Design and Performance Analysis of Sideband Microstrip Antennas on the Doppler VHF Omnidirectional Range

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Abstract. The proliferation of the digital world makes it easier for us to design even to create an antenna. Antennas that are developed to be used as research in the last deck are microstrip antennas, microstrip antennas have 3 parts, namely patches, grounds, and substrates, microstrip antennas have various types including square, rectangular, triangle, microstrip antennas have many advantages including lightweight, relatively cheap costs and flexible for many frequencies. In the world of antenna aviation is a vital part, DVOR has 49 antennas of the Alford loop type that work 108–118 MHz. This study aims to create an antenna with a frequency of 113 MHz and compare several parameters with the antenna Alford loop on DVOR. This design uses a rectangular microstrip antenna that has a substrate thickness of 1.6 mm, a patch thickness of 0.035 mm, a patch length of 846 mm, and a ground length of 1000 mm. The comparison between microstrip antennas with a frequency of 113 MHz and Alford loop antennas has a fairly significant difference in the return loss parameter (S11) the Alford loop antenna has a value of −26.02 dB while on the antenna −0.00083855236 dB. The next parameter is the VSWR antenna Alford loop when measured has a value of 1.1, while the microstrip antenna has a value of 20715.205.

Keywords: Microstrip Antenna · Alford Loop Antenna · DVOR

1 Introduction

DVOR is an air navigation aid that functions to provide information to the aircraft to navigate precisely on the intended airport track by sending information in the form of azimuth angles and artificial bearings to the aircraft against the DVOR (Doppler VHF Omnidirectional Range) transmitter located at the airport. The DVOR antenna will emit waves in all directions that the aircraft will receive and allow the pilot to determine the direction and destination of his flight to airports that are within his coverage area. This device works on a Very High Frequency (VHF) type frequency band which is within a frequency range of 30–300 MHz, while DVOR itself has a working frequency distance of 108.0–117.95 MHz with a maximum coverage area of 175 NM (315 km) at an altitude

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of 37500 feet and on DVOR the signal emitted is Line of sight or inline with the eye view.

DVOR has 49 antennas that function divided into two, namely sideband antennas and carrier antennas. Sideband antennas and antenna carriers use Alford Loop type antennas, where there are 48 sideband antennas located around the antenna carrier, while the antenna carriers are only 1 piece in the middle of a circle with a diameter of 13.5 m. The sideband antenna is used to emit LSB (Lower sideband) and USB (Upper sideband) sideband signals in the form of RF continuous wave with a carrier frequency of +9960 Hz for USB and −9960 Hz for LSB, thereby producing FM (Frequency Modulation) in the air. Alford loop-type sideband carrier antennas are used to emit Omni-directional on a horizontal plane. Forty-eight sideband antennas are installed at intervals of 7.5° on the perimeter of the 6.76 m circle (standard 113 MHz) of the carrier wave antenna. In the case of sideband antennas, the power is fed sequentially in the opposite direction to the clock has a rotational effect. Each sideband antenna, according to the order of the power feed, is numbered 1 to 48, starting from the antenna to the north of the magnet '1'. Alternating sideband antenna beams will produce an FM signal at each point after going through the FM detector in different phases. The different phases will be translated into information on the direction of the aircraft with indicators to or from the airport.

Microstrip antennas are a type of antenna that is in the form of a thin board and can work at very high frequencies. There are three main parts in microstrip antennas, namely the antenna patch section, a dielectric substrate, and the antenna ground plane. In this study, the microstrip antenna used was the one with a working frequency of 113 MHz (middle frequency DVOR 108 −118 MHz), with a gain of plus-minus 6 dB, directional radiation patterns, and horizontal/vertical linear polarization for DVOR sideband antenna applications.

The most populous parameters on microstrip antennas include; S-Parameter used to characterize a high-frequency circuit in place of an impedance or reception parameter. It is used to model the linear N-port of the electrical network [1], while the feedline is used for the link between the working patches of receiving or emitting electromagnetic waves [2–5]. Furthermore, impedance matching is one of the significant applications that play an important role in improving system performance. To guarantee the maximum power is transferred between the source and the sink of a system it is ensured that they match correctly [6]. Determination of the width on the patch (Wp) using the formula [7–11]:

$$\mathrm{W} = \frac{c}{2f_o\sqrt{\frac{(\varepsilon r+1)}{2}}} \tag{1}$$

where c is the speed of light and f0 is the desired frequency value while εr is the dielectric constant of the material used. The calculation of the patch length uses the formula [12]:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{\sqrt[2]{1 + \frac{12h}{W}}} \tag{2}$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon reff}} \tag{3}$$

$$\mathrm{L} = L_{eff} - 2\Delta\mathrm{L} \tag{4}$$

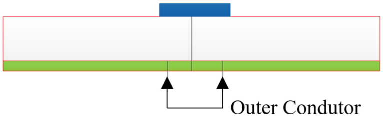

Fig. 1. Microstrip feed probe

where ε the chorus is the value of the effective dielectric constant and Leff is the value of the effective patch length and L is the actual patch length. The commonly used feeding connection method is coaxing or what we usually call a microstrip feed probe, in this type of splicing technique, namely connecting ground and patches through feeds in the antenna dielectric [13]. The connected patches through the feed that passes through the dielectric and ground materials, in Fig. 1 is a picture of the microstrip feed probe seen from the side of the antenna.

The advantage of the feed probe method is that the chances of spurious radiation will be very small, thus making the antenna more efficient and its implementation is relatively easy, making this splicing technique often used by researchers to create a study [14]. To determine the coordinates of the probe location can use the equation below [15].

$$X_f = \frac{L}{\sqrt[2]{\varepsilon_{reff}}} Y_f = \frac{W}{3\sqrt[2]{\varepsilon_{reff}}} \tag{5}$$

where Xf is the location on the x-axis and L is the length of the antenna patch and Yf is the location on the y-axis and W is the width of the antenna patch. Furthermore ground plane The last or very lower part of the substrate is the ground plane is usually made of a conductor material that serves as a reflector reflecting unwanted signals [16]. To determine the length of the ground plane use the formula:

$$L_g = 2xL \tag{6}$$

As for determining the formula of the width of the ground plane using the formula:

$$W_g = 2xW \tag{7}$$

Measurements on the antenna Alford loop use several formulas, measurement of reflected coefficient parameters with the formula:

$$\Gamma = \frac{v^{0-}}{v^{0+}} = \frac{Z_l - Z_0}{Z_l + Z_0} \tag{8}$$

The next formula is in the return loss parameter using the equation:

$$RL(dB) = 20log|\Gamma| = 10log\left(\frac{P_i}{P_r}\right) \tag{9}$$

Comparison of the characteristics of the Alford Loop Antenna and Microstrip Antenna in the use of the Sideband DVOR Mopiens 220 Antenna results in performance analysis from the parameter side as a good antenna function. Some of the antenna parameters in question are scattering, reflection coefficient, return loss, VSWR, bandwidth, radiation pattern, gain, directive, and polarization.

2 Methods

This research used 3 research methods, namely:

2.1 Field Study

Researchers measured the DVOR antenna with a VNA (virtual network analyzer) device owned by the aviation polytechnic campus. DVOR with the mopiens 220 brands has antenna specifications like Table 1.

It can be seen in Table 1 the specifications of the dvor mopiens 220 antenna that irradiates the signal that has formed on the transmitter.

2.2 Literature Studies

Researchers compared and analyzed a previous research journal compiled by totok warsito in 2019 with a study entitled "Design of Alternative Microstrip Antennas sideband Doppler VHF Omnidirectional Range Antennas at a Frequency of 113 MH", here is a comparison in Table 2.

It can be seen in Table 2 that the previous study was the same, namely using an alfred loop type DVOR antenna that worked at a frequency of 113 MHz, but the difference from the previous study was that it analyzed the differences in parameters shown between antennas.

Table 1. Specification of Alford Loop Antenna

No	Specifications	Information
1	Configuration	1 carrier antenna + 48 sideband antenna
2	Antenna type	Alford Loop Antenna
3	Physical dimension	Diameter: 0.8 m Height: 1.2 m–1.4 m
4	Working Frequency	108,000–117,975 MHz
5	Working temperature	– 40 ± 70 °C
6	Polarization	> 40 dB

Table 2. Comparison with previous studies

Previous Research	Difference	Equation
Microstrip Antenna Design Alternative Sideband Doppler VHF Omnidirectional Range Antenna at 113 MHz Frequency	Analyze the differences in detail the paramaeter used such as, S11, Reflective Coefficient, Return Loss and VSWR	The same uses an Alfred loop type DVOR antenna with a working frequency of 113 MHz

2.3 Simulation Studies

The simulation study was carried out using the first 2 measuring instruments, namely:

2.3.1 CST Simulation

Simulation is carried out using CST software with several measured parameters such as S11, VSWR, Bandwidth, and others.

2.3.2 VNA Simulation

Simulation is carried out when the antenna has been fabricated using a VNA (vector network analyzer) tool.

3 Result and Discussion

Transmitter settings on the Marconi Instrument Signal Generator 2230 are in the form of a certain frequency with a certain RF Level setting also to then measure the Receiver RF Level received in nav analyzer 7710 at the same frequency according to Table 3.

Seen at a frequency of 113 MHz the output of the transmitter emits a value of −20 dBm and the receiver receives a value of −39 dBm. The size of the antenna on the microstrip antenna made which has been calculated using the formula discussed in the previous discussion, here is the size of the antenna to be made (Table 4).

Table 3. Microstrip Antenna Level RF Measurements

Transmitter (Setting)		Receiver (Measurement)	
Frequency (MHz)	RF Level (dBm)	Frequency (MHz)	RF Level (dBm)
108	−10	108	−31
108	−20	108	−49
108	−30	108	−61
109	−20	109	−44
110	−20	110	−42
111	−20	111	−40
112	−20	112	−38
113	−20	113	−39
114	−20	114	−37
115	−20	115	−37
116	−20	116	−40
117	−20	117	−40
118	−20	118	−43

Table 4. Microstrip antenna sizes

Name	Value	Information
Hs	1.6 mm	Substra Thickness
Ht	0.035 mm	Patch Thickness
L	846 mm	Patch Length
Lf	423 mm	The location of the feed from the length of the patch
Lg	1000 mm	Ground length
W	612 mm	Patch Width
Wf	143 mm	Feed location from patch width
Wg	800 mm	Ground width

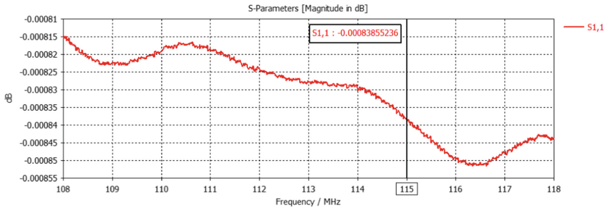

Fig. 2. S-Parameter Measurements

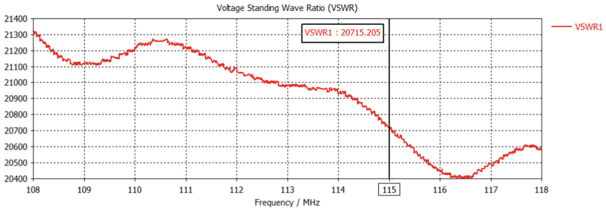

Fig. 3. VSWR Measurements

After determining the size of the microstrip anten we take the next measurement, namely the measurement of the S-Parameter (S11) on the microstrip antenna.

In Fig. 2 is a measurement for the S-Parameter on the microstrip antenna which has a value of −0.00083855236, the next measurement is VSWR, the result can be seen in Fig. 3.

In Fig. 3 is a measurement for VSWR on a microstrip antenna which has a value of 20715,205, the next measurement is gain, the result can be seen in Fig. 4.

While the results of measurements on the antenna alfrod loop using the equation described above are shown in the Table 5.

Table 5 has a voltage reflection coefficient value of 10 dB and 13 dB while the value of return loss has a value of −26.02 dB and VSWR has a value of 1.1.

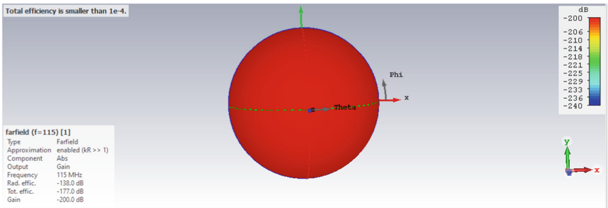

Fig. 4. Gain Measurement

Table 5. Alfordloop uran antenna scraping

Parameters	Value
Voltage reflection coefficient	1. At the time: 20 mW i.e.:10 dB v^{0+} 2. At the time: 32 mW i.e.:13 dB v^{0+}
Return Loss	−26.02 dB
VSWR	1.1
Bandwitdh	26.02%
RBW (Resolution Bandwidth)(span/10000)	10 kHz

4 Conclusion

Analysis of performance results from microstrip antenna simulations working at DVOR frequencies showed less than optimal results, based on the readings of the antenna parameters, so that the microstrip antenna could not replace the alford loop antenna on the DVOR.

References

1. T. Kshitija, S. Ramakrishna, S. B. Shirol, and P. Kumar, “Micro - Strip patch antenna using various types of feeding techniques: An implementation,” *Proc. Int. Conf. Intell. Sustain. Syst. ICISS 2019*, Iciss no. 318–322, 2019, https://doi.org/10.1109/ISS1.2019.8908066.
2. X. Zhao and S. Riaz, “A Dual-Band Frequency Reconfigurable MIMO Patch-Slot Antenna Based on Reconfigurable Microstrip Feedline,” *IEEE Access*, vol. 6, no. c, pp. 41450–41457, 2018, https://doi.org/10.1109/ACCESS.2018.2858442.
3. Z. Bao, Y. X. Guo, and R. Mittra, “An Ultrawideband Conformal Capsule Antenna With Stable Impedance Matching,” *IEEE Trans. Antennas Propag.* , vol. 65, no. 10, pp. 5086–5094, 2017, https://doi.org/10.1109/TAP.2017.2741027.
4. A. F. Alsager, “Design and Analysis of Microstrip Patch Antenna Arrays,” *Msc. Thesis , Univ. Coll. Boras, Sch. Eng.* , no. 1, pp. 1–80, 2011.

5. A. Elrashidi and K. Elleithy, Hassan Bajwa, "Input Impedance, VSWR and Return Loss of a Conformal Microstrip Printed Antenna for TM01 mode Using Two Different Substrates," *Int. J. Networks Commun.* , vol. 2, no. 2, pp. 13–19, 2012, https://doi.org/10.5923/j.ijnc.20120202.03.
6. R. Satyanarayana and Shankaraiah, "Performance enhancement of probe feed microstrip patch antenna for wireless applications," *Int. Conf. Electr. Electron. Commun. Comput. Technol. Optim. Tech. ICEECCOT 2017*, vol. 2018-Janua, pp. 135–140, 2018, https://doi.org/10.1109/ICEECCOT.2017.8284654.
7. A. Kumar, N. Gupta, and P. C., "Gain and Bandwidth Enhancement Techniques in Microstrip Patch Antennas - A Review," *Int. J. Comput. Appl.* , vol. 148, no. 7, pp. 9–14, 2016, https://doi.org/10.5120/ijca2016911207.
8. M. V. Mokal, P. S. R. Gagare, and D. R. P. Labade, "Analysis of Micro strip patch Antenna Using Coaxial feed and Micro strip line feed for Wireless Application," *IOSR J. Electron. Commun. Eng.* , vol. 12, no. 03, pp. 36–41, 2017, https://doi.org/10.9790/2834-1203033641.ACM, 1984, pp. 51–63. https://doi.org/10.1145/800057.808665
9. Y. Wang, Y. Lu, G. Lu, W. Cao, and A. A. Kishk, "Broadband Patch Antenna with Narrow Width Ground Plane," *2018 IEEE Antennas Propag. Soc. Int. Symp. Usn. Natl. Radio Sci. Meet. APSURSI 2018 - Proc.* , pp. 1735–1736, 2018, https://doi.org/10.1109/APUSNCURSINRSM.2018.8609024.
10. H. Werfelli, K. Tayari, M. Chaoui, M. Lahiani, and H. Ghariani, "Design of rectangular microstrip patch antenna," in 2016 2nd International Conference on Advanced Technologies for Signal and Image Processing (ATSIP), Mar. 2016, pp. 798–803. https://doi.org/10.1109/ATSIP.2016.7523197.
11. M. Bugaj, J. Law Bugaj, and R. Borkowski, "Microstrip Wideband Antenna with Rectangular Patch," 2016.
12. A. Elrashidi and K. Elleithy, Hassan Bajwa, "Input Impedance, VSWR and Return Loss of a Conformal Microstrip Printed Antenna for TM01 mode Using Two Different Substrates," International Journal of Networks and Communications, vol. 2, no. 2, pp. 13–19, 2012, https://doi.org/10.5923/j.ijnc.20120202.03.
13. R. Satyanarayana and Shankaraiah, "Performance enhancement of probe feed microstrip patch antenna for wireless applications," International Conference on Electrical, Electronics, Communication Computer Technologies and Optimization Techniques, ICEECCOT 2017, vol. 2018-Janua, pp. 135–140, 2018, https://doi.org/10.1109/ICEECCOT.2017.8284654.
14. A. Kumar, N. Gupta, and P. C., "Gain and Bandwidth Enhancement Techniques in Microstrip Patch Antennas - A Review," International Journal of Computer Applications, vol. 148, no. 7, pp. 9–14, 2016, https://doi.org/10.5120/ijca2016911207.
15. Ms. V. Mokal, P. S. R. Gagare, and Dr. R. P. Labade, "Analysis of Micro strip patch Antenna Using Coaxial feed and Micro strip line feed for Wireless Application," IOSR Journal of Electronics and Communication Engineering, vol. 12, no. 03, pp. 36–41, 2017, https://doi.org/10.9790/2834-1203033641.
16. Y. Wang, Y. Lu, G. Lu, W. Cao, and A. A. Kishk, "Broadband Patch Antenna with Narrow Width Ground Plane," 2018 IEEE Antennas and Propagation Society International Symposium and USNC/URSI National Radio Science Meeting, APSURSI 2018 - Proceedings, pp. 1735–1736, 2018, https://doi.org/10.1109/APUSNCURSINRSM.2018.8609024.