



Eterna Certification User's Guide

023-0003 rev 3

December 16, 2015

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1 Introduction

Electronic devices can be divided into two classes of devices, those that do not intentionally radiate electromagnetic radiation and those that do. Electronic devices that do not intentionally radiate typically require an expedient and relatively inexpensive scan to determine if the devices meet the radiations limits defined by regulatory bodies on a per geography basis. For example the FCC, regulates the United States and ETSI regulations apply to the European Economic Area. Electronic devices that intentionally radiate, most often require additional testing demonstrating the devices adherence to the specific regulations. In an attempt to reduce the burden of testing products, many geographies support the concept of modular certification. Modular certification allows for a module to be tested outside of product and then allows products that incorporate the module to be tested as an unintentional radiator. This enables the module to be tested once and then re-used in multiple products, reducing the overhead of the intentional radiator testing. While the majority of geographies support modular certification, some do not and those that do carry varying restrictions or requirements on the definition of a module. Restrictions or requirements can restrict the output power level, type of antenna or antenna connector, inclusion of an Radio Frequency (RF) shield on the module, and circuit implementation. Eterna is designed with the purpose of supporting world wide certification of the device as a product; however, devices based upon Eterna need to be designed with an understanding of the regulatory requirements for the target geographies.

1.1 Purpose

This document is provided to Original Equipment Manufacturers (OEMs) as both an introduction to radio certification requirements and to the features included in Eterna based devices provided primarily for the purpose of supporting regulatory testing. Linear Technology offers Printed Circuit Board (PCB) versions of its products that include all of the capabilities of the Integrated Circuit (IC) products and in addition include certifications for geographies including the United States, EU, Canada, Japan, Taiwan, India, Australia, and New Zealand. OEMs designing with Eterna based IC products will need to manage the certification of those products.

1.2 Scope

This document provides the LTC5800 specific technical information needed to complete most radio certifications. This information is both how to operate the device during a certification test to be able to perform the tests as well as the LTC5800 specific technical information that will be required when submitting a design for certification. This document does not provide certification regulations. To best understand the current regulatory requirements for a particular geography, Linear Technology recommends contacting an ElectroMagnetic Compatibility (EMC) testing facility with expertise in the target geography(ies). This document covers the following products.

- LTC5800-IPM
- LTC5800-WHM
- LTC5800-IPR

1.3 References

- [1] IEEE Std 802.15.4-2006, Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)
- [2] [ETERNA2 User's Guide](#)

1.4 Definitions

DUT	Device Under Test
Mote	A node in a mesh network
Low Channel	The lowest frequency channel occupied by Eterna is channel 0 centered at 2405 MHz. This channel corresponds to channel 11, as defined by [1].
Mid Channel	The channel closest to the center of the 2.4 GHz ISM band occupied by Eterna is channel 7, centered at 2440 MHz. This channel corresponds to channel 18, as defined by [1].
High Channel	The highest frequency channel occupied by Eterna is channel 14, centered at 2475 MHz. This channel corresponds to channel 25, as defined by [1].

1.5 Considerations

Radio certification will be required for every product per each geography. Certification costs can be as little as a few thousand US dollars for some geographies and as high as 10 to 20 thousand US dollars. Radio certifications can take from two to ten or more weeks to complete and longer if you are certifying in a geography for the first time. OEM's use of a modular certification, by creating their own module is common practice, as in many cases this will save time and cost relative to performing individual certifications on each product. Some geographies do not support modular certification, so consultation with an EMC testing facility prior to deciding on a system architecture is prudent.

Manuals provided for certification in some geographies are posted in the public domain. Some geographies have local language requirements for the manual and most have specific language that must be included in the manual. Creation of a manual specific for certification can reduce the exposure of intellectual property and reduce the work load in supporting the certification procedure. The certification user's manual for the ETERNA2 module, the [ETERNA2 User's Guide](#), provides an example of such a manual. It also provides an example of the language required for certifying in some of the more common geographies.

Regulation requirements vary considerably, especially with regard to modules supporting a connector to an antenna. OEMs should consult their EMC testing facility with their antenna requirements and specifications to ensure the testing completed during certification will cover all variations of the product and to determine the suitability of each antenna for each geography.

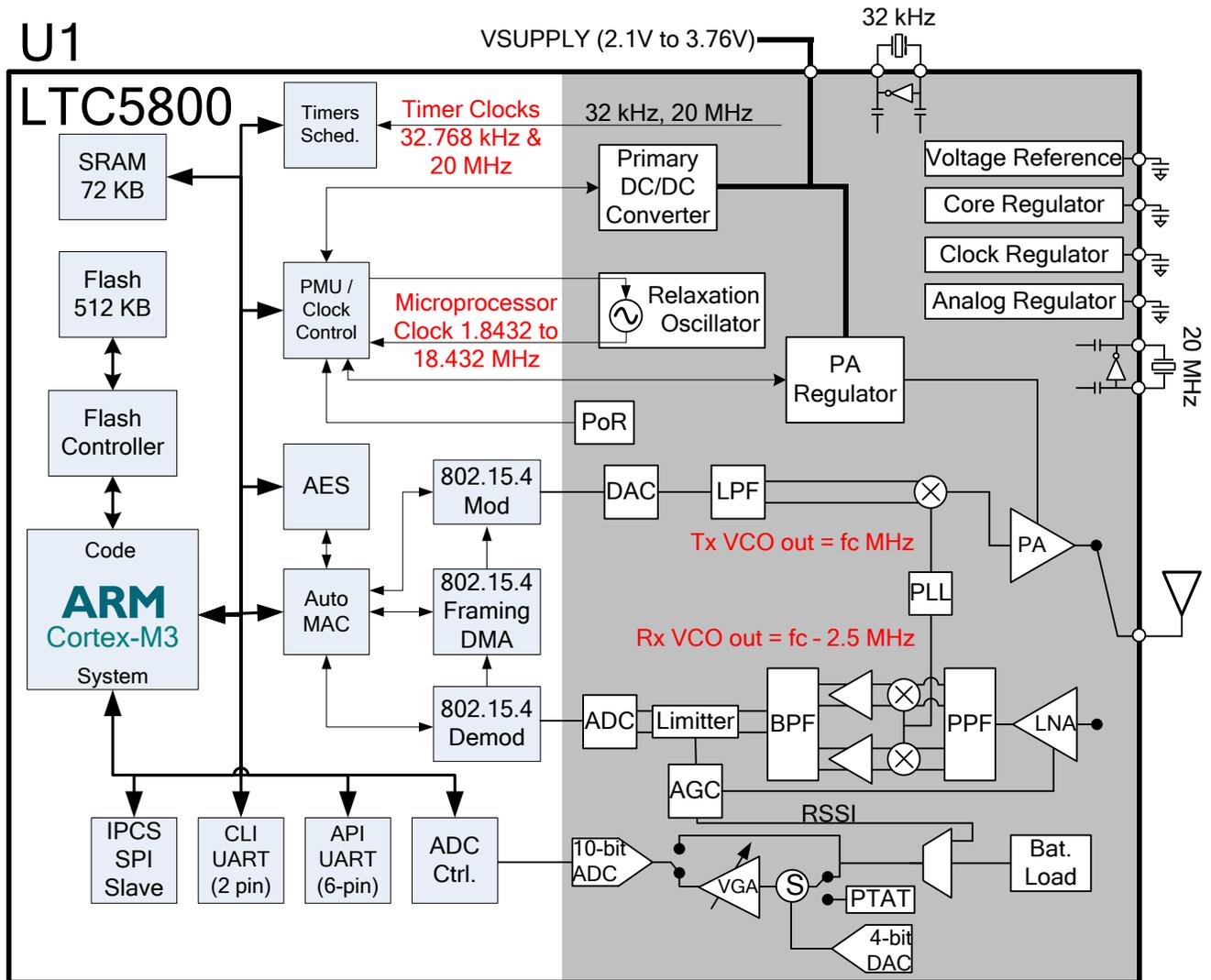
Regulation requirements will also dictate labeling requirements for both a module and a complete product. Consideration of the type of label and the space the label will need to provide the required information should be taken into account in the design of the module and/or the enclosure.

2 Technical Reference

2.1 General Description

Eterna combines a microprocessor and an IEEE-802.15.4 radio with networking capabilities to provide a time synchronized, ultra low power network, designed to enable operation from battery sources for extended periods of time.

2.2 Block Diagram



Note that $f_c = 2405 + n \cdot 5$ MHz, where $n = 0, 1, 2, \dots, 14$.

2.3 Operational Description

Eterna provides a IEEE 802.15.4 compliant radios that modulate a DSSS OQPSK set of symbols at a chip rate of 2 Mcps. Eterna radios operate on a TDMA time schedule that uses either 7.25ms (SmartMesh IP software) or 10ms (SmartMesh WirelessHART) timeslots. A transmit timeslot consists of 5 stages:

1. Initialization: radio is prepared for transmit (transmitter is off)
2. Ramp: transmitter is ramped to peak power
3. Transmit: 128 bytes of data maximum + 5 bytes preamble/SFD
4. Turnaround: radio is set to receive
5. Receive: radio waits in receive for ACK, then turns off

Total transmit time for a 128 byte packet plus all overhead (SFD / Preamble / Ramp) is 4.33ms.

A receive timeslot consists of 5 stages:

1. Initialization: radio is prepared for receive
2. Check for start of packet – if no packet is received within a guard time the radio is disabled and no further action is taken
3. Receive the packet: up to 128 bytes of data maximum + 5 bytes preamble/SFD
4. Turnaround: radio waits 1 ms and then is set to transmit
5. Transmit: radio sends an ACK (21 bytes of data + 5 bytes preamble/SFD), then turns off

Total transmit time for an ACK is plus all overhead (SFD / Preamble / Ramp) is 1.101 ms.

When the radio is not in operation, the CPU is occasionally (every few seconds for a few milliseconds) operating, monitoring temperature and voltage. The remainder of the time the Eterna is in a low power mode operating solely from a 32 kHz crystal source.

2.3.1 Duty Cycle Calculations

In some geographies, the United States included, duty cycling of the radio provides relief against some of the technical requirements. In these geographies, providing a duty cycle calculation may provide an easier path to complete certification. EMC testing facilities will want to have the duty cycle calculation in advance of testing to know if the device is passing or failing during testing. In typical operation Eterna radios spend the majority of the time inactive. In order to provide reliable communication all devices in the network are “over provisioned”, with radios listening more often than the packet throughput requires. This results in radios that have a low duty cycle for turning on their transmitter. The solution below is considered a pathological worst case duty cycle for an Eterna radio when shipped with its default over provisioning factor. The provided example is based upon the SmartMesh IP timeslot of 7.25ms over the FCC specified window of 100ms for calculating duty cycle.

When transmitting a packet, transmission duration during a timeslot varies as a function of the payload, with a maximum of 128 bytes. When receiving a packet the transmitted acknowledgement will be a maximum of 27 bytes. During network operation, radios receive three times, for every transmit slot, and as a result, the maximum possible duty cycle is created with the following sequence:

1. Transmit
2. Acknowledge
3. Acknowledge
4. Acknowledge
5. Transmit
6. Acknowledge
7. Acknowledge
8. Acknowledge
9. Transmit
10. Acknowledge
11. Acknowledge
12. Acknowledge
13. Transmit

$$\begin{aligned}\text{Maximum total transmit duration} &= 4*\text{Transmit [128 bytes]} + 9*\text{Acknowledge} \\ &= 4*[(128+5)*32\text{us} + 77\text{us}] + 9*[(24+5)*32\text{us} + 77\text{us}] \\ &= 4*[4.333\text{ms}] + 12*[1.101\text{ms}] \\ &= 27.241\text{ms}\end{aligned}$$

$$\text{Duty cycle} = 27.241\text{ms} / 100\text{ms} = 27.241\%$$

The worst-case sequence for SmartMesh WirelessHART based devices is lower as the sequence would only include numbers 1 through 10, given SmartMesh WirelessHART’s 10ms time slot.

2.4 Command and Response

SmartMesh IP and SmartMesh WirelessHART software provide APIs for controlling the radio over either the API or CLI UART interface. Providing instruction and equipment to support radio testing to a 3rd party is more easily done with the CLI interface as the API interface is HDLC encoded, while the CLI interface can simply be executed using a software terminal to generate the commands and monitor the responses. Products that require control of the radio in their finished form either due to potting or regulations will need to provide a pass through of at least the radio specific API calls to an external interface in order to test the radio in the products finished form.

2.5 CLI UART

Eterna includes a Command Line Interface, CLI, UART that supports a full set of text commands described in this document to enable product certification. The interface operates at LVTTTL levels matching the VSUPPLY input to Eterna. The UART is configured at 9600 baud, 8-bit, no parity, 1 stop bit, and does not support flow control. Refer to the product specific CLI guide for details:

Table 1 Product Specific CLI Guides

Product	Guide	Location
LTC5800-IPM	SmartMesh IP Mote CLI Guide	http://www.linear.com/docs/41885
LTC5800-IPR	SmartMesh IP Manager CLI Guide	http://www.linear.com/docs/41882
LTC5800-WHM	SmartMesh WirelessHART Mote CLI Guide	http://www.linear.com/docs/41892

In addition to enabling OEMs to load software images on Eterna, the [DC9010 Eterna Serial Programmer](#), provides a USB to serial port adaptation that can be used to control a module during certification testing, using the same header recommended for loading software images.

2.6 API UART

Eterna offers a comprehensive Application Programming Interface, API, that provides full programmatic access to control the device, monitor its status (such as battery charge and network status), and provide access to the wireless mesh network. Messages over the API UART are HDLC encoded and require specific software to support command and response communication required for regulatory testing. Refer to the product specific CLI guide for details:

Table 2 Product Specific API Guides

Product	Guide	Location
LTC5800-IPM	SmartMesh IP Mote API Guide	http://www.linear.com/docs/41886
LTC5800-IPR	SmartMesh IP Manager API Guide	http://www.linear.com/docs/41883
LTC5800-WHM	SmartMesh WirelessHART Mote API Guide	http://www.linear.com/docs/41893

3 Test Configurations

Test configurations can be divided into two distinct configurations, one for Radiated immunity and a second for Emissions and Conducted Measurements.

3.1 Radiated Immunity

Operation of the network in the presence of an interferer can most easily be monitored by operating Eterna as a mote participating in a network. In this configuration, the RF link between the Eterna and a network manager can be exercised and simultaneously monitored via the network managers UART CLI port. Communication to and monitoring of the UART CLI port can be done via generally available terminal emulation software, such as TeraTerm, HyperTerminal, or iTerm2.

3.2 Emissions and Conducted Measurements

Emissions and Conducted measurements can be made with Eterna on a module or fully integrated into a product. When integrated into a product a convenient method to invoke commands over Eterna's CLI or API UART should be considered as part of the product design.

4 Tests

4.1 Conventions

Input from the user during a test will be in **bold**. Command line information will be shown in Plain Text. Command parameters, either numerical, alphanumeric or enumerated, are shown between greater than and less than symbols. I.e. `<parameter>`.

4.1.1 Channel Map

Radiotest commands use the **<chanMask>** parameter to define which channel or channels the radio will operate on when a command is issued. The parameter **<chanMask>** is a hex bitmap of channels to use with the LSB corresponding to channel 0 and the MSB corresponding to channel 15. Channel 15 in product is never used. For example, 0x7fff results in operation on channels 0 through 14 and 0x0001 results in operations only on channel 0. Table 3 provides a mapping for single channel operation for each channel and the corresponding channel number as defined in this document.

Table 3 Channel Mask Parameter Channel Mapping

<chanMask> (Hex)	Center Frequency (MHz)	Channel #
0x0001	2405	0
0x0002	2410	1
0x0004	2415	2
0x0008	2420	3
0x0010	2425	4
0x0020	2430	5
0x0040	2435	6
0x0080	2440	7
0x0100	2445	8
0x0200	2450	9
0x0400	2455	10
0x0800	2460	11
0x1000	2465	12
0x2000	2470	13
0x4000	2475	14

4.2 Receiver Emission Tests

Much of the testing focused on the receiver can be accomplished by enabling Eterna's radio to receive for an extended period of time using the following sequence:

Power up Eterna and connect to the CLI port. Enter the following command

```
> radiotest on
```

Reset or power cycle Eterna and enter the following command

```
> radiotest rx <chanMask> <time> <stationId>
```

Where <chanMask> would nominally be set to 0x0001 (low) , 0x0080 (mid) or 0x4000 (high) and **<time>** in seconds. The **<stationId>** parameter was added in the version 1.1.2 of the SmartMesh WirelessHART mote. Earlier versions of software should omit the **<stationId>** parameter. The **<stationId>** parameter should be set to 0, zero, for all certification radio testing.

This sequence enables testing of:

- Receiver Conducted Spurious Emissions Operating (EN 300 328)
- Receiver Radiated Spurious Emissions Operating (EN 300 328, FCC 15.109)

- AC Conducted Emissions (FCC 15.207)

After completing tests that require radiotest commands (tx and rx) use the **radiotest off** command to return the device to its normal state:

```
> radiotest off
```

Reset or power cycle Eterna.

4.3 Transmitter Power and Spectral Tests

Much of the testing focused on the transmitter can be accomplished by enabling Eterna's radio to continuously transmit a modulated signal using the following sequence:

Power up Eterna and connect to the CLI port. Enter the following command:

```
> radiotest on
```

Reset or power cycle Eterna and enter the following command:

```
> radiotest tx cm <chanMask> <power>
```

Where <chanMask> would nominally be set to 0x0001 (low) , 0x0080 (mid) or 0x4000 (high) and <power> to 8, the highest output power setting used in the OEM product.

This sequence enables testing of:

- Effective Isotropic Radiated Power (EN 300 328)
- Maximum Spectral Power Density (EN 300 328, FCC 15.247(e))
- Frequency Range / Band Edge (EN 300 328 / FCC 15.247(d))
- Transmitter Conducted Spurious Emissions Operating (EN 300 328, FCC 15.247(d))
- Transmitter Radiated Spurious Emissions Operating (EN 300 328, FCC 15.247(d))
- AC Conducted Emissions (FCC 15.207)
- Bandwidth (FCC 15.247(a)(2), RSS 210 99% Bandwidth, EN 300 328)
- RF Power Output (FCC 15.247(b)(3))

After completing tests that require radiotest commands (tx and rx) use the **radiotest off** command to return the device to its normal state:

```
> radiotest off
```

Reset or power cycle Eterna.

NOTE: If testing encompasses measuring Eterna's output power or PSD, Power Spectral Density, over a range of voltages, the **radiotest off** command must be issued every time the voltage to Eterna is changed to ensure accurate output power measurements. During product operation Eterna, dynamically adjusts its regulation to its power amplifier, based upon the supply voltage to keep the supply to the PA constant. The **radiotest tx cm** and **radiotest tx cw** commands do **not** dynamically adjust the power to the PA, only taking a single measurement when the command is issued.

WARNING: It is possible to permanently damage Eterna, by initiating a **radiotest tx cm** or **radiotest tx cw** command at a low voltage and subsequently raising the voltage without issuing a **radiotest off** command.

4.4 Transmitter Carrier Tests

Testing Eterna's carrier frequency accuracy can be done by enabling Eterna's radio to continuously transmit an unmodulated signal using the following sequence:

Power up Eterna and connect to the CLI port. Enter the following command

```
> radiotest on
```

Reset or power cycle Eterna and enter the following command

```
> radiotest tx cw <chanMask> <power>
```

Where [<chanMask>](#) would nominally be set to 0x0001 (low) , 0x0080 (mid) or 0x4000 (high) and <power> to 8, the highest output power setting used in the OEM product.

After completing tests that require radiotest commands (tx and rx) use the **radiotest off** command to return the device to its normal state:

```
> radiotest off
```

Reset or power cycle Eterna.

4.5 Radiated Emissions

Radiated emission tests, such as described in EN 301 489-17, are designed to test that a DUTs unintentionally radiated emissions are below defined limits. As the radio itself has been modularly certified this is not a test of the emissions with the radio in operation. To prevent Eterna from actively running its radio during connect to Eterna's CLI port and enter the **set** command as follows:

```
> radiotest on
```

Reset or power cycle Eterna. The radio is now inactive and will remain inactive until a **tx** or **rx** command is given.

After completing tests that require radiotest commands (tx and rx) use the **radiotest off** command to return the device to its normal state:

```
> radiotest off
```

Reset or power cycle Eterna.

4.6 Radiated Immunity

Radiated immunity tests, such as described in EN-61000-4-3, are designed to test a DUTs operation due to an out of band interferer. When performing such tests the test system should be verified to prove the test system is not injecting noise due to harmonic distortion into the 2.4 to 2.4835 GHz band. To perform this class of test two or more Eterna motes should be placed in a network and the network function can be demonstrated as follows:

Create a network of devices with a network manager and two Eterna motes (the minimum configuration to form a network). Make sure the MAC addresses for both Eterna motes and the manager are clearly labeled on each device. Connect to the manager's CLI port and issue the following commands:

```
> login user
```

```
> show mote *
```

```
Mote #1, mac: 00-17-0D-00-00-19-20-2C, ver: 2.2.1.7
  State: Oper, Hops: 0.0, Uptime: 2561, Age: 0
  Number of neighbors (parents): 2 (0)
  Number of links (tx/rx): 17 (0/4)
  Number of no bitmap links : 13
  Neighbors:
    <- #2 Q: 28
    <- #3 Q: 28
```

```
Mote #2, mac: 00-17-0D-00-00-19-33-07, ver: 2.2.1.7
  State: Oper, Hops: 1.0, Uptime: 2475, Age: 13
  Number of neighbors (parents): 2 (1)
  Number of links (tx/rx): 15 (2/2)
  Neighbors:
    -> #1 Q: 28
    <- #3 Q: 29
```

```
Mote #3, mac: 00-17-0D-00-00-10-20-4D, ver: 2.2.1.7
  State: Oper, Hops: 1.4, Uptime: 2460, Age: 7
  Number of neighbors (parents): 2 (2)
  Number of links (tx/rx): 14 (2/0)
  Neighbors:
    -> #1 Q: 28
    -> #2 Q: 29
```

Note: It can take up to 10 minutes for the network to form and will take longer if the manager has been powered up for a lengthy period of time. For best results power up all devices within a couple of minutes. Mote 1 is always the mote in the Network Manager and the assignment of motes 2 through 3 are based upon order of joining the network which is not deterministic. To determine which mote number is which device use the MAC address as a reference.

To force a message to a particular mote enter: **ping <mote number>** which will look like:

```
> ping 2
```

```
> Sending ping request to mote 2
> Ping response from mote 2, time=900 msec v=3645 t=25
```

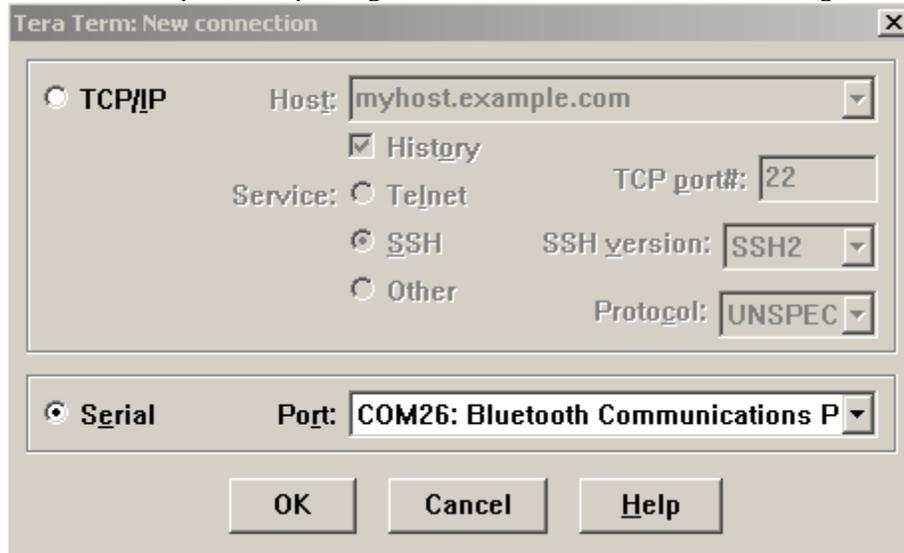
Ping commands that fail will return with a timeout error message:

```
Ping from mote 2 timed out
```

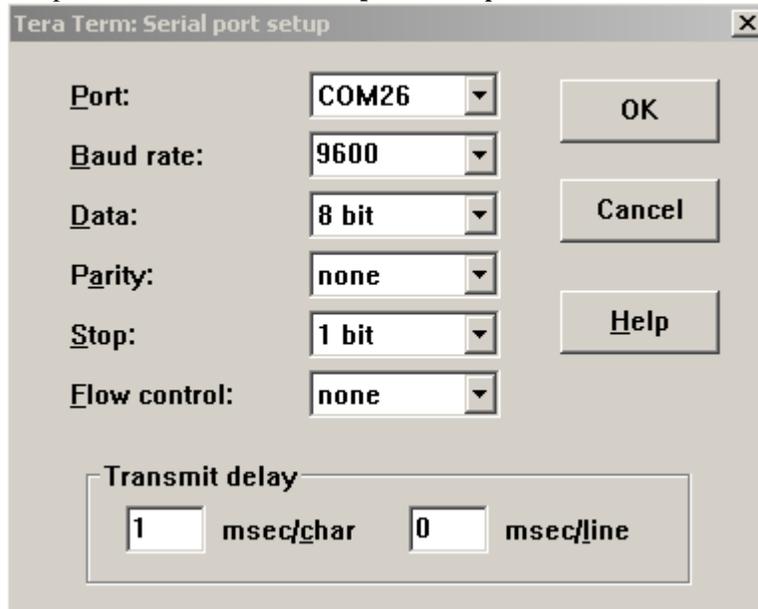
Inherently the manager CLI port will generate a notification when a device fails to communicate and falls off the network. During normal network operation devices are communicating at least every 15 seconds. To reduce dwell time the use of a script to ping the target device will increase the radio traffic. The traffic rate will be twice the rate of the ping command being sent. A simple method, uses the windows program TeraTerm Pro. TeraTerm Pro can be downloaded at <http://sourceforge.jp/projects/ttssh2/releases/>. Configure TeraTerm as follows to communicate with the network managers CLI port with the following steps:

1. Launch TeraTerm

2. Select the serial port corresponding to the CLI interface to the network manager



3. Setup the Serial Port via the **Setup -> Serial port ...** Menu item:



4. Create a TeraTerm macro, a text file with the extension *.ttl, with the following content:

```

; Tera Term macro for pinging Dust motes in a network over the managers CLI port
;
; File: ping_loop.ttl
; Description: Looping ping macro for support of Radiated Immunity testing of Dust
; Networks Radios. Set for one ping two messages every delayInMiliSeconds period,
; with 255 steps from 80 to 1000 MHz. For Radiated Immunity above 1 GHz testing is
; only intended to be performed for bands where portable radios are permitted to
; operate - this range and therefore the test duration will change over time.

```

```

timeout = 10
steps = 255
delayInMiliSeconds = 3000
sendln
for i 1 steps
    sendln

```

```

    sendln "ping 2"
    mpause delayInMiliSeconds

next

pause 5
sendln "#----- Macro Finish -----"
end

```

5. Call the macro from the TeraTerm menu **Control -> Macro** and load the created macro file.

This will create a series of Ping request and responses from the mote.

4.7 Duty Cycle, Tx-Sequence, Tx-Gap and Medium Utilization

The follow command sequences provide a method for demonstrating the maximum duty cycle ETERNA2 could generate in a SmartMesh IP or SmartMesh WirelessHART network:

```
> radiotest on
```

Start test:

```
> radiotest tx <testType> <chanMask> <power> <sysId> [<repeatCnt> {<pkLen>
<delay>...}]
```

<testType> is Type of transmission test to initiate: 'pkcca' = packets with clear channel assessment, 'pk' = packets, 'cm' = continuous modulation, 'cw' - continuous wave. **<chanMask>** is a hex bitmap of channels to use with the LSB corresponding to channel 0 and the MSB corresponding to channel 15. Channel 15 in product is never used. E.g. 7fff results in operation on channels 0-14 and 0001 results in operations only on channel 0. **<power>** sets the radio output power, a value of 8 should be used for maximum power. **<sysId>** is the network ID used for packet transmission this parameter allows for testing of multiple devices in the same RF space and is intended for manufacturing support, not radio certification testing. The **<sysId>** field for certification testing can be left at zero, 0. The transmitter will transmit in a sequence of packets and gaps defined by a series of alternating **<pkLen>** and **<delay>** parameters. The **<pkLen>** parameter defines the packet length in terms of bytes and is limited to a range of 2 to 125 bytes. Note the protocol will append 8 bytes to the packet payload, so the actual transmitted length of bytes **<pkLen> + 8**, for a maximum of 133 bytes. The **<delay>** parameter defines the delay from the start of one packet to the next in μ s. The **<repeatCnt>** parameter defines the number of times that the defined packet sequence will repeat. A **<repeat>** value of 0 results in the sequence repeating indefinitely. To demonstrate the maximum duty cycle of an IP system on the low channel using every slot issue the following command:

```
> radiotest tx pkcca 0x0001 8 0 0 125 10035 24 5700 24 5700 24 5700
```

This will demonstrate a sequence of one transmission of a maximum length packet followed by three acknowledge packets. To have the radio operate in a hopping sequence that enables hopping on all 15 channels issue the following command:

```
> radiotest tx pkcca 0x7FFF 8 0 0 125 10035 24 5700 24 5700 24 5700
```

To demonstrate the maximum duty cycle of a WirelessHart system on the highest channel when every slot is active, issue the following command:

```
> radiotest tx pkcca 0x4000 8 0 0 125 14733 24 8700 24 8700 24 5822
```

To have the radio operate in a hopping sequence that enables hopping on all 15 channels issue the following command:

```
> radiotest tx pkcca 0x7FFF 8 0 0 125 14733 24 8700 24 8700 24 5822
```

After completing tests that require the DUT to hop outside of a network, use the **radiotest off** command to return the device to its normal state:

```
> radiotest off
```

Reset or power cycle Eterna.

4.9 Radio Inactive Emission Tests

To test Eterna for emissions with the radio inactive:

Power up Eterna and connect to the CLI port. Enter the following commands:

```
> set mode slave
> reset
```

NOTE: The device will remain inactive through power cycling. To resume radio testing, enter the following commands:

```
> set mode master
> reset
```

5 Specifications

Table 4 Normal Operating Conditions

Parameter	Min	Typ	Max	Units	Comments
Operational supply voltage range (between V_{DD} and V_{SS})	2.1		3.76	V	Including noise and load regulation
Operating temperatures	-40		+85	°C	
Mass		4		grams	

5.1 Radio Specifications

Eterna operates as an IEEE-802.15.4 compliant radio, both transmitting and receiving in a TDMA channel access method.

Table 5 Radio Specifications

Parameter	Min	Typ	Max	Units	Comments
Frequency Band of Operation	2400		2483.5	MHz	
Number of channels		15			
Carrier Frequencies		$2400 + (n-10) * 5$		MHz	Where n = 11 to 25
Occupied Channel Bandwidth		2.7		MHz	At -20 dBc
Channel separation		5		MHz	
Frequency Accuracy	-40		40	ppm	
Output Power		8		dBm	
ITU Designation of Emission	2M70G1DDT (numbers in bold)				
Modulation	OQPSK				
Signal Information	IEEE-802.15.4, TDMA				