Electromagnetic Waves used in Global Positioning System and Device, Market trend, Future direction

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ABSTRACT — **WE PRESENT BASICALLY ABOUT GLOBAL POINTING SYSTEM(GPS). AND WE WILL PRESENT THE REASON WHY ELECTROMAGNETIC WAVES ARE USED IN GPS AND PRESENT REQUIRED ELECTROMAGNETIC WAVES' CHARATERISTICS. ALSO CURRENT MARKET TREND, FUTURE DIRECTION IS MOVING INTO WILL BE BRIEFLY PRESENTED.**

I. WHAT IS GPS

When SPUTNIK I, the first satellite of Russia was launched on October 4. 1957, few physicists were intrigued by the substantial Doppler frequency shift of radio signals from the first artificial earth satellite. And they knew the entire satellite orbit was able to be determined from careful Doppler measurements of several satellites' signals if we already know the position of ground tracking station. Based on this success, it was suggested that the process could be inverted. So the navigator's position could be determined with Doppler measurements from a satellite with an accurately known orbit. This is the basic concept of GPS.

The Global Positioning System (GPS) is a location system based on a constellation of about 24 satellites orbiting the earth at altitudes of 20,200 km in the Fig. 1. GPS was developed by the United States Department of Defense (DOD), for its tremendous application as a military locating utility. The DOD's investment in GPS is immense. Billions and billions of dollars have been invested in creating this technology for military uses. However, over the past several years, GPS has proven to be a useful tool in non-military mapping applications as well [1].

As a space-based radio positioning system, GPS can determine the PVT(position, velocity, time) in 3D, accurately. GPS can be used globally, at all weather condition, passive, unlimited users. For the navigator, GPS is like a radio. It uses broadcasting method. It propagates signals like a transmission tower for navigator receiving the signal. So the navigator having the receiver can determine his position. But GPS receiver needs to calculate the position using the signal unlike radio's reproduction.

GPS is based on satellite range-calculating the distances between the receiver and the position of 3 or more satellites (4 or more if elevation is desired) and then applying some good old mathematics. Assuming the positions of the satellites are known, the location of the receiver can be calculated by determining the distance from each of the satellites to the receiver. GPS takes these 3 or more known references and measured distances and "triangulates" an additional position in Fig. 2.

II. EM WAVES ARE USED IN THIS TECHNOLOGY

To use the GPS, we need satellite communication using electromagnetic wave(EM wave) propagation. Basically EM wave should pass through the atmosphere and the ionosphere. But only limited EM waves can pass through those layers in Fig. 3. That frequency spectrum is called 'cosmic window' or 'radio window'. So we should choose the EM wave that minimizes the effects by two layers.

The reason why we use EM waves at the satellite communication system is because of their general characteristics. Generally EM waves propagate further then sound or light, and they have a stable persistent oscillation. So they can be easily modulated and transmitted with information. Generally microwave used as GPS signal. Microwave frequency include with 300~3,000MHz of UHF(ultrahigh frequency) and 3~300GHz of SHF(superhigh frequency). The wavelength of microwave is very short, so microwave characteristics are close to the light, like a straightness, reflection,

bending, interference. So we can communicate uniformly at high speed without concerning the configuration of the ground. Furthermore high frequency can transmit large amount of data.

The intervening medium between earth stations and satellite affects EM wave propagation in several ways. The parameters mainly influenced are gaseous absorption in the atmosphere, absorption and scattering by cloud, fog, precipitation, atmospheric turbulence and ionosphric effects. The most significant impairments of EM wave propagation occur in the troposphere and the ionosphere.

The first few tens kilometers of the atmosphere in which clouds and rain are formed is known as the troposphere. Fig. 4 shows the total estimated one-way attenuation at moderate, 0% and 100% relative humidity for vertical earth-space path as a function of frequency between 1 and 200GHz at 45°N latitude using US standard atmosphere. It may be noted that there are specific frequency bands where the absorption is high. In the frequency range of 1-18GHz, the zenith one-way absorption is only in the range ~3.0-0.2 dB. Fig. 5 shows that rain attenuation constant becomes significant at frequencies above ~10 GHz [2].

The ionized region in space extending from about 80 to 1000 km constitutes the ionosphere. Ionization in this region is caused by the interaction of solar radiation with gas molecules. EM waves propagating through the ionosphere are affected in a number of ways. The main effects of the ionosphere are rotation in polarization or the Faraday effect. The polarization angle of a linear polarized wave is rotated in the ionosphere owing to interaction of the electromagnetic wave with the Earth's magnetic field. This phenomenon is known as the Faraday effect. Faraday effect reduces as $1/f^2$ with an increase in the frequency f, with significant effects limited to frequencies below around 2 GHz. So we need to choose circular polarization to minimize the impact of polarization rotation, although there remains virtually unaffected polarization by Faraday effect[3].

At present, the frequency range being used or under consideration for satellite communication is between ~100 MHz and 30 GHz. The frequency window of ~3-10 GHz is least affected and therefore it is not surprising that most satellite systems operate within this band.

For that reason, we can use microwaves that have frequency ~3-10 GHz in the GPS satellite communication system. And we can say that it is only way to communicate with moving objects at the space. Microwave has various frequency bands. But only certain frequency bands could be made available. We need several considerations.

The use of L-band gives acceptable received signal power with reasonable satellite transmit power levels, whereas the C-band path loss is roughly 10 dB higher in table 1. The large ionospheric delay and fluctuation in delay weighs against UHF as does the difficulty in obtaining two large(≈20MHz) bandwidth frequency assignments in the UHF band (two frequency band are necessary for ionospheric correction). Thus, L-band was selected, and dual frequencies permit ionospheric group delay measurement.

So, the GPS signal consists of two components, Link 1 or L1 and Link 2 or L2. The signals have stable frequency made by inner atom clock at the satellite. And basic frequency of these signals is 10.23MHz. For standard measurement, microwave carrier signal is 1,575.42MHz(L1) that is 154 times of basic frequency. For precision measurement, microwave carrier signal is 1,227.6MHz(L2) that is 120 times of basic frequency. Similarly, all of the signal clock rates for the code, radio frequency carriers, and a 50 bps navigation data stream are coherently related.

The frequency separation between L1 and L2 is 347.82 MHz or 28.3%, and it is sufficient to permit accurate dual-frequency estimation of the ionospheric group delay. (The ratio of L1/L2 = 77/60 = 1.2833.) The ionospheric group delay varies approximately as the inverse square of frequency, and thus measurement at two frequencies permits calculation of the ionospheric delay. The ionospheric group delay correction is obtained by subtracting the total L1 group delay τ_{GDL1} from the total L2 group delay τ_{GDL2} in order to cancel the true pseudorange delay. This difference $\Delta\tau$ is then (neglecting random noise for the moment) the following: $\Delta\tau = \tau_{GDL1} - \tau_{GDL1} = A/f_{L2}^2 - A/f_{L1}^2 = A/f_{L1}^2 \times 1/1.54573 = \tau_{iono}/1.54573$ or $\tau_{iono} = A/f_{L1}^2 = 1.54573\ \Delta\tau$ where τ_{iono} is the ionospheric group delay at L1, and $\Delta\tau$ is measurable difference between total propagation delays at L1 and L2. Thus, the frequencies L1 and L2 are separated far enough in frequency so that ratio is only a factor 1.54573 [4].

In this way, attenuation is the most significant consideration in GPS communication system. To minimize the attenuation, we use circular polarized microwaves in L-band. So EM wave characteristic selected the proper wave.

III. DEVICE & CURRENT MARKET TREND

Generally, GPS principle is used in 'navigation equipment'. Many kinds of transportation take advantage of this technique when they try to find out of their position, and want to know the location of object, and so on. Secondly, GPS is adapted in 'measurement equipment'. And GPS is used in 'CDMA wireless communication'. In synchronous type,

time plays an importance role. At least, exact time information is owned among many communication bases. So CDMA bases should equip the implementation of GPS, and then this time a use of GPS doesn't utilize to obtain 'position information', but 'exact time information'. Lastly, many kinds of service industries apply to GPS for control system composition. For example, almost of trash cars are operated by public corporation. In this case, if every car equips GPS receiver, central post can grip the location of scores or hundreds cars and send them toward required places promptly.

Substantially, we can touch the GPS directly with 'Telematics', which is a kind of IT service that can be transmitted image and voice through linking wireless network from and to the car. There will be comprehended drive information as well as common life information. Strategy Analytics by America market investigation institute anticipated that up to 2006 about 50% of car that are produced in the world will attach to telematics implement. Domestic car companies started the commercial business from 2002. For example, 'ATOM' service, Hyundae-Kia motor telematics service correlated LG-telecom, and 'Dream Net', Daewoo motor car telematics service correlated KTF, have been executed and the rate of products equipped Telematics terminals has been increasing by degrees [5].

IV. FUTURE OF GPS

Now public can come to approach the information from GPS. Error representing difference between real position and calculated position is fairly improved. It was possible because technologies like DGPS(Differential GPS), which uses principle that compare moving receiver with standard receiver and correct the difference of the two. But from now on experts require the error about mm or cm unit, keeping pace with this request developed nations are developing 'next generation GPS'. Because greatly elaborate position information guarantees comfortable life, industries related to GPS are immensely expanded. So competition among the nations is inevitable. Already to disturb exclusive possession of USA in GPS, EU and Russia are preparing to satellite navigation system alike GPS, such as GLONASS and Galileo. This competition is anticipated that accuracy of navigation will make better than now. Until the 2010, 'third-generation GPS' will be launched and commonly used, and then epochal changes will take place. As represented at recent trend, in transportation field that change will be remarkable. And vanishing the position error, automatic navigation will be possible, such as ship and airplane [5].

V. CONCLUSION

In this work, we can know the EM wave using at GPS communication system has specific frequency band and know that required EM wave in GPS has specific characteristic to satisfy the system. Conclusively we knew that using EM wave in GPS system is natural, because that is the only way to satisfy requirements.

GPS is devised for military purpose at first. But now GPS is broadly used in many fields. GPS technique & market is growing remarkably. But we should also think about the side effects, such as privacy invasion. And we will have to endeavor to minimiz these side effects.

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Performance parameter	uhf ≈400 MHz	L-band (1–2 GHz)	C-band (4–6 GHz)
Path loss for omnidirectional receive antenna-loss $\sim f^2$	Path loss lowest of the three	Acceptable	Path loss ≈ 10 dB larger than at L-band
Ionospheric group delay, $\Delta R \sim 1/f^2$	Large group delay, 20–1500 ns	Group delay 2–150 ns at 1.5 GHz	Group delay ≈ 0–15 ns
Other considerations	Galactic noise ≈ 150°K at 400 MHz	—	Rainfall/atmospheric attenuation can be significant in 4–6 GHz band 0.1 to 1 dB/km at 100 mm of rain/hour

Table. 1. Global positioning system trnsmission frequency band selection considerations
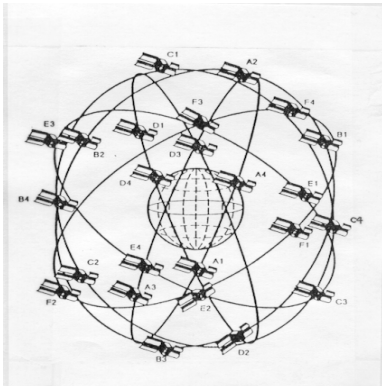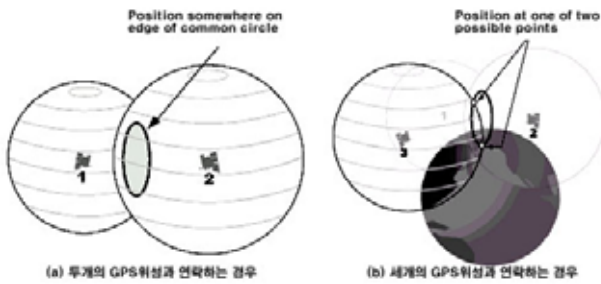

Fig. 1. Constellation of GPS satellites
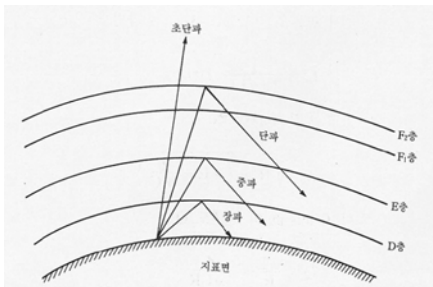

Fig. 2. Method of triangulation

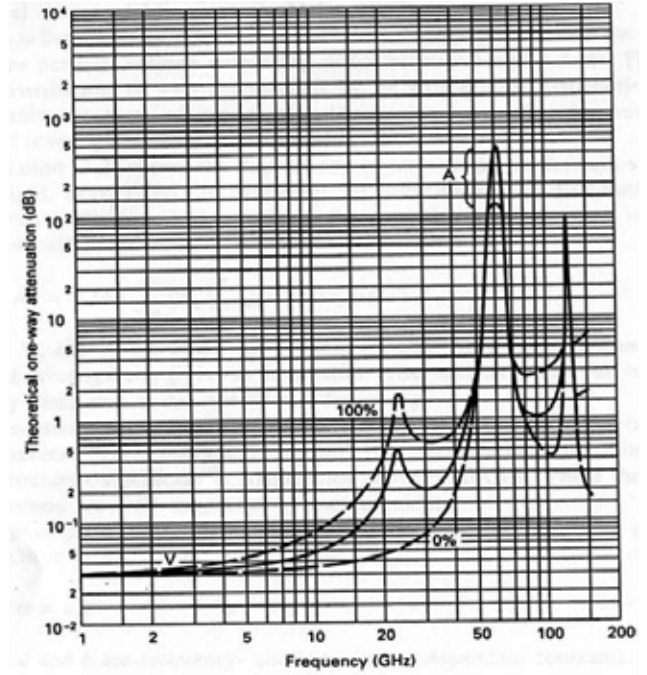Fig. 3. Composition of ionosphere

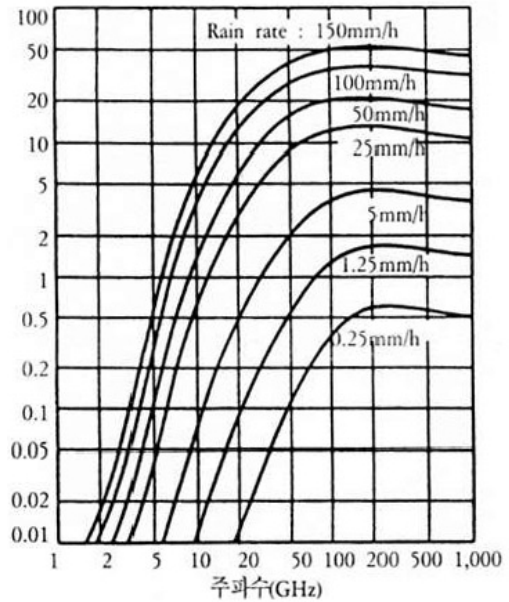Fig. 4. Theoretical one-way attenuation for vertical paths through the atmosphere

Fig. 5. Attenuation constant through rain drops(raindrop-size distribution : Law and Parsons 1943, terminal velocity of raindrops : Gunn and Kinzer 1949, Dielectric constant of water at 20°C : Ray 1972)