

Technical Report

Requirements of a C-CDMA Pseudolite Indoor Geolocation System

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The paper provides the requirements for building (or designing) a Carrier-Code Division Multiple Access (C-CDMA) pseudolite indoor geolocation system. A C-CDMA pseudolite indoor geolocation system consists of four C-CDMA pseudolites and one or more C-CDMA receivers. The purpose of this paper is to provide the requirements for building C-CDMA pseudolites and a C-CDMA receiver.

First, the pseudolite is assumed stationary and the geolocation information consists of the transmitter position and time. For each pseudolite this information is 4-ary encoded data at a symbol rate of 1 KHz. For example, an encoded geolocation signal is spread using a Kasami sequence which runs at a rate of 1.023 MHz and then the signal is modulated on [10 15 20 25] MHz carrier signals each one of which corresponds to each of pseudolite respectively via a Quadrature Phase-Shift Keying (QPSK) modulator to resist interference encountered in an indoor geolocation environment. A total of four pseudolites are simulated to enable a geolocation solution for the receiver. The spreading modulation is that of a Variable Binary Offset Carrier (VBOC) VBOC(2,1, α) which we have examined previously to provide a better spectrum utilization than the BOC(2,1) and definitely much better than the PSK.

Second, the receiver consists of four channels each one of which is assigned to a single transmitter. On each receiving channel the received signal is down-converted, de-spread using the Kasami sequence, demodulated and decoded.

Third, the channel consists of the following models: a realistic indoor path loss, realistic Rayleigh and Rician fading channels, receiver thermal noise, phase frequency offset, and additive white Gaussian noise. The system will include the ability to perform distance measurement; to take into consideration the effect of transmitter clock stability on position accuracy; such effects will include the transmitter and receiver oscillator drift (short term stability) on positioning accuracy; the signal processing on the receiver design will include techniques for detecting an extremely weak Line-of-Sight (LOS) signal and for maintaining lock on the LOS signal in the presence of severe multipath.

It is expected that this paper will provide the required overview for first designing the system components utilizing as much as possible commercial of the shelf components and provide the framework for Giftet Software solution products one of which is a global software solutions for a C-CDMA pseudolite indoor geolocation system to operate under heavy multipath and low signal to noise ratio environment. Simulation results in MATLAB and Simulink are provided.

Index Terms—Requirements, C-CDMA, pseudolite, indoor, system, heavy, multipath, low, signal to noise, ratio, environment.

1 Introduction

For several years now we have considered the analysis, simulation, and implementation of a Carrier-Code Division Multiple Access (C-CDMA) indoor geolocation system [2]-[12].

The analysis of the system primarily includes the C-CDMA indoor geolocation system concept, C-CDMA pseudolite signal selection characteristics, multipath parameters selection and modeling, receiver's signal processing [2]-[4].

The simulation of a C-CDMA pseudolite indoor geolocation system includes MATLAB and Simulink simulations [6], [11], [12].

The implementation of a C-CDMA pseudolite indoor geolocation system includes the implementation of a C-CDMA pseudolite and receiver [11], [12].

Moreover, we have performed a good deal of research on indoor geolocation channel models and selection of parameters of interests for path loss and multipath distribution which are illustrates in [3], [8].

In summary this procedure will provide sufficient information on the completeness of the multipath model for all geolocation systems.

With all these information we then proceed with the paper as follows:

First, we discuss the general requirements of a C-CDMA pseudolite indoor geolocation system. Here we focus on the system, pseudolite, receiver, and simulation requirements. Second, the technical methodology for designing a C-CDMA pseudolite indoor geolocation system will be discussed in the near future for illustrating Giftet Inc. software product solutions. Third, we conclude the paper.

2 General Requirements

The general requirements of a C-CDMA pseudolite indoor

geolocation system include: general system requirements, pseudolite (or transmitter) requirements, and receiver requirements. First, let us discuss the general system requirements of a C-CDMA pseudolite indoor geolocation system.

2.1 General Systems Requirements

The general system requirements of a C-CDMA pseudolite indoor geolocation system consists of the following:

1. A C-CDMA pseudolite indoor geolocation system must consist of at least 4 or more C-CDMA pseudolites and one or more C-CDMA receivers.
2. The coverage area of a C-CDMA indoor geolocation system is that of a semi-sphere with radius R which is a system parameter. Typically R would be in the range of 100 m or several hundred meters. Because R is a system's parameter that it's going to define the requirements of transmitter's signal power and channel bandwidth.
3. The pseudolites should be located at the outside perimeter and at a reasonable height or the highest possible position of the building or complex buildings.
4. The system should have the ability to perform distance measurement via time of arrival (TOA) measurement.
5. Under these conditions a C-CDMA pseudolite indoor geolocation system should provide cm level 3-D position accuracy and cm/sec level velocity accuracy 99.999% of the time.
6. Portability and flexibility are the desired in that the system should have the ability to reconfigure itself.

An example of a C-CDMA pseudolite indoor geolocation system is illustrated in Fig. 1 (a). The purpose of this example is to illustrate a typical pseudolite indoor geolocation system. These systems are becoming more and more prevalent given the need for precise geolocation inside buildings to protect civilians in cases such as parents guarding and monitoring their children, or doctors monitoring their patients in hospitals, or police or security forces monitoring their inmates etc.

This 3-D scenario of a C-CDMA pseudolite indoor geolocation system contains four pseudolites placed on top of an 11-story building. The true C-CDMA receiver location is shown in blue. The estimated C-CDMA receiver location is shown in red. As indicated in the figure the estimated C-CDMA receiver location is within cm levels of the true receiver location 99.999% of the time.

3 Pseudolite (or Transmitter)

The requirements for designing a C-CDMA pseudolite (or transmitter) include the following:

1. A frequency allocation for signal separation of at least 5 MHz/pseudolite. It appears that radio frequency spectrum is now on the orders of \$100 million for MHz which could implies that the frequency spectrum for a C-CDMA pseudolite would be \$0.5 billion and for four pseudolites would be \$2 billion. This parameter alone would make the system almost impossible to build and commercialize it.
2. Center of frequency spectrum of what is available and what is affordable in the frequency spectrum of 3.1-10 GHz as mandated by the FCC.
3. A pair of unique Kasami sequences for signal spreading for the in-phase and quadrature components.
4. Variable Binary Offset Carrier (VBOC(2,1, α)) for signal spreading modulation to further minimize multipath and interference effects [7].
5. Quadrature Phase-Shift Keying (QPSK) modulation for combining the I and Q channels and maintaining the time orthogonality between the I and Q channels.
6. Size of the pseudolite should be as small as possible using Commercial Off-The-Shelf (COTs) parts or components.
7. Pseudolite should be powered up from a 120V/60~ Hz outlet via a power supply via an AC/DC converter.
8. The pseudolite signal power should range from -50 to -100 dBm at distances from 10 m to 100 m from the pseudolite in free space. In an actual indoor environment signal degradation will be higher, which could lead to actual pseudolite signal levels at 100 m to be -150 dBm.
9. Data rate of at least 1 kHz or higher.
10. One of the pseudolites should be designated as the master pseudolite and all the others are designated as slave pseudolites. All the clock parameters of the other pseudolites should be referenced to the master pseudolite.
11. The user must be able to enter the pseudolite location via a

GPS receiver having surveying the location of the pseudolite first.

Some of the characteristics of a C-CDMA pseudolite signal design are presented below.

3.1 Signal design

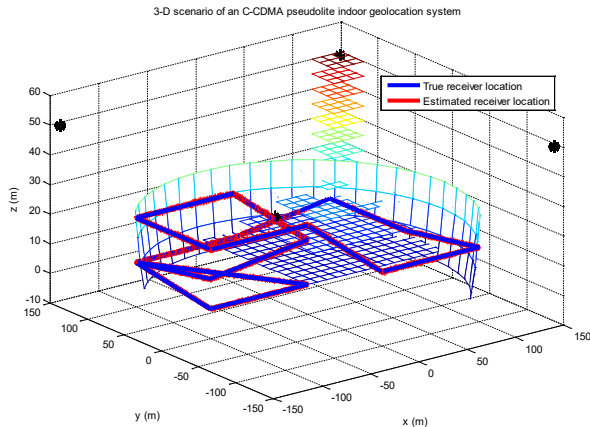
The signal structure of a typical C-CDMA pseudolite indoor geolocation system is illustrated in Fig. 1(b). As shown in Fig. 1(b) there are four pseudolites signals equal spread in the frequency range of 5 to 30 MHz with center frequencies of 10, 15, 20, and 25 MHz. Some of the benefits of this signal structure we have illustrated previously in [6]. The added benefit to the novel signal structure of a C-CDMA pseudolite indoor geolocation system is the VBOC(2,1,0.1) spreading modulation scheme [7].

The VBOC(2,1,0.1) modulation scheme was shown to provide further improvements of the multipath mitigation and cross-channel interference [7].

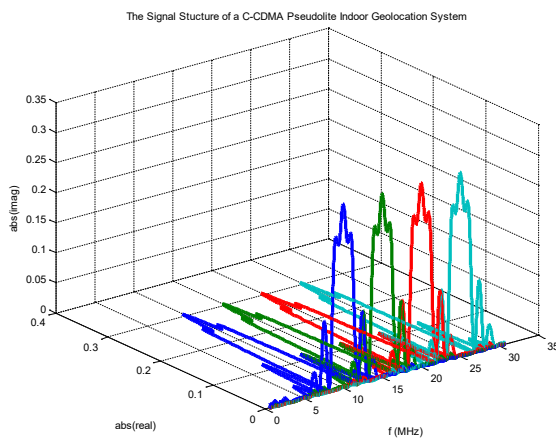
3.2 Receiver design requirements

The requirements for a C-CDMA receiver include but are not limited to:

1. A single or multiple antennae. Multiple antennae maybe desired if interference and jamming protection is required.
2. At least 80 dB of receiver dynamic range is required to enable signal acquisition and tracking from all the pseudolites [8].
3. If possible the receiver should perform the signal processing at the RF frequency via software defined radio.
4. The receiver should employ either a maximum likelihood parameter estimation or Bayesian Monte Carlo Markov Chain (MCMC) integration for joint signal acquisition and tracking [9], [10].
5. The receiver should have the ability to de-spread, demodulate, decode and perform distance measurement between the receiver and all pseudolites taking into account the effect of transmitter clock stability on position accuracy; such effects will include the transmitter and receiver oscillator drift (short term stability) on positioning accuracy.
6. The signal processing on the receiver design should include techniques for detecting an extremely weak LOS signal and for maintaining lock on the LOS signal in the presence of severe multipath, interference, and jamming.



(a) The 3-D scenario of a C-CDMA pseudolite indoor geolocation system.



(b) The signal structure of a C-CDMA pseudolite IGS using VBOC(2,1,0.1) spreading modulation.

FIGURE 1: Main requirements of a C-CDMA pseudolite IGS.

7. Each receiver channel should have a status indicating the quality of the signal from the following list:
8. *Excellent (EX)*: ideal signal reception. No signal reflection or obstruction or 0dB signal degradation which means that power loss is only due to transmitter receiver geometry; i.e., free space signal propagation.
9. *Very good (VG)*: very good signal reception, minor reflection or signal obstruction or -10dB signal degradation.
10. *Good (G)*: good signal reception, some reflection and signal obstruction or -20dB signal degradation.
11. *Average (AV)*: average signal reception due to reflections and signal obstructions or -30dB signal degradation.
12. *Poor (PO)*: poor signal reception due to significant

reflections and signal obstructions or -40 dB signal degradation.

13. *Very poor (VP)*: very poor signal reception due to extreme (or severe) signal reflections and signal obstructions or -50dB to -80 dB signal degradation.
14. *Noise (NO)*: no signal is present or no useful signal information is available.

This concludes the discussion on receiver design requirements. Next we present the discussion on simulation requirements.

3.3 Simulation requirements

Simulation requirements of a C-CDMA pseudolite indoor geolocation system are the following:

1. A C-CDMA pseudolite indoor geolacaiton system must be fully, accurately, and simulated in MATLAB and Simulink.
2. Simulink and MATLAB simulation must include signal characteristics, C-CDMA pseudolite design, C-CDMA receiver design, and channel characteristics.
3. Simulation must allow portability and flexibility in that signal characteristics and channel parameters can be changed and altered to allow simulation of desired scenarios and be able to test all the desired signal levels on the software.
4. Examples of simulation requirements are provided in [6], [11], [12] which may be reused and improved to include the added requirements of a C-CDMA pseudolite indoor geolocation system.

The methodology that we will follow will be illustrated further in Giftet Inc. software products which will be presented at the ION GNSS+ meetings.

4 Conclusions

In conclusion we have provided the requirements of a C-CDMA pseudolite indoor geolocation system which are: the system requirements, pseudolite signal requirements, and the C-CDMA receiver requirements.

We are at the state that we have accumulated an extensible body of knowledge for designing a C-CDMA pseudolite indoor geolocation system. We have provided the requirements and as such we are looking for investors and avenues for funding for continuing this research and ultimately for building a C-CDMA pseudolite indoor geolocation system.

Since 2007 when this paper was originally presented a lot

has occurred [15]. Although, this paper lacked a lot of mathematical background found in [15], it served as the bridge between the research that was initially published prior to 2007 [1]-[10], [16] and the research that was published after 2007 [15].

5 Acknowledgement

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