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Design of spiral labyrinth microstrip antenna for DVB-T application

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Abstract

Digital television broadcasting is technologies that have been developed by any country in the world. The advantages implementations of digital television broadcasting include reception of picture and sound sharper and better. This paper proposes a new design of spiral labyrinth microstrip antenna feed by microstrip line with array two element for Digital Video Broadcasting Technology (DVB-T) application at work frequency of 586 MHz. The design of spiral labyrinth is used to minimize the dimensions of microstrip patch antenna while maintaining the working frequency at 586 MHz and array technique used to improve gain of antenna. The proposed antenna design was originally a rectangular patch that has been modified by the labyrinth spiral method. From the measurement result obtained return loss of -14.15 dB and VSWR of 1.54 at working frequency of 586 MHz. Bandwidth of proposed antenna is 117 MHz (547 MHz–664 MHz) while gain of antenna is 7.78 dBi. Beside that, using of the labyrinth spiral patch successfully reduced the dimensions of the microstrip antenna until 62.2% compared with the conventional rectangular patch of microstrip antenna. This study is usefull for DVB-T application in order to achieve the maximum signal quality and picture.

***Keywords**: antenna, digital video broadcasting, labyrinth, microstrip, spiral*

1. Introduction

Digital television broadcasting is a technology that have been developed by any country in the world. The development of digital television broadcasting technology becomes very important things which nearly each country has and in the process towards the transition from analogue to digital broadcasting systems. The advantages implementation of digital television broadcasting include reception of picture and sound sharper and better. Beside that, the allocation of radio frequencies of Digital Video Broadcasting more efficiently compare with analogue system [1]. The development of the Digital Video Broadcasting system in Indonesia has been moving from DVB-T to DVB-T2 in accordance with regulations set by [2] related to the standard of Digital TV broadcasting system in Indonesia. For the work of frequency used for Digital Video broadcasting system in Indonesia is 478-694 MHz according to the rules set by [3] about master plan work of requency of DVB-T2 in Indonesia.

Many previous studies have attempted to produce antennas for Digital Video Broadcasting applications [4-6] using microstrip antennas. Microstrip antennas have a compact dimension, low profile and low fabrication cost [7]. In general, television antennas use a yaggi type antenna that is widely known by the public. Yaggi antenna has a dimension and size is quite thick and large, approximately about 1 meter, so this antenna is usually used as outdoor antenna (outdoor). In addition there is also research conducted by [8] which utilizes the antenna as a digital television receiver is a yaggi antenna which is included in the type of outdoor antenna for a digital television receiver that have dimension about 28.45 cm. Some studies of microstrip antennas as digital television broadcast receivers, as has been done by [9] using the log periodic method, research [10] using 16 array elements, while [11] with C-shaped slots fed with the probe feed. In addition to the several studied spiral labyrinth pacth can reduce the size of the antenna, as done by [12] and [13] using spiral loads fed into microstrip channels, while [8] using a spiral square with a probe feed.

According to several studied before, this paper proposed the microstrip antenna for Digital Video Broadcasting Application at working frequency of 586 MHz by using spiral labyrinth

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patch fed by microstrip line and then developed using array method to increase the gain. In the previous studied [13] only used a spiral shape but in this paper used a spiral form of Labyrinth. This antenna is called a labyrinth spiral because it has no open end or side (loop systems) while the spiral antenna is generally designed with an open end on the outside. The novelty of this paper is the design of microstrip antenna that used spiral labyrinth with loop system that can reduce the dimension of antenna until 62.2%. The main focus of the research is to provide scientific contribution by the implementation of Labyrinth spiral technique on microstrip antennas to produce compact dimensions for receiver of Digital Video Broadcasting application with return loss≤-10 dB and VSWR≤2 at working frequency of 586 MHz.

2. Design of Antenna

The design of the proposed antenna is used of FR4 Epoxy substrate with relative permittivity (ε_r) of 4.3, substrate thickness (h) of 1.6 mm each, and loss tangent (tan δ) of 0.0265. The initial patch used in this study is a rectangular with length (L) and Width (W). The dimensions of the rectangular patch antenna are determined by using (1), (2), (3), (4) and (5) [14].

$$W = \frac{C}{2f\sqrt{\frac{\varepsilon r+1}{2}}} \quad (1)$$

$$L = L_{eff} - 2\Delta L \quad (2)$$

$$L_{eff} = \frac{C}{2f\sqrt{\varepsilon_{reff}}} \quad (3)$$

$$\varepsilon_{r\,eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1 + 12\frac{h}{W}]^{-\frac{1}{2}} \quad (4)$$

$$\Delta L = 0.412.h\frac{(\varepsilon_{reff} + 0.3)\,(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)\,(\frac{W}{h} + 0.8)} \quad (5)$$

The feeder used in this study is microstrip line with characterictic impedance of 50 Ohm. Microstrip line feeder is used because it is more effective for adjusting the impedance of the antenna and the connector. Microstrip line feeder are determined based on the impedance of the connector used. The dimension of the microstrip line (W_z) is determined by using (6) and (7) [15].

$$W_z = \frac{2h}{\pi}\left\{B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}[\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}]\right\} \quad (6)$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_{eff}}}. \quad (7)$$

After successfully obtained the initial antenna dimension with rectangular shape then the next stage is to design a spiral labirinth microstrip antenna. The type of spiral labyrinth used is a closed loop with a spiral width (W_s) that rotates counter-clockwise. The use of spiral labirinth patch results in the shifting of the working frequency of the microstrip antenna becomes lower so that the dimensions of the antenna should be minimized in order to work on the initial frequency. To control the working frequency of the antenna can be done by iterating the width of the spiral labirinth. Design of single spiral labyrinth microstrip antenna with microstrip line feeder shown in Figure 1.

Figure 1 show the design of single spiral labyrinth microstrip antenna with dimension of W=95 mm , L=115 mm, W_p=75 mm, L_p=90 mm, W_z=3.1 mm, Lz=15 mm and W_s=1 mm. Dimension of Ws can be determined by iteration process as shown in Figure 2, Figure 3 and Table 1.

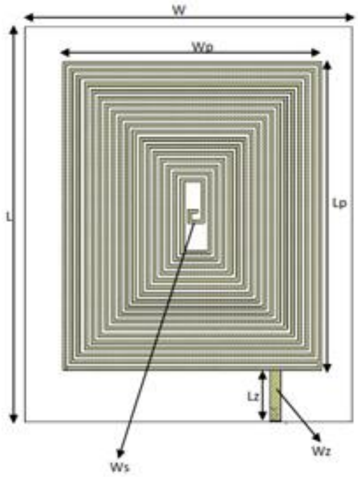


Figure 1. Design of spiral labyrinth microstrip antenna

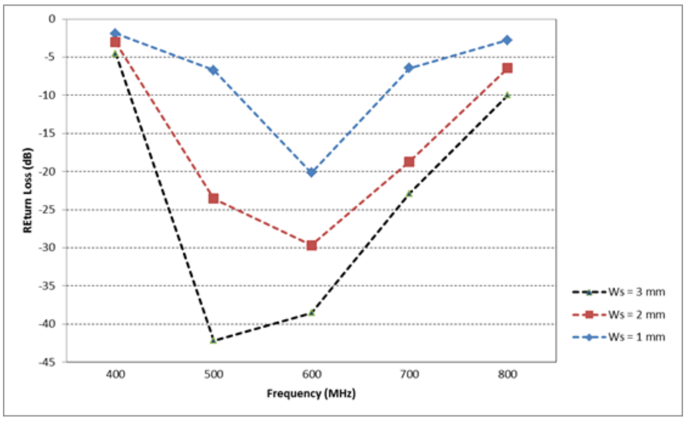


Figure 2. Simulation result of return loss from iteration Ws

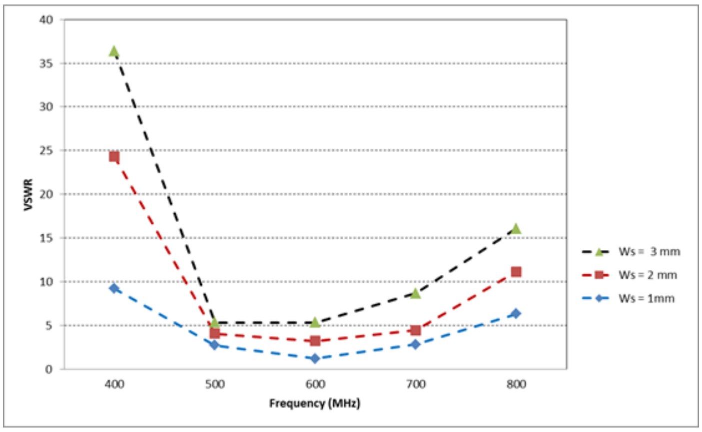


Figure 3. Simulation result of VSWR from iteration Ws

Table 1. Iteration Process of Ws

Iteration Process	Dimension of Ws	Return Loss	VSWR	Frequency
First	1 mm	-18.37 dB	1.427	586 MHz
Second	2 mm	-10.52 dB	1.914	586 MHz
Third	3 mm	-10.24 dB	2.004	586 MHz

Figure 2 and Figure 3 shows that work frequency of antenna can controlled by adjustring the dimension wide of spiral labyrinth patch. The summarize of simulation result of iteration process can be seen in Table 1. From Table 1 can be seen that the best simulation result of return loss and VSWR obtained at first iteration while Ws=1mm with return loss of -18.37 dB and VSWR of 1.427 at working frequency of 586 MHz. The next stage of this research is to design array microstrip antenna with two element to increase the gain. The distance between patches antenna and its related length can be obtained using (8) and (9) below [16]. The design of array spiral labyrinth of microstrip antenna show in Figure 4.

$$d = \lambda/2 \tag{8}$$

$$d\ array = d - L \tag{9}$$

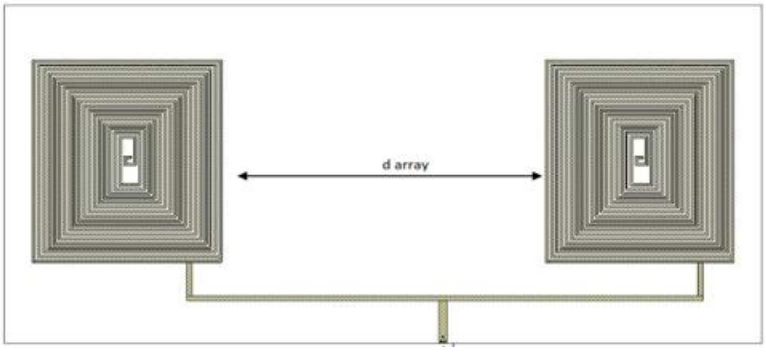


Figure 4. Design of array spiral labyrinth microstrip antenna

Figure 4 show the design of array spiral labyrinth microstrip antenna with two elemen. Patch of microstrip antenna separated each other with distance of d array. The gain of microstrip antenna can be controlled by adjusting the distance of d array. The simulation result of iteration process d array can be seen in Figure 5 below.

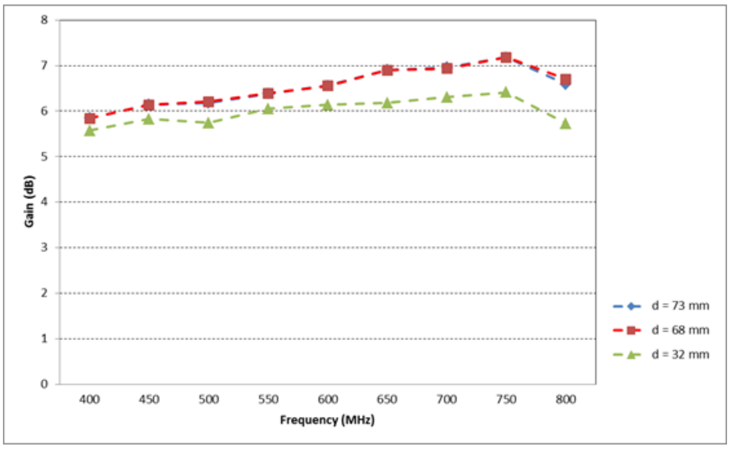


Figure 5. Simulation result of gain microstrip antenna

Figure 5 show that gain of proposed antenna can be controlled by adjustring the distance of d array. Observation of gain from the antenna is carried out in the frequency range from 400 MHz to 800 MHz by changing the distance between elements on the proposed antenna.The summarize of simulation result from iteration process show in Table 2.

Table 2. Iteration Process of D Array

Iteration Process	Distance of d array	Gain	Frequency
First	73 mm	6.511 dB	586 MHz
Second	68 mm	6.505 dB	586 MHz
Third	32 mm	6.111 dB	586 MHz

Table 2 shows that the best simulation result of gain obtained while the distance of d array=73 mm with gain of 6.511 dBi at working frequency of 586 MHz for Digital Video Broadcasing Application. From the overall simulation result can be concluded that spiral labyrinth microstrip antenna can achieved return loss≤-10 dB and VSWR≤2 while array method obtained gain of 6.511 dB at working frequency of 586 MHz.

3. Results and Analysis

After we get the best simulation result from iteration process, the next step is to fabricated the proposed antenna. The proposed antenna used FR4 Epoxy substrate with double layer while the spiral labyrinth patch at the top layer and ground plane (full cooper) in the lower layer. The connector that used of the proposed antenna is SMA Connector female type with characteristic impedance of 50 Ohm. The fabricated of proposed microstrip antenna shown in Figure 6.

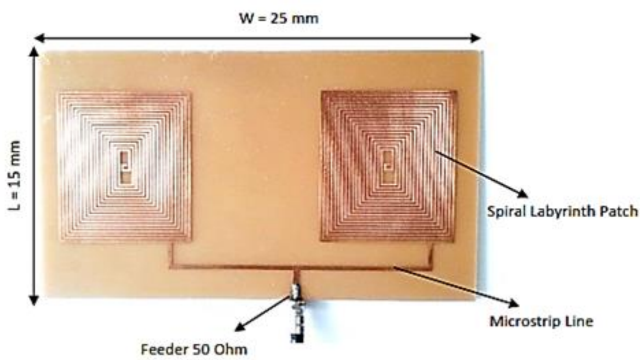


Figure 6. Fabricated of proposed microstrip antenna

The return loss (S_{11}) was measured using 300 kHz-1 GHz Vector Network Analyzer (VNA). An anechoic chamber was used to measure the radiation properties of the fabricated antenna. The equipment that used to measure return loss and VSWR are shown in Figure 7 below.

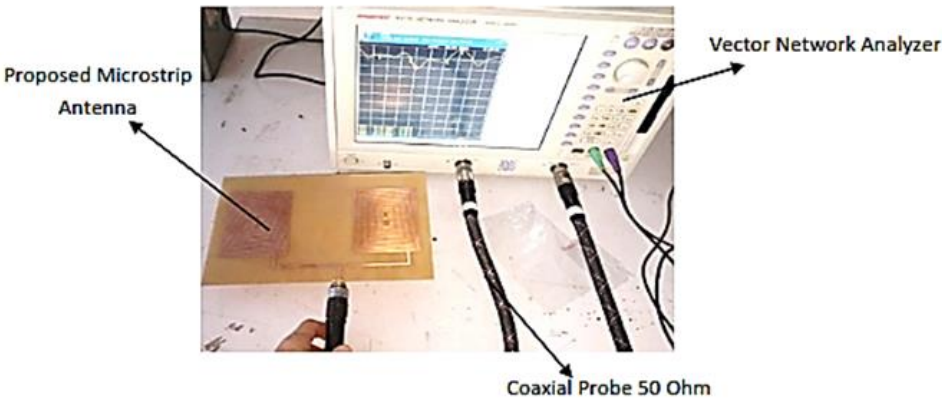


Figure 7. Measurement process of return loss and VSWR

The measurements result of return loss and VSWR that have been done in the laboratory are shown in Figure 8 and Figure 9. Measurements are performed using the ADVANTEST Vector Network Analyzer in the working frequency range of 300 KHz to 1 GHz. The proposed antenna is connected to VNA using a pigtail cable with an impedance of 50 Ohm.

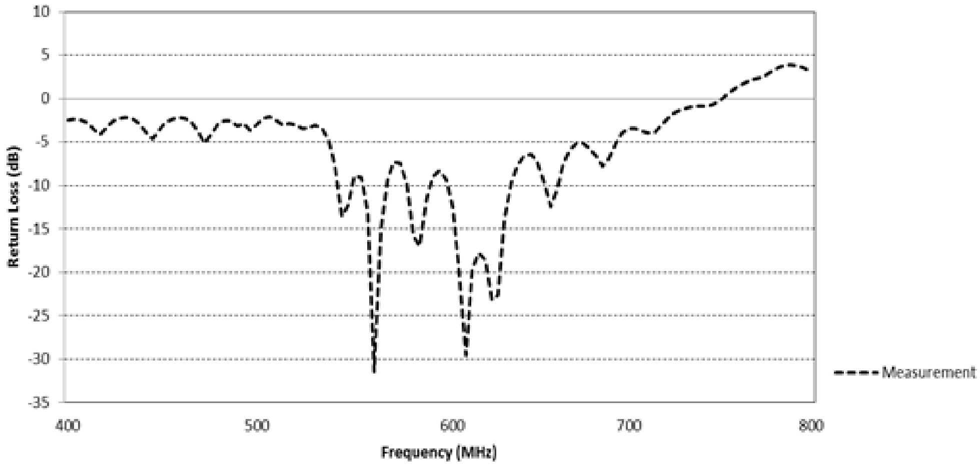


Figure 8. Measurement of return loss

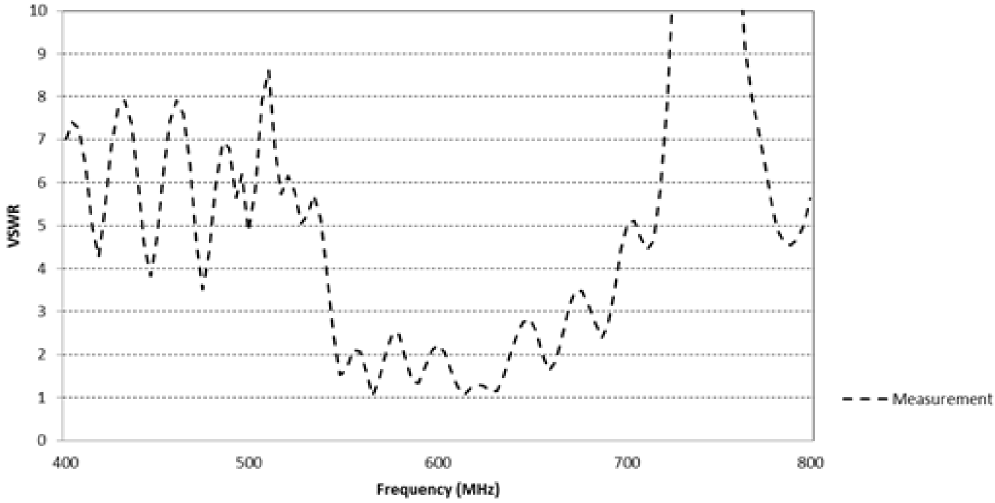


Figure 9. Measurement of VSWR

Figure 8 and Figure 9 shows the measurement result of proposed antenna obtained return loss of -14.145 dB and VSWR of 1.542 at working frequency of 586 MHz. Bandwidth obtained from proposed antenna is 117 MHz with range frequency of 547 MHz–664 MHz. The measurement results indicate that the proposed antenna can be a suitable design for Digital Video Broadcasting application with return loss≤-10 dB and VSWR≤2 at working frequency of 586 MHZ.

The graphic comparison of Return Loss and VSWR are shown in Figure 10 and Figure 11 respectively. Comparison is done by observing the value of the return loss on the proposed antenna obtained from the simulation process and the measurement process in the laboratory. This observation is carried out in the frequency range from 400 MHz to 800 MHz according to the working frequency for Digital Video Broadcasting

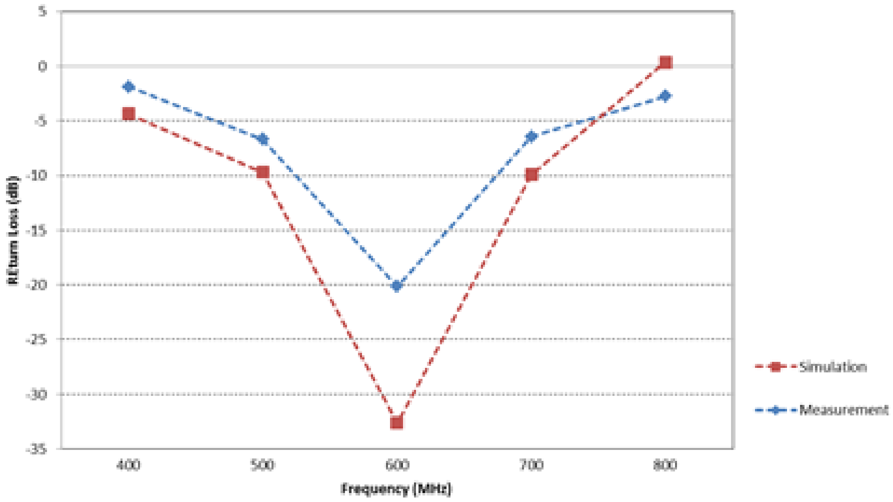


Figure 10. Comparison measurement result and simulation result of return loss

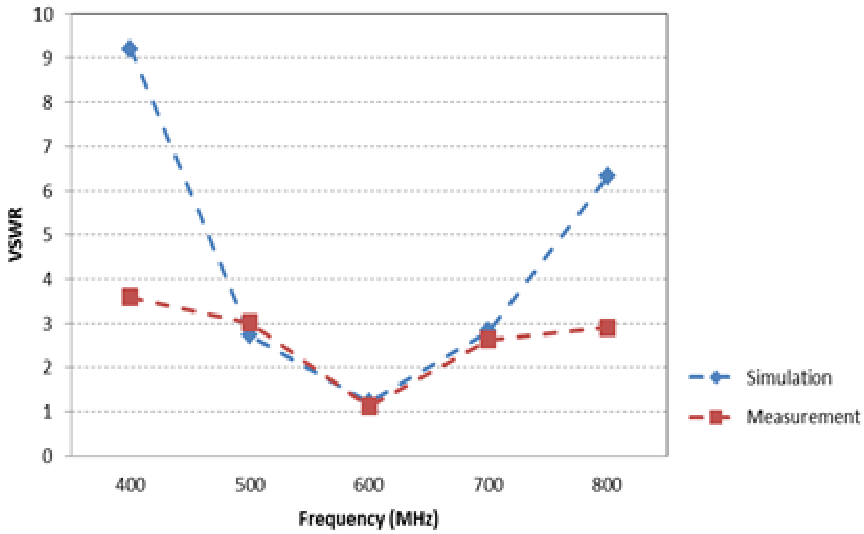


Figure 11. Comparison measurement result and simulation result Of VSWR

The summarize result of comparison between simulated and measured parameter characteristics of proposed antenna is shown in Table 3.

Table 3. Comparison between Simulated and Measured Parameter of the Proposed Antenna

Parameter	Simulation	Measurement
Resonant Frequency	586 MHz	586 MHz
Return Loss	-24.26 dB	-14.145 dB
VSWR	1.138	1.542
Bandwidth	150,7 MHz	117 MHz
Range Of Frequency	513,8 MHz – 664,5 MHz	547 MHz–664 MHz

It is evident from these results that the measured results are different (actually better) in the simulation. This caused by antenna fabrication process which is not 100% equal to the dimensions of the simulation, the imperfection of SMA connector soldering process also the main factor of missallignment result.

The radiation pattern measurement was conducted in the anechoic chamber by using a horn antenna (model SAS-200/571 frequency 700 MHz–18 GHz) as the reference antenna. The RF generator and spectrum analyzer were set to 586 MHz. The far field distance between the reference antenna and measured microstrip antenna has been calculated as 1 meter. The measured microstrip antenna was rotated with a 10^0 increment from 0^0 to 350^0. Figure 12 shows the radiation pattern measurement result from the proposed antenna design with Half Power Beamwidth (HPBW) of 85^0.

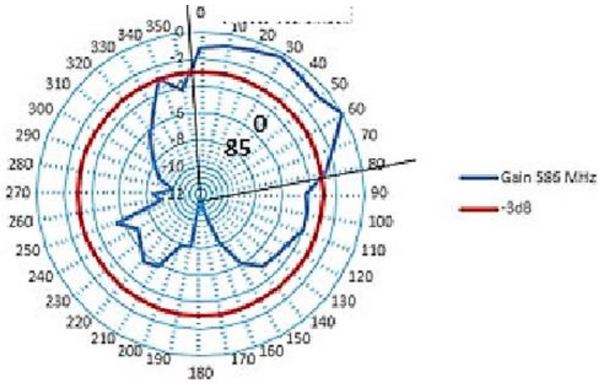


Figure 12. Measurement result of radiation pattern

The gain of the proposed spiral labyrinth antenna (G_T) was calculated by using the following formula [16]:

$$G_T[\text{dBi}] = G_0[\text{dBi}] + P_T[\text{dBi}] - P_0[\text{dBi}] \tag{10}$$

with P_T is the power received by the measured antenna, P_0 is the power received by the reference antenna, and G_0 is the gain of the reference antenna. Given the measurement value of P_T=-22.77 dBi, P_0=-14.24 dBi and G_0=12 dBi, the calculated gain of the proposed antenna at 586 MHz is 7.78 dBi.

After that, the final process is to apply proposed antenna into DVB-T2 application using set top box. The result of field measurement of proposed antenna compared with the yaggi antenna shown in Figures 13 and 14.

Figure 13. Comparison of field measurement of proposed antenna

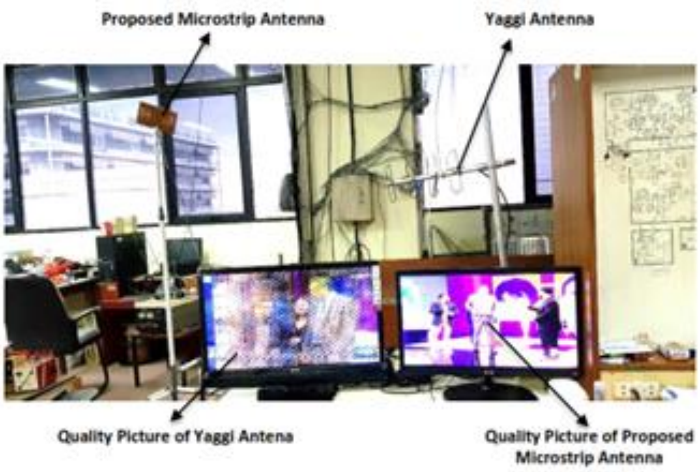
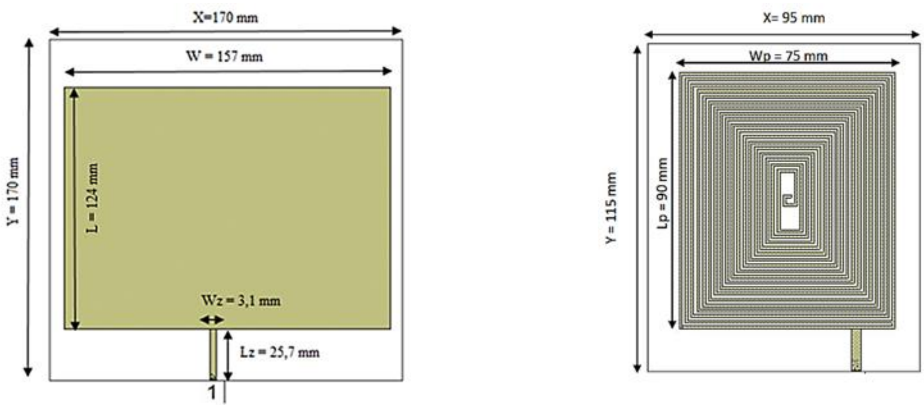


Figure 14. Field measurement of proposed antenna compare with yaggi antenna

From the test results as shown in Figure 13 and Figure 14 indicate proposed microstrip antenna has been successfully applied for Digital TV applications in the Region III DKI Jakarta with the quality picture better that the analogue system. Spyral labyrinth also has been successfully reduced the dimension of microstrip antenna until 65.2 %. Comparison between conventional rectangular patch microstrip antenna with spiral labyrinth microstrip antenna shown in Table 4 and Figure 15.

Table 4. Comparison Dimension between Conventional and Spyral Labyrinth Microstrip Antenna

Dimension Of Conventional Rectangular Patch Microstrip Antenna	Dimension Of Spyral Labyrinth Patch Microstrip Antenna	Percentage of Reduction
(170 x 170) mm	(95x115) mm	62,2 %



(a) (b)

Figure 15. Comparison dimension of conventional microstrip antenna with spryal labyrinth (a) conventional rectangular patch, (b) spiral labyrinth patch

4. Conclusion

A new design of spiral labyrinth of microstrip antenna using array method is eventually well proposed. From the measurement results obtained return loss of -14.145 dB and VSWR of

1.542 at 586 MHz. The working frequency of the antenna can be controlled by adjusting the dimension of Ws. Gain of proposed antenna can be controlled by adjusting the distance of d array. Designed antennas generate 117 MHz bandwidth with a frequency range of 547 MHz–664 MHz. The spiral labyrinth patch succeeded in reducing the dimensions of the microstrip antenna up to 62.2% compared to the rectangular microstrip antenna without changing the working frequency of 586 MHz for Digital Video Broadcasting Application. This study is usefull for DVB-T application in order to achieve the maximum signal quality and picture

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