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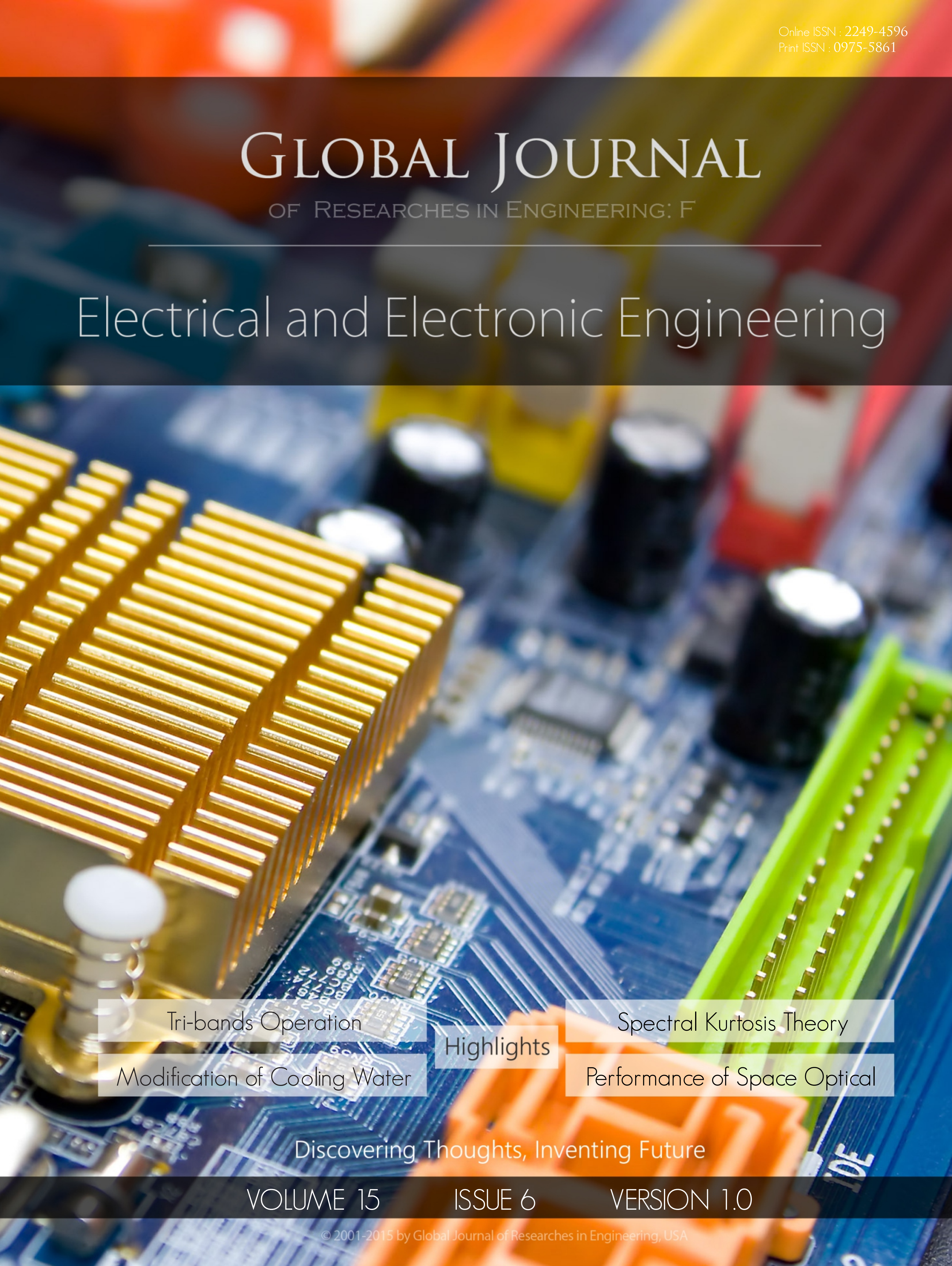

Highlights

- Tri-bands Operation
- Modification of Cooling Water
- Spectral Kurtosis Theory
- Performance of Space Optical

Discovering Thoughts, Inventing Future

VOLUME 15 ISSUE 6 VERSION 1.0

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A Rectangular Microstrip Antenna Loaded with Log-Periodic Stubs for Tri-Bands Operation

By Shripad S. Pingle & Veeresh G. Kasabegoudar
MBES College of Engineering, Ambajogai & India

Abstract- In this paper, a rectangular microstrip antenna loaded with two log periodic stubs is proposed. The antenna geometry is fed with a microstrip line which is tapered at the connection point. The proposed geometry is designed on easily available FR4_epoxy dielectric material and the dimensions of the dielectric substrate used are of 48 mm x 36 mm x 1.6 mm. Antenna geometry's performance is investigated in the frequency range between 2 GHz to 20 GHz. The geometry exhibits resonances at 7.76GHz, 11.27GHz, and 16.22GHz which lie in the C, X, and Ku bands. To validate the design, proposed geometry was fabricated and tested. Measured results fairly agree with the simulated data.

Keywords: *planar antennas, rmsa, stub loading, triple band antennas.*

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ARECTANGULARMICROSTRIPANTENNALOADEDWITHLOG-PERIODICSTUBSFORTRI-BANDSOPERATION

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A Rectangular Microstrip Antenna Loaded with Log-Periodic Stubs for Tri-Bands Operation

Shripad S. Pingle [α] & Veeresh G. Kasabegoudar [σ]

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Keywords: planar antennas, rmsa, stub loading, triple band antennas.

I. Introduction

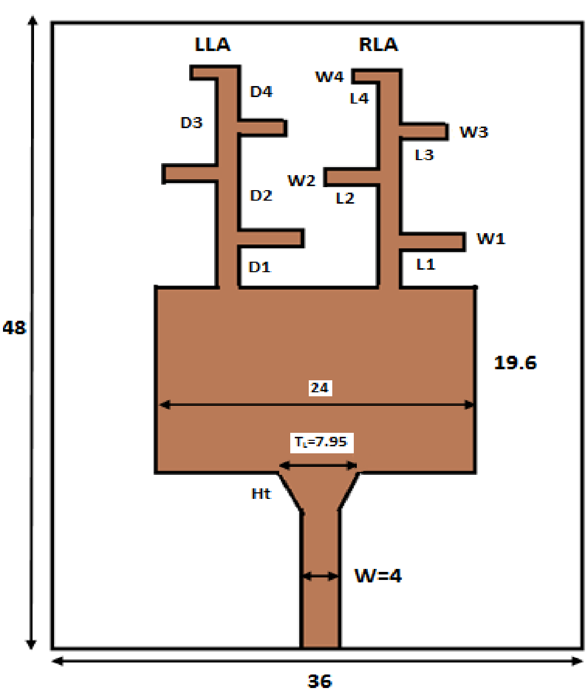
Log-periodic dipole antennas (LPDAs) were first reported by Rumsey's. Later, LPDA geometries for practical applications were developed by DuHamel, and Isbell [1]. After this, R. Carrel [2] reported mathematical analysis of LPDA and computed its various parameters like radiation patterns and input impedance. However, in modern wireless applications planar (2D) antennas are preferred over 3D antennas. Among planar antennas, microstrip antennas are most preferred ones because of their light weight, small size, low cost, and ease of fabrication and integration [3-6].

In order to increase the density and to reduce the size/volume the concept of substrate integrated circuits, particularly the laminated waveguide [6–9] and the substrate integrated waveguide (SIW) [10–19], has been proposed as a promising technology for microwave and millimeter-wave components & systems which helps in achieving low cost, planar, compact, and high-density integration. However, most of these geometries are complicated as whole geometry design depends on the log-periodic structure. In this work a simple rectangular microstrip antenna loaded with log-periodic stubs has been investigated thoroughly for exciting triple bands [20] with a very high gain of 10dB (conventional MSAs offer 5 to 6dB) and above at resonances. It should be noted that only stubs follow the LPDA technique whereas the base is a simple rectangular microstrip antenna (RMSA). Although, the proposed geometry exhibits multiple S11 bands, only three resonances are useful as gain is positive at these frequencies.

Antenna geometry is presented in Section 2. Section 3 presents geometry optimization procedure. Experimental results and discussions are covered in Section 4. Finally, the work is concluded in Section 5.

II. Antenna Design

The geometry of rectangular microstrip antenna loaded with log periodic stubs is shown in Figure 1 and its optimized dimensions are listed in Table 1. Log periodic stubs are added to excite the multiple resonances and to enhance bandwidth & gain of each resonance bands. The geometry was fed with the microstrip line which is tapered at the feed end for proper impedance matching. The proposed geometry was designed and optimized on easily available FR4_epoxy substrate with dielectric constant of 4.4 and thickness of 1.6 mm. The geometry was simulated with an Ansoft's high frequency structure simulator (HFSS) v.13 [21] which is electromagnetic simulation software. Section 3 gives the details of optimization procedure of the proposed antenna.



(a) Top view of RMSA with log-periodic stubs

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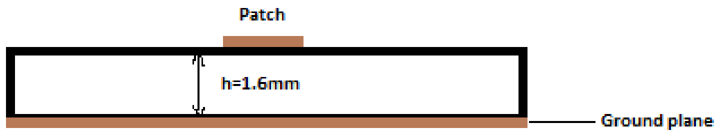


(b) Cross sectional view

Figure 1 : Geometry of the proposed antenna

Table 1: Dimensions of the optimized geometry

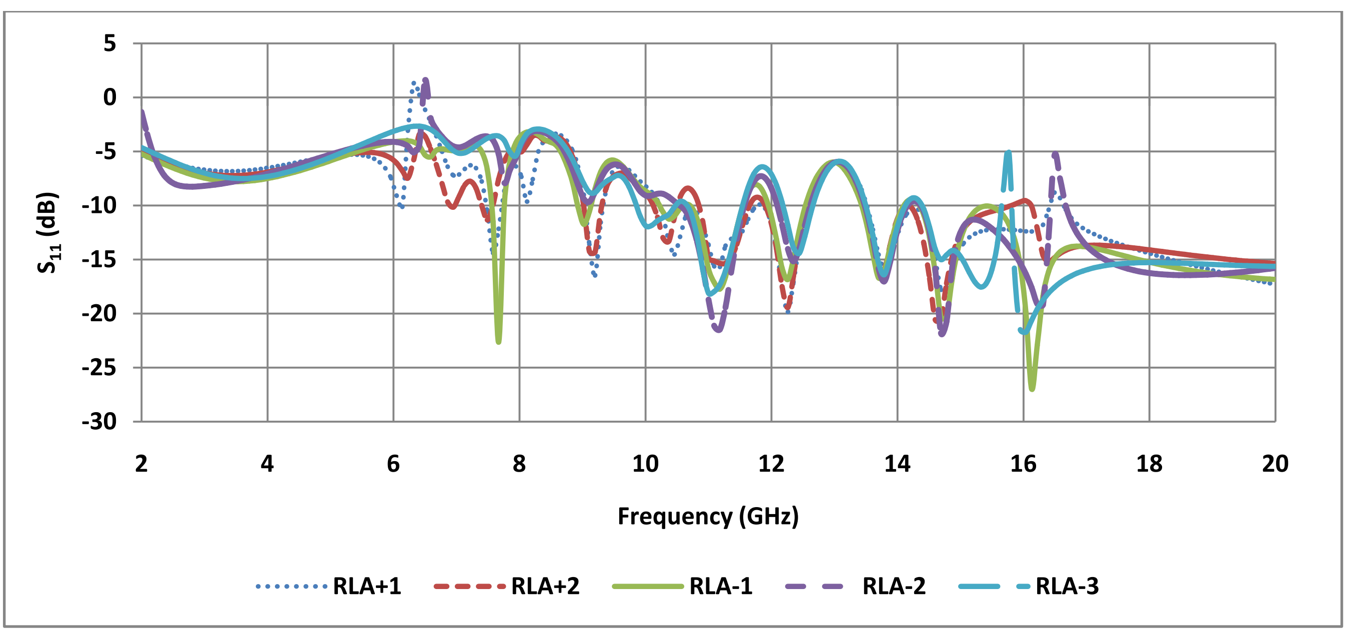
Parameter	L_1	L_2	L_3	L_4	W_1	W_2	W_3	W_4	D_1	D_2	D_3	D_4
Values (mm)	4	2.6	1.7	1.1	1	0.66	0.4	0.28	2.4	2	2	2

III. Geometry Optimization

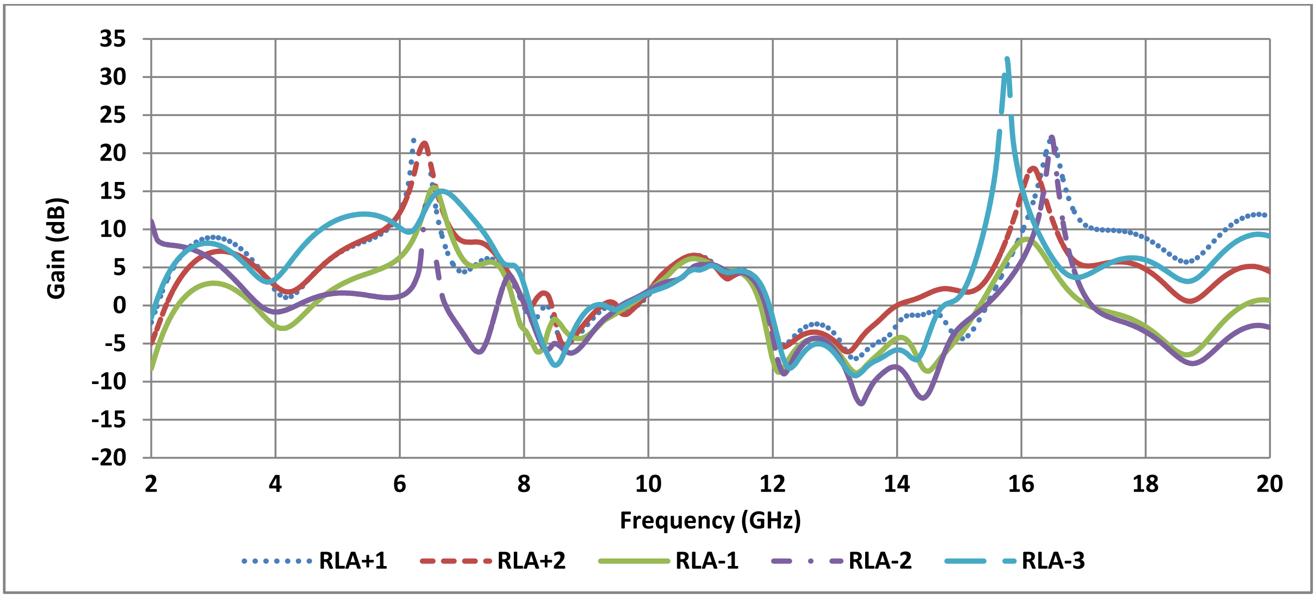
In this section parametric study is carried out for optimizing the proposed antenna geometry. Parameters chosen for optimization are position of right log arm (RLA), tapering length (TL), and feed arm width (W). Effect of all these parameters on antenna performance are investigated thoroughly and presented in the following sub-sections.

a) *Variation of Position of Right Log Arm (RLA)*

In this study right log arm (RLA w. r. t. right edge of rectangular base) position is varied from in steps of 2 mm and keeping all other parameters remains constant. The simulated results of reflection coefficient (S11) and gain of antenna are shown in Figure 2 (a) and (b) respectively. From the study of simulated reflection coefficient characteristics, gain of the antenna is optimum at RLA-1. (Note: RLA is the position of right log arm from edge of rectangular base and left movement is indicated by –ve sign and right movement is indicated by +ve sign).



(a) Effect of right log arm (RLA=4.5mm from right edge) variation on reflection coefficient characteristics



(b) Effect of right log arm (RLA=4.5mm from right edge) variation on gain characteristics

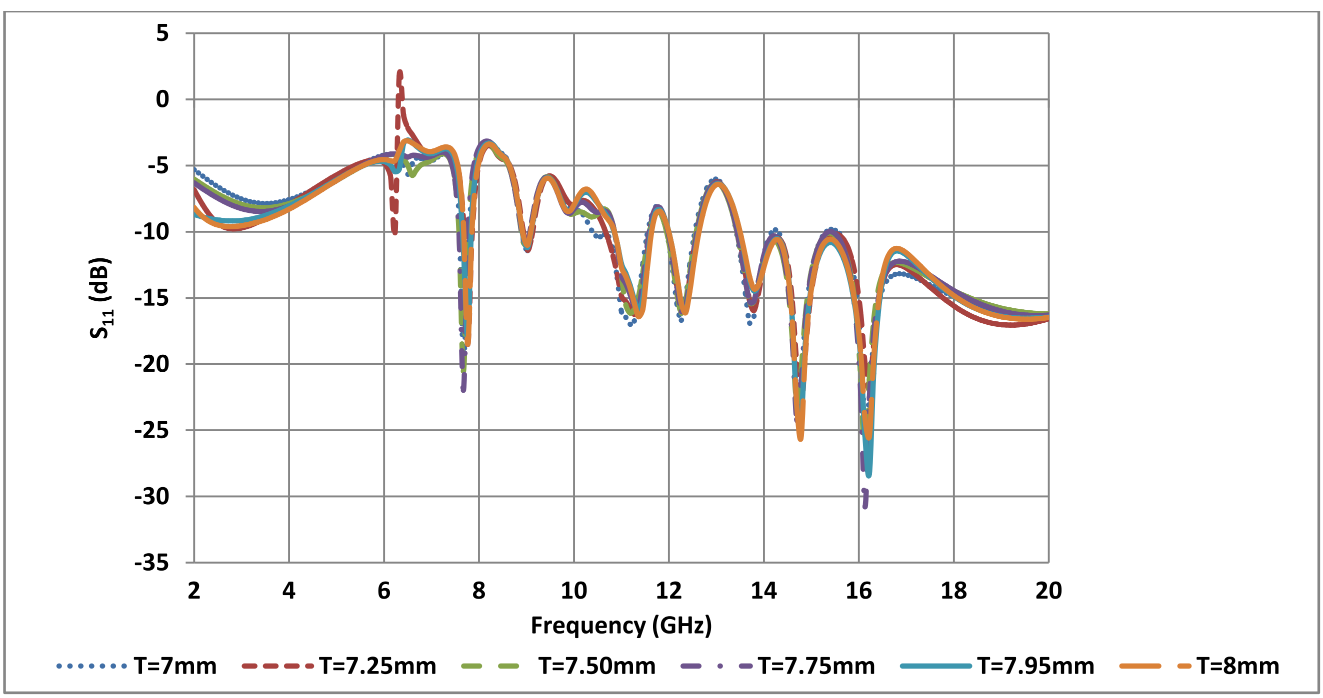
Figure 2 : Reflection and gain vs. frequency characteristics

b) Variation of Tapering Length (TL)

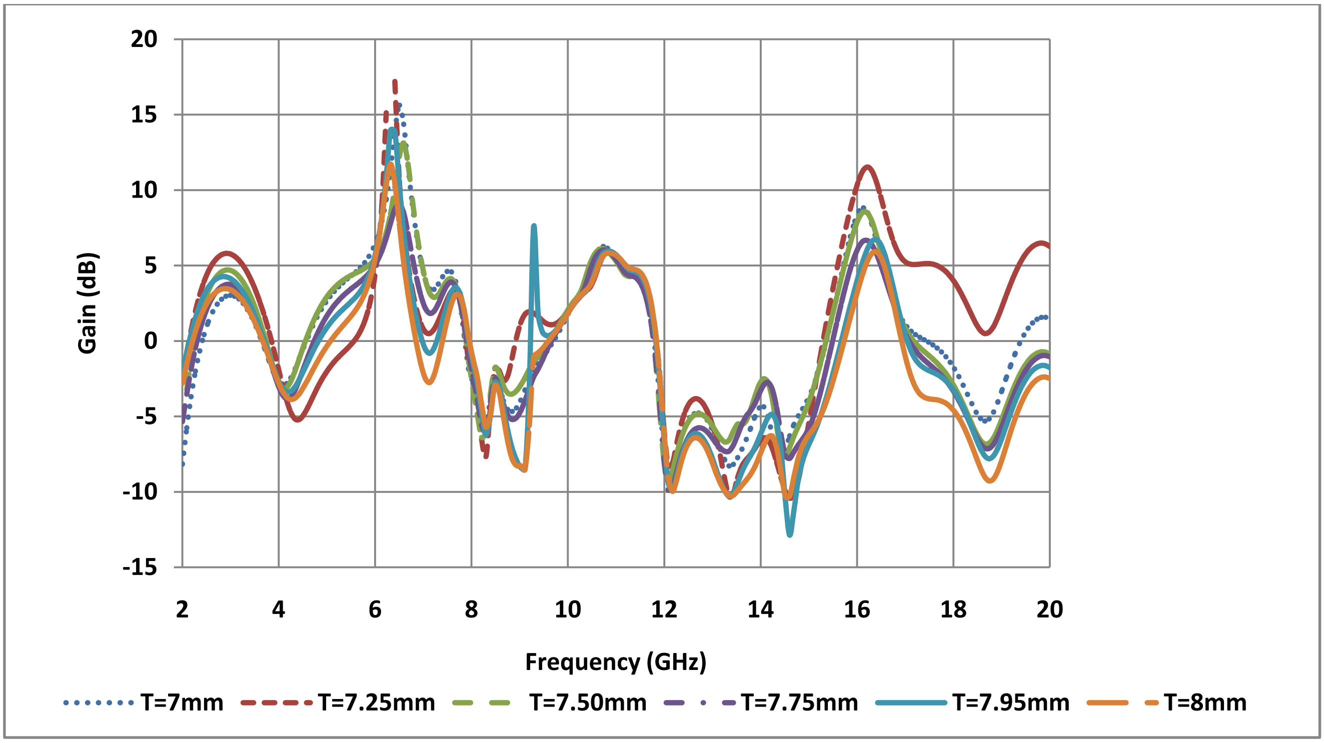
The proposed antenna is excited through microstrip line. However, for proper matching, the point at which the line is joined to antenna geometry is tapered. The tapering length (TL) at the connection point is varied in steps of 0.25 mm from 7mm to 8mm and keeping all other parameters constant. It is interesting to note that the geometry offers optimum results at TL = 7.95mm. The simulated results of reflection coefficient (S11) and gain of antenna are shown in Figure 3 (a) and (b), respectively. From the study of simulated reflection coefficient characteristics, optimum results are achieved for TL = 7.95mm.

c) Variation of Feed Arm Width (W)

In another effort, the width of microstrip feed line was varied to investigate its effect on antenna performance. The feed arm width (W) from 3.5mm to 4.5mm in steps of 0.25 mm and keeping all other parameters constant. The results (S11 and gain vs. freq) are presented in Figure 4 (a) and (b), respectively. From Figure 4 it may be noted that the optimum results can be obtained for W=4mm.

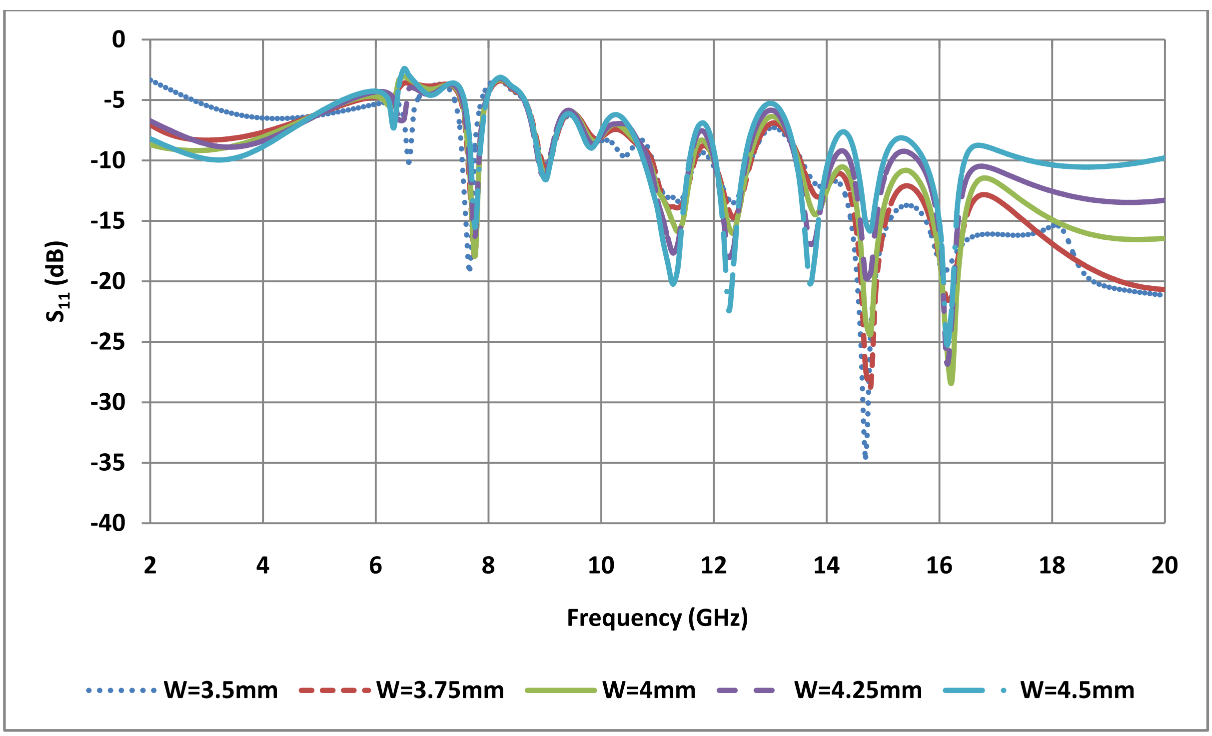


(a) The effect of tapering length (T_L) variation on reflection coefficient characteristics

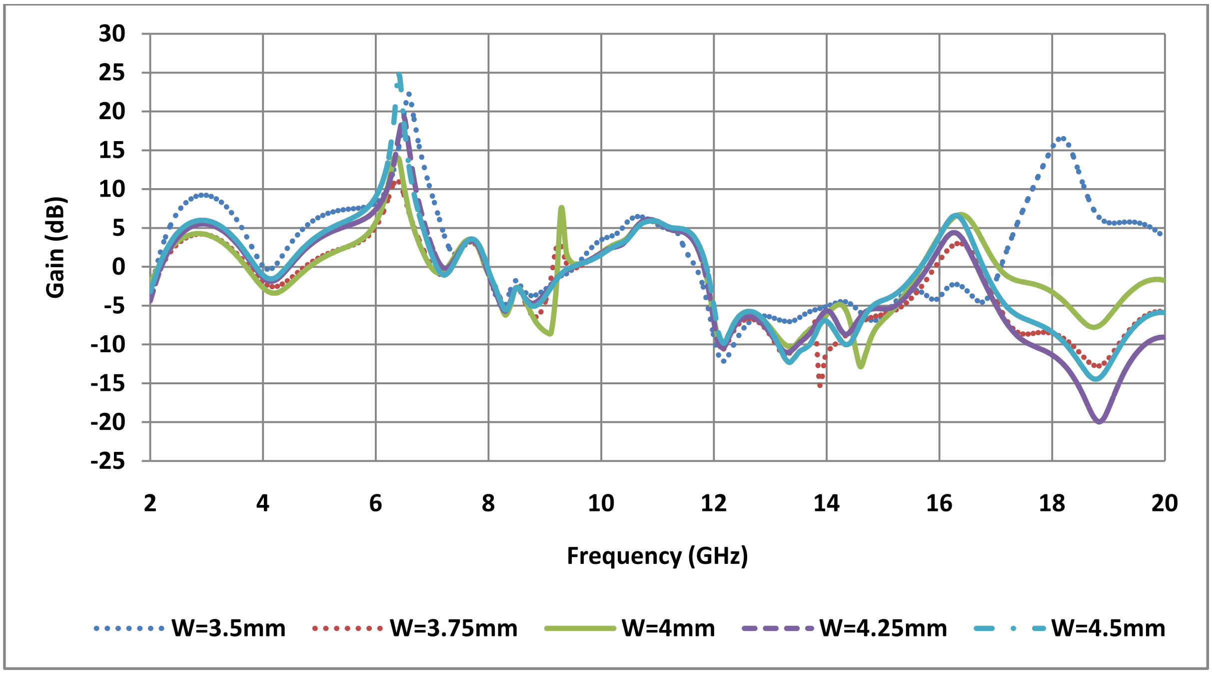


(b) The effect of tapering length (T_L) variation on gain characteristics

Figure 3 : Reflection and gain vs. frequency characteristics



(a) The effect of feed arm width (W) variation on reflection coefficient characteristics

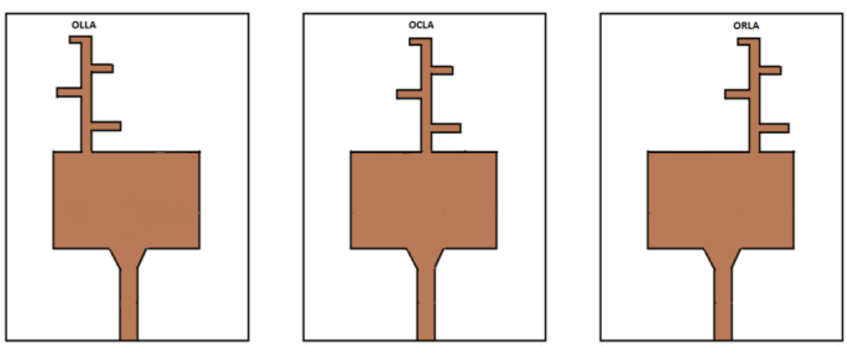


(b) The effect of feed arm width (W) variation on gain.

Figure 4 : Reflection and gain vs. frequency characteristics

d) Proposed Geometry with Single Log-periodic Stub

In order to understand the effect of individual stub, we used one at a time i.e., one arm is kept and other is removed. Also, the single arm effect was observed by keeping it at the center of the antenna geometry (Figure 5). However, no significant change in the results was observed (pl. ref. Figure 6).

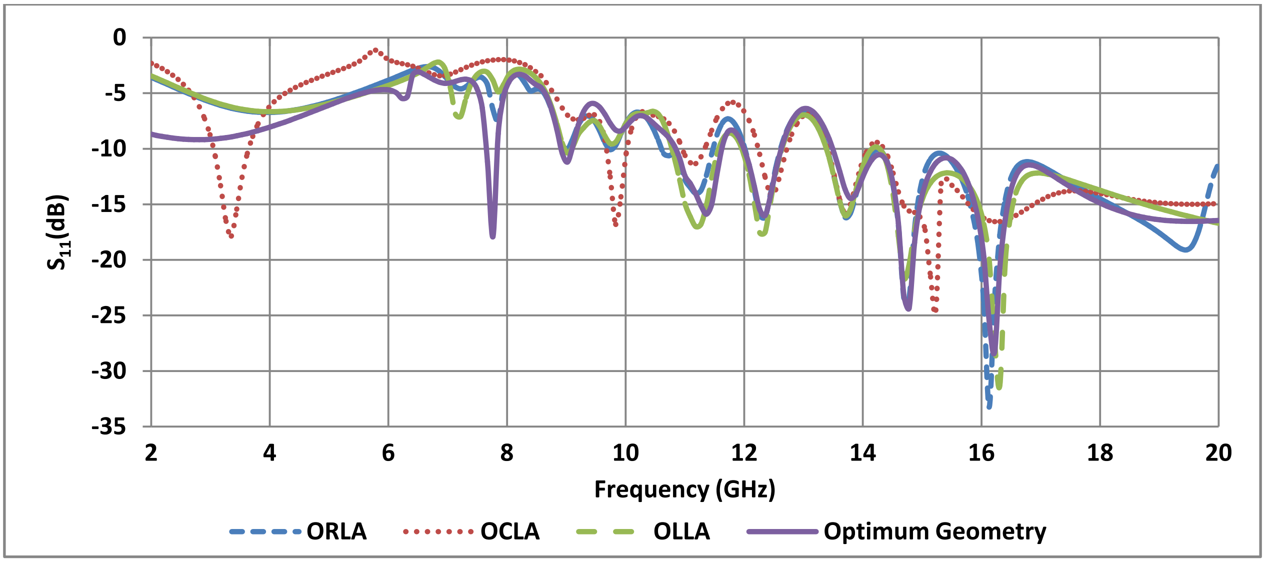


(a) (b) (c)

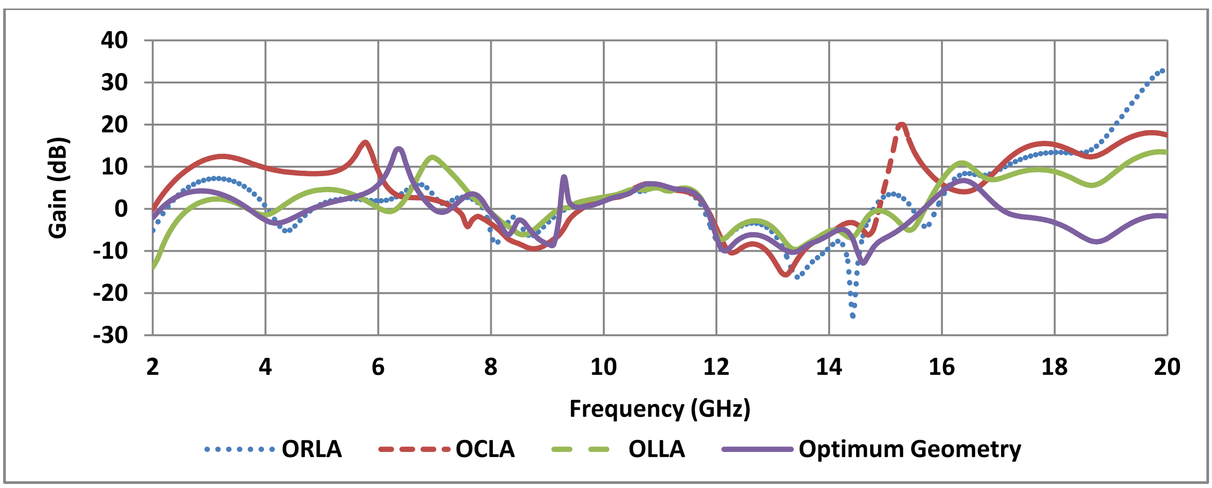
Figure 5 : Sketches of Geometry loaded with only one stub (a) Only left log arm (b) Only center log arm (c)Only right log arm

IV. Experimental Validation of the Geometry and Discussions

The proposed geometry shown in Figure 1 with its optimized dimensions listed in Table 1 is fabricated on FR4_epoxy substrate having dielectric constant of 4.4 and thickness of 1.6 mm. The photograph of fabricated prototype is shown in Figure 7. In Figure 8, the setup of measurement of reflection coefficient of antenna is shown. Reflection coefficient characteristics of measured results are compared with simulated values in Figure 9. From Figure 9 it may be noted that measured results fairly match with simulated data. Radiation patterns at all three resonances are plotted in Figure 10. From these plots it may be noted that the radiation characteristics are stable across the frequencies of operations.



(a) *The effect of log arm (LA) variation on reflection coefficient characteristics*.



(b) The effect of log arm (LA) variation on gain

Figure 6 : Reflection and gain vs. frequency characteristics (T=7.95mm case represents the optimum one)

(a) (b)

Figure 7 : Photograph of fabricated prototype (a) Front side (b) Back side

Figure 8 : Photograph of measurement setup

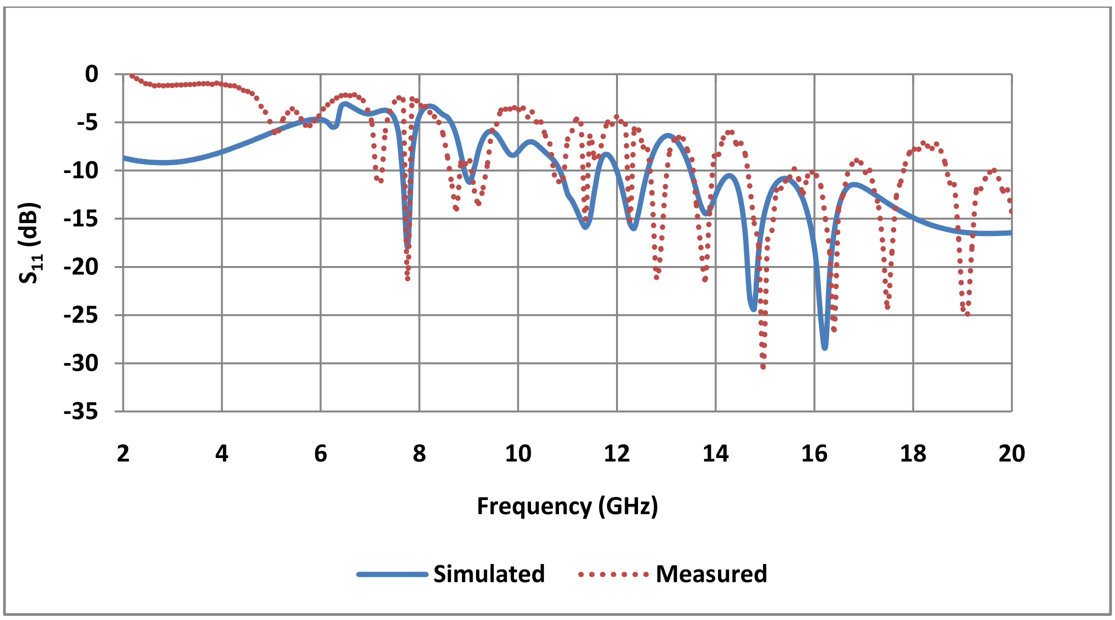
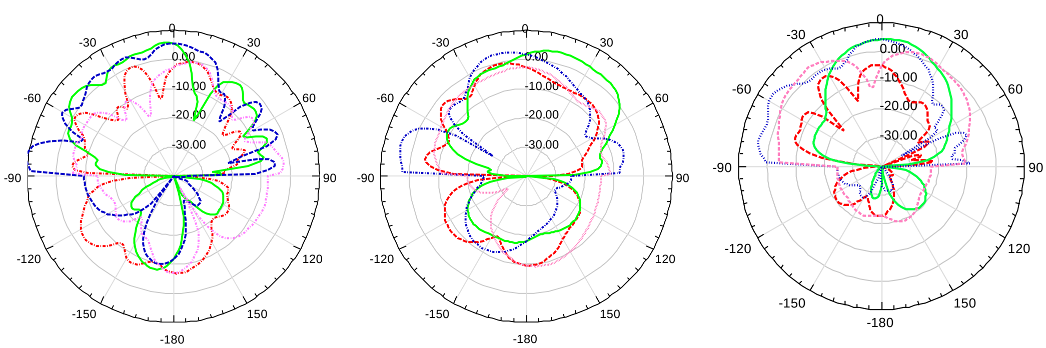


Figure 9 : Comparison of simulated and measured S11



(a) 7.76GHz (b) 11.27GHz (c) 16.22GHz

Figure 10 : Radiation patterns at three resonances of the antenna (Solid line (Green) H-Co Plon.; Dash-dot (Red) H-Cross Plon.; Dotted line (blue) E-Co Plon.; Dashed line (Magenta) E-Cross Plon.)

V. Conclusions

In this paper, a rectangular microstrip antenna loaded with two log periodic stubs is proposed. The proposed geometry is fed with a microstrip line which is tapered at the connection point for proper impedance matching. The proposed geometry is designed on easily available FR4_epoxy dielectric material and log periodic stubs are added to excite the multiple resonances and to enhance bandwidth of each resonance bands. Besides multiple resonances, the antenna offers high gain of greater than 10dB at the operating frequencies. The future work includes bandwidth enhancement of individual bands and possible investigation of excitation of four bands.

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Design Modification of Cooling Water System for Hydropower Plants [A Case Study of Middle Marsyangdi Hydropower Plant in Nepal]

By Shiv Kumar Shah & Dr. Rajendra Shrestha
Tribhuvan University, Nepal

Abstract- Middle Marsyangdi Hydropower Plant (MMHPP) in Nepal, has been currently facing a severe problem with the existing Cooling Water System (CWS) due to excessive silt which is coming with the flowing water in the open loop of CWS. Due to this, the existing system has been experiencing unexpected unit breakdown as well as frequent maintenance that ultimately cause a severe impact on the power generation.

This problem could be overcome by introducing a close loop circuit along with an open loop circuit of cooling water supply which passes through a Tubular Heat Exchanger directly submerged into Draft Tube water where heat transfer could takes place. Based on the suitable design parameters, existing site conditions of the plant and ensuring its technical feasibility, a detailed design of proposed Tubular Heat Exchanger has been carried out.

Keywords: middle marsyangdi hydropower plant (mmhpp) in nepal, cooling water system (cws).

GJRE-F Classification : *FOR Code: 090699*

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Keywords: middle marsyangdi hydropower plant (mmhpp) in nepal, cooling water system (cws).

I. Introduction

Middle Marsyangdi Hydropower Plant is located in Lamjung district of Nepal with an installed capacity of 70 MW and annual design generation of 398 GWh. It has two turbine units together with other Auxiliary equipment. It was commissioned in 2008 with assistance from Government of Germany and Government of Nepal at an estimated cost of NRs. 30 billion. Discharge from the river is diverted through 5.2 Km long power tunnel constructed along the right-bank of Marsyangdiriver up to Sinudibar where the Powerhouse is situated. The major components of MMHPP consist of combined concrete gravity and rock fill dam with gated Spillway, three numbers of underground Desander caverns, Headrace Tunnel, Surge Tank, Valve Chamber, Penstock, Powerhouse, Tailrace Structure, two numbers of Power Transformer bays and a 132 kV outdoor sub-station. The entire generated power is being sent to the Integrated Nepal Power System (INPS) via MMHPP 132 kV transmission line.

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Fig.1 : MMHPP Dam view from Downstream

MMHPP has been facing a severe problem with the existing Cooling Water System (CWS) due to excessive silt which is coming with the flowing water in the open loop of CWS. This excessive silt is not only causing frequent unit breakdown but also damaging various components associated with cooling water Pumps, Heat Exchangers, Automatic Water Strainers, Pipings, Backwash Flushing and other accessories. Frequent replacement of these damaged parts is not only expensive but also time consuming process when the unit cannot generate power. Cleaning of Heat Exchangers, Automatic Water Strainers and Pipings requires considerable time and the maintenance crews have to be engaged from time to time in carrying out such maintenance during monsoon affecting the other scheduled maintenances.

There is no doubt that the existing CWS of MMHPP is based on the latest and recent design and is better than the older system which exists at other large power plants such as Kaligandaki HPP, Marsyangdi HPP etc in Nepal. The older design incorporates only one loop i.e. open loop of Cooling Water Supply which either taps water directly from the Penstock (by gravity flow) or draws water from the Draft Tube by means of a water pump and supplies water to various consumers and sent back to the Draft Tube after cooling. Since MMHPP water from both sources is very dirty (full of silt) especially during monsoon, apart from damaging the associated components of CWS, it also damages the components associated with the various consumers at different locations where such dirty water is being supplied.

The existing compact Plate Heat Exchanger provides highly effective cooling and is very useful with clean water, however in context of Nepal, where most of the rivers are originated from Himalayas and have excessive quartzite sand, it is getting damaged quickly with sandy water as in the open loop of MMHPP.

Hence the existing system is not serving the desired purposes effectively and necessitates some design modification for improved and reliable cooling system which could have better performance even with sandy water. The concept is to design a Heat Exchanger in the form of a cooling coil or a Shell and Tube type of Heat Exchanger (without Shell) and the entire unit shall be placed directly inside the Draft Tube or Tailrace chamber at appropriate location where optimum cooling effect for the close loop circulating water with minimum erosion of the unit can be achieved with the flowing water coming out of the runner exit via Draft Tube.

Proper sizing and selection of material of the cooling coil, its configuration, connection to the existing system, appropriate location for easy installation shall be determined during the design phase of the entire unit is performed in detail installation work. Hence the main objective of this paper is to modify the design of existing Cooling Water Supply System of MMHPP in order to achieve improved plant reliability with reduced plant breakdown and maintenance costs.

II. Research Methodology

Review of existing design of CWS system of MMHPP was performed. All necessary design calculations associated with the modified system and proper analysis to ensure its technical and financial feasibility, were carried out.

a) *Review of Cooling Water System of Mmhpp) System Description*

MMHPP consists of FUNKE horizontally arranged Plate Heat Exchangers (PHE) is provided for exchanging heat between the closed and open circuit. It consists of a package of embossed heat transfer plates. The plates are assembled in a 180° angle to each other and provided with gaskets which seal the various flow gaps from the outside and separate the media from one another. Effective heat transfer, warm and cold media are normally led through the PHE in one-pass or multi-pass counter flow.

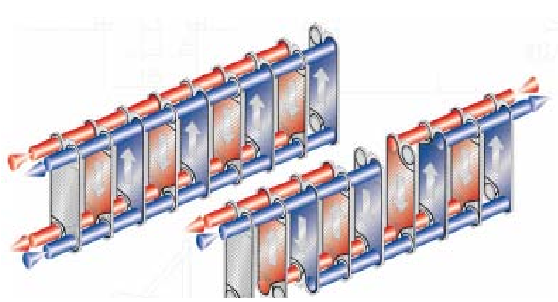

Figure 2.1 : Heat Exchanger Plates in Separated Position

Middle Marsyangdi CWS is designed to be in function fully automatic. No manual interference is required. Cooling system is divided in two main cooling circuits and two water entrance supplies. In the first entrance for open circuit, water is taken from Penstock before turbine inlet valve and directed to one of two "Automatic self-cleaning Filter". From this filter, water circulates through one of two "Heat Exchangers" and then discharges back to Draft Tube. In the second entrance for open circuit, water is pumped by two of two 50% capacity pumps, from Draft Tube and directed to one of two "Automatic self-cleaning Filter". From this filter, water circulates through one of two "Heat Exchangers" and then discharges back to Draft Tube. Sediments and dirt are automatically directed to the Pump sump of the powerhouse from self-cleaning filters.

In the closed circuit, water is circulated by one of two 100% capacity circulation pumps to following five consumers:

- Governor Oil Cooler: 1.3 m^3/h
- Turbine Guide Bearing: 1.5 m^3/h
- Combined Bearing: 14.1 m^3/h
- Generator Guide Bearing: 3.9 m^3/h
- Generator Air Cooler : 119.2 m^3/h

All cooling water pressure, flow and temperature in both open and close circuits are controlled by governor and in case of malfunction, stand by unit is automatically activated to cover and keep turbine in function.

For each closed circuit two circulation pumps with adjustable speed are provided, each one with 100% discharge capacity of the flow required under full load of the generator for the given temperature difference (35^{0}C to 28^{0}C).The discharge of one pump shall be not less than 40 lit/sec. The required head of the pump depends on the hydraulic resistance of all components within the closed circuit it uses motor capacity of 30 kW.

For each open circuit two centrifugal pumps with constant speed are provided, each one with 50% discharge capacity of the flow required under full load of the generator for the given temperature difference (25^{0}C to 28^{0}C).The discharge of one pump shall be not less than 70 lit/sec. The required head of the pump depends on the hydraulic resistance of all components within the open circuit it uses motor capacity of 55 kW. Water flow velocity for each circuit shall not be higher than 2 m/s.

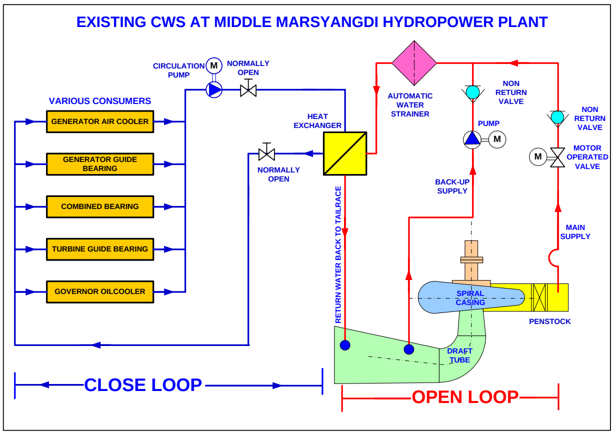

Figure.3 : Existing Cooling Water System with Plate Heat Exchanger at MMHPP

Despite of its innovative and compact design, the service of existing PHE has been severely affected by excessive silt present in Marsyangdi River. Hence, various components are getting damaged quickly with sandy water flowing in the CWS open loop of MMHPP. Water strainer also needs frequent repair due to sandy water.

b) Major Maintenance Works Carried out in the Cws of Mmhpp

During the years 2010, 2011 & 2012, mainly following major maintenance activities had been carried out in the Cooling Water System of MMHPP:

- Automatic Water Strainer (AWS) cleaning and maintenance;
- Heat Exchanger & Plates cleaning and maintenance;
- Replacement of ruptured Heat Exchanger Plates with the new ones;
- Cleaning and maintenance of Backwash filter with replacement of Diaphragm seal;
- Replacement of complete set Backwash shut-off valve of AWS and Backwash filter transformer;
- Cleaning and maintenance of Backwash flushing system;
- Cooling Water Inlet/Outlet Orifice plates cleaning and maintenance;
- Replacement of old tubes for AWS with the new ones;
- Removing mud and sand from motor operated valves of AWS;
- Replacement of Shaft Coupling for Cooling Water Pump;
- Repair, maintenance and replacement of Cooling Water Pump Impeller;
- Cleaning and maintenance of open circuit cooling water pipes and valves;

III. Data analysis and Processing

Unit/Plant tripping outage and maintenance related specific data with respect of Cooling Water System collected from MMHPP for the years 2010, 2011 & 2012 had been thoroughly reviewed and analyzed. The maintenance frequency and duration of the entire CWS (Heat Exchanger, Automatic Water Strainer, Valves, Backwash Flushing System, Pipings etc.) had been found to be considerably higher than their usual levels.

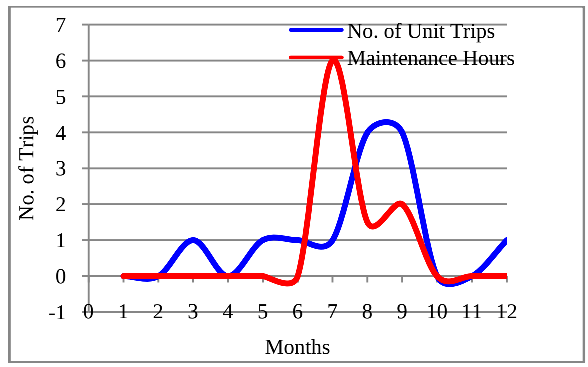

Fig.3.1 : Monthly tripping and maintenance hrs 2010

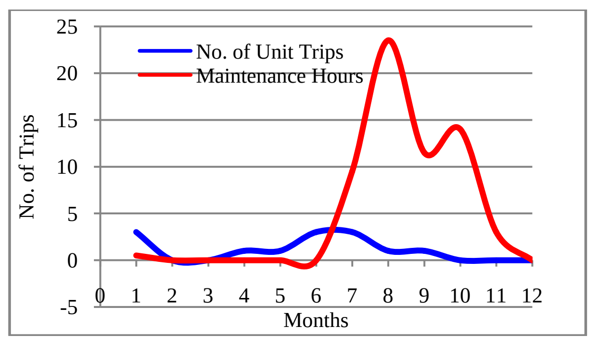

Fig.3.2 : Monthly tripping and maintenance hrs 2011

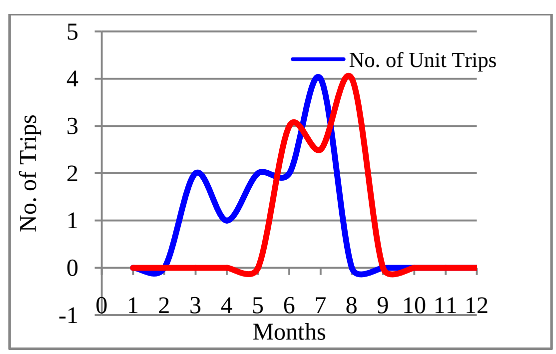

Fig.3.3 : Monthly tripping and maintenance hrs 2012

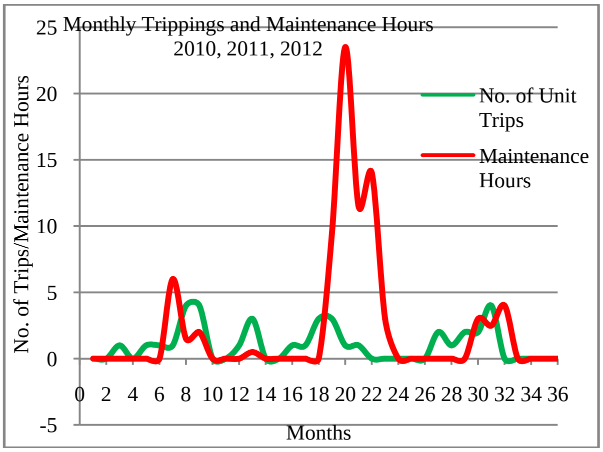

Fig. 3.4: Monthly tripping and maintenance hrs 2010, 2011 and 2012

All the above graphs show that most of the tripping has occurred during monsoon and longer hours are spent on maintenance during monsoon in the cooling system.

The above graphs reveal that the problem occurring in the Cooling Water System has lead to Unit/Plant breakdown resulting in significant outage time. These yearly outage hours as calculated are much above than the normal outage hours. The total annual energy loss by the Plant and monitory loss of NEA due to frequent problems occurring in the CWS of MMHPP is very high. Significant amount of energy has been lost every year due to problems occurring in the existing CWS of MMHPP resulting in a huge amount of monitory loss to the organization. The loss of energy and associated energy costs due to Unit/Plant breakdown has been found to be significantly high.

IV. Design of Submersed Tubular Heat Exchanger

Referring to the Operation and Maintenance manual of CWS, MMHPP, following major Design Parameters have been identified to be considered for designing the Proposed Tubular Heat Exchanger and installed in Draft Tube of the power plant.

- Quantity of water flowing inside the closed circuit pipe; Q_i (not less than) = 40 lit/s (≅144 m3/h)
- Flow velocity inside pipe should not be higher than 2 m/s; V_i = 2 m/s
- Temperature of hot water coming out of Consumers; T_o = 35 ^{0}C
- Temperature of cold water entering into Consumers; T_i = 28 ^{0}C
- Temperature of Draft Tube water; T_d = 11 ^{0}C
- Flow velocity inside the Draft Tube; V_o = 1.5 m/s
- Specific Heat Capacity of water at average temperature 31.5 0C; C_p = 4.175 KJ/Kg^{0}C

a) Design Considerations And Underlying Theories

Case being as forced convection, we should analytically consider the problem of heat transfer in fully developed laminar or turbulent tube flow as the case may be. The cases of underdeveloped laminar flow, flow systems where the fluid properties vary widely with temperature, and turbulent-flow systems are considerably more complicated but are of very important practical interest in the design of heat exchangers and associated heat-transfer equipment. These more complicated problems may sometimes be solved analytically, but the solutions, when possible, are very tedious. For the design and engineering purposes, empirical correlations are usually of greatest practical utility.

b) Flow Inside Tubes

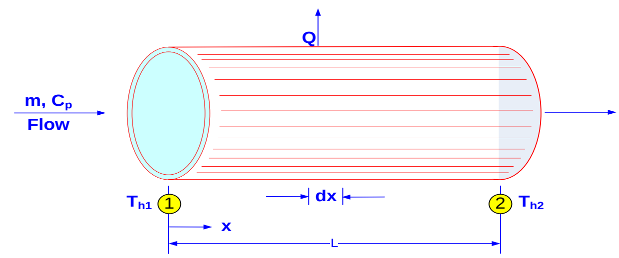

*Figure. 4.1 :*Total Heat Transfer in terms of Bulk-temperature Difference

For the inside tube flow, the total energy lost can be expressed in terms of bulk-temperature difference by –

$$Q = m \times Cp \times (T_{h1} - T_{h2})$$

Where Cp is reasonably constant over the length and

Q = Heat transfer rate
m = Mass flow rate of hot fluid flowing inside tube
C_p= Specific heat capacity of hot fluid flowing inside tube
T_{h1}= Temperature of hot fluid at inlet
T_{h2}= Temperature of hot fluid at outlet

In some differential length dx the heat lost dq can be expressed either in terms of a bulk-temperature difference or in terms of the heat-transfer coefficient:

$$dQ = m \times Cp \times dT_h = h\,(2\pi\rho)\,dx\,(T_w - T_h)$$

Where T_w and T_h are the wall and bulk temperatures at the particular x location. The total heat transfer can also be expressed as –

$$Q = h \times A \times (T_w - T_h)_{av} = h \times A \times (\Delta T)m$$

Where
h = Heat transfer coefficient
A = Heat transfer surface area
$(\Delta T)_m$ = Logarithmic Mean Temperature Difference = $(T_w - T_h)_{av}$

c) Taking 1.5" Nominal Diameter Mild Steel Tube

[Table A-11, "Heat Transfer" by J. P. Holman]

Calculation were performed for various sizes and best suitable is found for following parameters: Hence, if 1" diameter and 1.5 m long tubes are selected, 33 pieces will be required. Increased number of tubes leads to bulky heat exchanger with bigger flanges. Since the objective is to design optimum size Heat Exchanger, 1.5" mild steel tube is considered to reduce the overall size of the Heat Exchanger in Case II below:

Nominal Diameter (D_n) = 1.5" = 0.0381 m
Inside Diameter (D_i) = 1.61" = 0.040894 m,
Inner Radius (r_i) = 0.020447 m
Outside Diameter (D_o) = 1.9" = 0.04826 m,
Outer Radius (r_o) = 0.02413 m

d) Flow Inside Tube

Reynolds Number (Re) = (V_i× D_i) /ν

= (2 ×0.040894)/(9.8 × 10–7) = 83,457

Since Re > 4000, the flow inside tube is *turbulent*.

Prandtl Number (Pr) = (μ×C_p)/k = (9.8 × 10–4× 4.18 × 103)/54 = 0.076

For fully developed turbulent flow in circular tubes as stated in "Heat and Mass Transfer" by R. K. Rajput, Article 7.5.4 (Page 466) – "Turbulent Flow in Tubes", equation 7.164, Nusselt number proposed by Mc Adams:

Nu_d = 0.023 × (Re)0.8× $(Pr)^n$

Where, n = 0.3 for cooling (which is the case)

∴Nu_d = 0.023 × (83457)0.8× (0.076)0.3

= 0.023 ×8653× 0.461577

= 91.86

Also, Nu_d = (h_i× D_i) / k

or, h_i = (Nu_d× k) / D_i = (91.86× 54) / 0.040894 = 121,300

∴h_i = 121,300 W/m^2 ^{0}C

e) Turbulent Flow Over Cylinders

To calculate now h2, let's first verify whether the flow over cylinders is Laminar or Turbulent.

Reynolds Number (Re) = (V_o× D_o) /ν = (1.5 ×0.04826)/(9.8 × 10–7) = 73,867

Since Re > 4000, the flow outside tube is turbulent.

Prandtl Number (Pr) = (μ×C_p)/k = (9.8 × 10–4× 4.18 × 103)/54 = 0.076

For fully developed turbulent flow over cylindrical tubes as stated in "Heat and Mass Transfer" by R. K. Rajput, Article 7.5.5 (Page no. 467) – "Turbulent Flow over Cylinders", equation 7.169, Nusselt number is given by:

$$Nu_d = C \times (Re)^n \times (Pr)^{1/3}$$

Where C and n are constants and its value corresponding to Re = 73,867, the values for C and n come to be 0.027 and 0.805 respectively from this Table. Hence,

∴Nud = 0.027 × $(73,867)^{0.805}$× $(0.076)^{0.33}$

= 0.023 ×8300.5× 0.42724

= 81.56

Also, Nud = (h_o× D_o) / kor, h_o = (Nu_d× k) / D_o = (81.56× 54) / 0.04826 = 91,261

∴h_o = 91,261 W/m^2 ^{0}C

Now, the overall heat transfer coefficient (U_o) can be determined by using the equation 2–15 or 2–16 on Page no. 35 of "Heat Transfer" by J. P. Holman, eighth edition.

$$U_o = \frac{1}{\left(\frac{A_o}{A_i}\right) + \frac{1}{h_i} + \frac{A_o \times \ln\left(\frac{r_o}{r_i}\right)}{2\pi kL} + \frac{1}{h_o}}$$

Where,

U_o = Overall heat transfer coefficient
A_o = Outside surface area of tube
A_i = Inside surface area of tube
h_i = Heat transfer coefficient for water flowing inside tube
h_o = Heat transfer coefficient for water flowing over Cylinder
r_o = Outside diameter of tube
r_i = Inside diameter of tube
k = Thermal conductivity of mild steel

Here,

h_i = 121,300W/m^2 ^{0}C
h_o = 91,261W/m^2 ^{0}C
r_o = 0.02413 m
r_i = 0.020447 m

$$U_o = \frac{1}{\left(\frac{A_o}{A_i}\right) \times \frac{1}{h_i} + \frac{A_o \times \ln\left(\frac{r_o}{r_i}\right)}{2\pi kL} + \frac{1}{h_o}}$$

$$= \frac{1}{\left(\frac{r_o}{r_i}\right) \times \frac{1}{h_i} + \frac{r_o \times \ln\left(\frac{r_o}{r_i}\right)}{k} + \frac{1}{h_o}}$$

$$U_o = \frac{1}{\left(\frac{0.02413}{0.020447}\right) \times \frac{1}{121300} + \frac{0.02413 \times \ln\left(\frac{0.02413}{0.020447}\right)}{54} + \frac{1}{91261}}$$

U_o = 10,561 W/m^2 ^{0}C

The overall heat transfer coefficient is also related as:

$$A_s = \frac{Q}{U_o \times (\Delta T)_m} = \frac{1169 \times 10^3}{10561 \times 20.3} = 5.453\ m^2$$

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Thus, total surface area required to transfer the desired amount of heat with 1" mild steel tube comes to be 5.453 m^2. Because of space limitation inside the Draft Tube, 1.5 m long tube was assumed. Hence, number of 1.5 m long mild steel tubes; N required can be calculated as:

$$\mathbf{A_s = 2\pi r_o \times L \times N}$$

$$\mathbf{N = \frac{A_s}{2\pi r_o \times L} = \frac{5.453}{2\pi \times 0.02413 \times 1.5} = 23.97}$$
$$\mathbf{\cong 24\ Pcs.}$$

In this case with 1.5" diameter and 1.5 m long tube, we have found that only 24 pieces are enough to transfer the desired heat from the flowing water through tubes for the desired inlet and outlet temperatures. Such a reduced number of tubes leads to comparatively smaller size and compact Heat Exchanger and hence cheaper in price. Hence second option i. e. 1.5"ϕ× 1.5 m × 24 pieces mild steel tubes for making the required Heat Exchanger was considered.

f) Design Summary

Tube material: Mild steel
Tube diameter: 1.5"
Length of each tube: 1.5 m
Number of tubes required: 24
Tube spacing: 38 mm
Heat Exchanger flange material: Mild steel
Inlet and outlet dome material: Mild steel
Inlet and outlet flange thickness: 16 mm
Inlet and outlet dome thickness: 16 mm
Main inlet and outlet pipe material: Mild steel
Inlet and outlet 900 bends material: Mild steel
Inlet and outlet 900 bends size (ϕ): 200 mm
Inlet and outlet pipe material: Mild steel
Inlet and outlet pipe size (ϕ): 200 mm
Inlet and outlet flange material: Mild steel

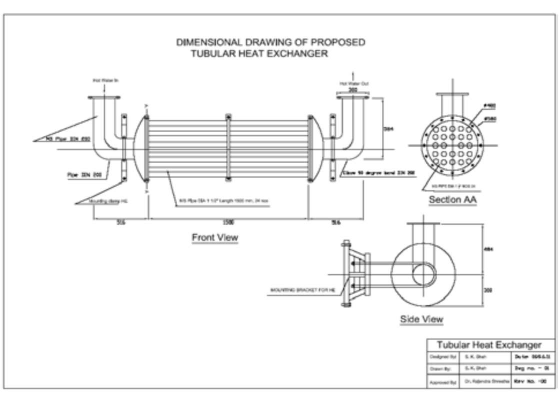

Fig. 4.2 : Dimensional Drawing of Tubular Heat Exchanger

g) Locating the Tubular Heat Exchanger

Heat Exchanger, due to limited access to the Draft Tube of MMHPP, it has been designed of smaller size but enough to transfer the desired quantity of heat from the hot water coming from the various consumers. Based on the existing CWS configuration, location, arrangements, space limitations and reviewing the relevant Mechanical as well as Civil As-Built drawings of MMHPP, the following figures are identified for the proposed modification works. The connections are shown by the Conceptual Drawing in Figure 4.3 below.

h) Advantages of Locating the Tubular he Beside the Side Wall of Draft Tube

Since the existing pipe aligns along the side wall, shorter pipe length is required by installing the HE Unit in the same alignment hence less loss in pipes and bends occur. No obstruction to free flow of draft tube water is achieved. No direct impact (hitting) of water and silt over the Unit protecting it against any physical damages.

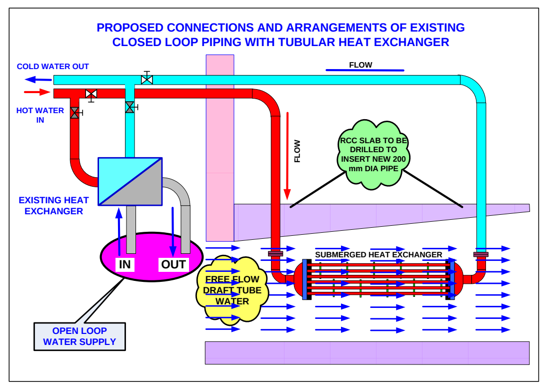

Fig. 4.3 : Proposed Connection of New Heat Exchanger (Conceptual)

i) Limitations of the New System

Chances of Tubular Heat Exchanger wearing fast in case of higher silt level in the tailrace water during monsoon (unless until the system is being tested). Replacement might be comparatively time taking and little more complicated.

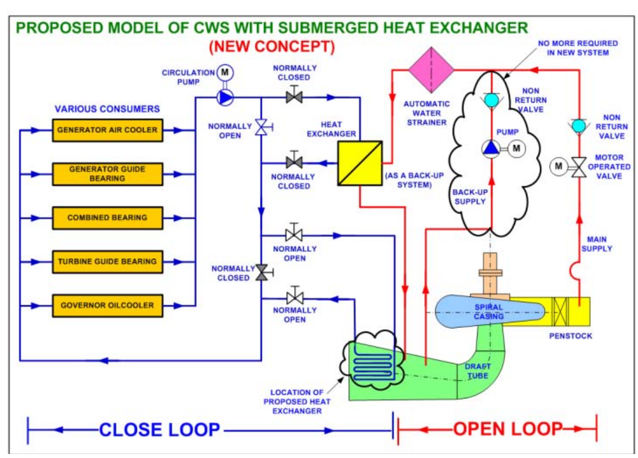

Figure. 4.4 : Cooling Water Flow Diagram for New Proposed System

j) Financial Analysis

Based on the Price Schedule received from Om Shakti Engineering Pvt. Ltd., Gothatar-9, Kathmandu and the Costs associated to entire modification works as determined, financial analysis for implementing the proposed modification has been presented below to confirm the economical viability of the system.

i. Payback Period based on both Energy Loss and Potential Savings

a. Implementation Costs

The total costs associated with the entire modification works = NRs. 2.345 million

Therefore, Implementation Costs =NRs. 2.345 million

b. Total Annual Savings

Savings on frequent Unit/Plant Breakdown = NRs. 7.1 million

Savings on Spare Parts Consumption = NRs. 1.4 million

Savings on Penstock Water = NRs. 5.4 million

Therefore, Total Annual Savings = NRs. 13.9 million

Therefore, Payback Period = Implementation Costs/Total Annual Savings = (2.345 $\times$ 12 months)/13.9$\approx$2 months

Thus, the Payback Period comes to be just two months if we consider the benefits that are achieved with new system which otherwise is being lost due to problems occurring in the existing CWS as well as the potential savings that can be achieved from saving on Penstock water.

V. Conclusions

Based on detailed study, analysis and design, the proposed design modification of the CWS, MMHPP sounds technically feasible. This new system would generate about 540,000 kWh of additional energy annually due to potential saving in Penstock water. On the other hand, spare parts consumption is expected to be reduced significantly. Consequently, new system will help to generate and feed sustainable power to the national grid in a much reliable way. Further, there is a significant reduction in construction costs for not requiring Draft Tube Pumps and Accessories for a new Hydropower Project. Tubular Heat Exchanger, which is the main damageable component of the system, costs much less as compare to the existing Plate Heat Exchanger. It is expected that it would reduce plant breakdown time considerably which has been currently spent because of problems in the existing CWS of MMHPP.

The purpose of this research study is not just limited for the betterment of NEA in Nepal but also it is highly recommended to implement this proposed new system in the hydropower utilities around the globe.

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Techniques in Image Classification; A Survey

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Abstract- This paper reviews on the current trends, problems and prospects of image classification including the factors affecting it. By the end of the session we will be summarizing the popular advanced classification approaches and methods that are used to improve classification accuracy. The main motive of this review is to suggest a suitable image processing procedure in order to have a successful classification of remotely sensed data into a thematic map.

Keywords: image classification, remote sensed data (rs), training samples (ts), isodata.

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TECHNIQUESINIMAGECLASSIFICATIONASURVEY

Strictly as per the compliance and regulations of :

Techniques in Image Classification; A Survey

Mr. S.V.S.Prasad [α], Dr. T. Satya Savithri [σ] & Dr. Iyyanki V. Murali Krishna [ρ]

Abstract- This paper reviews on the current trends, problems and prospects of image classification including the factors affecting it. By the end of the session we will be summarizing the popular advanced classification approaches and methods that are used to improve classification accuracy. The main motive of this review is to suggest a suitable image processing procedure in order to have a successful classification of remotely sensed data into a thematic map.

Keywords: image classification, remote sensed data (rs), training samples (ts), isodata.

I. Introduction

The image classification plays an important role in environmental and socioeconomic applications. In order to improve the classification accuracy, scientists have laid path in developing the advanced classification techniques. [1-9] However, classifying a remotely sensed data into a thematic map is still a nightmare because of the following factors such as landscape complexity, image sensing and processing and classification approaches. The review concentrates on recent classification approaches and techniques which are often not available.

a) Remote sensing classification process

RS classification is generally a complex procedure which needs many factors to be considered. This procedure includes following steps that begins with the identification of suitable classification system, choosing appropriate training samples, processing of an image and extracting its features, applying a right and indeed classification method, post classification and accuracy assessments.

b) Selection of remotely sensed data

Airborne and space borne sensor data comes under RS data stream, which varies in spatial, radiometric, spectral and temporal resolutions. In order to have better image classification a suitable RS data needs to be collected, which depends upon strength and weakness of sensor data. In literature the characteristics of remotely sensed data is summarized by [10], [11] in spectral, radio metric, spatial and temporal resolutions with polarization and angularity.

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It is preferred to consider the factors while selecting suitable sensor data as per the user's need, which includes scaling, study area characteristics, availability of various image data and their characteristics, cost, time constraints and analyst's experience in using selected images. Scaling determines the study area; earlier research encountered a problem of image resolution of remotely sensed data in classification. In regular practice, a fine-scale classification system is adopted in order to achieve high spatial resolution data. For example, IKONS and SPOT 5 HRG are at regional level medium spatial resolution data. However, the influence of atmospheric conditions in moist and tropical regions cannot be neglected and they are often an obstacle for capturing the high quality sensor data. Therefore, it always proves to be beneficiary to have multiple sources of sensor data.

c) Selection of classification system and training samples

A better classification can be achieved only when we consider a suitable classification system with sufficient number of training samples. Generally, in a wide variety of applications we adopt hierarchy classification systems because different conditions are taken into account. A classification system should consider spatial resolution of selected RS data, compatibility with its previous work, image processing and classification algorithm availability and time constraints. The ultimate goal of choosing any classification system is to satisfy the need of an end user.

The image classification broadly depends on number of training samples and their representativeness. Training samples can be prepared by fieldwork or it can also be obtained from other means such as aerial photographs of fine spatial resolution and satellite images. The results of the classification are affected by the selection of training data, which generally may be based on single pixel, seed or polygon, also affected by fine spatial resolution image data if proper care is not taken. If coarse resolution data is used for classification data then the selection of TS becomes tedious under complex and heterogeneous case studies as it contains large volumes of mixed pixels.

d) Data Preprocessing

The image preprocessing is a technique which includes detection, restoration of bad lines, geometric rectification, radio metric calibration, atmospheric and topographic correction. If data is collected from different sources, it is necessary to check the quality before stepping into classification. If the single data image is utilized in classification atmospheric corrections may not be required but on the other hand it becomes mandatory for a multi-sensor data. A variety of correction techniques are presented [12-23].If the study area includes rugged or mountainous regions a topographic correction is needed, which is detailed [24-30].

e) Feature Extraction and Selection

The quality of an image classification depends on the selection of suitable variables. A variety of variables used in classification includes spectrum signature, vegetation indices, transformed images, textual information, multi temporal images, multi sensor images and ancillary data. The process of feature extraction is needed in order to minimize data redundancy in remotely sensed data or to excavate specific land cover information, that includes principle component analysis, minimum noise fraction transform discriminant analysis, decision boundary, feature extraction, non parametric weighted feature extraction, wavelet transform and spectral mixture analysis.

f) Selection of suitable classification method

The question of choosing a classification method is ambiguous because many factors such as spatial resolution of RD, multi-sensor data, availability of different classification software are involved. Each classification method has its own merits and demerits.

g) Post classification processing

Classification confusions arise in the regions such as urban areas, for example, consider between commercial and high intensity residential areas or between recreational grass and crops. In present example to reduce classification confusions we need to consider the property of spectral signature because it is similar to commercial and high intensity residential areas but on the other hand their population densities are different. Pasture and crops are largely located away from residential areas with sparse houses and low population densities, at this stage expert knowledge can be developed based on the relationship between housing or population densities and urban land use classes to help separate recreational grass from pasture and crops.

II. Evaluation of Classification Performance

Evaluating the classified results is an important step in classification procedure. The evaluation process may include qualitative evaluation based on expert knowledge to quantitative accuracy based on sampling strategies. The classification accuracy assessment is the most common approach for the evaluation of classification performance [31-32].

a) Classification of accuracy assessment

By the knowledge of sources of errors, classification accuracy assessment can be implemented in addition to classification error, position error, which resulting from registration, interpolating error and poor quality of training which may affect the classification accuracy. The classification accuracy assessment includes three basic steps 1.Sampling design, 2.Response design,3. Estimation and Analysis procedures

b) Advanced classification procedures

The advanced classification procedures such as neural networks, fuzzy sets and expert systems are highly applied for image classification. In general image classification approaches it can be grouped as supervised or unsupervised, parametric and nonparametric or hard and soft classifiers or per pixel, sub pixel, per field. Table provides brief description of these categories.

c) Use of multiple features of remote sensed data

Any remote sensed data generally contains many unique and special spectral radio metric temporal and polarization characteristics; the effective use of these features can improve the classification accuracy. The summary of table 3 presents the research efforts in order to improve the classification accuracy by considering the features of remote sensed data.

III. Discussions

a) Uncertainties in image classification

Uncertainties in image classification occur at different stages, influence classification accuracy. Improving and understanding the stages those contribute to uncertainty results in quality image classification.

b) Impact of spatial resolution

Spatial resolution is an important factor that affects classification details and accuracy, which influences the selection of a classification approach. Various reduction techniques have been developed and presented by different authors in their literature.

c) Selection of suitable variables

In practice, making a complete use of multiple features of different sensor data, implementing feature extraction and selecting variables as input for a classification procedure becomes important.

IV. Conclusion

This study helps upcoming scientists and researchers for opting a suitable classification procedure in their specific study. In our presentation we have concentrated extensively on the work done from the past decade that includes 1. Development and advanced classification algorithms such as sub pixel, per field and acknowledged based classification algorithms; 2. We have considered various remote sensing features including spectral, spatial, multi temporal and multi sensor information; 3. Incorporating an ancillary data into classification procedures that includes topography, soil, road and census data.

Table 1 : A taxonomy of image classification methods

Criteria	Categories	Characteristics	Example of classifiers
Whether training samples are used or not	Supervised classification approaches	Land cover classes are defined. Sufficient reference data is available and used as training samples. The signatures generated from the training samples are then used to train the classifier to classify the spectral data into a thematic map	Maximum likelihood, minimum distance, artificial neural network, decision tree classifier.
	Unsupervised classification approaches	Clustering-based algorithms are used to partition the spectral image into a number of spectral classes based on the statistical information inherent in the image. No prior definitions of the classes are used. The analyst is responsible for labeling and merging the spectral classes into meaningful classes.	ISODATA, K-means clustering algorithm
Whether parameters such as mean vector and covariance matrix are used or not	Parametric classifiers	Gaussian distribution is assumed. The parameters (e.g. mean vector and covariance matrix) are often generated from training samples. When landscape is complex, parametric classifiers often produce 'noisy' results. Another major drawback is that it is difficult to integrate ancillary data, spatial and contextual attributes, and non-statistical information into a classification procedure.	Maximum likelihood, linear discriminant analysis.
	Non-Parametric classifiers	No assumption about the data is required. Non-parametric classifiers do not employ statistical parameters to calculate class separation and are especially suitable for incorporation of non-remote-sensing data into a classification procedure.	Artificial neural network, decision tree classifier, evidential reasoning, support vector machine, expert system.
Which kind of pixel information is used	Per-pixel classifiers	Traditional classifiers typically develop a signature by combining the spectra of all training-set pixels from a given feature. The resulting signature contains the contributions of all materials present in the training-set pixels, ignoring the mixed pixel problems	Most of the classifiers, such as maximum likelihood, minimum distance, artificial neural network, decision tree, and support vector machine.
	Sub pixel classifiers	The spectral value of each pixel is assumed to be a linear or non-linear combination of defined pure materials (or end members), providing proportional membership of each pixel to each end member.	Fuzzy-set classifiers, sub pixel classifier, spectral mixture analysis.
Which kind of pixel information is used	Object-oriented classifiers	Image segmentation merges pixels into objects and classification is conducted based on the objects, instead of an individual pixel. No GIS vector data are used.	E Cognition
	Per-field classifiers	GIS plays an important role in per-field classification, integrating raster and vector data in a classification. The vector data are often used to subdivide an image into parcels, and classification is based on the parcels, avoiding the spectral variation inherent in the same class.	GIS-based classification approaches
Whether	Hard	Making a definitive decision about the land	Most of the classifiers,

output is a definitive decision about land cover class or not	classification	cover class that each pixel is allocated to a single class. The area estimation by hard classification may produce large errors, especially from coarse spatial resolution data due to the mixed pixel problem.	such as maximum likelihood, minimum distance, artificial neural network, decision tree, and support vector machine.
	Soft (fuzzy) classification	Providing for each pixel a measure of the degree of similarity for every class. Soft classification provides more information and potentially a more accurate result, especially for coarse spatial resolution data classification.	Fuzzy-set classifiers, sub pixel classifier, spectral mixture analysis.
Whether spatial information is used or not	Spectral classifiers	Pure spectral information is used in image classification. A 'noisy' classification result is often produced due to the high variation in the spatial distribution of the same class.	Maximum likelihood, minimum distance, artificial neural network.
	Contextual classifiers	The spatially neighboring pixel information is used in image classification.	Iterated conditional modes, point-to-point contextual correction, and frequency-based contextual classifier.
	Spectral-contextual classifiers	Spectral and spatial information is used in classification. Parametric or non-parametric classifiers are used to generate initial classification images and then contextual classifiers are implemented in the classified images	ECHO, combination of parametric or non-parametric and contextual algorithms

Table 2 : A summary of classification methods

Category	Advanced classifiers	References
Per-pixel algorithms	Neural network	[33], [34], [35],[36], [37], [38], [39], [40], [41], [42], [43]
	Decision tree classifier, Spectral angle classifier, Supervised iterative classification (multistage classification)	[44], [45], [46],[47], [32],[8],[48],[49],[50], [51],[4]
	Enhancement-classification approach,MFM-5-Scale (Multiple-Forward-Mode approach to running the 5-Scale geometric-optical reflectance model)	[52],[53]
	Iterative partially supervised classification based on a combined use of a Radial Basis Function network and a Markov Random Field approach	[54]
	Classification by progressive generalization Support vector machine	[31],[55], [56], [57], [58],[59],[60], [61], [62], [63]
	Unsupervised classification based on independent component analysis mixture model, Optimal iterative unsupervised	[64],[65], [66]
	Model-based unsupervised classification, Linear constrained discriminant analysis	[67], [68] ,[69], [70]
	Multispectral classification based on probability density functions, Layered classification, Nearest-neighbor classification, Selected pixel classification	[71],[72],[73][74],[75],[76], [77]
Sub pixel algorithms	Imagine sub pixel classifier, Fuzzy classifier, Fuzzy expert system	[78], [3],[79],[80],[81], [82]
	Fuzzy neural network, Fuzzy-based multi sensor data fusion classifier, Rule-based machine-version approach	[3], [83],[84], [80], [85], [86], [87]
	Linear regression or linear least squares inversion	[88],[89]

Per-field algorithms	Per-field or per-parcel classification	[90],[5],[91]
	Per-field classification based on per-pixel or sub pixel classified image	[92]
	Parcel-based approach with two stages: per-parcel classification using conventional statistical classifier and then knowledge-based correction using contextual information	[93]
	Map-guided classification, Object-oriented classification, Graph-based, structural pattern recognition system, Spectral shape classifier	[94], [95],[96],[97], [98],[99],[100], [101], [102], [103]
Contextual-based approaches	ECHO (Extraction and Classification of Homogeneous Objects)	[104],[105], [106]
	Supervised relaxation classifier, Frequency-based contextual classifier	[107], [108], [109]
	Contextual classification approaches for high and low resolution data, respectively and a combination of both approaches	[110],[111]
	Contextual classifier based on region-growth algorithm, Fuzzy contextual classification, Iterated conditional modes	[112], [113]
	Fuzzy contextual classification, Iterated conditional modes, Sequential maximum a posteriori classification	[113], [59],[114], [115]
	Point-to-point contextual correction, Hierarchical maximum a posteriori classifier, Variogram texture classification	[116], [117], [118]
	Hybrid approach incorporating contextual information with per-pixel classification	[6]
	Two stage segmentation procedure	[119]
Knowledge-based algorithms	Evidential reasoning classification, Knowledge-based classification,Rule-based syntactical approach	[120],[121],[122], [123],[7],[124],[125] [107],[126], [97], [127],[128]
	Visual fuzzy classification based on use of exploratory and interactive visualization techniques	[129]
	Multi temporal classification based on decision fusion	[130]
	Supervised classification with ongoing learning capability based on nearest neighbor rule	[131]
Combinative approaches of multiple classifiers	Multiple classifier system (BAGFS: combines bootstrap aggregating with multiple feature subsets)	[132]
	A consensus builder to adjust classification output (MLC, expert system, and neural network)	[133]
	Integrated expert system and neural network classifier	[133]
	Improved neuro-fuzzy image classification system, Spectral and contextual classifiers, Mixed contextual and per-pixel classification, Combination of iterated contextual probability classifier and MLC	[134],[116],[135],[136]
	Combination of neural network and statistical consensus theoretic classifiers	[137]
	Combination of MLC and neural network using Bayesian techniques	[138]
	Combining multiple classifiers based on product rule, staked Regression, Combined spectral classifiers and GIS rule-based classification, Combination of MLC and decision tree classifier, Combination of non-parametric classifiers (neural network, decision tree classifier, and evidential reasoning),Combined supervised and unsupervised classification	[139],[140],[141][142],[97],[143]

Table 3 : Approaches for improving classification accuracy using multiple features of RS data

Method	Features	References
Use of textures	First-, second-, and third-order statistics in the spatial domain; texture features from the texture spectrum and from grey level different vector	[144]
	Grey-level co-occurrence matrices(GLCM)	[145],[146],[147],[148], [149]
	Co-occurrence matrices, grey-level difference, texture-tone analysis ,features derived from Fourier spectrum, and Gabor filters	[150]
	GLCM, grey level difference histogram, sum and different histogram	[151], [152]
	Fractal information	[153],[154]
	Triangulated primitive neighborhood method, Semi variogram, Geo statistical analysis, Gabor filtering	[155], [156], [157], [158], [159]
Fusion of Multi sensor or multi resolution data	AIRSAR and TOPSAR, SPOT MS and PAN data, TM and aerial photographs, TM and radar, TM and IRS-1C-PAN data, TM and SPOT PAN data, SPOT and radar	[160], [161], [162], [163], [164], [165], [166], [167], [168]
	Hyper spectral and radar, IRS LISS III and PAN	[169], [170]
Use of multi temporaldata	Using multi temporal optical Images, Using multi temporal SAR images, Using multi temporal optical and SAR images	[171], [172], [173],[174],[175], [176], [177], [178], [179]
Image transforms	Fuzzy partition method, Stepwise regression analysis	[180], [180]
	Principal component analysis, Tasseled cap	[180] [173]
	Rotational transformation, Wavelet transform	[181] [182]
	Spectral mixture analysis, Gaussian mixture discriminant Analysis, Normalized difference built-up Index	[183], [184],[185], [186], [187], [188],[189], [190], [191]
Fine spatial resolution data	IKONOS or Quick Bird, ADAR digital multispectral image, Aerial photography and lidar data, Color infrared aerial images	[192], [193], [95], [194], [195], [109], [196],[197], [97], [198], [199]
Hyper –spectral data	AVIRIS	[200], [201], [202], [203], [204], [205]
	HyMap hyper spectral digital data, DAIS hyper spectral data, EO-1 Hyperion, Data obtained from Field Spec Pro FR spectro radiometer	[127] [206] [207], [208]

Table 4 : Techniques to improve classification accuracy for ancillary data; A summary

Method	Features	References
Use of ancillary data	DEM Topography, land use, and soil Maps	[209] [210]
	Road density, Road coverage, Census data	[211] [212] [213], [214] [173]
Stratification	Based on topography, Based on census data, Based on illumination and ecological zone, Based on shape index of the Patches	[215], [210], [216], [217]
Post classification processing	Kernel-based spatial reclassification	[218]
	Using zoning and housing density data to modify the initial classification result, Using contextual correction,	[213], [219]
	Using filtering based on co occurrence Matrix, Using polygon and rectangular mode filters, Using expert system to perform post classification sorting, Using knowledge-based system to correct misclassification	[220], [221], [222], [223]
Use of multisource data	Spectral, texture, and ancillary data (such as DEM, soil, existing GIS-based maps)	[123], [224],[225],[137],[226], [227],[7],[228]

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Global Journal of Researches in Engineering (F) Volume XV Issue VI Version I Year 2015

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Design and Development of a Low Cost Solar Automated Vehicle

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Abstract- This paper represents design and development of a low cost solar automatic vehicle with two innovative approach. In both approaches, the solar automatic vehicle will be able to move on the roadturn to leftor right and stop at any obstruction on the road automatically. The automation is done by using three photosensors in the first approach and by using photosensorsand a microcontroller (PIC 16F877A) in the final approach.In the first approach, the photo sensors detects black or white color. Depending upon the color, the left and right photosensor will generates control instructions for the vehicle by observing the road so that the vehicle can turn left or right automatically and for any kind of obstruction found in road, the front sensor will detect it and send signal to the relay, which will stop driving the main power source to the driving unit and makesthe vehiclestop.In the final approach photosensors, depending upon color of the road, detect signals from the road and produce control instruction for the microcontroller. Microcontroller then process the instruction and generate instruction for the driving section. The driving section drives the vehicle according to the road.

Keywords: photosensors, solar automatic vehicle.

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Design and Development of a Low Cost Solar Automated Vehicle

Rony Sorkar α, Zubaear Alam σ & Galib Hashmi ρ

Abstract- This paper represents design and development of a low cost solar automatic vehicle with two innovative approach. In both approaches, the solar automatic vehicle will be able to move on the road turn to left or right and stop at any obstruction on the road automatically. The automation is done by using three photosensors in the first approach and by using photosensors and a microcontroller (PIC 16F877A) in the final approach.In the first approach, the photo sensors detects black or white color. Depending upon the color, the left and right photosensor will generates control instructions for the vehicle by observing the road so that the vehicle can turn left or right automatically and for any kind of obstruction found in road, the front sensor will detect it and send signal to the relay, which will stop driving the main power source to the driving unit and makes the vehicle stop. In the final approach photosensors, depending upon color of the road, detect signals from the road and produce control instruction for the microcontroller. Microcontroller then process the instruction and generate instruction for the driving section. The driving section drives the vehicle according to the road. For the driving section a L293D IC is used. Here 12 Volt, 10 Watt battery are used as power source and this battery is charged by a 16 Volt,12 Watt solar panel. There is an alternative option to charge the battery of the vehicle directly from the 220 Volt AC line. The prototype car developed show promises of safe driving and hopefully one day a fully automated solar vehicle will be on the street..

Keywords: photosensors, solar automatic vehicle.

I. Introduction

Road accident is rapidly increasing with the number of vehicle and with the extension of metro life. About 1.24 million deaths occurred worldwide in the year 2010 due to road traffic injuries[1], and the number of people are injured or disabled every year also in the range of tens of millions [2]. WHO, is already working with governmental and nongovernmental organizations around the world to raise awareness to avoid road traffic injuries [2].Many other organizations like, National Highway Traffic Safety Administration (NHTSA), USA, are on the pursuit of vehicle safety has led to focus attention on self-driving automated vehicles [3].Already Google got, first self-driven automated vehicle license in Nevada, USA [4]. Still there is lot of research work needed before the first low cost automated vehicle is on the road. For this purpose, this paper demonstrates design and development of a low cost solar automatic vehicle.

The demand of fuel energy is increasing day by day due to industrialization, transportation and inhabitation. According to BP(British Petroleum)- the Global demand will rise up to 5 to 20 Mb/d (Millions of Barrels per Day) from 2015 to 2035[5]. So renewable energy (energy from a source that is not depleted when used, such as wind or solar power) is indispensable for this crises. Renewable energy has a lot of advantages over the fuel energy, which is available abundant amount in nature with no negative effect on environment, having no solid wastes. It reduces pollution production and do not threaten the atmospheric levels. For these specific reasons, renewable energy to be used. The automatic solar vehicle is powered by solar energy and it is done by incorporating the vehicle with a solar panel.

This paper discuss about design and development of an automated solar vehicle. The schematics were drawn by using Proteus Lite software and the components were soldered intoveroboard. It was found that the automated solar vehicle is able to move around the road automatically by using three photosensors or using photosensors and a microcontroller (PIC 16F877A).

II. Background Study

a) Automated Vehicle

Automated Vehicle is a vehicle, which has at least one automated functions (like steering, acceleration etc.).According to National Highway Traffic Safety Administration (NHTSA), USA. At level 4, an automated vehicle will be able drive itself without a human driver[6]. The main reason for using automated vehicle is that, this technology will reduce crashes. Moreover, there will be less power consumption and pollution.

b) Solar Module / Panel

When groups of solar cells are interconnected and mounted together it is called solar panel or module. Like, a 12 V single solar module (panel) will contain 36 cells connected in series in a sealed weatherproof package[7]. Each solar cell in a solar module coverts light energy to electricity, so that the solar panel can be used as a power source. Because solar energy is

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available in abundance and considered the easiest and cleanest means of tapping renewable energy[8], solar panel is used in the design as a mean ofcharging the battery of automated solar vehicle.

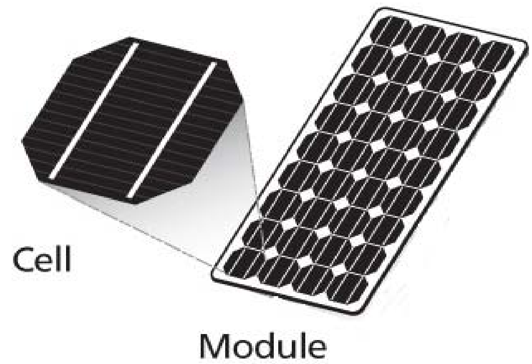

Figure 1: PV cell and Module

c) Photodetector or Photosensor

Photodetector or Photosensor is a device that can detect the presence of photons and converts optical signal to electrical signals [9]. Photodiodes operates in Photovoltaic or Photoconductive mode. In the photoconductive mode the photodiode operates in reverse bias and thus creates electric fields and increases the width of space charged region. When light falls, depending on the energy of the photon $h\upsilon$, electrons –holes pair are generated in the space charged region and the electric field (due to reverse bias) will swept away the e-h pairs and produces current in the external circuit[10]. In developing the solar automatic vehicle, photosensors / photodetectors are used. These photodetectors can detect black or white color, by which the vehicle can sense where it is and moves accordingly on the road.

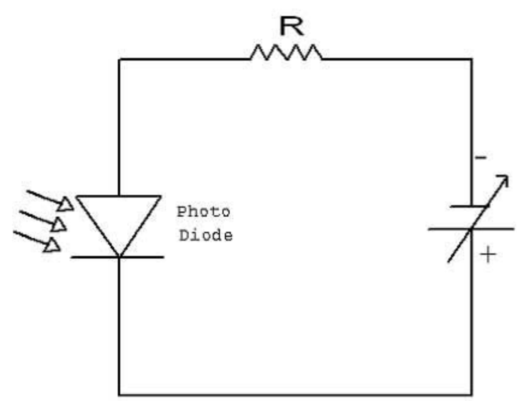

Figure 2 : Photodiode [11]

d) Motor Driver

Motor driver is a device which can drive motor or motors. Motor driver is used because a motor needs high current and a motor driver, amplifies low current to necessary high current, which drives the motor [12]. In designing the solar automated vehicle L293D motor driver IC is used. L293D has two inbuilt H-bridge driver circuits to drive two motors simultaneously. It is called H-bridge because four switches are arranged such that it resembles like ‘H’. Shown in figure 3.

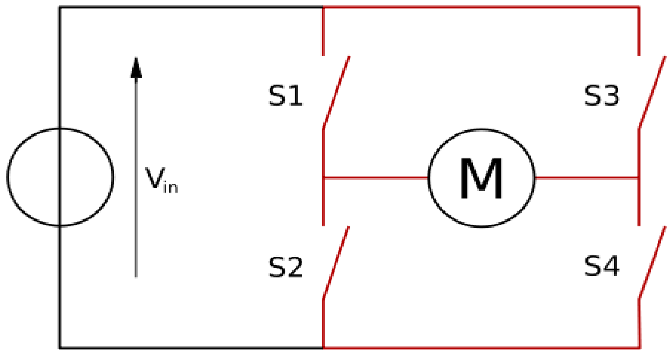

Figure 3 : H-bridge driver circuits [13]

The motor rotates in forward in clockwise direction, when switch **S1** and **S4** are **closed** and switch **S3** and **S2** are kept **open and** the motor rotates in reverse or in anti-clockwise direction, when **S3** and **S2** are **closed** then and **S1** and **S4** are kept **open.**

e) Relay

A relay is an electrically controlled electro-mechanical switch. It operates on the principle of electromagnet[14]. By the relay control circuit, when the relay coil is energized, the electromagnetic field of the coil forces the common switch element (moving part of the switch) inside the relay to disconnect its contact with the normally closed (NC) terminal and make connection with the normally open (NO)terminal. Otherwise, when the relay coil is not energized, the common switch element will stay atnormally closed (NC) terminal.

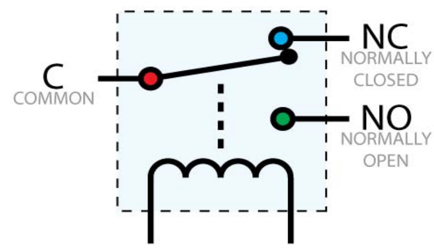

Figure 4 : Relay [15]

III. Principle of Solar Automated Vehicle

a) Block diagram of photosensor based automated solar vehicle

While the vehicle is on the road the black color is detected by the photosensors and if the vehicle is outside the road or there are any obstructions, white color is detected by the photosensors.

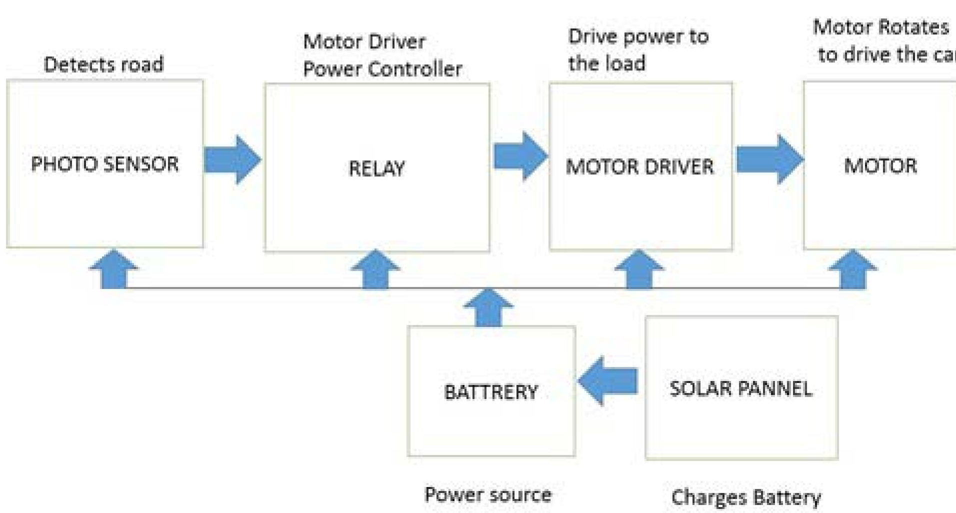

Figure 5 : Block diagram of photosensor based solar automated vehicle

After detection of light, the photosensors convert the light signal to electrical signal. Depending upon the electrical signal, the relay will provide isolation or electrical signal to the motor driver, the motor driver will provide necessary current to drive the motor and thus the vehicle will move around the road. The battery ensures necessary power to every components and a solar panel charges the battery.

Global Journal of Researches in Engineering (F) Volume XV Issue VI Version I Year 2015

b) Block diagram of microcontroller based automated solar vehicle

The only difference in the block diagram of microcontroller based solar automated vehicle is that instead of a relay block (in figure 5) there is a micro controller block (figure 5). The relay function is done by using microcontroller. After getting electrical signal from the photodiodes, the microcontroller sends control signal to the motor driver to drive the motor and the vehicle moves around the road.

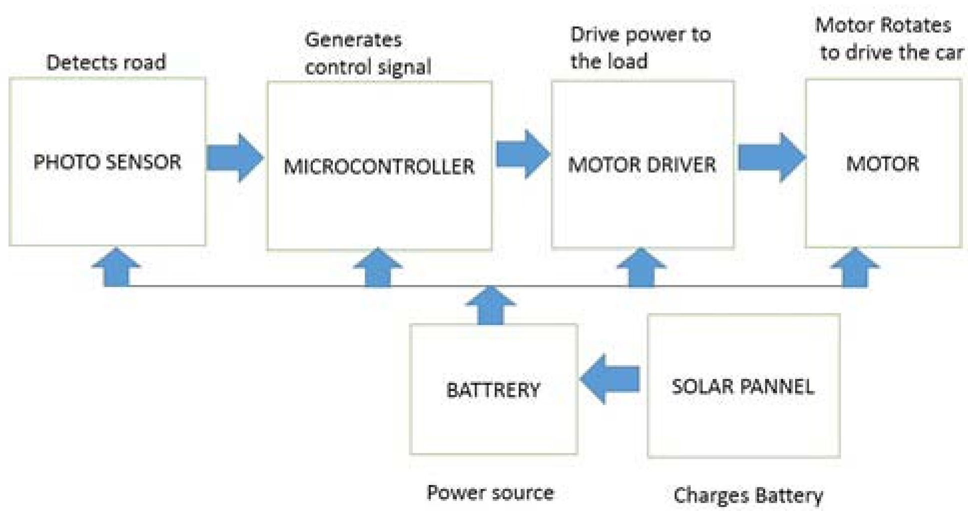

Figure 6 : Block diagram of microcontroller based solar automated vehicle

IV. Schematic Diagram of Solar Automated Vehicle

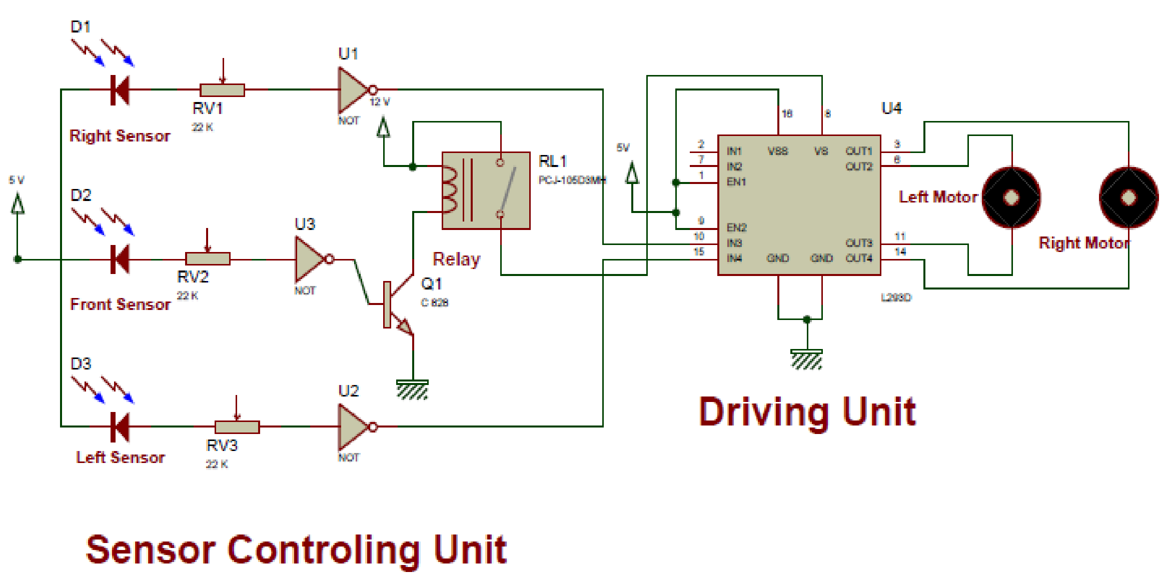

Figure 7 : Schematics of three photosensor based solar automated vehicle

Figure 7 shows the schematic diagram of three photosensor based solar automated vehicle. The schematic was drawn using Proteus Lite software. When there is no obstacle and no right or left turn is needed, there is only straight forward path, then the left and right photosensor detects black light and covert the black light to 0 volt, which goes through the not gate thus producing 5 volt to the input 3 and 4 (pin 10 and pin 15) of L293D motor driver IC. Thus inputting binary 11 signal to motor driver IC rotates both the motor and the vehicle moves forward. When the vehicle needs to turn right, the left photosensor will detect white color, thus converting the white color to 1 volt, which goes through the not gate thus producing 0 volt to the input 4 (pin 15) of L293D motor driver IC. At this moment the right photosensor detect black light and covert the black light to 0 volt, which goes through the not gate thus producing 5 volt to the input 3 (pin 10) of L293D motor driver IC. Because inputting binary 01 signal to motor driver input 3 (pin 10)and input 4 (pin 15)will give 12 volt to output pin 11 and 0 volt to output pin 14,So the right motor(figure 7) will stop and the vehicle will turn to the right.If there is a left turn, then right photosensor will detect white color and the left photosensor will detect black color, producing binary 10 signal to motor driver input 4 (pin 15)and input 3 (pin 10)will give 12 volt to output pin 14 and 0 volt to output pin 11, thus stopping the left motor(figure 7) and the vehicle will turn left. But if there is obstruction, the front sensor will detect white color, convert it to 1 volt, which goes through the not gate thereby producing 0 volt at the base of transistor. Thus the transistor will remain open, the relay coil will never magnetized, then the common switch element (moving part of the switch) remain open, 12 volt power will not go L293D motor driver IC power supply (VS, pin-8), making it powerless, and thereby making both the motor stops, as a result also making the vehicle stop.

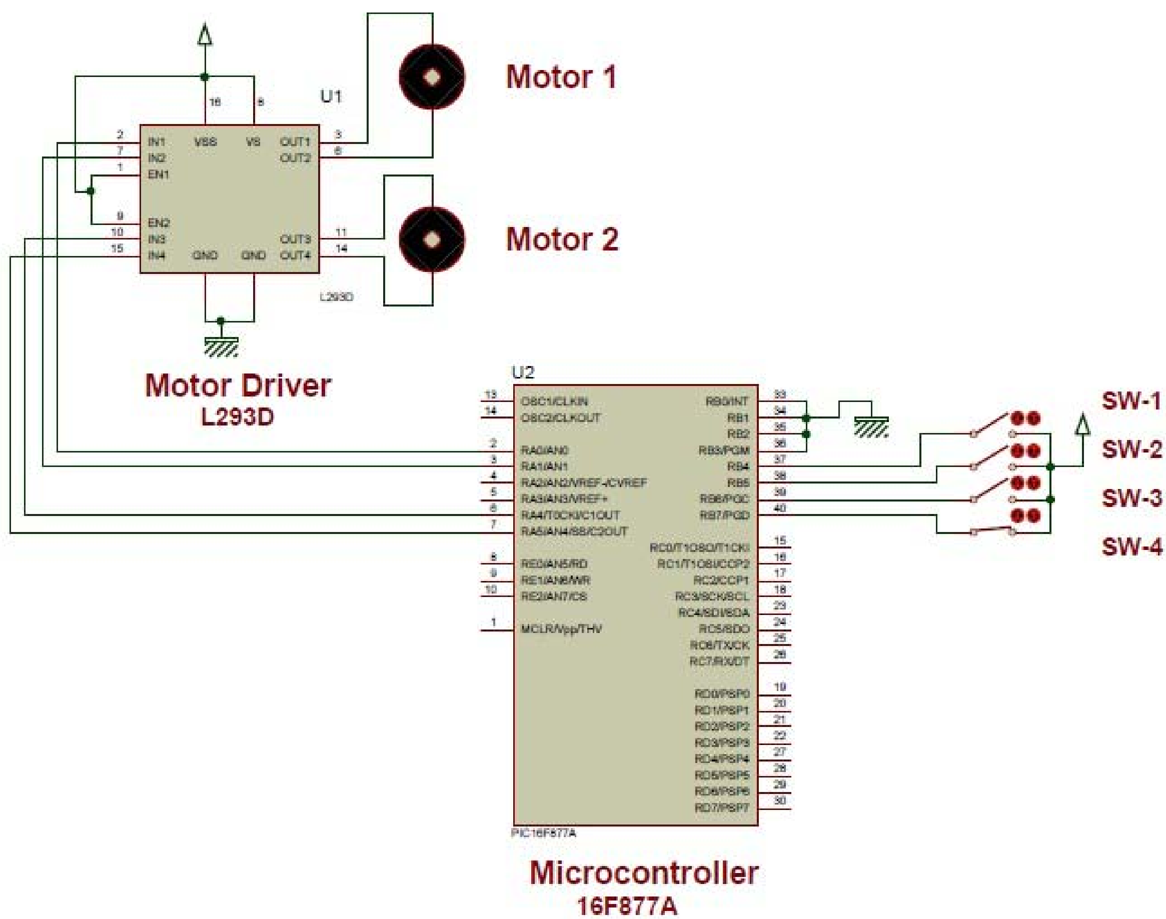

Figure 8 : Schematics of microcontroller based solar automated vehicle

Figure 8 shows the schematic diagram of microcontroller based solar automated vehicle. This schematic was also drawn using Proteus Lite software.

The procedure is almost same as three photosensor based solar automatic vehicle. In the previous schematic the driver circuit got signal directly from the photosensor. Here the photosensor first send signal to the microcontroller. Microcontroller then send signals to the driver IC, and thus the vehicle operates. MicroC Pro for PIC software was used to program the PIC16F877A microcontroller. For simulation to run photosensors were replaced by switches. The switches does the same function as photosensor in the simulation. When the switch is closed binary 1 is considered and when switch is open binary zero is considered. The automated vehicle function is summarized in the following table:

Table1: Condition for vehicle moving on the road

Input signal	Output signal	Function
RB4=1,RB5=1,RB6=1&RB7=1	RA0=1,RA1=0,RA4=1&RA5=0	Car will go forward
RB4=0, RB5=0,RB6=0&RB7=0	RA0=0,RA1=0,RA4=0&RA5=0	Car will stop
RB4=1,RB5=1,RB6=0&RB7=0	RA0=1,RA1=0,RA4=0&RA5=0	Car will turn left
RB4=0,RB5=0,RB6=1&RB7=1	RA0=0,RA1=0,RA4=1&RA5=0	Car will turn right
Other condition	RA0=1,RA1=0,RA4=1&RA5=0	Car will go forward

V. Battery Charging Section

A 12 volt Battery is used as power source of the solar automated vehicle. To charge the 12 Volt batterya 16 Volt, 12 Watt solar panel is directly connected(figure 9). The main purpose of using solar panel was to see whether the vehicle will be able to carry the weight upon driving. It is seen that, the vehicle can easily carry the weight of solar panel. Solar charge controller is not designed for this solar automatic vehicle, but it is proposed that a solar charge controller should be designed for better battery charge control.

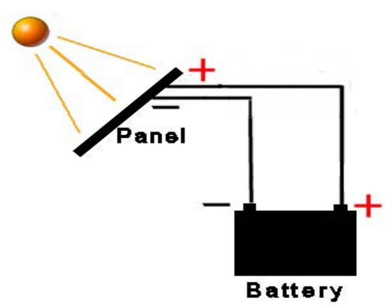

Figure 9 : Solar panel directly connected to battery

Beside the solar panel directly charging the battery, there is an alternative option to charge the battery of the vehicle directly from the 220 Volt AC line. The schematic of 220 A.C to 16 volt D.C charge controller is shown in the Figure 10. Here, mainly the four diodes are used as full wave bridge rectifier. The full wave bridge rectifier converts the A.C voltage to D.C voltage. With this circuit the vehicle battery charging operation can operate like a mobile charger.

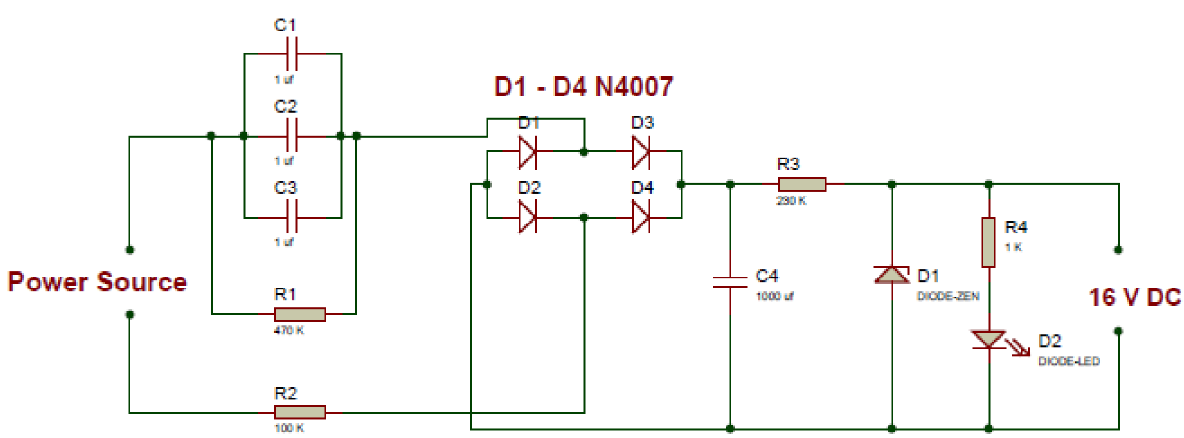

Figure 10 : 220 volt A.C to 16 volt D.C conversion circuit

VI. Implementing Solar Automated Vehicle

According to the schematics, at first all the equipment was soldered into veroboard and the three photosensor based solar automatic vehicle was developed. Figure 11 shows the internal circuitry of the solar automated vehicle. After assembling the prototype was tested first, then a road was constructed using black and white paper and seen that the solar automated vehicle moves around the road quite easily (Figure 12). An obstacle, was placed on the road while the vehicle was moving, and instantly the automated vehicle detect the obstacle and stop.

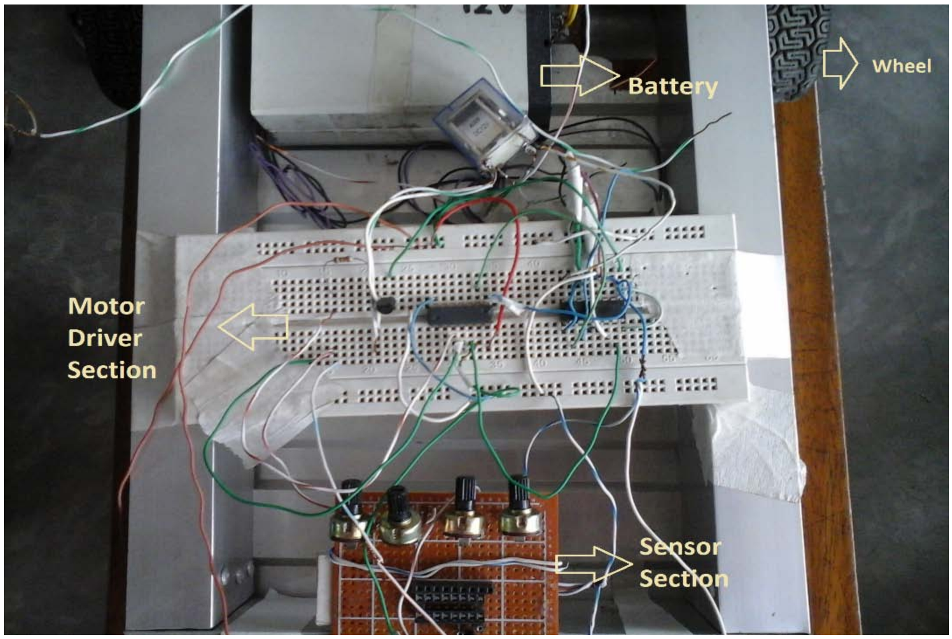

Figure 11: Internal circuit of solar automatic vehicle

A video of the solar automated vehicle is uploaded to you tube website [16]. After developing the three photosensor based solar automatic vehicle a microcontroller based solar automatic vehicle was developed and tested on the road. The microcontroller based vehicle also workaccurately as the three photosensor based solar automated vehicle. Figure 13 shows the microcontroller section and the microcontroller based solar automated vehicle.

Figure 12 : Prototype vehicle testing (on the left) & three photosensor based automated solar vehicle on the road

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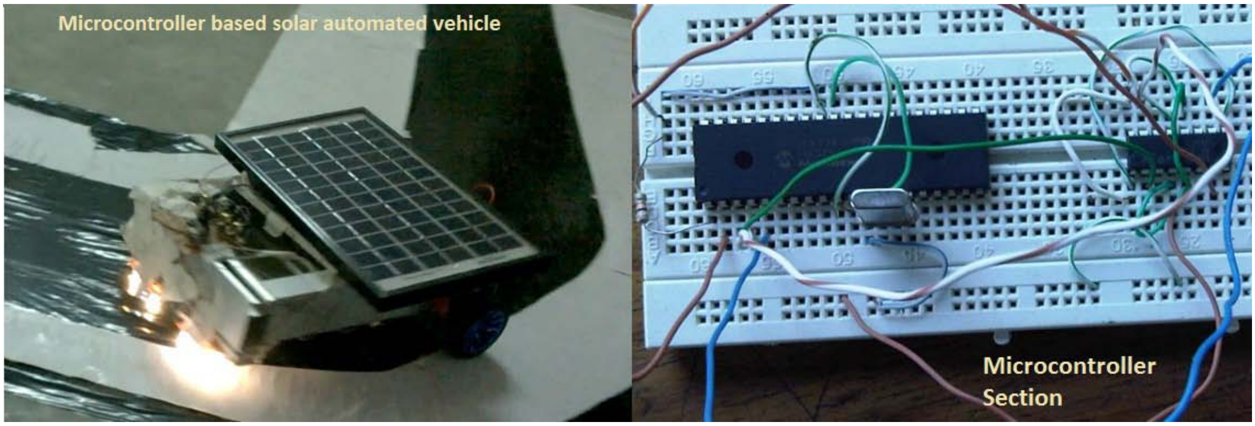

Figure 13 : Developed microcontroller based solar automated vehicle (on the left) & internal microcontroller section circuitry image (on the right)

VII. Discussion & Conclusion

It is seen that both design of solar automatic vehicle operates smoothly in the road.Furthermore, it is seen that the three photosensor based solar automated vehicle operates better than microcontroller based solar automated vehicle on the road. But the microcontroller will be able to provide more options because a real vehicle needs more options. It is seen that cost variation (From table 2) between microcontroller based and three photosensor based solar automated vehicle is less, so for further research work, a vehicle having more options it is suggested that microcontroller to be used.

Table 2 : Cost comparison between developing two system

Three photosensor based solar automated vehicle		Microcontroller based solar automated vehicle	
Product Name	Cost(tk)	Product Name	Cost(tk)
a) Motor Driver IC	90 tk	a) Microcontroller	250 tk
b) Motor (2 pieces)	600 tk	b) Motor Driver IC	90 tk
c) Car Frame	200tk	c) Motor (2 pieces)	600 tk
d) Resistors(5 pieces)	100 tk	d) Car Frame	200tk
e) Photosensors	50 tk	e) Resistors(5 pieces)	100 tk
f)Veroboard	30 tk	f) Photosensors	100 tk
g) Battery	600 tk	g)Veroboard	30 tk
h) Solar panel	1200 tk	h) Battery	600 tk
i)Car Wheel	150 tk	i) Solar panel	1200 tk
j)Others Apparatus	200 tk	j)Car Wheel	150 tk
		k)Others Apparatus	200 tk
Total cost	3220tk/ 40.25$	Total cost	3520tk/ 44.00$

Though the car moves successfully on the road there are some limitations. The vehicle cannot stop until the end of the road or switched off. Also the vehicle cannot park it on the side of the road. This problem can be solved, in the microcontroller based solar automatic vehicle. There should be a switch which can turn of the photosensors, and the vehicle will have to operate manually. Left, right turn and all other options can be done using (like in figure 8) switching function. Another limitation is there is no solar charge controller, it would be appropriate, if solar charge controller is incorporated with the vehicle to function more efficiently.

Despite the limitations, there are lot of advantages, like use renewable energy, safe driving, not producing any smokeand noise, very light weight, low cost etc. Still many research work is needed to bring the solar automated vehicle on the road for commercial use. Hopefully, the day is not too far away that everybody will see solar automated vehicle on the road.

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Bit Error Rate (BER) Performance of a Free Space Optical (FSO) Link Considering the Effect of Cloud-Induced Fading

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Keywords: FSO, fading, SISO, BER, IM/DD.

GJRE-F Classification : FOR Code: 090699

BITERROR RATEBERPERFORMANCEOFAFREESPACEOPTICALFSOLINKCONSIDERINGTHEEFFECTOFCLOUDINDUCEDFADING

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Bit Error Rate (BER) Performance of a Free Space Optical (FSO) Link Considering the Effect of Cloud-Induced Fading

Abu Jahid [α], Pranjan Das [σ] & Satya Prasad Majumder [ρ]

Abstract- Cloud- induced fading is occasional but one of the main impairments affecting free–space optics (FSO). In this paper, the bit error rate of intensity modulated FSO with direct detection (IM/DD) in single–input single–output (SISO) over Ray Leigh fading channels has been represented. It has been assumed that a single information-bearing signal is transmitted over fading channels. Only the effects of amplitude fluctuation have been considered. The expression for BER by finding the conditional probability of Bit Error has been expressed, for given amplitude fading and then averaging the conditional probability. The analytical derivations are built upon by considering that perfect inter symbol interference (ISI) due to broadening of the optical pulses arriving at the receiver. The performance of the FSO link by quantifying BER for different carrier wavelengths and for various transmission bit rate of the communication over cloud-induced fading channel has been investigated.

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I. Introduction

Current free space optical (FSO) communication systems employ intensity modulation with direct detection (IM/DD) and use point to point communication between two optical transverse along a line of sight [1, 2]. FSO communication is an attractive and license free high bandwidth access and cost-effective solution for high-rate image, voice and data transmission. Despite the major advantages of FSO communications, its widespread use is hampered by several challenges in practical deployment [3, 4]. In literature the performance of IM/DD FSO systems for different turbulence models and pointing errors has been well studied. The pairwise error probability of coded FSO links for the log-normal distributed turbulence model and a turbulence model with temporally correlated K-distributed for on-off keying (OOK) was carried out in [5, 6]. Later, Uysal extended their discussion to find out the pairwise error probability of the FSO links with the cases of independent Gamma-Gamma turbulence for coded on-off OOK keying [7]. For further study Ehsan, Bayaki find out the pairwise error probability of MIMO FSO link with Gamma - Gamma distribution for on-off keying (OOK) because of its excellent correlation with the measured data for a wide range of turbulence condition (weak to strong) in [8]. The FSO system performance can be degraded due to pointing errors since FSO communications requires line of sight (LOS) links. The concept of finding BER of an FSO channel model considering the effect of fading due to log-normal/Gamma-Gamma atmospheric turbulence was first introduced by Farid in [9]. On the same paper they also find out the pointing errors by considering detector size, beam width and pointing error variance. Another special case of Gamma-Gamma fading named K –fading is used to find out the BER and pointing errors of a SISO FSO link in terms of the Meijer G-function in [10]. This approach has also been extended to MIMO FSO links later on[11].Vavoulas et al. find out the design for robust FSO link for various weather condition, cases like snow, fog and rain[12]. For modelling multi-path electro-magnetic signal propagation through wireless environments Rayleigh distribution is being used for more than half a century and remains as the most acceptable model till outdated. The transmission error probability calculations are less complicated in comparison to other fading model. A large number of diffracted, reflected and scattered waves from buildings, trees and rough terrain are received by mobile antenna receivers. In such environment, the channel attenuation profile measured from different field measurement closely matches with the Rayleigh distribution[13]. In FSO link both the transmitter (Tx) and receiver (Rx) is fixed and there exist a line-of-sight (LoS). The received optical pulse shape due to the effect of cloud matches closely with the Rayleigh fading model (See result section) encourage us to analysis the performance of the SISO link assuming Rayleigh fading model.

In this paper, amplitude distortions due to beam wandering for the cloud-induced fading has been considered and it has been shown how performance is degraded compared to an Additive White Gaussian Noise (AWGN) channel. Then, using average Bit Error Rate (BER) as performance metric, possible analysis is investigated by varying transmission bit rate for different optical carrier wavelengths. Then the whole performance of the system is quantified in terms of power penalty for better understanding.

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II. System Model

A FSO link is normally consists of a transmitter, a channel which would be the medium of transmission and it would be atmospheric that includes cloud and finally a receiver to reproduce that transmitted signal. The simple BLOCK diagram is shown in Fig.1.

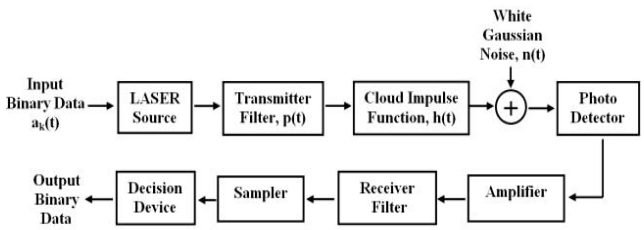

Figure 1 : Basic FSO system model

Most practical wireless optical channels use light emitting diodes or laser diodes as transmitters and photodiodes as detectors as shown above. These device modulate and detect solely the intensity of carriers not its phase which implies that all transmitted signal intensities are non negative. The input binary data is used to modulate the laser using intensity modulation and thus pass through the transmitted filter and then it passes through the atmosphere where the impulse response has a greater impact. The optical signal is detected by a photo detector and received by the receiver circuit. The sampler and decision device is used to determine the output binary data"unpublished"[14].

III. Performance Analysis

Basing upon Monte Carlo simulations mathematical models are developed for the temporal characteristics of optical pulse propagation through clouds. These include temporal impulse response, transfer function, bandwidth, and received energy. The simulation results strongly supports the use of double gamma function model to best describe optical pulse spread through clouds [15]

Optical radiation propagating through clouds experiences temporal distortions. A function that describes well the temporal impulse response is the double gamma function [15]-

$$h(t)=\left\{k_1(c_1)t\,e^{-[k_2(c_1)]t}+k_3(c_1)t\,e^{-[k_4(c_1)]t}\right\}U(t) \tag{1}$$

Where, h(t) is in m-2, c1 is a parameter defining the physical characteristics of the optical channel such as particulate size distribution, particulate refractive index, geometrical cloud thickness and radiation wavelengths, k1-k4 are the gammafunction constants depending on c1 and U(t) is a unit step function.

The temporal frequency transfer function can be evaluated by Fourier transforming the temporal impulse response [15]

$$H(f)=\int_{-\infty}^{\infty} h(t)e^{-(j2\pi ft)}dt \tag{2}$$

Where, f is the temporal frequency (Hz).
Substituting (1) into (2) yields-

$$H(f)=\left\{\frac{k_1(c_1)}{[k_2(c_1+j2\pi f)]^2}+\frac{k_3(c_1)}{[k_4(c_1+j2\pi f)]^2}\right\} \tag{3}$$

$$H(f)=G\left[1+j\left(\frac{f-b}{f_3}\right)\right]\left[1+j\left(\frac{f+b}{f_3}\right)\right]\Big/\left[\left[1+j\left(\frac{f}{f_3}\right)\right]^2\left[1+j\left(\frac{f}{f_2}\right)\right]^2\right] \tag{4}$$

For a given set of parameters [15]-

$$f_1=\frac{k_2}{2\pi}$$

$$f_2=\frac{k_4}{2\pi}$$

$$f_3=\frac{(k_1k_4+k_3k_2)}{2\pi(k_1+k_3)}$$

$$b=\frac{4\pi^2(k_1+k_3)}{(k_2k_4)^2}f_3^{\,2}$$

$$G=\frac{4\pi^2(k_1+k_3)}{(k_2k_4)^2}k_3^{\,2}$$

The transmitted optical signal is given by "unpublished"[14]

$$s(t)=\sqrt{2p_T}\sum_{k=-\infty}^{\infty}a_k p(t-kT_b)e^{(j\omega_c t)}$$

Where pT is the transmitted optical power, ak is the k-th information bit whose value is 1 and 0, p(t) is the optical pulse shape of bit duration Tb and carrier frequency of fc.

The received optical signal is given by

$$r(t)=\sqrt{2P_s}\sum_{k=-\infty}^{\infty}a_k g(t-kT_b)e^{(j\omega_c t)}+n_b(t)$$

Where, Ps is the received optical power and g(t)= h(t) p(t) is the received optical pulse shape which overlaps over a number of bits and produce Inter Symbol Interference (ISI) "unpublished"[14].

The photo current can be expressed as -

$$i(t)=|r(t)|^2R_d$$

$$=2R_dP_S\left|\sum_{k=-\infty}^{\infty} a_k g(t-kT_b)\right|^2 + i_n(t)$$

Where, Rd is the responsivity of the detector and in(t) is the noise current due to photo diode and receiver noise which can be expressed as

$$i_n(t) = i_{sh}(t)+i_{th}(t)$$

Without Fading

SINR can be defined as the ration of signal power to noise power [20]

$$SINR=\frac{\text{Signal Power}}{\text{Noise Power}}$$

$$=\left[\frac{{I_s}^2}{{\sigma_n}^2+{\sigma_{isi}}^2}\right]$$

Where,

$$\text{Signal Current, } i_s(t) = 2R_dP_s|a_0|^2.|g(t)|^2$$

"Mean Signal Current,"

$$I_s(t) = \overline{i_s(t)^2} = 2R_dP_s\frac{1}{T_b}\int_0^{T_b}|g(t)|^2\,dt$$

Mean ISI current,

$$\sigma_{isi}(t)=\overline{\sigma_{isi}(t)^2}=2R_dP_s\frac{1}{T_b}\int_0^{T_b}|a_kg(t-kT_b)|^2\,dt$$

Where,

$${\sigma_n}^2 = {\sigma_{shot}}^2 + {\sigma_{th}}^2$$

$${\sigma_{shot}}^2 = 2eBI_s$$

$${\sigma_{th}}^2 = 4KTB/R_L$$

The expression of BER for Intensity Modulation Direct Detection (IM/DD) can be expressed as [16]

$$BER=0.5\,\mathrm{erfc}\left(\frac{\sqrt{SINR}}{2\sqrt{2}}\right) \qquad (5)$$

With Fading

The analysis to a fading channel could be extended in two steps [17]-

To find the conditional probability of Bit Error $P_{b|\alpha}(\gamma_b|\alpha)$,given the amplitude fading α

To average of the conditional probability, $P_{b|\alpha}(\gamma_b|x)$ with respect to the PDF of α at α =x, in order to take into account the effect of all possible amplitude fading values on the transmission performance.

$$P_b(\overline{\gamma}_b)=\int_{-\infty}^{\infty}P_{b|\alpha}(\gamma_b|x)\,f_\alpha(x)\,dx \qquad (6)$$

Where, $\overline{\gamma}_b$ is the average received SINR/ bit with respect to α^2 and $f_\alpha(x)$ is the PDF of the amplitude fading α.

For a Rayleigh fading channel, α follows a Rayleigh distribution with PDF-

$$f_\alpha(x)=\begin{cases}\frac{x}{\sigma_\alpha^2}e^{\left(-\frac{x^2}{2\sigma_\alpha^2}\right)}, & x\geq 0\\ 0, & x<0\end{cases} \qquad (7)$$

For IM/DD it can be written-

$$P_{b|\alpha}(\gamma_b|\alpha)=\frac{\sqrt{x^2\gamma_b}}{2\sqrt{2}} \qquad (8)$$

Substituting the values from (6) and (7) in (8), hereby-

$$P_b(\overline{\gamma}_b)=\frac{1}{4}\left[1-\sqrt{\frac{\overline{\gamma}_b}{\overline{\gamma}_b+8}}\right] \qquad (9)$$

IV. Results and Discussions

Clouds having low level, noticeable vertical development and clearly defined edges are called Cumulus clouds. Cumulus clouds may appear alone, in lines, or in clusters. Cumulus clouds in appearance having the altitude of 200 and 6500 feet over the ground. This elevation range is very relevant for space communications involving planes. Cumulus clouds are often precursors of other types of clouds, such as cumulonimbus, when influenced by weather factors such as instability, moisture, and temperature gradient. Cumulus clouds are part of the larger category of cumuliform clouds, which include stratocumulus clouds, cumulonimbus clouds, cirrocumulus clouds, and altocumulus clouds[18].

A stratus cloud (St) termed as cumulus cloud because as it is formed from stratocumulus clouds, belonging to a class characterized by horizontal layering with a uniform base. Low lever stratus clouds are usually between 1000 and 2000 feet elevation and as such are unsuitable for aircraft communications. Since particulate scatter close to receiver is of more serious consequences than scatter far away from it. Therefore the study will be concentrate on cumulus clouds [19].

In this section the BER performance of SISO optical communication system in presence of cloud-induced fading modeled by Ray-Leigh function has been compared. For doing this, the numerical results of BER of the FSO link have been presented. The system has been simulated for the given set of Gama function constant for different wavelengths listed below.

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Table 1 : Double gamma function constants: Cloud thickness=200 m [15]

Gamma Function Constant	**Wavelengths**		
	0.532 µm	**0.8 µm**	**1.3µm**
k_1	120.1	62.4	16.5
k_2	1.9×10^7	1.8×10^7	1.1×10^7
k_3	1.55	2.9	0.67
k_4	3×10^6	3.5×10^6	2.13×10^6

Table 2 : Double gamma function constants: Cloud thickness=250 m [15]

Gamma Function Constant	**Wavelengths**		
	0.532 µm	**0.8 µm**	**1.3µm**
k_1	12.4	5.2	2
k_2	1.1×10^7	0.83×10^7	0.71×10^7
k_3	0.66	0.41	0.3
k_4	2.4×10^6	1.9×10^6	1.8×10^6

Fig. 2, demonstrate the received optical pulse shape. In this case the transmission bandwidth is considered 1GHz. It shows that the amplitude of the received bit is fluctuating for the total bit interval.

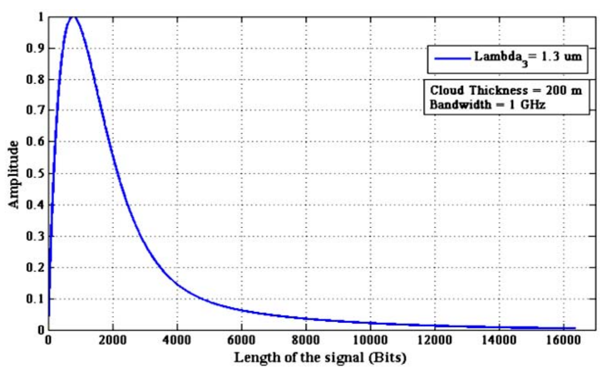

Figure 2 : Received optical pulse shape

Fig. 3, demonstrate the optical pulse shape for different amplitude fading considering the Rayleigh fading which is quite similar to the received optical pulse shape in fig. 1.

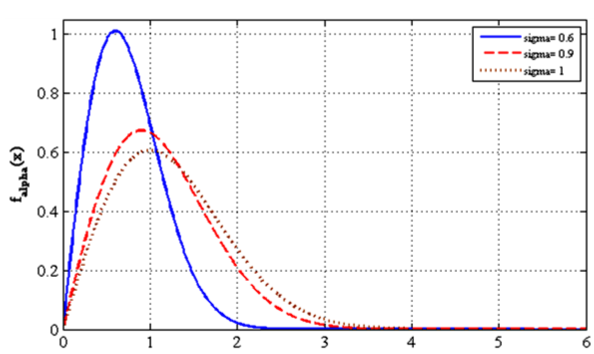

Figure 3 : Received optical pulse shape considering Rayleigh fading model

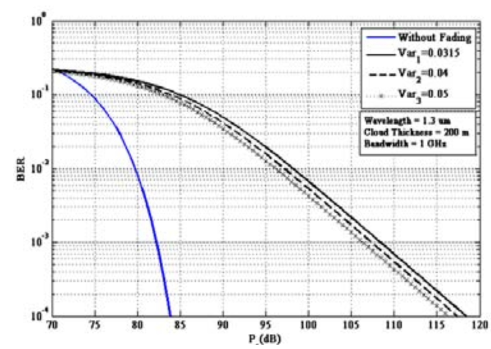

Figure 4 : BER performance of a FSO link with fading for different variance

It has been assumed that the Inter Symbol Interference (ISI) is available and Fig. 4, present the graphical representation of BER vs. received power in decibel considering the effect without fading and for different value of amplitude fading α. It demonstrate that for achieving a BER of 10-4considering the effect of fading it is needed to change the power level significantly in numerical value more than 1 kilo-Watt (KW).

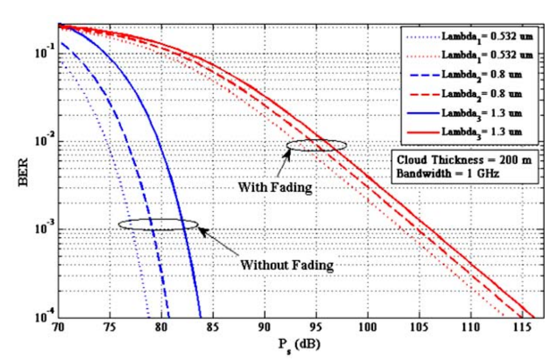

Figure 5 : BER performance of a FSO link with fading effect for Intensity Modulation Direct Detection (IM/DD)

In Fig. 5, the effect of fading for all carrier wavelengths considering the transmission bandwidth of 1GHz has been demonstrated. It shows that there are no significant advantages for any particular transmission wavelength.

For further investigation we varied the transmission bandwidth for different carrier wavelength communication. Fig. 6, 7 and 8 illustrate the BER performance of a SISO link for various bandwidths.

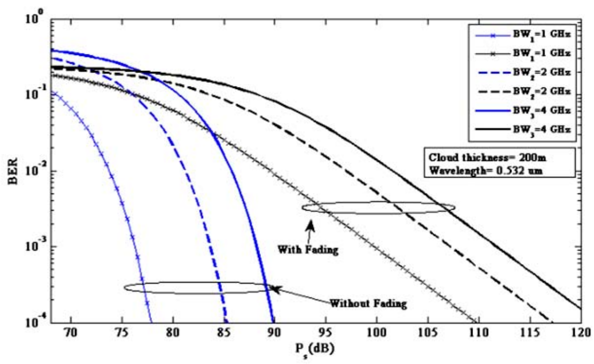

Figure 6 : BER performance of a FSO link with fading effect for different bandwidths

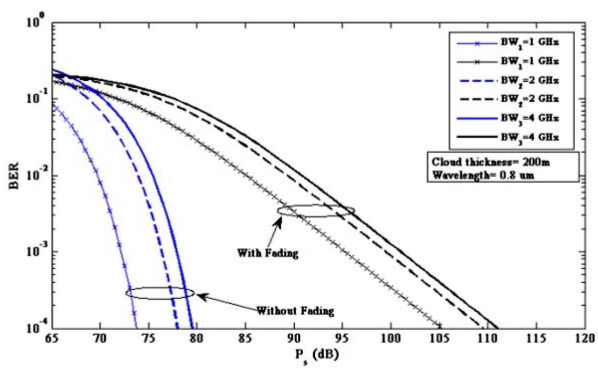

Figure 7 : BER performance of a FSO link with fading effect for different bandwidths.

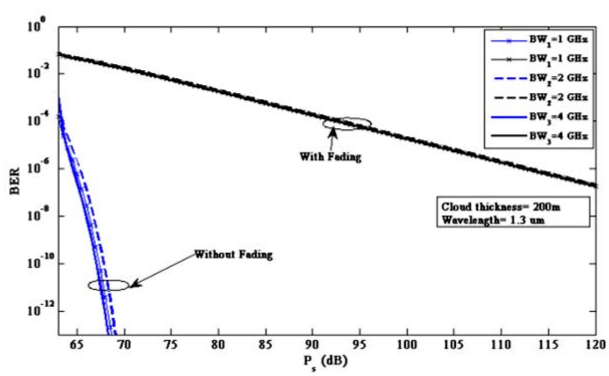

Figure 8 : BER performance of a FSO link with fading effect for different bandwidths

Fig. 8 depicts that, when the transmission bandwidth increases the received power needs to be increased. But for the wavelength of 1.3μm all the performance curves close to each other for various bandwidths.

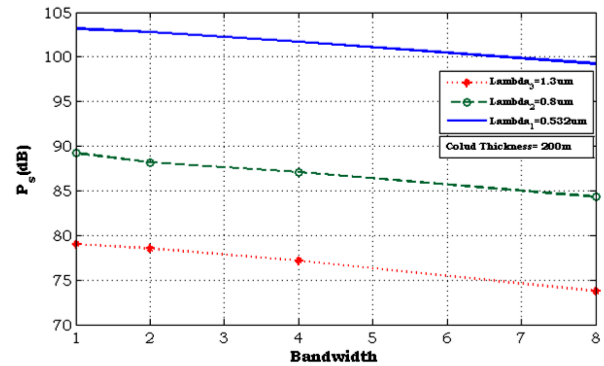

Figure 9 : Power penalty for different bandwidths (Cloud Thickness=200m)

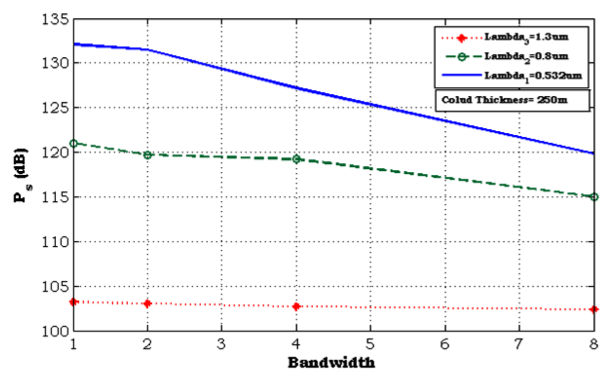

Figure 10 : Power penalty for different bandwidths (Cloud Thickness=250m)

Fig.9 and Fig. 10 depict the required optical power in dB for various transmission bandwidths for maintaining a bit error rate (BER) of 10-5.

From Fig.9, the required optical power (for the cloud thickness of 200 m) to overcome the inter symbol interference varies about 74 dB to 79 dB for a wide range of transmission bit rate (1Gb/s - 8 Gb/s) for the carrier wavelength of $\lambda=1.3$ μm. While the required optical power for the wavelength of $\lambda=0.8$ μm is about 84 dB to 89 dB; as for $\lambda=0.532$ μm the value is about 99 dB to 103 dB for the same bit rate. This analysis will surely help to choose the type of photo detector for the FSO link depending on the optical power budget.

In Fig.10, the required optical power (for the cloud thickness of 250 m) to overcome the inter symbol interference varies about 102 dB to 103 dB for a wide range of transmission bit rate (1Gb/s - 8 Gb/s) for the carrier wavelength of $\lambda=1.3$ μm while maintaining the mentioned BER. The required optical power for the wavelength of $\lambda=.8$ μm is about 115 dB to 121 dB. Whereas for $\lambda=.532$ μm the value is about 119 dB to 132 dB for the same bit rate.

So it can be said the power penalty is also in considerable level for the wavelength of 1.3μm.

V. Conclusion

In this paper, a very basic approach to performance analysis of SISO free space optical systems (FSO) due to the cloud-induced fading has been presented which was modelled as Ray Leigh fading. The proposed technique is based on finding the conditional probability of Bit Error, for given amplitude fading α and then averaging the conditional probability, with respect to the PDF of α, which is considered to follow the Ray Leigh distribution. It has been investigated that the BER performances for various optical wavelength communications by varying bandwidth. It is found that for the communication wavelength of 1.3μm, the received power is same for different transmission bandwidth. For high bandwidth transmission, wavelength of 1.3μm is preferable and power penalty is also considerable for that wavelength. But for all the cases required power budget is high.

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Spectral Kurtosis Theory: A Review through Simulations

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Abstract- Kurtosis of a time signal has been a popular tool for detecting nongaussianity. Recently, kurtosis as a function frequency defined in spectral domain has been successfully used in the fault detection of induction motors, machine bearings. A link between the nongaussianity and nonstationaity has been established through Wold-Cramer's decomposition of a nonstationary signal, and the properties of the so-designated conditional nonstationary (CNS) process have been analytically obtained. As the nonstationary signals are abundantly found in music, the spectral kurtosis could find applications in audio processing e.g. music instrument classification and music-speech classification. In this paper, the theory of spectral kurtosis is briefly reviewed from the first principles and the spectral kurtosis properties of some popular stationary signals, nonstationary signals and mixed processes are analytically obtained. Extensive Monte Carlo simulations are carried out to support the theory.

Keywords: spectral kurtosis, stft, random amplitude sinusoid, chirp, harmonic sinusoid, higher order statistics, wold-cramer's decomposition, mixing processes.

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Keywords: spectral kurtosis, stft, random amplitude sinusoid, chirp, harmonic sinusoid, higher order statistics, wold-cramer's decomposition, mixing processes.

I. Introduction

Characterization of a given signal as noise like or tone like finds several applications in music-speech classification [1,2,3], perceptual audio coding [4], Multi Band Excitation (MBE) model based perceptual coding of speech [5] and voice activity detection [6]. Within each category, the signals may be stationary/nonstationary/transient signal or gaussian/nongaussian. The Nongaussianity and/or nonstationary signal also occur when a radar signal is reflected by a fluctuating target or clutter [7] or when a communication signal passes through a fading wireless channel [8,9]. The fourth-order cumulant based kurtosis of the time signal was traditionally used for nongaussianity detection [10], Harmonic Retrieval from nongaussian processes[11], nonminimum phase system identification [12]. Recently the frequency dependent kurtosis defined in spectral domain was proposed and successfully used in bearing fault detection [13,14,15] and vibratory surveillance and diagnostics of rotating machines [16]. Spectral Kurtosis (SK) was originally introduced by Dwyer [17] where it was defined on the real part of the STFT filter bank output to overcome the deficiency of the power spectral density to detect and characterize the signal transients. Vrabie [18] justified the theoretical definition of SK and proposed an unbiased estimator of SK. Antoni [19,20] formulated SK differently by using Wold-Cramér decomposition with a theoretical basis for the SK estimation of non-stationary processes. He also practically used it for machine surveillance and diagnostics [16,21]. Other applications of spectral kurtosis reported in the literature include SNR estimation in speech signals [22], denoising [23] and subterranean termite detection [24].

In this paper, the important aspects of original spectral kurtosis theory is reviewed from fundamentals. The spectral kurtosis properties of both stationary and nonstationary signals as well as the stochastic mixtures are analytically obtained. Extensive Monte Carlo simulations are carried out to support the theory reviewed and the spectral kurtosis of several processes at different signal-to-noise ratios (SNRs) is estimated. The results are in perfect match with the previous analytical findings.

The paper is organized section wise as follows. The mathematical basics of spectral kurtosis are introduced in the section II. The Test Signal Set comprising several popular signals are analytically described in section III. Short time fourier transform (STFT) for dynamically estimating the magnitude spectrum and the expression for estimation of SK from STFT is given in section IV. In Section V the details of Monte Carlo simulations of the Test Signal Set and the derived mixture processes, and the simulation results are presented. Finally the review summary and future work is given in Section VI.

II. Spectral Kurtosis

a) Background

Wold-Cramer's decomposition uniquely describes a non-stationary signal *y(t)* as the response of a causal linear system with time varying impulse response *h*(*t*, *s*) excited by a signal *X*(*t*) i.e.

$$Y(t) = \int_{-\infty}^{t} h(t, t-\tau) X(\tau) d\tau \qquad (1)$$

Here *h(t,s)* means the linear causal impulse response of the system at time instant *t* when excited by an impulse

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at time instant *t-s*. The frequency counterpart of eq.(1) is given by

$$Y(t) = \int_{-\infty}^{\infty} H(t,f)\exp(j2\pi f t)\,dX(f) \qquad (2)$$

where *H(t, f)* is the time varying transfer function of the system, which can be interpreted as the complex envelope of signal *Y(t)* at frequency *f* and *dX(f)* is an ortho-normal spectral process associated with input driving process *X(t).* In many cases, *H(t, f)* is stochastic and can be represented with $H(t,f,\xi)$ where ξ is a representative random parameter of filter's time varying transfer function. Let *H(t, f)* be conditioned to ξ *i.e.* the shape *of H(t, f)* depends on the outcome of the random variable ξ. *H(t, f,* ξ*)* can be assumed to be time stationary, stochastic and independent of the spectral process *dX(f)*. Thus the signal *X(t)* is stationary in general but non-stationary for a particular outcome ξ. Such a process was designated as conditionally nonstationary (CNS) process in [19]. It may be noted down that the simplest way to convert a nonstationary process to a CNS process is the time datum randomization. Any CNS process driven by a white process *X(t)* of order $p \geq 4$ is likely to be leptokurtic i.e. its probability density function having tails flatter than those of its generating gaussian process and hence non-gaussian. *In fact, this connectivity between the CNS and nongaussianity makes the kurtosis, originally defined on time processes to characterize the nongaussianity, a very useful in analyzing the nonstationary processes through kurtosis defined in spectral domain*.

For the stationary white driving process *X(t)* of order $p \geq 2n$, the spectral kurtosis of the nonstationary signal *Y(t)* is defined as the normalized fourth-order spectral cumulant [19] as

$$\begin{aligned} K_Y(f) &= \frac{S_{4Y}(f)}{S_{2Y}(f)} - 2 \\ &= \frac{E\{|H(n,f)|^4\}}{E\{|H(n,f)|^2\}^2}(2+\kappa_X) - 2 \geq \kappa_X \\ &= \gamma_{4H}(f)(2+\kappa_X) - 2 \geq \kappa_X \qquad f \neq 0 \qquad (3) \end{aligned}$$

where the factor 2 in place of 3 as in usual definition of cumulants comes from the fact that *dX(f)* is a circular random variable, $\gamma_{4H}(f)$ is the kurtosis of the (stochastic) frequency response of the time varying filter and κ_X is the time kurtosis of the input process.

If *Y(t)* is a purely stationary process, then $\gamma_{4H}(f)$ is independent of frequency and is unity, then spectral kurtosis of *Y(t)* is given by

$$K_Y(f) = \kappa_X \qquad (4)$$

which is a constant and independent of the frequency. In particular, the spectral kurtosis of a stationary gaussian process is zero (i.e. $\kappa_X = 0$).

b) Mixing Processes

Let *Z(t)* be the mixture of two processes (i) a non-stationary process *Y(t)* and (ii). a stationary additive noise *N(t)* .

$$Z(t) = Y(t) + N(t) \qquad (5)$$

The spectral kurtosis of this mixture is given by [19]

$$K_z(f) = \frac{K_Y(f)}{[1+\rho(f)]^2} + \frac{\rho(f)^2 K_N(f)}{[1+\rho(f)]^2} \qquad f \neq 0 \qquad (6)$$

where $\rho(f)$ is the local Noise-to-Signal power ratio at the frequency *f* given by

$$\rho(f) = \frac{S_{2N}(f)}{S_{2Y}(f)} \qquad (7)$$

If the mixing process *N(t)* is stationary (white or colored) gaussian process, then $K_N(f)$ vanishes at all frequencies except at $f \neq 0$. Thus eq.(6) becomes

$$K_z(f) = \frac{K_Y(f)}{[1+\rho(f)]^2} \qquad f \neq 0 \qquad (8)$$

If the noise power is zero i.e. signal is clean, then $\rho(f) = 0$ and hence

$$K_z(f) = K_Y(f) \qquad f \neq 0 \qquad (9)$$

When the process *Y(t)* is gaussian, eq.(6) becomes

$$K_z(f) = \frac{\rho(f)^2 K_N(f)}{[1+\rho(f)]^2} \qquad f \neq 0 \qquad (10)$$

where $\rho(f)$ is finite. If the noise power becomes larger and larger, $\rho(f) \to \infty$, the process *Z(t)* becomes purely the mixing noise process, the spectral kurtosis becomes

$$K_z(f) = K_N(f) \qquad f \neq 0 \qquad (11)$$

III. Test Signal Set

In what follows, some commonly found signals are considered for analytically computing the spectral kurtosis. The spectral kurtosis of some other signals not considered earlier is also obtained analytically.

a) Real Sinusoids

A real sinusoid of constant amplitude and constant frequency is given by

$$y(t) = A\cos(2\pi f_0 t + \varphi) \qquad (12)$$

where φ is a constant initial phase from $U(-\pi,\pi)$.

$$K_Y(f_0) = \frac{S_{4Y}(f_0)}{S_{2Y}(f_0)} - 2 = \frac{E\{|A|^4\}}{E\{|A|^2\}^2} - 2 = -1 \qquad (13)$$

A real sinusoid of time varying amplitude and constant frequency is given by

$$y(t) = A(t)\ \cos(2\pi f_0 t + \varphi) \qquad (14)$$

If the amplitude decreases exponentially, the signal is called a damped sinusoid and is given by

$$y(t) = A\, e^{-kt}\ \cos(2\pi f_0 t + \varphi) \qquad (15)$$

where *k* is the damping (bandwidth) factor, e^{-kt} is the decaying real envelope and φ is the constant initial phase from $U(-\pi, \pi)$.

b) Random Amplitude Sinusoid

When a radar transmitted carrier signal is reflected by a fluctuating target, the carrier amplitude of the echo signal undergoes random fluctuations [7]. Similarly, a communication signal passing through a fading wireless channel, the amplitude of the signal at the receiver input undergoes random fluctuations [8,9]. In these cases, the time varying amplitude $A(t)$ in eq.(14) can be represented by

$$A(t) = A_c + A_r(t) \qquad (16)$$

where A_c is the constant part and the random part $A_r(t)$ which is also called as the multiplicative noise. In case of deep fluctuations the constant part becomes zero and then $A(t) = A_r(t)$. The spectral kurtosis of such a process is totally dependent on the probability density function of $A_r(t)$. In [25] the spectral kurtosis of such a random amplitude sinusoid was shown to be

$$K_Y(f) = \kappa_{A_r} + 1 \qquad (17)$$

where κ_{A_r} is the coefficient of kurtosis or time kurtosis of the random amplitude. The coefficient of kurtosis κ_{A_r} based on cumulants can be obtained from the following expressions [26, 27].

$$C_2 = M_2 - {M_1}^2$$

$$C_4 = M_4 - 4M_1M_3 + 6{M_1}^2M_2 - 3{M_1}^4$$

$$\gamma_2 = C_2$$

$$\gamma_4 = C_4 - 3{\gamma_2}^2 = C_4 - 3{C_2}^2$$

$$\kappa_{A_r} = \frac{\gamma_4}{\gamma_2} = \frac{C_4}{{C_2}^2} - 3 \qquad (18)$$

where M_k are the k-th standard moments, C_k are the k-th central moments and γ_k are the cumulants.

a) If the amplitude of the random sinusoid in eq.(16) is totally random with a gaussian density function, then from eq.(17) and eq.(18), the spectral kurtosis is given by

$$K_Y(f) = \kappa_{A_r} + 1 = \frac{3\sigma^4}{(\sigma^2)^2} - 3 + 1 = 1 \qquad (19)$$

b) If the amplitude of varies uniformly in the range (a, b), then the spectral kurtosis from eq.(17) and eq.(18) is given by

$$\mathrm{K}_Y(f) = \frac{{(b-a)^4}/{80}}{\left({(b-a)^2}/{12}\right)^2} - 3 + 1 = \frac{144}{80} = -0.2 \quad (20)$$

c) For a rayleigh distributed random amplitude, the standard moments are given by

$$M_{2k} = 2^k b^{2k} k! \qquad k = 1,2$$

Then from eq.(17) and eq.(18), the spectral kurtosis can be obtained as

$$K_Y(f) = 0 \qquad (21)$$

Similarly the spectral kurtosis for other density functions can be obtained. The focus of this paper is not to derive such expressions, but to show that $K_Y(f)$ is a positive constant depending on the probability density function. However for some more density functions, the simulations are carried out as described in the section V.

c) Harmonic and Inharmonic Sinusoids

A harmonic sinusoid comprises a sine wave of fundamental frequency $f_0$and its finite number of harmonics $f_m = mf_0$ as denoted by

$$y(t) = \textstyle\sum_{m=0}^{M-1} A_m\ \cos(2\pi m f_0 t + \varphi) \qquad (22)$$

where M is the number of harmonics. The amplitudes of the harmonics decay at different rates depending on the instrument or the note played. A typical profile of the harmonic amplitudes is given by $A_m = 1/m$. If the frequencies are independent and no harmonic relation among them i.e. $f_m \neq mf_0$, then the sinusoids are called inharmonic sinusoids. Both harmonic and inharmonic sinusoids appear frequently in music produced by several instruments.

d) Additive Gaussian Noise

Additive White Gaussian Noise (AWGN) signal is a noise commonly found in communication channel which adds to the transmitted signal. The spectrum of this signal is flat with a constant one-sided power spectral density η within the channel bandwidth.

If power spectral density of the noise within the channel bandwidth is function of frequency, then the noise is called colored noise and is characterized by *η(f)*.

e) Modulated Signals

An amplitude modulated signal with a carrier frequency f_c modulated by a sine wave of a low frequency f_m and is given by

$$y(t) = A_c(1 + m_A\, mes(\mathrm{t})\ \cos(2\pi f_c t + \varphi) \qquad (23a)$$

where A_c is the amplitude of the carrier and m_A is the modulation index, $mes(t)$ is the low frequency message signal. The Double Side Band (DSB) signal, the Lower Side Band (LSB) signal and the Upper Side Band (USB) signal can be formed by appropriate processing the AM signal.

The Frequency Modulated (FM) signal can be obtained as

$$y(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int_0^t mes(t)dt\right) \quad (23b)$$

f) Chirp Signal

A chirp signal is a frequency modulated signal in which the frequency of the carrier is linearly or hyperbolically varied. This kind of chirp signal is extensively used in pulse radars for achieving higher range resolution using a longer transmitted pulse, which is otherwise possible with a shorter transmitted pulse [14]. A phase modulated signal is given by

$$y(t) = A\cos\varphi(t) = A\cos 2\pi f(t)t \quad (24)$$

where $\varphi(t)$ is the time-varying phase of the carrier. The frequency profile *f(t)* can be linear, quadratic or logarithmic.

In a *linear chirp signal*, the carrier frequency *f* is varied as $f_c + \alpha t$, where $\alpha = df/dt$ is the chirp rate. Then time-varying phase of the carrier is given by

$$\varphi(t) = 2\pi\int_0^t f(t)dt = 2\pi\int_0^t (f_c + \alpha t)dt$$
$$= 2\pi\left(f_c t + \tfrac{1}{2}\alpha t^2\right) \quad (25)$$

Substituting eq.(23) in eq.(22), we get

$$y(t) = A\cos 2\pi\left(f_c t + \tfrac{1}{2}\alpha t^2\right) \quad (26)$$

If the start frequency at $t = 0$ is f_c and the end frequency at $t = t_1$ is f_1, then the chirp rate is given by $\alpha = (f_1 - f_0)/t_1$.

In a *quadratic chirp signal*, the instantaneous frequency is given by

$$f(t) = f_c + \alpha t^2 \quad (27)$$

where $\alpha = (f_1 - f_0)/t_1^2$.

In a *logarithmic chirp signal*, the instantaneous frequency is given by

$$f(t) = f_c \alpha^{t_1} \quad (28)$$

where $\alpha = (f_1/f_0)^{1/t_1}$.

IV. STFT Based Spectral Kurtosis Estimation

In this section a means of estimating the spectral kurtosis from the short time fourier transform (STFT) is presented. Here the input signal *y(n)* is divided into overlapping or non overlapping frames each of size *N*, multiplied by a window function *w(k)* like a hamming window of same size and analyzed by using the Fourier Transform. A matrix popularly known as a spectrogram is formed by arranging STFT coefficients as columns as given by

$$S(k,l) = \frac{1}{MW_n N}\left|\sum_{n=0}^{N-1} y(n+lM)\, w(n) e^{-j\frac{2\pi nk}{N}}\right|^2$$
$$0 \le k \le K-1,\ 0 \le l \le L-1 \quad (29)$$

where *k* is the frequency index, *l* is the time frame index, *M* is the hop size, K is the total number of frequency bins of one-sided STFT and *L* is the total number of frames contained in the signal.

An un-biased estimator of the spectral kurtosis is proposed in [19] based on L realizations of *K*-sample signal. The discrete fourier transform (DFT) on a K-sample signal computes the signal spectrum at K-number of discrete frequencies. If the L number of nonoverlapping frames used in the STFT analysis are considered as L number of the independent stochastic signal realizations, the spectral kurtosis $K_S(k_0)$ at the frequency index k_0 can be computed from the k_0-th row of the spectrogram matrix $S(k_0,.)$The spectral kurtosis at all frequency indices $0 \le k \le K-1$ is given by

$$K_S(k) = \frac{L}{L-1}\left[\frac{(L+1)\sum_{l=0}^{L-1} |S(k,l)|^4}{\{\sum_{l=0}^{L-1}|S(k,l)|^2\}^2} - 2\right]$$
$$0 \le k \le K-1 \quad (30)$$

V. Simulations and Results

The following signals are simulated using eq.(12), eq.(14), eq.(15) and eq.(20) through eq.(28).

1. A Constant Amplitude Sinusoid signal
2. A Random Amplitude Sinusoid signal
    a. A Uniform Amplitude Sinusoid signal
    b. A Gaussian Amplitude Sinusoid signal
    c. A Exponential Amplitude Sinusoid signal
    d. A Rayleigh Amplitude Sinusoid signal
    e. A Lognormal Amplitude Sinusoid signal
    f. A Gamma Amplitude Sinusoid signal
    g. A Weibull Amplitude Sinusoid signal
    h. A Chisquare Amplitude Sinusoid signal
3. A Damped Sinusoid signal

a. exp(-kt) envelope Sinusoid signal
b. exp(-kt²) envelope Sinusoid signal

4. A Harmonic Sinusoid signal
5. An Additive Gaussian Noise
   a. White Gaussian Noise
   b. Colored Gaussian Noise
6. An Analog Modulated signals
   a. An Amplitude Modulted signal
   b. A Double Side Band (DSB) signal
   c. A Lower Side Band (LSB) signal
   d. A Upper Side Band (USB) signal
   e. A Wideband Frequency Modulated Signal
7. Chirp signals
   a. A Linear Chirp signal
   b. A Quadratic Chirp (Convex) signal
   c. A Quadratic Chirp (Concave) signal
   d. A Logarithmic Chirp Signal

Different mixture processes are formed by adding two or more of the above simulated signals. The spectral kurtosis is estimated for each mixture process. In all simulations a sampling frequency of 44100Hz is used. Customized Matlab code is developed for generating the test signals, for computing STFT and for estimating the spectral kurtosis.

a) Mixture-1

A composite signal if formed by summing four sinusoids of frequencies 1800Hz, 4000Hz, 9000Hz and 18000Hz with respective amplitudes: 1.0, 0.25, 0.7 and 2.0 is formed. An additive white gaussian noise (AWGN) is added to the composite signal to form the first mixture process. Thus the mixture comprises a total five signals: four constant amplitude sinusoids and gaussian noise. The variance of AWGN is adjusted so as to obtain signal-to-noise ratios of 30dB, 20dB, 10dB, 0dB, -5dB and -10dB.

The mixture signal is generated for a duration of 1.1610 seconds. STFT is computed for frames or window size of 256 samples with 50% (i.e. 128 samples) overlap. Each frame is multiplied by a hamming window of 256 samples and a 256-point FFT is computed thus giving a spectrogram matrix of size 256 × 399

$$S(k,l)\,; \quad 0 \le k \le 255, \;\; 0 \le l \le 398$$

each of 256 frequency bins of spectrogram matrix is averaged over 399 frames to obtain a mean STFT spectrum $S_M(k) = \langle S(k,.)\rangle;\ 0 \le k \le 255$ which is called here as *Averaged STFT Spectrum*. Fig.1a gives the Averaged STFT Spectrum of Mixture-1 for different SNRs. Four peaks of different amplitudes observed in the spectrum correspond to four sine waves in the mixture. The low amplitude second peak is submerged in the noise floor at low SNRs below 0dB. As the SNR decreases, the noise floor also increases.

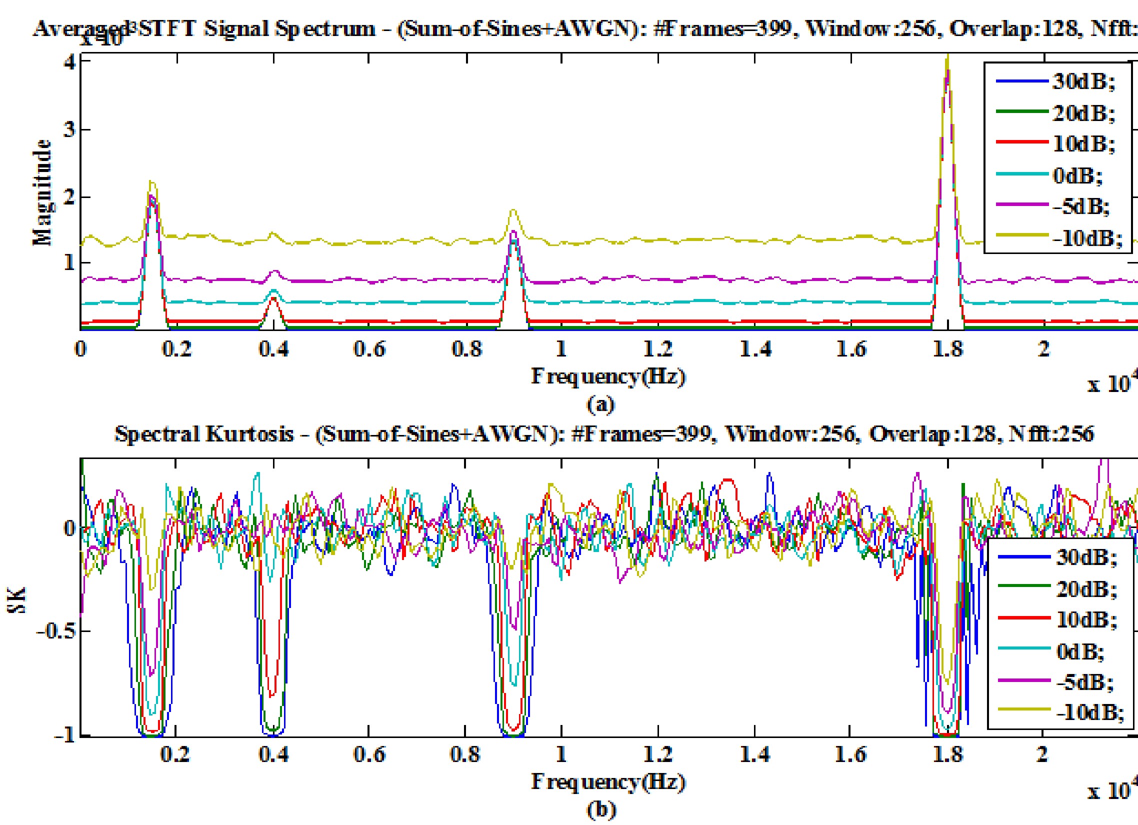

Fig. 1 : Sum of sinusoids (a). Averaged SFT spectrum of (b). Estimated Spectral Kurtosis for SNRs 30dB to -10dB

Global Journal of Researches in Engineering (F) Volume XV Issue VI Version I Year 2015

The spectral kurtosis $K_S(k); 0 \leq k \leq 255$ is also computed from the spectrogram matrix using eq.(28) as explained in section IV. It may be noted that $K_S(0)$ is to be ignored, as the kurtosis is not defined at $f = 0$. The Fig.1b gives the spectral kurtosis (SK) of Mixture-1 for different SNRs.

The spectral kurtosis has four negative peaks corresponding to four sinusoids. For higher SNR (30dB) the peaks have a value of -1 irrespective of the sinusoid amplitudes. As the SNR decreases, the peaks values increase from -1 towards zero. Local SNR computed at peak locations vary depending upon the amplitude of the sinusoid. Here it is maximum at 18000Hz and minimum at 4000Hz. It may be noted down that the SNR referred in the legend of the figures1(a) and (b) is the global SNR, which is computed based on the aggregate of all sinusoids. For global SNRs below 0dB, where the AWGN power dominates the aggregate power of all sinusoids, the mixture becomes more and more gaussian, the spectral kurtosis tends to zero, relatively faster at 4000Hz where the local SNR is minimum.

b) Mixture-2

The second Mixture process comprises six components: constant amplitude sinusoid(CAS), two damped sinusoids(DS1 and DS2) with different damping factors, colored gaussian noise(CGN), colored uniform(i.e. nongaussian) noise(CnGN) and AWGN. Global SNR is computed with respect to AWGN considering the other five components as composite signal. The CGN is obtained by passing white gaussian noise through a 6-order butterworth band pass filter having passband between 10KHz and 13KHz. The CnGN obtained by passing white uniform noise through a 6-order butterworth band pass filter having passband edges at 15KHz and 17KHz.

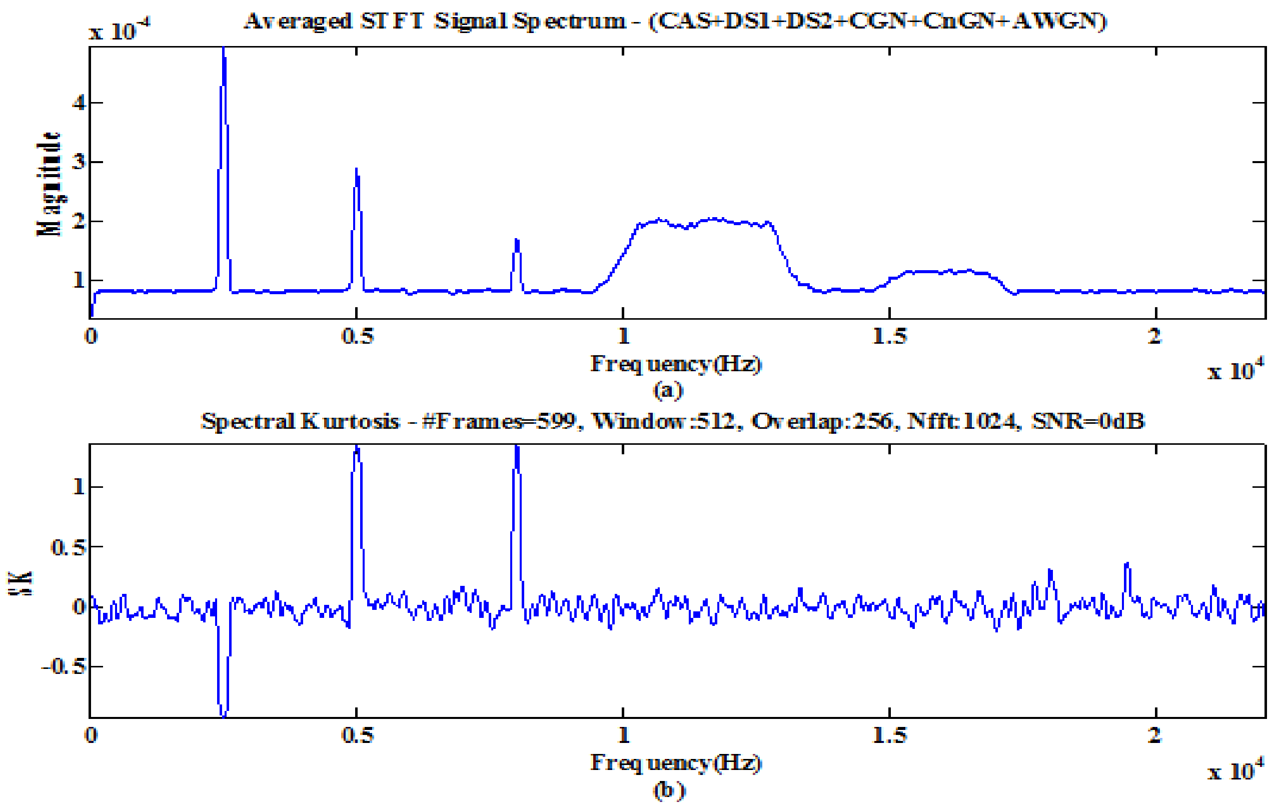

Fig. 2 : Mixture-2 (a). Averaged SFT spectrum of (b). Estimated Spectral Kurtosis for SNRs 0dB

Fig.2 gives the Averaged STFT Spectrum and SK of Mixture-2 for 0dB SNR. The first peak at 2500Hz having the spectral kurtosis of -1 the constant amplitude sinusoid. The peaks at 5000Hz and 8000Hz have the SK greater than zero indicate the nonstationary nature of the signals. In fact these signals correspond to damping sinusoids which amplitude is changing with time as e^{-kt} and e^{-kt^2}. The other two components: CGN and CnGN being stationary noise processes take a zero SK. The AWGN also takes a zero SK as expected.

c) Mixture-3

The third Mixture process is made up eight sinusoids, each having a random amplitude following different probability density functions: gaussian, uniform, exponential, Rayleigh, etc. The frequencies of these sinusoids are 1KHz, 2.5KHz, 4KHz, 5.5KHz, 7KHz, 8.5KHz, 10KHz, 11.5KHz, 13KHz, 14.5KHz and 16KHz. These sinusoids are generated one by one and processed separately to obtain the SK estimate separately. Then the SK functions of all sinusoids are overlapped and shown in single figure. Fig.(3) gives the STFT spectrum and the SK of these its random amplitude sinusoids for SNR=30dB. The eight peaks in STFT spectrum correspond to eight sinusoids. As shown in Fig3(b), the SK of first sinusoid at 1000Hz is -0.2, corresponding to uniformly distributed amplitude variations (see eq.20). The SK of the second sinusoid at 2500Hz is +1.0, corresponding to gaussian distributed amplitude variations (see eq.19). The SK of fourth sinusoid at 5500Hz is 0.0, corresponding to rayleigh distributed amplitude variations (see eq.21).

Fig.(4) gives the STFT spectrum and the SK of these random amplitude sinusoids for SNR=10dB. The SK values of the sinusoids at 10dB compared to the respective SK values at 30dB are different, but the trend is same.

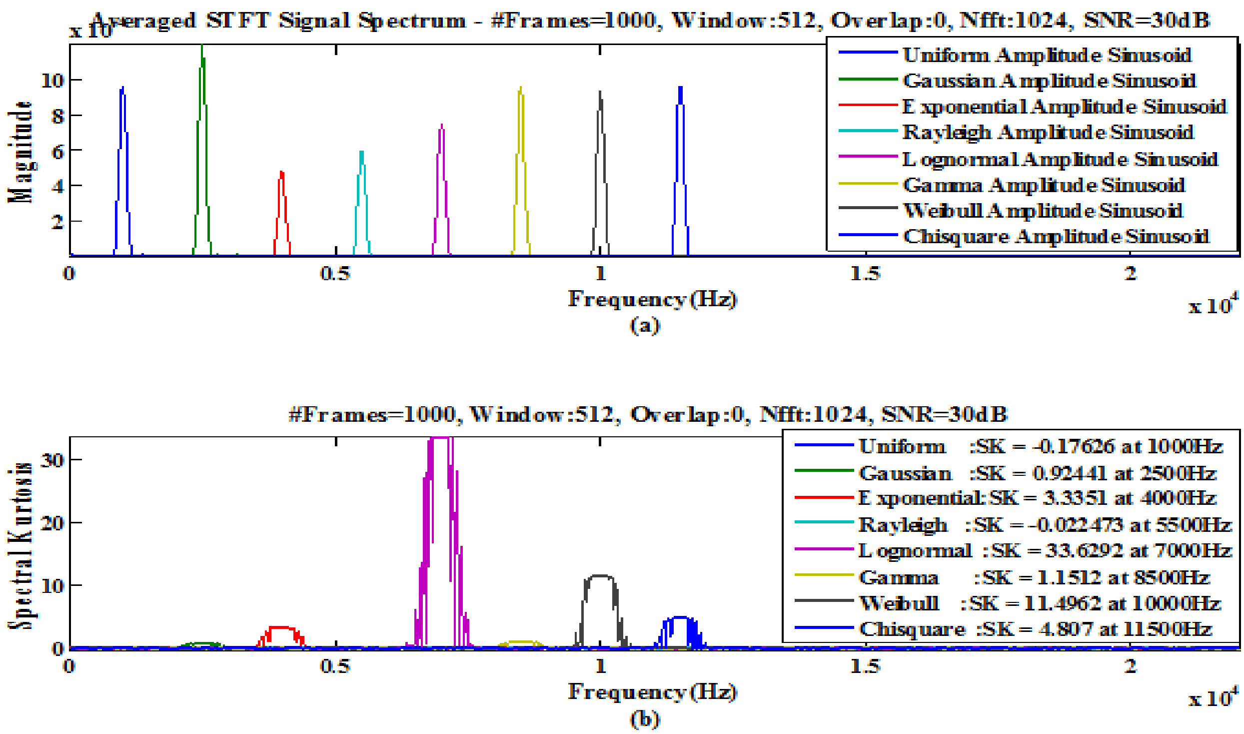

Fig. 3 : Mixture-3 (a). Averaged SFT spectrum of (b). Estimated Spectral Kurtosis for SNRs 30dB

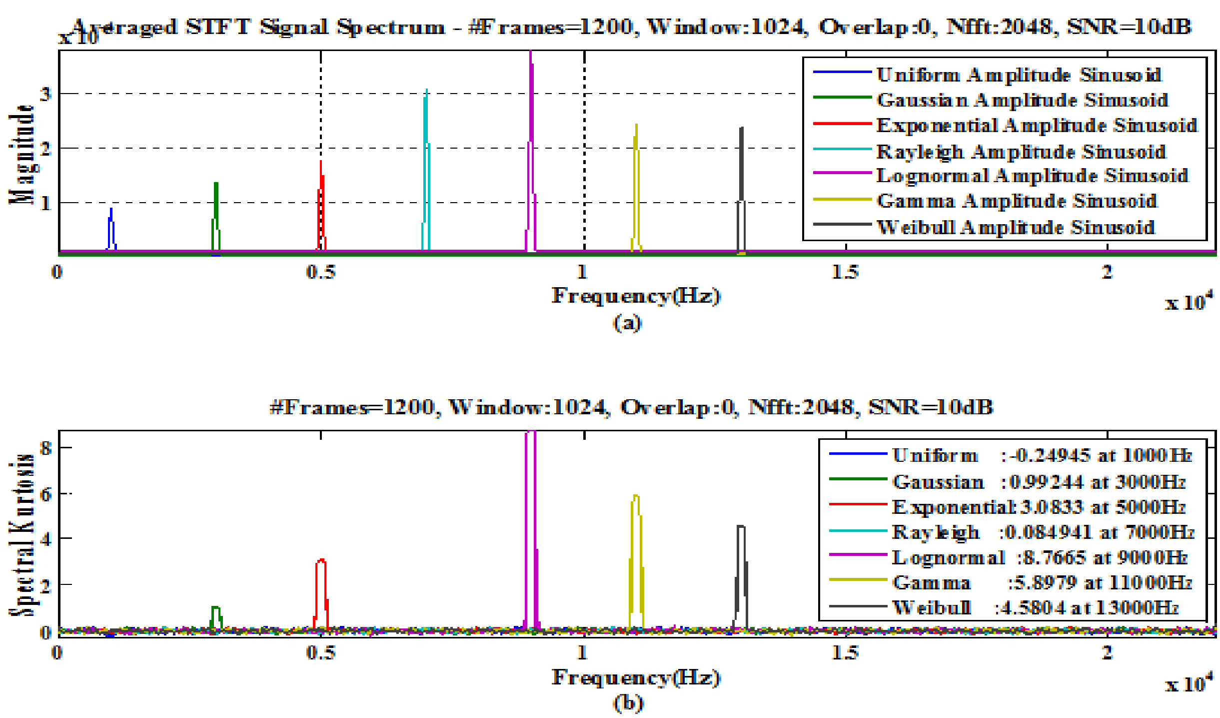

Fig. 4 : Mixture-3 (a). Averaged SFT spectrum of (b). Estimated Spectral Kurtosis for SNRs 10dB

d) Mixture-4

The fourth Mixture is basically a harmonic sinusoid with a fundamental at 800Hz and having 10 harmonics contaminated by an AWGN. The amplitude of n-th harmonic is 1/n, but this amplitude remains constant with time. The STFT spectrum of this mixture is shown in Figure 5(a) for SNRs of 20dB, 10dB and 0dB. The ten negative peaks in SK plot of Figure 5(b) correspond to seven sinusoids. Please note that each peak is -1 irrespective of the harmonic number for higher SNRs. As SNR decreases, the negative peaks move from -1 towards zero.

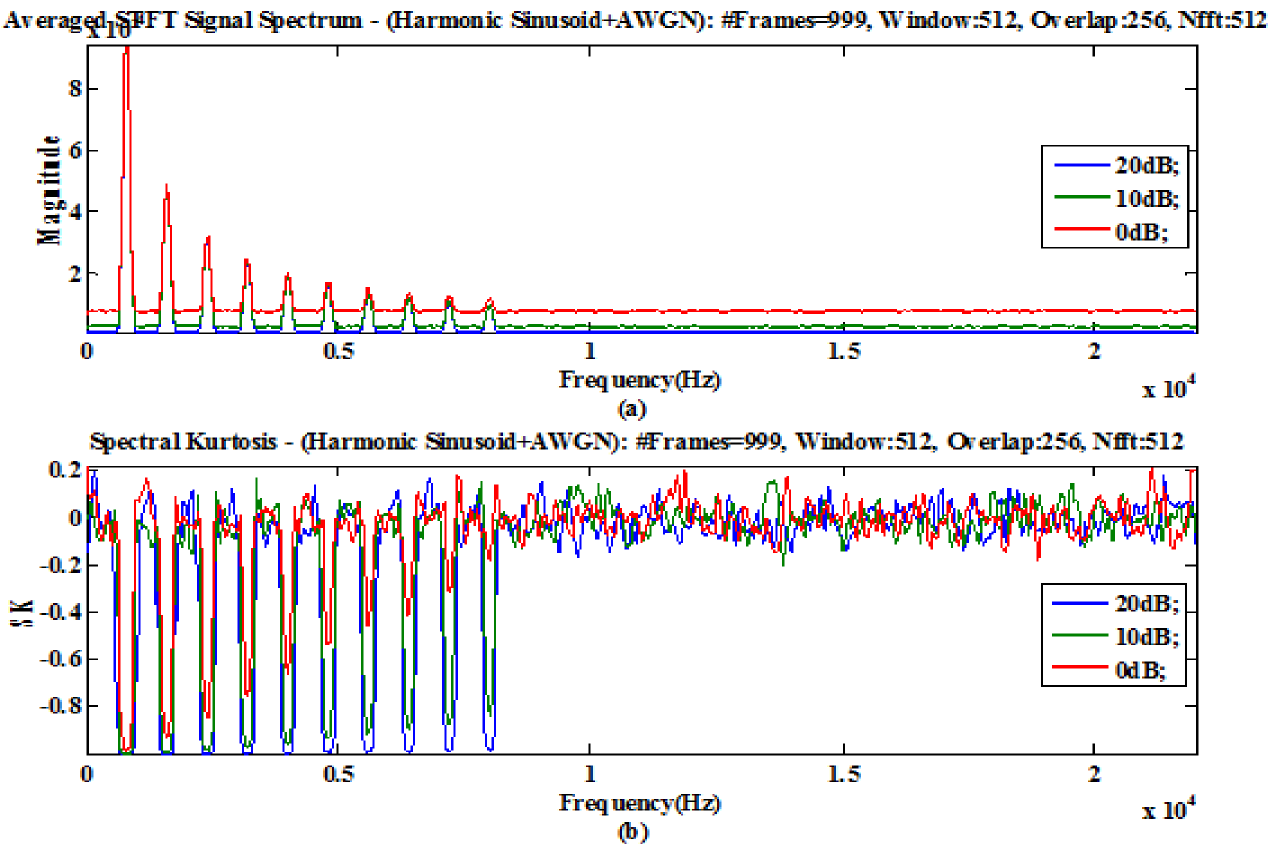

Fig. 5 : Mixture-4 (a). Averaged SFT spectrum of (b). Estimated Spectral Kurtosis for SNRs 20dB, 10dB and 0dB

e) Mixtures-5

In this category basically five analog modulation signals are considered; corresponding mixtures are are AM + AWGN, AM-SC (DSB) + AWGN, LSB+ AGWN, USB+ AGWN and FM+AGWN Fig.(6) through fig.(10) give the STFT spectra and SKs of these mixtures.

The SK of AM signal is -1.0 since the carrier is strong due to low modulation index and resembles a constant amplitude at carrier frequency of 12KHz.. The SK of DSB is positive at carrier frequency of 12KHz showing its nonstationary nature. The SK of the next two mixtures LSB and USB is over the signal bandwidth. However, at the band edges, the SK takes exceptionally large values.

f) Mixture-6

The sixth Mixture is made up of different chirp signals: linear, quadratic and logarithmic chirps generated using the eq.(24) through eq.(28). Each chirp is shown in different colors in Fig 11. The STFT spectrum of this mixture is shown in Figure 11(a) for SNR of 10dB. It may be noted down that the SK of a chirp signal is nonzero positive, over the chirp bandwidth. However, at the band edges, the SK takes exceptionally large values.

Global Journal of Researches in Engineering (F) Volume XV Issue VI Version I Year 2015

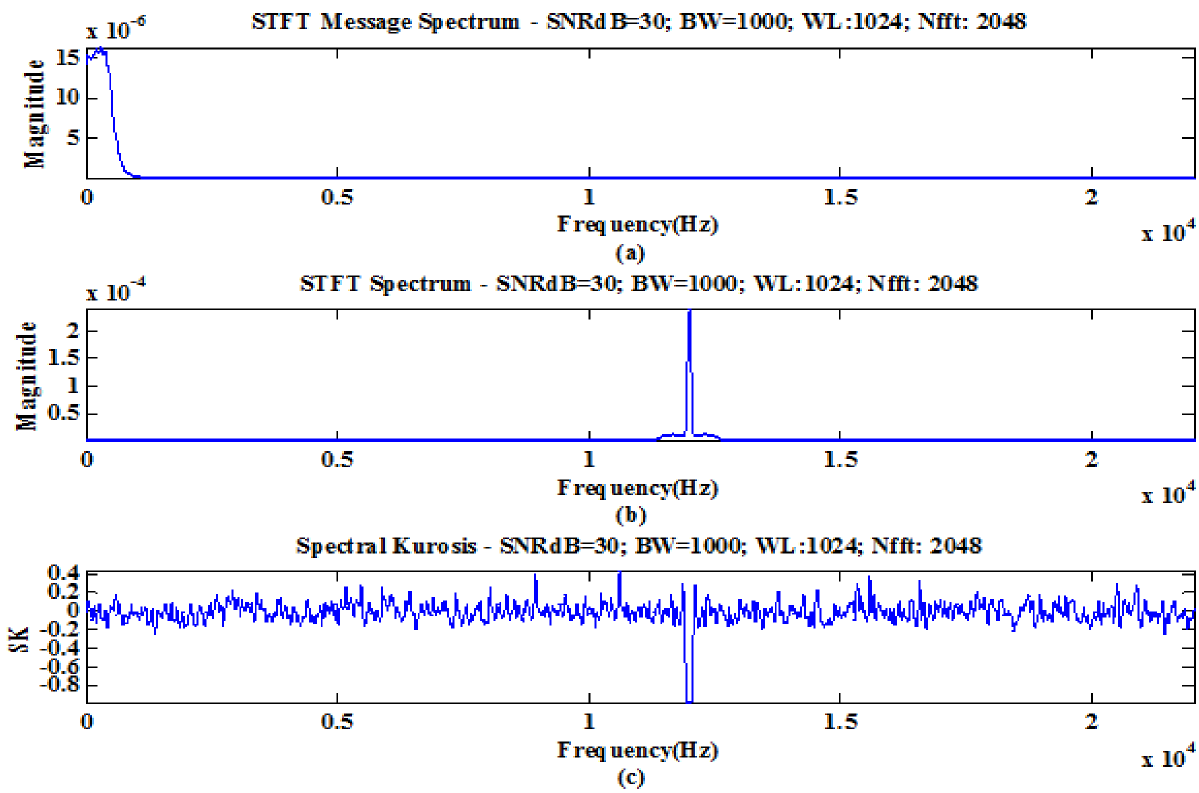

Fig. 6 (a) : Averaged SFT spectrum of AM+AWGN (b).Estimated Spectral Kurtosis for SNR=30dB

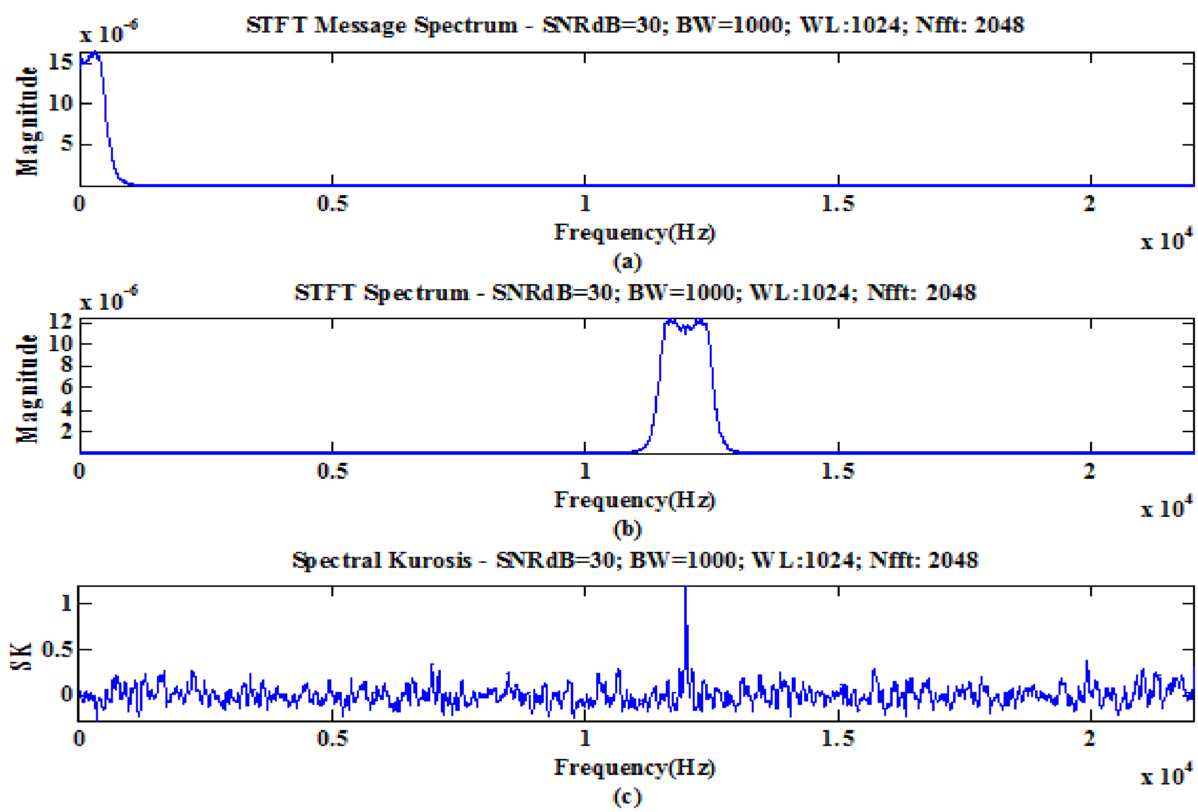

Fig. 7(a) : Averaged SFT spectrum of DSB+AWGN (b).Estimated Spectral Kurtosis for SNR=30dB

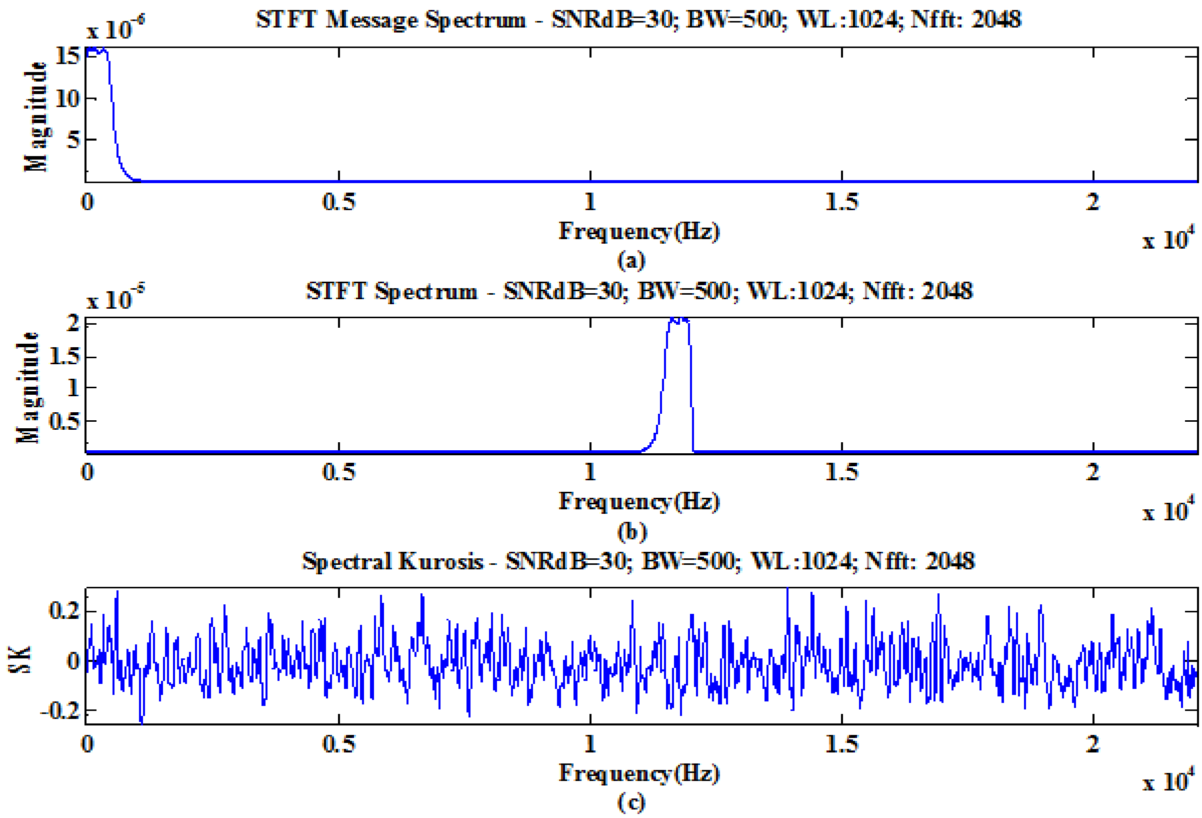

Fig. 8(a) : Averaged SFT spectrum of LSB+AWGN (b).Estimated Spectral Kurtosis for SNR=30dB

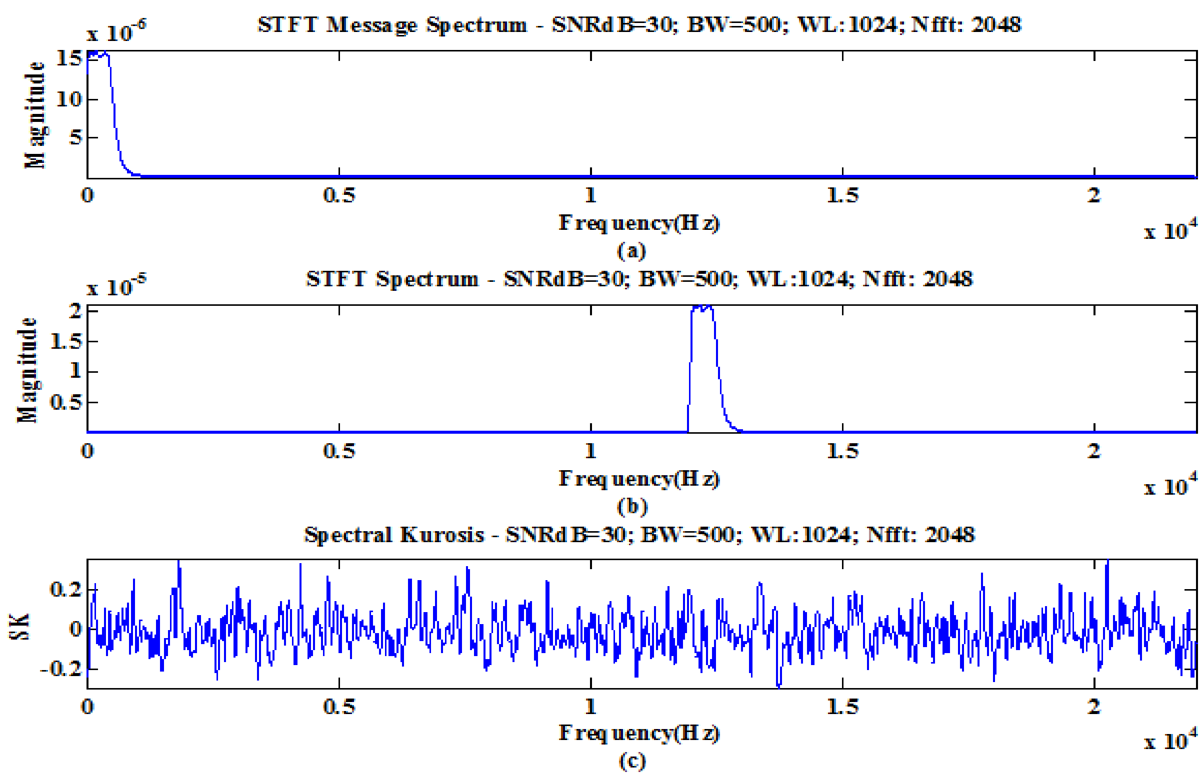

Fig. 9(a) : Averaged SFT spectrum of USB+AWGN (b).Estimated Spectral Kurtosis for SNR=30dB

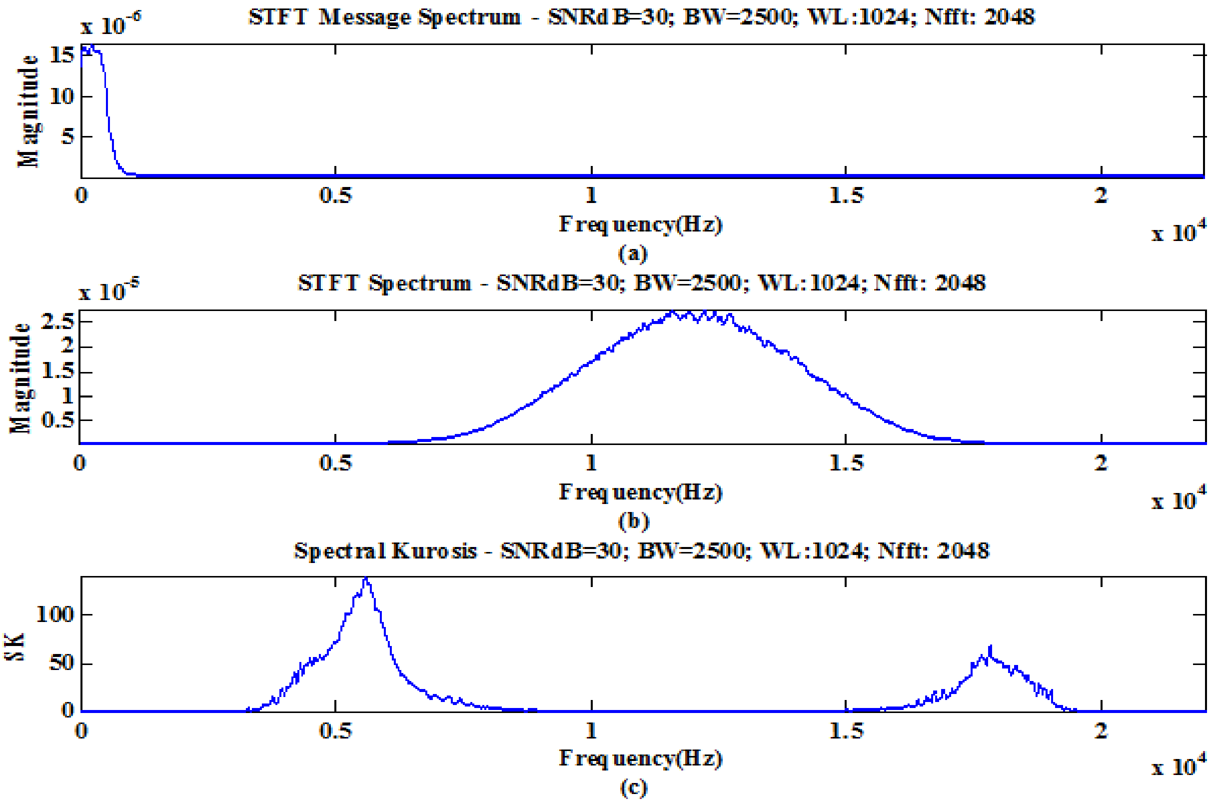

Fig. 10(a) : Averaged SFT spectrum of FM+AWGN (b).Estimated Spectral Kurtosis for SNR=30dB

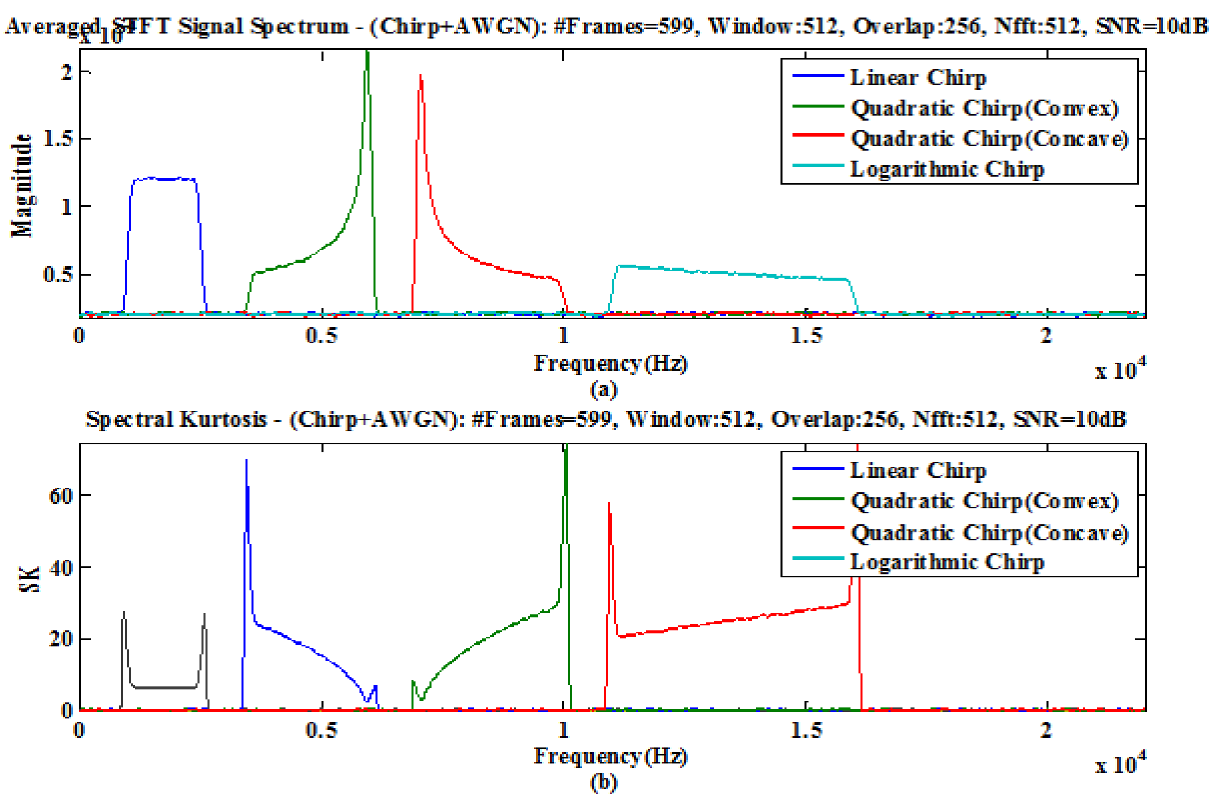

Fig. 11 : Mixture-6 (a). Averaged SFT spectrum of (b).Estimated Spectral Kurtosis for SNRs 10dB,

VI. Conclusions and Future Work

The cumulant based spectral kurtosis defined in frequency domain originally proposed for bearing fault detection and monitoring of electrical machines, is a promising tool for analyzing nonstationary signals. It complements the traditional power spectrum based on second order statistics. In this paper, the theory of spectral kurtosis is briefly reviewed from the fundamentals. The properties of spectral kurtosis of popular stationary signals, nonstationary signals and mixed processes are analytically given. Extensive Monte Carlo simulations were carried out to support the theory. The spectral kurtosis of the simulated stationary, nonstationay and mixed processes at different signal-to-noise ratios (SNRs) is estimated and the results are in good match with the previous analytical findings. The review highlights the usage of spectral kurtosis for other areas of signal processing like communications and radar signal processing. Future work could be (i). Obtaining closed-form expressions for spectral kurtosis of communication and radar signals (analog or digital modulated) (ii). classification of communication signals using spectral kurtosis at different SNRs.(iii). radar signal classification using spectral kurtosis.

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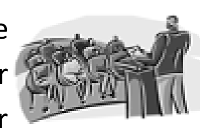

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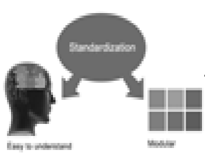

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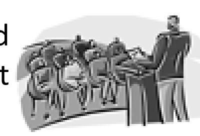

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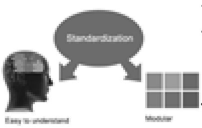

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Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be 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.

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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

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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.

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

INDEX

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