PERFORMANCE EVALUATION AND OPTIMIZATION OF ALUMINUM AND IRON DIPOLE ANTENNA FOR JAKARTA TV CHANNEL

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ABSTRACT: *This study presents the design and fabrication of aluminum and iron dipole antenna for TV channel in Jakarta, Indonesia. The frequency range of TV channel in Jakarta is 450MHz-950MHz. The obstacle to fabricate the Do It Yourself (DIY) dipole antenna that can cover this frequency is the dimension of the material is not always appropriate to the design. The range of the frequency that can be covered by the dipole antenna in this research is 644MHz-736MHz. The research was done to compare the result of simulation with the real fabrication using the old household appliances. This research is carried out by determining the frequency range of starting work, designing, doing simulation, fabricating, testing and optimizing. Performance investigation of the real implementation was tested at different floor from first, third and sixth floor inside the building. The location of testing is University of Al Azhar Indonesia, Jakarta. The comparison between dipole antenna using aluminum and iron at each floor, antenna simulation and antenna real implementation can be obtained from this research. Another objective of this research is to design a simple DIY dipole antenna that can be operated for TV antenna. The performance of the design can be seen from the gain, directivity, radiation pattern, Voltage Standing Wave Ratio (VSWR), and bandwidth of desired antenna in simulation and the number of channels obtained in the real implementation. The result showed that an aluminum dipole antenna has better performance than iron.*

Keywords: Dipole Antenna, Aluminum, Iron, TV Channels

1. INTRODUCTION

The antenna is an electromagnetic device that can transmit and receive radio waves. Antenna consists of electrical conductor designed for working with the radio frequency. Dipole antenna is a radio frequency antenna that can be made very simply by just using a wire. It is belong to wire antenna. It is made of one transmitter element which is divided into two parts. Power of radio frequency is applied in the middle of antenna, between the two conductors. This antenna has omnidirectional pattern which means the antenna radiates energy in a particular field, equally in all directions.

Dipole antenna is one type of antenna that is commonly used because its fabrications are easier and cheaper than other types of antenna. An appropriate design is required to get optimal results from the manufacturing of dipole antenna. This research focuses on the design of a dipole antenna using two different materials, namely aluminum and iron. The objective of this study is to compare the performance of DIY iron and aluminum dipole antenna in simulation using Computer Simulation Technology (CST) and the real fabrication that works at 644MHz-736MHz using old household appliances. This is the frequency range of television channel in Jakarta, Indonesia. The real frequency range of TV channel in Jakarta is 450MHz-900MHz [1]. The obstacle to fabricate the DIY dipole antenna that can cover this frequency is the dimension of the material isn't always appropriate to the design. So, we design antenna using the cheap existing material but still working for TV channel in Jakarta. Performance investigation of the real fabrication was done at the first, third and sixth floor of University of Al Azhar Indonesia, Jakarta.

2. DIPOLE ANTENNA

Dipole antenna has current distributions for the length of $2l = \lambda/10$, $\lambda/2$, λ and 1.5λ. Dipole antenna that is commonly used is single dipole antenna or a half-wave dipole antenna. The length of a single dipole antenna is ½λ, the corresponding input impedance is 73Ω and has a figure-eight shaped radiation pattern toward the front of the wire [2]. Fig.1 shows the structure of $\lambda/2$ dipole antenna.

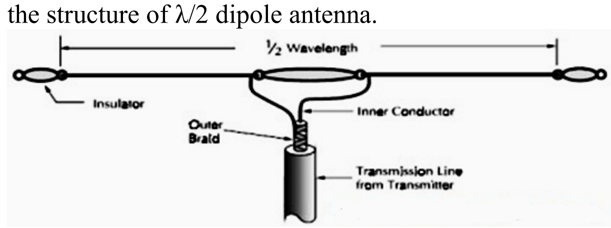


Fig.1: The structure of λ/2 dipole antenna [3].

Antenna parameters that can affect the quality of the antenna are directivity, gain, bandwidth, VSWR and radiation pattern. The wavelength of dipole antenna can be determined by using Eq.(1) [2].

$$\lambda = \frac{c}{f} \qquad (1)$$

Where:

λ Is wavelength in meter

c is velocity of electromagnetic wave (3×10^8 m/s)

f is center frequency in Hz

To determine the total length of the dipole antenna wire we use Eq.(2), Eq.(3) and Eq.(4) [4, 5].

Length of half-wave dipole antenna,

$$L = \frac{143}{f} \quad (2)$$

Feeding gap of the antenna,

$$g = \frac{L}{200} \quad (3)$$

Radius of the wire,

$$R = \frac{\lambda}{1000} \quad (4)$$

Equations above are used for the starting point to measure the dimension of dipole antenna. In this research we did optimization to meet the specifications.

3. ANTENNA PARAMETERS

Performance of dipole antenna can be seen from its directivity, gain, VSWR, radiation pattern and bandwidth. Directivity is the ratio of maximum radiation intensity with an average radiation intensity. It shows the ability of antenna to radiate the energy in certain direction.

Gain (directive gain) is the character of the antenna associated with the ability of the antenna to direct the radiation signal or reception signal from a specific direction. Theoretically, gain of dipole antenna-$\lambda/2$ is 2.15 dBi [2].

VSWR is a parameter that determines the quality of the transmission signal from the source to the load. Ideal value of VSWR is 1 and less than 2, which means that antenna has good matching impedance. The greater value of VSWR indicates that the power of the reflected is greater too [6].

The radiation pattern of an antenna is a graphical statement that describes the radiation properties of an antenna on a farfield as a function of the direction. The radiation pattern of the antenna can be vary based on the value of the specified parameter. In general, the radiation pattern illustrates the Farfield pattern, in which the gain or directivity is a function.

Bandwidth is defined as a value of operating frequency of an antenna associated with several characteristics including input impedance, radiation pattern and polarization. The bandwidth can be seen from the value of lower and upper frequency in S11 parameter. The antenna will work when the value of S11 parameter is $\leq$ -10dB. It means that the antenna has no reflected signal or all of the signal will be completely radiated by the transmitter and received at the receiver.

4. RESEARCH METHODS

The research method is done in several steps. Fig.2 shows the flowchart of the research.

The design of aluminum and iron dipole antenna is cylindrical. This shape is chosen because cylindrical is simpler than other shapes. Using this shape antenna only has three parameters, gap, length and radius. In Contrary, if cubical is chosen antenna will have five parameters, they are gap, length, radius, width and thickness. The calculation will be more complex to determine each parameter in designing dipole antenna.

The total cost of the real fabrication of dipole antenna in this research is shown as follow:

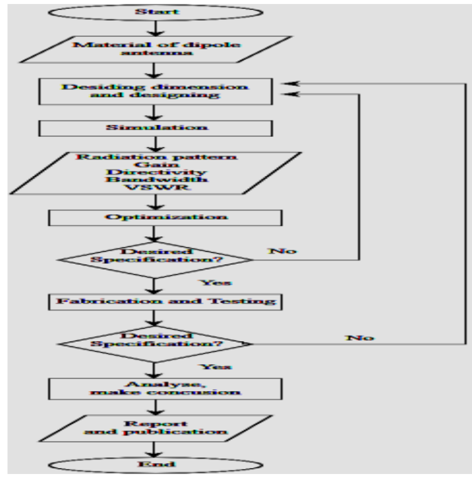
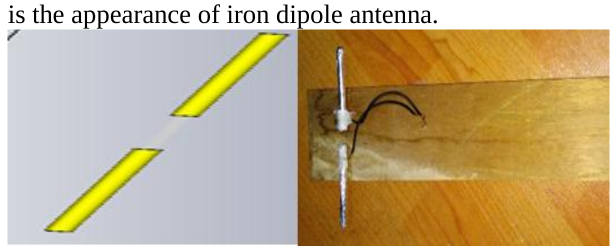


Fig.2: Research framework

Design of dipole antenna

Dimension of aluminum dipole antenna is shown in Table 1. In Table 1 the design is added with wood as the vacuum because aluminum is very lightweight. The wood then covered with aluminum. The thickness of aluminum is 0.016mm. So, the wood must be wrapped by aluminum 15 times to reach 0.2mm in thickness according to Table 1. Fig.3 is the appearance of aluminum dipole antenna. Cylindrical antenna is presented for both aluminum and iron [7]. Dimension of iron dipole antenna is shown in Table 2. Fig.4 is the appearance of iron dipole antenna.

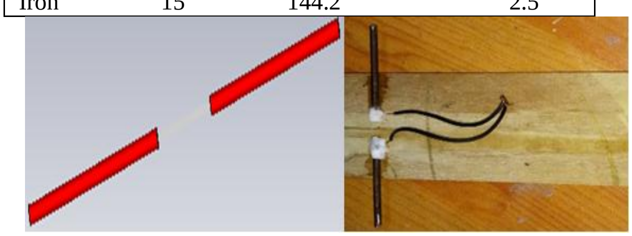


a. b.

Fig.3: Design of aluminum dipole antenna a). CST b). Real fabrication

Table 2: Dimension of iron dipole antenna

Material	Gap (mm)	Length (mm)	Radius (mm)
Iron	15	144.2	2.5



a. b.

Fig.4: Design of iron dipole antenna a). CST b). Real fabrication

A piece of unused Chopsticks	Free
Glue	IDR 2000,00
Coaxial Cable	IDR 9000,00
Aluminum Foil	IDR 5000,00
Old Plank	Free
Scrap Metal	Free
Fomer Copper Cable	Free

The total cost of the dipole fabrication for both aluminum and Iron is IDR 16.000,00. It is cheaper than we buy TV antenna in the store. The price of dipole antenna in the store is above Rp 50.000,00 [8].

5. RESULTS AND DISCUSSION

Based on design and simulation, we get the performance result of aluminum and iron dipole antenna. Fig. 5 shows the S11 parameters of both antenna and Fig. 6 shows the VSWR of both material for equal dimension.

Fig. 5 shows that the aluminum and iron dipole antenna works in the center frequency (680 MHz) since the value of S11 parameter is less than -10dB. It shows that energy from antenna for both material is fully transmitted. Aluminum has lower and upper operating frequency at 644.57 MHz and 727.59 MHz respectively. The total bandwidth is 83.02 MHz. On the other hands, Iron has 651.22 MHz to 736.16 MHz as lower and upper operating frequency with total bandwidth is 84.94 MHz. For the equal dimension, dipole antenna using iron has bigger bandwidth than aluminum. It means iron is more appropriate for designing antenna with large bandwidth. It can be seen from Fig. 5 that the lowest value of S11 parameter of iron (-26.742 dB) is higher than aluminum (-29.034 dB). The bigger value of S11 parameter will affect the reflection coefficient of antenna. Reflection coefficient must be zero in order to make the antenna match (VSWR < 2). The good value of VSWR is 1 that means antenna is in matching condition. The condition of VSWR is shown in Fig. 6. It shows antenna is working at the operating frequency since the VSWR is less than 2 for both aluminum an iron. From Fig. 6 we also can analyze that iron and aluminum is in good matching condition since the value of minimum VSWR is 1.095 for iron and 1.074 for aluminum.

Dipole antenna in this research has omnidirectional radiation pattern. This result is consistent with the theory [2]. Fig.7 shows the radiation pattern of Aluminum and Iron in upper, center and lower frequency. The radiation pattern of aluminum in upper, middle and lower is equal. The difference thing is the value of directivity, gain and HPBW. The value of this parameter can be seen in Table 3. The similar condition also experienced by dipole antenna using Iron.

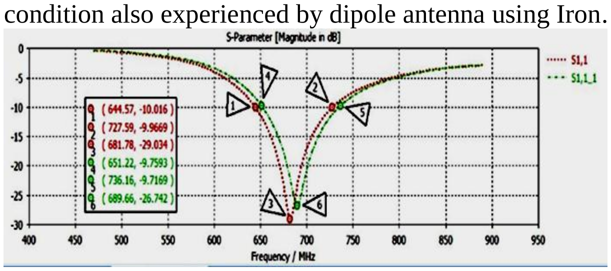


Fig.5: S11 Parameter Dipole Antenna of Aluminum (Red-dotted) and Iron (green-dashed)

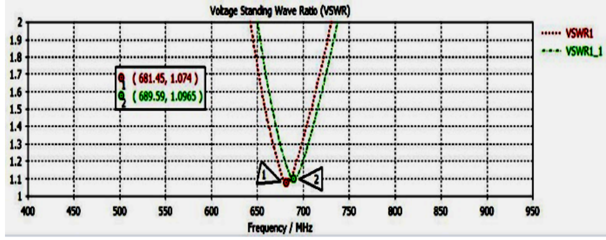


Fig.6: VSWR Dipole Antenna of Aluminum (Red-dotted) and Iron (Green-dashed)

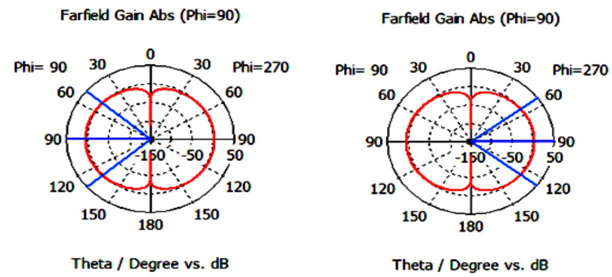


Fig. 7: Radiation pattern in the upper, center, and lower frequency of a). Aluminum and b).Iron

Table 3 shows the performance of aluminum and iron dipole antenna in CST for another parameters mentioned in section 3.

Table 3: Performance of Aluminum and Iron Dipole Antenna

Material	Frequency (MHz)	Directivity (dBi)	Gain(dB)	HPBW (deg)
Aluminum	644.57	2.03	2.01	81.7
	690	2.06	2.06	80.3
	727.59	2.09	2.1	79.2
Iron	651.22	2.04	2.02	81.5
	690	2.07	2.06	80.4
	736.16	2.1	2.11	79

Table 3 shows that gain and directivity of iron is bigger than aluminum. The greater gain means that antenna is more efficient to transfer the power from input to be radiated. So based on simulation, iron is more efficient for transferring the power from source. While directivity is the ability of antenna to radiate the energy from antenna in the certain direction. The directivity of aluminum and iron is getting increase from lower to upper frequency. Thus, Iron and aluminum has better directivity in high frequency.

Half Power Beam Width (HPBW) also can be investigated from Table 3. Iron and aluminum has no significant difference for HPBW. The HPBW of Iron is less than Aluminum.

From the analysis of the result we can choose material of antenna based on the purpose of application. If we want to use large bandwidth thus we choose Iron for dipole antenna. In contrary aluminum is recommended to be used for small bandwidth.

Now we move to performance investigation of the real fabrication. Table 4 shows the performance of aluminum and iron dipole antenna for real fabrication that is tested at first, third and sixth floor of University of Al Azhar Indonesia, Jakarta.

Table 4: Performance of Aluminum and Iron Dipole Antenna For Real Fabrication at Different Floor

No.	Channel	Aluminum			Iron		
		1st	3rd	6th	1st	3rd	6th
1.	INTV	-	D	D	-	D	D
2	RTV	D	D	D	D	D	D
3.	Kompas TV	D	D	D	D	D	D
4.	CTV	D	D	D	-	D	D
5.	NET	D	D	D	D	D	D
6.	KTV	D	D	D	D	D	D
7.	Trans TV	D	D	D	D	D	D
8.	INEWS	D	D	D	D	D	D
9.	TVRI	D	D	D	D	D	D
10.	O Channel	D	D	D	D	D	D
11.	Elshinta	D	D	D	D	D	D
12.	MNC	D	D	D	D	D	D
13.	TVRI	D	D	D	D	D	D
14.	Indosiar	D	D	D	D	D	D
15.	RCTI	D	D	D	D	D	D
16.	SCTV	D	D	D	D	D	D
17.	ANTV	D	D	D	D	D	D
18.	Trans 7	D	D	D	D	D	D
19.	Global TV	D	D	D	D	D	D
20.	TV one	D	D	D	D	D	D
21.	JakTV	D	D	D	D	D	D
22.	Metrotv	D	D	D	D	D	D
23.	DAAI	D	D	D	D	D	D
24.	Edukasi TV	-	D	D	-	D	D

Table 4 shows number of TV channels in Jakarta, Indonesia that can be covered by aluminum and iron dipole antenna for each floor. D in table means detected and – mean not detected. The testing was done by plugging in antenna into the port of TV manually. We only observe which channel that can be detected by antenna then search the frequency of this detected channel. From the observation we will get the range of frequency of antenna. From this table we can see that aluminum has better performance than iron because aluminum can cover 22 channel in first floor, while iron only cover 21 channel. In detail, aluminum can detect CTV in the first floor, on the other hand iron can't detect this channel in this floor. The number of channel that can be covered by both antenna in 3rd and 6th floor are equal, 24 channel. The result is contra with the simulation since the bandwidth of aluminum is less than iron. Besides, in simulation the total bandwidth is less than the real fabrication's. The real fabrication of antenna can cover bandwidth in almost all TV channel in Jakarta, Indonesia. The bandwidth of TV channel in Jakarta can be seen in Table 5 [1]. The different result may be caused by the environment of the testing area. One of example is it might be caused by the location of TV station transmitter close to the location of dipole antenna testing.TV station which is near to University of Al Azhar Indonesia might cause the quality of the TV channel is better and can be detected. Moreover, the location of testing is surrounded by building and office. It will cause multipath fading phenomenon and will affect the performance of dipole antenna.

Table 5: List of TV Channel in Jakarta, Indonesia

No.	TV Channel	Frequency (MHz)
1.	TVRI VHF	210,60
2.	TRANS TV	479.25
3.	ANTV	495.25
4.	CTV	511.2
5.	TVRI UHF	511.25
6.	KTV	527.2
7.	INDOSIAR	527.25
8.	RCTI	543.25
9.	MNC TV	559.25
10.	O CHANNEL	567.25
11.	SCTV	575.25
12.	ELSHINTA	583.25
13.	RTV	607.25
14.	KOMPAS TV	623.25
15.	GLOBAL TV	703.25
16.	TV ONE	719.25
17.	METRO TV	735.25
18.	TRANS 7	751.25
19.	NET TV	769.25
20.	DAAI TV	775.25
21.	INEWS TV	797.25

In Table 4 the quality of the detected channel isn't performed since there are no tools to measure it in testing location. We only observe manually from first, third and sixth floor. Overall, the quality of the detected channel is getting better from lowest to highest floor. In addition, the quality isn't as good as if we use fabricated antenna from a company. We have to set the positon of antenna over and over to get the good quality of the detected channel. It becomes a new case in this design. In our analysis this case is happened because of the dimension of antenna can't meet the specification of desired antenna. From Fig. 5 we see that dipole antenna doesn't works at frequency of TV channel in Jakarta. To overcome this case, we did optimization in our simulation using CST. From our works, we get the dimension for designing aluminum and iron dipole antenna so that this antenna can operate well. The dimension is listed in Table 6 and Table 7. The covered frequency and VSWR can be seen in Fig. 8 and Fig. 9 respectively.

Table 6: Dimension of aluminum dipole antenna after optimization

Material	Gap (mm)	Length (mm)	Radius (mm)
Aluminum	10	200	0.2
vacuum	10	200	30

Table 7: Dimension of iron dipole antenna after optimization

Material	Gap (mm)	Length (mm)	Radius (mm)
Iron	10	200	30

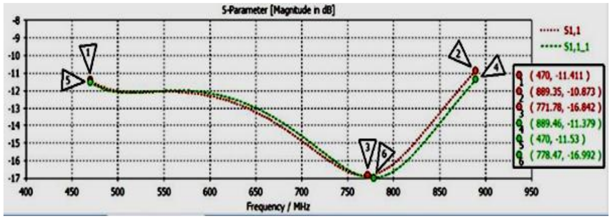


Fig. 8 Bandwidth of aluminum (Red-dotted) and iron (green-dashed) dipole antenna after optimization

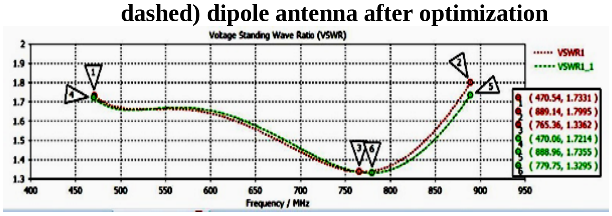


Fig. 9 VSWR of Aluminum (Red-dotted) and Iron (green-dashed) dipole antenna after optimization

From the result above we can see that dipole antenna can cover bandwidth from 470 MHz – 780 MHz that belong to frequency of TV channel in Jakarta, Indonesia. The larger radius of dipole antenna makes the bandwidth larger too.

6. CONCLUSION

This research presents the designed and investigated the performance of a dipole antenna using aluminum and iron at 644-736 MHz. In simulation, the gain of iron is bigger than aluminum with the value of directivity is getting increase from lower to upper frequency. The gain of iron in lower, middle and upper frequency is 2.02, 2.06, 2.11 dB and the directivity 2.04, 2.07 and 2.1 dBi. On the other hand the gain and directivity for aluminum is 2.01, 2.06, 2.1 dB and 2.03, 2.06 and 2.09 dBi respectively. The result is contra with the real fabrication as aluminum has better quality performance shown in Table 4. After doing performance investigation from the result of simulation we conclude that the bandwidth in the real fabrication is different with the simulation. The real fabrication covered more channel and the quality is depend on the area. The total bandwidth in real fabrication is 586.65 MHz and 84MHz in simulation. The different result may be caused by the environment of testing. We suggest to use larger radius in future works so that the bandwidths is bigger. The bigger bandwidth can covered more channels. The length and the gap in dipole antenna only influence the center frequency position in S11 parameter and lowest value of S11 parameter. Radius is parameter in dipole antenna that can adjust the total bandwidth. The dipole antenna in this research still needs improvement to make it more reliable and suitable between design and real fabrication.

7. ACKNOWLEDGEMENTS

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