

# **COMPREHENSIVE ANALYSIS AND QUANTIFICATION OF KEY PERFORMANCE MATRICES OF SWIPT SYSTEM**

**PROJECT REPORT (Phase I)**

*Submitted in partial fulfilment of the requirements for the award of  
B. Tech Degree in Electronics and Communication Engineering  
from the APJ Abdul Kalam Technological University*

**SUBMITTED BY**

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**DECEMBER 2024**

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Certified that the project phase I report entitled “**COMPREHENSIVE ANALYSIS AND QUANTIFICATION OF KEY PERFORMANCE MATRICES OF SWIPT SYSTEM**” is a bonafide report submitted by **MP FARDEEN(SCT21EC069), RAJARAM G(SCT21EC083) and SANDEEP S(LSCT21EC126)** in partial fulfilment for the award of Bachelor of Technology in **ELECTRONICS AND COMMUNICATION ENGINEERING** from **APJ Abdul Kalam Technological University**.

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## **DECLARATION**

We declare that this report titled **Comprehensive Analysis and Quantification of Key Performance Matrices of SWIPT System** in partial fulfilment for the award of the degree of Bachelor of Technology in **Electronics and Communication Engineering** of APJ Abdul Kalam Technological University, is a record of original work carried out by us and has not formed the basis for the award of any other degree or diploma, in this or any other Institution or University. In keeping with the ethical practice in reporting scientific information, due acknowledgements have been made wherever the findings of others have been cited.

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## ABSTRACT

In recent years, the integration of wireless power transfer with data communication has gained substantial attention, particularly in IoT and remote sensing applications where the availability of power sources is limited. This project delves into the comprehensive design, implementation, and performance evaluation of a Simultaneous Wireless Information and Power Transfer (SWIPT) system. SWIPT technology enables the simultaneous harvesting of energy and decoding of information from a unified wireless signal, which facilitates energy autonomy in connected devices and reduces the reliance on traditional power supplies.

The project's objectives encompass the creation of a SWIPT model, extensive simulation to understand its operational dynamics, and the derivation of a mathematical model for precise quantification of critical performance metrics. Utilizing MATLAB and Simulink, the SWIPT model is designed and simulated to explore the efficiency of power conversion and the robustness of information transmission. Key performance metrics are analyzed, including Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), throughput, energy conversion efficiency, and energy outage probability, each of which offers insights into the system's reliability and energy utilization.

The mathematical model derived for the SWIPT system provides equations that describe these performance metrics, enabling quantitative analysis and predictive modeling of system behavior under varying conditions. Simulation results highlight the effectiveness of the SWIPT system in environments characterized by different noise levels and energy requirements, offering a benchmark for future SWIPT implementations.

This project contributes to the growing body of knowledge on wireless energy and information systems, with implications for IoT, sensor networks, and remote agricultural monitoring. The findings underscore the potential for SWIPT systems to enhance operational efficiency in energy-constrained environments, supporting applications in agriculture, healthcare, and industrial IoT where uninterrupted data flow and power availability are paramount.

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## LIST OF SYMBOLS AND ABBREVIATIONS

|       |  |
|-------|--|
| SWIPT | Simultaneous wireless Information and Power Transfer |
| EH    | Energy harvesting                                    |
| ID    | Information Decoding                                 |
| PSR   | Power splitting Relay                                |
| BER   | Bit Error Rate                                       |
| SNR   | Signal To Noise Ratio                                |
| BPSK  | Binary Phase Shift Keying                            |
| DC    | Direct Current                                       |
| IoT   | Internet Of Things                                   |

# CHAPTER 1

## INTRODUCTION

The increasing proliferation of Internet of Things (IoT) devices and the demand for remote sensing technologies have highlighted the need for efficient power and data management solutions in constrained environments. Simultaneous Wireless Information and Power Transfer (SWIPT) has emerged as a promising technology to address these challenges by enabling both energy harvesting and data communication through a single wireless signal. This dual functionality not only reduces the dependency on conventional power sources but also extends the operational lifespan of devices, making SWIPT an ideal choice for applications in remote monitoring, smart agriculture, healthcare, and other IoT-driven fields.

In a SWIPT system, a wireless signal transmits both power and information concurrently. This setup allows IoT devices, such as sensors and cameras, to capture data, decode information, and harvest energy from the same signal, significantly optimizing energy consumption. This project focuses on designing and implementing a SWIPT model capable of supporting information decoding and energy harvesting, using MATLAB and Simulink to simulate the SWIPT system's behavior under real-world conditions.

The study aims to evaluate the effectiveness of the SWIPT model by quantifying several performance metrics, including Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), throughput, energy conversion efficiency, and energy outage probability. These metrics are vital for understanding the trade-offs between data communication quality and energy harvesting efficiency. By creating a mathematical model of the SWIPT system, the project also seeks to develop equations that predict performance under various scenarios, providing a reliable tool for future design improvements.

This project contributes to ongoing advancements in SWIPT technology, providing a foundation for developing sustainable, self-powering IoT devices. The insights gained from this study will serve as a guideline for optimizing SWIPT systems, with implications for real-world applications where long-term, reliable power and data transmission are essential.

## **CHAPTER 2**

### **LITERATURE REVIEW**

Simultaneous Wireless Information and Power Transfer (SWIPT) has gained significant interest in recent years due to its potential in enhancing energy efficiency and data reliability in wireless communication networks. As IoT, remote sensing, and autonomous sensor networks continue to expand, SWIPT offers an innovative solution to the constraints of limited power sources by allowing devices to both communicate and recharge using the same RF signal. The literature on SWIPT covers various aspects, including theoretical frameworks, energy harvesting models, modulation techniques, and practical implementations across different fields. This survey provides a comprehensive review of key contributions in the SWIPT domain.

#### **Theoretical Foundations and Energy Harvesting Models**

Fundamental studies on SWIPT have laid the groundwork by establishing basic theoretical models. Varshney (2008) was among the first to propose the concept of SWIPT, highlighting the potential of RF signals for simultaneous data and energy transfer. Following this, Grover and Sahai (2010) expanded the theoretical model to address the trade-offs between power transfer and data rate in SWIPT systems, providing insights into channel capacity and achievable throughput in energy-harvesting scenarios. Subsequent studies by Liu et al. (2013) focused on practical challenges in energy harvesting, specifically the nonlinearities in RF-to-DC conversion and their impact on system efficiency. These early works underscore the potential and challenges of SWIPT in balancing energy and data requirements in practical implementations.

#### **Performance Metrics and Mathematical Modelling**

As SWIPT systems moved closer to practical applications, researchers emphasized quantifying system performance. Surveying performance metrics like Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), and energy efficiency became central to evaluating SWIPT effectiveness in realistic scenarios. For instance, Zhou et al. (2014) explored the optimization of BER and energy conversion efficiency under varying noise conditions, identifying methods to maximize data reliability while ensuring sufficient energy harvesting. Additionally, the work by Chen et al. (2015) provided mathematical

models to measure throughput and energy outage probability, offering analytical insights to predict system performance and optimize SWIPT configurations for different applications. These metrics remain essential for assessing SWIPT systems in controlled environments before deployment in real-world applications.

### **Modulation Techniques and System Architectures**

To optimize the dual functions of SWIPT, researchers have explored modulation schemes and specialized architectures. As SWIPT requires managing interference between data and energy paths, modulation techniques like power-splitting, time-switching, and antenna-switching have been studied extensively. Zhang and Ho (2013) proposed the power-splitting method, which splits incoming signals into separate paths for energy harvesting and information decoding, balancing power needs with communication demands. On the other hand, Ng et al. (2014) examined time-switching, where time slots are allocated separately for data and energy transfer. These methods allow SWIPT systems to adjust dynamically based on signal strength, channel conditions, and application-specific requirements. New architectures leveraging multiple antennas, known as MIMO-SWIPT, have also shown promise, as explored by Ding et al. (2015), who demonstrated enhanced energy efficiency and data rate using MIMO configurations.

### **Challenges and Future Directions**

While promising, SWIPT faces challenges, including low energy conversion efficiency, interference between power and information signals, and dependency on line-of-sight communication. Recent reviews by Perera et al. (2018) discuss future challenges and suggest areas for improvement, such as advanced modulation schemes, better rectifier designs for higher RF-to-DC conversion, and machine learning for adaptive SWIPT optimization in varying environmental conditions. Integrating SWIPT with 5G and beyond could address many of these limitations, allowing for high-speed, low-latency SWIPT systems with robust energy-harvesting capabilities.

## **CHAPTER 3**

### **PROPOSED SYSTEM**

#### **3.1 PROBLEM STATEMENT**

With the rapid expansion of IoT and remote sensing applications, the need for reliable and sustainable power sources has become a significant challenge, especially in environments where regular battery replacement or wired power sources are impractical. Traditional power supply methods are limited in their ability to sustain long-term operations, particularly for devices deployed in remote areas, agriculture, or autonomous systems. Simultaneous Wireless Information and Power Transfer (SWIPT) has emerged as a potential solution, allowing devices to simultaneously harvest energy and communicate data over a single wireless signal.

Despite its promise, implementing SWIPT systems poses several challenges. Key issues include optimizing energy conversion efficiency, balancing the trade-off between energy harvesting and information decoding, and maintaining robust data transmission in varying environmental conditions. The interference between power and information signals further complicates SWIPT design, necessitating advanced modulation schemes and system architectures that can dynamically adapt to signal and channel conditions.

This project addresses these challenges by developing a SWIPT model capable of effectively harvesting energy and decoding information in realistic operational scenarios. The project aims to design, simulate, and analyze a SWIPT system, with a focus on quantifying performance metrics such as Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), throughput, energy conversion efficiency, and energy outage probability. By developing both simulation models and mathematical frameworks, this project seeks to provide a comprehensive solution that enhances the reliability and efficiency of SWIPT systems for IoT applications, laying the groundwork for sustainable and energy-autonomous networks in remote and resource-constrained environments.

### 3.2 OBJECTIVES

1. To design a SWIPT model that supports simultaneous wireless energy harvesting and information decoding.
2. To implement the SWIPT model using MATLAB and Simulink for realistic simulation and analysis.
3. To mathematically model the SWIPT system and derive equations for critical performance metrics.
4. To quantify and analyze key performance metrics, including:
  - Signal-to-Noise Ratio (SNR)
  - Bit Error Rate (BER)
  - Throughput
  - Energy conversion efficiency
  - Energy outage probability
5. To provide insights and recommendations for optimizing SWIPT systems for IoT and remote sensing applications.
6. To lay the foundation for future improvements in SWIPT technology, with applications in sustainable, energy-efficient IoT networks.

## CHAPTER 4

### METHODOLOGY

The project follows a structured approach to design, implement, and evaluate the SWIPT system, focusing on the simultaneous wireless transfer of power and information. The methodology includes the following steps

#### **Designing the SWIPT Model**

Begin with the conceptual design of a SWIPT model that supports both energy harvesting and data communication. The model will consider factors such as modulation schemes, energy harvesting paths, and data decoding processes to ensure seamless integration of power and information transfer.

#### **Signal Path Division for Energy Harvesting and Information Decoding**

- The SWIPT model splits the incoming RF signal into two primary paths: one for energy harvesting (EH) and the other for information decoding (ID). This split can be achieved using techniques such as **power splitting** or **time switching**:
  - **Power Splitting:** A portion of the RF signal is directed to the EH path, while the remainder is routed to the ID path. This method allows for continuous energy harvesting and data transmission but may involve a trade-off between energy availability and data strength.
  - **Time Switching:** The signal alternates between energy harvesting and information decoding in specific time slots, which can improve the efficiency of each function but requires precise timing control.

#### **Modulation Scheme Selection**

- Modulation is essential for encoding data onto the RF signal while ensuring that the signal remains suitable for energy harvesting. **Binary Phase Shift Keying (BPSK)** is often chosen for its simplicity and resilience to noise. BPSK modulates

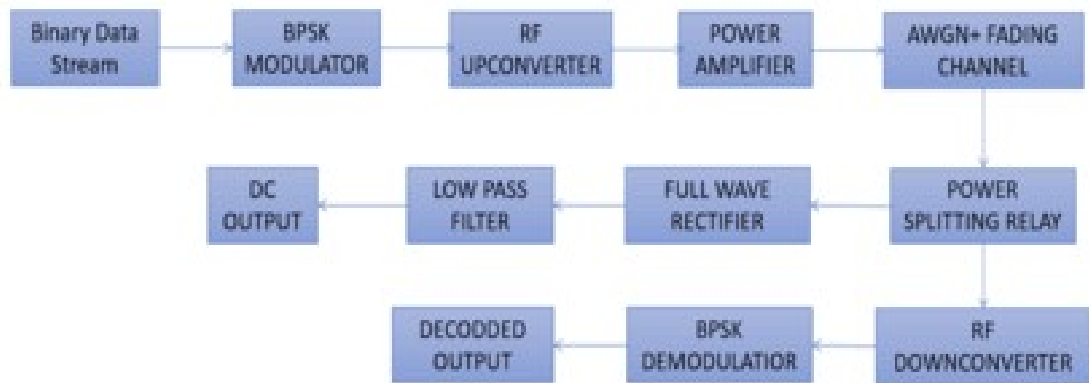
the signal by shifting its phase, making it easier to decode in the presence of noise while preserving sufficient energy for the EH path.

### **Energy Harvesting Circuit Design**

- The EH path includes a rectification circuit that converts the RF signal into usable DC power. Key components of the EH circuit include:
  - **Rectifier:** Converts the incoming RF signal to DC power using diode-based circuits, such as a voltage doubler or Schottky diode rectifier.
  - **Storage Element:** After rectification, energy can be stored in a capacitor or battery for later use, ensuring that the harvested power can support device operation even when the RF signal is weak.
  - **Matching Network:** A matching network optimizes power transfer to the rectifier, reducing reflection and maximizing the efficiency of energy conversion.

### **Information Decoding Circuit Design**

- The ID path includes components for demodulating and decoding the binary data. Major elements in this path include:
  - **Down conversion:** The RF carrier is downconverted to an intermediate frequency or baseband for easier data extraction.
  - **Demodulation Circuit:** The received signal is demodulated to retrieve the original binary data. In the case of BPSK, a phase detector can decode the information by detecting phase shifts.
  - **Filtering and Noise Reduction:** Low-pass filters can be applied to mitigate noise from the transmission channel, improving the reliability of the decoded data.



**Fig 4.1 Block diagram of SWIPT Model**

### 1. Simulation Setup

Implement the designed SWIPT model in MATLAB's Simulink environment. This involves setting up components for the energy harvesting (EH) path, information decoding (ID) path, and modulation techniques, as well as defining system parameters.

- Configure the simulation environment to assess how the SWIPT model operates under realistic conditions. Parameters like signal noise, frequency, and power levels are adjusted to replicate actual conditions in which the SWIPT system would operate.

### 2. Mathematical Modeling

- Develop a mathematical model of the SWIPT system to derive equations for performance metrics. These metrics include Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), throughput, energy conversion efficiency, and energy outage probability. Mathematical modeling is crucial to quantify and predict system performance.

### 3. Performance Metrics Quantification

- Using MATLAB code, calculate and plot the performance metrics based on the derived equations. This step involves running simulations to

gather data and applying the mathematical model to analyze the results comprehensively.

#### **4. Result Analysis**

- Evaluate the simulation results to determine the SWIPT model's effectiveness in energy harvesting and information transfer. The analysis helps identify strengths and potential limitations of the model, such as trade-offs between power efficiency and data reliability.

#### **5. Future Improvements and Recommendations**

- Based on the findings, propose improvements and optimizations to enhance the SWIPT system. Recommendations may include advanced modulation techniques, improved rectifier designs, or adaptive algorithms for dynamic environments.

This methodology provides a systematic approach to developing and assessing the SWIPT system, with the ultimate goal of enhancing performance in applications that require efficient power and data transmission

## CHAPTER 5

### SIMULATION AND RESULTS

The SWIPT Simulink model is designed to simulate the simultaneous transmission of power and information through a wireless signal. Built in MATLAB's Simulink environment, this model provides a virtual framework to analyze and evaluate the performance of a SWIPT system in terms of both energy harvesting (EH) and information decoding (ID). Here's a breakdown of the model's main components and their functions

#### 1. Binary Data Stream Generation

- The model begins with a binary data source, representing the information to be transmitted. This binary stream serves as the input for the information-decoding path, which will undergo modulation for transmission.

#### 2. RF Carrier Signal

- An RF carrier signal is generated and modulated with the binary data to enable wireless transmission. This carrier signal is essential for transporting both power and data, as it can be used in both the EH and ID paths.

#### 3. Modulation Scheme ( BPSK)

The binary data stream is modulated using a technique like Binary Phase Shift Keying (BPSK). BPSK provides robust data transmission by encoding data in phase changes, helping the system maintain reliable information decoding, even in noisy conditions.

#### 4. Energy Harvesting (EH) Path

- In the EH path, a portion of the RF signal is directed towards energy harvesting components. This signal path goes through an Additive White Gaussian Noise (AWGN) channel to simulate real-world signal conditions. After passing through the noise channel, the signal is rectified, converting the RF energy into DC output for powering devices.

#### 5. Information Decoding (ID) Path

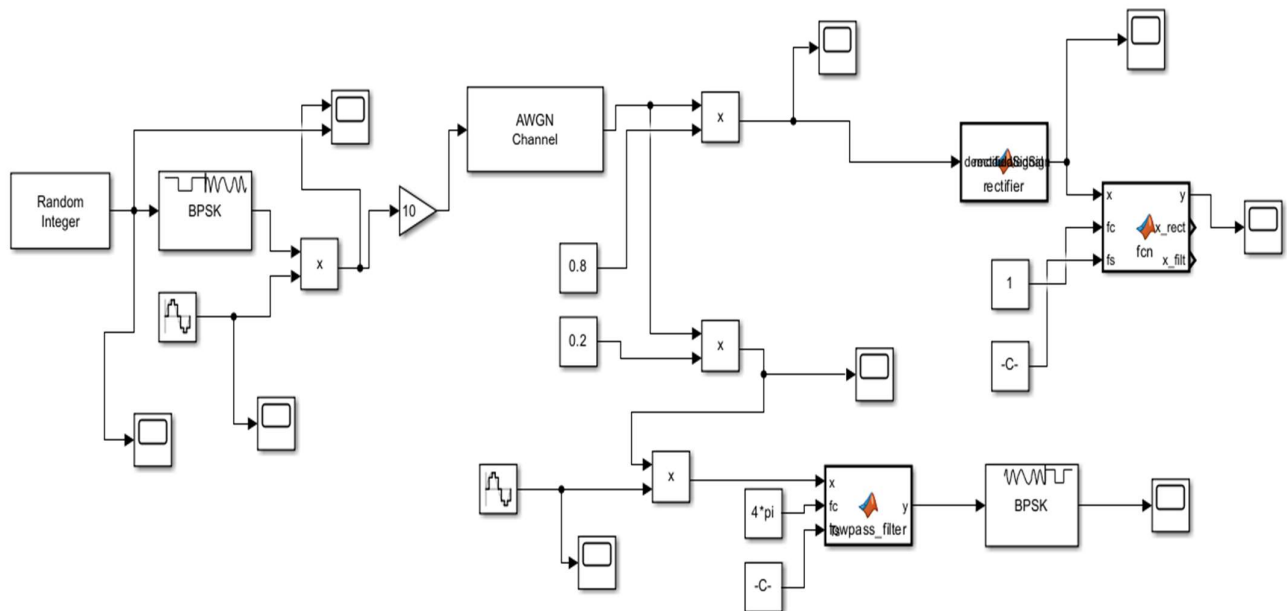
- Simultaneously, another part of the RF signal is directed towards the ID path. This path also encounters AWGN, simulating interference and signal degradation. In the ID path, the carrier signal is down converted to retrieve the modulated binary data stream, which is then decoded back into its original format.

## 6. DC Output and Signal Reception

- The model outputs two key results: the DC power harvested from the EH path and the received binary data from the ID path. These results are analyzed to evaluate the effectiveness of the SWIPT system in supporting both power and data transfer without significant degradation in either function.

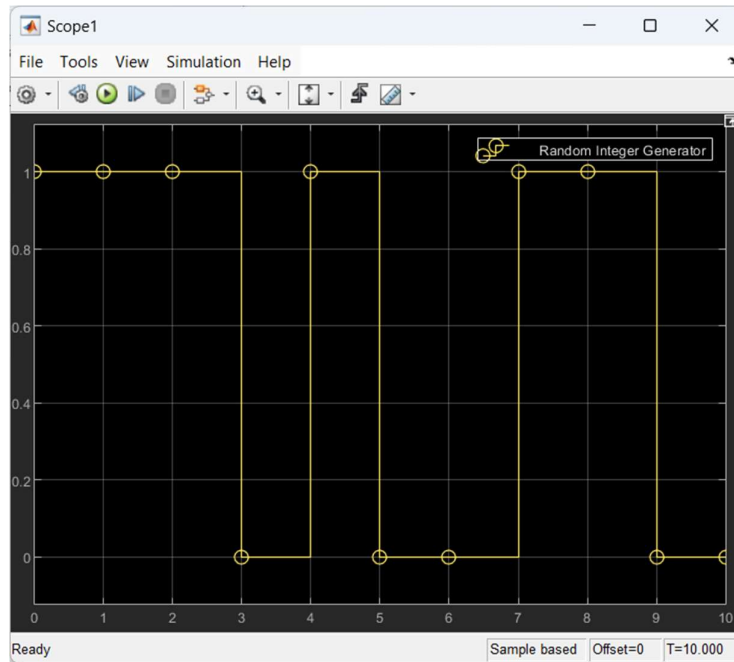
This Simulink model provides a comprehensive virtual setup to study the performance of SWIPT under various scenarios and noise conditions.

**F**

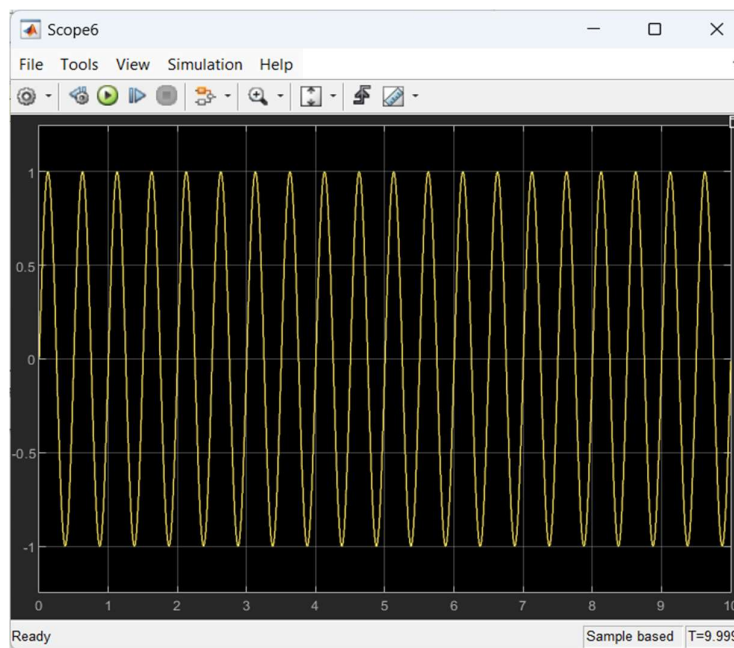


**Fig 5.1 Simulation in SIMULINK**

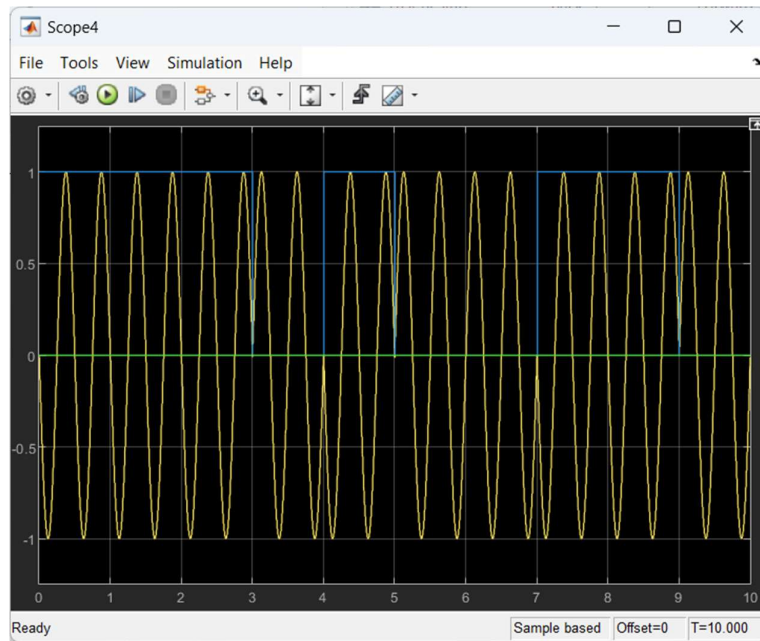
## SIMULATION RESULTS



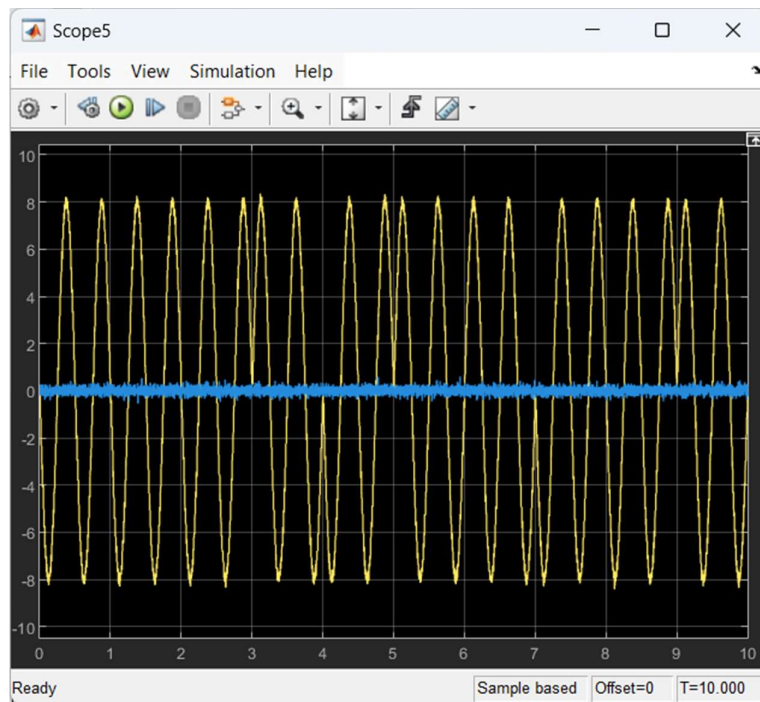
**Fig 5.2 Binary data stream**



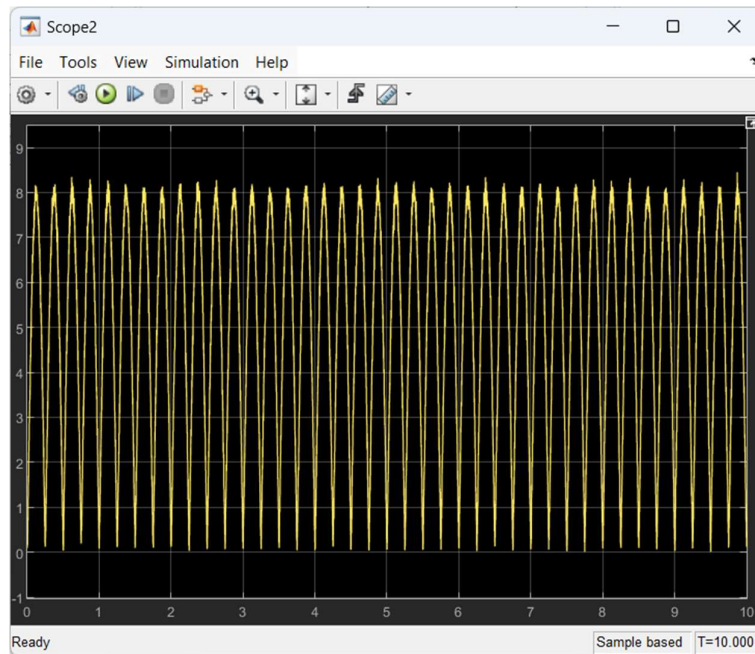
**Fig 5.3 RF Carrier Frequency**



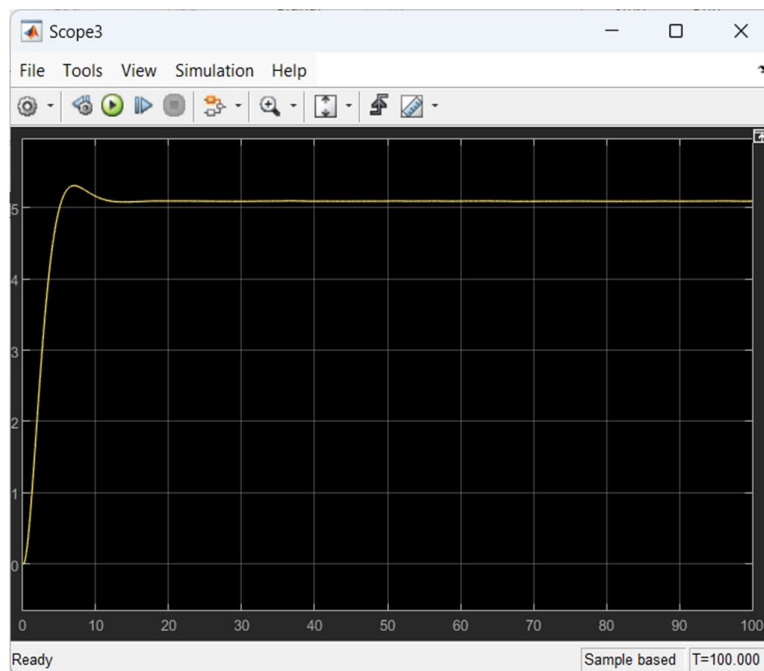
**Fig 5.4 BPSK Modulated Signal**



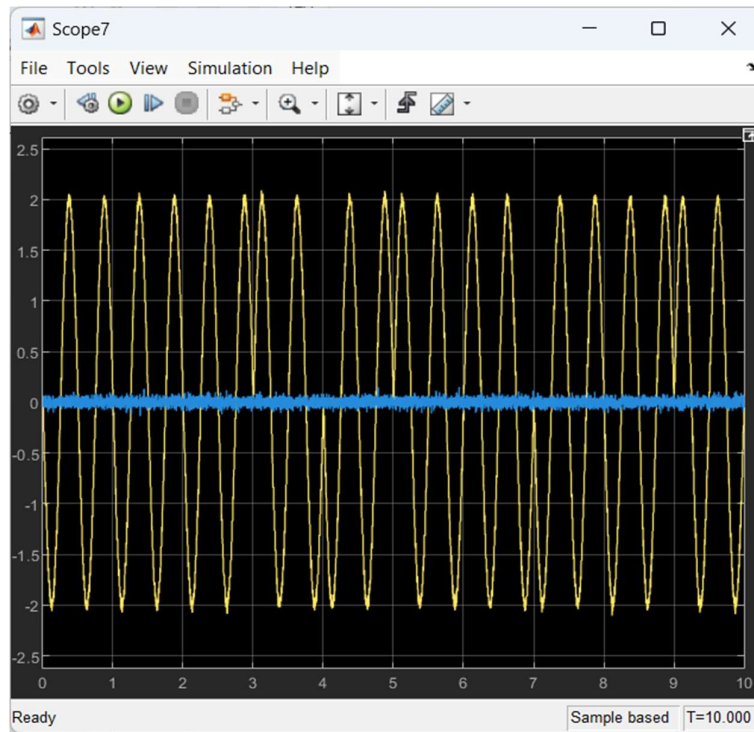
**Fig 5.5 Energy Harvesting path signal after passing through AWGN channel**



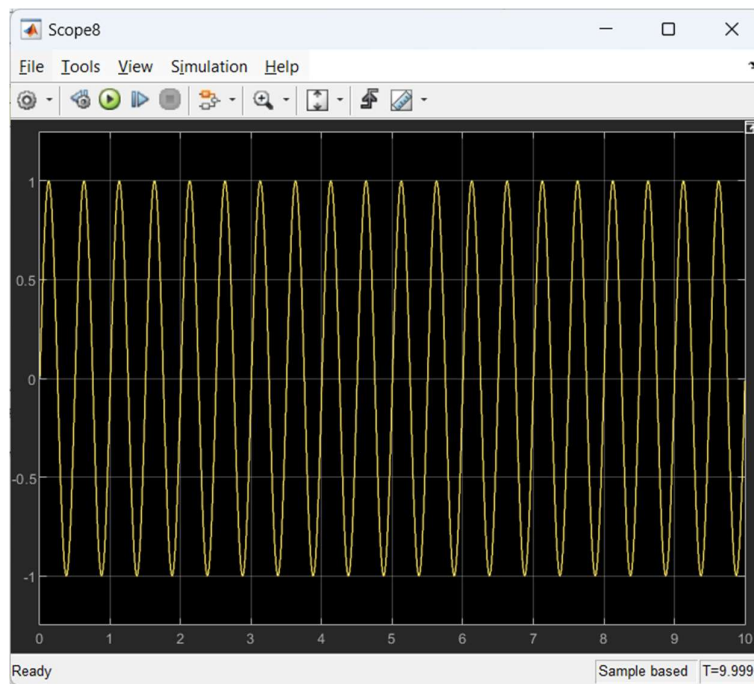
**Fig 5.6 Rectified Signal**



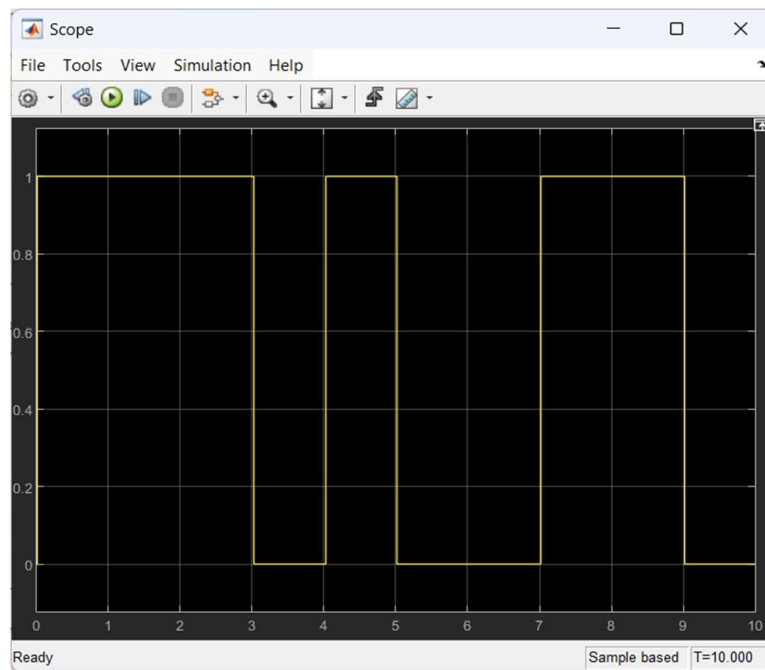
**Fig 5.7 DC output**



**Fig 5.8 Information Decoding path signal with noise**



**Fig 5.9 Carrier signal used for RF Down conversion**



**Fig 5.10 Received Binary data stream**

## CHAPTER 6

### MATHEMATICAL MODELLING OF SWIPT SYSTEM

The mathematical modeling of a Simultaneous Wireless Information and Power Transfer (SWIPT) system is crucial for understanding and quantifying the complex interactions between power harvesting and data transmission over a shared wireless signal. By deriving equations and establishing a mathematical framework, we can accurately predict the system's performance under different conditions, assess key performance metrics, and optimize the SWIPT design to meet specific application needs.

In SWIPT systems, the primary challenge is balancing the trade-offs between energy conversion efficiency and information decoding accuracy. This involves modeling the power splitting or time-switching mechanisms, signal propagation with noise, and the energy harvesting and information decoding processes. Through mathematical analysis, we can evaluate how factors such as Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), energy conversion efficiency, and throughput are influenced by the system's design parameters, such as modulation schemes, channel conditions, and power allocation.

The mathematical model provides the following benefits:

- **Performance Prediction:** It enables us to predict the behavior of the SWIPT system in various operational environments, facilitating adjustments to maximize both power and data reliability.
- **Quantification of Trade-offs:** By modeling the relationships between EH and ID, we can quantify trade-offs and guide design decisions for optimal balance.
- **Optimization:** The equations allow us to optimize the SWIPT model by adjusting parameters such as power splitting ratios, modulation schemes, and filtering, ensuring high efficiency and accuracy.

## 6.1 Transmitter Modelling

1. Binary data stream: Information represented as '0' and '1'

$$\{dn\} \text{ where } dn \in \{0,1\} \dots\dots\dots (1)$$

2. BPSK modulator: It maps 0 to -1 and 1 to +1

$$dn \in \{0,1\} \rightarrow dn^* \in \{-1, +1\} \dots\dots\dots (2)$$

$$s(t) = A \cdot \cos(2\pi f_c t + \theta_i) \dots\dots\dots (3)$$

Where  $f_c$  is the carrier frequency and  $\theta_i$  is the phase shift due to BPSK Modulation

3. RF up conversion:

$$s_{RF}(t) = A \cdot \cos(2\pi f_{RF} t + \theta_i) \dots\dots\dots (4)$$

Where  $f_{RF}$  is the RF frequency where  $f_{RF} = f_c + f_{LO}$

$f_{LO}$  is the Local Oscillator Frequency

4. Power amplifier: Boosts the modulated signal

$$s_{txn}(t) = G \cdot s_{RF}(t) \dots\dots\dots (5)$$

Where G is the Gain of the amplifier

## 6.2 Channel Modelling

The channel is modelled as AWGN and Rayleigh fading channel

- AWGN channel

$$r(t) = s_{txn}(t) + n(t) \dots\dots\dots (6)$$

Where  $s_{txn}(t)$  is the transmitted signal and  $n(t)$  is the AWGN noise

After incorporating the Fading channel

$$r(t) = h(t) \cdot s_{txn}(t) + n(t) \dots\dots\dots (7)$$

Where  $h(t) = |h(t)|e^{j\phi(t)}$

The channel output is:

$$r(t) = |h(t)| \cdot G \cdot A \cdot \cos(2\pi f_{RF} t + \theta_i + \phi(t) + n(t) \dots\dots\dots (8)$$

Where  $\phi(t)$  is the phase shift due to Rayleigh fading channel.

## 6.3 Receiver Modelling

### 1. Power splitter

- The signal  $r(t)$  is first fed into a power splitter, which divides the incoming signal into two paths:
- Energy Harvesting Path: A fraction  $\rho$  (where  $0 < \rho < 1$ ) of the signal power is directed here.
- Information Decoding Path: The remaining fraction  $(1 - \rho)$  of the signal power is directed here.

$$r_{EH}(t) = \sqrt{\rho} \cdot r(t) \dots \dots \dots (9)$$

$$r_{ID}(t) = \sqrt{1 - \rho} \cdot r(t) \dots \dots \dots (10)$$

### 2. Energy harvesting path

The Energy Harvesting (EH) Path contains a rectifier and low-pass filter to extract DC power.

Rectification: The rectifier converts the AC signal into a DC form. The rectified signal  $r_{rect}(t)$  is given approximately by:

$$r_{rect}(t) = |r_{EH}(t)| = |\sqrt{\rho} \cdot r(t)| \dots \dots \dots (11)$$

Substituting  $r(t)$ :

$$r_{rect}(t) = \sqrt{\rho} |h(t)| \cdot G \cdot A \cdot \cos(2\pi f_{RF}t + \theta_i + \phi(t) + n(t)) \dots \dots \dots (12)$$

### 3. Information Decoding Path

The **Information Decoding (ID) Path** includes **RF down conversion** and **BPSK demodulation**.

RF Down conversion: The signal  $r_{ID}(t)$  is down converted by mixing it with a local oscillator (LO) signal at frequency  $f_{RF}$ , producing a baseband signal.

$$r_{base}(t) = r_{ID}(t) \cdot \cos(2\pi f_{RF}t) \dots \dots \dots (13)$$

Substituting  $r_{ID}(t)$

$$r_{base}(t) = \sqrt{1 - \rho} \cdot (|h(t)| \cdot G \cdot A \cdot \cos(2\pi f_{RF}t + \theta_i + \phi(t) + n(t)) \cdot \cos(2\pi f_{RF}t)) \dots\dots\dots(14)$$

After down conversion the high-frequency components are filtered out, leaving the baseband signal will become

$$r_{base}(t) \approx \sqrt{1 - \rho} \cdot |h(t)| \cdot G \cdot A \cdot \cos(\theta_i + \phi(t)) + n_{base}(t) \dots\dots\dots (15)$$

Where  $n_{base}(t)$  is the noise component after down conversion

#### 4. BPSK demodulation:

$$r_{BPSK}(t) = \text{sign}(r_{base}(t) \cdot \cos(\theta_i + \phi(t))) \dots\dots\dots(16)$$

The **sign function**  $\text{sign}(x)$  is a mathematical function that outputs

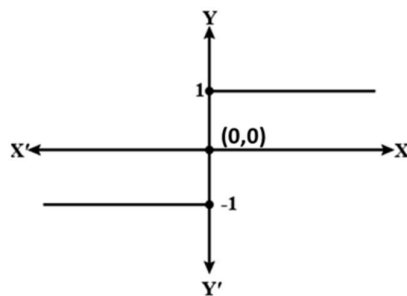
+1 if x is positive.

-1 if x is negative.

The **sign function** is used to determine the polarity of the resulting product, which corresponds to the original bit transmitted.

$$\text{sgn}(x) = \begin{cases} -1, & \text{if } x < 0 \\ 0, & \text{if } x = 0 \\ 1, & \text{if } x > 0 \end{cases}$$

**Graph of Signum Function**



**Fig 6.1 Signum Function Graph**

Signum function acts as a Decision Device in BPSK Demodulation Block

## CHAPTER 7

### WORK PROGRESS

The SWIPT project aims to advance the field of simultaneous wireless information and power transfer by designing, implementing, and evaluating a system that achieves both data transmission and energy harvesting from a single wireless signal. To begin, we established a structured plan encompassing model design in SIMULINK, where we simulated key signal processing components such as binary data streams, carrier signals for RF up/down conversion, and BPSK modulation, which is used in our setup to facilitate reliable data transmission. The model was further developed to include distinct pathways for energy harvesting (EH) and information decoding (ID), capturing signals as they pass through an AWGN channel. This simulation stage allowed us to visualize signal behavior in each path, assess rectification stages, and generate the received binary data for the ID path, thereby demonstrating the system's foundational capability for dual-function signal processing. The mathematical modeling phase is now underway, where we are deriving equations essential for quantifying performance metrics like Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), throughput, and energy efficiency. These derived models will be coded and analyzed in MATLAB to evaluate the SWIPT model's overall effectiveness in achieving optimized energy transfer and data accuracy. In the next phase, we plan to use MATLAB to plot these metrics, providing a clear representation of system efficiency and the impact of variables like noise and modulation type on performance, ultimately contributing to the refinement and validation of the SWIPT model.

1. Successfully developed a SWIPT model and simulated it in SIMULINK
2. Comprehensively analysed how each signal is processed in each block.
3. Mathematically modelled the SWIPT system

Till this is the work progress till now and we are working on the quantification and derivation of key performance metrics of the SWIPT System and coding in MATLAB for plotting the performance matrices

## CHAPTER 8

### CONCLUSION AND FUTURE SCOPE

#### 8.1 Conclusion

The SWIPT project successfully accomplished the design and initial evaluation of a Simultaneous Wireless Information and Power Transfer (SWIPT) model in SIMULINK, illustrating its potential for effective dual-functionality in wireless communication systems. Through a structured methodology, the SWIPT system was developed with pathways for both energy harvesting (EH) and information decoding (ID), handling simultaneous power and data transfer from a single wireless signal. Key elements, such as BPSK modulation and the integration of an AWGN channel, were incorporated to reflect real-world conditions and provide a robust test environment for signal analysis. The simulation outcomes demonstrated the model's capability to process signals effectively across both EH and ID paths, validating the fundamental SWIPT system structure. Additionally, the initial phase of mathematical modeling provided a framework for assessing critical performance parameters, including Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), throughput, and energy conversion efficiency, which are crucial for understanding the system's overall efficiency and data integrity. The project thus laid a foundation for exploring SWIPT systems with optimized energy and information transfer capabilities, addressing significant metrics that influence system reliability and energy sustainability.

#### 8.2 Future Scope

Building on the foundational SIMULINK model and mathematical framework, the next phase of the project will involve deriving further equations for performance matrices and implementing MATLAB code to compute and plot these metrics, enabling a visual representation of system performance. This quantification will aid in identifying areas where the SWIPT model can be refined for improved energy efficiency and data accuracy. In future work, the model can be extended to explore different modulation schemes, such as QPSK or OFDM, which may enhance signal resilience and system throughput under varying channel conditions. Additionally, refining the energy harvesting pathway, perhaps through adaptive or optimized rectifier designs, could significantly reduce energy outage probability and boost energy conversion efficiency.

This project also opens up potential for SWIPT applications in low-power wireless networks, the Internet of Things (IoT), and smart devices, where reliable power and data transfer are crucial. The research can further investigate the use of advanced error-correction coding, dynamic channel management, and adaptive power allocation techniques to support SWIPT systems under diverse environmental and operational conditions, ultimately advancing the applicability of SWIPT in energy-sensitive communication systems.

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