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Design of Rectangular Microstrip Antenna Using Inset Feed and DGS Methods for Digital Television at 598 MHz Frequency

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ABSTRACT

The development of a microstrip antenna for digital TV applications at the center frequency of 598 MHz has been carried out to meet the needs for optimal signal reception in urban areas such as Surabaya. In this research, a microstrip antenna is designed, simulated, and fabricated to verify its performance. The simulation results show that the antenna has a return loss of -12.27 dB, VSWR 1.639, bandwidth 359 MHz, gain 2.26 dBi, and an omnidirectional radiation pattern. After the fabrication process, antenna performance measurements show a return loss of -25.78 dB, VSWR 1.849, and bandwidth 154 MHz. Discrepancies between simulation and fabrication results are mainly due to manufacturing tolerances and material variations. Nevertheless, the results obtained show that the developed microstrip antenna has good performance and is suitable for digital TV applications at the targeted frequency, with the ability to receive signals omnidirectionally which is very important in dense urban environments.

1. Introduction

1.1. Background

In the current digital era, the need for fast and reliable access to information is increasing, including in terms of television broadcasting. Digital television offers better picture and sound quality compared to analog television, as well as the ability to transmit various types of additional information. One of the important elements in a digital television system is the antenna, which functions to receive signals from the transmitter [1]-[5].

Microstrip antenna is a type of antenna that is widely used in modern communication systems, including digital television. This antenna has several advantages, such as compact size, light weight, relatively low production costs, and ease of integration with other electronic devices. In addition, microstrip antennas can be designed to operate at certain frequencies with optimal performance.

Surabaya, as one of the largest metropolitan cities in Indonesia, has a high need for digital television services. To ensure good signal reception in this area, an antenna design that is appropriate to the broadcast frequency used is required. One of the center frequencies used for digital television broadcasts in Surabaya is 598 MHz.

This frequency is in the UHF (Ultra High Frequency) range, which is commonly used for digital television broadcasting. The design of a microstrip antenna operating at 598 MHz must consider several important factors, including gain, bandwidth, polarization, and radiation pattern. High gain is needed to ensure the signal can be received well even though the distance between the transmitter and receiver is quite far. A wide enough bandwidth will allow the antenna to receive multiple frequencies that are close together, thereby increasing flexibility in signal reception. Proper polarization will maximize compatibility with the transmitted signal, and appropriate radiation patterns will ensure optimal area coverage.

By considering these various factors, research and development of microstrip antennas for digital television in the Surabaya area is very important. The right design will ensure optimal signal reception quality, so that people can enjoy digital television services with the best quality.

1.2. Microstrip Antenna Characteristics

A microstrip antenna is a type of antenna that uses microstrip technology to send and receive electromagnetic waves. These antennas have a variety of unique characteristics that make them suitable for a variety of applications, especially in modern communications systems such as digital television, satellite communications, and wireless devices. [6]-[8] Following are some of the main characteristics of a microstrip antenna:

1. Structure and Composition: A microstrip antenna consists of several basic layers: a dielectric substrate, a conductive patch, and a ground plane. A conductive patch (usually made of copper or other conductive material) is placed on top of the dielectric substrate, while the ground plane is located beneath the substrate. These patches can be rectangular, circular, triangular, or other shapes, depending on the desired application.
2. Size and Weight: One of the main advantages of a microstrip antenna is its small size and light weight. This makes it especially suitable for applications that require compact and portable devices, such as cell phones, drones and medical devices.
3. Ease of Manufacturing and Integration: Microstrip antennas are easy to manufacture using photolithography printing technology, which is also used in the manufacture of printed circuit boards (PCBs). This allows easy integration with other electronic circuits, making these antennas a popular choice in modern electronic device design.
4. Operating Frequency: The operating frequency of a microstrip antenna is determined by the patch dimensions and the dielectric properties of the substrate. These antennas can be designed to operate over a wide range of frequencies, from a few hundred MHz to several GHz, depending on the desired application.
5. Polarization: Microstrip antennas can produce various types of polarization, including linear polarization and circular polarization. Linear polarization can be achieved using rectangular patches or other simple shapes, whereas circular polarization usually requires more complex patch designs or the use of special techniques such as truncation.
6. Gain and Efficiency: Microstrip antennas generally have lower gain compared to other types of antennas such as parabolic or yagi antennas. However, gain can be increased by using a microstrip array, which combines multiple patch elements to increase signal strength. The efficiency of a microstrip antenna is influenced by the nature of the substrate material and the quality of fabrication.
7. Radiation Pattern: The radiation pattern of a microstrip antenna is usually unidirectional or bidirectional, with the main lobe perpendicular to the patch. This radiation pattern can be modified by changing the shape and size of the patch, as well as by adding parasitic elements to direct the radiation energy.
8. Bandwidth: The bandwidth of microstrip antennas is generally narrow, which means they usually work optimally over a limited frequency range. However, techniques such as the use of substrates with low dielectric constants or the design of specially shaped patches can be used to expand the bandwidth.

Impedance and Matching: The input impedance of a microstrip antenna must match the impedance of the source or transmission line to maximize energy transfer and reduce signal reflections. Matching techniques such as the use of impedance transformers or stub matching are often used to achieve this condition.

2. Materials and Methods

2.1. Microstrip Antenna Design

The first step in the design is choosing the desired working frequency, in this design using a working frequency of 538-658 MHz. After that, choose the substrate material that will be used, namely FR-4 Epoxy. After these two things have been done, the antenna design can be carried out, starting from determining the dimensions of the patch, ground plane, substratum and feedline. Further, the design, simulation and optimization are used CST Studio Suite 2019 software. After fabrication, the antenna was tested using a VNA Analyzer and tested on Digital TV.

The preliminary antenna design is calculated using the equation, then the method used is antenna optimization (inset feed) and DGS Defected Ground Structure (DGS), which is by removing some ground plane elements.

2.2. Microstrip Antenna Calculation

The following formula calculations were carried out to obtain the dimensional values of a rectangular single patch microstrip antenna at a centre frequency of 598 MHz. In designing a rectangular microstrip antenna design, there are 5 calculation stages, including determining the patch width, patch length, substrate width, substrate length and supply channel width. For ground plane dimensions, the values are the same as the substrate. And then the ground plane will be cut until the results are as desired [9]-[11].

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$L = L_{eff} - 2\Delta L \tag{2}$$

$$\varepsilon_e = \frac{1}{2}\{\varepsilon_r + 1 + (\varepsilon_r - 1)F\} \tag{3}$$

$$F = \frac{1}{\sqrt{\left(1 + 12\frac{h}{W}\right)}} \tag{4}$$

$$L_{eff} = \frac{c}{2f_r}\frac{1}{\sqrt{\varepsilon_e}} \tag{5}$$

$$\Delta L = 0.412\,h\frac{(\varepsilon_e + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\frac{W}{h} + 0.813\right)} \tag{6}$$

Where, c is the Speed of light 3×108 m/s, W is the Width of the antenna patch, L is the Length of patch antenna, L_{eff} is the Effective length of patch antenna, ΔL is the Excess patch length due to fringing field effect, ε_r is the Substrate dielectric constant, ε_e is the Effective permittivity of the substrate, f_r is the Antenna working frequency (Hz), h is the Substrate thickness (cm), and F is the Logarithmic function of radiating elements.

Finding the patch width on a rectangular microstrip antenna can use equation (1). Next, calculate the patch length of the rectangular microstrip antenna using equation (2) by first finding the effective permittivity of the substrate using (3) and looking for the logarithmic function of the radiation element in equation (4). Once the length and width of the rectangular microstrip antenna patch are known, you can then calculate the length and width of the substrate and ground plane of the rectangular microstrip antenna using the following formula [12][13]:

$$L_g = 2 \times L \tag{7}$$

$$W_g = 2 \times W \tag{8}$$

Where, Lg is the Ground plane length, W_g is the Ground plane width, W is the Width of the antenna patch, L is the Length of patch antenna

The required output impedance of the antenna can affect the size of the feedline on the microstrip antenna. To obtain the width and length of the feedline from a microstrip antenna, the following formula can be calculated [14][15]:

$$Wf = \frac{2h}{\pi}\left\{B - 1 - \text{In}(2\text{B} - 1) + \frac{\varepsilon_{r-1}}{2\varepsilon_r}\left[\text{In}(\text{B} - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} \tag{9}$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} \tag{10}$$

$$\lambda_0 = \frac{c}{f} \tag{11}$$

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \tag{12}$$

$$L_f = \frac{\lambda_g}{4} \tag{13}$$

Information, B is the Constant, Z_0 is the Characteristic impedance (Ω), Wf is the Feed width (mm), ε_r is the Dielectric constant, λ_0 is the Wavelength (m), λ_g is the Transmission Wavelength, and L_f is the Feed length (mm). Next, the specifications for the microstrip antenna design that we have created shown in Table 1.

Table 1. Antenna Specification

No	Parameter	Specification
1	Dielectric Material	FR-4
2	Dielectric Constant	4.3
3	Dielectric Thickness	1.6 mm
4	Patch Material	Copper
5	Patch Thickness	0.035 mm
6	Patch Width	43.67 mm
7	Substrate Length	200 mm
8	Substrate Width	150 mm
9	Ground Length	50 mm
10	Ground Width	150 mm
11	Feedline Width	3 mm
12	Feedline Length	60 mm
13	Inset Width	3.5 mm
14	Inset Length	1 mm

3. Results and Discussion

3.1. CST Studio Suite 2019 Simulation

Fig. 1 shows the square-shaped antenna design using CST software on the front with inset feed optimization with the aim of improving s11. Fig. 2 shows the groundplane that was modified to have a radiation pattern close to omnidirectional.

Fig. 3 shows the s11 (Return Loss) results from the simulation, where a good antenna has a return loss under -10dB. S11 can also describe the working frequency of the antenna by calculating the minimum frequency and maximum frequency under -10dB. VSWR shown in Fig. 4. Radiation pattern and gain shown in Fig. 5.

3.2. VNA Fabrication and Measurement Results

The results of the fabrication and final process from the design process to printing the PCB and becoming a microstrip antenna with a rectangular design are as follows. Antenna front view shown in Fig. 6. Antenna rear view shown in Fig. 7.

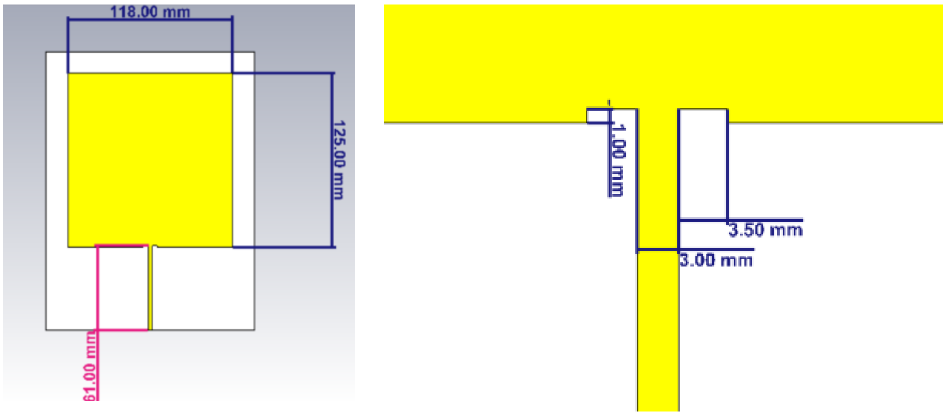

Fig. 1. Patch antenna microstrip and feedline dan inset feed

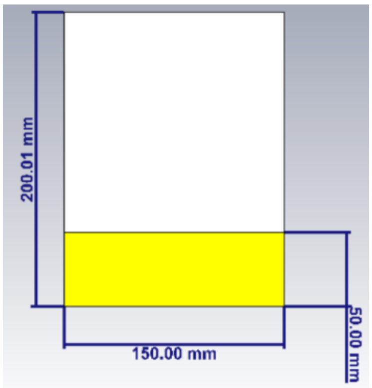

Fig. 2. Groundplane and substrate

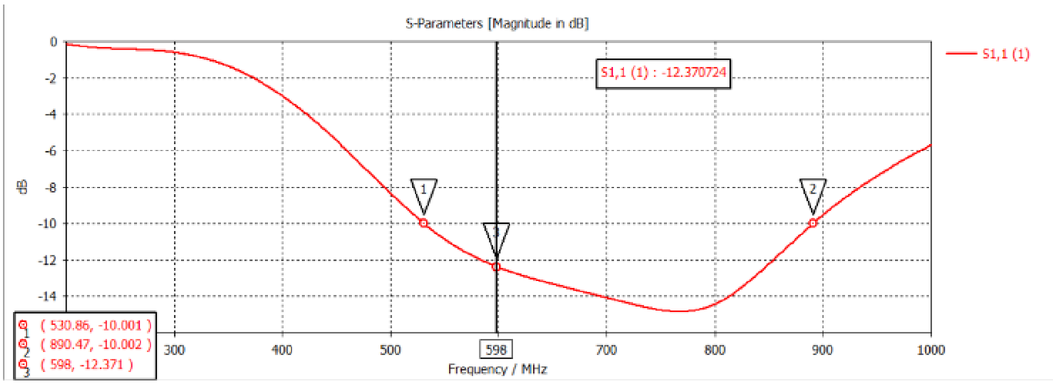

Fig. 3. S1,1 Return loss

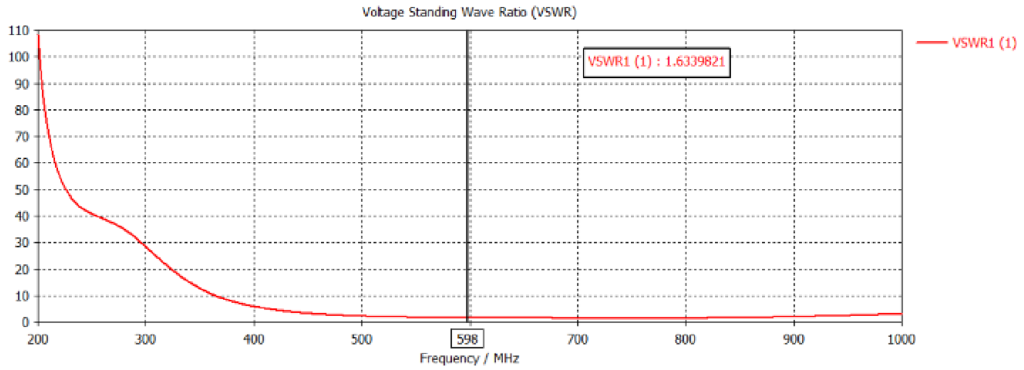

Fig. 4. VSWR

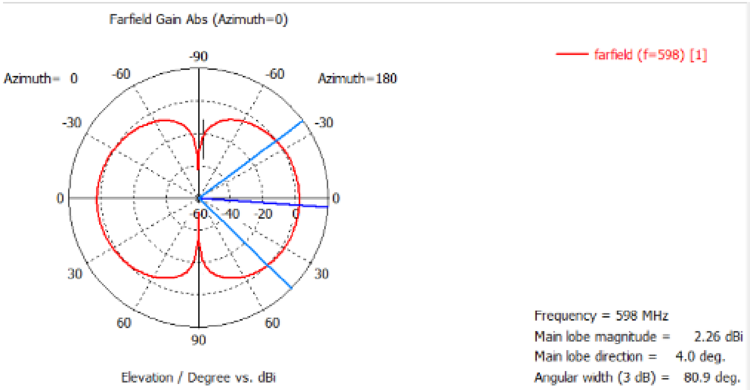

Fig. 5. Radiation pattern and gain

Fig. 6. Antenna front view

Antennas designed for digital TV are initially checked for their s1.1 value and VSWR value. The results from simulation and fabrication measurements have quite significant differences, in section S1.1 return loss shown in Fig. 8 there is an increase in VNA measurements or after fabrication, VSWR decreases shown in Fig. 9 but can still be tolerated, and the bandwidth results obtained from simulation and fabrication results decrease but are still sufficient to used according to the specified parameters. From the results of these checks, it appears that the designed antenna has a fairly good value where the bandwidth obtained is 154. Then the use of the antenna that we have made produces 9 channels on digital TV with images that look clear and pleasant to watch.

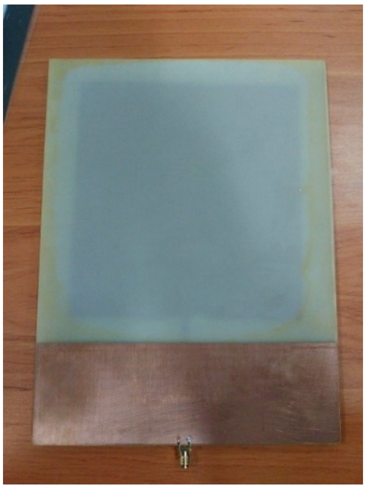

Fig. 7. Antenna rear view

Table 2. Antenna measurements between simulation and fabrication

Parameter	Simulation	Fabrication
Return Loss	-12.37 dBi	-25.78 dBi
VSWR	1.639	1.849
Bandwidth	359 MHz	154 MHz
Gain	2.26 dBi	-
Radiation Patterns	Omnidirectional	-

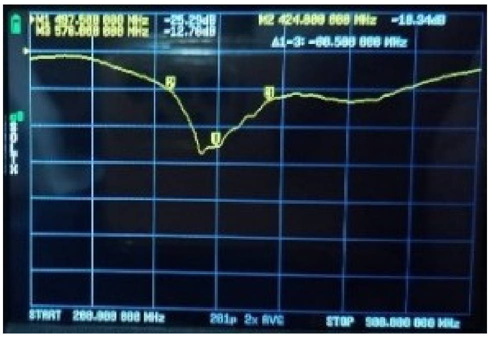

Fig. 8. S1.1 Return loss value

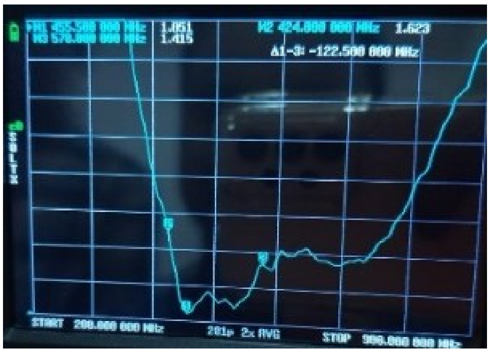

Fig. 9. VSWR

3.3. Experiment with Digital TV

From the results of experiments to digital TV in the Electrical Engineering study program at Trunojoyo University Madura shows the results of scanning channels as many as 9 TV channels including RCTI, TRANS TV, TRANS 7, MNC TV, GLOBAL TV, I NEWS TV, CNN INDONESIA, CNCB INDONESIA, and TV 9. The image produced from this antenna is very clear showing the quality of the signal that is very good. Picture of a digital TV antenna can be seen in Fig. 10.

Fig. 10. Picture of a digital TV antenna

4. Conclusion

Microstrip antennas with rectangular patches using the inset feed method and the DGS method are very good for use as digital TV antennas in the Surabaya area. This is proven by experiments with a microstrip antenna working at a frequency of 424–578 MHz with middle frequency at 598 MHz producing a bandwidth of 154 MHz with an output of 9 channels with an excellent signal.

References

[1] A. H. Ballado *et al*., "Design of indoor microstrip TV antenna for integrated services digital broadcast — Terrestrial (ISDB-T) signal reception at 677 MHz," *2014 International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM)*, pp. 1-6, 2014.

[2] M. D. Arza, Y. S. Rohmah and R. Anwar, "Design and Realization of Linear Array Triangular Patch Microstrip Antenna for Digital Television," *2018 International Conference on Control, Electronics, Renewable Energy and Communications (ICCEREC)*, pp. 226-230, 2018.

[3] A. N. Kulkarni and S. K. Sharma, "Frequency Reconfigurable Microstrip Loop Antenna Covering LTE Bands With MIMO Implementation and Wideband Microstrip Slot Antenna all for Portable Wireless DTV Media Player," *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 2, pp. 964-968, 2013.

[4] T. Pratumsiri and P. Janpugdee, "Development of built-in low-profile antenna for digital television," *2015 IEEE Conference on Antenna Measurements & Applications (CAMA)*, pp. 1-3, 2015.

[5] S. Marini *et al*., "Design Microstrip Patch Ground Mirror Rectangular Slit Horizontal Antenna As DTV Antenna Receiver," *2022 16th International Conference on Telecommunication Systems, Services, and Applications (TSSA)*, pp. 1-6, 2022.

[6] Warren L. Stutzman, Gary A. Thiele, *Antenna Theory and Design*, University of Michigan, Wiley, 1998.

[7] C. A. Balanis, *Antenna Theory: Analysis and Design*, *Wiley*, 1996.

[8] S. Dase, *Antena dan Propagasi: Teori dan Praktik*, *Andi*, 2022.

[9] H. Ai, C. Wu and S. Zhou, "Design and Simulation of Rectangular Microstrip Patch Antenna with 5Gmm-wave Coaxial Line Back-Feed and Microstrip Line Side-Feeds," *2020 5th International Conference on Information Science, Computer Technology and Transportation (ISCTT)*, pp. 179-182, 2020.

[10] C. Jansri, C. Phongcharoenpanich and S. Lamultree, "Double-Fed Rectangular Microstrip Patch Antenna for WLAN Applications," *2018 International Electrical Engineering Congress (iEECON)*, pp. 1-4, 2018.

[11] N. J. Shimu and A. Ahmed, "Design and performance analysis of rectangular microstrip patch antenna at 2.45 GHz," *2016 5th International Conference on Informatics, Electronics and Vision (ICIEV)*, pp. 1062-1066, 2016.

[12] A. Rukmana, A. Hasyim, R. Fauziyah, A. M. Ridwan, T. Romdoni and M. T. A. Hakim, "The Design of A Rectangular Patch Microstrip Antenna 2×2 Element on S-and Frequency for Beach Supervision Radar Applications," *2022 8th International Conference on Wireless and Telematics (ICWT)*, pp. 1-4, 2022.

[13] R. Nagpal, D. S. Dhaliwal and B. P. Garg, "Rectangular microstrip patch antenna parameters calculations using parallel Particle Swarm Optimization technique," *2013 2nd International Conference on Information Management in the Knowledge Economy*, pp. 75-79, 2013.

[14] M. Hardiwansyah, D. N. Purnamasari, “Design and simulation of rectangular patch microstrip antenna with inset feed for ADS-B system,” *Technium: Romanian Journal of Applied Sciences and Technology*, vol. 16, pp. 286-292, 2023.

[15] D. Saha, S. Mandal and K. Purkait, "Design of Rectangular Slotted Microstrip Patch Antenna for 5G Applications at 27GHz," 2022 International Conference on Intelligent Innovations in Engineering and Technology (ICIIET), pp. 15-19, 2022.