International Journal of Engineering & Technology, 7 (3.14) (2018) 333-336

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Performance Analysis of Discone Antenna for Radio Frequency Interference (RFI) Measurement

R. Umar[1], S. N. Hazmin[2*], M. S. Marhamah[1], A. A. Aziz[3], M. A. N. Zulaikha[1], A. R. S. N. Dianah[2], M. Roshidah[2], M. T. Ali[3], N. H. Abd Rahman[5], A. N. Dagang[4], H. Jaafar[5], M. K. A Kamarudin[1], M. E. Toriman[6]

[1]East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia
[2]School of Fundamental Science, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia
[3]Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[4]School of Ocean Engineering, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia
[5]Faculty of Electrical Engineering, Universiti Teknologi MARA, 23000 Dungun, Terengganu, Malaysia
[6]Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
**Corresponding author E-mail: norhazmin@umt.edu.my*

Abstract

Radio signal is basically generated from natural sources and human daily activity. In detecting radio astronomical signals from outer space, radio frequency interference (RFI) level monitoring and management are required to avoid the signal's disturbance for better radio astronomical observation. RFI profile need to be developed and the measurement should be done using appropriate antenna. Using an appropriate antenna is vital, so the signals detected are strong. This paper verified the performance of discone antenna for RFI study for Hydrogen line (HI). Three stages were performed: antenna simulation using Computer Simulation Technology (CST) Studio Suite software, antenna measurements done in anechoic chamber and RFI survey at Balai Cerap Kusza (BCK). Antenna simulation and measurement were then compared. We found that optimized frequency ranges are between 1.38 GHz and 2.14 GHz. RFI monitoring was done and we obtained the average power level of -76.2331 dBm (+/-0.7385) detected at BCK. This value exceeds the ITU-R RA.769.2 threshold level (-220 dBW) by 30.4601 dB.

Keywords: *Radio frequency interference (RFI); Antenna simulation and measurement; Hydrogen line*.

1. Introduction

Radio astronomy is a sub field of astronomy, which studies celestial objects with highly sensitive radio receivers and large radio telescopes. These radio astronomical measurements are performed in a wide range of frequencies, which are limited by the radio window set by the attenuation in the Earth's atmosphere and the man-made radio frequency interferences (RFI). RFI is an ever-increasing problem in radio astronomical measurements. All kind of radio broadcasts and new radio applications are deteriorating the radio frequency spectrum expected from the astronomical object of interest. Consequently, radio observatories are also generating remarkable amounts of radiation themselves, which might cause distortion to the astronomical data. RFI profile need to be developed and the measurement should be done using appropriate antenna. Using an appropriate antenna is vital, so the signals detected are strong. In detecting radio astronomical signals from outer space, RFI monitoring and measurement are required to avoid the signal's disturbance for better radio astronomical observation. In order to make sure that the data of RFI is reliable, we need to study the performance of antenna used in measurement. The antenna is an integral part of a wireless system and a well-designed antenna is critical for system performance.

In RFI measurement, an antenna is a crucial component for detecting the unwanted radio signal exists in the radio observation environment which may lead to the signal attenuation from the astronomical sources. For this research, the discone antenna was used to receive the radio signal waves from surrounding. It is similar to the study done to identify the FI pattern at BCK. Antennas have many different attributes and types that are needed depend on their characteristics and applications [1-3]. The discone is a popular choice of antenna for omni-directional, linearly polarised systems in many research [4-6]. A discone antenna is in a version of a biconical antenna in which one of the cones is replaced by a disc with impedance and radiation characteristics detained by the angle of the cone and the diameter of the disc [7-8]. The cone and disc must be separated each other by an insulator. The feed points usually placed at the center of the disc. The discone's radiation patterns are frequency dependent. At different frequencies, it has unequal patterns as it radiates sideward and downward [9]. However, the performance of the antenna should be evaluated first before the measurement is carried out. Several parameters need to be taken into account such radiation pattern, s-parameter, voltage standing wave ratio (VSWR) and gain measurement. Generally, an antenna which is

good in term of efficiency can radiates in between 50% to 60% of the energy fed to it [10-13]. Gain is the priority in measuring the efficiency of an antenna, thus, the performance of the antenna can be known by determining the efficiency of radiated output in one direction at a time.
Our main objective is to qualify the performance of discone antenna for RFI study for Hydrogen line (HI) study. In our work, we choose Balai Cerap KUSZA (BCK) (5° 32' 10" N and 102° 56' 55" E) situated at Merang, Terengganu for candidate site as a study case. Three stages were performed which antenna simulation using CST, antenna measurements done in anechoic chamber and RFI survey. The findings of this study will benefit radio astronomy observations, space science, and antenna study [14-17].

2. Methodology

For the purpose of RFI measurement in the range of HI frequency, the antenna had been designed using CST software. The antenna was then fabricated, tested and measured in an anechoic chamber to determine the antenna performance. Then, the simulation and measurement of the discone antenna was compared before it capable with utilization. Lastly, the radio signal power level from nearby HI frequency utilizing this antenna was recorded in 24 hours. It is highlighted that the structures of antenna are designed for the radio astronomy investigation.

2.1. Antenna simulation

The discone antenna was modelled and simulated specifically for HI detection application which is at 1.42 GHz with Omni-directional radiation pattern. The dimension parameters of the antenna have been optimized to achieve the desired frequency and radiation pattern then has been simulated and analysed using CST software to see the antenna performance based on finite difference-time-domain method. The schematic geometry of the discone antenna was illustrated as in Figure 1.

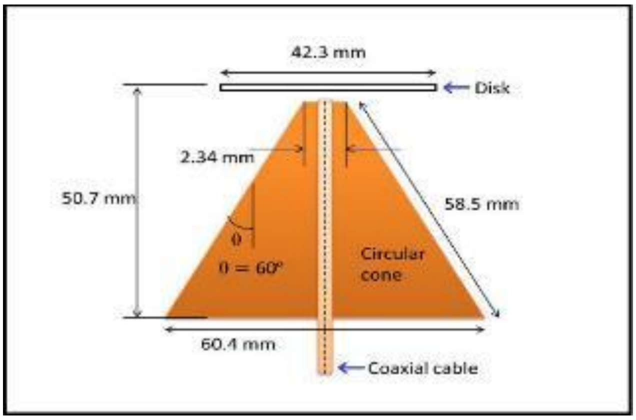

Fig. 1: The schematic geometry of the discone antenna.

The antenna then was fabricated by followed the dimension proposed. The structure of antennas was divided into two parts, which are the disc in diameter of 42.3 mm with a radius of 21.15 mm and the coaxial cone in diameter of 60.4 mm with a radius of 30.2 mm. The height of a cone is 50.7 mm, while the height of the disc is about 1 mm. All of these structures are made up from almost 100% of the copper smooth surface with 0.5 mm thick. It is has connected with 70 mm length of low loss coaxial cable in diameter of 2.34 mm [19]. Then, the performance of fabricated antenna has been measured in an anechoic chamber and was compared with the simulation measurement result.

2.2. RFI Data Measurement

The survey of radio frequency interference (RFI) using discone antenna was conducted in 24 hours. The observation is taken at 3rd February 2016. This survey was done at Balai Cerap KUSZA, Merang, Setiu, Terengganu, Malaysia. The location was selected because it is one of the astronomical observations in East Coast Malaysia with possible low profile RFI [20]. To get an enhancement the precision and continuous measurement of RFI, the record setting of spectrum analyzer was fixed in every 1 minute. In addition, it recorded in 12 sessions with two hour in time intervals due to the limitation extracting data software. The measuring RFI data survey was contained the discone antenna, Low Noise Amplifier (LNA) and 9 GHz spectrum analyzer (Keysight N9915A) with 180 kHz resolution bandwidth. Lastly, the RFI data will be transferred to a computer for analysis. The instrument set up was illustrated as Figure 2.

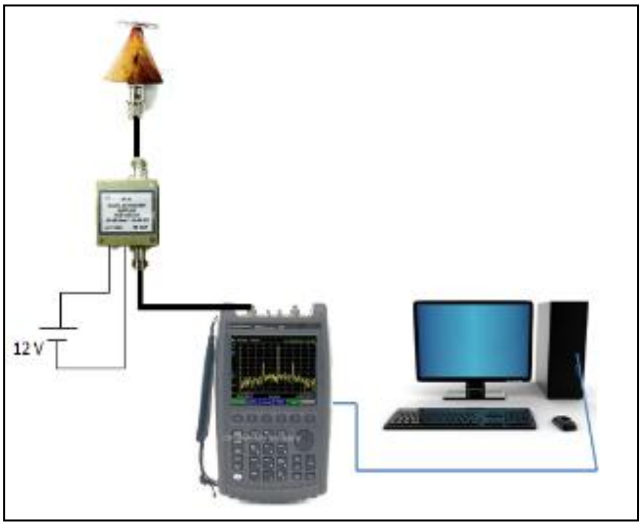

Fig. 2: The illustration of RFI connection set up [21].

A total of 24-hour RFI was plotted in a graph after averaging the power level (dBm) from 12 sessions. The RFI data have recorded in power level (dBm) from 0 Hz until 9 GHz. Then, the baseline of the RFI data was calculated and draws in the graph.

3. Results and Discussion

In this section, result is divided into two parts. The first part deals with antenna simulation and measurement. While, the second part report the RFI monitoring for HI spectrum using discone antenna as receiver.

3.1. Antenna Simulation and Measurement

The discone antenna for astronomy applications that resonant at 1.42GHz was simulated, fabricated and analysed in terms of standard antenna parameters that involved S-parameters, Bandwidth, realized gain, voltage standing wave ratio (VSWR) and polar plot radiation pattern [22-23]. S-parameter also known as reflection coefficient that describes how much electromagnetic wave being reflected which can be expressed with the ratio of the reflected voltage amplitude to the incident voltage amplitude. As indicated in Figure 3, the comparison of S-parameter between simulation and measurement demonstrated and observed at the resonant frequency. The magnitude of the simulation indicated that the antenna dipped at -36.8 dB (63.2% voltage amplitude reflected), while the measurement show at -13.2 dB (86.8% voltage amplitude reflected) with both reading show better than -10 dB (reference level). The antenna is said to be in a good performance at a certain resonant frequency when the reflection coefficient is below than -10 dB (90% voltage amplitude reflected). The smaller the percentage of voltage amplitude reflected, the higher the performance of the antenna at the resonant frequency. Besides that, the bandwidth of the discone antenna performs with the wideband characteristic with 1.75 GHz on simulation and 1.4 GHz for the measurements.

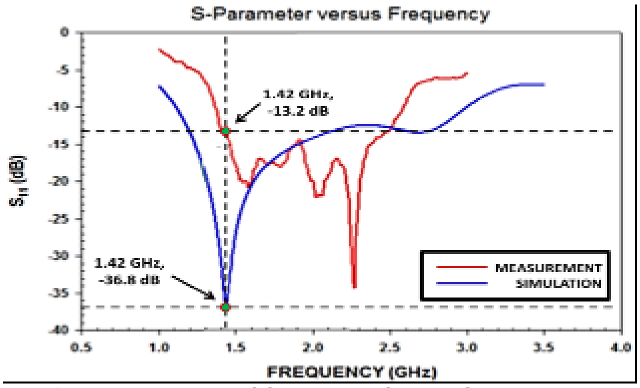

Fig. 3: S-parameter graph between simulation and measurement.

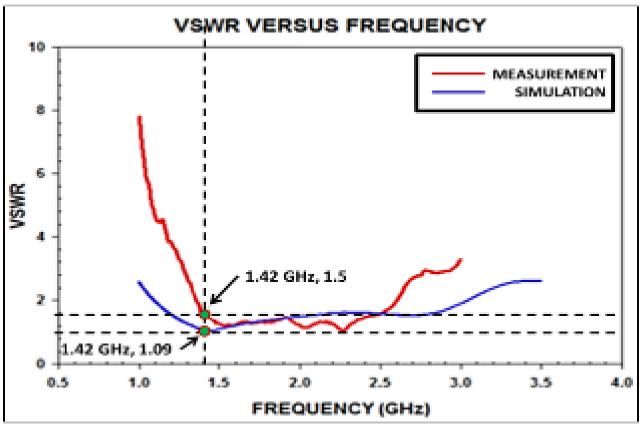

Fig. 4: VSWR plotting graph between simulation and measurement

Table 1: Correlation analysis results between Nigeria and Peninsular Malaysia

Parameter	Simulation	Measurement
S11	-36.8 dB	-13.2 dB
Observe Frequency	1.42 GHz	
Bandwidth	1.75 GHz	1.4 GHz
Realized Gain	1.05 dB	0.98 dB
VSWR	1.09	1.5

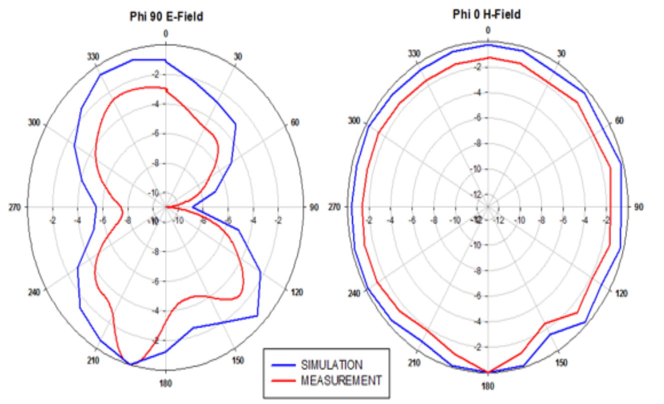

Fig. 5: Polar plot for proposed antenna (a) Phi 90 (b) Phi 0.

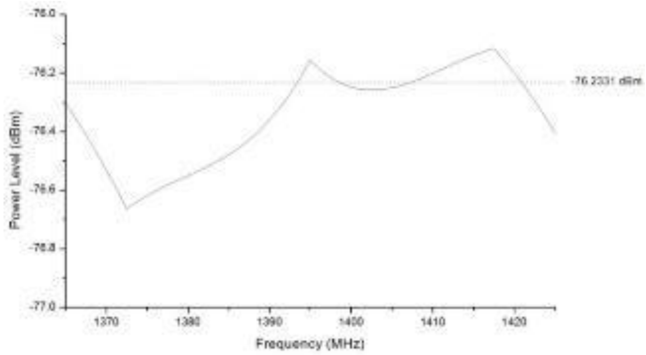

Fig. 6: Average RFI level in HI suggested minimum bandwidth

Next, the analysis focused on VSWR plotting to observe the ratio between forward and reflected power developed by proposed antenna. On simulation result, the antenna, perform the value of 1.09 while the reading of 1.5 reported for the measurement. The reflection ratio developed between simulation and measurement considered in normal range, since it occurs less than the value of 2. The plotting between simulation and measurement for proposed antenna indicated in Figure 4.

As indicated in Figure 5(a) phi 90 and Figure 5(b) phi 0, the antenna perform the omnidirectional polarisation with the power magnitude reduce from -1 dBm (simulation) to -3 dBm (measurement) for E-filed plotting and -0.5 dBm (simulation) to -1.8 dBm (measurement) for H-filed plotting. Even though, there are slight differences on magnitude data between simulation and measurement the physical orientation plotting of polar radiation indicates similarities and concluded succeeded.

The overall result between simulation and measurement for proposed antenna is tabulated in Table 1. The deviation that occurs between simulation and measurement contributed by the fabrication process that involved braising, bending and others mechanical process work that influence the changes of surface current. Even though, the deviation exists between the simulation and measurement result in the overall performance of the antenna quite promising with low magnitude reflection and VSWR reading.

3.2. HI Spectrum

Suggested minimum bandwidth as identified by General Assembly of the International Astronomical Union (IAU) for HI is between 1370.0 – 1427.0 MHz. The average RFI level detected in HI spectrum is shown in Figure 6 is -76.2331 dBm (± 0.7385) which equivalent to -76.2331 dBm + (-84.5125 dB) = -160.7456 dBm + (-30 dB) = -190.7456 dBW. To measure radio environment from surrounding, omnidirectional antenna were used which in this study; discone antenna. The correction resolution is given by 1.2057 dB. The power of RFI as measured by discone antenna is -190.7456 dBW + 1.2057 dB = -189.5399 dBW

According to ITU-R RA.769-2, a standard threshold interference level for HI is -220 dBW. However, interference detected using discone antenna exceeded the standard threshold by ITU-R RA.769-2 is 189.5399 dBW – (-220 dBW) = 30.4601 dB. Signal from radio astronomy sources are very small with spectral flux density 1 Jansky (Jy) = 10-26 Wm-^{2} Hz-1. However, many radio astronomical signals have flux density much lower than 1 Jy. In this study, average RFI level is equivalent to 2.5× 〖10〗 ^15 Jy. These results corroborate the ideas of ITU (2003), who suggested conducting spectrum survey before implementing radio telescope or observe radio astronomical signal [18].

4. Conclusion

This study set out to investigate the performance of discone antenna for RFI measurement. This research has shown that discone antenna constructed has S11 parameter measured in anechoic chamber, which is -13.2 dB at frequency 1.42 GHz compared to simulation value that is -36.8 dB. These findings suggest that in general, discone antenna constructed are suitable for RFI measurement in HI spectrum because S11 value exceed reference level (-10 dB). Another purpose of this study is to conduct spectrum survey in HI spectrum. It is found that the measured RFI exceed ITU-R RA.769-2 by 30.4601 dB. Taken together, these results suggest that the RFI excision have to be done before conducting radio astronomy observation. This research will serve as a base for future radio astronomy studies and provide RFI database in east coast of Peninsular Malaysia.

Acknowledgement

This study were supported by several university grants such as FRGS (FRGS/1/2015/SG02/UNISZA/02/1) and 68006/2016/79. The authors would like to convey a thankful to the team of EMRG-Malaysia and ARG team from UiTM for sharing their knowledge in antenna.

References

[1] Sabri, N. H., Umar, R., Mokhtar, W. W., Adli, W. Z., Abidin, Z. Z., Ibrahim, Z. A., Azid A, Juahir H, Toriman ME, & Kamarudin, M. K. (2015). Preliminary study of vehicular traffic effect on radio signal for radio. Jurnal Teknologi, 75(1), 313-318.

[2] Sabri, N., Syed Zafar, S., Umar, R., & Wan Mokhtar, W. (2015). Radio frequency interference: The effect of ambient carbon dioxide (Co2) concentration on radio signal for radio astronomy purposes. Malaysian Journal of Analytical Sciences, 19(5), 1065–1071.

[3] Vara, B. K., & Prudhvi, P. Y. (2015). Design and analysis of discone antenna. International Journal of Latest Research in Engineering and Technology, 1(3), 43–51.

[4] Li, X., Zheng, H. L., Quan, T., & Chen, Q. (2012). A printed discone ultra-wideband antenna with dual-band notched characteristics. Progress in Electromagnetics Research C, 27, 41–53.

[5] Umar, R., Abidin, Z. Z., Ibrahim, Z. A., Gasiprong, N., Asanok, K., Nammahachak, S., Aukkaravittayapun S, Somboopon P, Prasit A, Prasert N, Hamidi Z. S. (2013). The study of Radio Frequency Interference (RFI) in altitude effect on radio astronomy in Malaysia and Thailand. Middle East Journal of Scientific Research, 14(6), 861-866.

[6] Umar, R., Sabri, N. H., Zainal Abidin, Z., Azid, A., Juahir, H., Toriman, M. E., & Kamarudin, M. K. A. (2015). Preliminary study of radio astronomical lines effect of rain below 2.9 GHz. Jurnal Teknologi, 75(1), 7-11

[7] Marhamah, M. S., Umar, R., Hazmin, S. N., Zafar, S. N. A. S., & Mat, R. (2018). The influence of solar radiation on radio signal at UHF band. Journal of Fundamental and Applied Sciences, 10(1S), 268-277

[8] Zafar, S. S., Hazmin, S. N., Mat, R., Marhamah, M. S., & Umar, R. (2018). Wind speed on ultra high frequency (UHF) of radio signal. Journal of Fundamental and Applied Sciences, 10(1S), 278-287.

[9] Shafie, M. M., Umar, R., Sabri, N. H., Afandi, N. Z. M., & Ibrahim, Z. A. (2017). Radio environment analysis at Balai Cerap KUSZA for solar burst study. International Journal on Advanced Science, Engineering and Information Technology, 7(4), 1441-1447

[10] Dianah, A. R. S. N., Umar, R., Kamarudin, M. K. A., Dagang, A. N., & Hazmin, S. N. (2017). Exposure level from selected base station tower around Kuala Nerus: A preliminary analysis. Journal of Fundamental and Applied Sciences, 9(5S), 367-380

[11] Dianah, A. R. S. N., Hazmin, S. N., Umar, R., Jaafar, H., Kamarudin, M. K. A., Dagang, A. N., & Syafiqah, H. N. (2018). Spatial model of public non-ionizing radiation exposure on selected base station around Kuala Nerus. Journal of Fundamental and Sciences, 10(1S), 523-540

[12] Amin, M., Hong, J. S., Luo, C. M., Ming, X., & Abdullah, M. (2016). A high gain simple cubic dielectric resonator antenna with parasitic metal strip for ISM band WLAN applications. Proceedings of the 2nd IEEE International Conference on Computer and Communications, pp. 3035-3038.

[13] Shakib, M. N., Islam, M. T., & Misran, N. (2008). Design of a broadband low cross-polarization W-shape microstrip patch antenna for MIMO system. Proceedings of the IEEE International RF and Microwave Conference, pp. 311-313.

[14] Mat, R., Shafie, M. M., Ahmad, S., Umar, R., Seok, Y. B., & Sabri, N. H. (2016). Temperature effect on the tropospheric radio signal strength for UHF Band at Terengganu, Malaysia, 6(5), 770–774.

[15] Afandi, M., Zulaikha, N., Umar, R., Sabri, N. H., Abidin, Z. Z., Ibrahim, Z. A., Afandi M, Zulaikha N, Umar R, Sabri N. H., Abidin Z. Z., Ibrahim Z. A., Ishak A. N., Nurlisman Z. K., & Monstein, C. (2017). Identification of solar radio burst type II and Type III for space weather monitoring. Advanced Science Letters, 23(2), 1281-1284.

[16] Dianah, A. R. S. N., Hazmin, S. N., Umar, R., Kamarudin, M. K. A., & Dagang, A. N. (2017). A review on electromagnetics (EM) exposure measurement techniques from base station. Journal of Fundamental and Applied Sciences, 9(2S), 182–198

[17] Jusoh, M. H., Yumoto, K., Hamid, N. A., & Liu, H. (2012). Electromagnetic coupling on solar-terrestrial system: Possible effects on seismic activities. Proceedings of the IEEE International Symposium on Antennas and Propagation, pp. 1160-1163.

[18] ITU. (2003). Recommendation ITU-R RA. 769-2.

[19] Roslan, U., Nor, H. S., Zainol, A. I., Zamri, Z. A., Asyaari, M. (2015). Measurement technique in radio frequency interference (RFI) study for radio astronomy purposes. Malaysian Journal of Analytical Sciences, 19(5), 960-965.

[20] Umar, R., Abidin, Z. Z., Ibrahim, Z. A., Gasiprong, N., Asanok, K., Nammahachak, S., Aukkaravittayapun S, Somboopon P, Prasit A, Prasert N, Hamidi Z. S. (2013). The study of Radio Frequency Interference (RFI) in altitude effect on radio astronomy in Malaysia and Thailand. Middle East Journal of Scientific Research, 14(6), 861-866.

[21] Mohd Afandi, N. Z., Umar, R., Ibrahim, Z. A., Sabri, N. H., & Shafie, M. M. (2017). Influence of partial solar eclipse on the radio signal during 9 March 2016. International Journal on Advanced Science, Engineering and Information Technology, 7(2), 688.

[22] Sabri, N. H., Azlan, A. W., Umar, R., Sulan, S. S., Ibrahim, Z. A., & Mokhtar, W. Z. A. W. (2015). The effect of solar radiation on radio signal for radio astronomy purposes. Malaysian Journal of Analytical Sciences, 19(6), 1374-1381.

[23] Sabri, N., Syed Zafar, S., Umar, R., & Wan Mokhtar, W. (2015). Radio frequency interference: The effect of ambient carbon dioxide (Co2) concentration on radio signal for radio astronomy purposes. Malaysian Journal of Analytical Sciences, 19(5), 1065–1071.