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A NOVEL DESIGN AID FOR SCHEDULING POLICY TOWARD SEAMLESS FUTURE-ORIENTED LAND VEHICLE SATELLITE COMMUNICATIONS

Masato Takahashi
University of Tokyo
Tokyo 113-8656 Japan
National Institute of Information and Communications Technology
Tokyo 184-8795 Japan
mtakahashi@nict.go.jp

Abstract

A novel scheme is proposed and demonstrated where satellite visibility viewed from running vehicle is economically and effectively evaluated with such low cost GPS receivers like equipped in automobiles. Our preliminary experiment articulated even economical L1 C/A 1.5GHz GPS receivers can create enough precise database of ground feature blockage, compared to fisheye photograph method, if only two statistical parameters the author proposed are adequately set. Integrating the series of our efforts on this research field, the author also concluded it is feasible to develop an automatic database creation system by the cooperation of the government and the civil with low cost GPS receivers. With this database, the communication satellite's visibility to a running vehicle can be predicted. Satellites visibility chart against time can be drawn as well. As the chart reflects the status quo including the traffic jams and signal blockage correctly, scheduling strategy designers can make a precise judge to decide the best scheduling policy. This scheme can also be meaningfully taken advantage of as a test-bed to examine the effectiveness of a resource reservation mechanism for such a prioritized vehicle like an emergency vehicle in near future's Land Vehicle Satellite Communication society

Keywords: Seamless Communication, Global Positioning System, Communication Satellite, Land Vehicle, Satellite Visibility, Allocation, Blockage, Scheduling Policy

1. INTRODUCTION

Lately, one of high elevation satellite systems for land mobile satellite communications, QZSS (Quasi-Zenith Satellite System), has been discussed. QZSS uses inclined geostationary orbits. When observed from an adequate service area such like middle latitude areas, a satellite of QZSS traces a "figure of eight" pattern in the sky and provides elevation angle s as high as 70 degrees or more for eight hours a day. Thus, when three or more satellites are placed in adequate orbits, minimum elevation angle of as high as 70 degrees or more are available continuously. In this background it comes to be important to comprehend and evaluate the status quo of blocking by ground features such like buildings or mountains while vehicles drive on actual roads. However there was no adequate method to realize the demand in cost effective and simple way.

2. METHODOLOGY – BLOCKAGE ASPECT –

A simple method is introduced to evaluate the satellite visibility at the sky above vehicles moving in real roads. A GPS receiver with a recorder on the vehicle collects the signal strength data of each GPS satellite with elevation angle of more than 0 degrees. It also collects the azimuth and elevation angles of the GPS satellites. After collecting the data, the projected area in the sky is estimated in which the probability of signal blocking is less than a certain ratio for the entire evaluation period using a reasonable threshold for the signal strength.

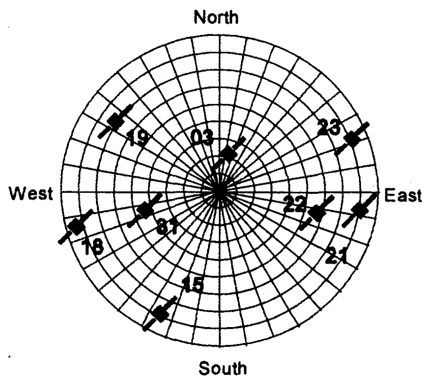

Fig. 1 An example of GPS satellite constellations viewed from Tokyo

The characteristics of the GPS antenna and the GPS receiver used in this experiment are described below. This is one of very common specifications for civil use GPS apparatus.

2.1 Antenna Specifications

Antenna specifications in our experiment are as follows:

Type:	Micro-stripped Plane Antenna Right-handed circular polarization,
Sensitivity:	-130dBm
Size:	54(w) x15.5 (H) x58 (D) mm
Weight:	0.12kg

2.2 Receiver Specifications

The specifications of GPS receiver in our experiment are as follows:

Type:	L1, C/A code GPS Standard Positioning Service
Channel:	8 channels
Positioning:	Parallel positioning (max 8 satellites)
Frequency:	1575.42MHz (L1-band)
Output Period:	1 second
Output:	Latitude, Longitude, Height, GPS Time, Orientation of Vehicle, Satellite ID, Elevation, Azimuth, Signal strength
Weight:	0.55kg

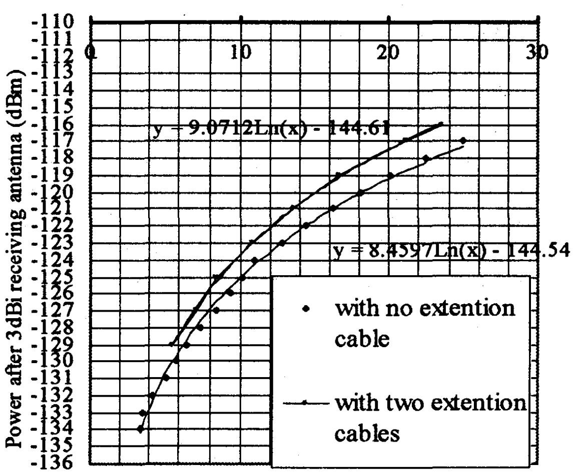

Fig.2 Calibration of signal strength output

2.3 Output of the Receiver

SPS (Standard Positioning Service) L1-band GPS antenna and receiver are used. Latitude, longitude, altitude, GPS time and orientation of the vehicle are recorded every second, as well as GPS satellites' ID, signal strength, elevation and azimuth as a result of positioning calculations.

2.4 Calibration of Signal Strength output value

A preliminary calibration was carried out on output value of signal strength by using GPS signal simulator used along with the GPS antenna and receiver described above.

The correspondence between the receivers's output value and absolute power level right after 3dBi GPS antenna is shown in Fig.2. The horizontal axis is the unit which is specific to the apparatus model. The vertical axis is the estimated power level right after 3dBi GPS antenna. The conversion formula from relative value to absolute value was created in this process. In Fig.2, the upper curve is data with two extension cables and the lower curve is data with no extension cables. GPS signal strength's dependency on GPS satellite elevation, which is shown in Fig.3, is also considered and properly corrected.

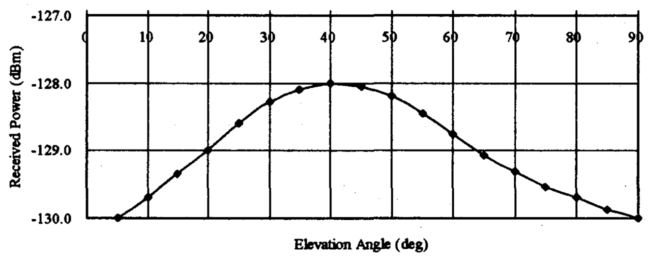

Fig. 3 Minimum power of the near-ground user-received L1 signal as a function of satellite elevation

2.5 Coordinate in Sky Hemisphere

In this study, when several satellite signal data are integrated together as sampling values for a certain orientation, the orientation is virtually considered not as a point but as a small circle. Its center is one of cross points determined by 5 degree increment in azimuth and 5 degree increment in elevation. The length of its radius is supposed to always have the angle distance of 5 degrees. The angle distance between two orientations, ($\varphi 1$, $\theta 1$) and ($\varphi 2$, $\theta 2$) in horizontal coordinate (azimuth, elevation), is generally obtained from the following formula:

$$\mathrm{acos}\{\cos(\theta 1)\cdot\cos(\theta 2)^{*}\cdot\cos(\varphi 1-\varphi 2)+\sin(\theta 1)\cdot\sin(\theta 2)\}$$

2.6 Ratio of Inevitable Lock off due to Receiver Nature

As our experiment uses an ordinary GPS L1 receiver not for dedicated purpose but for common use, the spontaneous lock off is a natural phenomenon. The ratio was measured that the power was less than the expected minimum power (-130dBm) with the path between the satellite and the receiver completely clear (shown as "Satellite in Visible State"). The ratio, f, was estimated as about 0.158 by the preliminary experiment as shown in Fig. 4.

2.7 Two Threshold Parameters

Based on the consideration described above, the two threshold parameters are used to process the many data on GPS signal strength. One threshold parameter is -130 dBm. The other threshold parameter is the accumulated frequency of 0.158. If, at an orientation, the accumulated frequency at the signal strength of -130dBm is at or less than 0.158 , the orientation was considered to be visible.

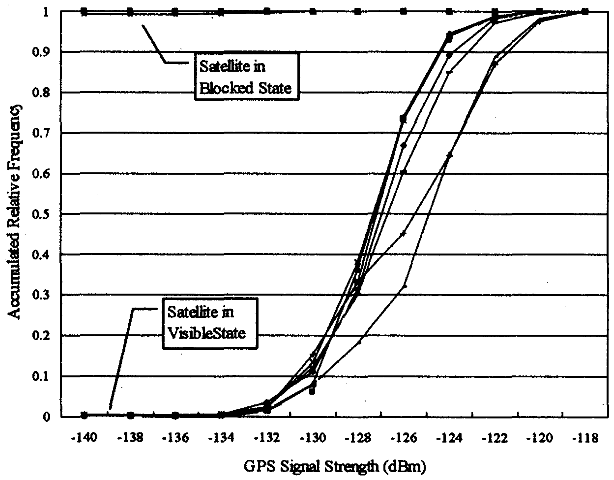

Fig.4 Accumulated Relative Frequency

A novel scheme is proposed and demonstrated where satellite visibility viewed from running vehicle is economically and effectively evaluated with such low cost GPS receivers like equipped in automobiles. Our preliminary experiment articulated even economical L1 C/A 1.5GHz GPS receivers can create enough precise database of ground feature blockage, compared to fisheye photograph method, if only two statistical parameters the author proposed are adequately set. Integrating the series of our efforts on this research field, the author also it is feasible to develop an automatic database creation system by the cooperation of the government and the civil with low cost GPS receivers.

3 METHODOLOGY – SCHEDULING ASPECT –

Once the blockage database is built, we can build various useful applications, including scheduling aids, as follows.

3.1 Visibility in the Sky at a Point

The blockage database can provide the information of communication path existence in the unfired form of the azimuth elevation coordination at the sky hemisphere above a ground point on a certain road. Blockage is a result of principle of superposition. It is cased by many obstacles. Those includes buildings, mountains, overhead roads and railways, any of three dimensional public display including billboard and public art and foliage. Unexpected object such like tall tracks at the adjacent lane in traffic jams is one of essential element of blockage. If the road is near a airport, airplane to take off and touch down can not be neglected as well. The evaluation of the status quo of such blockage can not be executed by simple simulation based on some layers on a geographical information system. In this context, this blockage archive created by our method comes to be very important because the archive can reconciles all objects' effects naturally. The easiness to create this kind of archive on GPS signal strength has a latent strength to open the door for the future-oriented "skyward path resource management" governance, including functions such like automatic detection system of illegal constructions, in cooperation with the civil GPS receivers on their vehicles.

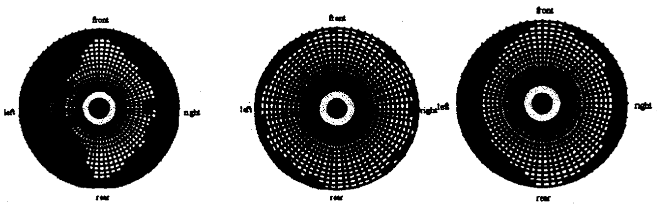

Fig. 5 Images of Visibility in the Sky by GPS data

3.2 Visibility Chart against Time

Once the blockage database based on the GPS signal strength is built, the communication satellite's visibility to a running vehicle comes to be adequately predicted. It is achieved by combining this blockage database as a layer with the satellite layer, which represents the behavior of satellites based on those orbital elements, and the vehicle layer, which describes the vehicle's route log on the ground or anticipates the vehicle's trace based on the route guidance. In this framework, a novel and effective scheduling aid tool based on the blockage database is established. Using this, satellites visibility chart against time is drawn. This chart reflects the status quo of the blockage which vehicles really encounter in real road environments, including effects of traffic jams and go-stop and tall tacks next lane as well as usual buildings and mountains as described above. The GPS signal blockage archive is reflecting so correctly those all phenomena that scheduling designers can relay the prediction of the blockage and make a adequate decision on the realistic scheduling policy which would most suitable to a certain circumstance in a real road.

The blockage database is to be used for the real time prediction of visibility state transition between a satellite and a vehicle. It enables us to make a real time handover. This practical feature is one of the most important aspects this blockage database scheme originally contains.

3.3 Visibility Duration Histogram

This blockage database has the additional feature which allows us to make extendable studies on a durability of vehicle satellite communication link. It is reflecting a specified road circumstance including the effects of the traffic jams, go-stop and tall tracks on adjacent lane as well as high-rise building and all other ground and airborne features. Such a feature like this histogram duration study enables us to analyze effective vehicle satellite communications system just before the real launch of real satellite which costs vastly.

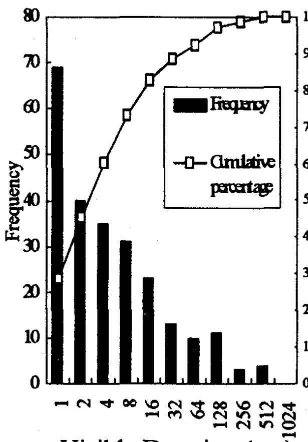

Fig.6 Histogram of Visible Duration to Geostationary Satellite from Vehicle

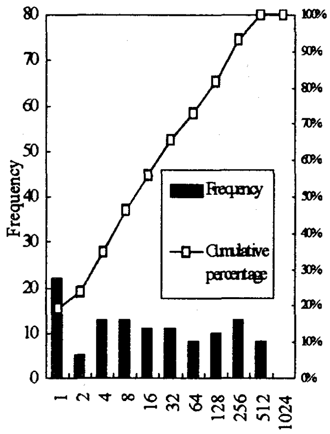

Fig.7 Histogram of Visible Duration to QZSS satellite from Vehicle

In this framework, it should be notable that it is easily achieved to reconcile the real vehicle movement with the real electromagnetic wave propagation. It should be noted also that the histogram studies open the new region on fitting parameter analysis, which searches the hidden parameter in the vehicular satellite communications in a city and an urban area for the first time. These parameters are supposed to be related to the city parameters such like the mean building height, the average road width, the seriousness of traffic jams of the city. This blockage database framework enables us to explore novel anticipations and confirmations of visible duration histogram fittings in other cities and satellite orbits in a cost-effective way for the first time.

4 FUTURE WORK

As to data transfer, standardization is required to the cooperation of the civil and government Further comparative studies using this blockage archive is planned to explore the parametric studies of the link duration histogram between a satellite and a vehicle in a real environment such like cities and mountain areas, including areas in south hemispheres. Further fisheye photograph comparisons are also planned.

5 CONCLUSION

A novel scheme is proposed and demonstrated where satellite visibility viewed from running vehicle is economically and effectively evaluated with such low cost GPS receivers like equipped in automobiles. Our preliminary experiment articulated even economical L1 C/A 1.5GHz GPS receivers can create enough precise database of ground feature blockage, compared to fisheye photograph method, if only two statistical parameters the author proposed are adequately set. Integrating the series of our efforts on this research field, the author also concluded it is feasible to develop an automatic database creation system by the cooperation of the government and the civil with low cost GPS receivers. With this database, the communication satellite's visibility to a running vehicle can be predicted. Satellites visibility chart against time can be drawn as well. As the chart reflects the status quo including the traffic jams and signal blockage correctly, scheduling strategy designers can make a precise judge to decide the best scheduling policy. This scheme can also be meaningfully taken advantage of as a test-bed to examine the effectiveness of a resource reservation mechanism for such a prioritized vehicle like an emergency vehicle in near future's Land Vehicle Satellite Communication society

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