# Performance of Wavelet Based Multiple Access Technique for Wireless Communication

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***ABSTRACT-*** **Wavelet theory has emerged as a new mathematical tool that can be applied in many fields such as image processing, biomedical engineering, radar, physics, control systems and communication systems. The important area of application of wavelets in communication: multiple accesses. Among the multiple access applications one of the most notable work is wavelet packet-based multiple access communication. The two new multiple access systems are Scale-Time-Code Division Multiple Access (STCDMA) and Scale-Code Division Multiple Access (SCDMA). STCDMA are analysed over a synchronous Additive White Gaussian Noise (AWGN) by using a multiuser detector based on decorrelating detector for real valued PN sequences. To be more specific, STCDMA is user-advantageous and SCDMA is information-advantageous. In STCDMA good PN sequences such as Kasami sequences are required because it decreases the multiple access interference. Number of users can enhance the performance (Gain and Bit Error Rate). Hence the performances of two users are compared by simulating each case in MATLAB.**

***Keywords-*** **Scale-Time-Code Division Multiple Access (STCDMA), Scale-Code Division Multiple Access (SCDMA), Bit Error Rate (BER), Hadamard PN sequences.**

## I. INTRODUCTION

In data communication, many transmitters transmit data simultaneously in single channel. This concept is called multiple accesses. Code Division Multiple Access (CDMA) employs multiple users to be multiplexed over a same channel. Time Division Multiple Access (TDMA) divides access by time, while Frequency-Division Multiple Access (FDMA) divides it by frequency. CDMA is a form of spread-spectrum signalling, because the modulated signal has higher bandwidth than the transmitted signal. CDMA uses different codes to modulate the signal, which decides the performance of the system. The performance is decided by the amount of separation between the signals of the original user and some other user. The separation is achieved by correlating the signal with the original signal. If the signal is same as the original signal then the correlation will be high and if it is not same, the correlation will be zero and it is called cross correlation. If the correlation is nearer to zero it is termed as auto-correlation. This type of correlation is used to decrease the multi-path interference. CDMA is classified as synchronous and asynchronous channels. With the recent remarkable advances in mobile communications technology, typified by digital cellular and cordless phones, the number of mobile communication subscribers is growing year by year. Special modulation techniques are used in digital communications to take full advantage of the excellent characteristics of digital signals. In America, a growing movement emerged in 1989 in favour of general use of CDMA one kind of spread spectrum communication system with the aim of making efficient use of the frequency spectrum, one of man's most important natural resources. Today, CDMA is in use as one standard for car and portable phone systems. Although CDMA offers a number of excellent features, it requires much more complex signal processing than other systems, and this has kept it out of the consumer field so far. Behind the process of bringing CDMA to the consumer market lie the remarkable advances made in digital modulation, semiconductor process, and circuit technologies. In the digital communications field, Sony has already released a number of functional ICs such as PLLs, modulators, and mixers. Now, we are enhancing our CDMA IC line-up, employing a combination of bipolar and GA As technologies.

## II. PROPOSED SYSTEM OF MULTIPLE ACCESS SYSTEM

The construction of orthonormal wavelets of compact support by Daubechies has promised a new kind of multiple access schemes by overlapping transmissions over multiple scales. Here, we present a new multiple access system called STCDMA which depends on the time,



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code, and scale orthogonality introduced by wavelets. A new multiple access system called STCDMA which depends on the time, code, and scale orthogonality introduced by wavelets. We use wavelets as an orthonormal set of symbols for signalling, and exploit their orthonormality over scale and time. In a STCDMA system, the channel is partitioned into different scales, and each scale into different time slots. For example, in the dyadic case (scale parameter is a power of 2) the first

In Fig 1. Transmitter uses a specific scale and time slot and is assigned a distinct (PN) sequence of different length that fits its corresponding time slot. So each user encodes its information symbols with a time-shifted and scaled replica (appropriate for its assigned scale and time slot) of the same basic wavelet, and then spreads it's translated and scaled wavelet by its PN sequence. At the receiver, the information streams for each user are decoded by using the orthogonality of the wavelets (wavelet transform) and of PN sequences. STCDMA averages the channel capacity per user by time-division multiplexing in each scale as opposed to SDMA where each user transmits its successive information symbols with time-shifted replicas of a basic wavelet in a specific scale. Moreover, STCD-MA equalizes the effect of noise on each scale by spreading each scaled wavelets bandwidth to a fixed larger spectrum as compared to SDMA where the effect of additive noise differs from scale to scale. For spreading purposes, we use orthogonal Hadamard code-based PN sequences and use DS-CDMA in each time slot.

We analyse the performance of STCDMA system communicating with dynamically scaled Haar wavelets and antipodal signalling. We show that STCDMA achieves optimum single user Binary Phase Shift Keying (BPSK) performance for synchronous transmission by using conventional single-user detector for each user. It also supports a larger number of users than conventional DS-CDMA (six or seven times that of DS-CDMA).

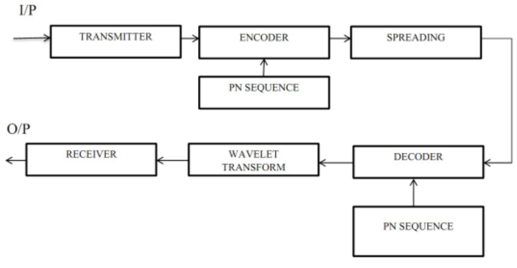


*Figure 1. Block diagram of STCDMA*

In ST-CDMA, each transmitter uses a specific scale and time slot and is assigned a distinct PN sequence of different length that fits its corresponding time slot. Each user encodes its information symbols with a time-shifted and scaled replica of the same wavelet, and then spreads its translated and scaled wavelet by its PN sequence. At the receiver, the information streams for each user are decoded by using the orthogonality of the wavelets and of PN sequences. ST-CDMA equalizes the effect of noise on each scale by spreading each scaled wavelets bandwidth to a fixed larger spectrum. For spreading purposes, it uses orthogonal Hadamard code-based PN sequences and use DS-CDMA in each time slot.STCDMA using Haar wavelet and complex-valued Hadamard sequences provides capacity improvement (supports more users) compared to conventional CDMA over the synchronous AWGN channel. Therefore, both performance and capacity improvements over a quasi-synchronous AWGN channel are expected in comparison to conventional CDMA and TD-CDMA. Consequently, we investigate the Bit Error Rate (BER) performance of a quasi-synchronous STCDMA system communicating with dyadically scaled Haar wavelets and BPSK over an AWGN channel by using a conventional detector (i.e. matched filter/correlator) for each user. In this work, MAI between different scales is reduced due to the fact that the quasi synchronous interference during the first half of Haar wavelet is compensated by the quasi synchronous interference during the second half of Haar wavelet that has the same magnitude but the opposite sign. As a result, MAI between different scales is decreased as the number of scales increases. Therefore, it will be shown that as the number of scales of STCDMA increases, STCDMA outperforms DS-CDMA and TD-CDMA in terms of both performance and capacity for the case of quasi synchronous communication when complex-valued Hadamard sequence set is employed. STCDMA averages the channel capacity per user by time division multiplexing in each scale as opposed to SDMA where each user transmits its successive information symbols with time shifted replicas of a basic wavelet in a specific scale (in SDMA lower scale channels can accommodate more information symbols than higher scale channels per unit time, i.e., the lower scale the higher the capacity. For example, in the dyadic case the capacity of each channel doubles that of the preceding higher scale channel).Moreover, STCDMA equalizes the effect of noise on each scale by spreading each scaled wavelet's bandwidth to a fixed larger spectrum as compared to SDMA where the effect of additive noise differs from scale to scale. Wavelets in different scales have the same



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energy because of an energy normalization term that depends on the scale parameter. Since the finer scale, the shorter wavelet width and thus the more bandwidth occupation, the constant energy of wavelets is distributed in bigger bands of the spectrum scale decreases. Therefore, the effect of additive noise differs from scale to scale. Thus, in order to equalize the effect of noise on each scale, one needs to spread each scaled wavelet's bandwidth to a fixed larger spectrum. For spreading purposes, we use orthogonal Hadamard code based PN sequences and use DSCDMA in each time slot. We will use antipodal signalling at the transmitter, i.e., transmit the Haar wavelet itself and the reversed one for the information symbols +I and –I, respectively. At the receiver, we use a conventional single-user detector for each user due to the perfect orthogonality of wavelets and Hadamard code-based signature waveforms. The conventional single-user detector correlates the received signal with the wavelet and the signature waveform assigned by the desired user.

## III. STCDMA WITH MULTIUSER DETECTOR

The near-far problem is the principal shortcoming of current radio networks using Direct-Sequence Spread-Spectrum Multiple-Access (DS/SSMA) communication systems. Those systems achieve multiple-access capability by assigning a distinct signature waveform to each user from a set of waveforms with low mutual cross correlations. Then, when the sum of the signals modulated by several asynchronous users is received, it is possible to recover the information transmitted by correlating the received process with replicas of the assigned signature waveforms. This demodulation scheme is conventionally used in practice, and its performance is satisfactory if two conditions are satisfied: first, the assigned signals need to have low cross correlations for all possible relative delays between the data streams transmitted by the asynchronous users, and second the powers of the received signals cannot be very dissimilar. If either of these conditions is not fulfilled, then the BER and the anti jamming capability of the conventional detector are degraded substantially. The reason why system performance is unacceptable when the received energies are dissimilar even with good (i.e., quasi orthogonal) signal constellations, is that the output of each correlator or matched filter contains a spurious component which is linear in the amplitude of each of the interfering users. Thus, as the multiuser interference grows, the BER increases until the conventional detector is unable to recover the messages transmitted by the weak users.

## IV. MULTIUSER DETECTION SCENARIO

Here, the amplitude of the first scale wavelet of a 2-scale STCDMA is modified provided that the energy of the waveforms in that scale remains unchanged and its performance is analysed with multiuser detection scenario I. By doing this modification, we intend to improve the performance of the first scale users of 2-scale STCDMA. In this scenario, the first half of the first scale wavelet has an amplitude of $\sqrt{3\epsilon/2}$ half of it is $-\sqrt{\epsilon/2}$ instead $\sqrt{\epsilon}$ and $-\sqrt{\epsilon}$ , respectively. The second scale is unchanged. Since the waveforms are normalised to have unit energy (i.e. T=1), the energy of the waveforms in the first scale is the same with and without modulation. Also, it is not difficult to derive and find that the power spectral densities for the both cases (with and without) are almost same. For this modified 2-scale STCDMA system, when the interval [0, T/2] is matched equations through still valid. However the first L diagonal elements of the amplitude matrix E are equal to $\sqrt{3\epsilon/2}$ and the second L diagonal element of E are equal to $\sqrt{\epsilon}$ . Thus the performance of the first and second slot users of the second scale are again expressed by equation but the performance of the scale users can be shown to be Equation 1.

$$p_{0,0,k} = \frac{1}{2}\,\mathrm{erfc}\,\sqrt{1.5\gamma_b/(R_1^{-1})_{kk}} \quad\text{................ 1}$$

Where K=1, 2...L. when the interval [T/2, T] is matched, the coefficient 1.5 argument of the erfc is replaced by (0.5). So, it will be more accurate to decide the information bits of the first scale users in the interval [0, T/2] than the interval [T/2, T]. Since$(R_1^{-1})_{kk} = 2(R_1^{-1})_{ii}$for k=1,...L and i=k+L, equation can be restated as Equation 2.

$$p_{0,0,k} = \frac{1}{2}\,\mathrm{erfc}\,\sqrt{7.5\gamma_b/(R_1^{-1})_{ii}} \quad\text{................ 2}$$

Where k=1,...L and i=k+L. Then as seen in equation the performance of any user of the first scale will be better than that of the same user of the system without modification and approaches that of the second scale user employing the same PN sequence. The performance of first scale users of the modified STCDMA with the multiuser detector I is a little bit worse than that of the first users of STCDMA with the conventional detector for Signal to Noise Ratio (SNR) less than 10 db, but it outperforms that for SNR larger than 10 db.However, is still possible to improve the performance of the first scale users of the modified STCDMA further at the expense of the amplitude change in power spectrum. In other words, instead of assigning $\sqrt{3\epsilon/2}$ and $-\sqrt{\epsilon/2}$ for the first and second half amplitudes of the scale wavelet, in general $\sqrt{a\epsilon}$ and $-\sqrt{(2-a)\epsilon}$ can be assigned respectively, where $1 \leq a \leq 2$ then in equation the coefficient 0.75 is replaced by a/2 thus larger the



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value of ‘a’ better the performance of the first scale users at the expense of ‘a’ decrease in the amplitude of the power spectrum. Large values of ‘a’ can be assigned for privacy and anti-jamming applications, where low amplitude of power spectrum is desired.

## V. WAVELET BASED STCDMA

In this work, a wavelet-based multiple access system, STCDMA, which is based on the scale, time, and code orthogonality, has been described and its performance has been analysed for synchronous transmission in an AWGN channel. In synchronous AWGN channel, Hadamard code based PN sequences keep their orthogonality and hence STCDMA achieves optimum single-user BPSK performance by using conventional single-user detector for each user. It also supports larger number of users than conventional DS-CDMA (six or seven times more than DS-CDMA) if the first (coarsest) scale is thought to be traditional DS-CDMA. When we use other wavelets than the Haar wavelet, or the signature waveforms exhibit some correlation in other environments such as asynchronous AWGN channel and multipath propagation medium, the system will have multiple access interference.We analyse BER performance of a recently proposed multiple access system called scale time code division multiple access for synchronous communication over an AWGN channel. STCDMA depends on code, time and scale orthogonality introduced by spreading sequences and wavelets. Wavelets are employed as an orthogonal set of symbols for signalling, and their orthogonality over scale and time is exploited. Information symbols of each user are encoded by the Haar wavelet in its scale and time slot, and then they are spread by its spreading code. Complex-valued Hadamard sequences are used as spreading sequences and conventional detector is used at the receiver. Results show that the performance of STCDMA gets much better than that of CDMA over the quasi synchronous AWGN channel as the number of scales increases.

STCDMA using Haar wavelet and complex-valued Hadamard sequences provides capacity improvement (supports more users) compared to conventional CDMA over the synchronous AWGN channel. Therefore, both performance and capacity improvements over a synchronous AWGN channel are expected in comparison to conventional CDMA and

TD-CDMA. Consequently, we investigate the BER performance of a synchronous STCDMA system communicating with dyadically scaled Haar wavelets and BPSK over an AWGN channel by using a conventional detector for each user. In this work, MAI between different scales is reduced due to the fact that the synchronous interference during the first half of Haar wavelet is compensated by the synchronous interference during the second half of Haar wavelet that has the same magnitude but the opposite sign. As a result, MAI between different scales is decreased as the number of scales increases. Therefore, it will be shown that as the number of scales of STCDMA increases, STCDMA outperforms DS-CDMA and TD-CDMA in terms of both performance and capacity for the case of synchronous communication when complex valued Hadamard sequence set is employed.

## VI. PERFORMANCE ANALYSIS OF STCDMA

Multiuser detection scenarios- based on the decorrelating detector and analysed the performance of 2- scale STCDMA. However multiuser detector II can be used in any STCDMA format. We have shown the STCDMA with these detectors provides much better performance than STCDMA with the conventional detector for both even and odd lb. In addition, STCDMA with multiuser detector II provides almost the same performance as DS-CDMA with a decorrelating detector for a moderate number of users, but as the number of user increases, it gets worse than that of DSCDMA. Then the performance degradation compared to DS-CDMA is compensated with the multimedia advantage provided by SCDMA.

## VII. RESULT

Figure. 2 represent the output of STCDMA, Conventional detector and multi user detector using synchronous AWGN and Rayleigh channel. In order to evaluate the performance of multiuser detector, it is simulated using different modulation techniques and it has been analysed. Here the output is considered for two number of users and the increase in number of users improves the capacity and performance of the system. So, by increasing the number of users, the capacity and performance can be improved and it can be implemented with various modulation techniques.

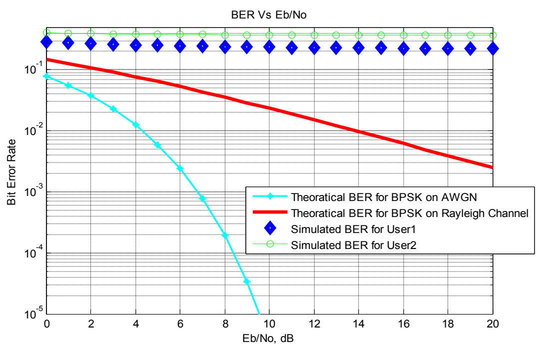


*Figure 2. BER Vs EB/N0 on AWGN and Rayleigh channel for 2 users*



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In the 2-scale STCDMA analysis, we have derived that STCDMA with multiuser detector provides much better performance than with conventional detector for both even and odd samples. Also STCDMA performance is compared with DSCDMA for more number of users. In this regard STCDMA is proved to be better than DSCDMA. As DSCDMA performs only for moderate number of users, we go for STCDMA which supports multiple users.

## VIII. CONCLUSION

In this paper, we have dealt with the new multiple access system, STCDMA, which depend on time, code and scale orthogonality introduced by time-division, PN sequences and wavelets. This system equalise the noise on each scale by spreading the bandwidth of each wavelet to a fixed large spectrum. In addition, because of spreading, the system provides interference immunity against jamming, multiple access interference, and multipath propagation interference. Spreading bandwidth can be adjusted on the basis of desired level of immunity, i.e., the bandwidth occupancy of the system can be changed. First of all, we have analysed STCDMA over the synchronous AWGN channel by using a conventional detector and employing real-valued PN sequences. We have proved that STCDMA achieves ideal BPSK performance for Hadamard PN sequences when an odd number of periods are assigned at the bottom scale and for Hadamard and extended Gold PN sequences when an even number of periods is assigned at the bottom scale. STCDMA supports the most number of users when two periods of the extended Gold PN sequences are used. Secondly, we have analysed STCDMA over the synchronous AWGN channel by using multiuser detectors and employing real-valued Gold PN sequences. We have found that the performance of STCDMA improves a lot multiuser detectors as compared to that with the conventional detector for the assignment of both an even and an odd number of periods. As compared to DS-CDMA, STCMDA employs such optimal PN sequences as Kasami and Bent can provide the assignment of more users in the media where these sequences are in demand. In other words, these classes of PN sequences can be very useful for multipath, jamming environments, synchronization purposes, etc.

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