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GPS Receiver and Mobile Satellite Signal Performance for Equatorial Region: Malaysia

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1. Introduction

The effect of ionosphere in the equatorial region is a major concern in the mobile satellite (MS) system that employs Global Positioning System (GPS) [1]. Integrating GPS technology into the MS user terminals such as in [2] will require signal performance study to be carried out to better understand the factors that might effect the quality of the received signal. In GPS, the signal delay caused by ionosphere is the major concern and must be corrected.

The GPS receiver is able to provide propagation data required to study the signal performance on the GPS link through the NMEA 0183 protocol. Its low cost and simple to manage approach allows MS real operating condition to be measured. MS propagation data can be recorded simultaneously from different satellites at any instant of time for different number of propagation environments with different elevations.

By using the portable GPS receiver, measurements were carried out for the open space environment in the equatorial region to determine the GPS signal performance in this region. This paper is organized in the following way. Section 1 will give some introduction about the research topic. Section 2 describes the experimental aspect of the propagation measurement under the open space condition. In Section 3, the experimental results are discussed followed by the conclusion in Section 4.

2. Measurement Procedure

2.1 Measurement Methodology

For our study, we used a commercially available, portable handheld Garmin GPS receiver. The receiver can track up to 12 satellites at the same time and by extracting the NMEA data from the receiver, propagation data such as signal-to-noise-ratio (SNR), elevation angle and azimuth can be obtained. These data are automatically recorded on a portable computer for later analysis. Measurements have been carried out on a rooftop of a building located in Kota Samarahan (1.28 N, 110.48 E), Malaysia. All measured data are for the open space and clear sky condition because this will provide the best possible measurement condition. There are no major obstacles such as trees or buildings in the surrounding area that can cause significant shadowing or multipath effect. Therefore, the received signal measured at the receiver antenna will be a function of the receiver system noise and the free space propagation loss. Provided that the surrounding temperature does not change significantly, the receiver system noise will be a constant parameter.

Butsch [3] has given that the value of the undisturbed SNR to be in the order of 45dBHz to 50dBHz. In this study, we have chosen the 45dBHz as the reference SNR (SNR_{ref}). Therefore, signal with values equal or greater than the 45dBHz are considered as the undisturbed SNR while that below the 45dBHz are considered as experiencing attenuation. By observing the SNR change with respect to the SNR_{ref}, we generalize the fading distribution for the open space measurement in the equatorial region. This receiver will have loss of signal lock when the received SNR is less than 30dBHz.

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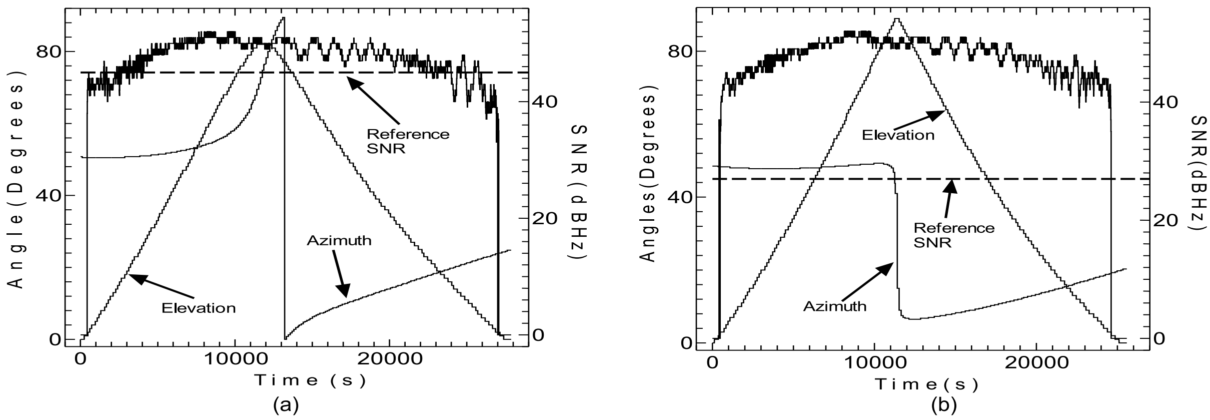

Figure 1: Open space SNR plotted against elevation and azimuth angles for (a) PRN3 and (b) PRN9. This data was measured in Fukuoka, Japan showing SNR exceeding SNR_{ref} for elevation angle greater than 15°.

2. 2 GPS Receiver Set Up

For this receiver, the best arrangement that will give optimum results in terms of SNR and number of satellite signal measured has been shown in [4]. That is by placing the receiver flat on the ground with the display panel facing the sky. The GPS satellites transmit signals by an array of right-hand polarized helices. This array is designed to illuminate the earth's surface with almost constant signal strength [5]. The radiation pattern of the patch antenna used in this receiver allows perfect signal reception from boresight with the response attenuated as elevation angle decreases. This arrangement will enable SNR of many satellites visible above the receiver in the sky to be measured. Each satellite is identified by the satellite's pseudorandom (PRN) code. PRN21 represents propagation data obtained from satellite which has been assigned the value of PRN code 21.

3. Results and Discussion

3. 1 Reference SNR (Fukuoka, Japan)

In this research work, we use the open space SNR measured in Fukuoka Japan as reference due to few reasons. Firstly, the open space measurement in Japan was carried out under fine weather condition with temperature variation between -2°C and 8°C. Furthermore, Japan is located outside the region that might experience severe ionospheric effect (equatorial and high latitude region). We consider Japan as one of the places that have optimum condition for measurement purpose.

Figure 1 shows the measured SNR for PRN 3 and PRN9 plotted against the elevation and azimuth angles. Measurement has been carried out in Fukuoka, Japan. From Fig. 1, PRN3 and PRN9 satellite has the maximum elevation angle of 82° and 90° respectively above the sky of Fukuoka. This allows measurement to be carried out for wide elevation range up to the maximum 90°. In this figure, the azimuth range is from 194° until 81°. The azimuth value should be multiplied by a factor of 4 to obtain the actual value. The SNR_{ref} indicates the undisturbed received signal for this open space measurement. The minimum elevation angle to obtain SNR equal or greater than SNR_{ref} is about 15°. Small fluctuations for SNR above the SNR_{ref} is due to multipath effect as explained in [6]. For the SNR of PRN3 and PRN9, severe attenuation only occurs at low elevation angle (<15°) due to the significantly reduced receiver's antenna gain and also due to the free space propagation loss because the longer path the signal has to travel at lower elevation angle.

3. 2 Measurement results in Samarahan

Figure 2(a) shows the open space SNR for PRN2 plotted against elevation and azimuth angles. From Fig. 2(a), SNR exceeding the SNR_{ref} can be observed for elevation range of greater than 15°. This is

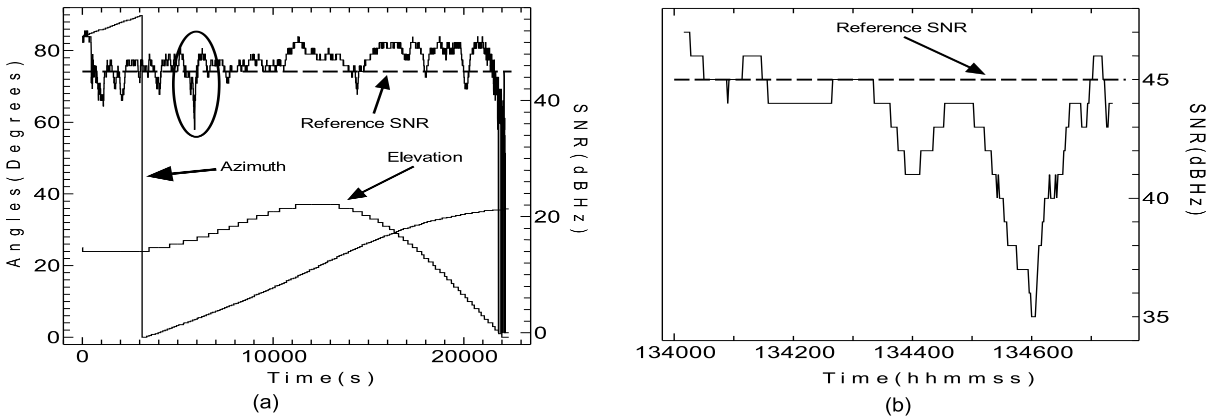

Figure 2: Figure showing the open space SNR for PRN2 measured in Samarahan, Malaysia. (a) Measured SNR of PRN2 (b) SNR fading at elevation angle of 27°.

consistent with the results obtained in Fukuoka. However, the signal fluctuations are quite severe and there are instants where the signal dropped below the SNR_{ref}. Comparing the results of Fig. 2 with that of Fig. 1, we can see that open space SNR in Samarahan experienced more severe fluctuations for the received SNR at elevation angles greater than 15°. This could be explained by the fact that Samarahan which is located in Malaysia is within the ± 20° from the geomagnetic equator. Irregularities in ionospheric layer in this region can at times lead to rapid fading in the received signal power level [7].

Another important factor that could cause signal degradation in Samarahan is the higher receiver system noise due to increase in temperature in the surrounding. This is severe especially during midday when the temperature normally exceeding 30°C. In Samarahan, high temperature exceeding 30°is experienced throughout the year. Combined with the ionospheric effect, SNR measured in Samarahan will show more fluctuations compared to that in Fukuoka. Figure 2(b) shows the SNR fading at elevation angle of 27°. This is part of the measured PRN2 shown by a circle in Fig. 2(a) which experience severe fading. The signal was well below the SNR_{ref} most of the time and fading of up to 10dB relative to the SNR_{ref} can also be observed. This fading occurred at 13:40 in the afternoon during which the temperature was very hot.

Figure 3(a) shows the comparison made between the open space SNR obtained for PRN26. The satellite are visibled both in Fukuoka and Samarahan. However, it is orbiting Fukuoka and Samarahan at different azimuth and elevation angles. Highest elevation angle observed in Fukuoka was 73° while 90° was observed in Samarahan. For the open space environment, SNR exceeding SNR_{ref} does not depend on the maximum elevation angle as can be seen in Fig. 3(a). In Figure 3(b), closer look at the fade difference of the two data set shows how severe signal fluctuates in Samarahan compared to Fukuoka. This figure is obtained by taking the difference between Samarahan SNR and Fukuoka SNR. Fade difference exceeding peak-to-peak value of 5dB could be observed in Fig. 3(b). The significant fluctuations in the received SNR is not just the function of multipath effect as explained in [7] but due to the ionospheric effect. For MS users receiving signal in difficult environments where received SNR is much lower than the SNR_{ref}, fading exceeding 5dB could cause drop in signal quality and for GPS users, loss of signal lock could happen.

4. Conclusion

We carried out studies in equatorial region (Malaysia) in order to know the MS signal performance in this region using the commercially available GPS receiver. Results have shown that open space signal measured using this method are consistent between each other with SNR exceeding SNR_{ref} even for low elevation angle values.

Due to factors such as high receiver system noise and ionospheric effect, signal measured in Sama-

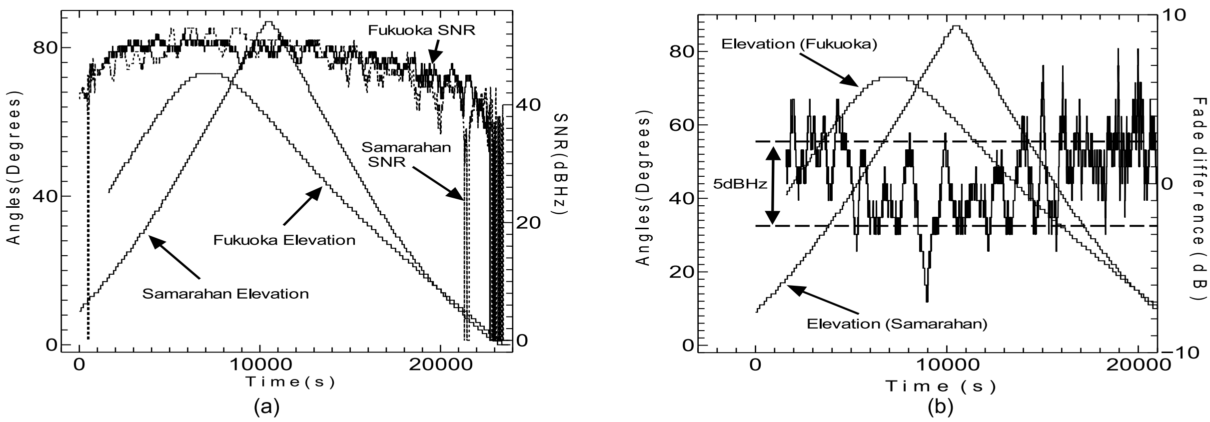

Figure 3: Figure showing the open space SNR for PRN26 measured in Fukuoka and Samarahan. (a) Open space Fukuoka SNR is shown as the solid line and Samarahan SNR is shown as the dotted line. (b) Fade difference exceeding 5 dB indicates the presence of ionospheric effect.

rahan exhibit severe fluctuations than that of Fukuoka. Fades exceeding the nominal peak-to-peak value of 5 dB were recorded in Samarahan. We have shown that higher receiver system noise could further attenuate the received signal quality . By taking these factors into consideration, MS signal performance for the equatorial region could be further investigated with this simple and cheap technique. Information obtain from many geographical regions will help MS network operators and service provider to find better method to mitigate these problems.

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