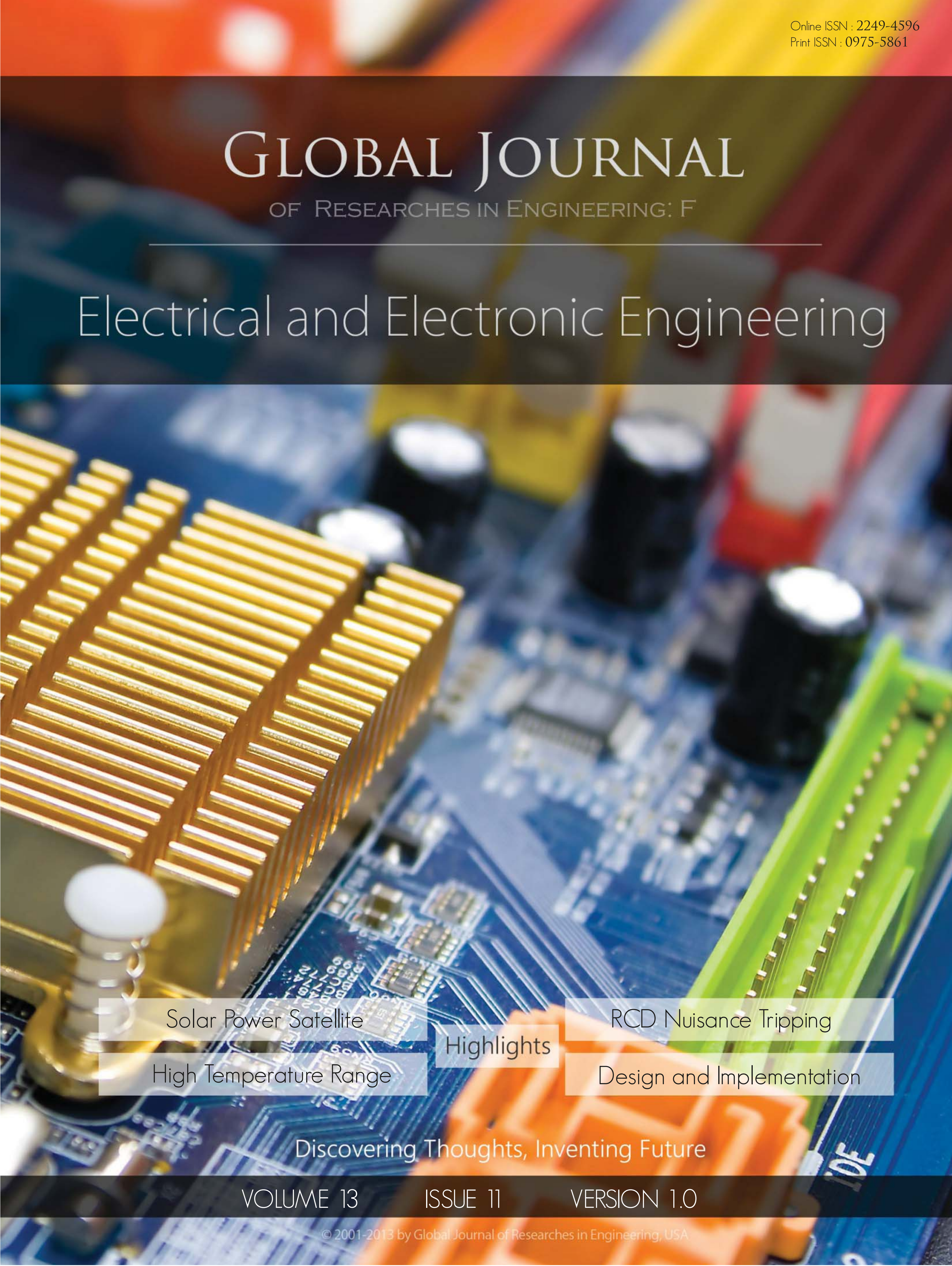

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Highlights

- Solar Power Satellite
- High Temperature Range
- RCD Nuisance Tripping
- Design and Implementation

Discovering Thoughts, Inventing Future

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Prospects of Solar Power Satellite in Bangladesh

By Masudul Haider Imtiaz, S. M. Safayet Hossain
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University of Dhaka, Bangladesh

Abstract - This paper is a quick study overview of the space solar power, its current status and the prospects of the implementation of Solar Power satellite (SPS) in Bangladesh. Collecting energy in space and to redirect it to Earth provides significant advantages in the continuity of supply with very little environmental impact. But, its development represents many challenges both technically and economically. Bangladesh is very close to launch its first communication satellite in space. It is proposed in this paper to integrate SPS module with that Satellite for providing the long time solution of the power crisis.

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PROSPECTS OF SOLAR POWER SATELLITE IN BANGLADESH

Strictly as per the compliance and regulations of :

Prospects of Solar Power Satellite in Bangladesh

Masudul Haider Imtiaz [α] , S. M. Safayet Hossain [σ] & Md. Jahangir Alam Khondokar [ρ]

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I. Introduction

Solar cell had been proved to be the best power source for space applications and extra-terrestrial missions (in 1950s) immediately after the successful development of solar cells at the Bell Telephone and RCA laboratories. After numerous research studies, during 1960-70s, more than 1000 satellites successfully integrated solar cells or panel to power them. It was found straightway that the solar energy available is space is billions of times greater than we use is Earth. But, a very little attention has been given till to date to utilize this enormous power to alleviate the increasing power crisis of Earth. Collecting energy from space might appear to be a distant and overly complex answer, but a careful look reveals surprising advantages and motivations. Responding these, a concept of Solar Power Satellites (SPS) has begun to implement very recently to capture the Sun's energy in space and to deliver it to Earth wirelessly as a non-polluting form of electrical power. It needs to employ some Microwave generators to convert sunlight to microwaves and to redirect the microwaves to Earth [1]. Also a rectena (rectifier and receiving antenna) is needed in the ground to convert it in the usable form of electricity. The drawbacks of this procedure are yet to be solved and the cost-effective versions are yet to be developed but we can take it immediately as we are in great threat of insufficient energy and we are seeking for permanent but renewable alternatives. SPS would serve us in both ways. The lifetime of the sun is an estimated 4-5 billion years, making space solar power a truly long-term energy solution. The radiation energy from Sun to Earth is around 1.77×10^{17} W which is fifty thousand fold of energy consumed by human beings. It seems properly oriented SPS can provide large quantities of energy to each and every person on Earth 24 hours in day and 7 days in week. Also it works regardless of cloud cover, daylight, or wind speed. Figure 1 depicts the idea of the utilization of space solar power.

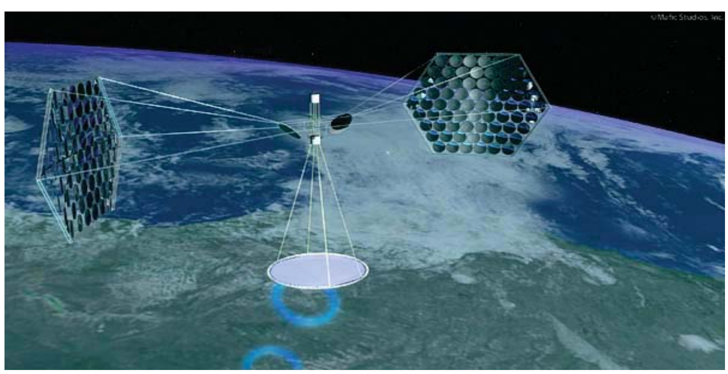

Figure 1 : An Example of the Solar Satellite Concept

Energy is the key to an industrialized economy, which calls for a doubling of electrical output every ten to twelve years [2]. Unfortunately Bangladesh is now facing worst power crisis due to declining production of oil and gas, environmental concerns with coal or nuclear and the insufficiencies of terrestrial wind and solar. To bring power to all the people everywhere in industry or private, only a space-based global power grid would do the job. The sooner we start and the harder we work to launch the SPS project, the shorter "long term" will be. But a poor developing country like Bangladesh must regard the concept as realistic, beneficial, and non-threatening as the challenges are not only the

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technology but also the economics and the legal issues. So, a deep research work and intelligent planning is mandatory to make a vision like SPS a reality.

II. Impacts of Space Solar Power

The Earth receives only one part in 2.3 billion of the Sun's output, as the maximum radiation is lost on its way through the atmosphere by the effects of reflection and absorption by the layers it intercept. As the SPS collects energy residing on an orbiting satellite instead of on Earth's surface, a higher collection rate and a longer collection period is obvious due to the lack of a diffusing atmosphere and the nighttime in space. Also it converts sunlight to microwaves outside the atmosphere, avoiding the losses and the downtime (and cosine losses for fixed flat-plate collectors) due to the Earth's rotation. Microwave beams are constant and can be beamed at densities substantially lower than that of sunlight. This delivers more energy per area than terrestrial solar energy. Even the peak density of the beam could be significantly less than noon sunlight. This low energy density and choice of the wavelength also means that biological effects (cancers or genetic damage) are less likely. The safety of the wild life wandering into the beam is not expected to be an issue. Also the size of the antenna makes microwave beaming unsuitable as a "secret" weapon. So, SPS would likely not face many liability issues resulting from microwave transmission or misuse [3].

The key to getting support for space solar power may be the growing awareness of the threat of rapid global environmental change. The world is now in huge pressure to find new sources of clean and renewable energy. Space solar power is poised to become the planet's most significant source of alternative energy. Unlike oil, gas, ethanol, and coal plants, it can solve our "energy and greenhouse gas emissions problems". Not just to help, not just to take a step in the right direction, but to solve. Also the impacts of wind circulations, ocean current, atmospheric vapor current that related to green-house gas could be controlled using SPS. Space solar power has a number of substantial advantages over other energy sources. Unlike coal and nuclear plants, it does not compete for or depend upon increasingly scarce fresh water resources. Unlike bio-ethanol or bio-diesel, it does not compete for increasingly valuable farm land or depend on natural-gas-derived fertilizer. Unlike nuclear power plants, it would not produce hazardous waste, which needs to be stored and guarded for hundreds of years. Unlike coal and nuclear fuels, it would not require environmentally problematic mining operations.

Although the cost of solar power is not at all compatible with the current prices of fossil fuels, there is a large initial cost of SPS prior to getting a return on the investment. The "Fresh Look at Space Solar Power" [4] study shows that the SPS implementation on an existing satellite may be feasible. The solar energy is routinely used on nearly all spacecraft today and the relevant technologies have reached its optimum level. It is likely to combine wireless power transmission to an established system and to supply the electrical needs of our planet. All it needs numerous research works which should be co-ordinated by both the Government and the private sectors.

III. The Origins of SPS and its Mechanics

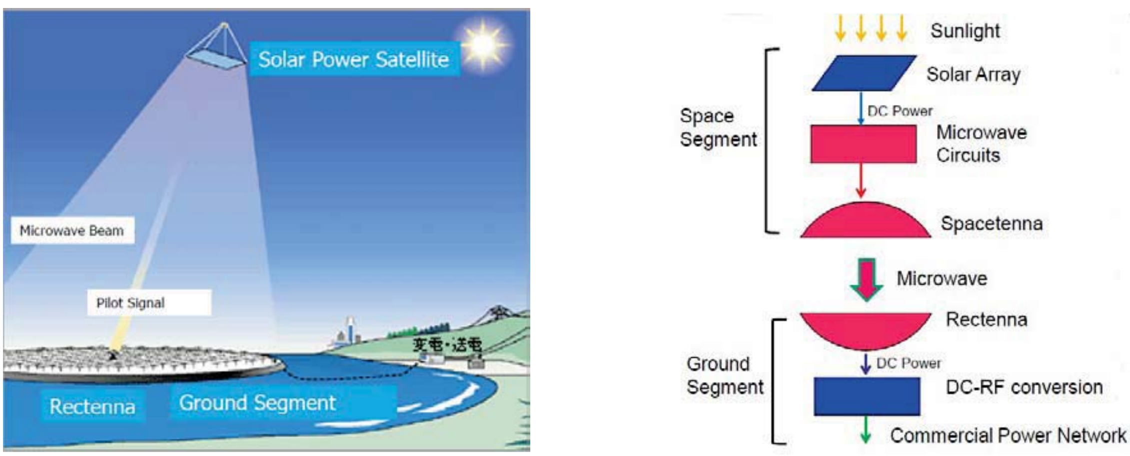
Before analyzing the prospects of solar power satellites in a developing country like Bangladesh, it is necessary to understand how the technology works and the historic advents. In 1964, William C. Brown demonstrated the use of microwaves to wirelessly send power to a miniature helicopter and enabled it to fly for over ten hours [5]. His experiment showed the basic premise of wireless power transmission as a transfer of energy emitted by a cavity magnetron and captured by diode receiver [5]. However, the Communication Satellite had been introduced quite earlier than that. In 1968, SPS concept was first proposed by Dr. P.E. Glaser. In '70s SPS assessments were done by NASA and DOE and the reference system was designed. Later in 1991-93 SPS feasibility study was also sponsored by NEDO and MITI. NASA had done Fresh Look Study in 1995-96 and Concept Definition Study on 1997-98. In 1998 NASDA defined SSPS concepts and R&D scenario to develop an SSP experiment satellite. In1999-2000 SERT program was launched by NASA and also SPS2000 Research. In 2000, Ralph Nansen, the president of Solar Space Industries, testified this system before the Congress. Later a 2007 NSSO study concluded that space based solar power is a viable solution to the looming international energy crisis[6].

Burt Rutan developed an evaluation of the air launch to enable the the upper stages to launch well above of the sensible atmosphere. This reduces aerodynamic loads, but may be limited by a reasonable takeoff weight. Current assembly concepts have assumed construction in low earth orbit. After completion, the solar power satellite would be transferred to a higher orbit like GEO or else. Propulsion to accomplish this is a critical issue. One concept that has the specific impulse to make transfer practical is Variable Specific Impulse Magnetoplasma Rocket (VASIMR). A NASA spinoff firm, Ad Astra Rocket Company, has announced a key milestone in ground testing of its prototype plasma drive technology, The VASIMR "helicon first stage" - which generates the plasma for acceleration and the rest of the drive would achieve its full rated power of 30 kilowatts using Argon propellant, according to the company. The idea of the plasma drives is to use electric power to blast reaction mass (in this case Argon) from its rocket nozzles at a much higher speed than regular chemical rockets can achieve [7].

There has been much advancement in subsystem technology that illustrates bright future of the SPS. These advances have included (a) improvements in photo-voltaic efficiency from about 10% (1970s) to more than 40% (2007); (b) increases in robotics capabilities from simple tele-operated manipulators in a few degrees of freedom (1970s) to fully autonomous robotics with insect-class intelligence and 30-100 degrees of freedom (2007); (c) increases in the efficiency of solid-state devices from around 20% (1970s) to as much as 70%-90% (2007); (d) improvements in materials for structures from simple aluminum (1970s) to advanced composites including nanotechnology composites (2007); (e) the application to large space structures; (f) high temperature super-conductors and many other technologies may be integrated into the design [7-8].

IV. Details of Solar Power Satellites (SPS)

To utilize the space as a power generation field, a highly efficient power transmission method is mandatory. Typical SPS system components can be classified as space segment and ground segment (schematics shown are in Figure2). Space segment constitutes solar array or panel to collect solar radiation, microwave circuits (like magnetron) to generate microwave, specetenna to transmit microwave to earth. The ground segment constitutes rectenna to receive microwaves and to rectify it in DC energy, DC-RF conversion section and commercial power network [2].



(a) (b)

Figure 2 : SPS illustrations (a) and the block diagram of the system (b)

Here a magnetron is a high power microwave oscillator in which the potential energy of an electron cloud near the cathode is converted into RF energy in a series of cavity resonators[]. The resonant frequency of a microwave cavity is thereby determined by the physical dimension of the resonator together with the reactive effect of any perturbations to the inductive or capacitive portion of the equivalent circuit. While the rectenna is a device designed to collect the energy associated to a free propagating EM wave and to transform it into Direct Current (DC) power, thus representing the key element for EM energy harvesting and wireless power transmission applications. Figure 3 shows the block diagram of the sub-sections of the rectenna.

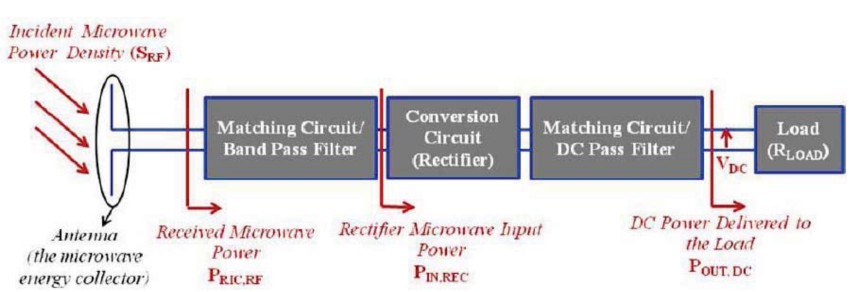


Figure 3 : Schematic representation of a rectenna

V. Drawbacks of SPS System

Lifting the satellites into orbit is extremely expensive, both financially and energetically. A series of launched could be necessary for optimized efficiency. Due to optical constraints, it is not feasible to scale down power satellites well, so 5 GW remains the smallest practical size possible which directly relates the cost of launching. Also, 50% of power generated by the time it is received on the ground would be lost due to conversion to microwaves, dispersion of energy during transmission and reconversion back from microwave. Outer space provides many potential hazards to the solar panels: space debris, space dust, asteroids, and extreme solar radiation. All of these could be very harmful to the integrity of the system. Nevertheless, a few practical experiments were conducted because even an experimental satellite power system would have cost billions of dollars to develop.

VI. Effectiveness of SPS in Bangladesh Perspective

People of Bangladesh now live in a society that has a growing demand for energy, while natural resources are being depleted. All current sources of energy here will sooner or later prove to be insufficient. So, the renewable and clean alternative sources are must. SPS would be an excellent solution in this regard. Also responding environmental threat, we need to move away from fossil fuels, diesels, oil from our transportation system. While electricity powers a few vehicles today in Bangladesh, hybrids will soon evolve into plug-in hybrids which would use electric energy from the grid. Due to rapid development of batteries, super-capacitors and fuel cells, the gasoline engine will gradually play a smaller and smaller role in transportation—but only if we can generate the enormous quantities of electrical energy. SPS can provide the needed clean power for any future electric transportation system. So, SPS would be really helpful for Bangladesh.

However, it involves placing satellites into space, outside the sovereign territory of any nation and to deliver energy to Earth via beams that pass through the atmosphere. Therefore, countries need to coordinate international agreements like available microwave transmission frequencies, satellite locations, and other necessary features of space operations in order to avoid international conflicts. The government of any developing country like Bangladesh would certainly have to play a critical role in international politics.

Although, SPS would be launched for the principal purpose of supplying power to earth, it would not only serve as the basis for the revitalization of the space industry which would be a luxurious thought for Bangladesh. We need to make sure of the maximum utilization of the SPS. It could be a key to the future economic strength and environmental health of our country. To justify the government investment in space solar power, the following factors would be important [8]:

- Space solar power would not require dependence on unstable or hostile foreign oil providers to meet energy needs, would enable us to expend resources in other ways.
- Space solar power could be exported to virtually any place in the world, and its energy could be converted for local needs — such as manufacture of methanol for use in rural places where there are no electric power grids. Space solar power can also be used for desalination of sea water.
- Space solar power would take advantage of our current and historic investment in aerospace expertise to expand employment opportunities in solving the difficult problems of energy security and climate change.
- Space solar power would provide a market large enough to develop the low-cost space transportation system that is required for its deployment. This, in turn, will also bring the resources of the solar system within economic reach.
- The Thunderstorm Solar Power Satellite (TSPS) is a concept for interacting with thunder-storms to prevent formation of tornadoes. TSPS benefits are saving lives and reducing property of the coastal areas which are in major weather threat.

a) Bangabandhu-1: The Probable Solution of SPS

Being a poor country, Bangladesh does not have the luxury of launching a series of test launch before the original SPS launch. Also it would remain a dream to launch a dedicated SPS besides communication Satellites. Even Bangladesh hasn't launched yet it's very first communication satellites. So, things aren't rosy here at all. But, the good news is Bangladesh is going to launch its first satellite into space in 2015, confirmed by Riajuddin Ahmed Raju, the current Posts and Telecommunications Minister of Bangladesh Government in a press conference on March 29, 2010. The project would cost 32,487 billion BDT and the satellite's life span would be around 25 years and the invests are supposed to be earned within first five years. The satellite would stay at 119.1˚e East longitudes. An US firm *"Space Partnership International (SPI)"* is assigned by the country to design and to launch the satellite [9]. SPS would be the intelligent integration with Bangabandhu-1, the proposed name of the Satellite. As the whole project is in initial stage, it would not be much problematic to include SPS module with the original design. As this research is a costly one, and the Government fund may not be so huge, the commercial involvement is also required here.

The Earth stations of satellite Bangabandhu 1 will be set up at Betbunia in Chittagong and the BTCL Staff College in Gazipur while a maintenance office will be established at the BTRC building at Ramna in the capital. In our SPS proposal, the placement of rectnna is always a complex issue although a little side effect is forecasted by the research work. As Bangladesh is an over-populated land and a few places are as open as rectenna placement demands. Bangladesh has a 724 km long coast line and many small islands in the Bay of Bengal. This vast area can be used intelligently in this regard. A floating rectenna can work in the same manner described earlier. The regions near the sea sore are the main areas to empower primarily by the proposed rectenna, and the other cities & villages also.

If Bangladesh can successfully launch only the Bangabandhu-1 satellite, it will earn more than $50m by renting out to other countries, such as Nepal, Bhutan, and Myanmar, every year. If the SPS module could integrate with that, more economical benefits would be confirmed.

VII. Conclusion

Space solar power would provide true energy independence for the nations that develop it, eliminating a major source of national competition for limited Earth-based energy resources. Bangabandhu-1 could be the one for us that can make a vision like SPS a reality. Here the Bangladesh government would certainly have to play a supportive role to assure that the best co-ordination. Before SPS modification can be safely attempted, the combined structure of the satellite must be simulated and tested well.

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A Comparison of Figure of Merit for Some Common Thermocouples in the High Temperature Range

By Jaspal Singh & S.S. Verma
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Abstract - Figure of merit along with low cost and easy availability are considered the important parameters of a thermoelectric material for its suitability and efficiency. This paper reports figure of merit for some common thermocouples as a function of thermal and electrical conductivity of thermoelectric materials in the high temperature range. The five different thermocouples are studied in normal mode (without any applied electric or magnetic field) for the generation of thermo emf and then the figure of merit is calculated. Finally, theoretical and experimental results are compared in the temperature range from 300-630 K.

Keywords : thermocouple, thermo emf, thermal conductivity, electrical conductivity and figure of merit.

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A Comparison of Figure of Merit for Some Common Thermocouples in the High Temperature Range

Jaspal Singh [α] & S.S. Verma [σ]

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Keywords : thermocouple, thermo emf, thermal conductivity, electrical conductivity and figure of merit.

I. Introduction

Thermoelectricity is a well known phenomenon to generate thermo emf by the thermoelectric materials. This phenomenon is based on the temperature gradient of the junctions a thermocouple. This technology is becoming famous due to a large number of thermocouple devices, which are able to generate energy in the considerable means and are also advantageous due to their pollution free nature, no moving parts and no complex designs. Applications range from house warmer systems to the advanced solar cell technologies [1-2].

Present days are the days of energy crises due to a much consumption of energy in all the fields with low efficient devices. Thermoelectricity can play a meaningful role to contribute towards energy crisis all along with renewable energy sources. This technique can easily generate the thermo emf in the considerable means with the advent of common thermocouples. The common thermoelectric materials like Cu, Fe, Al and Nichrome are very advantageous due to their low cost and easy availability [3-4].

The figure of merit is one of the most important term to describe the performance of the thermoelectric materials. This is the dimensionless quantity given by ZT $= \frac{\alpha^2 \sigma T}{\lambda}$ here α, σ and λ are the Seebeck constant, electrical conductivity and thermal conductivity of the thermoelectric material respectively. The temperature difference of the two junctions of the thermocouple is given by T. This has been observed that more is the figure of merit of a thermo electric material more is its efficiency and vice-versa. This is also clear from the relation that to enhance the figure of merit, the thermal conductivity should be minimum and the electrical conductivity should be maximum to the possible. Numbers of researchers working in the area of thermoelectric are oriented to improve figure of merit [5-7].

Normal mode of our study is the investigation of thermo emf generation under the conditions, i.e. without outside application of electric or magnetic fields [8-9]. We selected five thermocouples Cu-Fe, Fe-Nichrome, Constantan-Nichrome, Fe-constantan and Cu-Nichrome for present investigations on the basis of their less cost and easy availability. These thermocouples are investigated for the generation of thermo emf in wide temperature range from the room temp (300K) to 630K. The figure of merit for the thermocouples is calculated from the experimental data which is then compared with the calculated theoretical values. The standard equations of thermoelectricity are used for the calculations of present theoretical values.

II. Methodology

Present research findings represent to theoretical and experimental comparison of the figure of merit of some common thermocouples.

a) Theoretical Calculations

The figure of merit of all the thermocouples is calculated from the relation [10]:

$$Z = \frac{(\alpha_a - \alpha_b)^2}{[(\rho_a \lambda_a)^{1/2} + (\rho_b \lambda_b)^{1/2}]^2} \qquad (1)$$

Here α_a and α_b are the Seebeck constants (in V / °C) and and ρ_a & ρ_b are the resistivity's (specific resistances) (in Ω m) of both the materials of a thermocouple. Similarly, $\lambda_a$and λ_b are the thermal conductivities (in W $m^{-1}K^{-1}$) of both the thermoelectric materials. To calculate the figure of merit, we have used the theoretical values of all the physical properties of

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equation (1) for pure materials [10]. The X-ray diffraction peaks for elemental analysis of all four materials given in Figure 1 (a, b, c & d) show the presence of only major component of the main material and thus materials are taken near to be pure.

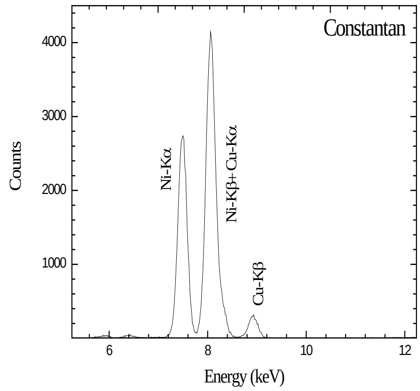

Figure 1(a) : Constantan Wire

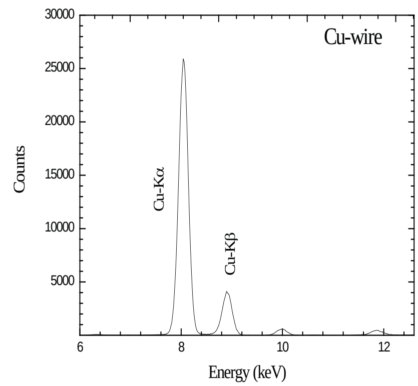

Figure 1(b) : Copper Wire

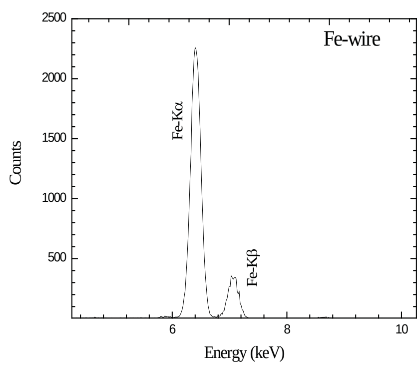

Figure 1(c) : Iron Wire

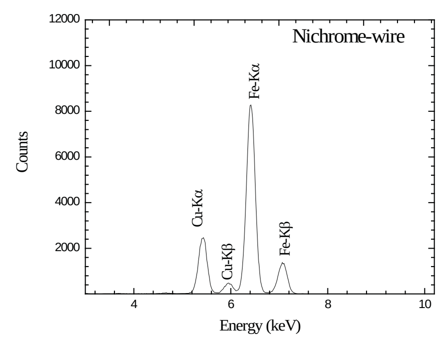

Figure 1(d) : Nichrome Wire

Figure 1 : (a, b, c & d): X-ray characterization graphs for different wires used presently to make the thermocouples

The values of all theoretical parameters take and thus calculated are given below in Tables 1 and 2:

Table 1 : Theoretical Parameters of the thermoelectric materials

Sr. No.	Parameter	Copper	Iron	Constantan	Nichrome
1.	Thermal Conductivity λ ($Wm^{-1}K^{-1}$)	401	80.4	19.5	11.3
2.	Seebeck Constant α ($\mu V/{}^0C$)	6.5	19	-35	25
3.	Resistivity ρ (Ohm-m)	$1.678x10^{-8}$	$9.6x10^{-8}$	$5x10^{-7}$	$1.5x10^{-6}$
4.	Electrical Conductivity σ ($S\ m^{-1}$)	$5.96x10^{7}$	$1.041x10^{7}$	$2x10^{7}$	$6.67x10^{5}$

Table 2 : Theoretical Values of Seebeck Constant (α) and Figure of Merit (Z) for different thermocouples

Sr. No.	Parameter	Cu-Fe	Fe-Nichrome	Cu-Nichrome	Fe-Constantan	Constantan-Nichrome
1.	Seebeck Constant α ($V/{}^0C$)	$1.3x10^{-5}$	$6x10^{-6}$	$1.9x10^{-5}$	$5.4x10^{-5}$	$6x10^{-5}$
2.	Figure of merit , Z (${}^0C^{-1}$)	$1.2x10^{-8}$	$1.3x10^{-7}$	$3.2x10^{-8}$	$1.22x10^{-5}$	$2.95x10^{-5}$

b) Experimental Calculations

We use the following mathematical equations to calculate the Figure of merit from the experimental parameters of the thermoelectric materials. The basic thermoelectric equation is:

$$E = \alpha t + \frac{1}{2}\beta t^2 \quad (2)$$

Here E is the thermo emf in mV and α, β are the Seebeck constants. The thermo power i.e. the rate of change of thermo emf w.r.t. time is given by: $\frac{dE}{dT} = \alpha + \beta t$ from (2) but β is very small so $\frac{dE}{dT} = \alpha$ and for the two thermoelectric materials (a thermocouple) α can be replaced by α_{ab} and by squaring we can write:

$$\left(\frac{dE}{dT}\right)^2 = (\alpha_{ab})^2 \quad (3)$$

Thus, the figure of merit is given by:

$$ZT = \frac{(\alpha_{ab})^2 T}{\rho\lambda} \quad (4)$$

We know that:

$$\rho = \frac{Ra}{l} \quad (5)$$

Here a and l are the area of crossection and length of the thermoelectric material respectively. Then from (3), (4) and (5), the figure of merit is given as:

$$ZT = \frac{\left(\frac{dE}{dT}\right)^2 T}{R\left(\frac{\lambda a}{l}\right)} \quad (6)$$

Putting $\frac{\lambda a}{l} = K$ then ZT becomes as [10]:

$$ZT = \frac{\left(\frac{dE}{dT}\right)^2 T}{RK} \quad (7)$$

As the final resistance of the thermocouple is a parallel combination of individual resistances, so R (of thermocouple) can be calculated as:

$$R = \frac{R_1 R_2}{R_1 + R_2} \quad (8)$$

Taking the value of K as:

$$K = \frac{K_1 + K_2}{2} \quad (9)$$

By using the values of K (Thermal Conductivity) and R (resistance) from equations (8) and (9) we calculate the figure of merit of equation (7). This is to note here that the value of $\frac{dE}{dT}$ is extracted from the slope of graph between thermo emf (E) and the temperature gradient (T) for the individual thermocouples. The equation for a linear fit of a graph is, $y = A + Bx$ and then the slope is $\frac{dy}{dx} = B$ but our graphs are between thermo emf (E) and the temperature difference (T) so $\frac{dE}{dT} = B$ (a constant numerical value i.e. Seebeck Constant α). Hence we can take $\frac{dE}{dT} = \alpha$

Table 3 : Experimental Calculations of Seebeck Constant (α) and Figure of Merit (Z) for different thermocouples

Sr. No.	Parameter	Cu-Fe	Fe-Nichrome	Cu-Nichrome	Fe-Constantan	Constantan-Nichrome
1.	$\frac{dE}{dT}$ = α (v/°C)	4.2×10^{-7}	1.32×10^{-6}	1.25×10^{-6}	1.955×10^{-5}	1.074×10^{-5}
2.	Z = $(dE/dT)^2$ / RK (°C^{-1})	1.7×10^{-10}	3.8×10^{-8}	1.3×10^{-9}	1.233×10^{-5}	8.5×10^{-6}

Table 4 : Experimental parameters of thermoelectric materials

Sr. No.	Parameter	Copper	Iron	Constantan	Nichrome
1.	Resistance (Ohm)	0.1918	0.7062	0.5174	1.6874
2.	Area of Cross-Section (m^2)	1.51×10^{-6}	9.5×10^{-7}	1.112×10^{-6}	9.7×10^{-7}
3.	Length (m)	48×10^{-2}	48×10^{-2}	48×10^{-2}	48×10^{-2}
4.	Resistivity ρ (Ohm-m)	6×10^{-6}	1.4×10^{-6}	1.2×10^{-6}	3.41×10^{-6}
5.	Electrical Conductivity σ (S m^{-1})	1.67×10^{6}	7.143×10^{5}	8.33×10^{5}	2.933×10^{5}

III. Experimental Setup

The four thermoelectric materials i.e., Cu, Fe, Constantan and Nichrome were used to fabricate five thermocouples of each wire of 48cm length. The basics of the experimental set up used in present studies stand same as in our earlier research [11] though with suitable modifications. A hot and cold temperature arrangement for thermocouple junctions was made with a wooden stand. An electric furnace was used to heat the junction and fresh water from tap with an arrangement was used to maintain the room temperature of the cold junction. The HP 34401 digital multi-meter was used to measure the thermo emf and resistance of the wires [11].

IV. Results and Discussion

Experimentally measured thermo emf as a function of temperature difference between hot and cold junctions for all five thermocouples is shown in Figure 2. Going through the performance comparison of different thermocouples from Figure 2, it is clear that for similar experimental conditions Fe-constantan thermocouple gives the maximum thermo emf generation where as Cu-Fe gives the least values. Thermo emf generation for Fe-constantan thermocouple increases to the highest temperature difference upto 3000C giving values to the range of 7mV.

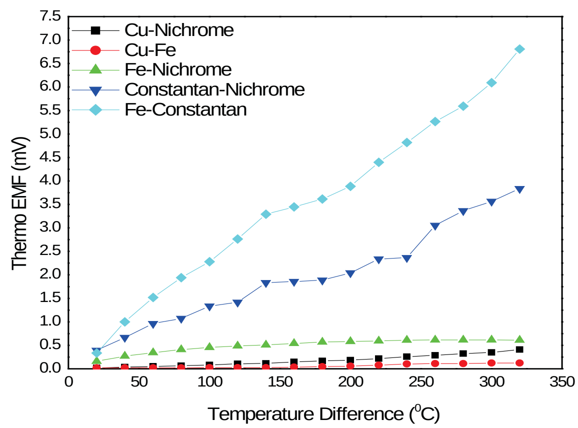

Figure 2 : Thermo emf generation with temperature difference of thermocouple junctions

From the above discussed theoretical and experimental calculations for Z, we obtained the theoretical and experimental values of dimensionless parameter ZT i.e. the figure of merit for all five thermocouples as a function of temperature difference, T in Kelvin of thermocouple junctions. A comparison of theoretical and experimentally calculated values of ZT with the temperature difference, T for each of the thermocouple was done and is shown in Figure 3 (a, b, c, d & e).

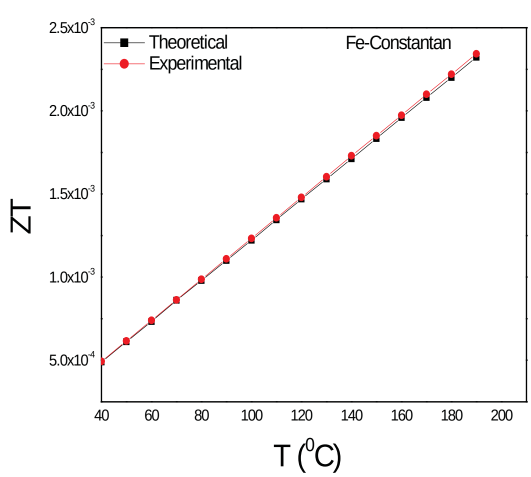

Figure 3(a) : Comparison for Fe-Constantan

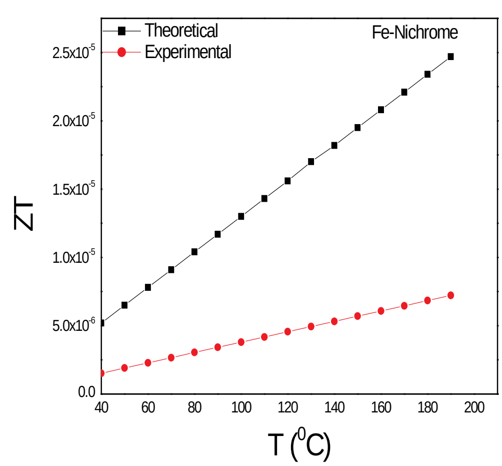

Figure 3(b) : Comparison for Fe-Nichrome

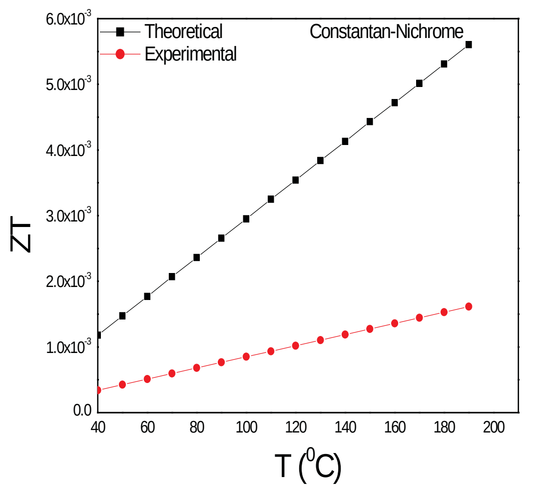

Figure 3(c) : Comparison for Constantan-Nichrome

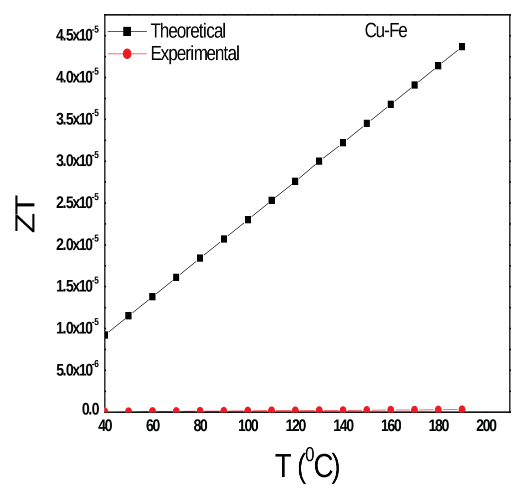

Figure 3(d) : Comparison for Copper-Iron

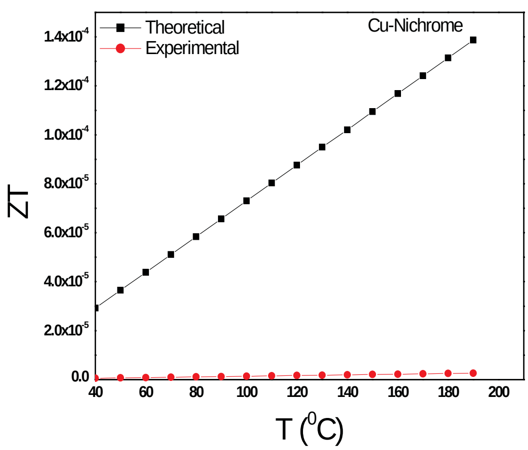

Figure 3(e) : Comparison for Copper-Nichrome

The comparison shows that there is a perfect matching between the theoretical and experimental values of figure of merit for the Fe-Constantan thermocouple, which not only confirms the accuracy of present measurements but also indicate the worthiness of this thermocouple for better performance in its uses in thermoelectrics. Theoretical vs experimental comparison also comes better for Fe-Nichrome and Constantan-Nichrome thermocouples but there was a significant difference between the values for other two i.e., Cu-Fe and Cu-Nichrome thermouples. The wide difference between theoretical and experimental values may be assigned to low levels of thermoemf generation in these thermocouples due their strong dependence on physical & chemical properties and operating parameters of thermocouple materials. Comparison of results directly indicates the superiority of Fe-Constantan thermocouple over other four thermocouples for their use in thermoelectrics.

V. Conclusions

This paper concludes that:

- Fe-Constantan shows a better thermocouple combination to match for their experimental and in the theoretical values of thermo emf generation.
- Poor matching of theoretical with experimental findings for thermocouples of Fe-Nichrome and Constantan-Nichrome indicates the uncertainty in the experimental behavior of Nichrome, significant contribution from its components or high inaccuracy in the values of its physical properties.
- More gaps between matching of theoretical and experiment values of thermo emf for Copper-Nichrome and Copper-Iron thermocouples again show the uncertainty in the experimental behavior of Nichrome, significant contribution from its components or high inaccuracy in the values of its physical properties.
- Influence of thermoelectric nature or properties of different thermocouple materials hence, indicates towards their performance in their thermoelectric applications.

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Performance Analysis of Four Wave Mixing Technique & Optical Add Drop Multiplexer(OADM) in Optical Fibre Communication System

By Avizit Basak & Md. Mohibur Rahman
University of Engineering & Technology (RUET), Bangladesh

Abstract - Optical fiber communication is the best for transmitting data at a high rate. While the fiber channel may be capable of transmitting terabit-per-second data rates, no existing single communication system can make complete use of this speed. Optical fibers in discussion that guide signals in the form of light are typically made of from two glasses. It is a cylindrical in shape waveguide consisting of a higher refractive index solid glass core which runs down middle of the fiber. The other solid glass with a lower refractive index surrounds the core and makes the homogeneous cladding. The two glasses are made of from the common material silica. Photonic crystal fibers can be divided into two modes of operation, according to their mechanism for confinement. Alternatively, one can create a photonic band gap fiber, in which the light is confined by a photonic band gap created by the micro structured cladding – such a band gap, properly designed, can confine light in a lower-index. Here, four wave mixing technique provides operational flexibility.

Keywords : OADM, WDM, FWM, DWDM, crosstalk, power penalty, dispersion etc.

GJRE-F Classification : FOR Code: 100506

PERFORMANCE ANALYSIS OF FOUR WAVE MIXING TECHNIQUE OPTICAL ADD DROP MULTIPLEXEROADMINOPTICAL FIBRE COMMUNICATION SYSTEM

Strictly as per the compliance and regulations of :

Performance Analysis of Four Wave Mixing Technique & Optical Add Drop Multiplexer(OADM) in Optical Fibre Communication System

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Abstract - Optical fiber communication is the best for transmitting data at a high rate. While the fiber channel may be capable of transmitting terabit-per-second data rates, no existing single communication system can make complete use of this speed. Optical fibers in discussion that guide signals in the form of light are typically made of from two glasses. It is a cylindrical in shape waveguide consisting of a higher refractive index solid glass core which runs down middle of the fiber. The other solid glass with a lower refractive index surrounds the core and makes the homogeneous cladding. The two glasses are made of from the common material silica. Photonic crystal fibers can be divided into two modes of operation, according to their mechanism for confinement. Alternatively, one can create a photonic band gap fiber, in which the light is confined by a photonic band gap created by the micro structured cladding – such a band gap, properly designed, can confine light in a lower-index. Here, four wave mixing technique provides operational flexibility. The effects of FWM are pronounced with decreased channel spacing of wavelengths and at high signal power levels. The interference FWM caused in WDM systems is known as inter channel crosstalk. FWM can be mitigated by using uneven channel spacing or fiber that increases dispersion. Moreover, OADM provides accurate operation while optical communication or telecommunication. With selective wavelength spacing, four-wave mixing is possible in OADM. Multiple channels of information carried over the same fiber, each using an individual wavelength in OADM. High optical fiber transmission is possible for four wave mixing and OADM. For this reason, OADM and four wave mixing is highly used in optical fibre communication.

Keywords : OADM, WDM, FWM, DWDM, crosstalk, power penalty, dispersion etc.

I. Introduction

In optical communications system the transmitter is a light source whose output acts as the carrier wave. An optical fiber transmission consists of three main parts: the transmitter block where the electrical signals will be transferred into optical fibers. The transmitter block consists of three major parts: the modulator, the carrier source, the channel coupler. First a transducer converts a non-electrical message into an electrical signal. This signal is called the message origin. Then the modulator converts it into proper message format. For long length transmission, laser diodes are used because of the narrow spectral width and high optical power that is used as carrier source to carry data over long distance. The light is then coupled into the transmission channel via the channel coupler to the optical fiber cable, where most of the dispersion and attenuation takes place. The receiver block which is the last part of the system which converts the optical signal back into the replica of the electrical signal using PIN-type photodiode then to the amplification stage before reaching the end. Narinder Kapany, the man who first coined the term "fiber optics" in 1956, developed the first fiberscope. This image-transmitting device used the first all-glass fiber. The early all-glass fibers experienced large amount of optical losses thus limiting the transmission distance. This was because the transparent transmitting rod was surrounded by air and as a consequence, excessive losses occurred at any discontinuities of the glass-air interface. This realization motivated scientists to develop glass fibers that included a separate glass coating. The fiber was made of two layers. The innermost region of the fiber referred to as the core, was used to transmit the light while the glass coating or the cladding prevented the light from leaking out of the core by reflecting it within its boundaries.

II. Multiplexing

Multiplexing is an essential technique for fibre optic communication. It is a method by which multiple analogue message signals or digital data streams are combined into one signal over a shared medium. The aim is to share an expensive resource. The multiplexed signal is transmitted over a communication channel, which may be a physical transmission medium. The multiplexing divides the capacity of the high-level communication channel into several low-level logical channels, one for each message signal or data stream to be transferred. Multiplexing technologies may be divided into several types. Such as space-division multiplexing (SDM), frequency-division multiplexing

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(FDM), time-division multiplexing (TDM), and code division multiplexing (CDM), Board WDM, Coarse WDM, Dense WDM, etc. CWDM, DWDM, OADM are mostly used in telecommunication & computer networks. Wavelength Division Multiplexing is the technology enabling cost efficient upgrade of capacity in optical networks. This explains the fundamental principles for optical networks.

III. Four-Wave Mixing

Four-wave mixing is an inter modulation phenomenon in non-linear optics, whereby interactions between two wavelengths produce two extra wavelengths in the signal. It is similar to the third-order intercept point in electrical systems. When optical communication systems are operated at moderate power it is important to consider the effect of nonlinearities. In case of WDM systems, nonlinear effects can become important even at moderate powers and bit rates. One type of nonlinear effects are caused by the dependence of refractive index on the intensity of the optical power. This is called four-wave mixing.Effectively, the FWM powers introduced before and after this point are summed instead of the electric fields being added in phase, resulting in a smaller FWM penalty.

IV. Optical ADD-DROP Multiplexer

OADM is a device used in wavelength-division multiplexing systems for multiplexing and routing different channels of light into or out of a single mode fiber. This is a type of optical node, which is generally used for the construction of optical telecommunications networks. An OADM may be considered to be a specific type of optical cross-connect. A traditional OADM consists of three stages: an optical demultiplexer, an optical multiplexer, and between them a method of reconfiguring the paths between the optical demultiplexer, the optical multiplexer and a set of ports for adding and dropping signals. The optical demultiplexer separates wavelengths in an input fiber onto ports.The optical multiplexer multiplexes the wavelength channels that are to continue on from demultipexer ports with those from the add ports, onto a single output fiber. All the light paths that directly pass an OADM are termed cut-through light paths, while those that are added or dropped at the OADM node are termed added/dropped light paths. Using a pair of MUX/DMUX'es at the intermediate node enables manual selection of the wavelengths to add and drop, using patch-cords for configuration. Gradual and flexible upgrade is then possible, adding capacity between the nodes according to where an increased need for more bandwidth is observed. When dimensioning an optical network using add/drop multiplexing, insertion loss of the MUX/DMUX units becomes a critical parameter for the link budget since several devices are coupled in series.

V. System Crosstalk & Power Penalty

Crosstalk occurs in multi channel optical transmission systems. Crosstalk can be caused by the following: the spectral skirts of one channel entering the de-multiplexing and filtering pass-band of another cause crosstalk, practical limits on selectivity and isolation cause crosstalk. Non-linear effects within the fiber at the high power densities possible in single mode systems can cause crosstalk or cross modulation, the mechanism is Raman scattering, which is a non-linear stimulated scattering effect that allows the optical power at one wavelength to affect scattering and thus the optical power in another wavelength. In optical communication the receiver sensitivity is defined with respect to the receiver noise for several basic detection scenarios. The power penalty is equal to the increase in signal power that is needed to keep the Q-factor and BER at the same level that would exist if no impairments were present. The impact of different impairments can cause different power penalties such as Power Penalty due to Extinction Ratio, Power Penalty due to Intensity Noise, etc.

VI. Performance Evaluation of Four Wave Mixing

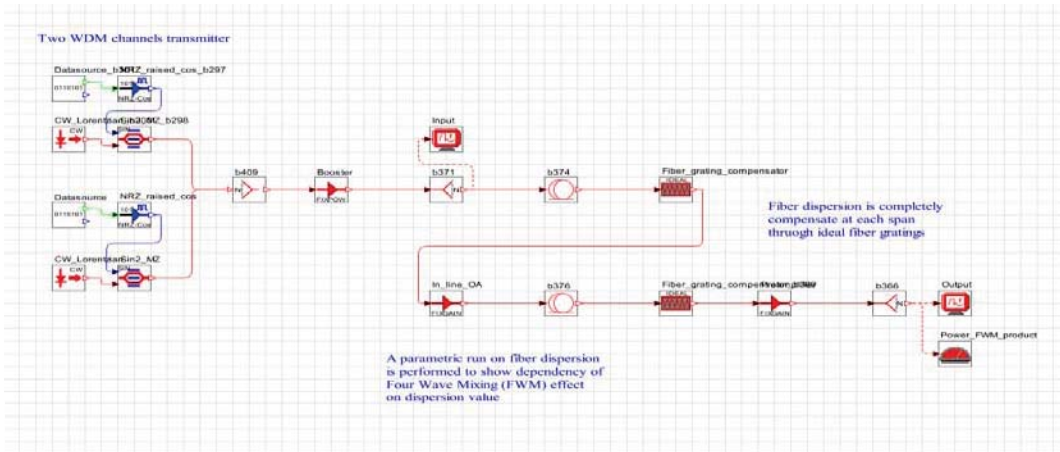

Figure 1 : Basic diagram of Four Wave Mixing

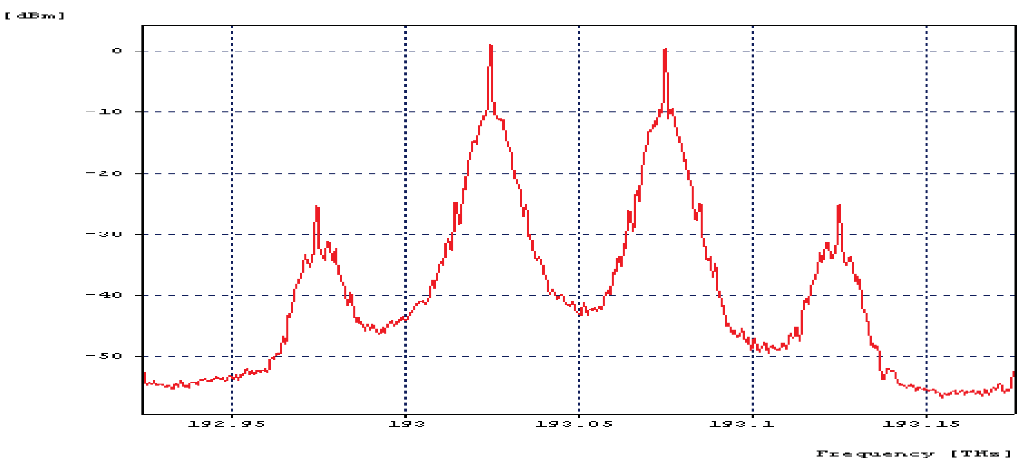

Figure 2 : Basic Optical Spectrum of Four Wave Mixing

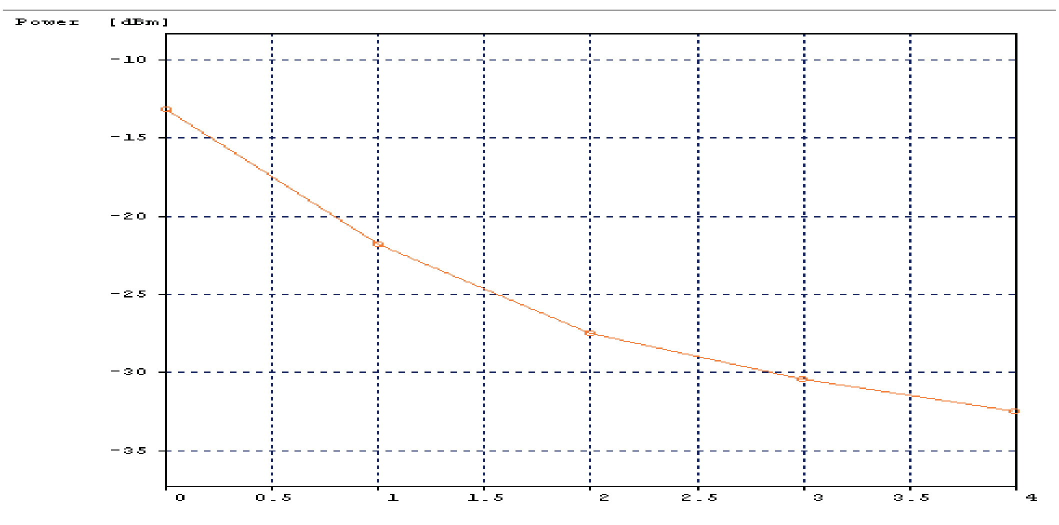

Figure 3 : Power level of Four Wave Mixing

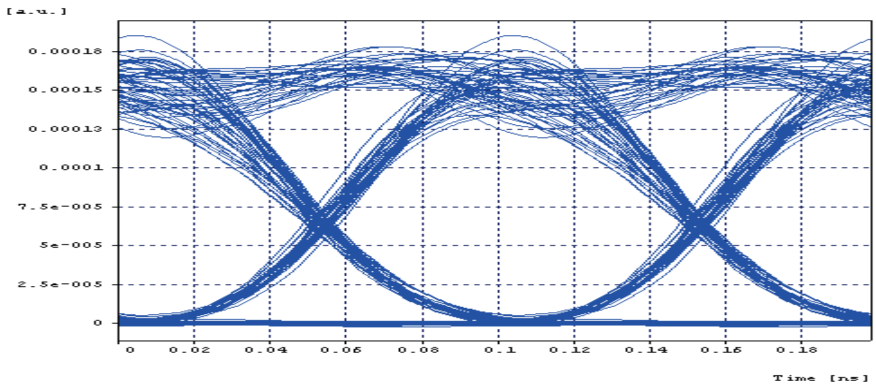

Figure 4 : Eye diagram while dispersion

VII. Performance Evaluation of Optical ADD DROP Multiplexer

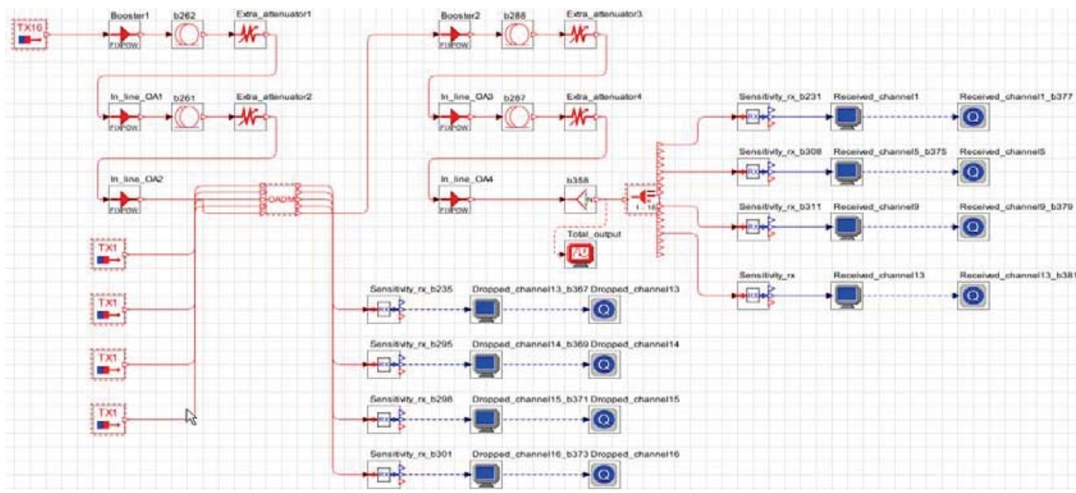

Figure 5 : Basic diagram of Optical add drop multiplexer

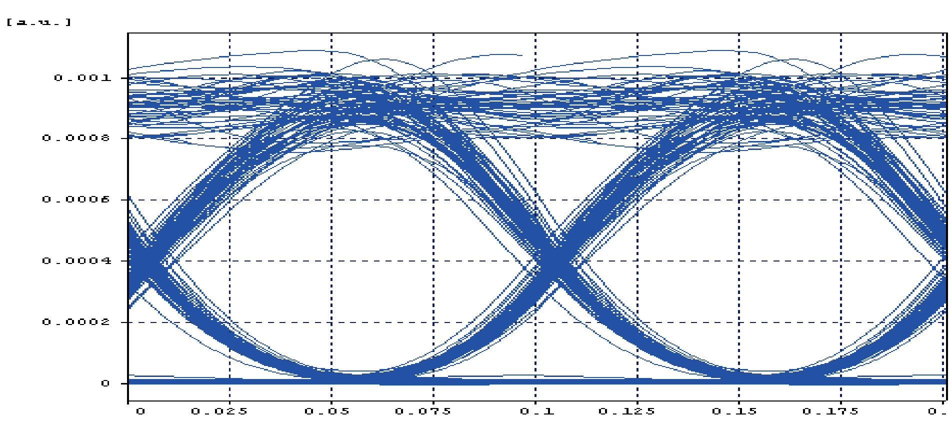

Figure 6 : Eye diagram of Optical add drop multiplexer

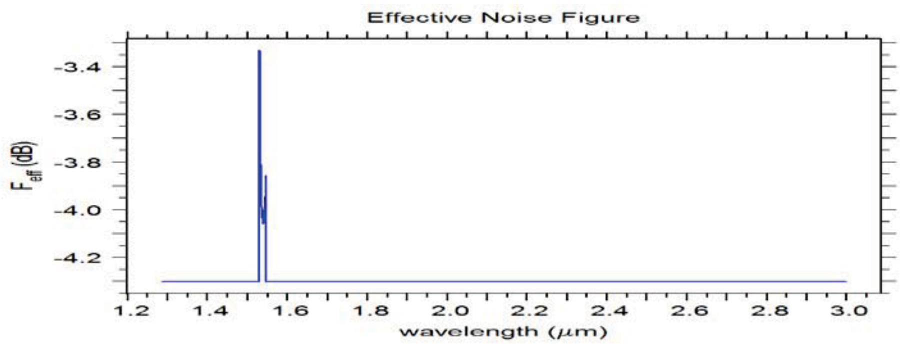

Figure 7: Effective noise figure while multiplexing

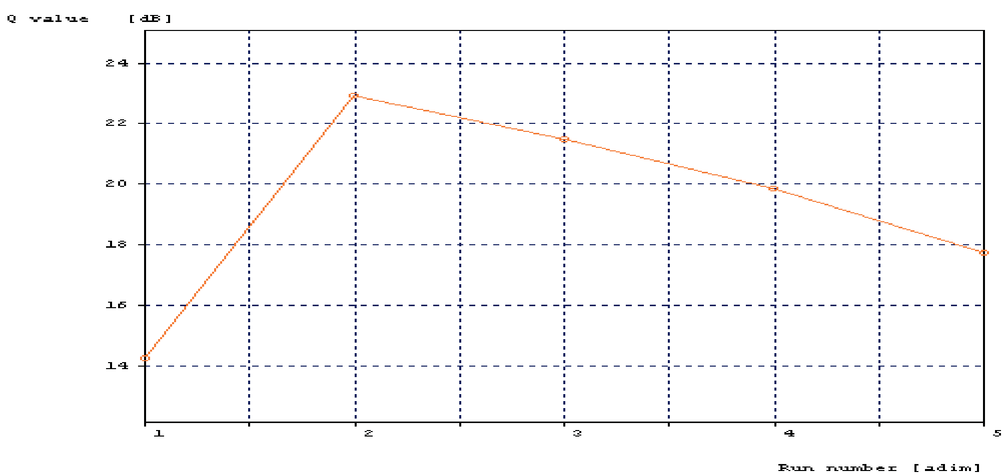

Figure 8 : Q factor of Optical add drop multiplexer

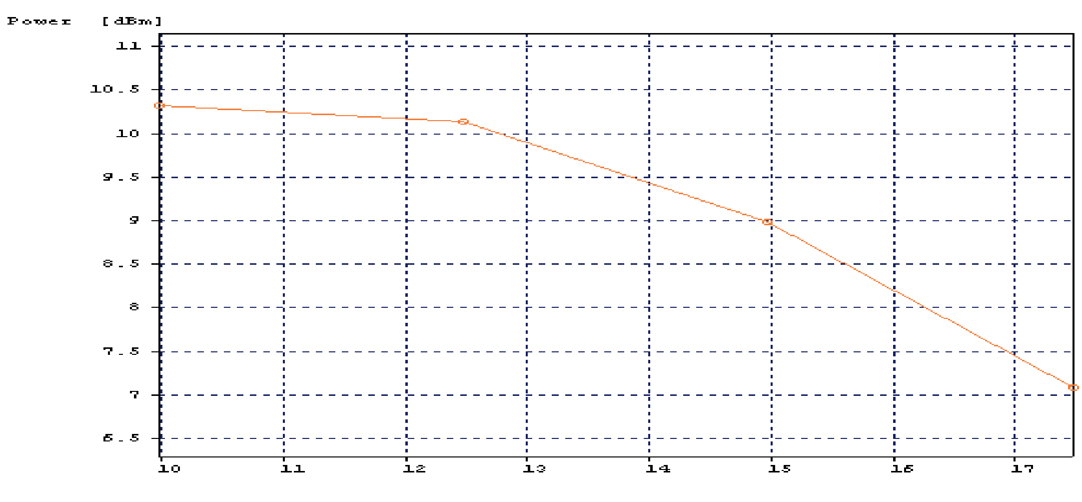

Figure 9 : Output power of Optical add drop multiplexer

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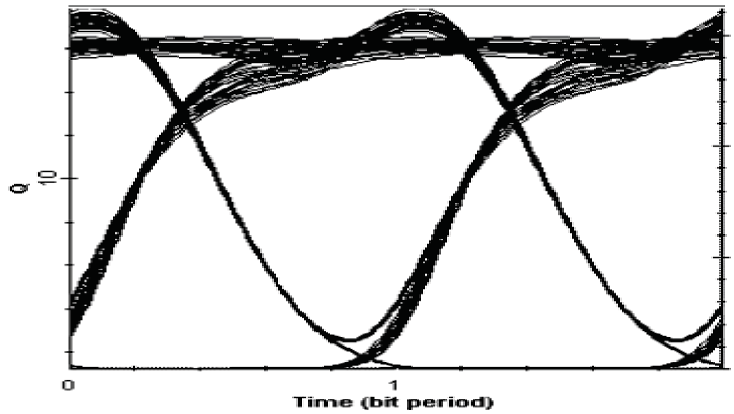

Figure 10 : Dispersion in fibre while multiplexing

VIII. Advantages of Optical Add Drop Multiplexer

The main advantages of OADM –

- Its multiplexing happens to coincide with the minimum loss area of single-mode fiber. This reduces the transmission loss of the light signal which can be transmitted relatively far distance.
- It is transparent to digital signal format and data rate.
- It is so wide that dozens or even hundreds of channels can be transmitted in the same fiber.
- It has low noise figure close to the quantum limit.
- Its gain saturation recovery time is long, and has a very small crosstalk between the respective channels.
- Narrow channel spacing or wavelength selection, giving rise to denser channels in the same wavelength range.
- With selective wavelength spacing, four-wave mixing is possible.
- Multiple channels of information carried over the same fiber, each using an individual wavelength.
- Repeater or amplification sites are reduced, resulting in a large savings of funding.

IX. Advantages of Four Wave Mixing

The main advantages of Four Wave Mixing –

- High optical fiber transmission capacity.
- Improve the utilization of the resources of optical fiber.
- High Mechanical sensitivity.
- Very good flexibility.
- Easily used in metro network.
- Excellent performance.

X. Conclusion

Here, investigations are made according to the specific wavelength range. From the numerical simulation results, better power level, low losses, better eye diagram, Q factor in the telecommunication operation. Moreover, Optical communications by OADM enabling high-speed, high capacity optical communication system for the Internet age. In addition, to the stability required for sources passive modules such as mux/demux and add/drop modules used in systems OADM also need to have very narrow filtering or wavelength separating characteristics that stay stable over a considerable temperature range. Moreover, to maintain proper operation with less losses and to confirm operational flexibility four wave mixing is used. In addition, we can choose the parameters in four wave mixing to achieve the desirable dispersion compensation over different communication band.

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Optimum Utilization of Spectrum Holes in Cognitive Radio Networks using Opportunistic Spectrum Band Allocation Policy for Handoff Prioritization

By Sudha Arvind, Dr. V. D. Mytri & Archana Hoskhande
Guru Nanak Dev Engineering College, India

Abstract - Two main problems in wireless communications are, limited available spectrum and inefficiency in the spectrum allocation policy. These problems lead to the blocking of both initial and hand-off calls. Cognitive radio (CR) offers solution by utilizing the spectrum holes in space without introducing an unacceptable fear of harmful interference for the primary user and also solves the spectrum inefficiency and spectrum scarcity problem. Spectrum allocation scheme is proposed in two phases. In the first phase, a collision between two calls for spectral band allocation is resolved. In second phase, spectral band allocation among a number of calls is considered. The main objective is to minimize the forced termination of hand-off calls and to achieve opportunistic spectrum channel allocation by assigning different priority levels to different calls.

Keywords : cognitive radio networks, wireless communication, spectrum allocation policy, hand-off.

GJRE-F Classification : FOR Code: 890405, 090699

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Sudha Arvind [α], Dr. V. D. Mytri [σ] & Archana Hoskhande [ρ]

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Keywords : cognitive radio networks, wireless communication, spectrum allocation policy, hand-off.

I. Introduction

Two critical problems play important role on the wireless communication network and they are (1) limited available spectrum (2) inefficiency in the spectrum allocation policy [5]. As the available spectrum is becoming insufficient due to growing demand, many schemes have been proposed to utilize the spectrum more effectively and efficiently. Actually a large pool of spectrum remains unused due to improper channel allocation policy. New paradigm called xG network, dynamic spectrum access network or the cognitive radio networks have been proposed to address the above mentioned problems [1][5]. The key enabling technology of xG networks is the cognitive radio. Cognitive radio techniques provide the capability to use or share the spectrum in an opportunistic manner.

Dynamic spectrum access techniques allow the cognitive radio to operate in the best available channel. More specifically, the cognitive radio technology will enable the users to determine which portions of the spectrum is available and detect the presence of licensed users when a user operates in a licensed band (spectrum sensing), select the best available channel (spectrum management), coordinate access to this channel with other users (spectrum sharing), and vacate the channel when a licensed user is detected (spectrum mobility). The main functions for cognitive radios in xG networks can be summarized as follows:

Spectrum sensing : Detecting unused spectrum and sharing the spectrum without harmful interference with other users.

Spectrum management : Capturing the best available spectrum to meet user communication requirements.

Spectrum mobility : Maintaining seamless communication requirements during the transition to better spectrum.

Spectrum sharing : Providing the fair spectrum scheduling method among coexisting xG users.

These functionalities of xG networks enable spectrum- aware communication protocols.

The xG network communication components and their interactions are illustrated in Fig 1. It is evident from the significant number of interactions that the xG network functionalities necessitate a cross-layer design approach [5].

Entire wireless network is divided into a number of cells also known as zones. Each cell serves two kinds of requests (1) Initial access request and (2) hand-off request [1]. Once a communication starts, user may not be fixed to a particular station but roams from one location to the other and demands for ubiquitous network access. While moving, user actually goes through a number of cells between both the locations, each time he leaves the currently occupied cell and enters into a new one. This is known as inter-cellular hand-off [2] and the call is known as hand-off call.

While leaving the existing cell and entering into a new one, the base station of the destination cell provides a new spectral band to continue the communication. If the destination cell does not have enough spectral bands the call will be blocked.

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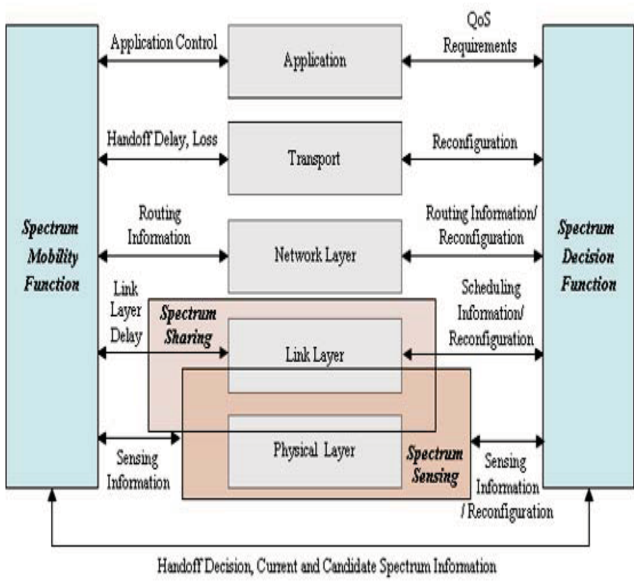

Figure 1 : xG network communication functionalities

Our approach is to limit the probability of this forced termination of an ongoing call. We can reduce the chances of unsuccessful hand-off by assigning higher priority to hand-off request than that assigned to initial access request. Efforts are made to propose a spectrum assignment policy having a tradeoff between minimization of the call blocking rate of an ongoing call for smooth hand-off and risk of compromising the whole traffic due to a priority based treatment of the calls.

a) Handoff Technique

The large geographic area covered by the network is divided into small zones called *cells*. The base station of each cell in the network has to serve two streams of requests, one coming from the cell itself (*initial access requests*), and the other coming from neighbor cells (*hand-off calls*). Once a call has started, the mobile station (MS) might leave the initial cell, entering a neighbor one, while remaining connected to the network. Mobiles crossing the cell boundary cannot continue to use the same frequency channel because different channels are assigned to adjacent cells to avoid radio interferences in the shared transmission medium. Intercellular handoff is the procedure by which the user, while releasing the old frequency channel belonging to the initial cell, is provided with a new one by the base station of the destination cell. This procedure is fundamental to avoid any interruption of the initiated connections. If the destination cell does not have enough channels to support the handoff, the call is blocked. It is important to limit the probability of forced termination, because from a user's perspective, the forced termination of an ongoing call is less desirable than getting a busy signal due to the block of an initial access attempt. The system can reduce the chances of unsuccessful handoff by assigning higher priority to handoff requests than that assigned to initial access requests.

These handoff prioritizing schemes provide improved performance at the expense of a reduction in the total admitted traffic [1].

CR users are generally regarded as `visitors' to the spectrum. Hence, if the specific portion of the spectrum in use is required by a PU, the communication needs to be continued in another vacant portion of the spectrum. This notion is called spectrum mobility. Spectrum mobility gives rise to a new type of handoff in CR networks, the so-called spectrum handoff, in which, the users transfer their connections to an unused spectrum band. In CR ad hoc networks, spectrum handoff occurs: 1) when PU is detected, 2) the CR user loses its connection resulting from the mobility of users involved in an on-going communication, or 3) with a current spectrum band cannot provide the QoS requirements.

In spectrum handoff, temporary communication break is inevitable because of the process for discovering a new available spectrum band. Since available spectrums are dis-contiguous and distributed over a wide frequency range, CR users may require the reconfiguration of operation frequency in its RF front-end, which leads to a significantly longer switching time.

Spectrum handoff has been done for cognitive radio networks especially in the case when transmissions are done over multiple channels in parallel. The spectrum handoff occurs when licensed users are detected in the channel. Thus, CR user has to leave the channel immediately and search for a new available one. During the handoff operation, the communication of CR user has to be interrupted and packets must wait in the transmission buffer. The communication can be resumed when the connection is successfully moved to the new channel. From this point of view, large waiting delays can be incurred and packets may be lost. Sometimes, licensed users may use the channel only for short periods intermittently. The frequency of spectrum handoff can be reduced if CR users wait until licensed users finish their transmission to send again over the same channel. Here, predicting the behavior of licensed users in the near future assists CR users to decide whether it should keep the current channel or leave it. Typically, prediction should improve the performance of the spectrum handoff [10].

In CR networks, the unlicensed devices (also Known as Secondary users) share the licensed spectrum without interfering with the transmission of other licensed users (also known as primary users). If this band is found to be occupied by a licensed user, the CR user moves to another spectrum hole to avoid interference, which is referred to as spectrum mobility. CR cellular networks lies in spectrum mobility, which gives rise to a new type of handoff in CR cellular networks, the so-called spectrum handoff [14]. Similarly in the DSA schemes, the SU and PU transmissions are

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treated as calls which are assigned dedicated frequency bands. However, an SU should relinquish its frequency band when a PU call claims it, because the PU call assignment is oblivious of any ongoing SU calls. The central controller admits an SU call if the requested bandwidth is available, and performs spectrum handoff (i.e., reassigning an SU call to another vacant frequency band when it interferes with a new PU call). an incoming SU call was queued till a new transmission opportunity was found. Also, the SUs which experienced handoff failure were dropped.

The effect of a buffer for SU call arrivals was considered. SUs which experienced handoff failure were dropped. The SUs were queued upon handoff failure and reassigned to channels when they are available. Thus, the SU transmissions were prevented from forced termination due to a PU arrival. Hence DSA scheme which considered channel reservation for SU handoff. An incoming SU call was assigned a channel only when the number of idle channels in the licensed spectrum exceeds the number of channels reserved for SU handoff. According to the DSA scheme, the central controller assigned as much as possible bandwidth to the SUs to improve the spectrum utilization. This bandwidth assignment was performed whenever the system state changed [16].

This paper in section-1 has a brief introduction of the problem, section-2 provides the problem objective and problem definition, section-3 consists of two spectrum allocation policies, section-4 gives analysis of the initial as well as revised scheme, section-5simulation results and section-6 concludes the paper with future work.

II. Problem Formulation and Goal

The two critical problems that are tackled using the concept of Cognitive Radio or Dynamic Spectrum Access are (1) Limited available Spectrum (2) Inefficiency in the spectrum usage and spectrum allocation policy [5]. These two problems mainly leads to the blocking of a hand-off call. Framework of a wireless cellular network is built up of a number of cells; each cell serves two types of request (1) Initial Attempt Request (2) hand-off Request [1].

a) Initial Attempt Request

Initial Attempt request is nothing but the request that has originated from the same cell for allocation of the spectrum to begin a communication in a cellular network.

b) Hand-off Request

The request to provide the spectrum bands as the user switches through different cells is made by the cellular user to achieve uninterrupted communication. This request is called hand-off request. A hand-off request may occur in following conditions with both primary (licensed) user and secondary (unlicensed) user [5].

c) Hand-off request with

Primary user : Hand-off occurs with primary users

- When quality deteriorates
- A spectrum band with better quality of service becomes available.

Secondary user: Hand-off occurs with secondary user

- When inter-cellular hand-off results due to roaming.
- When the licensed user for the band that is being utilized by a secondary user appears.
- When a better spectrum as per the requirement becomes available.

Problem occurs when the destination cell does not have enough spectrum bands as a result of it the hand-off call is blocked. It is less desirable to have the forced termination of an ongoing call and to provide the band to an initial request of which the communication has not yet been started.

Our efforts are projected to deal with the following issues:

- To overcome the problem of limited available spectrum through opportunistic usage.
- Improvement in spectrum allocation policy.
- Maximum possible utilization of available spectrum.
- To come up to the requirements and expectations of both licensed as well as unlicensed users.
- To allow the utilization of licensed spectrum in unlicensed user's zone opportunistically without any interference with the licensed users.

d) Why the problem is being addressed?

Today's trend is to have the exclusive rights of a specific portion of the spectrum, no matter whether the spectrum is really being utilized to the full of its strength or not. Spatially and temporally, the spectrum band stays idle most of the time with no communication activities being carried out by the primary user[5].

e) Our approach to solve the problem

Our approach is to minimize the probabilities of unsuccessful hand-off by assigning higher priority to the hand-off requests in comparison to the initial attempt request. This prioritizing scheme suggests better utilization of spectrum and also causes the reduction in total admitted traffic. This priority assignment treatment can be extended to the limit where the reduction in the over-all traffic due to the insufficient weight to the initial access request can be afforded. We have developed a prioritization scheme in which each incoming request will be classified based on four existing classes and treated accordingly.

All the incoming request are classified into four categories

- Primary hand-off request (PH)
- Primary initial request (PI)
- Secondary hand-off request (SH)
- Secondary initial request (SI).

The priority assignment policy will be in the order PH > PI > SH > SI.

III. Proposed Work

The proposed scheme has been designed through two phases and the second phase is an improvement of the first phase. Initially, we started out with a priority assigning policy in which the priority was being assigned to two different calls competing for spectrum band in various scenarios. The revised scheme deals with priority assignment and spectral band allocation among a set of requests.

a) Initial Scheme

The whole available spectrum is divided into two parts; (1) hand-off channels (2) Initial channels. The hand-off channels constitute that portion of the spectrum which has already been dedicated entirely for hand-off calls. On the other hand initial channels are to serve initial access request. The users are divided into two classes; (1) primary user (licensed user or exclusive right holder of the spectrum band) (2) secondary user (unlicensed user, has no exclusive right on spectrum). Finally the calls are categorized into four streams; (1) primary hand-off (PH) call (2) primary initial (PI) call (3) secondary hand-off (SH) call (4) secondary initial (SI) call.

- A PH call occurs when either the quality of the spectrum band deteriorates or a band of spectrum with better quality of service becomes available.
- A PI call occurs when a call generated from a licensed user.
- A SH call appears due to mobility of the user after the communication has been started. This can be due to (1) when the primary user of the band (currently used by secondary user) appears (2) when quality deteriorates (3) when a spectrum band with better quality of service becomes available.
- A SI call occurs when an initial access request from an unlicensed user originates

In this scheme, we have developed several rules to resolve the conflict between any two calls and one of the four possible scenarios in which bands occur in spectrum holes. In each case, a conflict is being considered between two users.

Conflict for channel accessibility between user one and user two can have following cases:

1) primary user (PU) vs primary user (PU)
2) secondary user (SU) vs secondary user (SU)
3) primary user (PU) vs secondary user (SU)

There are four scenarios assumed for the spectrum hole;

(1) No band is available (2) one band is available
(3) Two bands are available (4) More than two bands are available.

The notion in this initial approach is to first compare the priority of both the calls and one of the following scenarios will be examine.

- If bands are available then they will be allocated to each call smoothly.
- If only one free band is available then it will be allocated to the higher priority call and the other call will have to wait for a time duration ‘t’ (prespecified), within this time duration successive holes will be examined till a free band is achieved.
- If within this time duration no free band could be found, then the call will be dropped.
- If no band is available successive spectrum holes will be searched till a free band is accessed within the time duration ‘t’. The first free band will be allocated to the higher priority call while lower has to wait. If no free band occurs within time limit‘t’, then both the calls will be dropped.

As the spectrum is divided in two parts initial and the handoff, if at any point of time initial bands are available then they can be directly allocated to the calls irrespective of their type.

In case of hand-off bands if the requirement is to allocate them to some initial calls, first following three parameters will be examined.

1) Handsuccdur: Time between two successive hand-off
2) Handfreq: Frequency of occurrence of hand-off call
3) ExpectedHandTraffic: Expected hand-off traffic

If first parameter is greater than a specific threshold and second and third are less than their respective thresholds then hand-off band can be allocated to an initial call. Each time when an initial band is allocated to a hand-off request, first this band’s entry is made in the pool of hand-off bands and when a hand-off band is allocated to an initial request, first it is admitted to a pool of initial bands, after this allocation first free band will be assigned to the pool from which the band was borrowed.

b) Revised Scheme

The spectrum is divided into a number of primary user groups. In each primary user group, there are a number of mobile hosts or users. A specific licensed frequency band provided to each group with respect to which that group is a primary user group, rest of the spectrum band is unlicensed zone for the mobile hosts of that specific user group. With each primary user group four queues are associated;

1) Primary hand-off queue 2) Primary initial queue 3)Secondary hand-off queue 4) Secondary initial queue All the holes in the licensed zone of a specific primary user group are detected.

This proposed scheme has following two steps:

1) Spectrum is sensed to detect the primary users who are currently active.
2) Based on above information spectrum holes or white spaces will be recognized.

IV. Analysis of the Proposed Scheme

In this section, we are going to analyze both the schemes Initial as well as revised.

a) Analysis of Initial scheme

This scheme takes care of all the possible configurations in which a conflict for spectral band between two requesting calls can be resolved. In this scheme our effort focuses on three dimensions of wireless communications (1) Scarcity of available spectrum, (2) Inefficient spectrum allocation policy and (3) Reduction in the probability of forced termination of an ongoing call. The key idea that is being taken into consideration is giving priority to the band allocation to a hand-off request in comparison of the initial access request.

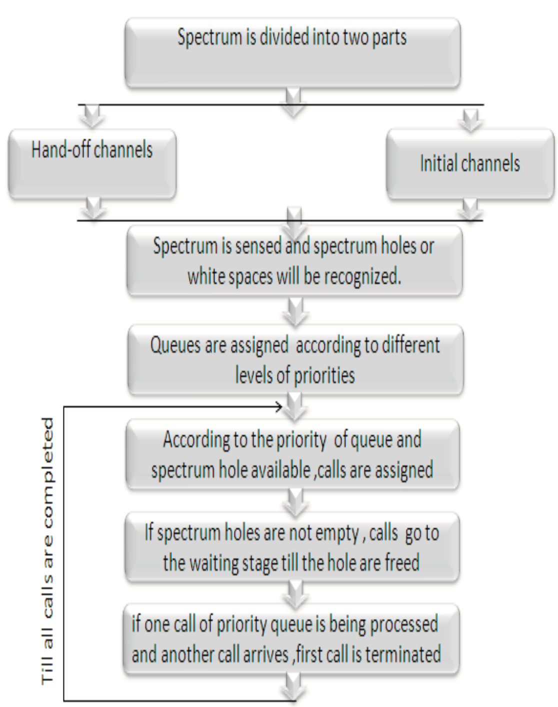

Figure 2 : Data Flow Diagram

Thus in the scheme first call is classified into four categories: a) Primary hand-off Request, b) Primary Initial Request, c) Secondary hand-off Request, d) Secondary Initial Request.

i. *Justification of priority assignment*

Primary hand-off is given highest priority as it is a request from a licensed user and also for ongoing communication. Second highest priority is given to primary initial, though it's a request to initiate a communication, but this request is made by a licensed user. Third higher priority is allocated to the secondary hand-off, though this request is from unlicensed user but is for an ongoing communication. Secondary initial is given the lowest priority because it is a request from an unlicensed user and it is to initiate a communication.

In this scheme total spectrum is divided into two parts 1) hand-off spectral bands and 2) initial spectral bands. The idea is to again give preference to the hand-off request. Thus the assumption is to dedicate some of the bands of this spectrum for hand-off calls.

The good part of the theorem is that if an initial band exists it can be allocated to the hand-off request directly but if a hand- off band is to allocate to an initial call then first three important parameters will be examined.

1. Average time duration between two successive occurrences of hand-off calls.
2. Frequency of occurrence of hand-off calls
3. Expected hand-off traffic

When all the three parameters will be satisfied only then a spectrum band will be allocated to an initial call. Each time an initial band is allocated to a hand-off request, the band's entry is made in the pool of hand-off bands and when a handoff band is allocated to an initial request, it is admitted to a pool of initial bands. This policy is to balance the population of both types of bands at any instant. It keeps a check on the number of bands shifted from hand-off to initial pool and returns the equal number of bands from the initial pool to the hand-off pool (vice versa).

b) Analysis of Revised Scheme

In our scheme we are taking into consideration four candidates PH, PI, SH, SI. The hand-off calls are assigned with more priority in comparison to initial calls and primary user calls are given higher priority in comparison of the secondary user. Our approach to minimize the probability of forced termination of an ongoing call is achieved, as hand-off calls are being provided a higher priority in comparison to the initial access request. Priority assignment policy assigns highest priority to the primary hand-off. Next priority is given to the primary initial though it's an initial call but is being generated by a licensed user. Third priority level is assigned to secondary hand-off which again is significant as being a handoff call though coming from a secondary user. The lowest priority is assigned to secondary initial, a request from an unlicensed user to originate a call.

The usage of four priority queues PHQ, PIQ, SHQ, SIQ is used for allocation of spectrum when a higher priority request is occurring along with other lower priority requests. If in the request pool multiple primary hand-offs, primary initials, secondary hand-offs and secondary initials are present, then all will be queued in appropriate queue and the queues will be processed according to the assigned priority and within each queue in FIFO order.

This scheme improves the spectrum utilization as all available spectrum holes or white spaces are observed periodically. Each time after assigning all the available bands of the spectrum hole, we move to a new white space. Unused holes due to non-existence of primary users at different instances and locations are exploited opportunistically. Once the communication is over, the band will be released and will again constitute a white space. With limited available spectrum and increasing number of users, this opportunistic usage of the spectrum bands leads to minimum wastage of the spectrum resources. Instead of utilizing the best available spectrum hole, this approach is based on the first available spectrum hole that satisfies the desired communication quality requirements. If there are many spectrum holes then the first hole which satisfies quality requirements will be selected instead of the best hole. This approach is used to have fast response time requirement.

A specific time duration is set when a call occurs (whether hand-off or initial) and a band if free is provided to the call immediately. But, in case when no spectral band is free in the current spectrum hole, a band is searched in next white space. If a new band is found within't' time, it will be allocated to the communication otherwise the call will be blocked.

This scheme also provides seamless communication as a call that appears in the PH queue will be allocated band but if it appears in SH hand-off queue and still many candidates are in the PI and PH are waiting to be serviced, this call may leave this spectrum hole and try in another zone where it can get a better priority. In the new zone, it will occupy the same priority level queue, but there may not be many candidates in the higher level queues. This is used to exploit the existing spectrum optimally as well as opportunistically.

Forced drop of a hand-off calls are minimized because

1) Hand-off request will always be provided with resources even if an initial access request is to be blocked
2) If enough bands are not available in current spectrum hole, it switches to the next available spectrum hole as all the holes have been detected.

V. Simulation Results

Extensive simulations were carried out with varying parameters. The simulation program is implemented using C#, using .Net frame work, and run under windows environment. Object oriented approach is adopted to simulate the real world environment. In the simulations, a spectrum was divided into a number of cells consisting of four queues and a group of primary users each. A fixed number of bands were taken into consideration on total communication traffic was increased gradually and we record the Average waiting time, communication success rate for both cognitive radio network and normal wireless network and call blocking rate. The developed application is built for handoff calls.

After running the application, the display menu is shown in Figure 2, in which we can select the algorithm (Handoff Scheme) and different options of parameters such as sensing range, simulation range, message sending duration and concurrent data transmission respectively.

While simulating the Opportunistic spectrum allocation Scheme, following assumptions are made. For this Proposed Scheme, we have assumed following ranges. Where all of having different ranges as follows:

- Sensing range-40 to 80m
- Simulation rang-1 to 1000
- Message sending duration-100 to 200mSec
- Concurrent data transmission-30 to 80
- Power supply values-10 to 100mJ

The details of each button are explained here as follows below:

- View Topology: To see the communication model and nodes.
- Start Simulation: To start the simulation and set up communications and handovers for continuous time period.
- Reinitialize Simulation: To simulate and set up communications and reinitialize.
- Test_config: To select algorithm and different parameters such as sensing range, simulation range, message sending duration and concurrent data transmission respectively.

Analysis Control: Plotting the graphs (results) for Call blocking rate of PH/PI/SH/SI communications and Total Communication Traffic Vs Average Waiting Time.

Figure 2 : Select the algorithm and the parameters as per your ease

In Figure 3, the infrastructure-based CR (cognitive radio) network is developed. In the network topology includes 32 wireless access nodes. Each wireless access node has Omni-directional antenna. They are assigned that 15 access nodes for primary users (licensed), and remaining15 wireless access nodes for secondary users (unlicensed) and access nodes are placed in random manner. Framework of a CR network is divided into eight cells, each cell have group of four access nodes.

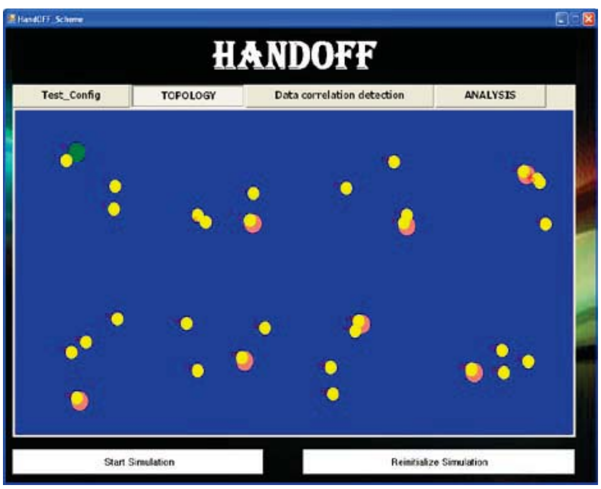

Figure 3 : Node Formation

Users take the handoff process in within the network, where a packet dropping will be occurred in the network because of improper spectral selection. The hand-off calls are assigned with more priority in comparison to initial calls and primary user calls are given higher priority in comparison of the secondary user. Handoff scheme will be different for different ranges (areas).Here there are two different kinds of handoff schemes are shown in Figure 4 (a) for simulation range of 1000 and Figure 4 (b) for simulation range of 10.

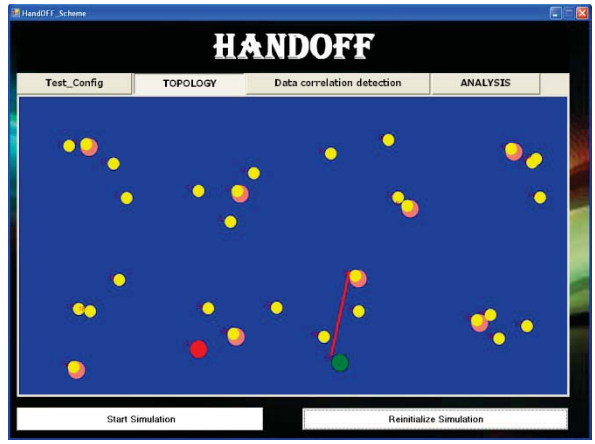

Figure 4 (a) : Handoff process (simulation range-1000)

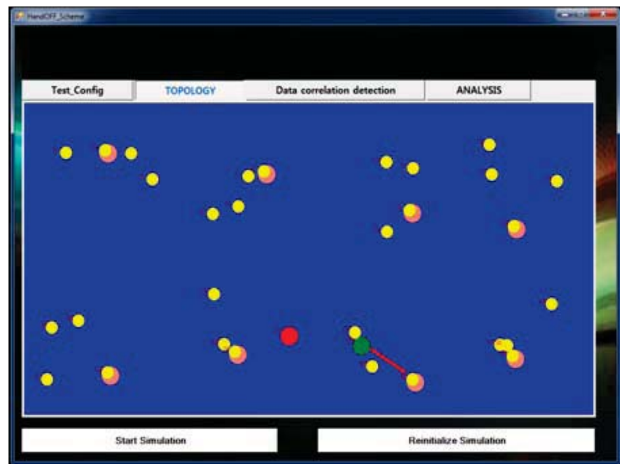

Figure 4 (b) : Handoff process (Simulation range-10)

Case 1 : In this case, select the algorithm (Handoff scheme) and different options of parameters, such as sensing range-50, simulation range-1000, message sending duration-170 and concurrent data transmission -60 respectively. And then run the application, the display menu is shown in Figure 5 and Figure 6, shows the data correlation detection table for node connection.

Figure 5 : Select the Algorithm and the Parameters

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The graph (Fig-7) drawn shows that the average waiting time, when there are number of bands in the network is 5 to 6 and the traffic at a point in time zero, is zero. But as the traffic increases from 0 to 10, the average waiting time increases to 60 but remains almost constant for very high traffic intensity also. The curve almost reaches to the stability beyond a certain point in the traffic where

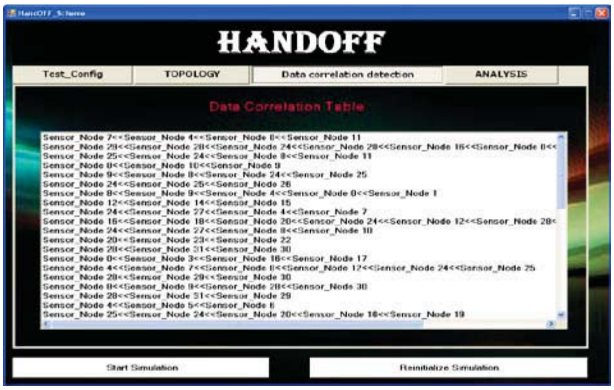


Figure 6 : Data correlation Detection(Node connection)

after increasing the amount of traffic it has very less affect on average waiting time. This curve proves that the algorithm is designed in such a way that there is not big variation in average waiting time even if the traffic is sufficiently increased against a certain number of bands in the network. Average waiting time is considered in units of 'tick' where a 'tick' represents the time to make an attempt of band allocation.

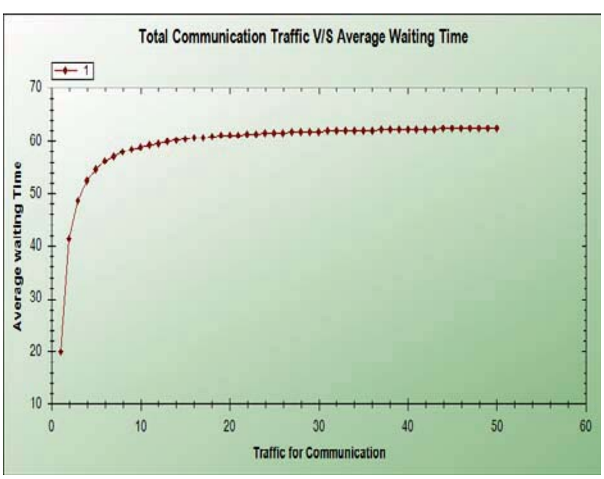
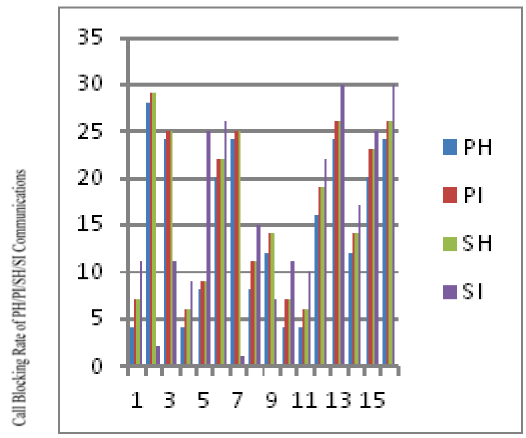


Figure 7 : Total communication traffic Vs average waiting time

The graph (Fig-8) is drawn between overall traffic for communication in a point of time and call blocking rate of primary hand-off, primary initial, secondary hand-off and secondary initial communi-cations. When the number of requests is equal to the number of free bands call blocking rate is zero for all four types of communications.

When this traffic increases and becomes twice the available free bands the call blocking occurs only in secondary initial communications. It is noticed that while increasing traffic 3 times, 4 times and up to 30 times with the same band strength no call blocking occurs in primary handoff communication. A small increase is found in primary initial with the increase in the traffic. This increase seems almost stable with a rapid increase in the traffic. The scenario is almost same with secondary handoff communications. The only significant blocking rate is with the secondary initial communication.



Traffic for Communication

Figure 8 : Call blocking rate of PH/PI/SH/SI communications

Case 2 : In this case, first select the algorithm (Handoff scheme) and different options of parameters, such as sensing range-70, simulation range-1, message sending duration-180 and concurrent data transmission of 80 respectively.

And then run the application, the handoff takes place and finally the Figure 9, shows the data correlation detection table for node connection as follows in below:

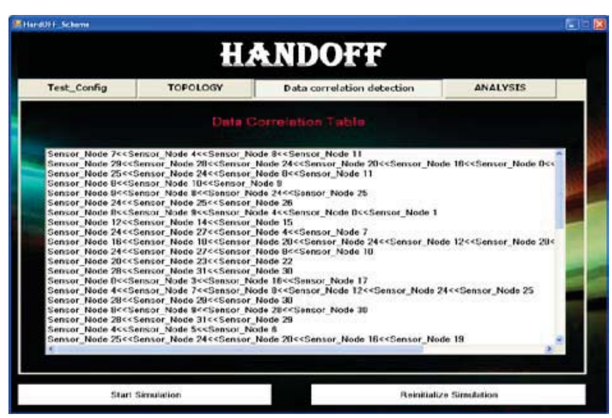


Figure 9 : Data correlation Detection (Node connection)

The graph (Figure 10) shows that the average waiting time, when there are number of bands in the network is 5 to 7 and the traffic at a point in time zero, is zero. But as the traffic increases from 0 to 2, the average waiting time increases to 64 but remains almost constant for very high traffic intensity also. The curve almost reaches to the stability beyond a certain point in the traffic where after increasing the amount of traffic it has very less affect on average waiting time.

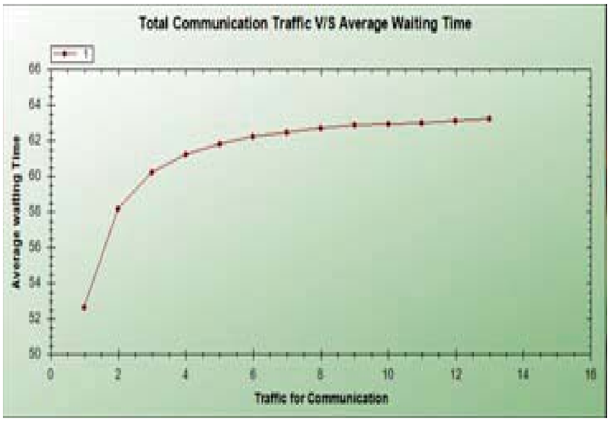


Figure 10 : Total communication traffic Vs average waiting time

Case 3 : In this case, first select the algorithm (Handoff scheme) and different options of parameters, such as sensing range-40, simulation range-100, message sending duration-160 and concurrent data transmission of 60 respectively. And then run the application, the handoff takes place and finally the Figure 11, shows the data correlation detection table for node connection as follows below.

The graph (Figure 12) shows that the average waiting time, when there are number of bands in the network is 4 to 6 and the traffic at a point in time zero, is zero.

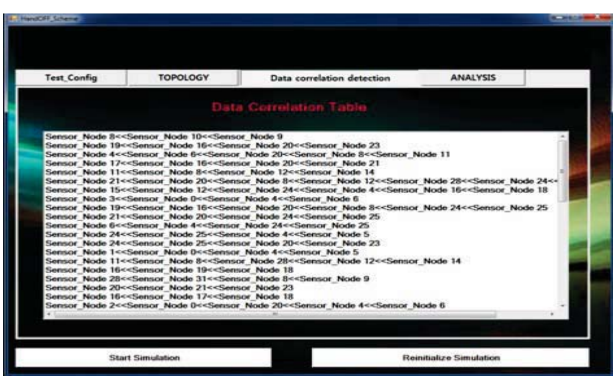


Figure 11 : Data correlation Detection (Node connection)

But as the traffic increases from 0 to 10, the average waiting time increases to 60 but remains almost constant for very high traffic intensity also. The curve almost reaches to the stability beyond a certain point in the traffic where after increasing the amount of traffic it has very less affect on average waiting time.

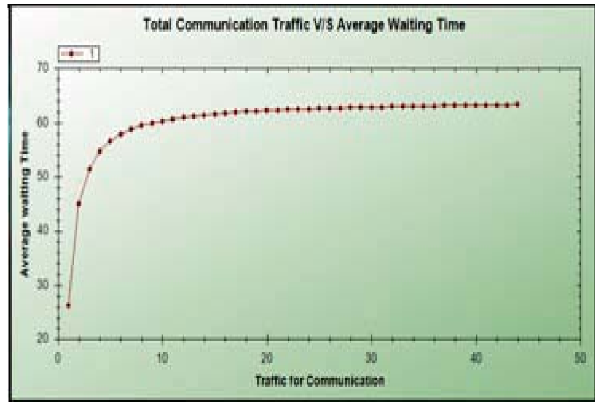


Figure 12 : Total communication traffic Vs average waiting time

VI. Conclusion and Future Work

Cognitive radio networks are the next generation networks which are developed to resolve the constraints in current wireless communication. The current problems in the wireless communications are discussed and the need to switch from wireless networks to next generation networks xG or cognitive radio networks is introduced. A two-phase scheme is introduced for spectrum allocation. In the first phase of the proposed scheme, a collision between two calls for spectral band allocation is resolved. In second phase of the scheme, allocation of spectral bands among a number of different types of calls is considered. The main objective is to have opportunistic spectrum band allocation policy and minimization of forced termination of a handoff request. This new spectrum allocation policy will fill the gaps of wireless spectrum and will satisfy the needs of both licensed as well as unlicensed zone without any compromise.

Although, the current scheme is focused on spectrum allocation policy and dynamic spectrum access/xG, it has the ability to carry out extensive research in all fields of the cognitive radio. And in future work, collision between more than two calls can be eliminated among unlicensed users in a multiuser spectrum handoff scenario.

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RCD NUISANCE TRIPPING WHOS GUILTY AND WHAT NEEDS TO BE DONE?

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I. Introduction

Residual current devices (RCD) are widely used all over the world in households and commercial enterprises as an additional protection against electric shock (RCD with differential tripping currents of up to 30 mA [1, 2]) and as protection from fire, which can result from temperature increases due to current flowing through broken cable insulation and other types of equipment (RCD with tripping currents from 100 to 300 mA [3, 4]).

Since RCD are used so widely, information about their nuisance tripping is in the public domain. It's one thing if power outage occurs in an apartment in a house; this can be easily fixed, by returning the RCD to its initial position. But it's absolutely a different thing if this outage occurs when complex commercial electronic equipment, computers, servers, etc are working. The losses in this case can be tremendous; and these losses can be not only material. Paragraph 7.1.81 of the Operational Codes for Electric Installations (OCEI-7) clearly prohibits installation of RCDs for electric consumers the disconnection of which can result in situations dangerous for consumers (disconnection of fire alarms, and the like). However, it is not always easy to predict the consequences of the disconnection of specific electric receivers wired through an RCD (such as computers, controlling a technological process, special communication devices and alarms, etc.). This is why the problem of nuisance tripping of RCD is very relevant. This topic is discussed in multiple articles found in special technical references [5 – 10], it is even mentioned in catalogues of large RCD manufacturers, such as ABB, Siemens, Schneider Electric, Merlin Gerin, Legrand, Eaton, Mueller and others.

Standards [11, 12] describe two major types of an RCD, i.e., AC and A. While standard [13] mentions two additional types, i.e., B and F. All of them differ in terms of current flowing through the RCD. For example, the AC type RCD is designed for sinusoidal alternating current only; the A type is designed for alternating sinusoidal current and rectifying current imposed to it; the B type is designed for alternating sinusoidal current with a frequency up to 1000 Hz and pulsing, direct or rectified smoothed current; and the F type ("F" stands for frequency) is designed for alternating sinusoidal or pulsing current as well as for non-sinusoidal current, which contains harmonics generated by frequency converters. Many additional types have been "invented" by manufacturers with the purpose of reducing nuisance tripping problems, such as, types U, K, AP-R, SI and others, which are not mentioned in standards. RCD can also be divided into general use devices (type G – general) and selective devices (S – selective). The latter have increased differential trip currents and are equipped with trip delays. They are used in branched cascade networks.

Despite the availability of multiple types of RCDs in the market, the problem of nuisance tripping is still relevant.

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II. Analysis of Reason for RCD Nuisance Tripping

Let's make it clear from the start: we will not be discussing faulty tripping of RCD as a result of RCD's failures. Rather we will be discussing only nuisance tripping of fully functional RCDs. The reader may ask: *Why? If an RCD is fully functional and meets all the requirements set for it, how can it be tripped falsely?* The issue is about specific conditions and operational modes which may occur in electric mains as well as those parameters of these mains and modes of operation of electric energy consumers. Due to the high sensitivity of the RCD, the operational modes of the main and consumers characteristics powered through the RCD have a direct impact on the device and often result in its faulty actuation.

a) Natural («background») leakage current to the ground through intact insulation of cables and electric loads

It is known that RCD responds to the so-called differential current, which is a difference between the phase current (or a sum of the phase currents in a 3-power network) and current in the neutral. If the current flows to a load through an RCD via a phase wire and returns to the RCD through a neutral wire, the differential current for which the RCD is set up will

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amount to zero. If part of the phase current that flows through the RCD is "leaked" to the ground through faulty insulation and does not return to the RCD through a neutral wire, a difference of currents will occur (differential current) to which the RCD responds. The distributed capacities related to ground wires, capacities between coils of transformers and motors related to grounded housings, capacities of multiple filters installed in the supply circuits of almost all types of electronic equipment are the ways through which current may "leak" to the ground. This is actually the current to which an intact RCD should react. According to the standards [14,15] the RCD's trip current may fall in the range of $0.5I_{\Delta N}$ - $I_{\Delta N}$. This means that a functional RCD with a nominal differential tripping current of 30 mA (maximum permitted current to protect people from electric shock) can be tripped at 50% of the nominal current, i.e., at 15 mA. For RCD types "A" and "B" the real trip current depends also on the pulsing component phase shift and according to standards [11, 12, 14] it falls into the range $0.11I_{\Delta N}$ - $2_{\Delta N}$.

b) Distortion of current form in the RCD circuit

The quality of electric power in household and commercial mains tends to deteriorate continuously due to expanding application of non-linear loads, such as powerful voltage regulators, frequency converters, UPS, LED light fixtures, computers, servers, controllers and other low power electronic devices with internal impulse mode power supply that consume non-sinusoidal current from the mains. This distorted current, containing a number of high-frequency harmonics, will flow through RCD as well, see Fig. 1, Table 1.

Past research [5-10] has shown that distorted current flowing through RCDs of electro-magnetic type leads to significant changes in the threshold of its tripping. The effect of high frequency harmonics on the condition of the magnetic core of the internal current transformer of the RCD and its other elements is rather complicated and controversial. In some cases it is possible to speak of the danger of RCD malfunction, whereas in other cases – about reduction of tripping threshold, i.e., the increase of probability of faulty actuations.

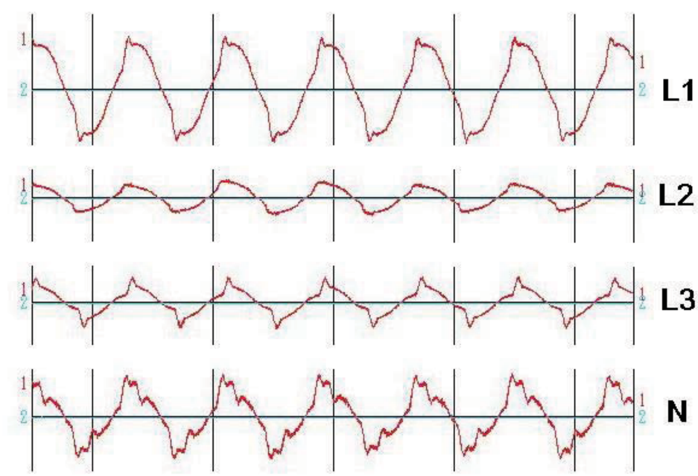

Figure 1 : Real oscillogram charts of phase and neutral currents flowing through RCD connected to supply mains of electronic communication equipment and resulting in several faulty disconnections of equipment

Table 1 : Real harmonics composition of currents flowing through RCD, connected to supply mains of electronic communication equipment and having registered cases of nuisance tripping

Harmonic's number	Contents of each harmonic in %			
	L1	L2	L3	N
1	100	100	100	100
2	1	0.9	3	1.3
3	14.6	23.7	46.3	58.2
4	0.9	0.9	2.5	1.3
5	22.5	17.3	45.2	26.8
6	0.8	3.2	2.6	4
7	15.2	10.8	34.6	21
THD, %	**34.5**	**33**	**80**	**78**

But high frequency harmonics not only change the RCD's tripping threshold, but also increase the total "background" leakage current through capacities of the mains and consumers. This is why we can find ourselves in a situation when even a specially selected RCD, which can work with distorted currents, may still be tripped erroneously.

c) Impact of current impulses in the RCD circuit

Besides harmonics, electric networks of private dwellings and especially networks of commercial enterprises are affected by atmospheric and switching overvoltages. These overvoltages are "cut" by various types of protection elements, such as gas arrestors, voltage-depended non-linear resistors (varistors) and specific non-linear semiconductor elements. These protection elements are installed directly in the network as separate elements and they are part of internal power supplies of all modern electronic devices. Short (parts of milliseconds) impulses of rather high current (hundreds of Amps) occur when these devices are actuated due to overvoltages and current flow between phase and ground as well as between neutral and ground. In any case this current is actually the differential current to which RCD should react.

As a rule, internal power supplies of electronic devices [16] contain input network filters, which include capacitors as their main elements and which are connected between the phase and the ground as well as between neutral and the ground. When the power supply is switched on, these capacitors produce the current surge between phase and ground to which RCD should react. In addition it should react when the working impulse power supply (this is the main power supply for all modern electronic devices) consumes current from the network in pulses [16]. The crest factor, in other words, is the ratio of peak value to the RMS. Current value, consumed by the load, amounts to 3, while it is 1.41 for a usual sinusoidal signal. This creates additional load for an RCD.

d) The effect of the direct current level on RCD performance

Unlike the above situation (see 2.2) with non-sinusoidal current flowing through an RCD, the expansion of powerful electronic devices (with their frequency converters, voltage regulators, invertors, powerful convertors and variable frequency electric drives) constitue conditions whereby high frequency sinusoidal current of pulse-width modulation and direct or rectified pulsing current flow through RCD connected to circuits with such devices. Normally RCDs of AC, A and even F types are not designed to work in circuits with this current. Since the input element of any RCD is represented by a current transformer with a ferro-magnetic core (see Fig, 2), it is obvious that the characteristics of such a transformer will largely depend on the availability of direct current level in the current. In other words the moment when the RCD is actuated will not be determined by its nominal value of differential current, but by random fluctuations of load and leakage current.

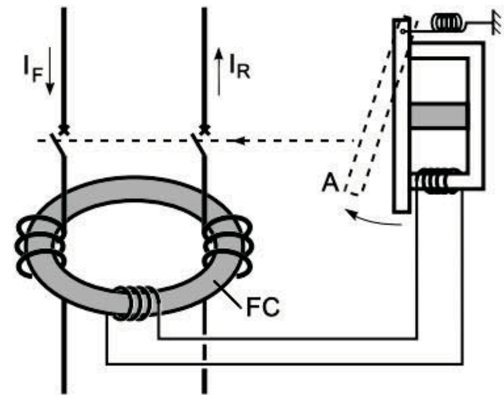

Figure 2 : Simplified layout of an RCD. FC – ferro-magnetic core ring of differential current transformer; A – contact system's release pusher

However, even if we select a type B RCD for these purposes, but do not take special measures, type B devices will also be affected by faulty actuations due to the influence of significant impulse current or background leakage current just like RCDs of other types.

III. What Needs to be Done?

a) Reducing the effect of natural (background) leakage current

In order to avoid faulty actuation of RCD the standard [15] and OCEI (7.1.83) suggest that it should be selected considering the actual value of the background leakage; it should not exceed 30% of the nominal actuation current. In other words for an RCD with $I_{\Delta N}$ = 30 mA the background leakage current should not exceed 10 mA. But what happens in practice?

Table 2 : Typical leakage currents for some types of electric equipment

Electrical appliances kind	Typical leakage current, mA
Computers	1 – 2
Printers	0.5 – 1
Portable domestic electrical appliances	0.5 – 0.75
Photocopy machines	0.5 – 1.5
Filters	~ 1.0

In the absence of actual (measured) values of the leakage current, the OCEI (7.1.83) suggests accepting the leakage current for electric consumers based on 0.4 mA for each 1 A of the load current and for wires based on 10 microampere for 1 meter of length of a phase conductor. As an example standard [15] provides typical values of leakage current for several types of electric equipment, see Table 2.

This means that one RCD can be connected to 4-5 computers and 1 printer located within several dozens of meters from the switchboard where the RCD is installed. How can we measure the real current of RCD actuation and the real background leakage current flowing through it? There are special devices for this; however, qualified personnel of commercial enterprises and companies can measure this current with a simple device, Figure 3, observing safety requirements. Initially, the RCD trip current is measured (by gradual reduction of resistance of R resistor) while the load is switched off. Then, the same measurement is performed with the load switched on. The difference in measurements will be the sought-for value of the background leakage current. If this value is higher than 10mA, then according to recommendations [15] the loads should be split, i.e., install an additional RCD and split the loads between two of them.

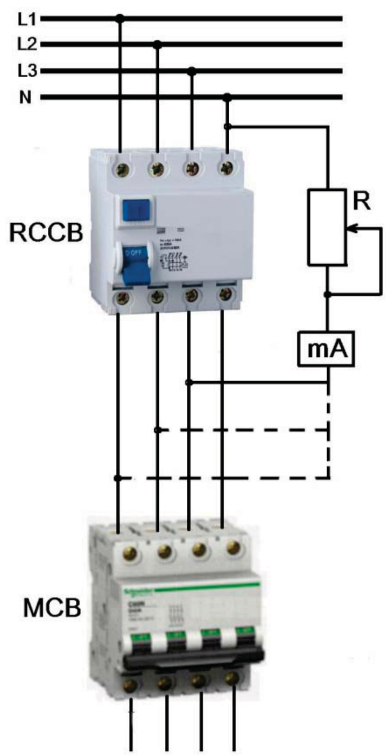

Figure 3 : Measurement of the background leakage current through RCD

In complicated branched networks which have an hierarchical (cascade) structure, the RCD should be connected at each level (cascade). Obviously, the background leakage current of upstream cascades will be represented by the sum of the background leakage current of downstream cascades. This is why in order to avoid the faulty actuation of RCD in such networks they should have specific selectivity like any other protection systems used in branched networks. There are S type RCDs (selective, with various trip current values and various trip delay values) for this purpose. They switch on different types of RCDs based on the specification of controlled current, Fig. 4.

This cascade connection of RCD allows elimination of their faulty actuation in a complex network. However, it should be considered that RCD with a trip current above 30 mA cannot be viewed as a reliable protection of people from electric shock. This means that the significant portion of the upstream network does not protect people from electric shock and the RCD is used as a fire protection only. On the other hand, it does not mean that a low power consumer connected through an ordinary plug somewhere upstream cannot be protected by a separate RCD with an actuation current of 30 mA. In this situation the leakage current from all downstream cascades will not flow through this RCD and its faulty actuations can be successfully avoided providing reliable performance without nuisance tripping.

In some types of RCD marketed as “super resistant” to nuisance tripping this "resistance" is ensured due to the increase of the minimum level of differential trip current from 0.5 $I_{\Delta N}$, which is actually not prohibited by standards, to 0.75 – 0.8 $I_{\Delta N}$.

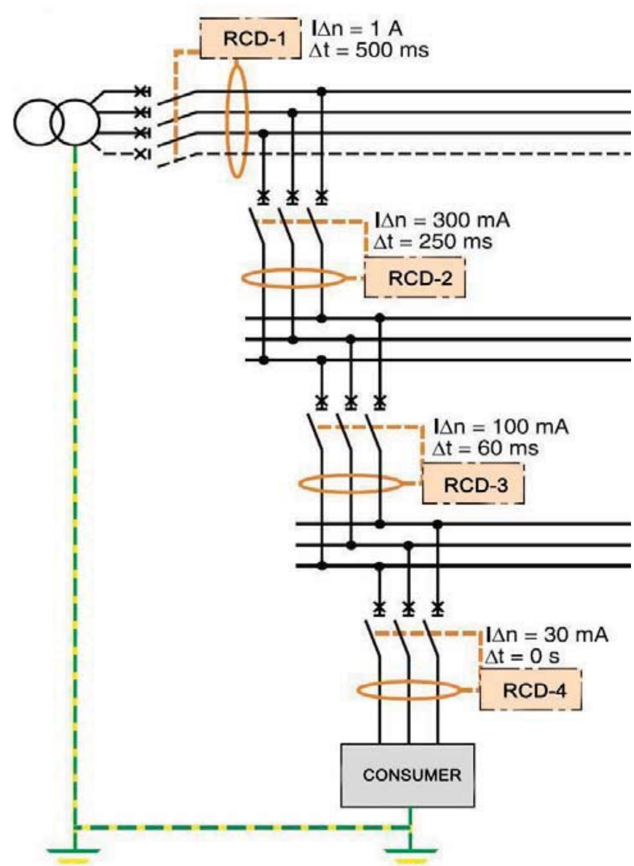

Figure 4 : An example of cascade connection of RCD in a branched network

b) Prevention of harmonics affect on RCD performance

Prevention of the affect of higher harmonics on the RCD is the second option to increase the RCD's resistance to nuisance tripping. It is clear that an RCD designed to work with current containing higher harmonics will behave more predictably compared with devices, which are not intended to work with high frequency current. In fact, this is the reason why special types of RCD (B and F) including special filters and limiting the effect of harmonics were developed. RCD of type F are not manufactured as separate devices, they are manufactured as a type A RCD with expanded frequency characteristics. This is why the marking of this type of RCD usually bears two letters: AF or A-F.

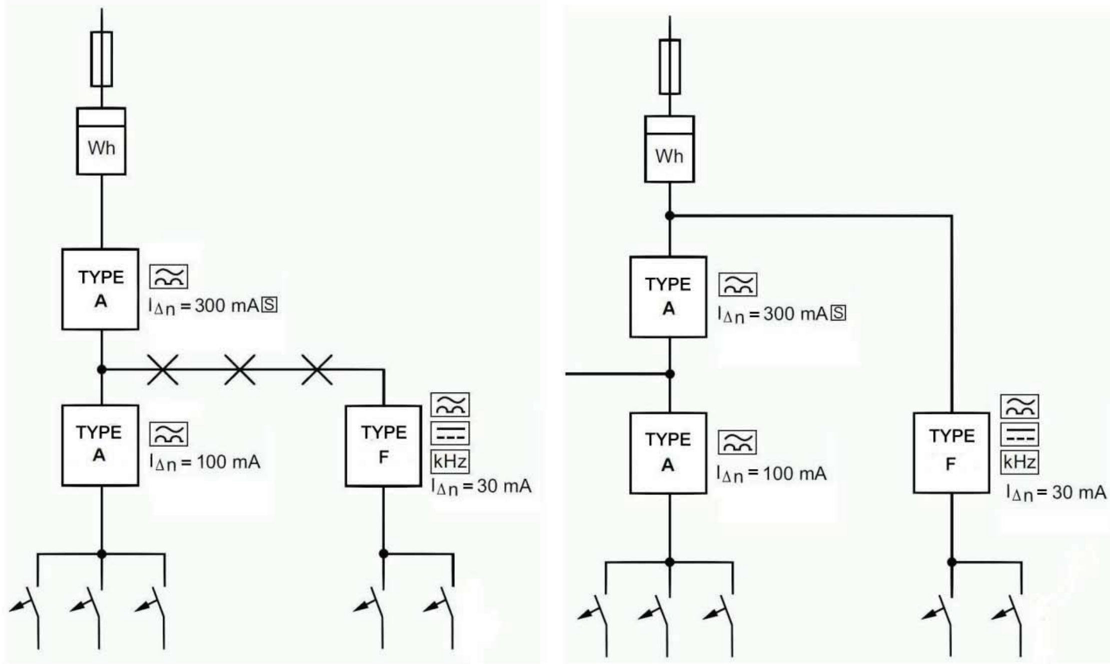

Figure 5 : Incorrect (left) and correct (right) connection of non-linear load with special type RCD

In the case of non-linear loads present in a network, which condition increases the level of high frequency harmonics and loads, and containing direct components, these loads should be separated from the common network in such a way so that the non-linear current and current containing the direct component do not flow through another RCD, Fig, 5., which will prevent their nuisance tripping.

It should be taken into consideration that the increased level of high frequency harmonics in the voltage leads to increase of leakages through capacities of wires and equipment, i.e., the increase of the background current thus making the use of special type RCD inefficient. The increased level of harmonics leads to an increase of voltage drops on elements connected in series (inductance chokes) built into the electronic equipment of network filters. This can result in the increase of high frequency voltage level and leakages to the ground through capacitors of these filters. At the same time past research suggests that electronic RCDs are less sensitive to harmonics than electromechanical RCDs, which may be strange at first sight. This is due to the fact that in an electronic RCD the controlled current containing harmonics is not used directly for actuation of the RCD trip unit, but is only a source of a controlling signal, which is cleared from harmonics, strengthened and converted. In order to influence the RCD trip unit, the energy of an auxiliary power supply is used. Phase voltage of the power network can be used as such a supply. An example of an electronic RCD (designated as U-type) is a device manufactured by Eaton-Moeller company under the brand dRCM-40/4/003-U+.

Unfortunately, the use of an electronic RCD (in the standards they are referred to as RCD with dependant power supply, i.e., requiring an auxiliary power supply) is not that simple. The problem is that when the contact in the neutral wire is broken, the RCD will lose its power supply and stop functioning, whereas an electromechanical RCD will actuate and disconnect a consumer due to current imbalance. Due to this, a lot of manufacturers started producing RCDs with a built-in element, which ensures its actuation and disconnection load in the case that the neutral wire is broken (in other words, when the RCD loses its power supply). In their opinion this algorithm was supposed to eliminate an obstacle in the way of using electronic RCDs. However, paragraph 7.1.77 of OCEI-7 prohibits using this RCD, which disconnects a consumer from the mains in the event of voltage outage or voltage dips in inhabited buildings. Why? The author has no reply to this question. And perhaps, not only the author, since V.A. Bulat, Doctor of Science, says the following in his recommendations regarding selection of a correct RCD [17]:

*«Among electronic RCD or differential automatic circuit breakers **the preference should be given to those that have protection from disconnection of neutral conductor** – the disconnection can lead to loss of input voltage by RCD which makes them non operable».*

In some European countries the use of electronic RCDs with dependent power supply in stationary electric mains is not allowed by national standards. French standard NFC 15-100 (§ 531.2.2.2) specifies that they should not be used in electric installations of residential buildings. In Russia the concept that an electronic RCD should not be used to protect people from electric shock was shuffled from one scientific article to another for a long time. It is interesting that there was one quote (about the danger of disconnection of zero wire), that was copied by many authors word by word. However, paragraph A.4.14 of the new edition [18] expressly says:

«RCD dependant from auxiliary power supply (electronic) and independent (electromechanical) can be used in residential installations as shock hazard protection».

There are no restrictions for RCD use in the new edition of OCEI-7 also.

The international standard [19] allows using electronic RCDs in two situations:

- When using an RCD as protection from indirect contact;
- When using an RCD in network and electric appliances services by qualified personnel.

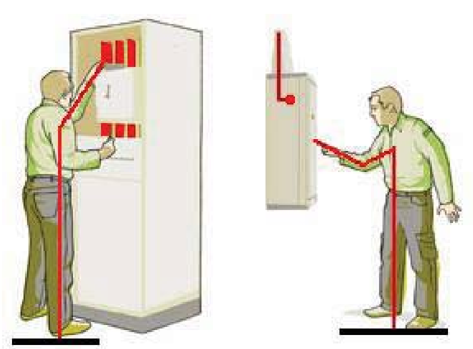

Figure 6 : Examples of direct (left) and indirect (right) contact

Direct contact means a contact of a person with current conducting parts inside an electric appliance, while indirect contact means a contact of a person with a casing or another part of an electric appliance, which are normally insulated and are under voltage only due to insulation breakage, Fig.6. It is clear that the probability of RCD working in the latter case is much lower than in the former case, this is why the standard allows using electronic RCD in this case.

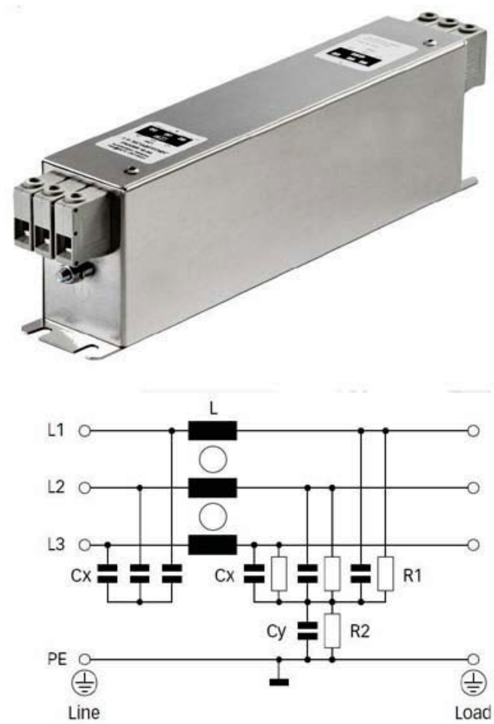

Figure 7 : Special 3-phase filter, type FN 3268 produced by Schaffner to prevent the effect of harmonics on RCD of all types

Special filters with low current leakage to the ground connected in series with an RCD are more efficient in protecting electromechanical RCDs of different types from the harmonics effect.

An example of this special filter is Filter FN3268 produced by the Swiss company Schaffner [20]. These filters are intended for nominal load currents of 7, 16, 30, 42, 55, 75 Amps for RCDs with a differential current of 30 mA and for currents 100, 130, 180 Amps for RCD with differential current of 300mA. They not only prevent the influence of high frequency harmonics on the change of the RCD trip threshold, but also reduce background leakage current, since their own leakage current is much less than the current leaking through capacities of the mains due to high frequency harmonics. This is the reason why these filters can be more efficient in preventing nuisance tripping of RCD than the use of special types RCD.

c) Prevention of current pulses effect on RCD performance

Actually, today it is not a problem to separate short (several milliseconds) current impulses by means of electronic circuits and block the effect of these short impulses. But when talking about very small and affordable devices (RCD) including those of electromechanical type, the only way to protect from such impulses is to use time lag so that impulses with durations less than this time lag could not activate RCD.

According to standards [11, 12], based on actuation time, RCD are distinguished G (general) and S (selective) types. In fact, RCD do not have strict and constant times of actuation. They possess a typical reverse time-to-current feature: the higher is the differential current, the less is the time lag to disconnect the protected circuit, Table 3.

Table 3 : Trip time of different types of RCDs at various rates of differential current according to IEC 61008-1 standard (Table 1)

RCD type	RCD trip time at variable values of differential currents I_{DIFF} (rms.), ms					
	I_{DIFF}		$2\ I_{DIFF}$		$5\ I_{DIFF}$	
	Min	Max	Min	Max	Min	Max
G	-	300	-	150	-	40
S	130	500	60	200	50	150

In technical literature [21] we come across erroneous interpretations of RCD actuation time and references to three instead of two types of devices, such as immediate action (without time delay), with a little delay (type G) and with increased delay (type S), Table 4.

In fact, according to the standards there is no immediate action type device at all. Indeed, for type G RCDs unlike type S the minimum actuation time (in the IEC standard it is called minimum time of non-operation) is not standardized. In other words, theoretically it can be as small as desired.

Clearly this very small time of the general type RCD (type G) actuation does not improve its resistance to nuisance tripping, but on the other hand type S RCD are not suitable as human protection devices.

Table 4 : Erroneous classification of types of RCD actuation based on its time delay [21]

RCD type		Time delay, ms at			
		$I_\Delta = I_{\Delta n}$	$I_\Delta = 2I_{\Delta n}$	$I_\Delta = 5I_{\Delta n}$	I_Δ = 500 mA
-	Common use, without time delay	<0.3	<0.15	<0.04	<0.04
G	With minimal time delay 10 ms	0.01…0.3	0.01…0.15	0.01…0.04	0.01…0.04
S	Selective, with minimal time delay 40 ms	0.13…0.5	0.06…0.2	0.05…0.15	0.04…0.15

Rather, type S are used to ensure selectivity in the upstream cascades of branched electric networks and have minimum actuation currents of 100 – 300 mA. This is why many manufacturers produce special type RCDs for differential current of 30 mA (i.e., intended to protect people) with a minimal standardized actuation time of 10 msec (this means they should not be actuated even at current impulses of large amplitude and lasting less than 10 msec). Such RCDs are classified as especially resistant to faulty actuation and are marked according to the manufacturer's wish. For example, Siemens marks this RCD as type "K", while the ABB company marks them as «AP-R».

d) Elimination of direct component effect on RDC performance

To eliminate the effect of a direct component on RCD performance in a network, where the occurrence of this component (and also high frequency sinusoidal current) is possible, the special type B RCDs are used, which have a differential transformer manufactured using special technology. Very small power taken off from such differential transformers makes it difficult to use electromechanical RCDs, which uses this power for relocation of are leaser of the trip unit. This is why the majority of RCD manufacturers either do not manufacture type B devices at all, or manufacture them in the electronic variant instead of electromechanical. The standard [13] determines the upper limit of the sinusoidal current frequency for which in addition to direct, pulsing and alternating current the type B RCD should be employed at 1000 Hz. A lot of manufacturers of this type of device guarantee their operation at frequencies of up to 2000 Hz, whereas for type "B+" devices – up to 20 kHz. Type B RCD is the most universal of all other types of RCDs, but is also the most expensive.

e) Correct selection of RCD type is a key to successful prevention of nuisance tripping

In real conditions of operation there can be a situation when a certain separate fully intact RCD device working in a group of other RCDs of the same type and installed in the same switchboard will have a trip current rating in the network with similar consumers, which is two times less than the nominal rating (which is accepted by the standards). In situations such as this in the event of the occurrence of some detrimental factors (e.g., harmonics, current impulse, results from impulse overloading and arrester actuation, background leakage current), which do not result in tripping of other RCDs, this unit can be actuated erroneously. Moreover, if the affect of detrimental factors repeats, nuisance tripping of this RCD installed in a group of other RCDs can also repeat itself. To prevent such situations sometimes it is enough to substitute this RCD unit by the similar RCD of the same type, but with actuation current rating higher than that of the RCD which actuated erroneously.

In some cases nuisance tripping happens because of accidental combination of events, each of which separately would not result in the faulty actuation of RCD. For example, if there is a certain constant level of harmonics in the circuit, which does not lead to RCD tripping and at the same time there is a powerful current impulse (which alone does not cause actuation), the RCD can be tripped and a consumer will be disconnected. Even such sophisticated and universal units as type B RCD can be susceptible to faulty actuation due to the effect of significant impulse current or background leakage current.

To ensure reliable power supply to consumers and prevention of accidental nuisance tripping of RCD in a network with low power quality, the units should be selected in advance (during design stage) and possess a special feature which ensures protection from harmonics, impulse current and background leakage current effect. If low quality of power was not anticipated before and appeared to be low in practice or deteriorated because of substitution (addition) of consumers, the usual RCDs that were installed before (AC, A) should be substituted by special type RCDs (F, B, U, K).

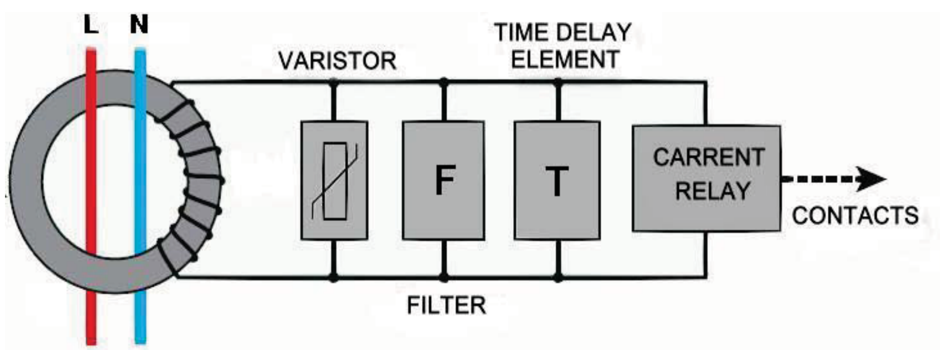

Figure 8 : Typical structure of electromechanical RCD especially resistant to faulty actuation

A similar situation can occur during a lengthy use of an electric installation, when due to natural insulation degradation process or its pollution (wetting) a gradual increase of background current occurs. In situations such as this a special type of RCDs is usually manufactured on the basis of standard electro-mechanical units of A type, but supplemented with built-in variable resistors, filters, time delay elements on the basis of RC-chain and have increased (up to 0.75-0.8 of the nominal rating) rating of minimum differential actuation current, Fig. 8.

Table 5 : Some principal technical features of RCD, type G (general) especially resistant to faulty actuation

No.	RCD type and manufacturer	Type	Nominal current, A	Trip current, $I_{\Delta N}$ mA	Drive type	Time delay, ms (at $I=I_{\Delta N}$)	Pole number
1	dRCM-40/4/003-U+ Cat. number 120850 Eaton (Moeller)	U	40	30	electronic	10	4
2	F374-40/0.03 ABB	A-F	40	30	electro-mechanical	10	4
3	F204 A-40/0.03 ABB	AP-R	40	30	electro-mechanical	10	4

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4	DFS 4F Cat. number 09134901 Doepke Schaltgeräte GmbH & Co.	A-F	40	30	electro-mechanical	10	4
5	5SM3 344-3 Siemens	F-K	40	30	electro-mechanical	10	4
6	4RC440SI30 (Clipsal) Schneider Electric	SI	40	30	electro-mechanical	-	4
7	FRCdM-40/4/003-G/B+ Cat. number 167881 Eaton (Moeller)	G/B+	40	30	electronic	10	4
8	5SM3 344-4 Siemens	B	40	30	electronic	10	4

Electronic RCDs are more diversified both in terms of design and in terms of functionality, but they have specific restrictions in use, which have been mentioned above.

A search for devices, which would satisfy all these requirements among dozens of RCD types manufactured by many companies, returned the following results, Table 5. As a rule, RCDs of the same type and possessing similar parameters are manufactured for nominal currents of 25, 40, 63A in two-pole (for single phase mains) and four-pole (for 3-phase mains) designs. In order to save space, Table 4 shows parameters of RCD with nominal current of 40A in a four-pole design only.

I regret to say that even the latest version of the main standard on RCD [11] does not interpret RCD classification accurately in terms of resistance to faulty actuations. For example, according to [11] the devices with a standard resistance to faulty actuation are type G (general) devices, whereas devices with increased resistance to faulty actuation are type S (selective) devices. It is obvious that type S devices intended for differential current in the range of 100-300 mA and higher will be more resistant to faulty actuations compared with type G devices with actuation currents of 10 – 30 mA. But as was mentioned above, type S units cannot be used to protect people from electric shock. This means that according to [11] there is no RCD resistant to faulty actuation intended to protect people from electric shock at all. It seems that the authors of the major international standard on RCD are comfortable with this situation, since this concept has been there for a long time and is copied from one edition of the standard to another. However, the data presented in Table 5 show inconsistency of the classification offered by the standard.

f) Automatic reclosing of RCD as an additional option to improve reliability of power supply to consumers

The automatic reclosing (AR) of an RCD cannot be called a means of preventing faulty actuation. It is rather a way to correct the results of nuisance tripping. However, an RCD with AR can be very efficient in solving the problem in those cases, when consumers accept short-time power supply failures. The AR function is easier to implement in some types of electronic RCDs. To return to the initial state an electromechanical RCD needs a special motor drive, which of course requires a separate auxiliary power supply. Some companies produce AR devices as separate blocks, which are installed close to RCDs of different types and reclosing them after tripping in the initial state by simulating the action of a person's hand by means of special protruding plastic lever.

Figure 9 : Different types of AR devices for RCD (some of them are shown with RCD)

The ABB Company also supplements their AR devices with a small transformer installed on a DIN-rail close to the RCD, which provides power to AR unit's drive from the supply mains. Some types of various AR devices are shown in Fig. 9.

The majority of types of AR devices allow the RCD to return into its initial condition electively: automatically with a small time lag or, remotely, on command. These devices are manufactured by ABB, Schneider Electric, Legrand, Hager, Circutor, Aoelec and others.

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Design and Implementation of a Real-Time Automated ECG Diagnosis (AED) System

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Strictly as per the compliance and regulations of :

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I. Introduction

The electrocardiogram (ECG or EKG from the German *Elektrokardiogram*) refers to the linear recording of quasi-periodical, rhythmically repeating small voltage signal (~1mV) synchronized by the heart, the bioelectric event generator [1, 2]. The term ECG was coined into medical practice 100 years ago by Nobel Prize winner, William Einthoven, who first introduced the fundamental function of the ECG [1]. Like a signature or figure-print, ECG provides electro-physiology that indicates an overview of the cardiac health. The non-invasive recording process and the visual interpretation facility have made it as a powerful tool for the medical professionals to extract clinical information about of their patients' health. The starting point for electrocardiography is the detection of R-spikes of QRS-complex and then P and T waves reflecting the process of depolarization of the ventricles, atria & final re-polarization of ventricular myocardium respectively [3]. Researchers of biomedical field have set the standard amplitude and duration values of those peaks and their derivatives. Deviation from the standard value and asymmetric phase relationships of the resulting ECG signal reflect abnormality of the human body. Thus, it is used as the primary diagnostic tool of almost all heart diseases. Sometimes, a short period ECG test in the clinical environment may prove not to be steady at all, as often it cause imperfect reports which is a threat to the potentially lethal patients. Arrhythmia, a disease caused by irregularity in heart rhythm has always been unpredictable for short time ECG Test [4]. Those limitations often let physicians to prescribe costly hazardous diagnosis instead this non-invasive method. In spite of these highlighted drawbacks of ECG accuracy, it does not lose its zeal in patient's mind because of its cost-effectiveness and availability. Regarding this issues, a lot of researches have been carried out recently to make ECG analysis as accurate as possible. To reduce the noise and artifacts as possible, highly efficient ECG machine with the combination of analog and digital filter is of ultimate necessity in modern cardio pathology. Again, automatic detection software is now also included in all ECG system with digital display and dedicated printing facility. But the philosophy of ECG detection method behind the gorgeous front end is not transparent at all and the accuracy factors. So, physicians often reject the diagnosis reports generated by this system and follow the traditional methods like visual inspection or manual comparison with standard waveform. So, the precise arrangement of automated ECG diagnosis (AED) system can not only reduce the physician's labor, but also can assist in complicate diagnosis. Also, it may let the patients to self-study their cardiac conditions even in lethal conditions without any help of the physician. This work mainly focuses on these issues and proposes an accurate solution with pointing out the pros and cons of the system.

II. ECG Details

ECG is the graphic tracing of the time duration and magnitude of 3-characteristics wave peaks P, QRS, and T. P wave is the epoch related to atrial contraction. The event of ventricular contraction is represented by QRS epoch. Atrial relaxation does not produce any distinct waveform in the ECG as it is overshadowed by the following QRS wave. PQ, ST segment are two isoelectric base-line indicators [1,2]. PR interval represents the time interval between the beginning of the de-polarizations of the atrium and the ventricle respectively. The QT interval extends from the beginning of the Q wave to the end of the T wave, represents the time of ventricular contraction and re-polarization [Figure1].

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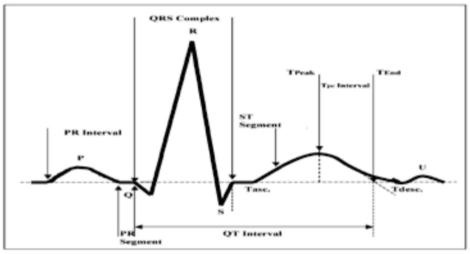


Figure 1 : Standard ECG wave with characteristic spikes & their derivatives

Table 1 : Standard ECG Parameters set by the biomedical researcher

Parameter	Range	Parameter	Range
Heart Rate	60 – 100 bpm	*RR Interval*	0.6-1.0 s
P Wave Duration	0.10 s	*QT Interval*	0.35 – 0.43 s
QRS Interval	0.08-0.12 s	*ST Interval*	0.05 – 0.15 s
T Wave Duration	0.16 s	*PR Interval*	0.12 – 0.20 s
P Wave Amplitude	0.25 mV	*T Wave Amp.*	0.1-0.5 mV
R Wave Amplitude	1.6 mV	*Q Wave Amp*	≤ 25% R wave

The heart rate simply describes the frequency of the cardiac cycle and is measured in contractions or beats per minute (bpm). The primary signal characteristics of an ECG signal has a useful frequency range of about 0.05Hz to 150Hz. The standard ECG parameters are listed in Table1. The deviation from these standard values & irregular phase relationships of the resulting waveforms reflect abnormality of a human body. These abnormalities with deviations are tabulated in Table2. For instance, two cardiac abnormalities named *Bradycardia & Tachycardia* have the syndrome of heart beat <60bpm and >200bpm with unlike standard RR interval. Figure3 illustrates some irregular ECG waveform.

Figure 2 : Regular ECG Waveform, Bradycardia & Tachycardia respectively

Normally the standard 12-channel ECG is obtained using four limb leads & chest leads in six positions. The response of the sensors attached at left arm, right arm & left leg are formulated to get leads I, II and III. Figure2 shows the different lead arrangements for ECG acquisition. Six chest leads (V1 - V6) are obtained from six standardized positions on the chest with Wilson's central terminal as the reference.

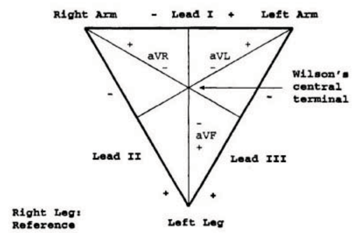


Figure 3 : Einthoven's triangle and the axes of the six ECG leads formed by using four limb leads [3]

III. State of the Art

The development of the electrocardiography was the culmination of scientific efforts aimed at improving the physiological phenomenon and the welfare of mankind [1]. Difficulties arise mainly from the huge diversity of the waveform, noises and artifacts accompanying non-stationary ECG signals. Hence, universally acceptable solution of feature extraction has not been found yet. Several QRS detection algorithms have been proposed in early eighties [3,7] mainly emphasized R spike detection by amplitude derivative approaches [8,9]. Fraden and Neuman [8] developed a QRS detection scheme where a threshold is calculated as a fraction of the peak value of the ECG. Algorithms [9-11] are based on the first derivative only or both first and second derivatives. Balda [10] suggested searching values exceeding the threshold in a weighted summation of the first and second derivative. Ahlstrom and Tompkins in [11] proposed that the absolute values of the first derivative would be smoothed and added with the absolute values of the second derivative. Numerous techniques have been proposed recently with different signal processing approaches; some common approaches are template matching (Dobbs et al. 1984), mathematical models (Pahlm and Sornmo, 1984), signal envelop (Nygards and Sornmo, 1983), matched filters (Koeleman et al. 1985), ECG slope criterion (Algra and Zeelenberg, 1987), dynamic time warping (Vullings et al. 1998), syntactic methods (Kohler et al. 2002), hidden Markov models (Clavier et al. 2002), beat detection by neural networks (Xue et al. 1992; Shyuand et al. 2004), adaptative thresholding (Christov, 2004; Madeiro et al. 2007), time-frequency decompositions by wavelet transforms (Addison, 2005) and geometrical approach (Surez et al. 2007) [7,13,14]. WT is proved more effective one. In 1995, Li et al. [15] used an algorithm based on finding the maxima larger than a threshold obtained from the pre-processed initial beats. Later in 1999, Kadambe et al. produced a method allocating a R peak at a point being the local maxima of several consecutive dyadic wavelet scales. In both methods, a post-processing is allowed to eliminate false R detections. Based on these two publications, a lot of researches were published on the beat detection based on the WT (Shyuand et al., 2004; Fard et al., 2007; Martinez et al., 2004; Addison, 2005; Chen et al., 2005; Chen et al., 2006) [16-18]. Based on the functionality, WT is categorized in sub sections, CWT, DWT; continuous and discrete. DWT is only the sampled version of CWT [19] although the choice of wavelets, scale factor, re-configurability is limited in CWT comparatively [16-19]. But, the main problem of any WT is that one has to choose the mother wavelet from a wide prototype range and the scales used to analyze the signal on an empirical basis. The mother wavelet can easily be chosen based on its characteristics and resemblance with a QRS wave, the ideal scale(s) at which the QRS are matched is harder to guess a priori [20]. All citation mentioned earlier are based on the MATLAB analysis using a dedicated tool box. MATLAB is always useful for research work as lots of built-in library functions are developing day-by-day to make it easier for end users. But, it is not at all useable in commercial software attached with a portable ECG machine. The exclusion of bulky computerized system from an ECG system is of ultimate importance which may sacrifice well-proved algorithms in research field due to the computational complexities. Hence, only thresholding based elementary algorithms are preferred to implement than any other established research patents. Responding all these motivations, authors were intended to develop acommercial software especially for the portable ECG machine. It was needed to make some trade-offs with WT based detection algorithm to make it implementable. So, the choice was limited to dyadic DWT approach and the Daubechies (DB) type wavelet families. A lot of arguments had risen between the effectiveness of two members DB4 and DB6; as both prove comparatively better in different approaches [22]. In this work, a comparative study has done and set DB4 as mother wavelet with specific scale factors. In noise reduction issue, an extra FFT-IFFT pair is engaged for further de-noising along with the popular WT tool. Feature extraction has been done here with some modification of the established algorithms of [18-22]. After proving the accuracy of this, MIT-BIH database is also engaged to prove the comparative accuracy and readiness of it.

IV. Theory of Wavelet Transform

Wavelet Transform process the same data at different scales or resolutions with assigned ranges of frequencies at every scale component [69-72]. The continuous wavelet transformation (CWT) of a signal *f(t)* is given by the convolution integral of *f(t)* with the time inverted and scaled wavelet function *Ψ(t)*.

$$W(a,b)=\int_{-\infty}^{\infty} f(t)\psi_{a,b}(t)dt$$

Ψ(t) should have specified properties like zero mean, non-zero finite energy function. From a mother wavelet function, one can obtain a family of time-scale waveforms (daughter wavelet) by translation and scaling like:

$$\psi_{a,b}(t)=\frac{1}{\sqrt{a}}\psi^*\left(\frac{t-b}{a}\right)$$

Where, * denotes complex conjugation, *a* represents dilation factor ($a > 0$), *b* the translation with $a, b \in R$. Mother wavelet is defined for $a = 1$ & $b = 0$. The key selection criterion of a good mother wavelet is its ability to fully reconstruct the signal from its decompositions. Depending on *a*, *Ψ(t)* compresses or dilates which allows WT to extract high and low frequency components of the signal. Small *a* let *Ψ(t)* to contract in time domain and the frequency response of the wavelet to shift in the higher frequencies, thus fine details or fast oscillations of the signal can be extracted. Similarly, more global signal properties and low frequency oscillations of the signal are possible to extract using larger *a*. The discrete wavelet transform (DWT) is the discrete counterpart of CWT where *a, b* are usually discretized with significant reduction of computational time. DWT of a function $x(t) \in L^2(R)$ can be written as a projection of this function on the predefined wavelet basis, let $\{\Psi_{m,n}(t)\}$:

$$T_{m,n}=\int_{-\infty}^{\infty} x(t)\psi_{m,n}(t)dt.$$

For each scale *m*, the wavelet coefficients $T_{m,n}$ are signals that represent the matching degree between wavelet $\Psi_{m,n}(t)$ and the analyzed function *x(t)* depending on location of n.

Wavelets may of orthogonal, orthonormal, bio-orthogonal, scalar or multi-wavelet type. This work is only limited to the orthonormal dyadic type having restricted resolution of order 2^j (where $j \in Z$) i.e. $a=2^j$ and $b=2^jk$. Such discrete wavelet associated with scaling functions *Φ (t)* can be convolved with *x(t)* to produce approximation coefficients *S*

$$S_{m,n}=\int_{-\infty}^{\infty} x(t)\phi_{m,n}(t)dt.$$

But the input signal coefficient S_0 is of finite length $N=2^M$. So the range of scales that can be investigated is $0<m<M$. Hence a discrete approximation of the signal is written as:

$$x_0(t) = x_M(t) + \sum_{m=1}^{M} d_m(t)$$

Where the mean signal approximation at scale M is:

$$x_M(t) = S_{M,n}\phi_{M,n}(t)$$

The detail signal approximation corresponding to scale *m* (error in approximation for finite length signal) is given by:

$$d_m(t) = \sum_{n=0}^{M-m} T_{m,n}\psi_{m,n}(t).$$

So, the signal approximation at a specific scale is a combination of the approximation and the detail at the next lower scale.

$$x_m(t) = x_{m-1}(t) - d_m(t)$$

If scale *m = 3* were chosen, the signal approximation is like:

$$x_3(t) = x_0(t) - d_1(t) - d_2(t) - d_3(t)$$

Corresponds to the successive stripping of high frequency information $d_m(t)$ from the original signal at each step, this is referred to as multi-resolution analysis of a signal using Wavelet Transform and is the basis of this work. Such decomposition/reconstruction can be shown as modified filter bank tree named Mallat algorithm [20] or Mallat Tree Decomposition (MTD) shown in Figure4 where the set of numbers $a_j[n]$ represents the 'coarse approximation' of the signal at the resolution $2^{(j-1)}$ & the set of numbers $d_j[n]$ represents the 'details' lost in approximating the signal at the resolution 2^j. Thus, given a discrete time-domain signal *X[n]* assumed to be at the resolution 2^0 is equal to $a_o[n]$ decomposed into two sets of numbers $a_1[n]$ and $d_1[n]$. $a_1[n]$ can be further divided into $a_2[n]$and $d_2[n]$ and so on. This happens by passing *X[n]* through successive low pass *G(w)* and high pass *H(w)* symbolic analysis filters. At every level, filtering and sub-sampling result in doubled frequency resolution, halved time resolution and the elimination of half of the samples to adhere the Nyquist criteria. Reconstruction process is the reverse of decomposition, where the approximation, the detail coefficients at every level are up-sampled by 2 and passed through exactly matched low-pass *G(w)* and high pass *H(w)* synthesis filters and finally added as shown in Figure4. The same number of levels is taken as in the case of the decomposition. This WT principle can be used significantly in noise elimination in ECG analysis.

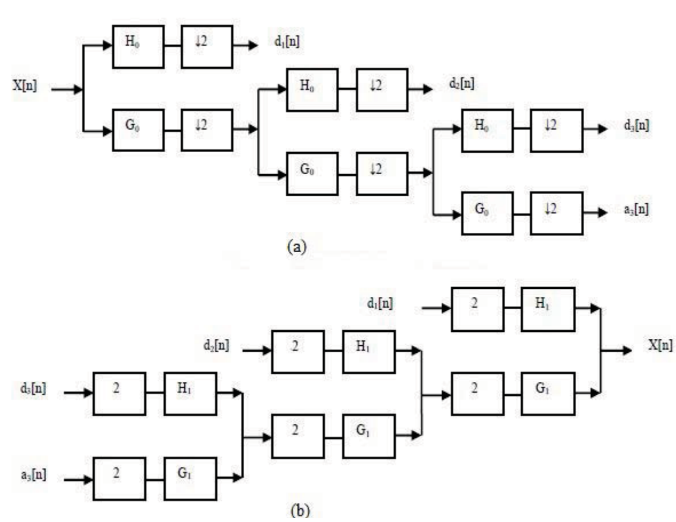


Figure 4 : Three level wavelet (a) decomposition and (b) reconstruction tree

V. Methodology

The process of analyzing ECG signal can be divided into two stages: preprocessing and the feature extraction. QRS spike is to be detected first and then P, T & other derivatives will come automatically. The algorithm of the proposed analysis technique is as follows:

Step1 : De-trending / removal of baseline wandering from the raw ECG waveform

Step 2 : De-noising/ removal of wideband noise from the de-trended ECG signal

Step 3 : Implementation of FFT and IFFT pair for further noise reduction

Step 4: Detection of QRS Complex

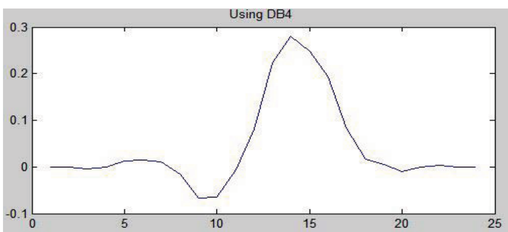
Step 5 : P and T wave detection

Preprocessing means removing cardio noise from the same frequency band caused by electro-myographical potentials of muscles, motion artifacts or background noise source. It leads to compression and the smoothing of the ECG signal. The stage of feature extraction from the cardio signal includes the process of finding the required information like the teeth, complex etc. The details of the methodology are:

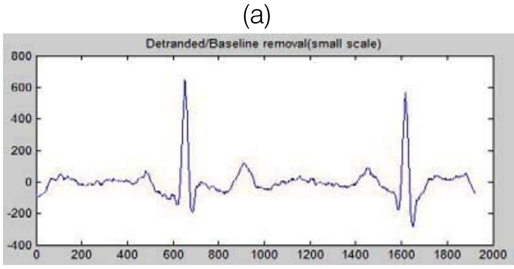
a) Preprocessing

i. *De-trending / Removal of Baseline Wandering*

The iso-electric baseline (indicating the PQ & ST segment) shifting usually comes from the respiration and the electrode impedance at frequency wandering in 0.15~0.3Hz range. As it is well under 0.5Hz, it can be suppressed without disturbing the original signal. Instead of conventional high pass (digital) filter, WT is a better approach to remove the baseline wandering as it introduces no latency and less distortion than the digital filter. Here, we decompose the ECG signal into 8 levels by using DB4 prototype and reconstruct the approximation (A8) and detail (D8) signals at level 8. The DB4 prototype wavelet and the details level (D1-D8) is shown in Figure5 and Figure6 respectively. The summation of A8 and D8 will be the low frequency component of ECG signal that causes the baseline shifting. This low frequency signal is deducted from the original ECG signal to get the one excludes baseline shifting. The problem of baseline shifting is solved here by an advance filtering techniques i.e. De-trended Signal (DS) Original Signal-(A8+D8). Figure5b depicts the result of De-trending process. This filtering technique is adapted influenced by [22] where DB6 was used as mother prototype. This approach achieves 8% more SNR than the proposal in [22].



(a)



(b)

Figure 5 : a) The DB4 prototype Wavelet used in this study b) The De-trended / Baseline removed ECG waveform (small scale)

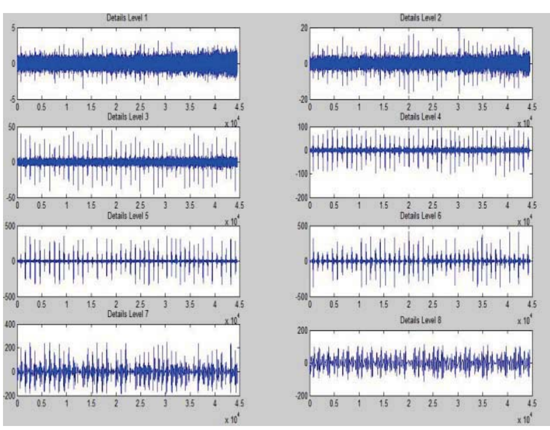


Figure 6 : The Details Level (D1-D8) of original waveform extracted by WT

ii. *De-noising/ Removal of Wideband Noise*

After removing baseline wander, the resulting ECG signal is now more stationary and explicit than the original one. However, some other types of noises may still affect feature extraction process. These noises may be of complex stochastic processes within a wideband, so one cannot remove them by using traditional digital filters. To remove such high frequency noises, one can efficiently use the Wavelet decomposed signal components found by earlier successive approximations. Each wavelet coefficient of those sub-bands can be modified by applying a threshold function & finally reconstructing the de-noised signal. This subtle approach confirms not to lose signal's sharpest features, discarding only the portions of the details that exceed a certain limit due to the occurrence of noise. Such global thresholding option is derived from Donoho- Johnstone fixed-form thresholding strategy for an unscaled white noise [22]. Hence, the lower details are removed from the original and the high frequency components are vitiated.

In this work, lower details D1, D2 are removed and the signal becomes smoother and noise disappears since noises are marked by high frequency components picked up along

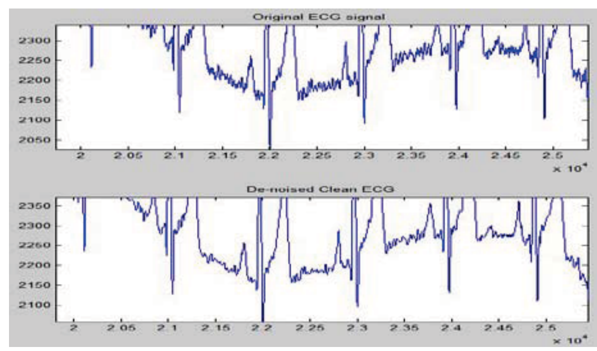


Figure 7 : The De-noised/High frequency removed ECG wave (small scale)

the ways of transmission. This is the contribution of the DWT where noise filtration is performed implicitly. Associated waveforms are shown in Figure7.

iii. *Implementation of FFT and IFFT pair*

After removing low and high frequency noise components by Wavelet Transform, it is desired to be of complete noise-free. Unfortunately, some noise component is still present even after successful WT De-trending and De-noising. Figure8 shows the clear indication of this phenomenon. This criterion is normally ignored in almost all research work. Hence, further filtering technique is mandatory to improve SNR value. It is obvious that, the non-stationary ECG signal is now converted into more stationary form after WT. So, the benefits of filtering approaches that best suited the stationary signals can be utilized after some parameter modifications. Responding this, FFT Transform is included in the current approach. After converting from time to frequency domain, high and low frequency components are sorted out to indicate the un-wanted noise components. Here, the sampling rate is an important factor to define the appropriate frequency range. The signal is isolated from the initial and last *5*fft_ length/sampling rate* samples in the frequency domain and thus filtered. The filtered signal is reconverted to the time domain and being ready for feature extraction process. A comparison is presented in Figure8 to emphasize the significance of FFT-IFFT. It is obvious that an additional FFT-IFFT pair confirms much smoothing than the WT alone.

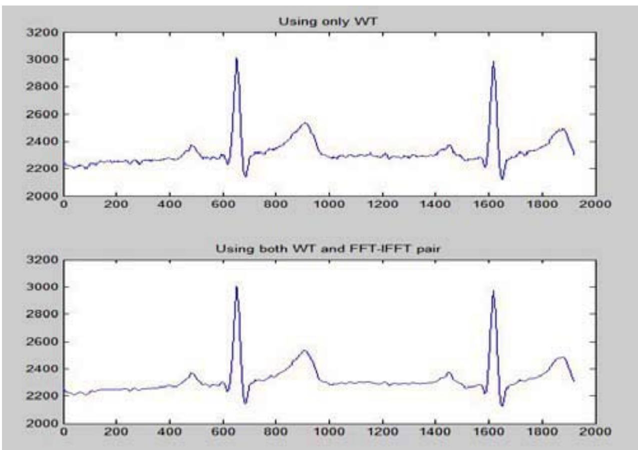


Figure 8 : Comparison of WT approaches with & without FFT (small scale)

b) Characteristic feature extraction

i. *Detection of QRS Complex*

QRS complex identification is the most important segment of any ECG feature extraction algorithm. The efficiency of total algorithm largely depends on the accuracy of this module. The R peaks have the largest amplitude among all, allowing them the easiest way to detect and good reference points for farther detections. In this study, for detecting R-waves, the benefits of WT are utilized intelligently. Only details up to the level D6 are kept for QRS complex detection and all the rest are discarded. By observing the average amplitudes of the R-waves, 30% of the maximum value is being set initially as the threshold level (T). any upward excursion that exceeds the T is taken as an R-wave otherwise termed as noise. Thus, by calculating two slope values, one upward & one downward, an R-wave can be detected. Consecutive R-waves are detected using the same technique and noise peaks are eliminated. The detection of the QRS complex is being done from identified R peaks based on modulus maxima [21-22]. The Q and S point occurs about the R Peak with in 0.15second. The left point denotes the Q point and the right one signify the S point. Calculating the distance from zero point or close to zero on the left side of R Peak within the threshold limit denotes the presence of Q point. Similarly the S point comes from the right hand detection [Figure9]. This is the most convenient way to measure those peaks and their derivatives.

ii. *P and T wave detection*

P wave is detected from filtered and de-noising ECG signal using the method "Length-Amplitude-Slope" introduced by [20]. To determine P wave amplitude, slope, starting point, destination and forms, the fourth scale WT information is employed here. Fourth scale is chosen based on energy analysis of P wave in ECG signal and the impact of baseline drift. This method is only possible if QRS detection and interval calculation is done correctly. Employing a threshold amplitude, P wave is searched in RR interval. RR and PR standard intervals are 0.6-1.0s and 0.12-0.20s respectively. It is assumed that this is a P peak in every 0.40s before the identified R spike. Then applying a threshold value of 30% of the standard value 0.25mV, all detected maxima points are leveled as P wave. Also the instantaneous P-R and P-P intervals are measured accordingly. After detecting P-wave and QRS-complex, “Curve Length Transform” described in [19] is followed as T-wave detection algorithm. The details are omitted here. Summarizing all the steps, outcome of the complete feature extraction method is shown in Figure10.

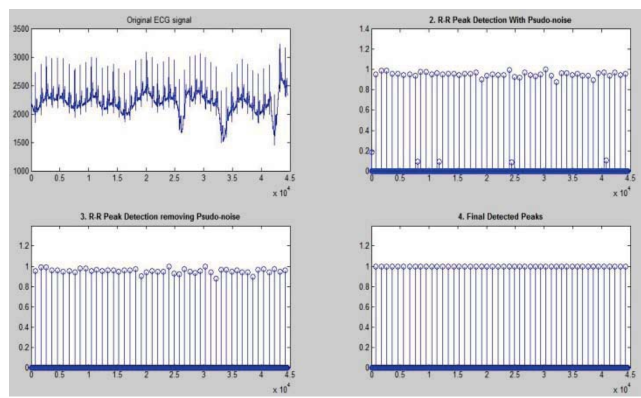


Figure 9 : Application of adaptive thresholding approach in R-detection

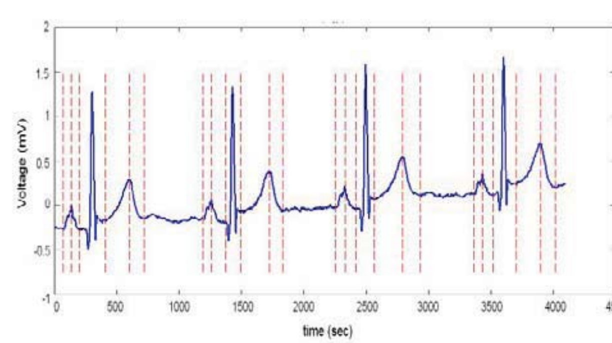


Figure 10 : The complete overview of featured detected ECG signal

VI. Software Implementation

The proposed AED system has faced the challenge to implement in the commercial environment.

To make any impression in physician's mind, it is needed a graphical user interface (GUI) with an input segment to provide the raw ECG signal and a separate report generation section. Being motivated by this, arule based architecture is designed based on the well known "Water Fall Method" of software development with the following steps: system requirement, system design, implementation & the verification. This system will extract the characteristic feature of ECG signal with the comparison of predefined standard parameters and predict the diagnosis based on abnormalities found on that

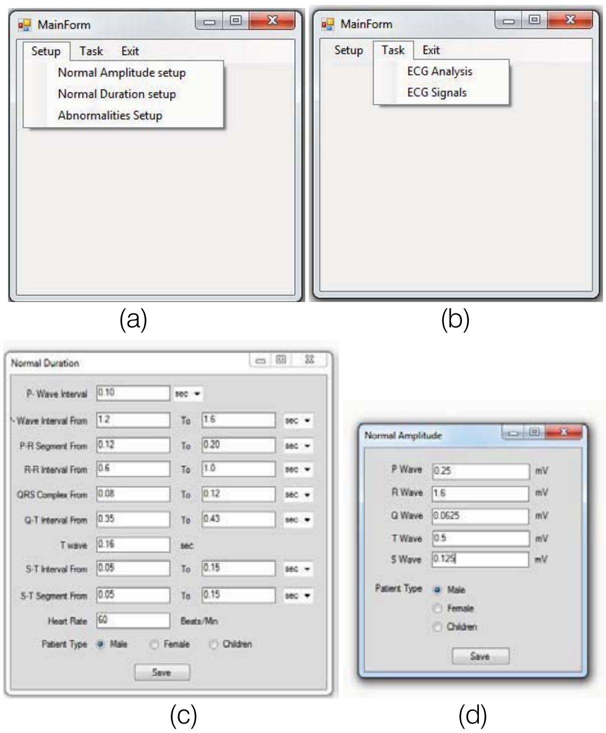


Figure 11 : UI main form (a, b) Standard Duration Form (c) and Amplitude Set up form (d) of the AED system

ECG signal. It will also provide a series of ECG graph in customizable format. A series of log files attached with the patient's name, age, weight & sex has been collected from the Dept. of Biomedical Engineering, University of Dhaka and the functionality of the software is being checked by a renowned physician for the approval of commercial use.

a) *User Interface and Set-Up Form*

The user interface form, termed as *"Main Form"* is designed for the end-user or physician. It contains three menus named "Setup", Task" and "Exit". *"Setup"* tab is to set the standard amplitude and duration values for three categorized patients: male, female & children in separated forms named "*Normal Amplitude*" & "*Normal Duration*" under "*Normal Amplitude Setup*" and "*Normal Duration Setup*" sub-menus of *"Setup"* menu [Figure11]. The total information of the deviation of standard parameters for any specific disease is needed to input in the *"Abnormalities"* form through the *"Abnormalities Setup"* sub-menu under the *"Setup"* menu. For an instance, *Hypocalcaemia,* a heart disease has deviations mainly in ST segment with the prolonged QT specified by the physicians. These syndromes are stored in the attached SQL server 2008 database in the process schematically shown in Figure12. These procedures are repeated many times to store all the deviations [Table2].

b) *Core/ Processing Unit*

The standard values and disease syndromes being input on *"Normal Duration*", "*Normal Amplitude*", "*Abnormalities"* forms are being stored in tables *"Wave Standard Duration", "Wave Standard Amplitude", "Abnormalities Symptom Data"* respectively in *"ECG Analytical Soft DB"* database. Another table, *"Patient"* is reserved for storing patient personal information attached with his/her ECG (.xml) file. The Relational Database schema is shown in Figure13. This user-friendly system is developed in .net framework using C# language. The characteristic features being extracted using De-noising, De-trending, WT, FFT-IFFT pair techniques, will be stored in "*Patient Real Data info"* table.

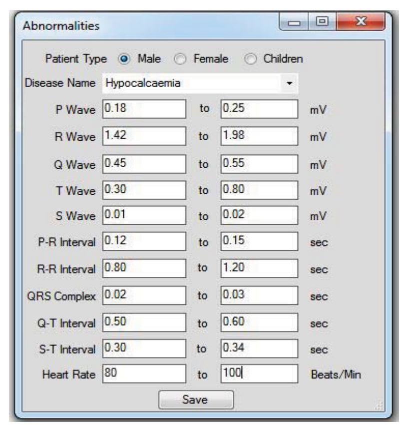


Figure 12 : Abnormalities Set-Up forms of Automatic ECG Diagnosis

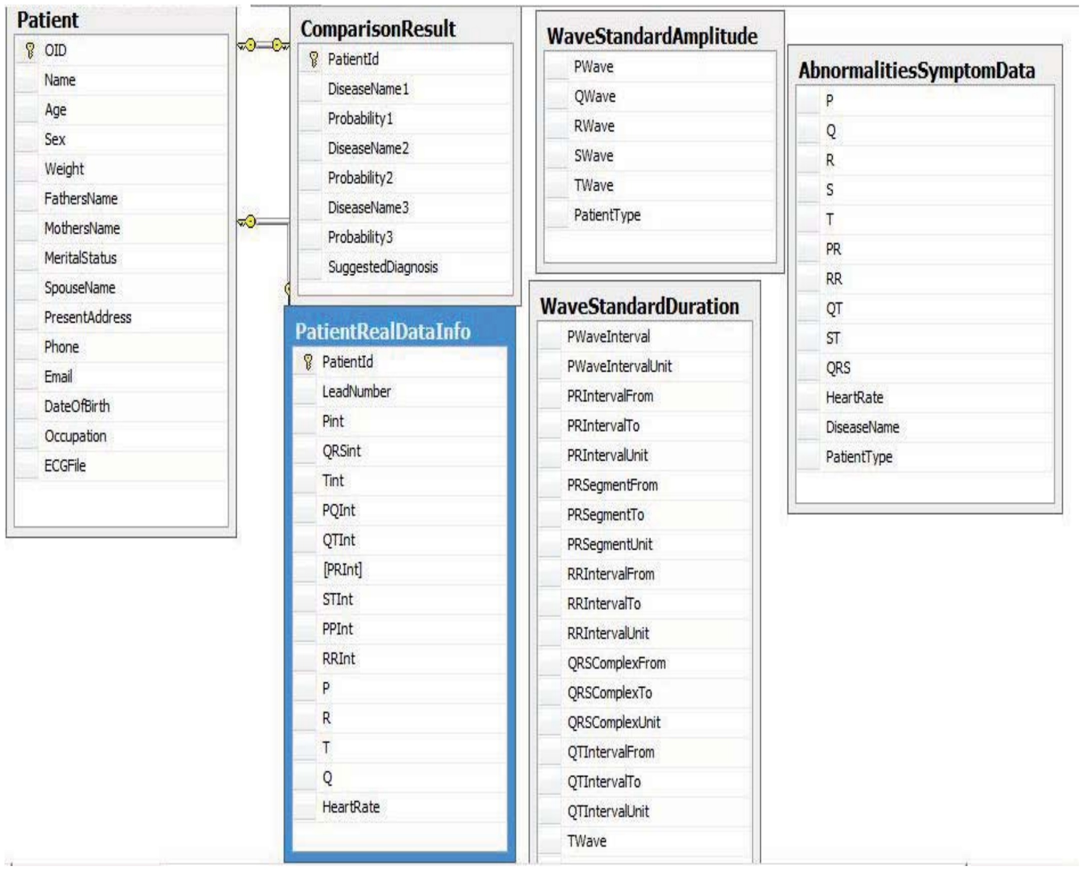


Figure 13 : The Relational Database Schema of the AED System

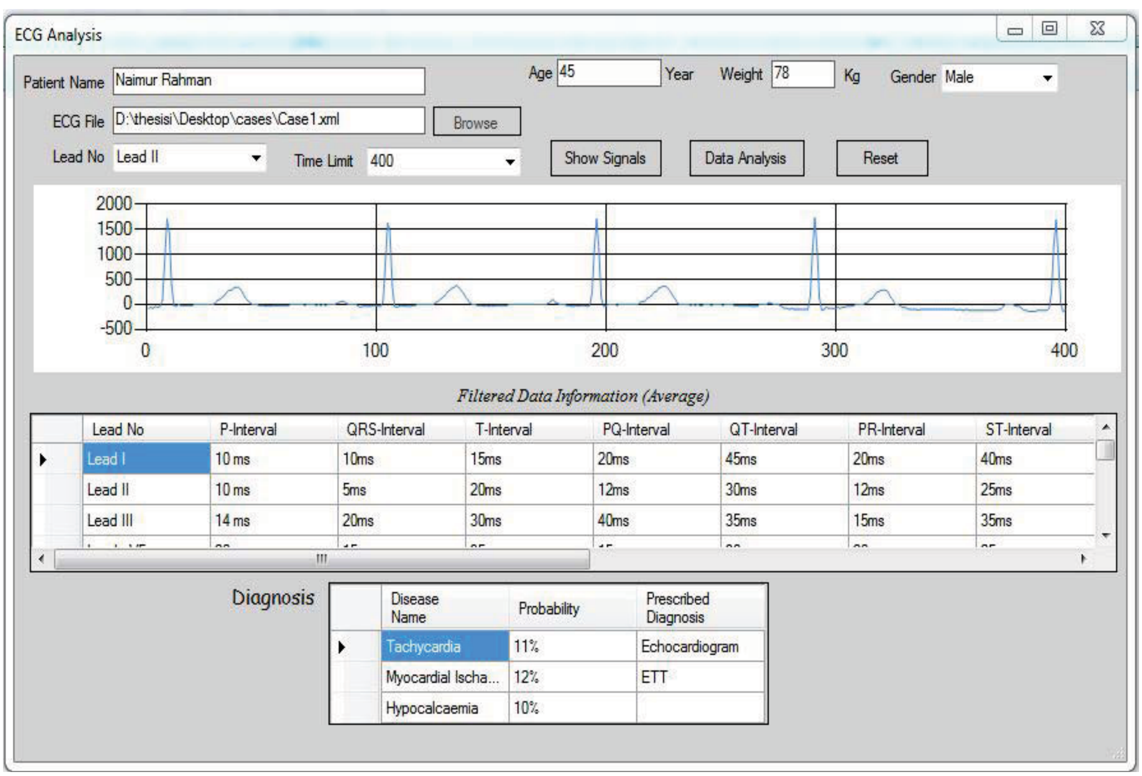


Figure 14 : Report generation unit of the Automatic ECG Diagnosis

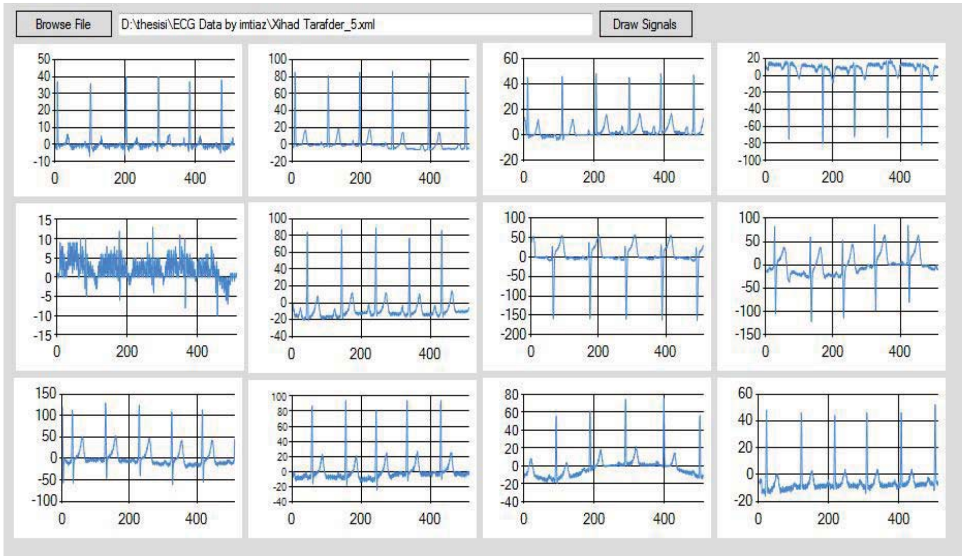


Figure 15 : Output graphs of the 12-lead input ECG signal of a patient

The fields of this table will be compared with the standard values and abnormalities stored earlier and will generate a probabilistic diagnosis based on this ruled based architecture. Thus *"Comparison Result"* table will be filled on and to display in report generation unit.

c) Report Generation and Case Study

"*Task*" menu containing "*ECG Analysis*" and "*ECG Signals*" sub-menu in the "*Main Form*" is the report generation section where to recognize/ browse the given ECG log file (.xml format) with patient details. Extracted characteristic features from all 12-leads will be displayed in tabular format with probabilistic diagnosis in "ECG Analysis" form Figure14. Again, in some analysis purposes, sometimes it is necessary for physicians to have visual representation of ECG waveform than to have the measured characteristic value, may be 12-lead graph all-together for comparison. "*ECG Signals*" form is designed (Figure15) for this purpose with the scales are in millisecond and millivolt in time & amplitude axis respectively.

VII. Analysis

To analysis the performance of the proposed system, it was needed the noise simulated raw ECG signal and the real life ECG data. Using advanced signal processing toolkit (ASPT) in Lab VIEW (Laboratory Virtual Instrument Engineering Workbench)-2009, the low noise ECG signal (used in earlier analysis) and the raw waveform from MIT-BIH Arrhythmia database are simulated by mixing different types of noises (Figure13). Figure13 b shows the wave form of such a noise

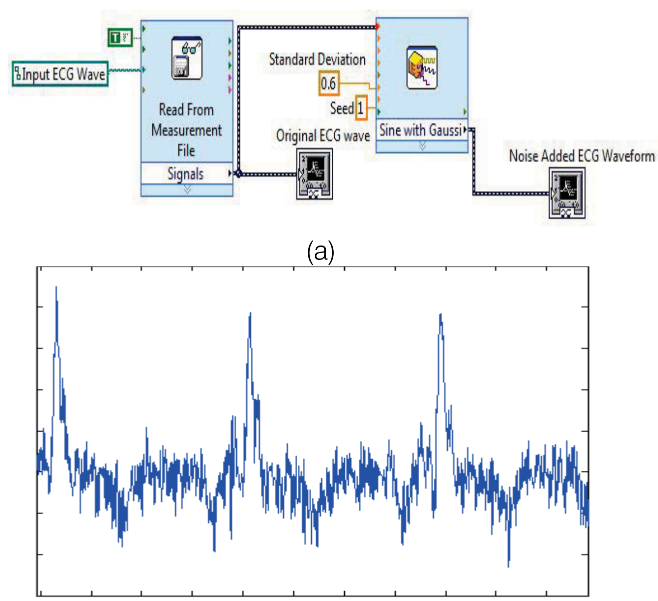


Figure 13 : (a) LabVIEW VI diagram for adding noise with ECG waveform b) Lab VIEW Simulated ECG waveform with maximum noise

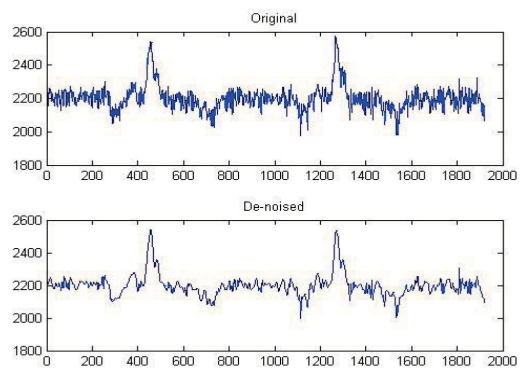


Figure 15 : The original and De-noised Simulated ECG Waveform in normalized scale (after the application of the proposed algorithm)

simulated ECG signal. The proposed algorithm of SectionV for De-noising and feature extraction using WT is executed on this waveform (Figure14). It is obvious from graphical interpretation that not all the noise or artifacts would be possible to remove but it presents a quite satisfactory margin for noise removal that can draw attention for any further reference. The performance of this proposed algorithm is also assessed with the help of MIT-BIH arrhythmia database. Regular ECG record 101m is more appropriate for this analysis as it contains moderate noise level. Applying the methodology on this database file, the R-R intervals are found 0.9733, 0.8666, 0.9211, 0.9516, 0.8996, 0.8980, 0.8694, 0.8117, 0.9000, 0.8999 and so on. Since these values are not constant throughout the ECG waveform, it indicates the abnormality of the heart. This result is quite considerable according the details attached with the header file. Table3 shows more the implementation of the proposed algorithm with the sensitivity *Se* calculation.

Table 3 : Performance analysis of proposed algorithm using reference MIT-BIH Database

Record No.	Total Beats	Detected Beats TP	Sensitivity (%)	Accuracy (%)
100	2273	2172	89.96	11.04
101	1865	1864	93.12	6.88
102	2179	2100	92.15	7.75
103	2078	2123	94.52	5.48
105	2543	2633	91.86	8.14
107	2124	2088	92.35	7.65
108	1775	1864	93.49	6.51
109	2530	2520	89.67	10.33
115	1953	1825	90.23	9.77
118	2278	2187	94.56	5.44
119	1987	1768	95.16	4.84
124	1473	1366	89.65	10.35
200	2601	2806	90.12	9.88

For the performance analysis of the proposed software, a series of raw ECG log files with the diagnosis report by their system has been collected from the Department of Biomedical Engineering, University of Dhaka. Table4 shows the comparisons with the proposed system developed in SectionVI. It is obvious from these outcomes that the diagnosis reports generated by the proposed algorithm are quite similar to the diagnosis report collected from the reference system with only 10% variation. The functionality of this software has also being checked by a physician.

Table 4 : Performance comparison of the diagnosis report of the proposed system with the reference diagnosis report

	Case 1		Case 2		Case 3	
ECG Features	This system	Ref. system	This system	Ref. system	This system	Ref. system
P-int	10ms	12ms	15ms	20ms	10ms	15ms
QRS-int	10ms	14ms	20 ms	18 ms	15ms	20ms
T-int	15ms	16ms	35 ms	30 ms	40ms	42ms
PQ-int	20ms	23ms	15 ms	18 ms	15ms	19ms
QT-int	45ms	40ms	30 ms	35 ms	35ms	32ms
PR-int	20ms	15ms	15 ms	20 ms	16ms	15ms
ST-int	40ms	38ms	20 ms	22 ms	25ms	28ms

VIII. Results and Discussion

The proposed algorithm obtains an average sensitivity rate of 93.7% and average error rate below 8% after analyzing 25 records. To our knowledge, only the R spike detectors based on Li's algorithm [15] obtained the comparable results with sensitivity between 99.7% and 99.9%. However, that algorithm makes use of several heuristic rules and requires the setting of many empirical parameters. Here the proposed algorithm achieves comparable performances with a simple non-parametric thresholding method and without any need of advanced post processing stage comparing to that article. Also, the presented the software implementation of this algorithm proves that the accurate diagnosis is always satisfactory utilizing this detection logic.

IX. Conclusion and Future Work

The large variety of ECG feature extraction algorithms and the continuous efforts for their enhancement proves that universally acceptable solution has not been found yet. In this study, emphasizing on wavelet thresholding, relevant noise removal and utilization of simple detection logic for the ECG characteristics detection is present. A robust and efficient tool for fast, less complex practical software is also provided that can be interfaced efficiently with commercial ECG machines. The complete verification of the proposed software can lead a massive utilization in even rural areas where the presence of the physicians is not so available. The day-by-day improvement in Bio-medical field demands the comprehensive update of the software's database to include the miniature researches. And the more attractive feature could have been included based on the interests of end-level users (patients). These are left open for the future.

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BER Analysis of 2x2 Spatial Multiplexing under AWGN and Rayleigh Channels for Different Modulations

By Anuj Vadhera & Lavish Kansal
Lovely Professional University, India

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Keywords : spatial multiplexing (SM), multiple-input multiple-output (MIMO), bit error rate (BER), zero forcing (ZF), minimum mean square estimator (MMSE).

GJRE-F Classification : FOR Code: 090609

BER ANALYSIS OF 2X2 SPATIAL MULTIPLEXING UNDER AWGN AND RAYLEIGH CHANNELS FOR DIFFERENT MODULATIONS

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Anuj Vadhera [α] & Lavish Kansal [σ]

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I. Introduction

As the demand for high-data rate multimedia grows, several approaches such as increasing modulation order or employing multiple antennas at both transmitter and receiver have been studied to enhance spectral efficiency[1], [2]. As per the requirements MIMO system has emerged as one of the most promising techniques in wireless communications due to its great potential to improve system reliability and increase channel capacity. Two typical approaches in the MIMO systems are to provide diversity gain as in space-time coding (STC) or to allow spatial multiplexing (SM). While STC systems are capable of improving system reliability through coding across space and/or time, SM systems are capable of increasing data transmission rate through spatial multiplexing. In this paper we focus on SM technique.

The basic concept of spatial multiplexing is to divide (multiplex) and transmit a data stream into several branches and transmit via several (independent) channels in space and different bits are transmitted via different antennas. One of the key advantages of MIMO spatial multiplexing is the fact that it is able to provide additional data capacity thus providing capacity gain.

MIMO spatial multiplexing achieves this by utilizing the multiple paths and effectively using them as additional channels to carry data such that receiver receives multiple data at the same time. The tenet in spatial multiplexing is to transmit different symbols from each antenna and the receiver discriminates these symbols by taking advantage of the fact that, due to spatial selectivity, each transmit antenna has a different spatial signature at the receiver . This allows an increased number of information symbols per MIMO symbol. In any case for MIMO spatial multiplexing, the number of receiving antennas must be equal to or greater than the number of transmit antennas such that data can be transmitted over different antennas. Therefore the space dimension is reused or multiplexed more than one time. The data streams can be separated by equalizers if the fading processes of the spatial channels are nearly independent. Spatial multiplexing requires no bandwidth expansion and provides additional data bandwidth in multipath radio scenarios [2].

The general concept of spatial multiplexing can be understood using MIMO antenna configuration. In spatial multiplexing, a high data rate signal is split into multiple lower data rate streams and each stream is transmitted from a different transmitting antenna in the same frequency channel. If these signals arrive at the receiver antenna array with different spatial signatures, the receiver can separate these streams into parallel channels thus improving the capacity. Thus spatial multiplexing is a very powerful technique for increasing channel capacity at higher SNR values. The maximum number of spatial streams is limited by the lesser number of antennas at the transmitter or receiver side. Spatial multiplexing can be used with or without transmit channel knowledge.

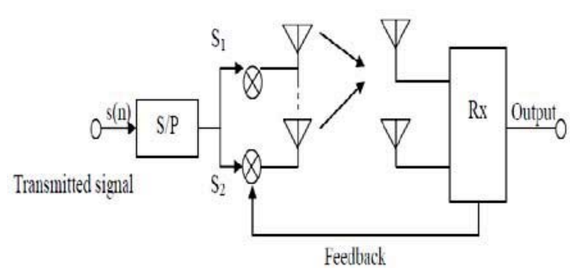

Figure 1 : Spatial Multiplexing Concept

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II. Multiple Input Multiple Output (MIMO)

Multiple antennas can be used at the transmitter and receiver, an arrangement called a MIMO system. A MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. MIMO systems may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity gain. Generally, there are three categories of MIMO techniques. The first aims to improve the power efficiency by maximizing spatial diversity. Such techniques include delay diversity, STBC and STTC. The second class uses a layered approach to increase capacity. One popular example of such a system is V-BLAST suggested by Foschini et al. [2] where full spatial diversity is usually not achieved. Finally, the third type exploits the knowledge of channel at the transmitter. It decomposes the channel coefficient matrix using SVD and uses these decomposed unitary matrices as pre- and post-filters at the transmitter and the receiver to achieve near capacity [3].

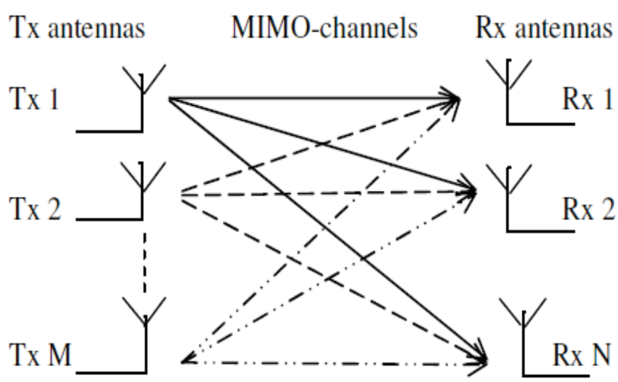


Figure 2 : Block Diagram of a generic MIMO system with M transmitters and N receivers

a) Modulation

Modulation is the process of mapping the digital information to analog form so it can be transmitted over the channel. Consequently every digital communication system has a modulator that performs this task. Closely related to modulation is the inverse process, called demodulation, done by the receiver to recover the transmitted digital information [4].

Modulation of a signal changes binary bits into an analog waveform. Modulation can be done by changing the amplitude, phase, and frequency of a sinusoidal carrier. There is several digital modulation techniques used for data transmission.

i. *Phase Shift Keying (PSK)*

Phase Shift Keying is a digital modulation scheme that conveys data by changing or modulating, the phase of a reference signal (the carrier wave). In M-ary PSK modulation, the amplitude of the transmitted signals was constrained to remain constant, thereby yielding a circular constellation. Modulation equation of M-PSK signal is:

$$s_i(t)=\sqrt{\frac{2E_S}{T}}\cos\left(2\pi f_c t+\frac{2\pi i}{M}\right) \quad (1)$$

i=0,1….,M

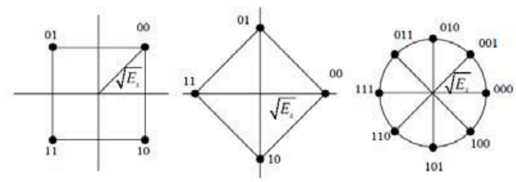


Figure 3 : Constellation Diagrams of M-PSK

(a) QPSK (b) QPSK (c) 8-PSK

b) Channels

Wireless transmission uses air or space for its transmission medium. The radio propagation is not as smooth as in wire transmission since the received signal is not only coming directly from the transmitter, but the combination of reflected, diffracted, and scattered copies of the transmitted signal.

Reflection occurs when the signal hits a surface where partial energy is reflected and the remaining is transmitted into the surface. Reflection coefficient, the coefficient that determines the ratio of reflection transmission, depends on the material properties.

Diffraction occurs when the signal is obstructed by a sharp object which derives secondary waves. Scattering occurs when the signal impinges upon rough surfaces, or small objects. Received signal is sometimes stronger than the reflected and diffracted signal since scattering spreads out the energy in all directions and consequently provides additional energy for the receiver which can receive more than one copies of the signal in multiple paths with different phases and powers. Reflection, diffraction and scattering in combination give birth to multipath fading.

i. *AWGN Channel*

Additive white Gaussian noise (AWGN) channel is universal channel model for analyzing modulation schemes. In this model, the channel does nothing but add a white Gaussian noise to the signal passing through it. This implies that the channel's amplitude frequency response is flat (thus with unlimited or infinite bandwidth) and phase frequency response is linear for all frequencies so that modulated signals pass through it without any amplitude loss and phase distortion of frequency components. Fading does not exist. The only distortion is introduced by the AWGN. AWGN channel is a theoretical channel used for analysis purpose only. The received signal is simplified to:

$$r(t)=s(t)+n(t) \quad (2)$$

where n(t) is the additive white Gaussian noise.

ii. *Rayleigh Channel*

Constructive and destructive nature of multipath components in flat fading channels can be approximated by Rayleigh distribution if there is no line of sight which means when there is no direct path between transmitter and receiver. The received signal can be simplified to:

$$r(t)=s(t)*h(t)+n(t) \quad (3)$$

where h(t) is the random channel matrix having Rayleigh distribution and n(t) is the additive white Gaussian noise. The Rayleigh distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function (pdf) given by

$$p(r) = \frac{r}{\sigma^2} e^{\frac{-r^2}{2\sigma^2}} \qquad 0 \le r \le \infty \quad (4)$$

where σ^2 is the time-average power of the received signal.

c) Signal Detection Techniques

There are numerous detection techniques available with combination of linear and non-linear detectors. The most common detection techniques are ZF, MMSE and ML detection technique. The generalized block diagram of MIMO detection technique is shown in Figure 4.

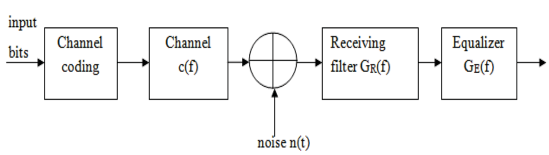


Figure 4 : Block Diagram of system with equalizer

i. *Zero Forcing (ZF) Detection*

The ZF is a linear estimation technique, which inverse the frequency response of received signal, the inverse is taken for the restoration of signal after the channel. The estimation of strongest transmitted signal is obtained by nulling out the weaker transmit signal. The strongest signal has been subtracted from received signal and proceeds to decode strong signal from the remaining transmitted signal. ZF equalizer ignores the additive noise and may significantly amplify noise for channel.

The basic Zero force equalizer of 2x2 MIMO channel can be modeled by taking received signal y_1 during first slot at receiver antenna as:

$$y_1 = h_{1,1}x_1 + h_{1,2}x_2 + n_1 = [h_{1,1} \quad h_{1,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1 \quad (5)$$

The received signal y_2 at the second slot receiver antenna is:

$$y_2 = h_{2,1}x_1 + h_{2,2}x_2 + n_2 = [h_{2,1} \quad h_{2,2}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2 \quad (6)$$

where i=1, 2 in x_i is the transmitted symbol and i=1, 2 in $h_{i,j}$ is correlated matrix of fading channel, with j represented transmitted antenna and i represented receiver antenna, is the noise of first and second receiver antenna. The ZF equalizer is given by:

$$W_{ZF} = (H^H)^{-1}H^H \quad (7)$$

Where W_{ZF} is equalization matrix and H is a channel matrix. Assuming $M_R \geq M_T$ and H has full rank, the result of ZF equalization before quantization is written as:

$$y_{ZF} = (H^H H)^{-1}H^H y \quad (8)$$

ii. *Minimum Mean Square Estimator*

Minimum mean square error equalizer minimizes the mean-square error between the output of the equalizer and the transmitted symbol, Instead of removing ISI completely; an MMSE equalizer allows some residual ISI to minimize the overall distortion. Compared with a ZF equalizer, an MMSE equalizer is much more robust in presence of deepest channel nulls and noise. The MMSE equalization is:

$$W_{MMSE} = \arg_G^{min} E_{x,n}[\|x - x^{\wedge}\|^2] \quad (9)$$

Where is W_{MMSE} equalization matrix, H channel correlated matrix and n is channel noise

$$y_{MMSE} = H^H(HH^H + n_o I_n)^{-1} y \quad (10)$$

III. Results and Discussions

The system discussed above has been designed and results are shown in the form of SNR vs. BER plot for different modulations and different channels. Here antenna configuration 2x2 is analysed using ZF and MMSE detection techniques. Analyses have been done for two channels AWGN and Rayleigh channel.

a) Simulations using ZF Detection

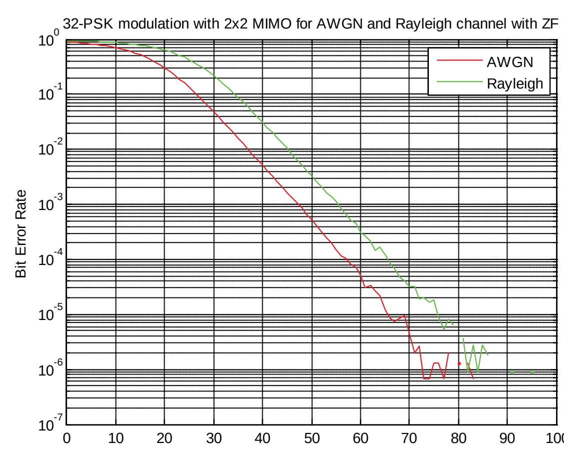
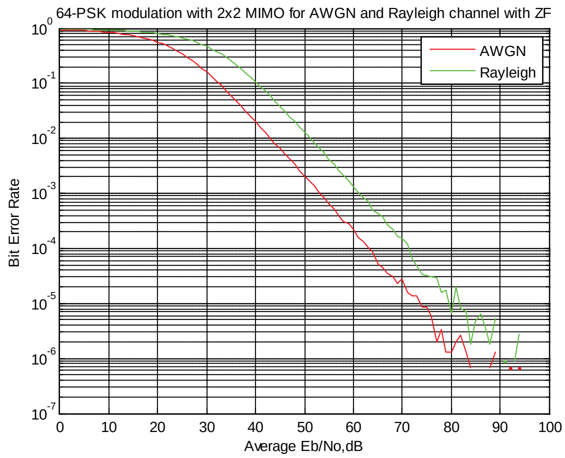


Figure 4 (a)



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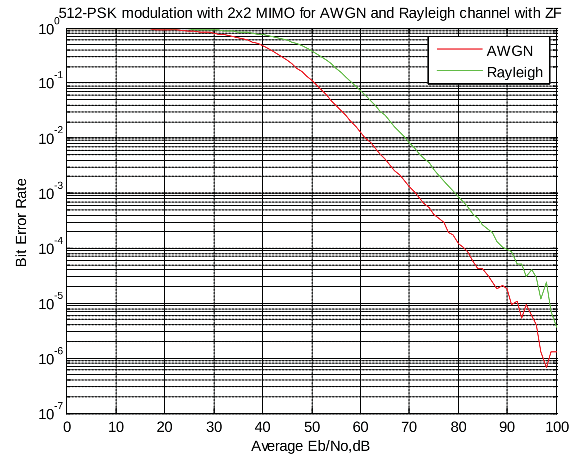

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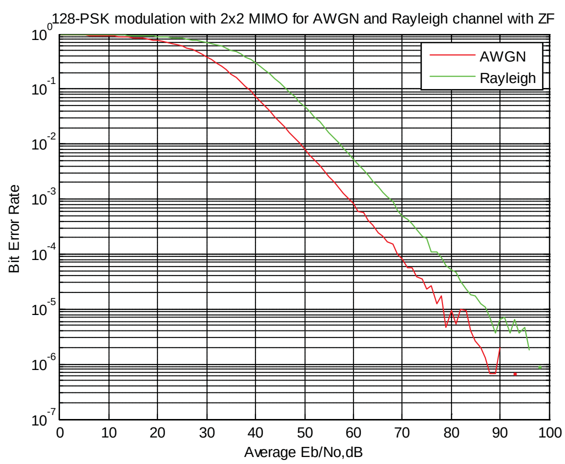

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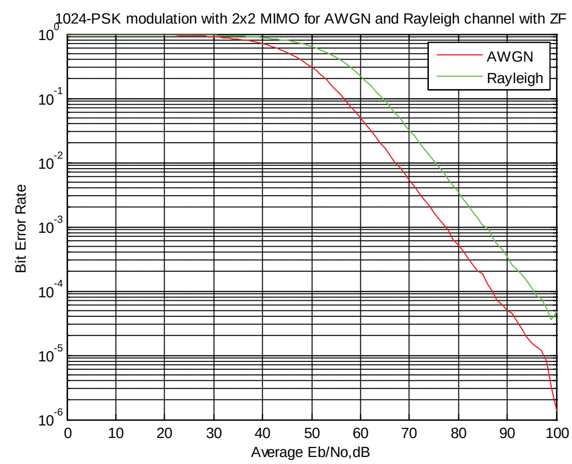


Figure 4 (f)

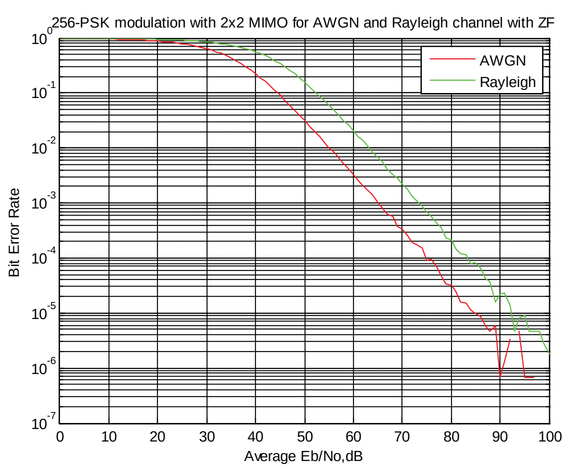


Figure 4 (d)

Figure 4 : BER vs. SNR plots over AWGN & Rayleigh channels for SM technique using 2x2 MIMO system: a) 32 PSK b) 64 PSK c) 128 PSK d) 256 PSK e) 512 PSK f) 1024 PSK

Table 1 : Comparison of different Modulation Techniques for Rayleigh & AWGN Channel for 2x2 MIMO Spatial Multiplexing using ZF Equalization

Modulations	Rayleigh Channel	AWGN Channel	Improvement
32-PSK	65dB	57 dB	8 dB
64-PSK	71 dB	64 dB	7 dB
128-PSK	77 dB	69 dB	8 dB
256-PSK	84 dB	76 dB	8 dB
512-PSK	90 dB	82 dB	8 dB
1024-PSK	96 dB	87 dB	9 dB

Table 1 presents that at 32-PSK, 128-PSK, 256-PSK, 512-PSK there is an improvement of 8dB, at 64-PSK and 1024-PSK there is an improvement of 7 and 9dB respectively at BER of 10^{-4}. Hence table shows the improvement in terms of decibels shown by proposed system employing SM technique for 2x2 MIMO system for different modulation schemes over different channels.

b) Using MMSE Detection

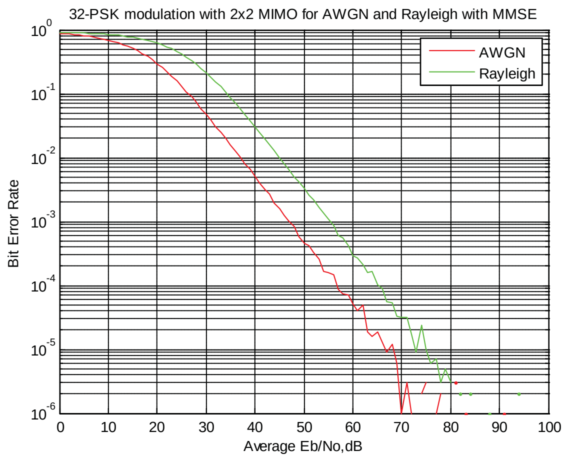
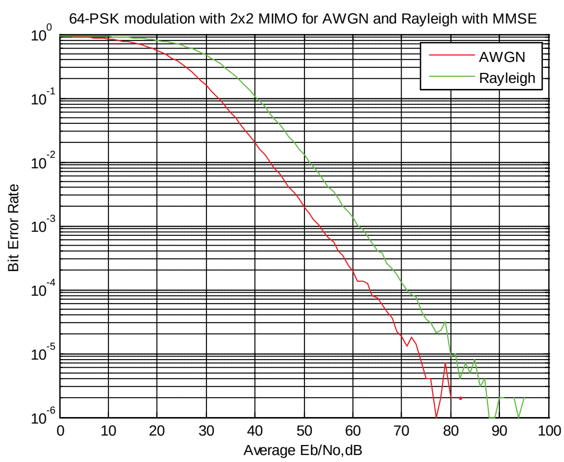


Figure 5(a)



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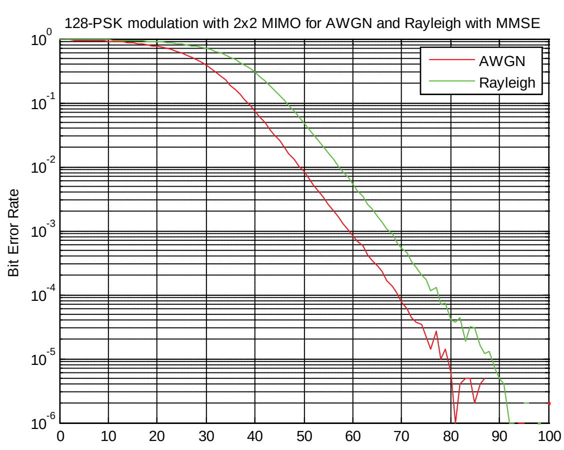

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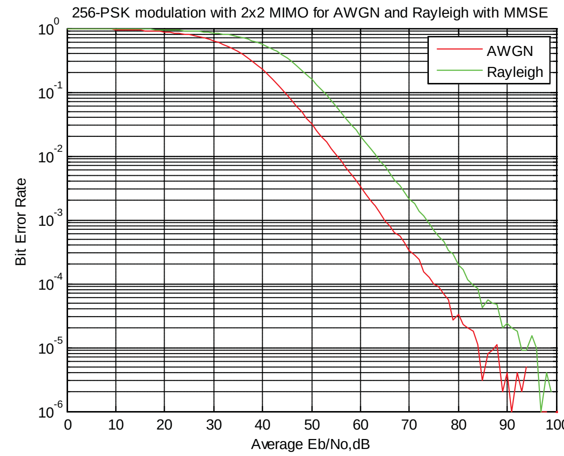

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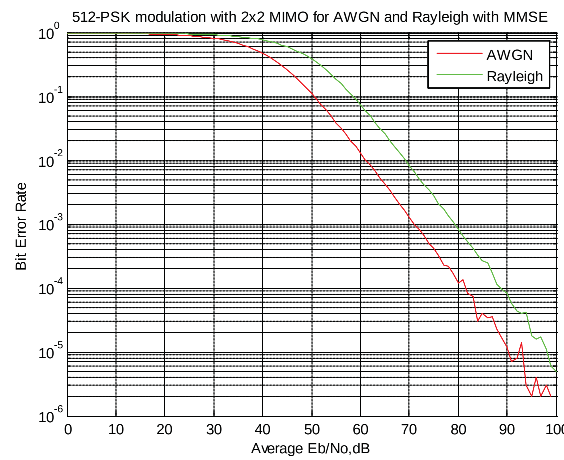

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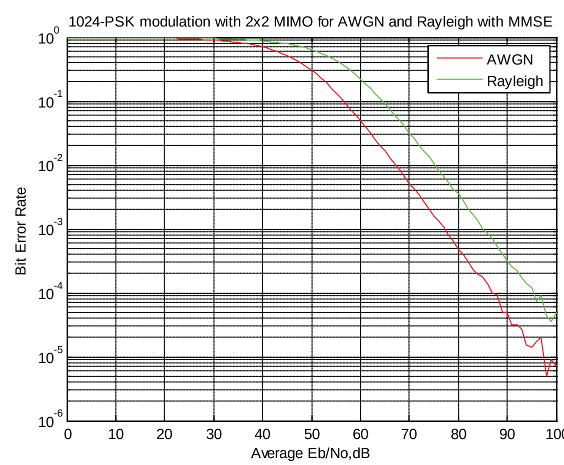

Figure 5(f)

Figure 5 : BER vs. SNR plots over AWGN & Rayleigh channe ls for SM technique using 2X2 MIMO system:
a) 32 PSK b) 64 PSK c) 128 PSK d) 256 PSK
e) 512 PSK f) 1024 PSK

Table 2 : Comparison of different Modulation Techniques for Rayleigh & AWGN Channel for 2x2 MIMO Spatial Multiplexing using MMSE Equalization

Modulations	Rayleigh Channel	AWGN Channel	Improvement
32-PSK	65dB	56 dB	9 dB
64-PSK	72 dB	64 dB	8 dB
128-PSK	77 dB	69 dB	8 dB
256-PSK	83 dB	75 dB	8 dB
512-PSK	88 dB	82 dB	6 dB
1024-PSK	96 dB	87 dB	9 dB

Table 2 presents that at 32-PSK, 1024-PSK there is an improvement of 9dB, at 64-PSK, 128-PSK, 256-PSK there is an improvement of 8dB and at 512-PSK there is an improvement of 6dB at BER of 10^{-4}. Hence table shows the improvement in terms of decibels shown by proposed system employing SM technique for 2x2 MIMO system for different modulation schemes over different channels.

IV. Conclusion

In this paper, an idea about the performance of the MIMO-SM technique at higher modulation levels and for 2x2 antenna configuration using different signal detection technique is presented. MIMO-SM technique can be implemented using higher order modulations to achieve large data capacity. But there is a problem of BER (bit error rate) which increases as the order of the modulation increases. The solution to this problem is to increase the value of the SNR so, that the effect of the distortions introduced by the channel will also goes on decreasing, as a result of this, the BER will also decreases at higher values of the SNR for high order modulations.

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Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

6.1 Proof Corrections

The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

As changes to proofs are costly, we inquire that you only correct typesetting errors. All illustrations are retained by the publisher. Please note that the authors are responsible for all statements made in their work, including changes made by the copy editor.

6.2 Early View of Global Journals Inc. (US) (Publication Prior to Print)

The Global Journals Inc. (US) are enclosed by our publishing's Early View service. Early View articles are complete full-text articles sent in advance of their publication. Early View articles are absolute and final. They have been completely reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after sending them. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the conventional way.

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6.4 Author Material Archive Policy

Please note that if not specifically requested, publisher will dispose off hardcopy & electronic information submitted, after the two months of publication. If you require the return of any information submitted, please inform the Editorial Board or dean as soon as possible.

6.5 Offprint and Extra Copies

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You must strictly follow above Author Guidelines before submitting your paper or else we will not at all be responsible for any corrections in future in any of the way.

Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Administration Rules Listed Before
Submitting Your Research Paper to Global Journals Inc. (US)

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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