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# Application Note 003a

**Closed loop Impedance Matching**
**Test Result for ETH-LORA-M-AX-01 (V1.2)**

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# Application Note 003a

## Closed loop Impedance Matching Test Result for ETH-LORA-M-AX-01 (V1.2)

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## OVERVIEW

The Ethertronics LoRa module ETH-LORA-M-AX-01 (V1.2) embeds two antenna RF technologies to maximize antenna performances:

- Closed loop Impedance Matching (IM), using Ethertronics EC686 chipset and a proprietary Impedance Matching (IM) algorithm, to maximize the power transferred to the antenna when the antenna is detuned by its environment.
- Active Steering Technologies to maximize link connectivity. With that feature, the radiation pattern of the active steering antenna is driven by Ethertronics Modal Cognitive Diversity (MCD) algorithm in order to enhance RF budget link and increase reliability and range.

The purpose of this document is to show the result of the Close loop Impedance Matching (IM) technology embedded in the module EtherLoRa ETH-LORA-M-AX-01 (V1.2).

This document is divided in the following parts:

- General description
- IM Result
- Conclusion

### REQUIREMENT

To perform the test of the IM algorithm the items below are needed.

**Hardware Tools:**

1. EtherLoRa module ETH-LORA-M-AX-01 (V1.2).
2. USB-UART Cable (FTDI USB-UART TTL Cable)
3. Computer with Windows OS
4. LoRa Gateway
5. Vector Network Analyzer (VNA)

**Software Tools:**

1. Driver for USB-UART cable
2. Ethertronics EtherLoRa Control Tool

### SCOPE

This document focuses on the Impedance Matching technology (and its algorithm). This algorithm is running independently of the other RF technology (Active steering and its MCD algorithm) and therefore can be used either with any passive antenna or with an active steering antenna. In this document, a passive embedded antenna is used.

## GENERAL DESCRIPTION

### IMPEDANCE MATCHING ALGORITHM

The impedance Matching algorithm is developed by Ethertronics to maximize the power transfered to the antenna. Even a well matched antenna can be detuned due to constant change in its environment especially in urban areas. Once the antenna impedance is no longer optimized for the current condition, the RF performance will degrade and this could result in data lost, or worst, connection lost between the module and the gateway. This algorithm helps to compensate these scenarios by automatically readjusting the matching of the antenna.

#### BLOCK DIAGRAM OF THE MODULE USED WITH A PASSIVE ANTENNA

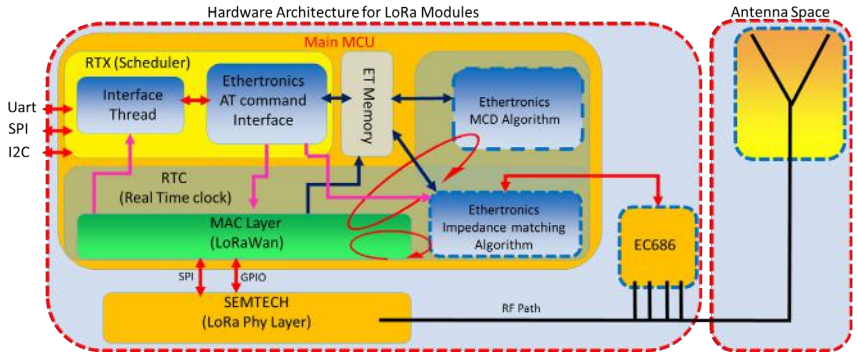


**Figure 1**

### PASSIVE EVALUATION BOARD

To facilitate the final product development, Ethertronics has built complete passive/active evaluation boards (EVBs) for ETH-LORA-M-AX-01 (V1.2).

In order to test the functionalities of the IM algorithm, a passive evaluation board is used. This evaluation board comes with test connectors to communicate with ETH-LORA-M-AX-01 using AT commands via UART interface. This board is also provided with Ethertronics' Prestta™ 1002232 Multi-Band ISM antenna which covers all the ISM frequencies (868/915/2400 MHz).

#### EVB PASSIVE (TOP VIEW)

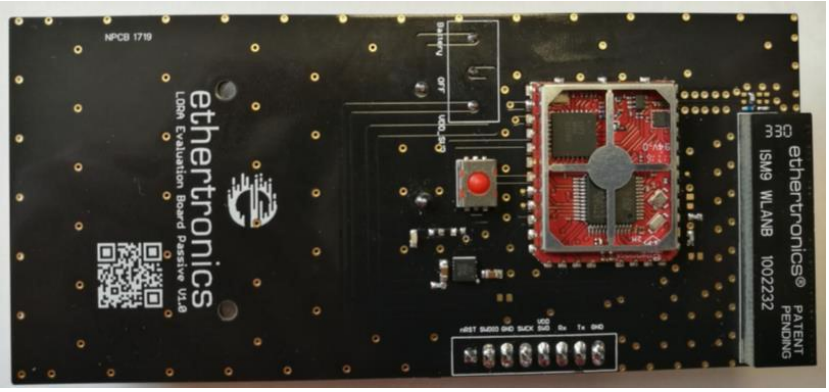


**Figure 2**

#### EVB PASSIVE (BOTTOM VIEW)

**Figure 3**

#### EVB PASSIVE COMPONENTS

| Component | Position | Function | Description |
|---|---|---|---|
| ETH-LORA-M-AX-01 | Top | LoRa Module | Module to communicate LoRa communication |
| Prestta™ 1002232 | Top | Passive Antenna | Emit/receive the signal |
| Push Button | Top | Reset button | Reset the ETH-LORA-M-AX-01 |
| Test connectors | Bottom | UART/Power Supply | To communicate using AT Commands and to supply the voltage to the module |
| Toggle switch | Bottom | Power Supply selection | To select the power supply whether from Battery or Test connector |
| Battery holder | Bottom | Place for 3 AA batteries | To supply the voltage to the module |

**Table 1**

### SETUP CONDITION

The measurement has been done for LoRa EU-868 band. Several cases where the detuning is created are studied:

1. Free Space
2. Loaded with Poron
3. Loaded with human tissue

### GLOBAL SETUP DIAGRAM

### RETURN LOSS MEASUREMENT SETUP

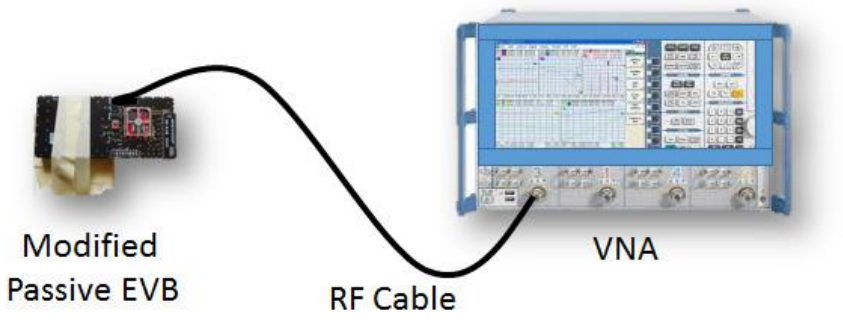


**Figure 4**

For the return loss measurement the passive EVB is modified to connect the RF cable on the PCB.

### RSSI MEASUREMENT SETUP

**Figure 5**

The control software is installed on the PC host. User can use this software to communicate with the module ETH-LORA-M-AX-01 using AT commands. The procedures are as follow:

1. Setup the IM algorithm parameters if necessary
2. Initiate the join procedure using OTAA with gateway
3. Start the IM algorithm
4. Start the listener to collect information necessary and the state of the algorithm
5. Send the message to the gateway every 20 seconds
6. For every response of the gateway, the information is logged for the post processing.

### PASSIVE EVB (DUT) SETUP

The passive EVB is then loaded with different configuration to study the effectiveness of the IM algorithm.

### DUT IN FREE SPACE

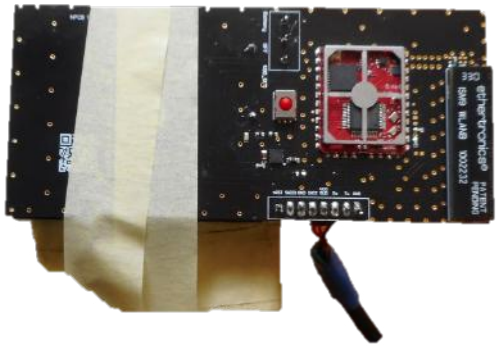

**Figure 6**

### DUT LOADED WITH PORON (TOP AND BOTTOM)

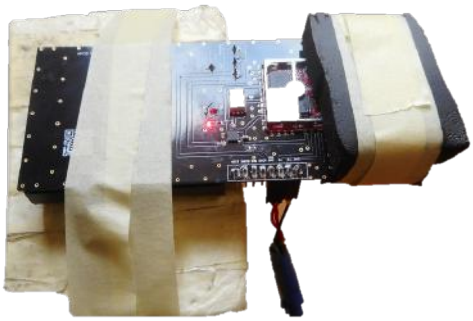

**Figure 7**

### LOADED WITH HUMAN TISSUE

The phantom hand (on the left) and the square block (on the right) are made from the same material that reproduces the human flesh. To facilitate the setup of the measurement the  square block material has been used.

### DUT LOADED WITH HUMAN TISSUE

**Figure 8**

## RESULTS

### RETURN LOSS MEASUREMENT

FREE SPACE

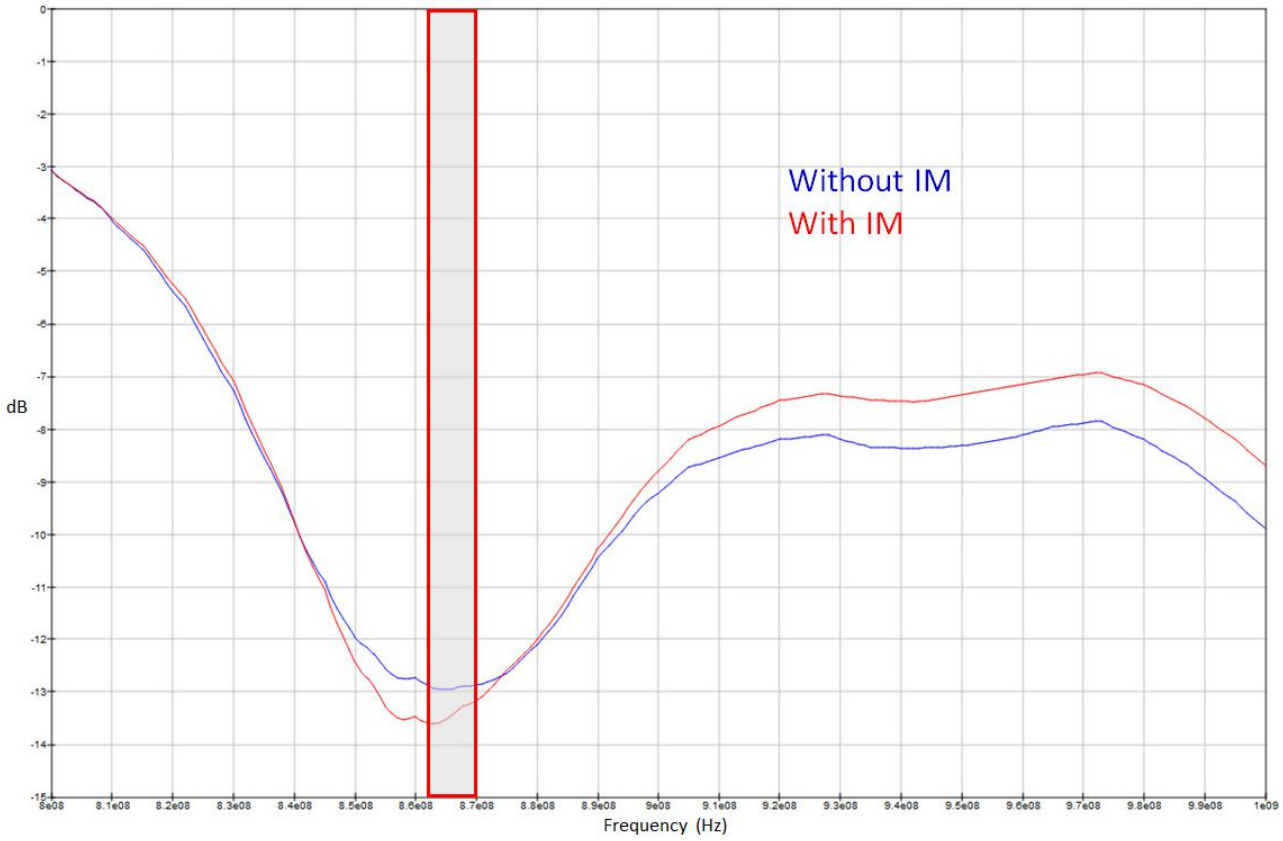


**Figure 9**

Ethertronics' Prestta™ 1002232 antenna is already well tuned for the free space condition. With IM algorithm, the return loss is a little bit improved by ~1dB.

PORON

RETURN LOSS WHEN LOADED WITH PORON

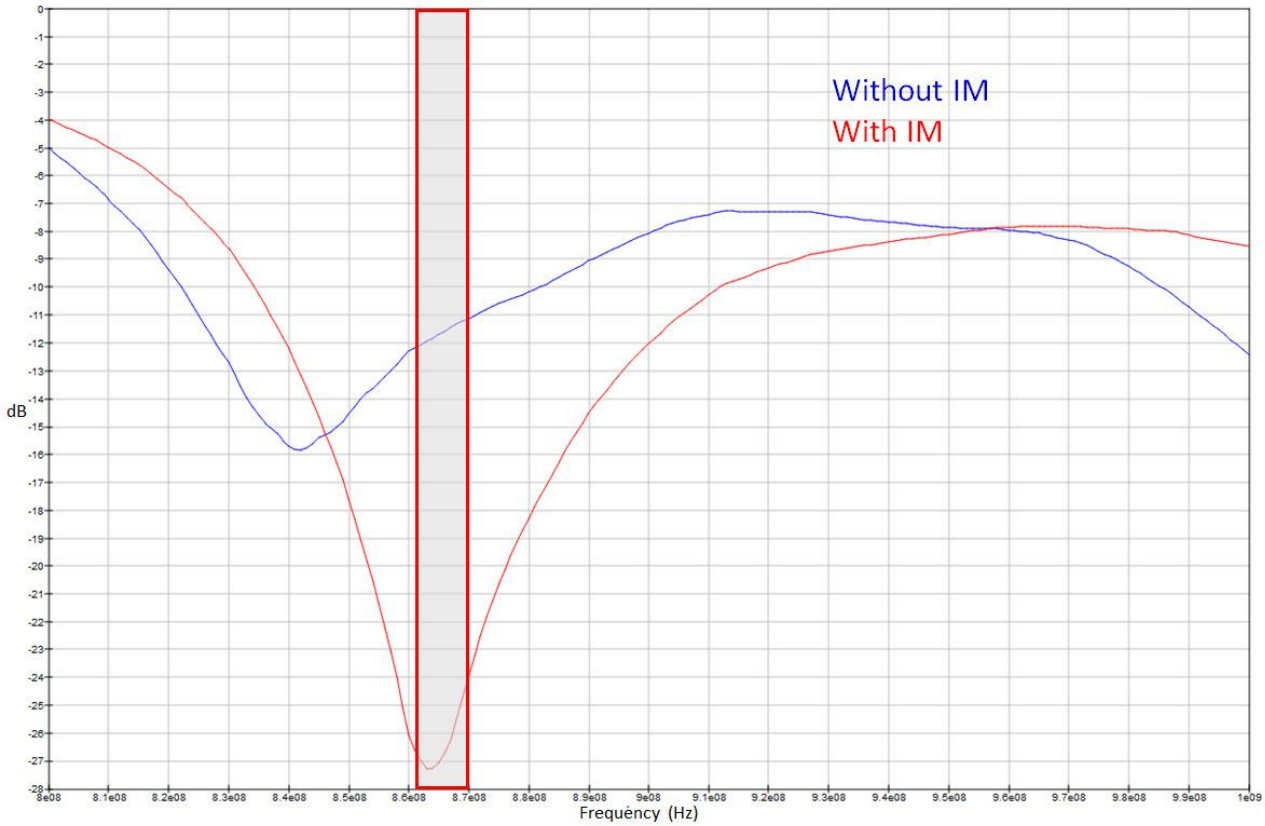


**Figure 10**

When loaded with Poron on the top and the bottom of the Prestta™ 1002232 antenna, the return loss is degraded. With help of the IM algorithm, the return loss can be shifted to right frequency. For LoRa EU-868 band, the return loss is improved by ~15dB, from -12dB to -27dB.

### HUMAN TISSUE

#### RETURN LOSS WHEN LOADED WITH HUMAN TISSUE

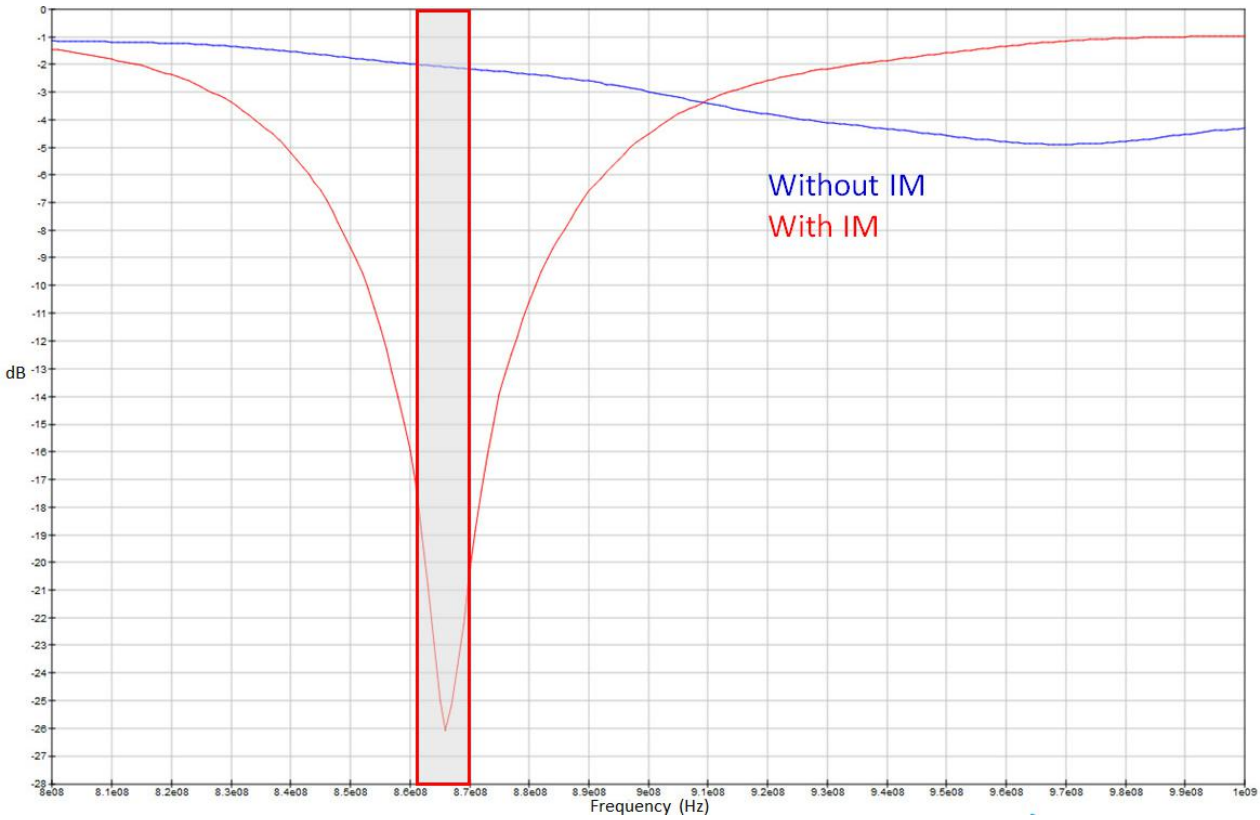


**Figure 11**

When loaded with the human tissue on the bottom of the Prestta™ 1002232 antenna, the return loss has been greatly degraded. With IM algorithm, the return loss in LoRa EU-868 Band can be improve significantly, thus helps to maximize the power transfer to the antenna.

## RSSI MEASUREMENT

#### RSSI AND IM STATE IN FREE SPACE

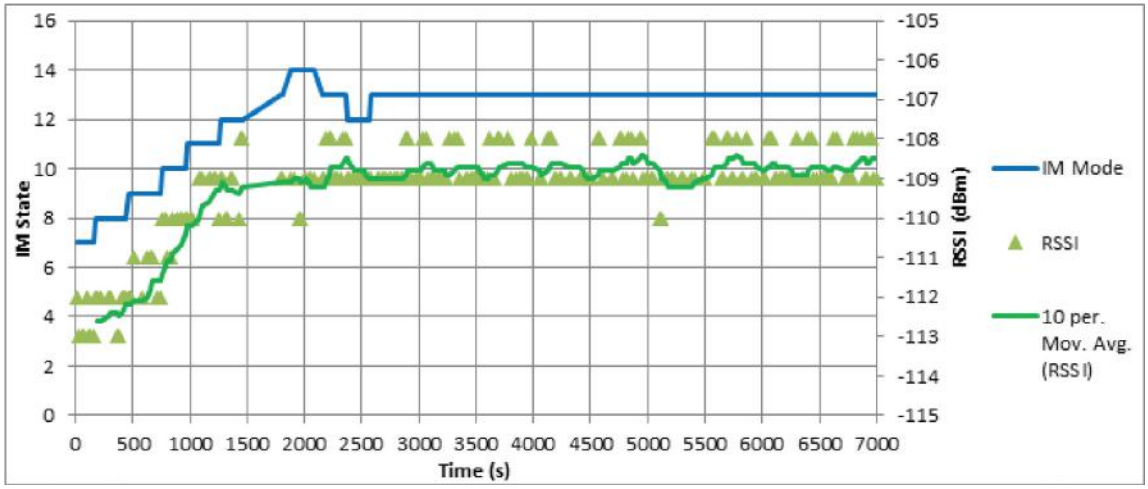


**Figure 12**

The IM algorithm converges to state 13 in the free space measurement. The best RSSI value can be achieved in this state.

### RSSI AND IM STATE WHEN LOADED WITH PORON

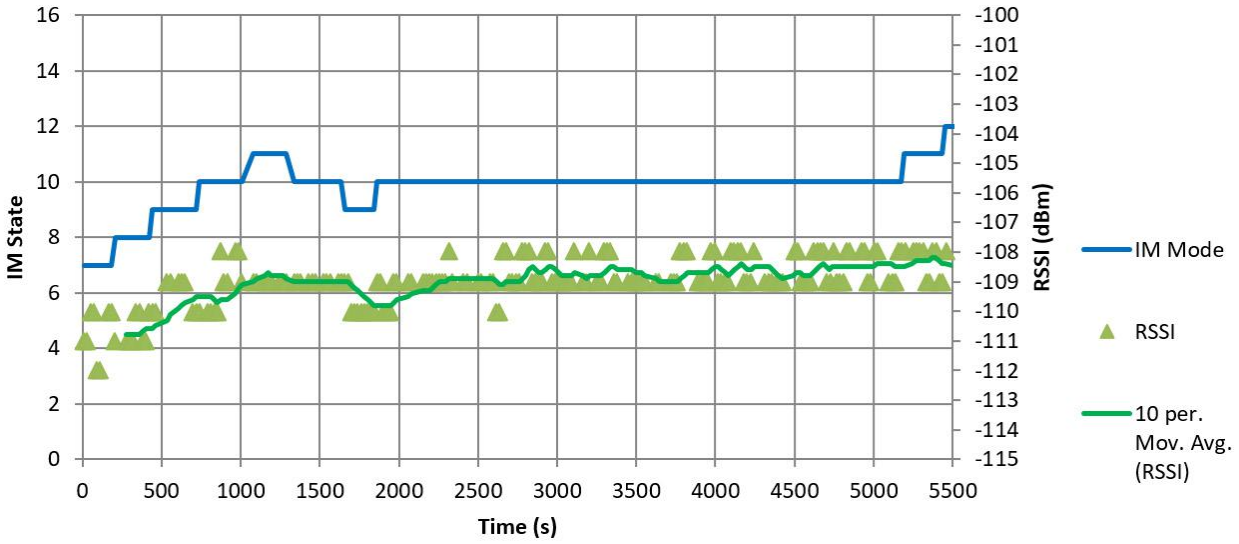


Figure 13

The IM algorithm converges to state 10 in the measurement loaded with Poron. The best RSSI value can be achieved in this state.

### RSSI AND IM STATE WHEN LOADED WITH HUMAN TISSUE

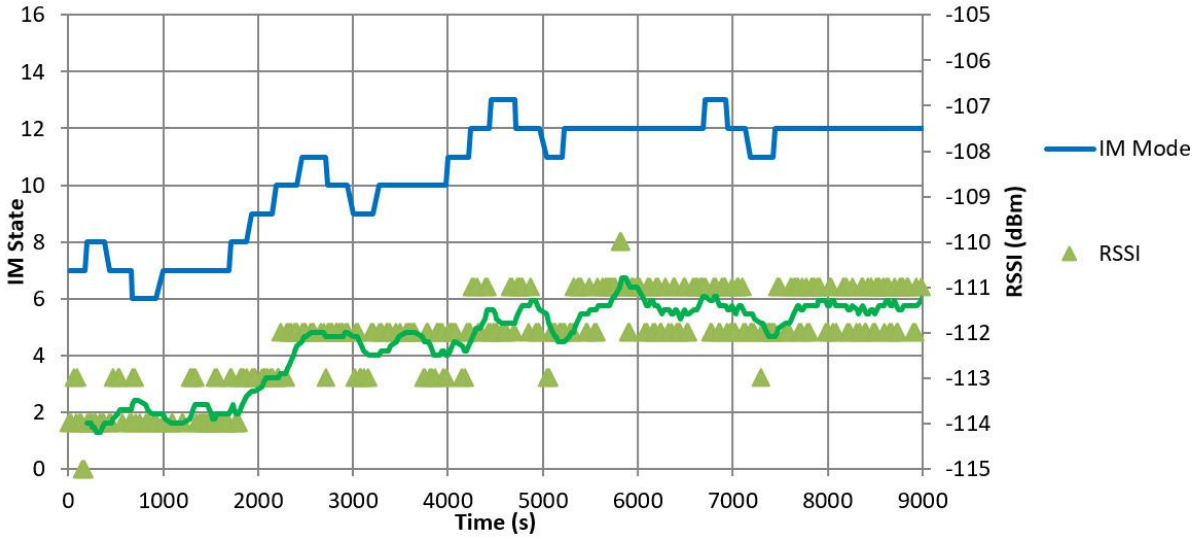


Figure 14

The IM algorithm converges to state 12 in the measurement loaded with human tissue material on the bottom. The best RSSI value can be achieved in this state.

### RSSI AND IM STATE WHEN CHANGING FROM PORON TO FREE SPACE

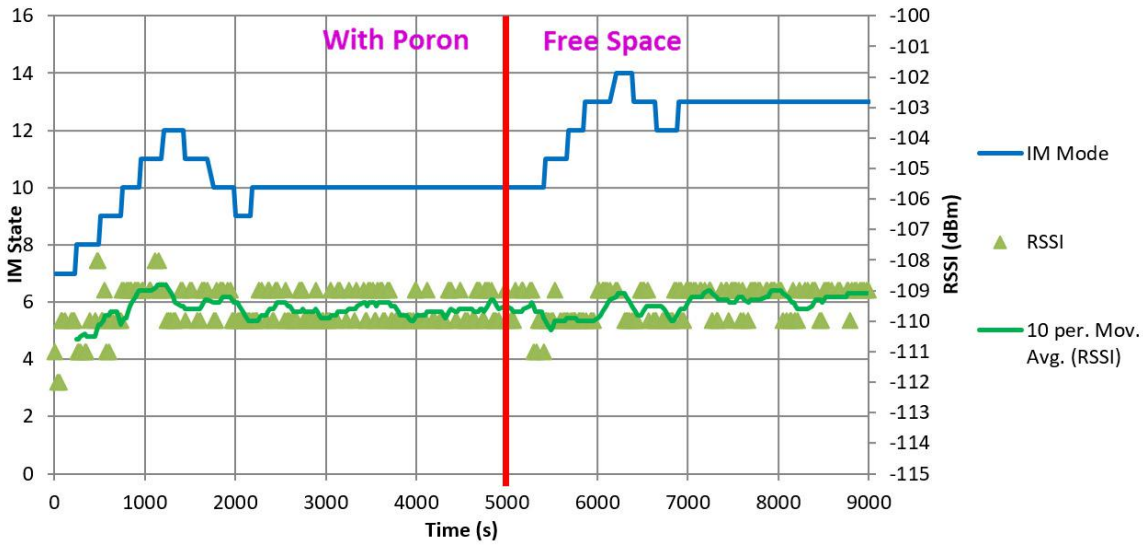


Figure 15

This measurement is done to see how the IM algorithm reacts when there is a change in its environment (from Poron to free space). The IM state converges to the correct value that has been found previously which is 10 when loaded with Poron and 13 when in free space.

### RSSI AND IM STATE WHEN CHANGING FROM HUMAN TISSUE TO FREE SPACE

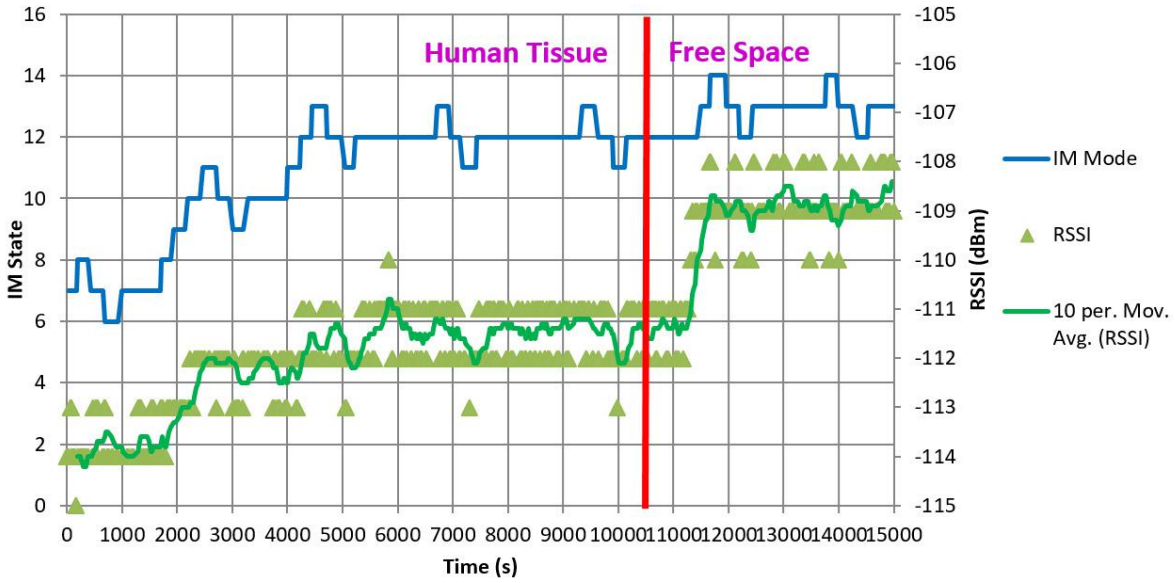


Figure 16

This measurement is done to show how the IM algorithm reacts when there is a change in its environment (from Human Tissue to free space). The IM state converges toward the correct value that has been found previously which is 12 when loaded with Human Tissue and 13 when in free space.

## CONCLUSION

From the return loss measurement, when loaded with Poron or human tissue, the Prestta™ 1002232 antenna is detuned and its return loss is degraded. IM algorithm has been proven to improve the return loss by automatically readjusting the matching of the antenna.

### RETURN LOSS MEASUREMENT SUMMARY

| Description | Return Loss Without IM | Return Loss With IM |
|---|---|---|
| Free Space | ~ -12.8 dB | ~ -13.6 dB |
| Poron | ~ -11 dB | ~ -27dB |
| Human Tissue | ~ -2 dB | ~ -26 dB |

Table 2

The IM algorithm tune the impedance seen my the LoRa Transceiver in order to select the best state for the best RSSI value of each cases. If the environment changes, the IM algorithm will automatically initiate another optimization phase and converge toward the best new configuration.

### IM STATE IN RSSI MEASUREMENT SUMMARY

| Description | Return Loss With IM |
|---|---|
| Free Space | 13 |
| Poron | 10 |
| Human Tissue | 12 |
| Poron to Free Space | 10 to 13 |
| Human Tissue to Free Space | 12 to 13 |

Table 3

In the case when the environment changed from “loaded with Poron” to “Free Space” , the RSSI value has been improved by ~1dB.

### RSSI IMPROVEMENT FOR THE CASE WITH PORON TO FREE SPACE

| Description | Return Loss With IM |
|---|---|
| When IM converges to state 10 with Poron | -109.5 |
| When the Poron is remove, entering Free Space | -110 |
| When IM converges to State 13 | -109 |

Table 4

For the case when the change was from “loaded with  Human Tissue” to “Free Space”, the RSSI value has been improved by ~3dB.

### RSSI IMPROVEMENT FOR THE CASE WITH HUMAN TISSUE TO FREE SPACE

| Description | Return Loss With IM |
|---|---|
| When IM converges to state 12 with Human Tissue | -111 |
| When the Human Tissue is remove, entering Free Space | -111.7 |
| When IM converges to State 13 | -108.8 |

Table 5

## LIST OF ABBREVIATIONS

LoRa: Long range
IM: Impedance Matching
MCD: Modal Cognitive Diversity
USB: Universal Serial Bus
TTL: Transistor–transistor logic level
UART: Universal Asynchronous Receiver/Transmitter
OS: Operating System
VNA: Vector Network Analyzer
EU: European Union
RF: Radio Frequency
EVB: Evaluation Board
OTAA: Over The Air Activation
DUT: Device Under Test
RSSI: Received Signal Strength Indicator

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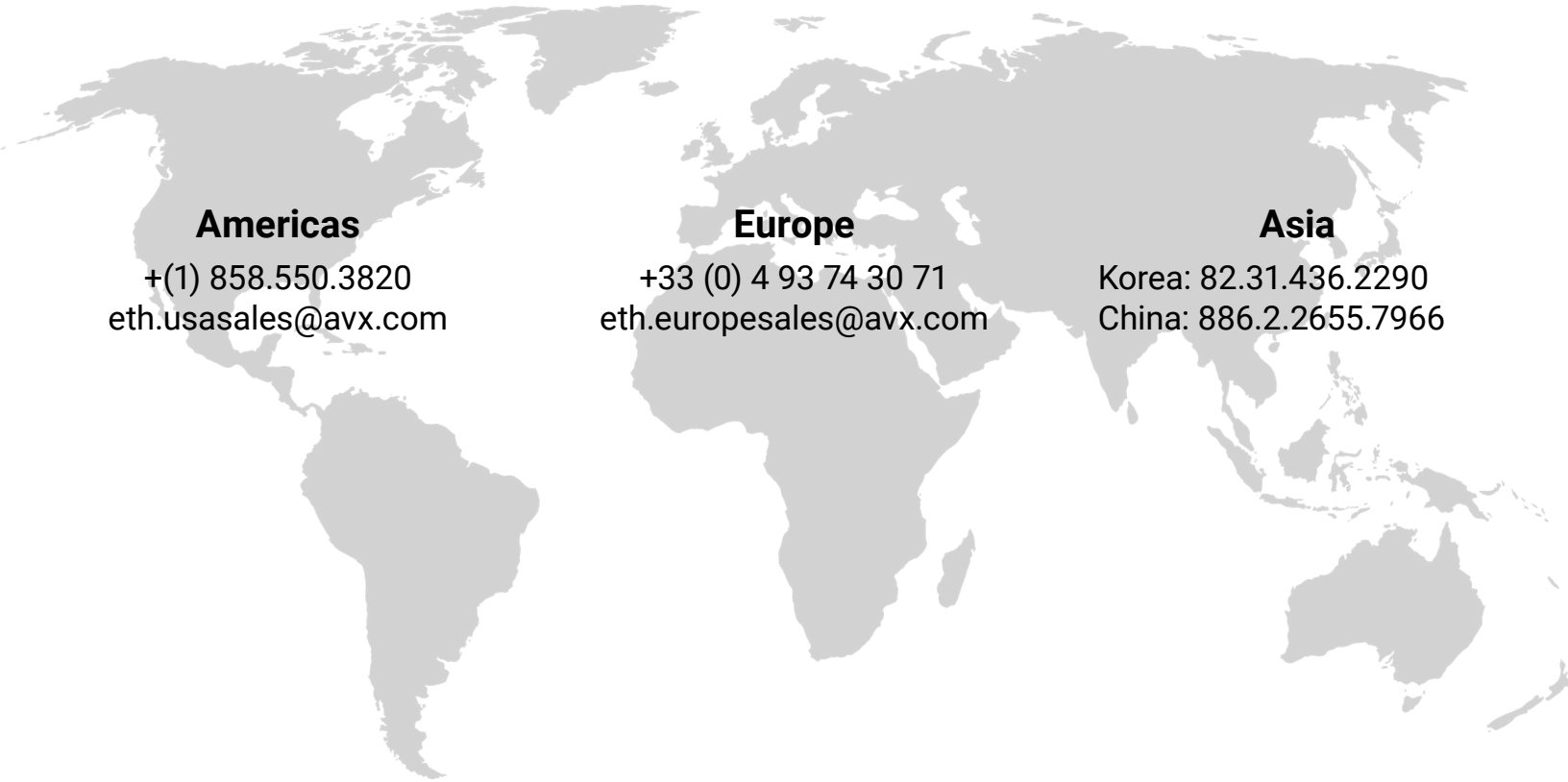


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