Reducing Multipath Effects in Indoor Channel for Analysis of GPS/Pseudolite Signal Acquisition

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Abstract- The GPS (Global Positioning System) is a mature technique in the navigation and positioning. But there are some limits in special applications such as mines. The main draw back of the GPS use indoors are the low signal power, and the presence of multi-paths, which may affect the signal acquisition and tracking accuracy[5]. The performance of GPS needs to be improved with technological advances. As a GPS-like ground transmitter, the Pseudolite provides a new research direction to achieve high positioning accuracy and reliability[5]. Pseudolites (pseudo-satellites) are local transmitters on Earth that output GPS satellite signals in order for augment the GPS system for use in locations where satellite signals may be obstructed. One of the challenges related to indoor positioning is to find suitable statistical models of the indoor propagation that give further insight on multi-path behavior and fading distributions[5].

In this paper, we proposed the basic technology of designing and simulation on the coarse acquisition (C/A) codes in constructing the GPS/pseudolite Integration system. We have generated code PRN1 to PRN32 it indicate GPS signal and PRN33 of PL by using (Interace Control Document) ICD-GPS-200C Date sheet. To show multipath efects on generated signals we have Considered Channel noise asWhite Gaussian Noise and Rayleigh Noise, These noises are added to generated PRN codes with the help of Mat-Lab tool, and removed with by using Equal Gain combining algorith (EGC) at the time of Signal Acquisition. Finally we acquired C/A code with the help of Correlation. The obtained results was compared with previous research data to show multipath effects in Indoor channel. It is shown that the pseudolite technology is ideally suited to augment the GPS alone and provide greater integrity, availability, and continuity of the navigation positioning system, especially for indoor use[5].

Index Terms- C/A: Course Acquisition, GPS: Global Positioning System, PRN: Pseudo Range Number, PL: Pseudolite

I. Introduction

GPS constellation consists of generally 24 satellites. GPS of United State of America From Department of Defense (DoD) is very Efficient for its great performance of the navigation and positioning and it can be used anywhere, any weather Condition, and any time. When the GPS receiver is used outdoors, at least four GPS satellites' signals need to be acquired and tracked to meet all kinds of the location based service requirements[1].

However, the satellite signal is sometimes blocked indoors so it is difficult for indoor positioning. The alternative for indoor positioning is Pseudolite. The pseudolite is not a real GPS satellite.

It only transmits a GPS-like signal and the signals are received by modified GPS receivers. The broadcasted signals are not affected by the ionosphere because it is based on the ground[1],[2].

The aim of the paper is to analyze the indoor signal fading characteristics and multipath effects in indoor GPS/Pseudolite Integration System. We have limited to the GPS Coarse Acquisition (C/A) signal because it is the most used civilian navigation signal.

II. Course Acquisition Code Generation

The GPS space segment satellite transmits a MW radio signal consists of two carrier frequencies at 1575.42 MHz as the L1 carrier and at 1227.60 MHz as the L2 carrier, modulated by two digital codes and a navigation message[1],[2],[17][18]. The GPS codes are called coarse acquisition (C/A code) and precision (P code) [1],[2],[17]. Each code is a stream of binary digits, zeros and ones, called bits or chips. The codes are commonly known as pseudo-range number (PRN) codes since they look like random signals. Generally, the pseudolite technology adopts the C/A code and L1 carrier to transmit the GPS-like signals[1],[2].

According to the signal structure, the pseudolite C/A code is generated according to ICD-GPS-200C[3]. Each $Gi(t)$ sequence is a 1023 bit Gold code which is itself the Modulo-2 sum (X-or Operation) of two 1023-bit linear patterns, $G1$ and $G2i$. The $G2i$ sequence is formed by effectively delaying the $G2$ sequence by an integer number of chips ranging from 5 to 950. The $G1$ and $G2$ sequences are generated, with $G1=1+X3+X10$ and $G2=1+X2+ X3+ X6+ X8+ X9+ X10$, by 10-stage shift registers having the following polynomials referred to as the shift register input. The 10-stage shift registers are the vectors of $G1$ and $G2$, and the initialization setting is 1111111111.

The C/A code repeats itself every millisecond and the chipping rate of the C/A code is 1.023 Mbit/s. Presently, the C/A code is

modulated onto the L1 carrier only[3]. Each satellite is defined by a unique C/A code, which is the ID of the transmit-ting signal of the GPS satellite[1,3,4]. The pseudolite signal is similar to the GPS signal in its structure and the generation theory[4].

The above concept of course acquisition code generation was implemented by below Fig.1
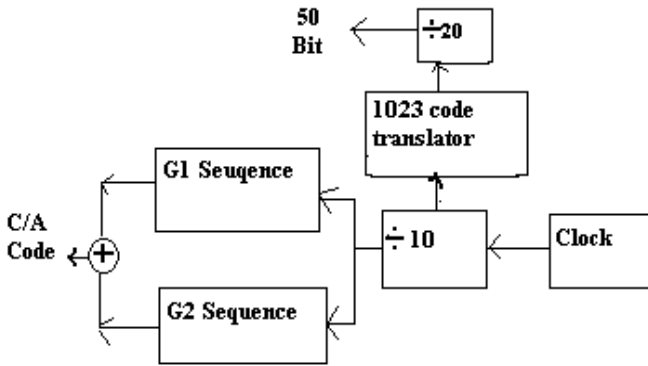

Fig 1: Concept of C/A code Generation

Theoretically, the C/A code generator can produce 1023 separate Gold codes besides the two base MLFSR (Modified Linear Feedback Shift Register) codes according to ICD-GPS-200C [3].

In this paper we are not going to discuss in detail of C/A code generation it is already well explained previous research. Here we have taken concept of previous researcher.

In this paper we have simulated the C/A codes and configure the PRN1 to PRN32 and PRN33 which are reserved for the GPS and Pseudolite respectively [4]-[8].

By using above concept we have generated course acquisition code and we have collected some samples as shown below Fig 2. It shows characteristics of GPS/PL signal[9,10].
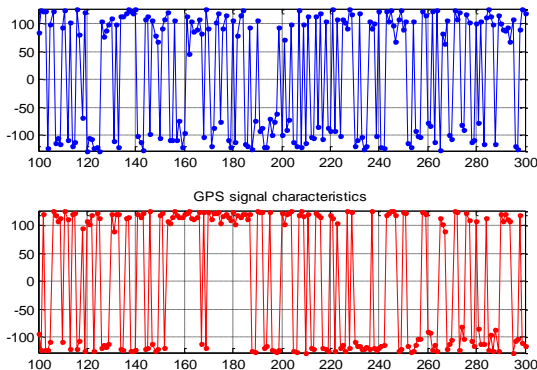

Fig 2: Generated GPS Signal Characteristics

GPS/PL signal Sample here we have taken GPS signal has length 32768 Divide this signal in to 8 frame that is 4096*8.

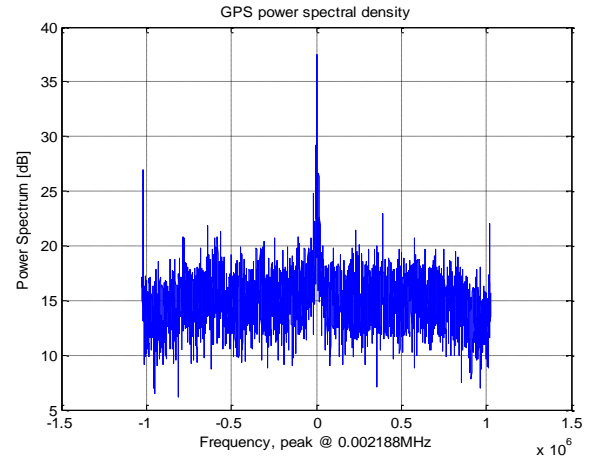After generation   GPS/PL signal We Obtained Power Spectral Density as shown Fig 3. At a frequency of 0.002188Mhz.

Fig 3: Generated Signal Power Spectrual Density

III.   MULTIPATH EFFECTS ON SIGNAL

Generally, The generated (C/A) code is transmitted by the pseudolite transmitter it is effected by the multipath transmission in indoor Environment. In this multipath transmission (multi path fading) includes Large scale fading and Small scale fading. Large scale fading corresponds   to average signal power attenuation, Small Scale fading is due to dramatic alterations in amplitude   and Phase[11]. Fig.4-5 Gives typical Scenario multipath reflected signal propagation in indoor and out door channel.

In this paper we have considered channel noise as Rayleigh noise and Gaussian noise. These Noises are added to PRN 1 to PRN32 and PRN33 of C/A code by using MATLAB tools to show Multipath Effects on the generated signal.
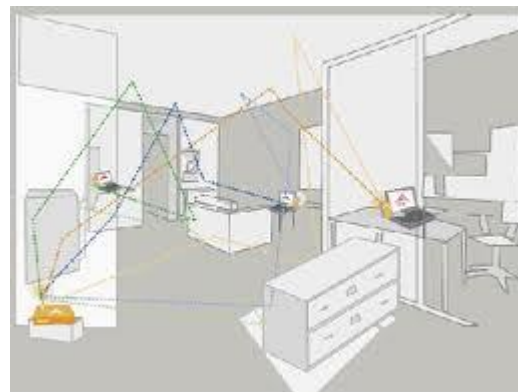
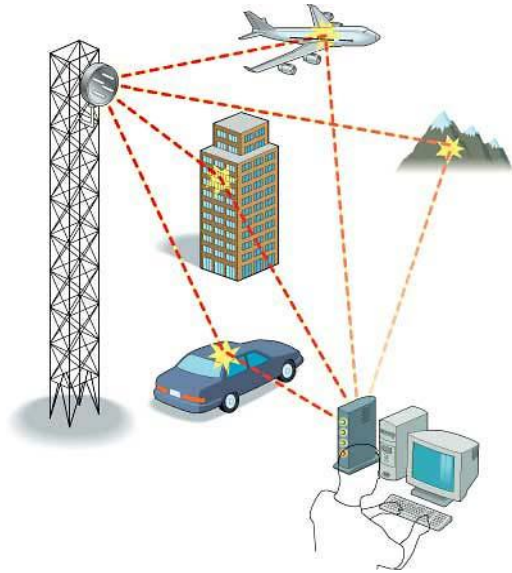

Fig 4: Signal Propogation in Indoor Channel.

Fig 5: Signal Propogation in ourdoor Channel.

The magnitude of the multipath effect on a phase observation can be estimated from the following mathematical relation eq.(1) [12].

$$\tan\Delta\Phi m \ = \ \beta.Sin\Delta\Phi/1+\beta.Cos\Delta\Phi \qquad (1)$$

where

$\Delta\Phi m$: Is the shift in carrier phase of the combined signal received at the antenna due to multipath.

$\Delta\Phi$: Is the shift of the reflected signal with respect to the direct signal.

B : Is a damping factor which varies between o (no reflection) and 1 (reflected signal as strong as direct signal).

Due to Rayleigh and Gaussian Noise, Receiver cannot track exact signal. At receiver front end various signals are available i.e. (direct signal from the pseudolite transmitter and reflected signal from various object) so signal power degrades and noise power increases. This signal is not sufficient for accurate indoor positioning.

From probability theory we know that the Received amplitude follows Rayleigh distribution as shown below eq.(3).

$$p\left(r\right)=\frac{r\exp\left(-r^{2}/2\sigma^{2}\right)}{\sigma^{2}} \ , \ r>0$$

(3)

Below Fig 6. Shows the Characteristics of the Amplitude, Rayleigh Distribution[13].

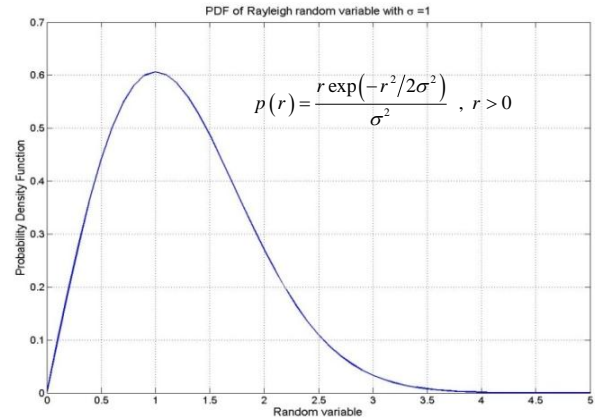$$p\left(r\right)=\frac{r\exp\left(-r^{2}/2\sigma^{2}\right)}{\sigma^{2}} \ , \ r>0$$

Fig 6: Rayleigh Distribution[19].

In probability theory, the normal (Gaussian) distribution is a continuous probability distribution, that has a bell-shaped probability density function[21], known as the Gaussian function or informally as the bell curve it is given by eq.(4)[14].

$$f(\mathrm{x}, \mu, \sigma^{2})= (\tfrac{1}{\sigma} \sqrt{2\pi})e^{-\frac{1}{2}(x-\mu/\sigma)^{2}} \qquad (4)$$

The parameter μ is the *mean* or *expectation* (location of the peak) and σ^{2} is the variance. σ is known as the standard deviation[21]. The distribution with $\mu = 0$ and $\sigma^{2} = 1$ is called the standard normal distribution or the unit normal distribution[21-24].

A normal distribution is often used as a first approximation to describe real-valued random variables that cluster around a single mean value[21-24].

The Gaussian Distribution function is shown in Fig 7. in this characteristic of Gaussian Distribution changes as Standard deviation[14].
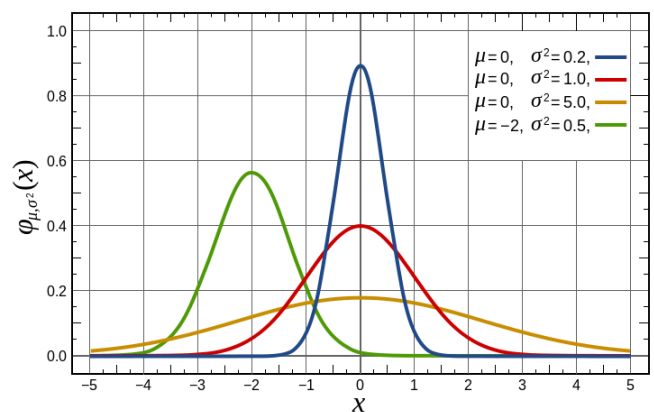
Fig 7 : Gassian Distirbution fuction[22]

REDUCING MULTIPATH EFFECTS BY USING EQUAL GAIN COMBINING ALGORITH

At receiver front end various signals are available i.e. (direct signal from the GPS/pseudolite transmitter and reflected signal from various object) due to this exact Signal reception is very difficult. To Reduce multipath effects at receiver front- end we have used Equal gain Combining Algorithm (EGC). In this we have taken average signal power of all the signals. So that we can improve the average signal power at receiver side[15].

The goal of the equalization techniques should be to reduce the effect of the fading and the interference.

Consider a transmitted signal s(t) = A cos 2πfct through a fading channel. The received signal can be expressed as eq.(5).

$$y(t) = A \sum_{i=1}^{N} a_i \cos\left(2\pi f_c t + \theta_i\right)$$

(5)

Where:

a_i is the attenuation of the ith multipath component.

θ_i is the phase-shift of the ith multipath component

It must be noted that a_i and θ_i are random variables. The above expression can be re-written as eq.(6).

$$y(t) = A \left\{ \left(\sum_{i=1}^{N} a_i \cos(\theta_i) \right) \cos(2\pi f_c t) - \left(\sum_{i=1}^{N} a_i \sin(\theta_i) \right) \sin(2\pi f_c t) \right\}$$

(6)

We Introduce Two Random Processes X1(t) and X2(t), Such that the above Equation becomes shown elow eq.(7).

$$y(t) = A\{X_1(t) \cos(2\pi fct) - X_2(t) \sin(2\pi fct)$$

(7)

The phase of the received waveform $\theta(t)$ is given by eq.(8).

$$\theta(t) = \tan^{-1} (X_2(t)/X_1(t))$$

(8)

In Equal Gain Combining (EGC), all the received signals are co-phased at the receiver and added together without any weighting it by suing in eq.(9), eq.(10).

Yegc=y(t)*exp(-j*θ(t))   (9)

θ(t)=angle of Rayleigh channel   (10)

GPS/PSEUDOLITE INTEGRATION SYSTEM

The GPS/pseudolite Integration system shown in Fig.8[4] consists of one pseudolite transmitter , one modified GPS Receiver antenna and GPS/Pseudolite receiver which is connected to system to verify Integrated results.
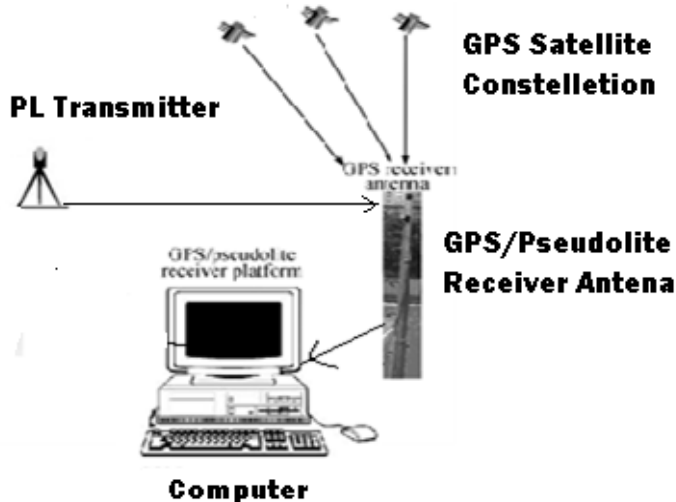

Fig 8 : GPS/pseudolite Integration System.

SIGNAL ACQUISITION USING CORRELATION

The acquisition is the first step upon receiving the signals. The received signals *s* are a combination of signals from all n visible GPS/PL shown in eq.(11).

satellites described by $s(t)= s1(t)+ s2(t)+…+ sn(t)$. (11)

When acquiring the GPS signal PRN1 to PRN32 and PRN33, the incoming signal *s* is modulated by the locally generated C/A code corresponding to the GPS signal. The cross correlation between C/A codes for different GPS implies that signals from other GPS are nearly eliminated by this procedure. To avoid eliminating the desired signal component, the locally generated C/A code must be properly aligned in time to have the correct code phase[4].

The correlation process is shown in Fig .9, in this un wanted signals are eliminated and we can obtain desired signal[4],[16].

Signals originating from PRN 1 to PRN 32 of the GPS and PRN 33 of PL are present in the received signal. This can be seen In Figure 10, significant peak in the acquisition plot. The peak location is related to a C/A code phase and a frequency of the signal.

The signal power of the pseudolite was set for −80 dBm at 10^{-8} mW. And the PRN of the pseudolite was set for 36 [4].
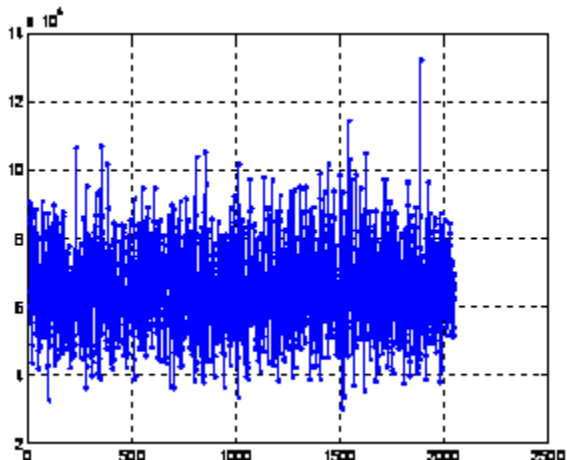
Fig9 : Obtaining GPS//Pseudolite sinals by Cross correlation

For acquisition of GPS/pseudolite signal we have used Mat-lab tool. Fig 10. shows   the acquisition result of PRN1 to , PRN32 of GPS and PRN33 of Pseudolite.
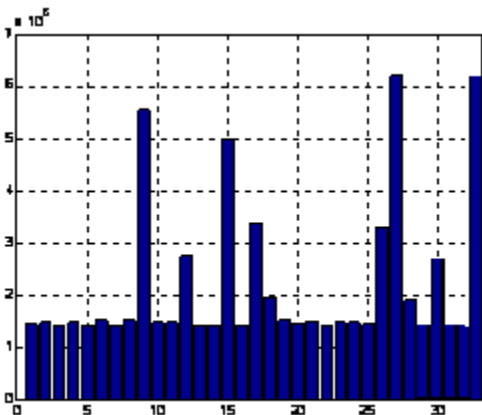

Fig 10: Simulation result of GPS PRN1 toPRN32 and PL PRN33.

We have Concentrated on PRN9, PRN15, PRN27 of GPS and PRN33 for Pseudolite to get maximum peak. In this it is clearly shown that multipath effect was removed.

We have gone through previous research members Practical acquired results of GPS/ Pseudolite Integration System shown in Fig11. In this they have received low peaks for Satellite signal PRN9, PRN21, PRN24,PRN29 which are effected by multipath and maximum peak for PRN36 for Pseudolite signal, and no peaks for other PRN codes shown in Fig10.

By observing Fig.10 and Fig.11 we conclude that multipath reduces the signal strength, in our simulation results we have removed multipath effects in maximum extents with the help of Equal gain combining algorithm..
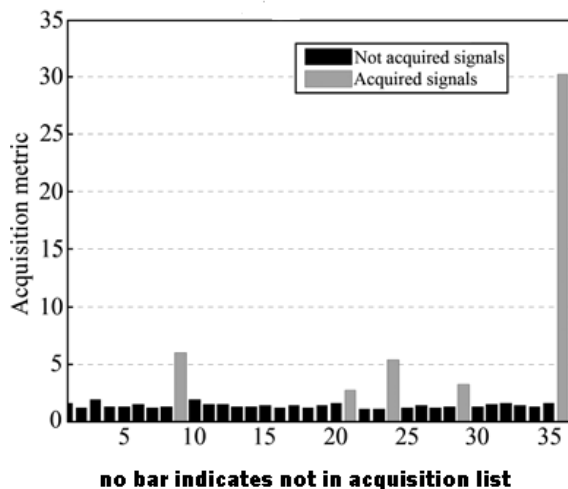

Fig 11: Practical GPS/Pseudolite integration system result [4]

APPLICATIONS

Pseudolite have wide verity of application in real life. It is mostly useful in door environment. But in some cases it is also useful in outdoor where GPS signal is very poor due to atmospheric (Ionosphere   and Troposphere) effect or unhealthy whether conditions such as heavy rain, peak summer days and at Equatorial plan where GPS signal undergo various effect so it is difficult   to   identify   exact   location.   In   such   cases GPS/pseudolites Integration is the other alternative .

In outdoor environment GPS /Pseudolite Integration can be most useful for Aircraft blind landing such as LAAS (Local area Augmentation System) and some other Military Services, it is also useful to identify enemy activities under signal Jamming condition.

Below Fig.12 shows one of the application of GPS/Pseudolite Integration for Aircraft navigation under un-healthy whether conditions.
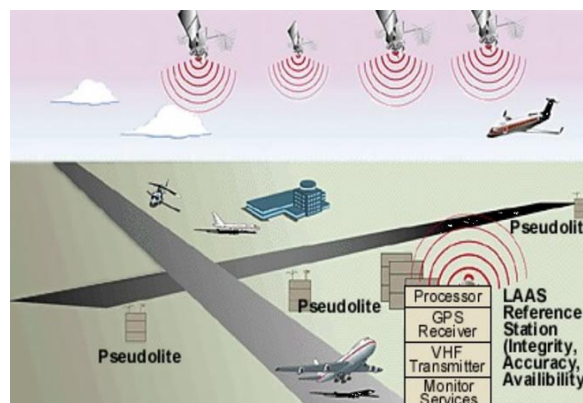

Fig 12: Application of GPS/PL in Air-Craft Navigation[23]

CONCLUSION AND FUTURE WORK

In this paper we have Generated C/A code of PRN 1to PRN32 of GPS and PRN33 for Pseudolite by using ICD-GPS-200C Document and Estimated multipath Effects in Indoor (Channel) environment, Multipath Effects occurred in Transmission channel so we have considered Channel noise as white Gaussian and Rayleigh Fading.

Due to multipath effects GPS/pseudolite signals may not reach same time at the Receiver and signal power reduces and noise power increases. To compensate this Multipath effects on received signal We have equalized these effects by using Equal Gain Combining Algorithm further Correlating the received signal with reference signal so that we can eliminate other unwanted signals. But obtained Signal has more noise power this signal may not sufficient to locate Indoor positioning in Centimeter level or millimeter level.

In this paper we have discussed only multipath effects, but in Indoor Environment there are some other problems like Near-Far and Inter symbol Interference. The future work for this paper is to develop new Algorithm to reduce Near and Far problems and Implement error detection mechanism to identify Inter symbol Interference, finally designing of Sufficient Filter to Reduce noise power so that we can Improve the performance of Pseudolite .

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