ember

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EM250 Radio Communication Module Technical Specification

The Ember EM250 radio communication module (RCM) offers a complete ZigBee wireless solution for development and deployment of a low-data-rate, low-power ZigBee application. The four-layer, ROHS-compliant RCM features the Ember EM250, a 2.4GHz, IEEE 802.15.4-2003 SOC running the Ember ZigBee-compliant EmberZNet PRO stack. In addition, it contains a 28-pin RCM interface connector, a RF Switch connector, a ceramic SMT antenna, and two low-profile crystals (32.768kHz and 24MHz).

Together with the EM250 breakout board and InSight Adapter, the RCM makes up a single instance of the EmberZNet PRO development kit. The RCM directly attaches to the EM250 breakout board, remotely attaches to the InSight Adapter through the InSight Port cable, or can be operated as a stand-alone node (under battery power). Therefore, the EM250 RCM offers the highest degree of flexibility when developing a ZigBee application.

This document provides the Technical Specification of the EM250 RCM. It describes the board-level interfaces as well as the key performance parameters of the Module. In addition, it provides the necessary information for a developer to either validate their design or integrate the RCM into their application.

New in this Revision

Added Note in “Appendix: Murata Chip Dieletric Antenna Matching.”

Contents

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RCM Features

The EM250 RCM offers:

- Selectable RF interface (RF connector or ceramic antenna)
- RX sensitivity of -99dBm typ. (-100 in boost mode) at 1% packet error rate
- +3dBm TX output power (+5dBm in boost mode)
- 16 RF channels spaced 5 MHz apart (2.405, 2.410, … 2.480 GHz)
- Wide range of supply voltage (2.1V to 3.6V)
- Minimal current draw (35mA in RX, 35mA in TX; VBRD at 3.0V)
- Operation over the industrial temperature range -40°C to +85°C
- Access to all 17 EM250 GPIOs
- Access to SIF signals
- Access to the InSight Desktop packet trace interface
- FCC and CE (EMC and RTT&E) compliant (pre-scan certification was completed)
- IEEE 802.15.4-2003 PHY and MAC Level 1 compliant platform
- Open Air, Line of Sight Range (Normal Mode, Ceramic Antenna) is 230m.

The RF characteristics stated within the *EM250 Datasheet* (120-0082-000) were validated on the EM250 RCM. In particular, they were measured using Ember's EM250 Lattice Balun Reference Design (Version B1) at 2440MHz and using the EmberZNet PRO software stack Version 3.0.1. The Typical number indicates one standard deviation above the mean, measured at room temperature (25C). The Min and Max numbers were measured over process corners at room temperature. Tables 1 through 4 summarize the mechanical and electrical parameters of the EM250 RCM.

Specifically, Table 1 illustrates the key RF characteristics of the EM250 RCM; Table 2 lists the DC electrical characteristics of the EM250 RCM; Table 3 shows the GPIO digital signal levels for the EM250 RCM; and Table 4 lists mechanical and physical characteristics of the EM250 RCM.

Table 1. RF characteristics

Parameter	Min.	Typ.	Max.	Unit
Frequency band (16 – 5MHz wide channels)	2.405		2.480	GHz
RX sensitivity (1% PER, 20-byte packet):				
Normal mode		- 99	-94	dBm
Boost mode		- 100	-95	dBm
Maximum TX power:				
Normal mode		3		dBm
Boost mode		5		dBm
Error Vector Magnitude:				
Normal mode		5	15	%
Boost mode		5	15	%
Adjacent channel rejection (defined by IEEE 802.15.4 spec)				
+/- 5MHz		35		dB
+/- 10MHz		43		dB
802.11(g) rejection		40		dB

Table 2. DC electrical characteristics

Parameter	Min.	Typ.	Max.	Unit
VDD supply (VBRD)	2.1		3.6	V
RX mode current (VBRD = 3.0V)				
Normal Mode		36.0		mA
Boost Mode		41.0		mA
TX active current (VBRD = 3.0V)				
Normal Mode		36.0		mA
Boost Mode		41.0		mA
Sleep mode current				
32.768kHz Osc, 25C			1.3	µA
RC Osc, 25C			1.0	µA

Table 3. GPIO digital signal levels

Parameter	Min.	Typ.	Max.	Unit
Input voltage for Logic Level 0	0		0.2*VBRD	V
Input voltage for Logic Level 1	0.8*VBRD		VBRD	V
Output voltage for Logic Level 0	0		0.18*VBRD	V
Output voltage for Logic Level 1	0.82*VBRD		VBRD	V
Input current for Logic Level 0			-0.5	µA
Input current for Logic Level 1			0.5	µA
Output current source GPIO[12:0] GPIO[16:13]			 4 8	 mA mA
Total output current (all GPIO)			40	mA
ADC VREF		1.2		V

Table 4. Mechanical and physical characteristics

Item	Description
RCM dimensions	1.61 in. x 0.95 in.
Antenna	Ceramic SMT antenna (ANT1)
GPIO interface	28-pin, 0.05″ pitch, dual row connector (J2)
InSight Port connector	10-pin, 0.05″ pitch, dual row connector (InSight Port) (J1)
Indicators	Two LEDs: • Red (DS1) • Yellow (DS2)
RF interface	Murata switch connector for direct attachment to test equipment (J3)
Compliance	• FCC CFR47 Part 15 (Section 209, 247) • CE EMC and RTT&E Directive • ARIB • IEEE 802.15.4-2003 PHY • IEEE 802.15.4-2003 MAC Level 1 • ZigBee Level 1

Components

Figure 1 and Figure 2 illustrate the components on layer 1 (top side) and layer 4, respectively.

Figure 1. Assembly print for layer 1

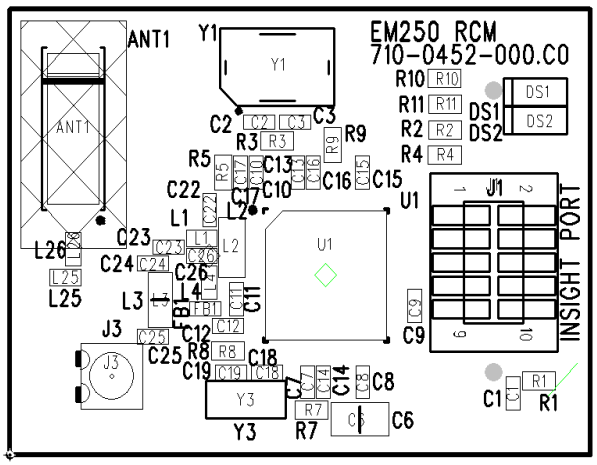
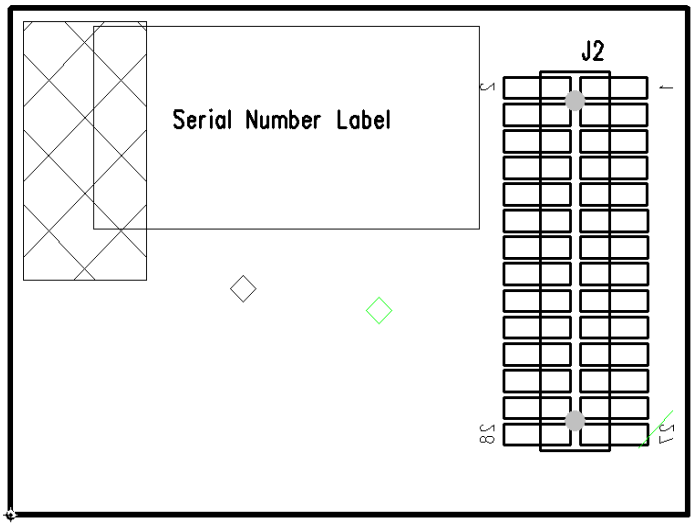


Figure 2. Assembly print for layer 4



EM250 (U1)

The EM250, a true ZigBee SOC wireless solution, integrates an IEEE 802.15.4-2003 transceiver with a 16-bit XAP2b microprocessor. It provides a hardware MAC that supports automatic acknowledgement generation and reception, complex packet filtering, and a packet trace interface for InSight Desktop, providing a true PHY level packet sniff. In addition, it contains 128 KB of integrated flash, 5 KB of integrated RAM,

a simulated EEPROM, and a number of application peripherals that target low-power, low-data-rate ZigBee applications.

These include:

- Two general-purpose 16-bit timers
- ADC
- Serial Controller 1 (UART, SPI, and I^2C)
- Serial Controller 2 (SPI and I^2C)
- Watchdog timer and power-on-reset
- Sleep timer (using either the 32.768kHz or RC oscillator as a source)
- Integrated 1.8V voltage regulator

The EM250 contains a protected area of flash, called the Flash Information Area (FIA), for permanent storage of customer manufacturing tokens.

Within the emberJoinNetwork API, there is a networkParams Structure that defines (among other things) the radioTXPower and radioChannel. Table 5 and Table 6 indicate the valid arguments for these two parameters.

Table 5. Available radioTXPower settings

radioTXPower (decimal, signed)
+3
+2
+1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-11
-12
-14
-17
-20
-26
-43

Note: The actual TX Power value (in dBm) varies depending upon voltage supply, temperature, and PCB component tolerances. However, the radioTXPower setting is nearly linear from settings +3 to -9 dBm and is non-linear from -12 to -26 dBm. RadioTXPower settings not shown are undefined.

Table 6. Valid EM250 channel settings

radioChannel (decimal)	Center Frequency (GHz)	radioChannel (decimal)	Center Frequency (GHz)
11	2.405	19	2.445
12	2.410	20	2.450
13	2.415	21	2.455
14	2.420	22	2.460
15	2.425	23	2.465
16	2.430	24	2.470
17	2.435	25	2.475
18	2.440	26	2.480

For more information on the EM250, refer to the *EM250 Datasheet* (120-0082-000).

InSight Port (J1)

The 10-pin, dual-row, 0.05-inch pitch InSight Port is the programming and debug interface for the RCM. It contains the four SIF signals (SIF_MOSI, SIF_MISO, SIF_LOADB, and SIF_CLK), two packet trace signals (PTI_EN and PTI_DATA), and voltage and ground connections. Through the InSight Port cable, it connects directly to the InSight Adapter, which allows programming and debug access within InSight Desktop. In order to make the development experience more efficient, the InSight Adapter can source VBRD for the RCM (if the power switch on the ISA is set to INT). However, the RCM could also be battery powered (be sure to select EXT on the ISA power switch).

The part used on the RCM is from Samtec (MFG P/N: FTSH-105-01-F-DV-K). It is keyed to guarantee proper connection with the InSight Port cable (Samtec P/N: FFSD-05-D-12.00-01-N). Figure 3 illustrates the pinout for the InSight Port, and Table 7 describes the pins.

Figure 3. InSight Port pinout

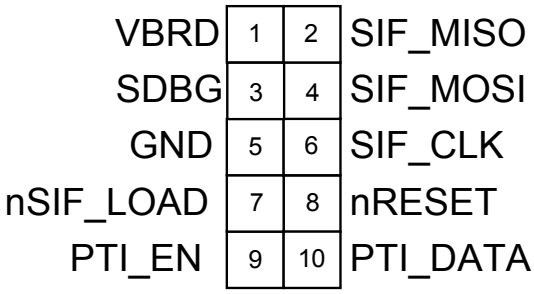


Table 7. Insight Port pins

Pin #	Signal Name	Direction	Description
1	VBRD	Power	2.1 to 3.6V VDD net on the RCM
2	SIF_MISO	Output	Serial interface, master in, slave out
3	SDBG	Output	Debug signal to be used on future Pin-compatible products
4	SIF_MOSI	Input	Serial interface, master out, slave in
5	GND	Power	Ground
6	SIF_CLK	Input	Serial interface, clock (internal pull-down within EM250)
7	nSIF_LOAD	I/O	Serial interface, load strobe (open collector with internal pull-up within EM250
8	nRESET	Input	Active low, EM250 reset (internal pull-up within EM250)
9	PTI_EN	Output	Packet trace frame signal
10	PTI_DATA	Output	Packet trace data signal; 500kbps

RF Switch Connector (J3) and Antenna (ANT1)

In order to offer a flexible module solution, the EM250 RCM contains two RF ports, an RF switch connector (J3), and a ceramic antenna (ANT1). If an application specifies a requirement that cannot be met by the ceramic antenna, you can attach an external antenna to the RCM through the RF switch connector. In addition, if the developer needs to perform RF measurements with the EM250 RCM, the RF switch connector offers a true 50 Ohm interface. The EM250 RCMs have a 1% PER range of 230m (open air, Line of Sight) when using the ceramic antenna.

RF Switch Connector (J3)

Ember chose the RF switch connector from Murata (MFG P/N: MM8430-2600RA1) for the EM250 RCM. It is a gold-plated, stainless-steel mechanical switch designed to minimize

insertion loss and maximize isolation between two RF interfaces. Table 8 details the key features of the Murata RF switch connector.

Table 8. Murata RF switch connector features

Parameter	Min.	Typ.	Max.	Unit
Insertion loss		0.1	.35	dB
Isolation		20		dB
Durability	5,000			Matings

Note: Ember ships one Murata-to-SMA cable assembly with each development kit). When attached to the Murata Switch, the cable assembly has 40 dB of isolation between the switch port and the antenna feed

Antenna (ANT1)

The EM250 RCM comes with a Murata ceramic antenna designed for the 2.4GHz ISM Band (MFG P/N: ANCW12G45SAA117TT1). Table 9 details the key parameters of the ceramic antenna. In addition, Appendix A contains the field pattern and matching exercise performed by Murata on the RCM.

Table 9. Ceramic antenna parameters

Parameter	Min.	Typ.	Max.	Unit
F_0		2450		MHz
Bandwidth		100		MHz
VSWR			2.5	V/V
Impedance		50		Ohms

RCM Interface Connector (J2)

The 28-pin, dual-row, 0.05-inch pitch connector on the bottom side of the RCM allows access to all 17 EM250 GPIOs, EM250 SIF signals, power (VBRD), and ground. This connector attaches directly to the EM250 Breakout Board and provides a robust and stable interface. To reduce the time spent in the application development phase, a software developer can attach the EM250 RCM directly to a custom board, provided that the proper mating connector is used. The connector on the RCM is from Samtec (MFG P/N: FTSH-114-04-F-DV). Samtec offers a wide range of mating connectors to the FTSH Series.

The EM250 GPIO Signals are routed to this connector and exposed on the Breakout Board for application development. The connector also exposes the supply voltage net (VBRD) and ground (GND), as shown in Table 7. Therefore, a Developer can assemble a simple battery pack and attach it to the RCM for remote application development.

Figure 4 shows the pinout of the RCM interface connector, and Table 10 describes the pinout and signal names. For more information on the alternate functions of the EM250 GPIO, refer to the *EM250 Datasheet* (120-0082-000).

Figure 4. RCM interface connector (J2)

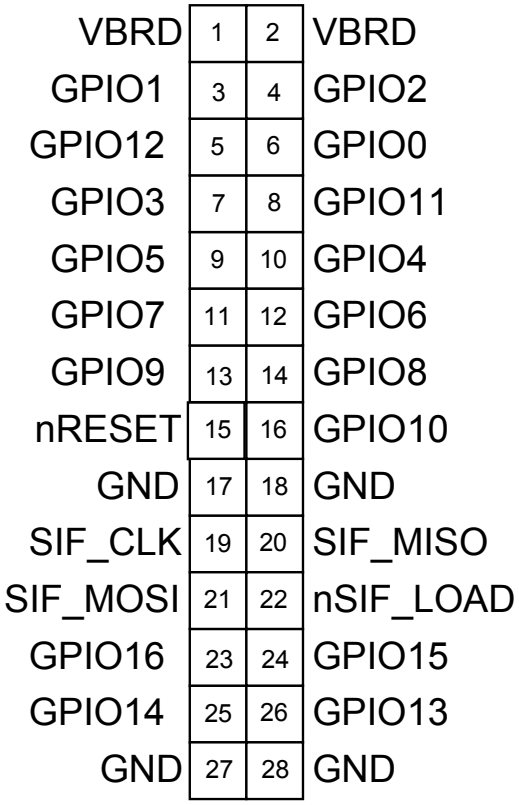


Table 10. Pinout and signal names of the RCM interface connector

Pin #	Signal name	Direction*	Description
1	VBRD	Power	2.1 to 3.6V DC power supply for RCM
2	VBRD	Power	2.1 to 3.6V DC power supply for RCM
3	GPIO1	I/O	Digital I/O
4	GPIO2	I/O	Digital I/O
5	GPIO12	I/O	Digital I/O
6	GPIO0	I/O	Digital I/O
7	GPIO3	I/O	Digital I/O
8	GPIO11	I/O	Digital I/O
9	GPIO5	I/O	Digital I/O
10	GPIO4	I/O	Digital I/O
11	GPIO7	I/O	Digital I/O
12	GPIO6	I/O	Digital I/O
13	GPIO9	I/O	Digital I/O
14	GPIO8	I/O	Digital I/O
15	nRESET	Input	Active low chip reset (internal pull-up within EM250)
16	GPIO10	I/O	Digital I/O
17	GND	Power	Ground connection
18	GND	Power	Ground connection
19	SIF_CLK	Input	Serial interface, clock signal (internal pull-down within EM250)
20	SIF_MISO	Output	Serial interface, master in/slave out
21	SIF_MOSI	Input	Serial interface, master out/slave in
22	nSIF_LOAD	I/O	Serial interface, load strobe (open collector with internal pull-down within EM250)
23	GPIO16	I/O	Digital I/O
24	GPIO15	I/O	Digital I/O
25	GPIO14	I/O	Digital I/O
26	GPIO13	I/O	Digital I/O

Pin #	Signal name	Direction*	Description
27	GND	Power	Ground connection
28	GND	Power	Ground connection

* with respect to the RCM

RF Balun (C1, C2, C3, L1, L2, and L3)

Due to the differential signal traces within the EM250 (U1), an external balun circuit must drive the unbalanced antenna port. To keep costs low, Ember focused on a discrete, lumped-element LC balun, minimizing the number of inductors and using lower-cost elements where applicable.

This balun performs three primary functions:

- Matches the unbalanced 50 Ohms to the balanced 200 Ohms of the EM250.
- Minimizes EVM by tuning PA Bond Wire inductance.
- Maximizes conducted 2nd harmonic suppression.

Due to the complex nature of developing the balun, Ember strongly urges application teams to resist changing the balun component values.

High-Frequency Crystal (Y1)

The high-frequency crystal is a 24MHz, surface-mount, two-pin, 3.5 x 6 mm package crystal oscillator. Table 11 lists the tolerances for this crystal. The manufacturer used for this module is ILSI America (MFG P/N: ILCX08-JG5F18-24.000MHZ). All EM250 RCMs are tested to ensure the frequency tolerance is at +/- 10ppm at room temperature.

Table 11. Frequency tolerances for the high-frequency crystal

Crystal requirements	Frequency tolerance
Total frequency error	+/-40ppm (as specified within the IEEE 802.15.4-2003 standard)
Calibration error	+/- 10ppm
Temperature error	+/- 20ppm
Aging	+/- 5ppm

Low-Frequency Crystal (Y2)

The watch crystal is a 32.768 kHz, surface-mount, two-pin, 3.2 x 1.2 mm crystal. The manufacturer used for this module is ILSI America (MFG P/N: IL3X-HX5-12.5-32.768KHZ). This crystal is optional if the internal RC oscillator is used to drive the EM250 sleep timer.

LED Indicators (DS1 and DS2)

Four EM250 GPIOs (GPIO[13], GPIO[14], GPIO[15], GPIO[16]) allow for high output drive for LEDs. The EM250 RCM uses two of these GPIOs to drive DS1 and DS2. In most of the Ember sample applications, these LEDs are defined as Heartbeat and Activity to give immediate indication that the software application and network stack are operating correctly. Since these are attached to EM250 GPIO[13] and GPIO[14], respectively, they are available for debugging at the application level.

RF Measurements

To perform RF Measurements (TX Power, RX Sensitivity, ACR, etc) with the EM50 RCM:

1. Attach the RCM to the Breakout Board.
2. Configure the Breakout Board for Serial Communication.
3. Attach the InSight Port Cable to the RCM and the InSight Adapter.
4. Load the RangeTest SW Image on the EM250.
5. Connect the Murata to SMA Adapter cable to the Murata Switch on the RCM.
6. Attach the SMA end of the Adapter to the Test Equipment.

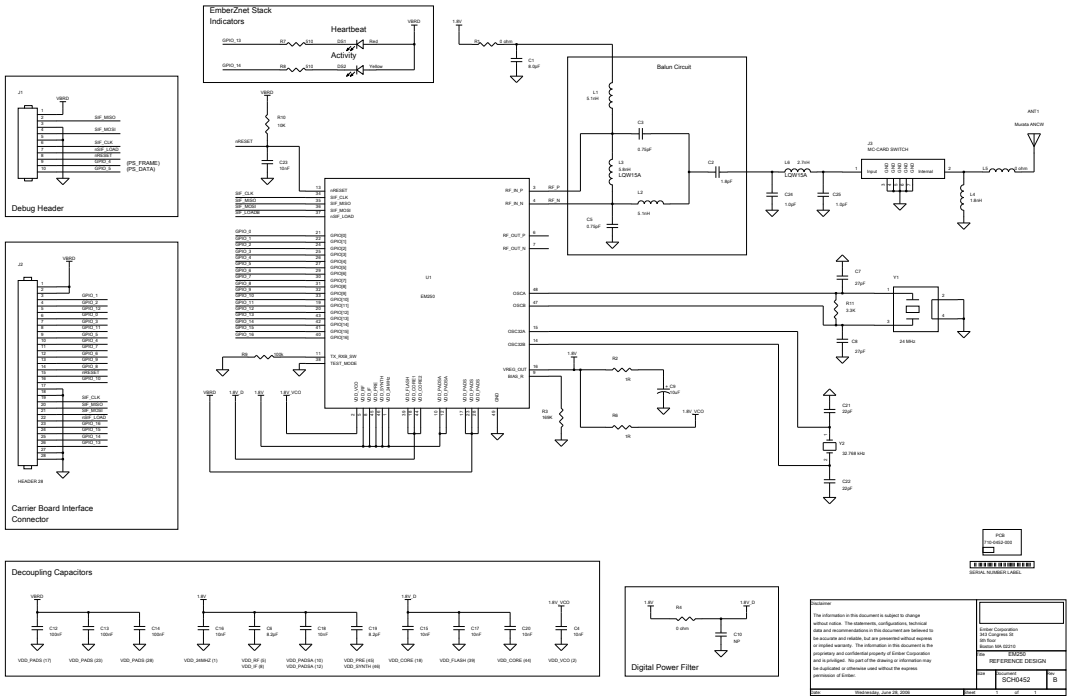
Performing Deep Sleep Current Measurements

To perform Deep Sleep current measurements with the EM250 RCM:

1. With the RangeTest Application loaded into the EM250 RCM Flash, remove the EM250 RCM from the Breakout Board.
2. Attach the DC power supply (with ammeter capability) to the RCM Interface Connector (J2).
3. Attach the InSight Port Cable to the RCM and the InSight Adapter.
4. With Virtual UART, issue the `SHUTDOWN x` command (where `x` is the delay in seconds before deep sleep is entered) to the RCM. The delay `x` should be chosen to allow time to remove the InSight Adapter from the RCM.
5. Measure the current draw from the DC power supply.

Schematic of the EM250 RCM

Figure 5. Schematic of the EM250 RCM

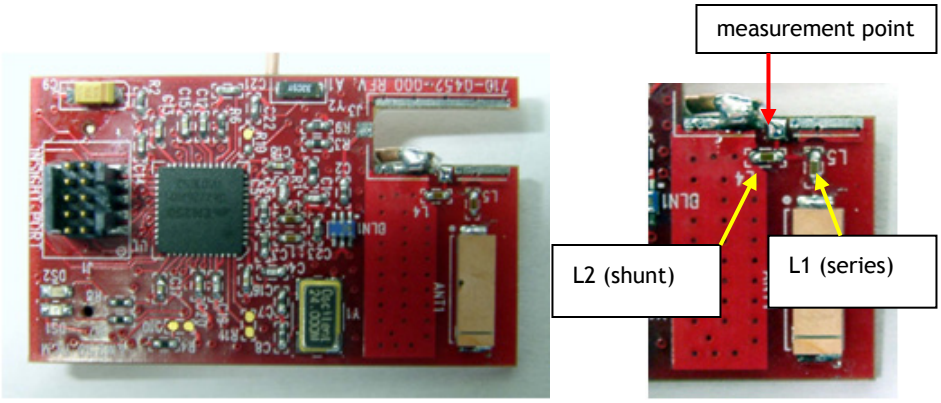


Appendix: Murata Chip Dieletric Antenna Matching

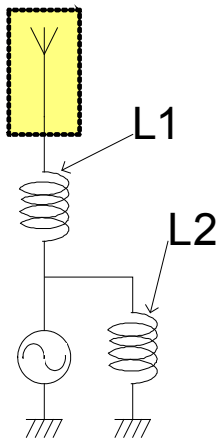
In most wireless applications, a certain amount of antenna tuning is required to guarantee a 50 Ohm interface and allow for the maximum performance. Because Ember uses a Murata ceramic antenna on its RCM, Ember worked with Murata to provide the best tuning configuration for the RCM. (Note: This is a free service offered by Murata to its customers.) Once the tuning was completed, Murata provided a report of the work accomplished. An excerpt from that report is included in this Appendix.

Note: This appendix is an example of the output from Murata's antenna characterization service. Ember used this service for Rev A1 of the EM250 Radio Communication Module. Ember is currently shipping Rev C0 with its development kits. Therefore, the photos of the module shown in this appendix are for reference only.

Mounted Condition

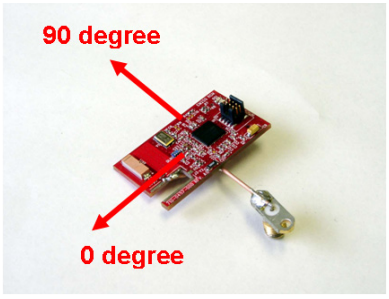


Measurement circuit

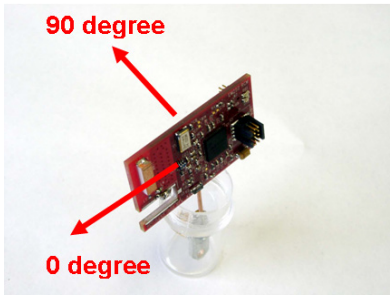


Measurement Condition

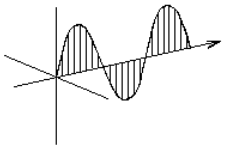
- **Condition 1: before tuning**
- **Condition 2: after tuning [L1(series): 0ohm, L2(shunt) : 1.8nH]**



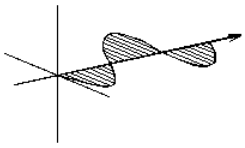
YZ-plane



ZX-plane



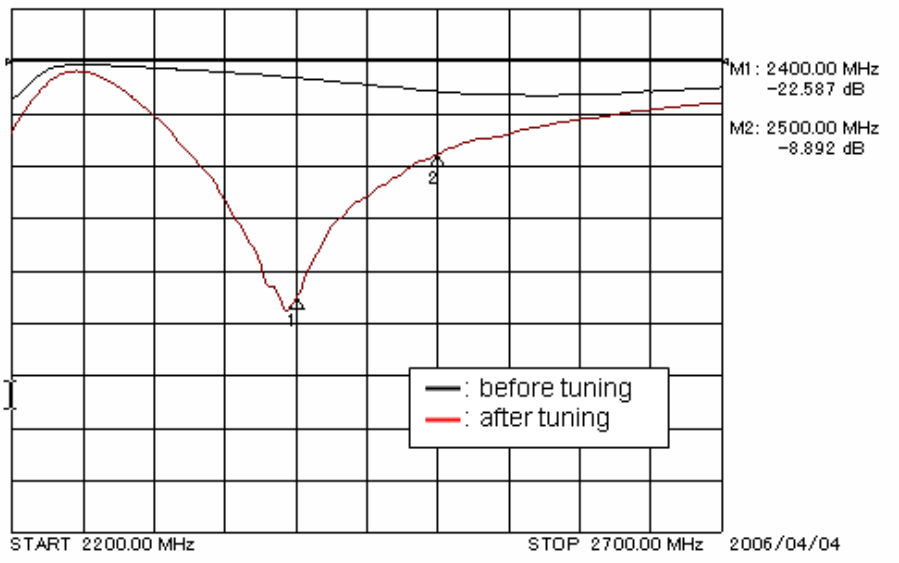
V



H

Measurement Result

Return loss



Antenna gain

Condition 1: before tuning

[dBi] [dB]

LINEAR POLARIZATION		YZ-plane hor.	YZ-plane ver.	ZX-plane hor.	ZX-plane ver.	Efficiency
2400 MHz	MAX	-5.2	-14.3	-1.4	-14.3	
	AVE	-7.9	-20.4	-6.1	-19.9	-5.2
2450 MHz	**MAX**	**-3.4**	**-12.6**	**-0.6**	**-12.3**	
	AVE	**-6.2**	**-18.3**	**-5.0**	**-18.0**	**-3.9**
2500 MHz	MAX	-2.5	-13.7	0.8	-12.5	
	AVE	-5.4	-18.6	-4.0	-17.4	-2.9

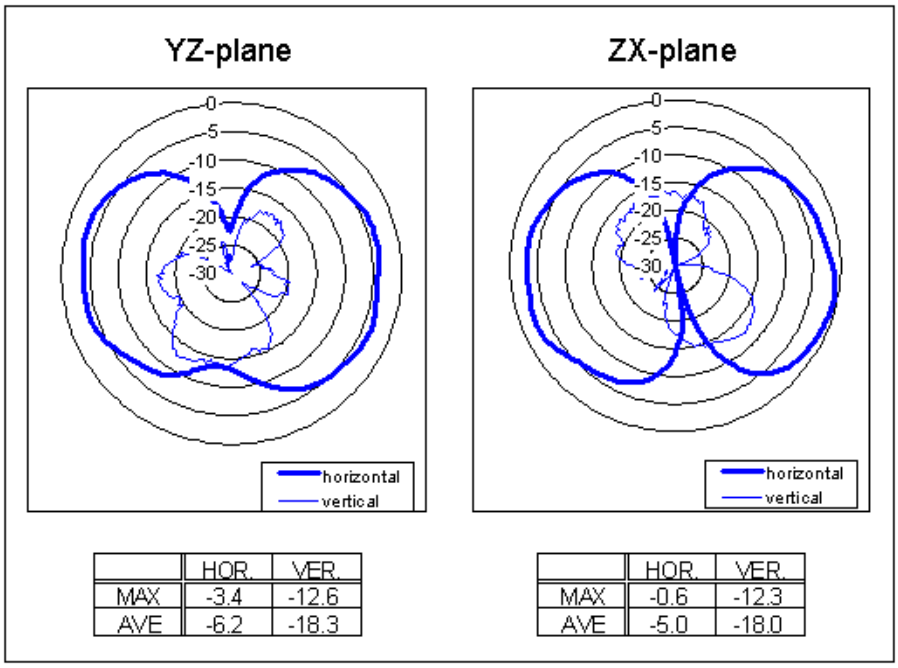
Condition 1: after tuning

[dBi] [dB]

LINEAR POLARIZATION		YZ-plane hor.	YZ-plane ver.	ZX-plane hor.	ZX-plane ver.	Efficiency
2400 MHz	MAX	0.5	-10.5	3.9	-7.9	
	AVE	-2.4	-17.0	-0.8	-13.6	0.1
2450 MHz	**MAX**	**0.5**	**-10.7**	**3.3**	**-8.8**	
	AVE	**-2.4**	**-16.3**	**-1.3**	**-13.8**	**-0.2**
2500 MHz	MAX	0.1	-13.0	3.7	-9.9	
	AVE	-3.0	-18.2	-1.3	-14.4	-0.4

Radio pattern

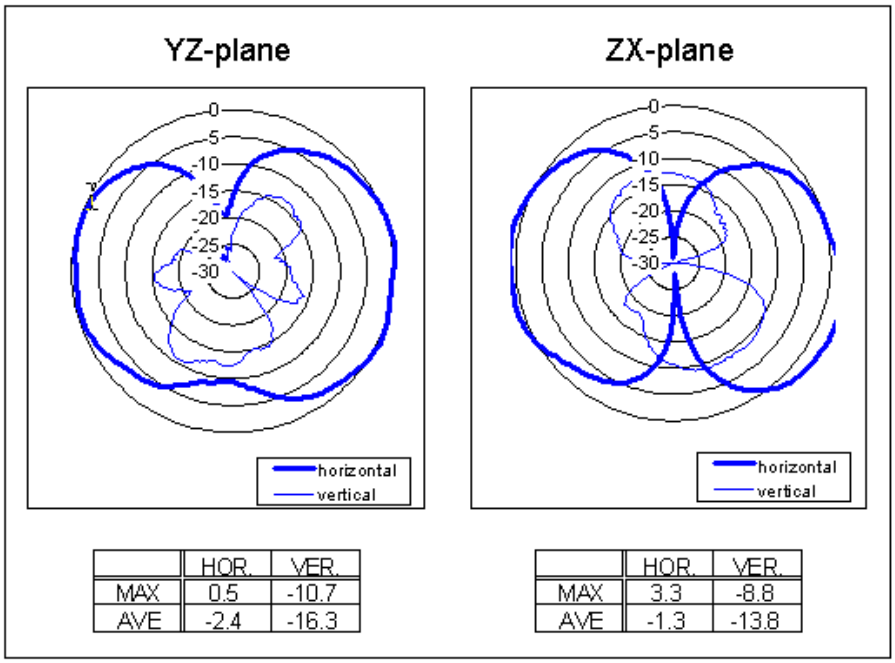
Condition 1: before tuning (unit dBi)



	HOR.	VER.
MAX	-3.4	-12.6
AVE	-6.2	-18.3

	HOR.	VER.
MAX	-0.6	-12.3
AVE	-5.0	-18.0

Condition 2: after tuning (unit dBi)



	HOR.	VER.
MAX	0.5	-10.7
AVE	-2.4	-16.3

	HOR.	VER.
MAX	3.3	-8.8
AVE	-1.3	-13.8

After Reading This Document

If you have questions or require assistance with the procedures described in this document, contact Ember Customer Support. The Ember Customer Support portal provides a wide array of hardware and software documentation such as FAQ's, reference designs, user guides, application notes, and the latest software available to download. To obtain support on all Ember products and to gain access to the Ember Customer Support portal, visit http://www.ember.com/support_index.html.

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