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# Spread Spectrum Improved Capacity Utilization (SSICU)

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## Abstract

*This paper discusses how spread spectrum can be used to send more data than the traditional spread spectrum while working with low signal-to-noise ratio (SNR) and with the same bandwidth allocated. Using [1] Parallel Combinations we can have higher bandwidth utilization and we can work with low SNR and anti-jamming. We will be able to send more information.*

*Using the above discussed technique, this paper then proposes position tracking system using spread-system (SS) communication technology. It includes dealing with spread-spectrum using Code Division Multiple Access (CDMA). This idea of position tracking is basically taken from triangular techniques used by Global Positioning System(GPS)*



## 1. Introduction

Spread Spectrum transmits data bit by bit and Bandwidth utilization is very low. As the number of users increase, chipping codes or the PN sequence increases, and chances of interference is increased and quality of communication is decreased abruptly. If we increase the length of PN sequence, more Bandwidth will be required and its utilization is decreased. However if we use [2]parallel combination of data or in other words if we add the signals together and define a mapper at transmitter and define inverse mapper at the receiver end, we can obtain the same data but this time more data is transmitted and hence utilization is increased and faster communication is obtained.

Using this technique of adding the data we can intelligently receive signals, from the transmitter located on the corners of the room, on the receiver, located on the body, add them up and can track the position of the human.

## 2. Existing Solutions

### 2.1. Second- Spread-Spectrum Multiple Access for Indoor Communication

[3]They emphasize on the fact that for multiple users within a limited bandwidth, code division multiple access (CDMA) is a perfect solution. For fading multipath indoor communication M-ary CDMA system is required and that M-ary signalling improved bandwidth efficiency as compared to binary signalling.

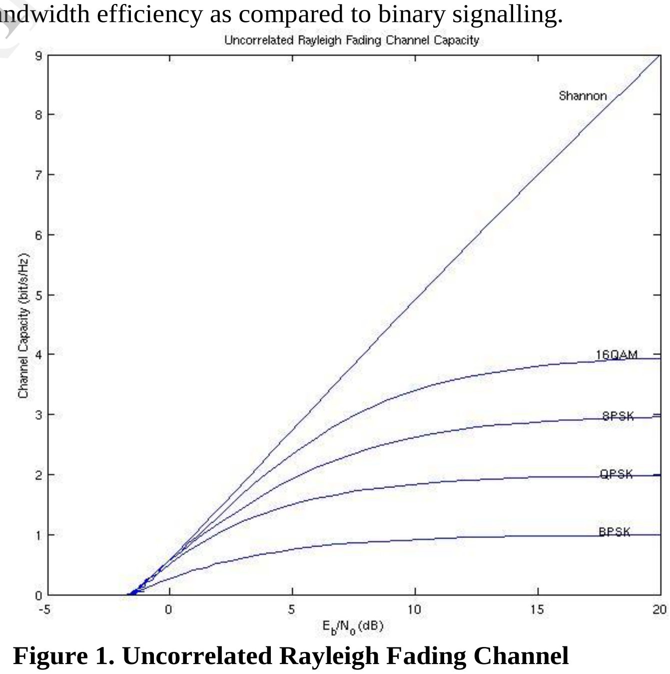


**Figure 1. Uncorrelated Rayleigh Fading Channel Capacity.**

### 2.2. Approximate Orthogonal Complex Sequence

[4]In this, spread spectrum uses Approximate Orthogonal Complex Sequence (AOC). One AOC sequence is selected from 6 input bits, it is then phase-rotated by another 2 input bits. It has better BER performance then complementary code keying (CCK) modulation scheme

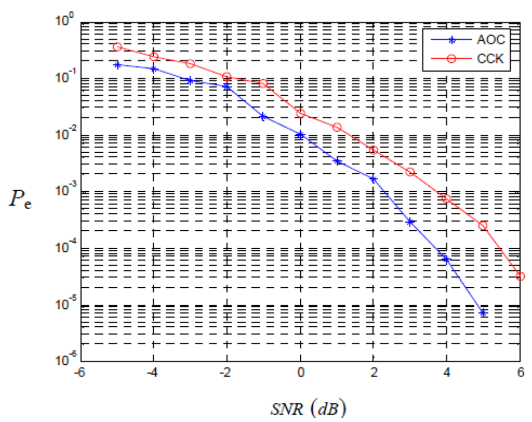


**Figure 2: Performance Of AOC versus CCK**

## 3. Review Of CDMA And Spread Spectrum

In order to explain the main theme of this paper, it is necessary to have an understanding of CDMA and Spread Spectrum and how they work. This is done just to guide the non-communication engineers to understand the techniques so that they can better understand the main idea presented in this paper

This paper presents a brief tutorial on how CDMA works, how it is better than other techniques like Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA), then it also describes how codes are used to achieve multiple access and why we use spreading code and finally spread spectrum is defined

### 3.1. Code Division Multiple Access (CDMA)

[5]Our main goal is to obtain multiple access, Since we can only use common air interface so the channel is same. In CDMA, we allot different codes to different users. In figure 3, we can see that two users are accessing the base station on a common channel but different codes are assigned to both the users.

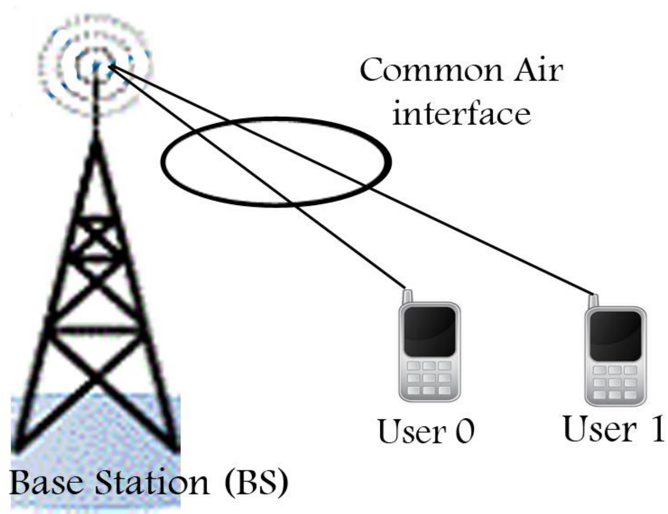


**Figure 1 Users accessing the Base station (BS)**

### 3.2. Time Division Multiple Access (TDMA)

In this technique different time slots are given to different users to communicate

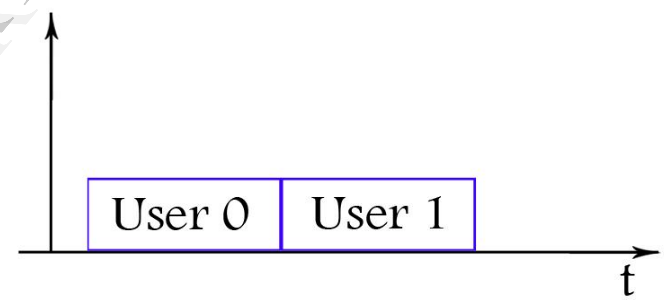


**Figure 4 Time Division Multiple Access (TDMA) for two users**

### 3.3. Frequency Division Multiple Access (FDMA)

In this technique different Bands are allotted to different users to communicate. User 0 has to tune to frequency band 0 to communicate. Similarly User 1 has to tune to frequency band 1 to communicate.

1st Generation Mobiles are basically based on FDMA

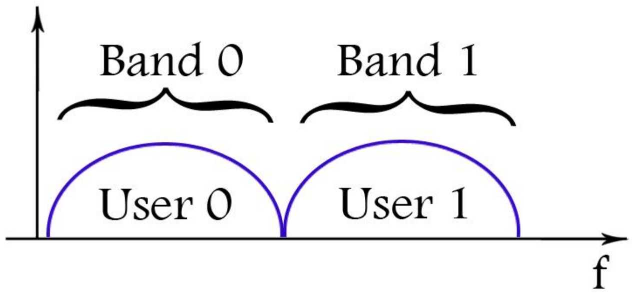


**Figure 5 Frequency Division Multiple Access (FDMA) for two users**

### 3.4. CDMA Codes

Suppose user 0 –$a_0$ is allotted the code sequence [1,1,1,1] and user 1 –$a_1$ is allotted the code sequence [1,-1,-1,1] Net signal is obtained by multiplying the signal with the codes and then adding them together to obtain a net signal

For user 0 – [$a_0$, $a_0$, $a_0$, $a_0$] – Code 0
For user 1- [$a_1$, -$a_1$, -$a_1$ ,$a_1$]- Code 1

Net signal: $a_0 + a_1$ , $a_0 - a_1$, $a_0 - a_1$ , $a_0 + a_1$

Now this signal will be transmitted over air

At receiver end we again multiply the received signal with the code of that particular user and then add them together to obtain the required sequence.
For example for user 0, the code was [1, 1, 1, 1]
Net signal: $a_0 + a_1$ , $a_0 - a_1$, $a_0 - a_1$ , $a_0 + a_1$
Code: 1, 1, 1, 1

$$(a_0 + a_1) + (a_0 - a_1) + (a_0 - a_1) + (a_0 + a_1)$$
$$= a_0 + a_0 + a_0 + a_0$$
$$= 4\,a_0 + 0$$

This 0 implies that interference by user 1 has been removed.

This multiplication is nothing but correlation. At user 0, correlate with its own code and we recover the signal

#### 3.4.1. Key Operations Of CDMA.

First we multiply the signal with the code
Combine the signals of all users
We correlate

Important point here is that codes must be orthogonal, that is the dot product between the codes must be zero to avoid interference

Code for user 0 $C_0$ = [1, 1, 1, 1]
Code for user 1 $C_1$ = [1, -1, -1 ,1]

1 + (-1) + (-1) + 1
= 0

So these codes are orthogonal.

### 3.5. Why we need spreading Codes?

Suppose we need to transmit $a_0$ of 1 Kbps
Time per symbol = 1/ 1kbps
T= 1 ms
Bandwidth required = 1/ T = 1/1ms = 1 KHz

Hence to transmit 1 kbps we need 1 KHz of bandwidth
Now if we split this symbol in to four symbols.
$a_0$ = [$a_0$ $a_0$ $a_0$ $a_0$ ]
T= 1ms / 4 – To keep time constant
T= 0.25 ms
Thus we need only now 0.25 ms to transmit a symbol
But for Bandwidth
Bandwidth required = 1/T = 1/0.25 = 4 kHz

Bandwidth is now increased
$C_0$ and $C_1$ are also called spreading codes and also pseudo-noise sequence



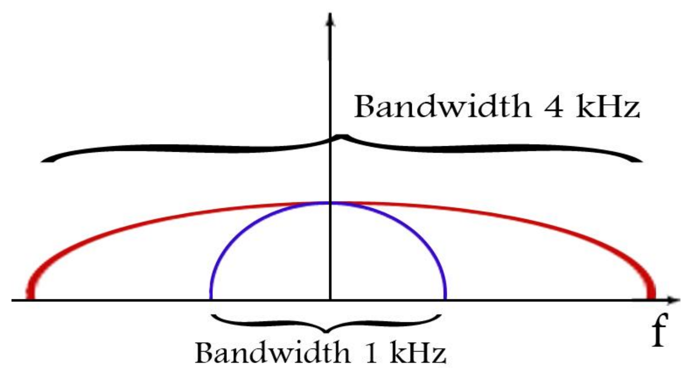


**Figure 6 Increase in Bandwidth for 1 kbps symbol – Spread Spectrum Technology**

## 4. Parallel Combinations Usage In Spread Spectrum Communication

Instead of sending the data serially, bit by bit , we can also send the stream of data in parallel[6]. The key idea is to add the signals to form new signals. The new signal is the sum of two signals and then sending it. The data rate is now doubled, where the Bandwidth requirement remains the same and hence efficiency is also increased. The main idea is shown in figure 7.

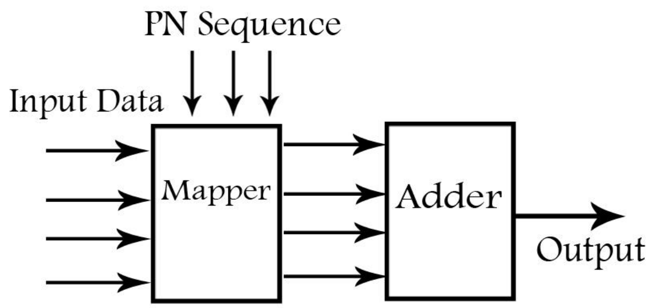


**Figure 7 representing the main idea of parallel combination and adding of signals**

In order to understand this phenomena better, let us consider an example. Consider four codes $C_0$, $C_1$, $C_2$ and $C_3$ as shown below

$C_0$ = +1 +1 +1 -1 -1 +1 -1

$C_1$ = -1 -1 -1 +1 +1 -1 +1

$C_2$ = +1 +1 +1 -1 +1 -1 -1
$C_3$ = -1 -1 -1 +1 -1 +1 +1

These are four PN sequences. Now we can form new sequences by arbitrarily adding the two sequences. We define $C_5 = C_0+C_2$ and $C_6= C_1+C_3$ and hence we get

$C_5$= +2 +2 +2 -2 0 0 -2
$C_6$= -2 -2 -2 +2 0 0 +2

We define a mapper, when source is 00, it means it is code $C_5$ and when source is 01, it means code is $C_6$

And at the receiver end, the reverse is true , if received spread sequence combination is C5, it means source data is 01

Hence the results show that bandwidth efficiency is greatly increased also the transmission capacity is now almost doubled. It can work at low SNR. System is reliable and steady.

## 5. Precision Ranging

Two unique characteristics of spread spectrum are Code Division Multiple Access (CDMA) and precision ranging. Accuracy may be achieved in millimetre range. When the signal is transmitted, the receiver must know the exact time when the signal is transmitted, in order to calculate the exact distance. [7] Frequency of radio signal vary from 3 kHz to 300 GHz. The speed of the radio signal is 2.9979245 x 10^8. This speed multiplied by the time taken by the signal to reach the receiver equals the range, in meters, between the two points.

[8] The timings of transmission are either embedded in the receiver or told by the external source. Accuracy of both clocks is a must

The next step is to relate the spread spectrum with the Global Positioning System (GPS)

## 6. Global Positioning System (GPS)

[9]Global Positioning System works on the same principle as CDMA. All the satellites uses the same frequency, they send their information via different codes. The receiver is also synchronized and has the exact copy of the PN codes.

The Global Positioning System tracks the position by [10]triangulation of pseudo ranges of the three satellites as shown in the figure below.

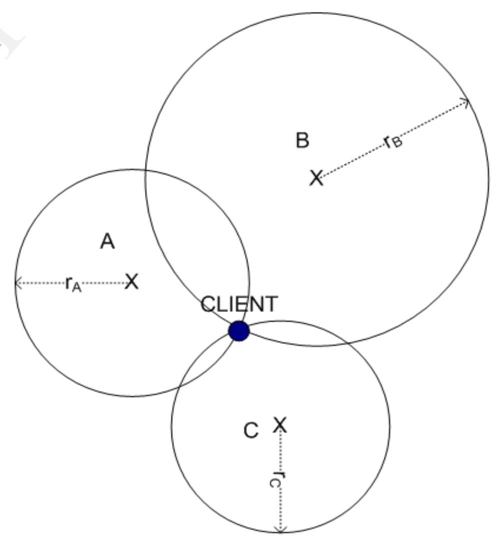


**Figure 8 Global Positioning System (GPS) Triangulation Technique to tract the client.**

Where $r_A$ is the range of satellite A, $r_B$ is the range of satellite B and $r_C$ is the range of satellite C

## 7. Position Tracking System Using Spread Spectrum

As described earlier, Spread spectrum has two distinct advantages, accurate ranging and Code Division Multiple access (CDMA). With these advantages, we can track the position of a person with millimetre accuracy.

Four transmitters are placed, one on x-axis, one on y-axis, one on z-axis and one for time. All the transmitters transmit on same frequency but having different codes.

Four Receivers are placed on the body, one for each transmitter. Each receiver receives the signal from the transmitter and calculate the position with respect to the origin.

Data from each receiver is multiplexed and goes to personal transmitter. Personal transmitter sends the multiplexed data to personal receiver, where position tracking computer might be placed.

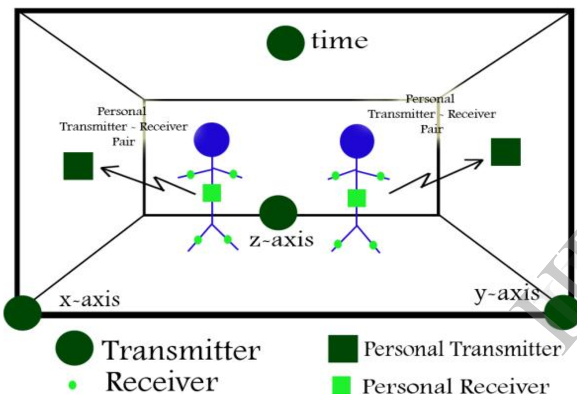


**Figure 9 Position tracking system using spread spectrum**

Hence Position tracking system is divided in to following parts 1) Stationary transmitters 2) Receivers on the body 3) Personal Transmitter-Receiver pair.

Construction is simple but the critical part is the timing. All the transmitters must send the PN sequence at the same time. Receiver calculates the position using the same triangulation method used in Global Positioning System (GPS) and data is then sent to the central processor by personal transmitter – receiver pair. And hence position of a person is known.

## 8. Conclusion

We started with the basics of communication. First described CDMA, then described PN sequences and then Spread spectrum. Then we described how the spread spectrum efficiency can be increased, how we can be used to send more data, how Bandwidth utilization is increased using the same SNR. After understanding the main characteristics of Spread spectrum we tried to track the position of a person using the same principle that is used in Global Positioning System (GPS)

This system is scalable and also stable. Tracking through spread spectrum depends on its implementation and not the size of the room.

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