

User Manual

for the Signal Generator/Tag

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- 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.
- This device may only be operated indoors. Operation outdoors is in violation of 47 U.S.C. 301 and could subject the operator to serious legal penalties.
- FCC ID: NUF -200SGT-0702
- Please consult with Time Domain Corp. if you have any questions, prior to use.

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1

Overview

The Signal Generator/ Tag (SG/T) is a transmit-only radio, with two distinct roles in the PulsON 200™ equipment family. The SG/T can be used for evaluation and propagation testing, or as an early-version tracking tag when used in conjunction with the Evaluation Kit radios. This application-specific development platform uses the PulsON 200 Timer chip as its core technology, and provides a robust UWB signal and data packet stream.

This equipment has been designed to be operated either alone, or with other Signal Generators for test scenarios. The Signal Generator/Tag (SG/T) is a hardware tool that sends out UWB signals for testing the signal strength and distance the PulsON signal propagates in an environment, and how well it coexists with other wireless devices. The SG/T can be used with laboratory equipment such as oscilloscopes and spectrum analyzers, with a wired trigger switch, to perform a variety of test procedures.

Paired with with Evaluation Kit radios, the SG/T will have the capability to be used as a tag. In this application, the SG/T can be configured as an element in a ranging and positioning system. It can be utilized as a mobile radio transmitter sending low data rate transmissions to be captured and analyzed by the receiving radio. Using special algorithms, Evaluation Kit radios can be configured to determine the SG/T's location. This use of the SG/T as a tracking tag will be described in an application note which accompanies the Evaluation Kit. In addition, the user will be able to attach a sensor via the RS-232 port, and transmit user-defined sensor data to the Evaluation Kit radio.

The SG/T consists of a radio frequency (RF) board, a digital board, a housing, and an antenna assembly. The RF board uses the same raw board as the PulsON 200 Evaluation Kit radio, but the receiver components are eliminated for this application. The digital board contains the PulsON 200 Timer chip and a Field Programmable Gate Array (FPGA) containing the logic for timer control, interface control, memory load, sleep mode, and data transformation.

Other components of the Signal Generator/Tag assembly include the BroadSpec™ Model P200 antenna assembly, a power supply, an additional antenna to be connected to a receiving oscilloscope or a spectrum analyzer, and a diskette containing application software.

System capabilities will be incrementally provided through the PulsON Technology Program website.



6 Chapter 1: Overview

Detailed applications of the Signal Generator/Tag are listed in Chap. 4: *Taking Measurements*, and Chapter 5: *Evaluating the Data*.

2 Getting Started


Unpacking & Initial Setup

In the process of getting started, we suggest you check the shipping contents and load the PC software to interface with the Signal Generator/Tag (SG/T). The items in Table 2.1 are supplied in your shipment.

Qty.	Name	Part #
1	PulsON 200™ Signal Generator/Tag	100-0011
1	Broadspec™ Model P200 Antenna, tag	200-0052
1	Broadspec Model P200 Antenna , receive-only	200-0053
1	Power Supply, 90-264 VAC in/7.5 VDC Out	024-0003
1	Power Cord	017-0029
1	Software CD	150-0008
1	User Manual CD	P200-320-0030

Table 2.1: Supplied items in the Signal Generator/Tag kit

1. Using a Phillips-head screwdriver, attach the Broadspec™ Model P200 antenna to the antenna bracket on the rear of the unit.
2. Connect the antenna cable to the SMA port labeled **Antenna Out**. The antenna is omni-directional. Once connected, do not adjust the antenna orientation as it may overstress the attached cable through unnecessary bending. Use of another antenna element other than the one provided in the kit is a violation of FCC rules governing the transmission of UWB signals.

 Ensure that the SMA cable connector nut is firmly tightened over the connection to avoid accidental disconnection. Do NOT overtighten. Seven to ten inch-pounds torque using an approved connector wrench (Huber & Suhner, part number 74Z0-0-21 or equivalent) is recommended. The connector center pins on the SMA cables are fragile. If you meet resistance when connecting a cable to a port, either during insertion or when tightening the connector nut, do not force the connection. Abort this attempt and try again. Damage to the SMA connector caused by over-tightening is not covered by the warranty.

3. Ensure that the **Event/Cont** toggle switch is set to **Event**. In its default state as shipped by Time Domain, the **Event/Cont** toggle switch acts as an Off/On switch when the SG/T is disconnected from a PC. In this state **Event** equals the Off function. This is true only if no periodic event has been programmed from the PC. Once a periodic event has been programmed by the user, selecting **Event** will start that sequence.

4. Apply power to the unit using the supplied power adapter.
5. Move the **Event/Cont** toggle switch to **Cont**. The LED labeled **C** lights, indicating your SG/T has power. When LEDs **A** and **B** illuminate, the pulser and timer are enabled (i.e. transmitting). In most cases this means it is transmitting on the manufacturer's default mode or the mode selected by the user through the software. See the System Checkout section of this chapter for a definitive operational test.

If your unit passes this simple test, you are ready to install the software on your PC and run the system checkout procedures. If you wish to operate your unit in the default mode, you may begin running the sample measurements found in Chapter 3: *Taking Measurements*.

If the unit fails to show the lighted LED sequence above, contact Time Domain Customer Support.

Installing Signal Generator Software

System checkout requires that you connect your unit to a PC running the Signal Generator/Tag (SG/T) software. To install and run the SG/T software you will need a computer running Microsoft® Windows NT® or Windows 2000®. No tests on other versions of Windows have been conducted.

1. Insert the supplied CD into your PC and access your CD drive. Access the CD using the **Run** function. Install the SG/T software by double-clicking over the Setup.exe icon and following the installation directions.
2. Attach an RS-232 cable between your PC and the SG/T port labeled **RS232**.
3. With power applied to the SG/T, double-click the SG/T icon on your PC Desktop. The SG/T interface appears. For a more detailed description of the software operation, see Chapter 3: *Operating the Signal Generator/Tag*.
4. If you see an **ID** number along with accompanying **Firmware #** and **Firmware Date** information appear in the **Tag Information** section of the software control screen, the software is successfully communicating with the SG/T unit.

If the software fails to connect with SG/T unit, check that the serial cable is the correct type and is connected. The correct cable is a standard nine-pin serial cable without crossover. Check also that the appropriate comms port is selected. The comms port can be selected from the SG/T software, See Chap. 3: *Operating the Signal Generator/Tag*. If the software does not connect with the unit, contact Time Domain Customer Support.

System Checkout

If the Signal Generator/Tag (SG/T) unit has powered up successfully, then you are ready to perform a checkout of the system to make sure it is transmitting. There are two methods of checking out the system:

Checkout Using A Spectrum Analyzer

The simplest way to test the SG/T is using a spectrum analyzer capable of measuring from 900 MHz up to 6 GHz in frequency. The test consists of measuring ambient spectrum with the SG/T off. This reading will be compared to the spectrum display with the SG/T broadcasting continuously with the antennas on the SG/T and the analyzer held in close proximity.

1. Hook the Broadspec™ receive-only antenna provided in the kit to the spectrum analyzer via a low-loss cable with SMA connectors. The 200-0053 antenna has a standard SMA connector that will *not* fit on the **Antenna Out** connector on the SG/T. Attempts to connect the unlike connectors may damage them.
2. Position the equipment so that the flat faces of the transmit antenna from the SG/T and the receive antenna attached to the spectrum analyzer can be placed within 2 cm. of each other.

3. Set the display on the spectrum analyzer for a span of 2 to 6 GHz. If your analyzer cannot display this great a span at once, make sure that it centers around 3.5 GHz. Lower the attenuation to 10 dB.
4. Set the resolution bandwidth to 3 MHz. The following discussion assumes a 3 MHz RBW.
5. Set a marker at 3.5 GHz.
6. With the SG/T powered down, or with the **Event/Cont** switch in the Event position (no LEDs lit or blinking), measure the ambient spectrum using the receive-only antenna. The spectrum should show a relatively flat line of power around -65 dBm at 3.5 GHz. (Figure 2.1).



If you have used the host PC to configure the SG/T, disconnect the serial communications cable prior to the test to eliminate the possibility of spurious emissions distorting measurements.

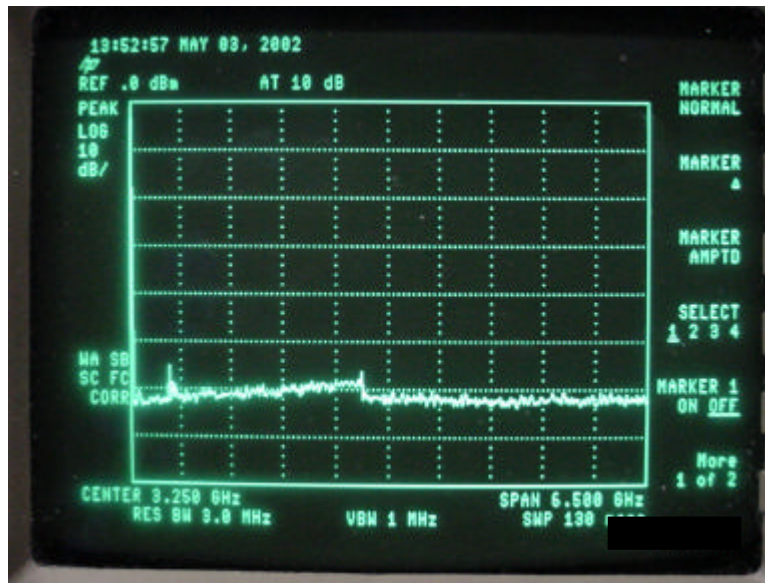


Fig. 2.1: Typical spectrum (centered at 3.5 GHz) without Signal Generator emissions

7. Power up the SG/T and switch the **Event/Cont.** switch to **Cont.** Hold the spectrum analyzer's receive only antenna within 2 cm. of the SG/T antenna. The two antennas should be held with flat faces parallel to each other and with the same orientation. With the spectrum analyzer on the same settings as before, you should notice a distinct, hump-shaped rise in the spectral power profile centered around 3.5 GHz as shown in Figure 2.2, or peaked at approximately -50dBm.

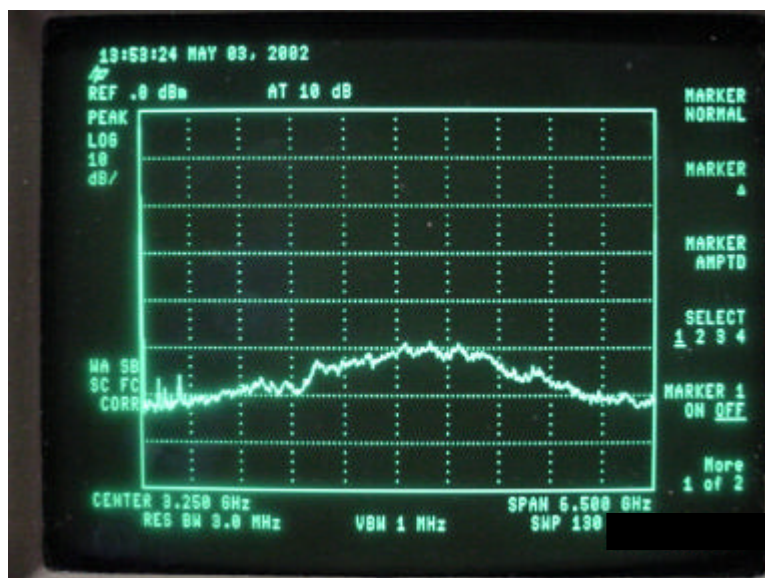


Fig. 2.2: Spectrum profile with Signal Generator operating through antennas

If you see a similar profile difference described in this procedure, your SG/T is operating and ready for use. If the spectral response before and after powering on the SG/T remains flat or the same, then the SG/T is not sending a signal. If the unit fails checkout contact Time Domain Customer Support.

Checkout Using A Digital Sampling Oscilloscope (DSO)

This method involves hooking up a DSO in the method described in Chapter 4: *Taking Measurements*. The required parts, equipment specifications and recommended equipment model numbers are identified in that chapter. The SG/T can be operated without hooking it to a host PC. If the settings have not been changed by the user, it will operate in a *Time Shift Continuous* mode. Using the settings described in the Chapter 4 test sections, the DSO can test the unit in either cabled or antenna-to-antenna configuraton.

3 Operating the Signal Generator/Tag

The Signal Generator/Tag (SG/T) is set up for operation and controlled by software running on a host PC computer and communicating with the SG/T via a serial cable. Once configured using the host software, the SG/T can operate without being attached to the host PC, in the configuration set and initialized prior to disconnecting.

The software is designed to give the operator total control of the SG/T. It will override any hardware settings (i.e. the **Event/Cont.** switch) while connected. When the user disconnects or exits the software, the hardware settings will be in effect.

At present, the SG/T 's transmissions are only intended for analysis by sampling lab instruments. With the release of the PulsON® Evaluation Kit radio, users will be able to send and receive data payloads and scan ramps for use in ranging/positioning tasks. Software upgrades will be available on the PulsON® Technology ProgramsSM website.

Connecting the Host PC to the Signal Generator/Tag

The software should be loaded and communications tested in accord with the procedures in Chapter 2, *Getting Started*.



Always connect the host PC's serial cable to the SG/T before starting the host software. Always close the software and allow the PC to update the SG/T before disconnecting the serial cable from the SG/T.

The software automatically establish communications and uploads Tag Information, Real-Time Clock, Transmission mode and Configuration settings. The software gives an error message if the cable connection is not established and brings up the **Communications** dialog box (Fig. 3.1) to allow you to select an alternate com port. The serial port to the SG/T can be set in the Communications settings function accessed through the **Edit** drop down menu in the main host software screen.

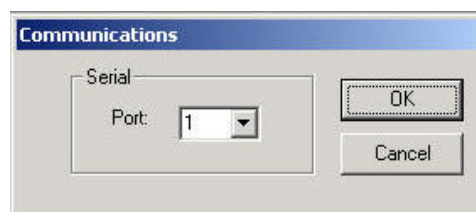


Fig. 3.1: Communication port control screen

Software Controls

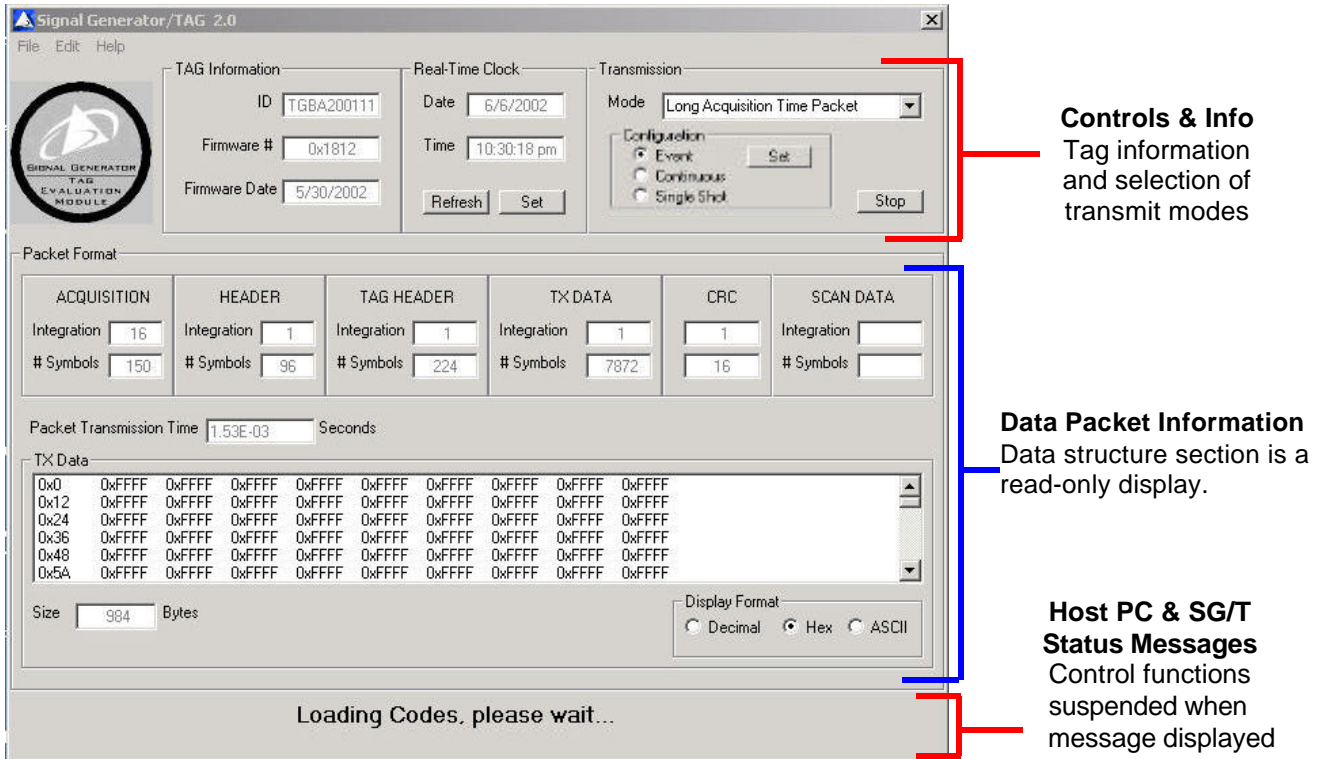


Fig. 3.2: The main Signal Generator/Tag controller software screen with active control, packet information-only functions and communications messages identified.

Tag Information Section

The information in this section of the main software screen is updated from settings in the Signal Generator/Tag (Fig. 3.3). The information is taken from the current firmware load and is read-only.



Fig. 3.3: Tag Information readout

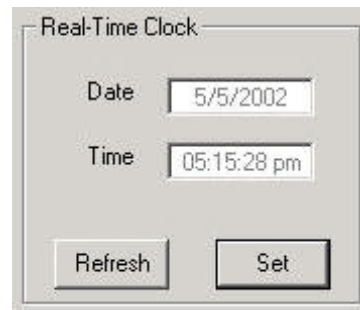


Fig. 3.4: Real Time Clock readout and controls

Real Time Clock

The Real Time Clock (Fig. 3.4) display reads the date and time of the internal clock in the Signal Generator/Tag. The readout on the software panel does not update automatically. Pressing the **Refresh** button updates the host PC software with the SG/T's Real-Time Clock's internal date and time.

To set the SG/T's internal Real-Time Clock, select the **TAG Clock** option on the **Edit** drop down menu, or click on the **Set** button on the **Real-Time Clock** section of the main screen. This will activate the **TAG Clock** screen (Fig. 3.5). Time zone, time, date and day information can be set by entering numbers and selecting from the drop down menus. This information will be downloaded to set the Real Time Clock in the SG/T unit only after the **OK** button is clicked.

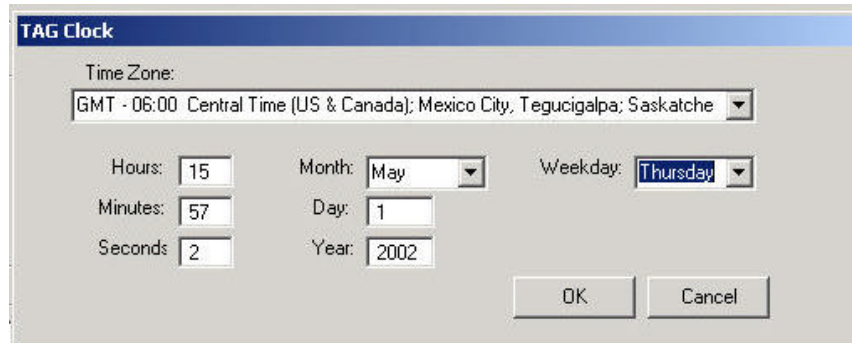


Fig. 3.5: Setting the Real Time Clock from the TAG Clock screen

Controlling the Type & Frequency of Transmissions

The SG/T will operate as a stand-alone device that will transmit packets for capture and analysis by laboratory instruments. There are two types of basic controls for the operator to set up these transmissions. You can select what *type* of transmission to make by selecting one of nine different packet types called **Modes**. In some cases the content of the packets and aspects affecting how they are transmitted can be set by the user. Others of these packets are preconstructed with content for specific purposes.

You can also select *how often* a chosen packet is transmitted by using **Configuration** controls to select the transmission period. Your transmission period choices range from a single transmission of one packet through variable periodic transmitting to continuously sending the same packet.

Those transmit modes and periods are selected by the **Transmission** section of the host Signal Generator GUI. (Fig. 3.6).

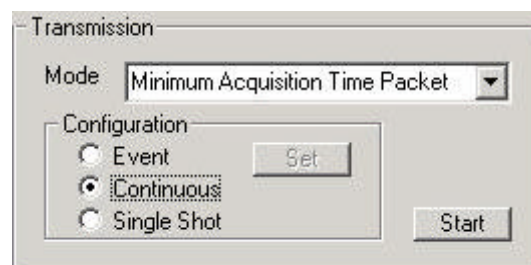


Fig. 3.6: The Transmission control panel used to select the transmission Mode.

Transmission Modes

Test Modes

The first five modes listed in the software, Time Shift Continuous, Acquisition, Minimum, Medium, and Long Acquisition Time Packet are representative modes for various transmission scenarios. In the software, these five modes are also referred to as “Test Modes.” These modes are useful for propagation and spectral studies. Refer to the Test Measurements section of this manual for more information on taking these measurements. Note that these modes are not intended to be received and demodulated by a P200 Evaluation Kit radio.

These modes are selected from the **Mode** dropdown menu in the **Transmission** panel:

Time Shift Continuous

This signal is an unmodulated pulse train where the individual pulses are positioned within a 104 ns frame according to a pseudorandom code.

Acquisition

This packet component consists only of acquisition symbols and integrations. No other information is included in the packet. It would be the header component of any packet transmitted.

Minimum Acquisition Time Packet

The type of signal used for a fused application of PLT and communications in a low multipath environment where acquisition and lock can be achieved rapidly. The pre-programmed data packet is 2000 bytes long and cannot be edited by the software operator.

Medium Acquisition Time Packet

The type of signal for a fused application in a moderate multipath environment. The pre-programmed data payload is 984 bytes long and cannot be edited by the software operator.

Long Acquisition Time Packet

The type of signal for a fused application in a high multipath environment. The pre-programmed data packet is 984 bytes long and cannot be edited by the software operator.

TAG Modes

The other four modes, TAG ID Only, TAG ID + Data, TAG ID + Scan Ramps, and TAG ID + Data + Scan Ramps can be received and demodulated by a P200 Evaluation Kit radio. They can be used to test spectral characteristics of various data packet types and test data transmissions appropriate to your application.

The software allows you to adjust transmission parameters such as integration for various multipath environments and to construct data packets using a special packet format dialog screen.

TAG ID Only

This mode transmits the unique unit ID number, firmware #, firmware date plus the Real-Time Clock date and time. This information is also displayed in the TAG Information and Real-Time Clock sections of the SG/T software interface. TAG IDs are useful in scenarios where multiple tags are active.

TAG ID + Data

In addition to the tag's unique identifier, a data payload of up to 2000 bytes can be included in the packet transmission. This data payload can be constructed or imported using the **Packet Format** dialog screen.

TAG ID + Scan Ramps

This mode is used specifically for angle-of-arrival (AOA) PLT applications. The scan "ramps" are symbols sent that allow a P200 Evaluation Kit radio to determine precisely the time of arrival of a signal from the SG/T. Sending multiple identical symbols allows the radio to lock onto the signal with one correlator while another correlator scans ahead of the lock point to determine the leading edge of the pulse. This leading edge detection is used to maximize accuracy. The number of scan ramps is variable and is set relative to the propagation environment in which the SG/T and receiving radio are operating.

TAG ID + Data + Scan Ramps

This packet structure is typical of a "fused" application where preloaded data packets or data from a smart sensor would be transmitted in addition to the scan ramps that allow for location of that mobile tag source.

Note that these TAG modes are active to allow studies of the spectral characteristics of transmissions. Variables that can affect the spectral characteristics of the various Modes:

- Acquisition pseudorandom coding [user selectable, not user programmable].
- Data payload pseudorandom coding [user selectable, not user programmable].
- Number of integrations for acquisition
- Number of integrations for data payload, TAG Header, CRC and Scan Data
- Size of the data payload
- Number of Scan Data symbols
- Transmission period [Continuous, Event (periodic) Single Shot]

Configuring the Packet Repetition Cycle

The SG/T can be programmed to transmit each of the transmission modes in the Transmission section **Modes** drop down menu. (These will be detailed in the next section.) The options for transmission periodicity are selected by radio buttons in the **Configuration** section as shown in Fig. 3.6. The choices are:

- **Single Shot:** The SG/T will send a single packet of whatever mode type is selected when the **Start** button is clicked. It will then cease until activated again. Although the Single Shot can be initiated by clicking on the button on the software screen or by pushing the button on the rear panel of the SG/T unit, the Single Shot configuration works only when the SG/T is connected to the host PC signal generator software and the Single Shot Configuration is selected.
- **Continuous:** Once activated by the **Start** button the device will repeat the selected packet until the **Stop** button is clicked, or until another configuration is selected on the software Transmission panel.
- **Event:** Selecting the **Event** radio button and then clicking on the **Set** button activates the screen for defining the transmission period. The minimum period is 1 second. The maximum period is 255 minutes (4 hrs. 15 min.).

To configure the repetition cycle of the signal, simply select the **Event** radio button, then click on the **Set** button. The **Event Period** dialog screen pops up. (Fig. 3.7) After selecting the **Transmit Interval** radio button, a period increment of either seconds or minutes can be selected from the drop-down menu. The size of the interval is typed into the first transmit interval field. The period defined can be up to 255 integers long. Those integers can represent seconds or minutes.

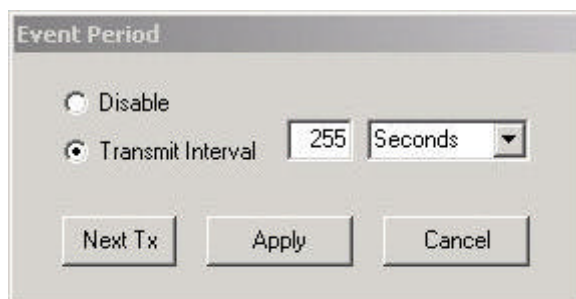


Fig. 3.7: Setting the periodic transmission cycle on the Transmission Period screen

Selecting the **Disable** radio button disables any value selected as the periodic transmission cycle. Clicking on **Next Tx** button displays the time until the next timed event.

Once the transmission period values are selected, click on the **Apply** button. This returns you to the main screen. The **Start/Stop** button in the Transmission section of the main screen turns the periodic event on and off.

Packet Format Display

The Packet Format section of the Signal Generator/TAG software is a display of structure and contents of the nine types of packets transmitted by the SG/T. This is only a readout. No changes in integration, number of symbols or data payload can be made from this screen (Fig. 3.8).

ACQUISITION	HEADER	TAG HEADER	TX DATA	CRC	SCAN DATA
Integration: 64	Integration: 64	Integration: 64	Integration: 64	Integration: 64	Integration: 64
# Symbols: 235	# Symbols: 96	# Symbols: 224	# Symbols: 7872	# Symbols: 16	# Symbols: 4000

Packet Transmission Time: 8.31E-02 Seconds

TX Data									
0	65535	65535	65535	65535	65535	65535	65535	65535	65535
18	65535	65535	65535	65535	65535	65535	65535	65535	65535
36	65535	65535	65535	65535	65535	65535	65535	65535	65535
54	0	0	0	0	0	0	0	0	0
72	65535	65535	65535	65535	65535	65535	65535	65535	65535
90	65535	65535	65535	65535	65535	65535	65535	65535	65535

Size: 984 Bytes

Display Format: Decimal Hex ASCII

Fig. 3.8: The Packet Format read-only screen

Packet Components

Acquisition

The front end of every data packet, the acquisition section is used by the receiving radio to acquire and lock onto the transmission. Its integration (repetition) value must be the same or higher than the following packet segments. This rule is enforced because achieving and maintaining signal lock is the critical part of the transmission link.

Header

This section contains information on what sections are included in the packet and the size of each following packet section.

Tag Header

The Tag Header contains the same information as displayed in the TAG Information and Real-Time Clock sections. This ID and time information is necessary for PLT applications where knowing which tag is sending and being able to time reference are at the heart of the task.

TX Data

This section displays the integration value and number of symbols in the data payload. Some payloads are preloaded with data as defaults. This section is optional, depending on the Mode selected.

CRC

The Cyclical Redundancy Check (CRC) is a portion of the packet used for determining bit error rate and evaluating data integrity for the **Tag Header** and **TX Data**.

Scan Data

An optional packet section, Scan Data includes symbols used for detection of the pulse leading edge, a critical function in the PLT application.

Other readouts and controls

Size ___ Bytes

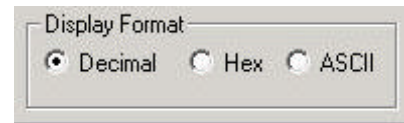
Indicates the size of the the payload section only.

Packet Transmission Time

Total transmit time for each complete packet (scientific notation). Example $3.06E-02 = .0306$ seconds.

Display Format

Selecting the desired radio button will alter the display of the data payload format between decimal, hexadecimal and ASCII formats. This same control is also active for the Packet Format data-entry section.



Controlling Acquisition and Data Packet Components

While operating the SG/T in one of the TAG modes, you can use the Host PC software to change the acquisition headers, the data payload and scan data used in PLT applications.

To activate the controls, the SG/T must be in one of the four TAG modes identified in the **Transmission** panel dropdown menu. Those Modes are: TAG ID Only, TAG ID + Data, TAG ID + Scan Ramps and TAG ID + Data + Scan Ramps. From the **Edit** menu, select **Packet Format**. Fig. 3.9 shows the Packet Format dialog screen.

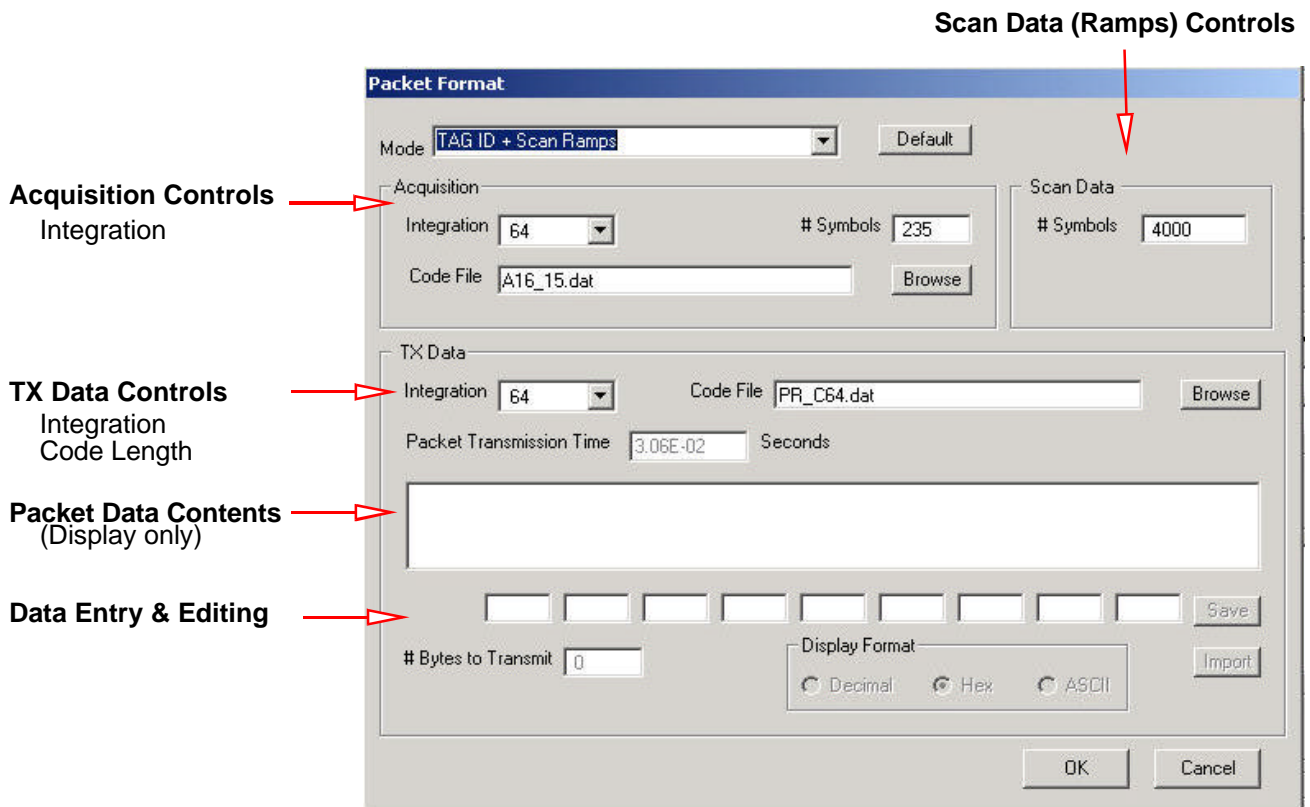


Fig. 3.9: The Packet Format screen with the major control and data entry sections identified

Mode Selection

In addition to being able to select among the nine possible modes from the drop down on the main software screen, the transmission **Mode** can be selected from the Packet Format controls screen (Fig. 3.10). Test Modes cannot be selected from the Packet Format section. In this screen you can change settings, load and edit data, but the main software screen will not reflect those changes until they have been programmed into the SG/T. The choice of **Mode** will determine which controls are active on the Packet Format screen. Choosing a mode without a data component disables some of the **TX Data** controls.

Default Button

This button shown in Fig. 3.10 will return all settings for each specific Mode --integration, symbols, data payload, scan symbols --to the original default settings programmed by Time Domain. All settings and changes made by the user will be lost.

Acquisition Settings

Integration:

Selectable from the drop down between 16 and 4096 integrations. In general, higher integrations are used in higher multipath and interference scenarios. A rule enforced by the software assures that the integration value for acquisition is always equal to or more than the integration values for the other sections of the transmitted packet (Fig. 3.10).

Symbols:

This value increases or decreases the length of the acquisition portion at the head of each packet. It is editable by typing in values in the window. Allowable symbol length ranges from 0-2047 in increments of 1.

Code File

There are 2 acquisition Code Files provided with the SG/T software. Neither can be edited by the user. Both have a code length of 16, but each uses different pulse position combinations within the 104 ns window. They have been selected for their spectral characteristics and each is linked to a specific **Mode** selection. Although clicking on the **Browse** button brings up a window displaying the codefiles, it is recommended that for initial SG/T release, you should not switch codefiles.



Note that the values for Integration and # Symbols are inter-related. Either or both can affect the ease of acquisition in challenging multipath environments. Depending on the physical and propagation environment, raising the integrations and the number of symbols can improve acquisition performance. Likewise, altering one value more than the other may also be appropriate in some instances. This document describes the tools but does not cover that experimentation, which must be carried out in conjunction with a P200 Evaluation Kit radio.

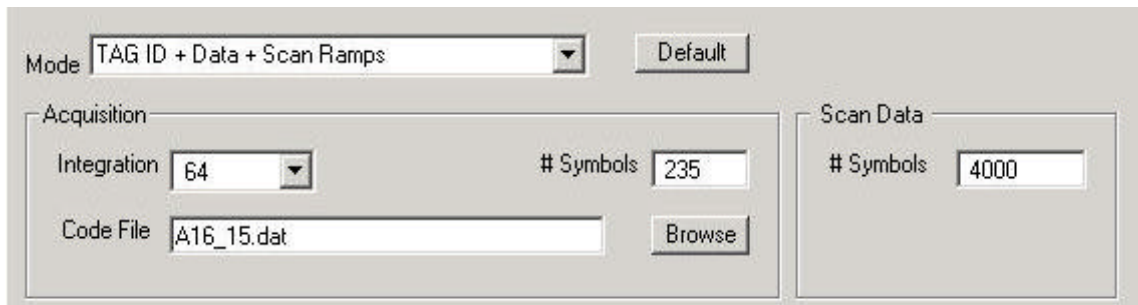


Fig. 3.10: The Acquisition section of the TX Data control screen

Scan Data Settings

Scan Data values set the number of symbols sent under the TAG ID + Scan Ramps mode or the TAG ID + Data + Scan Ramps mode. The scan ramps carry no information and are used solely to determine the leading edge of individual pulses for PLT applications. The values range from 0-65504 in increments of 32.

TX Data Controls

The TX Data section allows for manual entry or importation of data into the packet structure. The tool can also be used to edit existing data (Fig. 3.11).

Integration

The number of times the data packet is repeated. Integration values for data transmissions range from a minimum of 1 to a maximum of 1024. Compare this with the range of integrations for the Acquisition function. Acquisition integration ranges from 16 to 4096 repetitions of the symbol set.

Packet Transmission Time

Is the total length of time to transmit the particular packet specified by the choice of **Mode**. This time is variable and is calculated by the software as a function of TAG ID data size, packet type, data payload size and number of scan ramps. The value can not be manually entered.

Code File

There are 3 data transmission **Code Files** provided with the SG/T software. None can be edited by the user. They have been selected for their spectral characteristics and each is linked to a specific **Mode** selection. Although clicking on the **Browse** button brings up a window displaying the codefiles, it is recommended that for initial SG/T release, you should not switch codefiles.

The screenshot shows the 'TX Data' dialog box. At the top, there is a dropdown for 'Integration' set to '64' and a text field for 'Code File' containing 'PR_C64.dat' with a 'Browse' button. Below that is a text field for 'Packet Transmission Time' set to '1.37E-01' with the unit 'Seconds'. A table with 10 columns and 4 rows is displayed, with the first column containing values 0, 18, 36, and 54, and the remaining columns containing the value 65535. Below the table is a section labeled 'Manual Data Entry Fields' with a red arrow pointing to a row of input boxes, the first of which contains '65535'. To the right of these boxes are 'Save' and 'Import' buttons. Below the input boxes is a 'Display Format' section with radio buttons for 'Decimal' (selected), 'Hex', and 'ASCII'. At the bottom, there is a text field for '# Bytes to Transmit' set to '2000' and 'OK' and 'Cancel' buttons.

Fig. 3.11: The data entry tool for constructing data packets.

Data Payload Display

This field initially will display whatever data payload is specified for the Mode selected. This can be a default payload, or one previously programmed by the user. The display will change if you manually enter data, edit the existing data in the display or load a new data file (Fig. 3.11). The first column of each row specifies data file size up to the start of data for that row. The first row starts with zero, the second row with 18, and so on by increments of 18 bytes.

Bytes to Transmit

Before any data entry can take place, the total size of the data payload must be specified. The size, in bytes must be typed into the field displaying the value. The maximum size for a data payload is 2000 bytes. Each line in the display is 18 bytes. If you enter data less than 18 bytes, the software will add zeroes in the remaining fields to fill out the line. If you attempt to load more data than specified in the **# Bytes to Transmit**, the load will not be executed. After entering the data size, click the **Save** button to effect the change.

Manual Data Entry Fields

The manual data entry fields are located below the data payload display. Data cannot be entered unless the **TAG ID + Data** or **TAG ID + Data + Scan Ramps** mode is selected. Each individual entry field is 2 bytes and the total line is 18 bytes. Data is entered by typing into the fields. The choice of Decimal, Hex, or ASCII radio buttons in the **Display Format** field affects the form of the data entered. Clicking on the **Save** button enters data in the entry fields into the data display. Subsequent data entries display on sequential lines incrementing in 18 bytes. Note that the data entered is not programmed into the SG/T until the **OK** button is pressed.

Editing Existing Data

Existing data payload files can be edited by specifying the Mode that contains that data payload, then clicking on and highlighting the line containing the data to be edited (Fig. 3.12). The data from the highlighted line is transferred down to the data entry fields. Changes are made by typing in the appropriate fields, then clicking on the **Save** button, which substitutes the edited data line for the selected line in the data display.

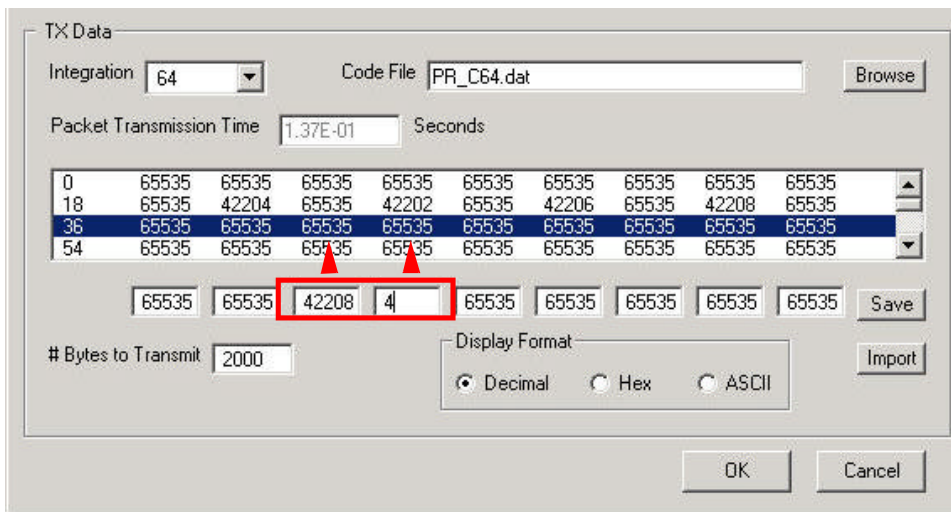


Fig. 3.12: Editing the contents of an existing data payload file.

Save

Enters manual data from the data entry fields into the payload data display. Also used to enter the **# Bytes to Transmit**.

Import

The **Import** function allows you to bring data payload directly into the data display without manual entry.

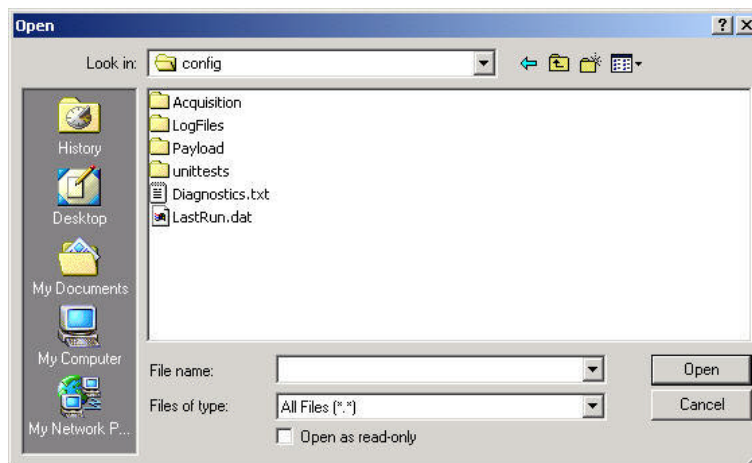


Fig. 3.13: The Config folder contains the data for both codefiles and data payload

The **Import** button brings up an open file dialog box that allows you to select any file to import into the data payload section. The file format is binary and can be up to 2000 bytes long (Fig. 3.13).

OK Button

Clicking this button downloads the data into the SG/T. A “Programming Tag...” message appears at the bottom of the dialog box and no further commands will be executed until the programming is complete. The software then closes the **Packet Format** window.

Master Reset Function

The **Master Reset** function can be accessed through the **Edit** drop-down menu. If the SG/T ever gets in a state where it is not functioning or its settings have been modified to the point where you aren't clear what the settings are or should be, using Master Reset will return the SG/T to its original factory settings for the **TAG ID Only** mode. Any **Event** transmissions currently programmed or operating will be stopped when Master Reset is used (Fig. 3.14).

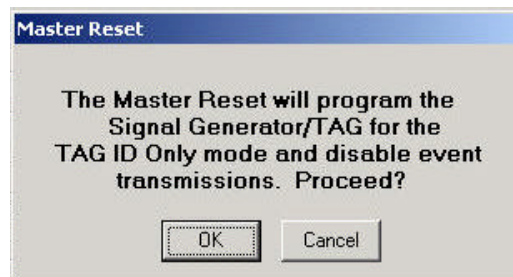



Fig. 3.14: The Master Reset function screen accessed from the Edit menu

Disconnecting from the Signal Generator/Tag

If you remove power from the unit, the settings you currently have loaded will remain in non-volatile memory and will be used when you re-apply power. The SG/T will always power up with the last configuration and mode configured by the software.


The software will always try to check SG/T status before it closes. If the unit is not connected, it will generate error messages. Therefore, the preferred procedure is to always close the software before powering down or disconnecting the serial cable from the SG/T. Disconnecting the serial cable from the SG/T before closing the software may cause you to lose the settings from the software.

4 Taking Measurements

 *Electrostatic discharge (ESD) on or near input connectors of any test equipment, including the Signal Generator/Tag, may result in damaged circuits inside the instrument. Before connecting a cable to an electrical input, momentarily short the center and outer conductors of the cable together. Personnel handling any element of the test setup should be properly grounded or should touch the frame of the instrument before touching any connector. Refer to the test equipment guides provided by the vendors for specific ESD considerations.*

Benchtop Cabled

This measurement test is designed to demonstrate Signal Generator/Tag (SG/T) performance as well as the configured setup using a coaxial cable and attenuation to replace the propagation channel, eliminating performance dependence on any interference that might be present.

 *Before any element of the cabled test is switched on, ensure that it has been properly grounded. Interruption of the protective conductor, inside or outside some test instruments, may result in injury.*

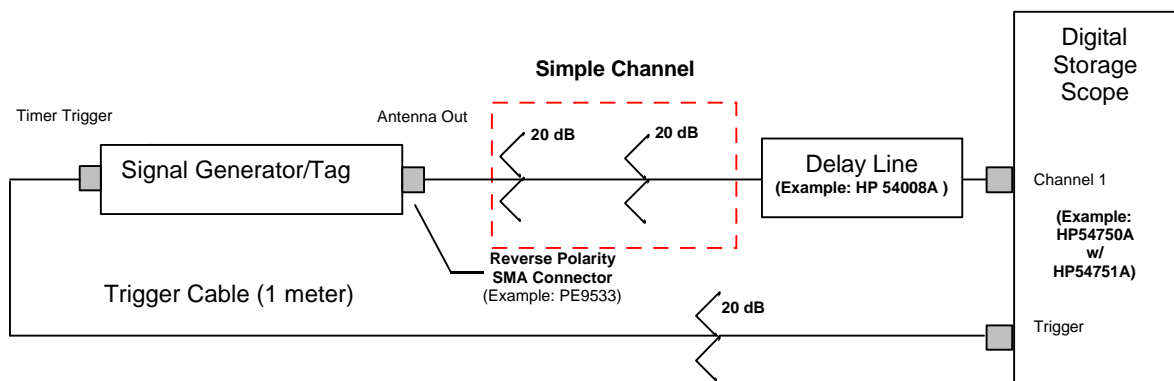


Fig. 4.1: Cabled benchtop schematic with components

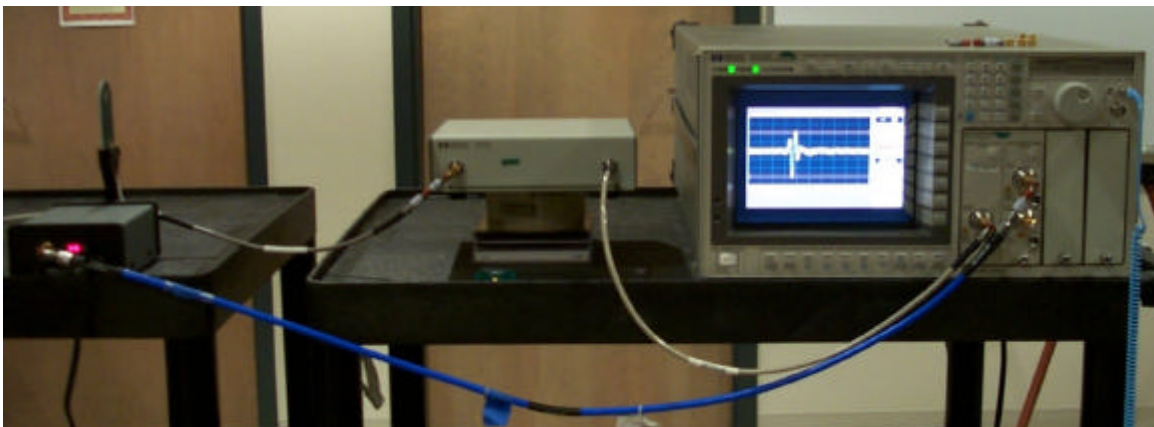


Fig. 4.2: Cabled benchtop setup

Recommended Test Instruments and Equivalents

To conduct this test and all the tests in this chapter, you will need the items in Tables 4.1, 4.3 and 4.5. Time Domain conducted its tests with the equipment listed in the tables, but equivalents are acceptable. The main requirements for digital sampling oscilloscopes [DSOs] is that they have a 20 GHz bandwidth and be able to track a vertical rise time of 30 picoseconds. Two alternatives that meet the specification are:

- Agilent 86100B DSO with an 834484A 2-channel 50 GHz module.
- TektronixTDS 8000 or CSA 8000 DSO with 80E03 20 GHz module.

These citations are for reference only. Time Domain has not used this equipment to verify its suitability. Note also that connector compatibility must be verified with the equipment vendor.

Qty.	Name	Part #
1	PulsON 200 signal Generator/Tag	100-0011
1	Reverse polarity SMA male-female connector	Pasternak Enterprises PE9533
1	12-inch long, 50-ohm cable w/SMA connectors	Tensolite-QMI 1-3636-301-.3212
1	24-inch long, 50-ohm cable w/SMA connectors	Tensolite-QMI 1-3636-510-3224
3	20 dB SMA connector attenuator, DC to 18 GHz	M/A-COM 2082-6148-20
1	20ns delay line	HP54008A
1	20 GHz bandwidth digitizing oscilloscope + 20 GHz plug-in	HP54750A + HP54751A
1	1-meter long, 50-ohm cable w/ SMA connectors	QMI64039
	Assortment of gender-changing & right angle SMA connectors	

Table 4.1: Required parts for cabled test setup

Antennas are not used for this setup. Because the PulsON 200™ transmit antenna has a non-standard connector, the PE9533 SMA connector is needed to adapt the RF output of the Signal Generator/Tag so that it can be connected to a standard SMA cable. The two 20 dB attenuators are required to attenuate the signal to a level that can be handled by the channel input of the digital sampling scope (DSO). Because the measurement setup requires *triggering* of the DSO by the signal generator, the HP54008A delay line is required to delay the pulse long enough for the trigger to travel down the trigger cable, trigger the DSO, and provide the necessary setup time required by the DSO. A schematic and photo of this setup are shown in Fig. 4.1 and Fig. 4.2.



The setup time required by the DSO is the time needed between the time it receives the trigger to the time it is ready to receive a waveform. For the HP54750A, the setup time is 22 ns. If your DSO has a delay feature built into the device, the delay line component can be eliminated from setup.

Because the trigger cable for this setup is relatively short, the 20 ns of delay provided by the HP54008A delay line is sufficient. As we will see with later setups, if a longer trigger cable is used, a longer delay in the signal path must also be used. Note that a 20 dB attenuator is also placed in-line with the trigger cable to attenuate the signal to a level that can be handled by the trigger input of the DSO.



In some cases, 20 dB attenuation can result in an unstable or inadequate trigger. If this situation occurs, reduce the trigger attenuation.

In order to be able to receive and capture the incoming pulses from the signal generator, the DSO must be configured properly. A description of the setup used by Time Domain's Propagation team is found in Table 4.2. These are the actual settings of the HP54750A that were used to make the measurements contained in this document, and are provided to aid in your initial measurement setups.

Trigger		Time Base*		Acquisition		Display		Channel 1	
Parameter	Setting	Parameter	Setting	Parameter	Setting	Parameter	Setting	Parameter	Setting
sweep:	triggered	scale:	200 ps/div	averaging:	off	persistence:	variable	display:	on
source:	trigger 2	position:	24 ns			persistence time:	1 sec.	scale:	400 mV/div
external scale:	20 dB	reference:	left			draw waveform:	high resolution	offset:	0 V
level:	500mV	windowing:	disabled					bandwidth:	12.4. GHz
slope:								external scale:	43 dB
hysteresis:	normal	*Time Base settings are approximate.Adjustments may be needed for specific test hardware configurations.							
trigger bandwidth:	DC -2.5 GHz								

Table 4.2: Recommended initial scope settings for cabled benchtop test

The Signal Generator/Tag has five pre-configured codes, accessible only through the software interface, for transmitting pulses. The pulse repetition frequency (prf) of all of the codes is 9.6MHz (i.e. a pulse transmitted nominally every 104 ns); however, the different codes use a combination of time hopping and pulse flipping to improve spectral qualities. For reference, the received pulse is shown for each of the code settings in the initial cabled setup. The profile on the scope for these five codes are shown in Fig.4.3 through 4.7.

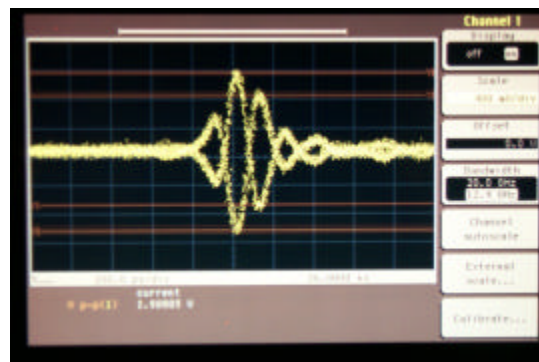


Fig. 4.3: Long Acquisition Packet

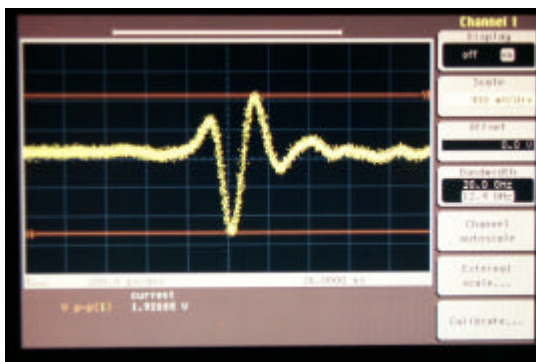


Fig. 4.4: Time Shift Continuous (default)

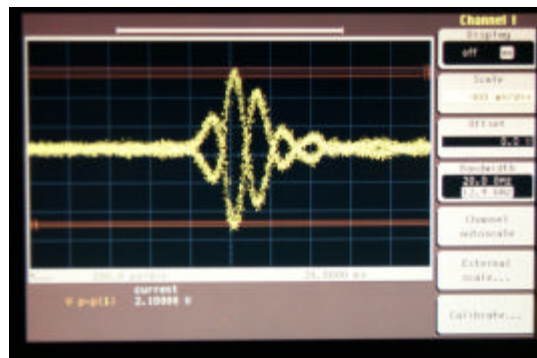


Fig. 4.5: Acquisition

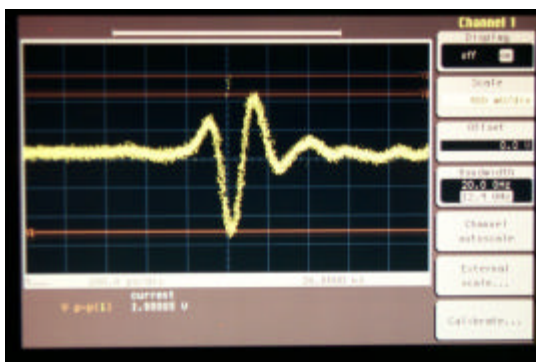


Fig. 4.6: Minimum Acquisition Packet

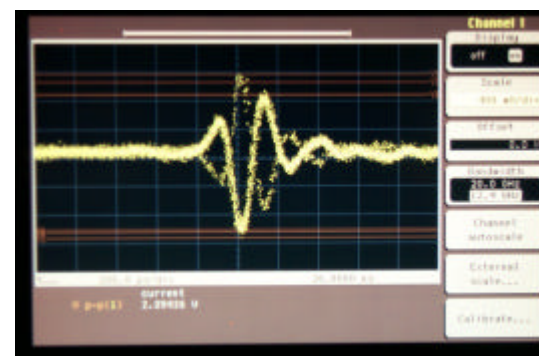



Fig. 4.7: Medium Acquisition Packet

Benchtop Wireless

The benchtop wireless measurement is designed to test initial wireless signal generator performance as well as the configured test setup using a short, simple 12-inch line-of-sight (LOS) propagation channel. By testing this basic wireless configuration, you can gain an initial understanding of the UWB wireless channel. The schematic for this setup and a photograph are shown in Fig. 4.8 and 4.9.

 Before any element of the wireless test is switched on, ensure that it has been properly grounded. Interruption of the protective conductor, inside or outside some test instruments, may result in injury.

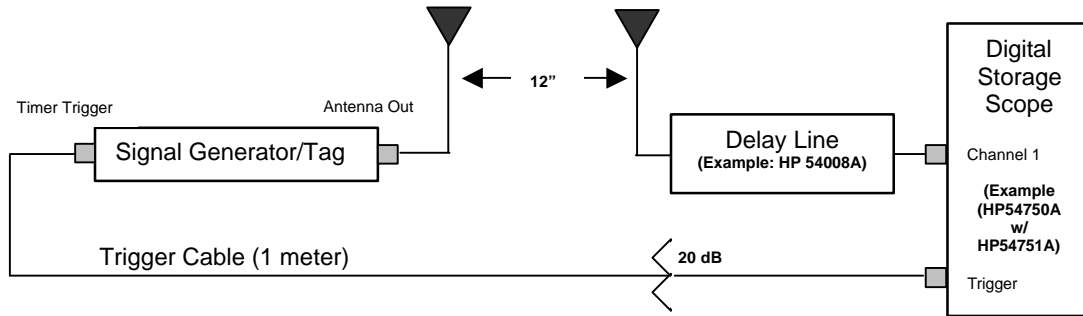


Fig. 4.8: Schematic of wireless benchtop setup with components.

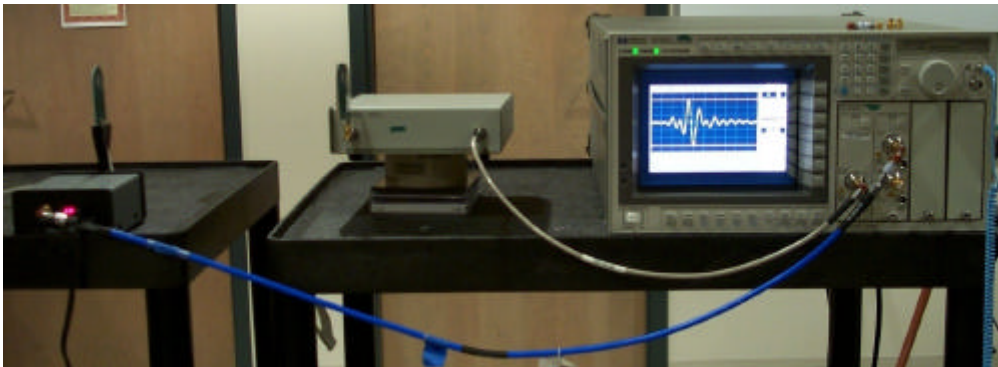


Fig. 4.9: Bench wireless setup

To setup this configuration, you will need the items in Table 4.3. Specific part numbers listed were used by Time Domain and are given for reference purposes. You will need to use the same equipment or their equivalents.

Qty.	Name	Part # (or equivalent)
1	PulsON 200 signal Generator/Tag	100-0011
1	Broadspec Model P200 Antenna , receive-only	200-0053
1	20 ns delay line	E-Z Form EX141DL100
1	24-inch long, 50-ohm cable w/ SMA connectors	QMI64023
1	20GHz bandwidth digital oscilloscope	HP54750A + HP54751A
1	20 dB SMA connector attenuator, DC to 18 GHz	M/A-COM 2082-6148-20
1	1-meter long, 50 ohm cable w/ SMA connectors	QMI64039
	Assortment of gender-changing & right-angle SMA connectors	

Table 4.3: Parts list for benchtop wireless test

The additional antenna included with the unit is used as the receive-only antenna. The two 20 dB attenuators (required for the conducted setup) are not required here due to the loss in signal energy due to the physics of a wireless link. Because the measurement setup requires *triggering* of the DSO by the signal generator, the HP54008A delay line is again required to delay the pulse long enough for the trigger to travel down the trigger cable, trigger the DSO, and provide the necessary setup time required by the DSO. Because the trigger cable for this setup is relatively short, the 20 ns of delay provided by the HP54008A delay line is sufficient.

Note that a 20 dB attenuator is also placed in-line with the trigger cable to attenuate the signal to a level that can be handled by the trigger input of the DSO.



In some cases, 20 dB attenuation can result in an unstable or inadequate trigger. If this situation occurs, reduce the trigger attenuation.

In order to be able to receive and capture the incoming pulses from the signal generator, the DSO must be configured properly. A description of the setup used by the Time Domain Propagation team for this setup is found in Table 4.4. These are the actual settings of the HP54750A that were used to make the measurements contained in this document, and are provided to aid in your initial measurement setups. An example of a benchtop wireless waveform capture is given in Fig. 4.10.

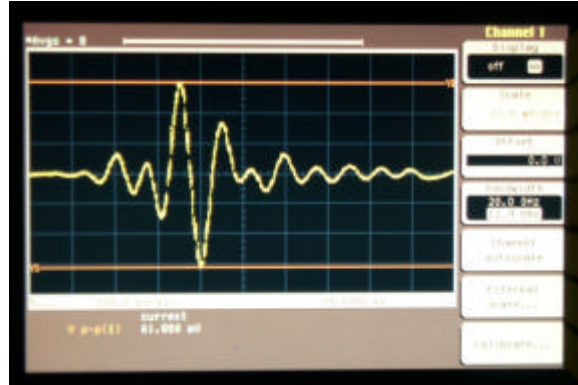


Fig. 4.10: Benchtop, Time Shift Continuous Pulse

Trigger		Time Base*		Acquisition		Display		Channel 1	
Parameter	Setting	Parameter	Setting	Parameter	Setting	Parameter	Setting	Parameter	Setting
sweep:	triggered	scale:	250 ps/div	averaging:	on	persistence:	variable	display:	on
source:	trigger 2	position:	24.5 ns	# of averages:	8	persistence time:	1 sec.	scale:	400 mV/div
external scale:	20 dB	reference:	left			draw waveform:	high resolution	offset:	0 V
level:	500mV	windowing:	disabled					bandwidth:	12.4 GHz
slope:								external scale:	45 dB
hysteresis:	normal	*Time Base settings are approximate. Adjustments may be needed for specific test hardware configurations.							
trigger bandwidth:	DC -2.5 GHz								

Table 4.4: Recommended initial scope settings for benchtop wireless test

Wireless Propagation

The two benchtop tests described earlier were designed to test both the signal generator performance and the basic measurement setup. The next setup, outlined in Fig. 4.11 through 4.13, configures the Signal Generator/Tag allowing you to investigate a complex UWB propagation channel.



Before any element of the wireless test is switched on, ensure that it has been properly grounded. Interruption of the protective conductor, inside or outside some test instruments, may result in injury.

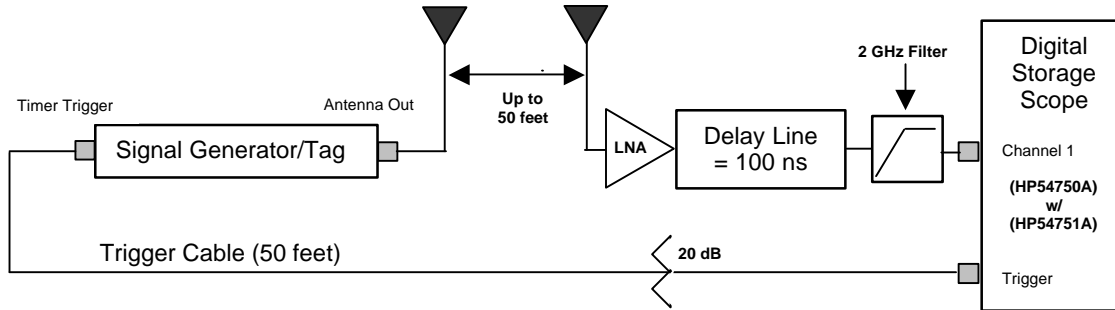


Fig.4.11: Schematic of benchtop wireless propagation setup covering longer distances.

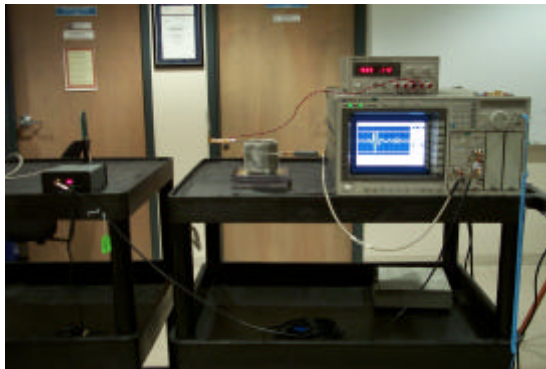


Fig. 4.12: Basic propagation test setup

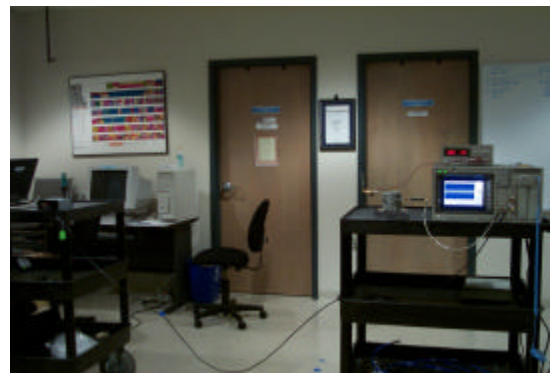


Fig. 4.13: Propagation 5-foot test setup

To setup this configuration, you will need the items in Table 4.5 . Specific part numbers listed were used by Time Domain and are given for reference purposes. You will need to use the same equipment or their equivalents.

Qty.	Name	Part # (or equivalent)
1	PulsON 200 signal Generator/Tag	100-0011
1	Broadspec Model P200 Antenna , receive-only	200-0053
1	LNA (1-% GHz, -30 dB gain across band, 2.2 dB noise fig..)	Miteq AFS3-00100400-22LN
1	15V LNA power supply	HP E3620A
1	100 ns delay line	E-Z Form EX141DL100
1	24-inch long, 50-ohm cable w/ SMA connectors	QMI64023
1	2 GHz HP filter	Micro-Tronics HPM12708
1	20GHz bandwidth digital oscilloscope	HP54750A + HP54751A
1	20 dB SMA connecor attenuator, DC to 18 GHz	M/A-COM 2082-6148-20
1	50-foot RG223/U Type 50ohm cable w/ SMA male connectors	
	Assortment of gender-changing & right-angle SMA connectors	

Table 4.5: Parts list for longer distance propagation studies

The additional antenna included with the unit is the receive antenna. The two 20 dB attenuators (required for the conducted setup) are not required here due to the loss in signal energy due to the physics of a wireless link. Because this setup is intended to investigate complex propagation channels, it will incorporate a low noise amplifier (LNA) and a 2 GHz high pass (HP) filter to improve the sensitivity of the receiver setup. The chosen LNA should have 20-30 dB of gain and a relatively low noise figure (<4 dB) to control the high noise figure of the DSO. In addition, the 2 GHz HP filter will help filter out any ambient interference (e.g. 1.9 GHz PCS). Note that for the setup shown above, a delay line with 100 ns of delay is used in conjunction with a trigger cable 50 feet in length.

The excess length of trigger cable allows the antennas to be separated by a distance of almost 50 feet. As mentioned previously, the received pulse must be delayed sufficiently to conform to the *triggering* setup time of the DSO. Since the trigger cable will delay the trigger pulse from reaching the trigger input, the received pulse must also be delayed accordingly. The potential for having the transmitted pulse reach the receiver before the trigger arises when making measurements at a short antenna range separation using a long trigger cable. In this scenario, the pulse does not have far to go to reach the receiver, however, the trigger pulse still must travel all the way through the trigger cable.



*If additional measurement distance is required, longer trigger cables can be used; however, a delay line with additional delay will be required. A rule of thumb would be $D(ns) = 1.5 * L_{cable} + t_{DSO_setup}$. Where L_{cable} is the trigger cable length (in feet) and t_{DSO_setup} is the DSO setup time in ns.*

The cable used for the trigger must be shielded to prevent radiation from the trigger pulse affecting the measurement of the transmitted pulse. The trigger cable must be a 50 ohm cable. Note that a 20 dB attenuator is also placed in-line with the trigger cable to attenuate the signal to a level that can be handled by the trigger input of the DSO.

In order to be able to receive and capture the incoming pulses from the signal generator, the DSO must be configured properly. A description of the setup used by the TDC Propagation team for this setup is found in Table 4.6. These are the actual settings of the HP54750A that were used to make the measurements contained in this document, and are provided to aid in your initial measurement setups

Trigger		Time Base*		Acquisition		Display		Channel 1	
Parameter	Setting	Parameter	Setting	Parameter	Setting	Parameter	Setting	Parameter	Setting
sweep:	triggered	scale:	500 ps/div	averaging:	on	persistence:	variable	display:	on
source:	trigger 2	position:	29 ns	# of averages:	8	persistence time:	1 sec.	scale:	20 mV/div
external scale:	20 dB	reference:	left			draw waveform:	connected dots	offset:	0 V
level:	500mV	windowing:	disabled					bandwidth:	12.4 GHz
slope:								external scale:	$L_{cable} + 1.5$ dB
hysteresis:	normal	*Time Base settings are approximate. Adjustments may be needed for specific test hardware configurations.							
trigger bandwidth:	DC -2.5 GHz								

Table 4.6: Recommended initial scope settings for a propagation test setup

The waveforms in Fig. 4.14 and Fig. 4.15 were measured with the propagation setup at distances of one and two feet. Note in the measurement at one foot, the reflection off of the DSO can be seen in the received waveform as a received pulse delayed in time by ~ 2 ns. Also notice that in comparing the two waveforms, the measurement at two feet is both reduced in amplitude as well as delayed in time.



Fig.4.14: Waveform at 1 foot separation



Fig. 4.15: Waveform at 2 feet separation

The waveforms can be further compared by using the functionality of the oscilloscope to save the measurement made at one foot and display it compared to the measurement at two feet on the same screen. (Fig. 4.16). The markers can then be used to look at the relative change in the two pulses. Because we doubled the measurement distance from one foot to two feet, we should expect that the voltage waveform be reduced in amplitude by half and be delayed by approximately one nanosecond. As can be seen from the figure at right, in moving from one to two feet, the waveform decreased in amplitude from ~ 50.0 mV to 25.2 mV and the main positive peak moved 1.1 ns in time.

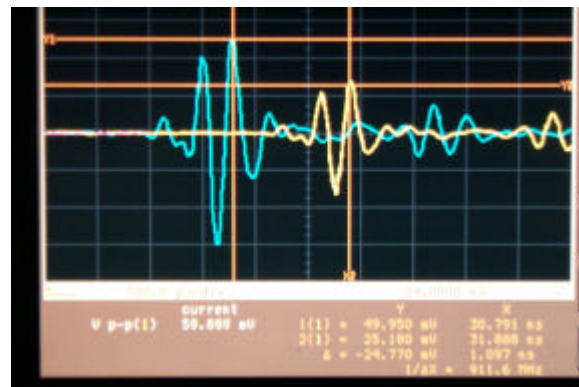


Fig.4.16: One foot vs. 2 foot compared

Although this type of propagation analysis behaves just as theory would predict for LOS free space propagation, in a non-LOS propagation channel there are objects or walls located between the transmitter and receiver. This type of analysis can be used to compute pathloss as a function of distance and exact time delays due to material penetration for the UWB channel in a complex environment.

An additional example of propagation analysis can be seen when comparing the two waveforms in Fig. 4.17 and Fig.4.18. Both waveforms were measured at a distance of 25 feet from Time Domain's Propagation laboratory out into the hallway. The first waveform was measured with a LOS between the transmitter and receiver. The second waveform, however, was measured with the large wood, double-doors closed. As you can see, the peak voltage of the initial received pulse for the non-LOS case is attenuated compared to the LOS case by about 2.7 dB. Thus, we can say that the attenuation of the doors for this signal is approximately 2.7 dB. Additionally, note that the multipath impulses following the initial received pulse also changed when the doors were closed.

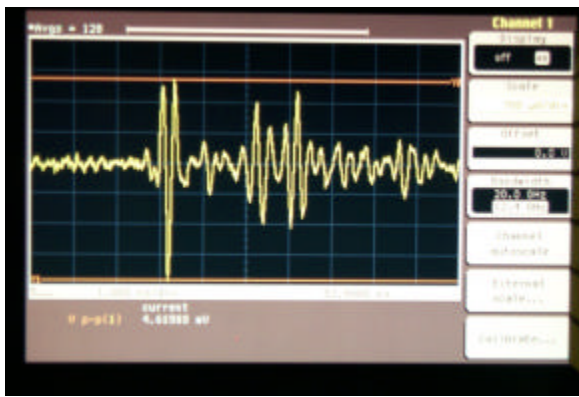


Fig.4.17: Line-of-sight waveform at 25 feet

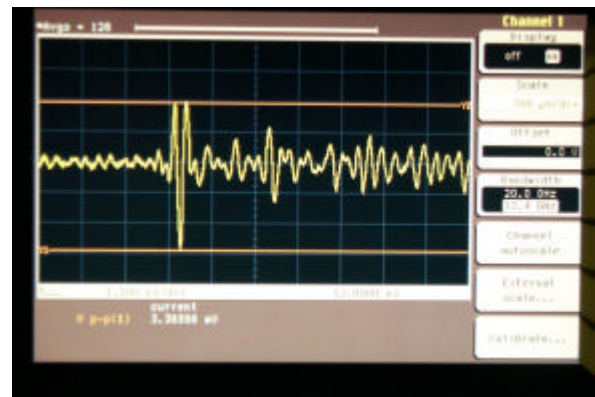


Fig.4.18: Non line-of-sight waveform at 25 feet

5 Evaluating Data

The following are some suggested evaluations that can be done with the PulsON 200™ Signal Generator/Tag on measurements made with the wireless setups presented in Chapter 4.

Understanding Pulse Integration: A Demonstration

Increasing pulse integration generally improves the quality of the received signal, particularly over longer distances and in more complex environments. A simple demonstration using the SG/T and a DSO illustrates this point. In Fig. 5.1 two received signal samples are superimposed. The samples were taken with different levels of averaging set in the DSO.

The light blue, background trace was taken averaging 4 samples per point on the trace. Notice the wider spread of the values and the fact that it is very hard to locate the leading edge of the pulse. The magenta, foreground trace was processed averaging 256 samples per point. The effect is dramatic. The main pulse lobes and leading edge are easily located and in general the values show much less spread. The demonstration measurement was taken through one wall at 15 feet between SG/T and the receiving antenna.

Changing the averaging value on the DSO is exactly analogous to altering the pulse integration value in a UWB receiver.



Fig. 5.1: Superimposed traces comparing 4 averaged samples vs. 256 samples per trace

Received Signal Voltage at Antenna Terminals

A quantity that may be of practical use to know for system implementation is the received peak signal voltage referenced to the receive antenna terminals. This can be measured with either wireless setup. The wireless benchtop setup is recommended because there are less components. This can be done by accurately entering the system losses of the measurement setup into the External Scale parameter of the Channel input menu. By entering these losses in the External Scale field, the DSO will account for them and the received waveform shown on the screen will effectively be referenced to the receive antenna terminals. The losses of the elements of the receiver measurement chain can easily be found by using a network analyzer to measure the cascaded elements of the receive chain.



This calculation is extremely dependent on the offset entered into the channel External Scale. For accurate measurement of voltage at antenna terminals, losses in receiver chain must be accurately accounted for.

Pathloss vs. Distance

By measuring the received peak voltage at several distances in a given environment, the pathloss as a function of distance can be calculated. This measurement should be made using the wireless propagation measurement setup. The steps of this measurement are as follows:



Pathloss measurements can be measured with the External Scale adjusted for attenuation in the Delay Line, or with a zero value entered in the External Scale. The loss ratio with distance will be the same in either case.

- Using the wireless propagation measurement setup, make an initial measurement at a reference distance (e.g. one foot or one meter)
- Record the peak voltage of the received pulse
- Move the signal generator to another location and measure the LOS distance from the signal generator to the receiver.
- Record the peak voltage of the received pulse at this location
- By referencing the peak voltage measured at a random location to the peak voltage measured at the reference position, the excess path loss for a given distance can be measured. This can be expressed in decibels by the following formula:

$$P_L = 10 * \log_{10} \left[\frac{V_{peak_random}^2}{V_{peak_reference}^2} \right]$$

- For the simple, LOS propagation channel (e.g. within a room) the results of this measurement should be easily predicted by theory; however, for a complex, non-LOS channel (e.g. wall penetration), this measurement technique can be used to quantify UWB propagation for that environment. By taking multiple measurements at various distances, an average quantification of the propagation for that environment can be obtained.

Advanced UWB Propagation Channel Analysis

Using the same type of measurement procedure laid out for the pathloss measurements (a reference measurement followed by additional random placement measurements), further analysis can be performed on the UWB propagation channel.

Channel Impulse Response Modeling

A frequency domain technique can be used to deconvolve the measurement system (i.e. the signal generator and the receiver setup) from the UWB propagation channel impulse response (CIR). This can be done by using the measurement made at the reference distance as a template waveform. If we model the transmitted signal of the **signal generator as $s(t)$ and the received signal for an arbitrary measurement location as $y_{RX}(t)$** , then the wireless transmission of $s(t)$ through an arbitrary propagation channel is given by

$$y_{RX}(t) = s(t) * h_{channel}(t) * h_{trans}(t)$$

Where $h_{channel}(t)$ is the propagation CIR and $h_{trans}(t)$ is the impulse response of the transceiver. By making a reference measurement with the system at a one meter LOS distance, the propagation channel can be considered to approximate free space, thus $h_{channel}(t)=1$. The one meter measurement, represented by

$$y_{1meter}(t) = s(t) * h_{trans}(t)$$

contains all of the effects of the transceiver system convolved with the transmitted signal. Now, $y_{RX}(t)$ for an arbitrary propagation channel can be written in terms of the reference one meter signal convolved with the arbitrary channel impulse response.

$$y_{RX}(t) = y_{1meter}(t) * h_{channel}(t)$$

Then, $h_{channel}(t)$ is found by taking the inverse Fourier transform of $H_{channel}(f)$.

$$H_{channel}(f) = \frac{Y_{RX}(f)}{Y_{1meter}(f)} = \frac{Y_{1meter}(f)H_{channel}(f)}{Y_{1meter}(f)}$$

The resulting $h_{channel}(t)$ is solely dependent on the propagation channel. For a measurement situation, this process involves taking the FFT of a received waveform from an arbitrary measurement point and dividing it by the FFT of a measurement made at a 1-meter distance. The result is the propagation channel transfer function; the CIR is obtained by taking the IFFT.

$$H_{channel}(f) \xrightarrow{IFFT} h_{channel}(t)$$

Delay Spread Calculation

Since the CIR resulting from this technique has had the effects of the measurement system removed, analysis of the CIR can be applied to any generic UWB system. The time dispersive nature of a CIR is used as a metric to compare the CIR of different measured channels. The mean excess delay spread, rms delay spread, and excess delay spread are statistical multipath channel parameters that can be determined from a power delay profile, where the power delay profile (PDP) is defined as $P(t)=|h_{\text{channel}}(t)|^2$ [2]. The mean excess delay spread and rms delay spread most commonly quantify the time dispersive properties of multipath channels. The mean excess delay spread is the first element of the PDP and is given by

$$\bar{t} = \frac{\sum_k P(t_k) t_k}{\sum_k P(t_k)}$$

The rms delay spread is the square root of the second central element of the PDP and is given by

$$s_t = \sqrt{\bar{t}_2 - (\bar{t})^2}$$

where

$$\bar{t}_2 = \frac{\sum_k P(t_k) t_k^2}{\sum_k P(t_k)}$$

Both the mean excess delay and rms delay are measured from the first detectable signal peak in the CIR. These calculations are not affected by the absolute power in $P(t)$ but only the relative amplitudes of the multipath components. The rms delay spread is a good measure of the multipath channel as it gives an indication of the potential for intersymbol interference and has been shown to be correlated to indoor wireless system performance [1].

The excess delay spread of the PDP is defined as the maximum delay relative to the first arriving peak at which a multipath component is within a set power threshold of the strongest arriving multipath peak. According to the equations above, each sample point with non-zero power is included in the rms delay spread calculation and represents a received signal component. This artificially extends the delay spread and causes errors in the calculated channel parameters [3].

To eliminate noise contributions from affecting these calculated spreads, a threshold is incorporated in the computation of the mean and rms delay spreads. Implementing this method, only the points of peak power above the threshold level are included in the computations. The statistical metrics defined can be graphically shown for an example CIR taken at a 30 feet LOS distance down a hallway (Fig. 5.2).

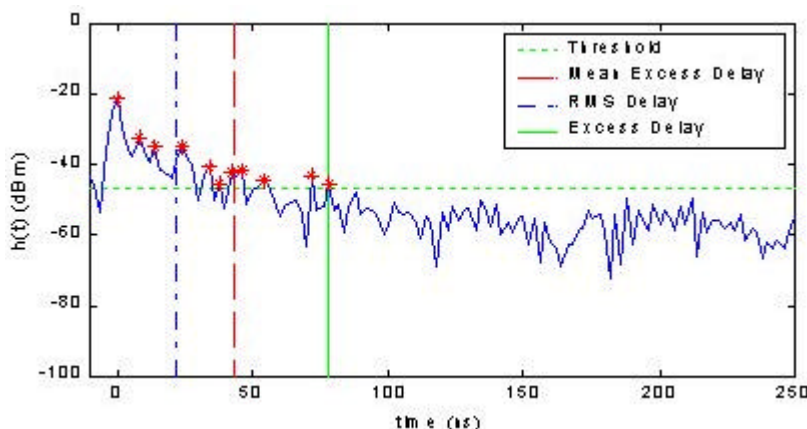


Fig. 5.2: Calculation of mean, excess and rms delay spreads

In Fig. 5.2, the starred peaks represent the points that are used to calculate the mean excess and rms delay spreads. Note that while several of the peaks actually span more than 2 ns (and therefore contain more than one sample point), each peak is weighted only by the single point of highest power. By doing so, each peak in the calculations is weighted equally. From the figure, it is seen that the calculation of the PDP statistics are extremely dependent on the chosen threshold as it determines the points from $h(t)$ that are included in the calculations

[1] H. Hashemi. “The Indoor Radio Propagation Channel,” Proceedings of the IEEE, Vol. 18, pp.943-968, July 1993.

[2] T.S. Rappaport. Wireless Communications: Principles and Practices. Prentice Hall, 1996.

[3] W.G. Newhall. Wideband Propagation Measurement Results, Simulation Models, and Process Techniques for a Sliding Correlator Measurement System. Master’s Thesis, Virginia Polytechnic Institute and University, 1997.

Propagation Channel Ray Tracing

In addition to the calculations presented above to quantitatively evaluate the propagation channel, we can also qualitatively investigate a received waveform by correlating the received multipath pulses in the waveform to actual propagation paths in the physical environment. For example, if the transmitter and receiver are set up at 10 feet separation in close proximity to a wall, then the waveform at the receiver will be comprised of 2 distinct pulses that are separated in time based on the difference in path lengths that each pulse took in traveling from the transmitter to the receiver. (Fig. 5.3)

This phenomenon can be seen in the received waveform for the measurement taken at 1 foot for the wireless propagation setup. Note that the received waveform consists of the LOS pulse as well as an additional pulse that is attenuated and delayed in time. The delayed, attenuated pulse has traveled from the transmitter, been reflected off of the DSO, and then received at the antenna. Because the path length for this pulse is longer than that of the LOS pulse, it is delayed in time.

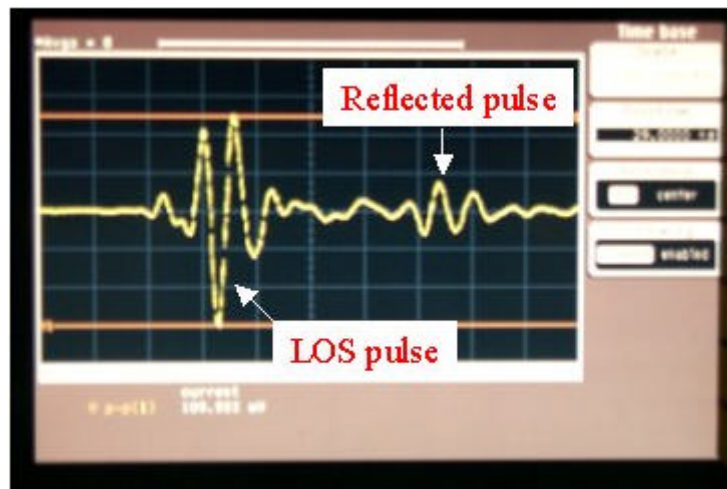


Fig. 5.3: Example of received waveform differences from multipath

The term “ray tracing” is commonly used for this type of analysis that investigates the multiple paths (i.e. multipath) by which a signal takes to arrive at a receiver. Because the PulsON 200® UWB system has extremely fine time resolution, ray tracing analysis can be used to correlate time-delayed pulses in the received waveform directly to spatial placement of physical objects in a given environment.

For a given transmitter-receiver separation d_0 , pulses that are delayed relative to the first arriving (LOS) pulse can be tied to a *range ellipse* that corresponds to the delay in time. By knowing the speed of light, the range ellipse for each time delay can be calculated (Fig. 5.4).

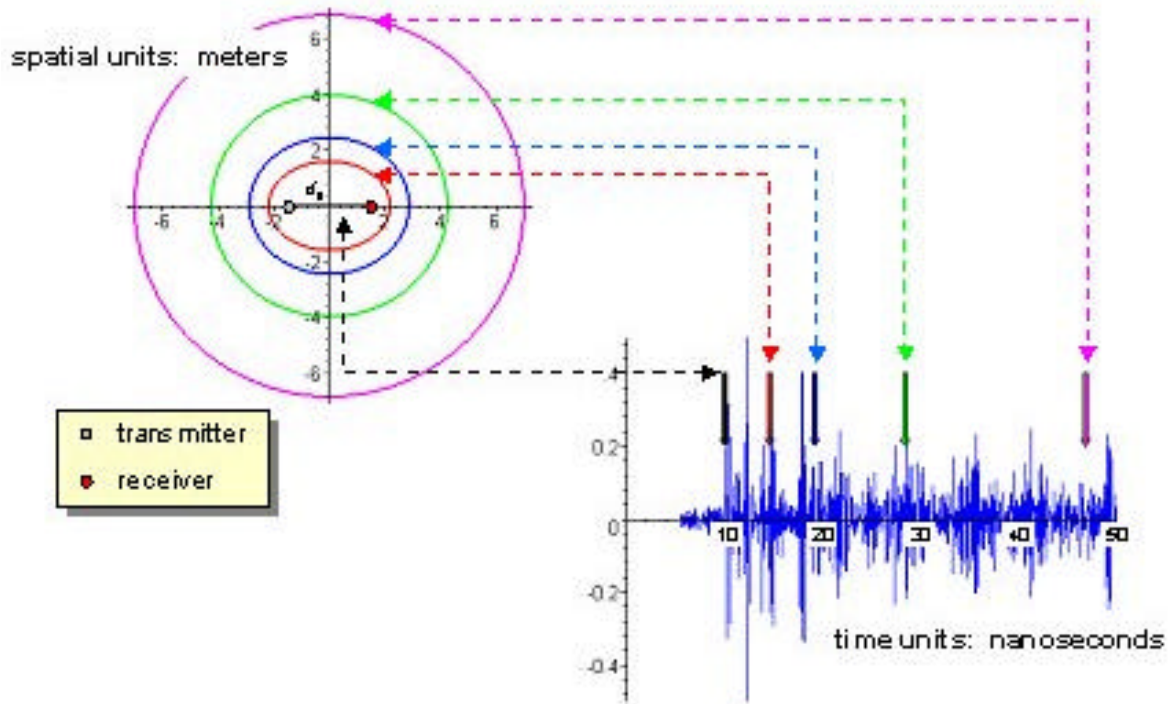


Fig. 5.4: Calculating time delays and corresponding range ellipses

Received E_b/N_o Calculation

In addition to propagation metrics that investigate the received peak voltage, we can also use the wireless propagation measurement setup to calculate an approximation to a received E_b/N_o . The received E_b/N_o can be approximately calculated by dividing the received peak voltage squared by two times the variance of the noise and is given by

$$\frac{E_b}{N_o} \approx \frac{V_{peak}^2}{2 \sigma_n^2}$$

The variance of the noise can be calculated from the received waveform by making the calculation over the portion of the waveform before the pulse arrives (i.e. where there is no signal present). This calculation can be graphically shown in Fig. 5.5.

The received E_b/N_o calculated with the measurement setup can be used as an approximation for the received E_b/N_o that the PulsON 200 system will encounter in a given environment. The actual received E_b/N_o for the PulsON 200 will be better than measured here due to the interference rejection capabilities of the PulsON 200™ receiver.

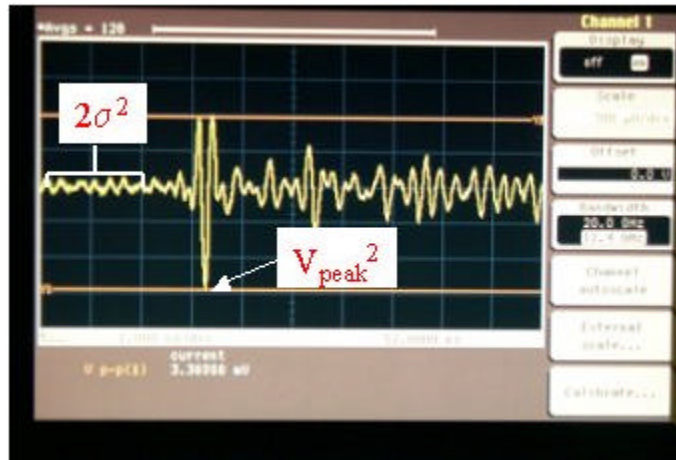


Fig. 5.5: Graphical representation of the E_b/N_0 calculation

A Hardware Interface

Front Panel

The front panel of the SG/T is shown in Fig. A1.

Timer Trigger

This SMA connector allows you to connect an external device such as an oscilloscope for propagation and interference studies. The signal provided on this line is taken at the Timer output trigger to aid in signal sampling.

The trigger pulse is 14.9 ns wide and peaks at 3.4 volts.

LEDs

A (Pulser)

When illuminated (steady), this LED indicates the pulser is enabled. No transmission will occur unless the pulser is enabled.

B (Real Time Clock)

When illuminated (steady), this LED indicates the Real Time Clock (RTC) is enabled. The RTC controls transmission events. This is a quick way of seeing if the SG/T is transmitting.

C (Power)

When illuminated this LED indicates that the unit has sufficient operating power.

Power In

The Signal Generator/Tag requires 6-9 VDC, 2 amp power input. The center pole is positive, the outer connector shield is negative ground.



Fig. A1: Front Panel

Rear Panel

The rear panel of the SG/T with antenna attached is shown in Fig. A2.

Antenna Out

This port connects to a UWB antenna through a coax cable. Use caution when connecting antennas. The SG/T has reverse polarity SMA connector. The connector on the oscilloscope receive-only antenna (200-0053) is a standard SMA connector. Trying to connect a receive antenna to the **Antenna Out** port can damage both connector parts.

Fire Pulser

The button on the back of the unit works only when the SG/T unit is connected to the host PC software. The user then has the option of activating the single shot pulse from the computer or remotely from the unit's location.

Event/Cont.

This switch allows you to choose from an **Event** driven transmission of a preset time interval, or a continuously transmitting signal. In its default state as shipped, the preset interval is disabled. The switch functions as on Off/On switch with **Event** being OFF, and **Cont.** (continuous) being ON. Once a periodic event has been programmed by connecting a PC switching to Event will not turn the unit off, but will run the programmed sequence. Any setting on the switch can be overridden by the software controls while the host PC is attached.



Fig. A2: Rear Panel

RS-232

The RS-232 port is a standard DB-9 serial port requiring a straight-through cable to connect to either a sensor or a PC. The port is configured for 19200 baud rate, 8 data bit, no parity, and 1 stop bit (8-N-1) as shown in Table A1.

Pin	Signal	Function
1	-	
2	RD	Transmit Data
3	TD	Receive Data
4	-	
5	GND	Signal Ground
6	-	
7	RTS	Awakens Signal Generator/Tag
8	CTS	Signals that tag is ready to accept data/commands
9	-	

Table A1: RS-232 connector pin functions

B Board Interface

Access

To remove the casing, you will need to remove the front panel and casing using a Phillips-head screwdriver and a 5/16 or 8 mm wrench (Fig. B1).

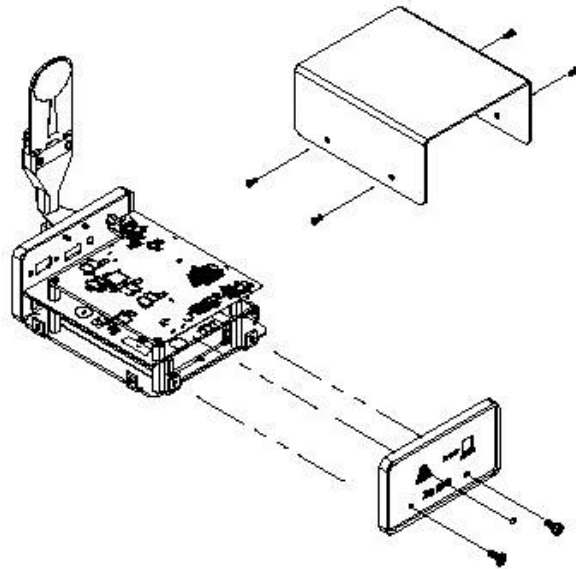


Fig. B1: Removing the cover from the SG/T unit

1. Using a 5/16 or 8 mm wrench, remove the nut and washer from the Timer Trigger SMA connector located on the front panel.
2. Using the Phillips-head screwdriver, remove the two screws located at the bottom of the front panel.
3. Remove the front panel from the unit
4. Using the Phillips-head screwdriver, remove the two screws located on each side of the gray casing (four screws total).
5. Slide the casing forward until it is clear of the internal boards . *Removing the front panel and casing will disturb special RF seals and gaskets detailed in the following section. They must be saved and reinstalled in the proper position when the unit is reassembled.*

Special RF Emissions Precautions

If you open the SG/T casing, you must use care to retain and not to damage special gaskets and seals installed to eliminate unintentional RF emissions. Note their position so they can be replaced properly (Fig. B2).



Fig. B2: RF gaskets sealing (L to R) DB9, SMA connectors (2) and front/rear faceplate screws (4) , Power-In connector (1)

Digital Board

The Digital board shown in Fig. B3 provides the pulse timing control, mode control options and interfaces for the Signal Generator/Tag. The components on the board essentially consist of the:

- PulsON™ 200 Timer chip
- FPGA : 200 K gate
- Real Time Clock (RTC)
- External oscillator
- Serial Flash
- RS-232 interface chip and various power supplies.
- Electronic interface and standoff support for the RF Board mounted above the digital board

The FPGA provides the logic necessary to convert acquisition and payload code structures and modulation schemes into individually placed pulses. The PulsON 200™ Timer chip provides a precise differential control to the RF module to initiate Pulser activity. An RS-232 interface port is provided external to the unit for interface to a PC for configuration control or to a sensor. Internally there is a JTAG interface used for FPGA firmware upgrades.

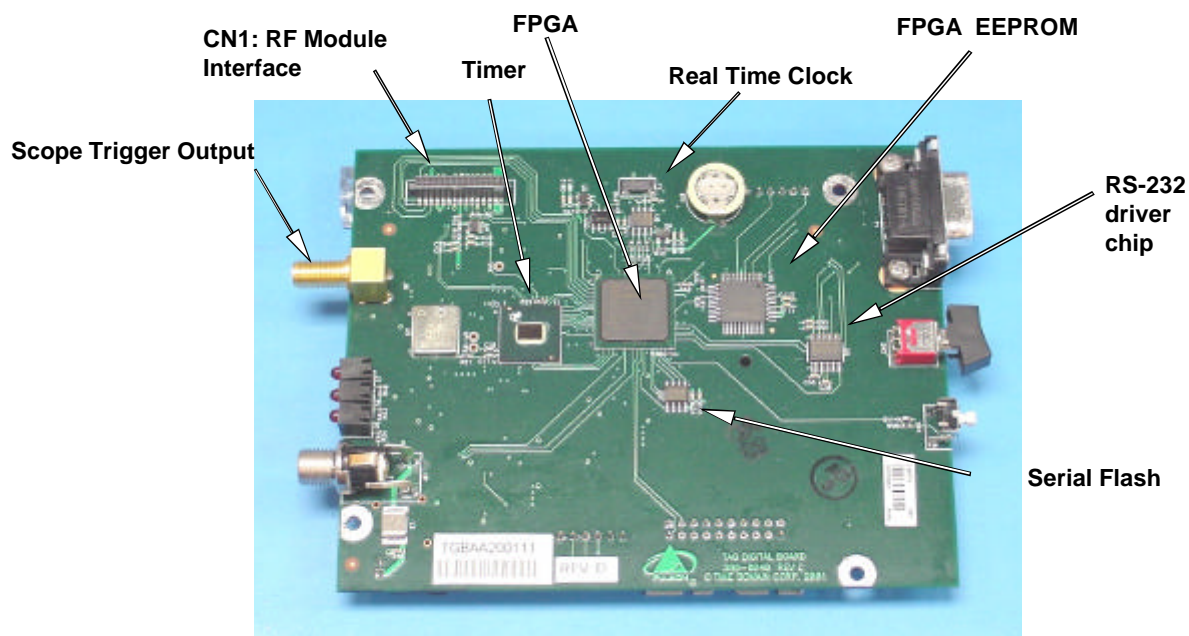


Fig. B3: Top side of the digital board with major electronic components.

Connections to Digital Board

Figure B4 shows the bottom side of the digital board with the connectors used for external access to the FPGA and the FPGA EEPROM.

FPGA

This port is a Joint Test Action Group (JTAG) port used to program the FPGA. It is designed to connect with a Xilinx® Parallel Cable III or MultiLINX™ cable running the Xilinx® JTAG Programmer or iMPACT software. This port is found on the digital board inside the unit as shown on the graphic above. To gain access to this port, you must open the casing using the instructions at the beginning of this chapter. The wiring color codes follow the Xilinx® Parallel Cable III specifications. Xilinx® JTAG Programmer and iMPACT are freeware and can be downloaded from <http://www.xilinx.com>.

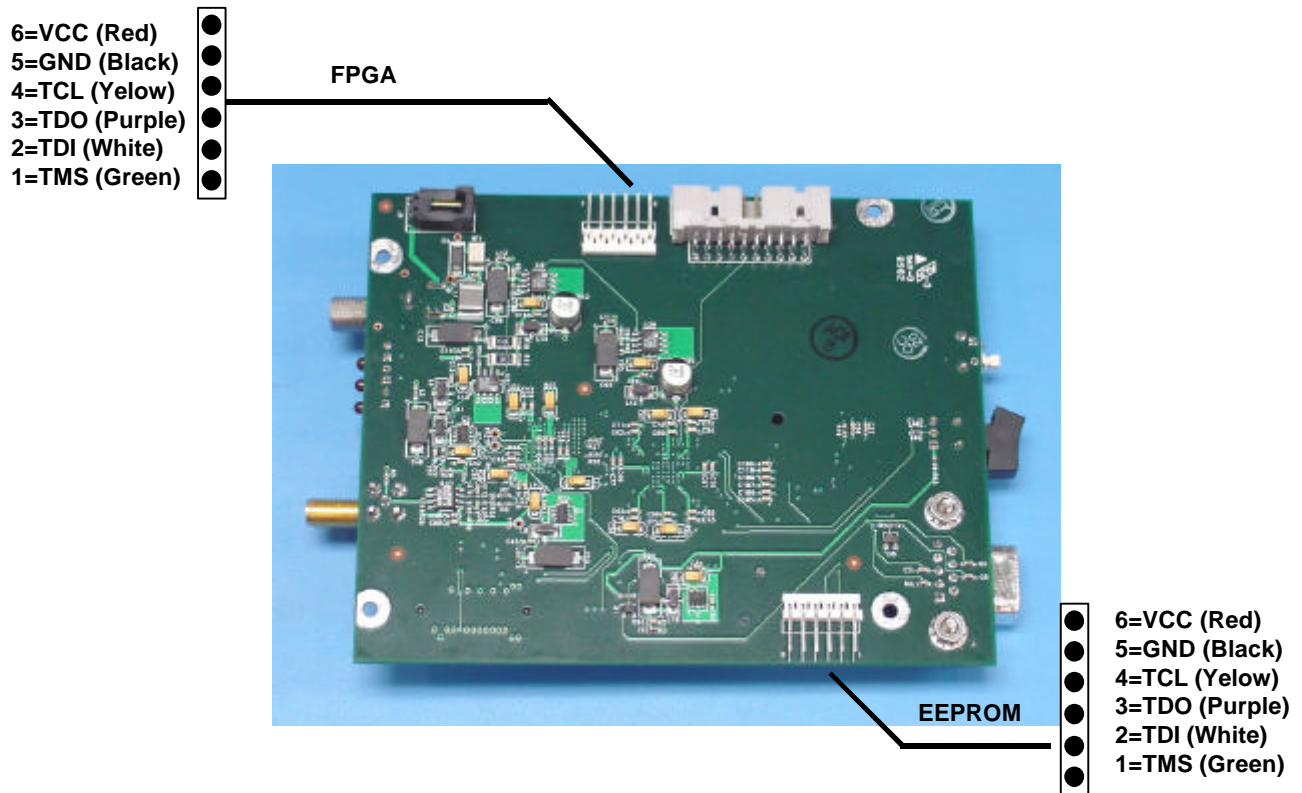


Fig. B4: Bottom side of the digital board with major electronic components

EEPROM

This port is a Joint Test Action Group (JTAG) port used to program the EEPROM. It is designed to connect with a Xilinx® Parallel Cable III or MultiLINX™ cable running the Xilinx® JTAG Programmer or iMPACT software. This port is found on the digital board inside the unit as shown on the graphic below. To gain access to this port, you must open the casing using the instructions in this section. The wiring color codes follow the Xilinx® Parallel Cable III specifications. Xilinx® JTAG Programmer and iMPACT are freeware and can be downloaded from <http://www.xilinx.com>.

RF Board



The RF board is similar, except for the Bill of Materials, to the RF board on the PulsON 200™ Evaluation Kit. The following description was extracted from the PulsON 200™ Evaluation Kit Hardware Manual and refers to the RF module in the Evaluation Kit.

The RF board creates UWB transmit pulses centered on 3.7 GHz (Rev.B, Rev. C) and passes them to an exterior antenna. It sits on top of the digital board and connects to the digital board via the RF module interface connector.

Interface Definitions

The RF module has two broadband coaxial interfaces and a 30-pin Samtec connector. The coaxial connection J1 to the exterior antenna is an end-launch reverse-polarity bulkhead SMA [Johnson Components 142-4701-801]. The RF module receives its power supply and signaling through CN1, a 30-pin male Samtec connector [TFM-115-32-S-D-A] having a 0.050 inch pitch on a 2x15 grid (Table B1).

For reliable operation, it is necessary that the antenna cable SMA connectors be properly torqued to between 7 and 10 inch-ounces at the RF module input and that the RF module be fully seated onto the 30-pin connector and the MMBX connector prior to securing the RF module to the digital board.

Signal Name	Connector Pin	Description
Antenna	J1	50-ohm coaxial SMA - Antenna I/O
V_Supply	CN1 -1,2,3,4	Supply voltage to RF Board, +7 VDC nom.
Ground	CN1 - 5,6,7,8,9,10 12, 13, 14, 16, 17, 18, 21, 22, 23, 24	Reference for Vsupply, return path for Vsupply current
Serial_Clk	CN1 - 25	Pins 25-30 are dedicated to an EEPROM to carry identification and calibration data. The chip is intended to exist in electrical isolation from other RF circuitry, hence the dedicated +3.3Vcc and Ground returns.
+ 3.3.V	CN1 - 26	
Serial_DI	CN1 - 27	
PROM_GND	CN1 - 28	
Serial_DO	CN1 - 29	
RF_PROM_CS	CN1 - 30	
Pulse_Trigger_+	CN1 - 19	Timer chip +3.3V referenced 900 mVpp differential lines with 150-ohm Odd Mode Impedance. Plus exceeding Minus will fire Impulse Generator in ~5ns.
Pulse_Trigger_-	CN1 _ 20	
Pulse_Polarity	CN1 - 15	3.3V CMOS logic from Timer chip which determines + or - version of output impulse.
Pulser_Enable	CN1 - 11	A positive 3.3V CMOS logic state will power enable the Impulse Generator circuit.
TR_RX_Select	CN1 - 7	A positive 3.3V CMOS logic state will connect the ANTENNA to the Impulse Generator.

Table B1: RF Board interface connectors with pin-outs for CN1 interface with the digital board

Circuit Descriptions

Impulse Generator (Pulser)

The Impulse Generator creates precisely timed transmitted impulses on command from the Timer chip.

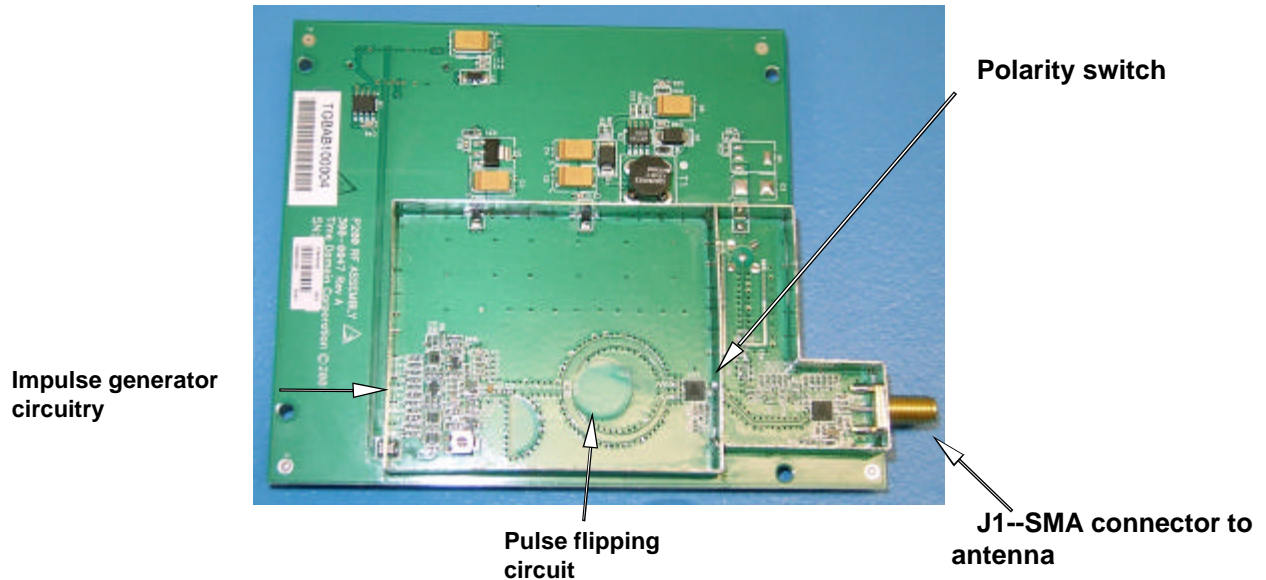


Fig. B5: Top side of the RF board showing major pulse generating sections

The impulse generator uses a Step Recovery Diode (SRD) to create a very fast output transition. In operation, this diode receives a pulsed forward-bias to place a charge in its junction followed by a quick extraction of that charge. This creates a large and fast $L \cdot dI/dt$ output swing when the diode goes to its high impedance state (*snap* in historic parlance).

At the time when the diode snaps, the transition is temporally and spectrally shaped by an impulse forming network. From there the impulse passes on to the Pulse Inverter. The `Pulser_Enable` signal line can be used to turn off the generator and place it into a sleep mode.

Pulse Inverter (Flipper)

The Pulse Inverter's function is to create and select either of two mirror-image versions of the impulse input for passing on to the T/R switch and antenna. It consists of a distributed implementation of an unbalanced-balanced transformer followed by a selector switch.

The incoming impulse is initially ground referenced. After transitioning to a double slot-line structure, it propagates as a balanced signal. When the impulse reaches the end of this slotline at the open-circuit termination it couples to an orthogonal co-planar waveguide (CPW) line that divides the signal into two equal and opposite impulses traveling outward from this node.

After counter-propagating on the CPW around this hole, a terminating broadband GaAs SP2T switch (U12) is used to select which of the plus or minus versions of the impulse is to be passed on to the antenna. The `Pulse_Polarity` signal line controls this selection.

