

CYIENT

A ROBUST FRAMEWORK FOR WIRELESS BATTERY MANAGEMENT SYSTEM

A robust wireless communication framework will make Wireless BMS more promising in Electric Vehicles (EVs) and vehicles for Urban Air Mobility (UAM).



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ABSTRACT

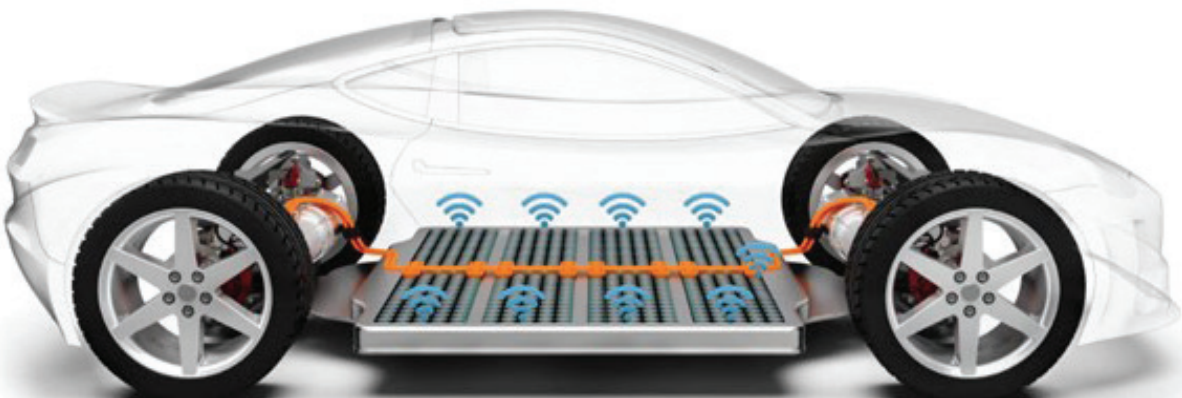
In an era where energy efficiency and sustainability are paramount, having an effective battery management system (BMS) is essential for electric vehicles (EVs) and battery-powered air taxis. While a wired BMS is effective, it has the limitation of maintaining complex wiring harnesses and which reduces flexibility. Wireless BMS technology addresses this by using wireless links instead of physical wiring. However, wireless BMS faces challenges against unwanted interferences in a complex physical environment inside a vehicle. This white paper presents a comprehensive solution for a robust wireless communication framework to overcome these challenges. The solution offers innovative design, advanced capabilities in antenna design, RF system modelling, hardware and software development, and environmental analysis.

INTRODUCTION

A Battery Management System (BMS) is vital for monitoring and controlling battery performance, ensuring safety, and prolonging battery life. Wired BMS configurations often encounter issues like complex installations, maintenance difficulties, and potential safety hazards due to extensive wiring. Additionally, scalability and adaptability to different vehicle designs becomes difficult. The Wireless BMS consists of sensor nodes distributed across battery packs which are physically independent. The nodes communicate data

to a central control unit via a wireless protocol (RF 2.4GHz ISM Band) thereby eliminating any physical interconnect.

However, the wireless connectivity between the central control unit and the nodes at the unit cells is prone to multiple interferences, such as Electromagnetic Interferences, Radio Frequency interferences and multipath reflections within the limited space available for the battery unit. Hence, the robustness of the wireless channel is the prime concern for current developers.



PROBLEM DEFINITION

Wireless BMS, although not yet operational in any production vehicle, is nearing reality in the automobile industry, aiming to balance its flexibility and disadvantages. Primarily, industry players are trying Bluetooth based wireless communication system which are prone to multiple wireless threats. Measures are being taken to strengthen the security levels of Bluetooth, but wireless threats and interference are increasing with time.

CYIENT has taken the initiative to explore the possibilities of using a non-Bluetooth wireless communication protocol and adopting smart RF system design for achieving a robust wireless BMS which will help to overcome the concerns of interferences, thereby providing OEMs an opportunity to leverage the flexibility of wireless BMS. The following sections will describe the solution developed at CYIENT.

HIGH-LEVEL SOLUTION

Solution developed by CYIENT employs a modular architecture to leverage the flexibility offered by a wireless BMS offers. Each wireless node is assigned to the smallest logical group of cells, referred to as a "battery pack". Making each cell array field-replaceable. The antenna for the wireless nodes can be fixed at

convenient locations to avoid interference and achieve better multipath performance. Each wireless node has powerful processing power for RF configuration as well as data handling operations. The following figure depicts the top-level view of the solution.

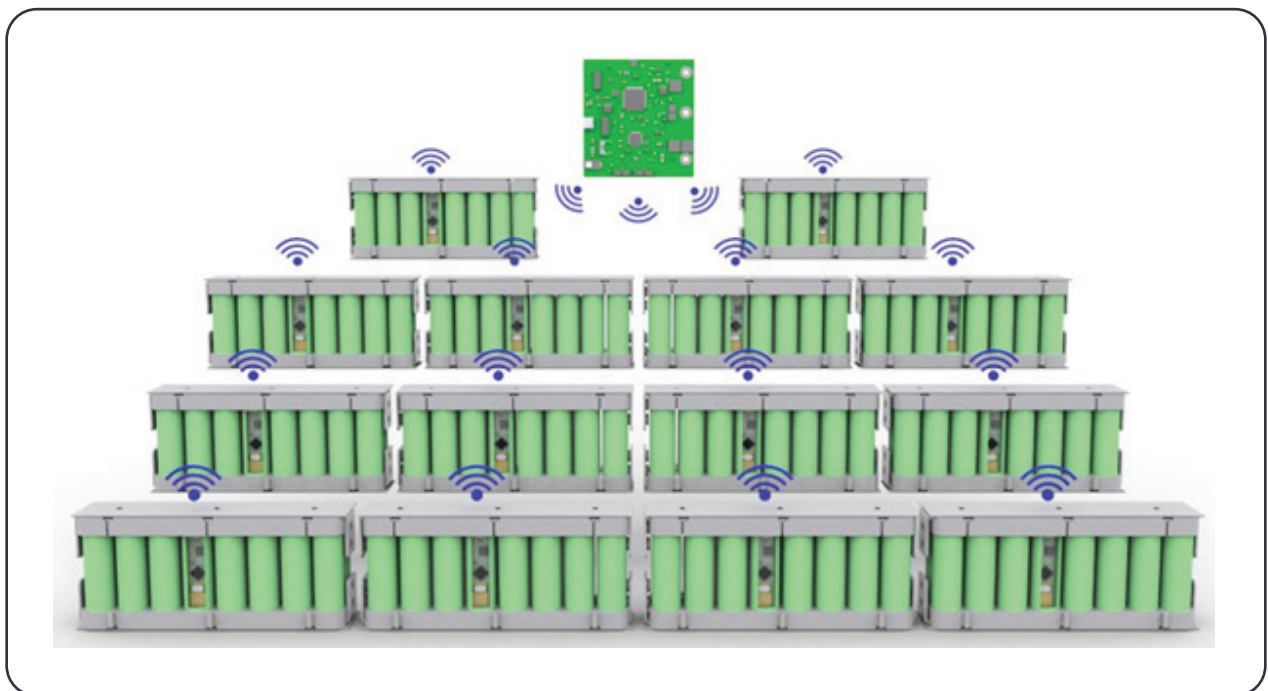


Figure 1: Wireless BMS solution by CYIENT

Following are the key points of the developed solution



RF Node

Operates each BMS system autonomously and reports necessary faults or addresses requests by the Main MCU. This capability supports identifying faulty battery packs and disconnecting them from the system.



Wireless Protocols

Utilizes RF technology with 2.4GHz at ISM Band. Proprietary protocol development and multiple modulation techniques adaptation ensure robust communication.



Compatibility

Engineered to integrate seamlessly with various battery chemistries and configurations. The battery module communicates with the wireless node via SPI and UART.



Scalability

The modular design facilitates easy expansion and adaptation to varying system sizes with no limit on battery module connections.



Solution Details

RF System Design

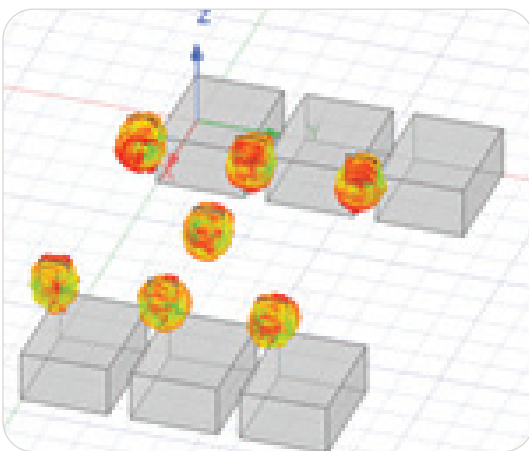
RF design is a critical component of the Wireless Battery Management System (WBMS), RF system design has taken care of the following:

- Efficient antenna placement within the given confined space of an automotive environment to optimize signal transfer from the node to the controller.
- Small yet robust form factor of the antenna.
- RF shielding mechanism.
- Configurable system design for scalability and adaptability to vehicle chassis.
- Digital modulation with Spread Spectrum technique to ensure robust performance in various operating environments.
- Integrated and parameterized system simulation with noise and interference analysis to provide faster solution for any new requirements.

Following figures show some of the system design features.

Arrangement 1

Batteries arranged in two rows, master node is in between two rows



Arrangement 2

All batteries arranged in a single row, master node at one side

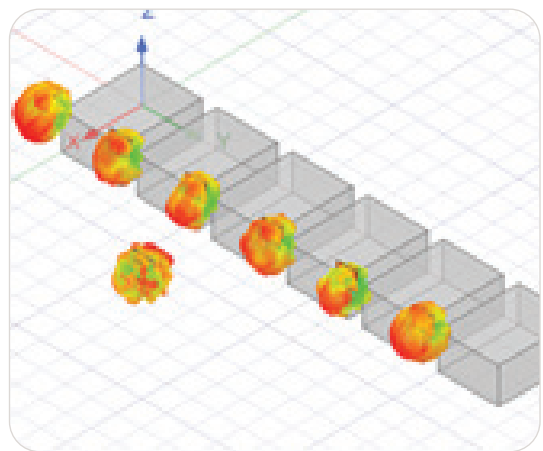


Figure-2: Parameterized battery placement and RF simulation

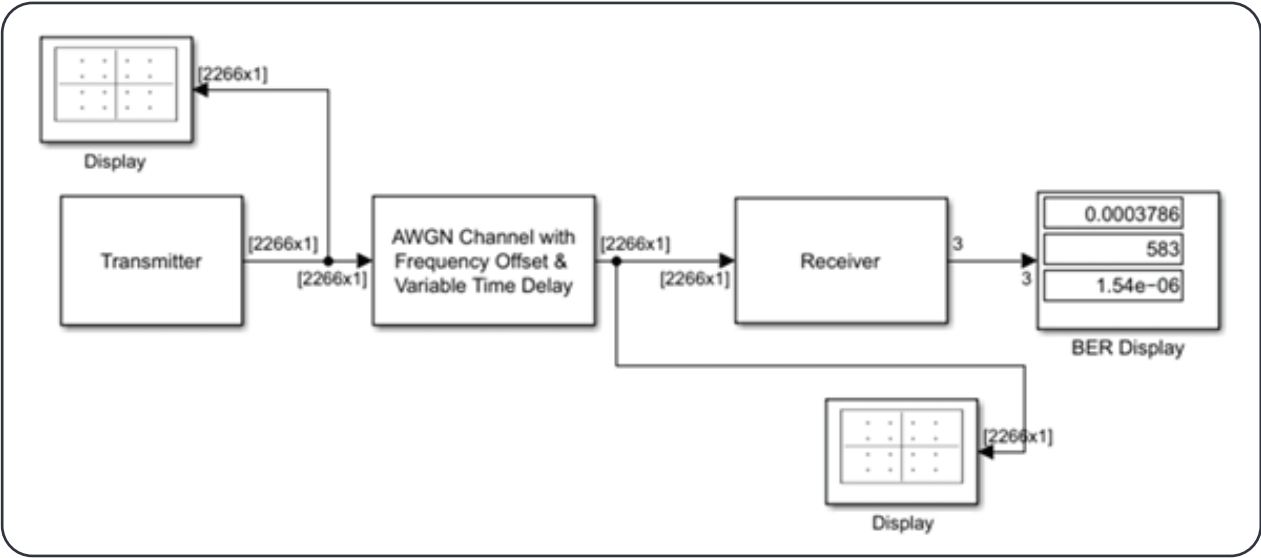


Figure-3: System modelling and simulation



Figure-4: Small and rugged antenna element

Antenna Design:

The antenna for the wireless BMS is required to be small yet rugged to sustain the harsh environment, particularly during maintenance in vehicle workshops. Optimizing the design is crucial for maximizing signal strength and coverage. Advanced antenna designs ensure minimal interference and signal degradation, facilitating reliable data transmission across the battery modules. Different types of small form factor antennas were studied, and one of them, such as PIFA, has been chosen for the prototype design.





Power Management:

Efficient power management is essential to ensure long battery life for the RF nodes. This involves designing low-power RF circuits and implementing energy-saving protocols to minimize power consumption without compromising communication quality. The current design has adopted a very low power wireless chip to address this.



Figure-5: Low Power RF Wireless Communication chip

Wireless Protocol Selection:

A digital modulation technique (non-Bluetooth) that enhances the efficiency and robustness of data transmission has been used for development. Combined with Spread Spectrum techniques, it significantly improves the reliability and security of wireless communication. The staggered phase transitions of the modulation scheme reduce phase noise of the signal, while the Spread Spectrum technique makes it difficult for unauthorized parties to intercept or jam the signal, enhancing communication security. This scheme is the one of the key features of the solution, showing advantages over conventional Bluetooth or Low Energy Bluetooth technologies in terms of robustness.

Hardware Design:

The hardware of the Wireless Battery Management System (WBMS) is meticulously designed to ensure reliability, efficiency, and seamless compatibility with wireless protocols. Special attention is given to designing the PCBs to match the dimensions of the battery packs, ensuring optimal integration and functionality. Key aspects of the hardware design include:

Custom PCB Design



The PCBs are tailored to fit precisely within the battery pack dimensions, ensuring a compact and efficient layout. This design minimizes space utilization and integrates all necessary components for monitoring and communication within the available space.

Robust RF Nodes



Each battery module includes an RF node that facilitates wireless communication. These nodes are designed for low power consumption, ensuring minimal impact on the overall battery life while providing reliable data transmission.

Sensor Integration



The hardware integrates various sensors to monitor voltage, current, temperature, and other critical parameters of the battery cells. These sensors provide real-time data that is crucial for the safe and efficient operation of the battery system.

Power Management



Efficient power management circuits are implemented to optimize energy use within the system. This includes low-power operation modes and energy-efficient components to extend the lifespan of the battery packs.

Safety Features



The hardware design includes built-in safety features such as overvoltage, undervoltage, overcurrent, and temperature protection. These features ensure the safe operation of the battery system under various conditions.



Software Design:

The software component of the wBMS is designed to provide intuitive interfaces for real-time monitoring, data analysis, and predictive maintenance. It also ensures secure data transmission using advanced RF modulation techniques and encryption. Key aspects of the software design include:



Configuration of RF Modulation Techniques: The software configures the RF nodes to use desired digital modulation with Spread Spectrum techniques, optimizing communication for reliability and efficiency. This configuration ensures robust data transmission even in environments with high interference levels.



Data Encryption and Security: To safeguard the integrity and confidentiality, the software employs advanced encryption algorithms. This ensures that data transmitted between the battery modules and the central control unit is hack-proof and secure from unauthorized access.



Real-Time Monitoring: The software provides real-time monitoring of battery parameters through a user-friendly interface. This interface allows operators to view and analyse data from all battery modules, facilitating timely decision-making and proactive maintenance.



Data Analysis and Predictive Maintenance: The software includes tools for data analysis, enabling operators to identify trends and potential issues before they cause failures. Predictive maintenance algorithms analyse historical data to forecast maintenance needs, reducing downtime and improving the overall efficiency of the battery system.



Architecture of Data Management: The software architecture is designed to handle large volumes of data efficiently. It includes data storage solutions that ensure scalability and reliability, with built-in redundancy to prevent data loss.



User Interface: The software offers a graphical user interface (GUI) that simplifies interaction with the system. This GUI is designed to be intuitive and accessible, providing operators with clear insights into the status and performance of the battery system.



System integration and tuning: Finally, the most important phase of the development is system integration, tuning and validation. Although, each individual element of the solution has been verified for the best performances, many signal integrity issues needed to be solved. Additionally, the modulation parameters needed to be optimized for better interference rejection capabilities. Thorough validation was carried out using worst case signal interferences including CW, modulated and commercial interference signals. A glimpse of the testing has been captured in the following image.

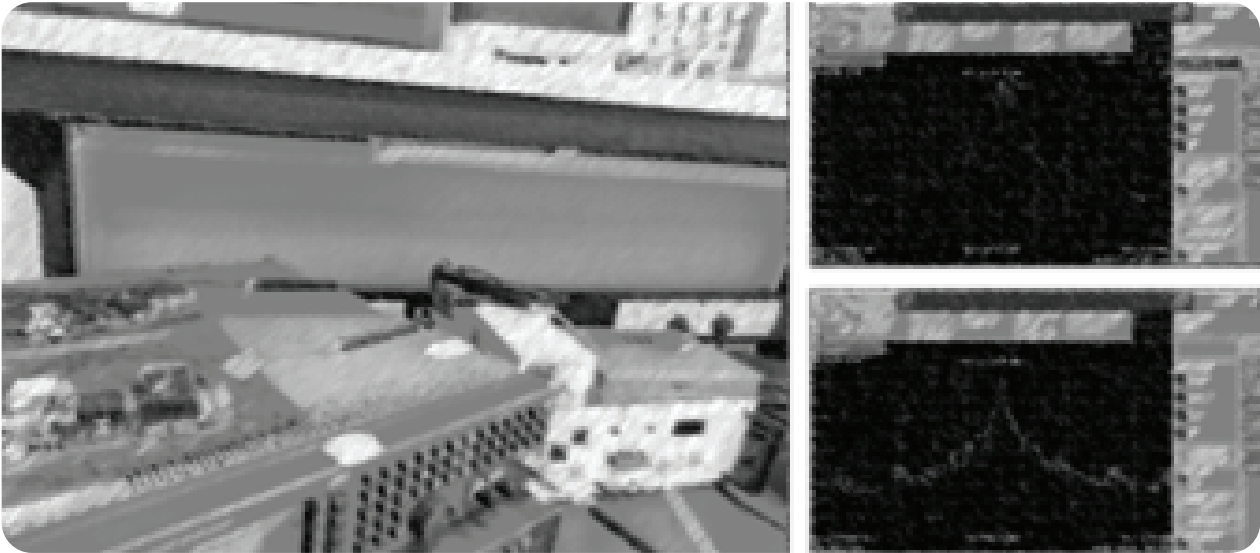


Figure-6: System integration and validation



THE CYIENT THOUGHT BOARD

CYIENT believes in bringing out solutions which are more versatile in nature and more flexible for being adapted to the need of many OEMs.

With increasing focus on wireless battery management system in the industry, a configurable solution will give flexibility to the vehicle/battery manufacturers for developing a robust and future ready battery technology using wBMS. The proposed solution will make the battery system development more agnostics to a particular semiconductor supply chain. Rather, the configurable design will enable the usage of generic wireless SoC supporting multiple protocols. The parameterized approach for system design will help the solution to become upgraded with the evolving needs of the EVs and UAM vehicles. The configurable models for the wireless protocol will help to build robustness to the future vulnerabilities.

Cyient has decades of experience in helping customers worldwide to research, deploy, integrate, migrate, and support different embedded applications, communications networks, and RF technologies. Sustainability, Automotive & Aerospace being key focus areas, CYIENT aims to bring out this solution to enhance the efficiencies of EV technology in near future.



CONCLUSION

The solution outlined in this white paper is a robust framework which can easily be configured to address the ever-growing needs of the EVs in the field of wireless BMS. It is not a one-size-fits-all solution; rather, it offers a customized architecture in a short time. In this way, CYIENT presents this as a paradigm shift in the concept of wireless battery management

technology. With its robust wireless connectivity, modular design, and emphasis on reliability and safety, it offers unparalleled advantages over traditional wireless BMS solutions. Our commitment to innovation and excellence ensures that wBMS meets the evolving needs of industries requiring efficient and reliable battery management systems.



ABOUT THE AUTHORS



Ranadeep Saha is an Electronics & Communication engineer with specialization in microwave and radar technologies and systems. He has over 21 years of industry experience in microwave and radar system research, design, and development. He has primarily worked in design and development of radars and other microwave systems for detection, sensing, and tracking, moving from design engineer to function lead to R&D head for radars. He has extensive experience in the application of microwave and radar technology in defense, space, and other industrial domains.



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ABOUT CYIENT

Cyient (Estd: 1991, NSE: CYIENT) partners with over 300 customers, including 40% of the top 100 global innovators of 2023, to deliver intelligent engineering and technology solutions for creating a digital, autonomous, and sustainable future. As a company, Cyient is committed to designing a culturally inclusive, socially responsible, and environmentally sustainable Tomorrow Together with our stakeholders.

For more information, please visit www.cyient.com



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