RESEARCH
www.commprac.com
ISSN 1462 2815

# THE PROPERTIES OF CLASSIFYING SIGNALS IN CONTINUOUS TIME AND DISCRETE USING THE MATHEMATICAL MODELING OF LAPLACE TRANSFORMATIONS

**Vehebi Sofiu [1], Denis Celcima [2], Yrmet Shabani [3], Ferid Selimi [4] and Muhaxherin Sofiu [5]***

[1,2,4,5] University of Business and Technology, Lagja Kalabria-Street Rexhep Krasniqi, Nr.56 Prishtina, Kosovo.
[3] RCLC- Recourse Center for Learning and Consulting; "Nënë Tereza", Prizren, Street: Hoxhë Tasini, nr. 221, 10000 Prizren, Kosova.
Email: [1]vehebi.sofiu@ubt-uni.net, [2]deniz.celcima@ubt-uni.net, [3]yrmet77@hotmail.com, [4]ferid.selimi@ubt-uni.net, [5]muhaxherin.sofiu@hotmail (*Corresponding Author)
ORCID ID: [1]0000-0001-6962-598X, [2]0000-0001-9956-1446, [3]00009-0002-0408-235X, [4]0000-0002-1065-4804, [5]0000-0001-6962-598X

**DOI: 10.5281/zenodo.12623040**

**Abstract**

The digital signal processed simplifies the parameters of accurate models within the control of impulsive generation in discrete and continuous time. In this paper, a new signal classification process is offered between models of continuous-time systems and simulated variables. Analytical control eliminates the errors of the time-continuous network by processing measurements obtained from sampling for signals with closed-loop cycles. Statistical data are compared with analytical models of signal transformations. As a physical process, the time of information transmission changes due to the time-varying phenomena that appear as a combination of input signals to the system. The parameters of a modelled transformation are based on the process in a partially networked control system that is monitored and modelled by an algorithmic function approach that controls the input signal errors in the system. Statistical measurements compared with the used signals rely on the statistical properties of the second-order input and output signals. An analysis of a discrete impulse covariance harmonization proposes to change the Laplace paradigm between the methods for comparing the spectral periodogram at different proposed frequencies. The used methods function according to the proposed dynamics for detecting signal damage during stationary noise within two-time series.

**Keywords:** Informative Signal, Recovering Filter, Impulsive Generation, Analytical Modulation, Function Design.

## 1. INTRODUCTION

The Laplace analytical approach to transformation is a mathematical method to analyse and manipulate functions in a timely or discrete time, transforming them into another domain known as the frequency domain. The system is a highly used tool in computer engineering and other technical sciences to solve differential or integral equations in complex forms of intervals to study frequency systems responses [1]. The classification actively controls simulations by identifying signals according to concepts in the field of systems and signals. To this end, the use of Laplace transformations can be useful for mathematical modelling. To analyse mathematically, the transformation replaces the function in continuous time with a complex function in the frequency domain [2]. When dealing with signals in the domain of simulations, such as in discrete systems, discretion Laplace transformation is used. This is a convenient tool to analyse discrete signals in the frequency context. Signal Type identification uses Laplace transformation for cases when the signal is distributed and depreciated. Laplace offers a convenient way to compare different signals and analyse the effect of changes [3].

The use of Laplace transformations enables the analytical system response to frequency review associated with systems and signals. [4]. Laplace's transformation can be complicated to use, especially when dealing with unapproved time systems. So the use of Laplace transformations for signal classification such as: linearity property, frequency shift property, integration, time multiplication, complex change property, time-turned property, time-turned property and time-turned-development properties in the context of time-streaming systems are a powerful analytical tool that can be used to understand and model the behaviour of systems and signals in various fields of science and engineering [5]. In the physical sense, signals we generally convey information by giving us information about the situation or behaviour in an operating system functioning. Impulses are synthesized for communicating and providing information between people, including artificial intelligence. [6-7]. The independent mathematical variables are represented by a constant independent variable for both time systems. [8]. Digital signals that have discrete amplitudes both at the input and at the output of the system, the signal transformation is processed the same and well-defined. [9]. A function is called piecewise continuous if it has a finite number of discontinuities and continues to infinity. [10]. The Laplace transform is the integral transform which helps in solving differential equations even when the function has complex variables [11]. Laplace's transformation is defined by the formula:

$$F(s) = \int_0^{+\propto} f(t)e^{-st}dt \qquad (1)$$

If we consider the signal x (t) = $e^{-at}$u(t) Laplace's transformation is given by:

$$X(s) = \int_{-\infty}^{\infty} x(t)e^{-st}\,dt = \int_0^{\infty} e^{-(s+a)t}dt = -\frac{1}{s+a}e^{-(s+a)t}\,|_0^{\infty} = \frac{1}{s+a} \qquad (2)$$

For as long as Re{s + a} > 0, or equivalent Re{s} > − a, whereby the Fourier Transformation is X (jω) = 1. Fourier transformation is positive for as long as the value of (a) is real and a> 0: $e^{-at}u(t)$ and $-e^{-at}u(t)$ have the same Laplace transformation$\frac{1}{s+a}$, but the verses of (s) for which each had a variable Laplace transformation [12].

## 2. EXPERIMENTAL METHODS

The approach of the analysis strategies imposes the decoding of the time domain of the transform functions for the scale of the impulsive unit of the signals.

The presentation of analytical performances with complex insights determines the way the results solution platform interacts with its scenarios.

The paper visualizes the analytical description of the Laplace Transform according to the principles of the algebraic defensibility of the most distinct properties. The control and information resource approach monitor and compares simulated algorithmic games with the basic parameters of signal transformations according to discrete paradigms.

### 2.1. Materials

The method of using double Laplace transformations applies to finding accurate solutions of differential equations subject to initial and border conditions. In recent years, a large intersection has been added to fractional differential equations due to frequent appearances of mathematical complexities. The method of disintegration of equations makes the partial solution of homogeneous and non-homogeneous functions. The method of analytical division of the fractional telegraph equation with non-homogeneous time is based on the conditions of Dirichlet, Neumann, etc. And it solves the equations with Laplace's only transformation with variation repetition [13]. Moreover, let it be a function f(x, t) with two variables (x) and (t) which is positive in the framework of the plane (x, t). The two-sided functioning transform (x, t) is taken by:

$$L_xL_t\{f(x,t)\} = \int_0^\infty e^{-px} \int_0^\infty e^{-st} f(x,t)dtdx \quad (3)$$

Because integral exit. Values (p) and (s) are complex numbers.

Laplace's transformation into two sides is an integral transformation that reflects a function of real value on the plane of time and a complex variable function on the frequency plane by formula (4)[14].

$$X(s) = \int_{-\infty}^\infty x(t)e^{-st}\, dt \quad (4)$$

Where the variable (s) is a complex: $s = \sigma + j\omega$.

$$X(\sigma + j\omega) = \int_{-\infty}^\infty [x(t)e^{-\sigma t}]e^{-j\omega t}dt \quad (5)$$

Laplace's transformation and z-transformations simplify differential equations into an algebraic equation using the MATLAB platform with standard identities. There are several objectives we can achieve using the platform and modeling them mathematically through Transformations[15]. Signal Classification is motivated by the trend of technological development, and its impact on electronic implications of configurations and populism for commercial applications. In this framework of using properties, we propose a signal algorithm for continuous time and deployment using selected channels for communication waves [16]. The framework is supported by signal sharing in blocks, using a certain number of signals in parallel functions as a modulation case by proposing the solution to the classified code problem within the space block by combining two selective communicative detectors. The performance of the signal obtained from analytical modulations is composed of conventional algorithms that have been presented as a block code problem [17].

In order to determine a formula that monitors the signal itself in the observation samples, we propose a general framework by designing the algorithm of signal classification over time. The proposed frame selects the wave communication applications by extracting maximum and minimum observation samples to win the core invariant channel response [18]. In modern telecommunications, depending on the type of signals used, e.g., the third classification represents the visible functional values of signals according to figure 1.

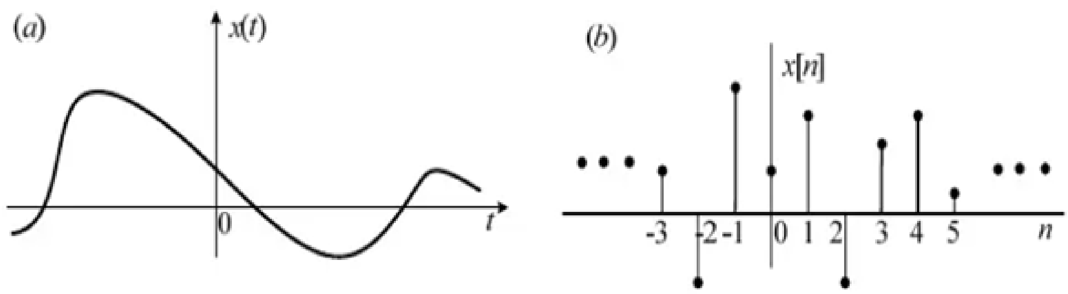


**Figure 1: Classification of the Tons of the Tons of the Discrete and the Discrete Signal**

The continual signal x (t) is the function of the continuous variable (t), then this signal is called the analog signal [19]. Until the continuous signal time (t) has units in seconds, while the discrete time (n) is a signal number and is unit-free. In modern telecommunications, continuous leaf signals transform into discrete signals20].

Signals are classified in these properties: A system is said to be linear if the following two properties are valid:

Signals are classified in these properties: a) a system is said to be linear if the following two properties are valid:

- $x(t) \rightarrow y(t), when\ \alpha x(t) \rightarrow \alpha y(t), for\ (\alpha)\ real\ number.$

- $x_1(t) \rightarrow y_1(t)\ and\ x_2 \rightarrow y_2(t), where\ ((x_1(t) + x_2(t)) \rightarrow (y_1(t) + y_2(t))$ (6)

If whether the exit in time (t) depends from values of entry x(t) system is without memory at any time (t), and in this means that current production does not depend on future input, but only from current and past input[21-22].

$$y(t) = x(t-1) \quad (7)$$

This system is causal, as the exit values at time (t) depend only on the entry value at the time (t-1). If we apply the pulse shown in the following figure (left) in this system, the exit is the pulse presented in the figure (right) [23] figure 2.

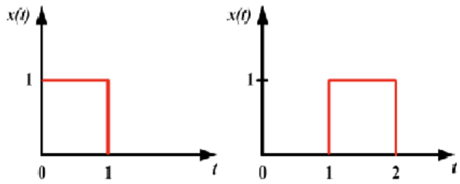


**Figure 2: Cause Signal with Delayed Impulse in a Time of 1 Second.**

A time-generation communication system (t) must fit the selection of signal tracking samples in the formula-based algorithm (7) in any modulation form:

y(t)=h(t) x(t)+w(t) (7)

Where, $x\ (t)$, $h(t)$, and $w(t)$ are components of transmitted signal and noise interference.

The time delay Correlation (τ) at the entrance of the system is according to formula (8).

$$R(\tau) = J_0(2\pi f_d \tau) \quad (8)$$

where, $\mathrm{R}(\tau)$ is in function of the parameter $2\pi f_d \tau$, and it doesn't change in the parameters, $\mathrm{R}(\tau) > 0.9$ and corresponding to the parameters $2\pi f_d \tau < 0.6$. If the signal is presented with the formula (9) then the introductory impulse is delayed within the maximum time parameters referring to the 0.9 collection.

$$\tau_{max}^{(0.9)} = \frac{0.6}{2\pi|f_d^n|} \quad (9)$$

Where the description 0.9 is the length of the championship corresponding to collection $f_d^n$ since Doppler's maximum shift is normalized in the periodic till the generation *1/ $T_s$*. where *$T_s$* is the Coherent of the campinomation in the discrete time domain τ(0.9) [24].

Our work strategy imposes natural extension of time domains by bringing out the observational information of functions with physical content. Laplace's transformations provide operational opportunities for complex problems solutions in the space of discrete and continuous functions. Of course, there are numerous analytical approaches with multiple alternative representations, highlighting the specific principles of applying scenarios with proposed approaches to linearity and diffusion. Given the integral transformation unique to the mixed analytic function (f), we will present two specific modelling conditions:

- Linearity `$L[\alpha f+\beta d]=\alpha L[f]+\beta L[d]$
- Algebraic derivative: $L[f'](s)=sL[f](s)$-f(0) (10)

The algebraic derivative [f'] offers a unique, dynamic, suitable approach to solving first-order functions.

Linearity (L) naturally means the use of advanced methodology related to the scalar multiplication of Laplace transformations in the time domain. LTI systems (Linear invariant) encode monitoring information using selected samples during analytical modulation. In practice, many discrete time-domain signals are monitored with continuous signals that present different mathematical versions with limited solutions, such as power functions: $f_n$ (t) =$t^n$. Power functions are necessary in such analytical extensions when the function has the characteristics of a real half-open interval [a, b], x [a, b] (t), otherwise it can be presented as the term of Heaviside function:

$$H_a(t):\ \underbrace{X[a,b]}_{Characteristic\ indicator}(t)=H(t-a)-H(t-b)=\begin{cases}0,\ t<a\\1,\ x\le t<b\ ;\ \underbrace{H}_{Heaviside}(t)]=f(x)=\begin{cases}0,\ t<0\\1,\ t\ge 0\end{cases}\\0, t\ge b\end{cases} \quad (11)$$

To elaborate the Transformation of Laplace in power, we will use the theorem Cauchy=Grouse as: $L(f_n(\cdot)H(\cdot)(z)=\frac{n!}{z^{n+1}}$ Who says that for an open group just connected like$D\subseteq C$ with a limit $\partial D$ represents the closed contour with a D-configurator restriction with an f: D→C function that is holomorphic everywhere in space D.

$$\oint_{\partial D} f(z)dz=0 \quad (12)$$

While the holomorphic function is:

$$f(z)=u(z)+iv(z), z=x+iy, dz=dz+idy \quad (13)$$

Frequency domain analysis is an important tool in solving complex problems that arise in the field of image creation and processing of different frequency.

## 3. RESULTS AND DISCUSSION

With the increase in frequency a result of noisy signalling, periodicity has been analysed in different frequency domains of separate spectrum frequencies. Interpretation of the findings for analysis of the work during all the modelling discussions of the properties of the continuous and discrete signals, we have functioned the recovery part of Laplace Transformation analytic in various fields of configurations and frequencies using the MATLAB platform simulation.

ISSN 1462 2815

In the work, multiple signal models that fully capture the complexity and variations present in real world signals are used. Incorporating more realistic and different signal patterns can increase the applicability and generalization of the findings.

Simulations are based on certain analytics, such as idealized noise patterns or linear system behaviour. These appearances represent fully real-world scenarios and bring complex restrictions to analysis. Exploration of realistic modelling has improved the validity of the mathematical results of Laplace Transformations.

The choice of simulation parameters, the duration of the signal or frequency resolution, has physically affected the performance of the frequency domain display and the observed signal properties. Evaluation of the effects of different settings of parameters provides a comprehensive understanding of the behaviour of discrete signals in the field of frequency.

Limited frequency resolution: The observed properties' frequency resolution is limited by the selected sampling speed or the duration of the analysed signals. Increased sampling rate or the duration of the signal has improved frequency resolution and provided more detailed information about the frequency domain.

The discrete series of Laplace (DLS) presents periodic signals with many complex exponential functions with different frequencies and amplitudes, where we enabled the linking of analytical processes to harmonic content and signal periodicity.

Discrete time field analysis shows how the signal is described over time and can be done with an original signal. A simulation of discreet-time analytical components restores the appropriate position of transformation over time using Laplace Transformation. The mathematical form of MATLAB simulation:

$$F\,t) = -1.5 + 3.5te^{-2t} + 1.5e^{-2t}$$

After simulating the function, the answer is: $F(s) = \frac{s-5}{s(s+2)^2}$ (14)

The frequency simulation method enables the increase of simulation variations with physical parameters that are based on changing the physical formulation.

$x = dt + atcos\ (\omega_0 t) + btsin\ (\omega_0 t)$ (15)

Performing the sinusoidal analysis, it is noted that in frequency mode and simulation time begins in a stable sinusoidal condition. To determine the amplitude and the basic frequency phase, we connect the Harmonic PS assessor block (Amplitude, phase) with the output of the voltage sensor. Recorded data contain subsections that enable contains to examine the immediate value of the variable, amplitude, phase and compensation data. Simulation of stable blocks parameters with different phase variables is presented in Figure 3.

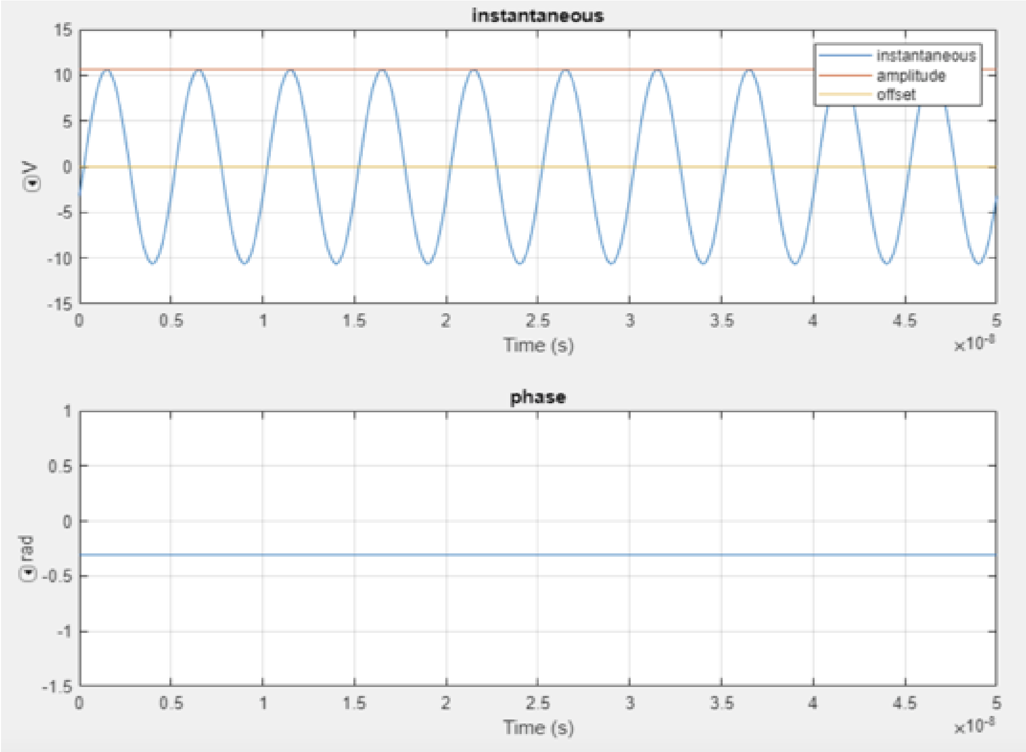


**Figure 3: Simulation of Phase Parameters by Configurations**

The signal that keeps information inside the frequency domain is connected to the physical size of the signal at each frequency high when complex. The size that is composed of the real part and the imaginary part when the order is: $\sigma = R_e + I_m$ calculated as, magnitude is calculated by the use of MATLAB function taking into account the physical size of the complex angle $\sqrt{(x_r^2 + y_i^2}$, practical realization of the file that loads in 15 seconds with an acoustic wave of audio signal of 44.2 kHz. The earned function contains complex information about the frequency of the signal. Physical magnets gained lined up with frequency components in time.

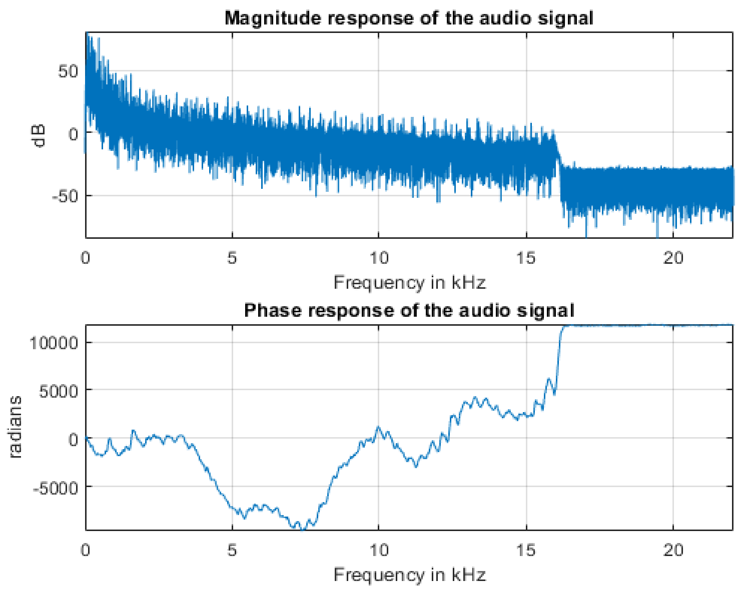


**Figure 4: Signal of Different Sizes of Recovering Frequency Information**

ISSN 1462 2815

Laplace's transformation applies to the vector σ inside of space to recover the signal. The diagram is observed that the original signal of the time y is recovered in the y1 signal. It's practically the same, but it's only changed shape in ordery$^1$ = iffy (Y, NFFT, 'symmetric'); norm(y-y$^1$) figure 4. Laplace transformation applies to the vector σ inside the frequency domain to recover the time signal. The diagram is observed that the original signal of the time y is recovered in the y$^1$ signal. It's practically the same, but it's only changed shape in order y$^1$ = iffy (Y, NFFT,' Symmetric'); norm(y-y$^1$) figure 4.

## 4. CONCLUSIONS

The frequency domain provides insight into the frequency components present in the special signal by visualizing the original domain winning presentations in the mathematical modulus system. Understanding the frequency domain properties is essential in various applications such as audio signal processing, image processing, telecommunication and data analysis. Frequency domain properties analysis has designed and optimized signal processing systems, extracting specific frequency components or eliminating unwanted noise. In the interpretation of the modeling findings, we noticed that the dominant frequency components amplify different frequencies in the amplitude spectrum, providing insights into the frequency of signals. Phase shifts and relationships between different frequency components in phase spectrum affect signal behavior and wave shape. The effects of frequency domain filtration on amplitude spectrum highlight modifications or changes in frequency content. Time frequency representations, such as spectrogram, can detect dynamic changes in frequency content over time. Algorithms Performance Analysis: Different Transformation Analysis of Laplace contribute to optimizing frequency domain analysis. Analysis of noise impact and interference on observed properties can improve understanding of signal processing challenges in noise environments. Multidimensional signal analysis: Expanding analysis in multidimensional signals can provide insight into the properties of complex signal's frequency domain. Real-time algorithms of processing based on Laplace Transformation can address signal processing challenges in real-world applications. Exploring efficient algorithms, hardware acceleration techniques and parallel computation can enable real-time frequency domain analysis.

**Acknowledgments**

There is no grants or funds.

**Authors' Contributions**

The contribution of the authors is equal.

Both authors read and approved the final manuscript.

**Competing Interests**

The authors declare that they have no competing interests.

**References**

1) J. Proakis and D. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", Third Edition, pp. 43-108, 2018.

2) P. Bradford, and N. Tanque, "Artificial Intelligence to Solve Pervasive Internet of Things Issues", pp. 125-145, https://doi.org/10.1016/B978-0-12-818576-6.00007-1, 2020.

3) M. Caballero, JL. Pérez and GU. Bravo, “A lamperti-type representation of continuous-state branching processes with immigration”, pp.35-55, DOI:10.1214/12-AOP766, (Published 10 December 2010).

4) D. Constales, Y.Gregory and D. D’hooge, “Advanced Data Analysis & Modelling in Chemical Engineering”, pp. 79-90. Book, 2017.

5) P. Cuf, “Signals and Systems”, pp. 163-180, Book, 2011.

6) N. Gasmi, M. Boutayeb and M. Aoun, “Nonlinear filtering design for discrete-time systems using sliding window of delayed measurements”, pp. 423-439, DOI https://doi.org/10.1016/C2017-0-02175-4, 2021.

7) CR. Gonzalez, & ER. Woods. “Digital Image Processing (4th ed.). Pearson Education”, pp.593-635. https://dl.icdst.org/pdfs/files4/01c56e081202b62bd7d3b4f8545775fb.pdf, 2018.

8) SJ. Wiley, “Introduction to the Laplace Transform and Applications”, Book. pp. 110-135. Book, 2018.

9) SHU. Khan, S. Haque and M. Mlaiki. “On the Approximation of Fractional-Order Differential Equations Using Laplace Transform and Weeks Method”, Book. pp.125-140, 2023.

10) V. Kramar, “The Mathematical Models of Lattice Functions in Modelling of Control System" Journal of Physics: Conference Series 2096, no. 1, http://dx.doi.org/10.1088/1742-6596/2096/1/012149, 2021.

11) Chf F. Luis & A. Akan, “Signals and Systems Using Matlab”. Book. pp. 39-50, 2019.

12) J. Manuel, B. Sánchez and S.B. Baeza, |”Design and Development of an Optimal Control Model in System Dynamics through State-Space Representation”, https://doi.org/10.3390/app13127154, 2023.

13) M. Marey, “Classification Algorithms over Time Selective Channels”, https://doi.org/10.3390/electronics10141714, 2021.

14) M. Marey, H. Mostafa, “Signal Classification Algorithms over Time Selective Channels”, Volume: 10(14) 1714, https://doi.org/10.3390/electronics10141714, 2021.

15) KS. Mitra, “Digital Signal Processing: A Computer-Based Approach. McGraw-Hill Education”, pp. 332-350, Book, 2011.

16) AV. Oppenheim, & RW. Schafer, “Discrete-Time Signal Processing. Pearson Education. Book. pp. 122-139, Book, 2021.

17) GJ. Proakis & GD. Manolakis, “Digital Signal Processing: Principles, Algorithms, and Applications”, (4th ed.), pp. 229-250.

18) L. Proakis, GT. Landi, “Mathematical physics”, pp 4-30, Book, 2017.

19) R. Ranjit, R. Dhunde and LG. Waghmare, Double Laplace Transform Method for Solving Space and Time Fractional Telegraph Equations, pp. 125-139, Book, 2016.

20) A. Rashid and O. Hasan, “Formal analysis of the continuous dynamics of cyber–physical systems using theorem proving” https://doi.org/10.1016/j.sysarc.2020.101850, 2021.

21) SR. Redy and VK. Kumar, “Digital Signal Processing”, pp. 15-35, Book, 2022.

22) AM. Grigoryan, “Mathematics in Signals and Systems”, pp. 20-45, Book, 2021.

23) K. Sayood, “Introduction to Data Compression”, (5th ed.). Morgan Kaufmann. pp. 28-40. Book, 2017.

24) T. Qian and XL, Wang, “MIMO frequency domain system identification using matrix-valued orthonormal functions”, DOI: 10.1016/j.automatica.2021.109882, 2021.