and measured on a grid antenna at GSM 900 MHz. This antenna is intended to serve as a supporting medium to enhance GSM signal reception in order to maximize signal acquisition and connection.**

Keywords— Grid antenna, driven, reflector, GSM, signal coverage

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I. INTRODUCTION

The rapid development of science and technology in various fields has brought significant influence to all aspects of life, including the field of telecommunications. The telecommunications industry has experienced rapid growth in recent years. With the passage of time, telecommunications devices have become essential tools needed by society.

The rapid development of telecommunications technology has resulted in high demands from users for easy and fast services, which are utilized as a medium for conveying information. Human life is inseparable from the interaction between humans as social beings and technology as the medium used by humans. Technological capabilities have addressed various human challenges in interacting with each other, where limitations of distance, time, and space are no longer barriers to human communication.

GSM is a cellular communication technology applied to mobile communication, especially in mobile phones, thus providing convenience as a medium for information dissemination. However, in remote or rural areas far from the BTS, signal coverage is very poor. This can disrupt communication services such as SMS, telephone calls, internet access, and other forms of communication[1].

Antennas are the main components of transmitters or receivers in communication media, one of which is the grid antenna. The grid antenna, which was previously only used as a television signal receiver, can now be used as a device to strengthen GSM signals[2]. The grid antenna has unidirectional polarization, meaning its emission and reception are focused in one direction only. With this polarization form, the antenna's signal transmission becomes stronger.

Therefore, the author is interested in creating a device as a final project titled "Development of a Grid Antenna to Enhance Reception of 900 MHz GSM Signals."

II. MATERIALS AND METHOD

A. Designing Grid Antenna

Design is a process carried out to design the grid antenna according to the desired function. The design must be done carefully to facilitate the construction of the grid antenna. The design and construction block diagram of the grid antenna is illustrated by Figure 3.1 below:

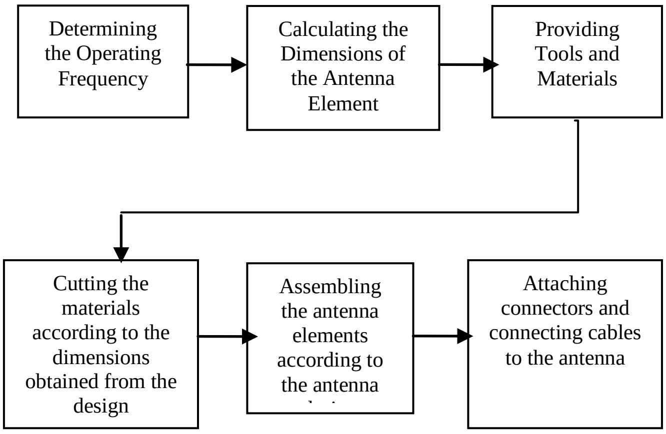

Figure 1. Design and Construction of Grid Antenna

Tools and Materials

Tools:

1. Ruler.
2. One piece of iron saw.
3. One piece of drill.
4. Screwdriver.
5. Cutting pliers.
6. Knife.

Materials:

1. Aluminum plate used as the framework for making the parabolic reflector of the grid antenna.
2. Aluminum mesh, used to cover the frame of the grid antenna which serves as a signal wave reflector.
3. 3/8-inch diameter Aluminum pipe, used to make the driven element of the grid antenna in the form of a dipole.
4. RG 58 a/u coaxial cable, used as connecting cable.
5. Rosettes and acrylic used as cable connection and driven element mounting.
6. 3mm diameter nuts and bolts, used to connect the frame to the aluminum mesh and also the grid antenna to the support pole.
7. Two pieces of male BNC connectors as connectors for coaxial cable.
8. Paralon pipe used as a support pole for the grid antenna.

B. Manufacturing of Grid Antenna

The manufacturing process of the grid antenna begins with determining the operating frequency of the antenna. The grid antenna is designed to amplify GSM signals, where GSM networks in Indonesia operate on two frequencies: 900 MHz and 1800 MHz. For this grid antenna, we will use the 900 MHz frequency. In the 900 MHz frequency band, the frequency range is from 890 MHz to 960 MHz, with the uplink frequency range being 890 MHz to 915 MHz and the downlink frequency range being 935 MHz to 960 MHz.

The frequency range to be used in the manufacturing of this grid antenna is the downlink frequency range, which is 935 MHz to 960 MHz. This is because the downlink frequency is used for transmission from the BTS tower to the mobile phone, while the uplink frequency is used for data transmission from the mobile phone to the BTS tower[3][4].

Therefore, the mid-frequency of the downlink frequency range of 935 MHz to 960 MHz can be calculated as follows:

$$Fc = Initial\ frequency + \left(\frac{\text{Initial frequency} - \text{final frequency}}{2}\right) \quad (1)$$

$$Fc = 935\ Mhz + \left(\frac{960\ Mhz - 935\ Mhz}{2}\right)$$

$$Fc = 935\ Mhz + 12{,}5\ Mhz$$

$$Fc = 947{,}5\ Mhz$$

$$Fc = 947\ Mhz$$

From the calculation above, the operating frequency of the grid antenna is found to be 947 MHz.

Manufacturing of the Reflector The reflector used in the manufacturing of this grid antenna is a parabolic reflector. Determining the wavelength can be done as follows:

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3x10^8\ m/s}{947\ Mhz}$$

$$\lambda = \frac{3x10^8\ m/s}{947x10^6\ Hz}$$

$$\lambda = 0{,}3167\ \text{m}$$

$$\lambda = 31{,}67\ \text{cm}$$

The diameter of the antenna can be calculated using the equation:

$$D = 2\ x\ \lambda$$

$$D = 2\ x\ 31{,}67 cm$$

$$D = 63{,}34\ cm$$

$$D = 64\ cm$$

Where the depth of the antenna can be calculated using the equation:

$$d = \frac{D^2}{16\ x\ F}$$

$$d = \frac{64^2 cm}{16\ x\ 17{,}01\ cm}$$

$$d = \frac{4096\ cm}{272.16\ cm}$$

$$d = 15{,}04\ cm$$

$$d = 15\ cm$$

The depth (d) of the parabolic reflector to be constructed is 15 cm. The focus point (F) can be determined using the equation:

$$F = \frac{D^2}{16\ x\ d}$$

$$F = \frac{64^2 cm}{16\ x\ 15\ cm}$$

$$F = \frac{4096\ cm}{240\ cm}$$
$$F = 17{,}06\ cm$$
$$F = 17{,}1\ cm$$

The depth (d) of the parabolic reflector to be constructed for the grid antenna is 15 cm. Since a front-feed parabolic antenna has a reflector with an F/D ratio of 0.25 to 0.4, a parabolic reflector with an F/D ratio of 0.25 is called a focus reflector[4]. In such a reflector, the focus point will be on the aperture plane. If the focus point (F) = 17.01 and the diameter (D) = 64 cm, then F/D = 0.26. After obtaining the values of Diameter (D), depth (d), and focus point (F), the next step is the construction of the grid antenna reflector. The steps for making the parabolic reflector for the grid antenna are as follows:

1. Prepare the tools and materials used in making the grid antenna.
2. Create a circle with a diameter (D) of 64 cm using aluminum plates.
3. After creating the circle, it will be attached using nuts and bolts that have been pre-drilled.
4. Next, create the depth of the grid antenna, which has a depth (d) of 15 cm. By measuring the depth using a ruler, then the aluminum plate is attached to the circle that has been made, forming a half-sphere.
5. After forming a half-sphere, attach the aluminum plates using nuts and bolts that have been pre-drilled using a drill, to ensure that the frame of the grid antenna is securely attached.
6. Cut the aluminum mesh into triangular shapes according to the shape of the parabolic reflector.
7. Attach the aluminum mesh to the frame of the grid antenna that has been made, one by one, and attach them using nuts and bolts.
8. At the back of the frame of the grid antenna, attach aluminum plates according to the existing frame, to strengthen the reflector. And the grid antenna reflector is finished.

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Figure 2: Antenna Reflector

C. *Manufacturing the Driven Element*

The driven element serves as the antenna balun. The driven element is an element that provides power from the transmitter, usually through the transmission line. The driven element has a length of ½λ.

$$L = 0.5\ x\ K\ x\ \lambda$$
$$L = 0.5\ x\ 0.95\ x\ 31{,}67\ cm$$
$$L = 15{,}04\ cm$$
$$L = 15\ cm$$

The steps for making the driven element of the grid antenna are as follows:

1. Prepare the tools and materials used in making the driven element of the grid antenna.
2. The material used is aluminum pipe.
3. Cut the aluminum pipe according to the predetermined size.
4. Bend the aluminum pipe according to the predetermined size.
5. Install the bent aluminum pipe onto acrylic and attach it using nuts and bolts.

Figure 3. Driven Antenna

D. *Assembly of the Grid Antenna*

After manufacturing the parabolic reflector and driven element of the grid antenna, the next step is assembly.
The assembly steps of the grid antenna are as follows:

1. Prepare the parabolic reflector and driven element that have been made for the assembly process.
2. Cut aluminum plates to be used as the focus point (F) with the calculated size of 17.1 cm.
3. Cut PVC pipes to be used as support poles placed behind the parabolic reflector.
4. Install the previously made focus point onto the parabolic reflector.
5. Place the driven element, which has been attached to the coaxial cable, at the installed focus point.

The grid antenna is now assembled, and the next step is the testing phase of this grid antenna. The designed and manufactured grid antenna is shown in Figure 4 below.

Figure 4. Grid antenna.

III. RESULT AND DISCUSSION

A. Antenna Measurement Results

Testing is the most crucial process in the designed grid antenna. During testing, it will be determined whether the constructed grid antenna meets the desired functionality or not. The testing process involves measuring the antenna's parameters such as gain, bandwidth, and polarization.

Tools Used:

1. RF (Radio Frequency) Generator: Used as a signal generator.
2. Spectrum Analyzer: Used to display received signals.
3. Folded Dipole Antenna: Used as a transmitter.
4. Base Transceiver Station (BTS): Used as a transmitter.
5. Dipole ½ λ Antenna: Used as a reference antenna.
6. Grid Antenna (antenna to be measured): Used as a receiving antenna.
7. Connecting cables: Used to connect the antenna with the RF Generator and spectrum analyzer.

Antenna Resonance Frequency Measurement Results: After conducting the measurement, the following data is obtained:

TABLE 1
Resonance Frequency Measurement Results with Transmitter Folded Dipole Antenna.

Frequency (MHz)	Received Power (dBm)			Average
	Testing I	Testing II	Testing III	
930	-71	-72	-71	-71
931	-71	-71	-71	-71
932	-70	-71	-70	-70
933	-69	-70	-68	-69
934	-68	-69	-69	-69
935	-67	-68	-68	-68
936	-67	-67	-68	-67
937	-67	-67	-66	-67
938	-66	-67	-66	-66
939	-66	-67	-65	-66
940	-65	-65	-66	-65

TABLE 2.
Frequency Response Measurement Results with BTS Transmitter.

Frequency (MHz)	Received Power (dBm)			Average
	Testing I	Testing II	Testing III	
930	-90	-89	-90	-90
931	-90	-89	-90	-90
932	-90	-90	-89	-90
933	-88	-90	-90	-89

B. Frequency Resonance Analysis

Determining the resonance frequency is the initial step in antenna measurement. The results of determining the resonance frequency are used to assess whether the designed antenna's operating frequency matches the measurements conducted. Measurements were conducted using two transmitters and different locations: using the folded antenna in the laboratory and using the BTS transmitter outdoors.

The graph of measurement results to determine the resonance frequency is as follows:

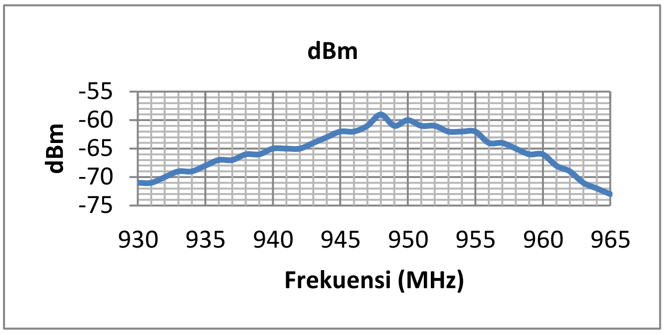

Figure 6. Frequency Response Graph of Grid Antenna with Folded Dipole Transmitter.

Based on the graph above, it is shown that the designed and constructed grid antenna has a maximum power of -59 dBm. The maximum received power is observed at the frequency of 948 MHz. Therefore, the operating frequency of the grid antenna is 948 MHz.

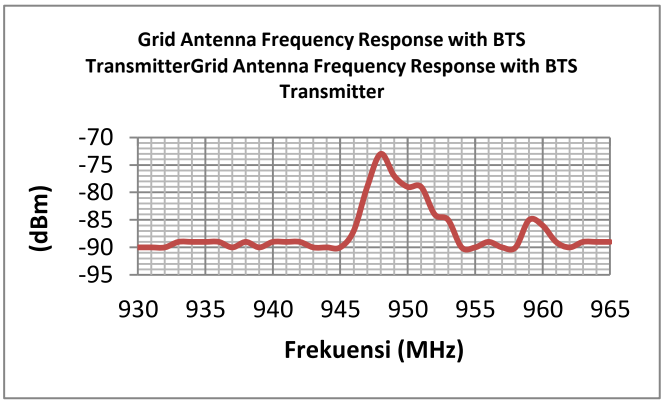

Figure 7. Frequency Response Graph of Grid Antenna with BTS Transmitter.

Figure 7 shows that the designed and constructed antenna achieves a maximum received power of -73 dBm at a frequency of 948 MHz. These measurements were conducted at different locations, indoors in the laboratory and outdoors. Despite being measured in different locations, they exhibit the same operating frequency of 948 MHz with different received power levels, namely -59 dBm and -73 dBm.

Bandwidth Measurement Bandwidth measurement is conducted to determine the frequency range within which the antenna can operate effectively. To obtain the bandwidth value.

To determine the bandwidth value, knowing the received power of the antenna, subtract the maximum received power by 3 dBm to obtain the power level at which the antenna can operate effectively. Once the maximum received power of the antenna is reduced by 3 dBm, the frequency range corresponding to the reduced power level can be determined.

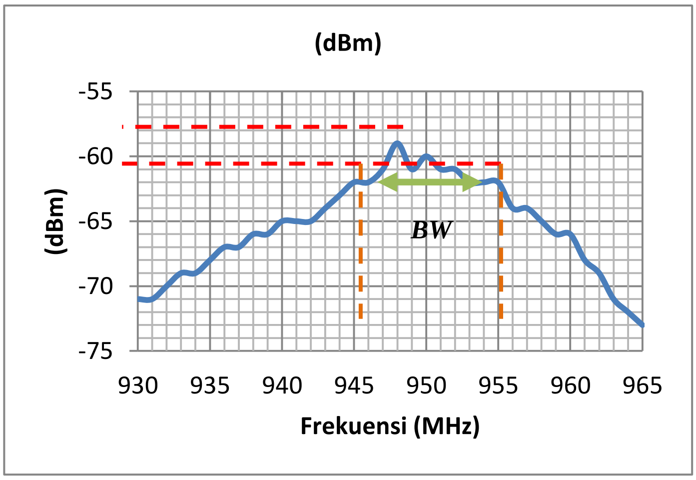

Figure 8. Graph for Determining the Bandwidth of the Grid Antenna.

From the graph above, the bandwidth can be observed and determined to be:

$BW = F_H - F_L$
$BW = 955\ MHz – 945\ MHz$
$BW = 10\ MHz$

From the above calculations, it can be determined that the grid antenna has a bandwidth of 10 MHz.

Results of Antenna Polarization Measurement After conducting the measurement, the following data shown on table 3.

TABLE 3.
Results of Grid Antenna Polarization Measurement with Folded Dipole Antenna Transmitter

Angle (°)	Received Power (dBm)			Average
	Testing I	Testing II	Testing III	
0	-59	-60	-59	-61
10	-65	-67	-67	-66
20	-69	-68	-68	-68
30	-77	-78	-77	-77
40	-81	-79	-78	-79
50	-77	-74	-75	-75
60	-78	-80	-81	-80
70	-71	-81	-78	-77
80	-78	-75	-76	-76

TABLE 4
Results of Polarization Measurement with BTS Transmitter

Angle (°)	Received Power (dBm)			Average
	Testing I	Testing II	Testing III	
0	-71	-70	-70	-70
10	-74	-73	-73	-73

Radiation Pattern Diagram of the Grid Antenna After obtaining the received power from the measurement results, the received power is then transferred into the radiation pattern diagram using Matlab 7.0, resulting in the radiation pattern of the grid antenna.

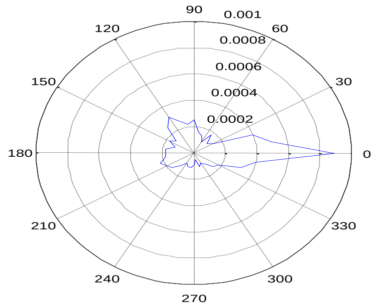

Figure 9. Radiation Pattern Diagram of the Grid Antenna with Folded Dipole Antenna Transmitter

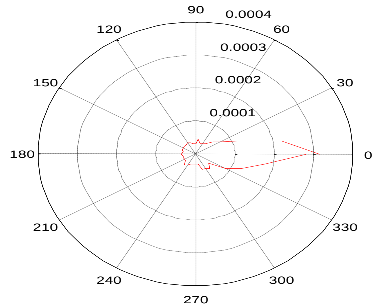

Figure 10. Radiation Pattern Diagram of the Grid Antenna with BTS Transmitter

C. Antenna Polarization Analysis

From the radiation pattern diagrams of the grid antenna above, it can be observed that they exhibit the same polarization, which is unidirectional. Unidirectional polarization means that the radiation pattern is focused in one direction only. This characteristic is advantageous for point-to-point communication, especially in rural or suburban areas. With unidirectional polarization, electromagnetic waves received are emitted in one direction only, typically towards the user's handset. These electromagnetic waves are transmitted from the BTS to the grid antenna and then directed to the handset via cables, enhancing the signal strength from weak to strong[5].

The maximum received power of the grid antenna can also be observed from the radiation pattern diagrams. In the radiation pattern using the grid antenna with a folded dipole transmitter, as shown in Figure 10, the maximum power is -57 dBm, while the grid antenna with a BTS transmitter achieves a maximum received power of -70 dBm. It can be noted that the radiation pattern of the grid antenna with the folded dipole transmitter extends farther compared to the one with the BTS transmitter. This difference is due to the variation in measurement distances. The measurement conducted indoors between the grid antenna and the folded dipole transmitter has a distance of 1 meter, whereas the measurement conducted outdoors between the grid antenna and the BTS transmitter has a distance of approximately 1 kilometer.

D. Antenna Gain Measurement

Antenna gain measurement is performed by comparing the radiated power of the antenna under test with that of a standard antenna[6]. The standard antenna used as a reference antenna is a half-wavelength dipole antenna, which is constructed and adjusted to the operating frequency of the grid antenna itself.

E. *Results of Antenna Gain Measurement*

After conducting the measurement, the following data was obtained:

TABLE 5
Results of Grid Antenna Gain Measurement with Half-Wavelength Dipole Reference Antenna with Folded Dipole Antenna Transmitter

Frequency (MHz)	Transmitter Power Folded (dBm)	Receiver Power dipole½ λ (dBm)	Antenna Grid Receiver Power (dBm)
948	+ 16,5	-70	-59

TABLE 6
Results of Grid Antenna Gain Measurement with Half-Wavelength Dipole Reference Antenna with BTS Antenna Transmitter

frequency (MHz)	Receiver Power dipole (dBm)	Receiver Power Grid Antenna (dBm)
948	-80	-70

Analysis of Antenna Gain Measurement Results

From the results, the gain value of the grid antenna can be determined as follows:

$$G = 10 \log \left(\frac{Pt}{PS}\right) (dB)$$

$$G = 10 \log \left(\frac{\text{The maximum received power of the antenna is measured}}{\text{Maximum received power of the reference antenna}}\right) (dB) \quad (2)$$

Calculation of antenna gain for folded dipole antenna transmitter and grid antenna receiver

P_{dipole} (dbm) = -70 dBm

$-70 = 10 \log \frac{P}{1\ mW}$

$\frac{P}{1\ mW}$ = Arc log -7

$\frac{P}{1\ mW}$ = 1×10^{-7} W

P_{dipole} = $1 \times 10^{-7} \times 10^{-3}$ W

P_{dipole} = 1×10^{-10} W

P_{dipole} = $0{,}1 \times 10^{-9}$ W

$P_{antena\ grid}$ (dbm) = -59 dBm

$-59 = 10 \log \frac{P}{1\ mW}$

$\frac{P}{1\ mW}$ = Arc log -5,9

$\frac{P}{1\ mW}$ = $1{,}2589 \times 10^{-6}$ W

P_{grid} = $1{,}2589 \times 10^{-9}$ W

$$Gain\ antena\ grid = 10 \log \frac{1{,}2589 \times 10^{-9}\ W}{0{,}1 \times 10^{-9}\ W} = 10{,}99\ dB = 11\ dB$$

or: $Gain = 11\ dB + 2{,}14 = 13{,}14\ dBi$

a. Calculation of antenna gain for BTS transmitter and antenna grid receiver

P_{dipole} (dbm) = -80 dBm

$-80 = 10 \log \frac{P}{1\ mW}$

$\frac{P}{1\ mW}$ = arc log -8

$\frac{P}{1\ mW}$ = 1×10^{-8} W

P_{dipole} = 1×10^{-11} W

$P_{antena\ grid}$ (dbm) = -70 dBm

$-70 = 10 \log \frac{P}{1\ mW}$

$\frac{P}{1\ mW}$ = arc log -7,0

$\frac{P}{1\ mW}$ = 1×10^{-7}

P_{grid} = $1.\ 10^{-10}$ W

$$\text{Gain antena grid} = 10 \log \frac{1 \times 10^{-10}\ W}{0{,}1 \times 10^{-10}\ W} = 10\ dB$$

or : $Gain = 10\ dB + 2{,}14 = 12{,}14\ dB$

From the calculation results above, it can be seen that the gain value of the grid antenna with a folded dipole antenna transmitter is 13.14 dB, while with the BTS antenna transmitter, it is 12.14 dB. This difference is attributed to the measurement being conducted at different distances, which affects the received power of the grid antenna. The farther the distance, the more factors come into play, such as tall buildings and hills that obstruct the transmission power of both the transmitter and receiver antennas.

F. *Analysis of the Impact of Grid Antenna Usage on Signal Quality in GSM 900 MHz Handphones*

To gain a clearer understanding of the impact of using a grid antenna on the signal quality of a handphone, the handphone used in the experiment was connected to the grid antenna using a pigtail cable in the handphone's antenna slot. The handphone used in this experiment is the Samsung Champ.

The results of the measurement only include signal bars displayed on the handphone. The signal strength before and after using the grid antenna can be observed in the Figure 11.

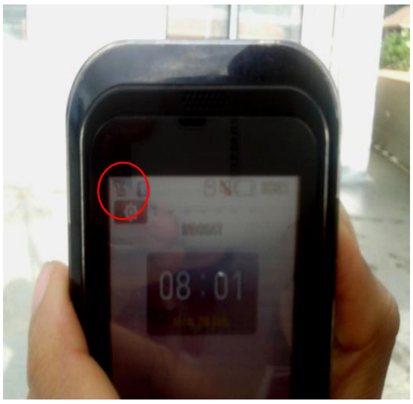

Figure 11. Signal strength displayed as bars on the phone before using the grid antenna.

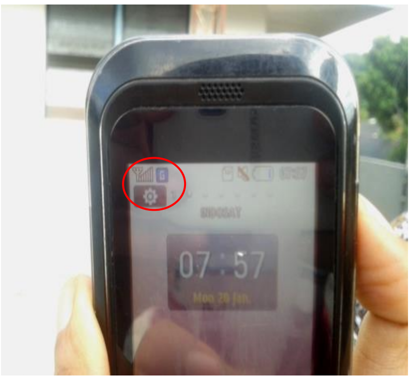

Figure 11. Signal strength displayed as bars on the phone after using the grid antenna.

From the figure 10, it can be seen that before using the grid antenna, the phone's signal reception strength was only 2 bars. According to the journal by Sobirin, Adi Wibowo, and Alhamdi Yosef Herman, having a signal strength of 2 bars indicates a very poor category. However, after using the grid antenna, the signal strength is categorized as good, with full bar reception.

For a clearer understanding, the signal reception using the phone according to the maximum power of each antenna can be seen in the table 3.6 below:

TABLE 6
Signal Reception Category Table

Handphone	Recieve (dBm)	Category
antenna dipole	-83	Poor
antenna grid	-70	Good

Thus, it can be seen that the signal strength in terms of signal bars has the same category, with the dipole antenna having a poor category with a maximum reception power of -83 dBm, while the grid antenna has a good category with a maximum reception power of -70 dBm. Therefore, this demonstrates that the designed and constructed grid antenna can enhance the signal strength on the cellphone..

IV. CONCLUSION

From all the aspects presented in this final project and the measurements conducted on the Yagi antenna, it can be concluded that:

1. The grid antenna can amplify signal reception in GSM 900 MHz. The reception power before using the grid antenna was -89 dBm, categorized as poor, while after using the grid antenna, the phone reception power became -70 dBm, categorized as good.
2. The working frequency of the designed and constructed grid antenna in the frequency range of 935 MHz - 960 MHz has a resonance frequency of 948 MHz. This is evidenced by resonance measurements with both the folded dipole transmitter and the Base Transceiver System (BTS).
3. The bandwidth of the designed and constructed grid antenna is 10 MHz.
4. The polarization of the designed and constructed grid antenna is unidirectional, as observed in measurements with both the folded dipole transmitter and the transmitter antenna at the Base Transceiver System (BTS).
5. The gain of the grid antenna using the folded dipole transmitter is 14.14 dBi, which is higher compared to the gain when using the Base Transceiver System (BTS) transmitter, which is 13.14 dBi.

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