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PRELIMINARY STUDY OF VEHICULAR TRAFfiC EFFECT ON RADIO SIGNAL FOR RADIO

Nor Hazmin Sabri[a*], Roslan Umar[b], Wan Zul Adli Wan Mokhtar[c], Zamri Zainal Abidin[d], Zainol Abidin Ibrahim[d], Azman Azid[b], Hafizan Juahir[b], Mohd Ekhwan Toriman[b], Mohd Khairul Amri Kamarudin[b]

[a]School of Fundamental Science, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Malaysia
[b]East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Terengganu, Malaysia
[c]Department of Physics, Faculty of Science and Mathematics, University Pendidikan Sultan Idris, 35900 Tanjung Malim, Malaysia
[d]Department of Physics, Faculty of Science, University of Malaya, 50603, Kuala Lumpur, Malaysia

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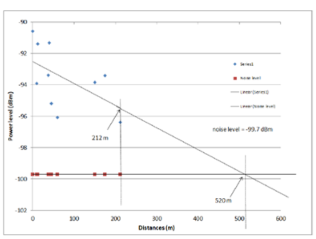
*Corresponding author
norhazmin@umt.edu.my

Graphical abstract



Abstract

Radio signals detected from the ground are very weak since it travels far from the universe. Radio wave carries photons with low energies compared to other electromagnetic spectra such as visible light, ultraviolet, X-rays, and the most energetic electromagnetic wave is gamma-rays. The microwave region is the shortest wavelength of radio waves. Hence, microwave photons have greater energy. Radio astronomy studies are restricted due to radio frequency interference (RFI) that produces by human daily activities. If this disturbance is not shrinkage, it poses critical problems in radio observation. There are many factors of man-made RFI, such as, the availability of mobile telecommunications, radio transmission, TV broadcasting, satellite communication, vehicular traffic area, power transmission line and many more. In this paper, we present a preliminary study of the radio sources (electronic system in the car) from the vehicular traffic area (highway) on radio astronomy observation. This study is important to assess how the vehicles affect the radio signal in radio astronomical sources of low frequency such as hydrogen line and deuterium (which wavelength more than 1mm). These research findings would benefit radio astronomy research, especially to profile the RFI pattern in Malaysia.

Keywords: Radio signals, man-made RFI, vehicular traffic, radio astronomical sources

Abstrak

Isyarat radio dari angkasa raya yang dapat dikesan dari permukaan bumi adalah sangat lemah memandangkan ianya datang dari objek alam semesta yang terletak sangat jauh. Gelombang radio membawa foton dengan kapasiti tenaga yang sangat rendah jika dibandingkan dengan spectrum electromagnet yang lain seperti cahaya nampak, ultra lembayung, X-ray serta gelombang electromagnet yang paling tinggi tenaganya iaitu gelombang gamma. Gelombang mikro adalah gelombang terpendek dalam julat gelombang radio, Ini meyebabkan foton dari gelombang mikro membawa tenaga yang paling tinggi. Kajian dalam bidang astronomi radio adalah terbatas kesan dari interferens frekuensi radio (RFI) yang dihasilkan dari aktiviti seharian manusia. Jika gangguan ini tidak ditangani, ianya akan memberikan kesan yang kritikal terhadap pemerhatian astronomi radio. Terdapat banyak faktor RFI buatan manusia, antaranya kemudahan telekomunikasi, transmisi radio, siaran TV, komunikasi satelit, kawasan trafik sesak dengan kenderaan, aliran arus elektrik, dan banyak lagi. Dalam artikel ini, kajian rintis mengenai kesan dari sumber gelombang radio (sistem elektronik dalam kenderaan) dari lebuhraya (kawasan trafik kenderaan yang tinggi) keatas cerapan isyarat astronomi radio akan ditekankan. Kajian ini penting bagi menilai bagaimana kenderaan yang bergerak memberi kesan keatas isyarat radio dari objek astronomi berfrekuensi rendah seperti jalur hidrogen dan deuterium yang mempunyai panjang gelombang lebih dari 1mm). Hasil dapatan kajian ini bermanfaat kepada penyelidikan bidang astronomi radio, terutamanya bagi menghasilkan corak RFI di Malaysia.

Kata kunci: Isyarat radio, RFI buatan manusia, trafik kenderaan, sumber astronomi radio

1.0 INTRODUCTION

The radio astronomy frequency is increasingly polluted by intentional and unintentional human generated radio frequency interference (RFI). Light pollution that disturbs optical observation is as an analogy to radio RFI which disturb radio astronomy study. In radio astronomy observation, all signals locating in observatory band does not relate to the radio sources consider as RFI. This RFI also can be defined as that interferes is any unwanted signal entering the receiver system [1].

The RFI is generated by essential human activities such as mobile phones, radio and television broadcasting, radar, satellite and so on. Another unintentional RFI, such as microwave oven, power line, electrical equipment, automobile ignition system and many more [2]. The presence of unintentional interference cannot be ignored. We need to monitor and concern since the frequencies transmitted by these electronic gadgets are playing a big role in detrimental the signal of interest (SOI). As a result, the growths in human technologies are somewhat harmful to the radio astronomy studies. Last decade, most of the interference had been occurring and limited number of services, such as microwave, satellite, military and radar systems [3, 4]. To protect this several frequency bands are allocated and reserved by the (ITU) for radio astronomy used. For example, the band 1400-1427 MHz is allocated for the Hydrogen (neutral hydrogen) spectral line (21-cm); an allocated band at 1660-1670MHz protects observation for the hydroxyl molecule (OH) maser (18-cm) spectral line and so on. Others radio astronomy windows and it is purposed is allocated by ITU below 2.8GHz can be seen in Abidin [5, 6].

Basically, RFI disturbing scientific observation occurs in many ways, for example: (a) spurious, harmonic and inter-modulation products due to nonlinear devices, (b) unwanted signal from out of band and nearby bands [7]. According to Keiser 1979, harmonic and spurious from the automobile ignition system, transmitted from frequency around 30-1000 MHz [8]. The vehicle ignition system-generated RFI signals at its entertainment radio antenna terminals have been measured in time and frequency domain. In general, it has been found that the received signals in the time domain are pulsed in nature, and very little correlation has been observed between two or more received pulses. Frequency components of a received pulse have been measured in the range 20 to 1000 MHz [9].

Several of the worst sources of radio frequency interference (RFI) for radio astronomy are low earth orbit (LEO) satellites. Unlike ground-based RFI sources, there is no place on earth where we can hide from such satellites. Because of their low orbit, their angular position on the sky, can vary faster than 1 degree per second. They broadcast strong signals that sometimes impinge on protected radio astronomical radio bands. For example, a recent study shows that the Iridium satellites generate unwanted signals that are 25dB above the detrimental level in the 1610.6-1613.8 MHz radio astronomy band [10].

Site selection studies are essential for decision makers propose where to build an astronomical observatory, especially in radio window with a highest efficiency. However, site selection is somewhat selective due to consider many factors such as contour shielding (topography), population density, rainfall, humidity and telecommunication and broadcasting transmitters [11]. In this paper, we discussed how the RFI from vehicular traffic affect the radio astronomy observation in L-Band windows and also listed the value of threshold compared to ITU.

2.0 EXPERIMENTAL

The discone has a pattern which is uniform in azimuth, with a maximum gain slightly below the horizon and nulls toward the zenith and nadir [10]. The antenna diagram and instrument details will be explained in the following antenna construction and instrument setup section. The L-band study was conducted to determine the range of frequencies where the RFI exists in the radio astronomy window and nearby to select and determine the appropriate frequencies of interest to be studied. To observe the RFI, Ambrosini reported that the discone antenna can be used for the SKA project to identify the low or high RFI [12, 13].

These antennas are primarily vertically polarized with uniform azimuthal directivity. The Discone antenna was used as a one solution in order to identify surrounding RFI near the observation site. Material for discone made from metal sheet (normally we used copper). Discone antenna very suitable for small indoor Very High Frequency (VHF) antenna such as WIFI. However, for lower frequency the discone made from metal wire is preferred [14]. To study RFI around 0-2800 MHz (optimize at 1420 MHz) the specified design in making discone is shown in Figure.1.

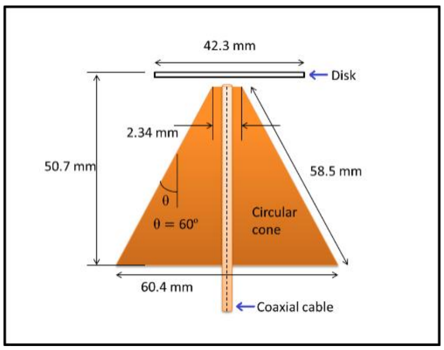


Figure 1 Dimension discone antenna used

The constructed discone in this study is shown in Figure 3(a). A discone antenna has three important components:

a) the disk
b) the cone
c) the insulator

The disk should have an overall diameter of 0.7 times quarter wave length of antenna minimum frequency. The antenna's feed point is at the center of the disc. A 50-ohm coaxial cable with connector is employed with conductor to the cone. The length of the cone should be a quarter wavelength of antenna minimum operating frequency. The disk should have an overall diameter of 0.7 times quarter wave length of antenna minimum frequency. The antenna's feed point is at the center of the disc.

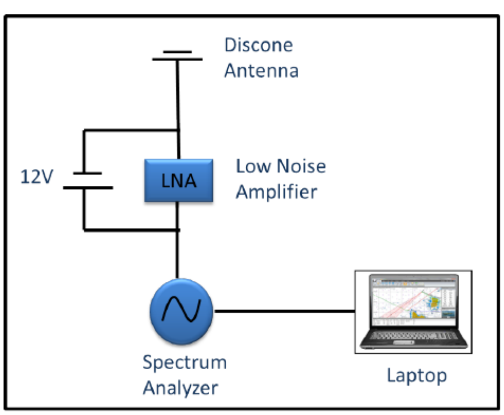


Figure 2 The instrument setup for observation work

They are then connected to the spectrum analyzer to acquire the RFI data at a certain time before the data is sent to the computer to be displayed and store to be analyzed later. The spectrum analyzer (Figure 3 (c)) utilized in this study is a high quality precision handheld style RF Field.

The discone is used as an antenna in the observation to detect radio frequency from the environment. The desired radio frequency window to be studied is L-Band window. The discone is attached to the 1.4 GHz LNA as shown in Figure 3(b) with 28 dB gain/0.34 dB noise frequency, to amplify the signal so the peaks are easier to read.

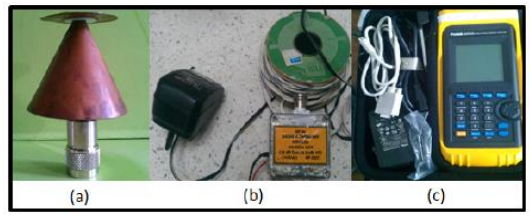


Figure 3 (a) The discone antenna (b) The LNA and (c) The spectrum analyzer, utilized in this study

They are then connected to the spectrum analyzer to capture the RFI data at a certain time before the data is sent to the computer to be displayed and analyzed. The complete instrument setup for an observation is shown in Figure 2.

Figure 4 Location of RFI study: Nearby UPSI

The spectrum analyzer (Figure 3 (c)) utilized in this study is a high quality handheld style RF Field Strength Analyzer with wide band reception with specification as shown in Table 1.

We manage to make an observation at several points of places ranging from 0 to 212 m away from highways to see how the RFI influence by unintentional interference produces from the activity at the highway. We choose the most common highway used in peninsular Malaysia called Projek Lebuhraya Utara Selatan (PLUS) between Tanjung Malim and Behrang toll plaza in the province of Tanjung Malim, Perak (Figure 4). We use the same method applied in the population density factor which is quantifying the threshold limit of the road network in order to determine the most suitable lower limit for radio observation site selection.

Table 1 RF field strength analyzer with wide band reception and detail specification

Mode	Protek 3290N
Frequency Range	100 KHz to 2.9 GHz
Resolution	3.1255 kHz
Modulation	180 kHz (W-FM), 12.5 kHz (N-FM)
Measurement Range	-20 dBm to -100 dBm
Average Noise Level	-100 dBm
Weight	1.4 lbs
Size	9.5" H x 4.0" W x 1.8" D

3.0 RESULTS AND DISCUSSION

Observations at longer wavelengths (centimeters to meters) created in the domain where the commercial use of the electromagnetic spectrum that much. In the meantime, the resulting radio emission from vehicles can easily the weaker signal astronomy. Therefore, many observatories are protected from harassment by limited delivery zone, where the limit or ban the transmitter and industrial activities [15, 16].

In this section, we discuss the effect of the road network (highway) to radio astronomy observation. As we noted, the road network related to the vehicles running on the road or highway. We assume that the active engines and electronic system from the vehicles may disturb the radio signals detected.

The RFI spectral observed in various distances are listed and analysis in Figure 5. We also determined how the distance from the source highway affect the threshold levels from 0-2.8GHz and we also calculated these threshold levels in all radio astronomical windows up to 2.8GHz.

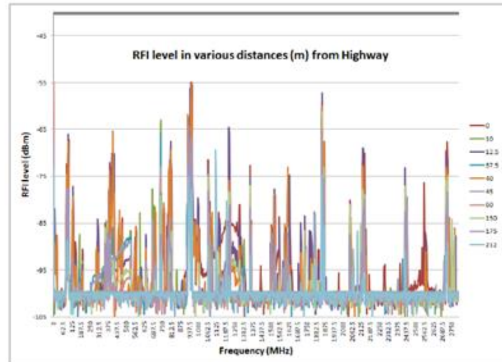


Figure 5 RFI profile in various distances from 0 to 2800MHz

From the graph, we can conclude that the power level of RFI is inversely proportional to the distance, d. Extrapolation of the graph at 99.7dBm noise level, we obtained d = 520m as shown in Figure 6.

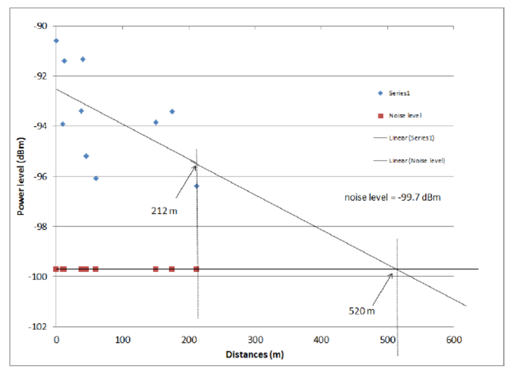


Figure 6 RFI profile in various distances from 0 to 2800 MHz

We also use this technique to identify the thresholds for the road network that produces the RFI. Using this method we found that, for frequencies up to 2.8GHz, the high, medium and low road network distance, affecting radio astronomy are below 212m, between 212m and 520m, and above 520m respectively. We also investigate the effect of road network distance on the RFI environment in three astronomical windows, namely the Deuterium, Hydrogen and Hydroxyl lines. We then compare our interference values to the RFI threshold standard levels within these spectrum windows as shown in Table 2.

As we can see that in Figure 5, we found that unintentional interference that affected to radio astronomy at three regions, there are between 250 to 625 MHz, 880MHz to 1312MHz and 1500 to 1875MHz. The threshold level that we have calculated within astronomical windows is summarized in Table 2.

Table 2 Average RFI (road network) at radio astronomy windows compared to ITU threshold

Average RFI (*dBm*)	Windows	RFI at Antenna(*dBm*)	ITU Threshold (*dBW*)	Exceed ITU by (*dB*)
-99 ± 1.0	DI	-46	-215	139
-100 ±2.2	HI	-34	-220	156
-99 ± 0.8	OH-1	-32	-220	158
-100 ± 0.7	OH-2	-33	-220	157
-98 ±0.8	Average	-32	-205	143

As we explained in the methodology section, we have obtained the total RFI received by our spectrum analyzer in this parameter. We used the average RFI level in the threshold windows which is at -98 dBm for average within 0 to 2.8 GHz (see in Table 2). Using same distance, d from receiver to antenna, we have determined a power level using the same formula; The Free Space Power Loss (FSPL), defined as;

$$FSPL = 20\log(4\pi d/c)$$

$FSPL$ is proportional to the square of the frequency of the radio signal (*f=1420 MHz*) and to the square of the distance between the transmitter and receiver (d) [6]. We have calculated the value of the $FSPL$ power level of these windows and we got *FSPL*=50 dBm. The total RFI seen at the antenna focus was -98 dBm + (50) = -48 dBm. This value converted to dBm become -78dBW. However, we need to add the correction values as recommended by ITU using the equation in Abidin [6]. As we mentioned before, this value was 16dB.

Therefore, the total RFI power generated at this particular site is expected to be the difference between the total RFI at the antenna and the correction value by ITU which is -62 dBW. This threshold is about 143dB higher than the recommendations limit set by ITU. By using the same method we calculated all the power level for radio astronomical windows and then also compared to the ITU threshold level. These are listed in Tables 2. The frequency with the highest peaks in these categories are at 412.5 MHz (-65 dBm), $1857.5 MHz (-57.25 dBm) and 955 MHz (-54.9 dBm), respectively.

4.0 CONCLUSION

From this study, we can also conclude that the RFI produced by vehicles disturb the radio astronomy observation in certain windows, for example, 250MHz to 625MHz, 880MHz to 1312MHz and 1500MHz to 1875MHz. We also can conclude that most of the unintentional RFI (ignition system) tends to detriment in low frequency especially in the L-band window. This band should be protected well by the ITU in the future.

From this study, to build a radio telescope, one has to find a site with the distance from the road network is far away. The interference will be very detrimental to radio astronomy observation below or near 212m. However, to protect interference it is not just only 520 m but more than 16 km as established and recommended by NRAO this due to the cost of building this radio telescope is very high. Due to the crowded of interferences exist radio astronomy project are located in the rural area such as the Square Kilometer Array. This study also will benefit to enhance the policy in the determination of radius for the core and limitation of Radio Quiet Zone (RQZ) establishment in the future.

It is also important to consider that the land use in the surrounding area, for example, trees, plantation, hill and mountain, and other factors or obstacles during locating the radio telescope. Beside the RFI contribution of the road network, others unintentional RFI, such as power grids and railway may also produce internal RFI to the measurements.

For future work, we suggest that the RFI measurements should be extended and repeated with consider others unintentional RFI varies due to human activities. In the current work the site selection is taken randomly near to the bridge. A different type or ignition system such electric and hybrid vehicles also practical to consider since in our observation we took vehicle randomly from the highway.

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