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Power Scenario of Bangladesh and Schemes of Sustainable Optimal Reduction in the Power System Loss

By Khizir Mahmud & A.K.M. Mahmudul Haque

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Abstract - The electricity supply with minimum possible losses is the challenge to the developing countries like Bangladesh. Limited energy sources, improper long term policies & some major system losses are responsible for hindering this challenge. Considering these problems of Bangladesh, some solutions have been proposed but still those fail to mitigate that problem fully. So this paper emphasizes based on the proposed solutions & the possible acceptance of the considerations which are applied in other countries.

Keywords : Bangladesh, FACTS devices, GDP, HVDC, Load Shedding, power, power generation, power system loss.

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Power Scenario of Bangladesh and Schemes of Sustainable Optimal Reduction in the Power System Loss

Khizir Mahmud^α & A.K.M. Mahmudul Haque^σ

Abstract - The electricity supply with minimum possible losses is the challenge to the developing countries like Bangladesh. Limited energy sources, improper long term policies & some major system losses are responsible for hindering this challenge. Considering these problems of Bangladesh, some solutions have been proposed but still those fail to mitigate that problem fully. So this paper emphasizes based on the proposed solutions & the possible acceptance of the considerations which are applied in other countries.

Keywords : Bangladesh, FACTS devices, GDP, HVDC, Load Shedding, power, power generation, power system loss.

I. INTRODUCTION

Providing access to affordable and reliable electricity to all citizens by 2021 is a befitting national goal of the Government of Bangladesh. Latterly the per capita generation is 236 KWH [11]. Only 48.5 percent of the country's population has access to electricity, which is very low compared to other developing countries in the world. [2] The performance of Bangladesh power sector in last two decades fell short of expectation of our citizen. Incongruous short term policies and some key technical problems like system losses are leading the desire to the access of electricity to whole country to a fiasco. To fulfill the goal firstly a brief overview of current situation of power scenario of Bangladesh is presented in this paper. In the latter part, the reasons behind the power crisis of Bangladesh have been mentioned. The major power loss occurs for system loss which is around 14.02% at present in Bangladesh. Finally some congruous ways have been discussed to provide the rising demand of power and to mitigate these huge system losses.

II. ELECTRICITY GENERATION AND GDP RELATIONSHIP IN BANGLADESH

A decreasing rate of electricity generation has resulted in the lower GDP growth. The current GDP growth of 6.66 percent might be the result of comparatively higher growth rate of electricity generation (6.19 percent) [2]. The average GDP between 2007 and 2011 was 6.22 percent whereas the average generation of electricity was 3748 MW [2]. Under the business as usual scenario, if an arbitrary calculation is made, it is observed that 603 MW generation of electricity might be required for the growth of one percent GDP. [2]

The economy of Bangladesh is mainly depending upon agriculture, industrial, commercial and other economic development. On the other hand, these developments directly and indirectly depend upon the fluent supply of electricity. A decreasing rate of electricity generation has resulted in the lower GDP growth. The average GDP between 2007 and 2011 was 6.22 percent whereas the average generation of electricity was 3748 MW [2]. Under the business as usual scenario, if an arbitrary calculation is made, it is observed that 603 MW generation of electricity might be required for the growth of one percent GDP. Therefore, it is difficult to achieve the target of seven percent GDP growth with the current generation of electricity within this fiscal year (2011-12).

III. CURRENT SCENARIO AND FUTURE DEMAND OF ELECTRICITY, GENERATION AND LOAD SHEDDING

The average maximum demand for electricity was 3970 MW in 2007 which has increased to 4833 MW in 2011 (May, 2011) with an average increasing rate of 216 MW per annum. Under the business as usual scenario, the average demand might stand at 5696 MW by 2015. On the other hand, the average generation was 3378 MW in 2007 which has increased to 4103 MW in 2011 (May, 2011) with an annual average increasing rate of 181 MW [2]. Continuation of this rate indicates that the average generation would be 4828 MW by 2015 which is far away from the vision of 11500 MW generations by 2015. Additionally, the average load

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shedding has been increased to 656 MW in 2011 (May, 2011) with an average increasing rate of 35 MW per year from 2007. If this increasing rate remains the same, the

average load shedding might be stood at 795 MW by 2015. The lower increasing rate of generation (5.37 percent) than that of the demand (5.43 percent)

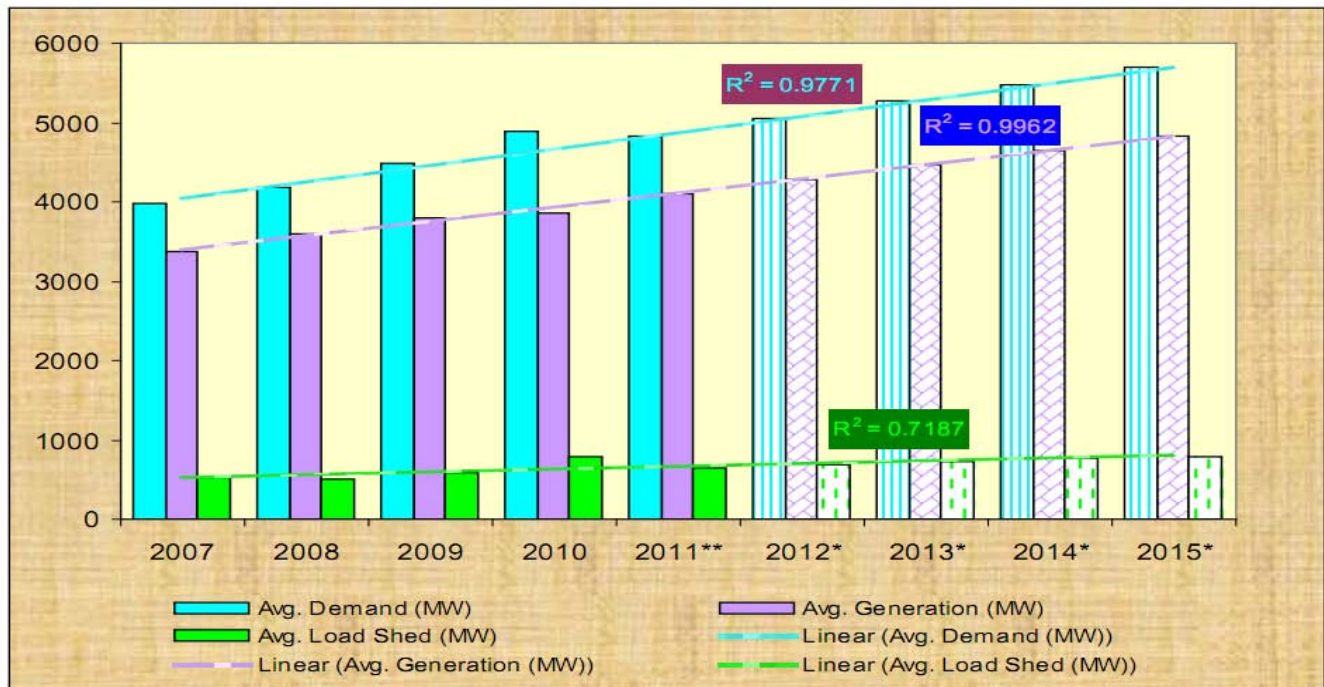


Fig.1 : Current situation and feasible future electricity demand, generation and load shedding.

has accelerated the rate of load shedding which has increased at a rate of 6.72 percent per annum during the same period. [2]

IV. POWER SYSTEM LOSS SCENARIO IN BANGLADESH

Alike the developing countries Bangladesh economy has grown by nearly 6% a year since 2005 and it faces rapidly growing energy needs to sustain its growth particularly in the industrial sector [5]. Inadequate power generation capacity and fuel shortages and power system losses have resulted in electricity sales in Bangladesh growing by only about 7% per annum since 1990. In response, the government has decided to develop 9400 MW of power capacity by the end of 2015 to meet its existing and future demand requirements. But High levels of losses, as a result of both technical factors and nontechnical factors of power, have been a continuing issue in Bangladesh. Between 1994 and 2003 power system losses have ranged between 28.4% and 37.2%. Excessive losses appeared as a continuing theme in documents going back to the 1970s, when losses ranged between 34.6% and 42.5% [5]. For the past 4 years, system losses have been on a downward trend and the provisional estimate of 28.4% for 2003 [5]. Some of these losses arise from technical factors such as losses in stepping down power and in transmission and distribution. However,

even after allowing for these factors, the system loss of 28.4% incorporates high levels of non-technical losses like electricity theft i.e. Frauds, Illegal connections, Meter tampering and some other administrative losses.

V. DIFFERENT Nontechnical Power Losses IN BANGLADESH

a) Single Fuel Dependence

About 85% of electricity in Bangladesh is produced from gas-based power plants [2]. Gas supply shortages have seriously impaired power generation, causing power cuts that have reduced economic output. Dependence on a single source of energy for power generation weakens energy security. *Coal hydropower, heavy fuel oil (HFO) and diesel are the other sources of energy for power generation. Inadequate investment in upstream gas field development in recent years has resulted in a shortage of gas for the industrial sector and for electricity generation. This has constrained power generation with electricity utilities resorting to load shedding while industrial consumers have been using captive generation facilities that require diesel.*

b) Improper Privatization Policy

In April 2010, 40 percent electricity was generated by private sector which has increased to 44 percent by April 2011 [2]. Rental, quick rental and peaking plants were under taken on a first-track basis to

address the immediate power crisis. But mostly, second hand equipments and less efficient machineries are used in such plants so the tariff rises. Furthermore, there is a lack of transparency in tendering persists in that process. Thus, the establishment and timely commencing production of the major segments of the power plant, contracted to be established on 'quick rental' basis in the country, are failing gradually. Thus, it is not only causing huge amount of financial loss to the national exchequer but also increasing the suffering of the citizen of the country. Here, the government has to face two types of challenges. One is the higher subsidy due to the costly quick rental power plants and the other is the lower production that is expected.

c) Lack of Timely Implementation of Allocated money

The government has given highest priority to the development in power sector which has been reflected in the allocation of annual development program (ADP). The total allocation in the power sector was Tk. 7145.28 for the fiscal year 2011-12. Over the last few years, there was a significant gap between the allocation and the implementation of ADP in the power sector [2]. Considering the last fiscal year, only 29 percent of the allocated ADP had been implemented during the first eight months of that fiscal year. When a huge amount of allocated money is required to be implemented within a short period of time, there creates corruptions. That's why; the lack of timely implementation has reduced the proper development in the sector of electricity, especially, in the generation of the electricity.

d) Political Reason

In Bangladesh, the governments come and go and the issue of electricity remains a struggling one. In order to win the mind of voters, the politicians are very much interested in covering a lot of areas without thinking the existing generation. This may bear information about the huge coverage of the electricity but in reality, it creates crisis. This type of politics makes the crisis more acute.

e) Over Population

There has been an increase electricity demand in the recent years as a result of industrial development and population growth. One of the common matters in the country is over population which creates a lot of problem in various development sectors. More population means more consumption of electricity. Population is increasing but the generation of electricity is not increasing as required. After all, there is an improvement in the life style of the citizen in the country. With the improvement of the people's life standard, the demand for electricity has also increased. As the generation has increased with a slower rate than that of the demand for electricity, the crisis of electricity is on the rise. [2]

VI. DIFFERENT TECHNICAL POWER LOSSES IN BANGLADESH

The main factors that contribute to high technical losses is inappropriate conductor size, lack of reactive power control, Corona loss, Induction and radiation losses, operating the system at high voltage, power transformer losses, low voltage pockets and different types of distribution losses like overloading of lines, Abnormal operating condition of distribution transformer, operation of primary and secondary distribution system at low power factors, loose connections, Unequal load distribution among three phase in LT systems causing high neutral currents, low voltages at the consumers terminals causing higher drawl of currents by inductive loads etc.

Table 1 : Year wise generation and system loss [3][12].

Financial Year	Actual Generation (MW)	Load Shedding (MW)	System Loss (%)
2001	3033	663	28.47
2002	3248	367	27.97
2003	3458	468	25.69
2004	3622	694	24.49
2005	3751	770	22.79
2006	3812	891	20.97
2009	3880	1000-1500	16.15
2012	6800	2000	14.02

a) Lengthy Distribution Lines in Practice

11 KV and 420 volts lines, in rural areas are extended over long distances to feed loads scattered over large areas. Thus the primary and secondary distribution lines in rural areas; by and large radials laid, usually extend over long distances. This results in high line resistance and therefore high I^2R losses in the line [1].

Table 2 : Different technical losses of different organizations of Bangladesh (Year 2011).

Organization	Transmission Loss (%)	Distribution Loss (%)	Total
PDB System	3.00	7.00	10.00
DESA System	2.00	7.50	9.50
System	0.50	8.50	9.00

b) Inadequate Size of Conductors

Rural loads are usually scattered and generally fed by radial feeders. But most of the cases feeder's conductor size is not adequate. Generally combination of copper, aluminum, and occasionally steel conductor is used in Bangladesh [6]. Although the rationale of using three-phase lines for increased transmission efficiency is valid, this applies more to high-voltage,

alternating-current transmission lines as well as to MV lines serving larger load centers. In these cases, the larger current-carrying capacity associated with three-phase lines are essential. But most of the times losses occur due to the lack of fulfillment of this criterion [6].

c) *Distribution Transformers not located at Load center*

Often distribution transformers (DTs) are not located centrally with respect to consumers.

Consequently, the far off consumers obtain an extremely low voltage even though a reasonably good voltage levels were maintained at the transformer secondary. This again leads to higher line losses in order to reduce the voltage drop in the line to the farthest consumers.

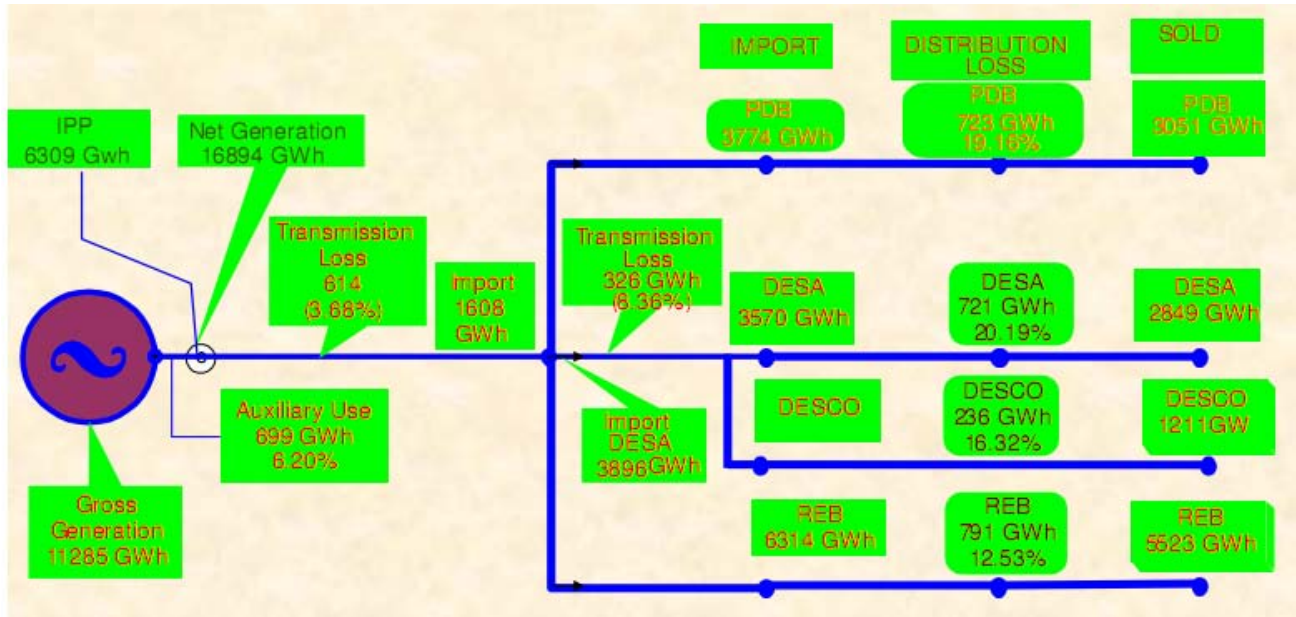


Fig. 2 : System Loss of the Utilities at Different Voltage Level (Financial Year 2005-06) [3]

d) *Overrated Distribution Transformers and hence their Under-Utilization*

Studies on 11 KV feeders have revealed that often the rating of DTs is much higher than the maximum KVA demand on the feeder. Over rated transformers draw unnecessary high iron losses. In addition to these iron losses in over rated transformers the capital costs is also high. For an existing distribution system the appropriate capacity of distribution transformer may be taken as very nearly equal to the maximum KVA demand at good power factor (say 0.85). [1]

e) *Low Voltage Appearing at Transformers and Consumers Terminals*

Supply voltage varies by more than 10% in many distribution systems. A reduced voltage in case of induction motor results in higher currents drawn for the same output. For a voltage drop of 10%, the full load current drawn by the induction motors increase by about 10% to 15% the starting torque decreases by nearly 19% and the line losses in the distributor increases by about 20%. Power losses can be divided into two categories, real power loss caused by resistance of lines and reactive power loss caused by reactive elements. The

total real and reactive power losses in a distribution system can be calculated using equation 1 and 2.

$$(1) P_{Loss} = \sum_{i=1}^{n_{br}} I_i^2 R_i$$

$$(2) Q_{Loss} = \sum_{i=1}^{n_{br}} I_i^2 X_i$$

Where n_{br} is total number of branches in the system, $|I_i|$ is the magnitude of current flow in branch i , R_i and X_i are the Resistance and reactance of branch i , respectively. Different types of loads connected to distribution feeders also affect the level of power losses. [1]

VII. PROBABLE SOLUTION OF POWER CRISIS OF BANGLADESH

There are three general solutions for solving the power crisis of Bangladesh. First one is control load demand by using compact fluorescent lamp (CFL), transformation of holiday, proper load management, encouraging Independent Power Producers (IPP) & reducing transmission losses. [8]. Second one is proper utilization of renewable energy. But using more renewable energy will put upward pressure on unit costs. Renewable energy doesn't have the same

operating characteristics, load factors, cost-volume drivers, or “dispatch ability” of conventional energy, especially base load plants. Renewable energy will stress transmission grids differently and significant investment will be needed to reconfigure bulk power networks. And the third one is allowing free market economy to come into play in the power sector & to fully privatize power generation, distribution & supply [7]. For the purpose of solving the energy crisis, whatever we think, we must see the thought & technology of other countries & emphasis on our national energy policy. Exploring other countries considerations for meeting energy demand efficiently the following solutions should be fruitful for energy crisis of Bangladesh.

1. Integration of renewable energy resources.
2. HVDC & FACTS for system interconnection & grid enhancement.
3. Smart grid initiatives.
4. Reforming the power sector by controlling electricity theft & improving revenue collection.
5. Boost efficiency in transmission.

a) *Energy Policy*

A successful energy policy must satisfy many goals such as:

1. Energy policy must be concerned not only with current supply, but with the country's long term needs.
2. Energy policy must be concerned with efficiency of production and distribution, as well as quantity.
3. Energy policy must enable improvements in energy access among all Bangladesh citizens.
4. Energy policy must reduce the pressure placed on the country's physical environment.

Realizing these goals requires several clear strategic decisions for the Government of Bangladesh. The six crucially important policies are:

1. Given what is known of natural gas and other mineral reserves, the Government of Bangladesh should not approve natural gas exports.
2. The Government of Bangladesh should place a very high priority on establishing the credibility of an energy regulatory commission.
3. The government should encourage the Rural Electrification Board (REB) to develop a network of small-scale (10 – 100 MW capacity) gas turbine plants whose power would, on a priority basis, be distributed independently of the national grid.
4. The government should encourage the sale of coal for domestic cooking in rural areas.
5. The government should continue to facilitate substitution of CNG for liquid petroleum fuels.
6. The government should undertake high profile social marketing activities intended to improve utilization of biomass fuels in rural areas.

But when we will see the other country's energy policy, then we can compare & modify our energy policies for meeting the energy demand. For example,

1. Japan's energy policy is based on market principles, but at the same time it seeks to ensure a stable supply and environmentally friendly production and consumption of energy [4].
2. The energy policy of India is largely defined by its burgeoning energy deficit & increased focus on developing alternative sources of energy [9].
3. Malaysia's energy policy depends on three objectives:
 - a. To ensure adequate, secure and cost-effective supply of energy.
 - b. To promote efficient utilization of energy & discourage wasteful and non-productive patterns of energy consumption.
 - c. To ensure factors pertaining to environmental protection are not neglected in production & utilization of energy [10].

VIII. CONCLUSION

Power crisis is one of the great barriers in the development of developing countries like Bangladesh. So government and other organizations related to this should pay the greater attention to minimize this power crisis. Bangladesh has already taken some sustainable initiatives to solve the prevailing problems. There are many possible ways in which the desire to access the electricity to whole country should be implemented. The lacking to solve the power crisis, can be minimized by considering the combination of existing solutions and considerations used by developing countries.

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Lightning Radiations Towards the H.V Electric Power Systems

By DIB Djalel & LABAR Hocine

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Abstract - The lightning is a natural phenomenon, unforeseeable and behaves as a perfect generator of the electrical current which can reach the two hundred Ampere kilos and then it is a problem classified like a serious wonder for the researchers.

The induced transient over-voltages in the electric systems following electromagnetic radiations of the lightning represent the most severe constraint and most significant on the electrical power networks.

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GJRE-F Classification : *FOR Code: 090607*



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Lightning Radiations Towards the H.V Electric Power Systems

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The induced transient over-voltages in the electric systems following electromagnetic radiations of the lightning represent the most severe constraint and most significant on the electrical power networks.

In this paper we present an lightning analysis in the capacity as a transient source of surge current following model MTLE chosen among others, then an original contribution which defines an analytical model of the electromagnetic field radiated by the lightning for a particular situation and which gave satisfactory results by simulation compared with experimental measurements that we carried out us even at the laboratory of high voltage in EPFL in Switzerland and also of the other authors like G Berger, M.Uman and Rakov in Florid.

A computation of the induced overvoltages in overhead electric lines on the basis of electromagnetic coupling model of Taylor interpreted the limit of our work in this paper

Keywords : Lightning, overhead lines, electromagnetic coupling, return stroke, models and induced overvoltages.

I. INTRODUCTION

The lightning can touch a power line by striking either a conductor or a tower or an earth wire, causing the important overvoltage's classified like the most dangerous constraints for the electric systems.

The direct and indirect impact of the lightning on the overhead line is illustrated by the bidirectional propagation of overvoltage wave of several hundred kV, it's the most harmful constraint in the coordination of insulations. The physical phenomenon of the lightning corresponds to an impulse power source, namely a very fast succession of discharges of an enormous electricity quantity. The form of real wave is very variable: it consists of a rise face until the maximum magnitude (1 μ s to 20 μ s) follow-up of a decrease tail of a few tens of microseconds. The spectral field associated extends in a band with KHz to MHz.

The principal objective in this work is to be interested in the coupling electromagnetic phenomenon between the field radiated by the lightning and the overhead line, while passing by the analysis of the various parts which enters in this state, the source of disturbances, the coupling devices and the victim.

In a first part, we are interest to the return stroke current as a source of disturbance and its space-temporal distribution along the lightning channel. A presentation of the existing models in the literature on this current $i(z', t)$.

Before analysing the coupling phenomenon, we tried to give an interesting detail on the evaluation of the electromagnetic field radiated by the lightning while basing on 03 assumptions:

1. The model of calculation of Uman [5] with three components of the field: Electric vertical, electric horizontal and magnetic azimuth.
2. Experimental measurements which we carried out at the laboratory of high voltage LRE-EPFL (Switzerland) on the electromagnetic fields radiated by the lightning pulses during the last trimester 2005.
3. Data experimental collected and offered by one of the leaders in this field professor Rachidi of LRE-EPFL in Switzerland

The model of Taylor is selected to analyze in term of this paper the transient electromagnetic coupling of the lightning with the overhead line. A new analytical formulation for the electromagnetic fields computation was developed in the temporal field and for not very particular conditions then integrated in a data-processing routine where the results were satisfactory.

II. MODELLING OF THE LIGHTNING RETURN STROKE

For a excellent protection of the electric systems against the disturbances generated by the lightning, it is necessary to know and characterize its impulse electromagnetic field. This is why in the last few years, several models of the return stroke, with various degrees of complexity, were developed [1,3,5,8] in order to allow the evaluation of electromagnetic radiation. One of the major difficulties related to the modelling of the lightning channel resides in the fact that the current cannot be measured that at the base of the channel; however, to

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determine the radiated electric and magnetic fields, it is necessary to know the current distribution along the channel, a significant property which makes the difference between the models proposed on the space and temporal distribution of the current along the lightning channel $i(z', t)$.

We present a summary of the existing models in table I and we adopt thereafter model MTLE (Modified transmission line) also named: model of the engineers modified, proposed by Nucci and Rachidi [4] and approved by results convincing by several authors in various works [4,5,6,9].

a) The Modified Transmission Line model, MTLE

Established by Nucci, Rachidi [4], the model MTLE corrects the defects of the TL model while keeping its simplicity by allowing an easy use in the coupling computation, based on this formulation of the space-temporal distribution along the channel of the current $i(z', t)$, defined by :

$$\begin{aligned} i(z', t) &= i(0, t - z'/v) \exp(-z'/\lambda) & z' \leq vt \\ i(z', t) &= 0 & z' > vt \end{aligned} \quad (1)$$

b) The Current at the Base of Lightning Channel

It is single the measurable parameter and represents a significant contribution in spatial-temporal modelling of the return stroke current along the lightning channel. Various analytical expressions can be used to simulate the pace of the lightning current.

Among those, the exponential functions, used by several authors and who have the advantage of having analytical Fourier transforms, which makes it possible to analysing directly in the frequential domain.

$$i(0, t) = I_{01} \cdot (e^{-\alpha t} - e^{-\beta t}) + I_{02} \cdot (e^{-\gamma t} - e^{-\delta t}) \quad (2)$$

$I_{01}, I_{02}, \alpha, \beta, \gamma$ and δ are the parameters which determine the exponential wave form [3].

More recently, Heidler [4,5] proposed a new analytical expression to simulate the current:

$$i(0, t) = \frac{I_0}{\eta} \frac{(t/\tau_1)^n}{1 + (t/\tau_1)^n} \exp(-t/\tau_2)^n \quad (3)$$

When :

$$\eta = \exp \left[- \left(\frac{\tau_1}{\tau_2} \right) \left(n \frac{\tau_2}{\tau_1} \right)^{\frac{1}{n}} \right]$$

I_0 the magnitude of the current in the channel base

τ_1 is the time-constant of the face

τ_2 is the constant of decrease

η is the factor of correction factor of magnitude and n is an exhibitor ranging between 2 and 10.

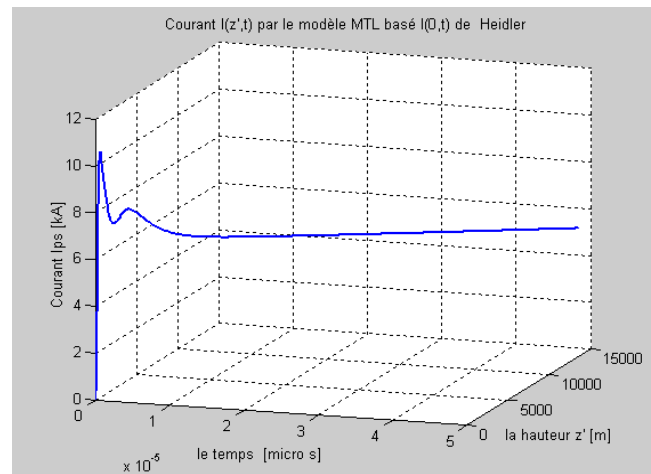


Fig. 1 : Current in lightning channel of the Model MTLE with $i(0, t)$ of Heidler

III. ELECTROMAGNETIC LIGHTNING RADIATION

The study of the disturbances generated by the lightning implies us directly in the electromagnetic compatibility domain (EMC) of which the final objective, is to make compatible the functioning of the electric and electronic system sensitive in a disturbed electromagnetic environment, while respecting some the 03 following criteria:

- No interferences with other systems.
- No susceptibility to the other systems emissions.
- No interferences of the system with itself.

To reduce the disturbances caused by the lightning electromagnetic radiation, must about it act on:

- The source, by decreasing its disturbing capacity, which is not always realizable (like the action on the climate to avoid the lightning).
- The victim, by increasing its immunity or by decreasing its susceptibility.
- Mode of the coupling, by reducing its effectiveness.

The principal device of the coupling in our case, is the electromagnetic field produced and radiated by the lightning, the evaluation of various dimensions of this last, is the most significant stage for such a subject.

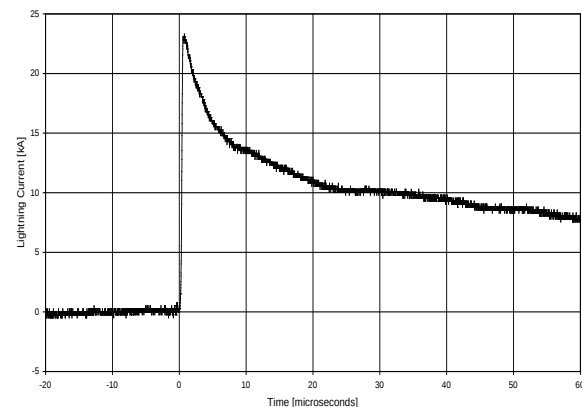


Fig. 2 : Current at the lightning channel base, experimental measurement

a) Computation of the Electromagnetic Field

The electromagnetic field radiated by a lightning discharge ground-cloud, is in general calculated on the basis of model geometry adopted by Uman[1] presented in Fig. 3. The lightning channel is regarded as a one-dimensional vertical antenna with height H , placed above a perfectly conducting plan. The return stroke current is propagated vertically starting from the ground with a speed v , its space-temporal distribution $i(z', t)$ determines the electromagnetic field in any point of space. By application of the Maxwell's equations to the geometry adopted for the general case with a perfectly conducting ground, makes it possible to obtain the electromagnetic field equations of Uman [1].

If we considered the finished ground conductivity, these equations use the Sommerfeld integrals whose analytical or numerical evaluation, will be a very delicate mission.

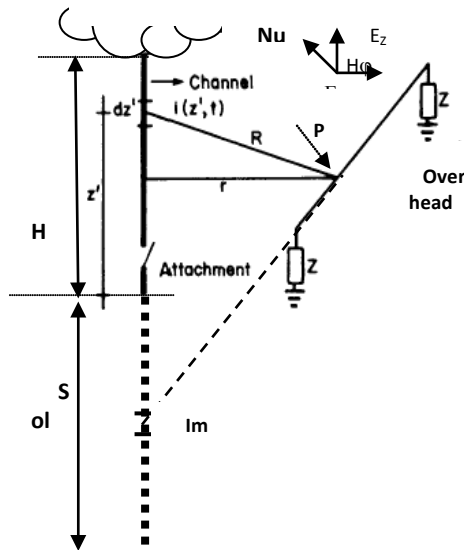


Fig. 3: Illustration model and the geometry adopted of the problem

By supposing a perfectly conducting ground, simpler expressions of the components vertical and horizontal of the electric field and the azimuth component of the magnetic field, can be developed according to the images theory by the expressions below (4,5,6), whose three terms intervening in the equations (4) and (5) representing respectively the fields electrostatics, induction and radiation, while the first term of the equation (6) represents the induction field and the second, the radiation field. The expressions of the lightning electromagnetic field are introduced in numerical routines [11] and give results very close to those to experimental measurements presented in [4].

$$E_r(r, z, t) = \frac{1}{4\pi\epsilon_0} \left[\int_{-H}^H \frac{3r(z-z')}{R^5} i(z', \tau - R/c) d\tau dz' + \right.$$

$$\left. \int_{-H}^H \frac{r^2}{c^2 R^3} \frac{\partial i(z', t - R/c)}{\partial t} dz' \right]$$

$$E_z(r, z, t) = \frac{1}{4\pi\epsilon_0} \left[\int_{-H}^H \frac{2(z-z')^2 - r^2}{R^5} i(z', \tau - R/c) d\tau dz' + \right.$$

$$\left. \int_{-H}^H \frac{2(z-z')^2 - r^2}{cR^4} i(z', t - R/c) dz' - \int_{-H}^H \frac{r(z-z')}{c^2 R^3} \frac{\partial i(z', t - R/c)}{\partial t} dz' \right] \quad (5)$$

$$B_\phi(r, z, t) = \frac{\mu_0}{4\pi} \left[\int_{-H}^H \frac{r}{R^3} i(z', t - R/c) dz' + \right.$$

$$\left. \int_{-H}^H \frac{r}{cR^2} \frac{\partial i(z', t - R/c)}{\partial t} dz' \right] \quad (6)$$

$$R = \sqrt{(z-z')^2 + r^2} \quad (7)$$

$$H = v(t - \frac{R}{c})$$

E_r, E_z : are the Horizontal and vertical electric field ; H_ϕ is Azimuth magnetic field.

b) The Influence of Finished Ground Conductivity

Only, the horizontal component of the electric field, which is much more affected than the others by the finished ground conductivity, Cooray and Rubinstein [6] proposed an approach (8) according to which the horizontal field with a height z above the soil can break up into two terms (4,5,6).

One horizontal field calculated for infinite ground conductivity and the second, represents the effect of the finished ground conductivity, the total horizontal field is given into frequential domain by:

$$\underline{E}_r(r, z, j\omega) = \underline{E}_{rp}(r, z, j\omega) - \underline{H}_{\phi p}(r, 0, j\omega) \frac{c\mu_0}{\sqrt{\epsilon_{rg} + \sigma_g / j\omega\epsilon_0}} \quad (8)$$

when $\underline{H}_{\phi p}(r, 0, j\omega)$ and $\underline{E}_{rp}(r, z, j\omega)$ are respectively, the Fourier transforms of the azimuth magnetic field on the ground level and horizontal electric field at altitude Z , these two grants are calculated by supposing a perfectly ground conductivity.

IV. NEW MODEL OF ELECTROMAGNETIC FIELD

The variety of the electromagnetic field equations used and presented in several work is very limited, which reduces possibilities of the profound and beneficial analysis. This limitation must with the complexity of the phenomenon and its dependence with other external parameters which are difficult to identify and to quantify.

From there, we propose an analytical development, based on the equations of Master and Uman (4,5,6) to succeed has a formulation which depends only on time for a possible original proposition. The extreme difficulties encountered in the computing

process are due primarily, to the not stability of the distance R of the observation place to the propagation the current impulse along the lightning channel and the complicity of variation between the propagation time, the speed, the ground conductivity and the geometrical parameters of the selected model.

With a fixed distance R of observation, we could have a result encouraging by new analytical expressions (9,10,11) of the electromagnetic fields in Fig. (6). The principle of our development consists in integrating the terms which depend on time τ between 0 and t , then we integrated the resulting expression which depends only on z' between $-H$ and H .

For this particular case, our objective is achieved by the simpler form of the electromagnetic field which depends only on the time of propagation.

The result was satisfying comparatively those already found by other authors with digital techniques and experimental measurements.

a) Material and Methods

To carry out our measurements of electromagnetic fields at the laboratories of high voltage at LRE/EPFL in Switzerland, we used the following equipment:

- A generator Marx 1100kV.
- A transformer of power HV of the type HEYFELY.
- Sensors of fields electric and magnetic.
- A fast Numerical Oscilloscope.
- Probes and transformers of current for adaptation.
- A copper bar 07 m length
- Support vertical reliable of 0 with 8m
- Resisting and Inductees loads.
- Lightning Arrester H.V.

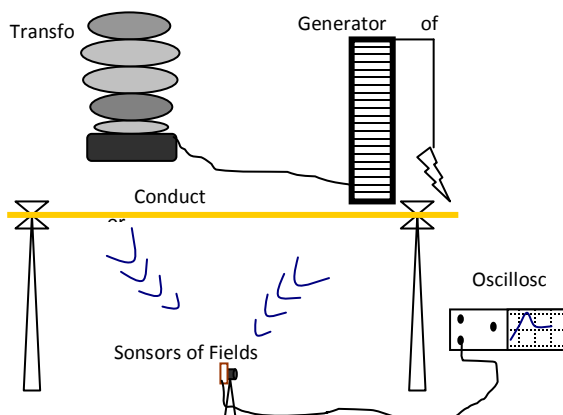


Fig. 4 : Equipment of experience measurements

The general principle of the method is to inject into the conductor starting from the generator of Marx of the impulse waves of the lightning with various magnitudes (from 40 to 800 kV) and polarities and in measurements thereafter the electric and magnetic fields according to the distance from the conductor on the ground and the sensor to the conductor.

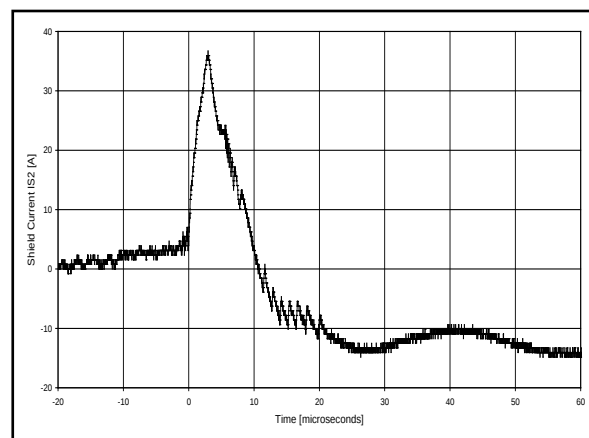


Fig. 5 : a) Lightning current impulse in overhead line closed with a ground resistance, measurements 2006 EPLF, by D.Dib

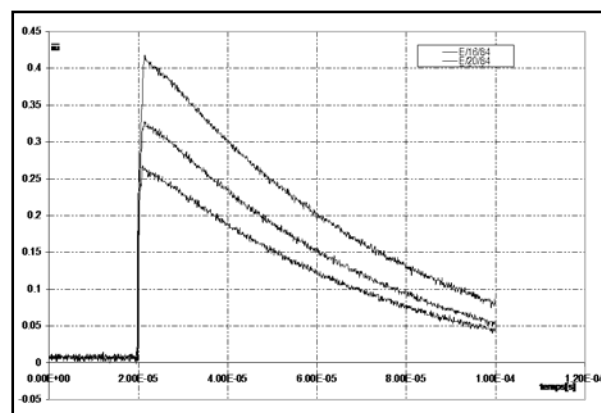


Fig. 5 : b) Magnetic field radiated by the lightning current impulse at different distances, measurements 2006 EPLF by D.Dib

The process of development is spread out over the following stages

- Application of the selected model of current MTLE.
- Application of the model two-exponential in the representation of the current at the channel base
- Calculation of the electric charge quantity deposited on the soil by the lightning.
- Calculation of the variation of derived for the return stroke current by micro second.

The use of the expressions (4), (5) and (6) in the development, leads us to very complex forms of integration, which makes the spot very delicate. The idea to fix the distance R from observation and to block its variation is just to check the validity of our development per comparison with the already existing numerical results and with measurements experimental realized by authors announced in the references.

In result, we give hope encouraging for a future analytical development which generalizes a real cartography of the electromagnetic fields radiated by the lightning channel. Our development, we are broken at the model which dependent only to time (9, 10, 11).

$$E_r(t, z, r) = \frac{1}{4\pi\epsilon_0} I_0 \left\{ \frac{3r}{R^5} (M_1 \cdot S_1 - M_2 \cdot S_2) + \frac{3r}{cR^4} (M_0 \cdot S_1 - M_{01} \cdot S_2) + \frac{r}{c^2 R^3} (-\alpha \cdot M_0 \cdot S_1 + \beta \cdot M_{01} \cdot S_2) \right\} \quad (9)$$

$$E_z(t, z, r) = \frac{1}{4\pi\epsilon_0} I_0 \left\{ \frac{1}{R^5} (M_1 \cdot S_{11} - M_2 \cdot S_{22}) + \frac{1}{cR^4} (M_0 \cdot S_{11} - M_{01} \cdot S_{22}) + \frac{r^2}{c^2 R^3} (\alpha \cdot M_0 \cdot T_1 + \beta \cdot M_{01} \cdot T_{11}) \right\} \quad (10)$$

$$H_\phi(t, z, r) = \frac{1}{4\pi\epsilon_0} I_0 \left\{ \frac{1}{R^3} (M_0 \cdot T_1 - M_{01} \cdot T_{11}) + \frac{1}{cR^2} (-\alpha \cdot M_0 \cdot T_1 + \beta \cdot M_{01} \cdot T_{11}) \right\} \quad (11)$$

Mij, Sij, Tij: are the terms of partial fields according to time, the distances r, z and the parameters which define the wave shape of the lightning current for

an explicit and simple presentation. The following figures are the result of these new expressions of fields

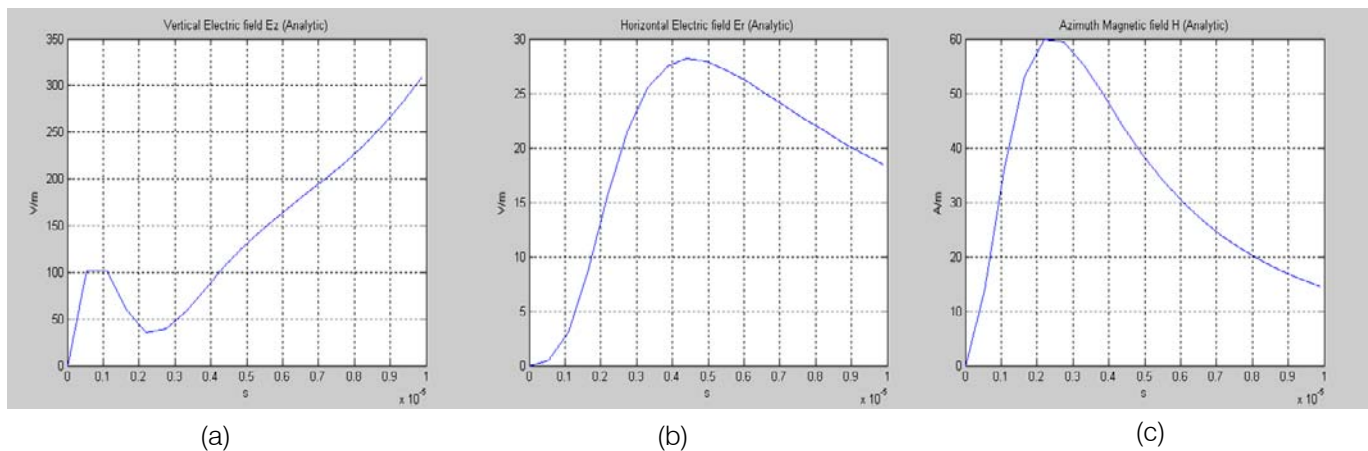


Fig. 6 : Electromagnetic fields calculated by the new formulation: a) vertical, b) horizontal, c) magnetic azimuth

V. OVER VOLTAGES INDUCED IN THE ELECTRIC LINES

The over voltages induced in the overhead lines following the lightning electromagnetic radiation were

studied and calculated by several authors [4,5,6,9] where the most recent model is that of Nucci and Rachidi [6]. Of our share, we limited to expose a model often used for such an evaluation; it is the model of Taylor.

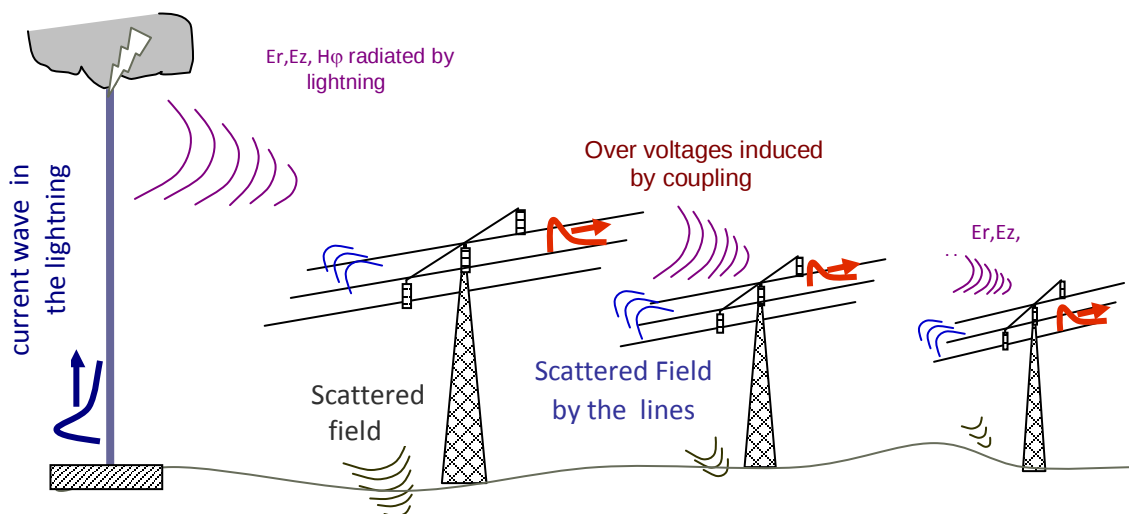


Fig. 7 : Electromagnetic coupling Phenomenon and illustration of induced overvoltages in electric power line

a) Equations of the Electromagnetic Coupling

From the first Maxwell's equation expressed for the total fields and by applying the theorem of Stokes, Taylor [3] proposes its equations (15) of the coupling according to the existing electric and magnetic fields in Fig. 7.

The electromagnetic fields existing E^e and B^e represent the sum of the incidental fields E^{Inc} and B^{Inc} and of the reflected fields by the ground.

$$\vec{E}^e = \vec{E}^{inc} + \vec{E}^{ref}$$

$$\vec{B}^e = \vec{B}^{inc} + \vec{B}^{ref}$$

The electric and magnetic total fields E and B are obtained by adding to the existing fields E^e and B^e , the reaction of the line by the diffused field ('scattered field') E^s and B^s :

$$\vec{E} = \vec{E}^e + \vec{E}^s$$

$$\vec{B} = \vec{B}^e + \vec{B}^s$$

By also neglecting the transverse conductance G' , the Taylor coupling model is defined by the following system

$$\frac{dU(x)}{dx} + j\omega L' I(x) = -j\omega \int_0^h B_y^e(x, z) dz \quad (12)$$

$$\frac{dI(x)}{dx} + j\omega C' U(x) = -j\omega C' \int_0^h E_z^e(x, z) dz$$

b) Boundary conditions

$$U(0) = -Z_A I(0) \text{ et } U(L) = Z_B I(L)$$

c) Equivalent circuit of coupling model

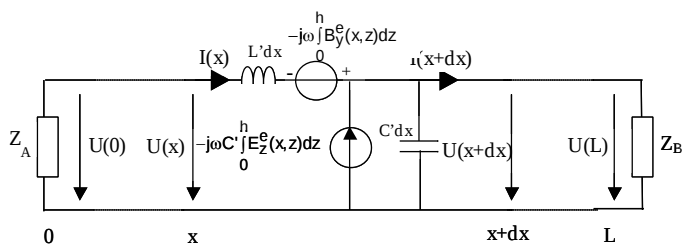


Fig. 8 : Equivalent circuit of coupling model of Taylor [5]

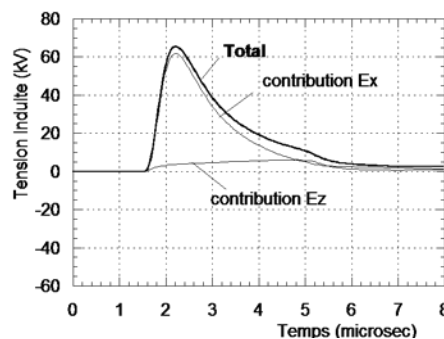


Fig. 9 : Induced over voltages calculated by Taylor model [5]

VI. CONCLUSION

The consequences of this work were very beneficial for a better coordination of electric insulations owing to the fact that we studied and analyzed the impact of the most severe constraint on the electric systems.

A theoretical description of the existing models on the spatial and temporal distribution of the current of the lightning return stroke along the channel and the adoption of MTLE model was the principal support for the work in this paper, because it represents the radiation source and in the coupling process.

With the current model MTLE and the electromagnetic field equations of M. Uman, we tried to reformulate a new analytical expression, but the instability, the speed and the variation between several parameters defining the phenomenon implied us in a very complicated calculation.

After using a method of approximation in particular for the observation distance R , we could create for this particular case where R is fixed, a new analytical model of the three components of the electromagnetic field.

A comparison between results and those which exist in the literature of other authors in theoretical and experimental forms us led to a result adjacent and encouraging.

In prospects, we consider future work to generalize the case and to take all the electric, physical and geometrical parameters in consideration thus to have a better identification of the behavior of the electromagnetic field radiated by the lightning and a more precise computation of induced overvoltages.

VII. APPENDIX

Table of symbols and abbreviations

BG	Bruce-Golde model
MTLE	Modified transmission line model with exponential current decay with height
MTLL	Modified transmission line model with linear current decay with height
TCS	Traveling current source model

MTL	Transmission line model
TL	Transmission line
$E_r(r,\varphi,z',t)$ volt/meter V/m	Lighting produced horizontal electric field in time domain
$E_z(r,\varphi,z',t)$ volt/meter V/m	Lighting produced vertical electric field in time domain
$H_\varphi(r,\varphi,z',t)$ ampere/mA/m	Lighting produced azimuthal magnetic field in time domain
$i(z',t)$ ampere A	Current distribution in the lightning channel carried by the dz' at time t
$i(0,t)$ ampereA	Lightning return-stroke current pulse
H km	Height of the lightning channel
loi kA	Amplitude parameter of the lightning channel base current
v m/s	Lightning return-stroke velocity
r meter m	Horizontal distance between the channel and the observation point
R meter m	Distance from the dipole to the observation point
n	Exponent having values between 2 to 10
λ meter m	Decay constant of the wave current with propagation
ϵ_0 f F/m	Permittivity of free space
φ degree °	Angle
η	Amplitude correction factor
μ_0 H/m	Permittivity of the vacuum;
σ_0 siemen S	permeability of the vacuum
τ_1 μ s	Front time constant
τ_2 μ s	Decay time constant
$\alpha, \beta, \gamma, \theta$ neper/meter	Attenuation constants determined the current wave forme
Cc m/s	Wave velocity (speed of light)

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Feasible Micro Hydro Potentiality Exploration in Hill Tracts of Bangladesh

By Khizir Mahmud, Md. Abu Taher Tanbir & Md. Ashraful Islam

Chittagong University of Engineering & Technology (CUET), Bangladesh

Abstract - The energy demand is expected to grow rapidly in most developing countries over the next decades. For Bangladesh, economic growth has been accelerating and it is expected that the population will grow from an estimated 162.20 million people in 2011 to 200 million by 2050, with almost half of the population living in urban areas. For meeting the expected energy demand as the population will rise and to sustain economic growth, alternative form of energy – renewable energy needs to be expanded. This paper tries to explore the possibility of finding the renewable energy mainly from micro hydro in different places of Chittagong hill tract region by thoroughly describing present condition of energy along with data collection, calculation and feasibility of power generation from July 2011 to Jan 2012.

Keywords : *Bangladesh hill tract region, micro hydro, renewable energy.*

GJRE-F Classification : *FOR Code: 090608*



Strictly as per the compliance and regulations of:



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Keywords : Bangladesh hill tract region, micro hydro, renewable energy.

I. INTRODUCTION

The development of a country is mostly dependent on per capita energy use. Bangladesh is one of the poor countries in the South Asian region. A large number of its population is out of electricity. Only 48.5 percent of the total population has access to electricity [5]. Most of the power generation of Bangladesh is based on fossil fuel sometimes which is playing a negative impact on finance in the long run operation. So to supply the electricity to the rest people is a great challenge. In future fossil fuel will not be able to supply the electricity to the user as it will be finished & not environment friendly also. So to search and depend on environment friendly renewable energy is now a great desire of the country. Bangladesh has a great probability of renewable energy. It has much different form of renewable energy resources. Among them micro hydro may play a major role specially to serve electricity in the remote area of Chittagong hill tract for ensuring economic growth of the country. Though a great potentiality of micro hydro to serve power in remote areas but real feasibility of implementation of this type of power generations are still behind limelight. Development of micro-hydro power plant can reduce

electricity scarcity problems so economically in remote areas of Chittagong Hill Tract without any major hassle.

II. PRESENT POWER SCENARIO OF BANGLADESH

In the South Asian region Bangladesh is one the most densely populated country (1099 people/km² in 2010) [7]. With high population Bangladesh is experiencing extreme energy challenges especially for the shortage of electricity. Shortage of electricity may be considered in two forms firstly, reviewing the scenario of per capita electricity consumption and percentage of population having access to electricity in Bangladesh compared to other countries and secondly, determining gap between demand and supply of electricity in perspective of country's economic situation and GDP growth. By the dichotomy of power generation and demand Bangladesh faces a severe load shedding. Bangladesh relies greatly on fossil fuels for its energy, but the present reserve would be depleted by the year of 2015[7].

Table 1 : Rate of use of different types of energy in producing electricity.

Fuel	Percentage of use (2010)
Furnace oil	2.81
Diesel	1.75
Hydro	3.39
Coal	3.77
Gas	88.29

a) Production of Power in Bangladesh

Bangladesh Power Development Board (BPDB), Ashuganj Power Station Company Limited (APSCL), Electricity Generation Company of Bangladesh (EGCB) is producing electricity in the public sector. On the other hand, through IPP (Independent Power Producer) and through Rental electricity is produced in the private sector which is purchased by the Government at a fixed rate [8]. At present nearly 54.40 percent of total electricity production is produced from public entities. BPDB alone produces 43.51 percent of total electricity production [5].

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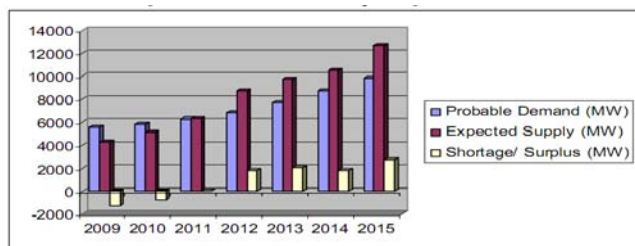
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Table 2 : Statistics of electricity production in Bangladesh (March, 2012).

Sector	Organization	Power Generation (MW)	Total
Government	BPDB	3483	4355
	APSCCL	662	
	EGCB	210	
Private	IPPs	1272	3650
	SIPP	225	
	Rental (15 years)	168	
	Rental (3/5 years)	1885	

b) Future power production Plan of Bangladesh

Bangladesh government has taken a long term plan to develop the power sector and mitigate the present power scarcity. According to the plan Electricity Generation in the country by 2013 will be 8500 MW and within 2015 this generation will rise to 11,500 MW and surplus power will be possible to give to national grid. Within the year of 2021 there is a plan to generate 20,000 MW power and to provide power to the whole area of the country [4].

**Fig. 2 :** Probable power shortage/ surplus of Bangladesh (2009-2015).**Table 3 :** Year wise expected power generation statistics of Bangladesh Power Division.

Year	Government Sector	Private Sector	Total
2010	360	432	792
2011	920	---	920
2012	505	1764	2269
2013	725	950	1675
2014	1170	---	1170
2015	---	2600	2600
Expected Extra Generation			9426

In last few years to meet up the scarcity of power so quickly government has taken some short term steps and thus establish quick rental power plant. So far, as many as 18 quick rental power plants have been approved and 14 of them are operational now. To fuel these power plants, the additional cost for the current

fiscal year, as projected by the World Bank is between Tk. 52 billion and Tk. 56 billion, which is about 0.6 per cent or 0.7 per cent of the Gross Domestic Product (GDP)[1]. Excess payment for quick rental power plants has already affected various government economic decisions and posing a serious threat to the economy. For this reason the topic to quest and establish renewable energy based power plant come to forward. So this paper has a little effort to meet the demand of searching that renewable energy sources and supply power to some remote areas.

III. RENEWABLE ENERGY SCENARIO OF BANGLADESH**a) Solar Energy**

Bangladesh is located between 20.30 to 26.38° North latitude and 88.04 to 92.44° East which is an ideal location for solar energy utilization. Here, the daily average solar radiation varies between 4 to 6.5 kWh per square meter. Infrastructure Development Company Limited (IDCOL) has supported NGOs in installation of Solar Home Systems (SHSs) and a total of 801,358 SHSs having capacity of about 36.5 MW have been installed till January 2011[6]. About 10 kW central AC solar PV systems have been installed in one selected market in each of the three Rangamati district's sub-districts [3].

b) Wind Energy

In Bangladesh, especially at coastal areas there are some Islands where wind energy can play a very important role to progress the economy of the country. BPDB installed a 160 feet tower at the Muhuri Dam site in the Feni district in May 2003. BPDB implemented a 1000 kW capacity wind battery hybrid power project (WBHPP) at the Kutubdia Island (Bay of Bengal) in the Cox's Bazar district. Under this project, total 50 nos. of 20kW capacity stand alone type wind turbines are being installed. The total capacity of all the wind turbines is 1 MW [9]. In another project, BPDB has implemented a 0.90 MW capacity of the Grid Connected Wind Energy (GCWE) at the Muhuri Dam areas in the Feni district in 2004 [3].

c) Biomass and Biogas

Biomass covers all kinds of organic matter from fuel wood to marine vegetation. Biogas is a mixture of CH₄ (40 to 70 %), CO₂ (30 to 60 %) and other gases (1 to 5%) produced from animal dung, poultry droppings and other biomass wastes in specialized bio-digesters [2]. In Bangladesh biomass accounts 70% of the total final energy consumption. IDCOL financed a 250 kW Biomass based power plant at Kapasia upazila under Gazipur district [9]. From 1971 to October 2009 About 41000 biogas plants has been constructed by different NGOs, under National Domestic Biogas And Manure Program (NDBMP) of IDCOL. Under NDBMP of IDCOL, 5688 biogas plants have been constructed in Bangladesh in the year of 2010 [9].

d) Hydro Energy

Kinetic energy from flowing or falling water is exploited in hydropower plants to generate electricity. In Bangladesh about 1.4 trillion cubic meters (m³) of water flows through the country in an average water year. Major rivers of the country have a high rate of water flow of about 5 to 6 months during monsoon season which is substantially reduced in winter season. At present only 230 MW of hydro power is utilized in Karnaphuli, Rangamati hydro station, which the only hydro-electric power plant operated by BPDB [9]. Microhydro and minihydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed. Hydropower plants are classified into two categories:

1. Large hydropower plants (>10 MW), usually with reservoirs, that cannot only produce electrical energy Continuously, but also are able to adjust their output according to electricity demand.
2. Small hydropower plants (<10 MW) that are less flexible with respect to load or demand fluctuation due to their dependence on the water resource.

IV. MICRO HYDRO POTENTIALITIES IN BANGLADESH

The scope of hydropower generation is very limited in Bangladesh because of its plain terrains except in some hilly region in the North East and South East parts of the country. However there are lots of canals, tributaries of main river Karnafuli, Shangu, Matamuhuri as well as tiny waterfalls having good potentials for setting up mini/micro hydropower unit in Chittagong Hill Tracts (CHT) region. To explore potential sites of micro hydro; several studies have been conducted by Bangladesh Water Development Board (BWDB) and BPDB in 1981.

Table 4: Potential Micro Hydro sites in Bangladesh.

District	Name of River/Stream	Potential Energy(KW)
Chittagong	Foy's Lake	4
Chittagong	Choto Kumira	15
Chittagong	Hinguli Chara	12
Chittagong	Sealock	81
Chittagong	Lungichara	10
Chittagong	Budia Chara	10
Sylhet	Nikhari Chara	26
Sylhet	RangaPani Gung	616
Jamalpur	Bi hugai-Kongsa	69
Jamalpur	Marisi	35
Dinajpur	Dahuk	24
Dinajpur	Chawai	32

Dinajpur	Talan at U/S	24
Dinajpur	Pathraj at Fulbari	32
Dinajpur	Tangon at D/S	48
Dinajpur	Punarbhaba	11
Rangpur	Buri Khora	32
Rangpur	Fulkumar	48

V. MICRO HYDRO POWER CALCULATION

The amount of power available from a micro hydropower system is directly related to the flow rate, head and the force of gravity which can be derived by the following equation:

$$P_{th} = Q \times H \times g$$

P_{th} = Theoretical power output in kW, Q = Usable flow rate in m³/s, H = Gross head in m and g = Gravitational constant (9.8 m/s²)

VI. MICRO HYDRO POTENTIALS SURVEY IN HILL TRACT REGION OF BANGLADESH

Greater Chittagong Region has a great geographical diversity and thus has a potentiality to get the micro hydro power. In last few decades several attempts have been made to find out the potential of micro hydro power generation. To explore the possibility of hydropower from small hilly rivers/streams in the country, a working committee was constituted on February 1981 with officers from Bangladesh Water Development Board (BPDB). A study was also conducted by a group of Chinese experts and by LGED in 2002-2003 [9]. This research has a goal to find some places according to mathematical scrutiny where the establishment of micro hydro is possible. Some places like Choto Kumira in Chittagong, Mahamaya Chora in Mirsora, Chittagong, Ruangchori Canal in Bandorban, Sailopropat Spring in Bandorban have a great potentiality to establish hydro power plant. The feasibility of the establishment of micro hydro power generation has been corroborated by the following calculation.

a) *Choto Kumira Canal, Chittagong, Bangladesh*
Head, $H = 3 \text{ ft} = .9144 \text{ m}$

Table 5: Width survey of Choto Kumira Canal, Chittagong, Bangladesh.

No of Obserbation	Width (ft)
1	7
2	11.3
3	12.5
4	11
5	10.8

Average Width, $W = 10.52 \text{ ft} = 3.21 \text{ m}$

Table 6 : Depth survey of Choto Kumira Canal, Chittagong, Bangladesh

No of Obserbation	Width (ft)
1	2.2
2	2.7
3	2.4
4	2.6
5	2.8

Average Depth, $D = 2.54 \text{ ft} = .774 \text{ m}$ and $\text{Area} = W \times D = 3.21 \times .77 = 2.48 \text{ m}^2$

For measurement of flow, passing the length of 13 ft or 3.96m following data were recorded.

Table 7 : Flow survey of Choto Kumira Canal, Chittagong, Bangladesh.

No of Obserbation	Time (Sec)
1	4.35
2	4.30
3	4.58
4	4.86
5	4.82

Average time, $t = 4.58 \text{ sec}$,

Velocity, $V = 3.96/4.58 = .86 \text{ ms}^{-1}$,

Flow Rate, $Q = V \times A = .86 \times 2.48 = 2.14 \text{ m}^3/\text{sec}$, Power, $P = 9.81 \times Q \times H = 9.81 \times 2.14 \times .9144 = 19.19 \text{ kw}$.

b) Mahamaya Chora, Mirosoyai, Chittagong, Bangladesh

Head, $H = .9144 \text{ m}$, Width, $W = 2 \text{ ft} = .6096 \text{ m}$,
Depth, $D = 3 \text{ ft} = .9144 \text{ m}$

Area $= W \times D = .6096 \times .9144 = .55741$

For measuring the velocity we took the following data of time(t) to pass a distance of 16 ft.

Here, $L = 16 \text{ ft} = 4.88 \text{ m}$

Table 8 : Velocity survey of Mahamaya Chora, Chittagong, Bangladesh.

No of Obserbation	Time (Sec)
1	4.72
2	5.03
3	4.8
4	4.95
5	4.86
6	5.07
7	5.05

Average time, $t = 4.92 \text{ sec}$,

Velocity, $V = L/t = 4.88/4.92 = .99 \text{ ms}^{-1}$,

Flow Rate, $Q = V \times A = .99 \times .55741 = .5518359$

Power, $P = 9.81 \times Q \times H = 9.81 \times .5518359 \times .9144 = 4.95 \text{ kw}$

c) Ruangchori Canal, Ruangchori, Bandorban, Bangladesh

Table 9 : Width survey of Ruangchori Canal, Bandorban, Bangladesh.

No of Obserbation	Width (ft)
1	69.5
2	65.3
3	89.1
4	77.7
5	82.5

Average width, $w = 76.82 \text{ ft} = 23.415 \text{ m}$, Average depth, $d = 4.5 \text{ ft} = 1.372 \text{ m}$ and Cross sectional area, $A = w \times d = 32.12 \text{ m}^2$

For measurement of flow the passing the length of $L = 1.2192 \text{ m}$ following time were recorded

Table 10 : Time survey for flow in Ruangchori Canal, Bandorban, Bangladesh.

No of Obserbation	Time (Sec)
1	50.45
2	51.08
3	50.3
4	50.45
5	51.25

Average Time, $t = 50.706 \text{ sec}$,

Velocity $v = L/t = 1.2192/50.706 = .024 \text{ ms}^{-1}$, Flow, $Q = V \times A = .024 \times 32.12 = .77088 \text{ m}^3/\text{sec}$ and Head, $H = 5 \text{ m}$.

Therefore Power, $P = 9.81 \times Q \times H = 9.81 \times .77088 \times 5 = 37.81 \text{ kw}$

d) Sailopropat Spring, Sailopropat, Bandorban, Bangladesh

Head, $H = 27.59 \text{ ft} = 8.41 \text{ m}$, Width, $W = 2 \text{ ft} = .61 \text{ m}$,
Length, $L = 4 \text{ ft} = 1.2192 \text{ m}$

Area, $A = W \times L = .74 \text{ m}^2$

For measurement of flow the passing the length of $L = 1.2192 \text{ m}$ following time were recorded.

Table 11 : Time survey for flow measurement of Sailopropat Spring.

No of Obserbation	Time (Sec)
1	1.75
2	1.73
3	1.65
4	1.81
5	1.79

Average time, $t = 1.74 \text{ sec}$,

Velocity, $V = L/t = 1.2192/1.74 = .7 \text{ ms}^{-1}$

Flow, $Q = A \times V = .74 \times .7 \text{ ms}^{-1} = .518 \text{ m}^3/\text{sec} = 518 \text{ litre/sec}$

Power, $P = 9.81 \times Q \times H = 42.74 \text{ KW}$

IX. CONCLUSION

There is a great potential of micro hydro in Chittagong hill tract region of Bangladesh. This paper shows some feasible places beside the government survey to establish micro hydro and generate power. There is a diversified geographical feature with hill, mountain, river, canal and spring exists in this region. This hill tract region has promising resources to play a great role in the economy of Bangladesh. But without abundant power and shortage of energy supply this promising resources can't be utilized. On the other hand it is so tuff to provide power from the national grid to the remote areas of Hill Tracts and it needs huge expenditure. So to provide the electricity in that region without extra expenditure it is very fruitful to establish the micro hydro power plant. This paper has an effort to bring the micro hydro power plant into limelight and also to show some new promising places with proper calculation where this kind of plant can be established. If it is possible to develop power plant using micro hydro then it will definitely change the overall scenario of electricity in these region which will certainly affect the life style and economic stability of the people in that region as well as Bangladesh.

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A TCAD Simulation Study of Cylindrical Gate All Around (CGAA) MOSFETs

By Santosh K. Gupta & S. Baishya

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Abstract - Due to aggressive scaling of transistors SCEs has become the limiting factor for further scaling of the conventional MOSFETs. To overcome this limitation a large number of new device architectures have been proposed. One of such device structures is cylindrical gate all around (CGAA) MOSFET that seems to be most suitable to be studied further for different applications point of view. In this paper we report the suitability analysis of CGAA MOSFETs for low voltage, low power and analog applications. We report many interesting findings through 3D TCAD simulations of CGAA MOSFETs.

Keywords : Cylindrical Gate All Around (CGAA) MOSFETs, analog, low voltage, low power, short channel effects (SCEs), 3D TCAD.

GJRE-F Classification : FOR Code: 090601



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A TCAD Simulation Study of Cylindrical Gate All Around (CGAA) MOSFETs

Santosh K. Gupta^α & S. Baishya^σ

Abstract - Due to aggressive scaling of transistors SCEs has become the limiting factor for further scaling of the conventional MOSFETs. To overcome this limitation a large number of new device architectures have been proposed. One of such device structures is cylindrical gate all around (CGAA) MOSFET that seems to be most suitable to be studied further for different applications point of view. In this paper we report the suitability analysis of CGAA MOSFETs for low voltage, low power and analog applications. We report many interesting findings through 3D TCAD simulations of CGAA MOSFETs.

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I. INTRODUCTION

To keep pace with the Moore's law the CMOS transistors has witnessed aggressive scaling in the last decade. Due to this scaling the device sizes has become very small and many secondary effects, widely known as short channel effects (SCEs) and hot carrier effects (HCEs) plays important role in the device characteristics.

In an ever increasing need for higher current drive and better short-channel characteristics, silicon-on-insulator MOS transistors are evolving from classical, planar, single-gate devices into three-dimensional devices with multiple-gates (double-, triple- or quadruple-gate devices). Multiple Gate Field Effect Transistors show great promise as an alternative to planar CMOS. They are known for their excellent immunity against SCEs due to better control of the channel by the gates. Several designs depicted in Figure 1 have been proposed including planar, vertical, fin, tri-gate and gate all around that all make use of enhanced gate control due to the action of multiple electrodes surrounding the channel [3]. Volume inversion (full inversion of the silicon film) [4] is the basic phenomenon found in thin film Multi-gate MOSFETs.

Out of these, the multi-gate transistor seems to be very promising due to its larger control on the channel as compared to the conventional MOSFETs. Recently Intel has revealed 22 nm

FinFET based processor to be used in next generation highly efficient applications. However, more techniques have to be investigated for even better solution for overcoming the limitation imposed on the conventional CMOS processes. The gate all around (GAA) MOSFETs controls the channel of the transistors from all sides and hence provides better control over the channel than any other configuration. To look into various aspects of this transistor a 3D TCAD simulation has been carried out and compared for the different parameters.

II. DEVICE STRUCTURE GENERATION

The device has been generated using the structure editor of Sentaurus TCAD of Synopsys. The channel region is lightly doped ($1.0\text{E}+16/\text{cm}^3$, Boron) so that there is almost no degradation of mobility due to doping. Gate oxide chosen is silicon dioxide (SiO_2) with thickness of 1 nm, to stop the gate tunneling current. The source and drain regions are heavily doped ($1.0\text{E}+20/\text{cm}^3$, Arsenic) and a mid-gap metal gate (work function 4.6 eV) has been taken of varied gate height. A spacer region has been used between the source and channel region for the purpose of reducing the source/drain effect on the channel. A spacer oxide (SiO_2) has been used in between gate and source/drain. The device has been simulated for its DC characteristics (threshold voltage) and analog characteristics (transconductance). A typical GAA MOSFET considered for simulation study is shown in the Figure 2. For comparison of the variation of different device parameters taken is given in Table 1.

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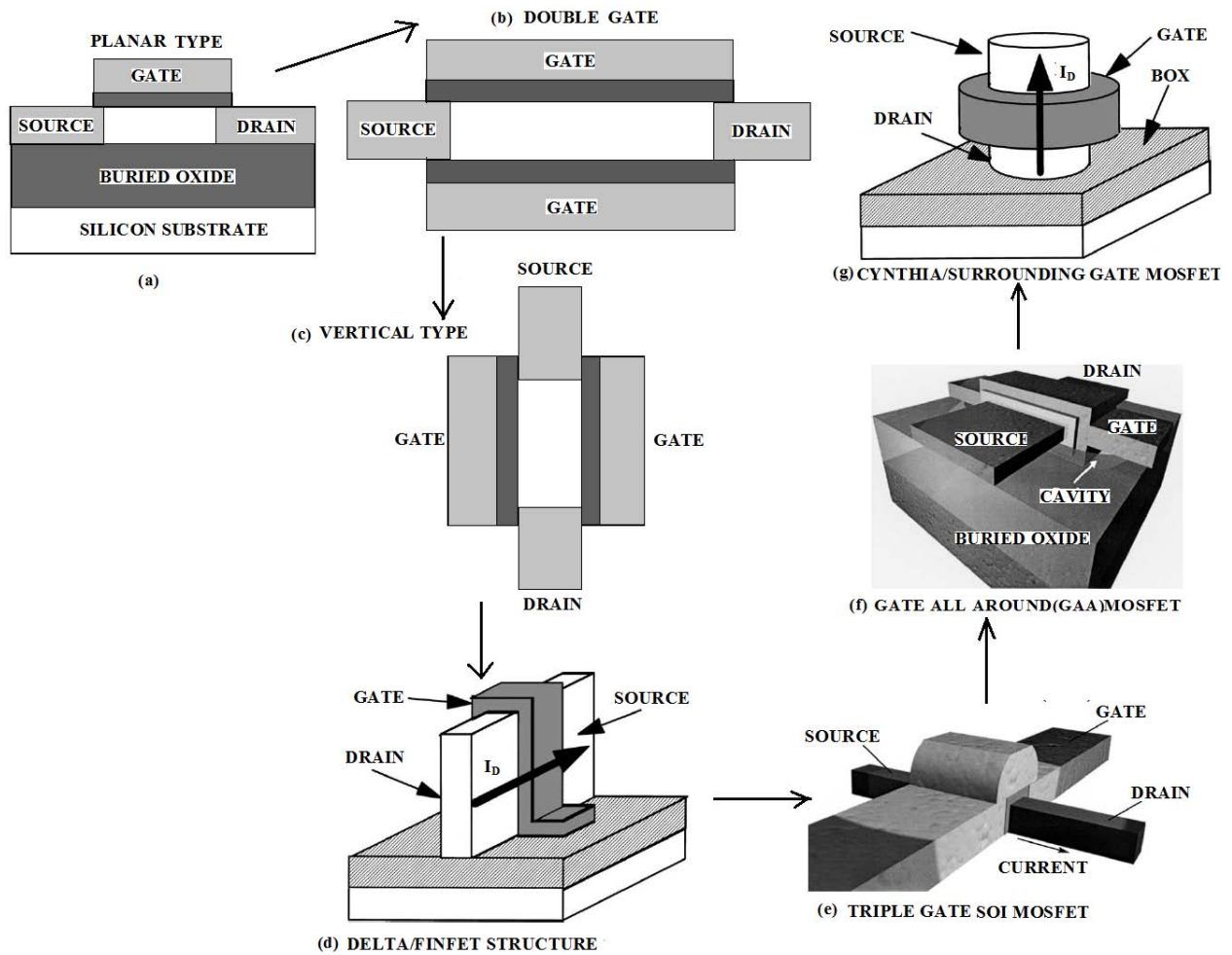


Fig. 1 : Evolution of multi-gate MOSFETs [3].

Table 1 : Device structure parameters

Structure	Gate length	Source/Drain extension	Gate height (4.6 eV)	Channel radius	Source/Drain doping	Channel doping	Gate Oxide
2 nm gate height	16 nm	10 nm	2 nm	10 nm	1E+20 (Arsenic)	1E+16 (Boron)	1 nm (SiO ₂)
	30 nm						
	50 nm						
10 nm gate height	16 nm	10 nm	10 nm	10 nm	1E+20 (Arsenic)	1E+16 (Boron)	1 nm (SiO ₂)
	30 nm						
	50 nm						
22 nm spacer length	16 nm	22 nm	2 nm	10 nm	1E+20 (Arsenic)	1E+16 (Boron)	1 nm (SiO ₂)
	30 nm						
	50 nm						

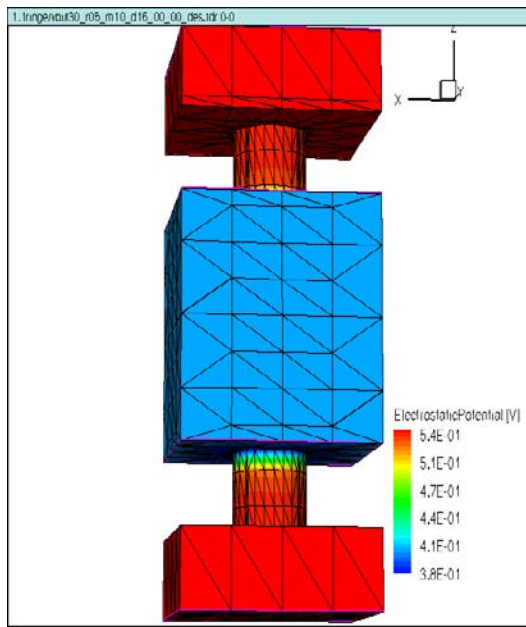


Fig. 2 : Structure of a cylindrical gate all around (CGAA) MOSFET used for simulations

III. RESULTS AND DISCUSSIONS

These MOSFETs has been simulated for the suitability of their use at lower operating voltages. This has become important nowadays because of the quest for low power devices for longer battery life. The simulation results obtained from above devices confirms the suitability of these for low voltage applications

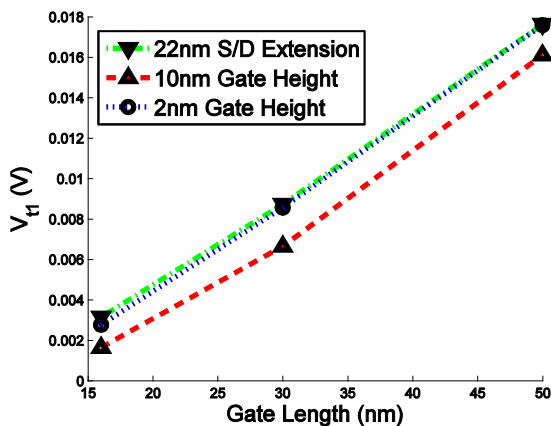


Fig. 3 : Variation of the V_{t1} for different gate lengths and different structures

Figure 3 shows the variation of the V_{t1} parameter extracted with inspect tool of the Sentaurus TCAD tool. V_{t1} is the threshold voltage extracted at a drain current $I_d = 0.1 \mu A/\mu m$. It can be observed that the V_{t1} is lower for large gate metal height and scales down with the gate length. Also V_{t1} increases with the increase of the source/drain extension regions and scale down with the gate length.

Figure 4 shows the variation of the threshold voltage (V_{th}) extracted by using the maximum slope intercept of the I_d-V_{gs} characteristics. It varies very similar to the V_{t1} but there is a sharp reduction in the threshold voltage at lower gate lengths. This is due to the reduction in charge carriers to be controlled by the gate. Due to lower threshold voltages of scaled CGAA MOSFET, it may better suit for the low voltage applications.

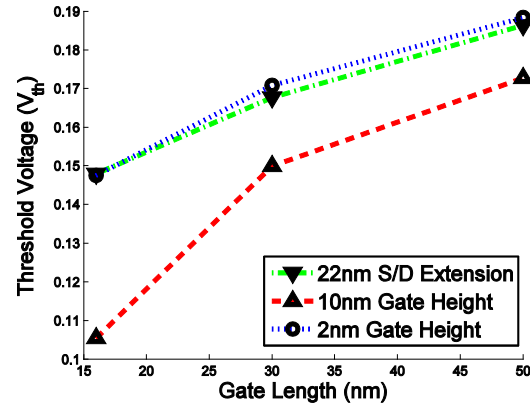


Fig. 4 : Comparison of threshold voltage for different gate lengths

Figure 5 shows the ON state channel resistance for different gate lengths. The ON state resistance is lower for lower gate height and lower source drain extension. This is due to the increased control of the gate over the channel and reduced parasitic resistance.

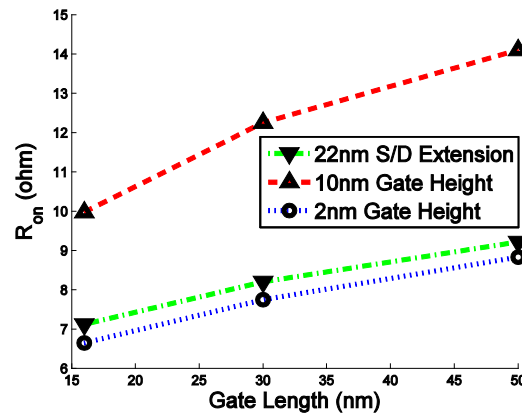


Fig. 5 : Comparison of the ON state channel resistance for different gate lengths

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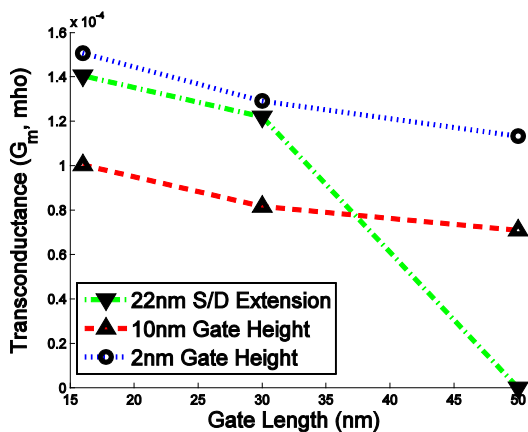


Fig. 6 : Comparison of transconductance for different gate lengths

In figure 6 the transconductance is compared. The transconductance is larger for larger source drain extension region and lower gate metal height. The transconductance improves as the gate lengths are scaled down for all the structures.

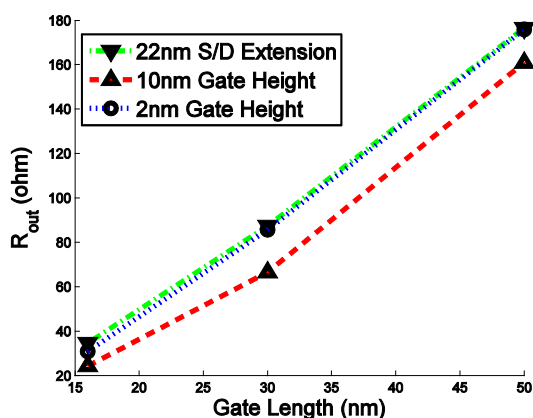


Fig. 7 : Comparison of the variation of the output resistance for different gate lengths

Figure 7 shows the variation of the output drain resistance of the CGAA MOSFET. Output drain resistance is almost same for different lengths of source/drain spacer region and scales down with the gate length. This is; however, lower for the larger gate metal height.

IV. CONCLUSION

The 3D simulations were carried out for varied range of gate lengths and source/drain extension regions. It has been found that the CGAA MOSFET has very good SCE immunity and is suitable to be used for low voltage low power applications. The transconductance is significantly larger and output resistance is lower at smaller gate lengths which mean it is also suitable for analog applications as well.



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Low Complexity Post-Coded MIMO OFDM Systems: Design and Performance Analysis

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Indexterms : Multiple input multiple output (MIMO), Orthogonal frequency division multiplexing (OFDM), precoding, postcoding, spreading codes, frequency diversity, coding gain, diversity gain.

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Low Complexity Post-Coded MIMO OFDM Systems: Design and Performance Analysis

Sanjeev Kumar^α & Dr.Amita Soni^σ

Abstract - This paper discuss the Low Complexity Post-Coded MIMO OFDM (PC-MIMO OFDM) Systems: Design and performance analysis. The signal is propagating from the transmitter to receiver along number of different paths, referred as multipath in wireless environment. Path loss, macroscopic fading and microscopic fading are propagating signal power drops. Orthogonal Frequency Division Multiplexing (OFDM) provides a viable solution to communicate over selective fading channels. OFDM offers several advantages like resilience to multipath fading in intersymbol interference, low complexity and others. Multiple input multiple output (MIMO) utilizes spatial diversity by having several transmit and receive antennas.

The combination of MIMO and OFDM has been designed to improve the data rate and Quality of service (QoS). The wireless system utilizes the multiplexing gain and/or diversity gain which is a major problem in communication. The combination MIMO-OFDM is very natural and beneficial, since OFDM enables support of more antennas and large bandwidths. Coded or precoded OFDM systems are generally employed to overcome the symbol recovery problem in uncoded OFDM systems. The post coded OFDM systems introduce frequency diversity by manipulating the OFDM systems in time domain so that the computational complexity of the system can be significantly reduced.

We discuss the design principle of PC-MIMO OFDM system transmitter that uses up sampling operation and spreading codes to introduce frequency diversity. We also describe the design of low complexity receiver for PC-MIMO OFDM systems to minimize error performance.

The main advantages of this scheme are reduce system complexity by having a simple encoder/decoder, smaller size inverse fast Fourier transform/fast Fourier transform (IFFT/FFT) modules, and lower clock rates in the receiver and transmitter leading to be lower energy consumption. The proposed system is found to be equally good over Gaussian and Fading channels where it achieves the maximum diversity gain of the channel. Simulation results show that PC-MIMO OFDM performs better than existing precoded OFDM systems.

Indexterms : Multiple input multiple output (MIMO), Orthogonal frequency division multiplexing (OFDM), precoding, postcoding, spreading codes, frequency diversity, coding gain, diversity gain.

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I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has been proven to be a viable technique to overcome multipath fading in wireless channels. OFDM offers several advantages like resilience to multipath fading, intersymbol interference, low complexity and others. It has been adopted in many wireless standards, such as digital audio/video broadcasting, the HIPERLAN/2 standard, the IEEE 802.11a and g standards for wireless local area network (WLAN). The need for high rate data services is growing, especially as multimedia applications are gaining popularity, as they require higher data rate with good quality of service (QoS). Thus, new wireless systems have to be designed considering the need for data and multimedia services [1].

In wireless technology biggest challenge is to overcome the effect of Rayleigh fading channel. The multipath nature of the channel leads to inter symbol interference (ISI) and as the bandwidth occupied increases, the ISI severity is pronounced.

To combat the ISI problem due to the multipath nature of the channel, equalizers are used. In a single carrier system, the equalizer is generally a linear filter whose purpose is to combine the signal components arriving at various time delays. The computational effort required for implementing an equalizer increases with data rate and the problem becomes more challenging when there is a time varying multipath channel in which case it need tracking. The orthogonal frequency division multiplexing (OFDM) transmission scheme is an efficient technique to combat ISI. In a conventional serial data system, the symbols are transmitted sequentially, with the frequency spectrum of each data symbol allowed to occupy the entire available bandwidth. As the data rate increases, the time a single symbol (one or several bits) is "on air" is decreased. In case of impulse noise or other short period noise with high energy, it is likely that a symbol gets distorted to such a high extent that it cannot be recovered. The shorter the period in which the symbol is available, the higher is the probability that the symbol is fully destroyed by bursts of noise [2].

But in OFDM instead of using a single carrier that occupies the whole available frequency band,

several orthogonal subcarriers are employed within the available frequency band. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth [3]. The key idea of the OFDM transmission is to make the symbol period long with respect to the delay spread of the channel. In the frequency domain this can be viewed as the subcarrier BW becoming smaller compared with the coherence BW of the channel, i.e., the individual subcarriers experience flat fading, which requires a simple one tap equalizer. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has a null at the centre frequency of other carriers in the system. This result is no interference between the carriers [4].

To cope with this problem of multipath channel, various techniques have been and continuously are being proposed by the researchers of system modeling. Orthogonal frequency division multiplexing is one of the widely used such techniques. The aim of this work to design a system to reduce the complexity without any performance loss and the overall computational cost of the system significantly reduced. The idea of precoded OFDM system for single and multiple antennas has designed already and post coded system for single antenna system has also designed. But if the idea of post-coding scheme from single antenna is extended to multiple antenna systems. The proposed Post-coded MIMO-OFDM system results low complexity in design, since number of IFFT blocks required by the system reduces to one in contrast to the traditional systems used in which this requirement equals number of transmit antenna. The post-coded system achieves this low complexity objective by manipulating the OFDM symbols in time domain.

It compared the computation cost of single and multiple antenna post-coded system with precoded systems and observed that for same system constraints, that is, for same structure of spreading code and modulation scheme used, the post-coded systems provide cost efficient system design. In short, PC-OFDM systems introduce frequency diversity by spreading the information symbols across all the subcarriers in the efficient manner so that the overall computation cost of the system is significantly reduced. The computation saving in PC-OFDM come from two sources: 1) smaller size IFFT and FFT are used as compared to frequency domain precoding and 2) the special structure of encoding matrices is exploited resulting in $O(N)$ operation instead of $O(N^2)$ operations [5].

II. MIMO SYSTEM

Multiple-Input-Multiple-Output (MIMO) systems use multiple antennas at the transmitter and receiver ends in a wireless communication system.

Multiple-Input-Multiple-Output systems are increasingly being adopted in communication systems for the possible gains in capacity.

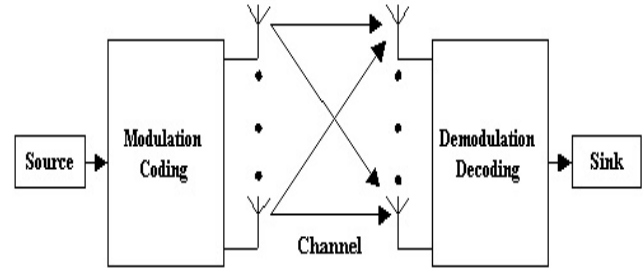


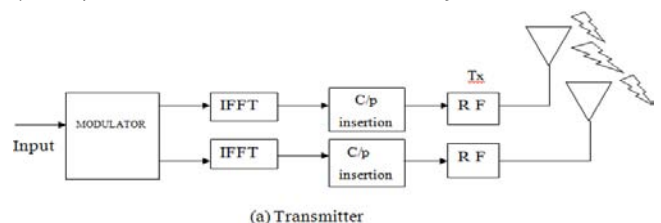
Figure 1 : Block Diagram of MIMO system

In Multiple-Input-Multiple-Output (MIMO) system, multiple antennas use the spatial dimension in addition to the time and frequency ones, without changing the bandwidth requirements of the system. For a communications link, it focuses on transmit diversity in lieu of traditional receive diversity. Let h be the channel coefficient between the T^{th} transmit antenna and R^{th} receive antenna. Let $S = [S_1 S_2 S_3 \dots S_N]$ be the transmitted data and $Y = [Y_1 Y_2 Y_3 \dots Y_N]$ be the received data. Then the relation is given by $Y = Hs + n$

III. MIMO-OFDM SYSTEM

MIMO-OFDM systems provide higher data rates, improve communication performance, support a large number of users with flexibility in Quality of Service (QoS) and provide high quality transmission in comparison with the existing ones. Also coding is being done on OFDM symbols to achieve further improved performance from the systems. But in order to fulfil these requirements some constraints have to be very well addressed such as limited availability of frequency spectrum, availability of total transmit power and nature of wireless channels. Also all these advantages come at the cost of high complexity in the system. Main tool for increasing the transmission rate with multiple transmit antennas system consist of transmitting more independent streams or layers of data from all available transmit antennas simultaneously [6].

a) Implementation of MIMO-OFDM System



(a) Transmitter

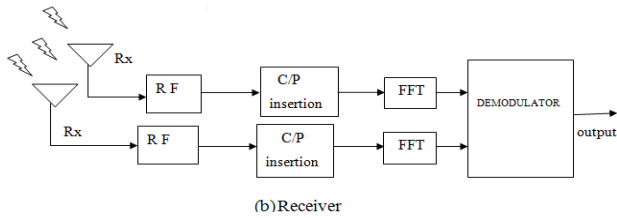


Figure 2 : Block Diagram of MIMO-OFDM Transceiver

The general transceiver structure of MIMO-OFDM is presented in Figure2. The system consists of N transmit and M receiver antennas, the cyclic prefix is assumed to be longer than the channel delay spread [6]. The OFDM signal for each antenna is obtained by using inverse Fast Fourier Transform (IFFT) and can be detected by Fast Fourier Transform (FFT).

The received MIMO-OFDM symbol of n^{th} subcarrier and the m^{th} OFDM symbol of i^{th} receive antenna after FFT can be written as

$$A_i[n, m] = \sum_{j=1}^N k_{i,j} [n, m] R_j[n, m] + W_i[n, m], i=1,2,3,\dots,M \quad (3.1)$$

Where $R_j[n, m]$ is the transmitted data symbol on n^{th} carrier and m^{th} OFDM symbol, $W_i[n, m]$ is the adeptive noise contribution at i^{th} receive antenna for the corresponding symbol in frequency domain and $K_{i,j}[n, m]$ is the channel coefficient in the frequency domain between the j^{th} transmit antennas and i^{th} receive antennas [9].

$$K[n, m] = \sum_{i=0}^{I-1} k_i[m] e^{-j2\pi t_i n/T}, n=0,1,2,3,\dots,N-1 \quad (3.2)$$

Where I is the number of channel taps in time domain and $k_i[m]$ is modulation as an independent zero-mean random Gaussian process [7].

IV. PC MIMO-OFDM SYSTEM

In Post-coded MIMO-OFDM system the spreading and encoding has to be performed in time domain, that is, after IFFT operation, in contrast to the precoded systems as discussed earlier, in which it is done in frequency domain. A MIMO-OFDM system with two transmitting antennas is considered. It uses Alamouti code for encoding the spread symbols as it considered in the precoded system. Since now it is to be performed in time domain, so instead of performing encoding separately, it include the effect of Alamouti coding in the modulated symbols and spreading matrix. It is to be noted that proposed structure of spreading matrix and modulated symbol vector is valid only for MIMO system with two transmitting antennas.

a) System Model for Post Coded MIMO OFDM System

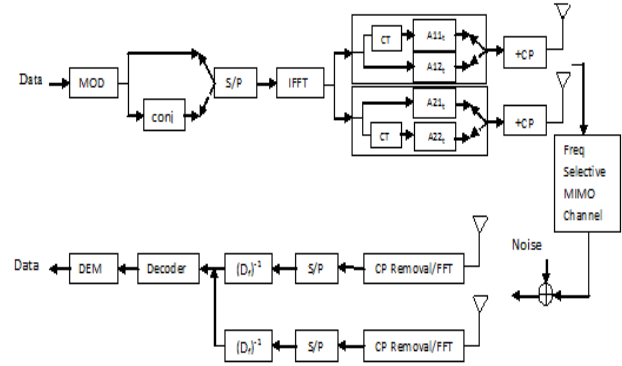


Figure 3 : Block Diagram Of Post-coded MIMO-OFDM system model

The structure of the spreading matrix and modulated symbol vector is modified in such a way that symbols generated after time domain spreading operation are equivalent to symbols which are spread as well as encoded in frequency domain and then transformed to time domain, that is, the precoded symbols.

The block diagram of Post-coded MIMO-OFDM system with two transmit and two receive antenna is as shown in figure 3 (CT represent time domain operation that is equivalent to conjugation in frequency domain). To include the effect of alamouti coding to the symbols, instead of directly transforming the symbols to time domain, it, the $N \times 1$ vector of modulated symbols in frequency domain. Indirectly, the part of alamouti coding is separately applied to modify the modulated symbols. Since, the system are required two transmit antennas is being considered, so two modified forms of the modulated symbol vector are required. If the original modulated symbol vector is,

$$b = [b_1 \ b_2 \ b_3 \ \dots \ b_N]^T \quad (4.1)$$

Then the first modified form required to include the encoding effect is,

$$b_{m1} = [b_1 \ b_2^* \ b_3 \ \dots \ b_N^*]^T \quad (4.2)$$

These modified symbols can now be transformed to time domain by IFFT operation,

$$s = F_N^H b_{m1} \quad (4.3)$$

The second modified form required is,

$$b_{m2} = [b_1^* \ b_2 \ b_3^* \ \dots \ b_N]^T \quad (4.4)$$

which is nothing but,

$$b_{m2} = b_{m1}^* \quad (4.5)$$

Now to obtain time domain equivalent of b_{m2} instead of using another IFFT block it use complex conjugate property of IFFT, that is,

$$s_{conj}(1) = (s(1))^* \quad (4.6)$$

$$s_{conj}(i+1) = (s(N+1-i))^* \quad (4.7)$$

Where $i=1 \dots N$.

The $N \times 1$ vector s_{conj} is the time domain equivalent of the vector b_{m2} or b_{m1}^* . This operation is represented by block CT in figure 3. The time domain equivalent of the symbol vectors, s and s_{conj} is now has to be spread using modified spreading matrix which generates post-coded symbols, equivalent to precoded time domain symbols. The same structure and design criterion is used for constructing spreading matrix and then it is modified to include the effect of encoding. For each transmitting antenna different form of spreading matrix is required [8].

b) Receiver

The transmitting symbols, generated from proposed post-coding technique for MIMO-OFDM system, are equivalent to precoded MIMO-OFDM symbols [9]. After removing CP and performing FFT operation, the data in frequency domain at Receiver is

$$U_{k,j} = \sum_{i=1}^{M_t} H_{j,i}^k x_{k,i} + W_{k,j} \quad (4.25)$$

c) Computational Complexity

In pre coded MIMO-OFDM systems, each transmit antenna requires one IFFT block, so total real multiplications and additions will be,
Real multiplication:

$$Mt \times 2N \log_2 N = 2MtN \log_2 N \quad (4.26)$$

Real additions:

$$Mt \times (5/2)N \log_2 N = (5/2)MtN \log_2 N \quad (4.27)$$

The Post-coded OFDM system requires only one IFFT block. As the complexity of one ordinary IFFT is $(N/2) \log_2 N$ complex multiplications and $N \log_2 N$ additions, and one complex multiplication is 4 real multiplications and 3 additions, so one ordinary IFFT has $2N \log_2 N$ real multiplications and $(5N/2) \log_2 N$ additions. Since the post-coded MIMO-OFDM system require single IFFT block, so the total number of real multiplications and additions required still remains $2N \log_2 N$ and $(5N/2) \log_2 N$ respectively.

V. SIMULATION RESULTS

In this section are presented simulation results for comparing the performance of both the schemes. Graphs are plotted between bit error rates (BER) and signal to noise ratio (SNR). For all simulations it defines

SNR as signal to noise ratio per bit and compute it as $\mathcal{E}_b / N_0$ where $\mathcal{E}_b$ is the bit energy and $N_0/2$ is the noise variance. Simulations are performed to compare the performance of Post-coded single antenna OFDM system with different spreading codes and with precoded system.

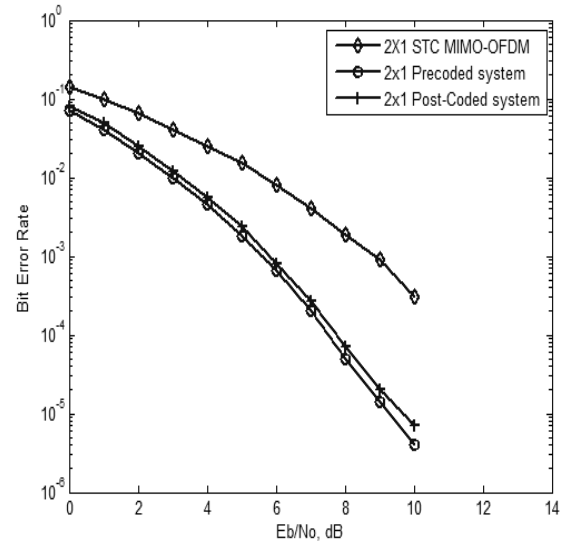


Figure 4 : BER of different coded MIMO-OFDM systems for 2Tx/1Rx antenna and BPSK constellation

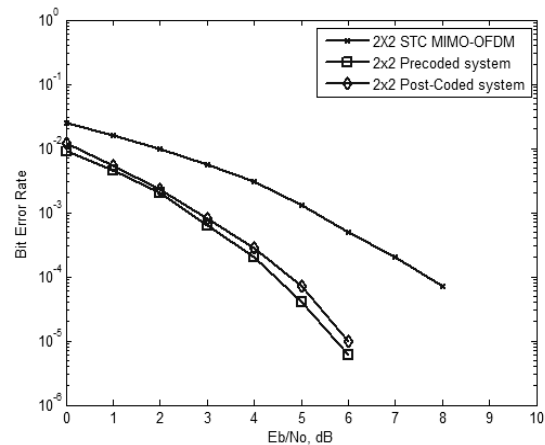


Figure 5 : BER of different coded MIMO-OFDM systems for 2Tx/2Rx antenna and BPSK constellation

VI. CONCLUSION

In this paper to design a system to reduce the complexity without any performance loss and the overall computational cost of the system significantly reduced. The proposed Post-coded MIMO-OFDM system results low complexity in design, since number of IFFT blocks required by the system reduces to one in contrast to the traditional systems used in which this requirement equals number of transmit antenna. The post-coded system achieves this low complexity objective by manipulating the OFDM symbols in time domain. It

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Area Optimized High Throughput IDMT/DMWT Processor for OFDM on Virtex-5 FPGA

By Anitha.K, Dr.Dharmistan.K.Varugheese & Dr N.J.R.Muniraj

Aarunai engg college/anna university

Abstract - OFDM is one of the most popular modulation techniques that is been widely used in most of the wireless and wired communication links. The OFDM architecture consists of QAM modulator and orthogonal frequency modulator. In this work we propose DMWT based orthogonal frequency modulator for achieving higher BER. The IDMT architecture is designed considering $N=4$, thus the preprocessing unit converts the QAM samples of N to $2N$ and is modulated using DMWT filters. The filtered output is further transmitted and is received at the receiver. During the post processing, N samples are extracted by use of DMWT demodulation technique. The complex architecture of IDMT and DMWT are reduced for its complexity and speed by the modified architecture. The DMWT architecture is modified for FPGA implementation improving the area, power and speed performances. The modified DMWT architecture is implemented on VirtexII pro FPGA which operates at 300MHz frequency and occupies area of less than 1%, with power consumption less than 28mW. The proposed design is suitable for real time and low power applications.

GJRE-F Classification : FOR Code: 090601



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Area Optimized High Throughput IDMWT/DMWT Processor for OFDM on Virtex-5 FPGA

Anitha.K ^{α} , Dr.Dharmistan.K.Varugheese ^{σ} & Dr N.J.R.Muniraj ^{ρ}

Abstract - OFDM is one of the most popular modulation techniques that is been widely used in most of the wireless and wired communication links. The OFDM architecture consists of QAM modulator and orthogonal frequency modulator. In this work we propose DMWT based orthogonal frequency modulator for achieving higher BER. The IDMWT architecture is designed considering $N=4$, thus the preprocessing unit converts the QAM samples of N to $2N$ and is modulated using DMWT filters. The filtered output is further transmitted and is received at the receiver. During the post processing, N samples are extracted by use of DMWT demodulation technique. The complex architecture of IDMWT and DMWT are reduced for its complexity and speed by the modified architecture. The DMWT architecture is modified for FPGA implementation improving the area, power and speed performances. The modified DMWT architecture is implemented on VirtexII pro FPGA which operates at 300MHz frequency and occupies area of less than 1%, with power consumption less than 28mW. The proposed design is suitable for real time and low power applications.

I. INTRODUCTION

The FFT based OFDM uses complex exponential bases function to reduce interference hence it was replaced with wavelets to produce better performance at the cost of loss in orthogonality between the carriers [1] [2]. Mutiwavelets preserves high frequency components and also increases sensitivity better than scalar wavelets [7]. Mutiwavelets show the perfect union of symmetry, orthogonally, finitely support and smoothness [8]. The design of orthogonal symmetric prefilter banks is shown with the discrete mutiwavelet transform for image coding and digital communications. The new DMWT structure increases computational complexity, energy compaction ratio as well as the compression performance when applying to a VQ based image coding system[9][10]. A biorthogonal multi-wavelets filter has many characteristics, such as symmetry, compact support, orthogonality and 3-order vanishing moment[11].

The Fourier based OFDM (FFT-OFDM) use the complex exponential bases functions and it's replaced

by an orthonormal wavelets in order to reduce the level of interference. It is found that OFDM based on Haar-based orthonormal wavelets (DWT-OFDM) are capable of reducing the inter symbol interference ISI and inter carrier interference ICI, which are caused by the loss in orthogonality between the carriers [1] [2].

To further improve the performance gains a new transform is implemented based on Multifilters called Multiwavelets (DMWT-OFDM). These filters shows more properties which is not achievable in other transforms (Fourier and wavelet) [3].

A most important Multiwavelets filter is the GHM filter proposed by Geronimo, Hardian, and Massopust. The Multiwavelets functions coefficients are 2×2 matrices, and they must multiply vectors instead of scalars during transformation step. Thus multifilter bank requires 2 input rows. To start the analysis algorithm and to reduce the noise effects, the preprocessing step associates given scalar input signal of length N to a sequence of length-2 vectors[4] [5].

II. PROPOSED SYSTEM FOR DMWT- OFDM

The block diagram of the proposed system for OFDM is depicted in figure (1).

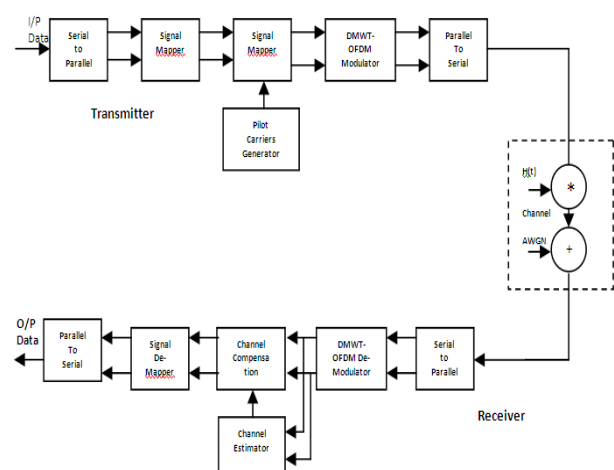


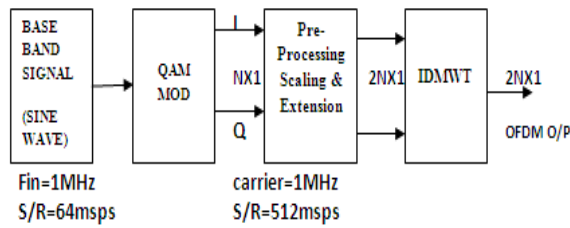
Figure 1 : Block Diagram of DMWT-OFDM System

The OFDM modulator and demodulator of DMWT-based OFDM are shown in figure (2).

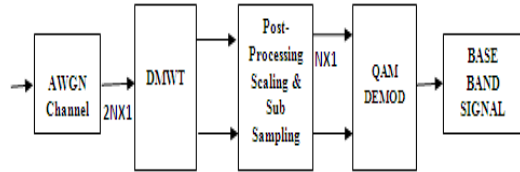
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(a) DMWT-OFDM modulator



(b) DMWT-OFDM demodulator

Figure 2 : DMWT-OFDM modem system

The S/P converter, the signal demapper and the insertion of training sequence are same as in DWT-OFDM. After that, a computation of IDMWT for 1-D signal is achieved by using an over-sampled scheme of preprocessing (repeated row), the IDMWT matrix is doubled in dimension compared with that of the input, which is a square matrix of $N \times N$, where N is in power of 2. Transformation matrix dimensions is equal to input signal dimensions after preprocessing. To compute a single-level 1-D discrete multiwavelets transform, the next steps are:

1. Checking input dimensions: With input vector of length N , where N is in power of 2.
2. Constructing a transformation matrix W as in 3, using GHM low and high pass filters matrices given in 1 and 2, after substituting GHM matrix filter coefficients values, a $2N \times 2N$ transformation matrix results.

$$H_0 = \begin{bmatrix} \frac{3}{5\sqrt{2}} & \frac{4}{3} \\ \frac{1}{-20} & -\frac{3}{10\sqrt{2}} \end{bmatrix} \quad H_1 = \begin{bmatrix} \frac{3}{5\sqrt{2}} & 0 \\ \frac{9}{20} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad \dots\dots\dots(1)$$

$$H_2 = \begin{bmatrix} 0 & 0 \\ \frac{9}{20} & -\frac{3}{10\sqrt{2}} \end{bmatrix} \quad H_3 = \begin{bmatrix} 0 & 0 \\ -\frac{1}{20} & 0 \end{bmatrix}$$

$$G_0 = \begin{bmatrix} -\frac{1}{20} & -\frac{3}{10\sqrt{2}} \\ \frac{1}{10\sqrt{2}} & \frac{3}{10} \end{bmatrix} \quad G_1 = \begin{bmatrix} \frac{9}{20} & -\frac{1}{\sqrt{2}} \\ \frac{9}{10\sqrt{2}} & 0 \end{bmatrix} \quad \dots\dots\dots(2)$$

$$G_2 = \begin{bmatrix} \frac{9}{20} & -\frac{3}{10\sqrt{2}} \\ \frac{9}{10\sqrt{2}} & -\frac{3}{10} \end{bmatrix} \quad G_3 = \begin{bmatrix} -\frac{1}{20} & 0 \\ -\frac{1}{10\sqrt{2}} & 0 \end{bmatrix}$$

$$W = \begin{bmatrix} H_0 & H_1 & H_2 & H_3 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & H_0 & H_1 & H_2 & H_3 & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ H_2 & H_3 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & H_0 & H_1 \\ G_0 & G_1 & G_2 & G_3 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & G_0 & G_1 & G_2 & G_3 & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & \dots & G_0 & G_1 & G_2 & G_3 \\ G_2 & G_3 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & G_0 & G_1 \end{bmatrix} \quad \dots\dots(3)$$

3. Preprocessing the input signal by repeating the input stream with the same stream multiplied by a constant α , for GHM system functions $\alpha = 1/\sqrt{2}$.
4. Transformation of input vector which can be done by apply matrix multiplication to the $2N \times 2N$ constructed transformation matrix by the $2N \times 1$ preprocessing input vector.

III. SOFTWARE REFERENCE MODEL RESULTS

In this section the simulation of the proposed DMWT-OFDM system in MATLAB version 7 are achieved. And the bit error rate (BER) performance of the OFDM system considered in different channel models, the additive white Gaussian noise (AWGN) channel, the flat fading channel, and the selective fading channel [6].

a) Performance of dmwt-ofdm in awgn channel

In this section, the result of the simulation for the proposed DMWT-OFDM system is calculated and shown in figure (3), which give the BER performance of DMWT-OFDM in AWGN channel. It is shown clearly that the DMWT-OFDM is much better than the two previous system FFT-OFDM and DWT-OFDM. This is a reflection to the fact that the orthogonal bases of the multiwavelets is much significant than the orthogonal bases used in FFT-OFDM and DWT-OFDM.

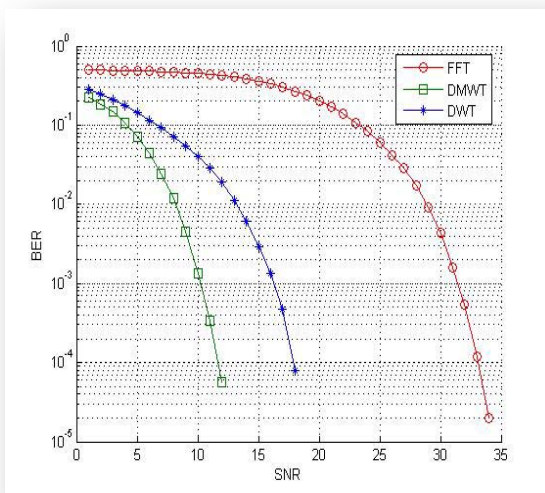
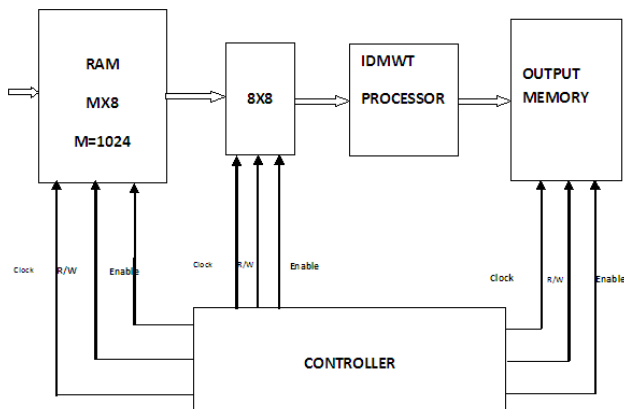


Figure 3 : BER performance of DMWT-OFDM in AWGN channel model.

IV. DESIGN OF DMWT/IDMWT ARCHITECTURE



In this work, design and FPGA implementation of a hardware efficient DMWT architecture is carried out. The QAM modulated data which generates the I and Q channel signals are preprocessed and is modulated using IDMWT, the OFDM modulated data is transmitted through AWGN channel and is demodulated using DMWT, the base band signal is extracted using QAM demodulation. Figure 2 shows the detailed block diagram of OFDM modulation and demodulation. The input signal is considered as 1MHz signal with sampling frequency of 64MSPs, the QAM modulator carrier frequency is chosen to be 64 MHz, the QAM symbols are obtained at 512MSPs. The OFDM modulator has to process the modulated data at the rate of 512MSPs. From the previous discussions, it is found that prior to OFDM modulation, the input samples are to be scaled and extended as $2N \times 1$ vector, which is the requirement for GHM based IDMWT. In order to achieve this the pre processing unit performs the scaling and extension operation, thus the incoming samples to preprocessing that are at 512MSPs are preprocessed to $2N \times 1$ with

1024 MSPs. The preprocessed data is to be processed using IDMWT, this has to operate at frequency greater than 1024MSPs.

V. DESIGN OF IDMWT

In this work, we select $N=4$, thus the QAM symbols are grouped into frames of 4 samples and is preprocessed. With $N=4$, the preprocessing unit extends the samples to 8 with scaling. The scaled samples are to be processed in the IDMWT with GHM wavelets of size $2N \times 2N$, with $N=8$, the GHM filter size is 8×8 . The GHM filter for $N=4$ is given in equation

$$W = \begin{bmatrix} H0 & H1 & H2 & H3 \\ H2 & H3 & H4 & H1 \\ G0 & G1 & G2 & G3 \\ G2 & G3 & G0 & G1 \end{bmatrix}$$

As we perform inverse IDMWT, the GHM filter coefficients are:

$$W = \begin{bmatrix} H0 & H2 & G0 & G2 \\ H1 & H3 & G1 & G3 \\ H2 & H0 & G2 & G0 \\ H3 & H1 & G3 & G1 \end{bmatrix}$$

Using the above equation, the preprocessed data is modulated to generate OFDM signal. The OFDM signal using GHM filter can be mathematically represented as:

$$[Y] = [W_T][X]$$

$$[2N \times 1][2N \times 2N][2N \times 1]$$

The above equation is implemented on FPGA. The input matrix is first stored in a memory of size $M \times 8$, where M is an integer of size 1024. The input memory is loaded from the preprocessing unit. The controller reads the data from input memory into an intermediate memory of size 8×8 , the controller also reads the corresponding GHM coefficients from memory. The input is multiplied and accumulated using dedicated multipliers on FPGA to compute the output samples. Figure below shows the top level block diagram of IDMWT logic for the I channel, which is similar for the Q channel.

VI. COMPUTATION COMPLEXITY OF IDMWT

As the input is of size 8×1 and is 8 bit per sample, every input frame is multiplied by $2N$ rows of GHM filter coefficients. Thus it requires $2N \times 2N$ multiplications and $2N(2N-1)$ additions. For computation of every output sample, it requires $2N$ clock cycles (write

data into intermediate memory) + 2N clocks for reading data from intermediate memory + 1 clock cycle for multiplication + 2N-1 clock for addition and another 2N clock cycle for write operation, thus for every output computation it requires 8N clock cycles. The latency is 8N clock cycles, throughput is 8N-1 clock cycles. In order to improve throughput and latency, it is required to modify the IDMWT architecture. In this work we propose a high speed DMWT and IDMWT architecture that is implemented on FPGA.

Modified DMWT architecture:

In the previous section the BER performance is analyzed and now the GHM matrix coefficients were calculated and substituted in equations 1, 2 and 3 the equations 4 to 11 are derived to design multiwavelets. Here it is scaled with scaling factor 128. The table below shows co-efficient before and after scaling.

Before Scaling	After Scaling
$3/5\sqrt{2}$	54
$4/3$	170
0.26819	34
0.1707	22
0.4145	53
0.7070	90
$3/10$	38
$2/3$	84
$1/2$	64
0.5207	66
0.08787	11
0.5207	68
0.362	46
0.6864	88
0.3793	48

Table 1 : Scaled and Un scaled co-efficient

$$\begin{bmatrix} Y_0 \\ Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \\ Y_5 \\ Y_6 \\ Y_7 \end{bmatrix} = \begin{bmatrix} 3/5\sqrt{2} & 4/3 & -3/5\sqrt{2} & 0 & 0 & 0 & 0 & 0 \\ -1/20 & -3/10\sqrt{2} & 9/20 & 1/\sqrt{2} & 9/20 & -3/10\sqrt{2} & -1/20 & 0 \\ 0 & 0 & 0 & 0 & 3/5\sqrt{2} & 4/3 & 3/5\sqrt{2} & 0 \\ 9/20 & -3/10\sqrt{2} & -1/20 & 0 & -1/20 & -3/10\sqrt{2} & 9/20 & 1/\sqrt{2} \\ -1/20 & -3/10\sqrt{2} & 9/20 & -1/\sqrt{2} & 9/20 & -3/10\sqrt{2} & -1/20 & 0 \\ -1/10\sqrt{2} & 3/10 & 9/10\sqrt{2} & 0 & 9/10\sqrt{2} & -3/10 & -1/10\sqrt{2} & 0 \\ 9/20 & -3/10\sqrt{2} & -1/20 & 0 & -1/20 & -3/10\sqrt{2} & 9/20 & -1/\sqrt{2} \\ 9/10\sqrt{2} & -3/10 & -1/10\sqrt{2} & 0 & 1/10\sqrt{2} & -3/10 & 9/10\sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} X_0 \\ X_1 \\ X_2 \\ X_3 \\ X_0(1/\sqrt{2}) \\ X_1/\sqrt{2} \\ X_2/\sqrt{2} \\ X_3/\sqrt{2} \end{bmatrix}$$

$$y_0 = (54*x_0 + 170*x_1 + 54*x_2) \text{----- (4)}$$

$$y_1 = (34*x_0 - 22*x_1 + 53*x_2 + 90*x_3) \text{----- (5)}$$

$$y_2 = (38*x_0 + 84*x_1 + 38*x_2) \text{----- (6)}$$

$$y_3 = (53*x_0 - 22*x_1 + 34*x_2 + 64*x_3) \text{----- (7)}$$

$$y_4 = (34*x_0 - 22*x_1 + 53*x_2 - 90*x_3) \text{----- (8)}$$

$$y_5 = (66*x_0 + 11*x_1 + 68*x_2) \text{----- (9)}$$

$$y_6 = (53*x_0 - 46*x_1 + 34*x_2 - 64*x_3) \text{----- (10)}$$

a) Computation complexity of reduced equation

Equation above have been derived based on the modified GHM filter coefficients. From the above equations it is found that to compute every output sample, it is required to perform minimum of 3 multiplications and 2 additions. Thus for N=4, the number of multiplications and additions are 28 multiplications and 20 additions respectively. The number of multiplications and additions are reduced by more than 50%. This reduction in multiplication and addition optimizes the design in terms of area and power requirement. It is also found that the latency of the design is 8N clock cycles, but throughput is 7N clock cycles, which is faster compared with existing design which is 8N-1. The latency and throughput can be further improved with parallel and pipelining architecture.

VII. FPGA IMPLEMENTATION OF MODIFIED DMWT/IDMWT

The HDL model for the modified equations of GHM filter is developed and simulated using ModeSim. Multiple test cases are chosen to test the functionality of the modified equation and is verified against software reference model results. The functionally correct HL code is synthesized using Xilinx ISE 10.1 targeting VirtexII pro FPGA. Next section discuss the results of FPGA implementation.

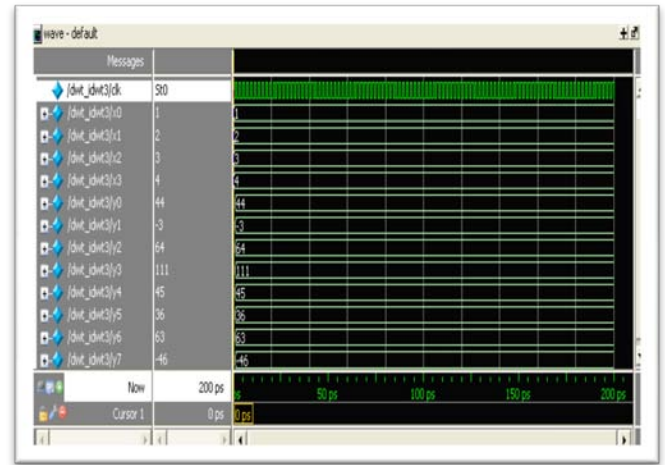


Figure 4 : Post Place and Route Simulation

It is seen that the pre-simulation and post place and route simulation results match, thereby proving that the design is perfectly mapped onto FPGA meeting the required design specifications.

The HDL co simulation of the design is performed using matlab simulation which is shown in Figure5 below.

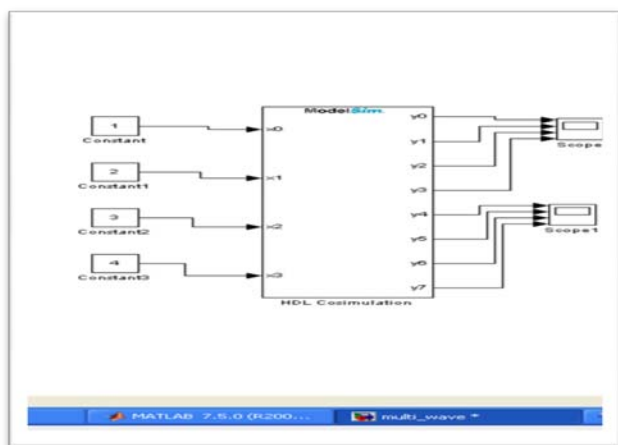


Figure 5 : HDL CO-Simulation

Figure 6 below shows the RTL schematic of the proposed design with interconnects between the various blocks. It is a technology independent schematic.

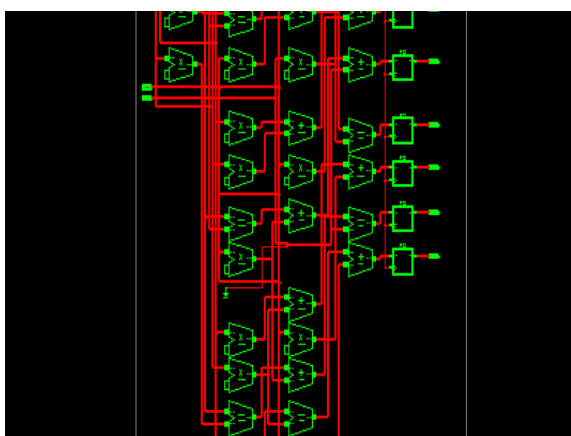


Figure 6 : RTL Schematic

a) Device utilization summary

Logic Utilization	Used	Available	Utilization
Number of 4 input LUTs	126	27, 392	1%
Number of occupied Slices	72	13, 696	1%
Number of bonded IOB'S	97	556	17%
IOB Flip Flops	64		
Number of MULT18X18s	18	136	13%
Number of BUFGMUXs	1	16	6%

b) Synthesis report

Target Device : xc2vp30-7-ff896

Minimum input arrival time before clock: 8.362ns

Maximum output required time after clock: 3.293ns

Total memory usage is 225952 kilobytes

VIII. CONCLUSION

In this work, we propose a modified GHM filter architecture for OFDM modulation and demodulation. Software reference model for DMWT based OFDM model is developed and simulated to find the BER performances for various SNRs. The simulation results show that the DMWT OFDM model outperforms FFT and DWT based OFDM models. The DMWT coefficients that are fractions are converted to integers and are modified to reduce the number of multiplications and additions. The reduced GHM filter coefficients are used to process the QAM modulated data, thus reducing the computation complexity and making it suitable for FPGA implementation. The modified equations are modeled using HDL and implemented on FPGA VirtexII pro. The design operates at maximum frequency of 300MHz and consumes less than 1% resources and thus is suitable for real time applications. The design can be further improved for its latency and throughput by designing a parallel and pipelined architecture for DMWT/IDMWT.

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Reliability Evaluation of Composite System with Aging Failure

By Tanay Lakshman

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Abstract - Reliability is concerned with the system capability of survival. In the past forty years, customer expectations have been increasing in response to evolving new technologies. As part of these evolutions, they are demanding from their suppliers: products with higher quality, low initial cost, improved customer support and products that are easy and inexpensive to maintain. For a supplier to survive, succeed and be profitable in today's market, It must do the following:

- a) Constant improvement in the quality of the products.
- b) Minimization of the cost.
- c) Be flexible and responsive to the customer's requirement.

This deals with reliability evaluation of combined generation and transmission system known as composite system. It describes a technique calculate composite system reliability with aging failure.

Keywords : Power System Reliability, Transmission, Generation.

GJRE-F Classification : FOR Code: 090601



Strictly as per the compliance and regulations of:



Reliability Evaluation of Composite System with Aging Failure

Tanay Lakshman

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This deals with reliability evaluation of combined generation and transmission system known as composite system. It describes a technique calculate composite system reliability with aging failure.

The reliability evaluation deals with the

- Calculation of aging failure rate & aging repair rate of all Components of the system.
- Calculation of EENS value of all Components of the system by performing Reliability Analysis using SKM'S PTW 6.5.

Keywords : Power System Reliability, Transmission, Generation.

I. INTRODUCTION

Reliability is concerned with the system capability of survival. In the past twenty years, customer expectations have been increasing in response to evolving new technologies. As part of these evolution, they are demanding from their suppliers:

Products with higher quality, low initial cost, improved customer support and products those are easy and inexpensive to maintain. For a supplier to survive, succeed and be profitable in today's market, it must do the following:

- Constant improvement in the quality of the products.
- Minimization of the cost.
- Be flexible and responsive to the customers' requirement.

Previously the criteria and techniques used for reliability assessment were all deterministically based. The essential weakness was that they did not account for the probabilistic or stochastic nature of system behaviour and component failures. However, the

probability theory alone cannot predict either the reliability or safety of the equipment. It is only a tool available to the engineer in order to transform his knowledge of the system for the prediction of future behaviour of the system.

II. OBJECTIVES

So basic Objective is to calculate EENS value of loads connected to the system with Skm's PTW 6.5 .

III. METHODS

The RBTS is a 6 bus system composed of two generator buses, 5 load buses, 9 transmission lines and 11 generating units. The total installed capacity is 240 MW and the system peak load is 185 MW.

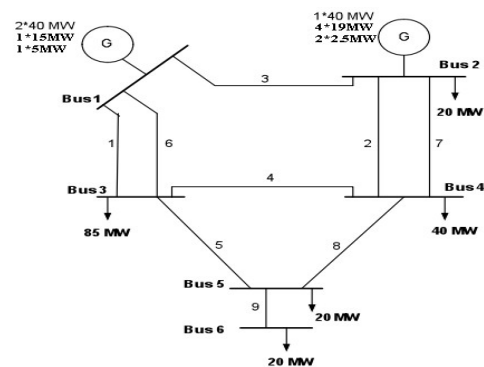


Figure 1 : Single Line Diagram of RBTS system

a) *Rbts Data**Table 1* : Bus Data for RBTS system

Bus	Peak Load,MW		PG	Q VAR Limit,MVAR		Voltage Limits,pu	
	Active	Reactive		Max	Min	Max	Min
1	0	0	1.00	50	-40	1.05	0.97
2	20	0	1.20	40	-75	1.05	0.97
3	85	0	0.00	0	0	1.05	0.97
4	40	0	0.00	0	0	1.05	0.97
5	20	0	0.00	0	0	1.05	0.97
6	20	0	0.00	0	0	1.05	0.97

b) *Generation Data**Table 2* : Generator data for RBTS system

Bus No.	Rating(MW)	Failure Per Year	Repair Time(hours)
1	40	6	45
1	40	6	45
1	10	4	45
1	20	5	45
2	5	2	45
2	5	2	45
2	40	3	60
2	20	2.4	55
2	20	2.4	55
2	20	2.4	55
2	20	2.4	55

c) *Rbts-Transmission Data*

The relevant reliability data for the nine 110 kV lines in Fig. 1 in terms of the permanent and transient failure rates and the permanent outage repair times are

given in [11]. The outage duration of a transient outage is considered to be less than one minute. Outages of substation components which are not switched as a part of a line are not included in the line data.

Table 3 : Line Data For RBTS system

From Bus	To bus	R	X	B	Current rating	Failure Per Year	Repair Time
1	3	0.0342	0.18	0.0212	0.49	1.5	10
2	4	0.1140	0.60	0.0352	0.409	5	10
1	2	0.0912	0.48	0.0564	0.409	4	10
3	4	0.0228	0.12	0.0142	0.409	1	10
3	5	0.0228	0.12	0.0142	0.409	1	10
1	3	0.0342	0.18	0.0212	0.49	1.5	10
2	4	0.1140	0.60	0.0352	0.409	5	10
4	5	0.0228	0.12	0.0142	0.409	1	10
5	6	0.0228	0.12	0.0142	0.409	1	10

Table 4 : Elements reliability data

Element	Failure rate		Duration		
	Permanent	Active	Permanent	Maintenance	Switching
Busbar	0.001	0.001	2.0	1.0	0.0
Cir.Breaker	0.02	0.02	24	1.0	0.0
Transformer	0.015	0.015	15	1.0	0.0
Disc.Switch	0.002	0.002	4.0	1.0	0.0

Table 5 : Load Reliability Data

Load at	Failure Frequency[1/yr]	Duration[h]
Bus 2	0.47	1
Bus 3	0.216	1
Bus 4	0.855	1
Bus 5	0.002	5
Bus 6	1.002	9.989

d) Aging Failure Rate

The Value of η is calculated from the following formula:

$$\eta = 1000000/$$

$$(\text{FailureRate} * \text{EXP}(\text{GAMMALN}(1 + 1/\text{ShapeParameter}(\beta))))$$

$$\text{Failure Rate Calculation Formula} = \left(\frac{\beta}{\eta} \right) \left(\frac{t}{\eta} \right)^{\beta-1}$$

Where β = Shape parameter

η = Scale parameter

Table 6 : Aging Failure rate for Aging of Tx's

Time(hr)	$\beta=0.5$	$\beta=1.0$	$\beta=1.5$
$t=8760 \times 1$	0.087	0.015	0.00236
$t=8760 \times 5$	0.039	0.015	0.00527
$t=8760 \times 10$	0.027	0.015	0.00746
$t=8760 \times 15$	0.022	0.015	0.00913
$t=8760 \times 20$	0.019	0.015	0.0105
$t=8760 \times 25$	0.017	0.015	0.0118
$t=8760 \times 30$	0.016	0.015	0.0124
$t=8760 \times 35$	0.015	0.015	0.0139
$t=8760 \times 40$	0.014	0.015	0.0149

e) Aging Repair Rate

The Value of θ is calculated from the following formula:

$$\theta = 1000000/(\text{Failure}$$

$$\text{Rate} * \text{EXP}(\text{GAMMALN}(1 + 1/\text{Shape Parameter}(\alpha))))$$

$$\text{Repair Rate Calculation Formula} = \left(\frac{\alpha}{\theta} \right) \left(\frac{t}{\theta} \right)^{\alpha-1}$$

Where α = Shape parameter

θ = Scale parameter

Table 7 : Aging Repair rate for Aging of Tx's

Time(hr)	$\theta=0.5$	$\theta=1.0$	$\theta=1.5$
$t=8760 \times 1$	2.73	15	0.000115
$t=8760 \times 5$	1.22	15	0.000257
$t=8760 \times 10$	0.866	15	0.000363
$t=8760 \times 15$	0.707	15	0.000445
$t=8760 \times 20$	0.612	15	0.000513
$t=8760 \times 25$	0.547	15	0.000574
$t=8760 \times 30$	0.500	15	0.000629
$t=8760 \times 35$	0.463	15	0.000679
$t=8760 \times 40$	0.433	15	0.000726

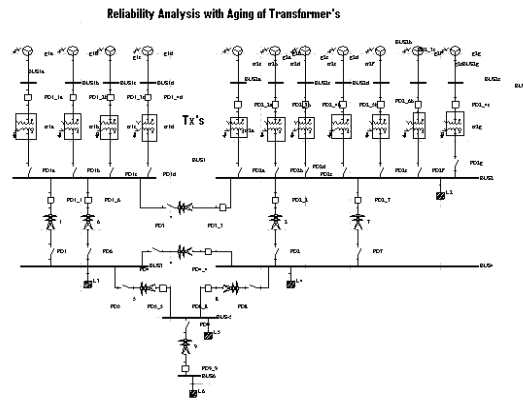


Figure 2 : One line diagram of RBTS system in SKM's PTW 6.5 for aging of Tx's

- f) *Case 3a : Non repairable aging failure for $\beta=0.5$* the life basin curve. Obviously, it corresponds to a decreasing failure rate and therefore can be modeled using an exponential distribution.
- A nonrepairable aging failure for $\beta=0.5$ refers to a random fatal failure in the normal operating stage of

Table 8 : EENS Value for Aging of Tx's for $\beta=0.5$

Time (hr)	Reliability Analysis				
	EENS (Kwh/year) Value for Aging of Tx's for $\beta=0.5$				
	L2	L3	L4	L5	L6
0	8855688.94	820.60	7000745.07	81967029.91	85576849.91
1	8855688.93	820.56	7000464.56	81966403.38	95575902.39
5	8855688.89	820.39	6999336.69	81963884.14	95572092.43
10	8855688.83	820.16	6997913.76	81960705.56	95567285.30
15	8855688.78	819.92	6996476.30	81957494.17	95562428.51
20	8855688.71	819.66	6995024.31	81954249.97	95557522.07
25	8855688.65	819.38	6993557.79	81950972.97	95552565.98
30	8855688.59	819.12	6992358.74	81948293.37	95548513.37
35	8855688.59	819.12	6992358.74	81948293.37	95548513.37
40	8855688.59	819.12	6992358.74	81948293.37	95548513.37

- g) *Case 3b : Chance Failure for $\beta=1$* constant failure rate and therefore can be modeled using an exponential distribution. fatal failure in the random basin curve. Obviously, it corresponds to a normal operating stage of the life.

Table 9 : EENS Value for Aging of Tx's for $\beta=1$

Time(hr)	Reliability Analysis				
	EENS(Kwh/year) Value for Aging of Tx's for $\beta=1$				
	L2	L3	L4	L5	L6
0	8855688.94	820.60	2065266.86	81867494.39	95477314.39
1	8855688.94	820.60	2065266.86	81867494.39	95477314.39
5	8855688.94	820.60	2065266.86	81867494.39	95477314.39
10	8855688.94	820.60	2065266.86	81867494.39	95477314.39
15	8855688.94	820.60	2065266.86	81867494.39	95477314.39
20	8855688.94	820.60	2065266.86	81867494.39	95477314.39
25	8855688.94	820.60	2065266.86	81867494.39	95477314.39
30	8855688.94	820.60	2065266.86	81867494.39	95477314.39
35	8855688.94	820.60	2065266.86	81867494.39	95477314.39
40	8855688.94	820.60	2065266.86	81867494.39	95477314.39

h) Case 3c : Wear Out Period for $\beta = 1.5$

A nonrepairable wear out failure refers to a random fatal failure in the normal operating stage of the

life basin curve. Obviously, it corresponds to a increasing failure rate and therefore can be modeled using an exponential distribution.

Table 10 : EENS Value for Aging of Tx's for $\beta = 1.5$

Time(hr)	Reliability Analysis				
	EENS(Kwh/year) Value for Aging of Tx's for $\beta = 1.5$				
	L2	L3	L4	L5	L6
0	8855688.94	820.60	2065266.86	81867494.39	95477314.39
1	8855689.41	822.60	2065267.87	81867494.89	95477314.89
5	8855690.81	828.56	2065270.89	81867496.40	95477316.40
10	8855691.82	832.84	2065273.07	81867497.49	95477317.49
15	8855692.49	835.69	2065274.51	81867498.21	95477318.21
20	8855693.24	838.87	2065276.12	81867499.02	95477319.02
25	8855694.36	843.63	2065278.54	81867500.23	95477320.23
30	8855696.03	850.74	2065282.14	81867502.03	95477322.03
35	8855698.31	860.43	2065287.06	81867504.49	95477324.49
40	8855701.13	872.40	2065293.13	81867507.52	95477327.52

IV. RESULTS & DISCUSSION

From the Reliability analysis we get the life basin curve by plotting EENS value with time for $\alpha = 0.5$, $\alpha = 1.0$, $\alpha = 1.5$.

V. DISCUSSION AND CONCLUSIONS

In this work, method has been presented to calculate reliability of composite system by calculating probability and frequency of failure of system under different conditions. This area of composite power system reliability evaluation is least developed and also one of the most complicated but in view of environmental, ecological, societal and economic constraints faced by most of power utilities, this area is developing and getting attention in international market.

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Study of Microstrip Slotted Antenna for Bandwidth Enhancement

By Kapil Goswami

Singhania University, Jhunjhunu (Rajasthan)

Abstract - Two printed wide-slot antennas with E-shaped patches and slots, for broadband applications, are proposed. They are fed by a coplanar waveguide (CPW) and a microstrip line with almost the same performances. Detailed simulation and experimental investigations are conducted to understand their behavior and optimize for broadband operation. Good agreement between the measurement and simulation has been achieved. The impedance bandwidths, determined by 10-dB reflection coefficient, of the proposed slot antennas fed by microstrip line and CPW are examined from both measurement and simulation. We have obtained the large operating bandwidth by choosing suitable combinations of feed and slot shapes. In order to achieve wider operation bandwidth both of the designed antennas have round corners on the wide slot and patch. Meanwhile, the proposed antennas exhibit almost omnidirectional radiation patterns, relatively high gain, and low cross polarization. A comprehensive numerical sensitivity analysis has been done to understand the effects of various dimensional parameters and to optimize the performance of the designed antennas. Results for reflection coefficient, far-field E and H-plane radiation patterns, and gain of the designed antennas are presented and discussed. At the end, we compare the simulated and measured results and found the enhancement of bandwidth of E-shape microstrip antenna.

Indexterms : Bandwidth, Directivity, Microstrip Antenna, Method of Moment (MOM).

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Abstract - Two printed wide-slot antennas with E-shaped patches and slots, for broadband applications, are proposed. They are fed by a coplanar waveguide (CPW) and a microstrip line with almost the same performances. Detailed simulation and experimental investigations are conducted to understand their behavior and optimize for broadband operation. Good agreement between the measurement and simulation has been achieved. The impedance bandwidths, determined by 10-dB reflection coefficient, of the proposed slot antennas fed by microstrip line and CPW are examined from both measurement and simulation. We have obtained the large operating bandwidth by choosing suitable combinations of feed and slot shapes. In order to achieve wider operation bandwidth both of the designed antennas have round corners on the wide slot and patch. Meanwhile, the proposed antennas exhibit almost omnidirectional radiation patterns, relatively high gain, and low cross polarization. A comprehensive numerical sensitivity analysis has been done to understand the effects of various dimensional parameters and to optimize the performance of the designed antennas. Results for reflection coefficient, far-field E and H-plane radiation patterns, and gain of the designed antennas are presented and discussed. At the end, we compare the simulated and measured results and found the enhancement of bandwidth of E-shape microstrip antenna.

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I. INTRODUCTION

Modern wireless systems are placing greater emphasis on antenna designs for future development in communication technology because of antenna being the key element in the whole communication system. The antenna in a system serves as the transducer between the controlled energy residing within the system and the radiated energy existing in free space. For the design of the antenna for next generation we are trying to reduce the size of antenna with enhanced bandwidth, so that we can use this type of antenna in any compact device like mobile phones, WLL and other devices. The microstrip antenna is very good for wireless communication due to its light weight, low volume and low profile planer configuration which can be easily made conformal to host surface. Additionally, it has the low fabrication cost. Its supportive nature for both linear and circular polarization and low sensitivity to manufacturing tolerance makes

this antenna very important for next generation. But major disadvantage of this type of antenna is that it has a very narrow bandwidth.

Antenna is one of the important elements in the RF system for receiving or transmitting the radio wave signals from and into the air as the medium. Without proper design of the antenna, the signal generated by the RF system will not be transmitted and no signal can be detected at the receiver. The development of MIC and HF semiconductor devices and printed circuits has drawn the maximum attention of the antenna community in recent years. In spite of its various attractive features like light weight, low cost, easy fabrication, conformability on curved surface etc, the microstrip element suffers from an inherent disadvantage of narrow impedance bandwidth and low gain. In principle, bandwidth enhancement can be achieved by several approaches [1].

In this paper, we remove such type of disadvantage of simple microstrip antenna by designing the E-Shape Microstrip antenna. The coaxial feed technique is used for the analysis of this antenna because it occupies less space and has low spurious radiations by using Teflon connector. The Method of Moment (MOM) [2] is used to discuss the electromagnetic radiation characteristics of the microstrip antenna.

II. THEORETICAL BACKGROUND OF MICROSTRIP PATCH ANTENNA

E-shape microstrip patch antenna can be designed by using a cavity model [3] suitable for moderate bandwidth antennas. The lowest order mode, TM_{10} , resonates when effective length across a patch is half of wavelength. Radiations occur due to fringing field. A brief description of resonant frequency and cavity model is given as follows;

a) Designing equations

Because of the fringing effects, electrically the patch of the antenna looks larger than its physical dimensions. The enlargement on L (Patch length) is given by:

$$\Delta L = \frac{0.412h(\epsilon_{\text{reff}} + 0.3)(Wh^{-1} + 0.264)}{[(\epsilon_{\text{reff}} - 0.258)(Wh^{-1} + 0.8)]} \quad (1)$$

Where h is the height and W is the width of patch.

Where the effective (relative) permittivity (ϵ_{reff}) is:

$$\epsilon_{\text{reff}} = \frac{\epsilon_e + 1}{2} + \frac{\epsilon_r - 1}{2\sqrt{1 + 12hW^{-1}}} \quad (2)$$

This is related to the ratio of h/W . The larger the h/W , the smaller the effective permittivity.

The effective length of the patch is given by:

$$L_{\text{eff}} = L + 2\Delta L \quad (3)$$

The resonant frequency for the TM_{100} mode is:

$$f_r = \frac{1}{2L_{\text{eff}}\sqrt{\epsilon_{\text{reff}}}\sqrt{\epsilon_0\mu_0}} = \frac{1}{2(L + 2\Delta L)\sqrt{\epsilon_{\text{reff}}}\sqrt{\epsilon_0\mu_0}} \quad (4)$$

An optimized width for an efficient radiator is:

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r + 1}} \quad (5)$$

The length L for the antenna is:

$$L = \frac{1}{2f_r\sqrt{\epsilon_{\text{reff}}}\sqrt{\epsilon_0\mu_0}} - 2\Delta L \quad (6)$$

b) Cavity model

Transmission line model ignores field variations along the radiating edges. This disadvantage can be overcome by using cavity model in which interior region of dielectric substrate is modeled as cavity bounded by electric walls on the top and bottom. The basis for the assumption is the following observations for thin substrate ($h \ll \lambda$). Since the substrate is thin; the field in interior region does not vary much in Z direction that is normal to the patch.

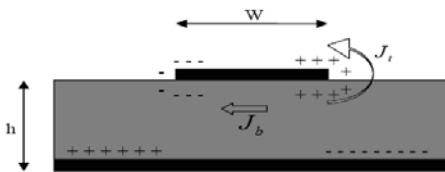


Figure 1 : Charge distribution and current density creation on the patch.

Consider Fig 1, When the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms, an attractive mechanism and a repulsive mechanism. The attractive mechanism applies between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism holds between the like charges on the bottom surface of the patch, which

causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on the top surface of the patch and as the height to width ratio further decreases, the current on the top surface of the patch would be almost equal to zero, which would not allow the creation of any tangential magnetic field components to the patch edges. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces.

III. DESIGN PARAMETERS OF PROPOSED ANTENNA

Consider a Microstrip E-SHAPE ANTENNA shown in Fig-2 and Fig-3:

Using above equations(1-6) the dimensions of the proposed antenna is summarized below:

Parameters	Dimensions
Resonant frequency(f_r)	2.5 GHz
Dielectric constant (ϵ_r)	4.2
Substrate thickness (h)	1.6 mm
Width of patch (W)	37.21 mm
Width between two slots (W_1)	7.44 mm
Slot width (W_s)	7.44 mm
Length of patch (L)	28.89 mm
L_1	14.445 mm
Slot length (L_s)	14.445 mm

Table 1 : Proposed antenna parameter

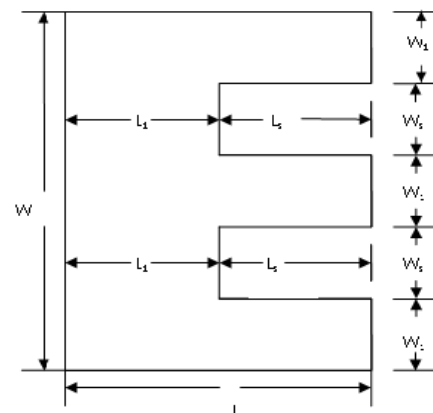


Figure 2 : Geometry of proposed E-shape antenna

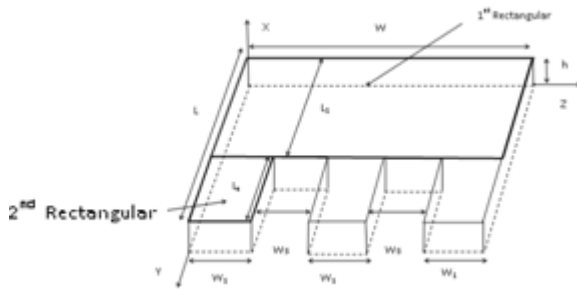


Figure 3 : E-shape microstrip antenna

IV. RESULT ANALYSIS BY SIMULATION AND DISCUSSION

All the antenna parameters are firstly calculated and plotted by using MATLAB coding and then simulated by IE3D based on Method of Moment. By using MATLAB [4], we find the values of return loss and VSWR on feeding points (27, 2.5) and also simulate the proposed antenna with IE3D [5]. Finally we compare output of simulated and theoretical results with the support of various graphs and charts given below. The probe feed antenna is shown in Figure 3. The E-shaped antenna is formed by inserting the coordinate. The coordinate of the antenna for the analysis is found out by using the total length and width of E-shape antenna. The probe feed is inserted in such a way so that maximum -10 dB bandwidth obtained. The probe is feed at point (27, 2.5) as shown in Fig 4.

E-SHAPE Microstrip Patch Antenna with feed point (27, 2.5) :

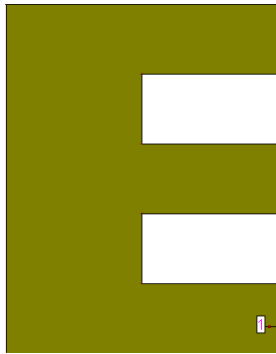


Figure 4 : Antenna shape with feed point

a) *Theoretical analysis using MATLAB based on cavity model*

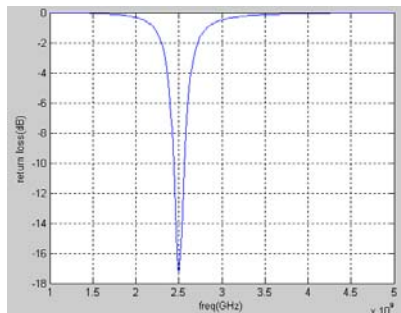


Figure 5 : Return loss of E-shape microstrip antenna

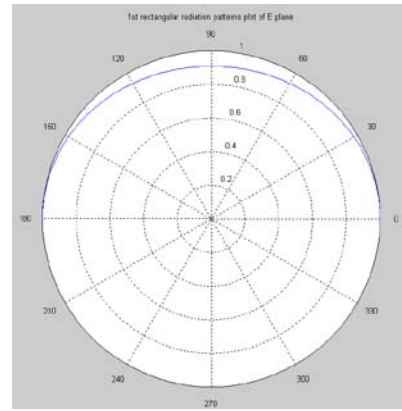


Figure 6 : Radiation pattern of 1st rectangle E-plane

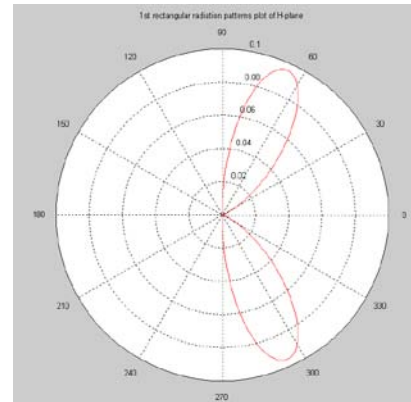


Figure 7 : Radiation pattern of 1st rectangle H-plane

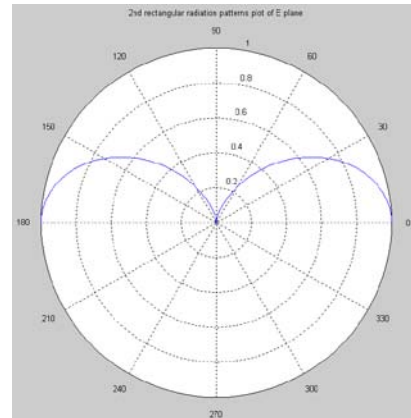


Figure 8 : Radiation pattern of 2nd rectangle E-plane

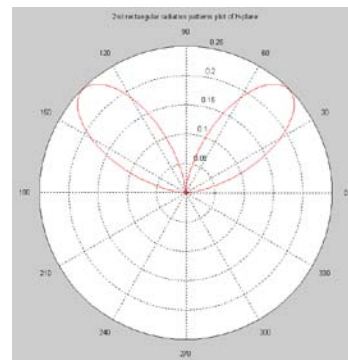


Figure 9 : Radiation pattern of 2nd rectangle H-plane

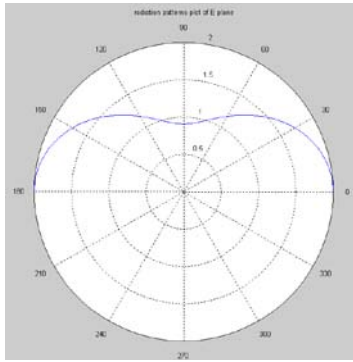


Figure 10 : Radiation pattern of E-shape microstrip antenna (E-plane)

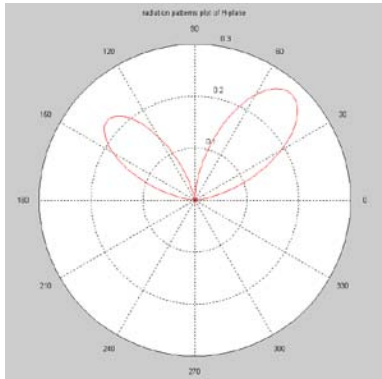


Figure 11 : Radiation pattern of E-shape microstrip antenna (H-plane)

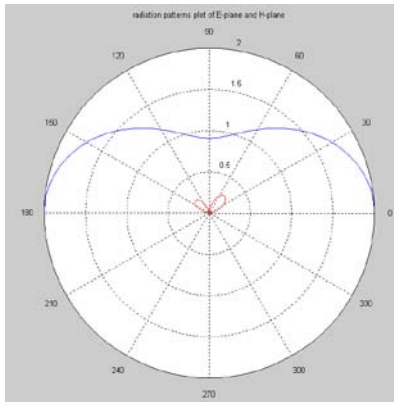


Figure 12 : Radiation pattern of E-shape microstrip antenna (E-plane & H-plane)

b) Simulated result by IE3D based on MOM Method

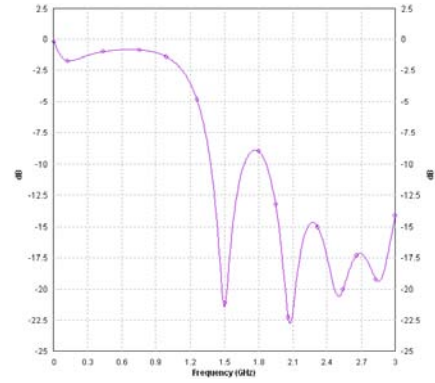


Figure 13 : Return loss versus frequency

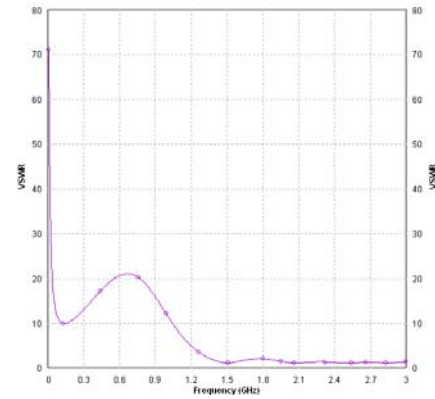


Figure 14 : VSWR versus frequency

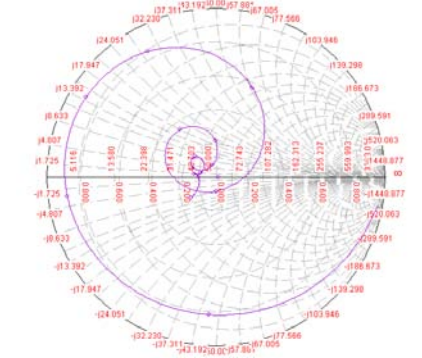


Figure 15 : Input impedance(Smith Chart) loci

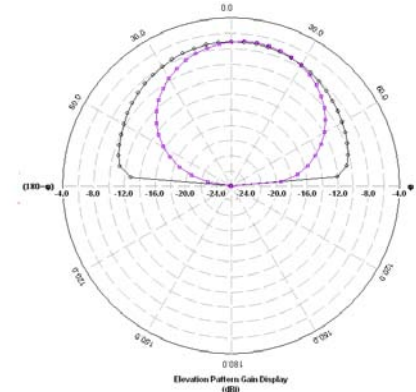


Figure 16 : Radiation pattern of E-shape microstrip antenna

V. DISCUSSION

On measurement, the proposed microstrip antenna (Fig-3) resonates at 2.46 GHz with return loss -13.5 dB and 2.886 GHz with return loss -14.7 dB (Fig-17). The measured -10 dB return loss bandwidth of antenna is 90 MHz or about 3.65% with respect to centre frequency 2.463 GHz. While on simulation, antenna resonates at 2.082 GHz with return loss -22.77 dB, 2.514 GHz with return loss -20.54 dB and 2.874 GHz with return loss -19.27 dB (Fig-13). The obtained impedance bandwidth also covers the frequency band of wireless systems.

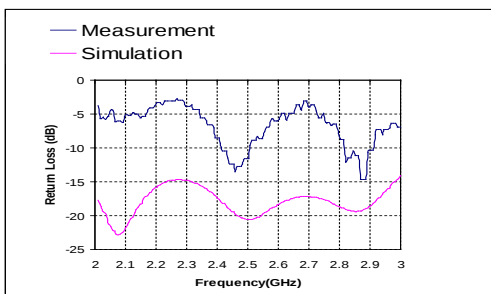


Figure 17: Simulated and measured return loss versus frequency

Through simulated and measurement analysis (figure 2- 9), we observe that the bandwidth increases when resonance frequency is greater than working frequency.

VI. CONCLUSION

Based on the theoretical, simulated and analysis of the E-shape microstrip antenna, we have discussed the size and design parameters. Then we simulated the antennas that can run at 2.5 GHz frequency and calculated its return loss by using IE3D based on Method of Moment and spectrum analyzer. Through theoretical, simulated and measured analysis, we find the bandwidth increases when resonance frequency is greater than the working frequency in microstrip antenna and the E type shape of this antenna is very helpful for the enhancement of bandwidth.

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References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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