Interference Analysis from Non-communication Device into GPS Service

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Abstract

We present interference analysis from Non-communication device which is used in many applications such as factory, home and hospital into Global Positioning System (GPS) Service. GPS service is used to detect location for car driving and safety of life. Nowadays, non-communication devices are increased rapidly. Therefore, in case that non-communication device and GPS receiver are operated in closed each other, GPS receiver can be affected from interference of non-communication device. In regarding with interference problem, this paper suggested the reasonable isolation distance between non-communication device and GPS receiver in order to guarantee good performance of GPS service.

Keywords: *non-communication device, GPS, Interference, Isolation distance*

1. Introduction

The Global Positioning System (GPS) is a space-based satellite navigation system that provides geographic location and time information in all weather, anywhere on or near the earth. The GPS has 24 satellites that detect location of object. Originally, GPS system is made in military to overcome the limitations of previous navigation system and is extended for civilians later. Recently, GPS has become a widely deployed and useful tool for commerce, scientific uses, tracking and surveillance. Such as automotive navigation, telematics, surveying, aircraft tracking, disaster relief service and so on.

Also, the equipment for using energy transmission has been increasing rapidly. Non-communication device that is presented as Industrial Scientific Medical (ISM) equipment is used for the energy transmission. Especially, according to International Telecommunication Union-Radiocommunication (ITU-R), the ISM band that reserved internationally for the use of radio frequency energy for ISM equipment other than communication is assigned. Therefore, communications equipment operating in these bands must tolerate any interference generated by ISM equipment, and users have no regulatory protection from ISM equipment operation. So, many counties including Korea designated ISM band and encourage usage of ISM equipment in these band.

But, GPS system that is used for safety life has higher priority than others even through in ISM band. So, in case that ISM equipment operates in close to GPS receiver, there is potential interference from ISM radiation power to GPS receiver. In order to remove interference, the protection method is needed for protecting GPS receiver.

In this paper, the scenario that ISM equipment is operating in close to GPS receiver was assumed and analyzed interference from ISM equipment to GPS receiver. Based on interference analysis, the isolation distance that is separation distance between ISM equipment and GPS receiver is calculated in order to protect GPS receiver. This isolation distance will be helpful for GPS service.

2. Interference Scenario

For interference analysis between ISM equipment and GPS receiver, interference scenario that multiple ISM equipments and GPS receiver are located in closed. ISM equipment is interferer that radiate interference signal such as RF induction heater, arc welder, microwave oven and signal generator. And, GPS receiver is victim affected by ISM equipment.

2.1. Interference Environment

The satellite for GPS is orbiting at an altitude of approximately 20,200 km. the GPS signal is transmitted by satellite and the signal is very weak due to the long distance between satellite and GPS receiver. Therefore, GPS received signal is sensitive from interference and can be generated positioning error due to interference. Fig.1. shows the interference scenario that ISM equipments such as Arc welder, Signal generator, RF induction heater, etc operated in closed to GPS receiver.

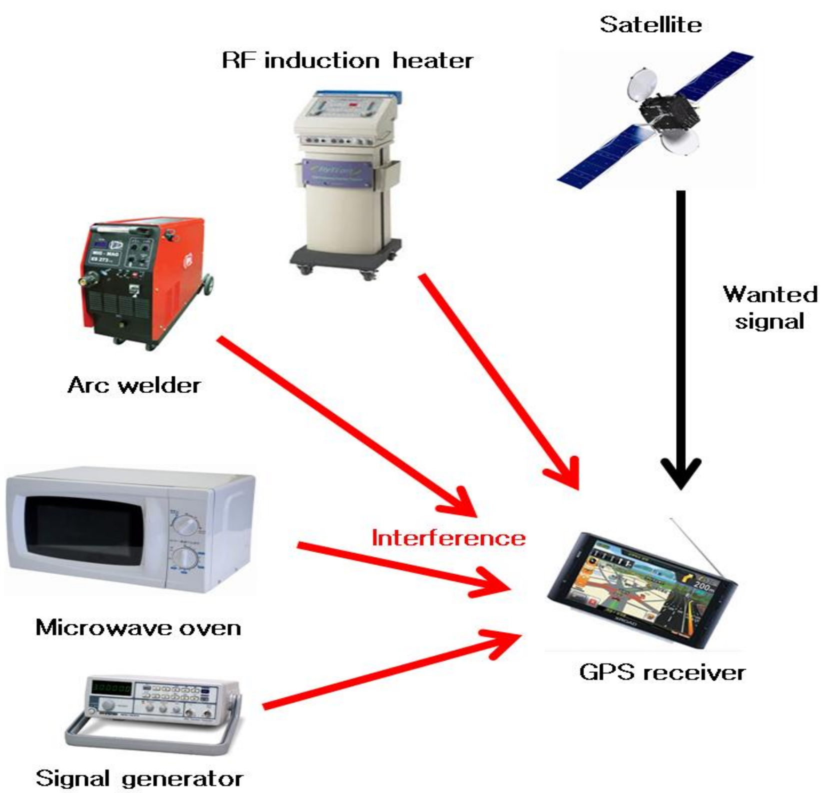

Fig. 1. Interference Scenario

In the interference scenario, the isolation distance that separation distance between ISM equipment and GPS receiver is needed in order to remove interference. As increasing the distance, the interfering signal can be attenuated by path loss.

2.2. ISM Equipment

For setting up interfering signal for ISM equipment, International Special Committee on Radio Interference (CISPR) 11 limit was applied. CISPR was founded to set standards for controlling electromagnetic interference in electrical and electronic devices, and is a part of the International Electrotechnical Commission (IEC). Also, CISPR 11 gives a regulation on radiation limit that is allowable maximum radiation field strength for ISM equipment.

In the frequency band of 1575.42 MHz (GPS system), the radiation limit is 92 dBuV/m according to CISPR 11 [1]. Then, it is assumed that interfering signal of ISM equipment is continuous radiating in the entire GPS reception band. This assumption can be the worst case among interference scenario.

This field strength (dBuV/m) from CISPR 11 is can be converted into power (dBm) with equation 1 as following,

$$P(dBm) = E(dBuV/m) - 20\log F(MHz) - 77.2 \tag{1}$$

Here, P : interfering power, E : interfering field strength, F : frequency

From equation 1, -49.15 dBm/MHz of interfering power was calculated and was applied to set up the interfering signal of ISM equipment.

2.3. GPS System

All satellites broadcast at the same frequencies, 1.5742 GHz (L1 signal) and 1.2276 GHz (L2 signal). The satellite network uses a CDMA spread-spectrum technique where the low-bitrate message data is encoded with high-rate pseudo-random (PRN) sequence that is different for each satellite. In this paper, the frequency of 1.5742 GHz is selected.

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include the information of time and orbit. In the case that interfering signal is received into GPS receiver, the distortion of information from GPS satellite is generated by interference signal then, positioning error is happen. Therefore, GPS receiver is needed to protection from interference in order to get accuracy position. For simulation, parameters of GPS system are summarized in table. 1 [2].

Table 1. Characteristics of GPS System

Parameters	Value
Frequency	1575.42 MHz
Bandwidth	2.046 MHz
Sensitivity	-130 dBm
Rx antenna height	1.5 m
Rx antenna gain	0 dB
Noise floor	-108 dBm
I/N	-12 dB
Propagation model	Free space

The parameters from Table 1 are used to get isolation distance. For statistic method, the I/N is used instead of C/I as protection ratio.

3. Interference Analysis Method

In this paper, there are two kinds of method that is Minimum Coupling Loss (MCL) and Monte Carlo (MC).

3.1. Minimum Coupling Loss (MCL)

The MCL method is useful for an initial assessment of frequency sharing, and is suitable for fairly static interference situations. But, it is not considering the mobility of GPS receiver. So, the result of MCL is for fixed scenario that interfering signal is not variable. The MCL is defined as path loss that should be attenuated to prevent interference between interfering transmitter and victim receiver. In order to calculate Interfering power in the GPS bandwidth, equation 2 is needed as following [3],

$$P_{GPS} = P_{ISM} + 10\log(BW_{GPS} / BW_{ISM}) \tag{2}$$

Here, P_{GPS} : Power in the GPS bandwidth, P_{ISM} : Power in the 1MHz bandwidth

Then, the MCL is obtained with equation 3 as following [4][5],

$$MCL = P_{GPS} - Sen. + G - L + 10\log N \tag{3}$$

Here, Sen. : Sensitivity of GPS, G : Antenna gain, L : Cable loss, N : Number of interferer

Finally, isolation distance can be calculated with equation 4 as following [6],

$$D = 10\text{^}[(MCL - 20\log(F) + 27.55) / 20] \tag{4}$$

Here, F : Frequency, MCL : minimum coupling loss

Equation 4 is path loss from free space model. This model is used in the line of sight path with no obstacles nearby to cause reflection of diffraction.

3.2. Monte Carlo (MC)

The MC method is statistic analysis based on Monte Carlo technique and is considering mobility of GPS receiver. In many practical applications, MC method is useful to predict the statistical error. Fig. 2. Shows interfering link and victim link which include Interfering transmitter (It : ISM equipment), Victim receiver (Vr : GPS receiver), Wt (Wanted transmitter : Satellite), Wr (Wanted receiver) [7]. The only requirement is that the physical or mathematical system be described by probability density functions (PDF). Once the PDF of the parameters are known, the MC simulation can proceed by random sampling. Many simulation trials are performed and the desired result is taken as an average value of trials.

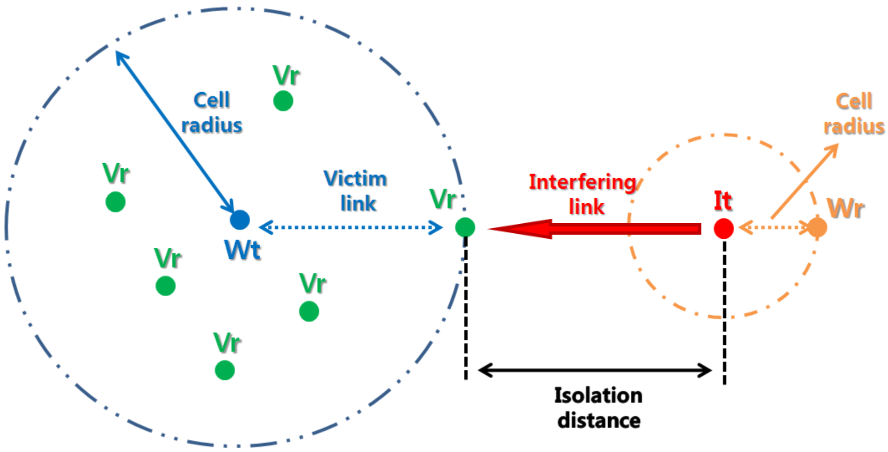

Fig. 2. Interfering Link and Victim Link

In this simulation, desired Received Signal Strength (dRSS) which is from Satellite and interfering Received Signal Strength (iRSS) which is from ISM equipment are different according to the location of Vr independently. So, statistic method such as probability was required.

Fig. 3 shows that how to calculate interference probability. The interference adds to the noise floor. The difference between the wanted signal strength and the interference signal is measured in dB, which is defined as the signal to interference ratio. This ratio must be more than the required C/I target if interference is to be avoided. The MC method is used to check over this condition and record whether or not interference is occurring [8].

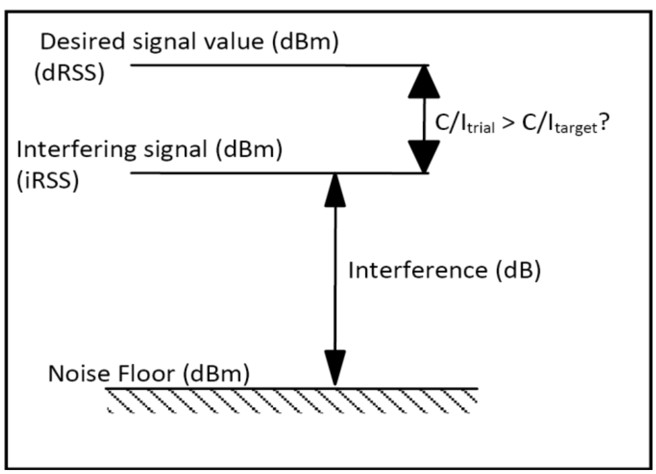

Fig. 3. Comparison between C/I and C/I Target

The MC method works by many independent instants in time. For each trial, each scenario is built up suing a number of different random variables. For example, how strong the wanted signal, number of interferer. If a sufficient number of simulation trials are considered then the probability of a certain event occurring can be calculated with a high level of accuracy.

The samples of C/I are compared against the C/I target to calculate the probability with the condition that the desired received signal strengths is greater than the sensitivity of the victim receiver with equation 5 as follow,

$$P = P(dRSS / iRSS > C / I \mid dRSS > Sensitivity) \quad (5)$$

Here, P : Probability that there is no interference.

Finally, interference probability of victim receiver is calculated with equation 6 as following,

$$P_I = 1 - P \quad (6)$$

Here, P_I : Probability of interference.

4. Isolation Distance

The isolation distance which is separation distance for protecting GPS receiver is obtained by using MCL and MC separately.

4.1. Isolation Distance by MCL

In the static case, the isolation distances were shown Fig. 4. according to number of interferer by using MCL. As increase of number of ISM equipment, higher isolation distance is need to protect GPS system.

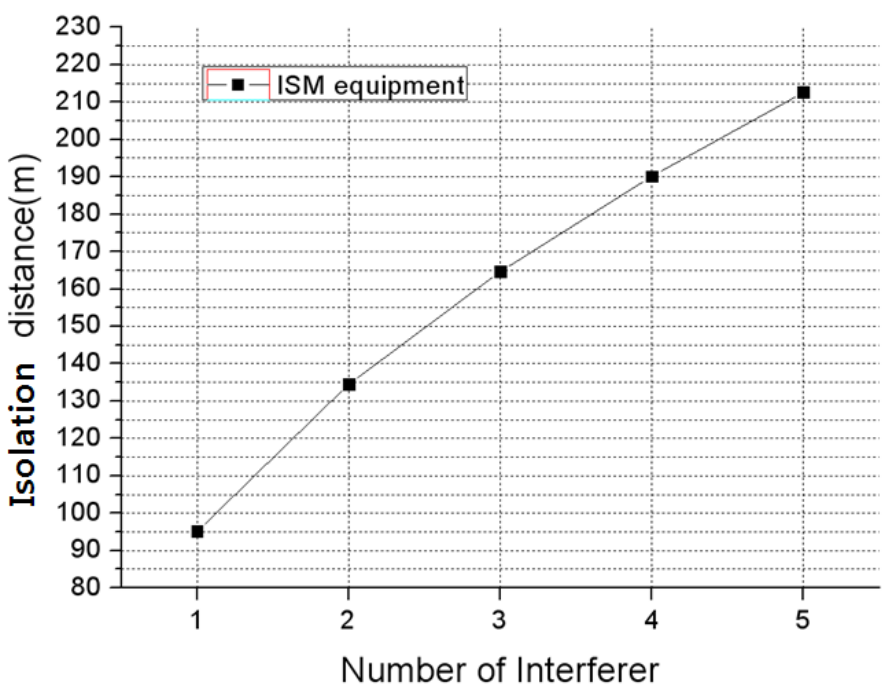

Fig. 4. Isolation Distance by MCL

As in Fig. 4, 95 m of isolation distance is needed to protect GPS system in case of one interferer. This isolation distance can guarantee no interference from ISM equipment to GPS system.

4.2. Isolation Distance by MC

In the statistic case, the Interference probabilities were shown in Fig. 5 according to number of interferer. As increase of number of ISM equipment, higher interference probability is calculated in the case that isolation distance is fixed.

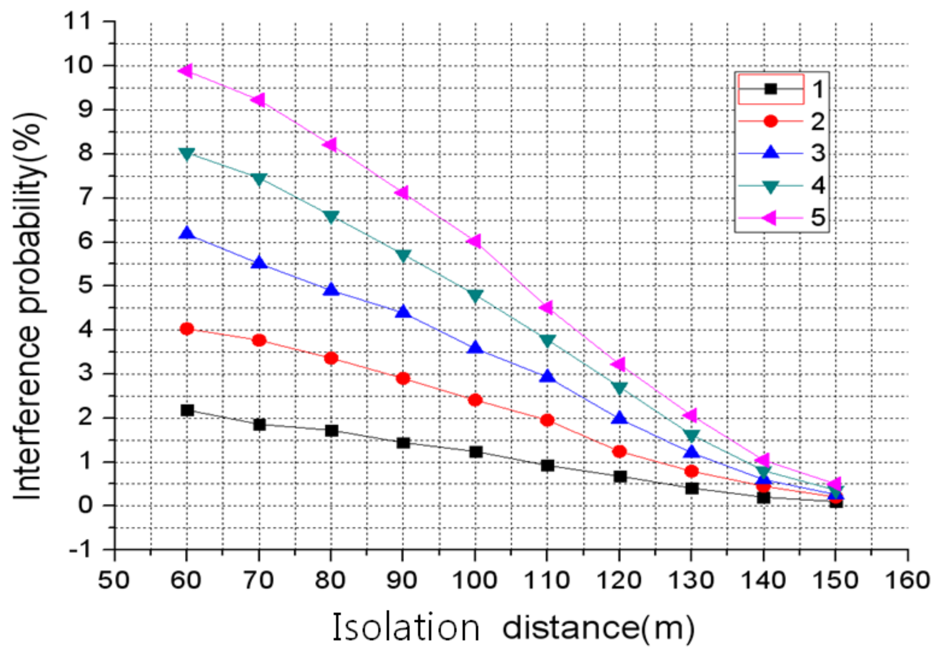

Fig. 5. Isolation Distance by MC

Fig.5. shows that the interference probability decreases as isolation distance increases. According to the result, the isolation distance is determined to meet 2 % below of interference probability. Therefore, in case of one interferer, 65 m of the isolation distance is required to protect GPS system. GPS system has high importance. As regarding this, the 2 % of interference probability that is stricter than others is applied for GPS system.

5. Conclusions

This paper is about compatibility between Non-communication device which be presented by ISM equipment and GPS system base on interference analysis from ISM equipment to GPS system. For the interference analysis, the scenario that ISM equipment is operated in closed to GPS receiver was set up. Then, isolation distance is calculated by using MCL and the interference probability is calculated by using MC method in the scenario.

As a result, 95 m of isolation distance was suggested by using MCL in the static case. And, 65 m of isolation distance was suggested by using MC in statistic case. These isolation distances will be helpful for the operation of stable GPS system.

References

[1] CISPR, Industrial, scientific and medical(ISM) radio-frequency equipment-Electromagnetic disturbance characteristics limits and methods of measurement. CISPR Publication 11, June.**(2004)**

[2] Dai Borre, Dennis M. Akos, Nicolaj Bertelsen, Peter Rinder, Soren Holdt Jensen, : A Software-Defined GPS and Galileo Receiver, Springer verlag, pp. 54.**(2005)**

[3] ERC Report 104, : Compatibility between Mobile Radio Systems operating in The range 450-470MHz and Digital Video Broadcasting-Terrestrial(DVB-T) System operating in UHF TV Channel 21(470-478MHz), ECC within CEPT, pp.54, June. **(2007)**

[4] ERC Report 101, : A comparison of the minimum coupling loss method, enhanced minimum coupling loss method, and the monte-carlo simulation, ERC, pp.25-26, may.**(1999)**

[5] Phip a. Dafesh, Paul Hanson, and Robert yowell, : A portable UWB to GPS emission simulator, : IEEE. Pp.405-413, Apr. **(2004)**

[6] Mike Reynolds, Andy Rhodes, Jeremy klein, “PMSE Spectrum Usage Right & Interference Analysis”, SEAMCAT, pp.14. June. **(2008)**

[7] CEPT Administrations, : Monte-Carlo Simulation methodology for the use in sharing and compatibility studies between different radio services or systems, ERC within the CEPT, Feb.2000

[8] ECO, : SEAMCAT Handbook, CEPT, pp.56.Jan**.(2010)**

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