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# Electrical and Electronic Engineering

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# Market-Neutral Portfolios: A Solution based on Automated Strategies

By Carlos A. Rodrigues & Eduardo G. Carrano
*Universidade Estadual de Feira de Santana*

*Abstract-* The equity market is known for its volatility and dependence on a number of factors that influence its trend. This characteristic inhibits many investors from entering this market, due to the fear of facing losses in their investments. A potential solution to this problem is to build portfolios that are neutral regarding their reference market. A neutral portfolio is constructed in such a way that its returns are obtained regardless of the trend, using automated trading systems (ATS). One of the advantages of these systems is that they carry out negotiations automatically, increasing speed and eliminating the emotional factor of manual negotiations. The proposed solution in this manuscript minimizes the correlation of portfolio returns with market index returns and uses the Walk Forward (WF) test for validation. Several portfolios are considered and the results demonstrate that in addition to being neutral, their returns exceeded the index returns. The best results were obtained for the portfolios that used a greater amount of automated strategies and made use of long/short trades.

*Keywords: portfolio optimization, market neutral portfolio, automated trading systems, computational finance.*

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# Market-Neutral Portfolios: A Solution based on Automated Strategies

Carlos A. Rodrigues [α] & Eduardo G. Carrano [σ]

*Abstract-* The equity market is known for its volatility and dependence on a number of factors that influence its trend. This characteristic inhibits many investors from entering this market, due to the fear of facing losses in their investments. A potential solution to this problem is to build portfolios that are neutral regarding their reference market. A neutral portfolio is constructed in such a way that its returns are obtained regardless of the trend, using automated trading systems (ATS). One of the advantages of these systems is that they carry out negotiations automatically, increasing speed and eliminating the emotional factor of manual negotiations. The proposed solution in this manuscript minimizes the correlation of portfolio returns with market index returns and uses the Walk Forward (WF) test for validation. Several portfolios are considered and the results demonstrate that in addition to being neutral, their returns exceeded the index returns. The best results were obtained for the portfolios that used a greater amount of automated strategies and made use of long/short trades.

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## I. Introduction

Automated investments began in the 70's and their importance in the market increases yearly (Haynes and Roberts, 2017; Paraná, 2017). It is estimated that on the New York Stock Exchange, more than 70% of trades are automated through ATS (Automated Trading Systems) or EA (Expert Advisors), being used by individuals, investment fund industry, and also financial institutions (Nuti et al., 2011; Kissel, 2013). In more stable economies, due to low interest rates, financial investments are concentrated in the equity market, which can provide reasonable returns. As an example, in the US alone, more than 50% of people have some investment in stocks and, in most cases, they are saving resources for their retirement (Parker and Fry, 2020). On the other hand, investment in stocks is increasingly becoming more dependent on computing resources in all its aspects due to the automation of its processes. Reinforcing this trend, ATS have the advantage of eliminating the emotional factor present in manual trading, in addition to use strategies that have already been tested and approved before being launched on the market. Studies show that investors who trade on their own in general obtain results below the market index, and, a significant part of them abandon this type of investment (Barber and Odean, 2000). Another advantage of ATS is the time saving since it is not necessary to be constantly following trades or market fluctuations. In addition, ATS can implement strategies that eliminate the factors that contribute to losses. Most manual trading strategies can be implemented automatically, eliminating the human factor. Currently, different strategies have been adopted in ATS, involving different areas, such as: computational intelligence (neural networks, genetic algorithms, machine learning, fuzzy logic, etc), technical analysis (trend followers, return to average, divergent and convergent, oscillators, etc), pattern recognition, among others (Nuti et al., 2011). However, if one of these strategies is adopted individually it can be subjected to prolonged periods of losses, known as drawdown or capital reduction. The combination of stocks in a portfolio generally contributes to the reduction of these sequences of losses (Chekhlov, Uryasev and Zabarankin, 2005). In Brazil, automation became more popular in 2014, when major brokerages started to provide platforms (Meta Trader, GrapherOC, Ninja Trader, Quantopian) with support for ATS (Folha Vitória, 2014). It is estimated that more than 40% of trading on the São Paulo Stock Exchange is carried out by ATS (Paraná, 2017).

Several people are afraid of ATS, or even stock markets, due to the higher exposure to risk. In risk theory, one of the methods to deal with this situation is diversification. Harry Markowitz, Nobel laureate in Economics in 1990 for the construction of the Portfolio Theory, proposed a strategy that involves building a portfolio composed of different assets with low correlation so that individual risk can be mitigated. Markowitz defined what became known as the efficient frontier that establishes how much of each asset will be allocated in the portfolio (Markowitz, 1952). This theory has been widely used by funding industry as a way to maximize profit and minimize risk, along with its variants. An existing problem in the application of this theory stems from the fact that the correlations are not stationary and, therefore, the stability of the portfolio may vary over time, increasing risk anyway. Another type of portfolio is the neutral portfolio, which consists of a set of financial assets that, under ideal conditions, should exhibit a yield independent of the index adopted

*Author α: Department of Exacts Sciences, Universidade Estadual de Feira de Santana, Feira de Santana, Brazil. e-mail: carod@uefs.br*
*Author σ: Department of Electrical Engineering, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil. (0000-0002-7663-8751) (orcid.org). e-mail: egcarrano@ufmg.br*



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as a reference. To obtain this result, one strategy is to carry out trades in the long and short position. In the long position, the investor buys an asset in the expectation that there will be an appreciation in price (for example, shares). If this happens, the investor will make a profit after its sale. In the short position, the investor borrows an asset and sells it in the expectation that prices will fall. After the price drop, the investor buys the asset and returns it earning a profit.

In this work, the results of the implementation of an ATS portfolio neutral in relation to the Brazilian stock market index (Ibovespa) and the dollar x Brazilian real market index (USDBRL) will be presented, trading contracts on the BMF Bovespa futures market. The choice of intraday trading was made to maintain a trend away from the daily chart. In addition, another criterion adopted was the minimization of the correlation of the daily returns of the portfolios' trading with the daily returns of the Ibovespa and the USDBRL. The main contribution of this manuscript is to introduce a methodology for obtaining market neutral portfolios by minimizing the correlation of ATS portfolio returns and the benchmark index. In addition it also shows that we can build neutral ATS portfolios and that neutral portfolios canbe profitable.

This article is organized as follows: Section 2 presents a review of the literature related to ATS, portfolios and neutral portfolios. In section 3, a formulation of the problem of implementing the neutral portfolio will be given for different combinations of ATS applied to the Brazilian stock market BMF Bovespa. Section 4 shows the computational results and in section 5, the conclusion is presented.

## II. Literature Review

The stock portfolio optimization model was proposed by Harry Markowitz (1952) in his original work "Portfolio Selection". This study supported the Modern Portfolio Theory (TMP), also known as the mean-variance model. This concept brought a revolution in the theory of finance by shifting the focus from the individual analysis of assets to diversification based on the concepts of covariance, risk, profit and their mathematical foundation. This approach seeks to identify the portfolio that provides the highest expected profit by indicating the number of shares that should be purchased for a given level of risk or the lowest possible risk for a given expected profit. Markowitz's results point to an "efficient frontier", which corresponds to a Pareto-front in the risk-return graph. One of the main elements of TMP is that risk minimization depends on the number of stocks for diversification and their low correlation.

Since TMP publication, several other portfolio optimization models have been proposed but TMP is still under use due to its ease implementation. Rosenberg et al. (2004) used the TMP to allocate portfolios with several US equity funds, for short and long-term strategies (converging and divergent), with results that contributed to decrease volatility and increase risk/reward ratio. Irala and Patil (2007) applied the TMP to the Indian stock market from 1999 to 2005 and concluded that the best diversification is obtained with a portfolio of 10 to 15 stocks for minimum risk, but recognize that this value may vary if the theory is applied in other periods. Santos and Tessari (2012) applied the TMP in several stock portfolios built from the stocks that are part of the São Paulo stock exchange index – Ibovespa. Based on different frequencies of portfolio rebalancing, they obtained statistically significant results in terms of lower volatility and risk-adjusted performance. The works by Valle et al. (2014a, 2014b, 2015, 2017) extend portfolio theory to portfolios of stocks that obtain positive returns independent of market variations.

Due to the difficulty in finding software for studying the portfolios, Prado and Bailey (2016) proposed an open-source code developed in Python that implements a version of TMP. This work contributes to the analysis of portfolio performance and the generation of its corresponding "efficient frontier". Prado (2016) also describes the instability problems of the TMP based on the fact that the correlation increases with the number of shares and develops a solution, the covariance matrix that does not need to be inverted, obtaining lower risk portfolios compared to traditional methods.

With the advances of computational intelligence, several works have been developed with the goal of optimizing stock portfolio using artificial intelligence algorithms. We can mention the use of genetic algorithms (Yang, 2006; Bao and Yang, 2008; Zainashev, 2011; Woodside-Oriakhi, Lucas and Beasley, 2011; Bermúdeza, Segurab and Vercher, 2012; Mousavi, Esfahanipour and Zarandi, 2014; Wang, Hu and Dong, 2015, Jalota and Thakur, 2018) and neural networks (Freitas, Souza and Almeida, 2009; Maknickiene, 2014; Raei and Karimi, 2014) as the most prominent techniques. On the other hand, the work by Prado, Bailey and Borweiny (2016) and Raudys et al. (2016) warn about the risk of these optimizations leading to excessive parameter adjustments (overfitting) and high correlation, becoming useless in different periods. Maknickiene (2014) highlights the importance of low covariance for risk reduction, presenting the concept of orthogonality of portfolios in the Forex market. In this work, the portfolio is built from the elements that have greater orthogonality (obtained by minimizing the covariance), selected through the predictions of the distribution of returns by a neural network, resulting in greater profits for orthogonal portfolios when compared to non-orthogonal ones.

On the other hand, the movement of stock prices has been widely studied through Technical



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Analysis (TA). Within this context, systems based on TA make use of indicators that are tested and used in order to define the beginning and end of a trade. This method assumes that the price of a share can follow trends according to investor psychology (Tanaka-Yamawaki; Tokuoka and Awaji, 2007). By repeating past patterns, a familiarity with the movement and behavior of prices can be developed, recognizing situations that may occur in the future. Through these patterns, different trading strategies can be implemented to be applied in different market trend situations. Lo, Mamaysky and Wang (2000) automated the identification of 10 patterns in US stock prices in the period from 1962 to 1996 and obtained promising statistical results. TA is based on three principles: the first is that price discounts everything, which allows you to disregard why prices move in a certain direction, but only to know their movement behavior. The second principle is that price has a trend. Thus, the price behaves according to the investors' position, but always obeying an uptrend, a downtrend, or having a non-trending behavior. Finally, the third principle considers that history repeats itself because the market is driven by the emotional behavior of people, who, in turn, have fears and anxieties, in a perspective of losing or winning (Murphy, 1999).

Computational intelligence has also been used to predict the movement of asset prices. Lin, Yang and Song (2011) used genetic algorithms to learn the trading rules of Technical Analysis and suggest the ideal moments for buying or selling a share. The developed system surpassed the S&P500 index of the New York Stock Exchange, in up or down trends, in the period from 2000 to 2005. Oliveira et al. (2013, 2014a, 2014b) used TA, linear regression and neural networks to trade in high-frequency trading (HFT) generating buy and sell signals for the same day in the Brazilian stock market. These systems are characterized by the high rate of volume and frequency of trades. The best results were obtained on the 5-minute time scale, which allows to send a big number of orders and increases market liquidity.

In addition to produce buy and sell signals, complete trading systems have been developed with the ability to perform all stages of the process automatically, not only generating the signals but also sending trading orders to the market and managing risk. These algorithms, that act directly on the broker's signal, are called ATS – automated trading system or EA – expert advisors (Nuti et al., 2011). Several works have been carried out for the development of ATS, considering the growing interest in the scientific/academic environment. Pimenta et al. (2017) proposed an ATS that brings a combination of genetic programming and Technical Analysis rules, applied to the Brazilian stock market from 2013 to 2016. This system was tested on the historical price series of six companies representing the Brazilian market, obtaining results higher than individual stock price changes over the same period. Neural networks are also being used for the development of automatic trading systems. Vanstone and Finnie (2009) present a methodology describing the steps involved in creating the neural network for use in the stock market and that adapts to real-world constraints. Another ATS that combines indicators from Technical Analysis was developed by Teixeira and Oliveira (2010). The strategy was applied to the Brazilian market and compared with the buy and hold (BH) method, with better results than BH in 12 of the 15 stocks analyzed in the experiment. The BH method consists of simply buying stocks of one or more companies without selling them during the entire period. The investment profit will come solely from the appreciation of the individual shares. Many strategies that involve successive purchases and sales are compared to the result of the BH method applied to the same actions in order to verify if the method brings any advantage. Creamer and Freund (2010) developed an ATS that applies machine learning, an online learning algorithm to a money management layer, which can be used with multiple market actions. One of the advantages of this approach is that the algorithm is able to select the best parameters from technical indicators. In addition, the online algorithm suggests whether to buy or sell the trade. Money management will validate whether it is possible to send the order or not. The ATS was applied to the data of 100 randomly selected stocks in the New York stock market during the period 2003 to 2005. The returns generated exceeded the market index returns.

An architecture for testing past quotes and automatic trading was proposed by Koors and Page (2011). This simulator was successful implementing simultaneous trading strategies and also making the direct connection with the real market. Ibrahim (2014) has been developing a system called GeneticForex, whose main objective is to generate strategies for an ATS portfolio with application in the Forex market. Evolutionary algorithms are used to generate several strategies but the system was not capable of eliminating redundant strategies. Among the future works is the creation of a portfolio of efficient ATS for trading with adaptive configurations in real time, where trading volumes are determined according to previous performance and that communicate with each other. Works that present studies of ATS portfolios are still rare. Treleaven, Galas and Lalchand (2013) provide an overview of the main concepts involved in the development of ATS, describe an architecture for a portfolio of different strategies and an implementation proposal. Some questions are left open, bringing numerous research perspectives to the future, such as: selection of the best computational statistics and machine learning algorithms, how news can be used to forecast market movements, ATS interaction algorithms and the market, high-performance computing and



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latency issues in negotiations and the use of new hardware. In this line, the works of Raudys and Raudys (2011, 2012), Raudys, Raudys and Pabarskaite (2012) and Raudys (2013) are also highlighted, who carry out the optimization of stock and HFT portfolios through the analysis of trading histories. One of the objectives of these studies is to determine what weights each ATS should have in the portfolio through the covariance matrix, using a two-stage multi-agent system for decision making. Their experimental results based on the out-sample validation methodology using the Walk-Forward steps applied to the US market from 2002 to 2012 confirm the effectiveness of the approach used, surpassing the original Markowitz model. A limitation presented in this study was the increase in the correlation of the system with the increase in the number of ATS. One challenge presented was the need to develop adaptive algorithms that take into account market changes.

Relatively few works address the implementation of neutral portfolios. With this objective, Ganesan (2011) applied the regression of the returns of individual stocks against several factors. They adopted Markowitz's (1952) mean-variance approach to portfolio development where they set the portfolio's exposure to these factors to be zero. Kwan (1999) also used a regression of stock returns against market returns, viewing the market-neutral portfolio as one where the weighted parameters of the regression in relation to the slope are equal. They formed a portfolio subject to this constraint by maximizing the Sharpe ratio indicator (1994). Pai and Michel (2012) used the regression of stock returns against market returns and viewed the neutral portfolio as one in which the weighted parameters of the regression in relation to the slope are nonlinearly related. In this work, the Markowitz mean-variance approach was also used to build a portfolio with a risk based on a nonlinear constraint. Valle (2014a) obtains neutral portfolios on a base of more than 1200 US stocks and a model based on minimizing the correlation of portfolio returns and S&P500 index, with results that outperform the regression-based approach with long and shorts.

## III. Problem

*a) Presentation*

A neutral portfolio is a portfolio that ideally has zero correlation with the market. In order to define which ATS will be part of this portfolio, we adopted the nonlinear model proposed by Valle (2014a), which minimizes the correlation of the returns of the ATS portfolio in relation to the returns of the reference market will be applied.

In sequence, the notation, constraints, and objective function considered are presented. The model uses trades generated by the trading strategies of intraday and daily long and long/short contracts on the BMF Bovespa future market.

*b) Notation*

Given the returns of the *N* ATS strategies and *T* time intervals *0,1,2,…, T,* the goal is to select the best set of *K* strategies (where *K* <= *N)*, and their weights.

Let:

$I$ indexes the portfolios
$T$ indexes the time intervals
$Vit$ is the value/margin (price) of a contract *i* at time *t*
$lpit$ is the profit/loss of strategy *i* at time *t*
$Ct$ *is the* value of portfolio capital at time $t = 0,\ldots, T$
$Co$ is the net capital of the portfolio at time $t = 0$
$It$ is Ibovespa value at time *t*
$Rt$ is one-period return for the Ibovespa at time *t*, i.e. $R_t = ln(I_t/I_{t-1})$
$\bar{R}$ *is the* average index return, ie $\bar{R} = \sum_{t=1}^{T} \frac{R_t}{T}$

*The decision variables are:*

$x^L_i$, $x^S_i$ the number of units (>=0) of strategies that will be held in long or short positions. In our approach, the integer constraint is relaxed and the continuous values are rounded to the closest integer value. Although this strategy is not optimal, it suitable to approximate problem solutions (Hillier and Lieberman, 2015), with polynomial computational complexity.

*c) Objective Function*

According to the definition adopted, the neutral portfolio must maintain a correlation between its returns and the return of the index equal to or close to zero. The correlation result is comprised within a closed interval [-1, +1]. For the definition of the model, the following additional variables will be defined:

$p_t$ neutral portfolio log return at time $t = 1, \ldots, T$
$\bar{p}$ neutral portfolio average return

*These variables are defined by the expressions:*

$$C_t = C_o + \sum_{i=1}^{K} x^L_i V_{it} + \sum_{i=1}^{K} x^S_i V_{it,} + \sum_{i=1}^{K} x^L_i lp_{it} + \sum_{i=1}^{K} x^S_i lp_{it,} \quad t = 0,\ldots, T \tag{1}$$

$$p_t = \ln(C_t/C_{t-1}), \quad t = 1,\ldots, T \tag{2}$$

$$\bar{p} = \sum_{t=1}^{T} p_t/T \tag{3}$$

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The eq. (1) demonstrates that at a given time the portfolio has a part of the capital $\sum^{K}_{i=1} x^{L}_{i} V_{it}$ in long positions and the other part $\sum^{K}_{i=1} x^{S}_{i} V_{it}$, in short positions, a net available capital $C_0$ and a floating part $\sum^{K}_{i=1} x^{L}_{i} lp_{it} + \sum^{K}_{i=1} x^{S}_{i} lp_{it}$, related to profits/losses. The eq. (2) defines the log-returns and eq. (3) to the average return.

In the model adopted to obtain the neutral portfolio, the objective is to minimize the correlation between the daily return of the portfolio and the daily return of the indices. This operation can be defined by the expression (4):

$$\text{minimize} \left| \frac{\sum_{t=1}^{T}(p_t-\bar{p})(R_t-\bar{R})}{\sqrt{\sum_{t=1}^{T}(p_t-\bar{p})^2 \sum_{t=1}^{T}(R_t-\bar{R})^2}} \right| \quad (4)$$

This minimization is subject to the constraints given in Eqs. (1–3).

*d) Constraint on In-sample Returns*

The model presented aims to obtain zero correlation between the return of the portfolio and in relation to the return of the index, but it does not intend to guarantee profit or exceed the return of the index in the period. To improve the results of the portfolio's in-sample return (which will not necessarily guarantee out-sample returns), the following constraint can be added:

$$\bar{p} \geq \bar{R} \quad (5)$$

This constraint ensures that the average return on the portfolio will be at least equal to the index return.

## IV. Computational Results

In this section, the computational results for performing the calculations applied to the returns of neutral portfolios will be presented. The algorithm was executed in a MacBook Air computer with an Intel Core i5 processor, 1.7 GHz, with 4 GB of RAM, with MacOS. The code was written in Python, using the Jupiter Notebook platform. The Python language is opensource and has several libraries for statistical treatment and finance (Seabold and Perktold, 2010), which motivates this use. The function corr from the Pandas library was used to calculate the correlation by Pearson's method and the minimize function from the SciPy library was used to perform the minimization, according to(4) and subject to the constraint(5) in some cases.

*a) Data and Methodologies*

In this work, historical data from 30 ATS based on TA (oscillators and trend following), developed by company Metarobôs were considered, Such a data covers the period from January 2015 to December 2018. The data mostly correspond to intraday (day trade) and daily trades, with each trade involving two mini-contracts of the BMF Bovespa (WIN) or dollar (WDO) index. The history corresponds to a total of 18,609 trades. This data was chosen because it was generated using a known and reliable trading strategies (white box).

The methodology adopted for the analysis is known as Walk Forward, developed by Robert Pardo (Pardo, 2008). It involves optimizing a portfolio in a period, called in-sample (IS), and applying the optimal solution obtained to the out-sample (OS) set. Fig. 1 represents the IS intervals in yellow and the OS intervals in green.

| H | 2015.1 | 2015.2 | 2016.1 | 2016.2 | 2017.1 | 2017.2 | 2018.1 | 2018.2 |
|---|---|---|---|---|---|---|---|---|
| IS/OS | | | | | | | | |
| IS/OS | | | | | | | | |
| IS/OS | | | | | | | | |
| IS/OS | | | | | | | | |
| IS/OS | | | | | | | | |
| IS/OS | | | | | | | | |
| IS/OS | | | | | | | | |

*Fig. 1:* Periods for the Walk Forward methodology

Initially, the interval of H = 6 months was adopted for both IS and OS. The value of C = 100,000.00 was considered for the initial capital. For each period, the daily returns of the portfolio, obtained through trades of the different daytrade and daily strategies, are accounted for. These returns are compared to Ibovespa's daily returns to minimize correlation. The minimization result applied to the IS history will define the new weights to be applied to the IS and OS period history strategies. The analysis also involves the composition of portfolios with only long trades, only trades with WDO contracts, and only trades with WIN contracts. A comparison of the results of the indices with the ATS portfolios, without optimization, was also made.

*b) Results without Optimization*

Tables 1 and 2 shows the results of ATS trades without optimization, using only TA, for three portfolios. The first involves all 30 strategies (16 of WIN and 14 of WDO), the second with only 16 of WIN and the third with 14 strategies of WDO. The first two were compared with the Ibovespa and the third with the USDBRL. The three



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portfolios were analyzed based on long and long/short trades. For this analysis, the WF methodology was not applied, since there was no optimization. Each trade always involved two contracts (WDO or WIN) and the objective was to compare the results of the combined strategies with their respective indices.

Correlation results indicate that long portfolios with fewer strategies have positive correlation with their respective indices. The correlation is close to zero when it involves the 30 strategies in the three long/short portfolios. It indicates that with the increase of different strategies in the portfolios and the addition of short operations, the correlation with the market tends to decrease. In all portfolios, there was excess return in relation to the index, lower volatility and higher value for the Sharpe ratio (return/standard deviation ratio). These results demonstrate that ATS strategies were more profitable than market indices, presenting a better return vs. risk ratio. This form of diversification already guarantees independence from the market. In the next sections, correlation minimization will be used to define the weights of strategies in portfolios.

*Table 1:* Summary of results without optimization – Long (H = 6)

| Index | Portfolio (N) | Correlation | Return | Excess | vol. Port. | vol. Index | Sharpe Port. | Sharpe Ind. |
|---|---|---|---|---|---|---|---|---|
| Ibov | 16WIN-14WDO | 0,09 | 0,32 | 0,18 | 0,01 | 0,05 | 6,3 | 2,8 |
| Ibov | 16WIN | 0,5 | 0,19 | 0,05 | 0,01 | 0,05 | 3,7 | 2,8 |
| USDBRL | 14WDO | 0,44 | 0,23 | 0,17 | 0,02 | 0,03 | 7,9 | 2,0 |
| | average | 0,34 | 0,25 | 0,13 | 0,01 | 0,04 | 5,97 | 2,53 |

*Table 2:* Summary of results without optimization - Long/Short (H = 6)

| Index | Portfolio (N) | Correlation | Return | Excess | vol. Port. | vol. Index | Sharpe Port. | Sharpe Ind. |
|---|---|---|---|---|---|---|---|---|
| Ibov | 16WIN-14WDO | -0,03 | 0,5 | 0,36 | 0,02 | 0,05 | 10,0 | 2,8 |
| Ibov | 16WIN | -0,04 | 0,34 | 0,2 | 0,01 | 0,05 | 6,8 | 2,8 |
| USDBRL | 14WDO | -0,04 | 0,36 | 0,3 | 0,02 | 0,03 | 12,0 | 2,0 |
| | average | -0,08 | 0,4 | 0,29 | 0,02 | 0,04 | 9,6 | 2,53 |

*c) Out-sample Results*

Tables 03 and 04 shows the OS results for two conditions, long and long/short respectively, for each analyzed portfolio. The correlation column provides the average correlations obtained in the seven applications of the WF method. The same applies to the Return, Excess, Volatility and Sharpe Ratio columns. The Excess column indicates how much the OS optimized portfolio outperformed the index average. Volatility is given by the standard deviation of the returns and the Sharpe ratio is obtained by the return/standard deviation ratio. In the last line, the average of each column is presented.

The most significant results in this modeling are those obtained in the OS simulation, since the IS results are only intended to obtain the weights that minimize the correlation in order to be applied in the OS intervals.

Comparing the non-optimized results (Tables 01 and 02) with the optimized OS results (Tables 03 and 04), it is observed that the values optimized achieved a reduction achieved a reduction in the average correlation from 0.34 to 0.14 for the long data and for the long/short data it remained practically stable close to zero, that is, without correlation in relation to to the indices. It can be seen that long/short trades have lower correlation averages compared to long trades. This demonstrates that this combination of trades contributes to increasing the neutrality of the portfolio in relation to the market. Analyzing the returns, it is observed that the average excess of the long portfolios increased from 0,13 to 0.46 and for the long/short portfolios from 0.29 to 1.03. Taking into account the number of strategies in each portfolio, the WIN only portfolio has 16 strategies, the WDO portfolio has 14 strategies, and the WINWDO portfolio has 30 strategies. When analyzing the influence of the number of strategies, it is observed that the portfolio with more strategies WINWDO obtained higher excess return and lower correlation in relation to the indices than the other portfolios with fewer strategies. This occurs both with long trades and also with long/short trades. These results show that the best results are obtained by increasing the diversity of strategies, including long/short operation. Also, all OS portfolios achieved a decrease in correlation and an increase in Sharpe compared to the respective portfolios without optimization.



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*Table 3:* Summary of out-sample results – Long (H = 6)

| Index | Portfolio (N) | Correlation | Return | Excess | vol. Port. | vol. Index | Sharpe Port. | Sharpe Ind. |
|---|---|---|---|---|---|---|---|---|
| Ibov | 16WIN-14WDO | 0.03 | 0.81 | 0.66 | 0.13 | 0.05 | 15.9 | 2.8 |
| Ibov | 16 WIN | 0.22 | 0.2 | 0.06 | 0.13 | 0.05 | 3.9 | 2.8 |
| USDBRL | 14WDO | 0.17 | 0.7 | 0.65 | 5.26 | 0.03 | 25.0 | 2.0 |
| | average | 0.14 | 0.57 | 0.46 | 1,84 | 0.04 | 14,9 | 2.5 |

*Table 4:* Summary of out-sample results – Long/Short (H = 6)

| Index | Portfolio (N) | Correlation | Return | Excess | vol. Port. | vol. Index | Sharpe Port. | Sharpe Ind. |
|---|---|---|---|---|---|---|---|---|
| Ibov | 16WIN-14WDO | -0.03 | 1.25 | 1.11 | 0.15 | 0.05 | 24.5 | 2.8 |
| Ibov | 16 WIN | 0.02 | 1.18 | 1.04 | 0.21 | 0.05 | 23.6 | 2.8 |
| USDBRL | 14WDO | -0.04 | 1 | 0.94 | 0.2 | 0.03 | 35.7 | 2.0 |
| | average | -0.02 | 1.14 | 1.03 | 0.19 | 0.04 | 27,93 | 2.5 |

*d) Variations*

Tables 5 and 6 consider the effect of including additional variations in the portfolio in the IS optimization to examine their reflections on the OS results. The constraint (5) was included in the IS period and the H interval was also reduced from 6 to 3 months. N = 30 (16 WIN and 14 WDO) was maintained for the number of strategies in the portfolios, with no comparison being made with the USDBRL index, only with the Ibovespa index. Since the IS periods are intended for optimization, only the OS results will be analyzed, in tables 5 and 6.

Adding constraint (5) with H = decreased the return index in the long/short portfolio but an increase in the excess in the long portfolio. On the other hand, decreasing the periods H to 3, there is an increase in excess return, Sharpe ratio, and volatility, in the long and long/short portfolios. The correlation increased in the long portfolio and remained close to zero in the long/short portfolio. Such results suggest that the narrowing of the WF range better captures short-lived market patterns.

*Table 5:* Summary of out-sample results - Long - N = 30

| Index | Correlation | Return | Excess | vol. Port. | vol. Index | Sharpe Port. | Sharpe Ind. | H | Restriction |
|---|---|---|---|---|---|---|---|---|---|
| Ibov | 0.03 | 0.81 | 0.66 | 0.13 | 0.05 | 15.9 | 2.4 | 6 | |
| Ibov | 0.03 | 0.99 | 0.85 | 0.13 | 0.05 | 19.4 | 2.4 | 6 | $\bar{p} \geq \bar{R}$ |
| Ibov | 0.15 | 1.05 | 0.9 | 0.25 | 0.05 | 21.4 | 2.4 | 3 | $\bar{p} \geq \bar{R}$ |

*Table 6:* Summary of out-sample results – Long/Short

| Index | Correlation | Return | Excess | vol. Port. | vol. Index | Sharpe Port. | Sharpe Ind. | H | Restriction |
|---|---|---|---|---|---|---|---|---|---|
| Ibov | -0.03 | 1.25 | 1.11 | 0.15 | 0.05 | 24.51 | 2.4 | 6 | |
| Ibov | -0.02 | 1.05 | 0.9 | 0.13 | 0.05 | 21.0 | 2.4 | 6 | $\bar{p} \geq \bar{R}$ |
| Ibov | -0.02 | 2.3 | 2.16 | 0.66 | 0.05 | 46.9 | 2.4 | 3 | $\bar{p} \geq \bar{R}$ |

## V. Conclusions

This work addressed the problem of implementing a neutral portfolio in relation to the BMF Bovespa market, using 30 trading strategies carried out by ATS in intraday and daily operations, in long and long/short positions. The model performs the minimization of the correlation of the daily returns in the IS period to obtain the weights of the strategies that will be applied in the OS period.

The strategies adopted are based on Technical Analysis and applied in the BMF Bovespa future market, trading Ibov index and dollar mini-contracts (WIN and WDO). The IS results obtained correlations close to zero in most cases in relation to their indexes and when applied in the OS period, an increase in the correlation was noted for long portfolios but close to zero in the long/short portfolios. In all OS portfolio combinations, returns outperformed the index.



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The results indicate that it is possible to obtain neutral portfolios by combining several ATS, proving to be an alternative option in relation to the funds available in the market. The model can be improved by adding more ATS to the portfolio with different strategies and involving other markets.

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*Competing Interests*

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*Author Contributions*

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Carlos A. Rodrigues. The first draft of the manuscript was written by Carlos A. Rodrigues and both authors commented and revised it critically for important intellectual content on previous versions of the manuscript. Both authors read and approved the final manuscript.

*Data Availability*

The data that support the findings of this study are available from Metarobos but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Metarobos. Additionally, we cannot apply an open licence to our dataset.

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# Pulse Resonance Active-Power Amplifier. Offer and Justification of Workability

By Yu. V. Batygin, S. O. Shinderuk & E. O. Chaplygin

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*Purpose:* The purpose of the work is to propose and justify the workability of a pulsed resonant amplifier of active electric power, consisting of two series contours with common capacitive energy storage, including analysis and numerical assessments of the main characteristics of ongoing electromagnetic processes.

*Formulation of the Problem:* This work was initiated by the current energetics needs, due to the depletion of natural resources and the rapidly growing needs of the world economy.

*Keywords:* *harmonic signals, series circuits, voltage resonance, pulse mode, active electric power amplification.*

*GJRE-F Classification:* *DDC Code: 621.3827 LCC Code: TK8320*


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# Pulse Resonance Active-Power Amplifier. Offer and Justification of Workability

Yu. V. Batygin [α], S. O. Shinderuk [σ] & E. O. Chaplygin [ρ]

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***Formulation of the Problem:*** This work was initiated by the current energetics needs, due to the depletion of natural resources and the rapidly growing needs of the world economy.

***Methodology:*** When deriving the main analytical relationships to justify the fundamental possibility of resonant amplification of active electric power, it turned out to be sufficient to confine ourselves to the proposal and study of an amplifier circuit with a single excitation of a current pulse in the load. The mathematical apparatus of research is a set of provisions and methods for calculating transient processes in electrical circuits with active-reactive elements.

***Novelty:*** For the first time, with a theoretical and experimental justification of the workability, a circuit of a pulsed amplifier of the active electrical power of a harmonic signal was proposed, consisting of two series contours with common capacitive storage. The first of them is a reactive power amplifier, and the second is a converter of reactive power into active power released when the excited current flows in any electrical load.

***Main Results:*** With the justification of capacity, a circuit of a pulsed resonant active electric power amplifier is proposed, consisting of two series circuits with common capacitive energy storage. Analytical dependencies are obtained for the main characteristics of the ongoing electromagnetic processes and it is shown that the phenomenon of voltage resonance allows one to achieve an increase (by more than an order of magnitude!) in the active power of a harmonic voltage source. Based on the analysis, numerical estimates, and experimental testing, the workability of the proposed circuit of a pulsed resonant amplifier of active electric power is substantiated.

***Practical Significance:*** A method for resonant amplification of the active electric power of harmonic signals is proposed. On a practical example, indicating the specific values of the circuit elements, its workability is illustrated. The results obtained can be used as the basis of a real technical device for obtaining resonant electrical energy from the surrounding space.

*Author σ: e-mail: s.shinderuk.2016102@ukr.net*

*Keywords: harmonic signals, series circuits, voltage resonance, pulse mode, active electric power amplification.*

## I. Introduction

The expert estimates of the growing need in power resources are convincing in the multiple works of the International Energy Agency that has been fairly recognized for reliability of various forecasts on the global economic development. The prospective analysis results discussed at the relevant global forums specifically point out the development of the electric-power industry as a prerequisite for successful solving the tasks of the modern scientific-technical progress. According to the thought leaders, by 2060, the share of electricity in all end-consumption sectors will have to increase by more than twice [1]. In the background of the depleted natural resources, the so-called alternative power sources become rather important and significant. The known developments include wind generators, solar cells, gravity-driven systems, etc. However, their multiple advantages do not surpass the limited practical use of such sources that is, primarily, due to low productivity and considerable dependence on climatic conditions.

Along with the given offers on using the Earth and Sun energy, the studies of resonance phenomena are becoming more relevant, this may provide for considerable increase in the power output of technical systems of specific purpose.

Resonance, as a key to the “energy burst” in oscillatory systems of any physical nature, was first noted in the works by Nikola Tesla. Based on this idea, he created an “Apparatus for producing electric currents of high frequency and potential” (1896) with extra high voltage conversion ratio ($k>1000$) [2]. The ideas of N. Tesla were then developed in a number of scientific articles and monographs [3-7].

Thus, in work [3], electric oscillations are excited by the sea-waves energy conversion. The authors of the cited work substantiated the usability of the offer and showed that this was in the resonant mode of the circuit designs with the resistance-reactance components where considerable increase in the power output took place.

The work [4] offered the resonance switching of several power sources and loads to be used in the integrated power supply systems. According to the authors, the main advantage of such decision is, first of



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all, significant savings of power resources due to loss reduction in the resonant modes.

The resonance power converters of the solar cells in the space vehicles are described by the authors of the work [5]. The specific character of the performed study is the impact of vacuum on the output characteristics of the electrical equipment with resistance-reactance components in the resonant mode.

The works [6, 7] can be combined by identical from the physical point of view approaches to creation of resonance reactive-power amplifiers. This, the Ukrainian patent [6] protects the circuit design solution, where the series parallel *RLC*-circuits are switched into the circuit of the high-frequency sine voltage source. According to the author, the multiple reactive power increase of the output signal should be in the regime of the current resonance. The other approach to the same task is offered in the work [7]. It offers the idealized circuit design with two inductive coupled series resonant circuits. The idealization with zero active resistance of the output circuit shows possible considerable increase in the reactive power of the harmonic output signal. The general disadvantages of the last offers are essential difficulties in their usability.

The work [8] is devoted to the creation of the resonance reactive-power amplifier that offers a scheme with real series contours and adjustable inductive coupling between them. The authors conducted the theoretical analysis of the existing processes and, in contrast to the previously cited works [6, 7], the successful practical approbation of the amplifier model version was implemented. The opportunity of the reactive power amplification by more than ~ 33÷35 times was demonstrated by experiment.

As to the usability of the mentioned developments, for example, the magnetic pulse attraction of thin-wall metals being the basis for the modern repair technology of the body components of vehicles can be referred to [9]. Introduction of the resonance amplifier as an element of the electrical circuits for the capacitor storage charge and the discharge to the attraction tool winding will provide for meeting the basic requirements for the modern processing technologies [10, 11].

The next step to solve the problems of the modern electric-power industry is the creation of the harmonic-signal active-power amplifiers. Such devices can operate in the single excitation mode of the current pulse in a load or in the mode when the current in the load is represented as the continuous subsequence of the recurring signals.

The purpose of the work is to propose and justify the workability of a pulsed resonant amplifier of active electric power, consisting of two subsequent contours with a common capacitive energy storage, analysis of ongoing electromagnetic processes and numerical estimates of their main characteristics.

## II. Subject of Investigations. Problem Statement

This paper is offering and studying the electrical scheme of the amplifier with single excitation of the current pulse in the load what is quite sufficient for substantiation of a practical possibility of the resonant of the active electrical power amplification.

*a) Electrical Circuit, Principle of Operation*

Fig. 1a shows the electrical circuit of the pulse resonance active-power amplifier. It consists of two series circuits with common capacitor storage $C$.

Circuit 1 is a subsequent $R_1L_1C$-contour ($L_1$ – inductance, $R_1$ – active resistance of conductors, including inductor winding). In the voltage resonance mode, the capacity $C$ is charged till the specified voltage level $U_{C0}$. The stored electric energy will be equal to $W_0 = \left(C \cdot U_{C0}^2\right)/2$ (Fig. 1b).

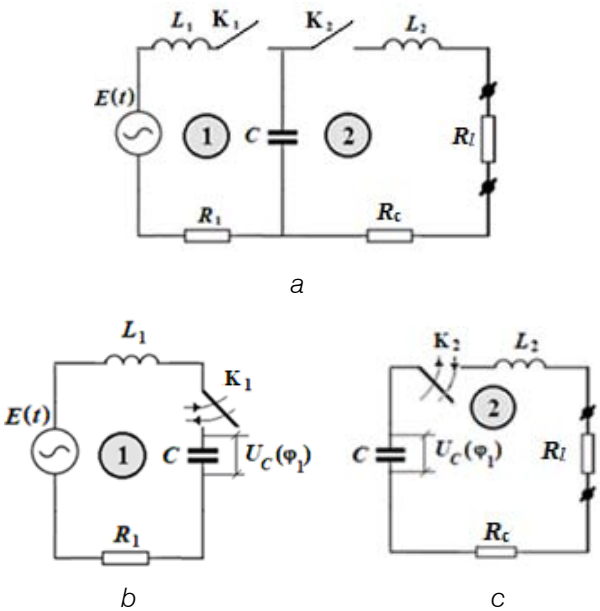


*Fig. 1:* Electrical circuit of the pulsed resonance amplifier of the active electrical power (a); the series contour of the harmonic-signal reactive-power amplification (b); the series contour with the active load of the amplifier – $R_l$ (c)

Circuit 2 is the active-reactive $R_2L_2C$-contour ($L_2$–inductance, $R_2$– total active resistance of all contour elements, $R_2=R_c+R_l$, $R_c$,$R_c$ – active resistance of the conductors, including inductor winding, $R_l$– active load of the amplifier). In the voltage resonance mode, the charged capacity $C$ is generating the active power in the load – $R_l$(Fig. 1c).

The pulsed operation mode of the proposed resonance power amplifier is implemented by single

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changeover of switches $K_{1,2}$ in the circuits. With the closed loop circuit $K_1$ and open circuit $K_2$, the capacitive storage $C$ is charged to the specified voltage level (Fig. 1b). Should mark in contrast to the known chargers [6, 9, 10], the proposed series contour, in the voltage resonance mode, provides for charging the capacity to the voltage that considerably exceeds the source voltage (by the number of times being equal to the tuned-circuit Q-factor). Further on, the switch $K_1$ opens, and the switch $K_2$ closes. The capacity $C$ is discharged to the active load $R_l$(Fig. 1c).

From the physical point of view, series contour 1 is the reactive power amplifier [6, 8], and contour 2 is the reactive-to-active power converter.

*b) Problem Formulation*

- Own resonant frequencies of the first and second circuits are – $\omega_1 = 1/\sqrt{L_1 \cdot C}$ and $\omega_2 = 1/\sqrt{L_2 \cdot C}$, respectively.
- The circuit 1 is excited by harmonic voltage $E(t)=E_m \cdot \sin(\omega_1 \cdot t)$, with the frequency being equal to own frequency of the first series circuit $\omega_1$ and amplitude $E_m$ ($t$ – time).
- The charge circuit 1 Q-factor should be quite large ($Q_1=(\omega_1 \cdot L_1)/R_1 >> 1$), to ensure minimum power loss and maximum possible voltage capacity $C$.
- The discharge circuit 2 Q-factor ($Q_2=(\omega_2 \cdot L_2)/R_2$ –var) in accordance with the charge circuit 1 Q-factor should ensure maximum possible active power amplification in the load $R_l$.
- We suppose that the load resistance is much more than the resistance of the other discharge circuit elements, thus, $R_l >> R_c$ and $R_2 \approx R_l$.
- Corresponding to the operation principle of the proposed scheme of the amplifier of the active power, the theoretical description of its operation provides for considering the transition processes in each of its individual contour.

## III. Design Ratios, Qualitative Analysis

*a) Charge circuit 1 of the capacitive storage C (Fig. 1b)*

In the Laplace image space, the equation of the state relative to the voltage on the capacitive storage at the zero initial conditions is as follows [7, 12]:

$$p^2 U_C(p) + 2\delta_1 \cdot pU_C(p) + \omega_1^2 \cdot U_C(p) = \omega_1^2 \cdot E(p), \quad (1)$$

where $p$ – is a variable in the Laplace space, $U_C(p)=L\{U_C(t)\}$, $U_C(t)$ – is the voltage on capacity, $\delta_1=R_1/2L_1$ – is the attenuation factor, $E(p)=L\{E(t)\}$, $E(t)$ – is the harmonic voltage of the source.

According to the problem statement made, the energy dissipation in the charge circuit is minimum that means sufficient small value of the relative attenuation factor $\delta_{10}=\delta_1/\omega_1=1/2Q_1<<1$ and provides for neglecting the second-order additive components relative to value $\sim \delta_{10}$.

In this case, the voltage original across capacity $C$, as it follows from equation (1), with the involved time dependence for exciting voltage of the source $E(t)$, will be described by expression [12]:

$$U_C(t) = E_m \omega_1 \int_0^t e^{-\delta_1 \cdot (t-x)} \sin\left(\omega_1 (t-x)\right) \sin(\omega_1 \cdot x)\, dx \quad (2)$$

After calculating the integral in (2), neglecting the $\sim \delta_{10}^2$ – order additive components and introducing a new variable $\phi = \omega_1 t$ – the excited signal phase, we obtain that

$$U_C(\varphi) \approx -E_m \cdot Q_1 \cdot \left(1 - e^{-\frac{1}{2 \cdot Q_1} \cdot \varphi}\right) \cdot \cos(\varphi) \quad (3)$$

The current in circuit 1 is determined by differencing the ratio (3) [7, 12]. Considering the voltage resonance condition $Q_1=(\omega_1 \cdot L_1)/R_1=1/(\omega_1 \cdot C) \cdot R_1$ when neglecting the $\sim 1/2Q_1$ values, we obtain that

$$J_1(\varphi) = (\omega_1 \cdot C) \cdot \frac{dU_C(\varphi)}{d\varphi} \approx \frac{E_m}{R_1} \cdot \left(1 - e^{-\frac{1}{2 \cdot Q_1} \cdot \varphi}\right) \cdot \sin(\varphi) \quad (4)$$

The reactive power of the signal in the capacity $C$ is determined as the product of expressions (3) and (4) [12].

$$P_1(\varphi) \approx -\frac{E_m^2}{R_1} \cdot \frac{Q_1}{2} \cdot \left(1 - e^{-\frac{1}{2 \cdot Q_1} \cdot \varphi}\right)^2 \cdot \sin(2\varphi) \quad (5)$$

As it follows from (5), in the established mode at $\varphi >> 1/2Q_1$ the amplitude ratio of the power output of the charge circuit to the power input of the voltage source is proportional to $Q_1$ that evidences the reliability of the ratios obtained for voltage, current and power.

The reactive power amplification ratio, as the relation module of the capacity power (5) to the voltage source power, will be described by the following dependence:

$$\left|\frac{K_1(\varphi_1)}{0,5 \cdot Q_1}\right| = \left|\frac{P_1(\varphi_1)}{P_{0m}}\right| = \left|\left(1 - e^{-\frac{1}{2 \cdot Q_1} \cdot \varphi_1}\right)^2 \cdot \sin(2 \cdot \varphi_1)\right|. \quad (6)$$

*Note:* Power amplitude of the voltage source with the voltage resonance in the series contour of charge is $P_{0m} = E_m^2 / R_1$.

The qualitative illustration of the obtained dependences of the charge voltage and the reactive power amplification ratio from the power source voltage



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phase till the moment of the charge finish for the charge circuit with the Q-factor of $Q_1$=5.0 is given in Fig. 2.

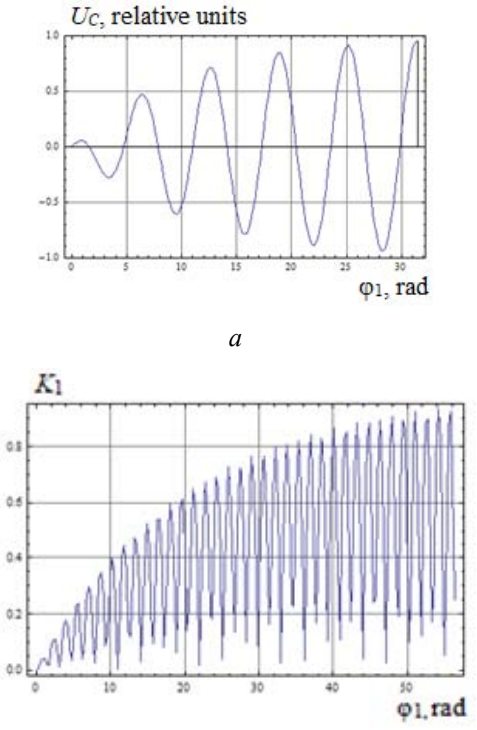


*Fig. 2:* Capacity charge voltage (a) and reactive power amplification ratio (b) ($\phi_1$ – phase at the time of the charge finish)

As it follows from the dependences in Fig. 2, the first maximum of the charge voltage is ahead of the amplification ratio maximum. Thus, we have $U_C \approx 1.0$ at $\phi_1 \approx 32$ rad., while $K_1 \approx 0.8$ with the same phase value when the charge finish (time moment the circuit opening!). That is, in this resonant circuit, the energy accumulation also continues after the first maximum of the charge voltage. The reactive power amplification ratio can reach maximum only at the circuit opening time that correspond to the positive or negative maximums of the charge voltage.

*b) Discharge unit 2 of the capacitive storage C (Fig. 1b)*

At the charge circuit opening time and the discharge circuit closing time, the voltage of the capacitive storage, as it follows from (3), will be determined by the dependence:

$$U_{C0} = U_C(\varphi_1) = -E_m \cdot Q_1 \left(1 - e^{-\frac{1}{2 \cdot Q_1} \cdot \varphi_1}\right) \cdot \cos(\varphi_1), \quad (7)$$

It is of practical interest to consider the modes when the circuit can have no inductance ($L_2$=0), that is, the capacity is discharged directly to the active load or when the active load is connected via the solenoid with the fixed inductance value ($L_2 \neq 0$).

i. *Capacitor discharge to active load ($L_2$=0)*

We suppose that the aperiodic capacitor discharge starts immediately upon charge finish. The current in the active load considering (7) will be described by the following dependence [7, 12]:

$$J_2(\varphi) = J_2(\varphi) = \frac{E_m \cdot Q_1}{R_2} \left(1 - e^{-\frac{1}{2 \cdot Q_1} \cdot \varphi_1}\right) \cos(\varphi_1) e^{-\frac{1}{(\omega_1 \cdot C) \cdot R_2} \cdot (\varphi - \varphi_1)} \quad (8)$$

$$\varphi \geq \varphi_1.$$

The instant signal power (8) in the load resistance $R_2$ is determined by the ratio [7, 12]:

$$P_2(\varphi) = J_2^2(\varphi) \cdot R_2 = \frac{(E_m \cdot Q_1)^2}{R_2} \times \left(1 - e^{-\frac{1}{2 \cdot Q_1} \cdot \varphi_1}\right)^2 \cdot \cos^2(\varphi_1) \cdot e^{-\frac{2}{(\omega_1 \cdot C) \cdot R_2} \cdot (\varphi - \varphi_1)} \quad (9)$$

The maximum amplification ratio is determined as maximum ratio of the power output in the load to the source power at $\phi_1 \rightarrow (\pi \cdot n,\ n = 0, 1, 2, \ldots) >> 2Q_1$ and $\phi = \phi_1$:

$$K_{2\max} = \frac{P_2(\varphi = \varphi_1)\big|_{\varphi_1 \rightarrow (\pi \cdot n,\ n=0,1,2.....) >> 2Q_1}}{P_{0m}} = \frac{R_1}{R_2} \cdot Q_1^2 \quad (10)$$

It follows from (10) that with certain selection of the element base of the proposed circuit, it is possible to strengthen the instant harmonic signal power, as:

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$$K_{2\max} = \frac{R_1}{R_2}\cdot Q_1^2 = \frac{\left(\frac{L_1}{C}\right)^2}{R_1 \cdot R_2} > 1 \qquad (11)$$

*Note:* $\sqrt{(L_1 / C)} = Z_1$ – is the wave resistance of the charge circuit.

For quantitative illustration of the obtained ratios, some preliminary estimates can be made. For example, for the charge circuit 1 Q-factor of $Q_1$=5, as it follows from the graph in Fig. 2a, the charge length can be minimally estimated by the value $\varphi \le 32 \approx 5$ of the power source voltage periods.

The calculations for phase distribution of the discharge current (8) with the same conditions and variations in the relative value of the active load $R_1/R_2$=var are given in Fig. 3.

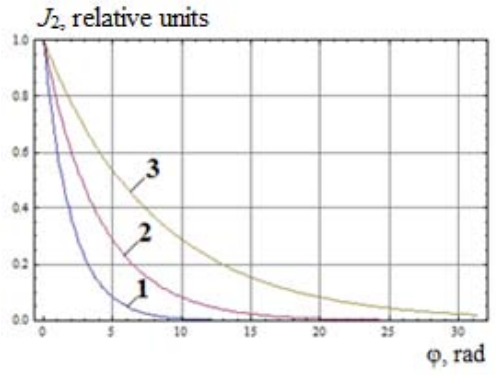


*Fig. 3:* Phase dependence of the discharge current rated to the maximum, 1 – $R_1/R_2$ = 0,1; 2 – $R_1/R_2$ = 0,05; 3 – $R_1/R_2$ = 0,025

As it follows from the calculations, the duration of the discharge current gets closer to the relevant duration of the charge of the capacitive storage with quite large load resistance values. But the increased load resistance at the constant voltage of the capacity charge means the decreased output signal power.

Therefore the discharge circuit design with the capacity connected immediately to the active load is of poor efficiency for the resonant amplification of the active power due to rather small duration of the discharge current in the load.

ii. *Capacity discharge through inductance to the active resistance, $L_2 \neq 0$*

In contrast to the previous considerations, since the amplifier circuits can work at different frequencies, the characteristics of the existing processes are better to be expressed not in the phase but in the time functional ratios.

We suppose that the variable capacity discharge in the voltage resonance mode starts immediately upon charge. The current in the active load considering at $\sqrt{L_2 / C} >> 0.5 \cdot R_2$ considering (7) will be described by the following exponentially-damping harmonic time dependence [7, 12]:

$$J_2(t) \approx \frac{E_m}{R_2}\cdot\frac{Q_1}{Q_2}\cdot\left(1-e^{-\frac{1}{2Q_1}\cdot\omega_1\cdot t_1}\right)\times \qquad (12)$$
$$\times\cos(\omega_1\cdot t_1)\cdot e^{-\frac{1}{2Q_2}\cdot\omega_2\cdot(t-t_1)}\sin(\omega_2\cdot(t-t_1)),\ t\ge t_1,$$

where $t$ is the current time, $t_1$ – is the end time of the capacity charge and the start time of the capacity discharge, $\omega_2 \approx 1/\sqrt{L_2\cdot C}$ and $Q_2=(\omega_2\cdot L_2)/R_2=1/(\omega_2\cdot C)\cdot R_2$ – is own frequency and tuned-circuit Q-factor in the representations that correspond to the voltage resonance in the discharge circuit.

The momentary signal power (12) in the load resistance $R_2$ is determined by the ratio [7, 12]:

$$P_2(t) = J_2^2(t)R_2 = \frac{E_m^2}{R_2}\left(\frac{Q_1}{Q_2}\right)^2\left(1-e^{-\frac{1}{2Q_1}\cdot(\omega_1\cdot t_1)}\right)^2\times \qquad (13)$$
$$\times\cos^2(\omega_1 t_1)e^{-\frac{1}{Q_2}\cdot\omega_2\cdot(t-t_1)}\sin^2(\omega_2(t-t_1)),\ t\ge t_1$$

The maximum amplification ratio is determined as maximum ratio of the power output in the load to the source power amplitude at $(\omega_1\cdot t_1)\to(\pi\cdot n, n = 0,1,2\ldots) >> 2Q_1$.

$$K_{2\max} = \frac{P_2(\omega_1 t_1 \to \pi\cdot n >> 2Q_1)}{P_{0m}} = \qquad (14)$$
$$= \frac{R_1}{R_2}\cdot\left(\frac{Q_1}{Q_2}\right)^2 e^{-\frac{1}{Q_2}\frac{\pi}{2}} = \frac{R_2}{R_1}\cdot\left(\frac{\omega_2}{\omega_1}\right)^2 e^{-\frac{1}{Q_2}\frac{\pi}{2}}$$

It follows from (14) that with certain selection of the element base of the proposed circuit, it is possible to strengthen the instant harmonic signal active power. In contrast to the analog previously considered, the amplification ratio contains dependence on the squared ratio of the charge and discharge circuit Q-factors that provides for additional opportunities for efficient implementation of the proposed circuit.

For quality illustration of the time dependence of the active power in the load, we write (13) with normalization to power accumulated in the capacity at the discharge initial time:

$$P_0(t) = \frac{P_2(t)}{\frac{E_m^2}{R_2}\left(\frac{Q_1}{Q_2}\right)^2\left(1-e^{-\frac{1}{2Q_1}(\omega_1 t_1)}\right)^2\cos^2(\omega_1 t_1)} = \qquad (15)$$
$$= e^{-\frac{1}{Q_2}\omega_2(t-t_1)}\sin^2(\omega_2(t-t_1)),\ t\ge t_1$$



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The calculation results are given in Fig. 4, where $Q_2=10$, $\phi=\omega_2\cdot(t-t_1)$, $\phi_2=\omega_2\cdot(t_2-t_1)=10\cdot(2\cdot\pi)$ – the phase length of the specified interval of the discharge process, $t_2$ – end time of discharge.

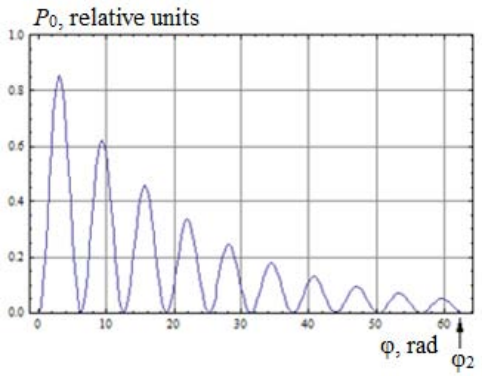


*Fig. 4:* Phase dependence of the power in the active loaded amplifier

The following indicators of the proposed amplifier at the specified length interval of the discharge process can be obtained from the dependence in Fig. 4.

- The maximum amplification ratio of the mean active power can reach:

а) if $\{Q_1/Q_2=10,\ R_1/R_2=1,\ 2Q_2>>\pi\}$, we obtain $\overline{K}_{2\max}\approx 15.2$;

б) if $\{Q_1/Q_2=50,\ R_1/R_2=0{,}1,\ 2Q_2>>\pi\}$, we obtain $\overline{K}_{2\max}\approx 38.0$.

- When selecting the amplifier circuit parameters, the mandatory exceedance of the charge circuit Q-factor in contrast to the similar discharge circuit value $(Q_1/Q_2)>>1$ should be used as reference.
- The allowed ratio of the active resistances of the charge circuit and the load value $(R_1/R_2)$ is corrected by the assumed ratio of the circuits Q-factors $(Q_1/Q_2)$ of amplifier, in general.

## IV. Numerical Estimates

We perform calculations that illustrate the potential efficiency of the proposed amplifier using the example of the model with discharge to load through inductance with single-time synchronous activation/ deactivation of switches of the charge and discharge circuits. The parameters of the accepted model are taken from analogs given in work [8].

*a) Circuit Operation*

i. The schematic circuit of experimental model No.1 is given in Fig. 1a.
ii. In the initial position, the switch $K_1$ is closed, the switch $K_2$ is open.
iii. Efficiency of charge circuit 1:
   a. With the switch $K_1$ closed and the $K_2$ open, the voltage source $E$ is connected, the capacity charge C takes place.
   b. When charged, the switch $K_1$ open, the capacity $C$ remains charged to the maximum possible resonant voltage $U_{C0}=E\cdot Q_1$, where E is the source voltage.
iv. *Efficiency of discharge circuit 2:*
   a. Simultaneously with the switch $K_1$ opening in charge circuit 1, the switch $K_2$ closes in charge circuit 2.
   b. The active power of the amplified input harmonic signal is determined in the load resistance $R_l\approx R_2$.

*b) Circuit Components*

i. *Harmonic signal reactive power resonant amplification unit*
   a. Harmonic voltage generator $E(t)=E_m\cdot\sin(\omega_0\cdot t)$, $E_m\approx 1\ldots 10$ V amplitude, $\omega_0=2\cdot\pi\cdot f_0$, $f_0=25000$ Hz – operating frequency.
   b. Inductance $L_1=172.8$ μH.
   c. Capacity $C=0.234$ μF.
   d. Active resistance $R_1=0.46$ Ω.
   e. Q-factor $Q_1=(\omega_1\cdot L_1)/R_1\approx 59$.

*Note:* Own design frequency of circuit 1: $f_1=1/2\pi\cdot\sqrt{L_1\cdot C_1}\approx f_0=25000$ Hz.

ii. *Active load connection unit*
   a. Inductance $L_2=172.8$ μH.
   b. Capacity $C=0.234$ μF.
   c. Active resistance of conductors $R_c=0.46$ Ω.
   d. Active load resistance $R_l=5$ Ω or $R_l=10$ Ω.
   e. According to the accepted assumption, the total active resistance of the circuit is $R_2\approx R_l$.
   f. Q-factor $Q_2=(\omega_2\cdot L_2)/R_2\approx 5$.

*Note:* Own design frequency of circuit 2: $f_2=1/2\pi\cdot\sqrt{L_2\cdot C_2}\approx f_0=25000$ Hz coincides with resonant frequency of the charge circuit $f_1$.

*c) Calculations*

i. *Charge voltage on the capacitive storage*

The design curve in Fig. 5 makes it possible to know the charge voltage for capacity that can be obtained depending on the charge time. This, the maximum voltage established by the charge circuit Q-factor requires charging for ~ 0.004 sec that makes ~ 100 source voltage periods for the assumed frequency of ~ 25 kHz. However, 50% of maximum voltage is achieved for much shorter time ~ 0.05 sec (almost by one order of magnitude lower than the charge time before maximum).



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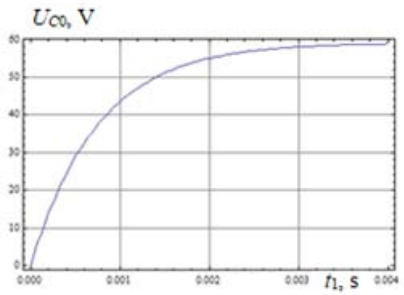


*Fig. 5:* Envelope of the maximum charge voltage normalized to the source voltage amplitude depending on the charge time

ii. *Amplification ratio (14)*

a. At $R_2$=5 Ω

$$\overline{K}_{2\max} = \left( \frac{J_{2\max}^2 \cdot R_2}{\frac{E^2}{R_1}} \right) = \frac{R_2}{R_1} \cdot e^{-\frac{\pi}{2 \cdot Q_2}} \Bigg|_{Q_2 \approx 5,0} \approx 8.6.$$

b. At $R_2$ = 10 Ω

$$\overline{K}_{2\max} = \left( \frac{J_{2\max}^2 \cdot R_2}{\frac{E^2}{R_1}} \right) = \frac{R_2}{R_1} \cdot e^{-\frac{\pi}{2 \cdot Q_2}} \Bigg|_{Q_2 \approx 2,5} \approx 12.4.$$

iii. *Discharge current as function of a variable* $\varphi=\omega_2 \cdot (t-t_1)$

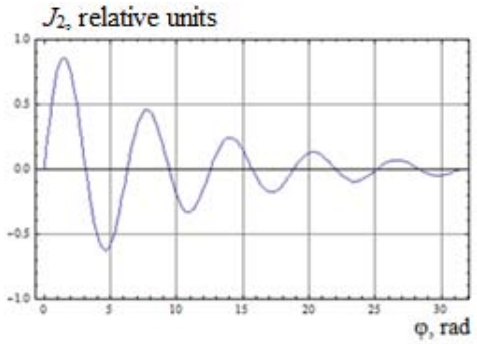


*Fig. 6:* Functional dependence of the current in the load normalized to the maximum

To summarize the results obtained, the dependences in Fig. 2, 5, 3 and 6 should be referred to.

Thus, the curves in Fig. 2 and Fig. 5 illustrate the capacity charge *C* to the specified voltage level $U_{C0}$ for any discharge circuit 1 design. The graphs in Fig. 3 and Fig. 6 describe the capacity discharge *C* to the active load in the absence and presence of inductance in discharge circuit 2.

For practical use, the comparison of dependences for various design solutions for output circuit in Fig. 3 and Fig. 6 is of particular interest. As it follows from calculations, when the inductance is connected in the discharge circuit, the duration of the current pulse in the load increases significantly. The noted fact allows us to recommend this circuit solution for operation not only in the pulse mode but also in the periodic mode of the proposed active power amplifier.

## V. Experimental Approbation

The operability of the proposed circuit of a pulsed amplifier of the active electric power of a harmonic signal and the reliability of the results of a theoretical study of the occurring electromagnetic processes were verified experimentally.

*a) The element base of the amplifier (the circuit diagram is shown in Fig. 1)*

i. *Circuit charge No.1:*

a. The sinusoidal voltage source with amplitude – $E_m = 1$ V and working frequency – $f_1$ = 25000 Hz;
b. The inductance – $L_1 = 172.2$ μH;
c. The capacity – $C = 0.234$ μF;
d. The active resistance of the circuit elements – $R_1 = 0.55$.

ii. *Circuit discharge No.2:*

a. The inductance – $L_2 = L_1 = 172.2$ μH;
b. The capacity – $C$ = 0.234 μF;
c. The active resistance of the circuit elements – $R_C$ = 0.55Ω.
d. The load active resistance – $R_l$ = 5.6 Ω.

*b) Experimental Results*

i. *Work of the experimental model*

The element base of the experimental model of the active electric power amplifier ensures its operation in the voltage resonance mode with an operating frequency of *~25 kHz*. The choice of the proposed scheme is explained by its relative simplicity. The peculiarity consists in the cyclical repetition of the "charge – discharge" processes, which is ensured by the synchronized operation of electronic switches – $K_{12}$. At a given minimum voltage on the capacitance –*C*, the key $K_1$ closes and $K_2$ opens. The capacity is being charged. At a given maximum voltage on the capacitance, the key $K_1$ opens and $K_2$ closes. Through the inductance – $L_1$ the capacitance – *C* is discharged to the active load – $R_l$.



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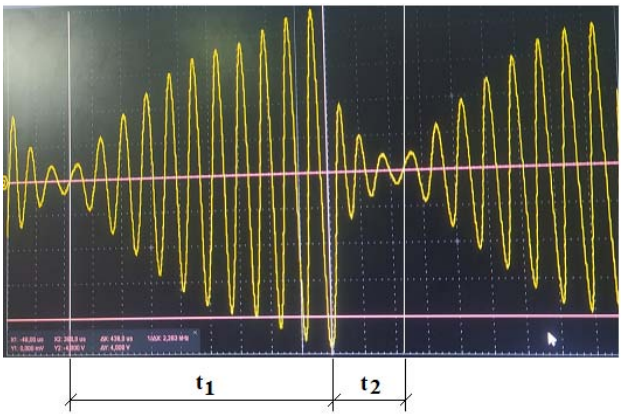


*Fig. 7:* A typical oscillogram of the voltage across the capacitance, $t_1$ – is a charge time (in terms of theoretical consideration – $t_1 = \Delta t$), $t_2$ – is a discharge time

ii. *Measurements and Calculations*

a. The voltage amplitude of the source – is $E_m = 1$ *V*, the working frequency – is $f_1 \approx 24930$ Hz;
b. The voltage on the reactive elements of the charge circuit: the amplitude on the inductance – is $U_{L_1} = 48.2$ V, the amplitude on the capacitance – is $U_C = 48.6$ *V* ($U_{L_1} \approx U_C$, but they have opposite directions what is verified the voltage resonance regime!);
c. The current amplitude in the charge circuit – is $J_1 \approx 1.8$ A;
d. The enter power amplitude – is $P_1 \approx 1.8$ W;
e. Q-factor of the charge circuit as the ratio of the average voltage on the reactive elements and the amplitude of the source voltage, – $Q_1 = 48.4$ (the calculation value ~ is 49.18);
f. The amplification of reactive power on the capacitance – is $K_C = \frac{U_C^2 \cdot (2\pi f_0) \cdot C}{E_m \cdot J_1} = 48.096$;
g. The current amplitude in the discharge circuit – is $J_1 \approx 1.7$ A;
h. The power amplitude in the load – is $P_l \approx 15.8$ W;
i. Q-factor of the discharge circuit – $Q_2 \approx 4.8$;
j. The coefficient of the amplification of active power in the load – is $K \approx 8.7$.

*Summary*

- The measurement results are quite close to the previously obtained numerical estimates of similar quantities.
- The experiments performed have demonstrated the workability of the proposed circuit of a pulsed resonant amplifier of active electric power.

## VI. Conclusions

1. A scheme of the pulsed resonant amplifier of the active electric power is proposed, consisting of two series circuits with a common capacitive energy storage.
2. Analytical dependences for the main characteristics of the occurring electromagnetic processes are obtained and it is shown that the phenomenon of voltage resonance allows to achieve an increase (by more than an order of magnitude!) of the active power of a harmonic voltage source.
3. On the basis of the analysis, numerical estimates and experimental testing, the viability of the proposed circuit of a pulsed resonant amplifier of the active electric power is substantiated.

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# The Technologies of the Smart Cities

By Hassan Saad Fadhil
*Mosul University*

*Abstract-* Smart cities are becoming a preoccupation for all life facilities. Every single day, smart cities become an urgent need to solve the problems of population increase and increase the amount and diversity of data over time. Although the task is not easy to transform into smart cities, the availability of some technologies makes the mission easier for us. In this paper, we reviewed the most prominent technologies used in smart cities, and we made a general overview of the most trending technologies that are used in smart cities.

*Keywords:* *smart cities, IoT, ICT, AI.*

*GJRE-F Classification:* *FOR Code: 090699*


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# The Technologies of the Smart Cities

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## I. Introduction

Cities have a significant impact on global environmental and socioeconomic aspects. In many cultural contexts, an increasing number of people are looking for the advantages of urbanization over traditional rural lifestyles and are drawn to the city infrastructure. By 2050, 6.5 billion people will live in cities, According to the Unities are experiencing several difficulties as a result of the ever-increasing strain placed on their infrastructure and resources.

Utilizing Information and Communication Technology (ICT) within an accessible integrated infrastructure is an emerging trend for managing and minimizing these challenges. Smart cities are the name given to this idea.

Academics and practitioners alike are paying significant attention to this topic, which is proving to be a robust area of research. Utilizing ICT to enhance various aspects of city operation and management is where a lot of cities are focusing their efforts to become "smarter," as evidenced by the following: environment, quality of life for citizens, local economy, transportation, traffic management, and electronic delivery of public services[1].

Throughout the last ten years, numerous urban communities all over the planet have pronounced the expectation to become smart urban areas. A somewhat shapeless term, overall there are three broad understandings of what is an intelligent city.

For some's purposes, a smart city is one in which metropolitan framework and administrations are overseen computationally, with organized computerized instrumentation implanted into the metropolitan texture, delivering nonstop surges of information that progressively feed into the executive's stems and control rooms, making new types of overseeing mindset. For other people, a savvy city is one in which the essential utilization of data and correspondence innovation (ICT) creates more brilliant residents, laborers, strategy, and projects; cultivates advancement, monetary turn of events, and business; and has metropolitan flexibility and supportability[2].

*Author: IT Engineer, Department of Computer Engineering, Mosul University, Iraq. e-mail: computer.eng.hassan@gmail.com*

## II. Why do we Need Smart Cities?

One of the reasons why there is a need for a smart city is rapid urbanization. The general concept of the growth of a nation rises its per capita output. This usually happens when a nation's economy moves from an agrarian to an industrial one. As people migrate to urban areas, cities are not able to sustain the growing population density. The smart city brings efficiency in the areas of infrastructure, water, transport, energy, and waste management systems by enabling the cities to use technological advancement to help its citizen [3].

### *a) The Future Internet and Smart Cities*

The social, financial, and mechanical points of view of new Web advances and their likely effect on urban communities and spatial biological systems were portrayed in two prescience reports ready by the Organization for What's in store [4].

#### i. *IoT Technologies in Smart Cities of the Future*

The Internet of Things (IoT) and relevant advancements in 5G networks and Mobile Edge Computing (MEC) are constantly being adopted by smart cities. Under this point of view, brilliant urban communities representing things to come can be considered as a microcosm of interconnected "objects" where exceptional and human-driven administrations can be given to residents as digital actual frameworks [5].

#### a. *IoT-Enabled Smart Cities*

IoT application development is primarily driven by smart cities. Depending on one's point of view, there are several ways to define a smart city. An urban center equipped with technologies that make use of digital data to provide better public services and make better use of resources is another definition of a smart city. Six main components make up a smart city: smart governance, smart economy, smart citizens, smart mobility, and smart living [6].

## III. Artificial Intelligence and Smart Cities

AI e can be utilized for various purposes, including security, financial exchange, salvage of the board, and transportation. Complex issues like



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monetary rebuilding, natural security, government, and versatility emerge comparable to the improvement of an intelligent city. Our examination centers around the meaning of simulated intelligence for the development of brilliant urban communities in the accompanying section. By adding customized highlights such as setting mindfulness, artificial intelligence can likewise be utilized in savvy homes, permitting it to outperform automation. The ICT-based framework for future savvy urban communities was encased in a four-layer pyramid by these creators [7] (Figure 1).

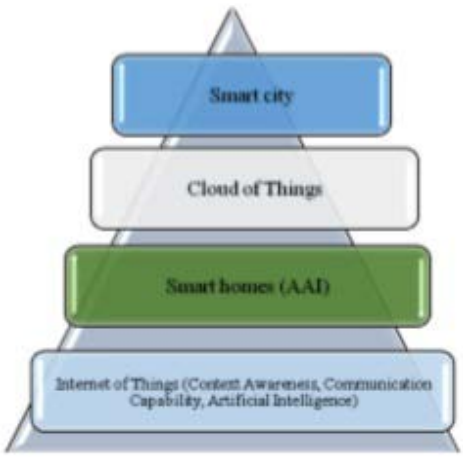


*Figure 1:* ICT-based infrastructure [7]

A smart city changes its social, business, and standard necessities, further fostering the assets it has open. Smart metropolitan regions depend on data and correspondence innovation (ICT) to give arrangements that work on a city's reasonability and work on its populace, economy, and the biological system as a whole. Its object is to assess a city because of the upgrades in private happiness and monetary prosperity accomplished by using ICT developments to configure, layout, produce, and work the city establishment [5].

## IV. Conclusion

After we reviewed the most important technologies used in smart cities and talked about the future of these technologies and the possibilities they offer to transform into a smart city environment, it is now possible to delve deeper into developing these technologies and move forward to improve the work of our environment and our lives.

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# FPGA Physical layer Implementation of Fixed WIMAX for Data Transmission

By Vasanth Kumar TR & Dr. K V Prasad
*Jain University*

*Abstract-* The telecommunication area in last decade has witnessed the interest towards the providing the quality of service to the users but achieving this QoS with increasing users as the most significant issue. As a result, various technologies have come into existence. The broadband wireless access is one of the ways to reach the high business demand for increasing the internet connection. The wireless solution has been found to remove the limitations in capacity in comparison to wired technologies. The significant technique called OFDM (Orthogonal Frequency Division Multiplexing) provides the better QoS but leads to high Cyclic Prefix (CP). The implementation of WiMAX standards on FPGA is a big challenge as this wireless standard is a complicated standard. The hardware modeling made here to simulate the physical layer of WiMAX on FPGA evaluates the system performance. This paper introduces a design of WiMAX physical layer implemented over FPGA and analyzes the performance of the implemented system. The methodology here is first to design the hardware architecture of the system being implemented on the FPGA and then to transfer the design on the FPGA board. The system performance is evaluated by generating a random digital data and transferring the data from the transmitter on the implemented communication system. The received data is then compared with the transmitted data to evaluate the Bit Errorrate of the implemented system.

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## I. Introduction

The popularity of Broadband Wireless Local Area Network (WLAN) over cable modems in past decade has encouraged the development of a wireless standard for Metropolitan Area network (MAN). In an account of this, a broadband wireless access standard named WiMAX (Worldwide Interoperability for Microwave Access) has come into existence [1]. This standard is recently gaining importance due to high demand for high-speed internet access. The WiMAX also termed as IEEE 802.16 standard can provide a data rate starting from 100MBps and a maximum range of 50 km for line of sight connectivity and 25km for Non-line of sight connectivity [2].

WiMax operates in 2.5, 3. 5 and 5.8 GHz bands of frequencies using Orthogonal Frequency Division Multiplexing (OFDM) technology in the physical layer. The OFDM signaling is implemented to achieve higher performance for multipath fading wireless channels. Apart from this physical layer may incorporate other functions such as randomisation, forward error correction and sometimes coding for multiple antenna technologies.

The design of a WiMAX system is influenced by critical requirements such as higher speed, flexibility, time to market and importantly the hardware platform selection. For the high-speed system, the platform has to support significant processing capabilities that can perform computationally intensive tasks such as FFT/IFFT, FEC, etc. Flexibility is another requirement that a WiMAX design is to incorporate as the Standard is under continuous revision process. In such scenarios, the WiMAX system should be designed with hardware flexibility to achieve in-field reconfigure ability. Finally, the time to market is an important criterion for gaining success in market share. The Digital Baseband physical layer can be implemented using a general-purpose processor or a DSP processor which can run several algorithms mimicking the signal processing operations of the physical layer. The other methods of implementing the system are to develop a custom Application Specific Integrated Circuit (ASIC) or use an FPGA to configure the device as WiMAX physical layer system.

The use of DSP based algorithm to implement a system involves lot of computational complexity which may result in delays in generating the output signal. The ASIC implementation is a very time-consuming and expensive which affects the time to market od the implemented design. However, FPGA implementation does not suffer from the above two issue. Hence to design a WiMAX system with such criteria FPGA's provide an ideal implementation platform.[1]

This paper discusses about the implementation and performance analysis of WiMAX system. The transmitter and receiver sections are designed with a Channel and implemented on FPGA module. The channel module models the noise that mixes with the transmitted signal and passes the noise added signal to the receiver. The implementation of the system is verified by transmitting a binary sequence of data through the transmitter sections, allowing the transmitted signal to enter the receiver and extracting back the binary sequence of data. The WiMAX system implemented here makes use of an additive White Noise module that is implemented in hardware to act as a source of noise to the signal.

*Author α: Research Scholar, Jain University Bangalore.*
*e-mail: vasanthkumar.tr@gmail.com*
*Author σ: Professor and Hod, Bangalore Institute of Technology, Bangalore.*



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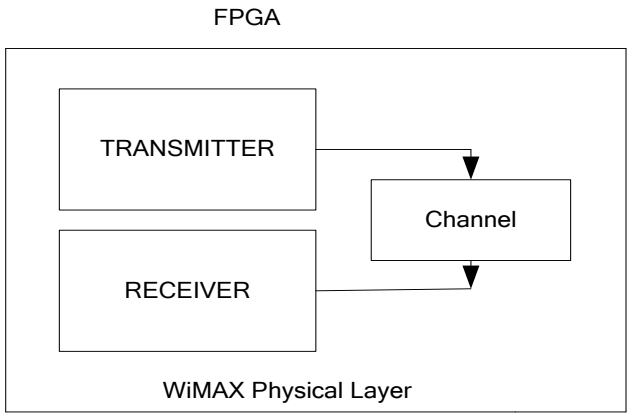


*Figure 1:* Wimax FPGA Implementation

*a) Background*

The WiMAX is a form of wireless transmission architecture which provides the speedy communication at low maintenance cost. This also gives the better use of bandwidth at higher frequency level. This part of the paper discusses the necessary concepts of the WiMAX system and its physical layer.

i. *WiMAX system*

The architecture of WiMAX system composed of various units in which base station (BS) and sink station (SS) are significant. Other components are CSN, MS, ASN, and CSN-GW, etc. The WiMAX Forum's Network Working Group (NWG) provides a network reference model according to the IEEE 802.16e-200. The reference model is logically divided into three units [5].

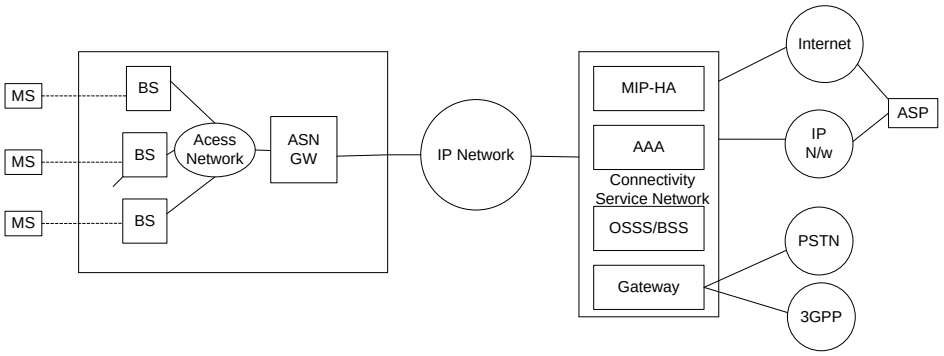


*Figure 2:* WiMAX Network architecture

*Mobile Station (MS):* This acts as end-user equipment for accessing the mobile network. It is portable and provides data and voice communication facilities to the users.

*Access Service Network (ASN):* This is a network that provides access services with efficient scalability and high mobility. Its ASN-GW controls the network and coordinates among data and networking elements.

*Service Network (CSN):* Provides IP-connectivity, address and policy management, managing location between ASN, ensuring Quality of Service, roaming facility, and security.

ii. *WiMAX Physical layer*

This layer is mainly responsible for setting the connection among the communicating devices and transmission of the data bits. The physical layer design defines modulation type and transmission power requirements. WiMAX physical layer has two types of transmission techniques Time Division Duplex and Frequency Division Duplex with operating frequency band below 11 GHz. The physical layer of IEEE 802.16 standard is based on OFDM which is mainly required for multimedia communication and digital video services as it provides very fast data speed on non-line of sight channels and multipath environment. The role of the PHY layer is to encode the MAC frames into analog signals and receive these signals from a communication channel [7].

*b) Research Problem*

The implementation of the physical layer of WiMAX system poses big challenges as this is a complicated standard and high-speed processing requirement. There are very few works that focussed on implementing the WiMAX physical layer on FPGA system, but design constraints could not satisfy for the real-time hardware implementation of the system. Here an effort is made to realize a Physical layer of WiMAX on



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FPGA system with an improved throughput and FPGA design parameters.

## II. Literature Review

This unit gives the discussion of the various research works towards the design and implementation of WiMAX based OFDM transmission system. Moises Sera [5] presented OFDM transmitter design as a part of Hiperlan/2 based transmitters. The issues in the implementation of OFDM based WLAN standard was presented by Ma.Jose Canet [6]. His work focussed on providing solutions to Baseband and IF OFDM signal generation. The work also benchmarked Optimised area results against system Generator results. Chris Dick[7] emphasized on designing the Software Defined Radio system on FPGA rather than on ASIC as FPGA provides a one-day solution to the implementation. His work provided a high-level view of FPGA implementation of OFDM receiver consisting of synchronization, packet detection; preamble correlates channel estimation and equalization functions. The implementation of 802.11 wireless standards on FPGA as a validating and prototype for ASIC was presented by Ludovico de Souza[8].Joaquin Garcia ad Cumplido [9] investigated the suitability of FPGA to support IF processing for 802.11a standard. The work majorly focussed on resource area and timing requirements that suit the implementation of rapid prototyping and also providing reconfiguration capability to support the different wireless standard. Awad et al. [10] implemented the physical layer of IEEE 802.20 and investigated the efficiency of OFDM transceiver. Lin [11] demonstrated the OFDM concept and investigated its efficiency changes by change in different parameters. The OFDM system was demonstrated by implementing the design in Matlab. Mohamed [12] presented an approach to implementing the OFDM system on FPGA. Harikrishna [13] presented FFT algorithm implementation on FPGA for WiMAX application. The author presented a memory based recursive FFT design which takes fewer gates, lower power and operates at high speeds. Upadhyaya et al. [14] presented an efficient FPGA implementation of address generation circuit for WiMax deinter leaver. A QAM architecture for WiMAX application covering carrier synchronization and timing synchronization issues was presented by Sahoo et al. [15].

## III. Proposed System

The OFDM physical layer system described here is an extension of the system described in chapter in chaper3 with few modifications that are added to the design. The modification to the hardware architecture of chapter1 includes the addition of Forwarding error correction technique. A convolution encoder for correcting the random errors and an inter leaver for overcoming the burst error effects are added at the transmitter section. The corresponding inverse function blocks such as a de-interleaved and a Viterbi decoder are added to the receiver section.

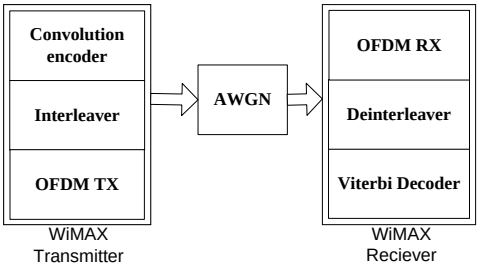


*Figure 3:* Design for Hardware implementation

*a) Convolution Encoder*

This module comprises four inputs and two outputs. The global clock (Clk), reset (rst) and enable input signal act as control signals to the encoder. The Din signal serves as a single bit data input to the encoder. The convolution encoder developed is an encoder with a code rate of 1/3; hence the encoder output is a 3-bit code word (Dout). The encoder is also designed to give another output En_out which is high for the proper and valid working of the encoder. The En_out is also required for proper synchronization of the output code word. The convolution encoder is implemented considering a state machine implementation which comprises memory element and a combinational circuit. The state machine for the convolution encoder consists of M single bit shift registers and n modulo-2 adders (Ex-or gates). The shift registers are connected to the adders based on a generator polynomial. The number of adders in the state machine gives the length of code words generated.

*b) Interleaver*

This block reorders the coded symbols to counter the effects of burst errors on the transmitted coded symbols. The reordering of the coded symbols spreads out the burst errors rather than localizing it.

*c) OFDM TX*

The interleaved coded bits are transferred into Tx block for generating the OFDM signal. The OFDM TX block includes the following hardware modules 16 QAM, Symbol generation, zero padding, IFFT and Cyclic prefix(CP). The interleaved coded sequence is converted to one of the 16-QAM modulation symbols by passing the sequence through a QAM modulator. The QAM symbols are then zero padded and passed to a 256 point IFFT block. The cyclic prefix appends a 48-bit cyclic prefix code to generate a complete OFDM symbol of 304 bits. The OFDM signal will then be transferred over the channel via a Parallel to serial converter.



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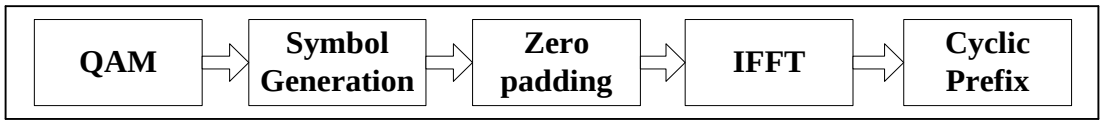


*Figure 4:* TX1 hardware blocks

i. *QAM*

The coded data to be sent on the subcarriers are converted to QAM symbols using a 16-QAM module. The input4 bit data are mapped as one of the 16 QAM symbols. Each of the QAM symbols is represented as real and imaginary components after the mapping process. The input 4-bit data is transformed into 16 real parts and 16 imaginary parts.

ii. *Symbol generation*

This block constructs the OFDM symbol from the QAM symbols. In this block, the incoming QAM symbols are shifted four times to generate a single OFDM symbol. As the 16 bit Real and imaginary parts of each QAM symbol are shifted four times, the OFDM symbol constructed is of 64 bits. the incoming16-bit QAM symbols are grouped in four to create an OFDM symbol of 64-bit.

iii. *Zero Padding*

The 64 bit OFDM sample is zero padded in this block. The real-part and imaginary-part of the symbols generated from the SG block will be input to the Zero padding block to pad zeros. The zeros are padded to increase the sampling rate of the symbol. The 64-bit symbol data will be padded with extra 64 zeros to construct a 128 bit real and imaginary symbol data.

iv. *IFFT*

The extended real and imaginary symbol data are passed through an IFFT block to generate the OFDM symbol. The IFFT module developed is a 256 point IFFT.

v. *Cyclic Prefix*

The Cyclic prefix module extends the OFDM generate from the IFFT block to mitigate the ISI effects. It extends the symbol by prefixing the OFDM symbol by repeating the tail part of the symbol generated from IFFT. The cyclic prefix developed here extracts the last 32 bits from the IFFT generated OFDM symbol and prefixed it to the start of the symbol. Thereby a total of 288 bit OFDM symbol is generated.

*d) AWGN Generator Module*

The AWGN generator module is used as AWGN Channel Noise module in Fixed-WiMAX system. The AWGN generator module generates the white Gaussian noise (WGN) of SND (standard normal Distribution). There are so many digital-synthesizing techniques are available to generate the random Gaussian variables depends on the transformation of UDR (Uniform distributed randomly) Variables. The hardware architecture of AWGN generator module is designed by using different techniques [79] like Central limit theorem(CLT), Box-Muller(B-M) Method, Rejection-acceptance Methods, Wallace Method and ICDF(Inverse Cumulative Distribution Function).In our design, ICDF method is adopted.

*e) OFDM RX*

The OFDM signal received from the AWGN channel is passed through an RX block which consists of the following hardware modules; Inverse Cyclic Prefix, FFT, zero removal and QAM demodulator. The Inverse cyclic prefix removes the appended 48-bits of imaginary data and passes the 256 OFDM data to FFT block. The FFT block transforms the subcarriers to transform domain from which data is extracted by removing the zeros and demodulating. A 16-QAM demodulator maps the QAM symbols to code bits which will be forwarded to Inter leaver.

*f) Deinterleaver*

The deinterleaving operation is the reverse of interleaving. This operation is performed to rearrange the symbols that were interleaved in the transmitter section. The interleaving and deinterleaving operation are performed by reading and writing through memory buffers.

*g) Viterbi Decoder*

A Viterbi decoder is used at the receiver to decode the convolution codes. This decoder uses a Viterbi algorithm which uses trellis structure for decoding operation. The decoding of the convolution encoded sequence is performed by finding optimal path in the trellis structure for the received sequence. After obtaining the optimal path, a distance measure is used to received and coded sequence to perform decision decoding.

## IV. Results Analysis

This section the performance of the model designed is evaluated under two conditions of the channel 1) with fading and 2) without fading.

*a) Simulation Outcomes*

The BER performance of the WiMAX system for these two systems is analyzed for the above mentioned two conditions and compared with the theoretically generated BER values for the designed system. The theoretical values are obtained using BER calculation module present in MATLAB software.



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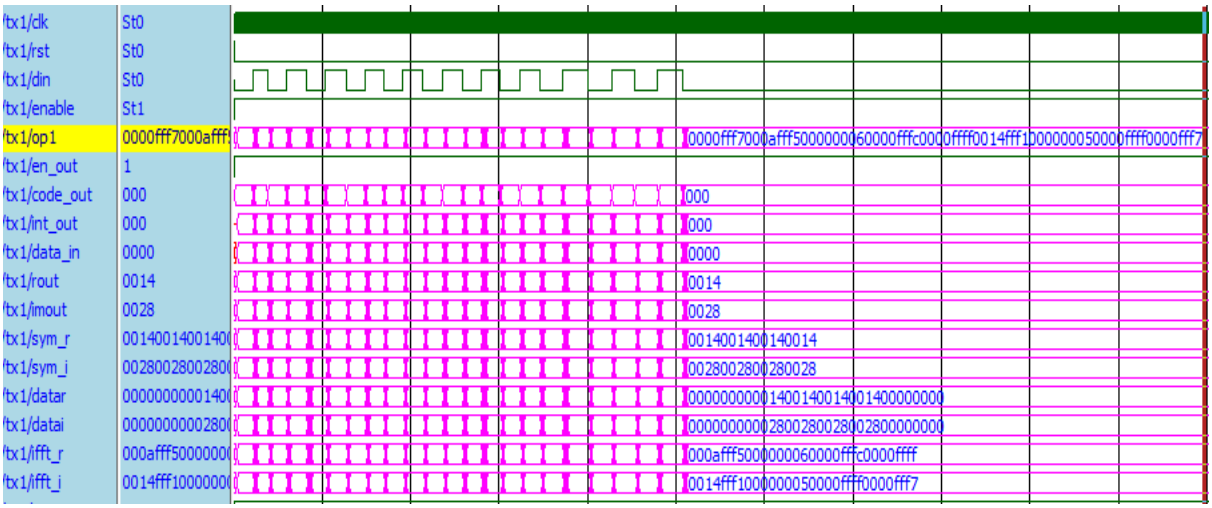


*Figure 5:* OFDM_FEC Transmitter Simulation waveform

The AWGN Generator simulation results are shown in the figure 5.44.When clock is activated, initial reset has high, then low. The enable sign is set high. Based on the design modules like T-URNG and I-CDF module designs. The random 16-bit is generated.

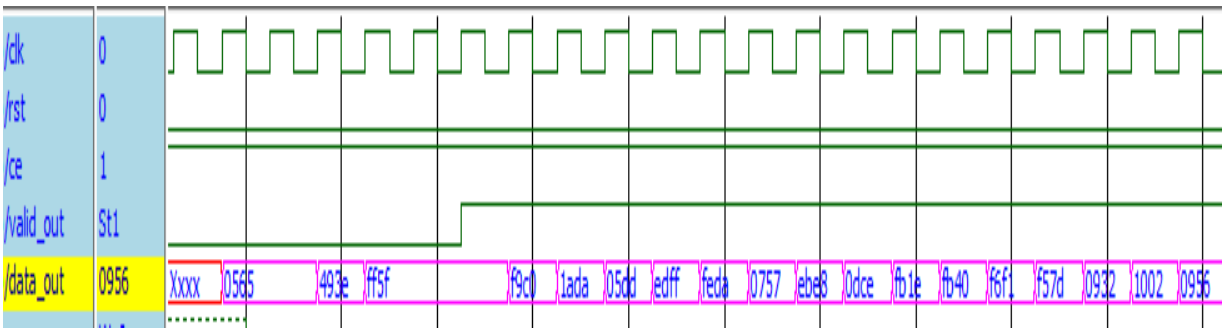


*Figure 6:* AWGN Generator simulation Results

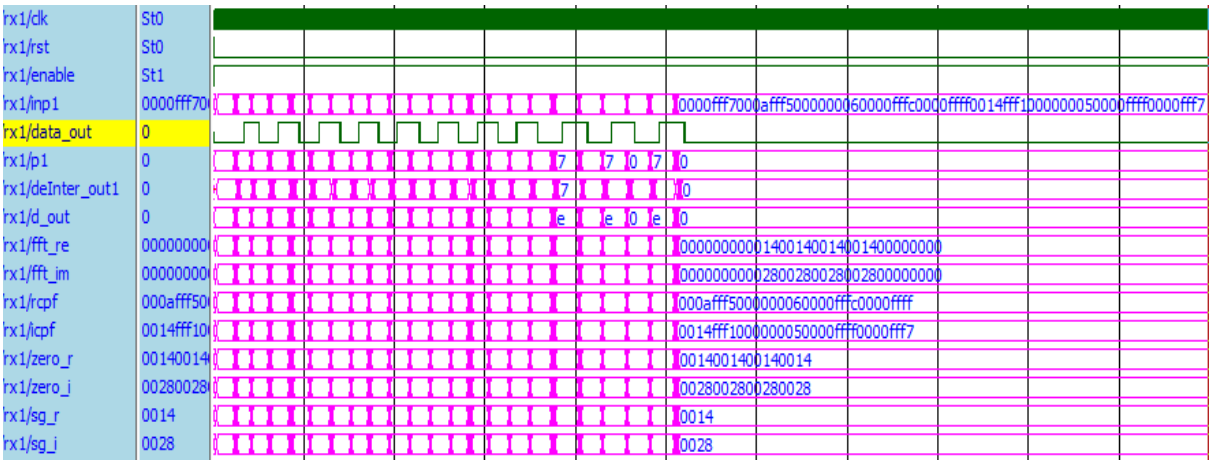


*Figure 7:* OFDM_FEC Receiver Simulation Results

*b) Performance Analysis*

i. *WiMAX System*

The total number of clock cycles to process each input bits information, the proposed design takes 2485 clock cycles it can also call it as Latency. The FPGA Operating frequency is set to 100MHZ and clock period is set to 10ns. To process the 1024 bit data, the throughput or bit rate is calculated as follows.

Throughput = [1/ (2485 * 10 ns)] * 1024 bits = 41.20 Mbps.



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*Table 1:* WiMAX Design comparison with work [16]

| Optimization Parameter | Device: Kintex-7 FPGA | | |
|---|---|---|---|
| | work[16] | proposed | Improvements |
| Latency (clock cycles) | 3607 | 2485 | 31.06% |
| Throughput (Mbps) | 28.3 | 41.2 | 31.31% |

The latency and throughput are improved both around 32 % concerning previous WiMAX architecture [16]. The Bitrate complexity is reduced.

Similarly, the WiMAX system is area overhead, and hardware complexity is important in real-time implementations. So the proposed design is compared with work [17] for area constraints.

*Table 2:* Area used in WiMAX Systems comparison

| Area used in WiMAX Systems | Virtex-6 | Work [17] | | Proposed | | Area Improved |
|---|---|---|---|---|---|---|
| Logic Utilization | Available | Used | Utilization | Used | Utilization | |
| Number of Slice Registers | 301,440 | 165,792 | 55% | 8422 | 2% | 94.92% |
| Number of Slice LUTs | 150,720 | 102,490 | 68% | 17516 | 11% | 82.90% |

In work [17], the design is used system generator to generate the VHDL Code; It consumes more area because the code is auto-generated by system. The proposed design is written in Verilog HDL, and both the designs are synthesized in Virtex-6 X240T-2FF784 FPGA for comparison purpose. The proposed design gives around 80-90 % improvement in area overhead concerning work [17] as shown in the table-5.2.

ii. *WiMAX Receiver*

The main part of the receiver is Viterbi decoder to decode the convolution encoded bits. The timing analysis of modified Viterbi decoder for WiMAX system related to work [18] on Vertex-6. The proposed design achieves the maximum operating frequency with 35 % improvement as shown in the table-5.3. So it will improve the overall bit rate.

*Table 3:* Viterbi Decoder Timing Comparison with Work [18]

| Viterbi Decoder Timing Comparison | | |
|---|---|---|
| Timing Analysis | Device -Virtex -6 FPGA | |
| | Work[18] | Proposed |
| Minimum period(ns) | 15.5 | 10.083 |
| Maximum Frequency(MHz) | 64.516 | 99.179 |
| Setup Time(ns) | 20.8 | 1.537 |
| Hold Time(ns) | 5.8 | 0.659 |

The proposed modified Viterbi Decoder is compared with work [19] [20] for area for power consumption comparison as shown in the table-4.

*Table 4:* Viterbi Decoder Area and power Comparison with Work [19][20]

| Viterbi Decoder Area and Power Comparison | | | |
|---|---|---|---|
| Parameters | Virtex2 -2000 | Zynq-7000 | Zynq-7000 |
| | Work[19] | Work[20] | Proposed |
| Total Power (mW) | NA | 106 | 100 |
| Slices | 3444 | NA | 1918 |
| LUT's | 6303 | 5614 | 3201 |

The proposed modified Viterbi Decoder improved the area with respect to work [19] with 44.33% slices and 49.21 % LUT's improvements. Similarly, with work [20], 42.98% LUT's improved and 6% improved in total power reduction in proposed modified Viterbi Decoder.



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The Proposed WiMAX system checks the BER Rate, The number of bits transferred 100 and the number of errors occurred during the processed time interval is 14. So the BER rate is 0.14. Interms of percentage is 14%.The original number of bits recovered is 86%.

## V. Conclusion

WiMAX is a wireless Broadband access technology that implements the Wireless MAN (IEEE 802.16) standard. A WiMax physical layer was designed such that it can be efficiently implemented on FPGA system withimproved throughput and reduced design parameters such as area and power. The system was designed with Forwarding error correction capability and also the design incorporated a channel model that generated AWGN signal. The performance of the system was analyzed by comparing it with other designs. The design presented in this paper proved to provide a better throughput than other designs. The BER rate is performed better out of 100 bits, errored bits are 14, and the Original bits recovered is 86%. The BER Rate is 0.14.

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**Changes in Authorship**

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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**Appealing Decisions**

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

**Acknowledgments**

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

**Declaration of funding sources**

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

## Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

***Manuscript Style Instruction (Optional)***

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

***Structure and Format of Manuscript***

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

## Format Structure

***It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.***

All manuscripts submitted to Global Journals should include:

**Title**

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

**Author details**

The full postal address of any related author(s) must be specified.

**Abstract**

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

**Keywords**

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

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

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

**Numerical Methods**

Numerical methods used should be transparent and, where appropriate, supported by references.

**Abbreviations**

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

**Formulas and equations**

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

**Tables, Figures, and Figure Legends**

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

**Figures**

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

## Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

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

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

## Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

***1. Choosing the topic:*** In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

***2. Think like evaluators:*** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

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

***4. Use of computer is recommended:*** As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

***5. Use the internet for help:*** An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

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

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

***8. Make every effort:*** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

***9. Produce good diagrams of your own:*** Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

***10. Use proper verb tense:*** Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

***11. Pick a good study spot:*** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

***12. Know what you know:*** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

***13. Use good grammar:*** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

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

***15. Never start at the last minute:*** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

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

***17. Never copy others' work:*** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

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

***19. Refresh your mind after intervals:*** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

***20. Think technically:*** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

***21. Adding unnecessary information:*** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

***22. Report concluded results:*** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

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

## Informal Guidelines of Research Paper Writing

***Key points to remember:***

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

**Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

**The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

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

**General style:**

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

**To make a paper clear:** Adhere to recommended page limits.

*Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

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- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

**Title page:**

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

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

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

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

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

**Approach:**

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

**Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

*The following approach can create a valuable beginning:*

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

**Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

**Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

**Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

**Methods:**

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

**Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

**What to keep away from:**

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

**Results:**

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

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

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**Content:**

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

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

**Approach:**

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

## The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

*Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection*.

*Segment draft and final research paper:* You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

*Written material:* You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

## Criterion for Grading a Research Paper (Compilation) by Global Journals

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

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

# Index

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