Real-Time Location and Tracking, Accurate within Centimeters, Made Possible by LF Antennas

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A. INTRODUCTION

In many industries, including automotive, healthcare, transportation and industrial, reliable communication and precise asset-tracking systems are crucial to optimize operational efficiency, safety, and security. However, many environments where these systems are deployed present significant challenges, including interference from environmental obstacles.

Conventional technologies like Bluetooth Low Energy (BLE) and Ultra-Wideband (UWB) often struggle to maintain signal integrity and reliability in these conditions, leading to operational gaps, potential security risks, safety implications and increased costs.

Low-frequency (LF) technology offers a robust alternative. Typically operating in the 125-135 kHz range, LF technology excels in penetrating materials that hinder higher frequencies. Its low power consumption and safe radiation levels make it an ideal choice for applications that require reliable performance in harsh environments.
LF technology provides a versatile, efficient and reliable solution for:

- Precise location and asset tracking in complex environments
- Secure communication between medical devices, staff and patients
- Contactless, secure access to buildings and transportation systems
- And much more

This white paper explores the advantages of Murata's LF technology, its various applications across key industries, and the specific product offerings designed to meet the challenges faced by today's communication and tracking systems.

By the end of this paper, readers will have a clear understanding of how LF technology can solve real-world problems where conventional systems fall short, as well as the exceptional value Murata's LF solutions bring to diverse sectors.

B. PROBLEM STATEMENT/BACKGROUND

In today's fast-paced automotive, healthcare, transportation and industrial sectors, ultra-reliable communication and tracking systems with highly accurate positioning as close as 5 centimeters are critical for optimizing operational efficiency, security, and safety. However, obstacle-laden environments are the norm, and interference-causing materials pose significant challenges for conventional technologies like Bluetooth Low Energy (BLE) and Ultra-Wideband (UWB), which often suffer from signal attenuation, reduced range, and inconsistent performance.

Furthermore, many applications, such as automotive keyless entry systems, industrial asset tracking, and medical device communication, require low-power, durable, and secure solutions that can operate reliably in harsh conditions. Higher-frequency solutions, while capable of high data transfer rates, frequently fail to meet the demands of environments where reliable penetration through dense materials, power efficiency, safety, and security are paramount.

This white paper addresses these issues and offers innovative solutions courtesy of Murata’s Low Frequency (LF) technology. It demonstrates how businesses can leverage LF technology to overcome the limitations of conventional systems, offering reliable communication and tracking in environments where performance and durability are critical.

The solutions outlined will also explore practical use cases across the automotive, healthcare, transportation and industrial sectors, showcasing how Murata's product offerings can meet the unique challenges these and many other industries face.

This white paper seeks to answer the following question:

How can businesses overcome the current limitations of tracking and location technologies, and what solutions does Murata’s LF technology provide to ensure highly accurate, reliable, efficient, and secure operations for a variety of applications across industries?

C. INDUSTRY-LEADING SOLUTIONS: MURATA'S INNOVATIVE LF ANTENNAS

1. Overview of LF Technology

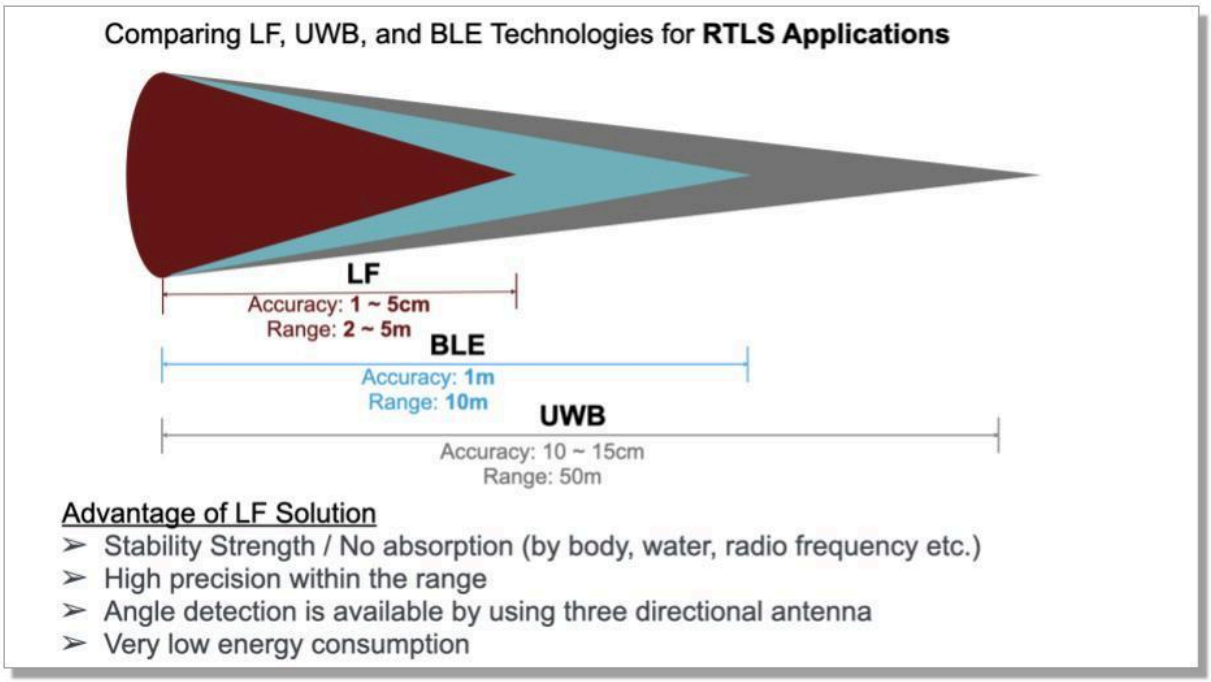
Low-frequency (LF) technology offers unique advantages in specific environments where other solutions, such as Bluetooth Low Energy (BLE) and Ultra-Wideband (UWB), fall short. LF operates in a lower frequency band, which enables it to penetrate environmental obstacles more effectively, making it ideal for applications where signal accuracy and stable communication are paramount.

The following diagrams help explain the differentiation:

Comparing LF, UWB, and BLE Technologies for **RTLS Applications**

	Accuracy	Range	Susceptibility	Multipath Fading	Blind Spot	Power Loss Battery life	Frequency Range
LF	<5cm	2 to 5m based on application	Low	Very Low	No blind spot	10mW (Rx side) 15uW (stand-by) Very High Battery Life	30 ~ 300KHz
BLE	1m	10m	Medium	High	Existing	50mW 10mW (stand-by) High Battery Life	2.4GHz
UWB	10 – 15cm	50m	Medium	Low	Existing	450mW Medium Battery Life	3.1 ~ 10.6GHz

The best solution exists according to the purpose of the application.



2. Advantages of LF Technology

Murata's LF technology stands out for its ability to function in environments that challenge BLE and UWB technologies. These key advantages include:

Penetration:

LF signals, at 30-300 kilohertz but typically working in the 125 kilohertz range, have superior penetrating capabilities through objects (walls, doors, etc.), weather and people, which typically cause significant attenuation in higher-frequency waves. LF antenna patterns are also virtually immune to blind spots, unlike BLE and UWB.

Power Efficiency:

LF devices consume less power, making them suitable for battery-operated and passive tag systems. This lower power consumption is particularly advantageous in RFID systems where battery longevity and efficiency are critical.

Safety:

LF technology is considered safer for many applications, such as medical devices or implants, due to its low radiation levels compared to higher-frequency technologies.

3. LF Technology Applications and Use Cases

LF technology excels in several environments where penetration through dense materials and low-power operation is required. Its applications span a broad range of industries, including automotive, medical, industrial, and more.

3.1 Automotive Industry

The automotive industry extensively utilizes LF antennas in various applications due to their ability to transmit signals through environmental obstacles, operate reliably with low power, and deliver pinpoint location precision.

Applications:

- **Passive Keyless Entry Systems (PKE)**: LF antennas are heavily used in passive keyless entry systems, which allow drivers to unlock and start their vehicles without using a regular key. The LF signal can penetrate the car's metal body, reach the key fob and ensure a secure connection between the vehicle and the user.

- **Remote Keyless Entry (RKE)**: LF antennas, in combination with RF signals, enable short-range communication in RKE systems. When the driver is near the vehicle, the LF signal facilitates the connection to unlock the doors.

- **Tire Pressure Monitoring Systems (TPMS)**: TPM systems use LF antennas to communicate with each tire individually based on proximity. The field is controlled finely enough to only affect the desired tire and not the others. Their ability to operate through metal (such as tire rims) and under extreme conditions ensures consistent and accurate tire health monitoring.

- **Airbag Deployment**: For larger vehicles such as vans or extended vehicles, placing tags on the seat and a transmitter (TX) antenna in the vehicle will identify occupied seats and, subsequently, trigger the availability of airbag deployment.

- **Seat Belt Reminders**: New regulations proposed by the National Highway Traffic Safety Administration (NHTSA) would require seat belt reminders for all passengers. LF technology can facilitate reminders for the appropriate seats.

3.1(a) Wireless Charging Alignment

An exciting area of development for the EV market is wireless charging alignment. The PKE's LF technologies enable high-accuracy wireless charging, a welcome alternative to expensive charging stations that are prone to breaking due to wear and tear.

However, one pitfall of wireless charging is the vehicle must be aligned precisely to achieve effective charging. It must be at an 85% efficiency rate, or it won't be able to charge at all due to time and magnetic field constraints.

LF technology improves the driver assist capabilities in parking over a charging pad with an LF tag. Now, drivers can use a vehicle's autonomous parking feature or even receive audio or video queues to properly align the vehicle over the tag to achieve the most efficient charging.

3.2 Healthcare Industry

In the healthcare sector, LF antennas play a crucial role in applications requiring safety, reliability, and low-power operation. The hospital's communication systems can monitor a myriad of applications via an iPad, smartphone or other device.

Applications:

- **Asset Management**
  Quickly locating important medical devices has never been easier than with LF technology, which improves hospital efficiency including:
    - Location of medical devices
    - Number of medical devices in a specific location
    - Status of devices (charged, not charged, etc.)

- **Safety and Security**
    - **Smart Access**: With tags on the staff and patients and LF in specific doors, hospitals can implement smart access—ensuring only authorized individuals can enter restricted rooms (newborn babies, drug storage, etc.).
    - **Hygiene Tracking**: With smart tags on staff and an LF antenna on the dispenser, hospitals can track whether or not staff has washed their hands before entering a patient's room.
    - **Contact Tracing**: By tracking patients, hospitals can identify individuals

with transmissible illnesses as well as other patients within a specific proximity to better control infection outbreaks.

- **Workflow Management**
  - Hospitals can locate staff and patients at a given time, location or other variable to determine appropriate staff-to-patient ratios and much more.

- **Facility Management**
  - Hospitals can determine more efficient floor, area and room layouts.
  - Identification of overcrowded areas, etc.

3.3 Transportation Industry

LF antennas are preferred in transportation environments to satisfy the need for touchless, secure entry and exit:

- **Hands-free, Contactless Access**: Whether in bus, subway or train systems, current technologies require individuals to hold their phones to scan an NFC or barcode reader for gate access. With LF technology in smart tags and on gates, individuals can be identified as they approach, enabling contactless entry and exit.

Applications: Gate control and accessibility for transportation systems.

3.4 AR/VR Industry

When you have location accuracy within centimeters, it enables some very unique applications:

- **Precise Movement Tracking**: Small tags in handheld devices can communicate with the AR/VR system, so an individual's hands become visible in the AR/VR environment. This enables the components to move as the individual moves.

Applications: On-the-job training and highly unique AR/VR games.

3.5 Farming/Ranching Industry

LF antennas are critical in animal identification systems due to their durability and ability to function in harsh environments:

- **Livestock Monitoring**: LF antennas and tags can track livestock information such as health, feeding and location, providing reliable communication for farms and ranching operations.

3.6 Secure Access Control and Authentication

LF antennas are widely adopted in secure access control systems for their reliability and security features:

- **Building Access Control**: LF tags and systems are employed in access control systems for restricted areas, such as specific building floors or rooms—delivering smart elevator systems for businesses.

3.7 Harsh and Hazardous Environments

LF antennas provide reliable communication in extreme environments where other technologies struggle:

- **Worker and Robot Protection**: With an LF tag, businesses can better protect workers using or on the floor with heavy machinery. For example, a forklift would receive a warning or be deactivated when in dangerous proximity to workers.
- With expensive autonomous robots traversing warehouses and other similar areas, businesses can protect these investments by keeping them out of busy or high-risk areas.

4. Murata LF Antenna Product Showcase

Murata offers two types of antennas that are revolutionizing magnetic field communications:

- TX antennas, which transmit the magnetic field.
- RX antennas, which receive the magnetic field.

4.1 Murata TX Antennas

Murata's latest product roadmap inspires a new vision. Rather than previous antenna models, which were highly customized and tuned to a vehicle, the company now offers standard models with more integration capabilities.

4.1(a) MSA1TDK: A one-dimensional TX antenna currently being developed (samples available September 2024).

Key features include:

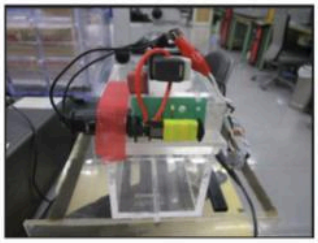
- Original structure design and winding technology
- All-in-one housing includes both the capacitor and connector
- Small influence of frequency

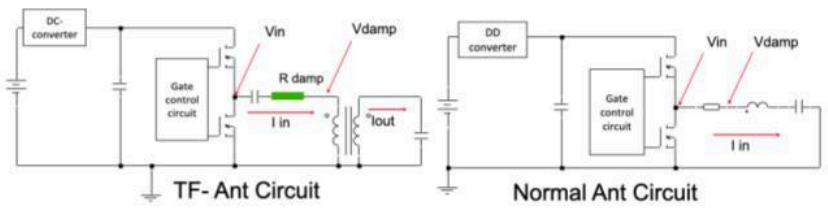
4.1(b) Transformer Antenna (TF Antenna): An actual transformer with primary and secondary windings enabled Murata to shrink the design. The smaller size offers less of a metal proximity effect.

Key features include:

- Easier integration into various modules, without a large connector or required mounting tabs, while producing the same magnetic field as the larger coil antennas.
- Produces 2.5x times the magnetic field (based on the winding ratio) and 1.5x distance while keeping the same core size.
- Reduces the core size to 40% while keeping the same magnetic field and the same distance.
- It offers the same input voltage and input current defined. However, the primary coil voltage and current are the only currents coming from the system.
- Uses less current (.25 power consumption) using the smaller TF antenna, enabling higher efficiency.
- Ultra-fast rise times as the resistor needed on the coil is smaller.

4.1(c) TF vs. Conventional Antenna Data Comparison





M/P	Size LWH [mm]	Frequency	Damping	Vin (7V)	Vdamp	Iin	Inrush	Iout(Ref)	Vin rms @ON time	Iin rms @ON time	Pin rms @ON time	Magnetic field strength	Rise up time 90%@Iout(Ref) for keeping same
		[kHz]	[ohm]	[Vpp] yellow	[Vpp] Blue	[App] Purple	[App] Purple	[App] Green	[Vrms]	[Arms]	[Wrms]	[dBμV/m rms@1m]	[μs]
MSAS1194 (TF-ANT)	40 x13 x11	125	3	6.98	6.5	0.17	1.47	1.467	1.809	0.052	0.094068	110.7	27.6
Normal Antenna (Referenece)	69x14x14	125	8	6.74	1.16	0.745	na	=Iin	1.744	0.195	0.34008	108.5	26

Efficiency @ Vin:7Vpp driving (Normal Prms / TF-ANT Prms)	3.615

Murata's TF Antenna can produce the same field strength as larger conventional antennas with 4x less current

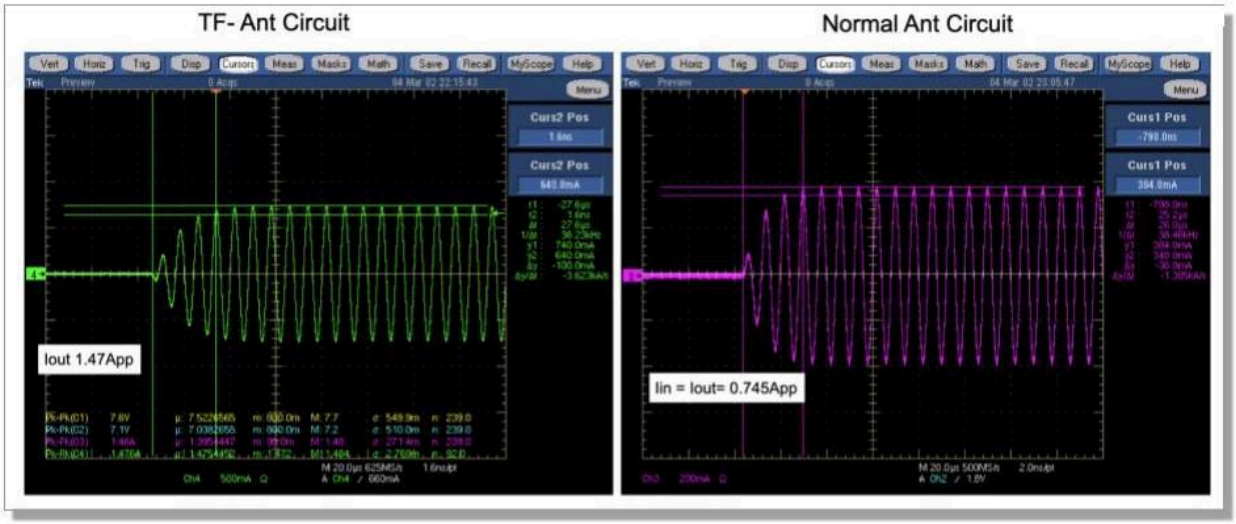
Summary:

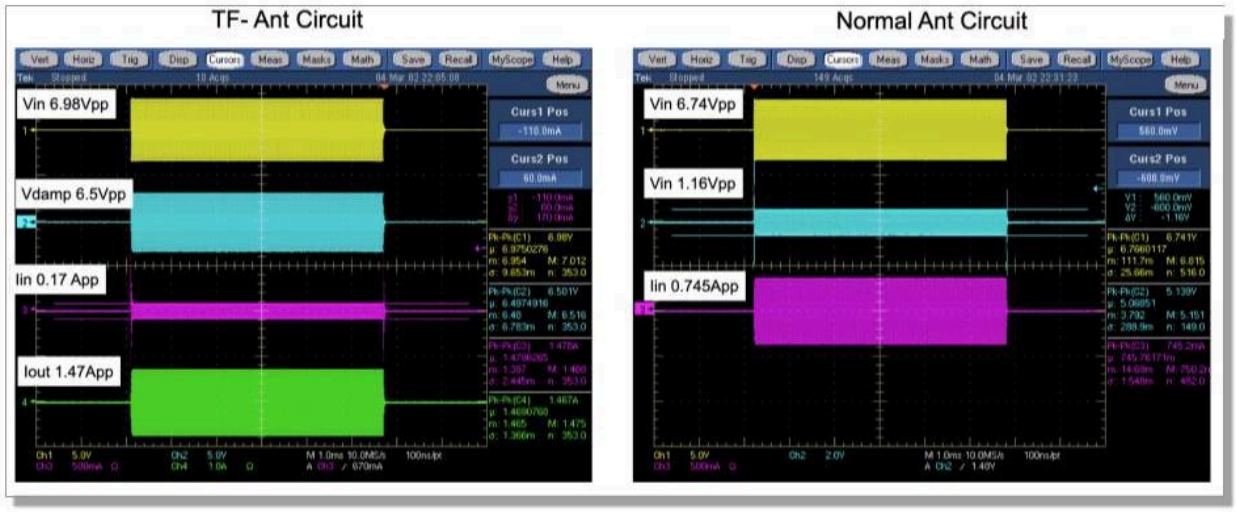
- The diagram illustrates the device's current measurements and the field strength generated by the antennas, both tuned to 125 kHz.
- The TF antenna measures 40 x 13 x 11 millimeters, while the conventional antenna is larger at 69 x 14 x 14 millimeters. Both antennas start with an input voltage of around 7 volts peak-to-peak. In the conventional design, 750mApp is needed to produce a magnetic field of 108dBuV/m @ 1m.
- In the TF antenna, the 170mV through the primary coil induces a current of 1.47App in the secondary coil, producing a similar magnetic field of 110dBuV/m @ 1m.

Key Takeaways:

- The TF antenna can produce the same magnetic field as a much larger coil but using much less current. Murata can also design the TF antenna larger, using the same current as the conventional coil while producing a much greater magnetic field—thus increasing the range of the LF system.

4.1(d) TF vs. Conventional Waveform Comparison





Key Takeaways:

- The diagram shows the input voltage and pulse cycles, with both coils receiving approximately 7 volts. After the damping resistor, the TF antenna maintains 6.5 volts, whereas the conventional antenna drops to 1.16 volts.
- It also highlights the input current to the primary winding and the inrush current spike. Although this spike occurs when driving the primary winding, it's brief and doesn't significantly affect the overall average system current.
- Additionally, the diagram shows that using only 170mA current induces a much larger current in the secondary winding—producing the same magnetic field as the larger conventional antenna.

4.2 Murata RX Antennas

Below is a review of Murata's receiving antennas. These antennas offer high-performance, compact solutions for wireless communication systems. They provide reliable signal reception with minimal interference. Their advanced design enables easy integration into compact spaces, providing increased efficiency without sacrificing performance.

4.2(a) SA3M08

The SA3M08 is a one-dimensional antenna with a tiny size, 8x3 millimeters. It can be used to receive a magnetic field in one direction.

Applications: TPMS for tire pressure monitor activation.

4.2(b) SA-X20

The SA-X20 is a 3D antenna with three windings (x, y and z). The antenna series consists of four parts currently available, which differ by the inductance of the windings.

Applications: Vehicle key fobs, asset tracking tags.

4.2(c) *NEW* Low Height 3D Antenna (Concept Phase)

Murata's new low-height 3D antenna reduces the antenna height to 3 or 2.5 millimeters. It's targeted for applications with a height restriction that still require sensitivity.

Applications: Small tags for asset tracking, key fobs and remote control devices.

4.2(d) *NEW* 3D Sheet Antenna (Under Development, Under Patent)

Murata's newest 3D antenna is called a sheet antenna. It features the thickness of a PC board at .7 millimeters thick and a unique layout that produces a spherical antenna pattern. The antenna's full dimensions are 50 x 50 x .7 millimeters, and it can be molded into an active, credit card-sized tag.

Murata's soon-to-be patented design creates a three-dimensional antenna pattern using a flat antenna and the rotational symmetry of each winding, offset by 120 degrees. The windings create a 35-degree angle off the horizontal.

Applications: Smart tags, badges and access cards for contactless, secure access to a building's restricted areas, a transportation system, a smart elevator system and much more.

5. Murata Demonstration Kit for LF Position Sensing

Murata now offers a comprehensive LF Demonstration Kit designed to allow businesses to explore and test the capabilities of its LF technology in real-world applications. This kit is particularly useful for businesses looking to evaluate the performance of Murata's LF products, which includes its antennas, tags, and modules, in various operational environments.

Demonstration Kit Components:

- **LF Antennas**: The kit includes a range of Murata's high-performance LF antennas, designed for effective signal transmission even in the presence of metal or other interference-causing materials.
- **LF RFID Tags**: Murata supplies a variety of passive LF RFID tags to demonstrate their durability, power efficiency, and reliability in location and asset tracking, access control, and other applications.
- **Customized Eval Board**: The kit comes with an eval board from Microchip that utilizes their ATA5293 IC and allows users to experiment with different configurations and see how the technology performs in diverse use cases.
- **Software and Firmware**: Murata includes easy-to-use software and firmware in the kit, allowing for testing and customization. Users can configure the system for their specific needs, fine-tuning parameters such as range, power consumption, and tag readability.

Key Features:

- **Ready-to-Use**: The pre-configured demonstration kit allows users to begin testing immediately with minimal setup.
- **Customization**: Users can adjust settings for various scenarios, increase or decrease drive current, add additional TX antennas to expand the working field,

capture RSSI data for statistics and evaluate the performance of LF technology in a specific environment.

- **Live Demonstration**: The kit allows for live demonstrations of LF technology at work, highlighting real-time performance of LF systems in applications such as location and asset tracking, access control, and data communication.

Core Benefits:

- **Hands-On Evaluation**: The demonstration kit provides a practical, hands-on way to explore the capabilities of LF technology. It's particularly useful for engineers and developers who need to assess how well Murata's products integrate with their systems.
- **Testing in Harsh Environments**: Users can test the robustness of LF technology in environments with a variety of objects or other interferences, ensuring the technology meets the operational demands of their use cases.
- **Accelerated Development**: The demonstration kit allows developers to quickly move from the evaluation phase to full implementation, reducing time to market for products that incorporate Murata's LF technology.
- **Engineer Support**: When needed, Murata can arrange for engineering support as well as support from Microchip on their IC implementation.

D. CONCLUSION

Murata's LF technology offers powerful, reliable solutions for applications that require robust communication and precise location tracking within five centimeters in challenging environments. The key benefits of LF technology—such as superior penetration through environmental obstacles, low power consumption, and safe radiation levels—make it especially suited for applications in the automotive, medical, transportation and industrial sectors.

Murata's diverse product offerings, including durable LF antennas, energy-efficient modules, and passive RFID tags, cater to a wide range of use cases. These products excel in environments where conventional technologies struggle and where safety and security are critical.

With a strong focus on delivering products that meet industry-specific demands, Murata's LF technology delivers pinpoint accuracy, robust performance and exceptional reliability even with low power. Whether used in automotive systems for keyless entry and wireless charging, medical device communication and hospital safety protocols, transportation systems needing handsfree, contactless entry and exit, or ultra-precise industrial asset tracking, Murata's solutions provide the durability and flexibility needed to excel in harsh or complex conditions.

In summary, Murata's LF technology is a superior choice for industries that demand reliable, highly accurate and low-frequency communication solutions, offering both the technical advantages and product range to support a wide array of applications across different sectors.

Murata's comprehensive suite of LF solutions ensures businesses can benefit from innovative LF technologies in a wide array of applications that revolutionize their efficiency and deliver next-gen technological advances today.