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Comparison of RNS Based PN Sequence with other CDMA Codes

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ABSTRACT:

Code Division Multiple Access (CDMA) is based on Spread Signal (SS) has emerged as one of the most important multiple access technologies for Second Generation(2G) and Third Generation (3G) wireless communication systems by its wide applications in many important mobile cellular standards.CDMA serves different users by spreading codes by different technique and various problems stem in spreading codes like Hadamard (WH) codes and Orthogonal Variable Spreading Factor (OVSF) codes, and the other being pseudo-noise or Pseudo Random (PN) sequences, such as Gold sequences, Kasami sequences, m-sequences, etc.It is proposed a PN sequence generation based on Residue Arithmetic to improve the performance of interference limited CDMA Technology. Then the new PN Sequence generator design based on RNS is discussed. Comparison of the generated PN sequence with respect to other standard sequence is done in terms of number of codes and correlation properties. RNS based PN sequence has enhanced performance to that of other CDMA codes by comparing the bit error probability in multi-user and multipath environment thus contributing a little towards the evolution of next generation CDMA technology.

BACKGROUND:

In conventional systems, due to the carry forward required by the weighted number system, a bit error may affect all the bits of the result. In] they proposed a parallel com-munication scheme based on RNS, which is a non-weighted Carry-free number system. The symbol to be transmitted is transformed to RNS representation, mapped into a set of orthogonal sequences and are transmitted in parallel. Error control was also incorporated in this paper using redundant RNS (RRNS) code. Performance of the same system over bursty communication channels. They have also proposed a modulation technique by combining RNS representation, PSK/QAM modulation and orthogonal modulation for Bandwidth efficiency in [9].

The error control properties of RRNS exploited in to be used as channel codes for protecting the speech bits. In residue arithmetic is used for representing the symbol to be transmitted. Redundant residue arithmetic system based multi-carrier DS-CDMA (MC/DS - CDMA) dynamic multiple access scheme has been proposed in references basically points to a parallel communication scheme where the symbol to be transmitted by each user is represented in residue arithmetic and an inverse RNS transform block is used at the receiver to get back the symbol. But generation of PN sequences by exploiting the properties of RNS and use of these to spread message signals for multiple user transmission has never been exploited. Wideband Code Division Multiple Access (WCDMA), the air interface technology for third generation (3G) systems specified by 3rd Generation Partnership Project (3GPP) applies DS-CDMA technique with Orthogonal Variable Spreading (OVSF) Code as channelization code for multiplexing different users[.The WCDMA downlink transmission is prone to self interference caused by the loss of orthogonality between spreading codes due to multipath propagation .

There are several techniques for interference cancellation and multiuser detection that improves the performance and capacity of the downlink WCDMA system Most of these techniques are designed at the expense of higher receiver complexity and with OVSF codes derived from Walsh-Hadamard code. Construction methods of OVSF-ZCZ sequences have been proposed in [to mitigate interference due to multipath propagation. Since the number of OVSF-ZCZ sequences is limited, various assignment algorithms are required to meet the demand of large number of users. The use of Orthogonal Variable Spreading Code (OVSF) code requires that a dedicated rate matching algorithm to be used in the transceivers [1]. This algorithm consumes a great amount of hardware and software resources and increases computation load and processing latency. In the OVSF code generation tree structure, the codes in the upper layer with lower spreading factor blocks the codes in the lower layer with higher spreading factor. I.e., fewer users can be accommodated in a cell.

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These issues indeed demand for the existing existing code replacement. In this context this paper presents a Channelization code based on Residue Arithmetic which counter the said limitations. RNS is already used in the design of decimation filters for WCDMA receivers .

RNS Based PN Sequence Generator:

In most communication systems, spreading codes or sequences can be generated in an offline way and is saved in a look-up table, which can be called whenever needed. Similarly RNS based PN sequence generation [27] also consists of an off-line process for the generation of Initial Primal Vector and finally the generation of the required PN sequence from the stored primal vectors which is done on-line. The offline process is summarized in Fig1 . The external inputs to these blocks include spreading factor β, and the Cross Correlation Threshold (CF). Moduli set, M, for a given β are selected either by consecutive method or exponential Consecutive method of moduli selection is used here. Table 3.1 shows the generated moduli set and dynamic range, R for various spreading factors using Consecutive moduli selection method.For a given spread factor, the number of users that can be accommodated is in comparison to other spreading codes.

A primal, J1 is randomly selected from the range, R in eq1. The corresponding residue set, Rs(J1)

Rs(J1) = fjJ1jp1; jJ1jp2; :::jJ1jpmg

$$R = \prod_{i=0}^{n} pi \quad (1)$$

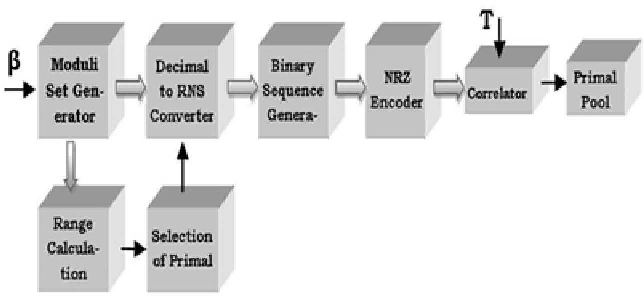

Figure 1: Off line process for RNS Based PN Sequence Generation.

Table 1:

β	MODULI SET P = (p1; p2; p3;........p)	RANGE, R
8	[255]	255
16	[255 254]	64770
32	[255 254 253 251]	4113089310
64	[255 254 253 251 247 241 239 233]	10^{19}
128	[255 254 253 251 247 241 239 233 229 227 223 217 211 199 197 193]	10^{40}

is the output of Decimal to Residue Arithmetic Converter. The generated residue numbers are concatenated and converted into 8 bit (since k = 8) binary sequence of 1 and 0. This sequence is passed through the NRZ encoder to get the sequence c1 corresponding to primal J1. This procedure is repeated for every primals in range, R. The generated sequences are tested for correlation amongst themselves such that correlation between ci and cj, i ≠ j has to be unity.correlation between ci and cj i ≠ j has to be preferably less than a threshold T. This threshold can vary for different applications based on the channel properties and error tolerance.The primal which satisfies this criteria forms the Primal Pool, J. Consider an example for the proposed PN Sequence Generation for _ = 16, M =[255 254] and CF = 0.25. Table 2 shows the generated the PN Sequence for the randomly selected primals. These sequences are then tested for correlation among themselves which is listed in Table 2. Since the defined system requires a threshold of 0.25, discard J5 and add J1; J2; J3; J4 to the final primal pool, J.

Depending upon the application and number of users active in the system, the Primal Vector, J

J = [J1; J2; J3; :::JU]T

Table 2: RNS Based PN Sequence Generation

Primal, J ¹	PN Sequence Based on RNS, c
1	-1 -1 -1 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 -1 -1 1
321	-1 1 -1 -1 -1 -1 1 1 -1 -1 -1 -1 -1 -1 1 1
550	-1 -1 1 -1 1 -1 -1 1 -1 -1 1 -1 1 -1 1 1
2356	-1 -1 1 1 1 1 -1 1 -1 1 -1 -1 -1 1 1 1
64000	1 1 1 1 1 -1 1 1 1 1 1 1 -1 1 1 1

Table 2.1 Length of the code set for different CDMA Codes

	Orthogonal Code		Pseudo Random Sequence		
β	WH code	OVSF code	m - sequence	Gold	RNS based sequence
8	code	8	7	9	255
16	16	16	15	17	64770
32	32	32	31	33	4113089310
64	64	64	63	65	10^{19}
128	128	128	127	129	10^{40}

Number of Sequences:

Table 2.1 shows the comparison of number of available codes for a cell for the proposed sequence with other CDMA codes for a given spreading factor.

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N length Walsh - Hadamard (WH) sequences are derived from Walsh - Hadamard matrix of size N _N to support N different users [52]. For a particular sequence length, the OVSF codes are basically the same as WH sequences. The only difference between the two is that the latter allow combinational use of WH sequences with different lengths [53].

This creates Code Assignment Blocking problem thus limiting the number of users close to one fifth of the maximal spreading factor [1].An n-stage shift register can generate a maximal length sequence of 2n-1 bits [52].Shifted combinations of this sequence gives N = 2n-1 number of sequences.

Gold Sequence are constructed by modulo-2 addition of two m-sequences of the same length with each other [51]. Including the two m-sequences used for addition a Comparison of RNS based PN sequence with other CDMA codes.

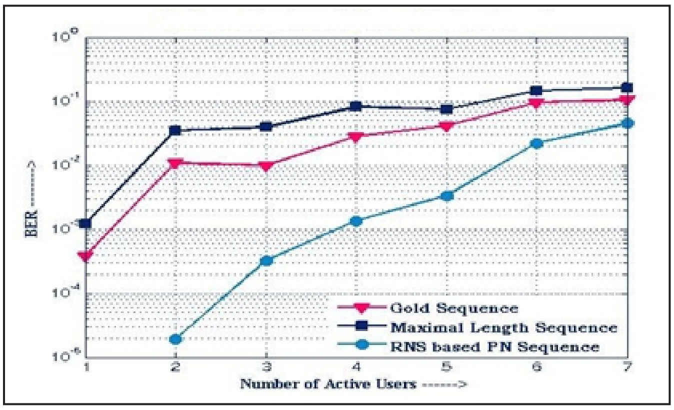

Figure 3.8: BER performance versus the Number of Active Users with spreading factor, _ = 8 for Maximal Length Sequence, Gold Sequence and RNS based PN Sequence Figure.

Inference and Conclusion:

The performance variations in different channels and the error floor reduction with increase in spreading factor shows that the proposed sequence behaves like PN sequences. In addition, the above results illustrate that it also incorporate real operational conditions with a provision to vary the correlation properties as per the system requirements. For applications which require better performance, the cross-correlation threshold should be reduced further so as to mitigate the multiple access interference.

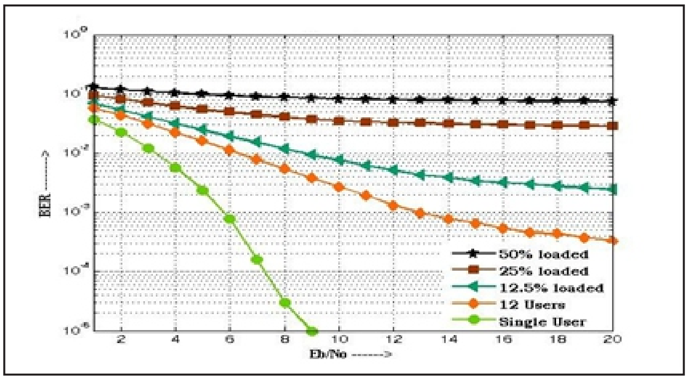

Figure 4.6: Comparison of RNS based PN sequence with Gold codes, Maximal Length sequence and orthogonal Walsh Hadamard code based on BER Plot for8 Users downlink WCDMA System, β = 128

Scope of Future work:

• VLSI along with embedded system implementation of the RNS based PN Sequence generator.
• Incorporating RNS based spreading sequence in RNS based CDMA System.
• The work can be extended to a mobile wireless communication.

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