July 23, 2004

Motorola XSUWBWDK Ultra Wideband Wireless Developer Kit for High Data Rate Wireless Applications

General Description

The Motorola XSUWBWDK Wireless Developer Kit (WDK) is an 802.15.3 application development platform and an ultra wide band technology evaluation tool. This technology is an ideal solution for media-rich applications requiring wireless connectivity, a high data rate and low cost.

Each Wireless Developer Kit contains two second generation Motorola UWB communications transceivers, model XSUWBWDK, antennas, power supplies, and a Software Development Kit (SDK) that together allow development of consumer electronics applications. The SDK supports configuration and control of Evaluation Kit nodes via software APIs and IEEE 802.15.3 functionality. Additional transceivers can be used to create a multi station pico-net configuration.

Each Developer Kit transceiver contains printed circuit cards mounted in a metal enclosure. The Hardware Overview section below summarizes the functionality of a UWB transceiver.

Test and configuration utilities are supplied which permit measurement under various operating conditions of both the RF performance of the UWB transceivers and the integrity of transferred data. Statistics reporting capability is built in to these utilities; results are displayed on a PC attached to each node. The SDK Utilities Manual describes the utilities and applications included with the WDK.

This manual contains instructions for configuring the UWB radios. . Additionally, this *Wireless Developer Kit User Manual* contains detailed RF testing procedures. These step-by-step instructions permit determination of FCC compliance, receiver sensitivity and immunity, signal penetration and antenna separation sensitivity.

The model number for the Wireless Developer Kit is XSUWBWDK.

Features

- 802.15.3 MAC Protocol
- Software Applications Programming Interface
- Transfer of Media-Rich Streams via a 1394 Interface is Supported
- Test and Configuration Utilities Streamline Radio Evaluation
- Bi-phase Encoding Supports Data Rates to 114 Mbps
- Selectable Forward Error Correction Values: 1, ¾, ½
- Selectable Data Rates Supported: 28.5, 57 and 114Mbps
- IEEE 1394 Physical Interface

Evaluation Kit Applications

- Development of 802.15.3 enabled multi media applications
- Video Streaming Evaluation and Demonstration
- Evaluation of Motorola’s UWB Chipset Physical Layer Performance Antenna Placement Evaluation
- End-To-End Performance and Data Throughput Testing

Revision Table

Rev	Date	Person	Description
0.7	Aug 1, 2003	EHB	Document redone to become combined SDK & transceiver User Manual.
0.8	Aug 4, 2003	EHB	Added DME, and video sender commands in sections 4.3.4 and 4.4.4. Modified section 1.5, Linux Installation Procedures. Updated all figures
0.9	Aug 15, 2003	EHB	Corrected DME explanations. Removed DIP switch configuration.
0.9.2	Oct 5, 2003	EHB	Corrected networking description. Added descriptions of recvfile, sendchk, recvchk applications.
1.0	Oct 24, 2003	MSG	Revised section describing SDK applications including sendfile, recvfile, sendchk, recvchk, dme, stats, mode, config, etc.
1.1	Jan 30, 2004	MSG	Placed descriptions of configuration and control utilities into separate *SDK Utilities Guide*. Updated hardware description to cover 1106- and 1116-based WEKs and added appropriate diagrams. Added Motorola part numbers for WDK. Added to and edited glossary and references sections.
1.2	Feb 5, 2004	MSG/EHB	Changed XSI, XtremeSpectrum and associated terminology to Motorola. Updated part numbers. Updated expected results in sections Spectral Mask Compliance, Average Transmit Power, Peak Envelope Power, and Video Transmission/Reception test sections. Changed “FCC Non-Compliance Statement” section to “FCC Compliance Statement” and updated the text.
1.3	June 2, 2004	MSG	Updated firmware download description in section 3.1 to use Quartus II Web edition. Corrected `dme map_send_stream` and `dme map_receive_stream` syntax descriptions. Fixed usage of `mode` and `config` commands (`config` works only in bridge mode) in PHY evaluation procedures. Updated list of CE devices that work with UWB Nodes. Corrected UWB chipset part numbers in Figure 3. Assigned part number MC270141 to MAC FPGA. Suggested use of a Motorola antenna in section 4.3 to assure FCC compliance. Added ESIB to Table 3 and notes regarding frequency domain measurements using the ESIB to section 5.4. Edited FCC compliance statement. Added additional references to section 12. Changed connector labels in Figure 1 & Figure 2 to reverse SMA,
1.4	July 23, 2004	MLS	Corrected manual to comply with FCC written comments received July 21, 2004. Section 4.3 was amended to allow use of only FCC approved antennas with this product; confidential markings were removed; the available software was re-verified to ensure device may not operate any differently than what is approved (statement also added in Section 8); a Declaration of Conformity (DOC) was added to Section 8; complete calculation of the peak measurement at the frequency of the highest emission (Fm, 4.1556 GHz) showing all correction factors (antenna, distance ….) in the receiver for this frequency was provided separately; and compliance with Section 15.517(a)5 was indicated in Section 4.1.

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1. Overview

1.1. Explanation of Model and Part Numbers

The model XSUWBWDK UWB transceiver contains a single PC board in an aluminum enclosure approximately 6 X 4.5 X 1.25 inches in size. Table 1 gives Motorola part numbers and descriptions.

Table 1: Motorola Part Numbers for UWB Development Hardware

Motorola Part Number	Description
XSUWBAR	A single UWB transceiver plus associated components such as antenna and IEEE1394 cables, UWB antennas, etc.
XSUWBWDK	Two UWB transceivers and associated components such as antenna and IEEE1394 cables, antennas, CDROM, etc.

1.2. Mechanical Layout

Figure 1 shows a top view of a model XSUWBWDK UWB transceiver with the top cover removed. It is shown in this manner only for reference. There is generally no reason to remove the top cover.

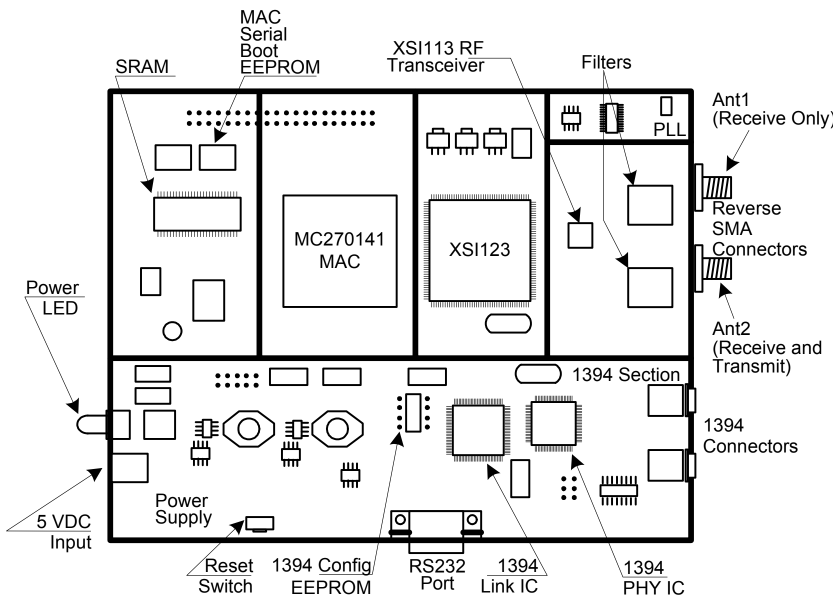

Figure 1: Top Side Layout of UWB Transceiver Model Number XSUWBWDK

Figure 2 depicts the bottom of a model XSUWBWDK UWB transceiver with the bottom cover in place. There is no reason to remove the bottom cover.

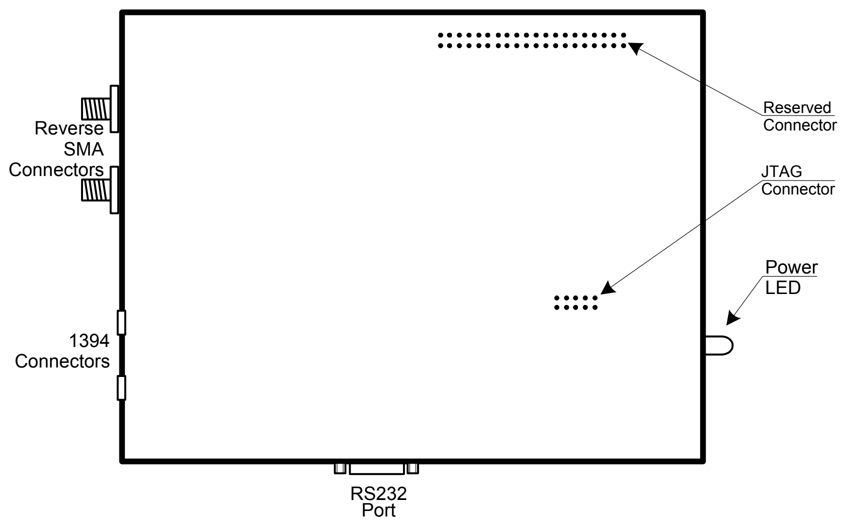

Figure 2: Bottom Side Layout of UWB Transceiver Model Number XSUWBWDK

1.3. Applicability of This Manual

This *WDK Hardware Guide* is intended for use with:

- UWB transceivers having a model number of XSUWBWDK.
- Version 2.0 or later of the Motorola XtremeSpectrum Software Development Kit.

2. Installation and Setup

2.1. Items Supplied by Motorola

A single Wireless Developer Kit contains the following items:

- Two model XSUWBWDK UWB transceivers in metal enclosures.
- Four UWB antennas.
- Four semi-flexible coaxial cables for connection of the Motorola antenna to a UWB transceiver.
- Two +5 VDC power supplies that accept 110 – 240 VAC input.
- Two IEEE1394 cables, each with four pin connectors on the ends.
- An SDK CDROM.. For the content of this CDROM, see the *XtremeSpectrum Software*
- *Motorola UWB Software Development Kit Utilities Guide*.
- A special cable for updating firmware used by the MC270141 MAC internal to the Evaluation Kit. This ByteBlaster^{TM} cable is manufactured by Altera Corporation. Note that this cable is supplied only to customers who have not received one previously from Motorola.

The minimum, and default, system configuration shipped by Motorola consists of two UWB transceivers. Additional transceivers can be purchased to form a multi-point configuration. Setup and use of such a configuration is covered in more detail in section 3.

Note: The expression “Wireless Developer Kit”, or WDK, refers to the complete set of hardware and software deliverables from Motorola. The expression “Software

Developer Kit", or SDK, specifically refers to the 802.15.3 SAPs and applications located in the directory ../XSUWBWDK-m.n.bxy/SDK.

2.2. User Supplied Items

- Two Linux PCs. If the transceiver will be used for PHY testing only, see section 2.2.1 for PC attributes. If the transceiver will decode and display streaming video, see section 2.2.2.
- Unencrypted video clips encoded in an MPEG-2 HD transport stream format.
- RF cables and associated test equipment with attributes as specified in Table 3.
- Two dual-male SMA barrels.
- The following items if MC270141 firmware internal to the Evaluation Kit will be upgraded:
  - A parallel port extension cable.
  - A PC running Windows XP, 2000, NT 4.0 or 98.

2.2.1. PC Attributes Used for PHY Testing Only

Minimal functionality is required if the transceiver will be used for PHY testing only. In this case a single PC can be used since it is only configuring a transceiver node and displaying statistics. The minimum hardware and software required are:

- 500 MHz CPU speed or faster.
- Linux Redhat 7.3 with 2.4.20-uwb or 2.4.20-XSI Kernels
- VGA-compatible video card and associated monitor with minimum resolution of 800X600.
- 128 Mbytes RAM minimum.
- A hard disk with 50 Mbytes free space on the C: drive.
- A CDROM drive.

2.2.2. PC Attributes Used for Streaming Video Display

Decoding and displaying streaming MPEG-2 video in real time places a heavy processing load on a PC and also requires a sophisticated video subsystem. If the WDK will be used for this purpose, each PC that decodes and displays video (and thus is connected to the destination transceiver) will require the following minimum hardware and software:

- 2.2 GHz CPU speed or faster.
- Linux Redhat 7.3 with 2.4.20-uwb or 2.4.20-XSI Kernels
- 256 Mbytes RAM minimum.
- A hard disk with 50 Mbytes free space on the C: drive.
- A CDROM drive.
- VGA-compatible video card and associated monitor with minimum resolution of 1024X768.
- A 1394 interface device permitting data transfer to/from an IEEE 1394 bus.
- Unencrypted video clips encoded in an MPEG-2 HD transport stream format.

Specific video subsystem requirements are dependent on the quality of the MPEG-2 transport-stream. To display a single MPEG-2 720 or 1180 HD-quality stream, a minimum of 128 Mbytes of high-performance video RAM on a 4x AGP2.0 interface is recommended. Motorola has used an nVidia Quadro2 700XGL graphics adapter in a Dell Precision Workstation 530 with good results.

2.3. Hardware Setup Procedure

1. Remove each UWB transceiver from its packing materials.
2. Place each transceiver so that it has a direct line of site to the other transceivers.
3. Remove the two antennas and associated semi-flexible coaxial cable for each Node from their packing.
4. Attach each antenna to its semi-flexible coaxial cable and connect said cable to one of the two RF connectors on the UWB transceiver housing.
5. Connect each AC transformer to an AC power socket providing the proper voltage and current as rated on the transformer. Plug the other end of the transformer into the receptacle on the transceiver housing.
6. Connect a Linux PC to the each Node via a 1394 cable.

3. Configuring Evaluation Kit Hardware

If you are receiving XSUWBWDK as an upgrade the firmware internal to the MC270141 MAC must be upgraded.

3.1. Updating MC270141 Firmware

An Altera programming application (Quartus II Web Edition) must be downloaded from the Altera Web site in order to update Evaluation Kit firmware. As discussed below, this application is usually located this file in the download section of the Alter Web site.

Note 1: The Altera programming software does not support automatic FPGA device detection so it is important that the correct firmware upgrade files be selected. Also, the versions listed above have been successfully used by Motorola personnel to update firmware. Later versions are also likely to work for this purpose.

To update WDK MAC firmware:

1. Connect the ByteBlaster cable to the parallel port of the PC and the 10 pin programming port of the radio. The red stripe on the cable indicates pin one, which corresponds to Pin 1 on programming connector on the radio board. Pin 1 is closest to the end of the radio where the power supply connector is.
2. Power on the UWB Node to be programmed.
3. Download the Altera Quartus II Web Edition software. It can be found on the Altera Web site (https://www.altera.com) by clicking the hyperlinks “download” and then “Quartus II Web Edition.”
4. Run the Altera Quartus II application on the Windows PC to which the ByteBlaster cable is attached. The Quartus version should be 2.1 or later.
5. A web license is available from www.altera.com. A license is not required for programming only. If no license is available do the following
   a. When prompted, Click on “specify valid license”
   b. Click OK
   c. Click cancel on the next dialog box

6. Respond `No` when prompted to create a new project.
7. Select Tools-> Programmer. A programming dialog box will appear.
8. Click the “Auto Detect” icon (third icon down on the vertical icon bar) on the programming dialog to cause Quartus II to query for Altera devices via JTAG.
9. Quartus II should find 2 devices and display them in the programming dialog. One will be an FPGA and the other will be an EPC16 configurator/Flash ROM. The EPC16/4/8 is used on both the 1106 and 1116 boards from Motorola/XtremeSpectrum. The PC board in a UWB Node is either an 1106 or an 1116.] The MC270141 device will be an EP1S40 on an 1116 board, or an EP20K1000C/E on an 1106 board. Note which FPGA device is present.
10. The File column for each device should say “<none>.”
11. Right click on the top listed Device (EP1S40 or EP20K1000C/E) to bring up a context menu and select the “Change File…” entry.
12. Browse to the directory where the desired .sof and .pof files are located. Select dummy file for the top (FPGA) device. The file name will be of the form dummy_xxxx.sof file where xxxx is the number of the radio board type (either 1106 or 1116).
13. The second device should be Device EPC16/4/8
14. Right click on the second device (EPC16/4/8) to display a context menu and select the “Change File…” entry.
15. Select one of two .pof files based on whether an EP20K1000C/E (1106 board in the UWB Node) or an EP1S40 (1116 board in the UWB Node) was listed in the programming dialog. For an EP20K1000C/E FPGA use the file named output_file_1000_tx.pof. For an EP1S40 FPGA, use the file named output_file_S40_tx.pof .
16. Click on the Program/configure check box for both devices
17. Click on the Verify box for the EPC16/4/8.
18. Click the “Start Programming” icon (top icon on the vertical bar).
19. The response should indicate success at the bottom of the screen.
20. The status of programming will be updated continuously at the bottom of the Quartus window. The programming process should take no longer than approximately three to four minutes. When it completes successfully the status will read `Programming Succeeded`. If programming fails, reboot the Windows PC and cycle power on the UWB Node then repeat steps 3 through 19.

Table 2: Summary of MC270141 Firmware Ugrade Files

Model XSUWBWDK Transceiver	
EPC16 Config File	**FPGA Config File**
dummy_1116.sof	output_file_S40_tx.pof

3.2. Updating Evaluation Kit EEPROMs

Each model XSUWBWDK Transceiver contains an EEPROM used to configure its 1394 interface and another EEPROM used during MC270141 bootup. Each of these is discussed briefly below.

3.2.1. 1394 Configuration EEPROM

The 1394 configuration EEPROM can be located using Figure 1. The label on this device should read "X100".

3.2.2. MAC Serial Boot EEPROM

This EEPROM is used each time the MC270141 MAC is reset or powered on. Its content is set at the factory. Its location can be determined using Figure 1.

4. Evaluation Kit Hardware Description

The Wireless Developer Kit (WDK) contains two UWB transceivers. Additional transceivers can be purchased to increase the size of a 802.15.3 piconet. Each node connects to a Linux PC for reporting of statistics, and is powered from an AC outlet via the supplied DC power supply. A logical block diagram of a transceiver is depicted in Figure 3.

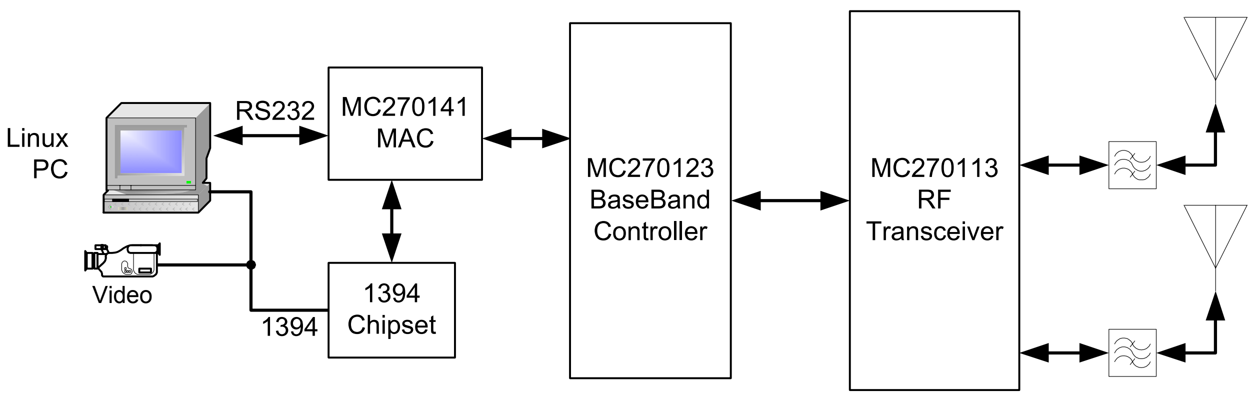

Figure 3: Wireless Developer Kit Logical Block Diagram

As can be seen in Figure 3, each transceiver contains three main subsystems as follows:

- A MAC subsystem.
- A PHY (physical layer) subsystem consisting of the XSI123 Base Band Controller and the XSI113 RF Transceiver components.
- Two antennas.

These subsystems are implemented on a single printed circuit. A summary describing interaction of these subsystems is provided here while each is described in slightly more detail below.

The MAC subsystem configures the PHY subsystem (Base Band Controller and RF-Transceiver) and implements an 802.15.3-like MAC layer. Included in this MAC layer are functions such as data buffering, framing and transfer, hardware retransmission, CRC generation or checking, etc. The MAC also collects performance metrics from the PHY subsystem and reports them to a host PC.

The PHY subsystem implements two RF processing channels, each called a finger. The presence of two fingers permits one channel to search for a stronger signal while the other receives data. The Base Band Controller in the PHY subsystem performs signal processing as well as forward error correction (FEC) in both receive and transmit modes. In receive mode it also acquires and tracks the incoming signal to extract correct bit values. The RF-Transceiver modulates or demodulates the UWB signal for each of the two fingers. It also supplies data and control signals to (transmit mode) or receives them from (receive mode) the Base Band Controller.

In the receive state, the RF Transceiver accepts the UWB signal from the antenna, filters and amplifies it, then extracts data and data and error (control) signals and supplies these to the XSI123 Base Band Controller for further processing.

UWB transceivers operate in one of three modes:

- Continuous transmit mode. A single header and one very long frame (one long payload) are sent in this mode. This mode is used only for FCC compliance testing.
- Bridge mode. In bridge mode the MAC transfers data or “bridges” between the 1394 bus and the radio link. Frames are sent by a source transceiver and acknowledged by a destination transceiver in this mode. This is the standard mode of operation. Frames in this context refer to Motorola radio frames.
- PERT mode. The PERT, or Packet Error Rate Test, mode is used for sending and receiving test frames and reporting associated statistics. This mode is used to measure the performance of a radio link. The MAC generates UWB radio frames that contain pseudo random data. The UWB frames is transmitted only once to a receiver and must be acknowledged. There are no frame retries. The receiver station validates the contents of the frame.

See the *Motorola UWB Software Development Kit Utilities Guide* for additional information about the software used to operate a UWB transceiver in one of these three modes.

4.1. MAC Subsystem Overview

The Motorola UWB transceiver contains an 802.15.3-like MAC implemented using an Altera FPGA, the MC270141. In addition to the MC270141, the MAC subsystem has flash ROM, SRAM, a serial boot EEPROM and a memory used to configure the MC270141 after every reset or power-on. Two serial ports are implemented on the MC270141 as is DMA and other control circuitry. The serial ports are brought to the external RS-232 connector that protrudes through the WDK enclosure.

As stated above, the MAC protocol built into the WDK is defined by the IEEE 802.15.3 standard, which is a TDMA (Time Division Multiple Access) based MAC. When the WDK is powered on, it remains quiet until the application enables the radio to “wake-up” because the user desires to communicate with another device. In wake-up mode, the radio listens and scans to see if there are other piconets that it might connect to. If none is found, it assumes the role of “piconet node controller” (PNC). In this role, it transmits a short coded-sequence synchronization signal (“beacon” – on the order of 0.5 millisecond) and then listens for a much longer period of time (on the order of 50 milliseconds) to effectively poll for other devices wanting to join the piconet. The PNC manages the piconet by accepting/authenticating devices into the piconet, assigning communication time slots to the various devices in the piconet, and by passing the role of PNC to another device, as appropriate. Therefore, each radio is only transmitting during: (1) it’s brief beacon period and (2) its communication time slot. A device in a piconet that does not have data to pass is not assigned a time slot, so it simply sleeps until the next beacon period. By virtue of this protocol, the requirements of Section 15.517(a)5 of the FCC Rules are met.

The configuration memory, an Altera EPC16, can be reloaded using the JTAG connector internal to the enclosure. Directions for doing so are provided in section 3.1.

In future versions of UWB transceivers the MC270141 will be replaced by a much smaller custom ASIC, or both the MAC and Baseband chips will be consolidated into a single chip.

An SDK is typically supplied with the WDK to permit configuration, control and statistics reporting. Sample applications that use the 802.15.3 API are included with the SDK.

The MAC subsystem implements a 1394 Firewire interface that is exposed on the outside of the enclosure as two 4-pin connectors. A single 1394 chipset is used to implement this external interface. Either PCs or consumer electronics devices can be connected to the 1394 interface on the UWB transceiver.

A single +5 VDC supply is used to power each UWB transceiver. An on-board DC-to-DC converter generates supply voltages from this input.

4.2. PHY Subsystem Overview

The physical layer is accomplished using two VLSI devices developed by XtremeSpectrum, the XSI123 Base Band Controller and the XSI113 RF Transceiver, plus a filter.

When receiving, the Base Band Controller provides analog-to-digital conversion of the demodulated signals. It converts the data and synchronization signals from the RF Transceiver to time correction values for each of the fingers. These time correction values are fed back to the RF Transceiver to cause the receiver to remain locked to the incoming data stream. The Base Band Controller also contains circuitry that implements channel equalization and FEC processing, and framing.

On transmit the Base Band Controller provides one-bit-wide transmitted data to the RF-Transceiver. This data is then encoded by the RF Transceiver before being sent to one of the antennas.

The RF Transceiver provides amplification, modulation, demodulation, and generation of a synchronized clock.. The XSI113 RF Transceiver connects to the antennas via a bandpass filter. The characteristics of the filter along with the waveform generated by the RF Transceiver guarantee compliance with the FCC emission limits, as long as the supplied antennas are used. The characteristic impedance of each antenna connection is 50 Ω.

4.3. Antenna

Each antenna is a printed circuit board. The antenna connects to the transceiver housing via semi-flexible coaxial cable. The frequency response function for this antenna as measured in an anechoic chamber is supplied on the distribution CDROM that accompanies each Wireless Evaluation Kit. The data graphed in Figure 4 is representative of the antenna’s response but should not be used for precise calculations.

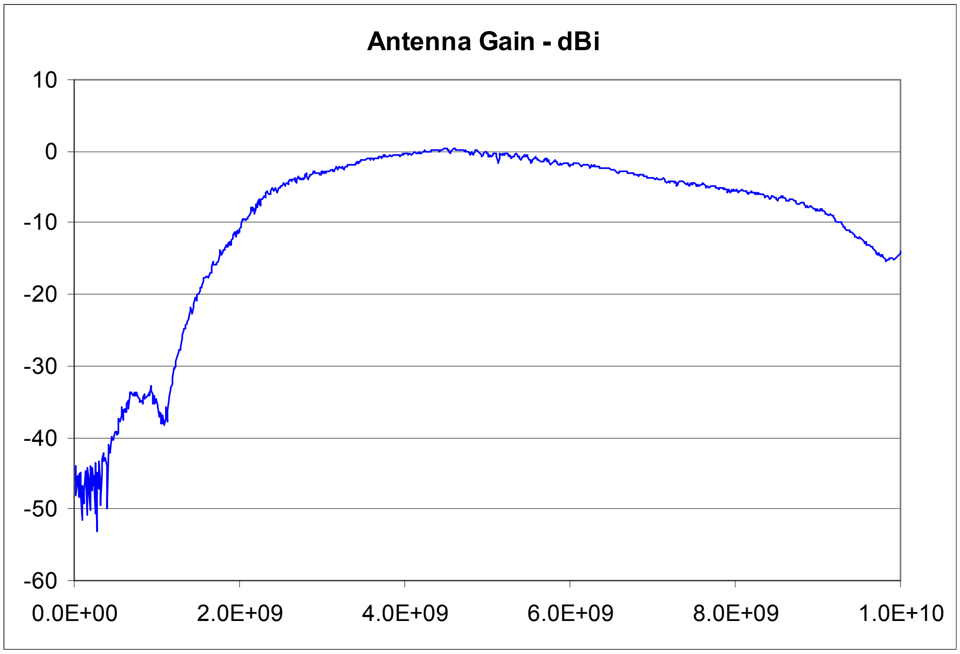

Figure 4: Antenna Gain Versus Frequency

Only FCC ApprovedmayThe WDK is FCC certification is valid only when the antennas supplied with the WDK antennas are used. The WDK is not FCC approved if any other antenna is attached.this product. If use of a different antenna is desired, MotorolaFreescale will assist in obtaining a new FCC certification to cover the attachment of the alternative antenna as commercially practicable.

4.4. Enclosure

The Evaluation Kit is housed in a milled aluminum box with two covers. The covers should always be installed during operation to prevent unwanted radiation through the air and to eliminate interference. Figure 1 depicts the layout of components inside the enclosure as well as the location of external connections.

5. PHY Evaluation Using the Wireless Developer Kit

5.1. Summary List of Test Hardware and Software Required

Table 3 summarizes the test equipment and associated devices (cables, terminators, etc.) that would typically be used to make RF and other measurements with the Evaluation Kit. The settings and connections for each are provided in more detail when each test is described. Equivalent devices can be used in place of those specified in the table if the substituted device has the same specifications.

For a list of firms from which test equipment can be rented or leased, see section 13.

Table 3: Summary List of Equipment for Motorola UWB RF Measurements

Quantity	Manufacturer and Model	Description	Tests Requiring This Equipment	Comment
8	Belden 1673J Coaxial Cable or equivalent	Coaxial cable length with SMA connectors attached. Cables must be low-loss and phase-stable. Use 3.5 mm SMA connectors.	Various	To connect Motorola Nodes to test equipment. Use same coax,equal length and identical connectors. Do not use to connect antennas.
4	Inmet 3016 or equivalent	1 Watt, 50 Ω terminator with SMA connector	Various	Flat frequency response to 12 GHz minimum, 18 GHz preferred.
2	Agilent 11667B or equivalent	DC to 26.5 GHz wideband power splitter, passive, 50 Ω impedance	Receiver Sensitivity Receiver Immunity	
2	Belden 1637A semi-flexible coaxial cable **OR** RG402 rigid coaxial cable	Coaxial cable length with SMA connectors attached.	Various	To connect Motorola Nodes to antennas. Use same coax,equal length and identical connectors.
2	Inmet 5020 **OR** Inmet 5044 or equivalent	Dual male SMA barrels, DC to 18 GHz	Scaled Range Versus Throughput	
2	Various	Linux PC with 1394 interface	All RF Tests and PC-Sourced 1394 Transmission & Reception	Sources and displays MPEG-2 HD data streams. Attributes specified in section 2.1.
2	Various	RS-232C Cables	Various	See section 2.1 for pinout.
2	Inmet 5009 or equivalent	Type "N" male to SMA female RF adapter, DC to 18GHz.	Various	
1	Tektronix SMT06 or equivalent **OR** Agilent 8665B or equivalent	5 kHz to 6 GHz Signal Generator	Receiver Sensitivity Receiver Immunity	Output power must be +12 dBm minimum.
1	Agilent 8494B Attenuator attached to Agilent 8495B Attenuator with Agilent 11716C Interconnect Kit or another equivalent manual attenuator.	Manual attenuator with both coarse (10 dB) and fine (1 dB) increments.	Receiver Sensitivity Receiver Immunity Penetration Scaled Range versus Throughput	Models specified have SMA connections. Attenuator with type "N" connectors may be more available in which case more type "N" male to SMA female adapters are needed.
1	Agilent E4418B power meter with Agilent 8481A Power Sensor attached	power meter and attached Power Sensor. 10 MHz – 18 GHz, 1 µWatt – 100 mW	Total Average Transmit Power	

Quantity	Manufacturer and Model	Description	Tests Requiring This Equipment	Comment
1	Inmet 18B-10 **OR** Inmet 18AH-10 **OR** Inmet 18DH-10 or equivalent	10 dB inline fixed attenuator	Receiver Sensitivity Receiver Immunity Penetration Scaled Range versus Throughput	
	Rohde & Schwarz FSU26 with FS-K3 noise figure software, FSU-B4 reference frequency and FSU-B25 Attenuator with preamplifier	20Hz-26.5 GHz Spectrum Analyzer with 50 MHz resolution bandwidth.	FCC Transmit Spectral Mask Compliance	50MHz resolution bandwidth required for a particular FCC compliance test. ** See notes 1 & 2 in section 5.4
	Rhode & Schwarz ESIB	20 Hz to 26 GHz EMI Receiver & Spectrum Analyzer	Alternative to FSU26 above	** See notes 1 & 2 in section 5.4
	Agilent 86100B Frame, with 54754 TDR-TDT Plug-in **or** Tektronix CSA8000 & 80E04 TDR Sampling Module	20 GHz dual channel digital sampling oscilloscope with dual channel TDR module	Peak to Average Transmit Power Ratio	A 20 GHz electrical plug-in can replace the TDR for the Peak to Average Transmit Power Ratio measurement.
1	Various	Four foot by eight foot sheet of ½ inch thick gypsum drywall.	Penetration	
1	Huber + Suhner 742-0-0-21 or equivalent	1.0 Newton-Meter torque wrench	Various	Can use a wrench rated for 8 inch-pounds.
	Various	MPEG-2 HD video source supplied via 1394 interface	Non-PC-Sourced 1394 Transmission & Reception	Isochronous packets only on channel 63. See Table 5.
	Various	Unencrypted MPEG-2 HD video clips.	PC-Sourced 1394 Transmission & Reception	

5.2. Equipment Handling

5.2.1. Attaching and Detaching SMA Connectors

The impedance characteristics of SMA connectors can degrade rapidly if they are not handled properly. Such degradation will almost certainly affect measured tests results. To ensure the accuracy of test results, follow these guidelines when attaching and detaching SMA connectors:

- Align center conductors carefully before mating connectors to prevent degradation.
- Never force a connection between two connectors that do not mate easily.
- Support cables or devices that are being connected to prevent lateral forces that can damage connectors.
- Regularly inspect connectors with a magnifying glass. Replace any that are damaged to prevent degradation of mating connectors. Damage may include: excessive thread wear or deformation, corrosion, misalignment, rounding off of edges, contamination or discoloration.
- Use a torque wrench (see Table 3) on the male side and a small open-ended wrench on the female side.
- Prevent rotation of SMA center conductors. Do this by holding the female stationary with an open-ended wrench while turning the hex nut on the male with a torque wrench while simultaneously preventing rotation of the cable attached to the male.

CAUTION: Turning the center conductor of an SMA female connector may permanently damage the connector and possibly invalidate any subsequent test results using it.

5.2.2. Avoiding Equipment Damage Due to Electrostatic Discharge

The center conductor of the Evaluation Kit's antenna input connects directly to a highly sensitive receiver circuit. As a result, avoid any static discharge into the antenna port since it can severely damage a UWB transceiver.

CAUTION: Take proper precautions to prevent electrostatic discharge while working with the WDK transceivers. All personnel working in or around the equipment should be properly grounded, as should all electronic or other equipment used during testing. Do not touch the antenna center conductor, particularly by wiping or brushing across it, as this may permanently damage internal circuitry.

5.2.3. Attaching the Antenna to a Transceiver

Use the a calibrated tourque wrench designed for SMA connectors when attaching the antenna to a transceiver and thereby decrease the likelihood of loosening the antenna when it is positioned during testing.

5.3. Guidelines for Running Tests

5.3.1. Order of Configuration and Test Command Execution

The order in which test and configuration commands are run can affect the accuracy of results. To ensure accurate results, follow the guidelines below:

- Always configure a UWB Node acting as a receiver before configuring a Node acting as a transmitter when running one of the tests specified below.

5.3.2. Statistics Display on a PC Connected to a Transceiver

The procedures in this section assume that a single Linux PC is connected to each transceiver. To decode and display streaming MPEG-2 video, follow the guidelines for PC selection in section 2.2.2.

5.4. Transmit Spectral Mask Compliance Test

Summary Description: This test nominally* confirms that Motorola UWB equipment complies with FCC spectral mask specifications and that the transmit power spectrum is within the limitations necessary to prevent interference with other frequencies. It has four components as follows:

- A wideband compliance test that checks the EIRP compliance of UWB emission between 960 MHz and 12 GHz. The power for each frequency band within this range is specified in paragraph (c) of section 15.517 of the CFR 47, Part 15 (Code of Federal Regulations. See section 12 for a full citation).
- A narrowband GPS interference test that considers the EIRP between 1164 – 1610 MHz. The power for each frequency band within this range is specified in paragraph (e) of section 15.517 of the CFR 47, Part 15.
- A peak to average power test that considers the peak emitted power per MHz over a 50 MHz resolution bandwidth about the center frequency in which a UWB device emits the greatest of power. The specification of this test can be found in paragraph (f) of section 15.517 of the CFR 47, Part 15.
- Adjustment of the above measurements for the antenna gain*.

During this test the UWB transceiver sends a continuous bit stream in unframed mode. In other words, a single, very long frame is sent containing only one header and one payload.

Prerequisites:

- None.

Connection Diagram

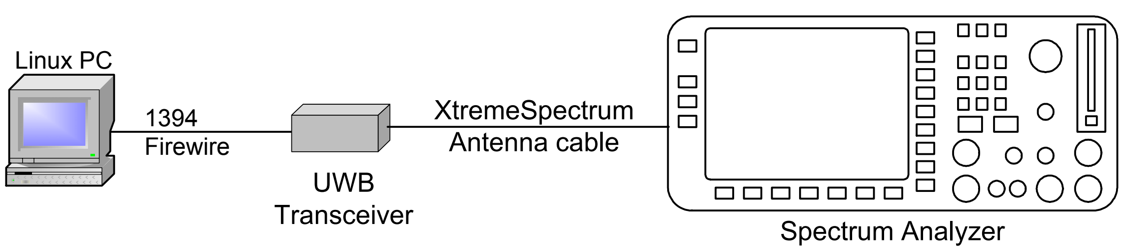

Figure 5: Equipment Setup for Transmit Spectral Mask Compliance Test

* Note that a measurement through wire and then adjusting for the antenna gain is not accepted by the FCC, which requires open air tests that includes all antenna effects. Since open-air tests require an outdoor test site and are far more time consuming and difficult, the approach outlined here is meant to provide a nominal indication of compliance that can be done quickly in a lab environment.

Test Procedure:

1. Set up equipment as indicated in Figure 5. Follow the guidelines in section 5.2.1 when making or breaking RF connections.
2. Turn on all test equipment and allow it to warm up for the length of time specified by the manufacturer.
3. Verify that the UWB transceiver is powered on.
4. Open a command window on the Linux PC.
5. Use the `cd` command as necessary on the Linux PC to move to the directory containing the `mode` application supplied with the Motorola SDK.
6. Run the following command in the Linux PC command window opened as explained above:

   ```
   ./mode BT
   ```

   See the *Motorola UWB Software Development Kit Utilities Guide* for definitions of the parameters used with the `mode` command.
7. While determining transceiver RF power output levels in steps 9 through 17 below, note the frequency of the highest RF output power. This frequency is called f_c and will be used later in this procedure.
8. Set the spectrum analyzer as follows:
   a. Measurement type: RF Power in dBm
   b. Sweep range: 900 MHz to 1700 MHz
   c. Sweep points: 10001
   d. Resolution bandwidth: 1 MHz
   e. Video bandwidth: Auto
   f. Detector selection: RMS
   g. Input attenuation: 0
   h. Markers: 960 MHz and 1610 MHz
   i. Input coupling: AC
   j. Trigger source: internal, free running
9. Note the RF power output of the transceiver between the two marked frequencies (960 MHz and 1610 MHz) and verify that it is below the –75.3 dBm ceiling specified in paragraph (c) of section 15.517 of the CFR 47, Part 15.
10. Change the spectrum analyzer settings as follows:
    a. Sweep range: 1500 MHz to 2100 MHz
    b. Markers: 1610 MHz and 1990 MHz
11. Note the RF power output of the transceiver between the two marked frequencies (1610 MHz and 1990 MHz) and verify that it is below the –53.3 dBm ceiling specified in paragraph (c) of section 15.517 of the CFR 47, Part 15.
12. Change the spectrum analyzer settings as follows:
    a. Sweep range: 1800 MHz to 3200 MHz
    b. Markers: 1990 MHz and 3100 MHz
13. Note the RF power output of the transceiver between the two marked frequencies (1990 MHz and 3100 MHz) and verify that it is below the –51.3 dBm ceiling specified in paragraph (c) of section 15.517 of the FCC CFR 47, Part 15.

14. Change the spectrum analyzer settings as follows:
    a. Sweep range: 3000 MHz to 11000 MHz
    b. Markers: 3100 MHz and 10600 MHz
15. Note the RF power output of the transceiver between the two marked frequencies (3100 MHz and 10600 MHz) and verify that it is below the –41.3 dBm ceiling specified in paragraph (c) of section 15.517 of the FCC CFR 47, Part 15. The transmit spectrum should be below -51.3 dBm above 4.9 GHz.
16. Change the spectrum analyzer settings as follows:
    a. Sweep range: 10000 MHz to 12000 MHz
    b. Markers: 10600 MHz
17. Note the RF power output of the transceiver above the marked frequency (10600 MHz) and verify that it is below the –51.3 dBm ceiling specified in paragraph (c) of section 15.517 of the FCC CFR 47, Part 15.
18. Change the spectrum analyzer settings as follows:
    a. Sweep range: 1164 MHz to 1169.067 MHz
    b. Resolution bandwidth setting: 1 kHz

Note 1: A digital spectrum analyzer such as the FSU26 measures RF power contained in a frequency span specified with the resolution bandwidth value. A digital spectrum analyzer takes this measurement by determining the power at many discrete points (called sweep points) between start and stop frequencies (the sweep span). The instrument divides the sweep span into a number of slices one resolution bandwidth wide, measures the power in each slice and plots the result. Note that sections of the sweep span will be missed (i.e. have no data points) if the sweep range divided by the number of sweep points exceeds the resolution bandwidth. The plot of resulting measured values would be meaningless. To prevent generation of such meaningless results, the measurements made in steps 18 through 23 of this procedure must be broken into sweep points that are about 4/10ths of a resolution bandwidth. For example, in the GPS band, the 1164 MHz to 1240 MHz span (sweep span = 76 MHz), 15 separate measurements (5.0667 MHz per measurement with 10001 points means 507 Hz per point) are made to provide approximately two data points per resolution bandwidth slice. For the 1559 MHz through 1610 MHz span (sweep span = 51 MHz), 10 separate measurements (5.1 MHz per measurement with 10001 points means 510 Hz per point) are made to provide approximately two data points per resolution bandwidth slice.

Note-2: An alternative to the FSU-26 is the ESIB which is designed to automatically make certified accurate EMI measurements. With general purpose analyzers, there is no guarantee the results are accurate -- it can be difficult to get known accurate results due to the flexibility and interaction of the various sweep parameters that are all under user control. The ESIB forces the steps of .4*RBW to insure that highly accurate results are obtained and no spectral peak is lost. It also has the following advantages:

(1) Built in transducer tables as well as a calibrated low-noise (9 dB NF) preamp, and multiple detectors including an RMS detector. These allow accurate measurements of the low signal levels in open-air tests because it allows a real-time display that is calibrated for all antenna and cabling effects. The real-time display allows frequencies and peak-levels at

different angles to the DUT to be identified as positioners are rotated and stopped at a peak-emission angle.

(2) The tests in the GPS bands require 1 kHz RBW resulting in 400 Hz steps covering 76 MHz (190k points) in one band and 51 MHz (127k points) in the other. The ESIB allows 250k points in a band, which allows each GPS band to be measured with a single sweep, significantly reducing the workload and time required to take document these measurements. The capture time is very important because even with the ESIB, it takes about 2 hours for each polarization (4 hours per UWB-code), and there are several codes that must be measured. – In addition to the raw speed, the ESIB can be configured to do this test easily on the front panel. So there is no need for a special script.

(3) 10 MHz RBW is built in, allowing somewhat better characterization of peak levels than the 1 or 3 MHz limit in many other instruments. While the FSU-26 was originally chosen because it had a 50 MHz RBW, it does not accurately measure peak and RMS levels at 50 MHz RBW due to the way it processes the signal (it uses a pulse stretching approach beyond a 10 MHz RBW). So the FSU-26 is only good to 10 MHz, and lacks all the other benefits of the ESIB.

19. Note the RF power output of the transceiver in the sweep range and verify that it is below the –85.3 dBm ceiling specified in paragraph (e) of section 15.517 of the CFR 47, Part 15.
20. Repeat steps 18 and 19 for each of the other 14 sweep ranges between 1169.067 MHz and 1240 MHz (each range is 5.0667 MHz wide). Setup files for the FSU26 and trace files are supplied for each of these ranges on the WDK distribution CDROM.
21. Change the spectrum analyzer settings as follows:
    a. Sweep range: 1559 MHz to 1564.1 MHz
    b. Resolution bandwidth setting: 1 kHz
22. Note the RF power output of the transceiver in the sweep range and verify that it is below the –85.3 dBm ceiling specified in paragraph (e) of section 15.517 of the CFR 47, Part 15.
23. Repeat steps 21 and 22 for each of the other 9 sweep ranges between 1564.1 MHz and 1610 MHz (each range is 5.1 MHz wide). Setup files for the FSU26 and trace files are supplied for each of these ranges on the WDK distribution CDROM.
24. Change the spectrum analyzer settings as follows:
    a. Sweep range: 500 MHz on either side of the frequency, f_c, with the highest output power as found in steps 9 through 17.
    b. Markers: 250 MHz above f_c and 250 MHz below f_c
    c. Resolution bandwidth setting: 50 MHz
25. Note the RF power output of the transceiver between the two marked frequencies (250 MHz above f_c and 250 MHz below f_c) and verify that it is below the 0 dBm ceiling specified in paragraph (f) of section 15.517 of the CFR 47, Part 15.
26. Correct all measured results using the Motorola antenna frequency response data on the CDROM supplied with the WDK.

Expected Results:
Contact the Motorola factory if the results of this test are not approximately those indicated in the text above.

5.5. Total Average Transmit Power Test

Summary Description: This test determines the total average transmitted RF power across the entire frequency band from a Motorola UWB transceiver. Note that this measurement is NOT conducted in the same fashion as that used for determining FCC UWB spectral mask compliance (see section 5.3.2), nor does it yield the same result. The average transmitted RF power, together with the receive sensitivity value, can help with link budget estimations and with determination of the useful range of UWB radios. The transceiver is run in continuous, unframed transmit mode during this test.

Prerequisites:

- Run the Transmit Spectral Mask Compliance Test (see section 5.3.2), if you have not already done so, before starting this test.

Connection Diagram

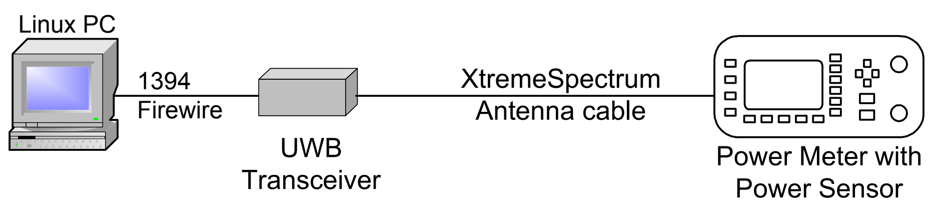

Figure 6: Equipment Setup for the Total Average Transmit Power Test

Test Procedure:

1. Set up equipment as indicated in Figure 6. Follow the guidelines in section 5.2.1 when making or breaking RF connections.
2. Turn on all test equipment and allow it to warm up for the length of time specified by the manufacturer.
3. Set the power meter measurement range to 0 dBm.
4. Verify that the transceiver is powered on.
5. Open a command window on the Linux PC.
6. Use the `cd` command as necessary on the Linux PC to move to the directory containing the `mode` application supplied with the Motorola SDK.
7. Run the following command in the Linux PC command window opened as explained above:

   ```
   ./mode BT
   ```

   See the *Motorola UWB Software Development Kit Utilities Guide* for definitions of the parameters used with the `mode` command.
8. Disconnect the power meter, run its zero calibration procedure, then reconnect it.

9. Note the reading on the power meter. It should be approximately -10 to -8 dBm. Save this value as it will also be used for computing the Peak to Average Transmit Power ratio as described in section 5.6.

Expected Results:
The power meter reading should be between -10 and – 8dBm.

5.6. Peak Envelope Power Test

Summary Description: This test computes the peak envelope power (PEP) of a transceiver. The peak-to-peak amplitude of the transceiver output is measured in this procedure then the PEP is determined using the equation below. This is a wired test that uses a 20 GHz bandwidth sampling oscilloscope with a time domain reflectometer plug-in. The transceiver is run in continuous, unframed transmit mode during this test. This test has no relationship to the FCC's narrow bandwidth peak test.

Note: Peak envelope power is a standard term used to measure transmitter power. It is defined as the emitted power averaged over the RF cycle having the greatest amplitude during a transmission. In other words, it is the power that a continuous sine wave would deliver to the load if the peak amplitude of that sine wave matched that of the largest RF cycle that ever occurs during a transmission.

Prerequisites:

- Run the Transmit Spectral Mask Compliance Test (see section 5.3.2) and Total Average Transmit Power Test (see section 5.5), if you have not already done so, before starting this test.

Connection Diagram

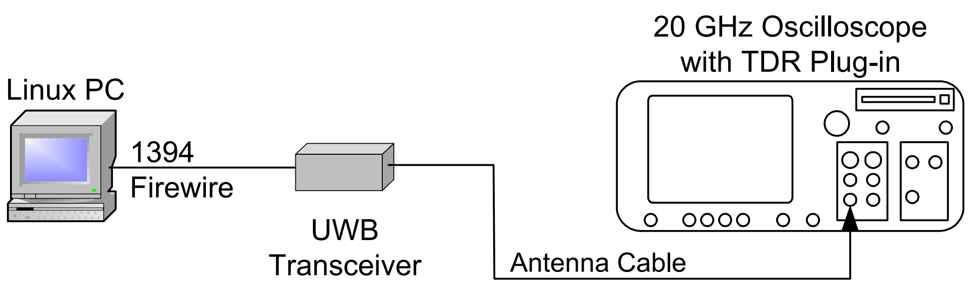

Figure 7: Equipment Setup for the Peak Envelope Power Test

Test Procedure

1. Set up equipment as indicated in Figure 7. Follow the guidelines in section 5.2.1 when making or breaking RF connections.
2. Turn on all test equipment and allow it to warm up for the length of time specified by the manufacturer.
3. Verify that the transceiver is powered on.
4. Open a command window on the Linux PC.

5. Use the `cd` command as necessary on the Linux PC to move to the directory containing the `mode` application supplied with the Motorola SDK.
6. Run the following command in the Linux PC command window opened as explained above:

   ```
   ./mode BT
   ```

   See the *Motorola UWB Software Development Kit Utilities Guide* for definitions of the parameters used with the `mode` command.
7. Set the oscilloscope electrical plug-in as follows:
   a. Time base: 1 nsec per division.
   b. Vertical scale: 100 mV per division.
   c. Trigger: free running.
   d. Persistence: 5 seconds.
   e. TDR Module Stimulus: off.
   f. Markers: Set to permit reading minimum and maximum voltage to permit computation of peak to peak amplitude.
8. Read the peak-to-peak voltage of the transmitter output signal on the oscilloscope. It should be approximately 300 mV.
9. Compute the peak envelope power out of the transceiver using the formula: $P_t = \frac{V_{pp}^2}{400}$

   where:

   P_t is the peak envelope power emitted by the transceiver in Watts (i.e. the power dissipated in a 50Ω load by a sine wave with peak to peak amplitude V_{pp}).

   V_{pp} is the peak-to-peak amplitude in Volts at the antenna terminals.

   Note: The equation above represents peak envelope power (PEP). It is derived from the expression $\frac{E^2}{R}$, where E is the voltage and R is the load impedance. Computing this involves summing the power in a single cycle (integrating from zero to one) using the following peak envelope power (PEP) expression: $\frac{1}{50}\int_0^1 \left(\frac{V_{pp}}{2}\sin 2\pi t\right)^2 dt$.

Expected Results
The peak-to-peak voltage should be approximately 300 mV.

5.7. Receiver Sensitivity and Scaled Ranged Versus Throughput Test

Summary Description: This test determines the sensitivity of the UWB receiver by measuring the minimum signal detected for frame error rates (FER) of 1%, 5% and 10%. Together the transmit power and Rx sensitivity values are useful in determining the link budget of a UWB subsystem. Both UWB transceivers are run in continuous, framed mode during this test.

In addition, this test has two other purposes. First, it determines the throughput (bits per second of payload) from UWB transmitter to UWB receiver for various FEC and raw channel rate settings in a line of sight (LOS) environment using a range of scaled antenna separation distances as simulated with a manual attenuator. This test also measures the effect on FER of various channel rate and FEC settings. Sample measurements are provided.

Prerequisites:

- Run the Transmit Spectral Mask Compliance Test see (section 5.3.2), if you have not already done so, before starting this test.

Connection Diagram

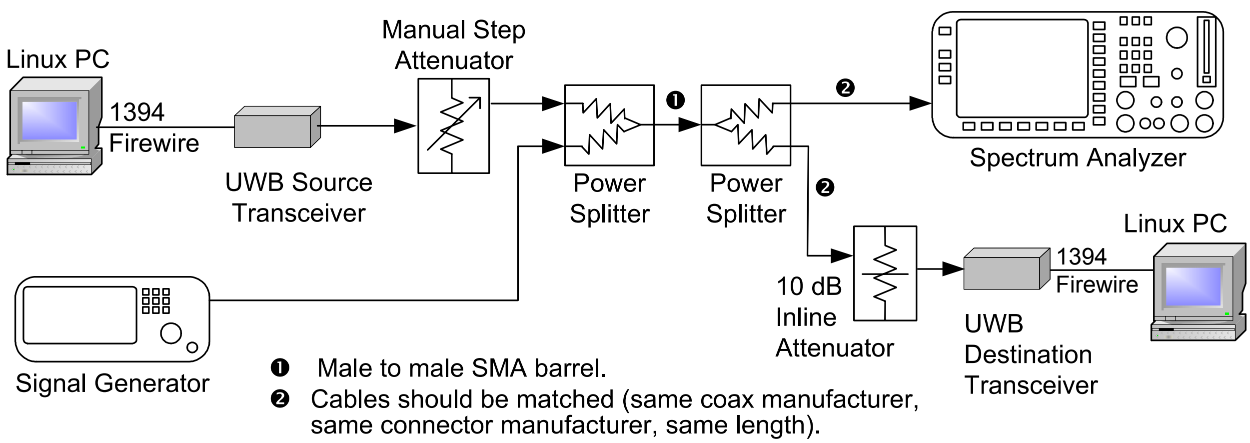

Figure 8: Setup for the Receiver Sensitivity, Scaled Range Versus Throughput and Receiver Immunity Tests

Test Procedure:

1. Set up equipment as indicated in Figure 8. Follow the guidelines in section 5.2.1 when making or breaking RF connections.
2. Turn on all test equipment except the signal generator and allow it to warm up for the length of time specified by the manufacturer.
3. Verify that the signal generator is off. It will not be used in this test.
4. Set the manual attenuator to 20 dB.
5. Set the spectrum analyzer as follows:
   a. Measurement type: RF Power in dBm
   b. Sweep range: 500 MHz on either side of the frequency, f_c, with the highest output power as found in steps 9 through 17 of the Transmit Spectral Mask Test described in section 5.3.2.
   c. Markers: 250 MHz above f_c and 250 MHz below f_c
   d. Resolution bandwidth setting: 50 MHz
   e. Detector selection: RMS
   f. Video bandwidth: Auto

g. Input attenuation: 0
h. Input coupling: AC
i. Trigger source: internal, free running

6. Verify that both UWB transceivers are powered on.
7. Open a command window on each of the Linux PCs depicted in Figure 8.
8. Use the `cd` command as necessary on each Linux PC to move to the directory containing the `mode` application supplied with the Motorola SDK.
9. Run the following commands on the Linux PC connected to the UWB destination transceiver:

```
./config 1 114 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

See the *Motorola UWB Software Development Kit Utilities Guide* for definitions of the parameters used with the `mode`, `config` and `stats` commands. Be sure to replace the parameter `MACAddress` with the proper value for the destination transceiver.

10. Run the following commands on the Linux PC connected to the UWB source transceiver (replace the `MACAddress` parameter with the proper value for the source transceiver):

```
./config 1 114 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

11. Verify that the FER reported at the destination transceiver is approximately 2%.
12. Adjust the manual attenuator setting (i.e. change the signal reaching the destination transceiver) until an FER of 10% ($1X10^{-1}$) is reached as reported by the statistics.
13. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 114 Mbps raw channel rate and a FEC rate of 1.
14. Repeat steps 12 and 13 for an FER value of 2% ($2X10^{-2}$). This lower FER value will be achieved by decreasing the loss in the manual attenuator.
15. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 114 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

16. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 114 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

17. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.

18. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 114 Mbps raw channel rate and a FEC rate of ¾.
19. Repeat steps 17 and 18 for an FER value of 2% ($2X10^{-2}$). This lower FER value will be achieved by decreasing the loss in the manual attenuator.
20. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 114 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

21. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 114 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

22. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
23. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 114 Mbps raw channel rate and a FEC rate of ½.
24. Repeat steps 22 and 23 for an FER value of 2% ($2X10^{-2}$).
25. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 1 57 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

26. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following command in a Linux terminal window on the same PC:

```
./mode B
./config 1 57 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

27. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
28. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 57 Mbps raw channel rate and a FEC rate of 1.
29. Repeat steps 27 and 28 for an FER value of 2% ($2X10^{-2}$).

30. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 57 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

31. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 57 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

32. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
33. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 57 Mbps raw channel rate and a FEC rate of ¾.
34. Repeat steps 32 and 33 for an FER value of 2% ($2X10^{-2}$).
35. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 57 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

36. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 57 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

37. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported at the destination transceiver.
38. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 57 Mbps raw channel rate and a FEC rate of ½.
39. Repeat steps 37 and 38 for an FER value of 2% ($2X10^{-2}$).
40. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 1 28.5 NONE 16k 0
```



```
./mode PR
./stats FRAM MACAddress
```

41. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 1 28.5 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

42. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
43. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 28.5 Mbps raw channel rate and a FEC rate of 1.
44. Repeat steps 42 and 43 for an FER value of 2% ($2X10^{-2}$).
45. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 28.5 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

46. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 28.5 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

47. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
48. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 28.5 Mbps raw channel rate and a FEC rate of ¾.
49. Repeat steps 47 and 48 for an FER value of 2% ($2X10^{-2}$).
50. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 28.5 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

51. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 28.5 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

52. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
53. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 28.5 Mbps raw channel rate and a FEC rate of ½.
54. Repeat steps 52 and 53 for an FER value of 2% ($2X10^{-2}$).
55. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 1 114 HIGH 16k 0
./mode PR
./stats FRAM MACAddress
```

56. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 1 114 HIGH 16k 0
./mode PT
./stats FRAM MACAddress
```

57. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
58. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 28.5 Mbps signal acquisition rate, 114 Mbps raw channel rate, FEC rate of 1 and a high SNR setting.
59. Repeat steps 57 and 58 for an FER value of 2% ($2X10^{-2}$).
60. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 114 HIGH 16k 0
./mode PR
./stats FRAM MACAddress
```

61. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.75 114 HIGH 16k 0
./mode PT
./stats FRAM MACAddress
```

62. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
63. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 28.5 Mbps signal acquisition rate, 114 Mbps raw channel rate, FEC rate of ¾ and a high SNR setting.
64. Repeat steps 62 and 63 for an FER value of 2% ($2X10^{-2}$).
65. Terminate the `stats` command running on the Linux machine connected to the destination UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 114 HIGH 16k 0
./mode PR
./stats FRAM MACAddress
```

66. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following commands in a Linux terminal window on the same PC:

```
./mode B
./config 0.5 114 HIGH 16k 0
./mode PT
./stats FRAM MACAddress
```

67. Adjust the manual attenuator setting until an FER of 10% ($1X10^{-1}$) is reached as reported on the destination transceiver.
68. Record the power on the spectrum analyzer at f_c in the dBm/MHz column associated with a 10% FER, 28.5 Mbps signal acquisition rate, 114 Mbps raw channel rate, FEC rate of ½ and a high SNR setting.
69. Repeat steps 67 and 68 for an FER value of 2% ($2X10^{-2}$).

Manual attenuator setting versus distance values were based on one of the following two free space equations:

$$P_r = \frac{P_t G_t A_e}{4\pi R^2}$$

OR

$$E_r = \frac{\sqrt{30 P_t G_t}}{R}$$

where:

P_r is the power seen at the receiver input in Watts/MHz.

P_t is the power emitted by the transmitter in Watts/MHz.

G_t is the gain of the transmitting antenna in (1 = isotropic).

A_e is the effective aperture area of the receiving antenna in square meters.

R is the distance between the transmitting antenna and the receiving antenna in meters.

E_r is the electric field at the receiving antenna in volts per meter at range R.

5.8. Receiver Immunity Test

Summary Description: This test determines the tolerance of the MOTOROLA UWB implementation to other RF technologies (IEEE 802.11b, IEEE 802.11a, cell phones, Microwave ovens etc.) using the same frequency bands. It uses the same setup as the Receiver Sensitivity test. This is a wired test that uses a power splitter and injects tones of various frequencies from a signal generator into the UWB receiver input then measures the power level of the interfering signal.

During this test the source transceiver operates in framed mode. In other words, numerous UWB frames, each with a header and payload, are sent.

Prerequisites:

- Run the Transmit Spectral Mask Compliance Test (see section 5.3.2) and Receiver Sensitivity Test (see section 5.6), if you have not already done so, before starting this test.

Connection Diagram

- Use the setup specified in Figure 8.

Test Procedure

1. Set up equipment as indicated in Figure 8. Follow the guidelines in section 5.2.1 when making or breaking RF connections.
2. Turn on all test equipment except the signal generator and allow it to warm up for the length of time specified by the manufacturer.
3. Verify that the signal generator is off or set it to no output.
4. Set the manual attenuator to 20 dB.
5. Set the spectrum analyzer as follows:
   a. Measurement type: RF Power in dBm
   b. Sweep range: 800 MHz to 1000 MHz.
   c. Marker: 900 MHz
   d. Resolution bandwidth setting: 1 MHz
   e. Detector selection: RMS
   f. Video bandwidth: Auto
   g. Input attenuation: 0
   h. Input coupling: AC
   i. Trigger source: internal, free running
6. Verify that both the source transceiver and the destination transceiver are powered on.
7. Open a command window on each of the Linux PCs depicted in Figure 8.

8. Use the `cd` command as necessary on each Linux PC to move to the directory containing the `mode` application supplied with the Motorola SDK.
9. Run the following commands on the Linux PC connected to the UWB destination transceiver:

   ```
   ./mode B
   ./config 1 114 NONE 16k 0
   ./mode PR
   ./stats FRAM MACAddress
   ```

   See the *Motorola UWB Software Development Kit Utilities Guide* for definitions of the parameters used with the `mode` , `config` and `stats` commands. Be sure to replace the parameter `MACAddress` with the proper value for the destination transceiver.
10. Run the following commands on the Linux PC connected to the UWB source transceiver (replace the `MACAddress` parameter with the proper value for the source transceiver):

    ```
    ./mode B
    ./config 1 114 NONE 16k 0
    ./mode PT
    ./stats FRAM MACAddress
    ```

11. Adjust the manual attenuator so that the FER reported on the destination transceiver is 2%.
12. Note the RF power reading on the spectrum analyzer at the marker frequency and correct it for the insertion loss of the manual step attenuator and the two power splitters (approximately 14 dB for the splitters). This RF power is the output level for the source transceiver at the interfering frequency.
13. Change the spectrum analyzer settings as follows:
    a. Sweep range: 1800 MHz to 2000 MHz
    b. Marker: 1900 MHz
14. Note the RF power reading on the spectrum analyzer at the marker frequency and correct it as discussed in step 12. This is the output level for the source transceiver at the interfering frequency.
15. Change the spectrum analyzer settings as follows:
    a. Sweep range: 2300 MHz to 2500 MHz
    b. Marker: 2400 MHz
16. Note the RF power reading on the spectrum analyzer at the marker frequency and correct it as discussed in step 12. This is the output level for the source transceiver at the interfering frequency.
17. Change the spectrum analyzer settings as follows:
    a. Sweep range: 2800 MHz to3000 MHz
    b. Marker: 2900 MHz
18. Note the RF power reading on the spectrum analyzer at the marker frequency and correct it as discussed in step 12. This is the output level for the source transceiver at the interfering frequency.
19. Change the spectrum analyzer settings as follows:
    a. Sweep range: 5300 MHz to 5500 MHz

   b. Marker: 5400 MHz
20. Note the RF power reading on the spectrum analyzer at the marker frequency and correct it as discussed in step 12. This is the output level for the source transceiver at the interfering frequency.
21. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following command on the PC connected to the source transceiver:
    ```
    ./mode B
    ```
22. Turn on the signal generator and wait for it to warm up the length of time specified by the manufacturer.
23. Change the spectrum analyzer settings as follows:
    a. Sweep range: 800 MHz to1000 MHz
    b. Marker: 900 MHz
24. Set the signal generator as follows:
    a. Frequency: 900 MHz
    b. Output level: -100 dBm (or the minimum for the instrument)
    c. Sweep: Off
    d. Modulation: None
    e. Pulse generation: Off
25. Run the following commands on the Linux PC connected to the UWB source transceiver:
    ```
    ./mode B
    ./config 1 114 NONE 16k 0
    ./mode PT
    ./stats FRAM MACAddress
    ```
26. Increase the output level on the signal generator until an FER of 10% ($1X10^{-1}$) is reported on the destination transceiver.
27. Terminate the `stats` command running on the Linux machine connected to the source UWB transceiver. Then run the following command on the PC connected to the source transceiver:
    ```
    ./mode B
    ```
28. Note the RF power reading on the spectrum analyzer at the marker frequency and correct it for the insertion loss of the two power splitters (approximately 14 dB) and the fixed in-line attenuator (10 dB). This is the output level for an interfering source at the frequency specified on the signal generator that is required to change the error rate from 2% to 10%.
29. Change the signal generator settings as follows:
    a. Frequency: 1900 MHz
    b. Output level: -100 dBm (or the minimum for the instrument)
30. Change the spectrum analyzer settings as follows:
    a. Sweep range: 1800 MHz to 2000 MHz
    b. Marker: 1900 MHz
31. Repeat steps 25 through 30 for this new interfering frequency (1900 MHz).
32. Change the signal generator settings as follows:

   a. Frequency: 2400 MHz
   b. Output level: -100 dBm (or the minimum for the instrument)
33. Change the spectrum analyzer settings as follows:
   a. Sweep range: 2300 MHz to 2500 MHz
   b. Marker: 2400 MHz
34. Repeat steps 25 through 30 for this new interfering frequency (2400 MHz).
35. Change the signal generator settings as follows:
   a. Frequency: 2900 MHz
   b. Output level: -100 dBm (or the minimum for the instrument)
36. Change the spectrum analyzer settings as follows:
   a. Sweep range: 2800 MHz to 3000 MHz
   b. Marker: 2900 MHz
37. Repeat steps 25 through 30 for this new interfering frequency (2900 MHz).
38. Change the signal generator settings as follows:
   a. Frequency: 5400 MHz
   b. Output level: -100 dBm (or the minimum for the instrument)
39. Change the spectrum analyzer settings as follows:
   a. Sweep range: 5300 MHz to 5500 MHz
   b. Marker: 5400 MHz
40. Repeat steps 25 through 30 for this new interfering frequency (5400 MHz).

Table 4: Transmit Frequencies of Common Devices in the UWB Frequency Range

Frequency Range	Source	Comment
900 MHz	Cell phone/Cordless phone	
1900 MHz	Cell phone	
2400 MHz	Cordless phone, microwave oven, 802.11b, 802.11g	
2900 MHz	Weather radar	
5400 MHz	Uniband 802.11a	

Expected Results

5.9. Minimum Antenna Separation Test

Summary Description: This test determines the effect on FER of subjecting the Motorola UWB receiver to a very strong input signal. Perform this test by moving the source transceiver antenna close to the destination transceiver antenna until a desired FER level is achieved. Then measure the physical separation of these two antennas.

During this test the source transceiver operates in framed mode. In other words, numerous UWB frames, each with a header and payload, are sent.

Prerequisites:

- Run the Transmit Spectral Mask Compliance Test (see section 5.3.2) and Receiver Sensitivity Test (see section 5.6), if you have not already done so, before starting this test.

Connection Diagram

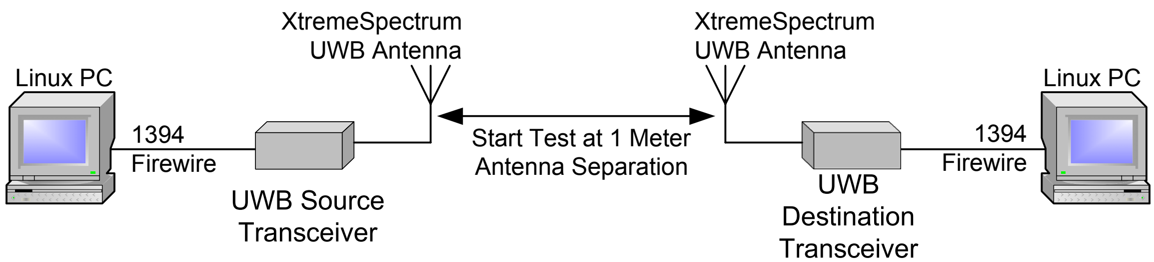

Figure 9: Setup for Minimum Antenna Separation Test

Test Procedure

1. Set up equipment as indicated in Figure 9. Follow the guidelines in section 5.2.1 when making or breaking RF connections.
2. Verify that both the source transceiver and the destination transceiver are powered on.
3. Open a command window on each of the Linux PCs depicted in Figure 9.
4. Use the `cd` command as necessary on each Linux PC to move to the directory containing the `mode` application supplied with the Motorola SDK.
5. Run the following commands on the Linux PC connected to the UWB destination transceiver:

```
./mode B
./config 1 114 NONE 16k 0
./mode PR
./stats FRAM MACAddress
```

   See the *Motorola UWB Software Development Kit Utilities Guide* for definitions of the parameters used with the `mode` , `config` and `stats` commands. Be sure to replace the parameter `MACAddress` with the proper value for the destination transceiver.
6. Run the following commands on the Linux PC connected to the UWB source transceiver (replace the `MACAddress` parameter with the proper value for the source transceiver):

```
./mode B
./config 1 114 NONE 16k 0
./mode PT
./stats FRAM MACAddress
```

7. Note the FER reported on the PC connected to the destination transceiver. It should be approximately.
8. Gradually move the UWB source transceiver closer to the destination transceiver (or vice versa) while noting the FER.

Expected Results
The Motorola UWB platform is not sensitive to a strong signal source, so antenna separation has no effect on the frame error rate experienced.

5.10. Penetration Test

Summary Description: This test introduces a single piece of ½" gypsum drywall between the transmit and receive antennas. As a result it simulates transmission through an interior wall.

During this test the source transceiver operates in framed mode. In other words, numerous UWB frames, each with a header and payload, are sent.

Prerequisites:

- Run the Total Average Transmit Power Test (see section 5.5).

Connection Diagram

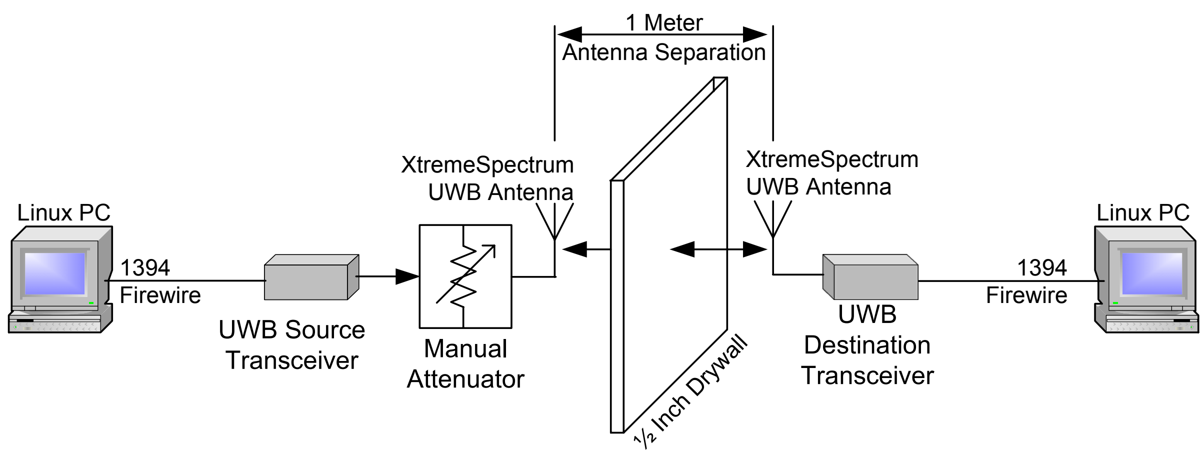

Figure 10: Setup for Penetration Test

Test Procedure

1. Set up equipment as indicated in Figure 10. Follow the guidelines in section 5.2.1 when making or breaking RF connections.
2. Make measurements that simulate the environment in which the final product will be operated. No specific procedure steps are provided here due to the wide variety of possible setups and associated results.

5.11. Video Transmission and Reception

Summary Description: This setup demonstrates the ability of the Motorola UWB implementation to transfer one or more video data streams from a source transceiver to one or more destination transceivers. Video data is input to the source transceiver via an IEEE 1394-compatible input port. Each destination transceiver has its 1394 port connected to a 1394 enabled television, PC, or camcorder display.

Connection Diagram

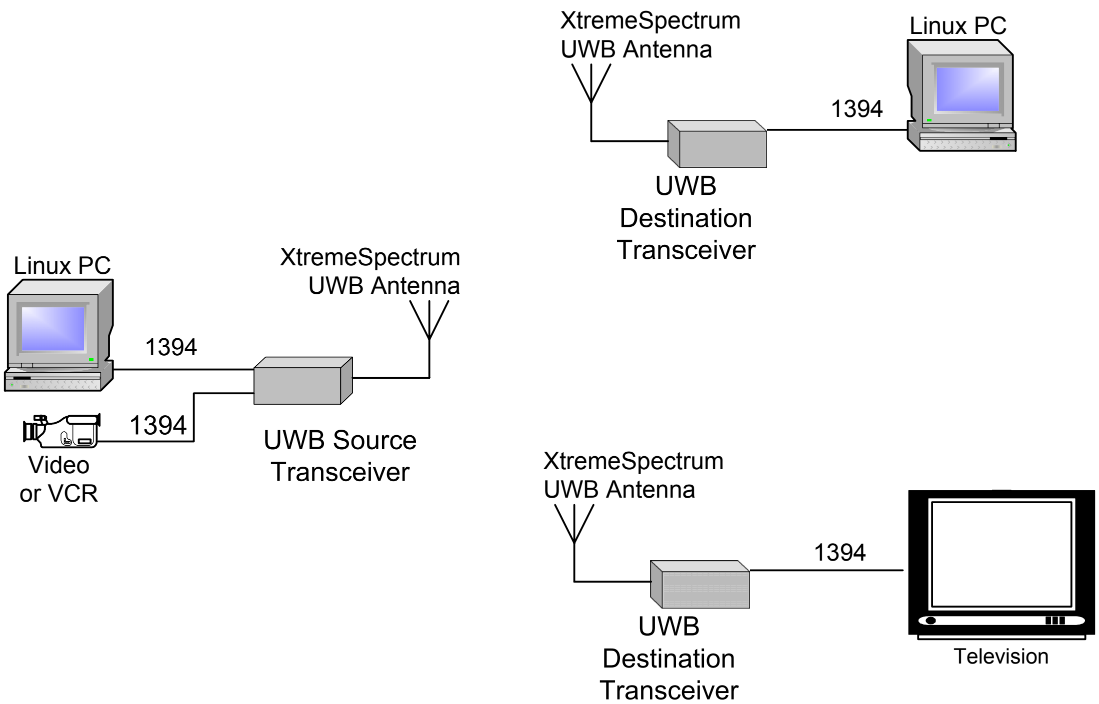

Figure 11: Setup for Video Transmission

Test Procedure

1. Set up equipment as indicated in Figure 11. Follow the guidelines in section 5.2.1 when making or breaking RF connections. When connecting a device that either sources or displays MPEG-2 data via the 1394 bus (i.e. the camera icon in Figure 11), be sure to use one of the devices listed in Table 5.
2. Verify that all transceivers are powered on.
3. Setup a piconet using the `dme` command described in the *Motorola UWB Software Development Kit Utilities Guide*.
4. Reset all transceivers.
5. At the source transceiver run the following command in a terminal window:
   `./dme join 0:2:3:4:5:6:7:8 56000`
   Since this is the first transceiver to join the piconet it becomes PNC.
6. At one of the destination transceivers run the following command in a terminal window to cause a transceiver to join the piconet as DEV 1:
   `./dme join 1:2:3:4:5:6:7:8 56000`
7. At the other destination transceiver run the following command in a terminal window to cause a transceiver to join the piconet as DEV 2:
   `./dme join 2:2:3:4:5:6:7:8 56000`
8. At the source transceiver run the following command in a terminal window to allocate a stream to DEV 1:
   `./dme allocate_stream 1:2:3:4:5:6:7:8 1 31`

9. At the source transceiver run the following command in a terminal window to allocate a stream to DEV 2:
   ```
   ./dme allocate_stream 2:2:3:4:5:6:7:8 2 31
   ```
10. At the source transceiver run the following command in a terminal window to map a stream to DEV 1:
   ```
   ./dme map_send_stream 1 163 0 63 50 15000 -1
   ```
11. At the source transceiver run the following command in a terminal window to map a stream to DEV 2:
   ```
   ./dme map_send_stream 2 162 0 62 50 15000 -1
   ```
12. At destination transceiver, DEV 1, run the following command in a terminal window to map its receive stream:
   ```
   ./dme map_receive_stream 163 0 63 250000 1
   ```
13. At destination transceiver, DEV 2, run the following command in a terminal window to map its receive stream:
   ```
   ./dme map_receive_stream 162 0 62 250000 1
   ```

Start the device(s) that will transmit an MPEG-2 stream via 1394 to the source transceiver (depicted on the right side of Figure 11) so that it begins to transmit. For the figure above, the camcorder or VCR will transmit on 1394 channel 63 by default. On the Linux PC open a terminal window and use the sendfile command to read an HD file from the hard disk and send it to the transceiver over the 1394 port.

```
./sendfile 62 filename 1 3
```

6. Operating Conditions and Characteristics

6.1. AC Power Consumption

The Evaluation Kit is supplied with an AC transformer that requires 100-240VAC as input and draws 1.2 Amps.

6.2. Temperature Range and Humidity Conditions

The Evaluation Kit is meant to be operated between +10 degrees C and +35 degrees C ambient air temperature under non-condensing humidity conditions.

6.3. IEEE 1394 Modes Supported

The transceivers support transfer of isochronous and asynchronous data. 1394 bus enumeration is not supported. Only the devices listed in Table 5 have been tested and found to operate with the Evaluation Kit.

Table 5: Consumer Electronics Devices that Operate with Motorola UWB Transceivers

Manufacturer	Model Number & Description	Comment
Sony Electronics	DCR-IP5 Camcorder	
JVC	HM-DH30000U VCR	http://www.jvc.com/product.jsp?modelId=MODL026758
JVC	HM-DH40000U VCR	http://www.jvc.com/product.jsp?modelId=MODL027070

Manufacturer	Model Number & Description	Comment
Samsung	LTN226W 22 inch HDTV LCD and S1R-T165 HDTV Tuner	http://www.samsungusa.com/SamsungUSA/PRODUCT/20030603/sirts165.pdf http://www.samsungusa.com/SamsungUSA/PRODUCT/20030924/ltn226w.pdf
Pioneer	PDP-4340HD 43 inch HDTV Plasma TV with Media Receiver	http://www.pioneerelectronics.com/pna/product/detail/0,,2076_4123_17600334,00.html
JVC	GR-HD1US High Definition Camcorder	This supersedes the model JY-HD10u HD Camcorder.
Mitsubishi	WS-55511 55 inch HDTV Rear Projection System	http://www.mitsubishi-tv.com/55511title.jpg
Sharp	Aquos LC-22AD1 22 inch HDTV LCD	http://www.sharp.co.jp/products/lc22ad1

7. Support

For additional support related to this device or document, please contact your local Motorola sales office or the Motorola XtremeSpectrum UWB operation at:

Email: uwbsupport@xtremespectrum.com
Fax: (703) 749-0248

8. FCC Compliance Statement

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment radiates radio frequency energy and therefore has the potential, though it is unlikely to cause harmful interference to other electronic devices. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to eliminate the interference by one or more of the following measures:

- Reorient or relocate the antennas of either the device being interfered with or this equipment.
- Increase the separation between the device being interfered with and this equipment.
- Connect the equipment into an outlet on a circuit different from that to which the device being interfered with is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate this equipment legally under the FCC rules. The software provided will not allow the device to operate differently or with emissions that are higher than what was approved in the FCC certification process.

Declaration of Conformity

NOTE: This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

9. License Agreement

The Motorola XSUWBWDK Wireless Development Kit is provided on loan for use in the United States of America for the purpose of engineering evaluation only. It shall at all times remain the property of Motorola and shall not be conveyed by the customer receiving it directly from XtremeSpectrum, Inc. to any other individual, company or third-party outside said original customer without the express written consent of Motorola.

10. Warranty Disclaimer

The Motorola XSUWBWDK Wireless Development Kit is supplied in as-is condition for the purpose of engineering evaluation only. It is not a commercial product nor is it meant to be used as one.

Motorola makes no warranty, either express or implied, with regard to the operational characteristics, merchantability or fitness for a particular purpose of said Wireless Evaluation Kit, including but not limited to its hardware, software, physical components.

11. Glossary

Table 6: Definitions for Terms, Abbreviations and Acronyms Used

Term, Abbreviation or Acronym	Definition
Bit Error Rate	The number of received bits that are in error divided by the total number of bits received, including those in error.
BER	See Bit Error Rate.
bridge mode	A mode in which the MAC transfers data or “bridges” between the 1394 bus and the air link.
CFR 47, Part 15	Code of Federal Regulations 47, Part 15. Describes FCC rules for devices that emit Ultra-Wideband signals.
continuous mode	A transceiver mode in which a single header and single, long payload are transmitted. It applies only to a transmitter; a UWB Node is never placed into continuous receive mode. This mode is only used for FCC compliance testing as discussed in section 5.
destination transceiver	An Evaluation Kit Transceiver that has been configured so that it can receive frames from a source transceiver and display statistics associated with them.
DEV	A UWB Node in a piconet that is not acting as a PNC.
EIRP	Effective Isotropic Radiated Power
FEC	See Forward Error Correction.
FER	See Frame Error Rate.
Forward Error Correction	Redundancy built into a data stream being transmitted over lossy media such as through the atmosphere to reduce end-to-end error rates by enhancing e. The transceiver implements FEC with soft-decision convolutional encoding and Viterbi decoding.
Frame Error Rate	The number of received frames that have either a header check sequence (HCS) error or a frame check sequence (FCS) error divided by the total number of frames received, including those in error.

Term, Abbreviation or Acronym	Definition
framed mode	A transceiver mode in which data is formatted into a continuous stream of frames, each with a header and payload, that are transmitted or received.
GPS	Global Positioning System
HD	High Density.
Mbps	Millions of bits per second.
MPEG-2 HD	An MPEG-2 high density image.
MPEG-2 SD	An MPEG-2 standard density image.
PERT	Packet error rate test.
PERT mode	A mode in which the MAC sends and receives test frames and reports associated statistics.
PNC	Piconet coordinator. This node in a piconet allocates bandwidth for all piconet traffic and sends out beacon frames to all other nodes the provide a time reference and specify transmit times for all DEVs requesting bandwidth.
radio frame	A proprietary data structure containing a header and payload that is used to package transferred data. The default frame size is 16320 bytes.
SDK	Motorola UWB Software Development Kit. This is a collection of utilities and applications used to configure, control and move data to and from Motorola UWB Nodes.
source transceiver	An Evaluation Kit Transceiver that has been configured so that it can transmit frames to a destination transceiver and display statistics associated with them.
UWB	An acronym for ultra wideband.
UWB frame	See radio frame.
UWB Node	A station capable of transmitting and receiving UWB frames.
UWB transceiver	A station capable of transmitting and receiving UWB frames.
WDK	Wireless Development Kit. This consists of two WEKs and associated components such as antennas, cables, etc. as well as an SDK.
WEK	Wireless Evaluation Kit. A single UWB Node.
Wireless Development Kit	
Wireless Evaluation Kit	A UWB Node. See the *WDK Hardware Guide* for additional information about model and part numbers.
wired test	An RF test in which a source transceiver is connected to a destination transceiver with cables. No antennas are used. Test equipment may also be used in such a configuration.

12. References

Code of Federal Regulations

- CFR 47, Part 15 Subpart F – Ultra Wideband Operation

Motorola Documentation

- *Motorola UWB Software Development Kit Utilities Guide*
- *XtremeSpectrum Software Development Kit Programmer's Guide*

IEEE 802.15.3 Standard

- IEEE Standard for Information Technology – 802.15.3 Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs). IEEE Std 802.15.3-2003.

13. Appendix A – Sources for Leasing of Test Equipment

The companies below rent the types of test equipment specified in Table 3. The availability of particular instruments will vary, so check directly with each supplier. The leasing cost per month is typically the equipment's list price divided by twelve.

CIT Technologies Corporation
Phone: (800) 874-7123
http://www.trsonesource.com/trs/default.asp

Continental Resources, Inc.
Phone: (800) 937-4688
http://www.conres.com/tm/T&M.html

Electro Rent Corporation
Phone: (800) 688-1111
http://www.electrorent.com/

Metric Equipment Sales
Phone: (800) 432-3424
http://www.metrictest.com

RenTelco
Phone: (800) 233-5807
http://www.rentelco.com

Telogy, Inc.
Phone: (800) 835-6494
http://www.tecentral.com/

TestEquity Inc.
Phone: (800) 732-3457
http://www.testequity.com