Design of the Pseudolite Pulsing Scheme

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Abstract: The pseudolites are ground-based transmitters that can be configured to emit GPS-like signals with the purpose of enhancing the GPS by providing increased accuracy, integrity, and availability. Although the use of the pseudolites offers many potentially significant benefits, a number of technical issues must also be addressed. One is the pseudolite signal power level which is related with near-far problem, and other issues include deployment requirements, signal data rate, signal integrity monitoring, and user antenna location and sensitivity. In order to solve the near-far problem, the frequency offset or the pulsing schemes is implemented in most the pseudolites. However, in the case of the previous pulsing scheme with the fixed code pattern, the near-far problem still remains.

This paper aims to design a sequential pulsing scheme to avoid the near-far problem. A pulse mode pseudolite has less interference than the continuous mode.

Keywords: Pseudolite, GPS, Near-far problem, Pulsed mode

1. Introduction

GPS microwave frequencies restrict the use of GPS to locations where the antenna of receiver has a line-of-sight view of the requisite number of satellites. Locating the antenna of receiver in a canyon or building can also limit the navigation performance. As a result, some of GPS applications need to the pseudolite to augment the satellite constellation. Each pseudolite mimics GPS satellite but it is located on the earth's surface.

Figure 1 shows the navigation system using GPS satellites and pseudolites.

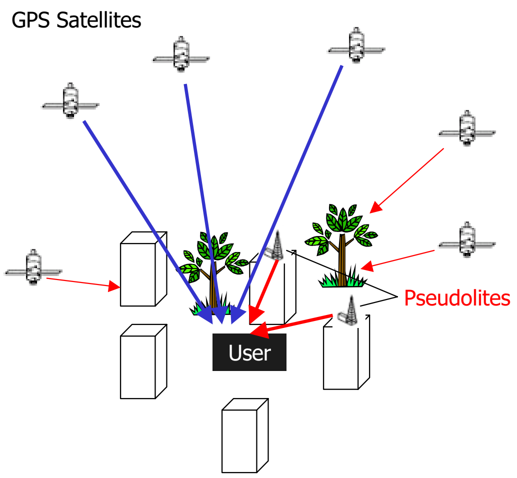

Fig. 1. Navigation system using GPS satellites & pseudolites

However, there are some problems when GPS and the pseudolite are used at same time. One of the most critical problems is near-far problem. Near-far problem is occurred when the signal of one transmitter is so stronger than the other transmitters. Figure 2 illustrates the near-far problem.

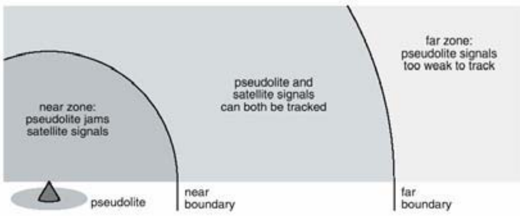

Fig. 2. Near-Far Problem

$$\Delta p = 10\log\left(\frac{R_a^{\ 2}}{R_b^{\ 2}}\right) \tag{1}$$

R_a : The distance between receiver and transmitter "a"

In the GPS systems, the difference between the power levels due to the receiver location is 2.1dB. (Equation 1) In case one pseudolite is located 1Km from the receiver and another pseudolite is locate 10Km from the receiver, the difference in power level is 20dB by using equation 1. This difference can jam the GPS signal. To solve Near-far problem, many solutions are suggested. In chapter 2, various solutions are introduced. And the pulsed mode pseudolite which is suggested by RTCM(Radio Technical Commission for Maritime Services)-104 is explained in chapter 3. In chapter 4, the various pulse schemes will be explained and analyzed. The interference of the designed pulse mode and continuous mode is simulated in chapter 5.

2. The solutions for the Near-far problem

In this chapter, three solutions are explained to solve the Near-far problem. The first solution is the out-of-band transmission. (Figure 3)

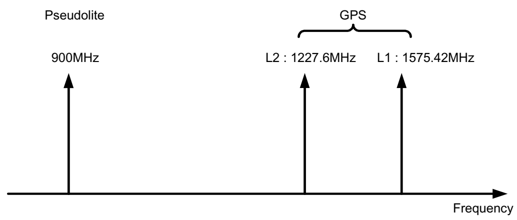

Fig. 3. Out-of-Band Transmission

In this solution, the pseudolite uses substantially different frequency with GPS system. Out-of-Band Transmission is the simplest solution to avoid the Near-far problem. However, this solution needs extra hardware to acquire the pseudolite signal.

The second solution is the frequency offset. (Figure 4)

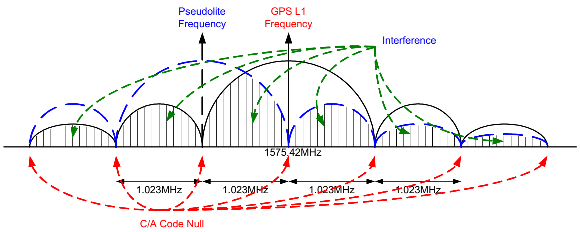

Fig. 4. Frequency Offset

This solution is that the pseudolite uses the null frequency of GPS signal. The benefit of this solution is that pseudolite can uses same GPS hardware. However, Figure 4 shows that large interference area still remains.

The last solution is the pulsed transmission (Figure 5).

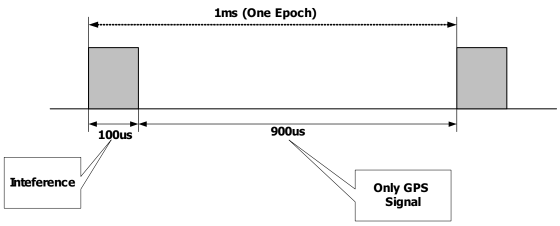

Fig 5. Pulsed Transmission

The pulsed transmission uses the same frequency as GPS which is 1575.42MHz. Therefore any hardware modification is not necessary. When the pseudolite uses the pulsed transmission, pseudolite signal just interferes 10% of GPS signal. The pulsed mode pseudolite was suggested by RTCM-104. The pulse mode pseudolite transmits signal at specific time during one period of C/A code. Therefore, the signal interference which causes the near-far problem is occurred only at specific time.

3. Pulse Scheme of RTCM-104

The pulse schemes which RTCM-104 suggests for the pseudolite have one-eleventh of duty cycle. In other words the pseudolite transmits the signal about 0.099msec during 1ms which is one period of C/A code. Figure 6 shows the pulse scheme has one-eleventh of duty cycle.

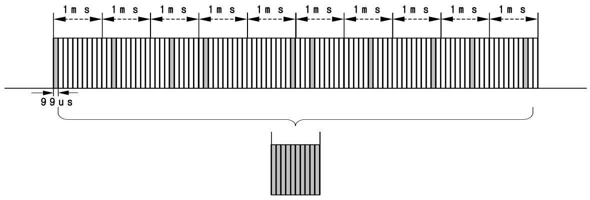

Fig 6. Pulse Scheme (Duty: 1/11)

Also RTCM-104 describes configurations of pulsed Transmission as follows

- TDM (Time Division Multiplexed)
- Minimizes change of receiver structure
- Interference only lesser than 10% of GPS signal
- Random pulse position
- The period of random pulse is 200ms
- Slot '0' and slot '10' are occurred at the same time
- Every 10ms whole C/A code is restored.

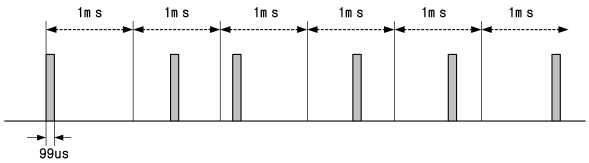

Fig 7. Random Pulse

Figure 7 explains the random pulse. The position of pulse differs from msec to msec. The random sequence is repeated every 200msec. (Figure 8)

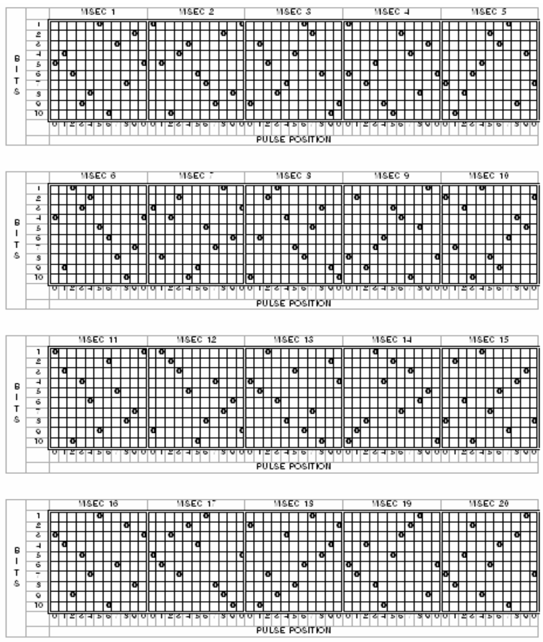

Fig 8. Pulse position within the 10 data bit, 200 msec patterns

4. Designed Pulse Schemes

In this chapter, the newly-designed pulse schemes are explained.

To design new pulse schemes, the duty cycle and the period of pulse occurrence is used.

Figure 9 shows the test block diagram to verify designed pulse schemes.

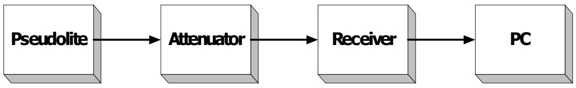

Fig 9. Test block diagram

Figure 10 shows the pseudolite which is developed by the navicom. This pseudolite has DIP switch to control output power level. Also, it includes 1pps input connector which can make synchronization among each pseudolite. In this paper these pseudolites are used for the test of pulse schemes.

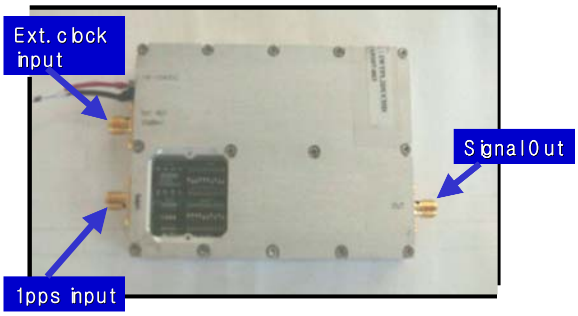

Fig 10. Pseudolite(Navicom)

The figure 11 shows the pulse scheme is suggested by RTCM-104. This scheme is developed by using the MAX+II and the verilog HDL.

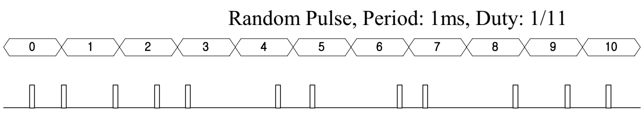

Fig 11. The pulse scheme suggested by RTCM-104

The figure 12 shows the various random pulse schemes have the 1ms period.

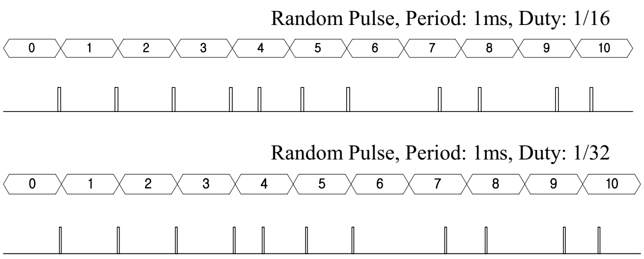

Fig 12. The random pulse scheme with 1msec period

To compare the random pulse scheme with the fixed pulse scheme, the pulse scheme has 1ms period and fixed pulse position is developed.(Figure 13)

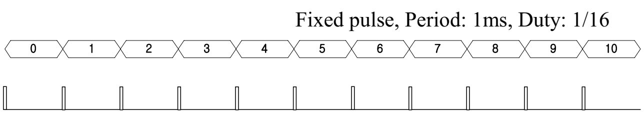

Fig 13. The fixed pulse scheme with 1msec period

The figure 14 and 15 show the designed pulse schemes has different period.

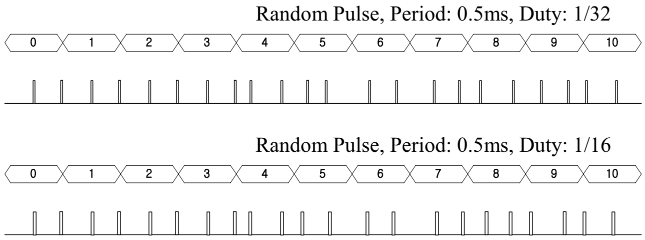

Fig 14. The random pulse scheme with 0.5msec period

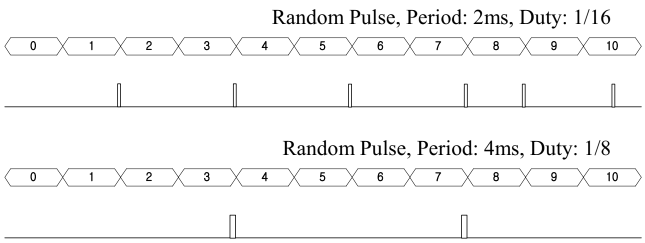

Fig 15. The random pulse scheme with 2msec and 4msec period

To compare designed pulse schemes, the power difference between main signal and side signal is used. (Figure 16)

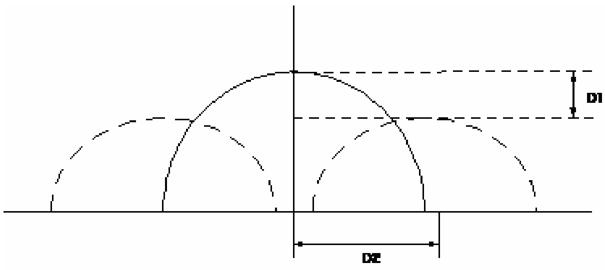

Fig 16. The power spectrum of pseudolite signal

The table 1 shows the result of test.

Table 1. The test result of various pulse schemes

Pulse Schemes								
Atten:60	1/11 (RTCM)	1/16					1/32	
		1ms (Random)	2ms (Random)	4ms (Random)	1ms (Fixed)	0.5ms (Random)	1ms (Random)	0.5ms (Random)
True Peak	14.5	11.7	X	X	11.8	12.8	X	12.2
D1	0.4	0.1	X	X	0.6	1.1	X	5.3
D2	1kHz	1kHz	X	X	Various	2kHz	X	2kHz

From this result, the pulse scheme has 0.5ms period and 1/32 duty is selected for the tested pseudolite pulse scheme.

5. Simulation

The figure 17 is the test block diagram to verify that the selected pulse schemes can reduce Near-Far Problem.

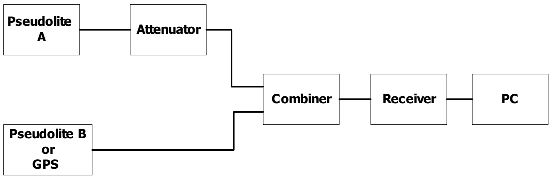

Fig 17. Test block diagram of near-far problem

The pseudolite A is connected to attenuator to control the output power. Power controlled the pseudolite signal and the pseudolite B(or GPS) signal are sent to receiver through combiner.

To confirm that the pulsed mode pseudolites have less interference than the continuous mode pseudolites, each mode of pseudolites is analyzed by using SNR(Signal to Noise Ratio).

The table 2 shows the result of the pulsed mode pseudoiltes.

Table 2. The test result of the pulsed mode pseudolites

PRN#33 (Control Attenuator)				PRN#36 (Fixed Attenuator)			
Atten	NCO	SNR	Status	Atten	NCO	SNR	Status
65	8600	9.8	stable	60	8400	11.1	stable
60	8500	11.1	stable		8400	11.1	stable
50	8500	12.1	stable		8400	11.0	Stable
40	8500	12.4	stable		8400	10.9	Stable
30	8500	11.7	stable		8500	10.9	Stable
25	X	X	X		8500	10.9	stable
20	X	X	X		8500	10.8	stable

The table 3 shows the test result of the continuous mode pseudoiltes.

Table 3. The test result of the continuous mode pseudolites

PRN#33 (Control Attenuator)				PRN#36 (Fixed Attenuator)			
Atten	NCO	SNR	Status	Atten	NCO	SNR	Status
65	8600	9.8	Stable	60	8400	11.1	Stable
60	8500	11.1	Stable		8400	11.1	Stable
50	8500	12.1	Stable		8400	11.0	Stable
40	8500	12.4	Stable		8400	10.9	Stable
30	8500	11.7	Stable		8500	10.9	Stable
25	X	X	X		8500	10.9	Stable
20	X	X	X		8500	10.8	Stable

Also the Live GPS signal and the pseudolite signal are used to verify which mode has less interference with GPS signal than the others.

The table 4 shows the test result of the pulsed mode pseudoilte and live GPS.

Table 4. The test results of the pulsed mode pseudolite with live GPS

PRN#33 (Control Attenuator)				Live GPS #11			
Atten	NCO	SNR	Status	Atten	NCO	SNR	Status
65	7700	10.1	Stable	0	2783	16.9	Stable
60	7740	11.9	Stable		2783	16.8	Stable
55	7740	12.5	Stable		2794	16.7	Stable
50	7780	12.8	Stable		2794	16.7	Stable
40	7780	12.4	Stable		2800	16.6	Stable
30	7780	11.8	Stable		2800	16.6	Stable
25	7780	10.9	Stable		2800	16.6	Stable
20	X	X	X		2800	16.6	Stable

The table 5 shows the result of the continuous mode pseudoiltes and live GPS.

Table 5. The test results of the continuous mode pseudolite with live GPS

PRN#33 (Control Attenuator)				Live GPS #11			
Atten	NCO	SNR	Status	Atten	NCO	SNR	Status
90	7800	10.1	Stable	0	2600	17.1	Stable
80	7800	11.9	Stable		2600	16.9	Stable
70	7800	12.5	Stable		2600	14.5	Stable
65	7800	12.8	Stable		2600	12.0	Stable

Those test results shows that pulsed mode signal has less interference than continuous mode signal. Therefore the pulsed mode pseudolite can avoid near-far problem more efficiently.

6. Conclusions

This paper explains that the pulse mode pseudolite can reduce near far problem that is the reason for signal jamming. Also, various pulse schemes are suggested to find most suitable scheme for pseudolite. From the test, it is verified that the pulsed mode pseudoite has less interference between each other and live GPS than the continuous mode pseudolites and live GPS.

References

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