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## **PREFACE**

We are delighted to welcome you to the twelfth issue of the International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS). In recent years, advances in science, technology, engineering, and mathematics have radically expanded the data available to researchers and professionals in a wide variety of domains. This unique combination of theory with data has the potential to have broad impact on educational research and practice. IJETCAS is publishing high-quality, peer-reviewed papers covering topics such as computer science, artificial intelligence, pattern recognition, knowledge engineering, process control theory and applications, distributed systems, computer networks and software engineering, electrical engineering, electric machines modeling and design, control of electric drive systems, non-conventional energy conversion, sensors, electronics, communications, data transmission, energy converters, transducers modeling and design, electro-physics, nanotechnology, and quantum mechanics.

The editorial board of IJETCAS is composed of members of the Teachers & Researchers community who have expertise in a variety of disciplines, including computer science, cognitive science, learning sciences, artificial intelligence, electronics, soft computing, genetic algorithms, technology management, manufacturing technology, electrical technology, applied mathematics, automatic control, nuclear engineering, computational physics, computational chemistry and other related disciplines of computational and applied sciences. In order to best serve our community, this Journal is available online as well as in hard-copy form. Because of the rapid advances in underlying technologies and the interdisciplinary nature of the field, we believe it is important to provide quality research articles promptly and to the widest possible audience.

We are happy that this Journal has continued to grow and develop. We have made every effort to evaluate and process submissions for reviews, and address queries from authors and the general public promptly. The Journal has strived to reflect the most recent and finest researchers in the field of emerging technologies especially related to computational and applied sciences. This Journal is completely refereed and indexed with major databases like: IndexCopernicus, Computer Science Directory, GetCITED, DOAJ, SSRN, TGDScholar, WorldWideScience, CiteSeerX, CRCnetBASE, Google Scholar, Microsoft Academic Search, INSPEC, ProQuest, ArnetMiner, Base, ChemXSeer, citebase, OpenJ-Gate, eLibrary, SafetyLit, SSRN, VADLO, OpenGrey, EBSCO, ProQuest, UlrichWeb, ISSUU, SPIE Digital Library, arXiv, ERIC, EasyBib, Infotopia, WorldCat, .docstoc JURN, Mendeley,

ResearchGate, cogprints, OCLC, iSEEK, Scribd, LOCKSS, CASSI, E-PrintNetwork, intute, and some other databases.

We are grateful to all of the individuals and agencies whose work and support made the Journal's success possible. We want to thank the executive board and core committee members of the IJETCAS for entrusting us with the important job. We are thankful to the members of the IJETCAS editorial board who have contributed energy and time to the Journal with their steadfast support, constructive advice, as well as reviews of submissions. We are deeply indebted to the numerous anonymous reviewers who have contributed expertly evaluations of the submissions to help maintain the quality of the Journal. For this twelfth issue, we received 152 research papers and out of which only 61 research papers are published in three volumes as per the reviewers' recommendations. We have highest respect to all the authors who have submitted articles to the Journal for their intellectual energy and creativity, and for their dedication to the field of computational and applied sciences.

This issue of the IJETCAS has attracted a large number of authors and researchers across worldwide and would provide an effective platform to all the intellectuals of different streams to put forth their suggestions and ideas which might prove beneficial for the accelerated pace of development of emerging technologies in computational and applied sciences and may open new area for research and development. We hope you will enjoy this twelfth issue of the International Journal of Emerging Technologies in Computational and Applied Sciences and are looking forward to hearing your feedback and receiving your contributions.



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## TOPICS OF INTEREST

**Topics of interest include, but are not limited to, the following:**

- Social networks and intelligence
- Social science simulation
- Information retrieval systems
- Technology management
- Digital libraries for e-learning
- Web-based learning, wikis and blogs
- Operational research
- Ontologies and meta-data standards
- Engineering problems and emerging application
- Agent based modeling and systems
- Ubiquitous computing
- Wired and wireless data communication networks
- Mobile Ad Hoc, sensor and mesh networks
- Natural language processing and expert systems
- Monte Carlo methods and applications
- Fuzzy logic and soft computing
- Data mining and warehousing
- Software and web engineering
- Distributed AI systems and architectures
- Neural networks and applications
- Search and meta-heuristics
- Bioinformatics and scientific computing
- Genetic network modeling and inference
- Knowledge and information management techniques
- Aspect-oriented programming
- Formal and visual specification languages
- Informatics and statistics research
- Quantum computing
- Automata and formal languages
- Computer graphics and image processing
- Web 3D and applications
- Grid computing and cloud computing
- Algorithms design
- Genetic algorithms
- Compilers and interpreters
- Computer architecture & VLSI
- Advanced database systems
- Digital signal and image processing
- Distributed and parallel processing
- Information retrieval systems
- Technology management
- Automation and mobile robots
- Manufacturing technology
- Electrical technology
- Applied mathematics
- Automatic control
- Nuclear engineering
- Computational physics
- Computational chemistry



# TABLE OF CONTENTS

International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

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(March-May, 2015, Issue 12, Volume 1, 2 & 3)

## Issue 12, Volume 1

Paper Code	Paper Title	Page No.
IJETCAS 15-305	Error Analysis in Determining Parameters of Overlapping Peaks Using Separation of Complex Spectra into Individual Components. Case Study: Triplets J. Dubrovkin	01-07
IJETCAS 15-307	Impact of MGSTC BLAST spatial multiplexing scheme on performance assessment of MCCDMA wireless communication system Mahmudul Haque Kafi, Md. Sarwar Hosain and Sk. Shifatul Islam	08-14
IJETCAS 15-308	Investigation of Influence of Defocusing and Pulse Duration for Marking on Samples of Steel HS18-0-1 with Fiber Laser Nikolay Angelov	15-18
IJETCAS 15-309	Hybrid Sampling Technique for MRI Image Reconstruction Tanuj Kumar Jhamb, Vinith Rejathalal, V.K. Govindan	19-25
IJETCAS 15-311	Analysis of Software Product Quality Models H. S. Shukla, Deepak Kumar Verma	26-30
IJETCAS 15-312	Performance Investigation of Different Signaling and Coding Rates in WIMAX Network Priyanka, Dr. Jyoteesh Malhotra	31-36
IJETCAS 15-313	Approaches to Process Performance Modelling B R Sharma	37-42
IJETCAS 15-315	Determining of the resonant transverse oscillations of a beam fixed at one end Tsanko Karadzhev	43-46
IJETCAS 15-316	Simulation of Invisible Image Watermarking Alpana Kakkar, Apoorva Gupta	47-52
IJETCAS 15-317	A Progressive Software Project Management Maturity Model (PSPM3) for GCC countries Akrati Koul, Dr. Sushila Madan	53-57
IJETCAS 15-318	Quality Assessment of Encrypted Color Image in a D-BLAST aided LDPC encoded SC-FDMA Wireless Communication System Md. Sarwar Hosain, Shaikh Enayet Ullah and Rubaiyat Yasmin	58-64
IJETCAS 15-319	Design of a Practical Type Transmission Lines by using COMSOL Multyphysics 5.1 S Nagakishore Bhavanam, Vasujadevi M, B Bhaskara Rao, V Krishna Naik	65-69
IJETCAS 15-320	K-means Cluster Model for Climate Prediction of Vindhya Region Shailendra Singh, Navita Shrivastava, R. K. Tiwari	70-72
IJETCAS 15-321	Analysis of a Discrete SEIR Epidemic Model A.George Maria Selvam, A. Jenifer Priya	73-76
IJETCAS 15-322	Statistical Behaviour of Software Process and its Impact on Process Performance B R Sharma	77-79
IJETCAS 15-323	Dermatoglyphics (Age Determination) Wavelet Approach Ajitha T.Abraham, Prof.Yasim Khan	80-84
IJETCAS 15-324	Online Opportunistic Routing in Cognitive Radio Ad-Hoc Network and Spectrum Management Harshal Solao, Prof. R M Goudar, Prof. Sunita Barve	85-90
IJETCAS 15-325	Comparative Study of Spectrum Sensing Methods in Cognitive Radio Network Sarwar Ali, Md Monirul Islam	91-95

## Issue 12, Volume 2

Paper Code	Paper Title	Page No.
IJETCAS 15-326	Database Teaching in Different Universities: A Phenomenographic Research Karwan Jacksi	96-100
IJETCAS 15-329	Comparison of Static Policy Enforcement Techniques of NAC Shalvi Dave	101-105

<b>IJETCAS 15-330</b>	Cloud Computing: Introduction to Cryptography Er. Rasneet Kaur Chauhan, Er. Sharanjit Singh	106-110
<b>IJETCAS 15-332</b>	Variation in Selection Operator of Genetic Algorithm to Optimize TSP Smita Sharma, Monika	111-114
<b>IJETCAS 15-333</b>	Improving the Process Capabilities of EDM: A Review Bikramjit Singh, Chandan Deep Singh	115-119
<b>IJETCAS 15-335</b>	Enhancing the Information Security Constraints for Speedy Transmissions using Encryption Methods over Android Platform Saurabh M.I. Prabhune, Indrajeet Sharma, Sachin Bayas, Prof. Trupti B. Mane	120-125
<b>IJETCAS 15-337</b>	Development of Project with Combined Efforts Using Cloud Computing Dalganjan Sengar, Mayank Bhardwaj, Vishal Neekhara, Prof. Manoj Sonkusre	126-129
<b>IJETCAS 15-341</b>	Thermodynamic and Acoustic properties of binary liquid mixtures of octan-2-ol with benzene and halobenzenes at 308.15 K Vijay Kiran, Jasbir Sangwan, Subhash C. Bhatia, Narender Singh	130-134
<b>IJETCAS 15-350</b>	Weighted PÁL-Type Interpolation on the Unit Circle Swarnima Bahadur and Manisha Shukla	135-139
<b>IJETCAS 15-351</b>	Image Processing Based Toll Automation Using ANPR Kavya.S, Mutturaj Hubballi, Priyanka.B.N	140-143
<b>IJETCAS 15-352</b>	Taguchi Design for Parameter Optimization of Size-Controlled Synthesis of Silver Nanoparticles Velhal S.G, Latpate R.V., Kulkarni S.D., Jaybhaye R.G.	144-149
<b>IJETCAS 15-354</b>	Review of Apriori Algorithm and its Recent Improvements Jagmeet Kaur, Neena Madan	150-152
<b>IJETCAS 15-355</b>	Study of Adaptive Algorithms for Removal of Power Line Interference from Electrocardiogram Signal Gulmeen Kaur, Amandeep Kaur	153-157
<b>IJETCAS 15-359</b>	KQML Based Communication Protocol for Multi Agent Systems Dimple Juneja, Aarti Singh, Ankit Jagga	158-162
<b>IJETCAS 15-362</b>	An Intelligent Hybrid Quick Reduct Particle Swarm Optimization Algorithm for Feature Reduction in Cardiac Disease Prediction Dr. Durairaj.M, Sivagowry.S	163-173
<b>IJETCAS 15-365</b>	Error Analysis in Determining Parameters of Overlapping Peaks Using Separation of Complex Spectra into Individual Components. Case Study: Quartets J. Dubrovkin	174-179
<b>IJETCAS 15-366</b>	Elastic Resource Allocation Challenges in Cloud computing System Dr. M. Durairaj, Kannan	180-184
<b>IJETCAS 15-367</b>	A Study on Distributed Database System Swati Gupta	185-188
<b>IJETCAS 15-369</b>	An E-Learning Environment Abha Sharma, Surabhi Thareja, Roshan Lal Chhoker	189-192
<b>IJETCAS 15-371</b>	Smart Materials & its Applications Mr. Aamir Mustafa Shaikh	193-197

### Issue 12, Volume 3

<b>Paper Code</b>	<b>Paper Title</b>	<b>Page No.</b>
<b>IJETCAS 15-376</b>	An Automatic File Replication Mechanism in Computational Grid Ch. Ramesh Babu, Dr. Ch. D. V. Subba Rao	198-205
<b>IJETCAS 15-382</b>	Hardware Implementation of ANN and SNN Model- A Survey Soni Chaturvedi, Dr. A.A.Khurshid, Dr. S.S. Dorle	206-208
<b>IJETCAS 15-383</b>	Introduction to CryptoCloud in Cloud Computing Er. Sharanjit Singh, Er. Rasneet Kaur Chauhan	209-213
<b>IJETCAS 15-387</b>	Skew Detection and Correction of Handwritten Document Images using Multiple projection profiles and skew angles N. Shobha Rani, Arun Kumar S, Mithun T	214-219
<b>IJETCAS 15-388</b>	Mapping of Soil Micronutrients in Someshwar Agricultural Watershed using IDW Interpolation Approach G.S.Yurembam, Harish Chandra, Vinod Kumar and A.K.Rabha	220-225

<b>IJETCAS 15-389</b>	Most Efficient Design Methodology of DC-Contact MEMS Shunt Switch Neeraj Devarari, Shivika	226-230
<b>IJETCAS 15-393</b>	Personality Identification Based on Handwriting Kanchana V, Bhavya Ottapurakkal, Silpa Suresh, Sajini RS	231-235
<b>IJETCAS 15-395</b>	Comparative study of few diatomic empirical potential functions B.P. Deshmukha, Supriya Beherea, S.H. Beherea	236-240
<b>IJETCAS 15-397</b>	Comparative Evaluation of LEACH based Routing Algorithms for Different Deployment Densities of WSN Manisha, Gurpreet Singh, Surender Singh	241-245
<b>IJETCAS 15-399</b>	Evaluating Performance of Various Lane Detection Technique Er. Iqbal Singh, Dr. S.B. Rana	246-249
<b>IJETCAS 15-403</b>	Offline OCR for Handwritten English Characters and Numerals using Shape numbers and Chain codes N. Shobha Rani, Lakshmi Prasanna Kumari.R, Nikhil Bopaya	250-256
<b>IJETCAS 15-404</b>	Low Power Low Complexity of State Parallel Viterbi Decoder for WiMAX Receiver R.Srinath , Dr.M.Anto Bennet, N.Srinivasan	257-260
<b>IJETCAS 15-405</b>	Real Time Patient Monitoring System Based On ECG Signals MS. SWAGATA B.SARKAR, GOKULA KRISHNAN R, GOPI KRISHNAN S, SIVARANJAN E, SATHISH K	261-264
<b>IJETCAS 15-410</b>	Techniques of Text Mining: A Survey Paramjit Kaur, Neena Madan	265-267
<b>IJETCAS 15-414</b>	Aspects and Approaches of Spectrum Sensing Techniques in Cognitive Radio Network: A Survey Ashima Rout, Srinivas Sethi, P. K. Banerjee	268-275
<b>IJETCAS 15-419</b>	Design of laser beam expander for LWIR spectrum range Dimcho Pulov	276-280
<b>IJETCAS 15-423</b>	Community Detection in Temporal Networks Anupama Angadi, Dr. P. Suresh Varma	281-285
<b>IJETCAS 15-435</b>	Embedded System Based Air Pollution Detection in Vehicles V. Siva Krishna, S. Arun, Dr. J.L Mazher Iqbal	286-289
<b>IJETCAS 15-439</b>	Computational analysis of effect of pitch on heat transfer performance in duct Rahul Saikhedkar, Yogesh Tembhurne	290-294
<b>IJETCAS 15-446</b>	Analysis of effects of an Earthquake using Differential Equations Mohammed Kamal Khwaja, Vishakh B V	295-301
<b>IJETCAS 15-447</b>	Preparation of Biodiesel from Crude Karanja Oil by Using KOH Catalyst HarshobSingh, ChandandeepSingh SunilMahla, PaliRosha	302-305
<b>IJETCAS 15-448</b>	Wrapper based Feature Selection and Classification for Real Time Dataset S.Visalakshi, V.Radha	306-311
<b>IJETCAS 15-450</b>	Performance of OFDM Systems: With Adaptive Modulation Pranav M.Patil and P.N.Kota	312-316





## Error Analysis in Determining Parameters of Overlapping Peaks Using Separation of Complex Spectra into Individual Components Case Study: Triplets

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**Abstract:** Based on the concept of Big Data Modeling, the errors in determining peak parameters of noisy Gaussian triplets using nonlinear least squares curve fitting have been evaluated. Calculations were performed using Gauss-Newton (with Levenberg-Marquardt modifications) and genetic algorithms. The probability that the relative error in estimating each model parameter is not greater than a priori given limit for a given fitting error has been calculated. It was shown that using the derivative mode for curve fitting has no advantage over the normal mode. It was demonstrated that the mean errors for the genetic algorithm are significantly greater than for the Gauss-Newton algorithm. It was found that the mean probability for triplets is higher than that for quartets. Obtained results showed that small fitting error does not guarantee that a fitting algorithm does converge to the correct peak parameters.

**Keywords:** spectrochemistry, overlapping peaks, curve fitting, Gauss-Newton and genetic algorithms, errors of peak parameters

### I. Introduction

Mathematical separation of overlapping analytical signals (peaks) is one of the widely used pre-processing methods in spectroscopy and chromatography (see references in [1]). Numerous computer-based algorithms have been developed to solve the separation problem (e.g., derivative spectroscopy and other peak sharpening methods). However, the most mathematically rigorous curve-fitting procedures for separation of badly resolved peaks are based on the fitting a priori model to the experimental data using the Gauss-Newton regression algorithm with Levenberg-Marquardt modifications (in what follows the Gauss-Newton algorithm) and genetic algorithm [2]. Curve-fitting model parameters are served as raw data for the qualitative and quantitative analysis. It is well known that the process of determining parameters of overlapping peaks in the case of uncertainty in the measured data is represented mathematically as an inverse ill-posed problem [3]. This problem can be solved only by using a priori information about the exact solution. Therefore, generally speaking, it was pointed out that one can only evaluate the probability ( $\Psi_{P_i}$ ) that the relative error in estimating parameter  $P_i$  of  $i^{\text{th}}$  peak is not greater than a given value for a given fitting error [4].

The previous paper [4] dedicated to the error analysis in determining parameters of unresolved peaks was based on the concept of Big Data Modeling [5]. We studied 771,750 Gaussian quartets which set of the parameters covered most common values. Although it is impossible to mimic all practical situations (a population) encountered in spectra, general qualitative and quantitative patterns have been obtained. It was shown that small fitting error does not guarantee that a fitting algorithm does converge to the correct peak parameters. The relationships between the mean probability over all quartet parameters and the parameters of the Gauss-Newton algorithm have been established. It was found that the probability  $\Psi_{P_i}$  strongly depends on the sample of quartets taken from the entire population.

It is impossible to increase essentially the size of the quartet population since the decomposition process is a very time consuming. However, the set of possible values of peak parameters may be significantly increased using triplets despite that their number decreases. "Small" size of a set of triplets allows studying the genetic algorithm which is significantly time consuming as compared to the Gauss-Newton method. Also it is interesting to compare results obtained for quartets and triplets.

In this paper we present an analysis of the errors in determining peak parameters of overlapping peaks using the least squares decomposition of complex spectra into individual components. Decomposition was carried out via the Gauss-Newton and the genetic algorithm. The spectra were simulated by the 254,016 combinations of three Gaussian peaks which parameters are varying in a very large range.

In what follows, for the sake of simplicity, term "line" is used instead of terms "peak, line and band". The standard algebraic notations are used throughout the article. All calculations were performed and the plots were built using the MATLAB software.

## II. Computer Modeling

Multiline spectra were simulated by Gaussian triplets:

$$Q(x) = \sum_{i=1}^3 F(x, x_{0i}, R_i, r_i), \tag{1}$$

where  $F(x, x_{0i}, R_i, r_i) = R_i \exp\{-[(x - x_{0i})/r_i]^2\}$  is the  $i^{\text{th}}$  line;  $x = 2\sqrt{\ln 2}j, j = [-7:0.02:7]$ ,  $x_{0i}, R_i$  and  $r_i$  are the position of the maximum, the relative intensity and the relative width of the  $i^{\text{th}}$  line, respectively. Parameter values of triplets are given in Table 1 (total number of combinations  $N_{total} = 254,016$ ). High and low resolution spectra of triplets and their first-order derivatives are shown in Fig. 1.

Table 1. Parameter values

Parameter	$x_{02}$	$-x_{01}, x_{03}$	$R_2$	$R_1, R_3$	$r_2$	$r_1, r_3$
Values	0	0.3:0.1:1	1	0.1, 0.2, 1/3, 0.5, 1, 2, 3, 5, 10	1	0.2, 1/3, 0.5, 1, 2, 3, 5

Curve fitting (non-linear regression) to three Gaussian lines was performed using Gauss-Newton (MATLAB function *nlinfit*) and genetic (MATLAB function *ga*) algorithm. The first algorithm was also applied to the first-order derivative of the triplets (the derivative mode).

For the Gauss-Newton algorithm the initial values of parameters ( $P_i^{init}$ ) except  $P_{x_{02}}^{init}$ , were equal to

$$P_i^{init} = LB + (UB - LB)\eta, \tag{2}$$

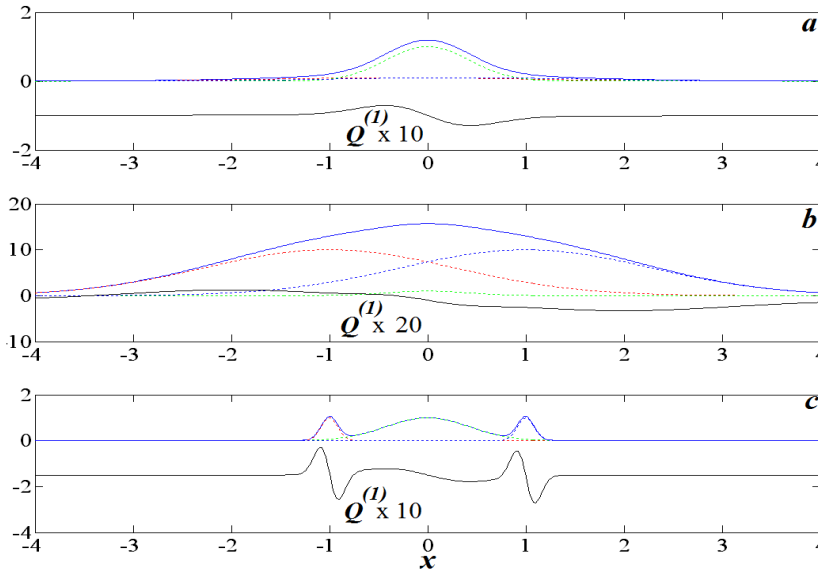
where  $LB = P_i^{true} lLim$  and  $UB = P_i^{true} uLim$  are the low and the upper bounds, respectively;  $P_i^{true}$  is a true parameter value;  $lLim$  and  $uLim$  are  $1 \mp lim$ , respectively;  $lim=0.2$  and  $0.5$ ;  $\eta$  is a random variable uniformly distributed in the range 0-1.

Since the true value of  $x_{02}$  is zero, then its initial value

$$P_{x_{02}}^{init} = -lim + 2lim \eta \tag{3}$$

For genetic algorithm the range of parameter values:  $P_i = [LB, UB]$  except  $P_{x_{02}} = [-lim, lim]$ .

Figure 1. Spectral triplets and their first-order derivatives



$[x_{01}, R_1, r_1, x_{03}, R_3, r_3] = [-0.3, 0.1, 3, 0.3, 0.1, 3]$  (a),  $[-1, 10, 3, 1, 10, 3]$  (b) and  $[-1, 1, 0.2, 1, 1, 0.2]$  (c).

Random noise with zero mean and standard deviation  $\sigma = 0.01$  was added to the each triplet (1).  $\sigma = 0.002$  for low noise triplets. At the next step triplet parameters were estimated. For randomization these two procedures were repeated 20 times. We studied two cases:

1. Unconstrained non-linear regression (UR) when whole curve-fitting data was considered valid.
2. Constrained regression (CR). In the case of the rank deficient program warnings of the Gauss-Newton algorithm and when the maximum number of generations of genetic algorithm exceeded, the obtained data was rejected. In both cases the following soft constraints were applied:

$$x_{01} < 0, x_{03} > 0, R > 0, r > 0 \tag{4}$$

The relative error (%) in estimating parameter  $P_i$  is equal to

$$\xi_{P_i} = 100(\bar{P}_i^{estim} - P_i^{true})/P_i^{true}, \tag{5}$$

where  $\bar{P}_i^{estim}$  is the mean value of the  $P_i^{estim}$ -values.

The fitting error:

$$\xi_{fit} = \sqrt{\sum_{j=1}^{701} (Q(x_j) - \hat{Q}(x_j))^2 / 701}, \tag{6}$$

where  $\hat{Q}(x_j)$  is obtained from Eq. 1 by substituting  $\bar{P}_i^{estim}$ .

The indicator for good model fit was

$$\xi_{fit} \leq K_{noise}\sigma, \tag{7}$$

where  $K_{noise}$  is the noise multiplier. The number of the good-fitting models  $N_{gf} < N_{total}$ . From these models only those triplets for which

$$\xi_{P_i} \leq K_\xi, \tag{8}$$

have been chosen.  $K_\xi = [20, 10, 5, 1]$  for all  $P_i$ , except  $P_{x02}$  for which  $K_\xi = [0.05, 0.025, 0.01, 0.002]$ .

Number of selected triplets depends on the coefficients  $K(N(K_{noise}, K_\xi))$ . The relative value (%):

$$\Psi_{gf} = 100N(K_{noise}, K_\xi)/N_{gf} \tag{9}$$

has been calculated. It was shown in [4] that  $\Psi_{gf}$  may be considered as the probability that the relative error in estimating parameter  $P_i$  is not greater than  $K_\xi$  for a given  $\xi_{fit}$  over good fit. Also we found that the mean probability  $\bar{\Psi}_{gf}$  weakly depends on the sample taken from the entire population of Gaussian quartets.

### III. Results and Discussion

Typical histograms of the  $\xi_{P_i}$  distributions for  $K_{noise}=3$  are given in Figs. 2-6. These plots are usually asymmetric unimodal, however for  $lim=0.5$  two modes appear for  $R_2$  and  $r_2$  in the case of the Gauss-Newton algorithm. For genetic algorithm the histogram shapes are differ from the corresponding histograms of the Gauss-Newton algorithm. This result is due to different use of initial parameters for both algorithms.

It is seen from the histograms that the number of the good-fitting models ( $N_{gf}$ ) significantly decreases for  $lim=0.5$  as compared to  $lim=0.2$ .

Table 2 represents the statistical parameters (mean, variance and skewness) of the error distributions. It is seen from this table that for experiments based on the unconstrained regression the absolute value of mean errors  $|\bar{\xi}_{P_i}|$  increase if the range bounds of initial guesses increase ( $lim$  increases from 0.2 to 0.5).

For experiments based on constrained regression (Eq. 4), the size of the sets meet the given constraints, decreases. For these sets  $|\bar{\xi}_{P_i}|$  decreases as expected. The exceptions are  $|\bar{\xi}_{R_3}|$  and  $|\bar{\xi}_{r_3}|$  for  $lim=0.2$  and 0.5, respectively. For the Gauss-Newton algorithm the values of  $|\bar{\xi}_{P_i}|$  in the derivative mode increase as compared to the normal mode.

Figure 2. Histograms of the error distribution for Gauss-Newton algorithm ( $lim = 0.2$ )

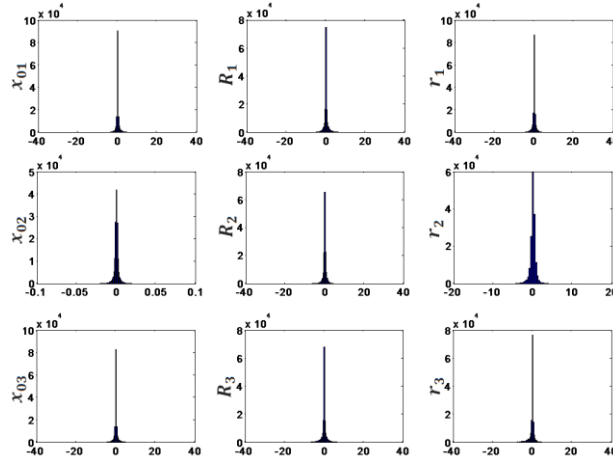


Figure 3. Histograms of the error distribution for Gauss-Newton algorithm ( $lim = 0.5$ )

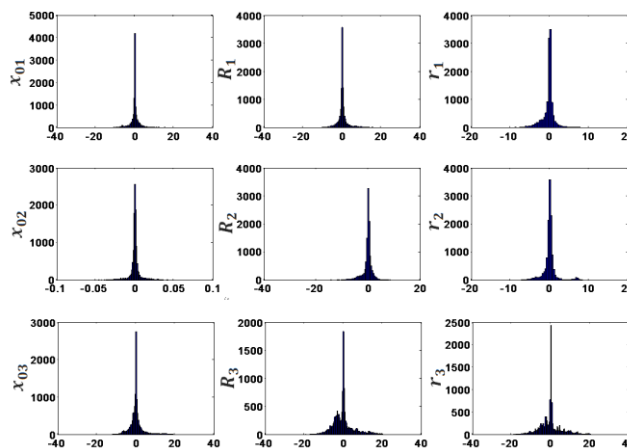


Figure 4. Histograms of error distribution for genetic algorithm ( $lim = 0.2$ )

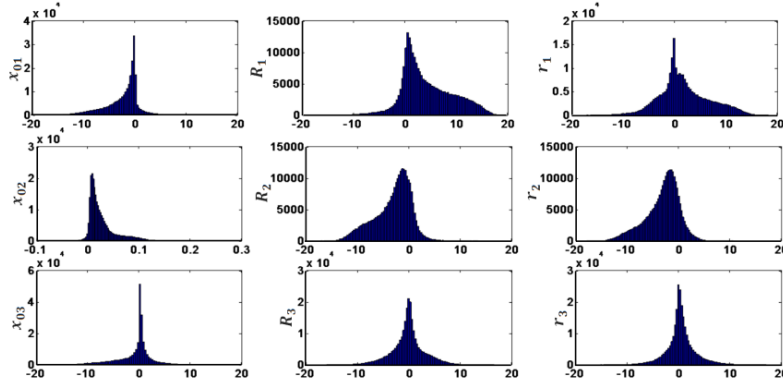
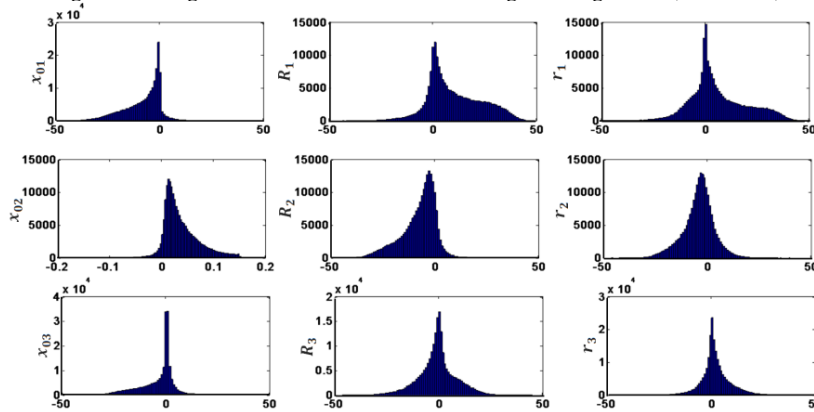


Figure 5. Histograms of the error distribution for genetic algorithm ( $lim = 0.5$ )



The mean errors for the genetic algorithm are significantly greater than for the Gauss-Newton method (Table 2). As expected, the mean errors of triplets are less than corresponding errors for quartets [4].

No dependence of skewness upon the errors of modeling parameters has been found.

Fig. 6 shows that in the most cases the correlation between errors is low.

The relative error probability is a very complex function  $\Psi_{gf}(P_i, lim, K_{noise}, K_{\xi})$ . Tables 3 and 4 represent some numerical values of this function for Gauss-Newton and genetic algorithms. From these tables the following conclusions can be drawn:

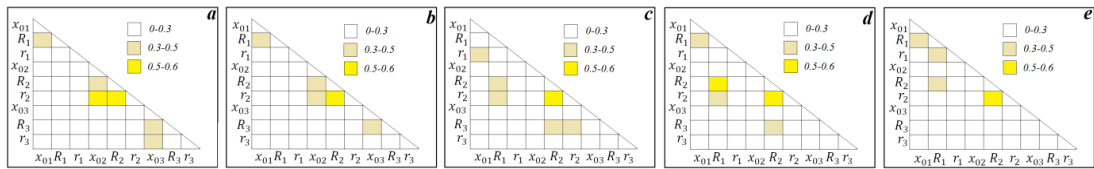
1. For both algorithms probability  $\Psi_{gf}$  increases while increasing  $K_{\xi}$ . The dependence  $\Psi_{gf}(K_{noise})$  is

Table 2. Statistical parameters of the error distributions ( $K_{noise} = 3$ )

lim	Regression	Parameters of triplets								
		$x_{01}$	$R_1$	$r_1$	$x_{02}$	$R_2$	$r_2$	$x_{03}$	$R_3$	$r_3$
Gauss-Newton algorithm. Normal mode										
0.2	UR	-	-0.24±	-0.73±	0	-0.39±	-0.23±	-	-0.25±	-0.75±
		0.074±	0.017	0.017	0	0.015	0.009	0.089±	0.017	0.017
	0.016	0.23	-0.43	-2.9	-0.36	-1.0	-2.4	0.079	-0.43	-2.8
	CR	-	0	-0.33±	0	-0.38±	-0.26±	-	-	-0.80±
0.061±	0.014	0.010	0	0.015	0.007	0.016	0.059±	0.072±	0.017	
0.071	1.0	-1.8	-0.69	-1.1	-1.1	0.65	0.75	-2.4		
0.5	UR	-1.05±	-0.24±	-1.61±	0	-1.05±	0.38±	-1.14±	-	-1.63±
		0.13	0.11	0.11	0	0.082	0.079	0.13	0.041±	0.12
	0.13	-0.26	-1.7	-0.21	-1.21	0.15	-1.1	0	-1.7	
UR	-0.11±	-0.14±	-0.26±	0	-0.11±	-	-0.18±	-0.10±	-0.27±	

	<i>low noise</i>	0.063	0.043	0.044		0.028	0.067± 0.015	0.058	0.050	0.045
		2.0	0	-6.9	-0.26	3.5	-0.61	1.7	1.9	-7.1
	CR	0	0.11± 0.073	-0.53± 0.051	0	-0.76± 0.066	-0.19± 0.042	0	-0.33± 0.11	-0.43± 0.11
		0.52	0.89	-0.94	-0.30	-1.7	0.38	0.84	0.26	0
Gauss-Newton algorithm. Derivative mode										
0.5	UR	-1.03±	-1.94±	0.72±	0	-4.16±	3.53±	-0.97±	-1.67±	0.52±
		0.23	0.27	0.24	0	0.29	0.25	0.23	0.26	0.23
	0.93	-1.7	1.0	-0.22	-1.3	1.31	-0.92	-1.7	0.82	
	CR	0	-1.88±	0.71±	0	-4.77±	2.31±	-1.14±	-1.33±	1.30±
±0.12		0.20	0.18	0	0.32	0.16	0.19	0.30	0.33	
		0.69	-2.0	1.9	-0.73	-1.2	1.3	-0.51	-0.77	0.85
Genetic algorithm. Normal mode										
0.2	CR	-2.67±	3.98±	1.58±	0.025±	-3.34±	-3.35±	-1.01±	-0.42±	0.17±
		0.025	0.037	0.023	0.0002	0.030	0.030	0.016	0.013	0.011
		-1.5	1.4	1.5	1.5	-1.3	-1.3	-1.8	-0.82	0.56
0.5	CR	-8.63±	9.6±	5.46±	0	-8.25±	-4.77±	-4.37±	-1.43±	1.43±
		0.086	0.10	0.076	0	0.081	0.054	0.055	0.041	0.034
		-1.4	1.4	1.6	1.3	-1.3	-1.5	-1.7	-0.96	1.3

Figure 6. Linear correlation coefficients between errors



Genetic algorithm: (*lim*=0.2 (a), 0.5 (b)). Newton-Gauss algorithm: normal mode (*lim*=0.2 (c), 0.5 (d)), derivative mode (*lim*=0.5 (e))

decreasing for the Gauss-Newton algorithm; however, for genetic algorithm it is increasing in many cases (red numbers in Table 4). Contrary to the Gauss-Newton algorithm it is rapidly approaching saturation at small values of  $K_{noise} = 3 \div 5$ .

2. The mean probability  $\bar{\Psi}_{gf}$  for *lim*=0.2 is higher than that for *lim*=0.5.
3. Constrained regression increases the values of  $\bar{\Psi}_{gf}$ .
4. The mean probability  $\bar{\Psi}_{gf}$  decreases in the derivative mode as compared with the normal mode. This result contradicts the conclusion of [6]. In this article it was pointed out that a chance of finding accurate values of line parameters increases with increasing resolution in the first-order derivative. However, the noise enhancement due to the differentiation decreases the probability  $\Psi_{gf}$ .
5. There is no general relationship between whose probabilities which satisfied the condition  $\Psi_{gf} < 0.95 * \bar{\Psi}_{gf}$  and triplet parameters. However, for constrained regression when *lim*=0.5 this condition is true for  $R_2$  and  $r_2$  in both modes. Only one exception exists. So, the intensity and the width of the middle triplet line are the most error-sensitive triplet parameters in decomposition process.
6. The mean probability  $\bar{\Psi}_{gf}$  [4] for quartets is significantly less than that for triplets (Table 5).

We tried to find correlation between probabilities  $\Psi_{gf}$  and multivariate selectivity in terms of the net analyte signal [7]. Unfortunately, no correlation has been found.

Like we mentioned in the previous article [4], obtained results show that a small fitting error does not guarantee that a fitting algorithm does converge to the correct line parameters. E.g., for constrained regression, using Newton-Gauss algorithm in the normal mode for *lim*=0.5, the minimal probability that the absolute value of the relative errors in determining parameters is less than 5%,  $\Psi_{gf}^{min} = 61.1\%$ . For *lim*=0.2  $\Psi_{gf}^{min} = 87.2\%$ . If  $K_{noise} = 1$  then  $\Psi_{gf}^{min} = 65.6\%$  and 30.7 for *lim*=0.2 and 0.5, respectively. Moreover, in the case of small fitting errors, the relative number of the good model fits decreases significantly (Table 6).

In conclusion, probability  $\Psi_{gf}$  increases when the initial guesses are close to the exact values of the parameters and noise decreases. In analytical practice the probability  $\Psi_{gf}$  can be increased by averaging of parameters obtained from multiple repetitions of the same experiment.

**Table 3. Relative error probability ( $\Psi_{gf}$ ) for Gauss-Newton algorithm**

lim	Regression	$K_\xi$	Mode	Parameters										
				$x_{01}$	$R_1$	$r_1$	$x_{02}$	$R_2$	$r_2$	$x_{03}$	$R_3$	$r_3$	mean	
0.2	UR	20	normal	95.4	94.5	96.3	95.4	94.4	96.2	98.5	98.8	100.0	96.6	
				91.6	90.5	93.3	91.6	90.4	93.3	94.0	94.8	99.4	93.0	
		10		92.1	90.7	92.8	92.0	90.6	92.9	95.1	95.9	99.1	93.5	
		5		87.1	85.2	88.8	87.1	85.2	88.9	88.3	89.6	96.4	88.5	
		1		87.3	85.7	89.3	87.3	85.5	89.3	88.1	91.5	97.2	89.0	
		81.4		78.9	84.4	81.4	78.8	84.4	79.8	83.5	91.4	82.7		
		72.0		<b>67.8</b>	74.2	71.9	<b>67.7</b>	74.1	<b>62.6</b>	73.5	80.3	71.6		
		65.5		<b>61.1</b>	68.8	65.5	<b>61.0</b>	68.7	<b>55.3</b>	65.1	71.0	64.7		
	CR	20		97.9	97.4	99.8	97.0	95.8	96.4	98.7	98.9	100.0	98.0	
		10		96.5	95.6	99.4	95.4	93.0	<b>90.8</b>	96.1	96.1	99.8	95.9	
		5		95.5	94.9	98.9	94.0	92.5	<b>93.7</b>	95.8	95.9	99.8	95.7	
		1		93.3	92.1	97.7	91.6	87.9	<b>86.1</b>	91.6	91.5	98.5	92.3	
		91.7		90.7	96.2	89.6	87.2	88.8	89.6	91.9	98.5	91.6		
		88.7		87.1	94.1	86.4	<b>80.7</b>	<b>79.6</b>	84.4	86.6	92.2	87.0		
		77.1		72.3	79.9	73.3	<b>67.1</b>	70.9	<b>65.6</b>	75.4	85.2	74.1		
		73.6		68.0	76.9	69.2	<b>59.5</b>	<b>61.3</b>	<b>61.5</b>	70.3	80.2	68.9		
0.5	UR	20	normal	<b>71.8</b>	<b>74.2</b>	<b>77.1</b>	<b>71.6</b>	<b>73.5</b>	<b>76.9</b>	92.4	98.0	99.7	81.7	
			derivative	<b>56.7</b>	<b>59.6</b>	64.5	<b>56.8</b>	<b>59.7</b>	64.6	67.0	86.3	91.8	67.5	
		10	normal	74.3	<b>64.8</b>	<b>65.3</b>	73.9	<b>64.9</b>	<b>65.0</b>	92.4	97.1	100.0	77.5	
			derivative	<b>56.9</b>	<b>52.8</b>	<b>56.2</b>	<b>57.1</b>	<b>53.0</b>	<b>55.9</b>	64.9	81.4	90.4	63.2	
		5	normal	<b>61.1</b>	<b>66.0</b>	<b>68.5</b>	<b>60.6</b>	<b>65.3</b>	<b>68.0</b>	75.6	91.5	92.5	72.1	
			derivative	64.7	<b>56.1</b>	<b>54.9</b>	64.4	<b>56.5</b>	<b>54.9</b>	76.2	87.6	90.5	67.3	
		1	normal	<b>43.8</b>	<b>42.8</b>	<b>45.0</b>	<b>44.6</b>	<b>42.8</b>	<b>44.9</b>	<b>44.5</b>	58.6	68.5	48.4	
			derivatives	<b>49.7</b>	<b>56.2</b>	59.7	<b>48.8</b>	<b>55.6</b>	<b>59.5</b>	<b>53.1</b>	78.6	75.6	59.6	
		CR	20	normal	<b>31.6</b>	38.9	44.5	<b>31.6</b>	38.8	44.6	<b>28.5</b>	50.5	49.3	39.8
				derivative	51.8	<b>48.6</b>	<b>49.1</b>	52.1	<b>49.1</b>	<b>49.8</b>	<b>46.2</b>	60.9	64.1	52.4
			10	normal	<b>30.6</b>	33.4	36.5	<b>31.6</b>	33.4	36.6	<b>23.9</b>	34.9	43.9	33.9
				derivative	<b>29.9</b>	35.4	40.0	<b>29.2</b>	34.3	40.0	<b>29.1</b>	42.1	39.0	35.4
			5	normal	<b>16.5</b>	19.9	23.8	<b>16.3</b>	19.5	23.9	<b>13.1</b>	21.4	19.9	19.4
				derivatives	27.9	32.3	35.5	29.5	33.2	36.5	<b>16.9</b>	<b>9.1</b>	<b>8.6</b>	25.5
			1	normal	14.1	17.8	19.8	14.3	18.3	19.9	<b>8.1</b>	<b>5.6</b>	<b>7.3</b>	13.9
				derivatives	95.9	96.6	97.2	94.8	<b>90.5</b>	92.2	96.4	98.4	99.9	95.8
	CR		20	normal	91.3	90.4	88.1	89.4	<b>70.7</b>	<b>64.8</b>	83.5	92.8	98.5	85.6
				derivative	97.4	96.1	91.5	89.1	<b>75.5</b>	<b>68.5</b>	96.0	97.8	99.9	90.2
			10	normal	90.5	88.0	83.4	78.2	<b>52.7</b>	<b>49.0</b>	81.8	91.6	97.9	79.3
				derivative	90.3	91.2	95.4	87.7	<b>80.3</b>	<b>80.0</b>	89.1	94.8	99.0	89.8
			5	normal	83.0	81.6	83.6	77.8	<b>53.7</b>	<b>48.2</b>	<b>71.0</b>	83.1	92.7	75.0
				derivative	93.6	87.5	81.2	80.4	<b>56.8</b>	<b>47.5</b>	86.0	89.2	98.3	80.1
			1	normal	81.6	75.3	72.3	63.9	<b>35.8</b>	<b>31.0</b>	65.8	76.7	89.8	65.8
				derivative	80.7	82.5	90.5	77.3	<b>63.5</b>	<b>61.1</b>	77.9	87.8	92.7	79.3
		5	normal	69.4	70.1	75.0	61.7	<b>35.2</b>	<b>31.2</b>	<b>57.8</b>	70.7	80.5	61.3	
			derivative	83.9	78.7	75.8	65.5	<b>40.3</b>	<b>34.6</b>	<b>62.7</b>	65.3	92.3	66.6	
		1	normal	66.7	62.3	62.7	<b>45.5</b>	<b>21.9</b>	<b>18.8</b>	<b>45.3</b>	51.2	75.6	50.0	
			derivative	55.4	56.4	66.2	<b>44.3</b>	<b>30.7</b>	<b>32.5</b>	52.6	61.5	72.8	52.5	
		5	normal	43.9	42.6	49.3	<b>29.1</b>	<b>13.4</b>	<b>13.4</b>	36.0	44.1	53.6	36.1	
			derivative	52.7	54.3	50.6	30.8	<b>19.3</b>	<b>17.9</b>	<b>27.4</b>	<b>3.4</b>	<b>9.7</b>	29.6	
		1	normal	37.4	36.9	36.8	<b>16.2</b>	<b>7.0</b>	<b>6.8</b>	<b>19.2</b>	<b>4.5</b>	<b>10.2</b>	19.4	
			derivative											

$K_{noise} = 3$  and  $10$  for upper and lower rows, respectively. Values  $\Psi_{gf} < 0.95 * \bar{\Psi}_{gf}$  are given in bold italic.

**Table 4. Relative error probability ( $\Psi_{gf}$ ) for genetic algorithm**

lim	$K_\xi$	Parameters									
		$x_{01}$	$R_1$	$r_1$	$x_{02}$	$R_2$	$r_2$	$x_{03}$	$R_3$	$r_3$	mean
0.2	20	100.0	100.0	100.0	100.0	<b>90.8</b>	100.0	100.0	100.0	100.0	99.0
		100.0	100.0	100.0	100.0	<b>84.3</b>	100.0	100.0	100.0	100.0	98.3
		100.0	100.0	100.0	100.0	<b>83.9</b>	100.0	100.0	100.0	100.0	98.2
	10	94.8	<b>80.6</b>	90.3	<b>74.9</b>	95.2	96.9	97.1	99.1	99.3	92.0
		95.7	<b>84.4</b>	92.1	<b>64.5</b>	94.7	95.7	97.5	99.1	99.4	91.4
		95.8	<b>84.5</b>	92.2	<b>64.0</b>	94.6	95.6	97.5	99.1	99.4	91.4
	5	75.9	<b>53.8</b>	<b>65.7</b>	<b>37.7</b>	76.6	81.1	82.9	86.5	90.4	72.3

1		79.4	<b>60.5</b>	70.2	<b>31.1</b>	72.8	74.9	84.6	86.8	90.8	72.3
		79.5	<b>60.9</b>	70.4	<b>30.8</b>	72.7	74.7	84.6	86.9	90.8	72.4
		31.5	<b>18.6</b>	22.7	<b>4.0</b>	<b>25.2</b>	<b>22.0</b>	49.0	37.5	45.3	28.4
		36.4	<b>21.4</b>	<b>24.5</b>	<b>3.4</b>	<b>23.2</b>	<b>19.4</b>	50.5	39.3	45.6	29.3
		36.6	<b>21.6</b>	<b>24.5</b>	<b>3.4</b>	<b>23.2</b>	<b>19.3</b>	50.6	39.4	45.6	29.3
0.5	20	82.9	<b>57.4</b>	<b>72.9</b>	86.6	98.0	99.9	89.3	97.2	86.6	86.9
		85.7	<b>71.2</b>	<b>78.6</b>	<b>75.1</b>	91.8	98.0	92.0	96.1	97.7	87.3
		87.2	<b>74.9</b>	<b>80.8</b>	<b>67.3</b>	89.7	96.3	92.4	95.8	97.5	86.9
	10	<b>56.2</b>	<b>36.6</b>	<b>51.3</b>	<b>62.8</b>	82.4	95.6	72.4	75.3	84.4	68.5
		<b>61.8</b>	<b>49.2</b>	<b>58.3</b>	<b>48.6</b>	71.7	83.6	76.1	75.6	84.3	67.7
		65.0	<b>53.3</b>	<b>60.5</b>	<b>42.6</b>	67.5	78.3	76.7	75.8	84.3	67.1
	5	<b>38.1</b>	<b>24.9</b>	<b>31.7</b>	<b>23.3</b>	56.1	73.4	60.2	48.5	63.3	46.6
		<b>42.6</b>	<b>33.8</b>	<b>38.8</b>	<b>17.5</b>	46.4	55.8	61.6	51.8	64.1	45.8
		45.9	<b>36.6</b>	<b>40.8</b>	<b>15.4</b>	<b>43.0</b>	50.7	61.9	52.9	64.2	45.7
	1	<b>13.2</b>	<b>8.4</b>	<b>10.9</b>	<b>3.1</b>	<b>13.5</b>	17.4	32.5	14.5	21.8	15.0
		15.2	<b>10.6</b>	<b>13.5</b>	<b>2.5</b>	<b>11.0</b>	<b>12.3</b>	32.7	16.4	23.2	15.3
		16.6	11.2	<b>13.8</b>	<b>2.3</b>	<b>10.2</b>	<b>11.1</b>	32.7	16.9	23.0	15.3

$K_{noise} = 1, 2$  and  $3$  from upper to lower rows, respectively. Values  $\psi_{gf} < 0.95 * \bar{\Psi}_{gf}$  are given in bold italic

**Table 5. Comparison of the mean relative error probabilities for triplets and quartets decomposed by Gauss-Newton algorithm**

$K_{\xi}$	20	10	5	1
Triplets	95.8	89.8	79.3	52.5
	85.6	75.0	61.3	36.1
Quartets	94.7	85.6	68.7	32.9
	81.7	65.0	45.8	18.3

$K_{noise} = 3$  and  $10$  for upper and lower rows, respectively.  $lim = 0.5$ .

**Table 6. Relative number of the good model fits ( $N_{gf}/N_{total}$ ,%)**

$K_{noise}$	Regression	$lim$	
		0.2	0.5
3	UR	70.8	6.2
	CR	66.3	5.4
10	UR	85.8	24.8
	CR	79.0	8.8

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## Impact of MGSTC BLAST spatial multiplexing scheme on performance assessment of MCCDMA wireless communication system

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**Abstract:** In this paper, an effort has been made to observe critically the Impact of MGSTC BLAST spatial multiplexing scheme on color image transmission in a MCCDMA wireless communication system. The simulated system incorporates various signal detection techniques such as MMSE, ZF, OSIC and MMSE-SIC under  $4 \times 4$  antenna configuration. In perspective of data protection,  $1/2$ -rated irregular LDPC and Repeat and Accumulate forward error correction(channel encoding) schemes have been used. It is noticeable from MATLAB based simulative study that the system shows quite satisfactory performance in retrieving transmitted color image under scenario of hostile fading channel environment with implementation of MMSE-SIC signal detection, 16QAM digital modulation and Repeat and Accumulate channel coding scheme.

**Keywords:** MCCDMA, MMSE, ZF, OSIC, MMSE-SIC, LDPC, Repeat and Accumulate, Signal to noise ratio(SNR)

### I. Introduction

The multi carrier CDMA(MC-CDMA) is a hybrid transmission technique employing an amalgam of Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) and is expected to combine the benefits of pure CDMA and OFDM techniques. The MC-CDMA is an attractive choice for high speed wireless communication as it mitigates the problem of intersymbol interference (ISI) with exploitation of frequency diversity. It supports multiple users with high speed data communications, The CDMA technique is widely used in current Third Generation (3G) wireless communication systems( W-CDMA-Wideband Code Division Multiple Access, UMTS-Universal Mobile Telecommunications etc) presenting a wide range higher data rate supported services such as voice/video/data (IP Television, video on demand, video conferencing, tele-medicine)[1,2].The OFDM techniques are employed in the American National Standards Institute's (ANSI's) Asymmetric Digital Subscriber Line (ADSL), High-bit-rate Digital Subscriber Line (HDSL), and Very-high-speed Digital Subscriber Line (VDSL) standards as well as in the European Telecommunication Standard Institute's (ETSI's) VDSL applications. In wireless scenarios, OFDM has been advocated by many European standards, such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting for Terrestrial television (DVB-T), Digital Video Broadcasting for Handheld terminals (DVB-H) Wireless Local Area Networks(WLANs) and Broadband Radio Access Networks (BRANs). The MC-CDMA transmission technique has become increasingly popular in wireless communications due to its high spectral efficiency, robustness to frequency selective fading and flexibility to support integrated applications.[3,4]. In our present study, a MGSTC BLAST spatial multiplexing scheme has been used in MC-CDMA system with a view to observing its system performance on color image transmission.

### II. Signal Processing and Detection Scheme

In our present study various signal processing and detection schemes have been used. A brief overview of these schemes is given below:

#### A. Repeat and Accumulate (RA)

In RA, a powerful modern error-correcting coding scheme, the extracted binary bits from the color image is rearranged into blocks with each block containing 2048 binary bits. The binary bits in each block is repeated 2 times and permuted by an interleaver of length 4096. The interleaved binary data block  $z$  is passed through a truncated rate-1 two-state convolutional encoder whose output  $x$  is the Repeat and Accumulate encoded binary data and is given by  $x = zG$ , where  $G$  is an  $4096 \times 4096$  matrix with 1s on and above its main diagonal and 0s elsewhere[5]. The RA encoded blocked binary data are further processed to produce a  $442368 \times 1$  single column vector data.

#### B. Low density parity-check matrix (LDPC)

In LDPC coding,  $1/2$ -rated irregular LDPC code is used with a code length of 1024 bits. Its parity-check matrix  $[H]$  is a sparse matrix with a dimension of  $512 \times 1024$  and contains only three 1's in each column

and six 1's in each row. The parity-check matrix  $[H]$  is formed from a concatenation of two matrices  $[A]$  and  $[P]$  ( $[H]=[A][P]$ ), each has a dimension of  $512 \times 512$ ). The columns of the parity-check matrix  $[H]$  is rearranged to produce a new parity-check matrix  $[newH]$ . With rearranged matrix elements, the matrix  $[A]$  becomes non-singular and it is further processed to undergo LU decomposition. The parity bits sequence  $[p]$  is considered to have been produced from a block based input binary data sequence  $[u]=[u_1u_2u_3u_4\dots\dots u_{512}]^T$  and three matrices  $[P]$ (of  $[newH]$ ),  $[L]$  and  $[U]$  using the following Matlab notation :

$$p = \text{mod}(U \setminus (L \setminus z), 2); \text{ where, } z = \text{mod}(P * u, 2);$$

The LDPC encoded  $1024 \times 1$  sized block based binary data sequence  $[c]$  is formulated from concatenation of parity check bit  $p$  and information bit  $u$  as :

$$[c]=[p;u]$$

The first 512 bits of the codeword matrix  $[c]$  are the parity bits and the last 512 bits are the information bits. In iterative Log Domain Sum-Product LDPC decoding Algorithm, the transmitted bits are retrieved [6,7].

### C. Multi-group space-time coding (MGSTC)

Spatial multiplexing is generally referred to transmitting multiple independent data streams over multipath channels. The multi-group space-time coding (MGSTC) scheme achieves both spatial multiplexing and spatial diversity simultaneously. In such scheme, the digitally modulated symbols are rearranged into four groups with each group consisting of sixteen symbols at a time. The total number of information bits processed in each group under each of the four space time encoder are sixty four as the 16th order digital modulations (16-QAM and 16-PSK) have been used. [8]

### D. Minimum mean square error (MMSE)

We assume that the color image is preprocessed through various schemes prior to Multi-group space-time encoding and transmitted through a MIMO fading channel. The received signal  $Y$  in terms of channel matrix  $H$ , transmitted signal  $X$  and additive white Gaussian noise (AWGN)  $N$  with a variance of  $\sigma_n^2$  can be written as

$$Y=HX +N \tag{1}$$

In Minimum mean square error (MMSE) based signal detection scheme, the MMSE weight matrix is given by

$$W_{MMSE} = (H^H H + \sigma_n^2 I)^{-1} H^H \tag{2}$$

Where  $(.)^H$  denotes the Hermitian transpose operation and The detected desired signal  $\tilde{X}_{MMSE}$  from the transmitting antenna is given by

$$\tilde{X}_{MMSE} = W_{MMSE} Y \tag{3}$$

### E. Zero-Forcing (ZF)

In Zero-Forcing (ZF) signal detection scheme, the ZF weight matrix is given by

$$W_{ZF} = (H^H H)^{-1} H^H \tag{4}$$

and the detected desired signal  $\tilde{X}_{ZF}$  from the transmitting antenna is given by [9]

$$\tilde{X}_{ZF} = W_{ZF} Y \tag{5}$$

### F. Minimum mean square error successive interference cancellation (MMSE-SIC)

In Minimum mean square error successive interference cancellation (MMSE-SIC) scheme,

The extended channel matrix  $\bar{H}$  and the extended received signal  $\bar{Y}$  in terms of identity and null matrices are given by

$$\bar{H} = \begin{bmatrix} H \\ (\sqrt{\sigma_n^2}) I \end{bmatrix} \tag{6}$$

$$\bar{Y} = \begin{bmatrix} Y \\ \mathbf{0} \end{bmatrix} \tag{7}$$

On QR decomposition of  $\bar{H}$ , an orthogonal matrix  $\bar{Q}$  and an upper triangular matrix  $\bar{R}$  are produced.

Equation (7) is multiplied with  $\bar{Q}^T$  to provide a modified form of received signal  $\bar{Y}$  with neglected noise component [10]

$$\bar{Y} = \bar{Q}^T \bar{Y} = \bar{Q}^T \bar{H} X = \bar{R} X \quad (8)$$

Considering a single time slot, the transmitted four signals  $\bar{X}_1, \bar{X}_2, \bar{X}_3$  and  $\bar{X}_4$  in terms of four received signals  $\bar{Y}_1, \bar{Y}_2, \bar{Y}_3$  and  $\bar{Y}_4$  (First through Fourth rows of  $\bar{Y}$  and neglecting other row data) and the components of matrix  $\bar{R}$  in first through fourth row) can be obtained from a matrix equation as:

$$\bar{Y}[:,1] = \begin{bmatrix} \bar{Y}_1 \\ \bar{Y}_2 \\ \bar{Y}_3 \\ \bar{Y}_4 \\ \bar{Y}_5 \\ \bar{Y}_6 \\ \bar{Y}_7 \\ \bar{Y}_8 \end{bmatrix} = \begin{bmatrix} \bar{R}_{1,1} & \bar{R}_{1,2} & \bar{R}_{1,3} & \bar{R}_{1,4} \\ 0 & \bar{R}_{2,2} & \bar{R}_{2,3} & \bar{R}_{2,4} \\ 0 & 0 & \bar{R}_{3,3} & \bar{R}_{3,4} \\ 0 & 0 & 0 & \bar{R}_{4,4} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \bar{X}_1 \\ \bar{X}_2 \\ \bar{X}_3 \\ \bar{X}_4 \end{bmatrix} \quad (9)$$

### G. Ordered successive interference cancellation (OSIC)

In Ordered successive interference cancellation (OSIC) signal detection scheme, its implementation is performed in four steps. In first step, the first detected signal/data stream  $\tilde{X}_{OSIC-1}$  and modified form of received signal  $\tilde{Y}_{OSIC-1}$  can be written as:

$$\begin{cases} \tilde{X}_{OSIC-1} = W_{(MMSE(1,:))} Y \\ \tilde{Y}_{OSIC-1} = Y - H_{(:,1)} \tilde{X}_{OSIC-1} \end{cases} \quad (10)$$

In second step, the second detected signal/data stream  $\tilde{X}_{OSIC-2}$  and modified form of received signal  $\tilde{Y}_{OSIC-2}$  can be written as:

$$\begin{cases} \tilde{X}_{OSIC-2} = W_{(MMSE(2,:))} \tilde{Y}_{OSIC-1} \\ \tilde{Y}_{OSIC-2} = \tilde{Y}_{OSIC-1} - H_{(:,2)} \tilde{X}_{OSIC-2} \end{cases} \quad (11)$$

In third step, the third detected signal/data stream  $\tilde{X}_{OSIC-3}$  and modified form of received signal  $\tilde{Y}_{OSIC-3}$  can be written as:

$$\begin{cases} \tilde{X}_{OSIC-3} = W_{(MMSE(3,:))} \tilde{Y}_{OSIC-2} \\ \tilde{Y}_{OSIC-3} = \tilde{Y}_{OSIC-2} - H_{(:,3)} \tilde{X}_{OSIC-3} \end{cases} \quad (12)$$

In fourth step, the fourth detected signal/data stream  $\tilde{\mathbf{X}}_{\text{OSIC-4}}$  and modified form of received signal  $\tilde{\mathbf{Y}}_{\text{OSIC-4}}$  can be written as:

$$\begin{cases} \tilde{\mathbf{X}}_{\text{OSIC-4}} = \mathbf{W}_{(\text{MMSE}(4,:))} \tilde{\mathbf{Y}}_{\text{OSIC-3}} \\ \tilde{\mathbf{Y}}_{\text{OSIC-4}} = \tilde{\mathbf{Y}}_{\text{OSIC-3}} - \mathbf{H}_{(:,4)} \tilde{\mathbf{X}}_{\text{OSIC-4}} \end{cases} \quad (13)$$

where,  $\mathbf{W}_{(\text{MMSE}(1,:))}$ ,  $\mathbf{W}_{(\text{MMSE}(2,:))}$ ,  $\mathbf{W}_{(\text{MMSE}(3,:))}$  and  $\mathbf{W}_{(\text{MMSE}(4,:))}$  are the first, second, third and fourth rows of MMSE weight matrix and  $\mathbf{H}_{(:,1)}$ ,  $\mathbf{H}_{(:,2)}$ ,  $\mathbf{H}_{(:,3)}$ , and  $\mathbf{H}_{(:,4)}$  are the first, second, third and fourth columns of the channel matrix respectively. The detected desired signal  $\tilde{\mathbf{X}}_{\text{OSIC}} \in \mathbb{C}^{4 \times 4562325}$  from the transmitting antenna is given by [11,9]

$$\tilde{\mathbf{X}}_{\text{OSIC}} = \begin{bmatrix} \tilde{\mathbf{X}}_{\text{OSIC-1}} \\ \tilde{\mathbf{X}}_{\text{OSIC-2}} \\ \tilde{\mathbf{X}}_{\text{OSIC-3}} \\ \tilde{\mathbf{X}}_{\text{OSIC-4}} \end{bmatrix} \quad (14)$$

### III. System Description

A RGB color image with 96 pixels (width)  $\times$  96 pixels (height) is processed in a MCCMA system depicted in Figure 1. The color image is converted into their respective three Red, Green and Blue components with each component is of 96 pixels  $\times$  96 pixels in size. The pixel integer values [0-255] are converted into 8 bits binary form and channel coded and interleaved and digitally modulated using 16QAM, 16PSK and 16-DPSK. The modulated complex symbols are copied and multiplied with Walsh-Hadamard (WH) orthogonal codes. The orthogonally encoded signals are processed in MGSTC BLAST aided Spatial multiplexing (SM) Encoding section to produce four independent data streams. Each of four data streams are serial to parallel converted, OFDM modulated, cyclically prefixed and subsequently parallel to serially converted and transmitted. In receiving section, the transmitted signals are detected and processed for serial to parallel conversion, cyclic prefix removal, OFDM demodulation, parallel to serial conversion and decoded in Spatial multiplexing (SM) Decoding section to produce data in single channel. The retrieved data are multiplied with Walsh-Hadamard (WH) orthogonal codes and decopied, digitally demodulated, deinterleaved, channel decoded, binary to pixel integer converted and eventually reconstructed for transmitted color image retrieval. [12,13]

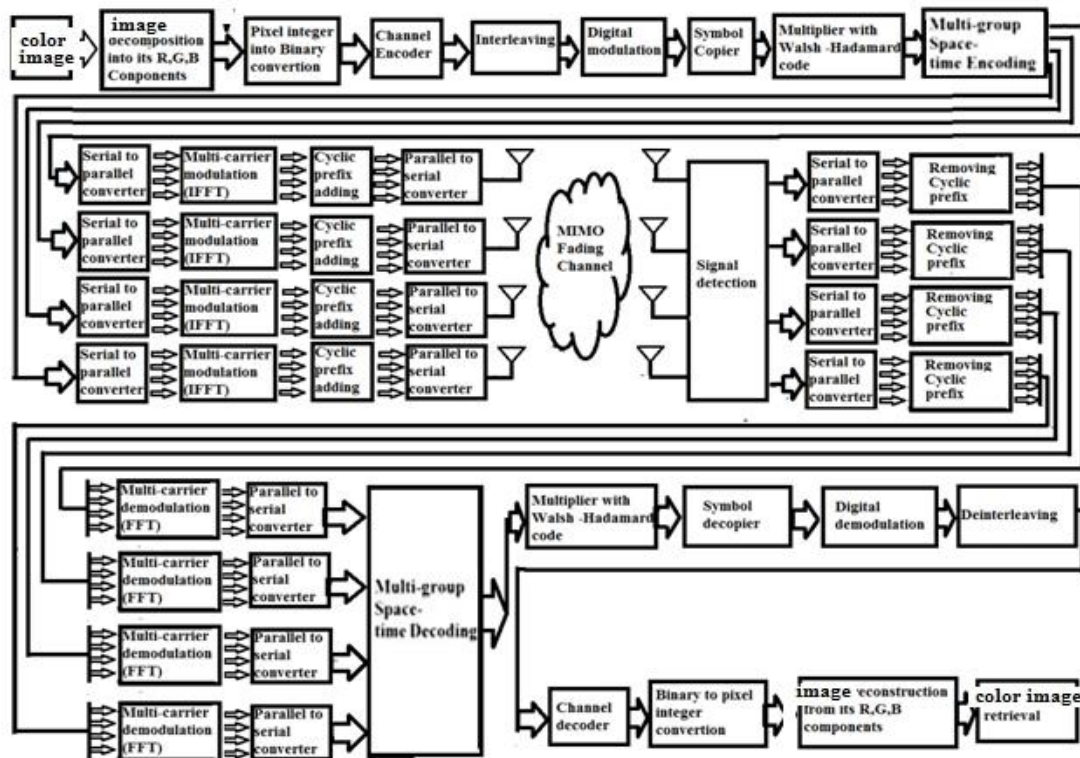


Figure 1: Block diagram of simulated MGSTC BLAST spatial multiplexing scheme aided MCCMA wireless communication system

#### IV. Results and Discussion

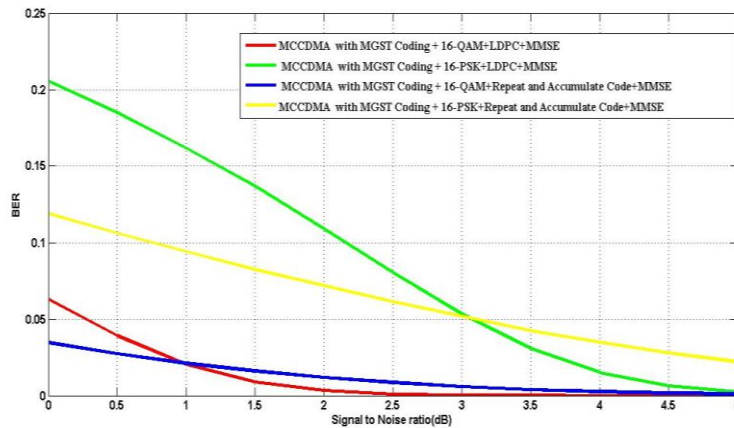
In this section, we have presented a series of simulation results to illustrate the significant impact of system performance in terms of BER in a multi-group space time encoded BLAST SM MCCDMA system with simulation parameters tabulated in Table 1.

**Table 1: Summary of the Simulated Model Parameters**

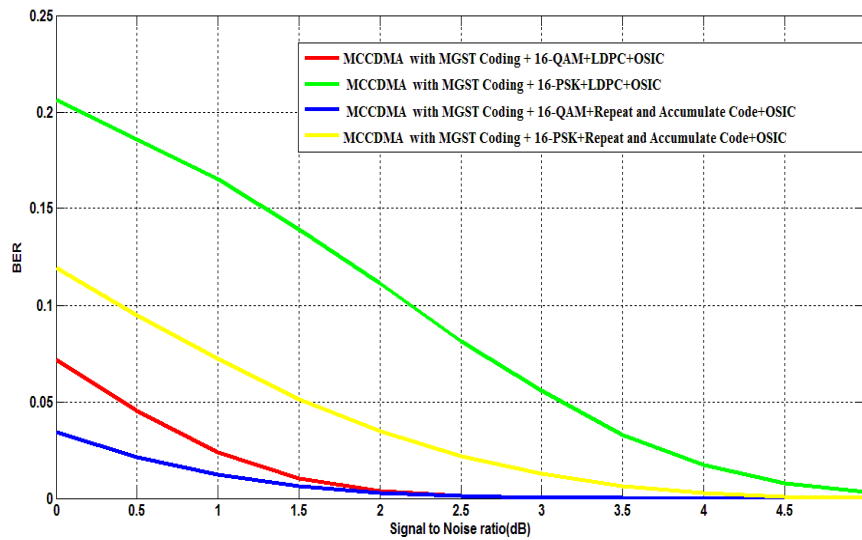
<b>Data type</b>	Color image (96x96x3 pixels)
Antenna configuration	4-by-4
Spatial multiplexing	Multi-group space time(MGST)
Channel Coding	Repeat and Accumulate Code and LDPC
Orthogonal spreading code	Walsh-Hadamard
Processing gain of Walsh-Hadamard code	8
Antenna configuration	4 × 4
Data Modulation	16-PSK and 16-QAM
IFFT/FFT size	1024
Signal detection Scheme	MMSE-SIC, OSIC, MMSE and ZF
Channel	AWGN and Rayleigh fading
Signal to noise ratio, SNR	0 to 5 dB

On critical observation of graphical illustrations presented in Figure 2 through Figure 5, it is quite evident that the MGSTC BLAST SM aided MCCDMA system shows comparatively satisfactory performance with 16QAM digital modulation and Repeat and Accumulate channel coding over a lower part of SNR values where the fading channel may be treated as hostile. In Figure 2 of MMSE implemented system, the estimated BER values for 16PSK digital modulation and LDPC channel coding as compared to 16QAM digital modulation and Repeat and Accumulate channel coding are 0.1849 and 0.0275 for a typically assumed SNR value of 0.5 dB which indicates a system performance improvement of 8.28dB. In case of identical signal and noise power at 0dB, the estimated BER value under utilization of MMSE, 16QAM and Repeat and accumulate channel coding is merely 3.46%. In Figure 3 for OSIC implemented system, the performance is very much well defined and discriminated. The system shows satisfactory performance in 16QAM and Repeat and accumulate channel coding over a low SNR value region. and worst performance in 16PSK and LDPC channel coding. Under such cases, the estimated BER values at 0.5 dB SNR values are found to be of 0.0214 and 0.1853 which makes a confirmation of 9.37 dB system performance improvement. At 5% BER, a SNR improvement of 2.7 dB is found in 16QAM and LDPC as compared to 16PSK and LDPC. In Figure 4 for MMSE-SIC implemented system, it shows satisfactory performance in 16QAM and Repeat and accumulates channel coding and worst performance in 16PSK and LDPC channel coding. In such cases, the estimated BER values are 0.0206 and 0.1874 for a typically assumed SNR value of 0.5dB which indicates a system performance improvement of 9.59dB.

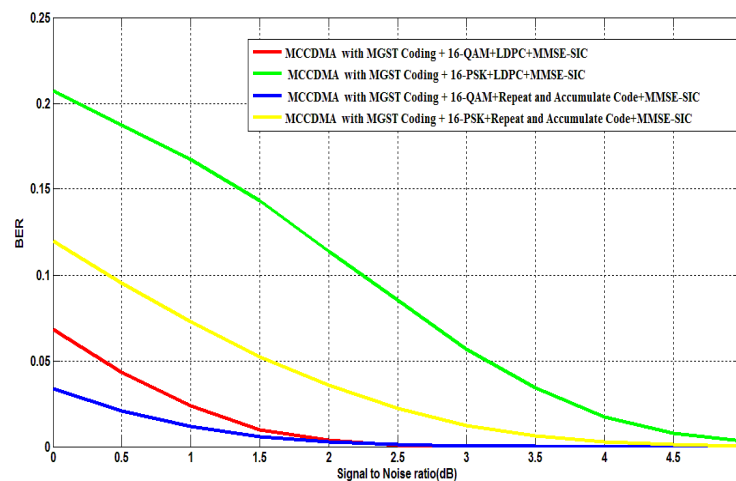
Figure 5 for ZF implemented system, it shows satisfactory performance in 16QAM and Repeat and accumulate channel coding and worst performance in 16PSK and LDPC channel coding., the estimated BER values are 0.0211 and 0.1839 for a typically assumed SNR value of 0.5dB which indicates a system performance improvement of 9.40dB. The system performance is found to be almost identical for a wide range of SNR values in case of 16QAM with LDPC and of 16QAM with Repeat and accumulate channel coding. On critical observation on all simulated results, it has been ratified that the simulated system shows satisfactory performance in MMSE-SIC signal detection and 16QAM digital modulation. In Figure 6, the transmitted and retrieved color images have been presented with MMSE-SIC signal detection, 16QAM digital modulation and Repeat and Accumulate channel coding.



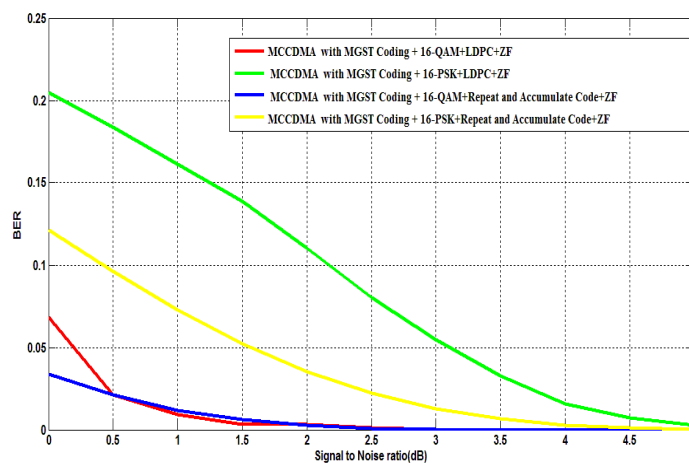
**Figure 2: BER performance comparison of MGSTC BLAST spatial multiplexing scheme aided MCCDMA wireless communication system under various digital modulations and MMSE signal detection scheme**



**Figure 3: BER performance comparison of MGSTC BLAST spatial multiplexing scheme aided MCCDMA wireless communication system under various digital modulations and OSIC signal detection scheme**



**Figure 4: BER performance comparison of MGSTC BLAST spatial multiplexing scheme aided MCCDMA wireless communication system under various digital modulations and MMSE-SIC signal detection scheme**



**Figure 5: BER performance comparison of MGSTC BLAST spatial multiplexing scheme aided MCCDMA wireless communication system under various digital modulations and ZF signal detection scheme**



**Figure 6: Performance indicator of MGSTC BLAST spatial multiplexing scheme aided MCCDMA wireless communication system under implementation of MMSE-SIC signal detection, 16-QAM digital modulation for a typical image at SNR value of 3dB**

## V. Conclusions

In this paper, the performance of MGSTC BLAST spatial multiplexing scheme aided MCCDMA wireless communication system has been investigated on color image transmission using various signal detection and FEC channel encoded schemes. The results show that the implementation of MMSE-SIC signal detection scheme with Repeat and Accumulate channel coding and 16QAM digital modulation ratifies the robustness of system performance in retrieving color image transmitted over Gaussian noise contaminated and Rayleigh fading channels. As MC CDMA radio interface technology exploits the advantages of both OFDM and CDMA, a great emphasis may be given on utilization of such technology in future generation wireless communication system.

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## INVESTIGATION OF INFLUENCE OF DEFOCUSING AND PULSE DURATION FOR MARKING ON SAMPLES OF STEEL HS18-0-1 WITH FIBER LASER

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**Abstract:** The studies relate to process raster laser marking of samples of tool steel H18-0-1 with fiber laser. The dependences of the contrast of marking from defocusing and pulse duration were obtained. Working intervals for the investigated magnitudes in visual perception of the marking are determined.

**Keywords:** laser marking, tool steel, fiber laser, defocusing, pulse duration, working intervals.

### I. Introduction

Laser marking of products from metals and alloys is a complex technological process. The realization depends on a number of factors [1] – [4], relating to:

- the thermo-physical and optical properties of materials – reflection coefficient, absorptance, absorption coefficient, penetration depth, thermal conductivity, thermal diffusivity, specific heat capacity, thermal diffusion length;
- the parameters of the laser – power, power density, pulse power, pulse energy, frequency, pulse duration, beam quality;
- the parameters of the process – speed, step, defocusing, number of repetition.

Defocusing and pulse duration are the basic parameters, influencing of studies process. To assist the operator of laser technological systems is need to define working intervals for them.

### II. Presentation

The purpose of the work is the study of the influence of defocusing and pulse duration onto the process of laser marking by melting for samples of tool steel H18-0-1 with fiber laser and receiving the working intervals of the defocusing and the pulse duration.

When working with defocusing, the quality of resulting marking depends on the length of Raleigh  $z_R$ . It is a characteristic of each type of laser. It is defined by the expression

$$z_R = \frac{\pi r_0^2}{\lambda}, \quad (1)$$

where  $\lambda$  is the wavelength of the laser,  $r_0$  is the minimum radius of the working spot.

When the condition  $\Delta f < z_R$  is satisfied, the diameter of the opening spot almost does not change, and therefore power density of laser radiation reduces very little in comparison with that focus.

When is satisfied the condition  $\Delta f > z_R$ , the diameter of the working spot almost does not change, and therefore power density of laser radiation reduces very little in comparison with that at focus.

In defocusing  $\Delta f$  power density of laser radiation reduces very quickly compared to operating mode at focus. The diameter  $d$  of the working spot for defocusing  $\Delta f$  (Fig. 1) greater than the distance of the Rayleigh  $z_R$  is given by the formula

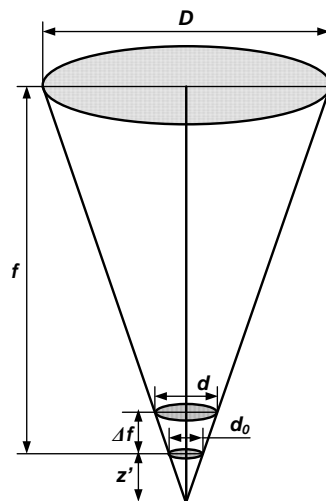
$$d = \frac{D(z' + \Delta f)}{f + z'}, \quad (2)$$

where  $D$  is the diameter of the laser beam, falling on the lens,  $f$  – focal length of the lens, and the parameter  $z'$  is defined from similarity of triangles (Fig. 1) by the expression

$$z' = \frac{d_f f}{D - d_f}, \quad (3)$$

where  $d_f$  is the diameter of the working spot at focus.

Figure 1



When  $\Delta f > z_R$  from formula (2) follows, that with increasing defocusing  $\Delta f$  increases the diameter  $d$  of working spot also, as the dependency is linear. The power density  $q_s$  of laser radiation is inversely proportional to the diameter  $d$  of the working spot of the second degree. It follows, that the power density  $q_s$  rapidly decreases with increasing defocusing  $\Delta f$ . This leads to the exit from the technological mode of marking and inability to obtain marking with requisite contrast.

As is known, the basic modes of the lasers are continuous and pulsed mode. Preferably is, the lasers for marking to work in pulse mode. In this mode are essential pulse power  $P_p$ , pulse energy  $E_p$ , pulse duration  $\tau$  and frequency  $\nu$ . They are connected to the average power  $P$  of the laser with the expressions

$$P = P_p \tau \nu. \tag{4}$$

$$P = E_p \nu. \tag{5}$$

Steel H18-0-1 is used widely in industry. Its basic thermo-physical characteristics are presented in Table I [5], [6].

Table I. Certain thermo-physical characteristics on steel H18-0-1

Parameter	Value
Thermal conductivity $k$ , W/(m.K)	26
Specific heat capacity $c$ , J/(kg.K)	420
Density $\rho$ , kg/m <sup>3</sup>	8770
Thermal diffusivity $a$ , m <sup>2</sup> /s	$7,06 \cdot 10^{-6}$

The experiments were made with the laser technology system with fiber laser. It is a modern laser, operating in the near infrared region and is suitable for the investigated process. The basic parameters of laser technological system for marking with this laser are shown in Table II [7] – [10].

Table III. Basic parameters of laser technological system for marking and used laser

Parameter	Value
Wavelength $\lambda$ , nm	1064
Power $P$ , W	40
Frequency $\nu$ , kHz	$1 \div 250$
Pulse duration $\tau$ , ns	$8 \div 250$
Pulse energy $E_p$ , mJ	$0,16 \div 1,33$
Pulse power $P_p$ , kW	$5,32 \div 17,8$
Beam quality $M^2$	1,05
Positioning accuracy, $\mu\text{m}$	2,5
Efficiency, %	40

**Tasks:**

**1. Investigation of the dependence of the contrast  $k^*$  of marking from the defocusing  $\Delta f$**

Onto samples of investigated steel are marked raster fields with sizes 5 mm x 5 mm. Used is a method of marking with immersed focus. Parameters, that are kept constant during the experiments are given in Table III. The defocusing vary in the interval  $\Delta f \in [0; 4,00]$  mm.

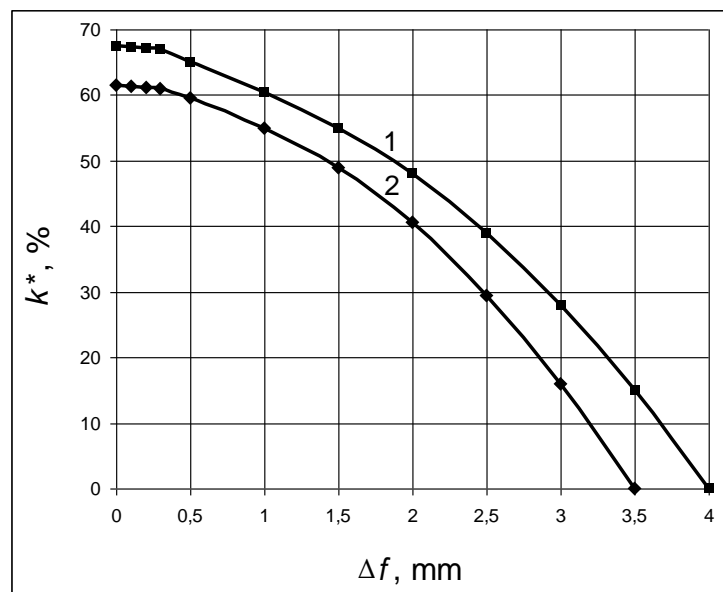
**Table IIIII. Parameters, that are kept constant**

Parameter	Value
Speed $v_1$ , mm/s	40
Speed $v_2$ , mm/s	60
Frequency $\nu$ , kHz	30,0
Pulse duration $\tau$ , ns	100
Step $\Delta x$ , $\mu\text{m}$	50
Number of repetition $N$	1

On Fig. 2 are shown graphs of the experimental dependence  $k^* = k^*(\Delta f)$  for two speeds of marking:  $v_1 = 40$  mm/s;  $v_2 = 60$  mm/s. From their analysis can draw the following conclusions:

- In the interval  $0 < \Delta f < 0,30$  mm contrast of marking almost aren't changed for both speeds. The result is consistent with the theory. It is worked in the area of Raleigh and the power density of laser radiation reduces very slightly;
- In the interval  $0,30 \text{ mm} < \Delta f < 4,00$  mm the contrast of marking quickly reduced. The rate of decrease the contrast of the marking:  
 18,1 %/mm from speed  $v_1 = 40$  mm/s;  
 16,5 %/mm from speed  $v_2 = 60$  mm/s;
- The working intervals of defocusing for marking with fiber laser for its visual perception are:  
 $\Delta f \in [0; 1,80]$  mm for speed  $v_1 = 40$  mm/s;  
 $\Delta f \in [0; 1,40]$  mm for speed  $v_2 = 60$  mm/s;

**Figure 2. Graphs of the dependence  $k^* = k^*(\Delta f)$  for marking with fiber laser on samples of steel H18-0-1 with speeds : 1 –  $v_1 = 40$  mm/s; 2 –  $v_2 = 60$  mm/s**



**2. Investigation of the dependence of the contrast  $k^*$  of marking from the pulse duration  $\tau$**

Parameters, that are kept constant during the experiments are given in Table IV.

**Table IVV. Parameters, that are kept constant**

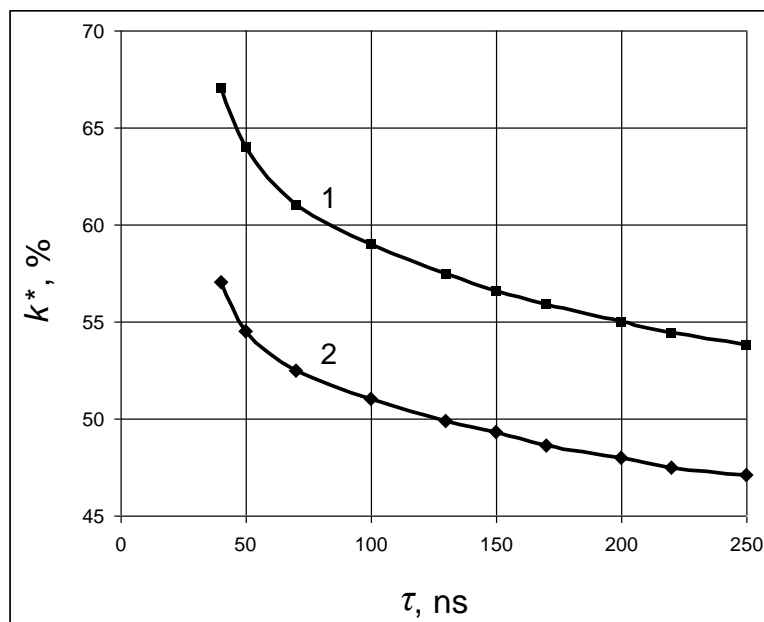
Parameter	Value
Speed $v_1$ , mm/s	40
Speed $v_2$ , mm/s	60
Power density $q_s$ , $\text{W/m}^2$	$2,39 \cdot 10^{10}$
Diameter $d$ , $\mu\text{m}$	40,0
Step $\Delta x$ , $\mu\text{m}$	50
Defocusing $\Delta f$ , mm	0
Number of repetition $N$	1

On Fig. 2 are shown graphs of the experimental dependence  $k^* = k^*(\tau)$  for two speeds of marking:  $v_1 = 40$  mm/s;  $v_2 = 60$  mm/s. From their analysis follows:

- By increasing the pulse duration was observed slight decrease on contrast of marking for both speeds. The reason for this is, that slightly are increased loss of thermal conductivity and heat affected zone are increased only slightly;

- The rate of decrease the contrast of the marking in the interval  $\tau \in [40; 70]$  ns is:  
0,20 %/ns for speed  $v_1 = 40$  mm/s;  
0,15 %/ns for speed  $v_2 = 60$  mm/s;
- The rate of decrease the contrast of the marking in the interval  $\tau \in [70; 250]$  ns is:  
0,040 %/ns for speed  $v_1 = 40$  mm/s;  
0,030 %/ns for speed  $v_2 = 60$  mm/s;
- The working intervals of pulse duration for marking with fiber laser for its visual perception are:  
 $\tau \in [40; 250]$  ns for speed  $v_1 = 40$  mm/s;  
 $\tau \in [40; 125]$  ns for speed  $v_2 = 60$  mm/s.

**Figure 2. Graphs of the dependence  $k^* = k^*(\tau)$  for marking with fiber laser on samples of steel H18-0-1 with speeds: 1 –  $v_1 = 40$  mm/s; 2 –  $v_2 = 60$  mm/s**



### III. Conclusion

The received the results of experimental studies allow the formulation of the following statements:

- Work in the mode of defocusing greater than the length of Raleigh hampers greatly the realization on the process of laser marking of tool steels;
- The influence of the pulse duration onto the contrast of the marking for studied speeds is less.

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## Hybrid Sampling Technique for MRI Image Reconstruction

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**Abstract:** The  $k$ -space data is obtained from signals generated by Magnetic Resonance Imaging (MRI) scanning machine, and these signals get captured at the radio frequency coils. Accuracy of reconstruction of MRI images involves many factors like data acquisition, data sampling and reconstruction algorithms. This paper investigates the effect of the type of sampling on the accuracy of the reconstruction. In this context, various sampling techniques have been reviewed, and the frequency encoding and the phase encoding for the  $k$ -space data have been explained. The related works in image reconstruction like, Sensitivity Encoding approach, SURE approach and signal acquisition protocol have been reviewed. The mechanism of  $k$ -space acquisition has been discussed, and a new approach for the  $k$ -space sampling has been proposed to improve the sampling of the captured  $k$ -space, and hence to provide a better reconstructed image. The performance of the proposed approach is evaluated using mean absolute error, mean squared error and peak signal-to-noise ratio. The results demonstrate that the proposed sampling approach, referred as “hybrid sampling of  $k$ -space”, can reconstruct better quality images when compared to the existing conventional sampling approaches.

**Keywords:** Frequency Encoding, Phase Encoding, FEG, PEG, CS, Radial Sampling, Hybrid Sampling

### I. Introduction

MRI is a riveting imaging technique that pictures human body or part of it. It is non-invasive technique and does not cause any ionization in the human body. MRI evolved from various rudimentary inventions made during 1980's and it underwent enormous development since the last three decades. Indeed, the objects imaged by MRI have an impressive quality, even comparable to photographs taken by digital cameras. Now days, MRI is recognized as the prime modality for diagnosing many common diseases, including cancer and stroke. It is not only used for imaging high spatial resolution images, but also offering good contrast for soft tissues. It has advantages over other imaging techniques like SPECT (Single Photon Emission Computed Tomography), Doppler Ultrasound, PET (Positron Emission Tomography), and computed tomography (CT) which cause ionization in the human body. The examination procedure through MRI does not involve any risk to the patient's health. The basics of MRI imaging processes is briefly introduced in the following sub sections.

#### A. Frequency Encoding and Phase Encoding:

A main magnetic field  $B_0$  is applied in the parallel direction of an object which aligns the nuclear spins of the protons. All the spins have the same Larmor frequency [1] and they are independent of the spatial location of the scanned object. A secondary magnetic field is applied in the form of gradient in Y and Z direction. The nuclei of an atom experiences stronger magnetic field in the positive X direction, and thus undergo with high Larmor frequency. Similarly, nuclei which are in the opposite (negative) X direction experiences low intensity magnetic field and thus undergo with lower Larmor frequency. This is referred to as frequency encoding. The field gradient is applied in Y direction; it induces spatial position dependent phase-difference. This is called phase encoding. Now, each spatial location of an object has a distinctive Larmor frequency and phase shift. An image can be reconstructed from these signals.

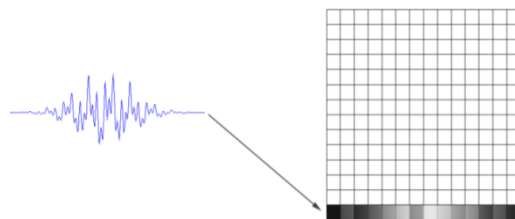
#### B. $k$ -space Data Acquisition:

The  $k$ -space data acquisition in MRI takes place in following steps:

- (i) An object is placed in the MRI scanning device and a strong magnetic field  $B_0$  is applied, which enables all protons of the object to undergo torque-induced precession at the Larmor frequency.
- (ii) The RF pulse applied, which tilts [2] the total magnetization present in the protons in a single direction and enables the in-phase precession for all protons in RF pulse.
- (iii) The PEG (Phase Encoding Gradient) is applied for making a phase difference with respect to the spatial position of an object.
- (iv) In this step, the FEG (Frequency Encoding Gradient) is applied which helps RF coils to capture the proton signal intensity from the excited protons when they return to their ground state.

The FEG shifts the Larmor frequency of the protons which is determined by the position of the object and then

**Figure 1 Generation of Raw Data Matrix (k-space) [1]**



the signal represents spectrum of frequencies. The phase also differs from the spatial position of the protons. Generally, each excitation and the "fall back" of the proton energy to ground state is read-out from RF coils and collected in the raw data matrix in row major order as shown in Figure 1. Basically, the entries in the raw data matrix are the frequency components of the proton density image.

### C. Image Reconstruction Algorithm

Image Reconstruction is the process of converting k-space data to an image that is visible and pictorially meaningful. An image reconstruction algorithm is required to generate the spatial domain images from the sampled k-space data obtained from MRI scan. There exist many algorithms [3] to reconstruct images from k-space data like Zero Padding Method, Phase Correction using Conjugate Symmetry method, Homodyne Reconstruction Algorithm, and Projections onto Convex set (POCS) method. Formally, the k-space obtained from the scanning machine can be represented in the form of continuous domain [5] that relates the density of protons  $m(r)$  to the signal received  $p(k)$ . The  $m(r)$  is related to  $p(k)$  by the following equation:

$$p(k) = \int_{FOV} m(r) e^{-i2\pi k \cdot r} dr \quad 1$$

where 'k' represents the frequency domain point and the 'r' represents the spatial domain point

## II. Related Work

An enormous amount of work has been done in the field of reconstruction of images from the signals acquired by scanning devices. There has been staggering improvement in the quality of reconstruction since 1970 [4]. A few of the notable works are reviewed in the following subsections:

### A. Sensitivity Encoding

One of the classical works in image reconstruction is that by Cheng and Dewey [6]. The authors described the concept of reconstruction of image from projections or raw data as an inverse problem, and implemented in cases where a large number of images to be reconstructed. Expectation maximization is employed for determining the class values that are not available. MRF (Markov Random Field) model of dynamic objects is used to achieve local regularity and increased smoothness during reconstruction. Pruessmann et al. [7] proposed a new approach for collecting the k-space data referred to as SENSE (Sensitivity Encoding). In classical technique, Fourier Imaging collects the data on RF coil at a very slow rate, but with the help of SENSE, the capability of Fourier Imaging can be enhanced at the double rate. This also reduces the time for scanning. In the normal Fourier encoding, the k-space data is sampled and transferred to the RF coil. If the Fourier Imaging is used with SENSE, it reduces the sampling density and collects the k-space more efficiently. Authors observed that SENSE enhanced gradient encoding and reduced scan time as compared to Fourier imaging.

### B. Stein's Unbiased Risk Estimator (SURE)

Alfred et al. [8] reviewed the theoretical results from sparse solutions of systems that are linear. Harmonic analysis of wavelets and applications of sparsity to signal in image processing are discussed. The sparsity based solution of linear equations in the application of image compression and image reconstruction is also discussed. The other concepts discussed in the paper are LU Decomposition, and Least Square method. Raich and Alfred [9] proposed sparse image reconstruction in radio astronomy. They proposed three sparse image reconstruction methods; the first uses Stein's unbiased risk estimator (SURE) for selecting the hyper-parameter for L1 estimator, and the other two are based on sparse prior; they used empirical Bayes denoising. These three methods are simulated and found to produce better results than sparse Bayesian learning (SBL) [10]. Sparse prior is the magnetization intensity falling on the body. Using sparse prior with SURE method enhanced the quality of signals leading to better reconstructed images.

### C. Signal Acquisition Protocol

Candes et al. [11] presented how to reconstruct an image from numerical optimization from the full-length signal/image using the raw data (k-space) that is also called projections. They also described a very simple and

efficient signal acquisition protocol that samples the signal which is independent of the rate of change in the projections. The final set obtained after the sampling allows improving the reconstruction power of sparse data, and permits better reconstruction of images.

Inspite of the large amount of existing development works in MRI image reconstruction, there still has issues like complexity in k-space acquisition process and requirements of large scan time for generating good quality images. Thus, there are further scopes for improvements in the quality of reconstructed images by introducing improvements in k-space acquisition process and reducing the scan time by enhancing gradient encoding. This paper proposes a hybrid sampling technique to improve the k-space acquisition process.

### III. Proposed k-space Sampling Approach

Generally, the sampling of k-space can be done in two ways: (i) Cartesian Sampling, and (ii) Radial Sampling. The order in which the RF signals are detected plays an important role in MRI image reconstruction. During the scanning of an object from the MR camera, the k-space data is collected at different times, which have different spatial intensities (state) of an object. As discuss in subsections given below, the central region of k-space is having more structural information about the scanned part and the farthest region of k-space (peripheral region) contains less information about the structural part of the object. In view of the above fact, to take care of this non-uniformity of the k-space, we proposed a combined approach for sampling in which the central region is sampled by radial sampling and the peripheral region is sampled by cartesian sampling. The basics of conventional sampling approaches and the proposed combined approach are presented in the following subsections:

#### A. Cartesian Sampling

In Cartesian sampling, the sampling is done by scanning each spatial location of k-space data in a rectilinear fashion row by row as shown in Figure 2. All the sampled points are equidistant from each other. Hence, the central regions are not much focussed for the reconstruction, which results in a poor quality reconstructed image. The samples obtain by Cartesian approach are all equidistant from each other which treat k-space uniformly. Hence, there should be more samples from the central region as compared to peripheral regions, but here it is not so. So, this sampling approach is not that acceptable for sampling k-space.

Figure 2 Cartesian sampling of k- space data [12]

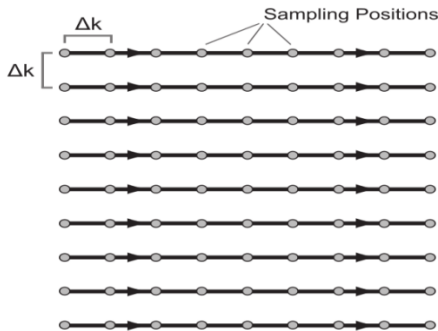


Figure 4 Co-ordinate of k-space in 2 Dimension [13]

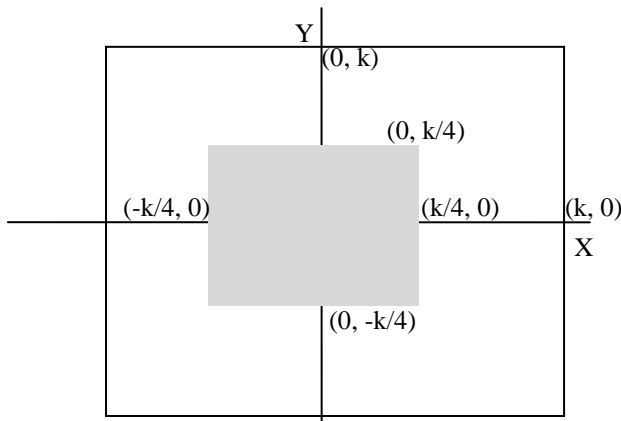


Figure 3 Radial sampling of k-space data [12]

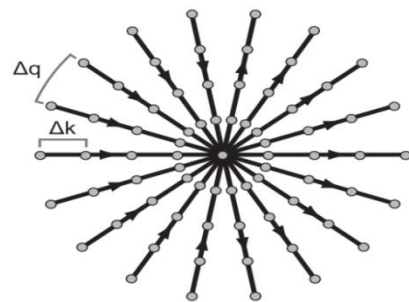
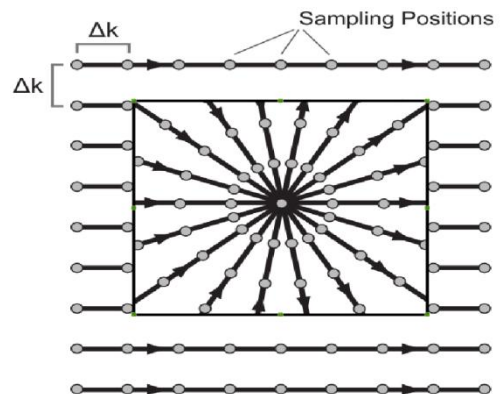


Figure 5 Diagrammatic representation of hybrid k-space sampling



### B. Radial Sampling

In radial sampling, the k-space data is processed from the low frequency region (origin) and continue in angular fashion as shown in Figure 3. The data near to the origin in k-space have the most information about the structure of an image like contrast, and the SNR, whereas the data at farther region helps in reconstructing smaller structures in an image [12]. With the help of radial k-space sampling, the low frequency regions (central regions) of an image get processed at every scan. Hence, using the radial sampling of k-space can generate good reconstructed images, but the peripheral regions are not getting processed much which sometimes result in lower quality reconstruction of small structures of an image.

### C. Hybrid Sampling

It has been discussed that the reconstructed images from the radial sampling of k-space are lacking information of small structural regions of the scanned object. Also, the drawback of cartesian sampling is that it assumes, the information in the k-space, as uniformly distributed. We can eliminate the drawbacks of the above two approaches by combining both the radial and Cartesian sampling techniques. In this approach, the central region of k-space data (Figure 4) is sampled using radial approach and the peripheral region is sampled using cartesian approach. As it can be seen from the Figure 5, the central region of k-space will get processed frequently and the distance between the samples is also very less. Here, the peripheral regions are also getting processed better when compared with a radial sampling approach.

## IV. Algorithm for Hybrid approach

It has been proved [13] that the most of the information in k-space lies up in *region*  $-k/4 \leq x \leq k/4$  and  $-k/4 \leq y \leq k/4$  as indicated in Figure 4. There is an assumption that the centroid of k-space data is the origin of 2D coordinates. Algorithm for hybrid sampling is presented as follows:

*Algorithm 1: Hybrid Sampling Algorithm:*

*Given:*  $S_1$ : Cartesian sampled raw data,  $S_2$ : Radial Sampled raw data,  $S$ : k-space data which is used to represent pictorial view of k-space,  $RI$ : Reconstructed image after applying hybrid sampling reconstruction algorithm

*Input:*  $S_1, S_2$

*Output:*  $RI, S$

1. Fix the extreme points for radial sampling as  $-k/4$  and  $+k/4$  at X and Y axes as shown in Figure 4. The rest of  $k \times k$  space will be sampled in rectangular Cartesian form.
2. Start sampling from  $(-k, k)$  to  $(k, -k)$  in row by row order:
  - For  $I = 0$  to  $k-1$
  - For  $J = 0$  to  $k-1$
  - if  $(-k/4 \leq I \leq k/4)$  and  $(-k/4 \leq J \leq k/4)$ : Reconstruct using radial sampling ( $S_2, I, J, S$ )
  - else: Reconstruct using cartesian sampling ( $S_1, I, J, S$ )
3. Image and k-space data can be displayed using  $RI$  and  $S$ .

*(i) Reconstruction using radial sampling: [14]*

*Input:*  $S_2, I, J, S$

*Output:* Updated  $RI$  and Updated  $S$  Compute the image reconstructed

- 1) Each sample point is having area ' $dk$ ', which can be represented in continuous domain as:

$$\hat{m}(r) = \int_{k-space} p(k) e^{i2\pi k \cdot r} dk \quad 2$$

$$\text{where } p(k) = \int_{FOV} m(r) e^{-i2\pi k \cdot r} dr \quad 3$$

Here, ' $k$ ' represents the frequency domain point and the  $r = (I, J)$  represents the spatial domain point and,  $\hat{m}(r)$  is the proton density and  $p(k)$  is the signal received. In the discrete domain, the above can be written, with a weighing function to account for the non-uniform sampling, as:

$$\hat{m}(r) = \sum W(k_{I,J}) p(k_{I,J}) e^{i2\pi k \cdot r} \quad 4$$

where  $W(k_{I,J})$  is the weighing function

*Weighing function* (refer [3]) is used for determining the non-uniform sampling and it is used to compensate the data points from radial lines into grids. Without the weighing, the radial sampled data cannot be processed further. The uniform distribution of spatial frequency in k-space data can be obtained by multiplying weighing function to the partial k-space in the equation above.

- 2) Update  $RI(I, J)$  with  $\hat{m}(r)$ , which is the contribution of k-space  $p(k_{I,J})$  to the image,  $RI(I, J)$ .

3) Update S with the grinding procedure [5] applied to  $p(k_{i,j})$

(ii) Reconstruction using cartesian sampling: [15]

Input:  $S_2, I, J, S$

Output: Updated RI and Updated S

1) All the sample points  $S_1$  are equidistant from each other. They all are in the form of Cartesian ordinate space; the proton density (image) can be given as follows:

$$\hat{m}(r) = \sum p(k_{i,j}) e^{i2\pi k \cdot r} \quad 5$$

where parameters are same as equation -4

2) Update RI(I, J) with  $\hat{m}(r)$  which is the contribution of k-space  $p(k_{i,j})$  to the image, RI(i,j).

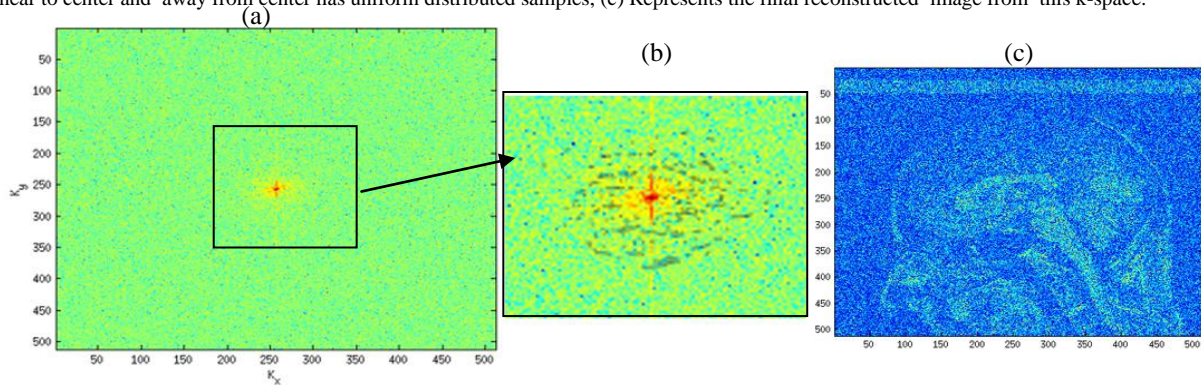
3) Update S with  $p(k_{i,j})$

## V. Experiment

The experiment is performed using *Matlab*, 7.10.0.499 (R2010a), 32-bit (*glnxn86*) running under Linux Operating System (ubuntu 32-bit, kernel 3.13.0.46-generic). The cartesian sampled raw data can be downloaded from <https://github.com/zacinaction/KickSat-AsteroidDemo/blob/master/Matlab%20Code/RawData.mat> and the radial sampled raw data from MRI machine can be downloaded from <https://github.com/zacinaction/KickSat-AsteroidDemo/blob/master/Matlab%20Code/rawdata.mat>. The simulation of Cartesian sampling, radial sampling, and hybrid sampling (the proposed approach) are performed using the downloaded raw data (both cartesian and radial sampled data). The experimental results of reconstruction with various sampling approaches considered are given in Figure 6, Figure 7, and Figure 8, respectively, for cartesian sampling, radial sampling and hybrid sampling. The corresponding images for all the k-space data are also given. It can be observed from the pictorial representations of k-space that the central region varies in all the sampling approaches.

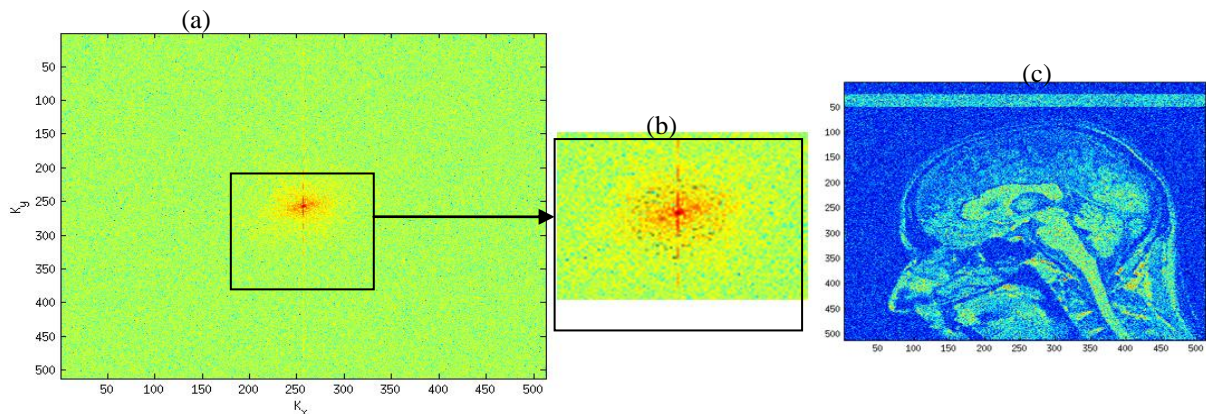
**Figure 6 Cartesian sampling image reconstruction**

(a) Gives the pictorial view of k-space obtained after cartesian sampling, (b) Red color portion represents the high intensity, black dots indicate the uniform distribution of samples and yellow area represents the intensity of sample points. It can be seen that the all the region near to center and away from center has uniform distributed samples, (c) Represents the final reconstructed image from this k-space.



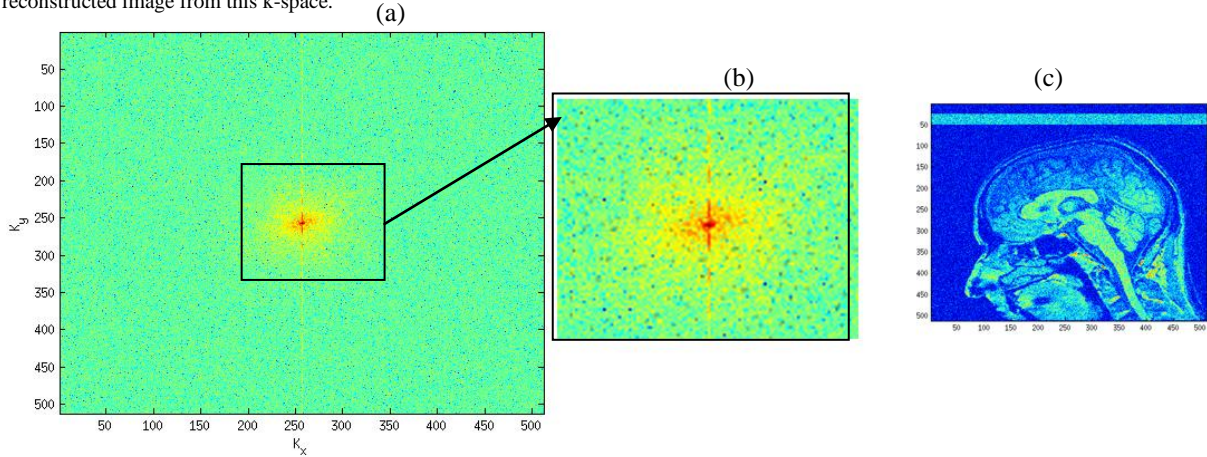
**Figure 7 Radial sampling image reconstruction**

(a) Gives the pictorial view of k-space obtained after radial sampling, (b) Red color portion represents the high intensity, black dots indicate the uniform distribution of samples and yellow area represents the intensity of samples points. It can be seen that the center region is denser than peripheral regions, (c) Represents the final reconstructed image from this k-space.



**Figure 8 Hybrid sampling image reconstruction**

(a) Gives the pictorial view of k-space obtained after hybrid sampling, (b) Red color portion represents the high intensity, black dots indicate the uniform distribution of samples and yellow area represents the intensity of sample points. It can be seen that the samples are denser at central region due to radial sampling and there is also better sampling at peripheral region due to cartesian sampling, (c) Represents the final reconstructed image from this k-space.



From the pictorial view of the results, it can be observed that the image reconstructed from k-space obtained using hybrid sampling provides better quality images. The objective evaluation and comparative analysis of hybrid sampling with radial sampling, and cartesian sampling are presented in the next section.

### V. Performance Evaluation and Comparative analysis

There are various measures for evaluating the quality of reconstructed images. This paper uses the Root Mean Square (RMS), Mean Absolute Error (MAE), and Peak Sound to Noise ratio (PSNR) for evaluating the quality of the reconstructed image. The various performance measures obtained for Cartesian sampling, radial sampling, and hybrid sampling are presented in Table 1. The performance of different approaches is graphically represented as in Figures 9. It is observed that the proposed radial approach is superior in terms of MSE, MAE and PSNR.

**Mean Squared Error (MSE):** MSE is an average of the square of the absolute error.

$$MSE = \frac{\sum_{i=1}^n (\hat{y}_i - y_i)^2}{n}$$

where  $y_i$  is the actual value,  $\hat{y}_i$  is the experimental value or predicted value at the  $i^{\text{th}}$  observation.

**Mean Absolute Error (MAE):** MAE is an average of the absolute error.

$$MAE = \frac{\sum_{i=1}^N |p_i - q_i|}{N}$$

where  $p_i$  is the actual value,  $q_i$  is the experimental value or predicted value at the  $i^{\text{th}}$  observation.

**Peak Signal to Noise ratio (PSNR):** Peak signal-to-noise ratio (in dB) is the ratio of maximum intensity (power) of pixel (signal) at a sample point to the intensity (power) of corrupting noised image.

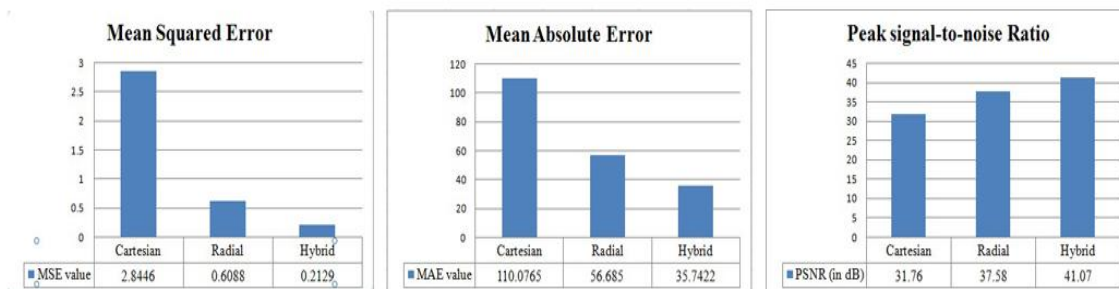
$$PSNR = 10 \cdot \log_{10} \left( \frac{MAX^2}{MSE} \right)$$

where  $MSE$  is the mean squared error,  $MAX$  is the maximum pixel intensity.

**Table -1: Performance Evaluation**

Sampling	MSE	MAE	PSNR (in dB)
Cartesian	2.8446	110.0765	31.76
Radial	0.6088	56.6850	37.58
Hybrid	<b>0.2129</b>	<b>35.7422</b>	<b>41.07</b>

**Figure 9 Comparative Analysis of hybrid sampling with radial and cartesian sampling in terms of MSE, MAE and PSNR**



From the bar diagram of MSE, MAE and PSNR, it can be seen that the MSE and MAE of our proposed sampling approach provides low error values when compared to Cartesian and Radial sampling approaches. Also, the PSNR for the proposed sampling approach is higher than that for Cartesian and radial sampling techniques.

## VII. Conclusion

This paper proposes a hybrid sampling technique for improving the quality of MRI reconstructed images. The raw data acquisition of k-space has been briefly discussed. The various features of k-space acquisition like phase encoding, phase shift, frequency encoding have been analyzed. The drawback of cartesian sampling is that it assumes uniformly distribution of k-space. The radial sampling of k-space gives better reconstructed images, but has few disadvantages like the small structures of objects are not properly reconstructed. The disadvantages of cartesian and radial sampling are eliminated by introducing the proposed hybrid sampling technique. The algorithm for hybrid sampling technique is implemented and the performances are compared with cartesian and radial sampling. The results demonstrate that the hybrid technique provides better performance figures in terms of PSNR, mean squared error and mean absolute error when compared to Cartesian and radial approaches.

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## **Analysis of Software Product Quality Models**

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**Abstract:** *The goal of software quality assurance is to remove quality problems in the software. These problems are referred to by various names- “bugs”, “faults”, “errors” or “defects”. But there is a great difference between error and defect. An error is a quality problem found before the software is released to end-users. While a defect is a quality problem found only after the software has been released to end-users. The errors and defects have very different economic, business, psychological and human impact. So the goal of software quality assurance is to find errors before they become defects. A software product quality model is a useful tool for meeting the objectives of software quality, reliability and software testing initiatives of different projects. In this paper we have done the survey of literature on software quality models. The objective of this paper is to provide a vivid description of the popular software quality models and presenting a more philosophical management view on software quality. We have compared the famous and important quality models on the basis of various attributes of quality.*

**Keywords:** *Software Quality, Quality Models, McCall’s Model, Dromey’s Model, Boehm’s Model.*

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### **I. Introduction**

Why software quality models are used? Generally models provide the stepwise product development tracks. If any software development organization, wants to develop specified quality products, than they needs to follow the organized manner, to produce the product in states phases, time, cost and environment. To achieve desired software quality, software quality models to identify high-risk program modules are used. A software quality model is a useful tool for meeting the objectives of software quality, reliability and software testing initiatives of different projects.

From long history many researchers have recognized the need of Software Product Quality: Traditionally, the quality of product is defined in terms of its fitness of purpose. Although fitness of the purpose is satisfactory definition of quality for hardware products, but it is not satisfactory for software products. There are a number of quality models in software engineering literature, each one of these quality models consists of a number of quality characteristics (or factors, as called in some models). These quality characteristics could be used to reflect the quality of the software product from the view of that characteristic. Selecting which one of the quality models to use is a real challenge. In this paper, we have discussed and compared the following quality models:

1. McCall’s Quality Model.
2. Boehm’s Quality Model.
3. Dromey’s Quality Model.
4. FURPS Quality Model.
5. ISO 9126 Quality Model.

McCall quality model attempts to bridge the gap between users and developers by focusing, on a number of software quality factors. The evaluation of software has been done by Boehm’s quality model uses a given set of attributes and metrics. More recently, model has been developed by Dromey’s which is focusing on the relationship between the quality attributes and the sub attributes, as well as attempting to connect software product properties with software quality attributes. In the next section of this paper we have described these software quality models for analysis/comparison point of view.

### **II. An Overview of Software Quality Models**

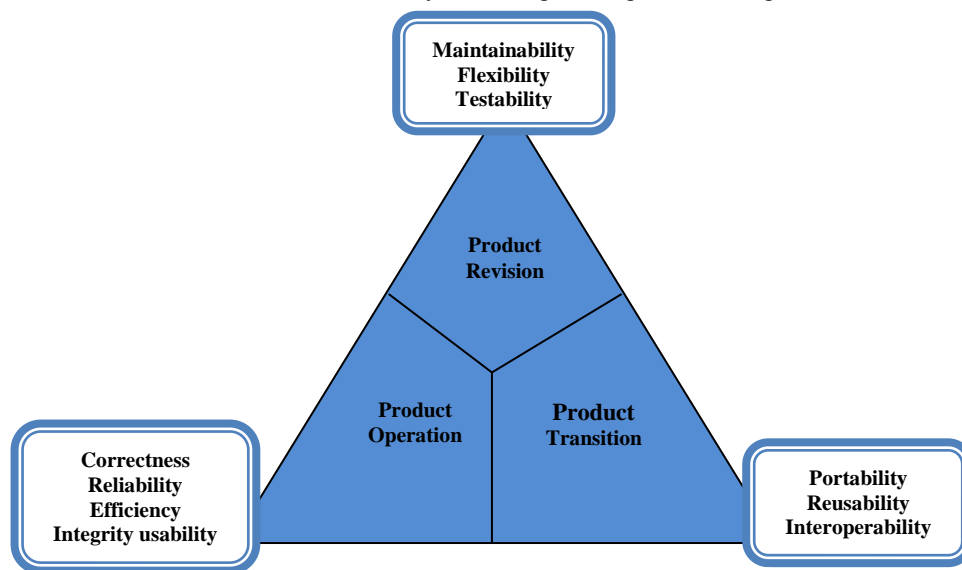
The purpose of this section is to provide an overview to popular quality models and presenting a more philosophical management view on software quality, because quality management philosophy can be sometimes a good alternative to the more formalized quality model. Number of quality prediction models has been proposed in Literature. In this paper we have chosen McCall, Boehm’s, Dromey’s, FURPS and ISO quality model for comparison purpose.

#### **A. McCall Quality Model**

This is the most popular Quality model in software engineering presented by Jim McCall in 1977 which is known as Mc Call Quality Model. This model is also known as General Electric’s Model of 1977. McCall

quality model reduces the gap between users and developers by focusing on a number of software quality factors that reflect both the users' views and the developers' priorities. The quality of software has been categorized in three different parts in this model namely *Product Revision* (maintainability, flexibility and testability, which contribute to product revision), *Product Operation* (correctness, reliability, efficiency, integrity and usability which contribute to product operation) and *Product Transition* (portability, reusability and interoperability which contribute to product transition) for defining and identifying the quality of a software product as shown in fig.1

**A.1 Product Revision:** It is the ability to undergo changes, including error correction and system adaptation.



**Fig.1: Mc Call Quality (Triangle) Model**

The quality of product revision includes:

- **Maintainability:** the effort required to locate and fix a fault in the program within its operating environment.
- **Flexibility:** the ease of making changes required by changes in the operating environment.
- **Testability:** the ease of testing the program, to ensure that it is error-free and meets its

specification.

**A.2 Product Operation:** It is the product's ability to be quickly understood, operated and capable of providing the required results. It is related to the characteristics of the product operation. The quality of the product operations depends on:

- **Correctness:** the extent to which a program fulfils its specification.
- **Reliability:** the system ability not to fail.
- **Efficiency:** it further categorized into execution efficiency and storage efficiency and generally meaning the use of resources, e.g. processor time, storage.
- **Integrity:** the protection of the program from unauthorized access.
- **Usability:** the ease of the use of the software.

**A.3 Product Transition:** it is about the adaptability of the product to new environments. The product transition quality of software includes:

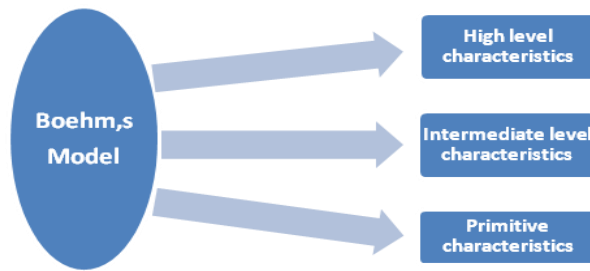
- **Portability:** the effort required to transfer a program from one environment to another.
- **Reusability:** the ease of reusing software in a different context.
- **Interoperability:** the effort required to couple the system to another system.

## **B. Boehm's Quality Model**

In 1978 Barry W. Boehm presented a new quality model that presents the characteristics of software on a larger scale as compare to Mc Call's model. The Boehm's Quality Model attempts to qualitatively define software quality by a given set of attributes and metrics. In this model As-Is-Utility describes how easily, reliably and efficiently software product can be used, maintainability describes how easily modified and retest the software product, and portability describes how the software product can be used even when environment has been changed. The fig.2 shows the hierarchical structure of Boehm's model:

**B.1 The high-level characteristics:** It represents basic high-level requirements of actual use to which evaluation of software quality could be put – the general utility of software. The high-level characteristics address three main questions that a buyer of software has:

- **As-is utility:** How well (easily, reliably, efficiently) can I use it.
- **Maintainability:** How easy is it to understand, modify and retest?



- **Portability:** Can I still use it if I change my environment?

**B.2 The intermediate level characteristic:** It represents Boehm's 7 quality factors that together represent the qualities expected from a software system:

• **Portability** (General utility characteristics): Code possesses the characteristic portability to the extent that it can be operated easily and well on computer configurations other than its current one.

• **Reliability** (As-is utility characteristics): Code

possesses the characteristic reliability to the extent that it can be expected to perform its intended functions satisfactorily.

**Fig.2: Boehm's Quality Model**

• **Efficiency** (As-is utility characteristics): Code possesses the characteristic efficiency to the extent that it fulfills its purpose without waste of resources.

• **Usability** (As-is utility characteristics, Human Engineering): Code possesses the characteristic usability to the extent that it is reliable, efficient and human-engineered.

• **Testability** (Maintainability characteristics): Code possesses the characteristic testability to the extent that it facilitates the establishment of verification criteria and supports evaluation of its performance.

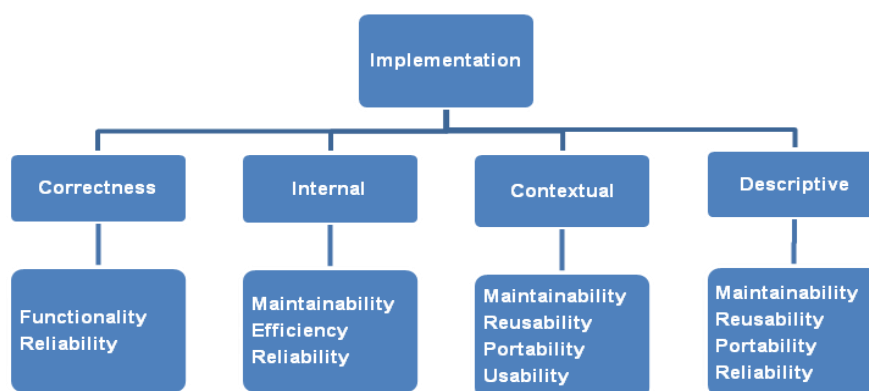
• **Understandability** (Maintainability characteristics): Code possesses the characteristic understandability to the extent that its purpose is clear to the inspector.

• **Flexibility** (Maintainability characteristics, Modifiability): Code possesses the characteristic modifiability to the extent that it facilitates the incorporation of changes, once the nature of the desired change has been determined.

**B.3 The primitive characteristics:** The lowest level structure of the characteristics hierarchy in Boehm's model is the primitive characteristics metrics hierarchy. The primitive characteristics provide the foundation for defining qualities metrics – which was one of the goals when Boehm constructed his quality model. Consequently, the model presents one or more metrics supposedly measuring a given primitive characteristic.

### C. Dromey's Quality Model

In the year 1995 a quality model presented by R. Geoff Dromey is more recent model similar to the McCall's, Boehm's and the FURPS quality model. Dromey proposes a product based quality model that recognizes that quality evaluation differs for each product and that a more dynamic idea for modeling the process is needed to be wide enough to apply for different systems. Dromey's proposes a working framework for evaluating Requirement determination, design and implementation phases. The framework consists of three models, i.e.



**Fig. 3: Dromey's Quality Model**

*Requirement quality model, Design quality model and Implementation quality model.* The high-level product properties for the implementation quality model include:

• **Correctness** evaluates if some basic principles are violated, with functionality and reliability as software quality attributes.

• **Internal** measures how well a component has been deployed according to its intended use, with

maintainability, efficiency and reliability as software quality attributes.

• **Contextual** deals with the external influences on the use of a component, with software quality attributes in maintainability, reusability, portability and reliability.

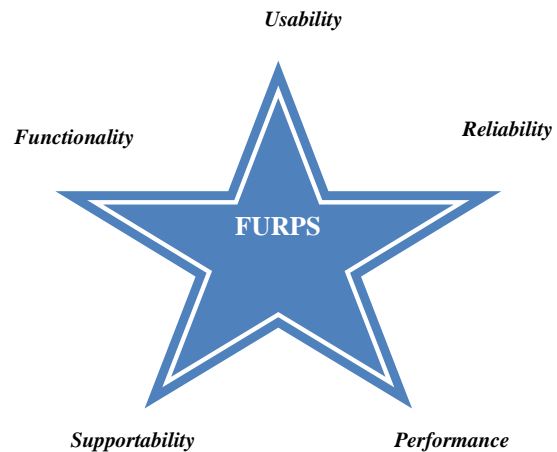
• **Descriptive** measures the descriptiveness of a component, with software quality attributes in maintainability, reusability, portability and usability.

Dromey is focusing on the relationship between the quality attributes and the sub-attributes, as well as attempting to connect software product properties with software quality attributes. The principal of Dromey's Quality Model shown in fig.3, after review of Dromey model, we find that the reliability attribute is common, which can be, achieve through product properties: correctness, internal and contextual. Also maintainability attribute is common in internal, contextual, descriptive properties of the product. The quality attributes: reusability, portability affects the contextual, descriptive properties of the product. In this model seven attributes have been chosen to define software quality product.

#### D. *FURPS Quality Model*

The FURPS model originally presented by Robert Grady[1992], then it has been extended by IBM Rational Software [Jacobson et al, 1999, Kruchten, 2000] into FURPS+, where the '+' indicates such requirements as design constraints, implementation requirements, interface requirements and physical requirements [Jacobson et al, 1999]. FURPS stands for:

- **Functionality**- which may include feature sets, capabilities and security.
- **Usability** - which may include human factors, aesthetics, consistency in the user interface, online and context sensitive help, wizards and agents, user documentation, and training materials?
- **Reliability** - which may include frequency and severity of failure, recoverability, predictability, accuracy, and mean time between failure (MTBF)
- **Performance** - imposes conditions on functional requirements such as speed, efficiency, availability, accuracy, throughput, response time, recovery time, and resource usage
- **Supportability** -which may include testability, extensibility, adaptability, maintainability, compatibility, configurability, serviceability, installability, localizability (internationalization)?



**Fig.4: FURPS Quality Model**

#### E. *ISO 9126 Standard Quality Model*

ISO 9126 is an international standard for the evolution of software. The standard is divided into four parts which address respectively the following subjects: Quality model, External metrics, internal metrics and quality in use metrics. ISO 9126 Part-1 is an extension of previous work done by McCall (1977), Boehm (1978), FURPS etc. ISO 9126 specifies and evaluates the quality of a software product in terms of internal and external software qualities and their connection to attributes. The model follows the factor-criteria-metric model and categorizes software quality attributes into six independent high-level quality characteristics: functionality, reliability, usability, efficiency, maintainability and portability. Each of these is broken down into secondary quality attributes, e.g. maintainability is refined into analyzability, changeability, stability, testability and compliance to standards, conventions or regulations. For the internal and external software products, each quality characteristics and its corresponding sub-characteristics are defined in ISO 9126-1 [ISO, 2001] as follows:

- **Functionality**: -“The capability of the software product to provide functions which meet stated and implied needs when the software is used under specified conditions”.
- **Reliability**:- “The capability of the software product to maintain a specified level of performance when used under specified conditions”.
- **Usability**:- “The capability of the software product to be understood, learned, used, and attractive to the user, when used under specified conditions”.
- **Efficiency**:- “The capability of the software product to provide appropriate performance, relative to the amount of resources used, under stated conditions”.
- **Maintainability**:-“The capability of the software product to be modified. Modifications may include corrections, improvements or adaptation of the software to changes in environment, and in requirements and functional specifications”.
- **Portability**: “The capability of the software product to be transferred from one environment to another”. It includes the following sub characteristics:

### III. Analysis / Comparison of Software Quality Models

This is a comprehensive study to enumerate different characteristics/factors of various software qualitative models and estimate their comparative viability. In this section we have presented a comparison between the availability of the characteristics (called factors or attributes) within the five popular quality models. We have

compared five popular software quality models (McCall's, Boehm's, Dromey's, FURPS and ISO 9126), in which each of the quality model has various quality characteristics or factors or metrics. In table 1 we have shown the comparison/analysis of these quality models based on various characteristics/factors of quality.

**Table 1: Comparison of Software Quality Models**

Criteria /goals (in ascending order)	McCall Model	Boehm Model	Dromey Model	FURPS Model	ISO 9126 Model
Clarity		*			
Correctness	*	*			
Documentation		*			
Economy		*			
Efficiency	*	*	*		*
Flexibility	*	*			
Functionality			*	*	*
Generality		*			
Integrity	*	*			
Interoperability	*				
Maintainability	*	*	*		*
Modifiability		*			
Performance				*	
Portability	*	*	*		*
Reliability	*	*	*	*	*
Resilience		*			
Reusability	*	*	*		
Supportability				*	
Testability	*				
Understandability		*			
Usability	*	*	*	*	*
Validity		*			
<b>Total = 22</b>	<b>11</b>	<b>17</b>	<b>7</b>	<b>5</b>	<b>6</b>

#### IV. Conclusion/Discussion and Future Work

Based on this comparison/analysis and discussion we analyze that- In McCall's quality model, the quality is subjectively measured based on the judgment on the person(s) answering the questions ('yes' or 'no' questions). The metrics in the lower level of the McCall's, Boehm's, Dromey's and FURPS quality models are neither clearly nor completely defined and connected to the upper level of the quality models. The FURPS quality model is built and extended to be used in the IBM Rational Software Company. Therefore, it is a special-purpose quality model, that is, for the benefits of that company. Three of the characteristics are used in the ISO 9126 quality model as sub- characteristics from other characteristics. The ISO 9126 quality model is the most useful one since it has been build based on an international consensus and agreement from all the country members of the ISO organization. On the basis of the analysis/comparison/discussion we can say that the software quality model may be useful for software developers to satisfy their need and thereby gaining the optimum quality within specified environment. In future we will develop a model for software product defect prediction to improve the quality of the software product.

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## PERFORMANCE INVESTIGATION OF DIFFERENT SIGNALING AND CODING RATES IN WIMAX NETWORK

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**Abstract:** WiMAX (Worldwide Interoperability for Microwave Access) is a promising technology which can offer high speed voice, video and data service up to the customer end. The IEEE 802.16 technology is a better alternative to 3G or wireless LAN networks for providing last mile connectivity by radio link due to its high data rates, low cost of deployment and large coverage area. In this paper, QoS performance of WiMAX network is analyzed in terms of QoS parameters i.e. delay, load, throughput, packet delay variation and packet end to end delay by using OPNET 14.5 simulator. Performance is carried out with different modulation techniques and coding rates like QPSK  $\frac{1}{2}$ , QPSK  $\frac{3}{4}$ , 16 QAM  $\frac{1}{2}$ , 16 QAM  $\frac{3}{4}$ , 64 QAM  $\frac{1}{2}$  and 64 QAM  $\frac{3}{4}$ . This paper concludes that coding rate  $\frac{3}{4}$  and QAM techniques perform best.

**Keywords:** WiMAX, OPNET, QPSK, 16 QAM, 64 QAM, OFDM.

### I. Introduction

The demand for broadband mobile services is continuously growing. Conventional high-speed broadband solutions are based on wired-access technologies such as digital subscriber line (DSL). This type of solution is difficult to deploy in remote rural areas because it lacks support for terminal mobility. Mobile Broadband Wireless Access (MBWA) provides flexible and cost-effective solution to these problems [1]. The IEEE WiMax/802.16 is a promising technology for broadband wireless metropolitan area networks (WMANs). WiMax technology ensures broadband access for the last mile. It provides a wireless backhaul network which enables high speed Internet access to small and medium business customers, residential and also Internet access for WiFi hot spots and cellular base stations. WiMAX becomes a promising standard nowadays because it becomes an excellent solution for the places where the cost of deployment and maintenance of technologies like DSL is not profitable. WiMAX offers a good solution for these challenges because it provides a cost-effective, rapidly deployable solution. Additionally, WiMAX will represent a serious competitor to 3G (Third Generation) cellular systems as high speed mobile data applications can be achieved with the 802.16e standard. The original WiMAX standard was only catered for fixed and Nomadic services. It was then enhanced to full mobility applications, hence the mobile WiMAX defined under the IEEE 802.16e standard. Mobile WiMAX supports full mobility, nomadic and fixed systems [2].

In wireless communication, parallel transmission of symbols concept is applied to achieve high throughput and better transmission quality. Many methods are proposed to combat the multipath effects in wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques used for parallel transmission. The idea of OFDM is to split the total transmission bandwidth into a number of orthogonal sub carriers so that to transmit the symbols using these sub carriers in parallel [4]. Each smaller data stream is then mapped to individual data sub-carrier and modulated using one of the Modulation techniques such as QPSK, 16-QAM, 64-QAM. OFDM needs less bandwidth than Frequency Division Multiplexing (FDM) to carry the same amount of information which converts to higher spectral efficiency. Besides a high spectral efficiency, an OFDM system such as WiMAX is more suitable in NLOS environment. It can easily overcome issues caused by multipath like interference and frequency-selective fading because equalizing is done on a subset of sub-carriers instead of a single broader carrier [5]. WiMAX uses a special type of modulation technique which is a mixture of ASK and PSK with a new name called Quadrature Amplitude Modulation (QAM). In QAM, amplitude and phase changes at the same time. Different types of QAM are available for WiMAX networks depending on throughput and range. 64 QAM has higher throughput but the lower range whereas 16 QAM has lower throughput but higher range to cover from the BS. WiMAX has the freedom to select Quadrature Phase Shift Keying (QPSK) and QAM as its modulation techniques depending on the situation [4].

To accommodate the Wireless medium 802.16 basically employ PHY (physical) and a MAC (media access control) layer.

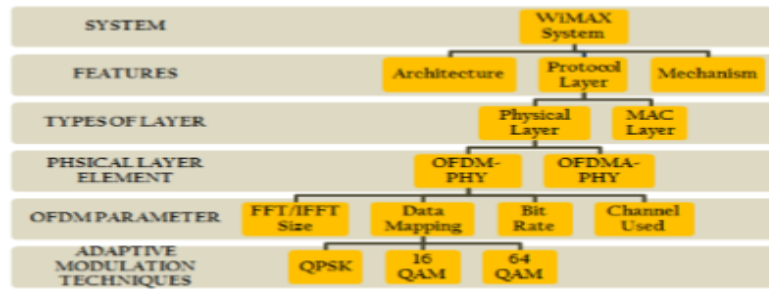


Figure 1 Specification of WiMAX system

These are the two layers of WiMAX which are very important. PHY layer plays a very important role in WiMAX network. PHY is the actually physical transport of data itself. A variety of technologies like OFDM, TDD, FDD, QAM and Adaptive Antenna Systems (AAS) are utilized to achieve maximum performance from the PHY itself. Modulation technique is one of the technologies used by PHY layer so it motivates to compare different modulation techniques with different coding rates to achieve best performance. In this paper different modulation techniques with different coding rates are compared with QoS parameters and concluded which gives best QoS.

This paper is organized as follows. Simulation model of network using OPNET modeler is described in section II. Simulation environment is also in section III then Results are discussed in section IV, before we finally conclude in Section V. References are given in section V.

## II. Simulation Model

In this study, we used OPNET to develop a simulation model. OPNET Modeler simulation tool was selected as the tool of choice given its widespread adoption in both commercial and military domains. Moreover, the OPNET Modeler included native support for WiMAX component technologies. A network topology shown in Figure 2, consisting of geographically separated video client and video services subnets, was employed to simulate a more realistic real world scenario [6].

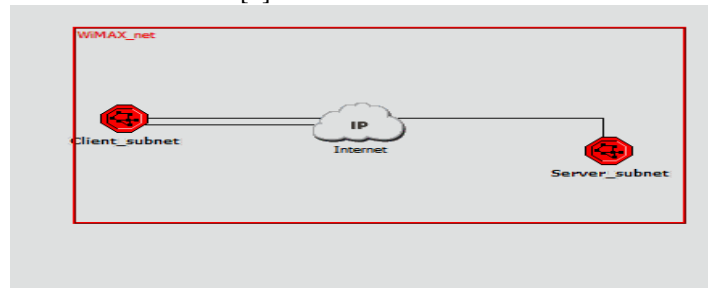


Figure 2 Network topology

The server subnet, shown in Figure 2 provisions a VoD server capable of streaming stored video content to video clients on request and client subnet encompass various video client stations that will access the same VoD services. Client subnet and server subnet shown in network topology are connected through IP backbone.

In the client subnet shown in figure 3, six fixed wireless WiMAX stations are located. The base station is connected wirelessly to all the client stations [7].

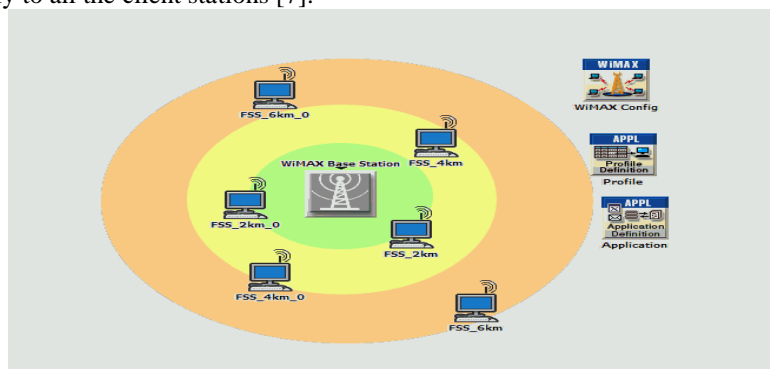


Figure 3 Simulation Model

## II. Simulation Environment

WiMAX service classes appropriate the QoS requirements of service flows, where service flows represent traffic flow between the base station and the subscriber stations. Service flows from the base station to the subscriber station are called downlink flow whereas service flows from the subscriber station to base station are called uplink flows. For a given service class, the key parameters are minimum sustainable traffic rate and the scheduler type, which enables WiMAX to provide QoS capabilities, thereby supports delay sensitive traffic such as audio and video services. There are four scheduler types: UGS (ungranted service), rtPS (real time polling service), nrtPS (non-real time polling service) and BE (best effort). The available bandwidth resources are first allocated to UGS then to rtPS and nrtPS flows. Lastly, any remaining resources are then assigned to BE flows. For the purpose of this study, we created one service class for the downlink using BE scheduling and 3.0 Mbps minimum sustainable data rate. Another service class was created using BE scheduling and 640 kbps minimum sustainable data rate as shown in Figure 4.

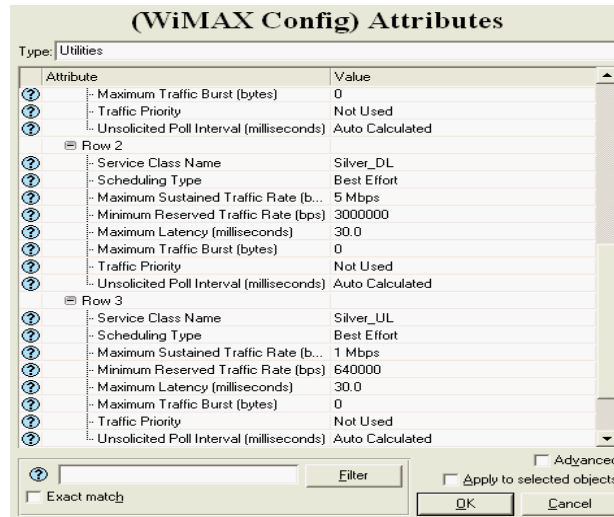


Figure 4 WiMAX Service Class Configurations

PHY layer access was configured to utilize OFDM over a 2.5 GHz base frequency with 5 MHz channel bandwidth that provisions 512 subcarriers. The client station transmit power was configured to use 33 dBm (2 watts) of transmit power using 14 dB gain antennas. The base station transmit power was configured to use 35.8 dBm (3.8 Watts) over the 5MHz channel bandwidth with 15 dB gain antenna. Moreover, a pathloss model fixed suburban (Erceg) was employed with a conservative terrain type that accounted for mostly flat terrain with light tree densities. The 2km FSS modulation and coding rates for both uplink and downlink service flows are shown in Figure 5.

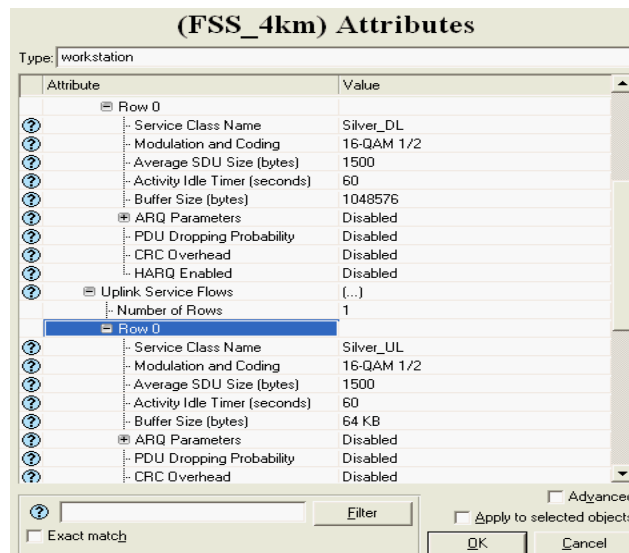


Figure 5 FSS service flow modulation and coding rates.

#### IV. Results and Discussions

In this section, the simulative investigations of different modulation techniques with different coding rates have been done to find out the optimum behavior of WiMAX network. OPNET provides a Virtual Network Environment that models the behavior of entire network. Performance of different modulation techniques with different coding rates are compared in terms of QoS parameters like delay, load, packet delay variation, traffic received and throughput.

In all figures from 6 to 10, first scenario that is blue line shows 16-QAM  $\frac{1}{2}$ , scenario 2 of red line shows 64-QAM  $\frac{3}{4}$ , and scenario 3 of green line shows 64-QAM  $\frac{1}{2}$ , scenario 4 of sky blue line shows 64-QAM  $\frac{3}{4}$ , scenario 5 of yellow line shows QPSK  $\frac{1}{2}$  and scenario 6 of pink line shows QPSK  $\frac{3}{4}$  adaptive modulation techniques. Simulation is done for 10 min. Initially up to 2m network takes time to establish connection so that packets can be transferred that's why comparison is achieved after 2m.

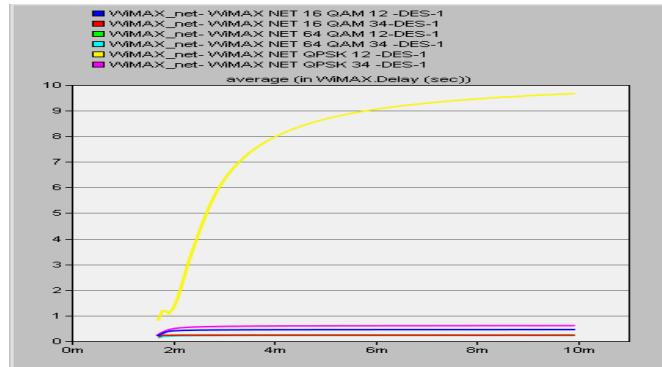


Figure 6 Comparison of average in WiMAX delay (sec)

Figure 6 represents delay which shows QPSK  $\frac{1}{2}$  has maximum delay which means it takes longer time for transmission from source to destination. 64-QAM  $\frac{3}{4}$  and 16-QAM  $\frac{3}{4}$  has minimum delay and 16-QAM  $\frac{1}{2}$  and 64-QAM  $\frac{1}{2}$  has moderate delay. It means 16-QAM  $\frac{3}{4}$  and 64-QAM  $\frac{3}{4}$  performs best.

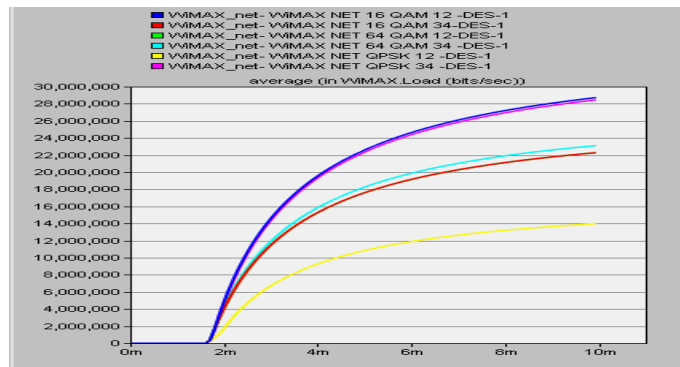


Figure 7 Comparison of average in WiMAX load (bits/sec)

Figure 7 represents load in bits/sec. Initially the load is constant for all techniques afterwards it eventually increases. Load is maximum for 64-QAM  $\frac{1}{2}$  and QPSK  $\frac{3}{4}$ , and minimum for QPSK  $\frac{1}{2}$ . 16-QAM  $\frac{3}{4}$  and 64-QAM  $\frac{3}{4}$  has moderate load.

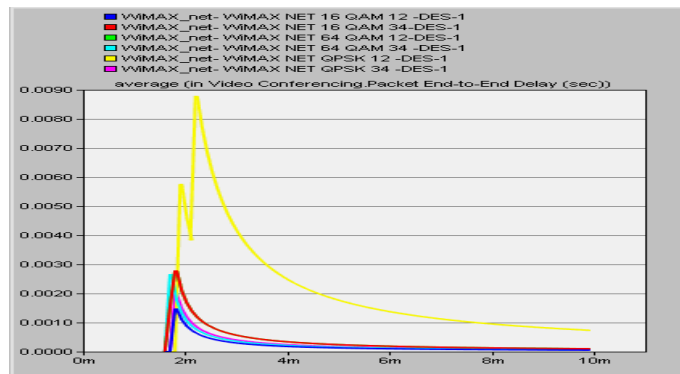


Figure 8 Comparison of Packet End to End delay (sec)

Figure 8 represents Packet End to End delay which shows end to end delay is maximum for QPSK 1/2 and 3/4 coding rate behaves almost same even though 16 QAM 3/4 and 64 QAM 3/4 has minimum delay

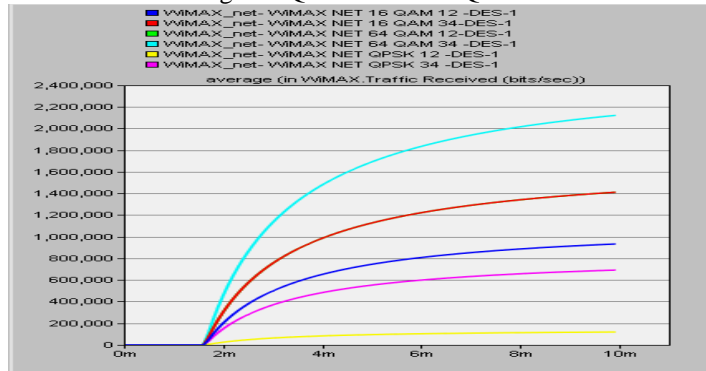


Figure 9 Comparison of Traffic Received (bits/sec)

Figure 9 represents Traffic Received which shows highest traffic is for 64 QAM 3/4 and minimum traffic is for QPSK 1/2 and all other techniques has moderate traffic received while 16 QAM 3/4 and 64 QAM 1/2 has more than 16 QAM 1/2 and QPSK 3/4.

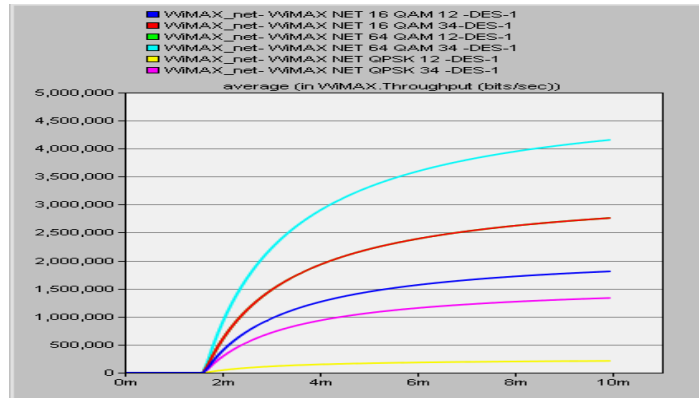


Figure 10 Comparison of average in WiMAX Throughput (bits/sec)

Figure 10 represents throughput in packets/sec. It shows throughput is maximum for 64 QAM 3/4 and minimum for QPSK 1/2. 16 QAM 3/4 and 64 QAM 1/2 has high throughput than QPSK 3/4 and 16 QAM 1/2.

Techniques/ Parameters	Delay	Throughput	Packet e2e Delay	Performance
Average Acceptable Values	< 300ms	2Mbps-5Mbps	< 60 ms	-----
16 QAM 1/2	< 100 ms	Around 2Mbps	< 20 ms	Acceptable
16 QAM 3/4	< 50 ms	Around 3Mbps	< 30 ms	Acceptable and better than 16 QAM 1/2
QPSK 1/2	1000 ms	1 Kbps	90 ms	Not Acceptable
QPSK 3/4	100 ms	Around 1.5 Mbps	20 ms	Not Acceptable
64 QAM 1/2	< 50 ms	Around 3 Mbps	< 20 ms	Acceptable
64 QAM 3/4	< 50 ms	Around 4.5 Mbps	< 30 ms	Acceptable and better than 64 QAM 3/4

Table 1 Performance Analysis

According to these values QPSK technique does have any parameter which can be acceptable while QAM techniques have acceptable values which shows that QAM techniques are much better than QPSK. Now all the comparative results shows that coding rate QAM techniques with coding rate 3/4 performs much better than QPSK technique and coding rate 1/2 in terms of QoS. So QAM techniques with coding rate 3/4 are best techniques to achieve best QoS for WiMAX network.

#### IV. Conclusion

This paper presents a comparative performance study of video streaming over WiMAX network with respect to different modulation schemes and coding rates. The performance has been evaluated in terms of average delay, average load, average traffic received, average packet End to End delay and average throughput. It has been demonstrated while using OPNET simulation. We concluded that the coding rate  $\frac{3}{4}$  and higher order modulation namely, 16 QAM and 64 QAM provide much better performance than QPSK and  $\frac{1}{2}$  coding rate.

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## Approaches to Process Performance Modelling

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**Abstract:** Project Management improves by adopting better processes models. It is vital to improved project management that efficient process models need to be developed. These processes be evaluated on continuous basis and improved with changes in operating environment and new learning. The quality metrics can be pre-identified for achieving the goals that may include delivered defect density, rejection rate, time estimation etc. In this approach to build PPM, the emphasis is on process enhancement so that efficiency can be increased rather relying fully on various components. The various process models discussed are Regression, Bayesian, Queuing, Neural networks etc. With details of theories and application areas these may be applied to.

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### I. Introduction

The CMMI defines Process Performance Model (PPM) as “relationships among attributes of a process and those of its work products. These work products are developed from historical process-performance data, and further calibrated, by using process and product output data results obtained from the project. PPMs are used for result prediction to be achieved by following a process.”

In any business case, a model on an organizational level is needed that is capable of predicting one or more business target results. This is called a process performance model and can plan and track organizational quality performance. The adoption of better PPMs helps understand or even predict the uncertainties better in CMMI Level 4 and 5 processes namely Quantitative Project Management and Qualitative Process Management. Thus it helps in reducing risk by controlling relevant process/sub-processes. Thus, PPMs are useful tools for managing projects/ processes. PPMs tools enable prediction of process performances, by Project Managers with a level of confidence as they better identify and understand risks with these tools. “What-if” analyses on PPMs enables to see impact various courses of action on their projects by varying a factor under control.

PPM models are by definition mathematical and statistical in nature. PPMs are empirical in nature and are never perfect in prediction but quite accurate to use available data and make a fair prediction about a process. The process of building PPMs involves following steps:

- Identify or Reconfirm Business Goals.
- Identify the sub-processes/process
- Identify Outcomes to Predict (y's)
- Identify Controllable factors (x's) to predict outcomes
- Include Uncontrollable x factors
- Collect Data
- Assess Data Quality and Integrity
- All data types of outcomes y and x factors needs to be identified.
- Create Process Performance Baselines (PPBs)
- Select the right analytical techniques and also type of regression equation.
- Based on analysis and make predictions with appropriate prediction intervals.
- Statistically manage sub processes with PPMs
- Take Action Based on PPM Predictions
- Maintain PPMs including calibration and reconfirming relationships

There are challenges of building PPMs due to limited quantitative data and low variability of available data. The PPM helps in predicting Quality and Process performance/ Business objectives. Once an organization decides its goals, it starts looking for PPMs

### II. Types of Models

PPMs Models can be classified as follows:

- Physical Models represent physical reality, for understanding, by scaling it down by building a prototype, for example a prototype of building.
- Mathematical Modelling involves representation of reality by a mathematical model in terms of a mathematical equation or other similar models.

- Process Modelling will have the Entire flow of Process with factors and conditions modelled to understand the bottlenecks in the process/system for correction.

### III. Process Modelling –Steps, Validation, Tools

PPMs can help in analysis whether the selected process for a project will be able to meet the project's performance objectives. A good PPM should have modelling characteristics as follows:

- PPMs can be statistical, probabilistic and simulation types that link past performance with predictable outcomes. PPM should have one or more measurable attributes. This attributes represent a controllable input to a process/sub-process and helps in monitoring performance of a process/ sub-process with “What if analysis” for planning, dynamic re-planning, problem resolution. Thus prediction accuracy of model is important.
- PPMs should give insight to predicted range of variation expected from predicted results with variation of input factors. PPMs can identify potential sources of the problems or defect. Thus calibration abilities of model have bearing on performance of model.
- Robustness and Data type of the variable and factors involved in a model have bearing on performance of the model. There is need of availability of relevant tools for building the model. Model to have ability to include all critical factors in primary data type.
- PPM should enable simulation of models and help enable finding optimization of input factors for planning process/sub-process and thus there is need for flexibility in varying factors in model.

### IV. How are PPMs Used

- Projects can use PPM for predicting the process performance after estimation and analysis of the defined processes. It can assist in selecting defects for analysis and also performance analysis for selecting processes or sub processes.
- PPMs can be used to understand the impact of improvements, related interaction of these improvement and resulting costs effect, and other benefits. They can be used to assess the ROI for process improvement work.
- PPMs help in estimation progress towards achieving planned quality for project and process performance objectives with the use of right tools. These estimates can be done in advance and not wait until a future phase of life cycle of project.
- When a sub-process is initially executed, based on prior instances of suitable data of similar sub-processes, process performance baselines or PPMs help to understand the impact/benefits of new innovations. PPMs provides insight into effect on process capability and performance due to effect of process changes. Also, PPMs can provide a means for analyzing possible effects due to effected changes to process elements

### V. Modelling Techniques in Real World

#### A) Regression based Models

Regression based process models estimate relationship in a mathematical equation among dependent and independent variables.. The model  $Y = f(x) + \text{Error}$  (unknown parameters) assumes that a sample data represents whole population, variables are random and have random errors, no correlation amongst independent variables and unknown factors represent a sub process/process, else these are a factors that affect data set, project or sample. A regression model can be developed with relevant indicators and that has characteristics of data, continuous or categorical.

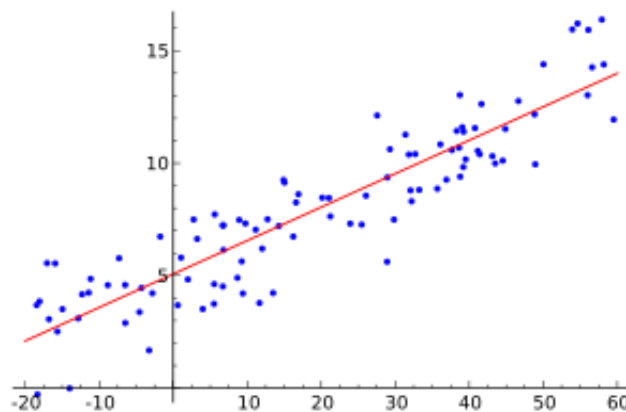


Figure 1: Illustration of linear regression on a data set.

Scatter plots amongst X versus Y helps to see if there is relationship (correlation). The coefficient of determination,  $R^2$  is a number that indicates how well data fit a statistical model, a line or curve.  $R^2$  values greater than 0.7, provides a better fit to the outcome. This explains how much the dependence Y has on X's. The fitment of model can also be checked by P values of independent variables X to be less than 0.05. This shows a significant relationship exists with Y.

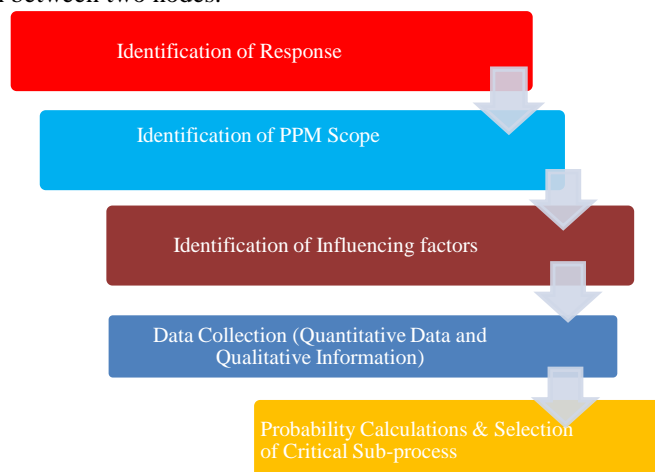
R Systems, an Indian company, developed the PPMs using this procedure for a Regression model. R Systems used ANOVA to check the homogeneity and divided the data collected in various domains and technologies. This was to understand whether there is any variance in data. R System did the following:

- Performed normality test to find the distribution of data
- Use correlation analysis between each X factor and Y. Then verify the “Coefficient of Regression”- R Square, the result was more than 80% between X and Y.

R-Systems work resulted in a multiple regression equation, with values **R-square 83.5%, R Square (Adj) 81.3%**. The p values less than **.05 at 95% confidence level**. This gives a significant model for DDD (Delivered Defect Density).

### B) Bayesian Belief Networks (BBN)

BBN is a probabilistic graphical model. BBN represents a set of variables and their probabilistic independencies (for example the probabilistic relationships between student and score). A BBN model can give quick insight into potential areas of improvements based on relevant quality factors and the current performance level of the organization. Bayesian Belief Networks (BBNs) offer another approach to modelling the quality of software products. These are probabilistic models with sets of nodes connected with arrows. These nodes represent certain relationships like: i) cause and effect ii) Without a confirmed cause and effect (probable) iii) Statistically observed correlation between two nodes.



**Figure 2: PPM Development through BBN**

In practice, BBNs can be constructed to cover a time dimension such as a life cycle. An iterative process is conducted by identifying what factors occurring just prior to the terminal child nodes, outcome might explain the child nodes. The iteration continues in that each parent node can be explained in terms of its own parent nodes occurring earlier in the life cycle.

A BBN can be an invaluable management tool by enabling a “what-if” capability during project planning, and subsequently during all processes and sub-processes in the life cycle. The discussion on Quantitative Project Management (QPM) and Organizational Process Performance (OPP) process areas for probabilistic nodal relationships leads to conclusion that BBN is ideal approach to process modelling related to these requirements. BBN is frequently used in the Causal Analysis and Resolution and also in Organizational Innovation and Deployment process areas.

In Software Process Modelling with Bayesian Belief Networks is a model usable for effort estimation/ defect prediction. With some adaptations this model can be used to estimate quality within a project, BBN model's ability to predict quality improvement at an organizational level remains unanswered question.

A Bayesian model to develop business solutions has number of merits, it takes into account prior knowledge of problem, applicable in situations with scarce failure data. This model can include decision nodes. This model can also predict situations that are new and can formally incorporate objective/subjective information.

Strengths of Bayesian model is its ability to use prior information for initial estimation and to use information as it becomes available to improve and adjust estimates. This model can predict design and test work and can be used to investigate and decide on process improvements. BBNs look promising for modelling quality on an organizational level. Some attempts have been made to build probability models for testing using BBNs.

### **C) Neural Networks**

Input/ Output nodes of a network are connected by links and hidden nodes. A human brain designs its reaction based on training simulation received by neurons under various instances/situations. A network similarly learns the input. The network produces its output, based on algorithm used and machine learning. There are number of network architecture exists, single layer, multi layer feed forward and recurrent architecture.

The network is supposed to learn and develop the patterns. Once a network learns right patterns, it reduces the overall network error. A sample data validates the network and checks the accuracy of its learning. A stable network has small learning and validation total mean squared error.

Normally continuous variable are used, however with new tools discrete data is also supported. Artificial Neural Networks is based on black box technique. In this approach inputs are used to determine the outputs, and normally no mathematical relationships can be defined between Input and Output. This approach gives better results than linear models.

If in a Modelling of manufacturing processes it is possible to define set of relationships which relate input and outputs of the process, then these descriptions are very useful in terms of optimization and controlling of the process. This is true for manufacturing problems related to process control, process optimization, system design and system planning. Artificial neural networks are thus a computational tool used in artificial intelligence for modelling manufacturing processes.

### **D) Reliability Modelling**

The ability to perform at designed level of a software product, without any failure, indicates its reliability under execution. The scale 0 to 1 is used to measure reliability of any product or activity. In software product development processes, technique known as Reliability Modelling is used. This can be used for defect prediction based on arrival of defects, in each phase of development. The technique can be also be used for testing pattern of arrival of defects. In warranty defect analysis and also forecasting reliability.

Reliability can be time-dependent and also is non- time dependent. In first case time is an important measure as the occurring defects wear out with time. The defect occurs by executing faulty codes or programs in certain time frame and recorded as and when they occur. This concept is much in use in IT industry for MTTR to know Incident Arrival Rate, etc.

Reliability models normally have distribution curve of defects the shape of which reduces from peak to a lower flatter trajectory. The curve most commonly used is Weibull, logistic, small extreme value to fit in probability distributions. It is possible that each phase of software development may have different probability distributions. The defect data is measured in terms of number of defects in a period (ex: 15 /30/45 per day) or time difference of defect arrival (ex: 20, 35, 50 minutes. The PDF, CDF (Probability and Cumulative Distribution Function) are tools to understand the pattern of defects. Pre-Queuing system entity enables the creation of demand on arrival that is to be served by limited resources of the system. The discrete events in the system are managed by its resources at any given point in time. The model captures time stamps of different discrete events and models their variation with the queue system. This model can used to understand the resource utilization of servers, idle time, bottlenecks in the system events, etc.

Reliability Modelling is used in IT Industry for application maintenance, incident and problem handling. This is also applicable in cases involving Standard change Requests or contexts where the arrival rate of defects and team size is important factor for delivery on time.

### **E) Queuing Process Modelling**

Queuing theory approach is applied to different types of problems, such as scheduling, resource allocation, and traffic flow. Queuing system model results in entity arrival that creates demand. This demand is to be serviced by limited resources assigned to the system. The Queuing system manages its resources to service various events at any given point in time. Queuing system is dependent on arrival of elements, utilization of servers, wait time/time spent in the system flows. It helps to understand the resource utilization of servers, bottlenecks in the system events, and idle time, etc.

In software Industry Queuing system can be simulated for use in application maintenance, incident/problem handling. This is also applicable in dedicated service teams /functions (ex: technical review team, Procurement). This model is applicable in a situation requiring standard change request, in which the arrival rate and team size has significance, in delivering on time. Queuing system modelling involves understanding of the tool "Process model".

**Setting up flow:** The actual flow of activities and resources in a system needs to be mapped and make a graphical flow and verify it. The distribution of time, arrival pattern of entities, input and output queue for each entity, resource capacity and assignment should be known. These can be solved by Time motion study for the first time. Once System knows pattern of entity arrival then by just adding storage the entities will be retained till resolution. Resources can be given in different shifts, by use of necessary functions and describing various scenarios. Their conditions of service can be changed to meet the real conditions.

**Simulation:** Simulation process is carried out to predict the outcomes of proposed queuing process. Replication of the simulation process can be carried out over a time period. The simulation results are displayed as output. Simulation reports can be customized by addition of new metrics and formulas. A Simulation situation can be run with or without animation. The output summary refers to idle time of entities or waiting time in queue. This is important area to work on process change and improve the condition. If there is no Hot Spot or idle time of entities, then there is need to study the activities with High Mean or Standard deviation or both of individual activities. These are critical sub processes to control.

**Optimization:** It is important to check that the system replicates the real life condition by comparing actual value with predicted values. This difference should be less than 5 %. It is desired to find the best combination of resource assignment along with different activities. The earlier defined scenarios are going to be the control factors and a certain range is provided in the tool (LSL and USL). The optimization is performed, with default value of convergence, simulation length left undisturbed. The tool looks at different combination of values with existing system. It selects the one which meets best our target, these values can be made use of in composition of processes (resource skill, activity and time taken etc).

#### **F) Fuzzy Logic**

Fuzzy Logic is a way of representation of a of problem expressed in a language with different variables that are fuzzy/vague in terms of their value, to take decisions. The variables do not have sharp boundaries in Fuzzy set theory and it permits overlapping. In Fuzzy systems membership values of fuzzy set are in 0 to 1 range with 0 for false value and 1 for absolute truth.

Fuzzy set theory is different from normal set theory for it allows each element of the given set belongs to that set to some degree between some value 0 to 1. For example if a person's skill index is 4.8 and we have two group which contains skill 3.4 to 5 and another group which contains 4.6 to 6. Member is part of both the groups with varying degrees, in this case. This shows the Fuzziness. This needs to understood that this is not probability but certainty with varying degree of membership in a group.

In Fuzzy logic the problem description in language is translated to the mathematical solution determined by Fuzzy rules. Fuzzy logic model use Fuzziness of data (overlapping values) in software problems, and mathematical/stochastic relationship determine the solution. Monte Carlo simulation is partially based on Fuzzy logic concepts.

#### **G) Monte Carlo simulation**

Monte Carlo methods are a class of computational algorithms that rely on repeated random sampling to obtain numerical results. Monte Carlo Simulation allow, modelling of variables that are uncertain in a range of values. The model is useful in predicting outcomes and is increasingly used.

- Monte Carlo simulation enables a detailed calculation of the potential business results for candidate improvement proposals. Since only the identified areas are calculated in detail, the lead time toward a business case is shortened significantly. This helps a company to make quicker decisions when improving quality.
- This helps in more accurate sensitivity analysis and enables analysis in simultaneous effects of many different uncertain variables.
- User-provided values are included in analysis for uncertain variables.
- The above results in confidence in a model output as it supports risk management.

Monte Carlo simulation shows the distribution of the outcome factors (child nodes) based on the certain and uncertain parent nodes. Monte Carlo simulation tools use random number generators to select a value for each parent node from the parent node's distribution and then compute the outcome child node. This step is repeated thousands, if not hundreds of thousands, of times so that a distribution of values for the child node is formed. The distribution for each child node can be used in Monte Carlo simulation for any successive child nodes of the child node. Additionally, the Monte Carlo simulation provides distributions for all child nodes such that a confidence level can be established for any given value of the child node. This proves quite helpful in using results from Monte Carlo simulation in project forecasting, business case development for process improvement, and risk management.

## **VI. Conclusion**

The solution to any problem is inherent in its definition and parameters governing the solution. A manufacturing engineer knows the quality of product produced at the shop depends not only on the design but also production process available at the site. Similarly in software solution it is possible to think parallel that efficient solutions will emerge based on the process selected. The selection of a particular project process model depends upon the nature of problem and quantum of data available. A model must yield actual results as closely as possible to the predicted result. In our approach to paper, suggestions have been given of various process models. The ability of engineer to pick up the best suitable model for the defined problem will lead to desired

efficient solution. Regression model thus will be applicable to problems with a defined relationship between variables impacting the solution in larger proportion. Bayesian Model will be appropriate where prior information of data related to a variable that impacts significantly on the posterior information which is basis of our solution.

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## Determining of the resonant transverse oscillations of a beam fixed at one end

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**Abstract:** Methods to determine own resonant transverse oscillations of a beam fixed at one end have been investigated. The beam is viewed as a system of parameters. The resonant frequencies have been defined both theoretically and experimentally and a comparison between them has been made. The obtained results can be used to determine (the modulus) of elasticity of the tested beam. The experimental measurements were made with an electromagnetic vibration table.

**Keywords:** beam; transverse vibrations; modulus of elasticity

### I. Introduction

Oscillation processes play an important role in engineering. According to their physical nature oscillations can be divided into mechanical, thermal and electrical. As it is well known, the following types of oscillations can be further distinguished - free continuous oscillations, freely dying oscillations, induced oscillations, parametric oscillations, self-excited oscillations, etc. Regardless of their type they are defined by the same physical laws and properties. Quite frequently oscillation processes in engineering are a sum of free oscillations, which makes the study of the latter extremely important in practice. Such oscillations are the lateral oscillations of a beam, a bar or a strip fixed at one end. These oscillations are used not only in engineering but also in some musical instruments like harmonica, xylophone and tuning fork

### II. Presentation

When we consider a real beam we should take into account both its inertial and elastic properties. That's why we should take into consideration the mass and the elasticity of the beam. This makes the beam a complex system with a large number of variables, where the position of each part of the beam during its movement in space is defined by individual coordinates.

The aim of this article is to explore methods of determining the natural frequencies of free, lateral oscillations of a beam fixed at one end; to create graphs to demonstrate the relationship between the natural oscillations and the length and thickness of the beam; to compare the theoretical and experimental curves.

The lateral oscillations of a beam are normally caused by the elastic bending strains. They are defined by a partial-differential equation. For the solution of the equation to be one-valued the respective initial and boundary conditions are used. The differential equation of free lateral oscillations of straight prismatic beams with distributed mass is worked out by using dynamic force analysis. It is known from theory that the differential equation of the elastic line is as follows:

$$EI \frac{\partial^2 y}{\partial x^2} = M_b \quad (1)$$

where  $I$  is the geometric inertia moment of the beam;  $E$  – modulus of elasticity;  $y=y(x,t)$  - deflection,  $M_b$  – bending moment.

$$\text{The dependency } q = \frac{\partial^2 M_b}{\partial x^2} \quad (2)$$

is used when spread load with intensity  $q(x,t)$  is present.

With free lateral oscillations the intensity of the lateral oscillations is determined by the apparent forces

$$q = S\rho \frac{\partial^2 y}{\partial t^2} \quad (3)$$

where  $S$  is the cross sectional area,  $\rho$  – the density of the material.

The condition of a prismatic beam is  $S=const$  and  $I=const$ . Double differentiating of (1) in relation to  $x$  and comparing (1), (2) and (3) results in

$$\frac{EI}{S\rho} \frac{\partial^4 y}{\partial x^4} + \frac{\partial^2 y}{\partial t^2} = 0 \quad (4)$$

Equation (4) defines free lateral oscillations of a straight prismatic beam. It is a linear, homogenous, partial-differential equation with constant coefficients. Its solution is of the type:

$$y(x, t) = X(x).T(t) \tag{5}$$

where  $X(x)$  is function, which depends of  $x$ ;  $T(t)$  is function, which depends of  $t$ .

The displacement and the angle of inclination at the built-in end are equal to zero. The following boundary conditions are derived:

$$X(0) = 0 \text{ and } \frac{\partial X}{\partial x}(0) = 0 \tag{6}$$

for the built-in end

$$X(\ell) = 0 \text{ and } \frac{\partial X}{\partial x}(\ell) = 0 \tag{7}$$

for the free end.

For the natural frequencies of the lateral oscillations of a beam fixed at one end the following expression is derived:

$$f_i = 0,046(2i - 1)^2 \frac{\pi^2 h}{4\ell^2} \sqrt{\frac{E}{\rho}} \quad i = 1, 2, 3, 4, \tag{8}$$

where  $h$  is the thickness of the beam and  $\ell$  is the length of the beam.

For the first three natural frequencies of the lateral oscillations of a beam fixed at one end the following expression is derived

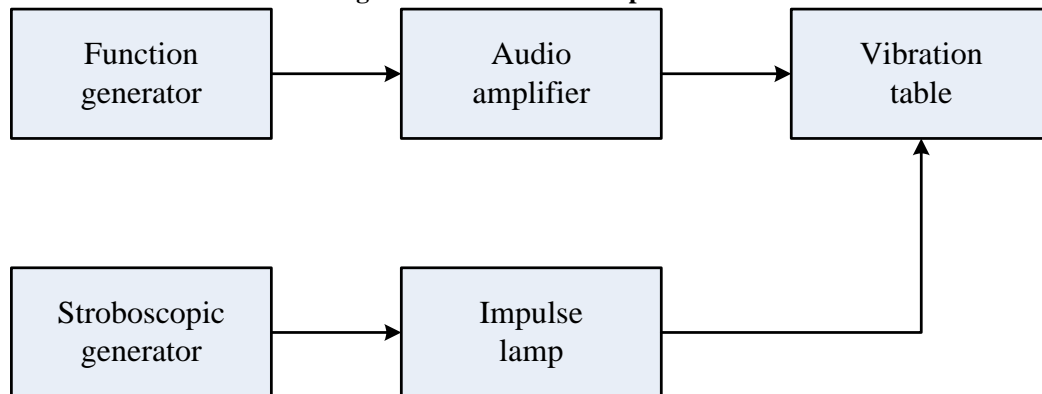
$$f_1 = 0,046 \frac{\pi^2 h}{4\ell^2} \sqrt{\frac{E}{\rho}} \tag{9}$$

$$f_2 = 0,046 \frac{9\pi^2 h}{4\ell^2} \sqrt{\frac{E}{\rho}} \tag{10}$$

$$f_3 = 0,046 \frac{25\pi^2 h}{4\ell^2} \sqrt{\frac{E}{\rho}} \tag{11}$$

### III. Scheme of the experiment and tasks

Figure 1 Scheme of the experiment



The sample is fixed on the vibrating table and the frequency of oscillations is changed by function generator while the beam begins to vibrate with maximum amplitude – until a resonance is achieved. The frequency of the blink of the pulse lamp of the stroboscopic generator changes until the image of the beam becomes stationary. Then the frequency is given from the stroboscopic generator.

**The following tasks are to be accomplished:**

- IV. To determine the relationship between the natural oscillations of a beam fixed at one end and its length –  $f = f(\ell)$  and to check it with the theoretical relationship  $f_{theor} = f(\ell)$ .**

Determine the relationship  $f_1 = f_1(\ell)$  for the first natural frequency of a steel beam with the following characteristics:

modulus of elasticity  $E = 3,12 \cdot 10^{11} \text{ N/m}^2$ ;  
 density  $\rho = 7,74 \cdot 10^3 \text{ kg/m}^3$ ;  
 thickness  $h = 2,80 \text{ mm}$ .  
 Experimental results:

**Table 1**

$\ell$ , mm	265	250	235	220	205	190	175	160
$f_{l,e}$ , Hz	29,1	32,7	37,0	42,2	48,6	56,5	66,6	79,5
$f_{l,t}$ , Hz	28,7	32,3	36,5	41,7	48,0	55,9	65,9	78,8

Determine the relationship  $f_1 = f_1(\ell)$  for the first natural frequency of a synthetic resin- bonded paper beam with the following characteristics:

modulus of elasticity  $E = 2,19 \cdot 10^{10} \text{ N/m}^2$ ;  
 density  $\rho = 1,294 \cdot 10^3 \text{ kg/m}^3$ ;  
 thickness  $h = 3,00 \text{ mm}$ .  
 Experimental results:

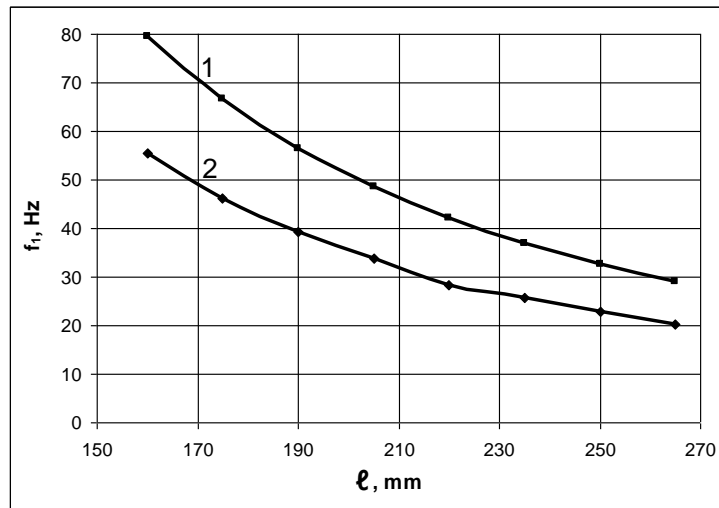
**Table 2**

$\ell$ , mm	265	250	235	220	205	190	175	160
$f_{l,e}$ , Hz	20,3	22,8	25,8	28,4	33,8	39,4	46,3	55,4
$f_{l,t}$ , Hz	19,9	22,4	25,4	28,9	33,3	38,8	45,7	54,7

From Table 1 and Table 2 shows that the experimental dependence  $f_1 = f_1(\ell)$  for a beam of steel and synthetic resin- bonded paper hardly differs from the theoretical.

Fig. 2 presents graphs of the dependence  $f_1 = f_1(\ell)$  for steel and synthetic resin- bonded paper.

**Figure 2** Graphs of the experimental dependence  $f_1 = f_1(\ell)$ : 1 – for steel; 2 – for synthetic resin- bonded paper.



**V. To determine the relationship between the natural oscillations of a beam fixed at one end and its thickness –  $f = f(h)$  and to check it with the theoretical relationship  $f_{theor} = f(h)$ .**

Determine the relationship  $f_1 = f_1(h)$  for the first natural frequency of a steel beam with the following characteristics:

modulus of elasticity  $E = 3,12 \cdot 10^{11} \text{ N/m}^2$ ;  
 density  $\rho = 7,74 \cdot 10^3 \text{ kg/m}^3$ ;  
 length  $\ell = 250 \text{ mm}$ .  
 Experimental results:

**Table 3**

$h$ , mm	2,20	2,40	2,60	2,80	3,00	3,20	3,40	3,60
$f_{l,e}$ , Hz	25,0	27,2	29,4	31,7	34,1	36,4	38,6	40,9
$f_{l,t}$ , Hz	25,4	27,7	30,0	32,3	34,6	36,9	39,2	41,5

Determine the relationship  $f_1 = f_1(h)$  for the first natural frequency of a synthetic resin- bonded paper beam with the following characteristics:

modulus of elasticity  $E = 2,19 \cdot 10^{10} \text{ N/m}^2$ ;  
 density  $\rho = 1,294 \cdot 10^3 \text{ kg/m}^3$ ;

length  $\ell = 250$  mm.  
 Experimental results:

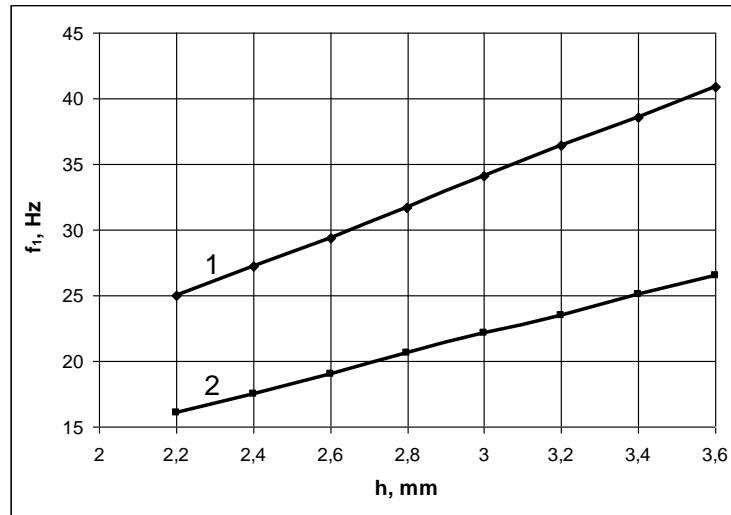
**Table 4**

$h$ , mm	2,20	2,40	2,60	2,80	3,00	3,20	3,40	3,60
$f_{1e}$ , Hz	16,1	17,5	19,0	20,6	22,1	23,5	25,1	26,5
$f_{1t}$ , Hz	16,4	17,9	19,4	20,9	22,4	23,9	25,4	26,9

From Table 3 and Table 4 shows that there is good correlation between experimental and theoretical results of dependence  $f_1 = f_1(h)$  for steel and synthetic resin- bonded paper beams.

Fig. 3 presents graphs of the dependence  $f_1 = f_1(h)$  for steel synthetic resin- bonded paper.

**Figure 3** Graphs of the experimental dependence  $f_1 = f_1(h)$ : 1 – for steel; 2 – for synthetic resin - bonded paper.



The beams used are made of steel and synthetic resin - bonded paper. The modulus of elasticity can be determined by means of obtained experimental results and the following equation:

$$E = \frac{f_i^2 l^4 \rho}{k_i^2 0.046^2 h^2} \quad (12)$$

where  $k = (2i - 1)^2$

## VI. Conclusion

The proposed analytical method for determining the resonance frequencies of transverse oscillations of a beam fixed at one end gives results that are very close to the experimentally obtained. The system in figure 1 can be used for measuring resonant frequencies of more complex parts which would be difficult to determine by means of analytical methods.

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## Simulation of Invisible Image Watermarking

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**Abstract-** Data security is an important issue these days. From small companies to big MNCs and government organization, data security and secure data transmission is a prime requirement. There are numerous methods and algorithms for encryption but we are focusing on digital image watermarking. Watermarking is the processes of hiding data in an image in which an image is transmitted by hiding it into another image. This process is also known as image cryptography. The motive is to present this process using LSB algorithm for invisible image watermarking in which the hidden image cannot be seen by any observer or eavesdropper. The paper will initially present brief aspects of a network, network security and various attacks on network that can steal our information and after that watermarking will be introduced with the simulation performed in MATLAB.

**Key Terms** LSB, Data encryption, Watermarking

### I. INTRODUCTION

Data needs to be encrypted to protect from various security issues and attacks to maintain integrity and restrict access. There are various methods of data encryption or secure data encryption and one of those methods is Digital Image Watermarking. Digital Image watermarking combines the concept of Image processing with that of cryptography and it is also known as image cryptography. In Digital Image Watermarking we will hide one image (data image) into another image (cover image) and compare them on the basis of their histogram [1] [2]. We will also see that normal vision would not be able to distinguish between watermarked image and non-watermarked image. Our algorithm will include the hiding of an image into another image and retrieving the image in the form of binary image after addition of the channel noise.

Normal encryption schemes are known as Disk encryption schemes generally operating on 512 byte data sectors which can be individually encrypted or decrypted using cipher mode like CRC or cyclic redundancy check[3]. However sometimes data is needed to be accessed through the middle of the disk alone itself and its not feasible then to decrypt or encrypt depending on previous or successive sectors[4][5].

Disk encryption can be attacked by using watermarking attack in which an attacker can detect any encrypted. This attack make it look weaker and newer and well as older disk encryption programs, are now deprecated loop [6][7].

In an active attack, the attacker tries to bypass the security or break into secured system environment. This can be done through hacking, stealth, viruses, worms, or by using Trojan horses i.e. backdoor. In active attacks an attacker attempts to break or overcome protection features, to introduce or write malicious code, theft or modification of existing information [8][9].

### II. LITERATURE REVIEW

#### A. Methodology

The paper is simulation based paper and simulation has been performed using MATLAB R2013b software package developed by Mathworks Inc. Matlab is an acronym for Matrix Laboratory working on interactive programming environment[10][11]. It is a very wide application tool with its domains of simulation ranging from Image Processing, signal processing to biomedical simulation. It consists of standard libraries LINPACK and EISPACK consisting of support functions files in .m format which is the file extension for matlab script files. Matlab can take any data in form of matrix from 1 dimensional arrays to 2 dimensional matrix. It works very well with numerical data and the presence of graphical output is also available to supplement numerical results.

Our project uses Image processing applications and tools of Matlab. Matlab uses built in adaptors for accessing devices like USB cameras or Webcam for accessing realtime image captures.

Filtering is a technique for modifying, or enhancing an image. For example, you can filter an image to emphasize certain features, or remove other features. Image processing operations can be implemented with filtering, it includes smoothing, sharpening, and edge enhancement[12][13]. Filtering is a neighborhood operation, in which the value of any given pixels in a output image is determined by applying some algorithm to the expected values of the pixels in the neighborhood of the corresponding input pixels.

#### B. Background Study

Data needs to be encrypted from various security issues, and attacks to maintain the integrity, and access control. There are various methods of data encryption or secure data encryption and one of those methods is a

Digital Image Watermarking. In this paper, we are presenting the process of a Digital Image Watermarking using LSB watermarking algorithm. In this we will hide one image (data image) into the another image (cover image) and compare them on the basis of their histograms. We will also see that the normal vision would not be able to distinguish between the watermarked image and

Image processing means converting an image into its digital form by analyzing it in pixel form and perform various operations on it. Matlab takes an image as input and open it as 2D matrix and then various characteristics like its histogram and intensity can be processed. It is very rapid growing technology in present era with its applications reaching various domains from research industry to security and multimedia and communications.

#### **B.1. What can be done by Image Processing ?**

- Transformations in an image such as enlargement, reduction, and rotation.
- Color corrections in an image such as adjustments in brightness, conversion to different color formats like grayscale to RGB or to binary format.
- Registration or alignment of two or more than two images.
- Segmenting an image into various regions.
- Editing Images and providing Retouch and many more functions

#### **B.2. Applications:-**

The application of image processing varies within various spheres. Some of them are listed below:

- Satellite Image Processing
- Medical Imaging
- Face detection and Recognition,
- Biomedical
- Microscope image processing
- Cryptography

### **III. WATERMARKING**

Watermarking is the process in which data in digital form is hidden in a cover image or signal. In invisible image watermarking, a message image is hidden under cover or carrier image [14][15]. The message or the data image is known as watermark as it is hidden. This particular type of digital image watermarking is also termed as invisible image watermarking. It is prominently used for tracing copyright infringements and also used for bank notes authentication. The Watermark is also applied to visible media like image or a videos, whereas the signal or the carrier can be in any form like audio, pictures, video or text. A signal or a carrier is capable of carrying different types of watermark at the same period of time. The phenomenon of such watermarking scheme is shown in figure 1 and is known as visible image watermarking and its drawback is that it degrades the quality of image [16][17].

A. What is a watermark?

A watermark usually is a visible embedded overlay on an image in digital format which could be a form of text, a logo, or digital form of copyright notice. The main purpose of a watermark is to identify the work and prevent its unauthorized use [18][19]. However a visible watermark can't prevent unauthorized use but it do makes it difficult for those who may want to steal and claim someone else's piece of work as their own [20].



Fig 1: Watermark Copyright

Our proposal involves invisible image watermarking. It is not the new phenomenon. Over One thousand years, the watermark on a paper has been used for a particular brand [21][22]. In a modern time, it is getting more and more important to provide authenticity as more of a worlds information is stored, as readily transferable

bits. Digital watermarking is therefore, an important process, where arbitrary information, is encoded into an image in such a way that the additional payload is imperceptible to the image observer. Hence Digital Watermarking technology is also involved with the large numbers of image processing algorithms, and also the mathematical tools [23][24]. If we use only ordinary programming tool to implement the functions of algorithm and modulation, it is very difficult. Therefore, using a high- performance science, and engineering calculation software is also very important [25] [26].

Watermarking your images and photos is an important part of protecting your online photos and images. The amount of image theft on the Internet and the growing attitude of people that everything is free for the downloading and copy paste is actually exploding the speed of the thefts. Also with the increase in technology, tools for image repairing are available which are making it even easier to remove watermarks. This justifies the need of watermark with complex algorithms. The complex here doesn't mean to create watermark but it should be made tough for the image processing software to remove the watermarks. [27][28][29].

#### **A.1. Types of Watermarking**

There are several ways of classification of digital watermarking techniques:

##### **On the basis of Robustness**

-Fragile Watermarking: When a watermark fails to be detected even after the slightest modifications, the scheme of watermarking is known as fragile watermarking. These are used for tamper detection.

-Semi fragile Watermarking: When a digital watermarking resists benign transformations, but fails its detection after the transformations.

-Robust Watermarking: A digital watermarking scheme is called robust if it can resist a designated class of transformations.

##### **On the basis of Perceptibility**

-Imperceptible: When the original cover image and the marked signal are perceptually indistinguishable, the watermarking scheme is known as imperceptible watermarking

-Perceptible: When the presence of the watermark can be noticed, the watermarking scheme is known as perceptible.

##### **On the basis of Capacity**

-Zero Bit Long Watermarking: When the message is conceptually with the length of zero bit and is designed to detect whether the watermark is present or absent over the marked object, the watermarking scheme is known as zero bit long watermarking. This is also known as 1 bit scheme because the value 1 denotes the presence of the watermark and the value 0 denotes the absence of the watermark.

-Non zero bit watermarking: in this scheme unlike the above mentioned scheme, the message is n bit long stream.

##### **On the basis of Embedding method**

-Spread Spectrum: If the marked signal is obtained by an addition modification, watermarking scheme is known as Spread spectrum watermarking. They are more robust but have low information capacity.

-Quantization Type: If the digital marked signal is obtained by the process of quantization, watermarking is known as quantization type. It has low robustness but high information capacity.

-AM Watermarking: When the mark signal is obtained by additive modification which is similar to the spread spectrum watermarking method but is embedded in the spatial domain.

#### **B. DIGITAL WATERMARKING VS OTHER TECHNIQUES**

The main basic difference between the digital watermarking and the other technologies are [30][31][32]:

- i. The encryption watermarking is imperceptible, so, the image will not be detracting from the aesthetic sense.
- ii. If the works are displayed, or converted into any other file formats, the watermarks will not be eliminated anymore.
- iii. The watermark have exactly the same information, as information of transformation.
- iv. A wide variety of techniques have been proposed, but it is very complex to measure their quality.

#### **C. APPLICATIONS OF DIGITAL WATERMARKING**

There are various applications of digital watermarking. Some of them are following [33][34]:

- i. Protection of copyrights
- ii. Source tracking
- iii. Monitoring Broadcast
- iv. Video authentication

#### **IV. ALGORITHM AND SIMULATION**

In addition, algorithm is partitioned into couples of ways; watermark embedding algorithm, and the watermark extraction algorithm. The watermarking embedding is composed of 3 steps:

- Processing Key
- Embedded algorithm

- Watermarked pre-processing  
Same way the extractions are also composed of 3 steps:

- Processing Key
- Algorithm Extraction
- Inverse watermark transformation

The above steps will be implemented in an Image Processing Tool known as MATLAB. Coding and Simulation will be done according to the MATLAB syntax. For the ease of understanding we are mentioning the step wise working of LSB Watermarking Scheme.

**Step 1:-** Read cover object (image) you want to use for Watermarking.

**Step 2:-** Read the message image (Data) you want to hide in the cover image.

**Step 3:-** Spread the images value on 256 gray-scale (for better efficiency).

**Step 4:-** Determined the size of the cover image and message object used for Watermarking.

**Step 5:-** Set the LSB of cover object to the value of the MSB of watermark.

**Step 6:-** add noise to watermarked image.

**Step 7:-** write to file the two images.

**Step 8:-** use LSB of watermarked image to recover watermark.

**Step 9:-** scale the recovered watermark.

**Step 10:-** scale and display recovered watermark.

The simulation has been performed on MATLAB. We took 2 images, one is the cover image and other one is the watermark. Our aim is to hide the watermark inside a cover image. The Figure 2 is the cover image and figure 3 is showing its histogram. The figure 4 is our watermark image which we want to hide in cover image i.e. figure 4 is to be hidden in figure 2



Figure 2 Cover Image

We took 2 images, one is the cover image and other one is the watermark. Our aim is to hide the watermark inside a cover image. The Figure 2 is the cover image and figure 3 is showing its histogram. The figure 4 is our watermark image which we want to hide in cover image i.e. figure 4 is to be hidden in figure 2.

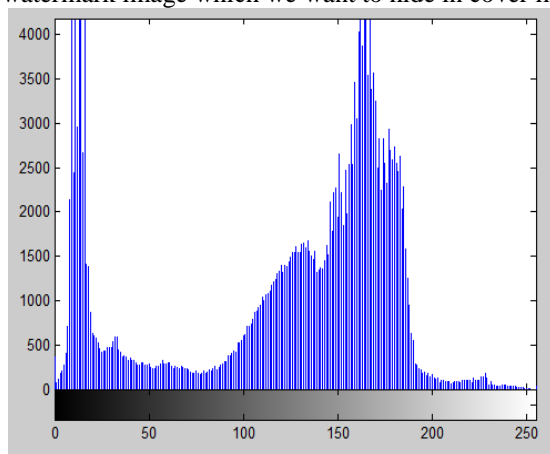


Figure 3 Histogram of the Cover Image



Figure 4 Watermark Image

The outcome of the LSB invisible image watermark algorithm is the figure 5 which is the watermarked image i.e. image in the figure 4 has been properly inserted in the image in figure 2. In the figure 5 i.e. the watermarked image we cannot see any watermark or the presence of watermark, this is because we are working on invisible

image watermarking, however in image i.e. visible image watermarking, watermark was clearly shown in the image that also degrades the quality of the image.

On looking at figure 2 and figure 5 together, there seems no difference as such. Normal human vision may not be able to recognize that the image has been watermarked, however if we look in to the histogram of the same image which is shown in figure 6, we can see the differences clearly.



Figure 5 Watermarked Image

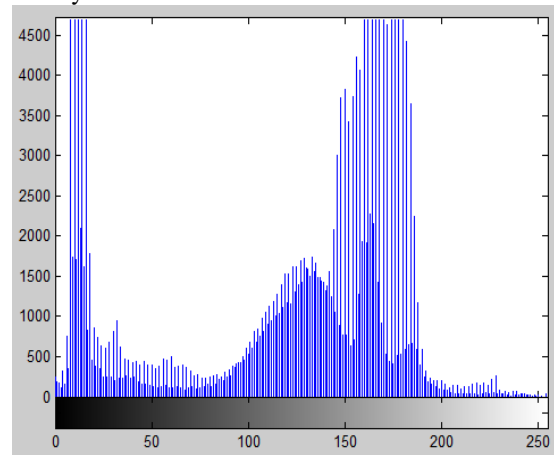


Figure 6 Histogram of the Watermarked Image

On comparison of histogram in figure 2 and figure 6 of figure 2 and figure 5 respectively only we can show the differences between watermarked and non-watermarked images.



Figure 7 Received watermarked Image at the destination (noisy)

The above is the received image at the destination with the addition of noise as it occurs in communication channel and below is the recovered watermarked image.

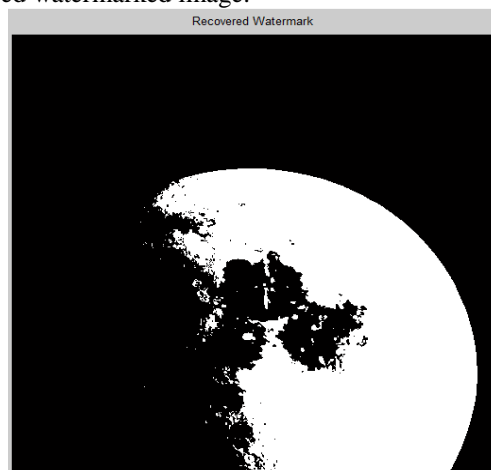


Figure 8 Recovered Watermark in Binary Form

## V. CONCLUSION

Digital Image Watermarking is a new and merging area of research. A large variety of watermarking techniques is currently available in the literature. It mainly deals with adding hidden messages or copyright notices in digital image. These watermarks, however, are not perfect and more could be done to improve a watermark's robustness or accuracy in detection. This paper shows the stepwise process of invisible image watermarking which will be easy to understand whoever read this and will serve as a base paper for understanding the concept for the new researchers. There are lots of other technologies for Digital Image watermarking which will be discussed in future works

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## A Progressive Software Project Management Maturity Model (PSPM<sup>3</sup>) for GCC countries

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**Abstract:** Software project management is a field of paramount importance as billions of dollars are lost each year due to project failure. It plays a vital role in any IT company. Many universal project management methodologies and procedures are in place. It has been noted that there are some developing countries where traditional software project management aspects are irrelevant. The scope of this research is an instance of the Gulf Cooperation Council (GCC) countries. A customized software project management maturity model has been proposed to provide a complete solution for all the problems faced by the IT projects in these countries. A couple of surveys conducted in GCC evaluate the need for an indigenous software project management methodology as well as lead to finalization of the key process areas (KPAs) that need to be incorporated in the proposed project management model (PSPM<sup>3</sup>). PSPM<sup>3</sup> is an outcome of the response received by software professionals and project managers. PSPM<sup>3</sup> provides us with a basic, flexible and significant approach for the management of software projects across GCC. In particular, PSPM<sup>3</sup> emphasizes on the key aspects of economic, cultural, social, legal, political impacts those are of huge significance while rating the success factors for the software projects. The model is simple, robust and easy to follow.

**Keywords:** Software Project Management; Maturity Model; Key Process Areas, Gulf Cooperation Council, PSPM<sup>3</sup>- Progressive Software Project Management Maturity Model

### I. Introduction

The concept of projects is not new. History has proven records that the projects like The Egyptian Pyramids, The Great Wall of China are very successful deliverables showcasing the highest level of intricacy and meticulous project management methodology. According to Jason (2003), "A Project management methodology can also be defined as a process that documents a series of steps and procedures to bring about the successful completion of a project [1]". Many universal project management methodologies and procedures are in place. The concepts of project management put forward by western world are not universally applicable.

It has been noted that there is another part of the globe where traditional software project management aspects are irrelevant. One such instance is the Gulf Cooperation Council (GCC). GCC is a political and economic union of the Arab states bordering the Persian Gulf and located on or near the Arabian Peninsula, namely Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates [2].

The software industry in GCC is growing rapidly. Many foreign software companies like Infosys and Accenture have opened branches in different GCC countries. These companies have expertise in software project development and management. Common project management methodologies like Capability Maturity Model Integration (CMMI), Project Management Body of Knowledge (PMBOK®), Projects integrating Sustainable Methods (PRiSM), PRINCE 2® have not been widely accepted by GCC software development companies. In fact, some of these companies lack in following any of the formal project management methodologies.

The solution to all the problems mentioned above is to develop a customized software project management methodology / model that can cater the challenges faced by the software projects in GCC countries. The proposed research is significant in terms of its usability in the project management in these countries. The successful implementation of the proposed model can help the software project success rate to improve tremendously. This can work as a catalyst to improve the country's economy, hence adding value to the overall world economy.

### II. Traditional project management methodologies/models/standards

The evidence of project management dates back to the Egyptian Pyramids (2500 B.C.) and [3] Great Wall of China (221 - 206 B.C.). The software industry saw a major boom in 1980. The various existing project management methodologies are explained below:

- **PMBOK** is a simple process model for project management. It takes care of the procurement management aspects of the project. It also identifies the need for human resource management and acquisition of team members with adequate soft skills [6]. However, PMBOK does not cater the features of configuration management and change control.

- **Euro method** focuses majorly at the contractual level of the project management. It provides a realistic approach towards decision making. However, the voluminous size of the documentation is a pitfall. Also, the name itself discourages the companies outside the European Countries to use it. The name in itself sounds that it has been developed keeping in mind the European standards of project management [7]. Due to this reason, the name has been changed to Information Services Procurement Library.
- **BS6079:1996** guidelines have been developed to suffice the requirements of small to medium sized companies. Finance Management and control has been the focal point under these guidelines [8]. However, it is intended to help the engineering companies in general rather than the IT companies in particular.
- **ISO 12207** is an international standard for software lifecycle processes, their development and maintenance. The standard constitutes of 23 Processes, 95 Activities, 325 Tasks and 224 Outcomes [9]. However, it does not specify how to perform the activities and the tasks related to the processes. Moreover, the sheer size of the documentation in itself is a drawback. This standard is useful in the larger arenas where project management activities play a vital role during the overall costing of the project. For smaller projects, to implement this standard in itself is a tedious task.

### III. Evaluation of Software Project Management Maturity in GCC countries

A software project management maturity model is a good perspective from which one can determine the process framework. If an organization adopts the framework with conviction and implements it appropriately, then the organization can achieve highest level of maturity in no time. It has been proven that there is a direct connection between software project management maturity and the success/ failure of an organization [10]. Also, a relation between maturity and success was proven by Sonnekus and Labuschagne (2004). That is why, it is advisable to maintain the maturity level of an organization and strive for the improvement of the same as that will directly impact the success rate of that sector.

An exercise was carried out by Sonnekus and Labuschagne (2004) in the South Africa [10] by distributing questionnaires to IT companies to evaluate their project management maturity level. Similar survey has been carried out in GCC countries to understand the level of project management maturity.

#### A. Research Methodology

Data collection was carried out during 2014 by issuing questionnaires to companies involved in software development in GCC. The companies were selected as per list of companies registered in GCC and published on the Website of directory of gulf network [11].

#### B. Analysis of Survey Data

The following twelve knowledge areas were framed for software development projects:

- Integration management.
- Scope management.
- Time management.
- Cost management.
- Quality management.
- Human resource management.
- Communications management.
- Risk management.
- Procurement management.
- Configuration management.
- Defect Prevention
- Security management.

The above knowledge areas were mapped onto five maturity levels based on the trend in most of the globally recognized project management maturity models.

The description of all the maturity levels was provided in the first section of the questionnaire and the respondents were requested to judge the overall maturity of the organizations based on that. An average value was calculated to acquire the maturity level of GCC software development organizations. Also, the maturity level of each knowledge area was calculated individually to analyse the strong and weak areas in the field of software development. An average value was computed from the results. It was observed that there was a minor overestimation by companies/individuals in the assessment of maturity levels.

#### C. Maturity Level by Process Groups

Each knowledge area was subdivided into a number of processes and was mapped onto the basic five process groups:

- Initiating
- Planning
- Executing

- Controlling
- Closing

The data so collected were further analysed and the results are summarized below:

**Table I Average maturity levels by process groups**

Knowledge areas and processes	Initiating	Planning	Executing	Controlling	Closing
<b>Integration Management</b>					
Plan Development		2.85			
Plan Execution			2.75		
Integrated Change Control				2.13	
<b>Scope Management</b>					
Initiation	3.29				
Scope Planning		3.29			
Scope Definition		2.96			
Scope Verification				2.79	
Scope Change Control				2.21	
<b>Time Management</b>					
Activity Definition		3.13			
Activity Sequencing		2.75			
Activity Duration Estimating		2.96			
Schedule Development		2.58			
Schedule Control				2.06	
<b>Cost Management</b>					
Resource Planning		3.48			
Cost Estimating		3.46			
Cost Budgeting		3.29			
Cost Control				2.54	
<b>Quality Management</b>					
Quality Planning		2.92			
Quality Assurance			2.46		
Quality Control				2.50	
<b>Human Resource Management</b>					
Organizational Planning		3.38			
Staff Acquisition		3.00			
Team Development			2.88		
<b>Communications Management</b>					
Communications Planning		3.33			
Information Distribution			3.13		
Performance Reporting				3.00	
Administrative Closure					2.96
<b>Risk Management</b>					
Risk Identification		2.46			
Risk Quantification			2.42		
Risk Response Development			1.75		
Risk Response Control				1.79	
<b>Procurement Management</b>					
Procurement Planning		3.17			
Solicitation Planning		2.88			
Solicitation			3.13		
Source Selection			2.63		
Contract Administration				3.04	
Contract Closeout					2.54
<b>Configuration Management</b>					
Configuration Planning		2.67			
Quantitative Configuration Analysis			2.50		
Configuration Control				2.13	
<b>Project Defect Prevention</b>					
Plan Defect Prevention		2.46			
Causal Analysis			1.92		
Defect Elimination and Control				1.79	
<b>Project Security Management</b>					
Plan Security Management		2.46			
Security Response Development			1.96		
Security Response Control				1.67	
<b>Average for each process group</b>	<b>3.29</b>	<b>2.97</b>	<b>2.50</b>	<b>2.30</b>	<b>2.75</b>

Almost all the process groups attained an average maturity level between 2 and 3 (last row of table I), other than initiation process group that achieved maturity level closer to initial range of 3. Therefore, it can be stated that GCC software development companies emphasize the most on the Initiation phase, which involves formal

announcement of the project, nomination of the project manager and kick off for the project. The survey result show that the GCC software development companies deal with factors like culture, politics, gender, climate, legal and economy at maturity level 2. Progress to the next level (Level 3) would certainly be desirable.

**D. Ladder towards the development of PSPM<sup>3</sup>**

It was identified that the proposed maturity model should be framed with a maximum of three (1 to 3) maturity levels. A set of continuous improvement process areas were also identified. All the key process areas were categorized into various maturity levels.

**Table II Classification of Key Process Areas for PSPM<sup>3</sup>**

	Respondents classification of KPAs at the different levels				Total no of respondents	Percentage response
	Level 1	Level 2	Level 3	Progressive		
Integration Management	3	2	4	5	1	100%
Scope Management	7	1	1	5	1	100%
Time Management	8	2	0	4	1	100%
Cost Management	9	2	0	3	1	100%
Quality Management	4	6	2	1	1	93%
Human resource Management	3	2	2	7	4	100%
Communication Management	3	5	2	3	1	93%
Risk Management	3	6	2	3	1	100%
Procurement Management	2	3	7	1	1	93%
Configuration Management	3	4	6	1	1	100%
Defect Prevention	2	2	6	4	1	100%
Security Management	4	3	1	6	1	100%
Environmental Management	11 out of 14 respondents mentioned that a KPA is essential that can take care of economic, cultural, political aspects of project management.					79%

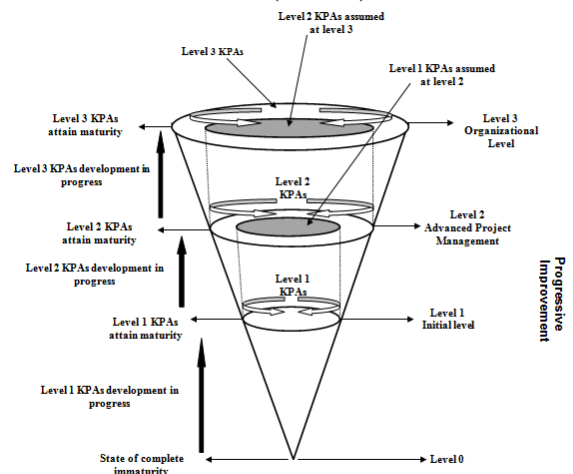
**IV. Progressive Software Project Management Maturity Model (PSPM<sup>3</sup>)– The Model**

PSPM<sup>3</sup>- the name in itself suggests that the proposed model strives to progress continuously to attain the project management maturity. Based on the combined survey and interviews conducted by Koul et al, and considering the preference of the companies in developing countries like GCC, it seems to be appropriate to have a maturity model with three levels.

The conceptual framework of the proposed model adopts the structure of a cone. At the apex of the cone, lies the level 0. This is the initial level where the organizations are considered to be immature with no processes or key process areas in place. Software development is carried out in ad-hoc manner at this level. The level 1, level 2 and level 3 KPAs are represented as sectors on the concentric base of the cone structure.

The progressive key process area group spans over all the maturity levels of PSPM<sup>3</sup>. Since, many key process areas are identified that have a relevance at all the three maturity levels, they are placed together and represented as progressive key process area group.

**Fig I Conceptual Representation of Progressive Software Project Management Maturity Model (PSPM<sup>3</sup>)**



## V. Conclusion

The main focus of this chapter was to find out the problems faced by the GCC nations in the field of information technology and also various obstacles that come across in delivering successful software solutions. GCC nations are steadily rising up global ICT rankings that indicate how well each country's economy is positioned to grow and benefit from the oncoming wave of the knowledge economy, 'Smart City' initiatives and tech innovations. Therefore, software project management is believed to play a key role in the development of the software deliverables. A detailed research done earlier has confirmed time and again that the traditional software project management maturity models that exist are not suitable for developing countries in general [4]. This was reconfirmed by the survey that was conducted by Koul et al (2014). The response of the survey affirmed that there is a need to develop a native software project management maturity model for GCC countries. PSPM<sup>3</sup> is an outcome of the response received by software professionals and project managers.

PSPM<sup>3</sup> provides us with a basic, flexible and significant approach for the management of software projects across GCC. It demonstrates a progressive improvement structure that is required to result in successful IT projects. The strengths and weaknesses of software projects have been kept in mind while framing the various KPAs. It consists of a total of 9 KPAs at three different levels and a set of progressive key process area group. In particular, PSPM<sup>3</sup> emphasizes on the key aspects of economic, cultural, social, legal, political impacts that are of huge significance while rating the success factors for the software projects. The model is simple, robust and easy to follow.

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## Quality Assessment of Encrypted Color Image in a D-BLAST aided LDPC encoded SC-FDMA Wireless Communication System

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**Abstract:** In this paper, we made a comprehensive study to evaluate the performance of LDPC encoded SC-FDMA Wireless Communication System on secure color image signal transmission. The 4-by-4 multi antenna supported SC-FDMA system incorporates various signal detection techniques such as Minimum mean square error (MMSE), Zero-Forcing (ZF), Zero-Forcing successive interference cancellation (ZF-SIC) Minimum mean square error successive interference cancellation (MMSE-SIC) and digital modulation schemes such as QPSK, QAM and DQPSK. It is observable from MATLAB based simulations that the system shows quite satisfactory and robust performance under scenario of ZF-SIC signal detection and QAM digital modulation schemes.

**Keywords:** SC-FDMA, LDPC, Signal detection scheme, SNR, D-BLAST

### I. Introduction

Over the last two decades, a significant expansion in mobile and cellular technologies is observable to meet up the increasing demand for high data rate transmissions. Single-carrier frequency division multiple access (SC-FDMA), a modified form of orthogonal frequency division multiple access (OFDMA), has been adopted as the uplink physical layer radio access technique for the 3GPP Long Term Evolution (LTE) and 4G LTE-Advanced. The SC-FDMA system has attracted much attention due to its low PAPR with exploitation of advantage of the OFDMA system in combination with DFT spreading prior to the OFDMA modulation stage. The main advantages of the SC-FDMA system are that the envelope fluctuations are less pronounced and the power efficiency is higher than that of the OFDMA system. The wireless communication systems equipped with multiple transmitting and receiving antennas in perspective of SC-FDMA Implementation and cooperative systems is a very promising way to achieve large spectrum efficiency and capacity of mobile communication systems [1],[2].

The use of multiple input multiple output (MIMO) technique with utilization of multiple transmit and receive antennas are adopted in various Commercial wireless standards such as IEEE 802.11n (WiFi), IEEE 802.16e (WiMAX), HSPA+ (Enhanced HSPA), LTE (3.9G), LTE-Advanced (4G) and 802.11ac (Enhanced 802.11n). Such standards incorporate different types of multi-antenna techniques such as Alamouti space-time coding for transmit diversity, Eigen beam forming spatial multiplexing, BLAST spatial multiplexing architectures, Conventional beam and null forming and Conventional receive diversity. Under BLAST spatial multiplexing (SM) architectures, three Bell Laboratory layered space-time (BLAST) SM techniques have been known as: Vertical BLAST (V-BLAST), Horizontal BLAST (H-BLAST) and Diagonal BLAST (D-BLAST) [3],[4]. The present study investigates the performance of D-BLAST architecture with 4 x 4 antenna configuration for a LDPC encoded SC-FDMA wireless communication system on secure color image transmission .

### II. Review of Signal Processing Techniques

We assumed that the color image is preprocessed in channel coding, interleaving, digital modulation, time domain to frequency domain and frequency domain to time domain signaling, spatial multiplexing (SM) encoding prior to transmission through a MIMO fading channel. The received signal  $\mathbf{Y} \in \mathbb{C}^{4 \times 243324}$  in terms of channel matrix  $\mathbf{H} \in \mathbb{C}^{4 \times 4}$ , transmitted signal  $\mathbf{X} \in \mathbb{C}^{4 \times 60831}$  and additive white Gaussian noise (AWGN)  $\mathbf{N} \in \mathbb{C}^{4 \times 243324}$  with a variance of  $\sigma_n^2$  can be written as

$$\mathbf{Y} = \mathbf{H}\mathbf{X} + \mathbf{N} \quad (1)$$

In Minimum mean square error (MMSE) based signal detection scheme, the MMSE weight matrix is given by

$$\mathbf{W}_{\text{MMSE}} = (\mathbf{H}^H \mathbf{H} + \sigma_n^2 \mathbf{I})^{-1} \mathbf{H}^H \quad (2)$$

Where  $(\cdot)^H$  denotes the Hermitian transpose operation and the detected desired signal  $\tilde{\mathbf{X}}_{\text{MMSE}} \in \mathbb{C}^{4 \times 60831}$  from the transmitting antenna is given by

$$\tilde{\mathbf{X}}_{\text{MMSE}} = \mathbf{W}_{\text{MMSE}} \mathbf{Y} \quad (3)$$

In Zero-Forcing (ZF) signal detection scheme, the ZF weight matrix is given by

$$\mathbf{W}_{\text{ZF}} = (\mathbf{H}^H \mathbf{H})^{-1} \mathbf{H}^H \quad (4)$$

and the detected desired signal  $\tilde{\mathbf{X}}_{\text{ZF}} \in \mathbb{C}^{4 \times 60831}$  from the transmitting antenna is given by

$$\tilde{\mathbf{X}}_{\text{ZF}} = \mathbf{W}_{\text{ZF}} \mathbf{Y} \quad (5)$$

In Zero-Forcing successive interference cancellation (ZF-SIC) signal detection scheme, the channel matrix  $\mathbf{H}$  is decomposed into a  $4 \times 4$  orthogonal matrix  $\mathbf{Q}$  and a  $4 \times 4$  upper triangular matrix  $\mathbf{R}$  and Equation (1) is multiplied with  $\mathbf{Q}^T$  to provide a modified form of received signal  $\bar{\mathbf{Y}} \in \mathbb{C}^{4 \times 243324}$  as:

$$\bar{\mathbf{Y}} = \mathbf{Q}^T \mathbf{Y} = \mathbf{Q}^T \mathbf{H} \mathbf{X} + \mathbf{Q}^T \mathbf{N} = \mathbf{R} \mathbf{X} + \mathbf{N} \quad (6)$$

In Equation (6),  $\mathbf{Q}^T \mathbf{N}$  is denoted by  $\mathbf{N}$  as the statistical properties of both component are identical. Neglecting noise component and considering a single time slot, the transmitted four signals  $\tilde{\mathbf{X}}_1, \tilde{\mathbf{X}}_2, \tilde{\mathbf{X}}_3$  and  $\tilde{\mathbf{X}}_4$  in terms of four received signals  $\bar{\mathbf{Y}}_1, \bar{\mathbf{Y}}_2, \bar{\mathbf{Y}}_3$  and  $\bar{\mathbf{Y}}_4$  and the components of matrix  $\mathbf{R}$  are estimated from solving the following matrix equation

$$\bar{\mathbf{Y}}[:,1] = \begin{bmatrix} \bar{\mathbf{Y}}_1 \\ \bar{\mathbf{Y}}_2 \\ \bar{\mathbf{Y}}_3 \\ \bar{\mathbf{Y}}_4 \end{bmatrix} = \begin{bmatrix} \mathbf{R}_{1,1} & \mathbf{R}_{1,2} & \mathbf{R}_{1,3} & \mathbf{R}_{1,4} \\ 0 & \mathbf{R}_{2,2} & \mathbf{R}_{2,3} & \mathbf{R}_{2,4} \\ 0 & 0 & \mathbf{R}_{3,3} & \mathbf{R}_{3,4} \\ 0 & 0 & 0 & \mathbf{R}_{4,4} \end{bmatrix} \begin{bmatrix} \tilde{\mathbf{x}}_1 \\ \tilde{\mathbf{x}}_2 \\ \tilde{\mathbf{x}}_3 \\ \tilde{\mathbf{x}}_4 \end{bmatrix} \quad (7)$$

$$\tilde{\mathbf{x}}_4 = \frac{\bar{\mathbf{Y}}_4}{\mathbf{R}_{4,4}}, \quad \tilde{\mathbf{x}}_3 = \frac{(\bar{\mathbf{Y}}_3 - \mathbf{R}_{3,4} \tilde{\mathbf{x}}_4)}{\mathbf{R}_{3,3}}, \quad \tilde{\mathbf{x}}_2 = \frac{(\bar{\mathbf{Y}}_2 - \mathbf{R}_{2,3} \tilde{\mathbf{x}}_3 - \mathbf{R}_{2,4} \tilde{\mathbf{x}}_4)}{\mathbf{R}_{2,2}} \quad \text{and} \quad (8)$$

$$\tilde{\mathbf{x}}_1 = \frac{(\bar{\mathbf{Y}}_1 - \mathbf{R}_{1,2} \tilde{\mathbf{x}}_2 - \mathbf{R}_{1,3} \tilde{\mathbf{x}}_3 - \mathbf{R}_{1,4} \tilde{\mathbf{x}}_4)}{\mathbf{R}_{1,1}}$$

In Minimum mean square error successive interference cancellation (MMSE-SIC) scheme, the extended  $8 \times 4$  channel matrix  $\hat{\mathbf{H}}$  and the extended  $8 \times 243324$  received signal  $\hat{\mathbf{Y}}$  in terms of  $4 \times 4$  identity and  $4 \times 243324$  null matrices are given by

$$\hat{\mathbf{H}} = \begin{bmatrix} \mathbf{H} \\ (\sqrt{\sigma_n^2}) \mathbf{I}_{4 \times 4} \end{bmatrix} \quad (9)$$

$$\hat{\mathbf{Y}} = \begin{bmatrix} \mathbf{Y} \\ \mathbf{0}_{4 \times 243324} \end{bmatrix} \quad (10)$$

on QR decomposition of  $\hat{\mathbf{H}}$ , a  $8 \times 8$  orthogonal matrix  $\hat{\mathbf{Q}}$  and a  $8 \times 4$  upper triangular matrix  $\hat{\mathbf{R}}$  are

produced. Equation (14) is multiplied with  $\hat{\mathbf{Q}}^T$  to provide a modified form of received signal  $\hat{\hat{\mathbf{Y}}} \in \mathbb{C}^{8 \times 243324}$  with neglected noise component

$$\hat{\hat{\mathbf{Y}}} = \hat{\mathbf{Q}}^T \hat{\mathbf{Y}} = \hat{\mathbf{Q}}^T \hat{\mathbf{H}} \mathbf{X} = \hat{\mathbf{R}} \mathbf{X} \quad (11)$$

Considering a single time slot, the transmitted four signals  $\hat{\hat{\mathbf{X}}}_1, \hat{\hat{\mathbf{X}}}_2, \hat{\hat{\mathbf{X}}}_3$  and  $\hat{\hat{\mathbf{X}}}_4$  in terms of four received

signals  $\hat{\hat{\mathbf{Y}}}_1, \hat{\hat{\mathbf{Y}}}_2, \hat{\hat{\mathbf{Y}}}_3$  and  $\hat{\hat{\mathbf{Y}}}_4$  (First through Fourth rows of  $\hat{\hat{\mathbf{Y}}}$  and neglecting other

row data) and the components of matrix  $\hat{\mathbf{R}}$  in first through fourth row) can be obtained from a matrix equation as:

$$\hat{\mathbf{Y}}[(:,1)] = \begin{bmatrix} \hat{\mathbf{Y}}_1 \\ \hat{\mathbf{Y}}_2 \\ \hat{\mathbf{Y}}_3 \\ \hat{\mathbf{Y}}_4 \\ \hat{\mathbf{Y}}_5 \\ \hat{\mathbf{Y}}_6 \\ \hat{\mathbf{Y}}_7 \\ \hat{\mathbf{Y}}_8 \end{bmatrix} = \begin{bmatrix} \hat{\mathbf{R}}_{1,1} & \hat{\mathbf{R}}_{1,2} & \hat{\mathbf{R}}_{1,3} & \hat{\mathbf{R}}_{1,4} \\ 0 & \hat{\mathbf{R}}_{2,2} & \hat{\mathbf{R}}_{2,3} & \hat{\mathbf{R}}_{2,4} \\ 0 & 0 & \hat{\mathbf{R}}_{3,3} & \hat{\mathbf{R}}_{3,4} \\ 0 & 0 & 0 & \hat{\mathbf{R}}_{4,4} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \hat{\mathbf{X}}_1 \\ \hat{\mathbf{X}}_2 \\ \hat{\mathbf{X}}_3 \\ \hat{\mathbf{X}}_4 \end{bmatrix} \quad (12)$$

Using identical formulas presented in Equation (8), the transmitted signals are detected [5],[6].

### III. System Description

A simulated single-user 4 x 4 D-BLAST spatially multiplexed LDPC encoded SC-FDMA Wireless Communication System as depicted in Figure 1 utilizes various signal detection schemes. In such a communication system, a color image is encrypted with Chaos-Based Image Encryption Scheme [7].

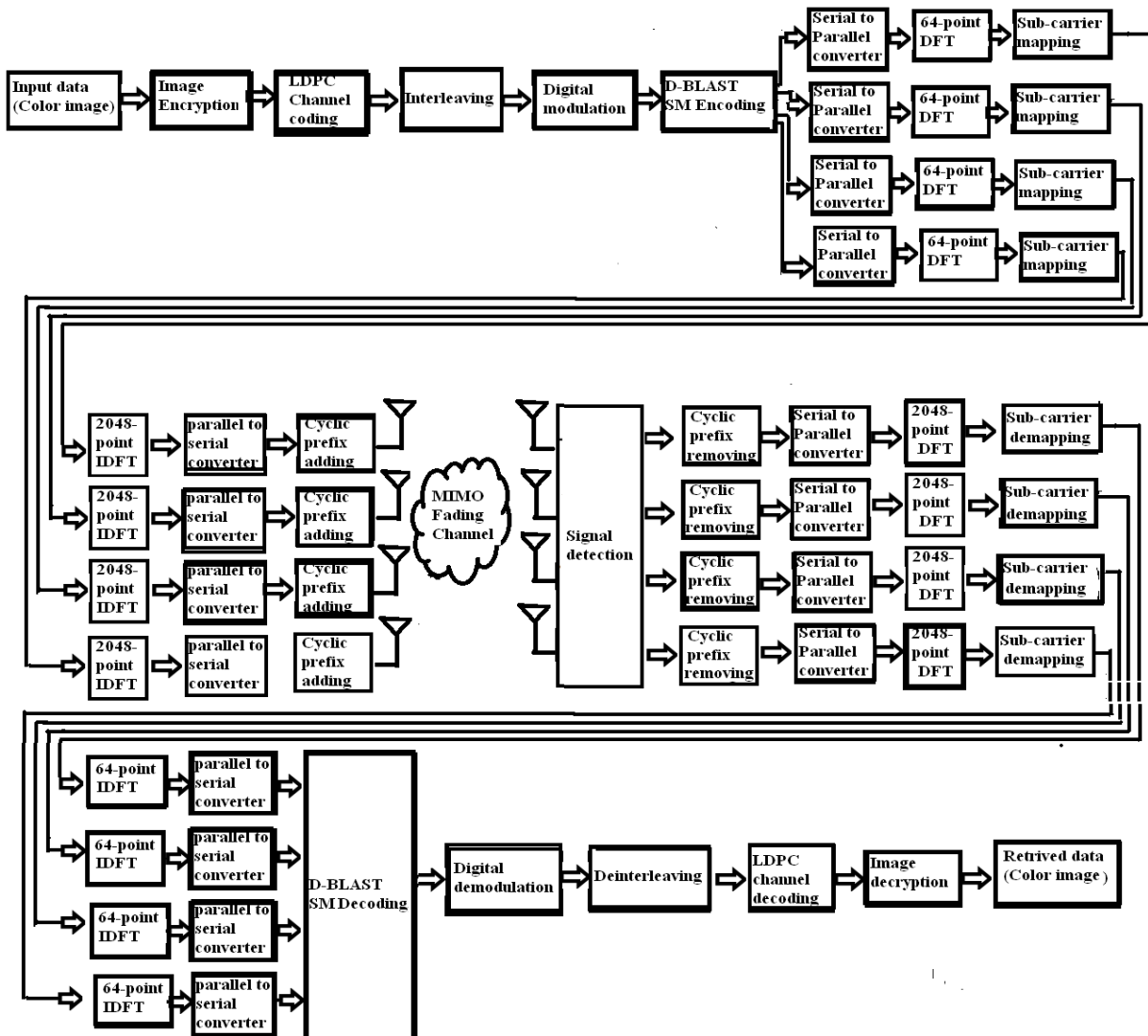


Figure 1: Conceptual Block diagram of D-BLAST aided LDPC encoded SC-FDMA Wireless Communication System

The encrypted data are channel encoded using low density parity check coding technique [8],[9] and interleaved for minimization of burst errors. The interleaved bits are digitally modulated using various types of digital modulations and spatially multiplexed using D-BLAST scheme to produce four independent data streams. Each data stream are serial to parallel converted, DFT-spreaded/precoded for enabling a low PAPR and subsequently subcarriers are mapped prior to OFDM modulation. The modulated complex symbols are cyclically prefixed, parallel to serial converted and transmitted. In receiving section, the transmitted signals are detected and processed cyclic prefix removal, serial to parallel conversion, OFDM demodulation, subcarrier demapping, DFT-despreaded/decoded, parallel to serial conversion and subsequently spatially demultiplexed under D-BLAST scheme. The demultiplexed data are digitally demodulated, deinterleaved, channel decoded and decrypted to recover the transmitted color image [10],[11].

#### IV. Result and Discussion

In this section, a series of simulation results have been presented graphically to illustrate the significant impact of various signal detection and merely LDPC channel coding techniques on reliable extraction of color image from a noisy and distortion producing channel. The simulation study has been made using **MATLAB 2014a** based on the parameters given in Table 1. In Figure 2, it is observable that the system performance is well defined and quite satisfactory under consideration of ZF-SIC signal detection and QAM digital modulation schemes. At a typical signal to noise ratio( SNR) value of 1dB, the estimated BER values are 0.0467, 0.049, 0.0236 and 0.0465 in case of MMSE,ZF, ZF-SIC and MMSE-SIC signal detection viz. the system performance improvements are 2.964049 dB, 2.793343 dB and 2.945409 dB respectively in ZF-SIC as compared to MMSE,ZF and MMSE-SIC. In case of identical signal and noise power, the rate of noise contamination in terms of bit error rate is 11.11 % for QAM and ZF-SIC. In Figure3, it is noticeable that the system performance is almost identical in QPSK digital modulation.

**Table 1 Summary of the Simulated Model Parameters**

Data type	Color image: 96 × 96× 3 pixels
Channel coding	½.-rated irregular LDPC
No of complex modulated symbols in OFDM block	2048
No of complex modulated symbols in DFT-spreading/precoding	64
Size of parity-check matrix used in LDPC coding	64 × 128
Length of Cyclic prefixing in number of complex symbols	205
LDPC decoding Algorithm	Log Domain Sum-Product
Data Modulation	QPSK, DQPSK and QAM
Signal detection	Minimum-mean-square-error(MMSE) , Zero-Forcing (ZF), Zero-Forcing successive interference cancellation(ZF-SIC) and Minimum mean square error successive interference cancellation(MMSE-SIC)
Channel	AWGN and Rayleigh
Signal to noise ratio, SNR	0 dB- 5 dB

and other signal detection schemes. At zero dB, the noise contamination in terms of bit error rate is 15.00 % for QPSK and ZF-SIC which is comparatively greater than the case of QAM and ZF-SIC adaptation. In Figure 4, the performance gap between different signal detection scheme and DQPSK modulation is almost negligible. In DQPSK, the system performance has been detected to be a worst case as compared to other QAM and QPSK. At 0dB, the noise contamination in terms of bit error rate is found to have a value of 25.89 % for DQPSK and ZF-SIC which is significantly high. In Figure 5, the transmitted, encrypted and retrieved images have been presented under consideration of a typically assumed SNR value of 5dB. The estimated bit error rate is zero and image retrieval with transmitted image encryption are quite satisfactory. In Figure 6, the histograms of RGB to Gray converted transmitted, encrypted and retrieved color images at SNR value of 5dB have been presented. It is quite evident from the presented histograms that the transmitted and retrieved image is highly correlated and the encrypted image is highly uncorrelated with other images. The majority of the pixels have their grayscale values ranging from 80 -200 in case of transmitted and retrieved images. In case of gray converted encrypted image, a wide distribution of pixel values ranging from 5-250 is noticeable. In Figure 7, 3-dimensional shaded surface with contour plot for RGB to Gray converted transmitted, encrypted and retrieved images are shown which ratifies that the presently considered simulated system is quite acceptable for secure data transmission.

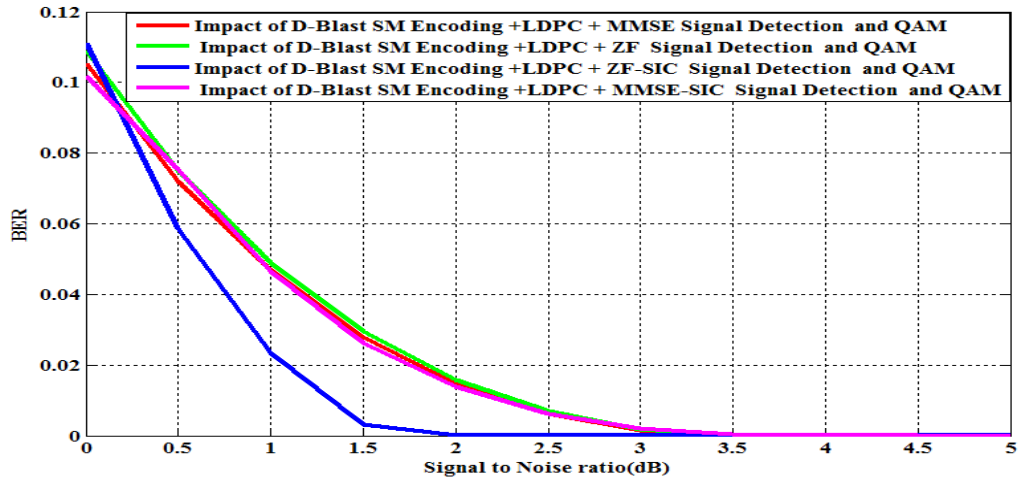


Figure 2: BER performance of a D-BLAST aided LDPC encoded SC-FDMA Wireless Communication System with implementation of various signal detection and QAM digital modulation scheme

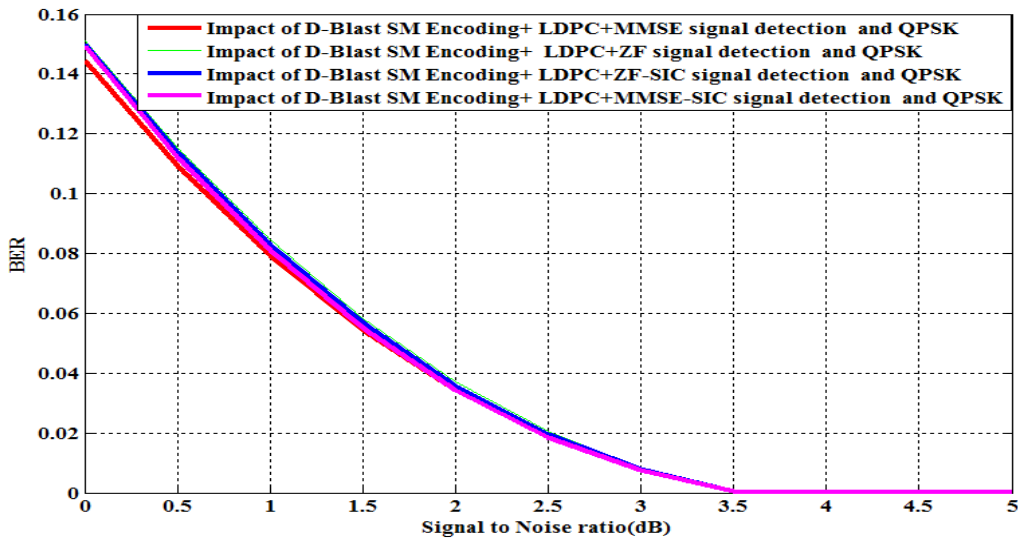


Figure 3: BER performance of a D-BLAST aided LDPC encoded SC-FDMA Wireless Communication System with implementation of various signal detection and QPSK digital modulation scheme

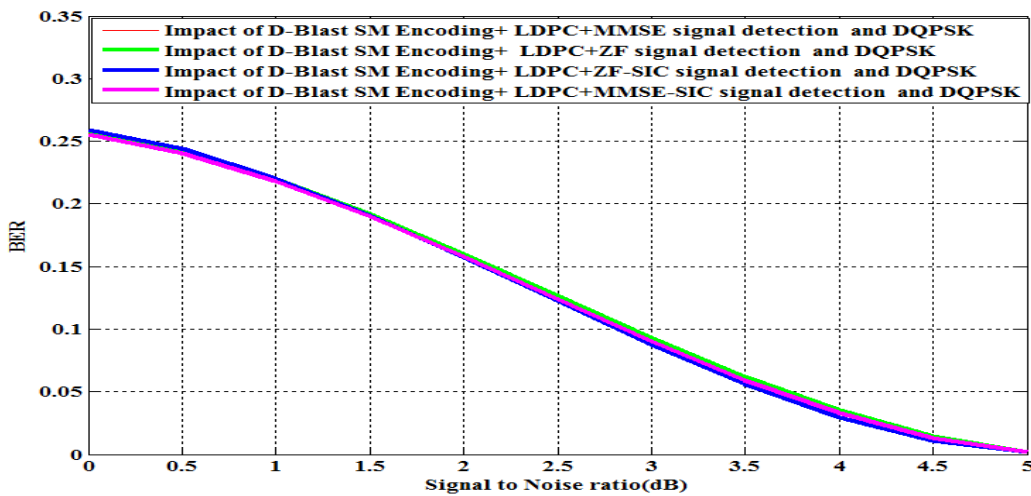


Figure 4: BER performance of a D-BLAST aided LDPC encoded SC-FDMA Wireless Communication System with implementation of various signal detection and DQPSK digital modulation scheme

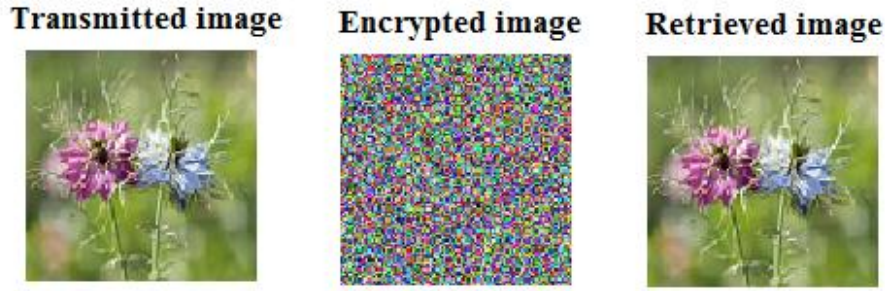


Figure 5: Pictorial views of transmitted , Encrypted and Retrieved image in a simulated D-BLAST aided LDPC encoded SC-FDMA Wireless Communication

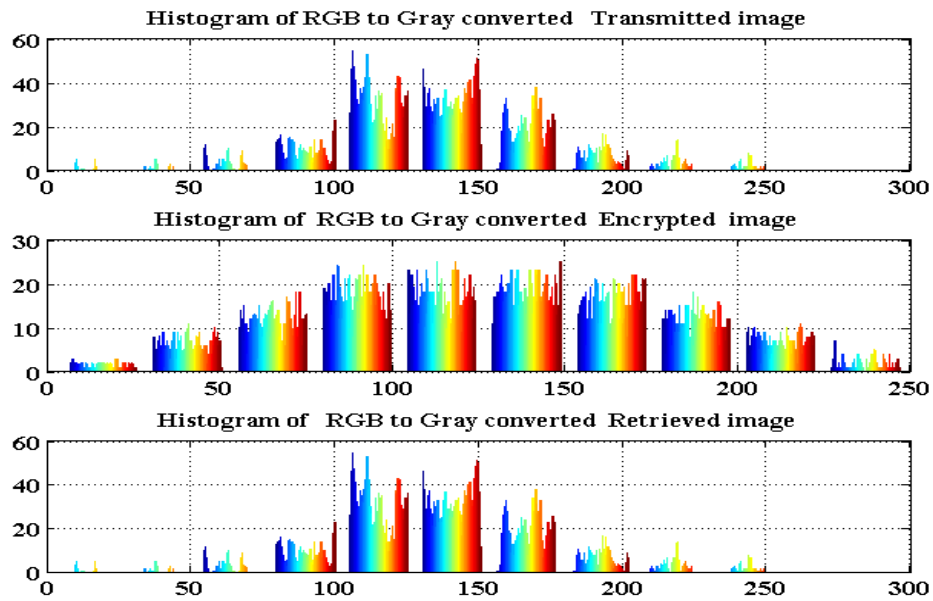


Figure 6: Histograms of transmitted, Encrypted and Retrieved image in a simulated D-BLAST aided LDPC encoded SC-FDMA Wireless Communication

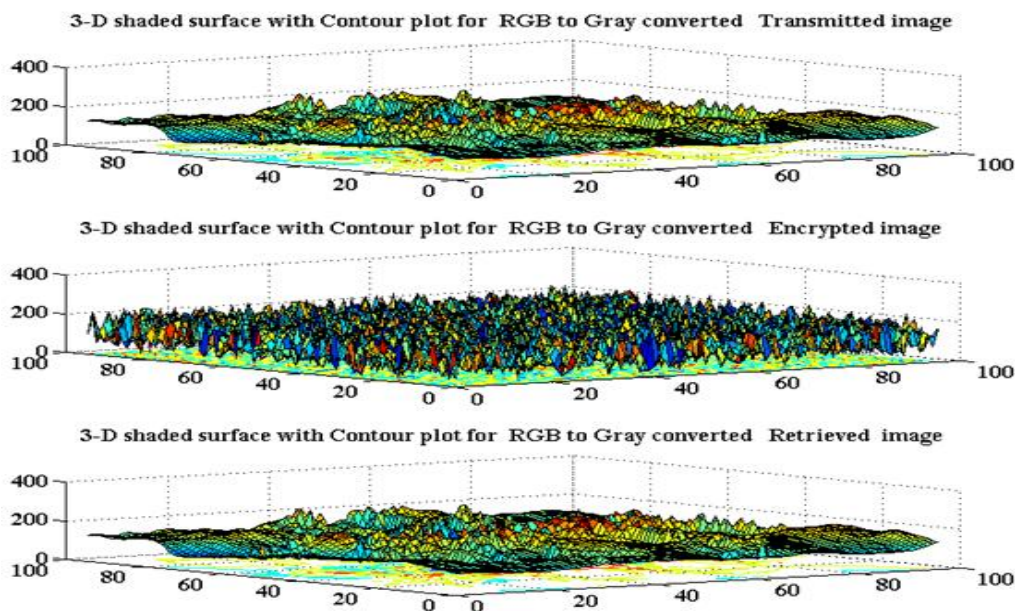


Figure 7: Three-dimensional shaded surface with Contour plot for RGB to Gray converted Transmitted, Encrypted and Retrieved images in a simulated D-BLAST aided LDPC encoded SC-FDMA Wireless Communication for a SNR value of 5dB.

## V. Conclusions

In this paper, the performance of LDPC encoded SC-FDMA Wireless Communication System has been investigated using D-BLAST Spatial multiplexing(SM) Encoding and various signal detection techniques. The system performance results highlight the impact of various signal detection techniques on secure color image transmission. In the context of system performance, it can be concluded that the implementation of QAM digital modulation technique with deployment of ZF-SIC signal detection technique provides satisfactory result for such a LDPC encoded SC-FDMA wireless communication system.

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## Design of a Practical Type Transmission Lines by using COMSOL Multyphysics 5.1

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**Abstract:** In communications and electronic engineering, a transmission line is a specialized cable or other structure designed to carry alternating current of radio frequency, that is, currents with a frequency high enough that their wave nature must be taken into account.

Transmission lines are used for purposes such as connecting radio transmitters and receivers with their antennas, distributing cable television signals, trunklines routing calls between telephone switching centers, computer network connections, and high speed computer data buses. This paper explains about the practical types of transmission lines i.e Coaxial Line, Twin Lead, Micro Strip and CPW models are designed by using COMSOL Multyphysics software.

**Keywords:** Transmission Lines; Coaxial Cable; Microstrip; Strip Line; CPW, COMSOL Multyphysics

### I. Introduction

Ordinary electrical cables suffice to carry low frequency alternating current (AC), such as mains power, which reverses direction 100 to 120 times per second, and audio signals. However, they cannot be used to carry currents in the radio frequency range or higher,<sup>[1]</sup> which reverse direction millions to billions of times per second, because the energy tends to radiate off the cable as radio waves, causing power losses. Radio frequency currents also tend to reflect from discontinuities in the cable such as connectors and joints, and travel back down the cable toward the source.<sup>[1][2]</sup> These reflections act as bottlenecks, preventing the signal power from reaching the destination. Transmission lines use specialized construction, and impedance matching, to carry electromagnetic signals with minimal reflections and power losses. The distinguishing feature of most transmission lines is that they have uniform cross sectional dimensions along their length, giving them a uniform *impedance*, called the characteristic impedance,<sup>[2][3][4]</sup> to prevent reflections. Types of transmission line include parallel line (ladder line, twisted pair), coaxial cable, stripline, and microstrip.<sup>[5][6]</sup> The higher the frequency of electromagnetic waves moving through a given cable or medium, the shorter the wavelength of the waves. Transmission lines become necessary when the length of the cable is longer than a significant fraction of the transmitted frequency's wavelength.

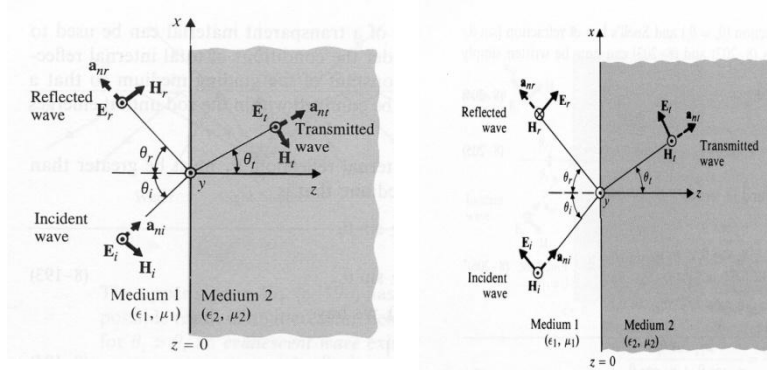
At microwave frequencies and above, power losses in transmission lines become excessive, and waveguides are used instead,<sup>[1]</sup> which function as "pipes" to confine and guide the electromagnetic waves.<sup>[6]</sup> Some sources define waveguides as a type of transmission line;<sup>[6]</sup> however, this article will not include them. At even higher frequencies, in the terahertz, infrared and light range, waveguides in turn become lossy, and optical methods, (such as lenses and mirrors), are used to guide electromagnetic waves.<sup>[6]</sup> The theory of sound wave propagation is very similar mathematically to that of electromagnetic waves, so techniques from transmission line theory are also used to build structures to conduct acoustic waves; and these are called acoustic transmission lines. In many electric circuits, the length of the wires connecting the components can for the most part be ignored. That is, the voltage on the wire at a given time can be assumed to be the same at all points.

### II. Characteristics of transmission lines

**Transmission line:** It has **two conductors** carrying current to support an EM wave, which is **TEM** or **quasi-**

**TEM** mode. For the **TEM** mode,  $\vec{E} = -Z_{TEM} \hat{a}_n \times \vec{H}$ ,  $\vec{H} = \frac{1}{Z_{TEM}} \hat{a}_n \times \vec{E}$ , and  $Z_{TEM} = \eta = \sqrt{\frac{\mu}{\epsilon}}$ .

The current and the EM wave have different characteristics. An EM wave propagates into different dielectric media, the partial reflection and the partial transmission will occur. And it obeys the following rules.



**Snell's law:**  $\frac{\sin \theta_t}{\sin \theta_i} = \frac{\beta_1}{\beta_2} = \frac{n_1}{n_2} = \frac{v_{p2}}{v_{p1}} = \frac{\eta_2}{\eta_1} = \sqrt{\frac{\epsilon_1}{\epsilon_2}} = \sqrt{\frac{\epsilon_{r1}}{\epsilon_{r2}}}$  and  $\theta_i = \theta_r$

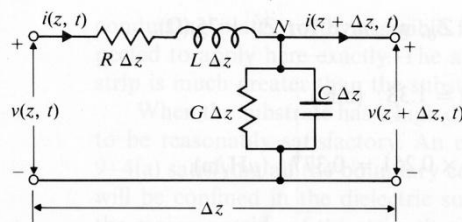
**The reflection coefficient:**  $\Gamma = \frac{E_{r0}}{E_{i0}}$  **and the transmission coefficient:**  $\tau = \frac{E_{t0}}{E_{i0}}$

$$\left\{ \begin{aligned} \Gamma_{\perp} &= \frac{\eta_2 / \cos \theta_t - \eta_1 / \cos \theta_i}{\eta_2 / \cos \theta_t + \eta_1 / \cos \theta_i} = \frac{n_1 \cos \theta_i - n_2 \cos \theta_r}{n_1 \cos \theta_i + n_2 \cos \theta_r} = \frac{\sin(\theta_i - \theta_t)}{\sin(\theta_i + \theta_t)} \\ \tau_{\perp} &= \frac{2\eta_2 / \cos \theta_t}{\eta_2 / \cos \theta_t + \eta_1 / \cos \theta_i} = \frac{2n_1 \cos \theta_i}{n_1 \cos \theta_i + n_2 \cos \theta_r} = \frac{2 \cos \theta_i \sin \theta_t}{\sin(\theta_i + \theta_t)} \end{aligned} \right. \quad \text{for perpendicular polarization (TE)}$$

$$\left\{ \begin{aligned} \Gamma_{\parallel} &= \frac{\eta_2 \cos \theta_t - \eta_1 \cos \theta_i}{\eta_2 \cos \theta_t + \eta_1 \cos \theta_i} = \frac{n_1 / \cos \theta_i - n_2 / \cos \theta_r}{n_1 / \cos \theta_i + n_2 / \cos \theta_r} = \frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)} \\ \tau_{\parallel} &= \frac{2\eta_2 \cos \theta_i}{\eta_2 \cos \theta_t + \eta_1 \cos \theta_i} = \frac{2n_1 / \cos \theta_t}{n_1 / \cos \theta_i + n_2 / \cos \theta_r} = \frac{2 \cos \theta_i \sin \theta_t}{\sin(\theta_i + \theta_t) \cos(\theta_i - \theta_t)} \end{aligned} \right. \quad \text{for parallel polarization (TM)}$$

In case of normal incidence,  $\left\{ \begin{aligned} \Gamma_{\perp} = \Gamma_{\parallel} &= \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}, \text{ where } \eta_1 = \sqrt{\frac{\mu_1}{\epsilon_1}} \text{ and } \eta_2 = \sqrt{\frac{\mu_2}{\epsilon_2}} \\ \tau_{\perp} = \tau_{\parallel} &= \frac{2\eta_2}{\eta_2 + \eta_1} \end{aligned} \right.$

**Equivalent-circuit model of transmission line section:**



$R(\Omega/m), L(H/m), G(S/m), C(F/m)$

**Transmission line equations:** In higher-frequency range, the transmission line model is utilized to analyze EM power flow.

$$\left\{ \begin{aligned} -\frac{v(z + \Delta z, t) - v(z, t)}{\Delta z} &= Ri(z, t) + L \frac{\partial i(z, t)}{\partial t} \\ -\frac{i(z + \Delta z, t) - i(z, t)}{\Delta z} &= Gv(z, t) + C \frac{\partial v(z, t)}{\partial t} \end{aligned} \right. \Rightarrow \left\{ \begin{aligned} -\frac{\partial v}{\partial z} &= Ri + L \frac{\partial i}{\partial t} \\ -\frac{\partial i}{\partial z} &= Gv + C \frac{\partial v}{\partial t} \end{aligned} \right.$$

Set  $v(z,t)=Re[V(z)e^{j\omega t}]$ ,  $i(z,t)=Re[I(z)e^{j\omega t}]$

$$\Rightarrow \left\{ \begin{aligned} -\frac{dV}{dz} &= (R + j\omega L)I(z) \\ -\frac{dI}{dz} &= (G + j\omega C)V(z) \end{aligned} \right. \Rightarrow \left\{ \begin{aligned} \frac{d^2V(z)}{dz^2} &= (R + j\omega L)(G + j\omega C)V(z) = \gamma^2 V(z) \\ \frac{d^2I(z)}{dz^2} &= (R + j\omega L)(G + j\omega C)I(z) = \gamma^2 I(z) \end{aligned} \right.$$

where  $\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \Rightarrow V(z) = V_0^+ e^{-\gamma z} + V_0^- e^{\gamma z}$ ,  $I(z) = I_0^+ e^{-\gamma z} + I_0^- e^{\gamma z}$

**Characteristic impedance:**  $Z_0 = \frac{V_0^+}{I_0^+} = -\frac{V_0^-}{I_0^-} = \frac{R + j\omega L}{\gamma} = \frac{\gamma}{G + j\omega C} = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$

### III. Practical Types

#### A. Coaxial Cable:

Coaxial lines confine virtually all of the electromagnetic wave to the area inside the cable. Coaxial lines can therefore be bent and twisted (subject to limits) without negative effects, and they can be strapped to conductive supports without inducing unwanted currents in them. In radio-frequency applications up to a few gigahertz, the wave propagates in the transverse electric and magnetic mode (TEM) only, which means that the electric and magnetic fields are both perpendicular to the direction of propagation (the electric field is radial, and the magnetic field is circumferential). However, at frequencies for which the wavelength (in the dielectric) is significantly shorter than the circumference of the cable, transverse electric (TE) and transverse magnetic (TM) waveguide modes can also propagate. When more than one mode can exist, bends and other irregularities in the cable geometry can cause power to be transferred from one mode to another. The most common use for coaxial cables is for television and other signals with bandwidth of multiple megahertz. In the middle 20th century they carried long distance telephone connections.

#### B. Microstrip:

A microstrip circuit uses a thin flat conductor which is parallel to a ground plane. Microstrip can be made by having a strip of copper on one side of a printed circuit board (PCB) or ceramic substrate while the other side is a continuous ground plane. The width of the strip, the thickness of the insulating layer (PCB or ceramic) and the dielectric constant of the insulating layer determine the characteristic impedance. Microstrip is an open structure whereas coaxial cable is a closed structure.

#### C. Stripline:

A stripline circuit uses a flat strip of metal which is sandwiched between two parallel ground planes. The insulating material of the substrate forms a dielectric. The width of the strip, the thickness of the substrate and the relative permittivity of the substrate determine the characteristic impedance of the strip which is a transmission line.

#### D. Balanced lines:

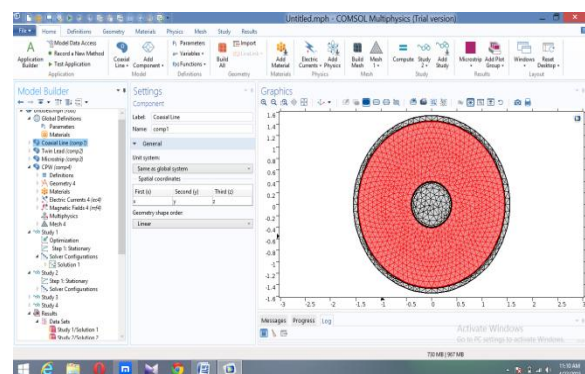
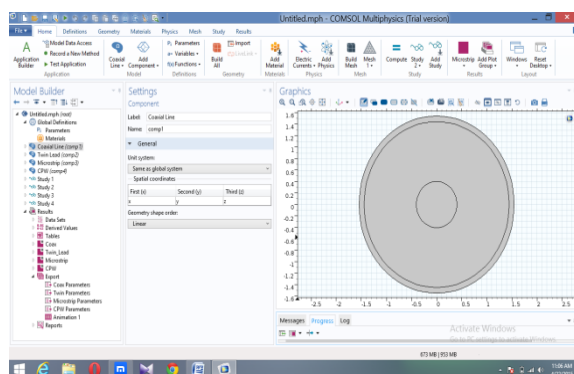
A balanced line is a transmission line consisting of two conductors of the same type, and equal impedance to ground and other circuits. There are many formats of balanced lines, amongst the most common are twisted pair, star quad and twin-lead.

#### E. Single-wire line:

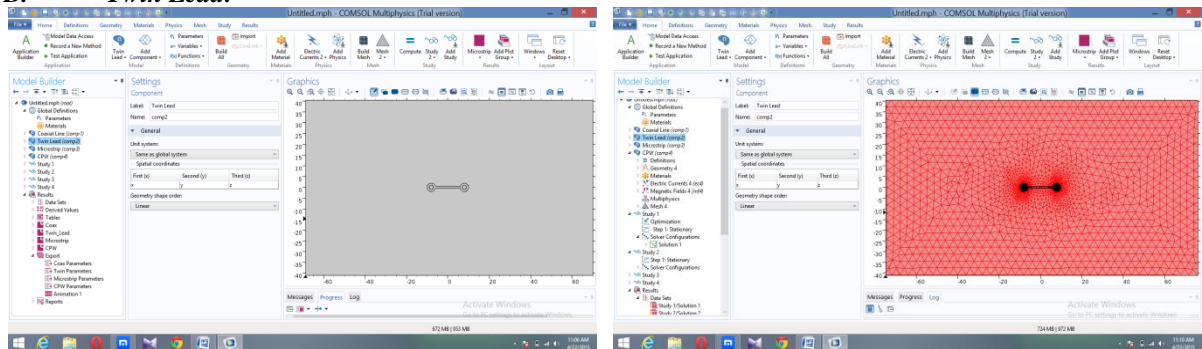
Unbalanced lines were formerly much used for telegraph transmission, but this form of communication has now fallen into disuse. Cables are similar to twisted pair in that many cores are bundled into the same cable but only one conductor is provided per circuit and there is no twisting. All the circuits on the same route use a common path for the return current (earth return). There is a power transmission version of single-wire earth return in use in many locations.

### IV. Design & Simulation Results by COMSOL

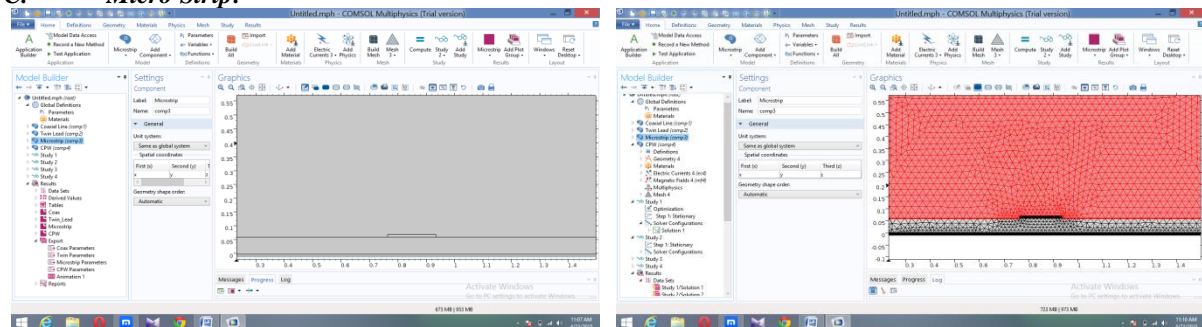
#### A. Coaxial Line:



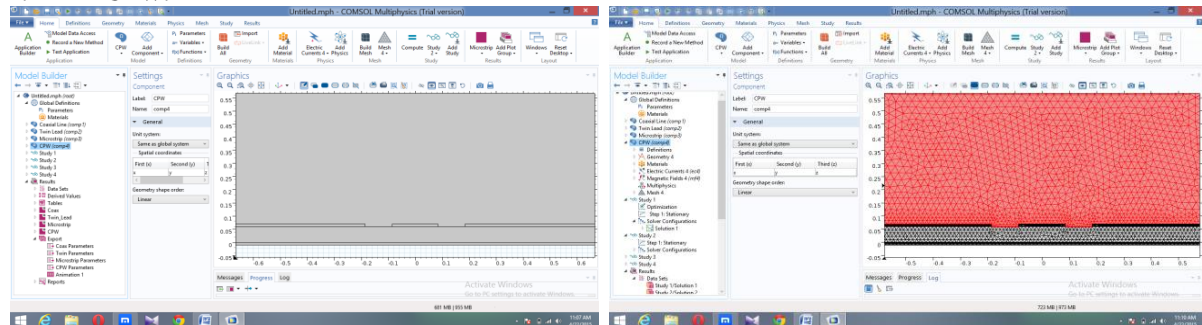
### B. Twin Lead:



### C. Micro Strip:



### D. CPW:



### Specifications:

#### Coaxial Line

Expression	Unit	Description
freq_coax	Hz	frequency
Ri_coax	m	inner radius
dR_coax	m	outer radius-inner radius
d_s_coax	m	screen thickness
epsr_coax		relative permittivity of dielectric
mur_coax		relative permeability of dielectric
sigma_d_coax	S/m	conductivity of dielectric
sigma_c_coax	S/m	conductivity of conductors
R_coax	$\Omega/m$	distributed resistance
L_coax	H/m	distributed inductance
G_coax	S/m	shunt conductance
C_coax	F/m	capacitance
Zc_coax	$\Omega$	characteristic impedance
gamma_coax	1/m	propagation constant

#### Twin Lead

Expression	Unit	Description
freq_twin	Hz	frequency
R1_twin	m	
t_ins_twin	m	wire insulation thickness
d_twin	m	insulation surface-to-surface
epsr_twin		relative permittivity of dielectric
sigma_d_twin	S/m	conductivity of dielectric
sigma_c_twin	S/m	conductivity of conductors
R_twin	$\Omega/m$	distributed resistance
L_twin	H/m	distributed inductance
G_twin	S/m	shunt conductance
C_twin	F/m	capacitance
Zc_twin	$\Omega$	characteristic impedance
gamma_twin	1/m	propagation constant

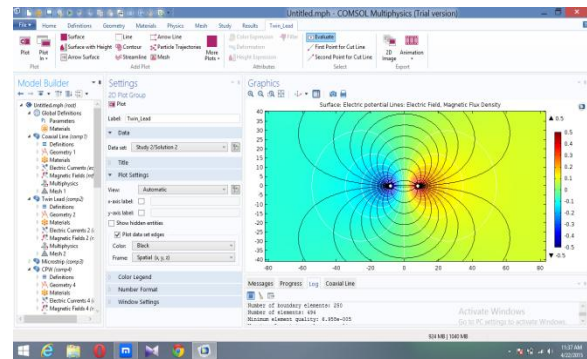
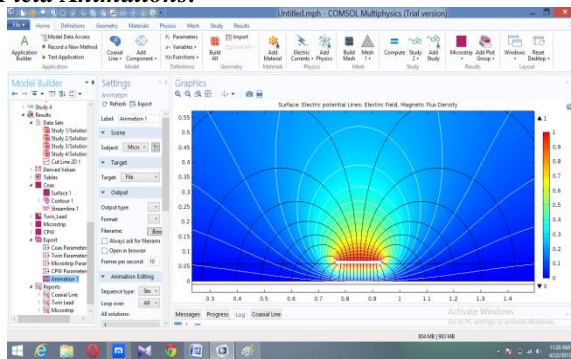
**Micro Strip:**

Expression	Unit	Description
freq_ms	Hz	frequency
W_ms	m	strip width
t_ms	m	strip thickness
h_ms	m	height of dielectric
t_gp_ms	m	thickness of ground plane
epsr_ms		relative permittivity of diel...
sigma_d_ms	S/m	conductivity of dielectric
sigma_c_ms	S/m	conductivity of conductors
R_ms	$\Omega$ /m	distributed resistance
L_ms	H/m	distributed inductance
G_ms	S/m	shunt conductance
C_ms	F/m	capacitance
Zc_ms	$\Omega$	characteristic impedance
gamma_ms	1/m	propagation constant

**CPW:**

Expression	Unit	Description
freq_cpw	Hz	frequency
bp_cpw		conductive back plane sw...
W_cpw	m	central track width
g_cpw	m	gap to ground width
t_cpw	m	track thickness
h_cpw	m	height of dielectric
t_bp_cpw	m	thickness of metallic back...
epsr_cpw		relative permittivity of diel...
sigma_d_cpw	S/m	conductivity of dielectric
sigma_c_cpw	S/m	conductivity of conductors
R_cpw	$\Omega$ /m	distributed resistance
L_cpw	H/m	distributed inductance
G_cpw	S/m	shunt conductance
C_cpw	F/m	capacitance
Zc_cpw	$\Omega$	characteristic impedance
gamma_cpw	1/m	propagation constant

**Field Animations:**



The above figures can represent the design models of Practical type transmission lines. Here the paper gives the technical specifications of individuals.

**V. Conclusion**

This paper concludes about the practical types of transmission lines i.e Coaxial Line, Twin Lead, Micro Strip and CPW models are designed by using COMSOL Multiphysics software. A transmission line is a specialized cable or other structure designed to carry alternating current of radio frequency.

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## K-means Cluster Model for Climate Prediction of Vindhya Region

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**Abstract:** In the present work an attempt has made to develop a novel predictive model that uses the historical climate data (rain, wind, speed, temperature, dew point etc.) for prediction. The present study describes how to use a data mining technique and how to develop a system that uses numeric historical data to forecast the climate of vindhya region. Cluster analysis can be used as a standalone data mining tool to gain insight into the data distribution, or as preprocessing steps for other data mining algorithms operating on the detected clusters. In this paper clusters are made by putting similar data into four groups. It is an unsupervised learning technique with the combination of various algorithms. Using k-means clustering algorithm we have developed clustering model for the training and test data set. The association between different climate attributes on the test data set i.e rainfall has been observed. The obtained cluster instances for the training data sets validate our model and clearly show the association of the climate attributes under taken on rainfall.

**Keywords:** k-means, unsupervised learning, data distribution, forecast.

### I. Introduction:

Climate forecasting is a way by which scientists are using to predict climate change. To produce these forecasts an extensive suite of computational forecasting tools have been developed including a multi model ensemble approach that required thorough validation of each model's accuracy level in simulation inter-annual climate variability. The detection and analysis of predictive models is also part of statistics and machine learning<sup>[1]</sup>. The choice of the predictor and response variables is relatively open in the data mining application. Through a lot of work has been done in this field of climate informatics in which various seasonal climate attributes have been used to develop the predictive models, but still there is a need to develop more robust, accurate, reliable and efficient model for climate prediction<sup>[2-3]</sup>. An artificial neural network is a computing method inspired by structure of brains and nerves system. A typical neural network consists of a group of inter-connected processing units, which are also called neurons. Each neuron makes its independent computation based upon a weight sum of its inputs and passes the results to other neurons in an organized fashion<sup>[4]</sup>. A neural network is trained from training data set. This makes neural network a desirable tool in dealing with complex systems.

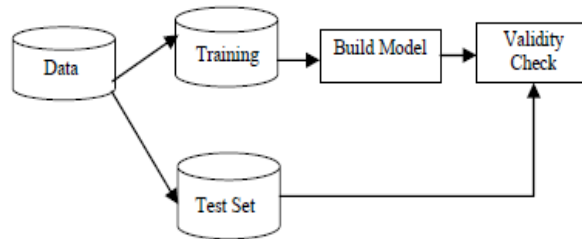
The process of finding useful patterns and information from raw data is often known as knowledge discovery in database. Clustering analyses data objects without consulting a known class label. The unsupervised learning technique of clustering is a useful method for ascertaining trends and patterns in data, when there are no pre-defined classes. There are two main types of clustering, hierarchical and partition. In hierarchical clustering, each data point is initially in its own cluster and then clusters are successively joined to create a clustering structure<sup>[5-6]</sup>. This is known as the agglomerative method. In partition clustering, the number of clusters must be known apriori. The partitioning is done by minimizing a measure of dissimilarity within each cluster and maximizing the dissimilarity between different clusters.

### II. K-Means Clustering

Clusters are natural grouping of data items based on similarity metrics or probability density models. K-means algorithm organizes objects into k-partitions where each partition represents a cluster. It is a partition method which finds mutual exclusive clusters of spherical shape. It generates a specific number of disjoint, non-hierarchical clusters.<sup>[7]</sup> Clustering algorithms produces high quality clusters to yield lower inter cluster similarity a high intra cluster similarity. k-means algorithm achieve this on vast and highly structured data. But it has difficulties in handling unstructured natural data which often contain outlier data points. The efficiency of the algorithm has to be further tested on a comparatively larger data set.<sup>[8]</sup> The outcome of the extracted data can be analyzed for the future planning and development perspectives.

### III. Data and Method of analysis

The data used for this work was collected from the web ([www.ipcc-data.org](http://www.ipcc-data.org)) and national climatic data center (NCDC) for vindhyan region. A monthly climate data for the period of 1901-2010 were collected and some data preprocessing has been applied in raw data sets. The flow chart for the proposed model is shown in the figure-1.



**Fig. 1- Proposed model for prediction**

Technique/ algorithms for proposed model along with appropriate data set have been identified for the development of the proposed model. Extraction, transformation and cleaning of the data set for desired parameter or attributes have been performed. We start out with initial set of means and classify cases based on their distances on their centers. We compute the cluster means using the cases that are assigned to the clusters. Then we reclassify all cases based on the new test set of means. This step repeats until cluster means do not change between successive steps. Finally we calculate the means of cluster once again and assign the cases to their permanent cluster.<sup>[9]</sup>

The data set were inputted in as per the k-means algorithms in the WEKA. We have received clusters centroids for different attributes of the given data sets. The cluster instances for the cluster 0 and cluster 1 can be viewed from the run information of the model.

#### IV. Result and Discussion:

In the present analysis we used clustering method for the climate prediction of vindhya region for longitude 24.53° N and Latitude 81.30°E. We have developed the model based on k-means algorithm. The data sets of the climate parameters have been inputted after preprocessing. The output of the model for full training set of rainfall show that the cluster instances for the cluster 1 and cluster 0 have 75% and 25% among the 11 attributes selected for the training data set of rainfall for the period of 1901-2010. The cluster centroids for the for the full data set cluster 0 and cluster 1 are given in the table-1. Now we have extended the method for testing data set, which contain four climates attribute as shown in the run information. The impact of the first three attributes on the rainfall is reported in terms of cluster instances values for the cluster 0 and cluster 1. We found that 67% instances of the full data set directly affect the rain. Our finding validate model for the prediction of climate. The run information of the k-means clustering from WEKA tool is for the reference.

Clustering algorithms maps a new data item into one of several known clusters. K-means algorithm has biggest advantage of clustering large data sets and its performance increases as number of clusters increases. The k-means is a widely used partitioned clustering method in the industries. The k-means algorithm is the most commonly used partitioned clustering algorithm because it can be easily implemented and is the most efficient one in terms of the execution time.

#### V. Output

Training Set	Testing Set																																																								
<pre> ==== Run information ==== Scheme: weka.clusterers.SimpleKMeans -N 2 -A "weka.core.EuclideanDistance -R first-last" -I 500 -num-slots 1 -S 10 Relation: rewa Instances: 12 Attributes: 11 Test mode: evaluate on training data ==== Clustering model (full training set) ==== k-Means ===== Number of iterations: 4 Within cluster sum of squared errors: 2.3427640507177223 Missing values globally replaced with mean/mode Cluster centroids: </pre> <table border="1"> <thead> <tr> <th>Attribute</th> <th>Full Data (12)</th> <th>Cluster 0 (3)</th> <th>Cluster 1 (9)</th> </tr> </thead> <tbody> <tr><td>1901-1910</td><td>81.835</td><td>271.1433</td><td>18.7322</td></tr> <tr><td>1911-1920</td><td>88.1692</td><td>269.15</td><td>27.8422</td></tr> <tr><td>1921-1930</td><td>92.3475</td><td>313.13</td><td>18.7533</td></tr> <tr><td>1931-1940</td><td>91.4292</td><td>290.0067</td><td>25.2367</td></tr> <tr><td>1941-1950</td><td>92.4367</td><td>304.6033</td><td>21.7144</td></tr> <tr><td>1951-1960</td><td>93.06</td><td>287.3267</td><td>28.3044</td></tr> <tr><td>1961-1970</td><td>88.8092</td><td>291.2833</td><td>21.3178</td></tr> <tr><td>1971-1980</td><td>90.31</td><td>278.3167</td><td>27.6411</td></tr> </tbody> </table>	Attribute	Full Data (12)	Cluster 0 (3)	Cluster 1 (9)	1901-1910	81.835	271.1433	18.7322	1911-1920	88.1692	269.15	27.8422	1921-1930	92.3475	313.13	18.7533	1931-1940	91.4292	290.0067	25.2367	1941-1950	92.4367	304.6033	21.7144	1951-1960	93.06	287.3267	28.3044	1961-1970	88.8092	291.2833	21.3178	1971-1980	90.31	278.3167	27.6411	<pre> ==== Run information ==== Scheme: weka.clusterers.SimpleKMeans -N 2 -A "weka.core.EuclideanDistance -R first-last" -I 500 -num-slots 1 -S 10 Relation: TCvtOR Instances: 12 Attributes: 4 Temperature Cloude Cover Vpressure Rainfall Test mode: evaluate on training data ==== Clustering model (full training set) ==== kMeans ===== Number of iterations: 4 Within cluster sum of squared errors: 1.4843695117982518 Missing values globally replaced with mean/mode Cluster centroids: </pre> <table border="1"> <thead> <tr> <th>Attribute</th> <th>Full Data (12)</th> <th>Cluster 0 (4)</th> <th>Cluster 1 (8)</th> </tr> </thead> <tbody> <tr><td>Temperature</td><td>74.2117</td><td>193.935</td><td>14.35</td></tr> <tr><td>Cloude Cover</td><td>36.5117</td><td>62.5775</td><td>23.4787</td></tr> <tr><td>Vpressure</td><td>18.6817</td><td>29.9025</td><td>13.0712</td></tr> <tr><td>Rainfall</td><td>25.5483</td><td>29.4925</td><td>23.5762</td></tr> </tbody> </table> <p>Time taken to build model (full training data) : 22 seconds</p>	Attribute	Full Data (12)	Cluster 0 (4)	Cluster 1 (8)	Temperature	74.2117	193.935	14.35	Cloude Cover	36.5117	62.5775	23.4787	Vpressure	18.6817	29.9025	13.0712	Rainfall	25.5483	29.4925	23.5762
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Attribute	Full Data (12)	Cluster 0 (4)	Cluster 1 (8)																																																						
Temperature	74.2117	193.935	14.35																																																						
Cloude Cover	36.5117	62.5775	23.4787																																																						
Vpressure	18.6817	29.9025	13.0712																																																						
Rainfall	25.5483	29.4925	23.5762																																																						

1981-1990	83.6083	255.3967	26.3456	=== Model and evaluation on training set === Clustered Instances  0    4 ( 33%) 1    8 ( 67%)
1991-2000	74.2117	224.54	24.1022	
2001-2010	87.6217	278.4897	23.999	
Time taken to build model (full training data) : 20 seconds === Model and evaluation on training set === Clustered Instances 0    3 ( 25%) 1    9 ( 75%)				

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## Analysis of a Discrete SEIR Epidemic Model

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**Abstract:** In this paper, we propose a discrete-time SEIR epidemic model described by difference equations. The basic reproductive number  $R_0$  for the discrete SEIR model is computed and the dynamical behavior of the model is studied. The stability of both the disease-free and endemic equilibrium are derived. It is proved that the disease free equilibrium is asymptotically stable if  $R_0 < 1$ . Numerical simulations are performed to illustrate the impact of threshold value on epidemic.

**Keywords:** SEIR Model, Reproduction Number, Equilibrium Points, Difference Equation.

### I. Introduction

History of mathematical models in epidemiology goes back to the eighteenth century (Bernoulli 1760). Great attention has been paid to the dynamics properties (including stable, unstable, persistent and oscillatory behavior) of the epidemic models. Most of the models in mathematical epidemiology are compartmental models, with the population being divided into compartments. Various epidemic models have been formulated and analyzed by many researchers. The classical susceptible-infected-recovered (SIR) model is a system consisting of three differential equations which assumes that the host population is constant [1, 3, 5]. Many infectious diseases in nature incubate inside the hosts for a period of time before the hosts become infectious. The basic SEIR model represents infection dynamics in a total population of size  $N$ . This is the simplest model for mass action transmission in a homogeneously-mixed host population. Transmission of infection from infectious to susceptible individuals is controlled by a contact term  $\frac{\beta IS}{N}$ . In this model, infected individuals move into the Exposed (not infectious) class after an average incubation period and subsequently through the infectious class. The model assumes that recovered individuals are immune from infection [1].

### II. Model Formulation and Equilibria

In this section, we formulate a model for epidemic outbreaks with exposed class. In the construction of the SEIR model, we will divide the total population into four epidemiological classes which are susceptible (S), exposed (E) infectious (I) and recovered (R). Few authors studied discrete epidemic models [2, 4, 6] whereas there exists a vast literature on continuous epidemic models [1, 5]. In this section, we analyze the following reduced discrete SEIR epidemic model.

$$\begin{aligned} S(n+1) &= a - b \frac{S(n)I(n)}{S(n)+I(n)} + dI(n) + (1-c)S(n) \\ E(n+1) &= b \frac{S(n)I(n)}{S(n)+I(n)} + [1-(f+c)]E(n) \\ I(n+1) &= fE(n) + [1-(d+c)]I(n) \end{aligned} \quad (1)$$

Where  $a, b, c, d, f > 0$  and the initial conditions are  $S(0) \geq 0, E(0) \geq 0, I(0) \geq 0$ . The parameters have the following meaning: 'a' represents recruitment rate of the population, 'c' is the death rate, 'b' is the constant rate at which the susceptible population is converted into the exposed population, 'd' is the recovery rate to susceptible population, and 'f' is the effective transmission co-efficient. The system (1) always has two equilibria: The first one, corresponding to a population with no infected individuals, is referred to henceforth as disease-free equilibrium  $E_0 = \left(\frac{a}{c}, 0, 0\right)$  and the second equilibrium corresponds to the case in which there is a significant group of infectious individuals referred to as the epidemic equilibrium  $E_1 = (S^*, E^*, I^*)$  where

$$S^* = \frac{af(f+c)(d+c)}{c(d+f)[bf-(d+c)(f+c)]+cbf^2}, \quad E^* = \frac{a(d+c)[bf-(f+c)(d+c)]}{c(d+f)[bf-(d+c)(f+c)]+cbf^2}, \quad \text{and}$$

$$I^* = \frac{af[bf-(f+c)(d+c)]}{c(d+f)[bf-(d+c)(f+c)]+cbf^2}.$$

### III. Dynamic Behavior of the Model and Numerical Simulations

We derive a threshold value  $R_0$ . An important technique for analyzing nonlinear systems qualitatively is the analysis of the behavior of the solutions near equilibrium points using linearization. For the discrete time model, stability of the equilibrium solution requires the dominant eigenvalue to have magnitude less than one. For the system described by equations (1), this reduces to requiring all roots of the following equation to lie in the unit circle. The local stability analysis of the model can be carried out by computing the Jacobian matrix corresponding to each equilibrium point. We first determine the stability of the system. The Jacobian matrix of system (1) is

$$\begin{pmatrix} -\frac{bI}{S+I} + \frac{bSI}{(S+I)^2} + 1 - c & 0 & -\frac{bI}{S+I} + \frac{bSI}{(S+I)^2} + d \\ \frac{bI}{S+I} - \frac{bSI}{(S+I)^2} & 1 - f - c & \frac{bI}{S+I} - \frac{bSI}{(S+I)^2} \\ 0 & f & 1 - a - d \end{pmatrix} \quad (2)$$

If  $R_0 < 1$ , then the epidemic cannot maintain itself because each individual, on average, infects less than one member of the population. The epidemic equilibrium is then unstable, while the infection-free equilibrium point is locally stable. Also, if  $R_0 > 1$ , then on average, each infected individual infects more than one other member of the population and a self-sustaining group of infectious individuals will propagate. A simple linear analysis shows that in this case, the epidemic equilibrium point is locally stable, while the infection-free equilibrium point is unstable.

#### A. Disease Free Equilibrium

At the disease-free equilibrium, the matrix of the linearization is given by

$$J(E_0) = \begin{pmatrix} 1 - c & 0 & -b + d \\ 0 & 1 - (f + c) & b \\ 0 & f & 1 - (d + c) \end{pmatrix}$$

The Eigen values of the matrix  $J(E_0)$  are  $\lambda_1 = 1 - c$  and  $\lambda_{2,3} = \frac{2(1-c) - (f+d)}{2} \pm \sqrt{(f-d)^2 + 4fb}$ .

We obtain the explicit expression for the basic reproduction number  $R_0$ . Then, it is shown that the disease-free equilibrium is locally and globally asymptotically stable if  $R_0 < 1$ . In this case, the disease always dies out. The basic reproductive number for our model is  $R_0 = \frac{fb}{(d+c)(f+c)}$ .

**Lemma.1** Let  $F(\lambda) = \lambda^2 + B\lambda + C$ . Suppose that  $F(1) > 0$ ,  $\lambda_1$  and  $\lambda_2$  are two roots of  $F(\lambda) = 0$ . Then  $|\lambda_1| < 1$  and  $|\lambda_2| < 1$  if and only if  $F(-1) > 0$  and  $C < 1$ .

**Theorem.1** If  $R_0 < 1$ , then the disease free equilibrium  $E_0 = \left(\frac{a}{c}, 0, 0\right)$  of the model (1) is asymptotically stable.

**Proof.**

The linearization matrix of (1) at the positive equilibrium  $E_0 = \left(\frac{a}{c}, 0, 0\right)$  is given by

$$\begin{pmatrix} 1 - c & 0 & -b + d \\ 0 & 1 - (f + c) & b \\ 0 & f & 1 - (d + c) \end{pmatrix}$$

The characteristic equation of matrix is

$$P(\lambda) = (1 - c - \lambda)[(1 - f - c - \lambda)(1 - d - c - \lambda) - fb]$$

We see that the equation  $P(\lambda) = 0$  has an Eigen value  $0 < \lambda_1 = 1 - c < 1$ .

Therefore, in order to determine the stability of the positive equilibrium of model (1), we discuss the nature roots of the characteristic equation,

$$P(\lambda) = \lambda^2 - \lambda(2 - 2c - f - d) + (f + c)(d + c) + (1 - 2c - f - d) - fb$$

When  $R_0 < 1$  the calculation yields,

$$P(1) = (f + c)(d + c) - fb > 0$$

$$P(-1) = 2[2(1 - c) - (f + d)] + (f + c)(d + c) - fb > 0 \text{ when } 2(1 - c) - (f + d) > 0$$

$$\frac{f + d}{2(1 - c)} < 1 \text{ and } c < 1$$

Furthermore, we have, Constant term  $= 1 + (f + c)(d + c) - (f + c) - (d + c) - fb < 1$  with

$$(f + c)(d + c) - fb < f + c + d + c$$

$$f + d + 2c > 0$$

The Jury Criterion implies that the roots  $\lambda_2$  and  $\lambda_3$  of equation  $P(\lambda) = 0$ , satisfy  $|\lambda_2| < 1$  and  $|\lambda_3| < 1$ .

### B. Numerical Examples

**Example.1** We choose the parameter values  $a = 0.05$ ;  $b = 0.006$ ;  $c = 0.075$ ;  $d = 0.025$ ;  $f = 0.05$ ;  $t = 50$  Here

$$R_0 = \frac{fb}{(d + c)(f + c)} = 0.024 < 1; \text{ so the equilibrium point } E_0 \text{ is globally stable, see fig - 1.}$$

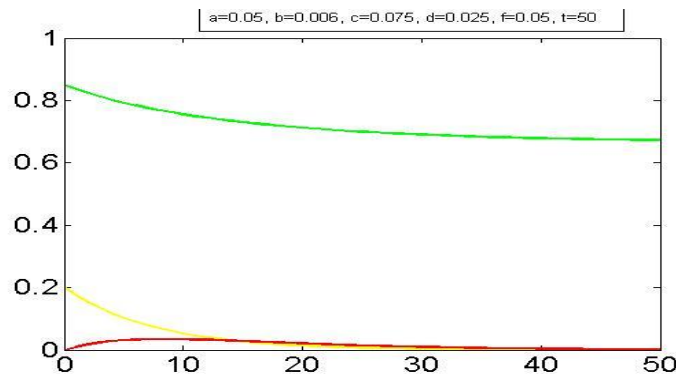


Figure 1. Time plot and Phase diagram for the system (1) with  $R_0 < 1$

Thus the disease free equilibrium of (1) is asymptotically stable when  $R_0 < 1$ .

**Example 2.** When  $R_0 > 1$ , there exists unique endemic equilibrium which is stable under certain conditions. In order to show  $E_1$  is stable when  $R_0 > 1$  we choose  $a = 0.005$ ;  $b = 0.073$ ;  $c = 0.0056$ ;  $d = 0.023$ ;  $f = 0.0234$ ;  $t = 500$  Here

$$R_0 = \frac{fb}{(d + c)(f + c)} = 2.05956 > 1, \text{ see fig - 2.}$$

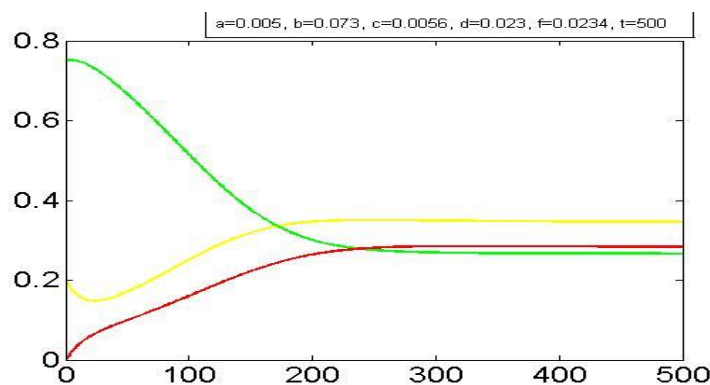


Figure 2. Time plot and Phase diagram for the system (1) with  $R_0 > 1$

**Example 3.** In this example we choose to illustrate the impact of the parameter  $b$  on the infective class.

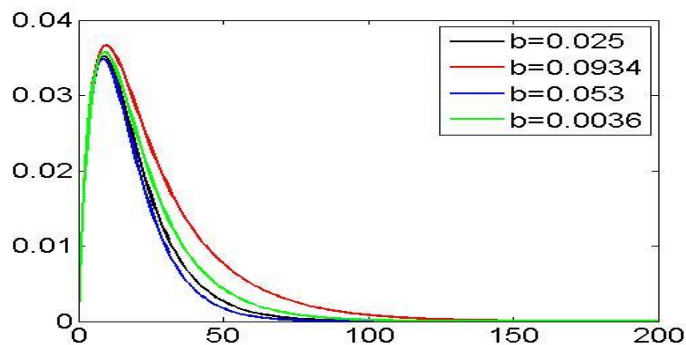


Figure 3. Impact on  $I(n)$

**Example 4.** The effect of  $R_0$  on disease propagation is demonstrated by taking several values of  $R_0 = 0.599$ ; 0.75130; 1.0550; 1.52627; 2.3904; 3.0. Here  $R_0 = \frac{fb}{(d+c)(f+c)}$ .

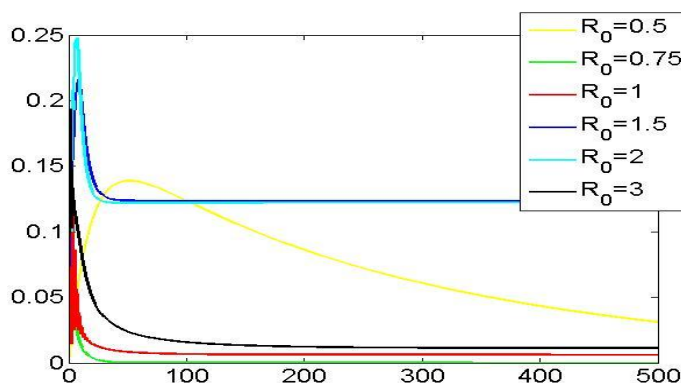


Figure 4. Impact of  $R_0$

In this paper, we formulated a discrete version of SEI model to describe disease transmission. Reproduction number is computed based on linearization theory and its effects on extinction and persistence are demonstrated.

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## Statistical Behaviour of Software Process and its Impact on Process Performance

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**Abstract:** Tools, methods, type of software, and the environment of development are the factors that can affect the performance of Software processes. The outcome of a software process can be controlled by application of SPC techniques. SPC is important in software processes because it can guide on how to stabilize and improve processes. SPC can also be used to demonstrate the improvement effects. Software development cannot be classified as pure SPC controlled process. Multiple issues need to be addressed by software development processes teams including Team Management, working with limited data, aligning business goals with development goals of project is very important for success of development project.

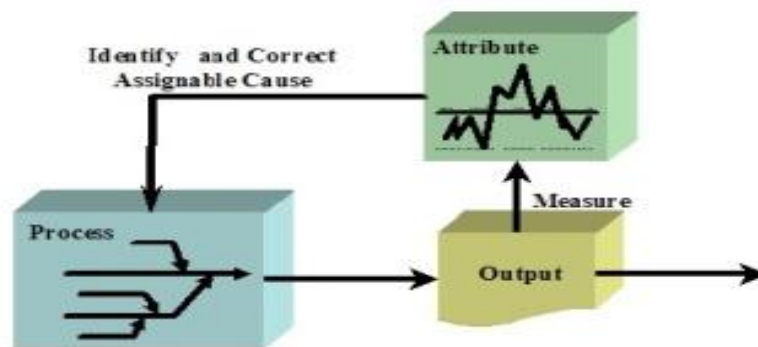
**Keywords** Process: Performance, SPC, Software Development Models

### I. Introduction

The optimal outcome of a process is normally ensured by strict monitoring and control based on techniques of Statistical Process Control (SPC). These can be applied to any process, like a tool, during its development/manufacturing stage, to measure the outcome of a product design specifications. SPC makes use of control charts, and monitors continuous improvement and on setting specialized experimental methods (DOE), in case required. Modern SPC systems have real time access to data and ability to respond to incoming data online.

The SPC is applied mainly in a process to following activities:

1. Understand a process and its specification limits.
2. To make a process stable, Eliminate assignable (special) sources of variation.
3. Use Control charts to monitor the ongoing processes, to detect any significant changes of mean or variation.



**Fig.1- Attributes of a Process monitored continuously**

SPC optimizes the information needed for a process measurement, which helps making management decisions. Statistical technique enables to work out the business baselines, support process improvements, and provide results of processes. SPC also helps in real time analysis to establish controllable process baselines; dynamic improvement of process capabilities; and focus on areas of improvement. SPC enables this decision making based on data analysis and not on opinion.

### II. Software Development Processes – Main Characteristics

A software development process in general has the following characteristics:

- (1) Software development processes are based more on thinking and are creative and unlike manufacturing. Results of software processes measurement can easily vary, and that makes a process difficult to control and minimize.

- (2) Multiple common causes: Tools, methods, type of software, and the environment of development are the factors that can affect the performance of these processes. Thus, the data obtained will be a mixed set of common cause results.
- (3) It is difficult to get a large set of homogeneous data, as can be gathered from manufacturing processes where daily production levels are high. This is due to each process having its own set of unique activities that need to be executed.
- (4) Software development follows “phase” and “cycle” concept which is quite different from continuous operations.
- (5) Process Capability is not clearly measurable as in Software Development because process limits and level of end quality not directly related.

SPC is important in software processes because it can guide on how to stabilize and improve processes, despite above stated constraints. SPC can also be used to demonstrate the improvement effects. These difficulties can be overcome by putting more emphasis on processes rather than products. Thus using product data and process data can increase the available data significantly. As the definition of software process involves people, tools, and work environment, SPC can bring stability or normalization to human activities. Multiple Common causes can be identified and separated using Statistical Process Control techniques.

### III. SPC and CMM Models

SPC can be applied to any process development requiring statistical control including software development processes. A process has multiple outputs as identifiable causes, as shown in Fig.1. In the CMMI model, the level 4 and 5 practices of the model use the SPC for process control. Whereas, SPC uses tools to monitor the performance of the production process to detect any significant variations to enable checking of production of a sub-standard article. The process output variations are categorized as follows:

1) "Common Causes" - is referred to as non-assignable or common, normal sources of variation. Such variations in any process are normally there and to be anticipated. This type of causes produces a stable and repeatable distribution over time.

2) "Special Causes" - is referred to as assignable sources of variation. These refer to any factor causing variation that affects only some of the process output. They are often intermittent and unpredictable.

These outputs, in turn, have measurable attributes. A process is under SPC if the observed process variation of process attributes is in the range of variation that of natural causes. When that variability of the process exceeds the range to be expected, the practitioner of SPC then identifies and corrects assignable causes.

If the dominant sources of variations are known, then appropriate change can be planned on these resources. It may be possible to remove these known sources and once removed, the process is said to be "stable". A stable process is one that has its variation within a known set of limits, until another assignable source of variation occurs.

SPC involves implementation of following key steps:

- Identification of defined processes
- Identification of measurable attributes of these process
- Understand natural variation of these attributes and characterize these.
- Process variation tracking

Maturity Level 4 of CMMI i.e. “Quantitatively Managed Process” involves Quantitative management is applied on the set of processes that produces a product. The significant contributors of these sub process, those impact overall process performance, are managed statistically. The results of process performance are analyzed statistically for the selected sub-processes. Thus, real time control charts like p-chart and c-chart can be used in Design phase of Software Development. Process uses Polynomial charts used in Coding phase, z-chart in testing phase and Early Customer Quality Index(ECQI) is used in beta phase. Any special causes that impact process variation are identified and appropriate correction is applied to the source of a special cause, where possible, and is corrected to prevent its recurrence.

Maturity Level 5 of CMMI that is, “Optimizing Processes”, the organization attempts improvement in its processes on continuous basis based on a quantitative understanding of the common causes of inherent variations in processes. These common causes of process variation are optimized by change in design of process. This change can be shift in the mean of the process. This can also be achieved as and when the process is re-stabilized by tuning variation. This leads to better process performance and also achieves desired process improvement objectives.”

Quantitative Project Management (QPM) process in the CMMI, (Goal #2) supports Statistical Managed Sub-process Performance with an objective to Understand process Variation.

CMMI uses statistical techniques to enable processes analysis, identify special causes of any variation in processes. This helps ensures process performance remains within well defined limits.” In addition, CMMI

Generic Practice #4.2 states "Stabilize Sub-process Performance" and explains "A stable sub-process does not exhibit significant indication in special causes of process variation. Stable sub-processes are predictable to the extent, the limits of which are established by the natural bounds of the sub process."

The emphasis placed upon SPC within the CMMI is such that, an organization cannot exceed a CMMI process maturity level rating of three. The degree of emphasis on SPC in CMMI process is more than any other measurement and analysis technique.

#### IV. Conclusion

SPC helps in understanding and improvement of processes like manufacturing and refineries, where the process is highly repetitive, it works very well. This is because these processes have a fairly consistent about their inputs and processing methods. The usefulness of applying SPC to human/knowledge intensive processes like engineering/training is not very clear and is questioned by intellectuals.

The human intensive processes like software development have performances which can vary widely from each project and have unique characteristics. Implementation of SPC in CMMI process of software development requires that 21 out of 25 process areas in CMMI, which are categorized in the maturity level 2 or 3 be applied first. SPC is applied only in remaining four process areas at level 4 or 5. This bottom up approach has impact on overall software development improvement. Nevertheless, software development cannot be classified as pure SPC controlled process.

Multiple issues needs to be addressed by software development processes requires that development teams need to focus on following:

- (i) Team Management and creativity
- (ii) Multiple issues which crop up unaddressed during development
- (iii) Working with limited available data and analysis of this data.

Nevertheless it can be shown that SPC based processes at level 4 and 5 have definite positive impact on the quality, productivity and cost reduction. This suggests that software development is required to focus more on process rather be product centric. Software development processes are team effort and creativity of individual is involved, team leader also need to take into consideration motivation factor of the team. In addition, alignment of development process with in the business goals is very important for the success of development project/product. SPC can helps in guiding as to how to improve processes in certain defined approach.

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## Dermatoglyphics (Age Determination) Wavelet Approach

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**Abstract:** *Dermatoglyphics means Science of fingerprint. This research implements a novel and simple method of age group classification using fingerprints. Two methods are combined for age determination. The first method is the Singular Value Decomposition (SVD), employed to extract fingerprint characteristics by doing synthesis and reconstruction. The second method is the analysis or feature extraction by using 2D Wavelet decomposition, up to 6 level decomposition used for the process of age identification. This method is experimented with the internal database of 420 fingerprints in different age groups, which contains both male fingerprints and female fingerprints. Tested fingerprint is grouped into following five groups: 6-7, 8-12, 13-15, 16-19, 20-30,31-50 and above 50. Overall classification rate of 55% has been achieved. Results of this analysis make this method a prime candidate to utilize in forensic anthropology for age classification in order to minimize the suspects search list by getting a likelihood value for the criminal.*

**Keywords:** *Fingerprints; SVD; Wavelets; BWT; Mode*

### I. Introduction

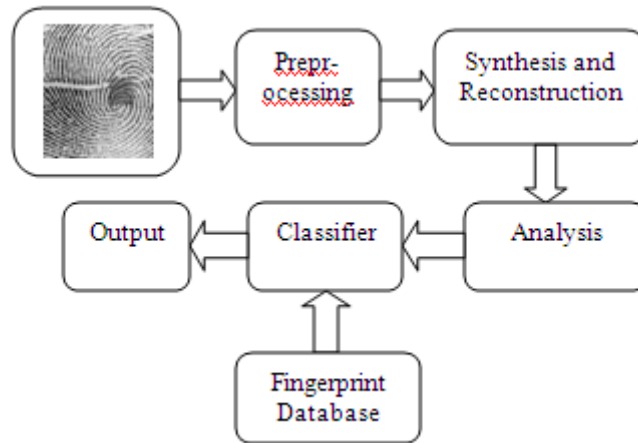
Age of a person can be identified using different biometric traits such as face, iris, retina, speech, gait, hand geometry and fingerprint. Fingerprint is one of the most common traits of human and can be easily obtained. Now a days thumbprints and fingerprint of each finger are taken in order to provide the identity proof to that particular person, e.g. to get a passport or a unique identity card in India, one had to give the impression of his/her thumb and fingerprints. A person's fingerprint is permanent even before they are born. Around 6-8 weeks after conception the volar pads (ball like structures that make up the contour of the fetal hand) form; by 10-12 weeks after conception the volar pads begin to recede; around the 13th week skin ridges appear and take the shape of the receding volar pad; lastly around the 21st week after conception the fingerprint patterns are complete[9].

A Fingerprint is the representation of the epidermis of a finger; it consists of a pattern of interleaved ridges and valleys. Fingertip ridges evolved over the years to allow humans to grasp and grip objects[1,2]. Like everything in the human body, fingerprint ridges form through a combination of genetic and environmental factors. This is the reason why even the fingerprint of identical twins is different [8]. Fingerprint is an impression of friction ridges, from the surface of the finger-tip. Fingerprints have been used for personal identification for many decades; more recently becoming automated due to advancements in the computing capabilities Fingerprints have some important characteristics that make them invaluable evidence in crime scene investigations:

1. A fingerprint is unique to a particular individual, and no two fingerprints possess exactly the same set of characteristics.
2. Fingerprints do not change over the course of person's lifetime (even after superficial injury to the fingers).
3. Fingerprint patterns can be classified, and those classifications then used to narrow the range of suspects [8].

In this work, age identification is mainly based on SVD which is used for synthesis and DWT is used for analysis. DWT is used to obtaining the approximation coefficients. Figure 1 illustrates the DWT and SVD based Age Classification system. function of the Features of fingerprints vary with sexes, ethnic groups and age categories. In this research the fingerprint is obtained from the Digital Persona Optical Fingerprint scanner. This paper is aimed in developing an algorithm for classifying the age through fingerprint.

Wavelet transform is a popular tool in image processing and computer vision because of its complete theoretical framework, the great flexibility for choosing bases and the low computational complexity [5]. As wavelet features has been popularized by the research community for wide range of applications including fingerprint recognition, face recognition and gender identification using face, authors have confirmed the efficiency of the DWT approach [4,5]for the identifications using fingerprint.



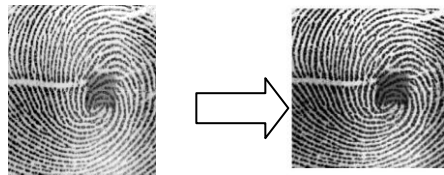
**Fig. 1 Block Diagram of Age Determination System.**

The SVD approach is selected for the gender discrimination because of its good information packing characteristics and potential strengths in demonstrating results. The SVD method is considered as an information oriented technique since it uses principal components analysis procedures (PCA), a form of factor analysis, to concentrate information before examining the primary analytic issues of interest [5]. Threshold gives very strong consistent results. It uses the database which was generated in the learning stage of the proposed system and it classifies genders of the fingerprints.

## II. Proposed Method

### A. Preprocessing

I have collected 420 fingerprints (210 males and 210 females) by Digital Persons Optical Fingerprint scanner. Those captured images were stored on .jpg format and in size of 310 X 420 number of pixels. The input fingerprint was enhanced by a series of techniques. Firstly the image was resampled by 300 X 350 no of pixels by using image resizer. Secondly it resized in to 256 X 256 no of pixels. Then the resized image undergoes enhancement technique like histogram equalization. The fingerprint image obtained undergoes image enhancement for improving quality of the ridges and valleys. The output of the preprocessing stage is shown in Figure 2.



**Fig. 2 Input image and Enhanced image**

Enhancement techniques used on the fingerprints varies with the quality of the image and types of database used. Poor quality fingerprint image obtained is enhanced for better implementation of algorithm.

### B. Singular Value Decomposition(SVD)

The Singular Value Decomposition (SVD) is an algebraic technique for factoring any rectangular matrix into the product of three other matrices. The SVD is the factorization of any real matrix into three matrices, each of which has important properties. Any real  $m \times n$  matrix  $A$  can be decomposed uniquely as

$$A = U D V^T \quad (1)$$

$U$  is  $m \times n$  and column orthogonal (its columns are eigenvectors of  $AA^T$ ) ie

$$AA^T = U D V^T V D U^T = U D^2 U^T \quad (2)$$

$V$  is  $n \times n$  and orthogonal (its columns are eigenvectors of  $A^T A$  ie

$$A^T A = V D U^T U D V^T = V D^2 V^T \quad (3)$$

$D$  is  $n \times n$  diagonal (non-negative real values called singular values)

$$D = \text{diag}(\sigma_1, \sigma_2, \dots, \sigma_n) \quad (4)$$

ordered so that  $\sigma_1 \geq \sigma_2 \geq \dots \geq \sigma_n$  (if  $\sigma$  is a singular value of  $A$ , it's square is an eigenvalue of  $A^T A$ ).

If  $U = u_1, u_2, \dots, u_n$  and  $V = v_1, v_2, \dots, v_n$  then

$$A = \sum_{i=1}^n \sigma_i u_i v_i^T \quad (5)$$

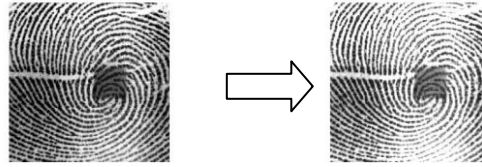
### C. Synthesis and Reconstruction

The generation of an image from a mathematical model rather than observation is known as image synthesis. Here image synthesis can be done by using equation

$$P=U * power(D, 5/4) * V^T \tag{6}$$

The image can be reconstructed by using equation

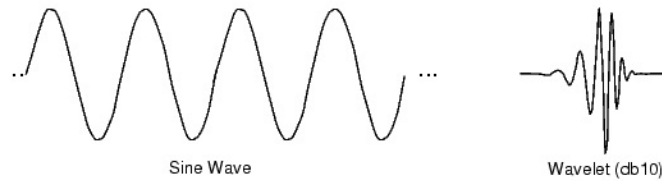
$$J=enhanced\ image + (0.25 * P) / (1 + 0.25) \tag{7}$$



**Fig. 3 Enhanced image and Reconstructed image**

**D. Analysis Using Wavelets**

Before knowing wavelet transform let us know about the wavelets. A wavelet is a waveform of effectively limited duration that has an average value of zero. In mathematical term wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale.



**Fig. 4 Comparison of sine wave and wavelet**

Fig.4 shows the comparison of wavelets with sine waves. Sinusoids extend from minus to plus infinity i.e. they do not have limited duration. Sinusoids are smooth and predictable whereas wavelets tend to be irregular and asymmetric. Wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or mother) wavelet. Fig.4 shows that signals with sharp changes might be better analyzed with an irregular wavelet than with a smooth sinusoid. Many kinds of wavelets exist can be chosen as per the requirement. The principle advantage is that they provide the advantage of knowing existence of a frequency at a particular time interval. Wavelet transform of any function  $f$  at frequency  $a$  and time  $b$  is computed by correlating  $f$  with wavelet atom as

$$Wf(a, b) = \int_{-\infty}^{\infty} f(t)\psi(t - \frac{b}{a}) dt \tag{8}$$

Wavelet transform is always defined in terms of a “mother wavelet  $\psi$ ” and a scaling function  $\phi$ , along with their dilated and translated versions. The use of wavelet transform on image shows that the transform can analyze singularities easily that are horizontal, vertical or diagonal which can be used in the fingerprint gender classification.

**E. Biorthogonal Wavelet Transform**

A biorthogonal wavelet is a wavelet where the associated wavelet transform is invertible but not necessarily orthogonal. Designing biorthogonal wavelets allows more degrees of freedom than orthogonal wavelets. One additional degree of freedom is the possibility to construct symmetric wavelet functions.

In the biorthogonal case, there are two scaling functions  $\phi, \tilde{\phi}$  which may generate different multiresolution analyses, and accordingly two different wavelet functions,  $\psi, \tilde{\psi}$ . So the numbers  $M$  and  $N$  of coefficients in the scaling sequences,  $\tilde{a}$  may differ. The scaling sequences must satisfy the following biorthogonality condition

$$\sum_{n \in \mathbb{Z}} a_n \tilde{a}_{M-1-N} = 2 \cdot \delta_m \tag{9}$$

Then the wavelet sequence can be determined as,

$$b_n = (-1)^n \tilde{a}_{M-1-N} \tag{10}$$

$$\tilde{b}_n = (-1)^n a_{M-1-N} \tag{11}$$

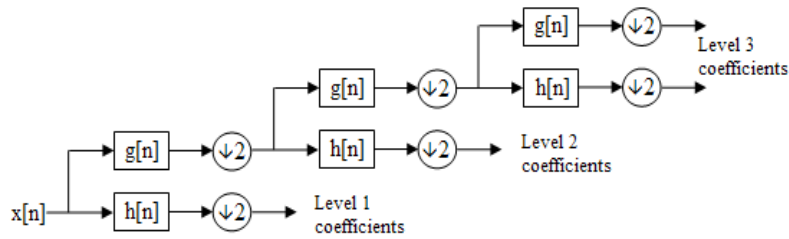
The scaling equations on the scaling functions and wavelets show that the decomposition and reconstruction of a signal from a resolution to the next one is implemented by perfect reconstruction filter banks.

**F. Wavelet Decomposition**

The pre-processed image undergoes Biorthogonal Wavelet decomposition in order to obtain vectors in frequency domain. Discrete Wavelet Transformation is a type of transformation in which wavelets are directly sampled. The DWT of a signal  $x$  is calculated by passing it through a series of filters. Firstly the sample image was passed through a low pass filter through impulse response  $g$  resulting in convolution shown in equation (12)

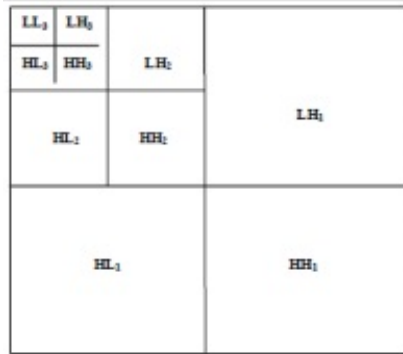
$$y[n]=x[n]*g[n]=\sum_{k=-\infty}^{\infty} x[k]g[n - k] \tag{12}$$

The signal is also decomposed simultaneously by using a high pass filter  $h$ . The two filters used had to be related with each other. This decomposition has halved the time resolution, since only half of each filter output characterizes the signal. Each output has half the frequency band of the input, so the frequency resolution has been doubled. This decomposition is repeated to further increase the frequency resolution and the approximation coefficients decomposed with high and low pass filters and then down-sampled as shown in Figure 5.



**Fig. 5 Level 3 Decomposition**

Two dimensional DWT decomposes an image into subbands that are localized in frequency and orientation. The decomposition of images into different frequency ranges permits the isolation of the frequency components as in [1]. The 2-D wavelet decomposition of an image results into four decomposed sub-band images referred to as low-low (LL), low-high (LH), high-low (HL), and high-high (HH) as shown in Fig.6



**Fig. 6 Subbands after decomposition**

Each of these sub-bands represents different image properties. Most of the information's of the images is in the lower frequencies. So the further decomposition of sub band is repeated in LL sub band. For  $k$  level DWT, there are  $(3*k) + 1$  sub-bands available. Here we using 6 levels of decomposition.

**G.Age Classification**

Further processing here we using LL sub band only. By an experimental study we choose an image statistical property as a parameter. Here mode is selected as estimated parameter. Mode of each age classification group is different. So that mode for each group can be set by calculating mean of mode under each group. Mean can be calculated in Matlab by using following equation

$$Mean = \frac{sum(mode)}{(number\ of\ modes)} \tag{13}$$

**III. Results And Discussions**

The algorithm of the proposed system is written in MATLAB R2014 and run in Intel Core 2 Duo, 2.20 GHz processor with 2.00 GB memory. Here, we proposed a new and simple method for Age Classification of fingerprints using DWT and SVD. The level 6 DWT is selected as optimum level for the gender classification. Mode of each age classification group is different. Results after each steps were given in previous sections. The success rate is more than 55%. Percentage of result after this study can be obtained is shown in below table.

**Table 1.Age Group Classification Accuracy**

Sl.No	Age Classification			Over all Accuracy
	Age Groups	Total Fingerprints-60	Accuracy	
1	6,7	32	53%	55%
2	8-12	34	56%	
3	13-15	30	50%	
4	16-19	32	53%	
5	20-30	32	53%	
6.	30-50	30	50%	
7	Above 50	34	56%	

#### IV. Conclusion

Here we proposed a new and simple method for age group classification from fingerprint images based on Wavelet Transform and SVD technique. This method considered the frequency features of the wavelet domain. The LL block is selected for further processing for the age classification. Mode was chosen as the parameter for gender classification. The proposed system is experimented only on the optical scanned image. Better results will be obtained for digital images. Fingerprint evidence is undoubtedly the most reliable and acceptable evidence till date in the court of law. Due to the immense potential of fingerprints as an effective method of identification an attempt has been made in the present work to analyze their correlation with gender of an individual. The fingerprints of different age groups vary in size and patterns and thickness of ridges and valleys. The fingerprints of people from various ethnic groups vary.

The further improvements hence planned to be done in conjunction with this are blood group determination and heredity checking.

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## Online Opportunistic Routing in Cognitive Radio Ad-Hoc Network and Spectrum Management

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**Abstract:** Accessing under-utilized licensed spectrum band using cognitive radio ad-hoc network improves the spectrum usage effectiveness. Due to use of opportunistic spectrum access the performance of routing in cognitive radio ad-hoc network will improve where no need of prior knowledge about topology and channel statistics in Ad-Hoc Cognitive radio Network. To deal with requirements of Ad-Hoc Cognitive radio Network, this paper is proposing opportunistic routing algorithm with the help of Reinforcement Learning. This proposed routing scheme collectively deals with, prior time channel selection as well as a link and relay selection on the basis of overall success probabilities of data transmitting. This advance learning scheme successfully finds out the opportunities in the dynamic environment of Ad-Hoc Cognitive radio Network.

**Keywords:** Cognitive Radio Ad-hoc Network; Spectrum Management; Hidden Markov Model; Routing Scheme; Reinforcement learning

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### I. Introduction

Research on cognitive radio networks (CRNs) was effectively launched in 2002 following a report by the FCC [1]. The report challenged for the first time the common belief of spectrum scarcity by pointing out that only less than 10 percent of available spectrum is used. The FCC also spot lit that a large portion of the licensed spectrum is used periodically, and geographical fluctuations in the usage of licensed spectrum portions oscillate from 15 to 85 percent with a high variance in time. To exploit under use portions of the spectrum, i.e. White spaces /spectrum holes, that prompts the need of smart reprogrammable radios which are able to interference sensing, channel state learning, and spectrum access dynamically. Recently the research community has started working on Ad-hoc cognitive radio network to unleash the potential of it in exploring the wide range of pervasive applications [2], [3].

Cognitive Radio (CR) [4] is a novel solution to the scarce spectrum resource problem. In cognitive radio network, cognitive devices or nodes are reprogrammable devices that sense the wideband spectrum and as per the environment, it re-configurable to work in a dynamic environment. The CR nodes sense spectrum and get unoccupied frequency bands also known as Spectrum Opportunities (SOP), then use specific policy or also known as rule to select one candidate for them.

Ultimately the intension of Cognitive Radio (Cognitive device/node) is to access the unused licensed spectrum bands in a dynamic environment to improve the spectrum usage [6]. Spectrum scarcity and underutilization can be improved by allowing SU's to access the licensed bands opportunistically without disturbing the PU's activity. The Cognitive device has additional functionality for spectrum sensing and sharing licensed band so use of Cognitive devices/nodes in an ad - hoc network will improve the bandwidth utilization under the dynamic environment.

### II. Related Work

Routing in ad-hoc Cognitive Radio Networks become challenging due to Dynamic environment. There are various approaches for routing depending on various schemes and Parameters. These approaches are studied and used in various ways worldwide. Conventional routing mechanisms where network attempts to find out fixed path to forward packets from source to destination [7], [8]. There is large number of routing protocols proposed for ad hoc cognitive radio network that finds a fixed path using route discovery processes [9]-[11]. Such fixed path strategies fail to address the uncertainties and dynamic changes in topology due to sporadic spectrum and route availability in network.

Allocation of the barely spectrum resource between cognitive nodes in stochastic environment increases the complexity due to uncertainty of the environment state [12]. Markov Decision Process (MDP) is promising mathematical framework for modeling environments like CRNs in which outcome is not only dependent on decision strategies but sometimes it can be random. MDP are useful for studying optimization problems solved via reinforcement learning [13-15]. Transition probability function and reward function of it can used to analyze the environment based on received feedback of any selected action.

There are many existing solutions for spectrum aware routing using conventional algorithms for ad-hoc cognitive radio networks were proposed. Channel selection as well as assignment and routing in semi static ad-

hoc networks is jointly addressed using a layered graph [5]. The layered graph plays layers equal to the number of available channels. Dynamic changes in the topology are captured using the link availability predictions based on the interference to the PU [16]. The resultant reliable topology is used for setting up multi-hop paths and to reduce rerouting. Cognitive Routing Protocol (CRP) gives explicit protection to the PU receiver [17]. It allows two classes of routes based on the service differentiation in cognitive radio network. Routing is achieved in two phases i.e. spectrum selection phase and next hop selection phase. Online opportunistic routing selects forwarding links based on the locally identified spectrum access opportunities [18].

This paper proposes the Online Opportunistic Routing Scheme for ad-hoc cognitive radio network. This Learning based online opportunistic routing scheme addresses the issue of routing packet in dynamic environment. Routing decisions are made with respect to the current state of the environment and actual transmission success probabilities. Proposed algorithm considers no knowledge of the topology and simultaneously learns channel statistics and good routes. The main contributions of this paper are as follows:

1. Channel availability prediction with the help of Hidden Markov Model
2. Markov Decision Process formulation using Temporal Difference (TD) implementation of Reinforcement Learning with incomplete and erroneous information of topology.
3. Softmax Action Selection Rule is used for balancing exploration and exploitation in relay selection process.

### III. Hidden Markov Model

We see a cognitive radio network in which each node works as a cognitive node that can scan and sense multiple channels periodically to compute interference temperature at each channel. This process gives us an observation sequence  $O$  for a first  $T$  time slot for considering channel  $c$ . If a node can predict the observation sequence for next  $2T$  time slot for same channel  $c$  then such prediction will be utilized by the node for selecting preferable communication channel prior periods. In order to resolve the above situation the Hidden Markov Model provides a suitable solution to the problem. The HMM has obtained noteworthy practical application in speech recognition [10] and bioinformatics [15]. The HMM is trained by using the observation sequence  $O$  also known as training observation sequence. In order to achieve the HMM, it is essential to define the followings:

1. The number of observed symbols,  $M$
2. The number of states,  $N$
3. The observation sequence  $O = \{O_1, O_2, \dots, O_T\}$
4. The state transition probabilities,  $A_{ij}$  subject to condition  $A_{ij} \geq 0$  and  $\sum_{j=1}^N A_{ij} = 1$
5. The symbol observation probabilities,  $B_j(m)$  subject to condition  $B_j(m) \geq 0$  and  $\sum_{m=1}^M B_j(m) = 1, 1 \leq j \leq N$
6. Initial State probabilities  $\pi$

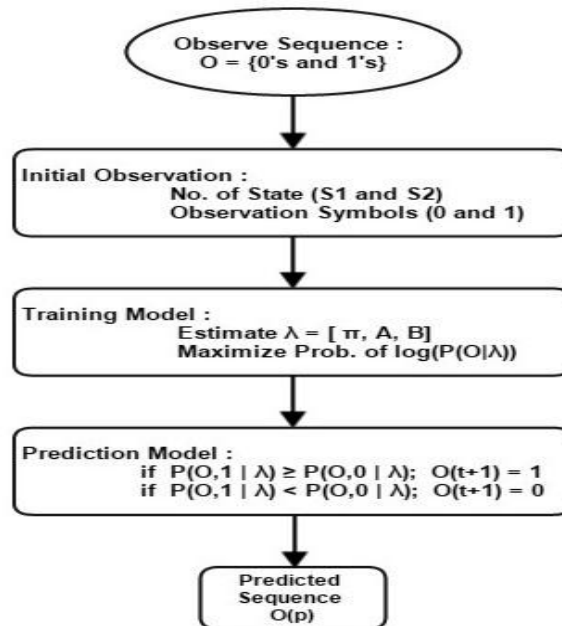


Figure 1: HMM training and Predictor

Here the observation sequence contains two symbols 0 and 1s also known as observation symbols  $M = \{0, 1\}$ . And set of states can be denoted as  $S = \{s1, s2\}$ .

The HMM can be denoted by the notation  $\lambda = [\pi, A, B]$  that is estimated by iterative method of the Baum-Welch Algorithm. After training model the HMM predictor will predict the required sequence for next  $2T$  time slot. The HMM prediction scheme is illustrated in Figure 1.

Where, the channel status is denoted by 1 and 0 for busy and ideal, respectively. The main goal of predictor is to predict the sequence  $O(p)$  on the basis of past  $T$  slot observation. For that the HMM should be able to generate the observation sequence  $O = \{O_1, O_2, \dots, O_T\}$  with maximum likelihood probability. Hence, the parameter  $\lambda = [\pi, A, B]$  are used to maximize the likelihood probability of generating the observation sequence, i.e., maximize the probability  $P(O|\lambda)$ . After completing the training, the joint probability of observing the sequence  $O$  followed by a busy slot or an idle slot at instant  $2T$  is predicted.

#### IV. Online Opportunistic Routing

The performance of online opportunistic routing in uncertain and dynamic wireless environment can be improved using Reinforcement Learning (RL) algorithm. RL can be used to learn optimal policy on-line from direct interaction with the environment for solving non-linear control problems [19].

##### A. Methodology

Methodology Using RL the agent learns how to achieve the given goal by trial and error interacting with environment. That improves performance of the agent from the received reward or punishment as a result of the performed action [20]–[22]. In online opportunistic routing, every cognitive node is considered as an intelligent agent and Ad-hoc network as environment. Temporal difference (TD) method learns directly from environment dynamics [23] without any knowledge of its model. It uses generalized policy iteration to update estimates i.e. value score, based in the parts on other learned estimates, without waiting for the final outcome. TD method wait only until the next time step, at  $t+1$  it immediately form a target and make a useful update using observed reward  $r_{t+1}$  and the estimate  $V(s_{t+1})$ . So estimated value score  $V(s_t)$  is updated by

$$V(s_t) \leftarrow V(s_t) + \alpha_{BRN} [r_{t+1} + \gamma V(s_{t+1}) - V(s_t)] \quad (1)$$

Where  $\alpha_{BRN}$ , is a step-size parameter that influenced by BRN i.e. Best relay node among willing neighbor. Markov decision process the task that satisfies the markov Property, i.e. all decisions and values are functions of the current state only, is called Markov Decision Process (MDP) [24]. MDP is defined by its state and action sets and by the one-step dynamics of the environment. Given the current state and action, one-step dynamics enable us to predict the next state, expected next reward and iteratively all future states and rewards.

##### B. Proposed Work

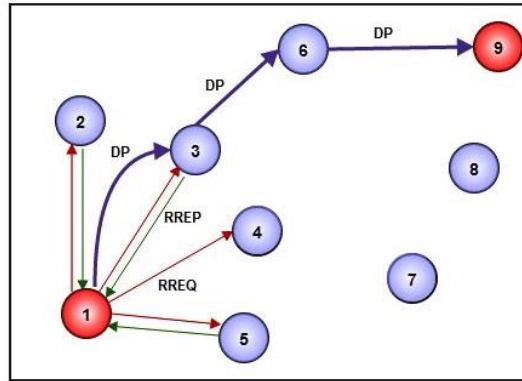
One potential application of HMM that we investigate and propose in this paper is to use the sequences generated by the trained HMM in selecting preferable channel for communication in multi-channel cognitive wireless network. Consider a multi-channel cognitive wireless network with  $n$  channels. Let us assume that the training sequences for these channels is obtained by a designated cognitive nodes, which construct hidden Markov model for each channel using these training sequences, as explained in section III.

$$CAM_i = A_i^0 + \frac{1}{(|OS^1|/|OS|)} \quad (2)$$

Where,  $A_i^1$  is average gap between any two 1's in given sequence,  $OS^1$  is number of 1's in given sequence and  $|OS|$  is length of sequence.

The node selects the channel having most eminent value of channel availability metric ( $CAM_i$ ), as the most preferable channel for communication. Now each node has their own CAM value for each available channel in there vicinity. All the nodes in the network send beacon message to neighbor nodes with available channel CAM values because of this the each node got the neighbors channel availability set. Then each node calculates the common channel with neighbor using intersection.

Then sender node choose most available channel as a control channel for sending control packets and other as a data channel for sending data packets. After finding common channel between neighboring nodes the sender node sends the RREQ (relay request) to neighbor nodes on every available control channel. Now some of them those who are interested to be part of routing will send the RREP (relay reply) on control channel also known as willing neighbor  $WN_i$  to sender as shown in figure 2



**Figure 2: Relay Request (RREQ), Relay Reply (RREP) and Data Packet (DP) Transmission**

Then sender node choose best channel as a control channel and other as a data channel. Then it will send data to the relay node then relay node send acknowledgment to sender on that basis sender update the estimated score for that relay node for future decision. Whenever in future the node wants choose the relay node for data transmission first it checks history record for available neighbor nodes score and as per statistics node will take decision quickly using Softmax action selection explained in section V.

The above process will be repeated by each relay node until the destination. After reaching the destination successfully it will get some rewards stored to source node for future decision. After reception of the packet at destination the cumulative link cost  $LC_c$  is subtracted from the fixed final reward received at the destination. Where,

$$LC_c = TT + LA + SC + CA + PD \quad (3)$$

Where, TT is time to transmit (estimated) , LA is link availability , SC is switching cost , CA is channel availability and PD is propagation distance. Selection of the lowest link cost at every hop finally increases reward at the destination.

So average per packet reward is maximized by selecting random hops h for the packets generated at the source s with index I for destination d is presented as,

$$RM = \frac{(\sum_{i=1}^M (R - \sum_{j=1}^h LC_c))}{M} \quad (4)$$

Where M is number of packet transmitted successfully, R is fixed reward received at destination.

### V. Balancing Exploitation and Exploration

For increasing learning rate and to increase overall score exploration and exploitation must be balanced at time of taking action. Selection of relay with the help of routing score can increase complexity and load on that single node that also known as greedy selection in such case if node is choose with the help of softmax action selection rule i.e. one of the non-greedy actions. This alters to explore, as it allows improving the values of non-greedy actions. Softmax action selection rule is effective in exploring and exploiting the network opportunities by taking a sequence of decisions which will increase routing score of every willing neighbor WN. Suppose estimated value of action A at  $t^{th}$  play,

$$Q_t(A) = WN + 1 \quad (5)$$

Softmax action selection method is instinct in balancing exploration and exploitation in online dynamic routing. It can be represented as,

$$P = \frac{e^{Q_t(A)/T}}{\sum_{A=1}^n e^{Q_t(A)/T}} \quad (6)$$

Where, T is a positive parameter called temperature. Because of high temperature equi-probable action selection is done. This enables exploration by improving estimate of non-greedy actions. Because of low temperature greater difference in selection probability for actions that differs in their value estimate. When  $T = 0$ , softmax action selection method will act as greedy action select exploiting the network by selecting the best candidate node as relay.

### VI. Algorithm and Flow Chart

1. Initialization
  - a. HMM predict sequence using given observation sequence.
  - b. Nodes share channel availability to neighbor node ( $N_s$ )
  - c. Select best channel as Control Channel (CC) and other as Data Channel (DC)
2. Relay Request

- a. Source (S) send a **RREQ** on CC for destination (D) using Control Packet (CP)
3. Relay Reply
  - a. Let  $N(s)$  is set that receive CP
  - b. **RREP** sent from  $WN \in N(s)$
  - c. Update Score for WN
4. Relay Selection and Data Transmission
  - a. Upon reception of **RREP** from WN node selects routing action  $a \in A(s)$  using Softmax Action Selection Rule P.
  - b. Sends data packet (DP) on most available common data channel between source to next node at time t
5. Reception and Acknowledgement
  - a. Upon successful reception of DP, an acknowledgement is sent back to sending node
  - b. Reward is updated by subtracting  $LC_c$
6. Step 1 to 5 are repeated until terminal node (Destination)
  - a. After successful reception of all DP average per packet reward is calculate
  - b. Acknowledgement is sent back to Source with reward

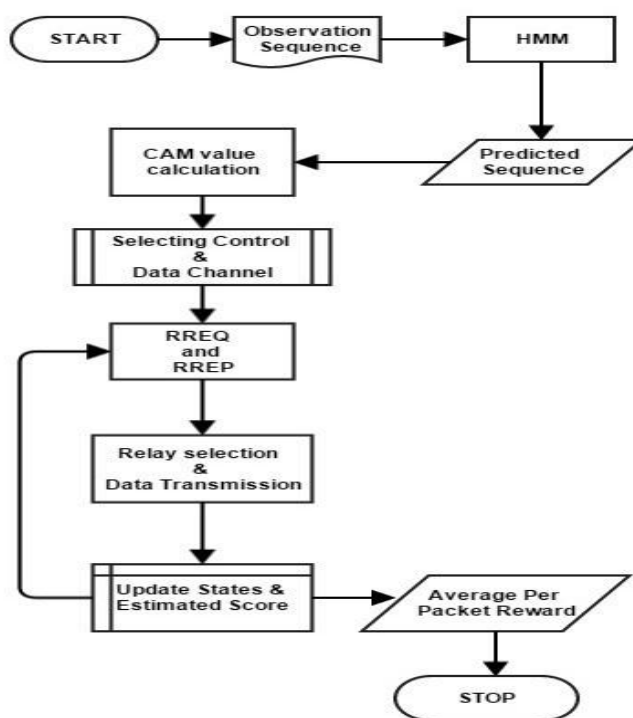


Figure 3: Flow Chart

### VII. Future Work and Conclusion

1. Study and analyze the consequence of the reinforcement signal on convergence of the RL in Cognitive Radio network and effect of Q values for improving the learning efficiency of the agent.
2. Design of the routing protocol under circumstance of the multiple agents who are modeled as evolutionary game for using wireless spectrum.

In online opportunistic routing reinforcement learning based routing algorithm is designed successfully to explore the spectrum and routing opportunities in dynamic environment of Cognitive Radio Ad-hoc Network. In contrast to the conventional routing of finding out a static route from origin to destination, proposed algorithm routes the packets online without considering topology.

Temporal Difference (TD) implementation of RL based routing accomplishes an optimum performance evaluated using average per packet reward. It attains the good quality of service requirement of cognitive users by decreasing the route re-discoveries.

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## Comparative Study of Spectrum Sensing Methods in Cognitive Radio Network

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**Abstract:** Rapid growth of wireless applications and services has made it essential to address spectrum scarcity problem in the limited available spectrum. Thus we need a new communication paradigm to utilize the existing wireless spectrum and efficient in spectrum usage. Cognitive Radio technology attempts to resolve this problem through improved utilization of radio spectrum, in which secondary usage of the spectrum resources is done without interfering with the primary usage of the licensed users. Spectrum sensing is a fundamental requirement in Cognitive Radio network to enhance the primary user signal detection probability in the spectrum. In this research, a comparative study has been made to evaluate the performance of three main spectrum sensing techniques i.e., Energy Detection, Matched Filter, Cyclostationary Feature Detection in Cognitive Radio. We also discussed about Cognitive Radio and different aspect of spectrum sensing. Summarization of the probability of false detection at different SNR associated with different types of spectrum sensing techniques have been made by MATLAB 2012a and the results are graphically represented. It is concluded that, the Cyclostationary Feature Detection is most suitable under low SNR in the case of non-cooperative spectrum sensing and Matched filter gives average performance than other techniques.

**Keywords:** Cognitive Radio (CR); Spectrum Sensing; Energy Detection (ED); Matched Filter Detection (MFD); Cyclostationary feature Detection (CFD).

### I. Introduction

The available radio spectrum is limited and it is getting crowded day by day as there is increased in the number of wireless devices and applications. It has been found that the allocated radio spectrum is underutilized because it has been statistically allocated not dynamically (allocated when needed). In the present scenario, it has been found out that these allocated radio spectrums are free 15% to 85% most of the time depending upon the geographical area. In order to overcome this situation, we need to come up with a means for improved utilization of the spectrum creating opportunities for dynamic spectrum access [1]. The issue in wireless communication can be solved in a better way by sensing this spectrum with the help of Cognitive Radio.

This work focuses on the spectrum sensing techniques that are based on primary transmitter detection and their performance in cognitive network. There are various types spectrum sensing techniques which, in general, could be classified as (1) energy-based sensing, (2) matched filter-based sensing, (3) cyclostationary feature-based sensing and (4) other sensing techniques. Different techniques serve different purposes based on their advantages and drawbacks. The energy-based sensing is the simplest method to sense the environment in a blind manner and most common way to detect signals. The matched filter-based sensing requires the complete information of the spectral-user signal and the cyclostationary-based sensing has better performance than others but, it is more complex and expensive and may require some information about the spectral user signal characteristics. To test the performance of spectrum sensing techniques in Cognitive Radio, simulation has been carried out using MATLAB R2012a.

### II. Spectrum Sensing in Cognitive Radio

The idea of Cognitive Radio was first presented officially in an article by Joseph Mitola III and Gerald Q. Maguire, Jr in 1999. Cognitive Radio is one of the new long term developments and can be define as "A radio that is aware of its environment and the internal state and with knowledge of these elements and any stored pre-defined objectives can make and implement decisions about its behavior" [2]. A major challenge in Cognitive Radio is that the secondary users need to detect the presence of primary users in a licensed spectrum and quit the frequency band as quickly as possible if the corresponding primary radio emerges in order to avoid interference to primary user (PU). For this it should detect the PU signals as faster as it can. This detection technique is called spectrum sensing. Most research work currently focuses on spectrum sensing in Cognitive Radio [1].

The main functions of Cognitive Radios are [8]: (1) Spectrum Sensing, (2) Spectrum Management, (3) Spectrum Sharing and (4) Spectrum Mobility. In these four functions spectrum sensing is an important and a sensitive task in Cognitive Radio. The main objective of spectrum sensing is to provide more spectrum access opportunities to Cognitive Radio users without interference to the PU networks. Since Cognitive Radio networks are responsible

for detecting the transmission of primary networks and avoiding interference to them, Cognitive Radio networks should intelligently sense the primary band to avoid missing the transmission of primary users [9]. One thing to consider is Spectrum Hole. A spectrum holes (also called spectrum opportunities) is a band of frequencies assigned to a PU, but at a particular time and specific geographic location, the band is not utilized by that user, hence can be accessed by secondary user (SU). In terms of occupancy, channels of the radio spectrum may be categorized as follows [5]: White hole (which are free of RF interferers), Gray hole (which are partially occupied by interferers as well as noise), and Black hole (the contents of which are completely full).

### III. Spectrum Sensing Techniques and Methods

Spectrum sensing techniques can be classified into four categories: (1) Primary Transmitter Detection, (2) Cooperative Transmitter Detection, (3) Primary Receiver Detection, and (4) Interference Temperature Management. In this paper only Primary Transmitter Detection technique is discussed. Primary Transmitter Detection sensing techniques from perspective of primary signal detection can be classified into these broad categories of sensing methods shown below in Figure 1 [10].

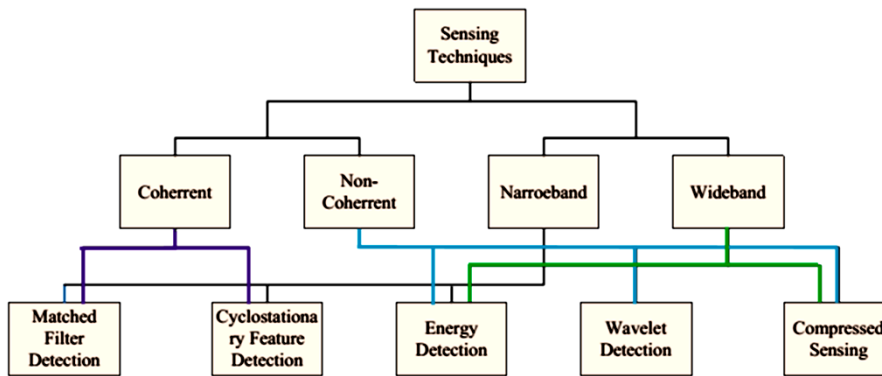


Fig. 1: Classification of sensing methods for primary transmitter detection technique [10].

A hypothesized model for transmitter detection is defined as that is, the signal detected by the (SU) is:

$$H_0: y(t) = w(t) \quad \text{and} \quad H_1: y(t) = h \times x(t) + n(t)$$

Where  $H_0$  represents the hypothesis corresponding to “absence of PU”, and  $H_1$  to “presence of PU”,  $y(t)$  is received signal,  $x(t)$  is transmitted signal,  $n(t)$  is Noise, and ‘h’ is the amplitude of channel gain (channel coefficient). For the two state hypotheses numbers of important cases are [3]:-

- $H_1$  is TRUE in case of presence of PU i.e.  $P(H_1/H_1)$  is known as Probability of Detection ( $P_d$ ).
- $H_0$  is TRUE in case of presence of PU i.e.  $P(H_0/H_1)$  is known as Probability of Miss Detection ( $P_m$ ).
- $H_1$  is TRUE in case of absence of PU i.e.  $P(H_1/H_0)$  is known as Probability of False Detection or False Alarm ( $P_f$ ).

The probability of false alarm or false detection is of main concern as it gives the false probability for the presence of noise in the frequency band.  $P_f$  should be kept as small as possible in order obtained better performance. The goal of this work is to analyze the  $P_f$  in a low SNR for three main schemes that have been developed for detecting the presence of PU in a particular frequency band as shown in Fig. 1. They are discussed below:

**(1) Energy Detection:** An energy detector senses the amount of energy in the signal received by the Cognitive Radio. One technique used to do ED is based on the use of the fast Fourier transform. It can be thought of as a means of determining the power in each frequency of the signal resulting in what is known as the power spectral density of the received signal. In order to measure the energy of the received primary signal, the received signal is squared and integrated over the observation interval. Finally, the output of the integrator is compared with a threshold to decide if a PU is present. The energy detector requires  $O(1/SNR^2)$  samples for a given detection error probability [6]. The Figure 2 illustrates the principle of the ED method.

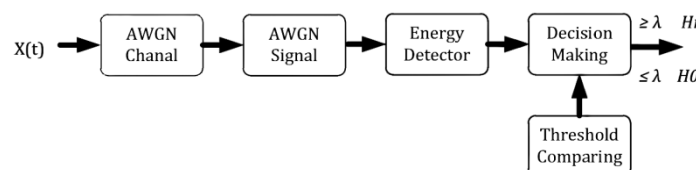


Fig. 2: Principle of Energy detection [10].

**Probability and Threshold Calculation:** The Probability of false alarm can be found, for a certain amount threshold needed for detection of the received signal, as given by [11]:

$$P_f = \text{prob}(u > \lambda | H_0) = Q\left(\frac{\lambda - \sigma_n^2}{\sigma_n^2 / \sqrt{M/2}}\right) \dots \dots \dots (1).$$

Here  $Q(x)$  is the Marcum's Q function,  $\sigma_n^2$  is the power density of intensity of the AWGN signal,  $M$  is the detector gain. Now the energy in a sample of duration  $T$  is approximated by  $2T\omega = 2u$ , where  $u = T\omega$ . If we take a predetermined value of probability of false alarm then we can find the value of threshold needed for detection which would be:  $\lambda_f = \sigma_n^2 \left(1 + \frac{Q^{-1}(P_f)}{\sqrt{M/2}}\right)$ .

**Advantages:** It is a non-coherent detection method and easy to implement. While using ED we do not require the prior knowledge of primary signal and it is the most popular sensing technique in cooperative sensing. Computational and implementation complexity is low [3].

**Disadvantages:** The computation of the threshold used for ED is highly susceptible to unknown and varying noise level which result in low SNR environments. By ED technique it is difficult to distinguish primary signals from the Cognitive Radio user signals since these detectors cannot discriminate among the sources of the received energy. ED not suitable to detect spread spectrum signals [3]. High sensing time needed to achieve a given probability.

**(2) Matched Filter Detection:** MFD is applied if a Cognitive Radio user has a priori knowledge of PU transmitted signal. A matched filter (also referred to as coherent detector) is obtained by convolving the unknown signal with a conjugated time-reversed version of the known signal template to detect the presence of the template in the unknown signal [9]. The principle of MFD method is shown in Figure 3.

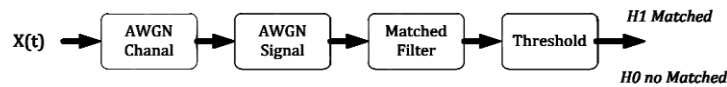


Fig 3: Matched filter detection [10].

**Probability Calculation:** It can be shown that the Probability of false alarm  $P_f$  for the test are given by,

$$P_f = \frac{1}{2} \left[ 1 - \text{erf} \left( \frac{\tau}{\sqrt{NM}} \right) \right] \dots \dots \dots (2).$$

Where  $\tau$  is the threshold of the signal after the matched filter,  $N$  is the signal power and  $M$  is the matched filter gain and  $NM$  represents the noise power after the matched filter. So Probability of false detection can be written as,  $P_f = \frac{1}{2} [1 - \text{erf}(\sqrt{SNR})]$ , where  $\frac{\tau}{\sqrt{NM}} = \sqrt{SNR}$ .

**Advantages:** Matched filter is an optimal detector since it maximizes the received signal SNR [11]. Advantage of this filter is that its sensing time is low as compared to other detectors [3] and needs less time to achieve high processing gain.

**Disadvantages:** Matched filter requires a prior knowledge of every primary signal [3] and if the information is not accurate then it performs poorly which leads to an undesirable missed detection of primary users [11]. Also the most significant disadvantage of MFD is that a Cognitive Radio would need a dedicated receiver for every type of PU. Since large number of receivers requires, so different algorithms need to be evaluated and thus power consumptions is large [3] and computational complexity is also high.

**(3) Cyclostationary Feature Detection:** For a cyclostationary signal, its spectral-correlation density (SCD) function takes nonzero values at some nonzero cyclic frequencies. On the other hand, noise does not have any cyclostationarity at all. Hence, we can distinguish signal from noise by analyzing the SCD function. Again, it is possible to distinguish the signal type because different signals may have different nonzero cyclic frequencies [4],[7]. Figure 4 shows principle CFD method. If  $S_x^\alpha$  Spectral correlation function then maximum of the spectral correlation function  $C = \max(S_x^\alpha)$  is compared to a threshold to find the presence of a PU.

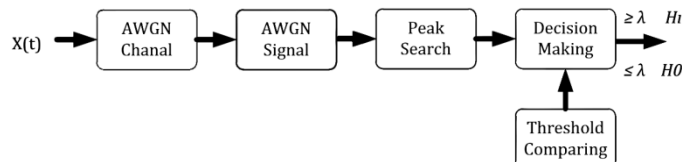


Fig. 4: principle of cyclostationary feture detection [10].

**Probability Calculation:** The probability of false alarm for the CFD is given as [3],

$$P_f = \exp\left(-\frac{(2N + 1)\lambda^2}{2\delta^4}\right) \dots \dots \dots (3).$$

From the above equation the threshold can be calculated as,  $\lambda = \sqrt{\frac{2\delta^4}{(2N+1)} \ln(P_f)}$ . Here ' $\delta$ ' is the variance of the received signal and ' $N$ ' is the number of samples values of the signal.

**Advantages:** It is one of the useful techniques of signal determination on the basis of SCD. CFD can differentiate the modulated signal from the additive noise and can be used at very low Signal to Noise Ratio (SNR) [3]. The benefit of this detection is that it improves the overall Cognitive Radio throughput.

**Disadvantages:** It suffers in multipath fading and shadowing environments. It deals with all the frequencies to generate the spectral correlation function, which makes it to do a very large calculation. Observation time is longer for achieving a satisfactory performance. The main drawback is the complexity of calculation [3], [11].

#### IV. Results and Discussions

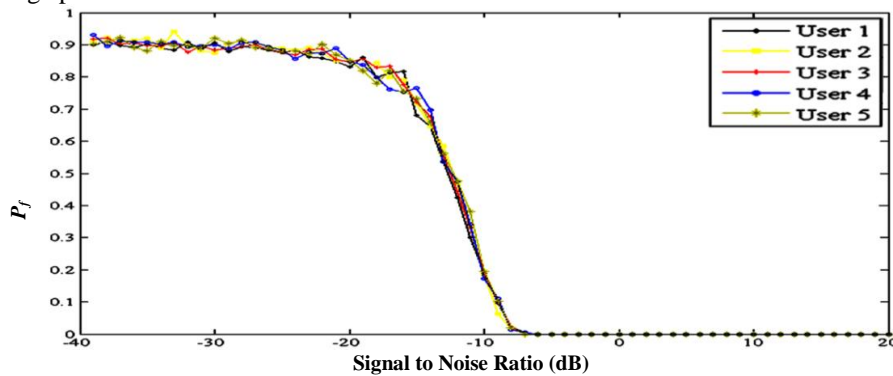
We have conducted simulations in MATLAB R2012a to evaluate the comparative performance of 3 main spectrum sensing techniques of Cognitive Radio. The performances are measured in terms of the ( $P_f$ ) with varying SNR and the channel model is AWGN with zero mean under mainly 16-QAM modulation scheme. Common parameters for all detection methods are shown in table 1:

**Table 1: Summary of the simulation parameters**

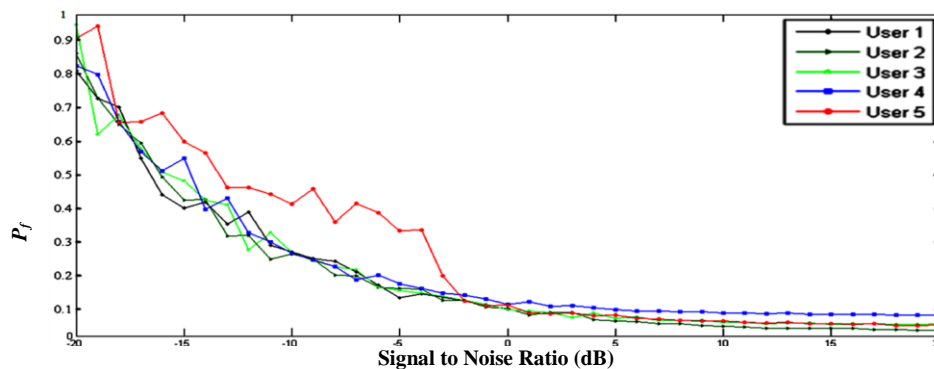
<b>Modulation:</b>	AM or, 16-QAM
<b>Initial phase (q) (only for AM):</b>	0, 0.9, 0.8, 0, 0.78
<b>Modulating frequency (<math>F_m</math>) [in kHz]:</b>	50, 100, 150, 200, 250
<b>Sampling frequency (<math>F_s</math>) [in kHz]:</b>	22000
<b>Carrier frequency (<math>F_c</math>) [in kHz]:</b>	5000, 8000, 10000, 7000, 9000
<b>Threshold:</b>	30%

We used 5 modulating frequencies which are indicated by user 1 to 5. In Figure 5, is it observable that the  $P_f$  values approach to minimum in ED after -8 dB SNR and gives nearly stable 90%  $P_f$  values after -30 dB SNR. In Figure 6, overall performance is better for MFD. The Simulation gives nearly same curves for 5 users up to 0db SNR, but before that the performance varies for different user i.e. different frequencies. For CFD method in Figure 7, the  $P_f$  versus SNR curve gives better performance at highly noisy situation which is not more than 55% probability of false detection up to -30 dB SNR or less than it. For this figure of CFD, we limited the minimum  $P_f$  to 0.1, because it gives ripple value at minimum level which is difficult for curving the graph.

**Comparative Results:** Figure 8 illustrates the average Probability of false detection ( $P_f$ ) curve of 5 users for three primary transmitter detection based spectrum sensing which depicted the comparative performances. At highly noisy situation, performance degradations are different for these 3 techniques, but for SNR greater than 0 dB the performances are almost same. At -10 dB SNR value, ED gives the better performance than others, but with the increase of noise its performance decreases and at -40 dB or less than -40 dB SNR, CFD gives satisfactory performance and  $P_f$  of CFD is much smaller as compared to other two methods. However matched filter has average performance than other methods and its curve is smooth.



**Fig. 5:  $P_f$  vs. SNR for PU signal detection in Energy Detection Method.**  
Here SNR is kept between -40 to 20 db for  $P_f$  range from 0.001 to 1.



**Fig. 6:  $P_f$  vs. SNR for PU signal detection in Matched Filter Method.**  
Here SNR is kept between -20 to 20 db for  $P_f$  range from 0.01 to 1.

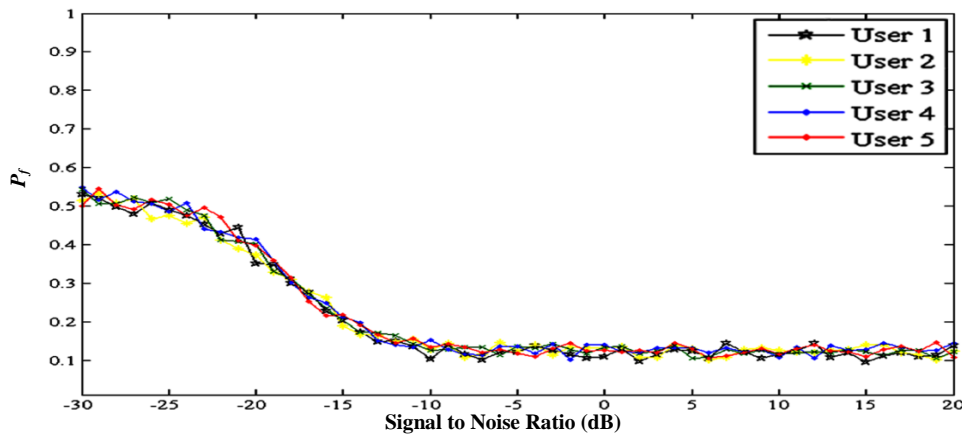


Fig. 7:  $P_f$  vs. SNR for PU signal detection in Cyclostationary Feature Detection. Here SNR is kept between -30 to 20 db for  $P_f$  range from 0.1 to 1

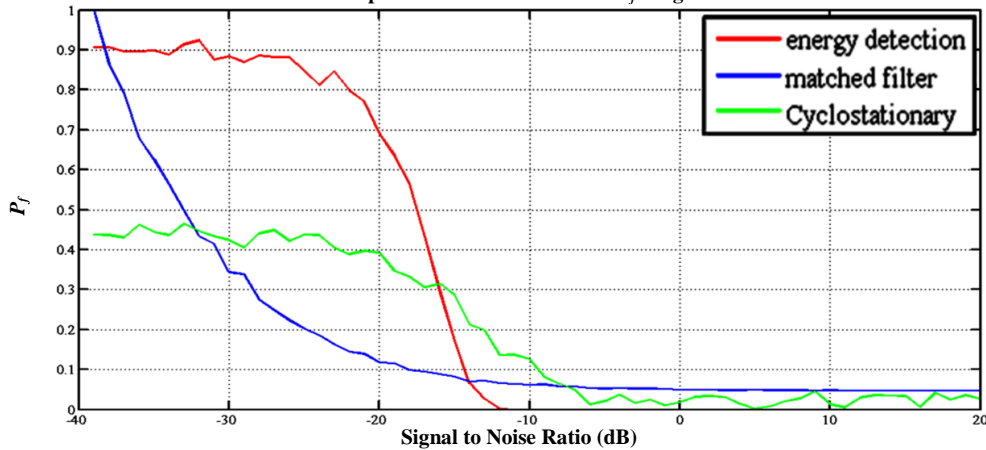


Fig. 8: Average Probability of false detection ( $P_f$ ) for each method with SNR change. Here SNR is kept between -40 to 20 db for  $P_f$  range from 0.001 to 1

## V. Conclusions

To efficiently utilize the wireless spectrum Cognitive Radios were introduced which opportunistically utilize the holes present in the spectrum. The most essential aspects of a Cognitive Radio system are spectrum sensing and various sensing techniques which it uses to sense the spectrum. In this Paper, summarization of the  $P_f$  at different SNR associated with different types of spectrum sensing techniques have been simulated, where  $P_f$  needs to be as small as possible for better performance. The main focus was to compare the performances of these three main spectrum sensing techniques under the conditions of low SNR. The result in the paper shows that ED method is a poor detection method compared to MFD which is an average detection method, but CFD is better than both the previous detection techniques in responding to low SNR for detecting primary user signals.

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