

## **M.TECH. THESIS ABSTRACT 2013**

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## Power & Control

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*Title* : *Sliding Mode Control strategies for Maximum Power Point Tracking of a Photovoltaic Array*  
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*Roll No* : *11104009*  
*Supervisor(s)* : *Behera Laxmidhar*

***Abstract:***

Free solar energy and high installation cost of Photovoltaic (PV) system encourages to extract maximum power from solar radiation. Since classical hill climbing and incremental conductance methods can not differentiate change in power due to perturb voltage and changing weather condition, both algorithms are prone to failure under rapidly changing weather condition. This thesis is concerned with maximum power point tracking (MPPT) of solar panel under varying solar radiation and cell temperature using nonlinear control methods. The proposed techniques can be enumerated as follows: Incremental conductance method is used to calculate desired value of PV voltage corresponding to MPPT and steady state analysis is performed on state equation to find out desired inductor current and output capacitor voltage. Since all the three states are connected through one to one mapping, convergence of any two of three states guarantee convergence of other state as well as whole system stability. In the first part, a sliding mode control(SMC) is applied to control inductor current and converter output voltage to track maximum power point and then convergence and tracking of PV output voltage is achieved. Stability of sliding (SS) is guaranteed using Lyapunov stability theory. Second part deals with the use of Approximate dynamic programming (ADP) while choosing the appropriate sliding surface. The idea has been implemented for MPPT of the same PV model. Cost function is formed using inductor current and capacitor output voltage. Minimization of cost function results in formation of SS which converges both the errors sufficiently close to zero in finite time.

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**Title** : *Partial Dynamic Algorithms for Lowest Common Ancestors Problem in Directed Acyclic Graphs*  
**Author(s)** : *Kowdeed Raghuram*  
**Roll No** : *Y8127384*  
**Supervisor(s)** : *Potluri Ramprasad&Baswana Surender*

**Abstract:**

Let  $G = (V;E)$  be directed acyclic graph with  $n$  vertices,  $m$  edges. For a pair of vertices  $u, v$  the vertex  $w$  is defined as common ancestor (CA) of  $u, v$  if both  $u, v$  are reachable from  $w$ . Further vertex  $w$  is said to be lowest common ancestor of  $u, v$  if  $w$  is a common ancestor of  $u, v$  and none of the descendants of  $w$  are common ancestors of  $u, v$ . We study the lowest common ancestor problem in dynamic directed acyclic graph (insertion and deletion of edges). We present both incremental and decremental algorithms for partial dynamic All Pair All LCA problem (updating LCAs for every pair of vertices after insertions or deletion of edges). The amortized update time of both algorithms are  $O(n*n)$ . The total time complexity of the incremental algorithm for All Pairs All LCA matches with time complexity of the static All Pairs All LCA algorithm. We also define a generalized version of All Pairs All LCA problem called Parametrized All Pairs LCA problem in which for a given a subset  $S$  of  $V$  we only maintain lowest common ancestors belonging to  $S$  for every pair of vertices. The amortized update time of both incremental, decremental Parametrized LCA algorithms are  $O((|S|*(mn + n*n))/m)$ . We can solve incremental All Pairs All LCA problem using incremental Parametrized All Pairs LCA algorithm by setting  $S = V$  which takes the same time as that of static All Pairs All LCA algorithm

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*Title* : *A Study on the Assessment of Voltage Stability of Electric Power Systems*  
*Author(s)* : *Kundu Raj Protim*  
*Roll No* : *11104084*  
*Supervisor(s)* : *Chakrabarti Saikat*

### *Abstract*

In modern power systems, maintaining the stability is a very big challenge to the operators. Voltage instability is one of the major stability problems encountered in power systems in recent years. It occurs when there is no adequate reactive power reserve present in the system. An index based on the total reactive power generation is described here. This index is very useful for the system having high reactive power demand. A sensitivity based method is also proposed here which can be used to predict the effect of load increase or generator outage or generator rescheduling on reactive power generation and this method is also able to find the most suitable location for placing reactive power compensation device to improve the voltage at desired buses. To take any preventive action, it is very important to identify the weak portion of the system. To identify the weakest lines or buses of the system, a index based on branch power flow can be used. Derivation of this index and how it can be used to monitor voltage stability of the system is shown in this thesis. For a big system, it is very difficult to monitor all the buses or branches. Here a method based on network reduction is proposed. It is also shown how the steady state stability limit for any bus can be estimated from the reduced network with reasonable accuracy.

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*Title* : *Design and Control of a 5 kW Multi-input Solar Interface*  
*Author(s)* : *Roy Jinia*  
*Roll No* : *11104043*  
*Supervisor(s)* : *Mishra Santanu Kumar*  
*Abstract*

With the increasing demand of electricity, the burden on electric generation as well as transmission infrastructures is gradually increasing. Central Plants could arguably no longer deliver competitively cheap and reliable electricity to more remote customers through the grid. The distributed generation (DG) based on Renewable Energy Source (RES) concept emerged as a way to integrate multiple power plants of smaller rating, increasing the power supply reliability, reducing emissions, and providing additional power quality benefits. In this thesis, a 5 kW Multi input Solar Interface (MISI) for DG system is designed. The design incorporates multiple boost converters from separate solar sources to be linked to a common DC link. All the boost converters can be controlled separately to extract maximum power from the solar panels. Because of the presence of boost diode at the output of each boost converter, it acts as a natural OR-ing control to block reverse power flow. This philosophy of using separate solar panels with individual boost converters ensures that the solar power extraction is less susceptible to shedding. In a real-life implementation, a voltage source inverter will be cascaded to the DC link, and it is not a part of this study. The boost stage is digitally controlled to implement DC link voltage regulation and MPPT. The primary contribution of this thesis is the identification, implementation, and verification of various building blocks to implement a digitally regulated MISI. The power stage is implemented using 3 phase four legs Semikron Module. The digital control of MISI is implemented in FPGA with the Spartan-3A/3AN FPGA Starter Kit Board. A voltage mode control has been incorporated with a single input source and its operation is verified by regulating the output for different loads and for different level of input voltages. Higher power operation is demonstrated with multiple inputs with open loop control. Maximum Power Point Tracking is also implemented with battery interface and at a lower power level. Other building blocks essential for the system realization are current and voltage sensing cards to sense converter variables for regulation and MPPT. This sensing block includes the input panel voltages, DC-link voltage, and input solar panel currents. The sensed signals are converted to digital outputs using a serial ADC and interfaced to the FPGA using dedicated cards. The FPGA output is then converted to an isolated amplified signal using an output interface card, which is interfaced to the power module. A common bias circuit generates various bias voltages for all the control blocks from the inputs (300 V) or DC link (600 V). The lab prototype is verified with 230 V-330 V input and 600 V DC-link at 1.5 kW-3 kW load.

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**Title** : *Grid Integration of Three Level Inverter for Modular PV Applications*  
**Author(s)** : *Yelaverthi Dorai Babu*  
**Roll No** : *11104031*  
**Supervisor(s)** : *Das Shyama Prasad*

### ***Abstract***

Due to the ever increasing power demand and environmental concerns associated with it, there is a growing interest in efficient distributed generation systems based on renewable energy sources (RES). Solar energy is one of the most promising RES. Using photovoltaic modules solar energy can be directly converted to electrical energy. The PV modules provide a very reliable, pollution free way of extracting solar energy. One important aspect while dealing with PV modules is, Maximum Power Point Tracking (MPPT). The extractable power from a PV module is a function of solar insolation, ambient temperature and the terminal load characteristics. Hence to extract maximum power available from the PV module, the terminal load has to be varied accordingly. The power output of one PV module is low. To achieve a considerable power rating for the PV power system, many of these modules have to be connected in series-parallel combination. Since the output of PV module is DC, an inverter stage (converts DC to AC) is needed before the power extracted can be fed to the utility grid. Presently multistring topology is considered the state of the art as it uses localized MPP tracker to maximize the power extracted and a central inverter to feed this power to grid. In the present work, an improvement for this topology is proposed by using a three-level neutral point clamped inverter stage and a modified multistring panel configuration. The present plant topology doubles the localized MPP trackers and increases the plant modularity. The design and control of the MPP Trackers and grid converter are made. Simulation of this new plant topology is made in MATLAB/SIMULINK. Finally experimental validation is performed for a lab prototype of 3 kWp installation. The experimental results show reasonable correlation with the theory

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**Title** : *Power System State Estimation with External Network  
Equivalents Considering Measurement Transformations*  
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**Supervisor(s)** : *Chakrabarti Saikat*

### ***Abstract***

Interconnected power systems have evolved over decades. They are generally composed of several utilities connected through tie lines. Power system state estimation is carried out to assess operating point of power system and facilitate effective monitoring and control. Change in operating condition of a utility or group of utilities depends on topology information and power distribution in rest of the power system. However utilities are generally reluctant to share network data and measurements due to security reasons. Also to handle such large amount of data for online applications is difficult. Thus to achieve quicker monitoring of concerned area, simplified model of remaining power system is desired. This thesis proposes a method to consider effect of remaining power system on internal area enabling quicker solution for internal area. A relation between power distribution in a power system and reduced version of the same is obtained. Hence reduced system measurements are expressed as combination of original system measurements. For small changes in operating condition reduced system measurements can be computed with sufficient accuracy. Additionally a sensitivity analysis is used to identify significant measurements from external area so as to minimize data transfer between the two areas. Performance with use of all measurements and sensitive measurements from external area is compared. Modified IEEE-14 bus and 118 bus test system are used for verifying the method

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*Title* : *Performance Study on the Techinques for Monitoring Power System Oscillations*  
*Author(s)* : *Srinivas Chitturi*  
*Roll No* : *11104104*  
*Supervisor(s)* : *Singh Sri Niwas& Chakrabarti Saikat*

### *Abstract*

Power system is the largest interconnected system in the world, generating power on economical basis and transferring power from surplus area to deficit area through transmission network. The power transferred through transmission network is limited due to various stability limits. In recent years, increase in electricity demand and economic pressure from electricity markets forced system operators to operate power system on the verge of instability. Any disturbance in the system may lead to oscillations of increasing amplitude and result in system collapse. To avoid oscillations, online assessment of dominant oscillating modes of the system are required. For real time oscillation monitoring of power systems, measurements are required at faster rate. With the advent of Phasor Measurement Units (PMUs), which provide measurements at faster rate, wide area oscillation monitoring of power systems has become feasible. The work reported in this thesis concentrates on measurement based methodologies such as Prony analysis and Matrix Pencil method to estimate dominant modes of system. These measurement based methods utilize transient response having observable oscillations obtained from PMUs. These methods are applied on various power signals of test systems built in Matlab Simulink. To evaluate the performance of Prony analysis in real time, PMU is interfaced to real time digital simulator. PMU sends time synchronized measurements to Synchrophasor Vector Processor (SVP) which performs Prony analysis on snapshot of measurements in real time. The results obtained from the hardware setup are very similar to the analytical results

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*Title* : *Controller Design and Dynamic Analysis of PV System*  
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*Roll No* : *11104057*  
*Supervisor(s)* : *Singh Sri Niwas*

### *Abstract*

Solar power is one of the most popular renewable sources and has been proved as potential source for electricity generation with minimal environment effect. In recent years, there has been a significant interest in utilization of PV solar for high power ratings (1 - 10 MW), at sub transmission and distribution system voltage levels of power system, under the name of PV-DG (Photovoltaic Distribution Generation). The rapid increase in number of PV-DG, which is having the discontinuous characteristics (power varies thorough out the day), represents new challenges for distribution utilities. Due to the industrial norms single-stage grid connected topology is used in PV-DG. This thesis proposes control architecture and provides stability analysis for a typical single-stage, three-phase PV system that is connected to a distribution network. The control architecture is based on an inner current control loop and outer DC-link voltage control loop. Moreover, the DC-link voltage controller is based on the Feedback Linearization (FBL) technique in order to make performance of controller independent to nonlinear characteristics of PV array. This, in turn, improves the performance of DC-link voltage controller for wide range of operating conditions. The effectiveness of the control strategy and important transients are analyzed through simulation studies conducted on a detail PV system model built in PSCAD/EMTDC software environment. Further, mathematical model for PV system and the distribution network are derived. Based on this mathematical model, a linearized model of the augmented PV system is derived and verified. Small signal study is performed on the linearized model in order to characterize the dynamic properties of PV system. Small signal analysis confirms that, under the proposed control strategy, DC-link voltage controller is independent of the nonlinear characteristics of PV array. It also shows that modes of PV system are independent of the network modes. Therefore, PV system maintains its stability in case of variation of the network parameters

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**Title** : *Solar Radiation Forecasting and Maximum Power Point Tracking Control of Photovoltaic Power Generation Systems*  
**Author(s)** : *Kumar Avanish*  
**Roll No** : *11104021*  
**Supervisor(s)** : *Behera Laxmidhar*

### ***Abstract***

The estimation of solar irradiation data is very important for renewable energy, solar energy systems applications. The forecasts can be used to predict the output power of photovoltaic systems installed in power systems and control the output of other generators to meet the electricity demand. In this study, An Adaptive Recurrent Neural Network (ARNN) method is used to calculate Daily, Monthly mean and Hourly solar Irradiations. The meteorological data we have used here were recorded in Rajasthan, India. First, an algorithm is derived for Layered Recurrent Neural Network (RNN) which is similar to Real time recurrent learning(RTRL) algorithm. A fixed learning rate in the Recurrent Neural Network can be replaced by an adaptive learning rate which is calculated using Lyapunov function approach. The results of proposed ARNN method were compared with the MLP having two hidden layers based on statistical parameters such as root mean square error (RMSE), mean absolute percentage error (MAPE) and Correlation Coefficient (R2). Subsequently, the unknown test data set produced very accurate estimation, with root mean square error (RMSE) not exceed 15% between the actual and predicted data for any case, mean absolute percentage error (MAPE) never exceeds 10% also the correlation coefficient obtained for the validation data set is above 0.9 which indicates that the proposed model can successfully be used for prediction and modeling of Solar Irradiations. Next, we are building a robust controller using Maximum Power Point Tracking (MPPT) strategy for a solar power generation system by implementing Takagi- Sugeno (T-S) Fuzzy model of the power system. A DC-DC buck converter is used to control the power output from the Photovoltaic (PV) Array. We propose a method to design a state feedback controller to regulate power output by controlling the duty cycle of the converter while maintaining the system Lyapunov stable. A fixed gain and two variable gain state feedback controllers are proposed. In addition, a tracking controller is designed which searches for Maximum Power Point (MPP) to optimize systems performance without actually calculating the MPP or measuring the solar radiation. The controller is also robust to disturbances in atmospheric conditions. The performances of all the controllers are compared on the basis of rise time and efficiency. The proposed system is found to be extremely efficient even in rapidly changing weather conditions. The system is found to reach optimal operation point within few milliseconds. The stability analysis is shown wherever appropriate. All the results are shown in the form of simulations.

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*Title* : *Speed/Position Sensorless Control of Interior Permanent Magnet Synchronous Motor*  
*Author(s)* : *Raghavender K*  
*Roll No* : *11104082*  
*Supervisor(s)* : *Das Shyama Prasad*

### *Abstract*

Reliability is the critical aspect of the modern drive applications. Rotor position sensors such as encoders affect the reliability of the permanent magnet synchronous motor (PMSM) drives. Rotor magnets are buried inside the rotor core for increased robustness in interior permanent magnet synchronous motor (IPMSM). Initial rotor position information is very crucial for self-synchronous control and vector controlled techniques in IPMSM drives. Two basic methods for the initial rotor position estimation are sinusoidal carrier signal injection and special pulse voltage injection. Sinusoidal carrier signal injection is a well-established method to estimate the initial rotor position but the rotor saliency should be high. The interior permanent magnet synchronous motor which is used in the present thesis, has inherently very low saliency ratio. The stator current change which is proportional to the saliency and has rotor position information is very small and sensing this current change becomes difficult. Special pulse voltage injection technique has been used here to estimate the initial standstill rotor position by considering saturation saliencies. Extended Kalman Filter (EKF), which is a nonlinear observer, has been used to estimate the speed and position of the IPMSM in the running condition. The state transition model of the EKF is modeled in the stationary frame which is easier to implement. The initial rotor position along with the rotor position under running condition has been used for closed-loop speed control of the IPMSM drive with rotor flux oriented vector control. The closed loop speed control of IPMSM is simulated and experimentally realized with incremental encoder using PC and Matlab-Simulink based realtime platform. This is followed by simulation and experimental realization of speed/position sensorless control of the drive without encoder using standstill position detection and extended Kalman filter based estimation

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*Title* : *Magnetic Resonance Compatible Neural Stimulator*  
*Author(s)* : *Gupta Tanvi*  
*Roll No* : *11104109*  
*Supervisor(s)* : *Sensarma Partha Sarathi*

### *Abstract*

Magnetic resonance (MR) compatible implants and diagnostically relevant equipment has gained significant importance in recent times. This is because patients with implants are excluded from getting an MR imaging and also there are some therapeutic procedures, like electrical stimulation, which could be better understood if the devices involved were 3 T MR compatible. Electrical stimulation has been known to be used as a drug-free therapy for conditions like epilepsy, stroke, depression etc. The effectiveness of this therapy can be validated through stimulation during an MR procedure, which has not yet been possible due to an unavailability of a 3 T MR compatible stimulator. This poses an interesting challenge from an electrical engineering stand point. The electrical or nerve stimulator is required to be compatible with a high magnetic field and effectively produce a controllable low frequency, low amplitude and low duty-cycle current with a low error tolerance for a variable load. The introduction of this device into the MR environment should not cause harm to the equipment, patient or operator and the MR images obtained should be free from artifacts. This thesis, details the design, development and testing of a 3 T MR compatible nerve stimulator. A closed loop multistage amplifier is designed for this purpose and the basic circuit uses a transconductance amplifier followed by a voltage amplifier stage. The controller is designed for robust performance to ensure constant output current under varying load impedance. Minimal interference between the magnetic field and amplifier electronics is ensured by connecting the stimulator electrodes through a long cable. The cable is chosen to have a non-metallic composition and the electrodes are standard MR compatible. The cable output is modeled as a transmission line to ascertain current attenuation during transmission through this distributed parameter circuit. The current is controlled using a user interface for which details of the hardware and the algorithm are presented. Apart from the multistage amplifier, the power supply for this device and the function generator to define the stimulation waveform was also designed. Performance of the hardware in a 3 T MR environment show minimal artifacts with no perceptible heating or mechanical forces.

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**Title** : *Input-Series Output-Parallel Configuration of Single-Phase UPF Buck Rectifier*  
**Author(s)** : *Samanta Suvendu*  
**Roll No** : *11104108*  
**Supervisor(s)** : *Sensarma Partha Sarathi*

### ***Abstract***

Traditionally, in ac-supplied traction systems the available catenary voltage lies in the range of 25 kV/50 Hz to 16 kV/16.7 Hz. These high voltages need to be stepped down by a line-frequency transformer, before the final rectification stage. This results in large volume and weight, as well as poor efficiency and lack of redundancy in the system. Recent research on traction power-train has been motivated towards the removal of this transformer from the circuit. This is achieved by connecting medium rated converters in input series and output parallel (ISOP) configuration, such that high catenary voltage and high load current are shared by the modules. ISOP configuration of the converters not only provides a light weight solution, but also provides greater reliability through redundancy due to its modular nature. In spite of low output voltage requirement for traction drives (0.5-3 kV), conventionally the source current waveshaping is ensured by the usage of boost-rectifiers. This results in higher module count. Considering the module count and requirement of high source current quality, a new converter topology based on buck-rectifier is proposed which is amenable to connection in ISOP configuration. The required isolation for ISOP configuration is provided in dc-dc stage to reduce the size and cost of magetics and control complexity. The mathematical model of a single module and ISOP configured two-module structure is derived. The basic control method for a single module has a single loop structure and basically ensures unity power factor at input, while maintaining the desired output voltage. ISOP configuration can be realized in two different ways. One of the options employs uncoupled dc-link inductors while the other option is to use coupled dc-link inductors. While the first option leads to strict modularity, the second ensures lower specific weight and volume. The control objectives viz. upf operation at input, transient stability, equal power and input voltage sharing are achieved through a two loop controller structure. The proposed controller is shown to perform identically well for both the coupled and uncoupled inductor options. All the analytical results are validated by numerical simulation and experimental results obtained with a 2 kW (2 1 kW), grid connected, laboratory prototype

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*Title* : *Novel Usages of Boost Converter in Battery Powered Applications*  
*Author(s)* : *U Arun Sankar*  
*Roll No* : *11104013*  
*Supervisor(s)* : *Mishra Santanu Kumar&Joshi Avinash*

### *Abstract*

Boost converter is a well known switched mode power converter which is capable of boosting a dc input voltage to higher dc output voltage. Boost converter and its derived topologies are used in many applications. Boost interface for Photovoltaic (PV) applications, Power Factor Correction (PFC) circuits, etc., are some popular examples. In this thesis, two applications of a boost converter are studied for use in practical scenario. The thesis is divided into two parts, Part A and Part B. In Part A of thesis, a Multi-Input-Single Control (MISC) converter derived from boost converter is proposed. It accepts multiple inputs and boosts the voltage to charge a battery using a single controlled switch. The operation of a two input MISC converter has been analyzed. The analysis has been experimentally verified using an experimental prototype with two different sources, viz., a solar panel with higher power rating as master source and a voltage source or another solar panel with relatively lower power rating as a slave source. In Part B of this thesis, the use of boost converter topology based PFC for AC-DC rectifier application in Medium voltage Uninterrupted Power Supply (UPS) architecture is discussed. An input series connected boost PFC structure is discussed, which uses lower voltage devices to realize a high input voltage rectifier. The closed loop control strategy is developed for DCM as well CCM operation of circuit. The simulation results of the circuit for 20 kW output power rating working in both DCM and CCM have been presented. A scaled down prototype is implemented to experimentally verify the feasibility of proposed converter and its control structure.

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*Title* : *Integrated dual output converter (IDOC) and its application in rural dc nanogrid*  
*Author(s)* : *Josyula Anil Prasad*  
*Roll No* : *11104010*  
*Supervisor(s)* : *Mishra Santanu Kumar&Joshi Avinash*

### *Abstract*

Multi-port DC-DC converter topologies are used to generate multiple DC outputs from a single DC input source. The outputs can be step up or step down type. Compared to dedicated converters, these integrated topologies have higher efficiencies and lesser Bill-of-Material. This work proposes a multi-port DC-DC converter topology which generates two outputs - step-up as well as step-down, from a single DC input. The converter architecture is realized by replacing the controlled switch of a boost converter with a half bridge network and a low pass filter. In contrast to two separate buck and boost converters, this proposed topology performs the same function with lesser number of switches and exhibits better EMI noise immunity. Operating modes, steady state behavior, and Dynamic modeling of the proposed converter has been studied in the thesis. A suitable control scheme to control both outputs has been described. The performance of the proposed converter, both in open loop as well as in closed loop, has been verified using a 150 W laboratory prototype, which produces a step-up voltage of 18 V and a step-down voltage of 6 V from a single 12 V input. Good cross-regulation performance of the converter is experimentally verified. The thesis also proposes the application of this converter in realization of a Rural DC Nanogrid. A prototype of a Rural Nanogrid using this converter is developed. The Nanogrid supplies commonly used residential loads like CFL, Mobile adapter, Fan, etc. The impacts of these loads on the converter performance are validated

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**Title** : *Cost Benefit Analysis for Maintenance of Machines*  
**Author(s)** : *Khatravath Sreevidya*  
**Roll No** : *Y8127506*  
**Supervisor(s)** : *Verma Nishchal Kumar*

### ***Abstract***

Cost investment in maintenance of machines is important for industries as it impacts revenue generation. In the present study, most commonly used maintenance strategies i.e. corrective maintenance and preventive maintenance are reviewed using our proposed Cost Benefit Analysis method. Calculations to find net revenue generated by machine, optimal and cost effective alternative for machine maintenance to be chosen by an industry are discussed. Methodology of calculating net revenue analysis has been enhanced by accounting factors such as labor cost, failure rate, utilization factor, availability etc. Cost benefits Analysis (CBA) for maintenance of machines using different multi-unit models propose a robust method to calculate net revenue. Multi-unit models discussed are Markov Renewal Process (MRP) and Queuing theory. Using MRP, queuing process we try to formulate, calculate net revenue. Maintenance strategy like condition based monitoring's (CBM) data is used for machine maintenance and cost calculations. Impact of individual components of a machine like failure rate on different parts of machine & effect on the income generated by a machine are explained using multi-unit model. Comparison of estimated, statistical, trained data is used for analyzing multi-unit models. Case studies on air compressor, semiconductor industry and power generation plant are used to validate results of profitability with this suggested method. Results show that formulated net revenue for a multi-unit model generates revenue similar to real industrial machines. Net revenue engendered by an industry can be calculated by the formula which we propose as it accounts all factors which effect machine(s) productivity. Formulated net revenue gives satisfactory results when compared with industrial information on machine maintenance strategies. Realistic data is used to analyze revenue with different maintenance strategies. From results it is concluded that though condition based maintenance as maintenance strategy has high initial investment cost, with time it has higher revenue generation compared to other maintenance polices.

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**Title** : *Tracking and Erosion Behaviour of Silicone Rubber Based Composites with Micro and Nano Sized Fillers*  
**Author(s)** : *Chakerwanti Harish Kumar*  
**Roll No** : *11104037*  
**Supervisor(s)** : *Gupta Nandini*

### ***Abstract***

Polymer based insulating dielectric materials are currently replacing ceramic dielectric materials due to their better electric, thermal and mechanical properties. One major advantage of polymeric materials is that they can easily be moulded into required shape and size. Room temperature vulcanized silicone rubber (RTVSR) is hydrophobic in nature and consequently has leakage current losses. Over the time, surface discharge degrades the properties of insulating materials. This may ultimately lead to failure of concerned systems. In recent times, nanodielectrics are increasingly having researched for their better properties. Nano fillers are used for improving electrical, thermal and mechanical properties of polymeric materials. In this work we investigate the possibility of using nanometric fillers in RTVSR in order to improve its electrical performance. A very small concentration (2 or 3 wt %) of nano Alumina (Al<sub>2</sub>O<sub>3</sub>) and nano silica (SiO<sub>2</sub>) fillers (5% wt) were mixed with the silicone rubber. Micro-filled composites (20 wt %) were also prepared for comparison, in case of alumina. Mechanical mixing and ultrasonic mixing is used for reducing the agglomeration of nano fillers. Dispersion analysis was done for nano alumina and nano silica filled composites to evaluate the quantity of dispersion of the nano particles. Breakdown tests were performed to evaluate the improvement in breakdown strength. Tracking and erosion are the prevalent cause of failure in outdoor insulations. Inclined plane test for erosion (IPTET) was performed as per the Standard IEC60587 on each composite. SEM, FT-IR and weight loss analysis were performed in order to evaluate the extent of erosion. Optical profile was used to understand better the eroded surface pattern in IPTET. Both nano alumina and nano silica composites show better resistance to erosion in comparison to pure RTVSR and micro alumina based composites

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*Title* : *DSP Controlled UPQC-Q with Improved DVR Performance*  
*Author(s)* : *Hasan Shamim*  
*Roll No* : *11104098*  
*Supervisor(s)* : *Das S P*

### *Abstract*

The Unified Power Quality Conditioner is one of the most comprehensive solutions to the power quality related problems. The UPQC essentially consists of two active power filters, one known as a shunt active power filter or STATCOM (Static Compensator) and the other known as a series active power filter or DVR (Dynamic Voltage Restorer). These both active filters (i.e. shunt and series) are voltage source inverters with other passive filtering elements which are controlled in a coordinated manner to ensure sinusoidal voltage at its nominal value at load terminals and sinusoidal source current through the source in phase with the source voltage. The DVR is connected in series between source and load through series transformer and the STATCOM is connected in parallel. The present work deals with UPQC-Q in which the voltage injected by the DVR is in the quadrature with the source current. A novel control technique is proposed to control the voltage injected by the DVR using feedforward plus feedback control with synchronously rotating reference frame. The implementation of feedforward plus feedback control ensures faster restoration of voltage at the load-end in case of voltage sag in the source voltage with injected DVR voltage being in quadrature to source current. The existing peak detector method using feedforward plus feedback controller, is slower as it waits for the peak of the sinusoidal signal to compute voltage sag. The proposed method is compared with existing method by simulation in Matlab Simulink to demonstrate the improvement in response time and finally simulation results are verified by the hardware results from the experimental prototype where the control scheme is implemented in a Digital Signal Processor

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**Title** : *Design of Microinverter for Grid Connected Photovoltaic Applications*  
**Author(s)** : *Chakkalakkal Sreejith*  
**Roll No** : *11104103*  
**Supervisor(s)** : *Sensarma Partha Sarathi*

### ***Abstract***

The increased concerns over the climate changes and other environmental impact due to the extreme dependence on fossil fuel have led to the proliferation of renewable energy sources like wind and solar photovoltaic power across the globe. Solar photovoltaics is a sustainable energy source, which currently ranks third among the most deployed renewable energy sources in the world, after hydro and wind power. AC modules are considered as the new face of photovoltaic (PV) power and it employs a commercial PV module together with an inverter called microinverter. The composite system is more flexible, easier to handle and feeds power directly into the utility grid by satisfying all the utility requirements like power quality, utility safety etc. Such modular pv systems are also beneficial for powering the remote locations where utility grid is not available. Unlike ideal power sources, electrical characteristics of PV cells are non-linear in nature, which complicates the process of energy conversion to an usable form. Because of the high costs involved and moderate PV efficiencies, it is always desired to extract the maximum possible electrical power under the given conditions. In contrast to typical topologies of PV arrays, AC modules (microinverters) have individual control over each PV module thus making it an effective method for better utilization of the PV module. AC modules are self contained PV systems and hence the associated inverter needs to be small and compact. Filter magnetics are a major contributor to the increased size of any power electronic converter, but can be significantly reduced by switching such converters at higher frequency. The power output of an AC module must meet the utility requirements in power quality, DC current injection, power factor etc. Use of higher order passive ripple filters like LCL filter reduces the filter volume effectively, at the same time providing proper attenuation for the current harmonics. Grid synchronization is another major concern for grid-interfaced systems requiring the grid variables to be monitored continuously. Reference template for the injected current waveform has to be derived from these grid variables so that the frequency and phase of the injected current is synchronized with the grid. Phase Locked Loop (PLL) has been used for extracting the phasor data and a 16-bit Digital Signal Controller(DSC) is used for implementing PLL and other control schemes in the hardware. Designed microinverter system has been modelled in Matlab/Simulink and the effectiveness of the proposed control scheme is evaluated. A laboratory prototype is built and tested. All the analytical results were in conformity with the simulation and experimental results and hence the effectiveness of the scheme is validated

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**Title** : *Virtual Grid Realization Using Three Phase Back-to-back Converter*  
**Author(s)** : *Sen Soumik*  
**Roll No** : *11104102*  
**Supervisor(s)** : *Sensarma Partha Sarathi*

### ***Abstract***

Use of renewable energy sources (RES) like solar and wind power as generators of electrical energy has increased all over the globe due to the increased concerns of climate change and environmental impact of fossil fuel. These energy sources need not be centralized like their thermal counterparts and can be used in small scale which is termed as distributed generation (DG). A DG system consists of RES and a power electronic converter that acts as a grid interface (GI) between RES and grid. Before connecting this DG directly to real grid it is always desirable to test the control and protection algorithms of the GI by connecting it to a virtual grid (VG). VG is a programmable voltage source that can emulate the grid very closely and can produce the common grid disturbances like voltage sags and short circuits, when commanded to do so. In this thesis a VG has been designed and simulated using three phase back-to-back power electronic converter. The two converters of the back-to-back converter are called the gridside converter (GSC) and the load-side converter (LSC). The filter capacitor voltage of the LC filter connected to the output of LSC constitute the VG. The control objective of realizing VG has been achieved by the LSC controller which has fast dynamics and high bandwidth. The active power flowing from the DG under test is fed to grid using the GSC. GSC controller serves the dual purpose of ensuring unity power factor grid injection while maintaining a constant dc link voltage. In order to design a three phase LCL filter for obtaining high quality grid current compliant with IEEE 519-1992 standards, a step-by-step design procedure is included in the thesis. The system is simulated in Matlab Simulink to verify the performance of the virtual grid. Simulation results show that the voltage controller of LSC tracks the input reference accurately, enabling the use of LSC as a voltage amplifier in power hardware in loop (PHIL) simulations. Experiments are performed to verify effectiveness of the grid current controller, using DSP TMS 320F2812 as the digital control platform

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**Title** : *On Recurrence Times, Large Deviations and Zero Entropy-  
With Application to Sliding Window Lempel-Ziv Algorithm*  
**Author(s)** : *Jain, Siddharth*  
**Roll No** : *Y8127496*  
**Supervisor(s)** : *Bansal Rakesh K*

### ***Abstract***

The Sliding Window Lempel-Ziv (SWLZ) algorithm has been studied from various perspectives in information theory literature. In this thesis, we provide a general law which defines the asymptotics of match length for stationary and ergodic *\emph{zero entropy}* processes. Moreover, we use this law to choose the match length  $L_o$  in the almost sure optimality proof of Fixed Shift Variant of Lempel-Ziv (FSLZ) and SWLZ algorithms given in literature. First, through an example of a stationary and ergodic process generated by an irrational rotation we establish that for a window of size  $n_w$ , a compression ratio given by  $O(\frac{1}{n_w^a})$  where  $a$  is arbitrarily close to 1 and  $0 < a < 1$ , is obtained under the application of FSLZ and SWLZ algorithms. Further, we give a general expression for the compression ratio for a class of stationary and *\emph{totally}* ergodic processes with zero entropy. Recurrence time statistics plays an important role in the analysis of SWLZ algorithm. Therefore, in the latter part of the thesis, we do a careful study of the asymptotic behavior of recurrence times . More precisely, we extend the study of Ornstein and Weiss on the asymptotic behavior of the *\emph{normalized}* version of recurrence times and establish the *\emph{large deviation property}* for a certain class of mixing processes. Further, an estimator of entropy based on recurrence times is proposed for which large deviation principle is proved for sources satisfying similar mixing conditions.

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**Title** : *Algorithms for Crowd Surveillance using Passive Acoustic Sensors over a Multi-Modal Sensor Network*

**Author(s)** : *Agarwal Rohit*

**Roll No** : *Y8127424*

**Supervisor(s)** : *Hegde Rajesh Mahanand*

**Abstract**

Crowd detection and monitoring is an active area of research because of its significance in many areas especially law enforcement. Crowd monitoring systems can be realized on sensor networks that consist of either passive or active sensors. Passive sensors are of interest herein since they sense the data without actively probing and changing the environment. On the other hand active sensors actively probe the environment to gather data. Earlier work on crowd monitoring have used various modalities like infrared imaging, video feed, received signal strength indicator, RFID, GPS signals, audio tones through mobiles among others. In this thesis a method which uses passive acoustic sensors in a multi-modal sensor network for crowd monitoring has been proposed. This multi-modal system uses three modalities namely carbon-dioxide level, sound intensity level and received signal strength indicator for crowd detection and monitoring. The first two modalities are sensed using passive sensors while the last one is an active sensor. This combination makes the proposed algorithms efficient both computationally and in terms of energy. The multi modal crowd monitoring algorithm requires an effective clustering method. Hence three clustering algorithms that utilize Temporal, spatial and Spatio-temporal information are first proposed in this context. Subsequently an algorithm that fuses information in various modalities is also proposed for improved crowd monitoring. The algorithms proposed in this thesis require the development of attenuation, reverberation and additivity models. These models are developed using real sensors deployments and the sensor density, sensor height, acoustic sensor variable etc are first determined. The proposed algorithms rely on the deployment of a grid of microphones in the area to be analyzed. These sensors used to measure the sound intensity or pressure averaged over a few samples. This methodology saves both the bandwidth required and computation time. Using an interpolating function a scaled probability surface is computed by interpolating the microphone data. Crowd clusters are then identified from this probability surface. Algorithms for improving performance through multi sensor data fusion are then described wherein carbon-dioxide sensors are used to refine the large area and identify areas of interest. In the indoor context this corresponds to separating rooms inside a house. . These segmented areas that are formed are independent of each other thus enabling parallel computing on each of them to increase speed. Finally all the crowd clusters formed after acoustic sensor clustering are validated using active received signal strength indicators. Both simulation and real field experiments are conducted to evaluate the performance of the proposed algorithms in indoor and outdoor spaces. The results of crowd detection and monitoring obtained from these methods are motivating to use it in limited deployment scenarios

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**Title** : *Analysis and Classification of Acoustic Patterns Using Spectrographic Seams*  
**Author(s)** : *Barnwal Shubhranshu*  
**Roll No** : *Y8127494*  
**Supervisor(s)** : *Hegde Rajesh Mahanand*

### ***Abstract***

Analysis and classification of acoustic patterns is a challenging problem and has applications in several areas. In this thesis algorithms to analyze acoustic patterns using seam carving on audio spectrograms are proposed. The use of spectrographic seams is motivated by seam carving, a content aware image resizing technique. Additionally the methodology also uses dynamic programming on spectrographic seams. In contrast to conventional methods that attempt to capture time-frequency patterns as represented by spectral envelopes or peaks, the proposed method captures patterns of high-energy tracks, or seams, of maximum whiteness across frequency in spectrograms. The hypothesis is that these seams could potentially carry relatively invariant signatures of underlying sounds. Additionally the approach of Seam Carving can be used to track harmonics in the acquired acoustic signal. Based on these concepts this thesis develops two applications using seam carving on audio spectrograms. The first application develops a method for estimating a vehicle's speed by analyzing its drive by acoustics with a passive audio microphone. Analysis of the vehicle's acoustics would primarily use the phenomenon of Doppler shift, and the instant at which vehicle is at closest-point-of approach. This approach uses the Seam Carving technique to track harmonics formed by vehicle particularly its engine noise. The method proposed is computationally inexpensive and can very easily be developed into mobile application. The second application effectively computes patterns for classification of speech sounds by computing feature vectors from seam patterns for discriminative word spotting. We show experimentally that spectrographic seam patterns are indeed distinctive for different spoken words, and are effective for speech keyword recognition and spotting. The performances of the two methods are evaluated by conducting experiments on real vehicle audio and speech data. The experimental results are reasonable and motivating for possible utilization in real scenarios.

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***Title*** : ***Multi-Sensor Data Fusion Methods for Indoor Activity Recognition using Temporal Evidence Theory***  
***Author(s)*** : ***Kushwah Aseem***  
***Roll No*** : ***Y8127137***  
***Supervisor(s)*** : ***Hegde Rajesh Mahanand***

### ***Abstract***

Information fusion has been widely used in context aware applications to create situational awareness. Situational awareness in un-supervised and semi-supervised settings requires fusion of data acquired from multiple sensors. The reliability of such techniques is hugely affected by the noisy and missing data. Unpredictable human behavior and dependence on training data are other challenges in this context. Activity recognition is a very important and integral to building situation aware systems using multi-sensor networks. In this thesis, a multi sensor fusion methodology using temporal evidence theory is proposed for indoor activity recognition. The fusion method develops an incremental conflict resolution method within the D-S theory frame work. This method has distinct advantages over the proportional conflict resolution technique of D-S theory. The key contribution of this thesis lies in introduction of temporal information into the fusion methodology in a multi-sensor environment. The Dempster-Shafer theory, its drawbacks and modifications are first examined in this thesis and then the theory has been extended further to take into account the temporal characteristics of events. Prior knowledge is also established in form of evidence propagation network in proposed framework is used for activity detection in smart homes. Two smart home data sets are used in the experiments on activity recognition wherein the data is recorded through a series of passive sensors. The experimental result obtained for activity recognition are motivating enough to be useful in applications like assisted living. It is also significantly noted that the framework reduces the dependence on prior information for activity recognition as is generally required by conventional methods.

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*Title* : *A Framework for Acoustic Event Detection using Coarsely Labeled Multimedia Data*  
*Author(s)* : *Anurag Kumar*  
*Roll No* : *Y8127115*  
*Supervisor(s)* : *Hegde Rajesh Mahanand*

### *Abstract*

The rapid growth of multimedia content on the internet has led to an unprecedented amount of online multimedia data. This calls for intelligent mechanisms for automatic content analysis of multimedia data for indexing, retrieval, cataloging and tagging of online multimedia data. Audio is an important component of multimedia data and hence acoustic event detection is important. In this thesis, a framework for event detection using the audio content in multimedia data is developed. The framework specifically deals with multimedia data recorded in unconstrained conditions where no assumptions regarding the ambient conditions can be made. The co-occurrence of different events and the availability of coarsely labeled data make the acoustic event detection task even more challenging in this context. These issues are addressed by proposing a multiple instance learning based framework for acoustic event detection on coarsely labeled data in this work. A robust method of representing events in short duration audio is first developed. This representation is then used in the multiple instance learning frameworks to build event detection models. The utility of the method is demonstrated in temporal localization of events on several test recordings. In general it is shown that the proposed approach provides a complete description of a test recording rather than broad classification labels. The performance of the proposed method is evaluated on TRECVID-MED2011 data set developed by NIST for Multimedia Event Detection task. The performance metrics obtained using our method of representing short audio segments indicates a reasonable improvement when compared to bag of audio words approach. The proposed framework for event detection using coarsely labeled data gives reasonable success in detecting events. This is significant because this method can be used to avoid the expensive and time-consuming process of manually annotating multimedia data which is typically done for building multimedia event detection models.

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**Title** : *Fast Accurate and Efficient Computation of Stereo Depth Maps*  
**Author(s)** : *Ghosh Pallabi*  
**Roll No** : *11104070*  
**Supervisor(s)** : *Venkatesh K S*

### ***Abstract***

We present here our approach to the problem of improving the efficiency of stereo depth map computation. The algorithm is applied on rectified images. Graph cut is used for energy minimization. The descriptors used are both SIFT and DAISY. This algorithm produces fast results of approximate disparity maps from two images. The main advantage of our algorithm is its efficiency and nearly an order of magnitude reduction of computation time, in addition to an improvement of the error performance. To achieve this, we initially use a sparse global matching technique using SIFT to determine the necessary labels and then obtain a dense correspondence using graph cuts upon DAISY. On the other hand, there are other sources of error in stereo systems than those arising out of miscorrespondence. We refer here to quantization errors that follow a square law with respect to distance. One remedy for this limitation is to adopt a multicamera arrangement. We deal with the physical aspect of arrangement of a multi camera system that helps to reduce quantization error of the camera system, and attempt to make the quantization error more uniform with respect to distance (over a certain range), using multiple baseline stereo. The quantization error depends on a number of factors like baseline lengths, depth values, focal lengths of cameras and dimensions of the camera pixel. We describe a technique to find the optimum values of these factors to minimize the quantization error.

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*Title* : *Study of Robustness on Complex Network*  
*Author(s)* : *Kumar Rahul*  
*Roll No* : *11104083*  
*Supervisor(s)* : *Singh Yatindra Nath*

### *Abstract*

Recent advancement in the science of complexity have revealed that complex networks exist in many fields e.g. Internet, the world wide web, power grids, transportation system, food webs ecosystems, genetic network, social networks etc. These are scale free networks and characterized by power law degree distribution. For these networks the threshold become vanishingly small which disintegrate the network into a small component in the limit of infinite system size. The question one may ask that whether we can analyse the robustness of the networks against the different attacks and failure. Therefore, we can procure the network and make them more robust against attack. In general higher degree or hub nodes are the first priority of attacker to attack the network. Hence, if we attack those nodes, we can potentially break down the network more efficiently. This will help in studying that how much robust the network is against the attack. The main two strategies are: one is random failure in which selection of nodes done randomly that is to be attacked. But this strategy is not much efficient for attackers as they need to attack almost 80-90 % of nodes to disintegrate the network. The other is targeted attack in which the hub nodes are targeted for attack and removed. In this case, we should have the knowledge about hub nodes in the network which in most of the cases are not possible practically. Thus, we can use acquaintance attack strategy in which we don't need to have a full network information but only requires a partial. This strategy is better than the random attack but not superior than targeted. We can also find the most influential nodes for the attack using graph spectra. Here, we have the network structure information but this strategy is slightly better than targeted attack. Due to increase of complexity this strategy will not efficient for the large number of nodes. Therefore, the robustness of the scale free network is studied efficiently against the different attacks and failures

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**Title** : *Airborne Network Design and Optimised Air Backbone Topology for aircraft operations*  
**Author(s)** : *Pajhal Rohit*  
**Roll No** : *11104120*  
**Supervisor(s)** : *Singh Yatindra Nath*

### ***Abstract***

Airborne network is a type of adhoc network, where network is provided by airborne platforms to other flying platforms. The need of the hour is to have a strong air-backbone network, which have sufficient bandwidth and can support real time data transfer between aircrafts and ground based control centers. My project's main aim was to give a practical shape to this idea and come up with a design, which is suitable for creating an airborne network. After in-depth literature review and analysis of existing technology and airborne platforms, a design for Airborne Network is proposed, which utilizes UAVs as platforms for creating backbone network in air at an altitude of 20-25 kms. Aerostat terminals are proposed as component, which will act as gateway between air and ground backbones and provide connectivity to Global Information Grid (GIG). Various topologies are studied and compared, using which backbone in air can be created. Then a topology is proposed where UAVs moves in a circular orbit at same altitude to provide seamless connectivity in desired area of coverage. Routing for this type of opportunistic network is also proposed, wherein we use existing adhoc routing protocol AODV (Adhoc On demand Vector) as base protocol and suggested modifications on it to suit our Airborne Network design. This thesis also specifies the types of links to be utilized on UAVs for connectivity of aircrafts to GIG. The frequency bands utilized for different type of links are proposed along with free space optical links for UAV to UAV (i.e. in backbone network) communication. The endeavor was to keep design simple and practicable considering available resources and technology.

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*Title* : *Optimal Video Scheduling Policies for Real Time Wireless Video Streaming*  
*Author(s)* : *Otwani Jitendra*  
*Roll No* : *11104044*  
*Supervisor(s)* : *Jagannatham Aditya K*

### *Abstract*

In the last few years with the advancement in emerging technologies and smarter end devices, the demand for uninterrupted multimedia services has grown drastically. Bandwidth available in a wireless scenario is limited and thus has to be efficiently utilized. Video coding is used to effectively utilize the available bandwidth. Scalable video coded stream consists of the packets corresponding to the base layer and the enhancement layers. The problem of scheduling these H.264 scalable coded layered video packets is considered here. We schedule these video packets in such a way that it maximizes the received video quality and minimizes the associated jitter. For real time wireless video transmission, due to higher delay sensitivity of the video packets, it is not possible to wait for the receiver to acknowledge whether the packets arrived are intact or not. Moreover, erratic nature of the wireless channel leads to the packet loss. Hence, we formulate a Non-ARQ system by removing the feedback channel for acknowledgments and to ensure reliable transmission through the fading wireless environment, we selectively repeat some of the video packets based on the information of transmitter's estimate of the received SNR during the packet reception interval. To employ selectivity in repetition of the video packets along with jitter minimization, Markov decision process framework is used to model the scheduling problem. Along with this, we demonstrate the structural behavior of the proposed scheduler's optimal policy leading to the faster computation of the optimal policy. Furthermore, we extend the proposed Non-ARQ system to a multiple user scenario where we resolve the issue of user selection as a part of scheduling policy. Simulation results show that the proposed scheduler outperforms the existing schedulers in both the single and multi-user scenario.

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**Title** : *Resource Allocation in OFDMA Relay Networks with Perfect and Outdated CSI*  
**Author(s)** : *Vyas Nitin*  
**Roll No** : *Y8127326*  
**Supervisor(s)** : *Chaturvedi Ajit Kumar*

### ***Abstract***

In this thesis, we propose subcarrier and power allocation algorithms for downlink multi-user multi-relay OFDMA networks. We consider the cases of channel state information (CSI) being perfect and outdated at the source. First we assume that perfect CSI is available at the source and the availability of direct channel from source to users. The optimization problem formed is of high complexity and it is therefore not efficient to solve it in practical scenarios. In the proposed scheme, the problem is divided into sub-problems which focus upon subcarrier allocation, relay and source power allocation respectively and therefore the complexity is reduced from exponential to polynomial time. Our scheme performs better than the schemes considering only "always relaying" in the literature. Next, the work for perfect CSI is extended to consider the outdatedness of CSI. Using the exact expression for objective function increases the complexity of optimization problem therefore upper bounds of objective functions are used for optimizing subcarrier allocation, relay power and source power allocation. A stochastic model is used for the outdated CSI and the upper bounds of objective functions of sub-problems are computed using the distribution models of channel gains. Our scheme for outdated CSI performs better than perfect CSI without selective relaying and incorrect CSI

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*Title* : *Clock Synchronization Algorithms in Wireless Sensor Networks*  
*Author(s)* : *Gupta Hitesh Kumar*  
*Roll No* : *Y8127219*  
*Supervisor(s)* : *Chaturvedi Ajit Kumar*

### *Abstract*

Time synchronization is a critical block of infrastructure in any distributed system. In WSNs time synchronization is of paramount importance. For integrating the collected data by constituent nodes and coordinating their actions time synchronization is essential. Though sensor networks need more precise synchronization than traditional distributed systems limited energy resources poses problems to achieve these goals. Recently, various attempts have been made to develop timing synchronization protocols for wireless sensor networks (WSNs) with the goal of minimizing the power utilization and maximizing the accuracy. In this thesis we propose clock skew and clock offset estimators assuming Gaussian as well as exponential delay distributions to achieve energy-efficient network wide synchronization for WSNs. In case of Gaussian delay distributions maximum likelihood estimators (MLLE) are derived to estimate relative skew/offset. Lower bounds are also calculated and numerically compared with the MLLE's mean square error (MSE). The complexity of MLLE's is far less than that of MLE's while performance is in acceptable range. The lower complexity of synchronization algorithm amounts to greater saving in computational energy and hence longer duration of sensor networks. Clock synchronization problem for wireless sensor network (WSN) under exponential delay in Reference broadcast synchronization (RBS) has also been addressed. Maximum likelihood estimators are derived to estimate relative skew/offset for channels with exponential delay distributions. Approximate CRLBs are accordingly derived and numerically compared with MLE's mean square error (MSE). Simulation results show that the precision of proposed estimators increases as number of signals increases.

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**Title** : *Optimal Joint Source Channel Decoding for Multihop Wireless Sensor Networks*  
**Author(s)** : *C Manoj*  
**Roll No** : *11104059*  
**Supervisor(s)** : *Jagannatham Aditya K*

### ***Abstract***

Wireless Sensor Networks is drawing attention of researchers from diverse fields. Recent advancements in semiconductor technology and wireless communications has enabled the development of smaller, cheaper and power efficient sensor nodes. This makes the sensor nodes unreliable and the wireless channel also introduces errors in the sensed data. So, correcting the errors and ensuring reliability is one of the major challenges in design and development of wireless sensor networks. In this thesis, we develop a framework for optimal joint Source-Channel Maximum Likelihood decoding in wireless sensor networks. The proposed scheme exploits the spatio-temporal correlation of the narrowband sensor data for detection in Wireless Sensor Networks. The analytical union bound for the mean squared error of sensor data for a system employing the proposed joint decoding scheme is derived based on the pairwise error probability criterion. The analytical bound shows improvement in performance over the maximum likelihood decoding scheme. An optimal sequential detection scheme based on Viterbi Algorithm is proposed. To make the scheme tractable for practical implementation, a novel data likelihood tree based error correction algorithm with reduced complexity is developed using the joint Source-Channel Maximum Likelihood scheme. The sphere decoding based algorithm further decreases the complexity of the error correction algorithm. The performance of the proposed algorithm is validated against maximum likelihood detection by simulations performed on a PEGASIS wireless sensor network. The results show improved performance of proposed algorithm. To check the robustness of the algorithm, the performance of system is validated in cases where the source data model is not known precisely. Further, we validate the algorithm on a practical sensor data from the Intel Berkeley Lab dataset.

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*Title* : *Adaptive Push and Adaptive Pull for First-Push-Then-Pull Gossip Algorithm*  
*Author(s)* : *Mali Abhijeet Chandrakant*  
*Roll No* : *11104058*  
*Supervisor(s)* : *Singh Yatindra Nath*

### *Abstract*

Real world networks are generally modelled as Scale-Free networks viz. Social networks, Business networks and Transport networks. Growing applications of such networks need optimum algorithms for information dissemination. One suitable way is Gossip algorithms which are useful in information dissemination over distributed networks. These algorithms are popular because of their scalability and simplicity. One cost efficient gossip algorithm is First-Push-Then-Pull (FPTP) algorithm which combines the advantages of Push and Pull strategies. As Push being cost effective in initial rounds and Pull in later rounds, FPTP gives a cost efficient way of information dissemination. Scale-Free networks follow Power Law degree distribution which shows presence of few higher degree nodes (hubs) and more low degree nodes in the network. Capability of hubs to communicate to large number of nodes can be used for efficient dissemination. Considering this idea while analyzing gossiping over Scale-Free networks we observed that some adaptations in Push and Pull strategies can improve the performance of overall First-Push-Then-Pull (FPTP) algorithm. Making these high degree nodes informed in early stages in Push algorithm helps to improve the rate of Pull and to decrease the cost in Push strategy. We present Adaptive Push and Adaptive Pull strategies to be used in First-Push-Then-Pull gossip algorithm which improves overall performance. Further we simulate our algorithm for different transition rounds and show that algorithm works with minimum cost when the transition round to switch from Adaptive Push to Adaptive Pull is close to  $\text{Round}(\log_2(N))$ . Furthermore, we compare our algorithm with Push, Pull and First-Push-Then-Pull and show that the proposed algorithm is the most cost efficient over Scale-Free networks. We then show that Adaptive FPTP converges in lesser rounds than Push, Pull and FPTP algorithms by delivering message to all nodes in the network. We also show that the Adaptive FPTP works efficiently over several runs with random transition rounds

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*Title* : *Subspace based direction of arrival estimation for large size active phased array radars*  
*Author(s)* : *Kumar Prabhat*  
*Roll No* : *11104076*  
*Supervisor(s)* : *Sharma Govind*

### *Abstract*

Large array based real time direction finding systems like phased array radars require very fast processing of data. Subspace based array signal processing, with its excellent properties, attracted tremendous interest mainly due to introduction of MUSIC algorithm. Arbitrary accuracy and resolution can be achieved if the data collection time is sufficiently large or the signal to noise ratio (SNR) is adequately high. However high computational complexity of search based MUSIC algorithm prohibits its use for large size arrays. Root MUSIC was proposed to reduce the computational complexity of MUSIC algorithm. It avoids the 1-D search in MUSIC by polynomial rooting to estimate DOA. Later it was found that root MUSIC gives performance improvement also over MUSIC algorithm. However the computational complexity of polynomial root finding is still high for large array based real time systems. In this thesis we propose DFT MUSIC algorithm where the polynomial rooting in root MUSIC is replaced with Discrete Fourier Transform (DFT) which can be computed efficiently with Fast Fourier Transforms (FFT). Thus, reducing the computational complexity greatly for large size array. Simulation studies have been carried out to establish the performance of DFT MUSIC approach compared to other commonly used methods for DOA estimation like MUSIC, root MUSIC, Capon beam-former and Bartlett method. It is found that the performance of DFT MUSIC is similar to subspace based methods provided DFT length is sufficiently long. Another bottleneck for subspace based methods is finding noise or signal subspace. Eigenvalue decomposition (EVD) of co-variance matrix to estimate subspace is computationally intensive. We have chosen adaptive techniques for subspace estimation which requires much lesser computations compared to EVD. Another approach for reducing computational complexity for larger arrays is beam-space processing. It reduces the dimension of the input data. Processing in reduced dimension drastically reduces the computational complexity of finding subspace. Advantages of batch processing can be utilized in beam-space setting along with reduction in computational complexity. DFT MUSIC can be applied in beam-space setting also. Algorithm based on DFT MUSIC with low complexity subspace estimation, can be used for large array based real time systems

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*Title* : *Routing in Tactical MANETs*  
*Author(s)* : *Mandal, Saurabh*  
*Roll No* : *11104095*  
*Supervisor(s)* : *Singh Yatindra Nath*

### *Abstract*

Over the past decade, MANETs have attracted a lot of research interest mainly because of their direct application in the areas like military communication and emergency services. The requirements of military communication, in particular, are very demanding in terms of security, availability and reliability. MANETs are found to be best suited to meet these unique requirements. Today a battle is not only fought with weapons but also information (data). The battlefield has gone digital with emergence of new applications and services. One such application is Blue Force Tracking. Traditionally, this requirement is met by using voice based VHF communication. However, with the tactical battlefield fast becoming more and more data centric, this method is no longer going to meet the pressing requirements of today's battlefield. To cater to that particular need, we propose an efficient location service for tactical networks. With time, the focus has also shifted from just availability to reliability and security of communication. The challenges in security design of MANETs are non-trivial. Since security and privacy are paramount in a tactical network, the security solution for tactical MANETs should provide complete protection spanning entire protocol stack and resiliency against external as well as Byzantine attacks. For this, we propose a Resiliency Oriented Design for communication among various nodes in a tactical network. We have also identified various attacks and vulnerabilities/issues related to security of Link layer and Routing layer in the tactical networks along with the detection and prevention (mitigation) techniques for some of these attacks. To achieve this, a hybrid protocol based on reactive route setup and proactive route repair is proposed to ensure reliability in the presence of threats

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**Title** : *Robust Estimator Correlator Based Spectrum Sensing For Cognitive Radio*  
**Author(s)** : *Tripathi Bhishm*  
**Roll No** : *11104022*  
**Supervisor(s)** : *Jagannatham Aditya K*

### ***Abstract***

Cognitive Radio is a paradigm shift in the area of wireless communication. The current form of rigid frequency allocation can not accommodate the ever increasing demands of wireless communication and services and hence leads to crowding of the spectrum. So, the problem is not the scarcity but the underutilization of the spectrum. Hence, the need to sense and access the spectrum dynamically has made the spectrum sensing a very interesting and active research field. This challenge led to the innovations and novel techniques which can utilize the spectrum opportunistically to fulfill the growing demands. But the CR needs efficient and reliable spectrum sensing techniques so that it does not interfere with the privileged user. In our thesis, we propose robust spectrum sensing techniques to detect the presence or absence of Primary user. The Multi-Input Multi-Output(MIMO) channel is considered to be frequency flat. Two detection techniques have been devised, based on convexity and non-convexity of the objective function. We have used receiver operating characteristic as a measure of performance comparison. We have demonstrated that our proposed detection schemes successfully mitigate the effect of the perturbation in the eigen-values of signal covariance matrix.

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*Title* : *Robust cooperative spectrum sensing for with partial and unknown CSI*

*Author(s)* : *Biswas Sinchan*

*Roll No* : *11104100*

*Supervisor(s)* : *Jagannatham Aditya K*

*Abstract*

In the era of wireless communication spectrum scarcity has become a huge problem. To tackle the above mentioned problem the paradigm of Cognitive radio was proposed. The Cognitive radio works on the basis of sensing the primary licensed user spectrum and using the spectrum in the absence of primary user. Being one of the highly significant task of Cognitive radio architecture the spectrum sensing methods are subjected to huge amount of research interest. The most important objectives of the spectrum sensing is sensing of the available spectrum of primary user as reliably as possible and at the same time stop transmitting in the band as soon as it senses the presence of primary user. Meeting this requirements become very tough because of the practical problem like channel estimation error. To combat this problem, in this thesis we have proposed a framework where we have considered the Channel State Information(CSI) uncertainty. In our system model we have considered the process of Cooperative sensing method as opposed to non-cooperative spectrum sensing methods because of its higher reliability in situation of involving CSI uncertainty. In the above mentioned architecture of cooperative spectrum sensing we have also decided to restrict our attention to the soft decision schemes as fusion scheme in the fusion center, because of its higher performance. We also have introduced a novel approach of transmitting multiple transmit beacons irrespective of just one in the Multiple Input Multiple Output(MIMO) environment. In this thesis we have formulated different detection scheme which would be robust with respect to channel uncertainty. Comparing this different robust detection schemes with respect to any uncertainty agnostic schemes like matched filter, we can say that this robust techniques performs far better compared to any uncertainty agnostic schemes.

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**Title** : *On Optimal Resource Allocation in Two-hop Cooperative Cognitive Radio Networks under Interference Power Constraints*  
**Author(s)** : *Majhi Subhajit*  
**Roll No** : *11104105*  
**Supervisor(s)** : *Chaturvedi Ajit Kumar*

### ***Abstract***

Cognitive radio (CR) technology provides a promising solution to the problem of spectrum scarcity by introducing the concept of dynamic spectrum access. One of the paradigms of CR operation is the underlay mode, where the CR transmits in the same frequency band as primary users (PU), but keeps the interference power inflicted on the PUs within specified limits by adapting its transmit power. In this context, a constraint on interference power inflicted at PU proves to be beneficial for CR compared to transmit power constraints. On the other hand, cooperative communication provides an effective means to withstand fading and improve the throughput of the network using spatial diversity. Hence, a CR network can improve its performance by employing relay assisted communication. At first, we consider a single user cooperative two-hop CR network under joint peak and average interference power constraints at PR, where the communication is assisted by decode-and-forward (DF) relays. We show that the ergodic capacity and symbol error rate performance of the network is improved by using DF relays. Next, we consider the problem of achieving the ergodic sum capacity of a multiuser cooperative two-hop CR broadcast network under the same constraints and derive the optimal transmit power allocation policy, with D-TDMA user scheduling scheme. We observe that the ergodic capacity of the network is enhanced as the number of relays increase, signifying the impact of “cooperative diversity” on the network performance. Existing literature shows that the achievable rate of single user CR networks under interference power constraints is higher compared to the case of transmit power constraints, and here we demonstrate similar results for the multiuser CR network. Finally, we focus on the problem of maximizing the weighted sum rate (WSR) of a multiuser cooperative two-hop MIMO CR network under average transmit and interference power constraints. We propose an iterative solution to the problem that maximizes the WSR in two hops of the network. We notice that the network achieves high data rates while effectively suppressing the interference at PUs, which can be attributed to the spatial multiplexing and beamforming capabilities of multi-antenna nodes.

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*Title* : *Optimizing Signal Constellations*  
*Author(s)* : *Ahuja Kartik*  
*Roll No* : *Y8127238*  
*Supervisor(s)* : *Chaturvedi Ajit Kumar*

### *Abstract*

Previous works in the area of signal constellation design to minimize symbol error rate have dealt with the problem at asymptotic SNR values. Optimal constellations which achieve minimum possible symbol error rate or bit error rate at any given SNR have not been established. In this work we come up with solutions to this problem for 1 and 2 dimensional constellation for AWGN and fading channels. Shape of optimal signal constellations varies with SNR value and this fact has interesting implications for fading channel. Depending on the channel gain, the transmitter decides the amount of power and which geometry to use to have a minimum average symbol or bit error rate, optimal solutions to this problem are arrived at. Optimal signal constellations arrived at are compared with the best ones known in literature to show the improvements. We show that necessary conditions in literature for optimality of 2 dimensional constellations at asymptotically high SNR values are inaccurate and thus, arrive at a new set of necessary conditions

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**Title** : *Blind EM Based Time Varying Channel Estimation For Coded Uncoded MIMO Wireless Communication*  
**Author(s)** : *R Gayathri*  
**Roll No** : *11104032*  
**Supervisor(s)** : *Jagannatham Aditya K*

### ***Abstract***

A novel scheme for joint symbol detection and channel estimation using data-aided Kalman Filter (KF) based Expectation Maximization (EM) algorithm has been proposed in this thesis. This blind EM based approach provides a robust technique for channel estimation in coded and uncoded Multiple-Input Multiple-Output wireless systems in fast fading wireless scenarios. This combination of EM and KF leads to an iterative procedure where the symbols detected are further used to fine tune the channel estimate and vice-versa. The E-step and M-step of the EM algorithm respectively perform channel estimation using dataaided KF and symbol detection using various decoding schemes for both uncoded and coded systems. Sphere decoding based Maximum Likelihood (ML) detection is employed for an uncoded system in the M-step of the proposed REKF scheme. Similarly Viterbi decoding and Space Time Trellis Code (STTC) decoding is employed for coded systems. The scheme proposed is termed as Random Parameter EM based KF (REKF) since the fast fading channel is considered as the random parameter in the E-step of the algorithm. The proposed scheme has lower computational complexity compared to the existing framework for EM based KF for data-aided channel estimation. The complexity analysis is presented which shows the computational complexity comparison. Simulation results further demonstrate that the REKF has a superior performance compared to the existing scheme in terms of the Bit Error Rate (BER) of symbol detection. We also present the simulation results in terms of the Mean Squared Error (MSE) of channel estimate for both the proposed REKF and existing deterministic parameter based scheme. The Bayesian Cramer-Rao Bound (BCRB) for the MSE of channel estimate for the proposed REKF technique is also presented

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*Title* : *Multi-user beamforming schemes and analysis for cooperative MIMO cellular scenario*  
*Author(s)* : *Tandon Nitin*  
*Roll No* : *11104067*  
*Supervisor(s)* : *Jagannatham Aditya K*

### *Abstract*

As most of multimedia applications are point to multipoint in nature, cooperative power allocation and beamforming is an emerging concept in which different base stations (BSs) in multicellular environment coordinate among themselves to provide multiple copies of data to a user or user groups subscribed for same multicast services. Thus it is an excellent means of providing multi BS diversity. We describe a joint power allocation and beamforming scheme, based on eigenvalue decomposition along with pooled power constraint for all cooperating BSs. We demonstrate that the proposed scheme provides superior sum rate performance compared to existing beamforming schemes in cooperative scenario. We then modify the scheme to include per BS power constraints and formulate a Semi Definite Programming (SDP) form of convex optimization problem. We then consider unicast/ multicast scenario with interference among users/user groups and describe two schemes, successive constrained eigen beamforming (SCEB) and interference whitening scheme (IWS). These schemes are shown to provide superior performance compared to existing Block Diagonalization (BD) scheme in low SNR regime. We discuss the performance of user scheduling schemes in allocating time-frequency resources to subscribed users. We compare the video quality obtained by employing various schedulers for supporting H.264 based scalable video transmission. We then consider uncertainty in channel state information (CSI) and design a robust downlink beamforming scheme, based on minimizing the worst case interference, in multiple input single output (MISO) downlink scenario using second order cone programming (SOCP) formulation of convex optimization and extended it for MIMO scenario also. Successive beamforming of users and perturbation theory for eigenvectors has been utilized for obtaining beamformers in MIMO downlink scenario. For the uplink scenario, we have shown that the multidimensional covariance fitting (MDC) approach used for direction of arrival (DoA) estimation, can be efficiently utilized to evaluate receive beamformers

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*Title* : *Raptor code for error resilient wireless video streaming*  
*Author(s)* : *Mehta, Rajesh Chandrakantbhai*  
*Roll No* : *11104060*  
*Supervisor(s)* : *Singh Yatindra Nath & Jagannatham Aditya K*

### *Abstract*

The explosive increment in utilization of internet with its fast growth and easy availability of multimedia gadgets at cheapest price triggered the need of live video streaming application. But the bandwidth, delay and loss requirement posed by real time video is not fully guaranteed by current infrastructure of internet. Moreover, support of multicast video makes this issue more complex and that's why it is most challenging research area for industry and academia. Towards this, we propose the design and development of schemes to guarantee the Quality of Service (QoS) parameters. The selection of schemes have been done after exhaustive analysis of present schemes. We have carried out the implementation of such schemes which were not available as open source. These schemes include the implementation of Raptor code, class of fountain code and "insertion of synchronization marker" for error resilient coding and demonstrated live video streaming. Thus, the thesis presents realistic solution for real time, reliable and error resilient video streaming over the Internet.

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***Title*** : ***H.264 Scalable Video Codec Implementation for Wireless Video Streaming***  
***Author(s)*** : ***Thammireddy Mahesh***  
***Roll No*** : ***11104111***  
***Supervisor(s)*** : ***Jagannatham Aditya K***

### ***Abstract***

Advances in digital communications have changed the communication industry over the past decade. Digital TV, DVD video, HDTV, internet video streaming, video conferencing and mobile technology have expanded the boundaries of communication systems to include a rich visual dimension. Video compression has played a vital role in the realization of these technologies by bridging the gap between the demand for quality, performance and limitations of current storage and transmission capabilities. The H.264/AVC video coding standard offers significant improvement in compression efficiency and flexibility compared to earlier standards like H.263,H.261 etc. The Scalable Video Coding Extension of the H.264/AVC Standard provides a very efficient and network friendly scalability benefits with the slight increase in the decoder complexity. We used Context-adaptive variable-length coding (CAVLC) for encoding the quantised transform coefficients. CAVLC is more efficient than the methods generally used to code coefficients in other standards.This thesis provides an overview of the implementation of H.264 scalable video codec for wireless video streaming.

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*Title* : *Designing Algorithms for Optimal Base-Station Location and Three Dimensional Localization in Wireless Sensor Networks*  
*Author(s)* : *Undrajarvarapu Kishore Kumar*  
*Roll No* : *11104046*  
*Supervisor(s)* : *Sircar Pradip*

### *Abstract*

In this thesis we consider the problem of finding optimal base-station location, with an objective of minimizing the total energy consumption in Wireless Sensor Networks. Particle Swarm Optimization (PSO) is a swarm based heuristic algorithm, which has been widely used in finding nearly optimal solutions for optimization problems. We propose a PSO based algorithm to find the optimal location of base-station in wireless sensor networks. Our proposed algorithm considers nodes suffering from both free space and multi-path loss communication with the base-station. Subsequently we have employed another heuristic technique, Shuffled Frog Leaping Algorithm (SFLA) to show the performance of PSO based algorithm in find the optimal base-station location. Experimental results show that the proposed PSO based algorithm has out performed the earlier methods with high rate of success in finding the true optimal location of base-station. Further, on the problem of three- dimensional localization in wireless sensor networks, we proposed an anchor free localization algorithm using quaternion rotations. In computing the rotation transformation, quaternion rotation is more efficient in terms of computational speed when compared to rotation matrix.

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*Title* : *Flutter Shutter Based Motion Deblurring on Complex Videos*  
*Author(s)* : *S Harshavardhan*  
*Roll No* : *11104038*  
*Supervisor(s)* : *Venkatesh K S&Gupta Sumana*

### *Abstract*

Clear digital photography requires no relative motion between camera and object in the scene. The moving object in an image is blurred along the direction of motion. This is called motion blur, and it is the most common artifact in digital photography. If the blur length is large it is even difficult to distinguish moving objects. Also, motion blur removes high spatial frequencies like letters and lines. These lost kinds of scene information cannot be recovered by any of the post-processing techniques, as motion blur is ill-posed problem. In the concept of flutter shutter, the shutter of the camera is opened and closed according to a pseudo-random code, instead of opening it for the complete duration of exposure time. This converts the temporal box filter into a broad band filter which preserves high frequency spatial information, thus making the problem well-posed. In this thesis, we discuss the deblurring of complex videos in different scenarios like partial static occlusions and dynamic occlusions. We have applied the flutter shutter in a virtual fashion where the coded exposure images are obtained by simulation. Deblurring is applied only on the moving object so as not to affect the background. To further enhance the image, we use a denoising technique to decrease the noise levels after deblurring.

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*Title* : *Stereo Image To Graphics Conversion For Indoor Environment*  
*Author(s)* : *Bhadouria Vishw Mitra Singh*  
*Roll No* : *11104117*  
*Supervisor(s)* : *Venkatesh K S*

### *Abstract*

In computer graphics, a real world scene is pictorially represented by using a collection of different basic polygonal shapes. An outdoor scene may contain objects of arbitrary shapes such as trees, flowers, clouds, rocks etc, however, most objects found in a 3D urban scene can be broken into a collection of planes of different sizes, depths and orientations. Thus, the determination of these planes effectively provides a way for representing the 3D scene as graphics. In this work, we use a pair of uncalibrated stereo images with corresponding camera calibration matrices for estimation of physically existing 3D planes in 3D scene. Due to the richness of straight lines in urban environments and their potential capability to reduce the search region, we use straight lines as features in this thesis. To extract the 3D edge from an available 2D stereo image pair, first, straight lines are detected from both the images and a correspondence is established between both sets of straight lines; then, the end points of the common region of an edge pair are triangulated to find the end points of 3D edges. Using these 3D edges, we find the equations of the planes in 3D. For the rejection of non-existing planes (because any pair of coincident planar 3D lines can form a plane, but the plane need not exist in the physical scene), we use the SIFT algorithm for identification of key points within the region under test and accept or reject the plane hypothesis depending on whether or not a 3D point corresponding to the matched sift point pair satisfies the plane equation within a threshold. We have innovated on the following fronts: an algorithm for straight edge detection; an algorithm for finding matching line endpoints across the stereo images; postulating planes between coplanar 3D lines and eliminating pseudo planes.

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*Title* : *Stereo Image To Graphics Conversion For Indoor Environment*  
*Author(s)* : *Bhadouria Vishw Mitra Singh*  
*Roll No* : *11104117*  
*Supervisor(s)* : *Venkatesh K S*

### *Abstract*

In computer graphics, a real world scene is pictorially represented by using a collection of different basic polygonal shapes. An outdoor scene may contain objects of arbitrary shapes such as trees, flowers, clouds, rocks etc, however, most objects found in a 3D urban scene can be broken into a collection of planes of different sizes, depths and orientations. Thus, the determination of these planes effectively provides a way for representing the 3D scene as graphics. In this work, we use a pair of uncalibrated stereo images with corresponding camera calibration matrices for estimation of physically existing 3D planes in 3D scene. Due to the richness of straight lines in urban environments and their potential capability to reduce the search region, we use straight lines as features in this thesis. To extract the 3D edge from an available 2D stereo image pair, first, straight lines are detected from both the images and a correspondence is established between both sets of straight lines; then, the end points of the common region of an edge pair are triangulated to find the end points of 3D edges. Using these 3D edges, we find the equations of the planes in 3D. For the rejection of non-existing planes (because any pair of coincident planar 3D lines can form a plane, but the plane need not exist in the physical scene), we use the SIFT algorithm for identification of key points within the region under test and accept or reject the plane hypothesis depending on whether or not a 3D point corresponding to the matched sift point pair satisfies the plane equation within a threshold. We have innovated on the following fronts: an algorithm for straight edge detection; an algorithm for finding matching line endpoints across the stereo images; postulating planes between coplanar 3D lines and eliminating pseudo planes.

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**Title** : *Performance Analysis And Outage Optimal Power Allocation Scheme For Opportunistic Cooperative Communication*  
**Author(s)** : *Kumar Sandeep*  
**Roll No** : *11104092*  
**Supervisor(s)** : *Sharma Govind*

### ***Abstract***

A threshold based opportunistic relaying cooperative communication protocol has been analysed in this thesis. The relay is selected opportunistically to maximize the end-to-end signal to noise ratio received at the destination. The relay selection may be proactive and reactive. The underlying communication protocol at relay is decode and forward cooperation. At destination Maximal Ratio Combining(MRC) is done to exploit diversity. The statistics in terms of (PDF) and (CDF) have been derived and used for determining outage probability, symbol error rate(SER) and the diversity gain. The asymptotic high SNR approximation of outage probability for proactive non-threshold opportunistic relaying has been derived and shown that it is a tight upper bound for proactive threshold opportunistic relaying. The approximate outage probability has been minimized subject to fixed total power and outage optimal power allocation ratio has been derived for varying channel conditions at source and relay. The outage performance with perfect and imperfect channel state information(CSI) have been compared and from simulation result the diversity loss in case of imperfect CSI is clearly evident. A new performance metric probability of miss of best relay has been proposed to have a better insight on the effect of the performance when CSI is imperfect. Probability of miss is higher in proactive opportunistic relaying than reactive opportunistic relaying.

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*Title* : *Adaptive Frequency Hopped Alamouti-Coded OFDM System*  
*Author(s)* : *Akhtar Javed*  
*Roll No* : *11104040*  
*Supervisor(s)* : *Sharma Govind*

### *Abstract*

In modern wireless communication, power and bandwidth are two of the most important constraints for a system that has to be taken into account. Recent demands for high data rate and high capacity has set an urge for systems that can support large chunks of data and large number of users. For a power and bandwidth limited system, enhancing the system performance provides a good solution to meet these demands. In this thesis we consider OFDM and Alamouti-Coded OFDM systems with an objective of improving the system performance using adaptive hopping. In this context we propose an AFH (Adaptive Frequency Hopped) system that improves the performance of the system. We use Alamouti-Coded OFDM system that has the advantage of transmit diversity as well as high data rate. Simulation results demonstrate that the proposed scheme provides high gain and hence enhances the performance of the system

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*Title* : *Reconstruction of partial color artifacts and blotches in videos using histogram matching and sparse technique*  
*Author(s)* : *V Narendra*  
*Roll No* : *11104112*  
*Supervisor(s)* : *Gupta Sumana*

### *Abstract*

In this thesis we have proposed methods for detection and restoration of an artifact called Partial Color Artifact(PCA) which occurs frequently in old video lms. The PCA occurs due to partial loss of information in the upper color layers of the video film. As the inner most color layer is unaffected, detection and restoration is performed by using information present in this inner most color layer of the film. The proposed methods are based on the principle that the difference color layers of the film have the same structural information, but they differ only in contrast. We have proposed spatial and temporal reconstruction techniques for the reconstruction of PCA artifacts. Spatial reconstruction technique uses only the information present within the frame to reconstruct the PCA pixels. The spatial reconstruction process fails to reconstruct those objects where the PCA artifact covers the entire region of the object. This is because spatial reconstruction method requires some part of the object to be artifact free in order to reconstruct the affected part of the object. The proposed temporal reconstruction method overcomes this limitation as it uses information from either the previous frame or previously reconstructed frame to reconstruct the PCA pixels present in the current frames. The proposed temporal reconstruction method reconstructs those objects that are entirely covered by PCA artifacts. Another commonly occurring artifact in the old video frames are Blotches. We propose a novel reconstruction method using sparse recovery to reconstruct these blotches. The proposed blotch reconstruction process is computationally efficient because the image is segmented into non overlapping blocks and reconstruction is done block wise

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*Title* : *Relay Selection In MIMO Relay Networks*  
*Author(s)* : *Gagrani, Mukul*  
*Roll No* : *Y8127306*  
*Supervisor(s)* : *Chaturvedi Ajit Kumar*

### *Abstract*

Recently multiple antenna systems (MIMO) and cooperative communication using relays have attracted a lot of attention due to their potential to meet the growing demands of higher data rates and reliable communication. In the presence of large number of relays in a network with limited transmit power at the relays, using all the relays for transmission would be sum rate suboptimal. In this thesis we consider the problem of relay selection in a MIMO relay network with the aim of maximizing the sum rate. First we consider a setup where all the nodes in the network are equipped with multiple antennas and have perfect channel state information (CSI). We propose a low complexity relay selection algorithm where it is assumed that all the receive and transmit antennas of the selected relay will be used for transmission. Next we argue that selecting all the antennas of a relay is suboptimal. We propose an optimal pairing algorithm for joint receive and transmit antenna selection and a low complexity greedy pairing algorithm. Simulation results confirm the superiority of antenna selection scheme over relay selection and greedy pairing gives nearly same performance as optimal pairing with lesser computations. Next we consider the case when partial CSI is available at the transmitter side and the relay nodes have a single antenna. We study a random beamforming scheme and a finite rate feedback scheme for obtaining quantized channel direction vectors at the source. Low complexity relay selection algorithms are proposed for both the schemes and it is observed that as the number of feedback bits are increased the sum rate performance approaches the perfect CSI case.

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**Title** : *Optimal Subcarrier and Power Allocation for Video Quality Maximization in Multihop Wireless Sensor Networks*  
**Author(s)** : *Ramagiri Vamshi Krishna*  
**Roll No** : *11104114*  
**Supervisor(s)** : *Jagannatham Aditya K*

***Abstract***

In this paper, we maximize the video quality in SISO and MIMO wireless network systems. In this frame work we consider a wireless network with source, intermediate nodes and a destination node where we use OFDM resource allocation. We propose three techniques Stable matching, Greedy matching and random allocation algorithms for resource allocation to the wireless links. We propose two frame models namely Sum Optimization and Max-Min Optimization models where in Sum Optimization we maximize the sum qualities of sources and in Max-Min Optimization we maximize minimum quality among sources. We calculate quality by considering Scalable Video Coding(SVC) with constant power allocation to all nodes and with Optimized power allocation. In simulation results, we show the Quality with Stable matching Resource allocation is better than the other two proposed algorithms and we also show that Quality with Optimized power allocation is better than constant power allocation

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*Title* : *Video Stabilization and Camera Motion Estimation using SPREF*  
*Author(s)* : *Dinesh Karthik*  
*Roll No* : *11104050*  
*Supervisor(s)* : *Gupta Sumana*

### *Abstract*

Spatiotemporal Regularity Flow (SPREF) gives us the directions in which a video is regular. By regularity we mean direction in which the intensity value of the pixels varies the least. This can be achieved through the condition that sum of the directional gradients is minimum along the flow directions. In our thesis, using the concept of SPREF which approximates the motion vectors, we have looked into various applications. First application is the video stabilisation. With the advent of multimedia devices there comes the ability to capture video. Capturing stable video is always a difficult task. Instability in a captured video occurs because of many reasons like shaking of hand while capturing the video etc. Using the concept of SPREF we try to stabilise the video by smoothing the unstabilized global motion. Camera motion estimation is the second application we have considered. Camera motion estimation can also be termed as global motion estimation as camera movements like pan, tilt, zoom etc is for the entire frame of a video. Estimated camera motion has been used in variety of applications in the past, one of them being the video stabilisation itself. In our thesis we have tackled the problem of camera motion estimation using the SPREF. The other application in which SPREF has been used is camera motion characterisation, background subtraction and object tracking. Camera motion characterisation helps us to find the kind of motion that exists between any two frames of a video. Angle histogram of the direction specified by the SPREF is used for this application. Tracking motion with subtracted background of simple videos with static backgrounds is concentrated upon in this thesis.

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**Title** : *Natural Daylight Colour Visualization for Multispectral Imaging in NIR(700-1100nm)*  
**Author(s)** : *Singh, Adersh Kumar*  
**Roll No** : *11104004*  
**Supervisor(s)** : *Venkatesh K.S&Gupta Sumana*

### ***Abstract***

All night vision cameras (Near infrared (NIR) or infrared (IR)) produce monochrome (gray level or greenish) images. Such monochrome images do not give a good impression of the scene contents to a human observer. This may cause illusions, loss of situational awareness, and outright detection failure of objects of interest. Also likely is a greater reaction time in identifying objects due to the lack of colour information. The objective of addressing visualization in natural colour for multi-spectral images in near infrared (NIR, 700-1100 nm) is to give night vision imagery an intuitively meaningful natural colour appearance. This would expedite as well as improve the viewer's scene comprehension and facilitate the construction of a more complete mental representation of the perceived scene. It has been found that scene understanding and recognition, reaction time, and object identification are faster and more accurate with colour imagery than with monochrome imagery. Colour imagery has several benefits over monochrome imagery for surveillance and security applications. In order to provide colour visualization for night time imagery, we propose a colour transform method that gives night vision imagery a day time appearance. This proposed method transfers the colour characteristics of day light imagery into multi-spectral NIR images and thus gives a natural appearance in the scene. In multi-spectral NIR imaging, the surface reflectance at a given wavelength has physical characteristics inherent to the object surface. The spectral analysis can be used for detailed analysis of the object surface and for near realistic image production. We capture multi-spectral NIR video by synchronizing a high speed CCD camera and three infrared light illuminators at 750, 850 and 950 nm wavelength. We also have a visual colour image of the same scene as a reference. These three NIR bands would be sufficient for colour visualization. In this method, we define 3-D vectors of corresponding pixels in three successive frames at different wavelength of the multi-spectral video and find a suitable transformation to map these vectors to the 3-D vectors corresponding to the pixels of the reference visual colour image. This algorithm needs very less computation, and hence can be implemented in real time. With a hardware implementation of the algorithm, we can display for the user a visual image with near-natural colour information from the input, multi-spectral night imagery in NIR.

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*Title* : *Spatio-temporal multi-view synthesis for free viewpoint television*  
*Author(s)* : *Kumar Katta Phani*  
*Roll No* : *11104051*  
*Supervisor(s)* : *Venkatesh, K S&Gupta Sumana*

### *Abstract*

Interest in view synthesis is growing rapidly as it has tremendous applications in free viewpoint television (FTV), 3DTV, games, virtual reality etc. In FTV, a user can freely navigate through the space to see different views of the same scene. This provides much more realistic and immersive video experience to the viewer. View synthesis is a process of generating views of a virtual camera from one or more reference views taken from real cameras. The main problem of view synthesis is that the virtual view contains holes in disoccluded regions. These holes can be filled by using various inpainting techniques or by using more than one reference view. We propose a hole filling algorithm to fill the disocclusion holes in the virtual view by exploiting the temporal information of the reference views. We also propose an algorithm to avoid the shining of background pixel through a foreground object due to the absence of foreground pixel information. We generate different zoomed views of the scene by applying the concept of view synthesis and observe the variation of holes with different zoom scales. Finally, depth based image segmentation is used to separate the scene into a number of depth parametrized layers. This can be useful in realizing parallel computing. Experimental results show that good quality virtual views are generated with high PSNR and with fewer artifacts.

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**Title** : *Algorithms for Unsupervised Active Speaker Detection Using an Audio-Visual Sensor Array*  
**Author(s)** : *KheradiyaJatin*  
**Roll No** : *11104039*  
**Supervisor(s)** : *Hegde Rajesh Mahanand*

### ***Abstract***

Humans can perform active speaker detection (ASD) inadvertently, accurately in robust manner, even under noisy environment because of their multiple senses working together. However automatic active speaker detection is a challenging problem. Traditional methods address the active speaker detection problem by feature extraction in tandem with hierarchical clustering approaches. In all these approaches either the audio or the visual modality is used. In this thesis, the problem of multi modal ASD in meeting rooms is addressed. The method proposed in this thesis uses an audio-visual sensor array for ASD. A circular microphone array is used and camera array with common field-of-view, capture audio-visual data. TDOA is used to find the pivot mic corresponding to active speaker. The audio features are extracted from pivot mic. Direction of Arrival (DOA) using the audio modality is used to localize the speaker. Active speaker is localized by lip activity detection method, followed by stereo triangulation using video modality. A Pivot camera is also detected and used to extract correlation based video features. Multimodal active speaker detection is performed by the weighted fusion of audio and visual modality decisions. A decision level fusion is used herein for improved ASD performance. Extensive experiments are performed on the MONC database and data recorded using the MiPS lab testbed. The multimodal approach proposed in this thesis for active speaker detection indicates better performance than existing clustering based method in terms of detection rate and diarization error rate.

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*Title* : *A Bayesian Approach To Estimation of Speaker Normalization Parameters*  
*Author(s)* : *Ram Dhananjay*  
*Roll No* : *11104030*  
*Supervisor(s)* : *Hegde Rajesh M&Kundu Debasis*

### *Abstract*

Large variation in speakers causes the performance degradation of a speaker independent speech recognition system significantly, compared to the speaker dependent speech recognition system. In an attempt to compensate for this degradation in performance, this thesis proposes a Bayesian approach to speaker normalization. The vocal tract length normalization (VTLN) parameters are estimated using a novel Bayesian approach which utilizes the Gibbs sampler, a special type of Markov Chain Monte Carlo method. Additionally the hyperparameters are estimated herein using maximum likelihood estimation. This model is proposed assuming that human vocal tract can be modelled as a tube of uniform cross section. It captures the variation in length of the vocal tract of different speakers, more effectively than the linear model used in literature. The thesis has also investigated different methods like LSE, and MAE for the estimation of VTLN parameters. Both single pass and two pass approaches are then used to build a VTLN based speech recognizer. Experimental results on recognition of vowels and hindi phrases from a medium vocabulary indicate that the Bayesian method improves the performance by a considerable margin.

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**Title** : *Formulation of control variable for path determination in loop free multipath routing*  
**Author(s)** : *Bhutto Zulfikar Ali*  
**Roll No** : *11104119*  
**Supervisor(s)** : *Singh Yatindra Nath*

### ***Abstract***

Multipath Routing provides a way to forward traffic towards destination via multiple next hops. In Internet, it is essential for a router to route packets in a way so that packets don't get lost on transit, leading to packet loss. One of the main causes of packet loss is occurrence of routing loops. Of all the Routing Algorithms at work in Internet, almost all of them try to avoid or rectify the appearance of routing loops. Most of the Single Path Routing Algorithms use various techniques to deal with routing loops. But those techniques don't necessarily help in avoiding routing loops in Multipath Routing. In our thesis we have proposed a new dynamic loop-free multipath routing algorithm which not only increases network throughput and converges rapidly but also eliminates the occurrence of routing loops. The main idea is to formulate and evaluate a Control Variable for path determination. The Control Variable, which depends upon the current network scenario for a node, provides a value, which when applied to a specified equation given by us never leads to selection of a path that may eventually lead us to a routing loop.

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*Title* : *Application of Stable Marriage Problem to Spectrum Leasing in Cognitive Radio Networks*  
*Author(s)* : *Sharma Pranay*  
*Roll No* : *Y8127348*  
*Supervisor(s)* : *Chaturvedi Ajit Kumar*

### *Abstract*

For over a decade there has been continuously growing body of work in the field of Cognitive radio, to better utilize spectrum resources. Dynamic Spectrum Leasing is a relatively new paradigm in this literature. It has been shown that both primary (licensed) and secondary (unlicensed) users gain from primary involvement in the spectrum access process. Earlier works concentrated on simpler models with single primary user. Recently, more generalized models have been introduced, with multiple primary and multiple secondary users. This work considers a multiple primary multiple secondary model in which all users are independent of each other. Primary-secondary interaction is modelled using auction mechanism. But, with multiple auctions taking place simultaneously, channel allocation becomes a non-trivial problem. Each secondary gains by cooperating with a particular primary, and so do the primary users when they lease their spectrum. Imposing the constraint that each primary can lease its spectrum to a single secondary and each secondary can cooperate with a single primary, the allocation problem boils down to the form of the well known stable marriage problem with secondary acting as proposers and primary being the reviewers/acceptors. The solution is distributed, has less complexity and gives performance comparable to the case when channel allocation is done centrally by the secondary system. Other algorithms of channel allocation (Hungarian algorithm, and another based on English auctions) have been used for comparison. Bounds on performance have also been obtained. Another system model based on cooperative Automatic Repeat Request (ARQ) has been considered for the same problem and performance gains have been shown. The results suggest that in any case if the secondary can rank primary users in a preference order, a performance benefit can be achieved by using stable marriage algorithm for channel allocation. In the end, an attempt has been made to eliminate the one-primary one-secondary constraint and solve it using an extension of stable marriage solution. Analysis and performance comparisons have been given for this case.

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**Title** : *Optimal Power Allocation for Ergodic and Outage Capacity Maximization in OFDM based CR Network with Perfect and Imperfect CSI*  
**Author(s)** : *Swain Partha Sarathi*  
**Roll No** : *11104074*  
**Supervisor(s)** : *Banerjee Adrish*

### ***Abstract***

Cognitive radio (CR) opportunistically makes use of the unused licensed spectrum bands to increase the spectrum efficiency. Also, OFDM has been proved as a suitable technique for CR network because of its flexibility in allocating the spectrum and ease in nullifying the spectrum for primary transmission. In this thesis work, we formulate a power allocation scheme for capacity maximization in OFDM based CR network in interweave scenario and the numerical results show how the variation in the PU band width and utilization factor affects the throughput of the system. We consider primary user utilization factor because we assume primary user queue is not occupied all the time. We propose power allocation scheme for joint interweave-underlay scenario and analysed it for both OFDM based primary user and non-OFDM based primary user. We also formulate a power allocation scheme that considers imperfect CSI with probabilistic interference constraint and we show results under cases like outdated CSI, estimated CSI, actual CSI and no-CSI. The expression for Outage capacity for OFDM based CR network is derived. We also propose a power allocation scheme that maximizes the outage capacity in interweave scenario. We compare the proposed scheme with different classical power allocation schemes like water- filling scheme, uniform scheme showing that the proposed scheme performs better than the other two. Similar analysis is carried out for joint interweave and underlay scenario

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***Title*** : ***Online Signature Verification by using Stereo Camera and Tablet***  
***Author(s)*** : ***Dave Jay D***  
***Roll No*** : ***11104027***  
***Supervisor(s)*** : ***Venkatesh K S***

### ***Abstract***

Signature is a behavioral biometric as it depends upon a person's behavior or habit, like his speech patterns. Signature is not a physical biometric like face or fingerprint. Signature verification can be done online or offline depending upon the availability of input data. In offline (static) signature verification, we have only the static visual record or shape of signatures. In online (dynamic) signature verification, we have dynamic properties of signatures such as pen trajectories or pressure information in addition to the signature's shape. The conventional offline approach only uses either a single camera to track the pen tip position or a tablet to extract the dynamic features of the signature, hence the signature has only two spatial dimensions. In this thesis, we are combining a pressure sensitive device (tablet) and stereo vision to make signatures in 3D. Stereo vision is made by two low cost cameras which track the pen tip position in X, Y & Z spatial directions in each frame. A pressure sensitive device (tablet) measures the pen tip pressure while doing the signature. Then, the distance between the input signature's features and template signature's features which were collected in the training phase is computed using a Dynamic Time Warping (DTW). Finally, the calculated distance is compared with a threshold value. By that we can classify that input signature is genuine or a forgery. In this way we are adding one additional feature to the conventional approaches to get a low Equal Error Rate (EER).

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*Title* : *Channel-Adaptive Sensing and Access Strategies for Energy Harvesting Cognitive Radio*  
*Author(s)* : *J Jeya Pradha*  
*Roll No* : *11104041*  
*Supervisor(s)* : *Banerjee Adrish*

### *Abstract*

We consider an energy harvesting cognitive radio which opportunistically accesses the primary user's frequency bands. Secondary user may not possess the full knowledge of availability of all the primary network's channels. Sensing all channels is energy inefficient since aggressive use of energy may lead to energy outage resulting in insufficient energy for transmission. On the other hand, overly conservative use of energy may not be able to accommodate the newly harvested energy due to less usage of stored energy. By adapting power and rate of secondary user based on the channel state information of the secondary links, the throughput can be further improved and the transmission energy is conserved. We propose the channel selection reward criterion as a function of primary network's belief state, energy availability, spectral efficiency and bandwidth of the channels. This channel-aware strategy gives better performance than the reward criterion based on belief and bandwidth of the channels. Our objective is to determine the series of optimal sensing and access decisions under energy neutrality constraints and fading conditions. We cast this problem under Partially Observable Markov Decision Process framework with partially observable primary network's states and fully observable energy availability and channel gain for a single user scenario. We perform Monte-Carlo simulations for the proposed model in the presence of sensing errors and collisions taking both the circuit power consumption and transmission power consumption into account. A sub-optimal policy incorporating the proposed channel selection criterion, which reduces the computational complexity with comparable performance is also developed. We extend this setup to multi-user multi-channel scenario with collision avoidance schemes at the MAC layer. Also, we have determined the optimum network throughput which serves as the upper bound.

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***Title*** : ***Real Time Stabilization and Deblurring of Thermal Images***  
***Author(s)*** : ***Singh Bhoopendra***  
***Roll No*** : ***11104024***  
***Supervisor(s)*** : ***Venkatesh K S***

### ***Abstract***

Digital Image Stabilization (DIS) is a key requirement to improve the visibility of the objects in real time or in recorded shaky videos. The unwanted shaky motion comes from unintentional camera motion which can be due to unstable platform or hand shake. DIS consists of motion estimation and motion compensation modules. Motion estimation is a crucial part of DIS system. We have developed a fast algorithm using integral projection on a gray coded bit plane image to estimate the motion parameters. Integral projection converts two-dimensional search problem to a pair of one-dimensional search problem which is computationally inexpensive compared to block matching. We have used a gray coded bit plane for motion estimation which is robust to irregular conditions. Our proposed algorithm reduces hardware requirement significantly as we are using a single bit plane of an image. Motion blur is the result of relative motion between a camera and an object during capture time of an image by the imaging device. While capturing the image, fast moving objects present in the scene get blurred in the direction of motion because of the finite exposure time. This temporal filtering destroys important high-frequency spatial details of the scene captured using a thermal camera. Thus image de-blurring becomes an ill-posed problem. Fluttering of the shutter while taking image, changes the filter response to a broad-band filter without zeros which preserves the high frequency spatial details and thus the corresponding de-convolution becomes a well posed problem. We show that motion blurred infrared images can be de-blurred. We have also discussed the dependence of different modulating codes in the de-blurring process. Coded exposure images are simulated using the Matlab. Certain code sequences whose frequency response are broadband in nature give better de-blurring results as compared to any random binary code sequence. The dependence of length of code on the blur size is shown.

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*Title* : *Turbo Coded Cooperation with Selective Decode-and-Forward using Pilot based Channel Estimation*  
*Author(s)* : *Noman Tariq*  
*Roll No* : *11104110*  
*Supervisor(s)* : *Sharma Govind*

### *Abstract*

Diversity in wireless systems can be achieved using multiple antennas at the transmitter/receiver. But in systems with limitation of power and/or size, employing multiple antennas is not feasible. Cooperative communication schemes can provide diversity in such systems in which users with single antenna cooperate with each other. Coded cooperation is a modified cooperation scheme in which cooperation is combined with channel coding in order to achieve both diversity and coding gain. In this thesis, a coded cooperation scheme using distributed turbo codes is considered and selective decode-and-forward(DF) protocol is used for relaying. A modification is proposed to the existing selective DF protocol in the turbo coded cooperation framework which reduces complexity at the receiver by avoiding the use of Maximal Ratio Combining(MRC). Performance of the proposed turbo coded cooperative system is compared with the existing one which uses MRC at the receiver through simulations and the results show that both the schemes give almost the same performance. Knowledge of the channel state is required for demodulation and decoding at the receiver and also for MRC. A simple pilot-based channel estimation technique is used in this thesis to estimate the channel coefficient and the performance using this estimate is compared with the ideal case where the channel state information(CSI) is known at the receiver. Using channel estimates also, the proposed scheme gives the same performance as the existing scheme.

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*Title* : *Local Quadrature Reconstruction on Smooth Manifolds*  
*Author(s)* : *Dhingra, Bhuwan*  
*Roll No* : *Y8127167*  
*Supervisor(s)* : *Mukerjee Amitabha&Venkatesh K S*

### *Abstract*

Non-Linear Dimensionality Reduction (NLDR) techniques such as ISOMAP, LLE, Laplacian Eigenmaps etc. attempt to estimate low-dimensional latent descriptors for data assumed to be drawn from an  $m$ -dimensional manifold in an ambient  $n$ -dimensional space. Out-of-Sample Extension - the problem of estimating the latent vectors for novel data - has attracted considerable attention in the literature. In this thesis, we consider the opposite problem, that of reconstructing new high-dimensional points, given a novel latent-vector in a previously discovered embedding. Such a procedure finds relevance in applications such as video interpolation or robot motion planning. Some global methods can be applied to the problem, but these are polynomials on the total number of data points  $N$  resulting in a complexity of  $O(N^3)$ , where  $N$  is often in the thousands. In contrast, we propose a Local Quadrature Reconstruction approach that looks at only the local  $k$ -neighbourhood for which the complexity reduces to  $O(k^3)$  ( $k$  may be about 10). LQR achieves low error by estimating the second order error terms based on a second order differential geometric formulation for a small neighbourhood around the query point on the manifold. Main features of LQR include its fast reconstruction time and lack of a training phase, but since  $k$  increases as  $O(m^2)$  it is currently limited to manifolds with low intrinsic dimension. Performance analysis of LQR on several point and image sets is presented, and a possible application for frame interpolation on videos is also studied.

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*Title* : *Dataslots Allocation and Performance Evaluation of a Local Control Channel Based Cognitive Radio MAC Protocol*  
*Author(s)* : *Pishke, Surya Chandra Prakash*  
*Roll No* : *11104069*  
*Supervisor(s)* : *Singh Yatindra Nath&Roy Amitabha*

### *Abstract*

Proliferation of wireless applications have increased the demand for the radio frequency spectrum. With most of the radio spectrum being allocated to the licensed (privileged) users, there is a need for a new communication method to use the unlicensed and underutilized-licensed spectrum. Cognitive Radio networks allow wireless devices to intelligently access the radio spectrum without causing any interference to the licensed users. Cognitive radio users form a network and use a common medium for their control information exchange, this common medium is called a control channel. Depending on the way in which control channel is selected we have three major types of control channels- Common Control Channel(CCC), Non-Common Control Channel(Non-CCC) and Local Control Channel(LCC). Out of the three types of the control channels LCC mechanism is the recent research interest. In the existing LCC MAC protocols Cluster Based Cognitive Radio MAC protocol(CRAHN) proposes more stable cluster formation algorithm. We have modified the superframe structure of CRAHN such that gateway nodes and remaining members of the clusters can properly communicate. We have also proposed a novel dataslots allocation method for both single and multichannel data transmission. The data slots are allocated in such that primary hidden node problem is completely eliminated and secondary hidden node problem is minimized. Simulation results show that the network characteristics of CRAHN have better performance than the Non-CCC MAC protocol

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*Title* : *Development of test bench for reputation management in peer to peer systems using gnutella client phex*  
*Author(s)* : *Banshiwala Suhas*  
*Roll No* : *Y8127512*  
*Supervisor(s)* : *Singh Yatindra Nath*

### *Abstract*

Peer-to-Peer networks have recently gained loads of popularity. It is a distributive network in which peers collaborate and make use of resources like storage memory, computing power and bandwidth to supply basic services, such as content sharing, processing or messaging to each other. Each peer acts as a server as well as a client to other peers. Due to the presence of millions of peers in some peer-to-peer networks, performance and scalability become important issues. Trust is another important issue in peer-to-peer systems as peers interact among themselves without having much knowledge about the authority of the counterpart. As users in peer to peer based file sharing systems are human beings, one can expect that some group of peers would have similar interest. Thus, they would be more interested in downloading data from peers with similar interests. In such systems, a peer connects to other peers (Bootstrapping) and sends queries to acquire resources from them (Query Searching). Generally, this is done on random basis. Significant amount of network resources like bandwidth and time are wasted in peer-to-peer networks when these processes are performed on random basis. In this work, we modify the source code of such a peer to peer based Gnutella network client 'PHEX' in a way such that the bootstrapping and query searching work on a preferential basis to enhance the performance of the network.

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*Title* : *Carrier Frequency Offset Mitigation In OFDM Using Correlative Coding*  
*Author(s)* : *Goel Shashank*  
*Roll No* : *11104099*  
*Supervisor(s)* : *Vasudevan Kasturi*

### *Abstract*

The Orthogonal Frequency Division Multiplexed (OFDM) signal is highly sensitive to inter-carrier interference caused by Doppler frequency shifts and carrier synchronization errors resulting in high bit error rates. In order to suppress this interference various time and frequency domain techniques have been proposed namely time windowing technique, polynomial cancellation coding and frequency domain equalizers etc. This thesis analyzes some existing polynomial cancellation coding techniques, specifically self-cancellation ( $A - A$ ) and correlative ( $1-D$ ,  $1-D-D^2$ ) coding, over flat fading mobile channel using BPSK-OFDM. The channel impulse response is then modified to frequency selective fading and new CIR formulas are developed and plotted. Furthermore, to take more advantage of coding gain, the correlative coding is extended to modified  $2-D-D^2$ , and  $3-D-D^2-D^3$  coding. Lastly, to test the robustness of these schemes in varying mobile channel environment, BERs are evaluated and compared for different normalized frequency offset values

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**Title** : *Studies on Environmental Sound Recognition using Time-Frequency Dictionaries*  
**Author(s)** : *Gajelli Suresh Kumar*  
**Roll No** : *11104106*  
**Supervisor(s)** : *Hegde Rajesh Mahanand*

### ***Abstract***

Environment audio recognition is an area of interest in many applications in robotic navigation, assistive robotics and remote device based services where context awareness is often needed. In any environmental sound recognition system, proper selection of features is the key factor to achieve effective system performance. A wide variety of features have been proposed for audio recognition in temporal domain such as Zero Crossing Rate (ZCR), Short Time Energy (STE), Mel Frequency Cepstral Coefficients (MFCCs). However majority of these features have shown to work well for structured sounds like speech and music, but fail to work well for unstructured environmental sounds. Recent work on environmental sound recognition has used Matching Pursuit (MP) based time-frequency feature dictionaries to analyze environmental sounds resulting in a flexible and physically interpretable set of features. The MP features in tandem with MFCC features have yielded high recognition accuracy for environment sounds. In this thesis, an extensive study is conducted over three different time-frequency dictionaries namely, Gabor, Modified Discrete Cosine Transform (MDCT) and Gammatone dictionaries to observe the effectiveness of MP features. Joint MP-MFCC features for classification of ten different environmental sound classes using two classification methods namely, Gaussian Mixture Model (GMM) and Weighted Distance k-Nearest Neighbor (WDKNN) classification method are also studied to evaluate the efficacy of these methods. Classification results obtained using MP features when compared to that of using various temporal and spectral domain features are also analyzed. It is observed that by using MP based features in all the three dictionaries, it is indeed possible to achieve better recognition performance by a careful selection of the atoms from these dictionaries. Optimal selection and tuning of the time frequency feature dictionary and classifier is also found to improve the performance of the environmental sound recognition system

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**Title** : *A Low Complexity Non-Linear Orthogonal Space-Time Block Code for Four Transmit Antennas and One Receive Antenna*

**Author(s)** : *Kakumanu Jagadeesh Kumar*

**Roll No** : *11104048*

**Supervisor(s)** : *Vasudevan Kasturi*

**Abstract**

In wireless communication scenario, fading is one of the major challenge which has to be overcome to make the communication reliable. To avoid fading and reduce the error in communication, thereby increasing the throughput of the system, is one of the major goals in wireless communication system design. Diversity is an elegant technique which decreases the error of the system considerably by sending multiple copies of the same signal. Space Time Block Codes exploit both spatial and temporal diversity of the system and enhances the performance of the system. It was shown that full rate and full diversity cannot be achieved simultaneously for a system using complex symbols and having more than two transmit antennas. In this work, we develop a non-linear Orthogonal Space Time Block Code for four transmit antennas employing M-PSK modulation. We start with a code having full rate but not full diversity and we modify the code matrix to make it full diversity, without affecting the rate. An optimal receiver for this code is also described. The receiver decouples the symbols into pairs and thereby reduces the computational complexity of the receiver considerably. The code also outperforms the quasi-orthogonal codes for four transmit antennas. To compare the performance of the code with other space time block codes, we simulate a communication system employing the proposed code and compute the symbol error rate. We also simulate the systems with other codes like ABBA code, half rate code and space time transmit diversity Orthogonal transmit diversity code for four transmit antennas. Simulation results show that the non-linear orthogonal code outperforms all other codes

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**Title** : *Adaptive Multimodal Information Fusion for Feature Uncertainty Compensation in Audio-Visual Speech Recognition*  
**Author(s)** : *Sreenivasulu Dakala*  
**Roll No** : *11104026*  
**Supervisor(s)** : *Hegde Rajesh Mahanand*

### ***Abstract***

Performance of Speech recognition systems can be improved by the fusion of the audio and visual modalities when compared to using a single modality. In this thesis a multimodal information fusion method that compensates for feature uncertainties using entropy as a stream weight is proposed. This method is proposed within the framework of score level fusion using both direct fusion and dynamic fusion using adaptive weights based on the uncertainty in the data. The weights are varied according to the reliability of the modality and the noise level present in the individual modalities. The dynamic weights are selected by normalizing the posterior probabilities as computed from the N-best recognition log-likelihoods obtained from the recognizer. The final dynamic weights are computed by a mapping function, which is derived from the entropy values. Some assumptions are made to get entropy values based on relation between entropy, signal to noise ratio and the weights. The proposed multimodal score level fusion method is evaluated for their performance by conducting experiments for various types of noises on the GRID Multimodal corpus primarily for word level recognition. Reasonable improvement in word error rates (WER) are obtained when compared to conventional fusion methods reported literature for dynamic weighting schemes.

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**Title** : *Channel Estimation in OFDM systems using pilot patterns and windowing method*  
**Author(s)** : *Adakane Darshan Vishwanath*  
**Roll No** : *11104003*  
**Supervisor(s)** : *Vasudevan Kasturi*

### ***Abstract***

Orthogonal Frequency Division Multiplexing (OFDM) is a popular multicarrier transmission technique since it offers high data rate transmission capability and robustness to multipath fading. The bandwidth is divided into large number of subcarriers which are orthogonal to each other and thus provide bandwidth efficiency. Therefore OFDM has become a promising modulation technology for fourth generation (4G) mobile, wireless and broadcast applications. Wireless channel is time-variant and is susceptible to inter-symbol interference (ISI) and noise. Channel estimation is one of the research areas that play an important part in functioning of OFDM systems. Many algorithms have been proposed in recent years to study this issue. The two basic methodologies adopted are pilot-based channel estimation and blind channel estimation. As opposed to blind channel estimation that uses statistical properties of the input, pilot-based channel estimation multiplexes pilot with the user data. In this thesis, we compare different pilot patterns and their application in interpolation based methods of estimating channel state information. A new pilot pattern is proposed for channel estimation. Further, windowing is used to reduce spectral leakage in limited measurement time and help detect narrowband signals in presence of noise. Bit error rate (BER) performances of various channel estimation methods are compared using simulations. It is also shown via simulations that the new pilot pattern yields a lower BER performance compared to other pilot patterns

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*Title* : *Optimum Resource Allocation for Relays with Perfect and Outdated CSI under Fairness Constraint*  
*Author(s)* : *Palle Anirudh*  
*Roll No* : *11104071*  
*Supervisor(s)* : *Banerjee Adrish*

### *Abstract*

Cooperative communication has gained popularity as an efficient diversity technique to combat the effects of fading. Relaying creates multiple independent copies of the signal at the receiver and decreases the Bit Error Rate (BER). In this thesis, we address the problem of resource allocation for the source and relay of a three node system. We perform this allocation for a practical scenario where the relay also has its own data to be transmitted. We also bring in the notion of fairness to ensure that each node gets its share of throughput. As the joint power and channel allocation is complex, we perform power allocation to all possible channel allocations. Finally, the same problem in the case of outdated channel state information is also dealt with. The current CSI is estimated from the outdated CSI by calculating their correlation constant. In all the cases, we pose the allocation as a convex optimization problem where we maximize the total system throughput. The system throughput without any fairness constraint is observed to be more (as is intuitive) than the one with a fairness constraint. But fairness motivates a node to act as a relay.

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**Title** : *Non-coherent detection for cooperative communications in wireless fading channels*  
**Author(s)** : *Chary Vishwarupa*  
**Roll No** : *11104055*  
**Supervisor(s)** : *Vasudevan Kasturi*

### ***Abstract***

Cooperative communications, which can provide extra spatial diversity for conventional single antenna transceivers to combat fading in wireless communication networks, have received more and more attention from both academia and industry and have been widely used in ad-hoc wireless networks and sensor networks. Relaying and cooperative diversity allow multiple wireless radios to effectively share their antennas and create a virtual antenna array, thereby leveraging the spatial diversity benefits of multiple-input, multiple-output (MIMO) antenna systems. Many studies of cooperative diversity focus on information-theoretic perspective employing either Shannon capacity or outage capacity as performance measures assuming receivers can exploit accurate channel state information (CSI) perfectly. This work examines the benefits of cooperative diversity in real networks especially those such as sensor networks with delay constrained application and complexity constrained radios. One of the constraints is that the channel estimation for all mobile-to-mobile links may become unrealistic since it may impose both an excessive complexity and a high pilot overhead especially when the channel conditions fluctuate relatively rapidly (i.e., fast fading) in wireless environments. It is particularly challenging for destination to accurately estimate the source-relay channel using pilots in amplify-and-forward (AF) protocol since the pilots may be further contaminated by noise amplification. Therefore to bypass complex yet potentially inaccurate channel estimation, low complexity non-coherent detection became an attractive design alternative. In particular, non-coherent detection is explored for two protocols, namely, amplify-and-forward (AF) and detect-and-Forward (DF). Under AF protocol a near-maximum likelihood (ML) receiver and diversity combining receiver, both expressed in closed form and rely only on second order statistics of the fading coefficients are examined. Under DF protocol two cases are considered, one in which both destination and relays cannot estimate CSI and second in which only relays can estimate CSI, named as partial CSI, are examined. Simulation results show that proposed detectors outperform a non-cooperative system which employs non-coherent ML detection in Rayleigh fading environment. However, when the relay is under short-term power constraint, the proposed detectors do not exhibit diversity benefits over non-cooperative system

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*Title* : *Study of estimators for signal and interference power in Rayleigh flat-fading Channels*  
*Author(s)* : *Kumar Ashim*  
*Roll No* : *11104015*  
*Supervisor(s)* : *Vasudevan Kasturi*

### *Abstract*

Parameter estimation is an important part of communications. Signal and interference power are two such parameters. For better and reliable communication, these parameters are required to be estimated with a certain degree of precision. Many signal processing blocks like the turbo decoder and RAKE receiver require prior information of these parameters for optimum detection and combining operations. Also in CDMA, the receivers need to have proper estimates of the signal and noise power for transmit power control. However, these quantities vary significantly over time depending on the channel conditions. As such, the receiver needs to have an accurate estimate of the channel before the parameters can be estimated. Once the channel information is obtained, we have different kinds of estimators that serve our purpose. The estimators that we have dealt with are the minimum variance unbiased estimators, the maximum likelihood estimators and the subspace estimators

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**Title** : *Coherent predictive iterative detection of turbo coded orthogonal frequency division multiplexed signals*  
**Author(s)** : *Pitchuka M K Vara Prasad*  
**Roll No** : *11104054*  
**Supervisor(s)** : *Vasudevan Kasturi*

### ***Abstract***

This thesis addresses the problem of coherent detection of turbo coded orthogonal frequency division multiplexed signals, transmitted through frequency selective Rayleigh fading channels using conventional turbo decoding and predictive iterative decoding. The transmitted frame structure for OFDM consists of a known preamble, cyclic prefix and data. For timing synchronization we use a filter matched to the preamble. Channel estimation is done in the time domain using maximum likelihood (ML) estimation. Frequency offset estimation is done using a two-stage ML detector, to reduce the complexity compared to the single stage ML detector. Turbo decoding is done after timing synchronization, frequency offset and channel estimation. Since the channel is correlated at the receiver, the bit-error-rate performance of the turbo decoder is adversely effected. Decorrelating the channel using an interleaver has been studied earlier. In this thesis we use a prediction filter to decorrelate the received signal. Since the prediction filter has memory, the trellis states should be modified for turbo decoding. The decoding operation is done using a super trellis. The bit-error-rate (BER) performance of the prediction filter approach is better than the conventional turbo decoding, and as good as the interleaver approach. Simulation results show that BER performance of the practical coherent receiver is close to the ideal receiver for data lengths nearly equal to the preamble length.

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**Title** : *To study best practices in existing software development life cycle models and to conceptualise open agile software development life cycle model for brihaspati project at IIT KANPUR*

**Author(s)** : *Singh Virender*

**Roll No** : *11104116*

**Supervisor(s)** : *Singh Yatindra Nath&Misra Subhas Chandra*

### ***Abstract***

Software development Life Cycle (SDLC) has always been the core methodology for any Software Engineer that depicts the entire development process which an organization is bound to utilize to achieve successful software. This work brings forth the underlying SDLC models by analyzing the best practices in SDLC, comparing the existing models together to include conventional SDLC, Agile methodologies and the Open source Software, thereby bringing forth the best practice available. The best practice available triggers formulation of another model which further optimizes the efforts involved while adopting such a practice. The initial purpose of this work was to summarize and compare existing knowledge of various SDLC models so as to achieve a best practice for an ongoing software project named “Brihaspati” at IIT Kanpur. Eventually on analyzing the issues involved such as tight budget and timelines, it led us to formulate a newer concept “Open Agile Software Development Life Cycle model” (OASDLC). The OASDLC is hypothesized specifically for “Brihaspati” project and is formulated keeping in mind the gaps and limitations posed by existing SDLC models. OASDLC is further put to test for achieving lower costs and efforts involved. The tests are further substantiated by means of hypothesis validation through execution of a survey based research. The thesis provides ample material evidence by means of case studies and existing literature yielding support to our proposed conceptual model

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*Title* : *Cluster formation and topology management for energy efficiency in MIMO wireless sensor networks*  
*Author(s)* : *Gembali Sampath Kumar*  
*Roll No* : *11104091*  
*Supervisor(s)* : *Jagannatham Aditya K*

### *Abstract*

Recent advancements in Wireless Sensor Networks and other related technologies, ensure better multimedia communication in energy-limited Wireless Sensor Networks. This thesis is divided into two parts. In first part, We consider OFDMA based Wireless Sensor Networks for intra-cluster communication which offer better performance than conventional TDMA based WSNs. In our model we consider nodes equipped with multiple antennas, which provides antenna diversity along with Channel Diversity offered by OFDMA. This intra- cluster communication is a two level optimization problem, CH selection followed by optimal node-subcarrier allocation. Optimal allocation of subcarriers to nodes can be formulated as Bipartite matching, and we solve it using Stable, Auction-based, Hungarian and observed the performance of the same. In Multimedia WSNs, optimality is about maximizing sum data rate or sum quality of videos under transmission. Next, we selected a Cluster Head which maximizes the sum data rate or sum quality more than any other node which is doing CH duty. We compare above mentioned three matching algorithms along with random and greedy matching algorithms for CH selection and illustrate that our scheme outperforms the latter. In second part, we present a novel scheme for interference aware topology management in MIMO based Wireless Sensor Networks. Topology Management techniques produce network topologies that guarantee connectivity, coverage or lifetime. We propose an algorithm that finds an optimal spanning tree with optimal set of beamformers in a Wireless Sensor Network. For this purpose we formulate a link metric which takes into consideration, the interference it causes to other nodes in it's coverage area. Employing the formulized metric in WSN, we find a spanning tree which maximizes sum-metric. We also determine optimal set of beamformers cooperatively among links in spanning tree. Hence, improving the SINR performance of all links in spanning tree.

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**Title** : *Novel Light Field Panorama using Cylindrical Light Field System*  
**Author(s)** : *Kurmi, Indrajit Ramvilas*  
**Roll No** : *11104052*  
**Supervisor(s)** : *Venkatesh K S&Gupta, Sumana*

### ***Abstract***

Recent times has seen emergence of a new field known as Computational Photography, created by the convergence of computer graphics, computer vision and image processing. It tries to overcome the limitations of the traditional digital photography. Computational photography refer to those imaging techniques, which are enhancing and extending the capabilities of traditional photography. Light Field is one of the computational photography techniques which provides significant advantage over traditional image synthesis process. It provides features like refocusing and novel view synthesis. The previous works in light field have been focused on creating single viewpoint image. While traditional photography is aiming to increase the field of view of an image by using mosaicing to create panorama. Nowadays panorama imaging techniques has become an integral part of digital photography, supported by most of the cameras today. Light fields can be merged to generate panorama, but merging of light fields gives undesirable artifacts such as change of focal plane depth. There is inherent complexity involved with capturing of light fields (4D representations of Plenoptic Function) as it require complex setups. Thus to capture different light fields to merge them makes capturing of large environment more difficult. In this thesis, we acquire light fields using cylindrical arrangement of cameras which resolve the complexity issue of acquisition of light field and merging them. We then use our system to generate novel "Light Field Panorama" from the captured light field, which gives a wide field of view similar to the other panoramas (2D representation of the plenoptic function). Moreover they can also be manipulated in the same way as the other light field images. Zooming options provided in traditional camera either tends to change the relative shape of the objects in image or introduces pix-elation effect. Hence we use true zoom so as to improvise the zooming effect. In this thesis, we generate novel "True Zoomed Light Field Panorama" using our system. This type of panorama gives user a feeling of being closer to or farther from the whole environment at the same time. It also allows user to focus on particular regions as desired.

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**Title** : *Studies on FEM and XFEM based solutions to the forward problem in Fluorescence Diffuse Optical Tomography*  
**Author(s)** : *Gottam Omprakash*  
**Roll No** : *11104068*  
**Supervisor(s)** : *Naik Naren*

### ***Abstract***

Fluorescence diffuse optical tomography (FDOT) is a imaging technique which is used to visualize the spatial distribution of tissue parameters based on their metabolic activities. High metabolic activity in the tissue helps in realizing the presence of cancer cells in the domain. This imaging modality involves reconstruction of the unknown optical and fluorescence parameters of a region of interest, from boundary measurements of the optical fluence at emission and excitation wavelengths. These reconstructions need as a pre-requisite, the solution of the coupled partial differential equation (PDE) governing the propagation of optical fluence through a medium. Conventionally the finite element method (FEM) is used to solve the forward problem of FDOT. Employing the finite element method to solve the PDE requires realignment of the mesh along the discontinuity. Modelling the problem with extended finite element method (XFEM) potentially eliminates the necessity of realignment. To the best of our knowledge there is no work in literature that solves the FDOT forward problem with XFEM. XFEM incorporates the discontinuity in the solution of emission field which are due to spatial variation of the tissue properties. It is thus important to investigate whether there are significant differences in the behaviour of the forward solutions between FEM and XFEM. In the present work, the FEM forward solution is implemented and verified. Preliminary results of the XFEM in an elemental parameter-space basis are presented.

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**Title** : *Study of constant gain Kalman filtering approach for heterogeneous data fusion in WSN ground target tracking*  
**Author(s)** : *Awasthi Peeyush Pani*  
**Roll No** : *11104075*  
**Supervisor(s)** : *Singh Yatindra Nath&Naik Naren*

### ***Abstract***

Unattended ground sensor (UGS) systems is one among the most sought after systems to be used in different scenarios due to their inherent advantages i.e. intelligence, reconnaissance and surveillance (ISR). The present work has been about the study of data fusion from various sensors used in an UGS system. There has been a variety of simulations performed with respect to the data fusion obtained from variety of sensors like Passive Infrared (PIR), acoustic and seismic sensors with application of different fusion approaches. The data fusion in WSN has been studied with respect to three sensors i.e. PIR, acoustic and seismic. The data fusion for homogeneous as well as heterogeneous sensors has been carried out. The comparison of the performance of extended Kalman filter with constant gain Kalman filter under different fusion schemes has been done. The GA (genetic algorithm) has been used for optimization of innovation cost function in CGEKF setting. A potential research domain is in battle field awareness wherein an important application is target tracking. Sensitive area or vital installations security breach by unauthorized people is one such scenario where a tactical deployment of wireless nodes employing suitable tracking algorithms can be used to check such breach of security

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*Title* : *Peformance of LDPC coded MIMO, MIMO-OFDM systems with low complexity detection*  
*Author(s)* : *Srikanth Sallabathula*  
*Roll No* : *11104090*  
*Supervisor(s)* : *Vasudevan Kasturi*

### *Abstract*

The modern day wireless communication systems are aimed to attain high data rate transmissions as well as reliable communication. Some applications like high quality video transmission over wireless channels has led to increase in demand for high data rates. There are several smart antenna techniques that provides high data rate, the multiple-input multiple-output (MIMO) systems is one of them. The complexity of detection in MIMO is a main concern. List fixed-complexity sphere detection (LFSD) is capable of achieving near-ML (Maximum Likelihood) performance while keeping complexity requirement low. For reliable communication, low-density parity-check (LDPC) codes has gained much significance in recent times due to their error correcting capabilities and are associated with low complexity decoding. In this thesis, bit-error rate performance of LDPC-MIMO system with low complexity detection methods has been evaluated. Further, Orthogonal Frequency Division Multiplexing (OFDM) has been employed to mitigate inter symbol interference (ISI) effects due to frequency selective channel and performance of LDPC coded MIMO-OFDM system with low complexity detection methods has been evaluated. Finally, the LDPC coded MIMO-OFDM system has been analyzed for video data transmission employing Unequal Error Protection (UEP) and Equal Error Protection (EEP) schemes. The LDPC coded MIMO-OFDM system with UEP scheme has been suggested for video transmission.

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*Title* : *Video Colorization And Its Application To Removal Of Color Artifacts*  
*Author(s)* : *Karthik, D*  
*Roll No* : *11104049*  
*Supervisor(s)* : *Gupta Sumana*

### *Abstract*

A colorization scheme for monochrome images/videos is proposed in this work. A set of reference frames called the "Keyframes" which signify maximum information present in a group of frames is determined. Keyframe Selection is done based on the content of the frames. For this purpose, we perform background subtraction in order to extract the foreground information which actually depicts the change in the moving frames. By choosing appropriate frames containing maximum information of the foreground regions extracted, we select them as Keyframes and color them using the image colorisation technique. The rest of the frames are colored by transferring the color information from the nearby frames which is either manually colored or colored with the aid of its previous frames. For image colorisation process, we segment the image to be colored to the desired number of regions and then spread the color in the segments with their marker colors respectively. We also propose a novel application of colorisation technique to restore images/videos affected by artifacts like partial color artifacts, blotches and scratches. For this purpose, we first reconstruct the Y-plane of the concerned image and then colorise the Y-image using the proposed image colorisation technique using the colors from the original degraded image. The results achieved are of acceptable visual quality.

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**Title** : *OFDM based out-of-band dedicated common control channel design for cognitive radio networks*  
**Author(s)** : *Bhonagiri Ravikiran*  
**Roll No** : *11104023*  
**Supervisor(s)** : *Banerjee Adrish&Sircar Pradip*

### ***Abstract***

Cognitive radio (CR) is one of the most promising technologies developed to cater the needs of increasing spectrum demands by improving spectrum utilization. In the CR ad hoc networks, nodes must undertake the spectrum related issues, as there is no central controller to coordinate, to maintain an end-to-end coordination of network, a common control channel (CCC) is required. In the literature, various schemes were proposed to design a CCC. CCC design must be robust to primary user activity and should have universal coverage. The out-of-band dedicated CCC approach will serve this purpose. In this thesis, Orthogonal Frequency Division Multiplexing (OFDM) based non-contiguous system is considered for the design of dedicated out-of-band CCC. It exploits the guard bands in the licensed spectrum band for its out-of-band dedicated CCCs which performs control broadcast and unicast communications. The design is undertaken in two stages: First stage: Based on the parameters of the subcarriers like the number of the subcarriers, transmit power, CR transmission range and given the constraints of OFDM technology, the total interference caused to PU is calculated. Second stage: This stage deals with the sub-carrier activation within the guard bands based on the PU pattern studied by CR users. Methods like Heuristic, Suboptimal and Powerloading has been proposed to activate the subcarriers. Powerloading algorithm has been proposed based on interference and power constraints

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**Title** : *Fabrication of inverted P3HT:PCBM bulk hetero-junction organic solar cells on flexible PET substrates*  
**Author(s)** : *Sen Sharma Mayank*  
**Roll No** : *Y8127286*  
**Supervisor(s)** : *Iyer S Sundar Kumar*

### ***Abstract***

The main problems currently faced by organic solar cells on flexible substrates are low lifetime and low power conversation efficiency. Both these problems have to be solved before organic solar cells can be commercialized. This thesis presents some ways to improve the efficiency and lifetime by process modification and by building inverted device structure on flexible polyethylene terephthalate (PET) substrates. The various steps involved in the fabrication process have been studied in detail and two of them have been optimized to improve the efficiency of the bulk hetero-junction organic solar cell. Firstly, a simpler, cost efficient and time saving patterning technique of (indium tin oxide) ITO has been introduced. Secondly, the process of poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) (PEDOT:PSS) film deposition was optimized. Prior to the spin coating of PEDOT:PSS, substrates were exposed to ultraviolet light. After coating PEDOT:PSS, substrates were annealed using a procedure which ensured minimum exposure of substrates to the environment. To address the issue of device degradation and to improve the efficiency of organic solar cell on flexible PET substrate, organic solar cells with ‘inverted’ device structure of has been fabricated. All fabrication was carried out outside any glove boxes. Average efficiency of 1.5% was achieved with the best device showed an efficiency of 1.9%. This was typically more than two order of magnitude more than the efficiency of regular (non-inverted) devices fabricated on flexible substrates – probably due to the poor stability of these devices fabricated on PET substrates. The inverted solar cells on the other hand were comparatively quite stable. The extent of efficiency degradation of inverted organic solar cells over a period of two weeks was less than 14%. A low temperature process with maximum processing temperature below 70°C by using zinc sulphide as the hole blocking layer has also been tried out. The preliminary results are presented.

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**Title** : *Optimising layer thickness in inverted organic solar cells for maximum efficiency with the help of opto-electronic models*  
**Author(s)** : *Kannan K T*  
**Roll No** : *11104047*  
**Supervisor(s)** : *Iyer S Sundar Kumar*

### ***Abstract***

Organic solar cells have the potential to become cost-efficient and sustainable power sources. Thus, there have been a lot of research activities directed towards increasing the efficiencies and stability of these solar cells. Among the different device structures being explored, 'inverted' bulk heterojunction solar cells has been gaining attention due to their relatively high efficiency, stability and low rate of degradation. These structures are also suitable for fabrication on non-transparent substrates. In this thesis the optimum thickness of the layers in inverted solar cells is determined with opto-electronic models for maximum short circuit current and efficiency and verified with results from fabricated devices. The optical transfer matrix model used to find the electric field distribution is initially described, followed by the method of finding total exciton generation rate and short circuit current. Based on this model, an inverted solar cell structure for glass substrate - glass/ITO/ZnO/P3HT:PCBM/MoO<sub>3</sub>/Ag – is evaluated. The optimum P3HT:PCBM layer was determined to be between 180 nm and 200 nm and the ZnO layer thickness was to be between 80 nm and 120 nm respectively. The model was verified by fabricating this device structure for different P3HT:PCBM layer as well as the ZnO layer thicknesses. The best solar cell with a power conversion efficiency of 4.26 % was obtained. For solar cells with the optimized layer thicknesses, the median value of efficiency obtained was 2.98 %, which was higher than the median efficiency values for devices with other combination of thicknesses. The inverted solar cells structure of PEDOT/P3HT:PCBM/ZnO/Zn/paper corresponding to printed solar cells on paper was then evaluated using the opto-electronic model. The optimum thicknesses of P3HT:PCBM and ZnO for these devices was determined to lie between 190 nm and 210 nm and 15 nm and 30 nm respectively.

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***Title*** : ***Novel Junctionless transistors***  
***Author(s)*** : ***Surana Neelam***  
***Roll No*** : ***11104064***  
***Supervisor(s)*** : ***Ghosh Bahniman***

### ***Abstract***

As MOSFETs are scaled down to sub-32 nm node, fabrication of steep doping profile for source and drain become critical. MOSFETs have several short channel effects like DIBL effect, high subthreshold slope, hot carrier effect etc. Recently junctionless transistor has proposed and fabricated successfully by J.P. Colinge. Junctionless transistor has simple structure with source, drain and channel having same type of doping profile. In the thesis we optimized the performances of double gate junctionless transistor (DGJLT). In case of thick channel DGJLT gate is unable to fully deplete the channel to turn-off the device. For fully depletion of the channel we have proposed differentially graded DGJLT, in which middle layer of channel is lowly doped so that gate can fully deplete device channel and offers better Ion/Ioff compared to uniformly doped DGJLT. In the next chapter we propose Ge/Si graded hetero-junction DGJLT and compared to silicon and germanium channel DGJLT. In the off state silicon and germanium channel have band overlap between valence band of channel and conduction band of drain region which produces large band to band current and increases off-state leakage current. Ge/Si graded hetero-junction DGJLT increases tunnelling width and reduces off-state current. In next section we propose InGaAs channel DGJLT and compared with silicon, germanium and GaAs channel DGJLT. GaAs channel DGJLT reduces band to band tunnelling leakage current in off-state but suffers from low on-current. To increase on-current we have proposed InGaAs channel DGJLT which has better on-state current.

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*Title* : *Design and Analysis of Digital Circuits using Quantum-Dot Cellular Automata*  
*Author(s)* : *Agrawal Puneet*  
*Roll No* : *Y8127375*  
*Supervisor(s)* : *Ghosh Bahniman*

### *Abstract*

Current transistor based IC fabrication technology faces many trivial issues such as those of excess power dissipation, expensive fabrication and short channel effects at very low device size. QCA (Quantum-Dot Cellular Automata) based digital electronics on the other hand provide scope for further development in the future by shrinking the device size. Current QCA logic circuits are based on logic synthesis using Inverters and (Three or Five input) Majority Gates. In this work, a new design methodology has been described that can be used to create circuits with even greater device substrate densities than what are currently achieved in existing QCA designs. Based on the proposed methodology, many new circuits and device modules are designed and analyzed. Finally, an attempt is made to characterize and categorize possible defects in modern QCA circuits, as such a work has not been published till date. Through the analysis of complex QCA circuits in the domain of defect characterization, many interesting and important conclusions are drawn. Thus this work aims to improve the performance of existing QCA circuit designs and develop methodologies for creating robust and fault tolerant circuits

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*Title* : *A novel design paradigm for Quantum Dot Cellular Automata Circuits*  
*Author(s)* : *Kumar Rohit*  
*Roll No* : *Y8127427*  
*Supervisor(s)* : *Ghosh Bahniman*

### *Abstract*

In this thesis, a novel design paradigm for Quantum-Dot Cellular Automata (QCA) based circuit has been proposed. In QCA circuits, fundamental building blocks are Majority gate and Inverter. Any other logic gates like AND/OR gates can be constructed by fixing the polarity of few of the inputs of Majority gate. In contrast to earlier methods of placing all the QCA cells of an logic gate in a single layer, in this thesis, Multilayer gate design technique, using which, one is not restricted to design a circuit only in one layer, has been proposed. Designing a circuit in this paradigm gives the freedom to a circuit designer to explore the third spatial dimension to make their circuit compact, which in turn leads to reduction in QCA cells requirement, area and input-output delay. Two designs of 1-bit and 2-bit adders, in the proposed design paradigm, have been presented using 3-input and 5-input majority gates respectively. Designs have been simulated in QCADesigner software for the verification. By comparing the designs with their conventional counterpart, it has been shown that, in the proposed design paradigm, due to compactness of circuit, requirement of QCA cells significantly reduces and input-output delays also improve. Additionally, in this thesis, it has been shown that use of higher input majority gate can make the circuit design more economical. For this purpose, by fixing polarity of three of the inputs of a 7-input majority gate, a 4-input OR gate is constructed, which in turn is used in the design of priority encoder. It is shown that area, QCA cells requirement and delay reduces significantly. This thesis also addresses the issue of the bi-directionality of the QCA cells. A proper clock scheme can solve the problem that arises due to bi-directionality

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*Title* : *Junctionless Transistor Device Design*  
*Author(s)* : *Khan Uzma*  
*Roll No* : *11104123*  
*Supervisor(s)* : *Ghosh Bahniman*  
*Abstract*

As the gate length of metal oxide semiconductor field effect transistor (MOSFET) scales down, various short channel effects come in picture and it also becomes very difficult to achieve super-steep doping profiles at the source–channel and channel–drain junctions. Recently, the concept of junctionless transistor (JLT) is proposed which overcomes the challenges faced by the conventional MOSFET. A junctionless transistor is an ultrathin and highly scalable device, having no pn junction and the doping concentration is equal throughout the source, channel and drain. The thesis aims at improving the performance of junctionless transistors. Single gate ultra-thin Silicon on insulator junctionless transistor (SOI-JLT) and bulk planar junctionless transistor (BPJLT) are most interesting as they are compatible with industrial standard planar CMOS process flow. However, major issues associated with SOI-JLT structure is self heating and lower breakdown voltage. Introducing the buried oxide selectively in junctionless transistor (SELBOX-JLT) provides a lot of advantages over conventional SOI-JLT structure. It helps in reducing lattice heating effect, an improved subthreshold slope (SS) and an improved Ion/Ioff ratio, and also shows low drain induced barrier lowering (DIBL) effect. In the later part of the thesis, device simulation of BPJLT is carried out with new channel materials like Ge, GaAs and InGaAs. In III-V compound semiconductors charge carriers travel at a much higher velocity than silicon, offer higher mobility and can be used at higher temperature and at higher operating frequencies. The III-V compound semiconductors have unique optical and electronic properties and thus have the potential to replace the silicon channel.

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**Title** : *Development of SiO<sub>2</sub> dielectric by TEOS PECVD for Indium Gallium Zinc Oxide TFTs*  
**Author(s)** : *Uttwani Pankaj Kumar*  
**Roll No** : *11104121*  
**Supervisor(s)** : *Mazhari Baquer&Gupta Deepak*

### ***Abstract***

In past few years indium gallium zinc oxide (IGZO) TFTs have been studied actively for their application in pixel circuits of flat panel displays. They have properties like high mobility, high on current, low off current and small subthreshold slope which are desirable for switching element of pixel circuits. The purpose of this work is to develop stable IGZO TFT which can be used in TFT backplanes. To achieve the target of low off current and high on current, a gate dielectric of good insulating and interface quality is required. Silane being pyrophoric in air and difficult to handle, a silane based plasma enhanced chemical vapour deposition (PECVD) system was substantially modified to a tetraethyl orthosilicate (TEOS) based PECVD for silicon dioxide (SiO<sub>2</sub>) deposition. The key modifications were design of couplings to add TEOS vapour line in the existing system, thermal management of gas delivery lines, redesign of showerhead. Following modifications, good quality SiO<sub>2</sub> film on glass substrates were deposited in the system. Post deposition annealing was employed to further enhance the film quality. Electrical properties of film were studied through metal-insulator-metal capacitor structure and finally SiO<sub>2</sub> films with breakdown field of 2 MV/cm for 160 nm thick film were achieved. TFTs were fabricated with SiO<sub>2</sub> as gate dielectric and IGZO as active layer which was deposited by sputtering at room temperature. Bottom gate top source/ drain contact TFTs with channel dimension (width/length) of 100/40 μm and 100/60 μm were made by photolithography. Low leakage TFT devices with off current of 10<sup>-12</sup> A, drain current on/off ratio of 10<sup>5</sup>, subthreshold slope of 1.8 V/decade and mobility of 1.7 cm<sup>2</sup>/V.s were achieved. Annealing of IGZO films in TFTs was found to be important to reduce hysteresis and improve stability.

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*Title* : *Charge Pumping Measurement for Organic Diodes*  
*Author(s)* : *Singal Anuj*  
*Roll No* : *11104012*  
*Supervisor(s)* : *Mazhari Baquer*

### *Abstract*

Characterization techniques play a very important role in the development of any technology. Small signal ac capacitance and conductance measurements as a function of frequency and voltage are widely used to characterize organic diodes and transistors. Although, a simple parallel equivalent circuit of capacitance and conductance is used to obtain the experimental data, it is well recognized that the actual behaviour of the circuit is far more complicated and complex, requiring equivalent circuits with many elements to explain the measurements. As a result, measured capacitance is often not indicative of charge stored in the device and the real device capacitance as well. The present work describes a charge-pumping technique to obtain an unambiguous estimate of charge stored in the device. It takes inspiration from the well known charge-pumping technique used to estimate interface state density in MOSFETs but unlike the latter technique, a pair of diodes are used to separate the charging and discharging paths. Simulation results are used to highlight the validity and advantages of the proposed technique. It is shown that presence of moderate number of traps can result in large increases in capacitance measured using the conventional technique which can wrongly be interpreted as large stored charge. The charge pumping technique, however, correctly shows negligible increase in charge stored. Since the technique gives the actual charge stored in the device, it is shown that transit time of the carriers also can be easily estimated. A completely automated experimental setup was used to characterize P3HT diodes and P3HT:PCBM solar cell devices. Charge pumping results showed that observed negative capacitance in these devices did not occur due to decrease in charge stored with voltage. Pristine low efficiency solar cells and degraded high efficiency solar cells showed very high charge stored in the device. Preliminary results on P3HT:PCBM devices indicate that the technique can also be used to estimate the series resistance in the diodes.

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*Title* : *Spin Transport in Novel Materials*  
*Author(s)* : *Katiyar Saurabh*  
*Roll No* : *Y8127460*  
*Supervisor(s)* : *Ghosh Bahniman*

### *Abstract*

The research in the field of spintronics has gained significant attention because of tremendous potential shown by spin based devices. Spintronics, in simple terms, means spin electronics. It is, nowadays, a major area of research with new advances in technology coming up. Spintronics in semiconductors combines two basic properties of electron- charge and spin. It can combine the capabilities of semiconductors with the capabilities of the magnetic materials. This allows us to design devices with unprecedented capabilities. Spin relaxation is a critical factor in deciding the suitability of a semi-conductor material for spin based devices. We have examined spin transport using a semi-classical Monte Carlo method. There are many magnetic and opto-electric properties of a material which influence spin transport. The main mechanisms which are responsible for spin relaxation have been discussed in detail in our work. Numerous semiconductor materials and structures are being investigated for use in spintronics. In this work, we have examined spin transport in graphene and topological insulator. We have studied spin transport in strained monolayer graphene and compared it with unstrained monolayer graphene. We have also analyzed the role of electron-electron scattering on spin transport in single, bilayer and trilayer graphene. Effect of electric field and temperature on spin polarization on the surface of topological insulator has also been examined.

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*Title* : *Adder and Divider Circuits in Single Spin Logic Paradigm*  
*Author(s)* : *A Ajay*  
*Roll No* : *Y8127042*  
*Supervisor(s)* : *Ghosh Bahniman*

### *Abstract*

In recent times, it has been observed that further scaling of devices is becoming difficult because a level has been reached where Quantum Effects start coming into picture. The normal operations of devices are affected because of Quantum effects and makes them unsuitable for several applications. This demands some new design methodology which can reduce the circuit area and power consumption is kept as low as possible. In this thesis to achieve these requirements, circuit design techniques using Single Spin Logic paradigm has been done. In Single Spin Logic, single electron hosted in Quantum Dots is used as a binary logic device in which spin orientation of electrons encodes the bit information in presence of weak magnetic field. Three different entities namely 2-bit CMOS Full Adder, 2-bit high performance Kogge-Stone Adder and 2-bit Binary Divider have been designed using Quantum Dots and Spin Polarized Scanning Tunneling Microscopy in Single Spin Logic paradigm. A huge advantage of the designed circuits is that they will not require any physical interconnects between devices as information is transferred by nearest neighbor exchange interaction. A theoretical analysis in terms of area and propagation delay shows reasonable performance of the designed circuits. Moreover, it is found that Kogge-Stone adder design is much more complex and occupies larger area compared to than 2-bit CMOS full adder design. However, Kogge-Stone adder turns out to be faster than 2-bit CMOS full adder.

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**Title** : *Design of Dividers and Novel Circuits in Quantum Dot Cellular Automata*  
**Author(s)** : *Yadav Arun*  
**Roll No** : *Y8127130*  
**Supervisor(s)** : *Ghosh Bahniman*

### ***Abstract***

Quantum Dot Cellular Automata (QCA) is a promising nanotechnology for digital electronics circuit implementation, with the prospective for high operating frequencies, low power consumption and dense circuit as an alternative to the conventional transistor-based technology. The basic element in QCA technology is a simple QCA cell, which acts as building block to construct wires and gates. Fundamental gates of QCA circuits are Inverter and Majority gates (Analogous to NAND and NOR logic in case of CMOS circuits). In this thesis work, first analysis of introducing time-delay in QCA circuits is presented. Its application include generation of un-symmetric output waveforms by introducing time-delay via clocking in 3-input and 5-input majority gate is presented. Also monostable circuit or transition-triggered one-shot circuit is presented in QCA architecture. In later part of thesis work, optimized designs of 2-bit multiplier circuit, 2-bit binary magnitude Comparator circuit and 2-bit binary Divider circuits are presented. A detailed observation and comparison on the basis of area of circuit, number of cells used and total time-delay between input signal and output signal are presented. For an Optimized QCA design it is required that the number of logic levels and gate counts should be as much less as possible. All the circuit schematic, layout and simulation results obtained are presented. The circuits are simulated and captured using QCA design software called QCA Designer 2.0.2.

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**Title** : *Extraction of Threshold Voltage and Channel Length Modulation Parameter in Organic Thin Film Transistors*  
**Author(s)** : *Sachin*  
**Roll No** : *Y8127431*  
**Supervisor(s)** : *Mazhari Baquer*

### ***Abstract***

Organic thin film transistors (OTFT) have gained worldwide attention in both academia and industry, due to their potential for development of back panels for active matrix displays, RFID tags and several other applications falling in the domain of low cost and flexible macro- electronics. To realize large scale organic electronic circuits, availability of a compact model of an OTFT becomes a key requirement. Development of a compact model requires judicious use of assumptions to obtain simplification and requires deep insight into the operation and physics of the transistor. In this thesis, threshold voltage and channel length modulation in saturation region have been studied in detail. Although threshold voltage is a very well understood parameter, its extraction from measured characteristics is far from straightforward because of gate field dependence of mobility. A new method for estimation of threshold voltage is proposed, whose extraction depends only on the basic fact that current is exponential below threshold voltage and follows power law above it. Simulation results show that the proposed method works better than other reported techniques when significant interface traps are present. It is shown that the proposed method is insensitive to series contact resistance as well, hence threshold voltage can be extracted from the experimental I-V data directly, without removing the effect of contact resistance. A study of saturation in both bottom and top contact transistors shows that the simple model of channel length modulation fails due to strong two dimensional nature of current flow prevailing close to the drain. Despite significant structural differences, both top and bottom contact devices have comparable channel length modulation parameters. In the top contact devices, there is a tradeoff between gate-drain capacitance and output resistance. To explain the above observations, Silvaco simulations have been carried out and models for channel length modulation based on the two dimensional flow of current near the drain have been suggested.

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***Title*** : *Spin Transport in Dilute Magnetic Semiconductors*  
***Author(s)*** : *Chishti Sheikh Sabiq*  
***Roll No*** : *11104088*  
***Supervisor(s)*** : *Ghosh Bahniman*

### ***Abstract***

The recent advancement in the domain of spintronics has triggered a plethora of research on the topic. Most of them involve harnessing the spin degree of freedom which offers significant advantages over the conventional electronics. The metal spintronics has found place in the computing industry. The systems are now used as harddisk read-heads. The semiconductor spintronics is still to demonstrate its potential. Semiconductor spintronics is an attractive field as it can exploit both the properties of an electron- the charge and the spin. In this work the Spin transport in Dilute Magnetic Semiconductors of II-Mn-VI type (Mn being Manganese) and II-VI type semiconductor nanowires is studied. Heuristic Model has been developed to simulate the spin behavior of individual carriers inside a stand-alone nanowire and a core-shell nanowire structure. Using semi-classical Monte Carlo method the spin dephasing in seven DMS materials and four II-VI materials has been studied. Coupled with spin density matrix calculation and five different scattering mechanisms namely Acoustic Phonon Scattering, Optical Phonon Scattering, Surface Roughness Scattering, Spin Flip Scattering and Magnon Scattering, the spin behavior is modeled to study the effects of various parameters on the Spin Relaxation Length. These parameters are driving electric field, temperature, cross-sectional area and core-shell configuration.

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**Title** : *Optimized Load Design for Inverters Using Top-Contact Organic Thin Film Transistors*

**Author(s)** : *Subhechha Subhali*

**Roll No** : *Y8127508*

**Supervisor(s)** : *Mazhari Baquer*

**Abstract**

Organic semiconductor based circuits are gaining importance due to their low cost and flexible form factors. This work focuses on inverter, an essential building block of all digital circuits. Various inverter topologies using the p-channel organic thin film transistors have been analyzed and their design is optimized with respect to different performance parameters such as gain, noise margin, voltage swing and propagation delays including ring oscillator frequency. A novel topology using an organic diode as a load element has been proposed. It is shown that for comparable voltage transfer characteristics, use of a diode as a load element can yield 17% higher ring oscillator frequencies compared to a diode connected transistor load. Basic universal gates like NAND and NOR gates, with higher swings have been demonstrated using this topology. Interface state defects in organic thin film transistors have a significant impact on their characteristics including mobility and subthreshold slopes. Although the impact of these defects on static characteristics have been well documented, their significance under transient operating conditions have been less studied. Taking inverters as an example, this thesis shows that the impact of defects on ring oscillator performance is much less than that implied by changes in static characteristics.

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**Title** : *Spin Transport in Core-Shell Nanowires*  
**Author(s)** : *Verma Ashwani*  
**Roll No** : *11104020*  
**Supervisor(s)** : *Ghosh Bahniman*

### ***Abstract***

Spintronics is a growing branch of Electronics which exploits both properties of electron i.e. the charge and the spin. The advantages of Spintronics over the conventional electronics enable us to design devices with exceptional capabilities and new functionalities, suggesting that it will dominate conventional electronics in future. Semiconductor Spintronics is very attractive as it can combine the capabilities of semiconductors with the capabilities of magnetic materials. In this thesis we mainly focus on the spin relaxation length because for most of the proposed application of spintronics it is an essential factor for improving the overall efficiency of the device. We have used Semiclassical Monte Carlo method to study the spin relaxation length in III-V compound semiconductor core-shell nanowires and in Bilayer Graphene. The spin relaxation mechanisms used in our simulation are D'yakonov-Perel (DP) caused due to bulk inversion asymmetry and structural inversion asymmetry. Spin flip due to Elliott-Yafet is also taken into account. In III-V compound semiconductor core-shell nanowires, we have taken one III-V material as core and another as shell and finds its spin relaxation length and compared it with relaxation length of nanowire after swapping the core and shell materials. We have also studied the dependence of spin relaxation length on different parameters such as variation of lateral electric field, temperature and core dimensions. We have reported the simulation results for electric field in the range of 0.5 kV/cm-10 kV/cm, temperature in the range of 77K- 300K and core length range from 2nm to 8nm. In bilayer Graphene we study the dependence of spin relaxation length on the potential difference and the distance over which potential is applied between two layers of bilayer graphene.

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*Title* : *Low power ROM design using SCSC technique*  
*Author(s)* : *Jain Saurabh Jain*  
*Roll No* : *Y8127459*  
*Supervisor(s)* : *Qureshi Shafi*

### *Abstract*

In this thesis an idea is proposed as well as implemented up to the chip level for designing a “Low power ROM ” of size 2 Kbytes with UMC\_180nm technology that takes much less of power as compared to the conventional dynamic ROM. Total power consumption reduces by a factor of 2. This ROM was tested with a load of 1pF on each of the 16 bit outputs and the power consumption for this ROM is reported to be 1.42 mW in comparison with power consumption of conventional ROM which was 3.06 mW. The Technique proposed here is based on charge sharing and reducing the bit line swing of each of the bit line to a value which is almost 6 times less than supply voltage value. This ROM is tested with 50% zeroes and 50% ones stored in it. Design is tested for a variation in supply voltage and it is found this design can sustain and give proper results for a range of supply voltage from 1.5 V to 2.5 V at a frequency of 40 MHz. The post layout static timing Analysis showed that chip design gave correct results at frequency up to a value of 62.4 MHz. Also the analysis of power consumption at different supply voltages was done. Back end design of layout was integrated with I/O pads and bond pads making the whole idea compiled finally at chip layout level.

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**Title** : *Design of Adder and Novel Circuits in Quantum-dot Cellular Automata*  
**Author(s)** : *Agarwal Ankita*  
**Roll No** : *Y8127096*  
**Supervisor(s)** : *Ghosh Bahniman*

### ***Abstract***

CMOS scaling is currently facing a technological barrier due to constant reduction in device sizes. Novel technologies are being proposed to keep up with the need for computation power and speed. One of the proposed ideas is the quantum-dot cellular automata (QCA) technology. QCA uses quantum mechanical effects in the device at the molecular scale. QCA systems have the potential for low power, high density, and regularity. This thesis studies various QCA devices and presents innovative solutions for making them more efficient in terms of area and complexity. Improvements are made in the existing designs at gate level. Majority gates are the fundamental blocks of QCA devices; these are of two types: 3-input and 5-input. Several CMOS structures have been successfully implemented in QCA using these gates. In this thesis new circuit designs are presented for multi-bit adders (Brent-Kung and Kogge-Stone adders), memory structures (ROM), multiplexers (4x1 and 8x1) and priority encoder using 5-input majority gate. These designs have been created previously using 3-input majority gates. The layouts are verified by simulating on QCADesigner and are compared with the existing designs. It is concluded that the new circuits are more compact in terms of size and cell count, without their performance and efficiency being affected.

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*Title* : *Prediction of the Transistors and Inverter Structures Experimentally from a Single Test Structure*  
*Author(s)* : *GupteHimanshu Vilas*  
*Roll No* : *11104036*  
*Supervisor(s)* : *Mazhari Baquer*

### *Abstract*

In the today's era of large area electronics everyone is looking for the high speed circuits which are in turn realisable if there are high performance Organic Thin Film Transistors are available. With the use of novel fabrication techniques which improve the mobility of the charge carriers, a relatively simpler approach is to scale the dimensions of the OTFTs to get the high currents. Unlike the crystalline Si MOSFETs while scaling the OTFTs one has to consider non negligible contact resistance, which does not remain constant with scaling. Some highly scaled devices may cease to show transistor action. This fact is attributed to increased contact resistance as compared to the channel resistance. One can check the feasibility of scaling by actually fabricating the small channel device, but the option is too costly, time consuming and hence impossible to realise. Thus it is important to check the feasibility of the scaled devices quickly before actually fabricating them. This work presents a simple and quick method to check the feasibility of the scaled transistor structure by using experimental data of the single existing bigger test structure. The proposed technique uses only limited number of models but fairly accurately predicts the performance of the scaled device. Also some inverter circuits have been designed using fabricated as well as proposed device characteristics including resistive load as well as active load. All these inverter circuits show gain exceeding '-1' with maximum gain about '-14' which can further be increased

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***Title*** : ***Implementation of Resistor Using Organic Semiconductor***  
***Author(s)*** : ***Prasad Ashutosh***  
***Roll No*** : ***11104018***  
***Supervisor(s)*** : ***Mazhari Baquer***

### ***Abstract***

Organic semiconductor devices including light emitting diodes, solar cells, thin film transistors and sensors are being actively developed due to their several potential advantages including low cost and flexible form factors. Resistors, an integral part of most circuits, have not attracted the same interest, perhaps due to their perceived simplicity. However, due to difficulty in doping and due to non-linear nature of current-voltage (I-V) characteristics of undoped organic semiconductors, implementation of resistors is not straightforward. In this work, resistors are implemented by exploiting the linear I-V characteristics of a single layer organic semiconductor device in the low voltage regime. By stitching together a number such segments, the effective voltage drop across each segment is kept low and linear operation of the overall device is extended to higher voltages. Simulation results are used to validate the proposed approach and show that a 16-segment device can yield linearity better than 17% (RMS error) and total harmonic distortion less than 6%. Experimental results obtained with an ITO/PEDOT/P3HT/Au device showed that despite the initial single segment characteristics being highly non-linear even for low voltages, the characteristics of a 16-segment had linearity better than 18% (RMS error) and the estimated total harmonic distortion was lower than 7%. Impedance measurement showed that the 16-segment device can be modelled as frequency independent till a frequency of 11 kHz.

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**Title** : *Junctionless transistors:New device paradigm*  
**Author(s)** : *Bal Punyasloka*  
**Roll No** : *11104081*  
**Supervisor(s)** : *Ghosh Bahniman*

### ***Abstract***

As we scale down the metal oxide semiconductor field effect transistor (MOSFET) to sub-30 nm regime, it faces fundamental challenges and major difficulties in fabrication of sharp doping gradient at the source and drain junction. Due to low power demand alternative transistors such as conventional TFET has been proposed. Tunnel FET has better SS than inversion mode (IM) device but it has low ON current and fabrication becomes challenging in sub-20nm region. This practical challenges and roadblock in further optimisation of tunnel FET neutralises its advantages in case low power demand. So with decrease in technology node, there is a need of transistor without any junction. Junctionless transistor is a uniformly doped gated resistor which has full CMOS functionality, without need of any sharp doping gradient. In the first part of our thesis we have worked on device simulations of junctionless transistors and we have suggested a way to improve the performance of device by lateral grading of doping concentration. Though junctionless transistor has improved ON current and easy fabrication steps, still its SS is limited to 60mV/decade. By taking these limitations in to account new device architecture named junctionless tunnel FET (JLTFET) has been proposed, which provides combined advantage of junctionless transistor and tunnel FET. This thesis aims at the review of physics, design and optimisation of JLTFET and the potential and drawbacks with respect to conventional MOSFET. Next we proposed the novel architecture of dual metal gate (DMG) JLTFET, which provides better SS and ON to OFF ratio, which cannot be achievable by single metal gate configuration. In the last part of our thesis, the device physics of JLTFET with low band gap semiconductor like germanium as the channel material is studied and effect of drain engineering and work function engineering on its device performances are investigated

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**Title** : *A comparative study of thin film CYTOP and conventional glass-epoxy based encapsulation of Organic Solar Cell Devices*

**Author(s)** : *Singh, Sumitabh*

**Roll No** : *Y8127516*

**Supervisor(s)** : *Iyer, S Sundar Kumar& Garg, Ashish*

### ***Abstract***

In Organic Solar Cells industry, degradation is one of the major challenges faced and is important to resolve in order to bring them into the market. There are several reasons for degradation and it is required to look at each one of them carefully to maximize lifetime. Encapsulation is one of the ways, not affecting the fabrication technology but at the same time is very effective in increasing the lifetime. An encapsulant must provide a good barrier for water and oxygen and on the other hand must have a cost effective way to coat over the module. In my thesis work, I have tried to replace glass encapsulation by a thin film encapsulation of Cyclic Transparent Optical polymer (CYTOP) which is innovative as it reduces the weight significantly and can be easily spin coated over the substrate which will help in the commercialization of solar cells, unlike glass encapsulation which has significant weight. Optimization of parameters for coating CYTOP and comparison with glass-epoxy encapsu...

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*Title* : *Transmission Line Modeling of Source Resistance in Top Contact Organic Thin Film Transistors*  
*Author(s)* : *Agarwal Ankit*  
*Roll No* : *Y8127081*  
*Supervisor(s)* : *Mazhari Baquer*

### *Abstract*

Organic thin film transistors (OTFTs) have received increasing attention because of their potential applications in back panels for active matrix displays, logic circuits, sensors, RFID tags, and in the area of low cost flexible macro-electronics. The current driving capabilities in OTFTs are limited by contact resistance. Building models is required to understand the effect of various parameters on the contact resistance. Contact resistance arises due to the difference in the work function of contact electrode and the ionization potential of the accumulation layer. In this thesis, effect of injection barrier at the source and bulk mobility, on the source resistance have been studied in great detail. For this purpose a transmission line model is developed, consisting of series connected diodes and PMOS (as variable resistor) for the bulk part of the OTFT and another PMOS is used for channel. This model is simulated in microcap. For the I-V characteristics of the diode, a simulator has been developed in C++ for single layer devices, which includes models for charge injection, charge transport, carrier concentration dependent mobility, field dependent mobility. The simulator is verified by various test cases and results available in the literature. The data of the I-V characteristics thus obtained from the simulator is used as a look up table based diode model in the microcap. Through the simulations, it has been observed that there is about 3 orders of decrease in magnitude of source resistance as the transistor goes from linear to saturation region, at high injection barrier of 0.5 eV at the source. With decrease in the injection barrier, the difference between the linear and saturation region values of source resistance decreases. Through this model, the dependence of source resistance on oxide thickness and the length of source contact have also been shown and analyzed

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*Title* : *Simulational Studies of Junctionless Transistors*  
*Author(s)* : *Mondal, Partha*  
*Roll No* : *11104073*  
*Supervisor(s)* : *Ghosh Bahniman*  
*Abstract*

As the physical gate length of MOSFETs scales down to the order of nanometers, it becomes very difficult to fabricate abrupt metallurgical p-n junction for making source/drain, to reduce the short channel effects (SCE). Recently, the concept of Junctionless Transistors (JLTs), which contains no metallurgical junction, has been investigated. It works on the principle of volume depletion of carriers in channel. This thesis presents a planar junctionless transistor (JLT) in silicon-on-insulator (SOI) with non-uniform channel doping in vertical direction to improve the ON to OFF drain current ratio by suppressing the leakage current flowing through the bottom of the device, decreasing the conductivity at the bottom of the device layer. In off-state, at drain side a significant band overlap between valence band of channel region and conduction band of drain region triggers electrons to tunnel from valence band of channel region to conduction band of drain region leaving behind hole in the channel, results in increase of the sub-threshold leakage current and the accumulation of holes in the channel forms a parasitic bipolar junction transistor (n-p-n BJT for n channel JLT) by the source (emitter), channel (base) and drain (collector) . Two solution is proposed: (a) Hetero-Gate-dielectric double gate Junctionless Transistor (HGJLT), taking high-k gate insulator at source-side and low-k gate insulator at drain-side and (b) Junctionless transistor with high-k spacer, to reduce the effects of band-to-band tunnelling (BTBT) in off-state. The JLTs devices require a uniformly doped ultrathin channel. Though we take uniform doping for simulation study but in practice, after thermal annealing, the impurity profile in ion-implanted semiconductor device becomes uniform along the lateral channel direction and non-uniform along the vertical channel direction. In this thesis, the effect of non-uniform doping in channel of JLTs has been studied.

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**Title** : *Quantum Dot and Magnetic Quantum Dot Cellular Automata Circuit Design*  
**Author(s)** : *Kumar Ankit*  
**Roll No** : *Y8127089*  
**Supervisor(s)** : *Ghosh Bahniman*

### ***Abstract***

A Quantum Dot Cellular Automata (QCA) is a nanotechnology which in future can be used as an alternative for transistor based technology. A simple 12 ALU is designed using QCA. A simple 12 ALU is capable of performing 12 operations depending on the input signals. In order to tackle the problem of input connections with the circuit a second layer of QCA is used to transfer input signals to the points located deep inside the complicated circuits. In this design I have tried to minimize the number of gates, cells and area. QCA designer was used to design and simulate the circuit. Majority Gates and Inverters mainly form the basic building blocks in QCA circuit design. The Three-input Majority Gate is most widely used in logic synthesis and design. In this paper, a Nine-input Majority Gate is proposed which would find use in multi-bit arithmetic circuits by reducing overall cell counts and delays. Further, the proposed design is simulated on QCA designer to prove its functionality and uses. This thesis also deals with Magnetic QCA. It aims at finding out an optimum size for nanometer scale magnets for implementation of digital circuits using Magnetic-dot Cellular Automata(MQCA) systems. The delays in MQCA wirings and three-input majority logic gate are calculated for different sizes of magnetic cells and alpha. The signal transfer delay shows definite variation with size. Since MQCA consume very low power and can be operated at room temperature, they play a useful role in quantum circuits.

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***Title*** : ***A Novel Resistance-Based Approach For Drain Current Modeling in Graphene FETs***  
***Author(s)*** : ***Jain Soumya***  
***Roll No*** : ***Y8127502***  
***Supervisor(s)*** : ***Dutta Alope***

### ***Abstract***

In this work, we present a resistance-based drain current model for dual-gate Graphene Field-Effect Transistors (GFETs). During the course of development of this model, we have formulated an analytical expression for the sheet charge density for dual-gate structures, hitherto numerically computed, resulting in a significant saving in terms of the computational time; while at the same time, extended it for single-gate architectures. Also, in order to ensure charge and potential continuity throughout the device, again unaccounted for so far in literature, we have introduced a new parameter, Debye length for graphene, and proposed a heuristic model for it. The carrier mobility in graphene, which shows peculiar behavior with respect to the applied voltages, has so far been modeled in terms of both the sheet charge density and the voltages; while in this work, we have modeled this parameter through an empirical expression, which is a function only of the voltages - this also results in significant savings in terms of computational time. This expression has been developed by proposing a new hypothesis for carrier transport in the graphene layer in GFETs. Also, the source and drain region resistances (taken to be a constant so far, which is physically unjustified) have been modeled in this work based on the charge distributions in these regions. The results of our drain current model showed a very good match with the experimental data published elsewhere, while reducing the maximum error as compared to the simulated results of some existing works.

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*Title* : *Studies on Magnetic Tunnel Junctions*  
*Author(s)* : *Banerjee Abhishek*  
*Roll No* : *Y8127016*  
*Supervisor(s)* : *Ghosh Bahniman*

### *Abstract*

Magnetic tunnel junctions are the basic building blocks of one of the most promising candidates for universal memory technology: Spin Torque Transfer RAM or STT-RAM. The possibilities offered by this revolutionary memory technology are almost limitless including sub-nanosecond bit switching, non volatile storage with exorbitantly large shelf lives, compatibility with existing bulk CMOS technology, ultra-high device density and zero standby power consumption: a utopian dream for every memory technologist. However, there are challenges that need to be overcome before STT-RAM can become viable enough to eclipse existing technologies like DRAM and FLASH in terms of efficiency and cost. Switching current densities required to toggle the MTJ bits are still prohibitively high leading to large-size driving transistors and high power consumption. Thermal stability of magnetization which determines shelf-life inevitably decreases when switching currents reduce. Low tunneling magnetoresistance ratios and high switching delays further degrade performance. In this thesis, we investigate four different solutions to solve some or all of the current problems plaguing magnetic tunnel junctions. The first solution entails a double barrier magnetic tunnel junction with perpendicular anisotropy: we discuss the double spin filter effect and quantum interference enhanced tunneling magnetoresistance. The second solution describes a unique device design that takes advantage of internally generated microwave rf fields to enhance resonance switching of MTJs with perpendicular anisotropy. Third, we investigate the voltage-controlled magnetic anisotropy (VCMA) effect: a peculiarity of thin film ferro-magnets wherein an electric field is used to facilitate magnetization reversal instead of conventional spin currents or magnetic fields. We show that a smartly designed combination of STT and VCMA can lead to significant reductions in the energy delay products. Finally, the fourth solution discusses the future of scaling in MTJs. We argue that to maintain high thermal stability factors while maintaining similar switching current densities under scaling, 3-dimensional MTJs vastly outperform the conventional planar designs.

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***Title*** : ***Non-Equilibrium Green's Function Studies of Spin Field Effect Transistors***  
***Author(s)*** : ***Saxena Vivek***  
***Roll No*** : ***11104118***  
***Supervisor(s)*** : ***Ghosh Bahniman***

### ***Abstract***

This work addresses various issues in the computational simulation of ballistic quantum transport of charge in a Spin Field Effect Transistor (SpinFET) through the Non-Equilibrium Green's Function (NEGF) formalism, incorporating the effect of electron spin. The NEGF formalism connects quantum mechanics to observable and measurable quantities, and enables device engineers to determine current-voltage characteristics of devices subject to various physics and boundary conditions, including regimes which are not accessible to the experimentalist. However, the NEGF method is computationally intensive and is typically employed only in geometries which are spatially one-dimensional, with two dimensional effects being factored in approximately. This thesis describes an extension of the one-dimensional NEGF algorithm to simulate charge and spin transport in a material with no strong correlations but with nearest neighbor, next-to-nearest neighbor or similar higher order neighbor interactions in two dimensions, effect of electron spin, and a self-consistently determined electrostatic potential. Various issues that arise in setting up the simulation model, and the underlying physics are examined. A comparison of the computational efficiency of different approaches is also attempted.

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**Title** : *Estimation of the extrinsic series resistance in organic solar cells*  
**Author(s)** : *Singh Shantanu*  
**Roll No** : *Y8127470*  
**Supervisor(s)** : *Mazhari Baquer*

### ***Abstract***

Organic Solar Cells commonly use a transparent conductive oxide (TCO) as an anode to allow the light rays to pass to the active semiconductor layer. As a result of a trade-off between the transparency and the electrical properties of TCO, its sheet resistance is often significant resulting in an additional voltage drop that causes a degradation in device's characteristics including short circuit current and more significantly fill factor. The series resistance includes both intrinsic and extrinsic components. This work describes a technique for estimating the extrinsic series resistance – through use of an additional floating electrode introduced on the side of the anode that is opposite to the contact. The voltage measured at this electrode together with I-V characteristics allow the extrinsic resistance to be estimated. The method was validated using results obtained from Silvaco based device simulation for different values of TCO sheet resistance. The proposed method was applied to P3HT:PCBM organic solar cells where an extrinsic resistance REX was obtained. After subtracting the effects of the extrinsic series resistance, the characteristics of intrinsic solar cell were obtained. The efficiency and fill factor of fabricated OSC was found to increase from 1.39 to 1.49 and 0.415 to 0.438 respectively. A method for obtaining the parameters of the dark characteristics at higher current values by appropriately taking into account intrinsic series resistance using a transmission line model is also described

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*Title* : *Study on Polarization-Insensitivity, Bandwidth-Enhancement and Equivalent Circuit Modelling of Metamaterial Microwave Absorber*

*Author(s)* : *Ghosh Saptarshi*

*Roll No* : *11104093*

*Supervisor(s)* : *Srivastava Kumar Vaibhav*

### *Abstract*

Microwave absorbers have several applications in commercial as well as military domain where high performance absorbing materials over a broad frequency band are required. However, the large thickness of the standard microwave absorbers is the limitation for using them in radar cross section (measure of detectability of an object with radar) application in stealth technology. Recently, metamaterial absorbers provide major breakthrough in this area, where the ultra-thin structures comprising periodic unit cells in the sub-wavelength regime can be used to obtain near unity absorption. But the bottlenecks of such metamaterial absorbers are their structural asymmetry and narrow absorption bandwidth. This thesis discusses several types of metamaterial absorber designs to deal with the above shortcomings. Firstly, two polarization-insensitive metamaterial based absorber structures have been discussed. The first one is a tetra-arrow absorber and the second one is a circular absorber. Both the structures are highly absorptive for all polarization angles as well as for wide incident angle ranging from 0 degree to 60 degree for both TE and TM polarizations. After that, another metamaterial absorber structure has been discussed based on bandwidth-enhancement application. An ultra-thin single-band circular absorber has been initially proposed and by optimizing the dimensions of the resonating structures, a bandwidth-enhanced absorption with a full width at half maximum (FWHM) of 1.04 GHz has been realized. Next, both the polarization-insensitivity and bandwidth-enhancement has been incorporated in a single metamaterial absorber structure. The initially proposed single-band structure has been scaled and using two different variants of the structure in a 2 X 2 array, a broadband of 0.68 GHz for all polarization angles has been realized. Both the single-band and the bandwidth-enhanced structures are fabricated, measured and compared with the simulated data. Lastly, an equivalent circuit modelling technique has been developed to mathematically deduce the absorption frequency of a prototype metamaterial microwave absorber structure based on microstrip environments. The numerical and simulated results are compared for different parametric variations to validate the modelling technique.

**Title** : *Study on Metamaterial-Inspired Structure for Dual-band Antenna and Band-Notched UWB Antenna*  
**Author(s)** : *Sarkar Debdeep*  
**Roll No** : *11104028*  
**Supervisor(s)** : *Srivastava Kumar Vaibhav*

### ***Abstract***

Design of efficient antenna for wireless communication technology is a very active and challenging research area, considering the fact that design specifications are becoming increasingly stringent with time. Planar microstrip antenna systems provide a number of features which modern day mobile radio and wireless communication systems demand, like low-profile, conformability to planar and non-planar structures, compatibility to MMIC technology, mechanical robustness, ease of fabrication in PCB labs. On the other hand, metamaterials are artificially engineered periodic structures where the unit-cell size is kept much smaller compared to the operating wavelength. One can tailor the permittivity and permeability of the effectively homogeneous metamaterial medium by judicious tuning of the unit-cell design parameters. Since the experimental realization of metamaterials in the start of twenty first century and subsequent development of transmission-line metamaterials, engineers have are working on use of metamaterials or metamaterial-inspired concepts to control the performance of microwave devices like antennas, filters and couplers. The objective of this thesis-work is to study on design of planar microstrip antennas employing metamaterials-inspired concepts. First, dual-band antenna structures targeted at WiMAX (3.3-3.8 GHz) / WLAN (5.15-5.85 GHz) application-bands are proposed where a coax-fed microstrip patch antenna is loaded with complementary split-ring resonators (CSRRs) and placed over a partially defected ground plane. In these antennas, the CSRRs help in excitation of low-frequency resonant modes and the defected ground plane acts as a capacitive impedance surface, facilitating impedance matching over a wide frequency band. Secondly, metamaterials-inspired resonators like SRRs, CSRRs and Modified Mushroom resonators are embedded in UWB antennas (3.1-10.6 GHz) to obtain sharp-notch bands, which can mitigate the problem of electromagnetic interference caused by existing narrowband systems like WiMAX (3.3-3.8 GHz) / WLAN (5.15-5.85 GHz)/ X-band Communication links (7.9-8.4 GHz). Three band-notched UWB antennas are proposed in this work. The design concepts are validated by fabrication and measurement of one proposed triple band-notched antenna.

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**Title** : *Performance of UHF RFID Tag Placed on Conductive Surfaces*

**Author(s)** : *Jain Akshay*

**Roll No** : *11104006*

**Supervisor(s)** : *Harish A R*

**Abstract**

The increased use of UHF based passive RFID tags is attributed to its small size and high read range. The performance of tags shows a dependency on object parameters to be tagged. For instance tag placed in the vicinity of a conductive surface suffers severe degradation in performance. Traditionally, the dimensions of the tag are optimized to enhance the performance on the conductive surfaces. Recently, the introduction of the decoupler between the tag and object has also gain lot of attention. A design methodology has been proposed for the tag placement studies on conductive surface, without the need of decoupler or a specially designed tag for metallic applications. This work relates to placing the dipole based RFID tags on conductive surfaces. A modification on the planar conductive surface is introduced to improve the performance of tag. We have considered a variety of conductive surfaces including metal sheet, unidirectional wire grids and wire mesh. The deformation is in the form of slotted section, length of a half wavelength long is created on a surface. An electrical short on both the sides of the section resembles to two quarter wavelength long transformer. It forms a high impedance region in the middle, over which the RFID tag is placed. This technique of enhancing the performance has been extended to all the above mentioned planar conductive surfaces. A parametric sweep over the dimensions of the slotted section is aimed at optimizing the performance of the tag placed above it. We also considered tag placement study on cylindrical surfaces with the tag placed around the surface and parallel to the axis of cylinder. The simulated results are validated by the experimentally measured threshold power. Along with it radiation pattern measurement is made and compared with simulation results.

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*Title* : *A Study of Printed Dual Mode Resonator Filter*  
*Author(s)* : *Rathore Akhil Kumar Singh*  
*Roll No* : *11104122*  
*Supervisor(s)* : *Harish A R*

### *Abstract*

A microstrip line loaded with a radial stub operates as a dual mode resonator. By controlling the amount of coupling between the two modes as well as the coupling between the resonator and source/load, it is possible to realize transmission zero with a single dual mode resonator. It is also possible to locate the transmission zero either above or below the pass band region by approximately changing the nature of different couplings. In this thesis, apart from proposing the dual mode resonator, we also conceive an equivalent circuit to understand the behavior of the resonator. The equivalent circuit has been used to design band pass filter using the proposed dual mode resonator. Using the proposed method two filters are designed, fabricated and tested. First filter has higher selectivity at the high side of the passband than the other side. This is achieved by placing the transmission zero on the higher side of the passband region. Second filter exhibits a higher selectivity on the lower side of the passband thus providing a good stopband rejection below passband. Three pole filters with Chebyshev and Elliptic responses are also designed, fabricated and tested. Source to load coupling is also introduced to enhance the selectivity of the filter. Capacitive coupling is introduced between input and output. It is also verified by simulation that using capacitive coupling between input and output feed line can produce a transmission zero on the high side of the pass band.

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*Title* : *Study on Inductively Loaded and EBG Grounded PIFA Antennas for Mobile Applications.*  
*Author(s)* : *Kosuru Geethanjali*  
*Roll No* : *11104033*  
*Supervisor(s)* : *Srivastava Kumar Vaibhav*

### *Abstract*

The rapid advancement in the mobile technology has demanded a sophisticated antenna catering all its needs. The planar inverted F antenna is a promising antenna with multiband operations. The PIFA antennas are generally held at a height from the ground plane, which increases the volume occupied by the device. This space constraint is addressed by printed PIFA antennas. In this work, novel configurations of PIFA antennas are proposed. To reduce the volume of the PIFA structure, the air gap between the radiating antenna and the ground plane is removed. The miniaturization of antenna is obtained by meandered line technique, which also improves the antenna performance to dual band. To accommodate other communication bands, new resonances are obtained by introduction of inductive loading elements. A dual band PIFA which supports 610 MHz bandwidth at 2.40 GHz frequency and having a second resonance at 5.42 GHz is designed. This antenna is modified and loaded with an inverted L shaped metallic strip to enhance the antenna performance and to get a third resonance. To study the behaviour of electromagnetic band gap (EBG) ground planes in PIFA environment, EBG Structures are introduced between the designed single band antenna and ground plane. The surface waves on the backside of ground plane are suppressed and the EBG grounded antenna has good directivity and less backside radiation at the designed frequency.

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*Title* : *Analysis of Multipaction Breakdown in RF Systems*  
*Author(s)* : *Sundaram Ravi Krishna*  
*Roll No* : *11104086*  
*Supervisor(s)* : *Harish A R*

### *Abstract*

The multipaction phenomenon is the resonance build up of electrons inside RF/Microwave components, if applied power is higher than the threshold value. When a seed electron hits the wall with sufficient energy to cause secondary emission of more than one electron and if at the same time electric field changes its phase then all these newly generated electrons again face the same resonance condition and cause further emission of electrons. In this way the electron population inside the component increases exponentially. The multipaction effect can damage the microwave components in several ways e.g. detuning of resonator, physical damage to the components, increase in the passive intermodulation level and degradation of return loss. If multipaction is sustained for a long period of time, it may cause irreparable damage to the components. In this work 2-D and 3-D multipaction codes to predict the onset of multipaction are developed. 2-D code is developed to analyse structures that have field variations only in two dimension e.g. axi-symmetric structures whereas 3-D code can be used for multipaction analysis of any arbitrary geometry with conducting boundary. In order to design multipaction free devices, it is necessary to find exact location that are susceptible to breakdown. The postprocessor of this multipaction code also provides a graphical view of the electron trajectory, which shows exact location of multipaction. Electron population growth is also plotted with respect to the time which in turn indicates the strength of multipaction. The electron grows quickly for low order multipaction whereas high order multipaction are not that much detrimental. This work comes under the broad category of power handling analysis of RF/Microwave components. For RF designer, it is very necessary to know the exact mechanism of break-down and maximum power that the device can handle, so that he can take appropriate measures to mitigate the multipaction and also consider sufficient power handling margin during the design

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**Title** : *Study on Bowtie and Cylindrical Shaped Dielectric Resonator Antennas for Circular Polarization and Wideband Applications.*

**Author(s)** : *Prachi*

**Roll No** : *11104077*

**Supervisor(s)** : *Srivastava Kumar Vaibhav*

**Abstract**

Dielectric resonators (DRs) possess features such as low loss and high quality factor which makes them suitable as effective resonating elements in shielded microwave circuits. However DRs kept in open environments, have been demonstrated as efficient radiators. This discovery has laid the foundation for using DRs as highly effective antennas. Dielectric resonator antennas (DRAs) possess numerous desirable characteristics like high radiation efficiency, temperature stability, flexibility in design, etc. Wideband DRAs have become indispensable in the present scenario due to development of high data rate applications like wireless and mobile communication. In addition circular polarization designs have also been proposed for DRAs which are specifically useful in satellite and wireless communication. In this thesis, two wideband DRAs and a circularly polarized DRA have been proposed. The first structure consists of a bowtie DRA which has been excited by a conformal strip. The proposed structure achieves a measured impedance bandwidth of 102.9% covering a frequency range of 4.02 GHz-12.53 GHz. In the second structure, a microstrip line has been used to feed the bowtie DR, through a cross shaped asymmetrical slot. The proposed structure achieves circular polarization with a measured axial ratio bandwidth of 7.4% spanning 7.8 GHz – 8.4 GHz in the broadside direction. It achieves a measured impedance bandwidth of 43.8 % covering frequency range of 6.75 GHz – 10.53 GHz. The third structure is a hybrid antenna consisting of a cylindrical DR fed by a rounded bevel shaped patch and excited by a coplanar waveguide feed. The proposed structure achieves a measured impedance bandwidth of 124.4% covering a frequency range of 4.4 GHz-18.9 GHz.

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**Title** : *Study on Transformation Optics and its Application in Microwave Cloaking*  
**Author(s)** : *Gupta Ashish*  
**Roll No** : *11104016*  
**Supervisor(s)** : *Srivastava Kumar Vaibhav*

### ***Abstract***

Transformation optics (TO) is evolving as an interesting area to work on, as it provides the facility to control the wave as per the requirement in order to design the new optical devices for various applications. Utilizing the concept of transformation optics, a lot of novel optical devices have been proposed, such as invisibility cloaks, optical wormholes, optical black holes, illusion devices. The invisibility cloaks have found huge practical applications in defence to make spacecraft invisible for the radar. Designing an invisibility cloak is very challenging research area since invisibility cloak with ideal parameters can not be achieved by any naturally available material. Research on metamaterials has been growing ever since the first experimental realization of a double negative medium. One can control the permittivity and permeability of effective homogeneous metamaterial medium by judicious tuning of unit cell design parameters. The theory of transformation optics offers a perfect tool to exploit the vast possibilities of the constitutive parameters of metamaterials. The aim of this thesis is to study the basic theory of transformation optics, and use it to design microwave cloaks. First, the theory of TO is discussed and formulae of transformed material parameters and fields are thoroughly derived. Simulation results are shown to validate the perfect cloak. Thereafter, properties obtained for perfect cloak are reduced resulting to less number of parameters in order to decrease the complexity. Also, the realization of reduced material parameters has been discussed for designing practical cloak using metamaterials. Secondly, non-singular and thin cloaks are proposed based on linear transformation to remove extreme parameter from perfect cloak. Then properties of linear and non-singular cloaks are reduced to make two out of three constitutive parameters (CP) constant for the ease of realization. Finally, nonsingular and thin cloak based on second order transformation are proposed. In this cloak, extreme values of material parameters are removed while keeping the good cloaking performance. All the cloaks designed are validated by simulations.

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**Title** : *Dual Band SIW Slot Antennas*  
**Author(s)** : *Srivastava Ashutosh*  
**Roll No** : *11104019*  
**Supervisor(s)** : *Biswas Animesh&Akhtar M Jaleel*  
**Abstract**

Substrate integrated waveguide (SIW) is an emerging as well as active microwave technology for moderated power handling systems. Initially, this technology came as post wall and laminated waveguide technology. In last decade, antenna designing based on SIW technology was a challenging task. Now days, SIW structures are becoming famous in microwave industries because of their low cost and easy fabrication techniques. The devices based on SIW technology can be easily integrated with other planer microwave devices. The slot antennas based on SIW technology are getting attention in microwave industries. Different types of slot antennas based on Substrate Integrated Waveguide have been realized in this thesis. These slot antennas are designed to operate in X-band and Ku-band for narrow band applications. Firstly, a SIW transmission line is designed to achieve low input reflection coefficient ( $S_{11}$ ) in X-band and Ku-band. The achieved  $S_{11}$  in these bands are atleast -15dB. Then a transversal slotted SIW antenna is designed and fabricated. The transversal slot produces single band measured response with frequency range of 10.18 GHz to 10.34 GHz with 10.25 GHz as the central frequency. The achieved gain of the transversal slotted SIW antenna is 7.35 dB at 10.24 GHz. Along with it, the longitudinal slotted SIW antenna produces single band measured response with frequency range of 13.16 GHz to 13.38 GHz with 13.28 GHz as the center frequency. The achieved gain of the longitudinal slotted SIW antenna is 7.83 dB at 13.28 GHz. Now, A dual-band L-shaped substrate integrated waveguide (SIW) slot antenna is designed and fabricated. The designed L-shaped structure is constructed using two different slots oriented along longitudinal and transversal direction to feed-line. The transversal and the longitudinal slots are combined into a single L-shaped slot, which produces dual band measured response with frequency range of 10.85 GHz to 11.03 GHz and 12.60 GHz to 12.78 GHz. The center frequencies are 10.93 GHz and 12.69 GHz. The gain of the designed antenna is 6.04 dB and 6.47 dB at 10.93 GHz and 12.69 GHz, respectively. A C-shaped slot SIW antenna is also designed and fabricated to achieve higher gain, larger bandwidth and low cross polarization level. Actually, this C-shaped slot SIW antenna is a modified form of L-shaped slot SIW antenna. The C-shaped slot SIW antenna is designed to enhance the result of L-shaped slot SIW antenna. The designed C-shaped slot SIW antenna produces dual band measured response with frequency range of 11.05 GHz to 11.30 GHz and 12.80 GHz to 13.30 GHz. The center frequencies are 11.19 GHz and 13.06 GHz. The measured gain of the designed antenna is 8.81 dB and 8.70 dB at 11.19 GHz and 13.06 GHz, respectively. Both, the gain and the bandwidth of C-shaped slot SIW antenna are more than L-shaped slot SIW antenna. The cross polarization level in C-shaped slot SIW antenna is lower compared to it's L-shaped prototype. The analysis is carried out using the HFSS software, and the simulated results are verified using the measurements

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*Title* : *Design of Dual Passband Filter Based on Dual Mode Dielectric Resonators*  
*Author(s)* : *Dwivedi Prashant Kishor*  
*Roll No* : *11104079*  
*Supervisor(s)* : *Biswas Animesh &Srivastava Kumar Vaibhav*

### *Abstract*

In modern satellite and wireless communication systems, band pass filters are finding the critical role. These applications demand the filters having quite high performance with less insertion loss and small mass and size. Dielectric Resonators come up with high-Q characteristics with least loss and better selectivity. With the evolution of the communication system technology, it has been required to support the several bands by a single front end. This has been the motivation to design dual-band and multi-band filters. In this thesis, dual-mode and dual-band filter is presented. A cylinder dielectric resonator can be chosen according to the diameter to height ratio to give four modes or two mode pairs resonating at the same frequency. This property makes the resonator, a quadruple-mode resonator. The structure of the quad-mode resonator is modified by cutting it along the central axis of the cylinder making it a half cut dielectric resonator. It will produce two modes resonating at the same frequency which makes it a dual- mode dielectric resonator. The advantage of using dual-mode filters is the reduction in the physical structure of the filter. Dual band filters can be realized by making the separate frequency bands on different resonant modes of the design structure. The control of center frequencies of the resonances and the couplings can be achieved. There are various topologies in which a dual band filter can be realized. The topology determines the number of couplings to be realized the structure. It allows the filter realizable for different bandwidth, frequency and return loss specifications. Half cut dielectric resonators discussed in this work provide various levels of mass and size reduction in microwave communication systems

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**Title** : *Direction of Arrival of Radio Controlled Improvised Explosive Device's(RCIED) Trigger*  
**Author(s)** : *Vyas Ashish*  
**Roll No** : *11104017*  
**Supervisor(s)** : *Kumar K Pradeep*

### ***Abstract***

The objective of this thesis is detection of direction of Radio Controlled Improvised Explosive Device (RCIED)'s trigger working in 136 – 174 MHz frequency range. As soon as signal is detected current equipment locates the presence of a malicious signal in remote area. But location of RCIED transmitter is still unknown because these technologies require a finite amount of time to track the source whereas time interval of RCIED trigger signal is only order of 2-3 seconds. There are lots of techniques already in markets but in most of techniques they use single antenna rotary mechanism. The problem in this type of system is, it takes a lot of time for detection of signal and also one side signal is missed when antenna is scanning other sided signal. In this thesis we design a passive system that consists of dual antenna, RF front end and FPGA. In antennas section we describe a dual-antenna design. Each array consists of 8 dipole-fed corner reflector antennas mounted in a circular arrangement, radiating mainly in azimuth and elevation planes respectively. Received signal from both arrays are processed using an RF front end and passed to FPGA. On FPGA we implement an amplitude comparison algorithm to estimate the angle of arrival signal and return the co-ordinates  $(\theta, \phi)$  with frequency component present in a signal. We also simulated and studied the error performance of our array system as a function of angle and distance to the array for 1 degree of resolution. Our system is suitable for detection of radar signal and digital transmitter signal such as base and mobile station.

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**Title** : *Microwave Characterization of Metamaterials and Advanced Composites for Absorber applications using rectangular waveguide method*  
**Author(s)** : *Baskey Himangshu Bhusan*  
**Roll No** : *10104045*  
**Supervisor(s)** : *Akhtar M Jaleel*

### ***Abstract***

For most of the electromagnetic applications, the materials can be defined in terms of their constitutive properties usually expressed in terms of their effective permittivity and permeability. The accurate knowledge of these properties is quite helpful in order to understand and analyze various concepts. These properties are also required for the effective usage of materials in various scientific and industrial areas. Recently, the knowledge of effective constitutive properties of artificial dielectrics such as composites and metamaterials has become quite important especially for the design of an efficient electromagnetic absorber using these materials. This thesis deals with the extraction of effective constitutive properties of artificial dielectrics including various composites and metamaterial structures using the short circuit waveguide method. The validation of the proposed approach has been carried out with the conventional transmission-reflection method for a number of standard materials. The proposed method has successfully been used for the extraction of the effective constitutive properties of a number of standard dielectrics as well as metamaterial structures e.g thin wires parallel to the electric field, thin wires perpendicular to the electric fields, split ring resonators have been simulated using the CST microwave studio and fabricated. The metamaterial absorbers based on the cross shaped dipole and ring based structures were also designed and fabricated in order to provide appropriate electromagnetic attenuation in the specified frequency band. The scattering parameters of all these fabricated structures were measured using the short circuit waveguide method with the help of a network analyzer. The effective constitutive properties of these structures were finally extracted in terms of the measured scattering data using the proposed approach in order to study their absorption characteristics in the desired frequency band.

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*Title* : *One-dimensional microwave imaging using iterative approach*  
*Author(s)* : *Govind Greeshmaja*  
*Roll No* : *11104034*  
*Supervisor(s)* : *Akhtar M Jaleel*

### *Abstract*

Recently, there has been an increase in interest in the domain of microwave imaging due to its widespread application in various fields like remote sensing, radiolocation, bio-medical tomography, etc. The reconstruction of the depth-dependent permittivity profiles is one of the basic problems of general active microwave imaging. The overall reconstruction process usually involves the measurement of the scattered electromagnetic data in the spectral domain and their translation into an appropriate spatial domain. Different approaches for this inversion of data exists in literature, categorized broadly into analytical and iterative methods, each method having the advantages and disadvantages of its own. The goal of this research is to combine the virtues of the analytical and numerical methods. A numerical method to invert the dielectric profile from the Riccati equation is described and the initial profile used as the starting point for the inversion is obtained by another method that reconstructs the profile analytically using a renormalization technique. The computation time is reduced considerably without having the need of any a priori information, as the initial guess is close to the final solution, and over and above this, the convergence and stability of the solution too is improved. The proposed scheme for solving the one-dimensional inverse scattering problem has been successfully implemented, and validated with the help of independent simulated and experimental data.

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**Title** : *Design Of Ultra Wide Band Vivaldi Antenna for Microwave Imaging Applications*

**Author(s)** : *B N Abhijith*

**Roll No** : *11104002*

**Supervisor(s)** : *Akhtar M Jaleel*

**Abstract**

Microwave imaging of dielectric media plays a major role in non-destructive testing, remote sensing, medical imaging etc. The procedure usually requires the measurement of reflection coefficient data of the object under test in free space over a wide frequency band. Most of the ultra-wideband antennas are designed in FCC regulated 3.1-10.6 GHz communication band, but for microwave imaging the operating frequency band has to extend both on the lower and the higher side of the spectrum. This thesis describes the design of an antipodal Vivaldi antenna operating in the frequency range of 1-18 GHz fabricated on the FR-4 substrate with improved directivity for a typical microwave imaging application. The design is optimized by studying the parametric variations of various dimensions of the antenna. The directivity is enhanced using a dielectric director of hemispherical shape made of Teflon which is fixed on the endfire direction of the antenna. The proposed antenna with very wide frequency band and high directivity is a very good candidate for the microwave imaging applications. The design of the antenna is carried out using the full wave EM simulation software, the CST microwave studio and various parameters such as return loss, radiation pattern, directivity and input impedance are computed and optimized. The simulated design is validated by fabricating a number of antennas and measuring their return loss as well as radiation characteristics. The use of the designed antenna for the prototype microwave imaging setup is presently being explored.

**Title** : *Guided Optical Wave Mode Conversion Using Spin Wave–Optical Interactions in YIG–GGG Films*  
**Author(s)** : *Jangid Alok*  
**Roll No** : *11104008*  
**Supervisor(s)** : *Kumar K Pradeep*

### ***Abstract***

In this thesis, we study mode conversion of guided optical waves (GOWs) due to magneto-static waves (MSWs) propagating non-collinearly in YIG–GGG films with arbitrarily oriented magnetization. Using coupled mode theory, we derive closed form expressions for coupling coefficients and mode conversion efficiency (MCE) between GOWs of arbitrary mode orders. Our calculations show that Cotton–Mouton effect, when induced in addition to Faraday effect, results in increase of MCE by a significant factor. We found increase in MCE by a factor of 100 for collinear geometry over non-collinear geometry with modes of the same order. MCE reduces by a factor of 500 when GOWs of different mode orders are coupled. We report the effect of type of MSW–GOW interaction and the geometry of interaction on MCE. Further, this work involves theoretical as well as numerical analysis of different MSWs–optical interactions based on various physical and geometrical parameters. We compare the results of GOW mode conversion due to three types of MSW–optical interaction: surface, forward, and backward volume waves. For the same parameters, MCE due to surface wave–optical interaction is larger by a factor of 5 over forward-wave and 1.5 over backward-wave interactions.

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**Title** : *Non-invasive Conductor Backed Coplanar Microwave Sensor for Complex Permittivity Measurement of Liquids*  
**Author(s)** : *M Shaji*  
**Roll No** : *11104096*  
**Supervisor(s)** : *Akhtar M Jaleel*

### ***Abstract***

Measurement of dielectric properties of liquids in the RF and Microwave frequency range has numerous applications such as for the microwave heating in the polymer and composite industry, to detect contaminations in the food and agricultural industry etc. For microwave heating applications, the dielectric properties of the test material should either be known or measured in order to define the full heating cycle of a particular material using microwaves. Similarly, the contamination in various food and agricultural products can be detected using microwaves by observing the changes in the dielectric properties of the resultant material. This thesis is based on the development of a coplanar based microwave sensor to determine the dielectric properties of viscous liquids such as resins and other fluids, in a non-invasive way. A conventional coplanar waveguide on a dielectric substrate consists of a center strip conductor with semi-infinite ground plane on either side of it. This structure supports a quasi-TEM mode of propagation. The coplanar structure has several advantages over microstrip line, such as ease of fabrication, being less dispersive than microstrip line, the impedance remaining almost constant over a wide frequency range (0.5 to 40 GHz) etc. Hence the coplanar based sensor is ideal for broad band permittivity extraction of dielectric samples. In this thesis, a conductor backed coplanar sensor is designed for 50 ohms impedance, having the even mode field. The air gap between the conductor and the ground is kept small so that most of the fields confine into the air gap. Then the sensor is placed over the sample holder filled with the liquid, whose permittivity is to be measured. The loaded sensor is connected to the two ports of the VNA (Vector network analyzer) for measuring the scattering parameters. The effective permittivity of the structure is calculated from the measured scattering data using developed algorithms. The fill factors are calculated from geometry of the structure with the help of standard relationships, and the complex permittivity of the sample is finally extracted in terms of the fill factor and the effective permittivity. The designed conductor backed coplanar waveguide sensor for the permittivity measurements of liquids is tested by extracting the permittivity of various standard liquid samples. The extracted values are compared with the reference data, and both the measured permittivity values are found to be in very good agreement with the reference data available in literature.

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*Title* : *Circularly Polarized Compact Antenna*  
*Author(s)* : *Kumar Mukund*  
*Roll No* : *11104061*  
*Supervisor(s)* : *Harish A R*

### *Abstract*

RFID (Radio Frequency Identification) technology is getting extensively used for identification, tracking and contactless storing/accessing data remotely. This technology uses RFID reader for reading and writing data on a chip located in the RFID tags. As the orientation of a tag cannot be predetermined, the RFID antenna is usually circularly polarized rather than linearly polarized. This work is related to the study of compact antennas which are circularly polarized and cover the full RFID frequency band (860 MHz - 930 MHz), a portion of which being used for RFID applications in India, Europe, USA and many other countries in UHF range. In this work we consider three different antennas viz., stacked patch, printed dipole and antenna above a high impedance surface. We study the effect of antenna geometry on the input reflection coefficient bandwidth and axial ratio bandwidth. It is demonstrated that with the use of high impedance surface it is possible to reduce the total volume of the antenna without significantly compromising the performance.

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*Title* : *Microwave Non-Destructive Testing of Cement Based Structures*  
: *Barman Binoy Krishna*  
*Roll No* : *11104025*  
*Supervisor(s)* : *Akhtar M Jaleel&Misra Sudhir*

### *Abstract*

The cement based structures (mortar, concrete etc.) are nowadays quite often being used in the construction of modern buildings. The strength of these cement based structure depends on various properties such as water/cement ratio, density etc. The compression strength is strongly influenced by the water/cement (w/c) ratio as well as the quality of the aggregate added to the resultant structure. The w/c ratio and the compaction dictate the porosity inside the cement based structures, which traps the moisture in it. The higher value of w/c ratio indicates more porosity, which usually indicates the lower compressive strength of the cement based structure. Hence the determination of w/c ratio of the cement based structure can be used to indirectly determine the strength of the cement based structures. The amount of water or moisture content inside the concrete can be modelled in terms of dielectric constant. Compared to other non-destructive testing methods, the microwave based methods are not hazardous, are low in cost compared to radioactive methods, are non-contacting, and offer good spatial resolution along with better penetration in non-metallic objects. In this thesis, the microwave based time domain method has been used to estimate the dielectric constant of the cement based structures. The determination of dielectric constant of various cement based structures helps to characterize these samples, and accordingly the strength of these structures can be evaluated in a non-destructive way. The proposed approach is first validated here using some standard reference samples such as Teflon and Polyethylene etc. Finally, a number of specially prepared cement based samples are measured using the proposed approach, and the results are compared with the data available in literature. A good match is observed between the proposed method and the available data, which shows the applicability of the proposed scheme

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