TECHNIUM

Romanian Journal of Applied Sciences and Technology

ISSN: 2668-778X

vol. 16 / 2023

The 7th International Conference on Science Technology

organized by
Faculty of Social Science and
Law Universitas Negeri Manado and
Consortium of International Conference
on Science and Technology

The Innovation Breakthrough in Digital and Disruptive Era

PLUS COMMUNICATION

International Communication & PR

Technium: Romanian Journal of
Applied Sciences and Technology
Vol. 16, 286-292, October, 2023
ISSN: 2668-778X
www.techniumscience.com

Design and simulation of rectangular patch microstrip antenna with inset feed for ADS-B system

Muttaqin Hardiwansyah [1, a)] Dian Neipa Purnamasari [1, b)]

Author Affiliations

[1] *Department of Electrical Engineering Universitas Trunojoyo Madura Bangkalan, East Java, Indonesia*

Author Emails
[a)] muttaqin.hardiwansyah@trunojoyo.ac.id
[b)] dian.neipa@trunojoyo.ac.id

Abstract. The ADS-B system serves to track the location of aircraft. Ground station in the ADSB system is a receiver system that captures aircraft location signals using frequency 1090. Antenna is a key device for ADS-B communication. This paper is intended to develop a square microstrip antenna that has a working frequency of 1090 MHz. The material used is FR4 substrate, and the dielectric material is chopper. The antenna design is simulated using Matlab's Antenna Toolbox with its various conveniences. The simulation results of the patch antenna design with inset feed optimization resulted in a working frequency close to 1090 MHz, a VSWR value close to 1 and a Gain of 9.59 dBi.

I. INTRODUCTION

Radio Detection And Ranging (RADAR) is an aircraft surveillance system that can track the position of aircraft. However, RADAR still has shortcomings, namely the distance to detect an object is limited, because RADAR uses a reflection system [1]. Therefore, a system was created that can provide more information on aircraft, namely Automatic Dependent Surveillance - Broadcast (ADS-B). ADS-B is a newly developed aviation system that is capable of sensing data such as RADAR. The ADS-B system utilized Global Navigation Satellite System (GNSS) technology to identify the location of the transponders and ground station [2]. The ADS-B receiver system utilizes a carrier frequency of 1.09 GHz, with vertical linear polarization and omni directional radiation pattern [3]. Automatic Dependent Surveillance Broadcast is an aircraft monitoring system used to capture aircraft location, aircraft code, elevation, and related information. regularly emits location information and related data to exchange information with other aircraft, to satellites, and to the ground station. Aircraft that use satellites are equipped with the ADS-B system [4]. There are 2 types of ADS-B, namely ADS-B In and ADS-B Out. Both systems have different functions. ADS-B in capabilities to receive information between aircraft and send information to the ground station or ATC (Air Traffic Control) at the airport. ADS-B out capabilities to obtain route information and the estimated arrival time of each flight, and to provide information on aircraft identity, altitude, speed, and position. [5].

The ADS-B system consists of 3 (three) sub-systems namely: Signal Processing Unit (SPU), Site Monitor (SM) and GPS Rx antenna. a) ADS-B Ground Station AS 680 Each Ground Station A and B consists of the Signal Processing Unit (SPU), Site Monitor (SM) and GPS Rx antenna. A and B consists of Signal Processing Unit (SPU), Site Monitor (SM) and GPS Rx antenna. In general, the SPU will receive signals from the ADS-B antenna containing aircraft data and receive GPS signals as reference data for Timing and Station location [6]. Data output is in the form of ASTERIX Cat 21 format which will be distributed through the computer network system, raw data and video signal monitor. SPU is used to check the equipment directly, by taking data through the antenna monitor probe. Through the control cable to the LCMS, It is possible to know the parameters of the equipment. The GPS receiver uses GPS frequency L1 (1575.42 MHz). The positioning process is based on time reference to produce accurate data. Accuracy is determined by the HPL (horizontal level of protection) which is the same as on the plane. HPL indicates the ability to determine satellite errors, also used to determine position and time as the basis for the timing system [6].

One of the important components in ADS-B RADAR is the antenna. Because the antenna is an electronic device that emits and detects electromagnetic waves. There are several types of antennas, including parabolic, horn, loop, helix and Microstrip Patch Antenna (MPA) or often called microstrip antennas. Microstrip antenna is a kind of antenna that is in the shape of a narrow sheet of metal and is able to operate at very high frequencies. Microstrip antennas are fabricated by using a substrate that consists of three layers of the substrate structure as follows. These layers consist of trace or conductor, dielectric and ground plane[7]. This trace, also called a patch, is the top layer of the substrate, These layers are usually made of conductor. Conductors are usually constructed from a layer of copper, aluminum, or gold. This layer is molded into a specific shape to achieve the desired radiation pattern. Dielectric material is used in the center of the substrate. Thick dielectric has a relative permittivity (ε_r) ranging from 2.2 to 10. To increase the spillover field useful for radiation, the dielectric constant is made low. The ground plane, which has a simple geometric shape, is the bottom layer of the substrate e.g. circle, rectangle, triangle or any other shape that acts as a reflector to eliminate undesirable signals[8].

Microstrip antennas have been widely used in recent years due to their good characteristics. The antenna is widely used in various applications because it has advantages including an easy-to-fabricate design with relatively small size. Behind these benefits are the following, there are weakness of microstrip antennas such as tight fit bandwidth and low gain values [9]. The shortcomings that exist in microstrip antennas can still be improved with certain methods to improve the desired parameter values.

In this research, a microstrip antenna with a patch shape was designed with inset feed optimization resulted in a working frequency close to 1090 MHz, a VSWR value close to 1 and a Gain of 9.59 dBi.

II. METHOD

Formula calculations are carried out to obtain the dimensional value of a single patch rectangular microstrip antenna at a working frequency of 1. 090 MHz. In the design of the rectangular microstrip antenna design, there are 5 stages of calculation, including determining the patch width, patch length, substrate width, substrate length, and supply channel width. For ground plane dimensions, the value is the same as the substrate [10].

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

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

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

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

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

$$\Delta L = 0{,}412\, h\frac{(\varepsilon_e+0{,}3)\left(\frac{W}{h}+0{,}264\right)}{(\varepsilon_e-0{,}258)\left(\frac{W}{h}+0{,}813\right)} \tag{6}$$

In wicth:

c	= The speed of light ($3 \times 10^8\ m/s$)
W	= Width *patch* antenna
L	= Length *patch* antenna
L_{eff}	= Effective lengths patch antenna
ΔL	= Excess patch length due to fringing field effect
ε_r	= Dielectric constant of substrate
ε_e	= Permetivitas efektif substrat
fr	= Effective permeability of the substrate (Hz)
h	= Thick substrate (cm)
F	= Logarithmic function of the irradiating element

Finding the patch width of the rectangular microstrip antenna can use equation (1). Next, calculate the length of the rectangular microstrip antenna patch using equation (3) by first finding the effective permittivity of the substrate using (4) and finding the logarithmic function of the radiating element in equation (2.2c). After 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 [11].

$$L_g = 2 \times L \quad (7)$$

$$W_g = 2 \times W \quad (8)$$

Where is :

L_g = Length of *ground plane*

W_g = Width of *ground plane*

W = Width of the antenna patch

L = Length of the antenna patch

transmission lines that enter the patch (inset-feed) of 1 or 2 mm. For substrate permittivity $2 \leq \varepsilon_r \geq 10$, the calculation of the inset-fed distance from the edge of the patch (y_o), is obtained from the following equation [12].

$$y_o = \frac{L}{2} \times 10^{-4}(0.001699\ \varepsilon_r^7 + 0.13761\ \varepsilon_r^6 - 6.1783\ \varepsilon_r^5 + 93.187\ \varepsilon_r^4 - 682.69\ \varepsilon_r^3 + 2561\ \varepsilon_r^2 - 4043\ \varepsilon_r + 6697) \quad (9)$$

Calculation results using equation (9) are not accurate. It needs to be multiplied by a number s=0.83477 as a correction factor, so we get

$$y'_o = (S) \times \frac{L}{2} \times 10^{-4}(0.001699\ \varepsilon_r^7 + 0.13761\ \varepsilon_r^6 - 6.1783\ \varepsilon_r^5 + 93.187\ \varepsilon_r^4 - 682.69\ \varepsilon_r^3 + 2561\ \varepsilon_r^2 - 4043\ \varepsilon_r + 6697) \quad (10)$$

Where:

L = Length *patch*

y_o = Inset-fed length of the patch edge

S = The correction factor

The required output impedance of the antenna can affect the feedline size of the microstrip antenna. To get the width and length of the feedline of a microstrip antenna, the following formula can be used. [13][14][15].

$$Wf = \frac{2h}{\pi}\left\{B - 1 - In(2B-1) + \frac{\varepsilon_{r-1}}{2\varepsilon_r}\left[In(B-1) + 0{,}39 - \frac{0{,}61}{\varepsilon_r}\right]\right\} \quad (11)$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} \quad (12)$$

$$\lambda_0 = \frac{c}{f} \quad (13)$$

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \quad (14)$$

$$L_f = \frac{\lambda_g}{4} \quad (15)$$

Remarks:

B = Constant

Z_0 = Impedance characteristic (Ω)

Wf = Width of the feed (mm)

ε_r = Dielectric constant

λ_0 = Wavelengths (m)

λ_g = Transmission Wavelength

L_f = Length of feed (mm)

From the simulation in Matlab, the antenna design is obtained which is an application of the above formula in the form of the table below.

Parameters	Microstrip patch	with inset feed
	Nilai (mm)	Nilai (mm)
W (patch width)	12,377 mm	12,377 mm
L (patch length)	12,377 mm	12,377 mm
W_g (substrate and ground width)	27,504 mm	27,504 mm
L_g (length of substrate and ground)	27,504 mm	27,504 mm
W_f (width of feeding channel)	-	0,78583 mm
L_f (Length of feeding channel)	-	1,8336 mm
y_o (inset-feed length)	-	1,3752 mm

III. RESULT AND DISCUSSION

In this research, Matlab Software's antenna toolbox is used to perform simulations. The center frequency of the antenna is expected to be 1,090 Mhz, FR-4 as the substrate element material and copper as the dielectric material. These materials are easily available and affordable. The different antenna designs are described in the figure below. In the left antenna image, the antenna design is square and the right antenna shape is square with an inset feed added as an optimization process.

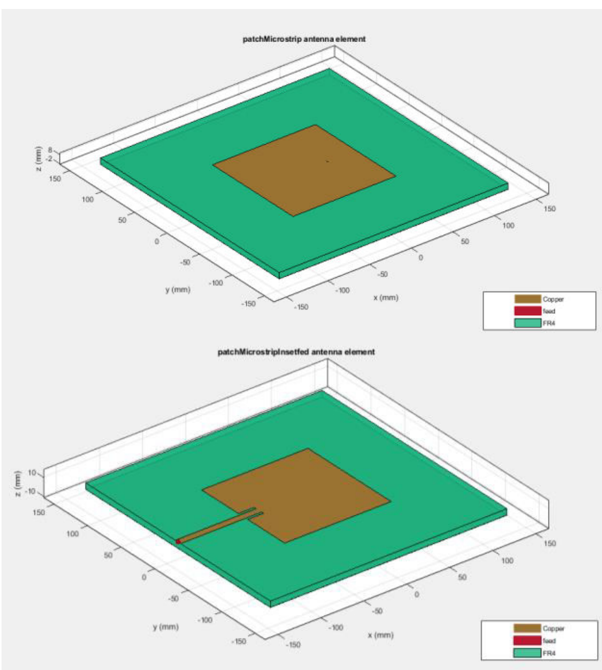

Figure 1. Design antenna rectangular microstrip vs inset feed optimation

The first analysis can be seen from the return loss value or known as the s_{11}. The return loss value can be interpreted as the working frequency of the antenna. If the value exceeds -10dB, it means that at that frequency the antenna can receive signals well. In the first antenna, the best s_11 value was obtained at a frequency of 1,160 MHz,

Technium: Romanian Journal of Applied Sciences and Technology
Vol. 16, 286-292, October, 2023
ISSN: 2668-778X
www.techniumscience.com

while the target of this design is 1,090 MHz. After optimization using the inset feed technique, the working frequency of the antenna design shifts to 1,100 MHz, which means there is an improvement in the working frequency of the antenna.

The second analysis is viewed from the VSWR (Voltage standing wave ratio) value of an antenna is said to be good if it has a value between 1 and 2. Anta patch without optimization has a VSWR value of 25 at a frequency of 1090 MHz, which means that this antenna design is not good when used for ADS-B communication systems. Meanwhile, after the optimization process, the VSWR value at a frequency of 1090 MHz is close to 1, which means that this antenna meets the criteria for a good ADS-B communication system.

Furthermore, in terms of radiation patterns, the antenna designs without optimization and with optimization have almost the same Gain values of 9.29 dBi and 9.59dBi. This means there is no significant difference using inset feed optimization. However, it can be seen in the next figure that the angular width of the radiation pattern in the antenna design after optimization has increased, because the ADS-B communication system model requires a maximum angular width of 180° in order to detect aircraft from all directions.

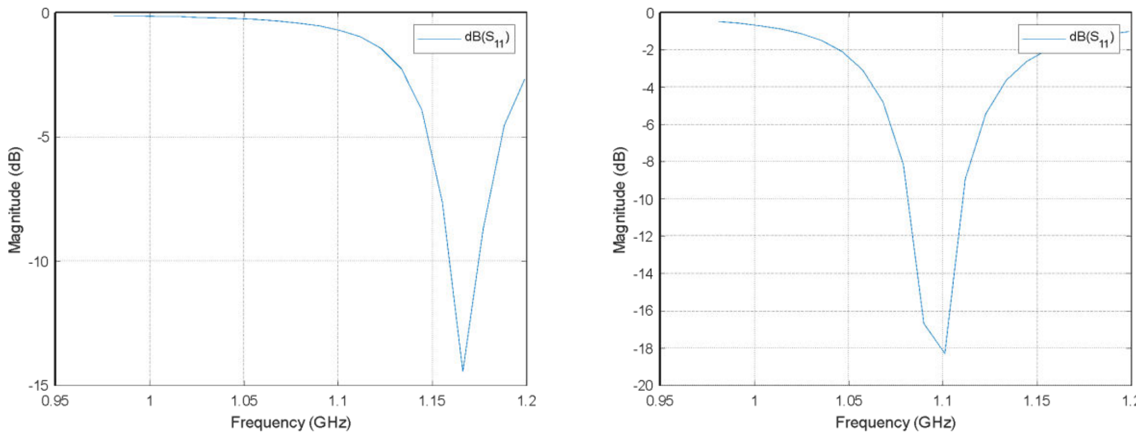

Figure 2. Return Loss antenna rectangular microstrip vs inset feed optimation

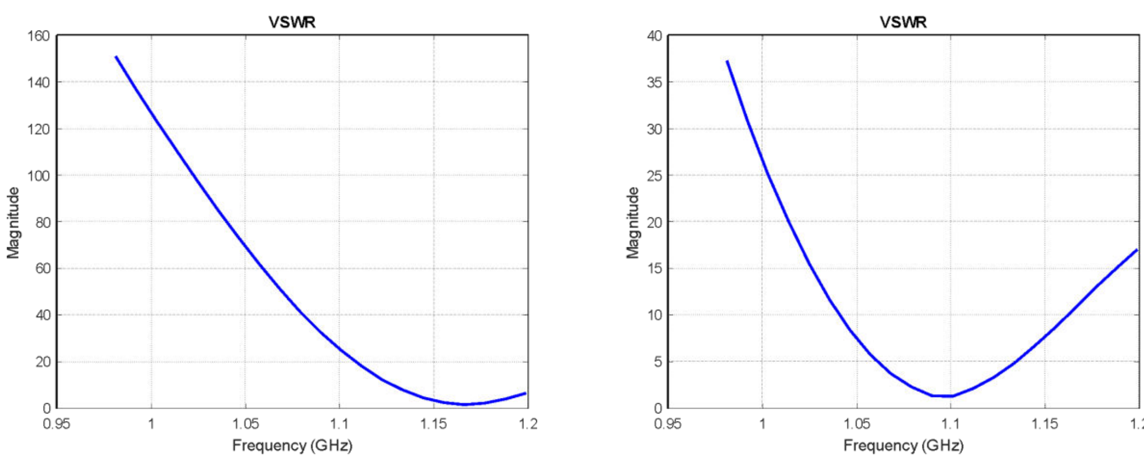

Figure 3. VSWR antenna rectangular microstrip vs inset feed optimation

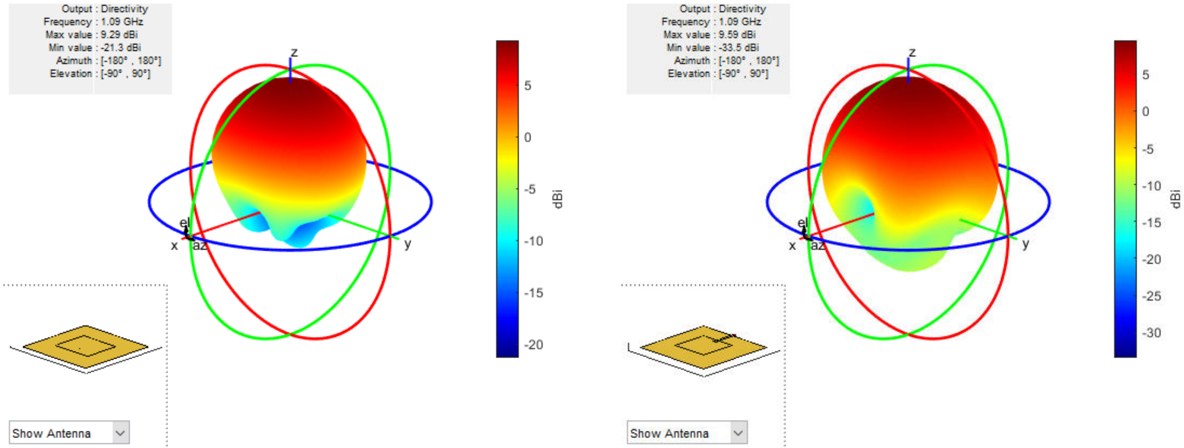

Figure 4. Radiation Pattern antenna rectangular microstrip vs inset feed optimation

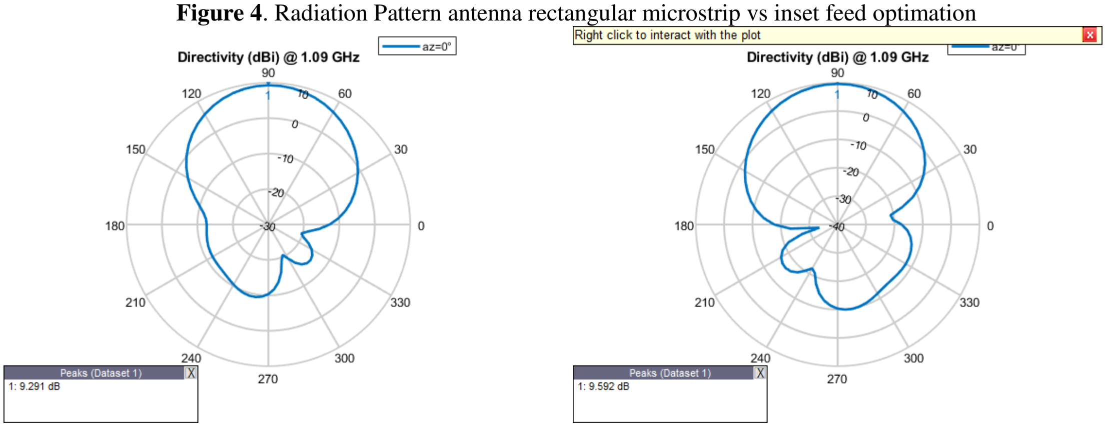

Figure 5. Radiation Pattern elevation of antenna rectangular microstrip vs inset feed optimation

IV. CONCLUSION

This research produces a microstrip patch antenna design for ADS-B communication system, with working frequency close to 1090 MHz, VSWR value close to 1 and Gain 9.59 dBi. The inset feed method can improve the working frequency of the antenna, improve the VSWR value and improve the shape of the radiation pattern which has a wider angle so that it is more optimal if used for ADS-B communication.

REFERENCES

1. B. S. Ali, "System Specifications for Developing an Automatic Dependent Syrveillance-Broadcast (ADS-B) Monitoring System," Int. J. Crit. Infrastruct. Prot., p. 2, 2015.
2. A. Abdulaziz, A. S.Yaro, A. A. Adam, M. T. Kabir, and H. B. Salau, "Optimum Receiver for Decoding Automatic Dependent Surveillance Broadcast (ADS-B) Signals," Am. J. Signal Process., pp. 23–31, 2015.
3. R. Garg, Microstrip Antenna Design Handbook. Artech House, 2001.
4. J. Wiley and Sons, Antenna Theory Second Edition. C. A. Balanis, 1938.
5. Ristekdikti, "Sistem Pemantau Penerbangan Nir Radar Berbasis ADS-B Buatan dalam Negeri," Kementrian Ris. Teknol. dan Pendidik. Tinggi, 2016.
6. F. Gunawan, L. O. Nur, and Edwar, "Perancangan dan Realisasi Antena Mikrostrip Patch Berbentuk L Array Pada Frekuensi 9,4 GHz Untuk Aplikasi Radar Cuaca," e-Proceeding Eng., vol. 6, no. 2, pp. 4555–4562, 2019..

7. H. Madiawati, A. B. Simanjuntak, E. Sulaeman, and M. S. I. Hibban, “Antena Mikrostrip Array untuk Aplikasi Radar Cuaca pada Frekuensi C-Band Menggunakan Metode Defected Ground Structure,” *JTERA (Jurnal Teknol. Rekayasa)*, vol. 7, no. 2, p. 181, 2022, doi: 10.31544/jtera.v7.i2.2022.181-188.
8. B. Pratiknyo Adi Mahatmanto and C. Apriono, “Rectangular Configuration Microstrip Array Antenna for C-Band Ground Station,” 2020.
9. D.-G. Fang, Antenna Theory and Microstrip Antennas. 2009.
10. S. Dase, Antena dan Propagasi, I. Andi, 2022.
11. B. B. Harianto, N. Pambudiyatno, P. Asih, B. Junipitoyo, and P. P. Surabaya, “Desain Antena Mikrostrip Circular Patch Menggunakan Insert Feeding Pada Frekuensi L-Band Untuk Aplikasi Psr,” *J. Penelit. Politek. Penerbangan Surabaya Ed. XXX*, vol. 5, no. 4, pp. 240–249, 2020.
12. B. Malik, Praveen, Kumar; Padmanaban, Sanjeevikumar; Holm-Nielsen, Jens, Microstrip Antenna Design For Wireless Application. CRC Press, 2022.
13. F. Amelia, Y. G. Adhiyoga, F. Yuli Zulkifli, and E. T. Rahardjo, “Microstrip antenna design with dual linear polarizations for X-band weather radar applications,” Proc. - 2018 Int. Conf. Radar, Antenna, Microwave, Electron. Telecommun. ICRAMET 2018, pp. 90–93, 2018, doi: 10.1109/ICRAMET.2018.8683910.
14. R. Rianza et al., “Antena Vivaldi Konvensional untuk Penerapan pada Radar Cuaca (9.4 GHz),” Elektron J. Ilm., vol. 14, no. April, pp. 1–6, 2022, doi: 10.30630/eji.14.1.236.
15. D. Christviyana, H. Wijanto, and Y. P. Saputera, “Antena Array 2x2 Dengan Polarisasi Ganda Untuk Radar Cuaca X-Band,” e-Proceeding Eng., vol. 6, no. 2, pp. 3550–3558, 2019.