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Design of Microstrip Meander Line Antenna for Frequency Resonance 332 MHz on Portable ILS/VOR Receiver for Navigation Aids

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ABSTRACT

The Portable ILS/VOR Receiver (PIR) device is used for conducting Ground Inspection activities. The PIR antenna has traditionally employed a long-dimensioned dipole antenna. The design of the microstrip meander line antenna aims to reduce the antenna's dimensions for easy portability with the PIR device. The microstrip antenna is designed for Glidepath equipment in the frequency range of 328,6 MHz – 335,4 MHz, centered around 332 MHz. With antenna dimensions of 150 mm x 50 mm, simulation results indicate that the microstrip meander line antenna meets the desired standard specifications. At the center frequency of 332 MHz, it achieves a return loss of -19,65 dB, VSWR of 1,23. Bandwidth of 7 MHz and impedance of 48,94 Ω. Moreover, it exhibits an omnidirectional radiation pattern.

Keyword : Microstrip Antenna, Meander Line, Glidepath, ILS

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1. INTRODUCTION

Flight navigation serves as a guide and reference for pilots, aiming to ensure safety during every phase of the flight, starting from takeoff, throughout the air journey, up until the landing process at the destination airport (Irfansyah et al., 2020). ILS is one type of equipment included in flight navigation. ILS is a landing aid tool for aircraft, consisting of 3 (three) sub-system components, namely the ILS localizer, glide path, and markers. One type of ILS is the Glidepath, which operates in the UHF frequency range between 328.6 MHz – 335.4 MHz to determine the landing angle (Siddharth Saxena, 2016).

In accordance with Regulation KP 35 of 2019 concerning Maintenance and Reporting Procedures for Flight Telecommunication Facilities, this regulation addresses the necessary steps in maintaining communication facilities (Kemenhub RI, 2019). Thus, Flight Ground Inspection is required to check the maintenance of flight navigation facilities to be used at the airport. The implementation of ground inspection is carried out using a Portable Instrument Receiver (PIR) (Iswanto, 2022). The purpose of this ground inspection activity is to examine the output signals emitted by the ILS equipment, specifically the GlidePath. The antenna utilized in the PIR device is a dipole-type antenna with dimensions long enough for ease of portability. With the advancement of technology, microstrip antennas have become a choice for various electronic equipment due to their compact and portable design.

In Ester Mella's research (Mella et al., 2019), designing a microstrip dipole antenna in the frequency range of 328,6 MHz to 335,4 MHz showed simulation results that meet specifications at the center frequency of 332 MHz, with a return loss of -25,42 dB and a VSWR of 1,52. Furthermore, in As'ad Muhammad Nashrullah's study (As-ad et al., 2019), designing a microstrip meander line antenna in the UHF band with a center frequency of 924 MHz resulted in a return loss of -27,78 and a VSWR of 1,36. Based on the findings from previous research, the researcher designed a microstrip meander line antenna for the frequency range of 328,6 MHz – 335,4 MHz with a center frequency of 332 MHz for Glidepath equipment. The aim is to achieve parameter results that match the desired specifications, namely a return loss of ≤10 dB and a VSWR of < 2.

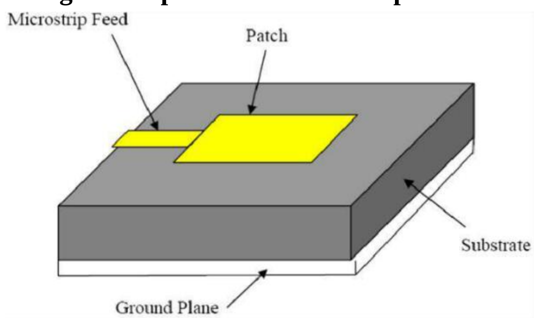
2. REASERCH METHOD

In the design of the microstrip meander line antenna, the researcher employed an experimental method with the aim of testing whether the design process can align with the desired specification standards (Hamid et al., 2021). This microstrip meander line antenna is designed using simulation software that will be created and simulated to evaluate the antenna's performance. In this simulation, the goal is to obtain desired parameter values such as Return Loss, VSWR, Bandwidth, and radiation pattern of the antenna. The design of this microstrip meander line antenna is intended to minimize dimensions for low-frequency usage while achieving parameter results in accordance with the specifications.

A. Design and Theory

In general, an antenna functions as a transducer to convert electromagnetic waves into electrical waves or vice versa (Balanis, 2005). A microstrip antenna is one type of antenna that can be utilized. This antenna consists of several elements, including a ground plane that acts as a reflector for electromagnetic waves, a substrate containing dielectric material to propagate electromagnetic waves, and a patch that serves as the element to radiate electromagnetic waves (Ardianto et al., 2019).

Fig 1. Components of Microstrip Antenna

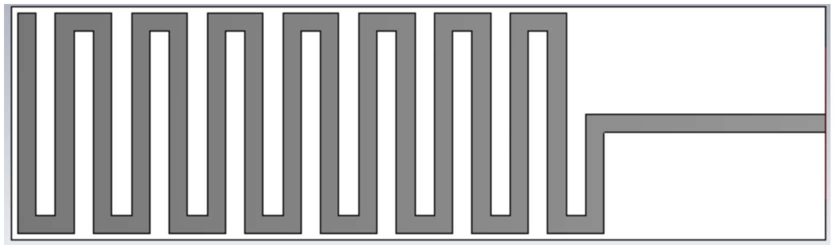


A microstrip antenna is composed of three parts (Tiara Dewi, Muhammad Amir Masruhim, 2016). The Patch is the top part of the substrate, typically made from copper, aluminum, or gold. In this section, electrical and magnetic waves will also be radiated into the air. The Substrate is also called the dielectric as it separates the patch from the ground plane. The substrate comes in various types depending on the value of the dielectric constant (Epsilon r) used, as the antenna size is inversely proportional to the value of this constant. The Ground Plane is the bottom part of the substrate, which functions as a reflector for unwanted signals. Generally, the ground plane covers the entire bottom part of the microstrip antenna.

Meander Line Antenna

Meander line antennas can be created from monopole or dipole lines that are bent to reduce their size. In general, these antennas have the capability to generate multiband signals with narrow bandwidth and low gain, which tends to result in lower efficiency (Sujith & Augustine, 2018). The meander line antenna itself doesn't have a definitive formula for calculating patch dimensions. As a reference for creating meander line antennas, calculations are done using formulas from monopole or dipole antennas (Michel et al., 2018). Once the patch length results are obtained, bending is then applied to reduce the antenna's dimensions (Michel et al., 2012).

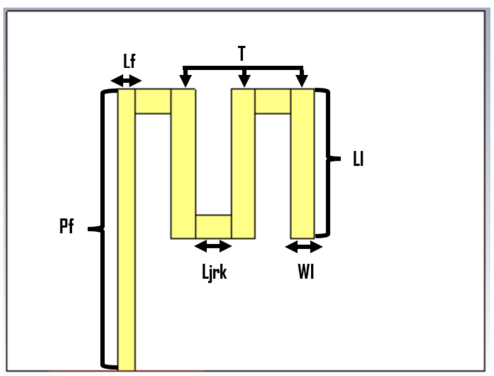
Fig 2. Microstrip Monopole Meander Line Antenna



Size and Number of Lines

The width, length, and number of lines are determined through various simulation experiments using different sizes in software. Subsequently, the results of these simulations are compared to obtain the optimal parameter dimensions (Panangian Mahadi Sihombing, 2021).

Fig 3. Design of Meander Line Antenna



Pf	= Feedline Length
Lf	= Feedline Width
Ljrk	= Distance Between Lines
T	= Number of Lines
Wl	= Line Width
Ll	= Line Length

Substrate and Ground Plane Dimensions

The substrate dimensions of the meander line antenna follow the number of lines on the patch, and the ground plane size is obtained through optimization. For the initial ground plane size, it is taken as 100% of the substrate length.

B. Calculation of Antenna Feedline Dimensions

The main feed of the antenna employs a feedline with a 50 Ω impedance and an SMA female connector. To calculate the width of the main feedline with a 50 Ω impedance (Utami et al., 2021), use the following equation:

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} = \frac{60(3{,}14)^2}{50\sqrt{4{,}3}} = 5{,}70570\ mm \tag{1}$$

The width of the 50 Ω trace can be calculated as follows:

$$W_f = \frac{2h}{\pi}\left\{B - 1 - In(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[In(2B-1)0{,}39 - \frac{0{,}61}{\varepsilon_r}\right]\right\}$$

$$W_f = \frac{2(1{,}6)}{3{,}14}\left\{5{,}7057 - 1 - In(2(5{,}7057)-1) + \frac{4{,}3-1}{2(4{,}3)}\left[In(2(5{,}7057)-1)0{,}39 - \frac{0{,}61}{4{,}3}\right]\right\}$$

$$W_f = 3{,}11\ mm$$

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Next, to calculate the length of the feedline, use the following equation:

$$\frac{W_f}{h} = \frac{3,11}{1,6} = 1,9 > 1$$

Since W = f/h > 1, to calculate the dielectric constant, use the following equation:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12\left(\frac{h}{W_{50}}\right)}}\right]$$

$$\varepsilon_{eff} = \frac{4,3 + 1}{2} + \frac{4,3 - 1}{2}\left[\frac{1}{\sqrt{1 + 12\left(\frac{1,6}{3,11}\right)}}\right] = 3,26$$

After obtaining the value of ε_eff, use the following equation:

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{1,09\ \times 10^9} = 0,275\ m = 276mm$$

$$\lambda_d = \frac{\lambda}{\varepsilon_{eff}} = \frac{276}{\sqrt{3,26}} = 152,72\ mm$$

$$l_f = \frac{\lambda_d}{4} = \frac{152,72}{4} = 38,1\ mm$$

C. Substrate Parameters

In the microstrip meander line antenna design, the determination of substrate parameters used in antenna design is carried out.

Table 1. Substrate Material Specifications

Substrate Type	FR-4 Epoxy
Dielectric Constant	4,4
Substrate Thickness	1,6 mm
Patch thickness	0.035 mm

D. Meander Line Antenna Design Specifications

In this design, there are several antenna parameter specifications for the initial design phase. Here is a table of parameters used for the initial design of the microstrip meander line antenna:

Table 2. Predefined Meander Line Antenna Specifications

Parameter	Mark
Frequency resonance	332 MHz
Return loss	< -10
VSWR	≤ 2
Bandwidth	6.8 MHz
impedance	± 50 Ω

3. RESULTS AND DISCUSSION

The antenna design process is carried out in a software simulator, and then the parameter results are observed after determining the parameters.

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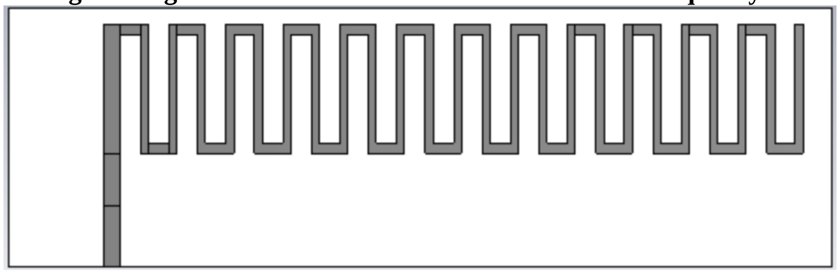
A. Antenna Parameters

Fig 4. Design of Meander Line Antenna at 332 MHz Frequency



The above diagram is a design of a 332 MHz frequency meander line, optimized from dimension calculations using equations and formulas. To achieve optimal results, the calculated antenna dimensions are further subjected to optimization for determining the parameter values of the number of lines, line width, line spacing, and ground plane size. As an initial design for the meander line antenna, the parameters of the lines are based on the length and width of the feedline.

Table 3. Design of Antenna Before Optimization and After Optimization

Parameter	Before Optimization	After Optimization
Feedline length	38,1 mm	47 mm
Feedline width	3,11 mm	3 mm
Line length	19.05 mm	25 mm
Line width	3,11 mm	1,5 mm
Distance between lines	3,11 mm	4 mm
Number of lines	-	24
Substrate length	200 mm	150 mm
Substrate width	80 mm	50 mm
Ground plane length	200 mm	60 mm
Ground plane width	80 mm	2 mm
Patch thickness	0,035 mm	0,035 mm
Substrate thickness	1,6 mm	1,6 mm

B. Simulation Results

As any antenna can be characterized by parameters such as center frequency, bandwidth, radiation pattern, and impedance, we have simulated all of these parameters. The return loss, defined as the ratio of reflected power to incident power (Kumar et al., 2016), has also been simulated. At the center frequency, the return loss is -19,65 dB. With a bandwidth of 7 MHz in the frequency range of 32899 MHz to 335,9 MHz, the return loss is -10,0 dB.

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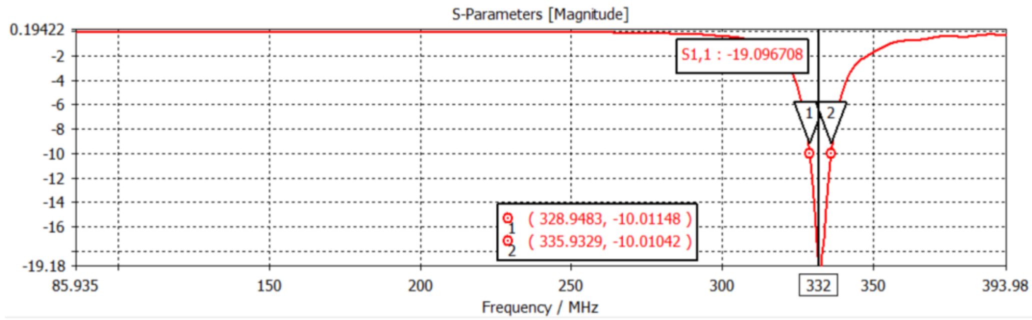
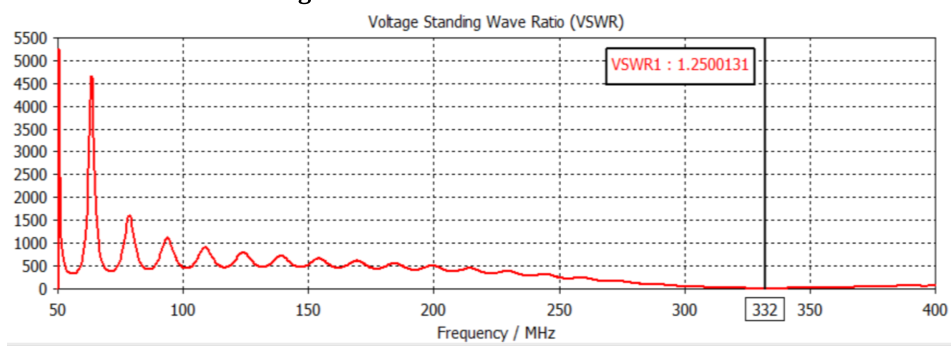


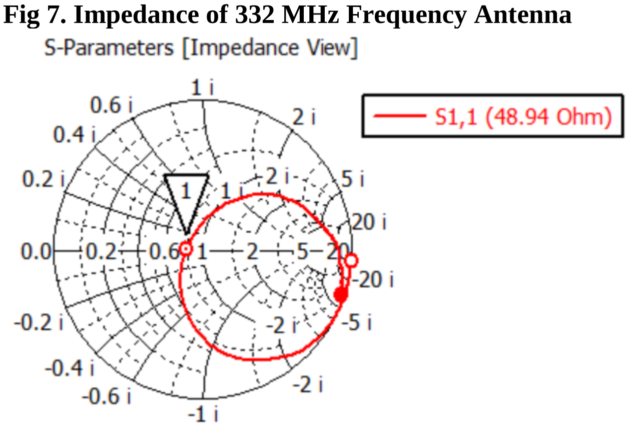
VSWR reflects the level of matching between the transmission line and the antenna. However, the optimal value considered for each antenna to function well is <2. In the simulation, the VSWR at the center frequency of 332 MHz was found to be 1,2.

Fig 6. Simulation Results for VSWR



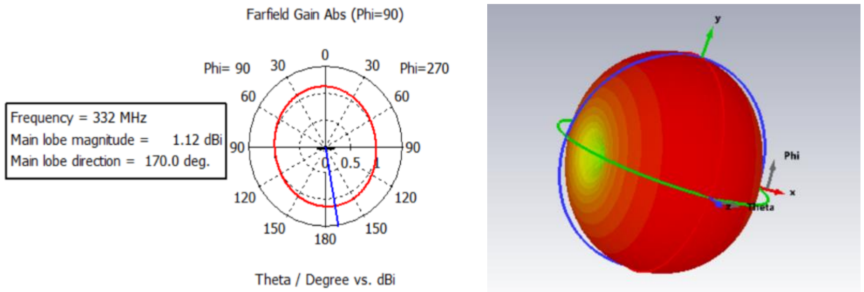
Impedance is a measure of the ratio between voltage and current, or the electric field and magnetic field that corresponds to the orientation of the antenna. The simulation results also show an impedance value obtained of 48.94 Ω. This impedance value is close to the specified specification of 50 Ω.

Fig 7. Impedance of 332 MHz Frequency Antenna



The radiation pattern is a graphical representation of an antenna's radiation characteristics in the far field, dependent on direction. In the simulated microstrip meander line antenna, an omnidirectional radiation pattern was obtained.

Fig 8. Radiation Pattern Results of Meander Line Antenna



4. CONCLUSION

The microstrip meander line antenna design has compact dimensions of 150 mm x 50 mm, with specification parameters in accordance with the defined standard for the Portable Instrument Receiver (PIR) as the Ground Check equipment for Glidepath. Simulation results at the center frequency of 332 MHz show a return loss of -19.65 dB, VSWR of 1.23, bandwidth of 7.3 MHz, and impedance of 48.94 Ω. This design also exhibits an omnidirectional radiation pattern.

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