Wave User Guide

Revision 1
August 2009

IMPORTANT
Please read this entire document before
attempting to operate
the Wave System

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Read Me First

Warnings

In all NDI documentation, warnings are marked by this symbol. Follow the information in the accompanying paragraph to avoid personal injury.

1. Do not operate the Field Generator within 200 mm of an installed pacemaker. The magnetic field produced by the Field Generator may interfere with the operation of the pacemaker. This interference may result in personal injury.
2. Do not use the Wave System if the SCU is connected to a non-approved workstation. If the SCU is not connected to IEC 60950 or IEC 60601 approved workstations, leakage currents may increase beyond safe limits and result in personal injury.
3. Do not disconnect the Field Generator from the system while it is tracking. Disconnecting the Field Generator while it is tracking may generate arcing, and result in personal injury.
4. Do not immerse the Wave System in liquids, or allow fluid to enter the equipment in any way. Exposing the Wave System to liquids may result in equipment damage, produce a fire or shock hazard, and result in personal injury.
5. Apart from replacing the SCU fuses, there are no user serviceable parts in the Wave System. All servicing must be done NDI. Unauthorised servicing may result in personal injury.
6. Switch off power to the system before cleaning it. Failure to do so may result in injury.
7. Do not change either fuse without first disconnecting the SCU from its power source. Failure to disconnect the system may result in personal injury.
8. Do not use cables, transducers or accessories other than those listed in the table above, with the exception of those sold by NDI or by NDI-authorized manufacturers. To do so may result in increased emissions and/or decreased immunity of the Wave System.
9. Do not use the Wave System in the presence of other magnetic fields. To do so may lead to misleading or inaccurate transformations and possible personal injury.
10. Do not expose sensors to a high magnetic field, such as a Magnetic Resonance Imaging Machine, as they may become magnetized. Tracking with a magnetized sensor may result in incorrect transformations and possible personal injury.

Cautions

Caution! In all NDI documentation, cautions are marked with the word "Caution!". Follow the information in the accompanying paragraph to avoid damage to equipment.

1. To move or ship the Wave System, repack in the original containers together with all protective packaging to prevent damage.

2. Do not use aerosol sprays near the equipment as these sprays can damage circuitry.
3. Do not use any solvent to clean the Wave System. Solvents may damage the finish and remove lettering.
4. Do not autoclave any Wave System component. Autoclaving may damage the system.
5. Do not push or pull connectors in constricted areas. Doing so may damage the connectors.
6. Do not put heavy objects on cable connectors. Doing so may damage the connectors.
7. Do not leave cable connectors where they can be damaged, particularly on the floor, where they can easily be stepped on and damaged.
8. Pull connections apart by gripping the connector. Do not pull them apart by tugging on the cable as this can damage the connecting cable. Never force a connection or a disconnection.

Disclaimers

1. All NDI tracking systems are designed to exclusively use NDI specific components. NDI is not responsible for any outcome that should arise from using non-NDI compliant components.
2. This equipment has been investigated with regard to safety from electrical shock and fire hazard. The inspection authority has not investigated other physiological effects.
3. The Wave System is designed only for research use. It has not been designed, investigated or approved for medical use.
4. This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

   a) this device may not cause harmful interference, and

   b) this device must accept any interference received, including interference that may cause undesired operation.

Questions?

If you have any questions regarding the content of this guide or the operation of this product, please contact us:

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http://support.ndigital.com

1 Wave System Overview

1.1 Introduction

This user guide provides information on the NDI Wave System. The Wave System is an electromagnetic non line-of-sight motion capture system, designed specifically for speech research.

Note The Wave System is designed only for research use. It has not been designed, investigated or approved for medical use.

The system calculates and records, in real time, the position of discrete points on, for example, the tongue, palate, jaw, lips and face. As an option, audio is simultaneously recorded and synchronized with the motion capture data for post-hoc analysis. (A customer supplied microphone is required for this option.)

The Wave System can also be integrated with the Optotrak Certus System or the 3D Investigator System, providing the ability to synchronise with additional research equipment.

1.2 Wave System Components

The Wave System comprises the following main components:

- Field Generator (page 2)
- System Control Unit (SCU) (1 with basic system, 2 with extended system) (page 4)
- Sensor Interface Unit (SIU) 4 (8 with an extended system) (page 7)
- Wave connector block cable assembly 4 (8 with an extended system) (page 7)
- Disposable sensors, single use, (16 with basic system, 32 with extended system) (page 8)
- Synchronization cables (extended system, audio and Optotrak integration)
- 6D reference sensor (page 8)
- 6D palate probe (optional) (page 9)
- Field Generator Mounting Arm (page 9)
- Application software CD
- A host computer, customer supplied

The basic Wave System incorporates one SCU, which supports up to eight sensors, (via four SIU). As an option, the system can be extended with an additional SCU, increasing the number of sensors to sixteen (via eight SIU). In this extended system, one SCU is designated SCU (1) and the other SCU (2).

1.3 Host Computer Requirements

A host computer is also required to operate the system. The host computer is customer supplied and must meet the following minimum specifications:

- Processor - Pentium 2 GHz or later
- Operating System - Windows XP 32 bit, Windows Vista 32 bit
- Stereo audio input
- USB Interfaces (one per SCU in the configuration)
- Video card supporting OpenGL

1.4 Field Generator

The Field Generator produces electromagnetic fields that cover a known measurement volume, that consists of either a 300 mm or 500 mm cube. The measurement volume is illustrated in Figure 1-2 on page 3. The volume is projected outwards from the Field Generator's front face, offset by 50 mm from the Field Generator. The Field Generator is described in the following table and illustrated in Figure 1-1 on page 3.

Table 1-1 Field Generator

Part	Description
Front face	Origin of the measurement volume. This side is distinguishable from the others as it has both the Wave logo and NDI logo printed on it.
Mounting point	Designed to attach the Field Generator to the NDI Field Generator Mounting Arm (P/N 8800728), refer to page 9.
Field Generator connector	Connects the Field Generator cable to the SCU. The Field Generator connector is a 19 pin circular metal connector.
Field Generator cable	Connects the Field Generator to the SCU.
M8 tapped holes (thread pitch 1.25 mm, depth 13 mm) x 4, 2 per side	Allows the Field Generator to be attached firmly to a fixture.

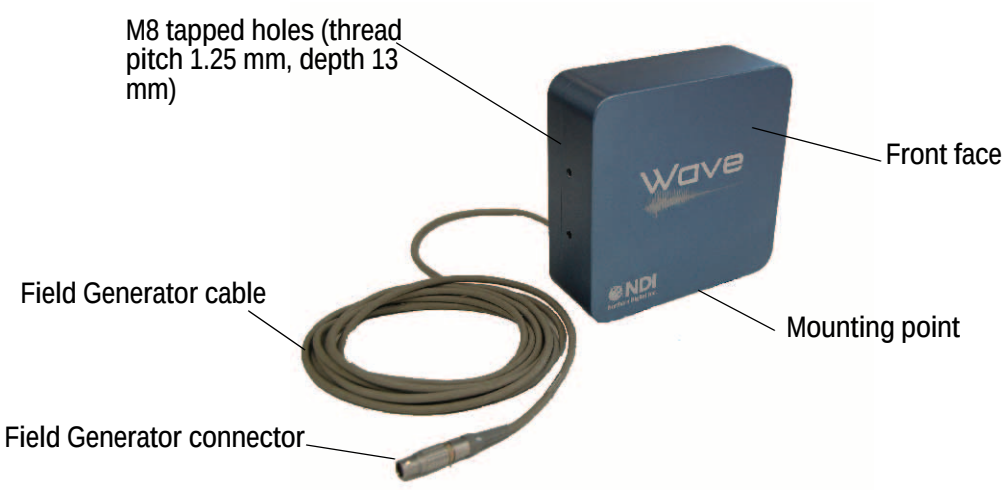

Figure 1-1 Field Generator

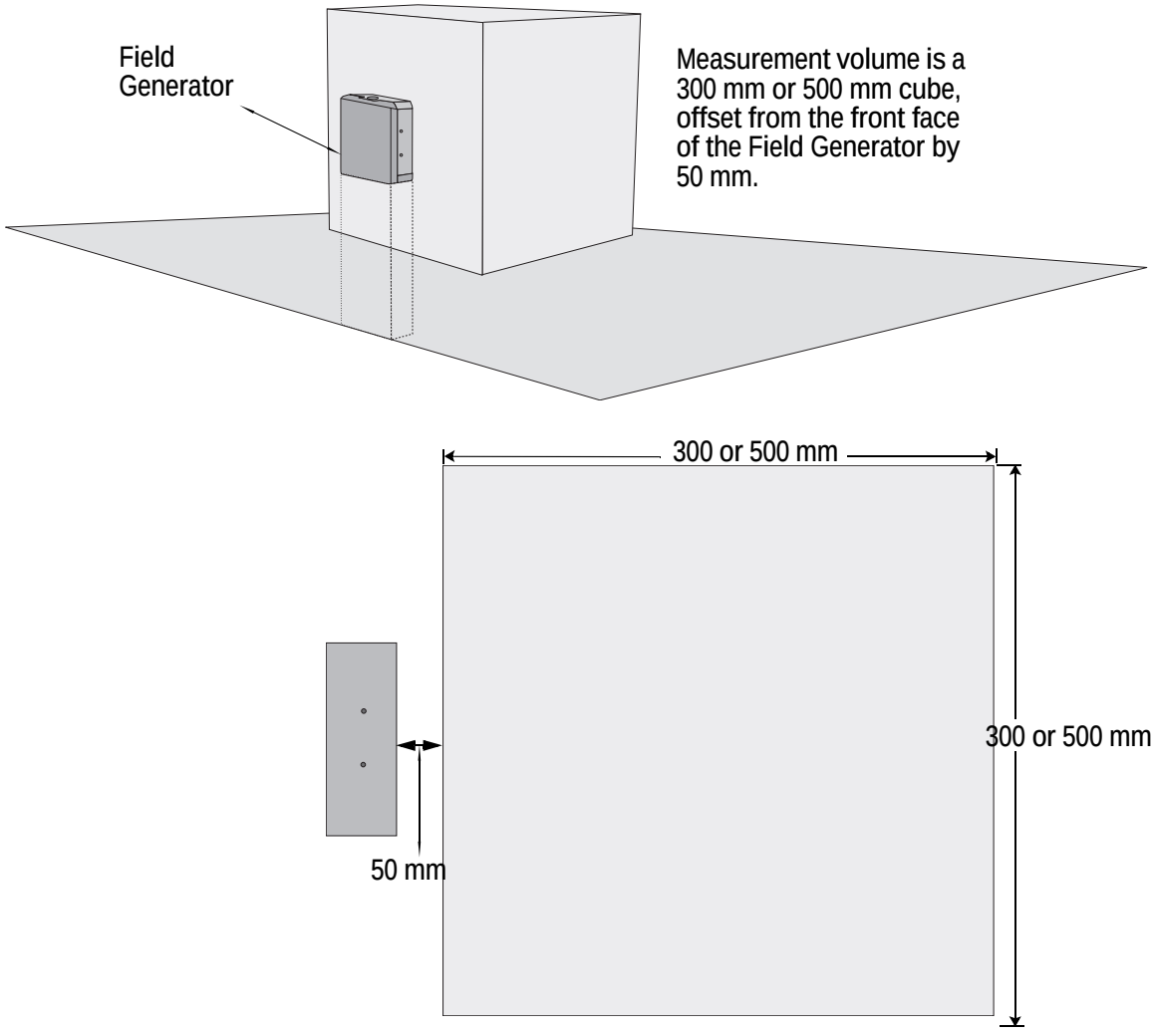

Figure 1-2 Wave System Measurement Volume

1.5 System Control Unit

The basic 8-channel Wave System incorporates one SCU. The SCU (Figure 1-3) is the interface between the system components. It also provide visual status indications. A brief overview of the SCU functions is as follows:

- supplies power to the Field Generator and controls the Field Generator's electromagnetic output.
- collects sensor data (via the SIU) and sends it to the host computer.
- produces and sends an audio signal to the host computer. The audio signal contains the Wave data frame number being measured. This frame number is encoded in the audio signal using SMPTE timecode encoding. It is used for temporal synchronization of the recorded microphone audio signal with the Wave data.
- provides visual status indications.
- interfaces with the host computer.

The Wave System can be extended to incorporate a second SCU, providing an additional eight sensors to the system. In the extended 16 channel configuration, the SCUs are designated (1) and (2), with SCU (1) being connected to the Field Generator and providing the SMPTE signal.

Figure 1-3 System Control Unit

SCU Front Panel

The SCU front panel houses the following ports and status indicators:

Table 1-2 System Control Unit Front Panel

Part	Description
Power light (green)	Lights when the SCU is powered on.
Error light (amber)	The error light is not yet implemented.

Table 1-2 (Continued) System Control Unit Front Panel

Part	Description
Code light (amber)	The code light is not yet implemented.
Field Generator port	Connects the SCU to the Field Generator cable.
SIU ports	Connects the SIU to the SCU, allowing communication between the system and connected tools.
SIU port status lights	Off - No tool is connected to this port. Amber - A tool is connected to this port, but the port has not been initialized for use. Green - A tool is connected to this port, it has been initialized, and it is ready to be used.

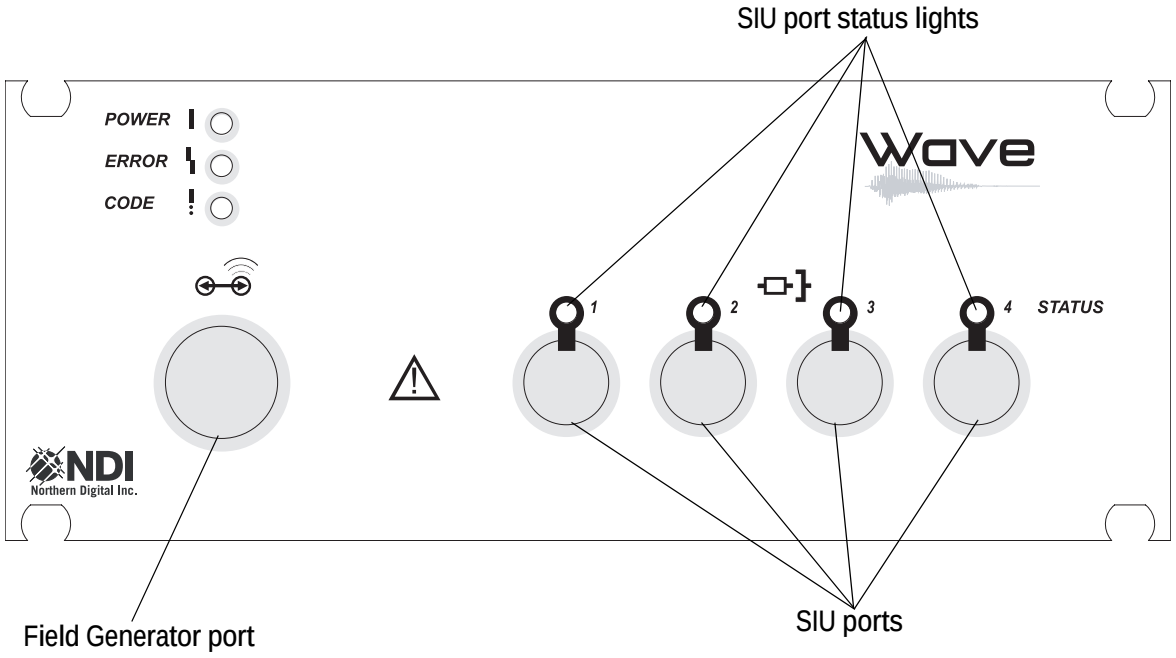

Figure 1-4 System Control Unit Front Panel

SCU Back Panel

The SCU back panel houses the following components:

Table 1-3 System Control Unit Back Panel

Part	Description
Ventilation opening	A fan is installed behind the ventilation opening.
Communications port	A DB9 male serial communications port, used to connect the SCU to the host computer.

Table 1-3 (Continued) System Control Unit Back Panel

Part	Description
Synchronization port	A DB9 female serial communications port, used to synchronize the two SCUs. Also used to synchronize the Wave system with external devices.
SMPTE port	A 3.5 mm jack socket that outputs the SMPTE audio signal, used for temporal synchronization of the microphone audio signal with Wave data.
USB port	not implemented
Power entry module	A sub-assembly that comprises a system power switch, fuse, and power cable connection port.

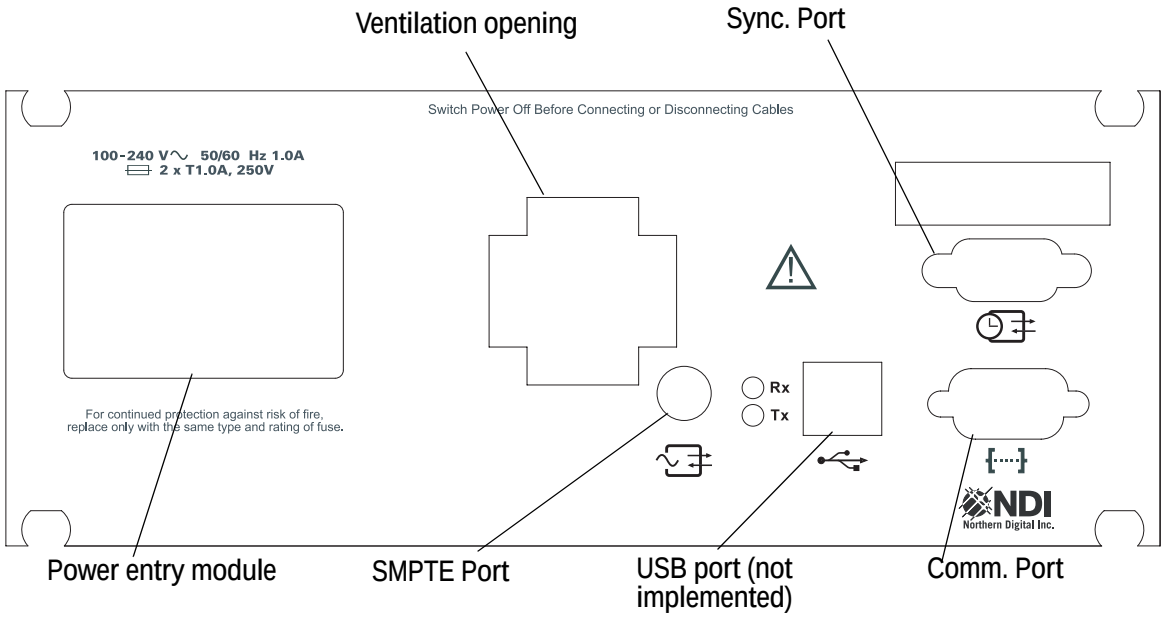

Figure 1-5 System Control Unit Back Panel

Serial Number Label The SCU back panel also incorporates a serial number label that shows the item ID, model, serial number, and manufacture date of the SCU.

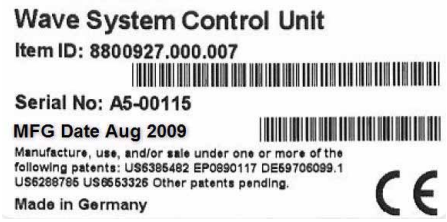

Figure 1-6 System Control Unit Serial Number Label

1.6 Sensor Interface Unit

The SIU is the interface between the sensors and the SCU. The main function of the SIU is to convert the analog signals, produced by the sensors, to digital signals. The digital signals are sent to the SCU for processing. The basic Wave System incorporates four SIU. The extended Wave System incorporates eight SIU.

Table 1-4 Sensor Interface Unit

Part	Description
Tool cable port	Connects the SIU to sensors. This port is a 10-pin circular plastic connector.
SIU connector	Connects the SIU to the SCU.

Figure 1-7 Sensor Interface Unit

1.7 Wave Connector Block Cable Assembly

The connector block cable assembly (Figure 1-8) provides the means to connect the sensors to the system. It connects to the SIU tool cable port and incorporates the connector block, to which the sensors attach.

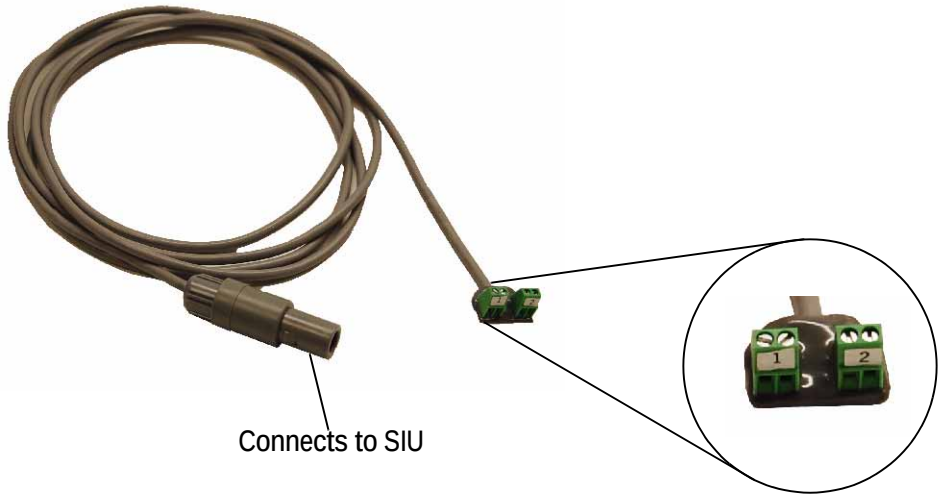

Figure 1-8 Wave Connector Block Cable Assembly

1.8 Disposable Sensors

The Wave System incorporates up to eight (basic system) or sixteen (extended system) single use, disposable, 5D sensors (two per SIU). The sensors are attached to the subject as required. Connection to the SIU is by means of an integral flying lead through the miniature connector block on the Wave connector block cable assembly.

1.9 Reference Sensor

The reference sensor (Figure 1-9) is a 6D sensor that may be attached to, for example, the subject's incisors. It allows for data to be collected with reference to it.

Figure 1-9 Reference Sensor

1.10 Palate Probe

The palate probe (Figure 1-10) is a 6D sensor that is used for palate tracing.

Figure 1-10 Palate Probe

1.11 Field Generator Mounting Arm

The Field Generator Mounting Arm is designed to accurately position the Field Generator. This metal arm incorporates several articulated joints that enable you to position the Field Generator at the desired position and angle. The Field Generator Mounting Arm is used with a general purpose clamp that attaches to a table, counter edge or T-rail

Figure 1-11 Field Generator Mounting Arm and General Purpose Clamp

2 Setting up the Wave System

2.1 Introduction

This section provides information on how to set up the Wave System and get it ready for use.

The Wave System is shipped with:

- Field Generator (page 2)
- System Control Unit (SCU) (1 with basic system, 2 with extended system) (page 4)
- Sensor Interface Unit, (SIU) (4 with basic system, 8 with extended system) (page 7)
- Wave connector block cable assembly 4 (8 with an extended system) (page 7)
- Disposable sensors, single use (16 with basic system, 32 with extended system) (page 8)
- 6D reference sensor (page 8)
- 6D palate probe (optional) (page 9)
- Audio splitter cable, (3.5 mm stereo to two mono)
- Mono audio cable, 3.5 mm
- Mono audio adapter to allow connection to customer pre-amplifier
- Serial communications cable (1 with basic system, 2 with extended system)
- Synchronization cable (extended system, or for synchronization with Optotrak)
- USB to serial adapter (1 with basic system, 2 with extended system, plus 1 for synchronization with Optotrak)
- Screwdriver (for attaching sensors to terminals)
- Field Generator Mounting Arm and general purpose clamp (page 9)
- Application software CD
- Documentation

When unpacking the system, be sure to handle all system components with care. Keep the packaging in good condition; you will need to use it if the system is ever transported.

2.2 Field Generator

To mount the Field Generator, proceed as follows:

1. Choose a location that minimizes interference:
    - If the Wave System is being set up within 10 m of another Wave System, there is a potential for interference when in tracking mode. For more information, contact NDI.
    - Ensure that the Field Generator cable is not wrapped around the Field Generator or looped anywhere along its length.

- The Field Generator should not be in the vicinity of any metal equipment or sources of power within a radius of 1.0 m (with the Field Generator as the centre of this sphere).

2. Place or mount the Field Generator on a rigid support system that can carry the full weight of the Field Generator and the Field Generator cable (2.8 kg). The support system must also be designed to minimize vibrations, as vibrations may introduce measurement errors. The Field Generator may be mounted in two ways (refer to Figure 2-1):

   a) By means of four mounting holes, two on either side of the Field Generator. The holes are M8 tapped, thread pitch 1.25 mm, depth 13 mm.

   b) By means of a mounting point. The mounting point allows you to use an NDI-supplied Field Generator Mounting Arm (P/N 8800728), to position the Field Generator in any direction, in a manner that helps reduce its proximity to metal disturbances. For more information, contact NDI.

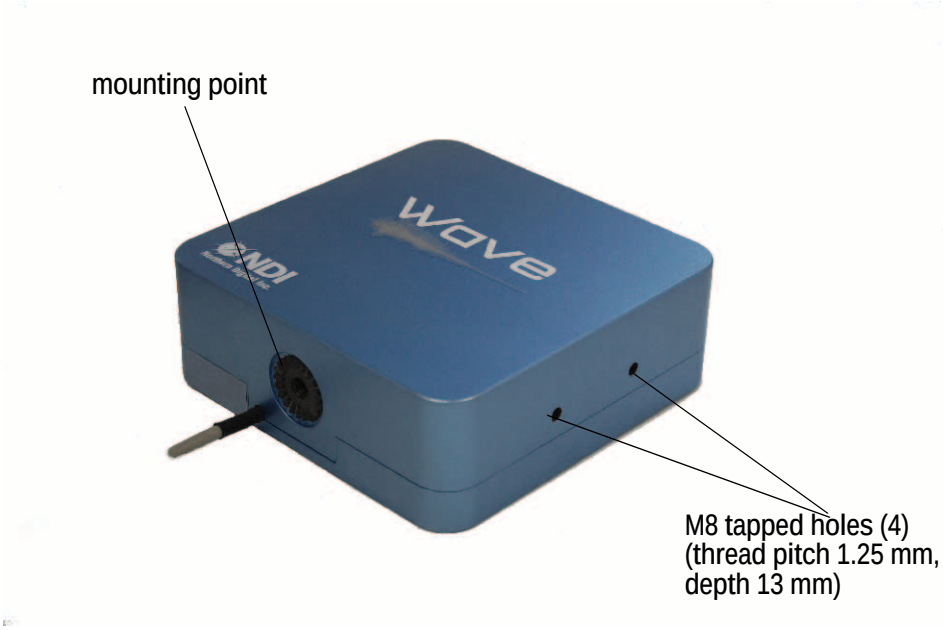

Figure 2-1 Field Generator - Mounting Options

3. Mount the Field Generator so that the measurement volume encompasses the area of interest (area where the sensors will be tracked; refer to Figure 1-2 on page 3).

4. Orient the Field Generator so that the global coordinate system is positioned as shown in Figure 3-4 on page 21.

5. The Field Generator may be bagged or draped to fulfil sterility requirements.

2.3 System Control Unit

1. Position the SCU(s) as follows, appropriate to the system configuration.

Note In this guide the SCUs are designated (1) and (2). SCU (1) is connected to the Field Generator

- **Basic System** - Place the SCU on a flat surface and make sure the ventilation ports are not blocked.
- **Extended System** - Place SCU (1) on a flat surface and place the SCU (2) on top of SCU (1). Make sure the ventilation ports on both units are not blocked.
- **Integrated with Optotrak System** - Place the Optotrak SCU on a flat surface. Place the Wave SCU(s) on top of the Optotrak SCU. Make sure the ventilation ports on all units are not blocked. (For complete information on integrating the Optotrak System with the Wave System, refer to Appendix A.)

2. Make sure that the cable connecting the SCU(s) to the host computer does not come close to other cables in the Wave System, such as the Field Generator cable.

Note The power entry module, located at the back of the SCU, has a switching power supply with universal input voltage of 100 to 240 VAC. As such, the voltage need not be manually changed.

2.4 Sensor Interface Unit

Place each SIU on a flat surface and make sure that each tool cable can reach an SIU, but that tool cables do not lie close to the Field Generator cable.

2.5 Connecting the Components

Read the following cautions before you connect the Wave System components.

Caution! Do not push or pull connectors in constricted areas.

Do not put heavy objects on cable connectors.

Do not leave cable connectors where they can be damaged, particularly on the floor, where they can easily be stepped on.

Pull connections apart by gripping the connector. Do not pull them apart by tugging on the cable as this can damage the connecting cable. Never force a connection or a disconnection.

Note The following instructions assume an extended system. If this is not applicable, ignore references to SCU (2).

For details on integrating the Wave System with an Optotrak Certus or 3D Investigator System, refer to Appendix A.

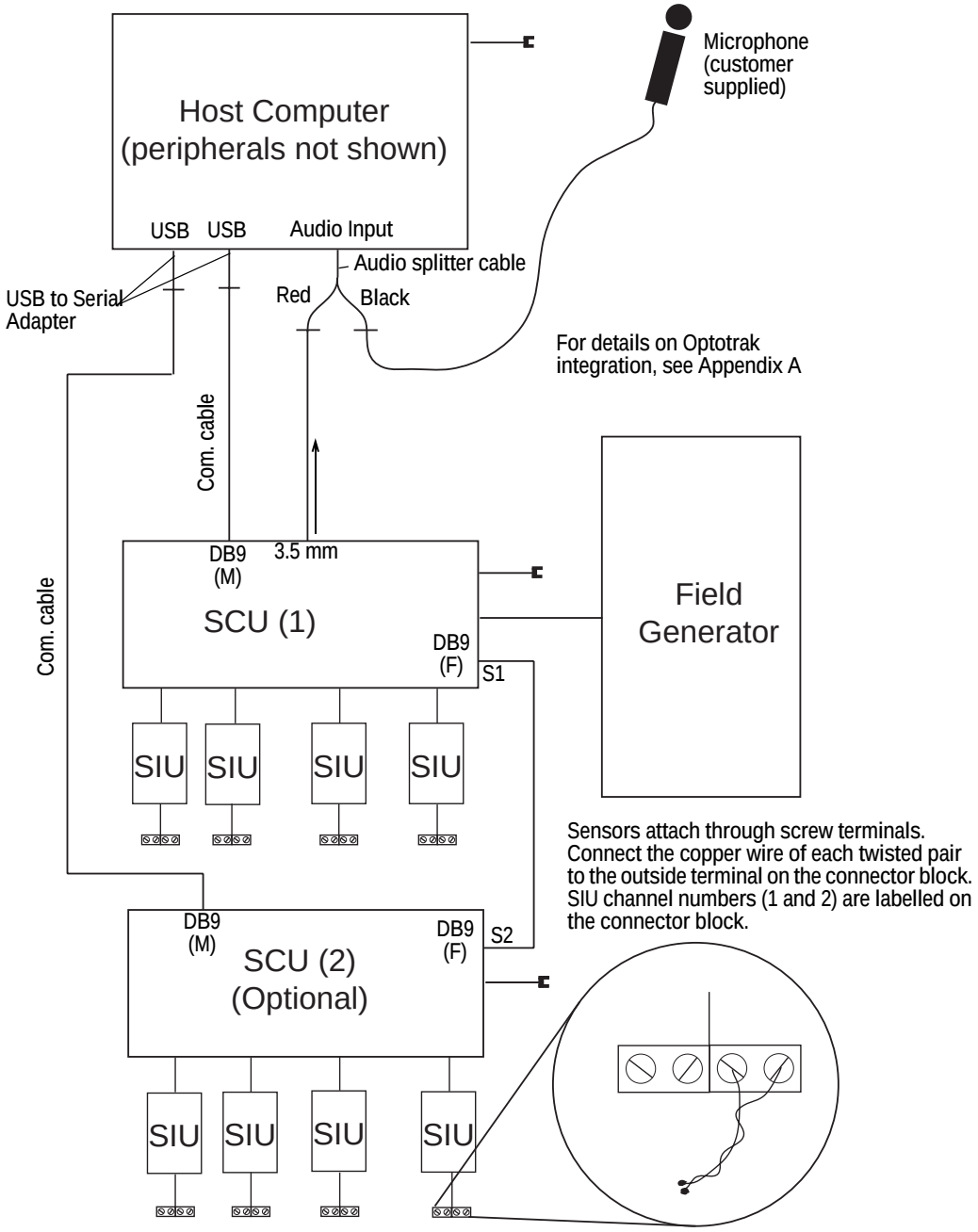

Figure 2-2 Wave System Connection

Connect the Wave System components as follows:

1. Install the host computer and its peripherals in accordance with the manufacturer's instructions.
2. Insert the Field Generator cable connector into the Field Generator port, located on the front of SCU (1).
3. Connect the SCU (1) to SCU (2), using the synchronization cable between the two female DB9 synchronization ports on the back of the SCUs.
4. Insert each SIU connector into one of the SIU ports (located on the front of the SCU).

Note Only sensors and tools supplied by NDI should be used with the Wave System.

5. Connect a microphone to the black 3.5 mm jack socket of the stereo splitter cable. (The microphone is customer supplied.)

Note A mono audio adapter is supplied with the system, to enable the microphone to be connected to a pre-amplifier if required.

6. Connect a mono audio 3.5 mm cable between the 3.5 mm SMPTE socket on SCU (1) and the red 3.5 mm jack socket on the stereo splitter cable.
7. Connect the stereo splitter cable to the stereo microphone input on the host computer.

Note Steps 6 and 7 ensures that the data will export into .tsv format file. If you do not complete steps 9 and 10, only raw data format will be available.

8. **DO NOT** connect the USB to serial adapters to the host computer at this stage. You will be prompted to connect the converters during software installation. Refer to “Software Installation” on page 16.
9. Connect the USB to serial adapters to the SCU(s) with the supplied communication cables.
10. If the system is integrated with a NDI Optotrak System, connect the Wave SCU (1) synchronization cable male DB9 connector to the Optotrak SCU synchronization port  and DB9 female end to the host computer RS-232 port. (For details on connecting the Optotrak System, refer to the documentation delivered with that system.)
11. Plug a power cable into the power entry module on the back of both the SCU.
12. Attach the required number of 5D sensors to the subject and connect each pair of sensor wires to a separate sensor connector block, using the screwdriver provided with the system. Plug each connector block cable assembly into its respective port (located on the front of the SIU).

    Sensors attach through screw terminals. Connect the copper wire of each twisted pair to the outside terminal on the connector block, creating a copper, dark, dark, copper pattern. Sensors can be disconnected and reconnected into any connector block while the system is running (hot-plugging).

Note Consistent connection of sensors ensure that data will always be returned in the same orientation from experiment to experiment.

13. If required, connect the reference sensor to the system as follows:

a) Identify the pair of wires on the reference/probe marked with “1”. Attach this pair of wires to the sensor connector block marked with “1”. Connect the copper wire to the outside terminal of the connector block.

b) Attach the unmarked pair of wires on the reference/probe to the sensor connector block marked with “2”. Connect the copper wire to the outside of the connector block

14. Check that all (5D and 6D) sensor cables are at least 30 mm from the Field Generator cable.

3 Wave System Operation

3.1 Introduction

This section provides information on how to use the Wave System to collect and record position data and synchronised audio for post-hoc speech research analysis. As an option the Wave System can be integrated with the NDI Optotrak System, refer to "Optotrak System Integration" on page 40.

Warnings

Read the following warnings before using the Wave System, to avoid the risk of personal injury.

Do not operate the Field Generator within 200 mm of an installed pacemaker. The magnetic field produced by the Field Generator may interfere with the operation of the pacemaker. This interference may result in personal injury.

Do not use the Wave System if the SCU is connected to a non-approved workstation. If the SCU is not connected to IEC 60950 or IEC 60601 approved workstations, leakage currents may increase beyond safe limits and result in personal injury.

Do not disconnect the Field Generator from the system while it is tracking. Disconnecting the Field Generator while it is tracking may generate arcing, and result in personal injury.

Do not immerse the Wave System in liquids, or allow fluid to enter the equipment in any way. Exposing the Wave System to liquids may result in equipment damage, produce a fire or shock hazard, and result in personal injury.

3.2 Software Installation

To install NDI WaveFront application software, proceed as follows:

1. Insert the CD that was delivered with the system into the CD drive on the host computer.
2. Use Explorer and navigate to the CD and double click on **NDI WaveFront version x.exe** (where x is the software version number).
3. The NDI WaveFront Setup wizard launches. Follow the on-screen instructions. At the prompt, connect the USB to serial adapter(s) to the USB ports on the host computer.
4. When the Setup wizard is complete, the NDI WaveFront application is installed and can be accessed through the  icon placed on the desktop during installation.

3.3 Software Removal

To uninstall NDI WaveFront application software, proceed as follows:

1. Disconnect the USB to serial adapter(s) from the host computer.
2. Open the Windows Control Panel and navigate to “Add or Remove Programs”.

3. Select “NDI WaveFront” and click the “Remove” button. The software will be removed.

Note After the “NDI WaveFront” has been removed, the “Wave Proxy” will still appear to be present in the installed programs list, but it will have been removed.

4. Remove both instances of “Windows Driver Package- FTDI CDM Driver Package” in the same manner as “NDI WaveFront”.
5. Reboot the host computer and make sure all the software has been removed.

3.4 Session Setup

1. Make sure the system is connected as detailed in Section 2.
2. Switch on the host computer and allow it to initialise.
3. Make sure the sensors are placed as required and securely connected to the sensor connector blocks. (Refer to “Connecting the Components” on page 12.)
4. (Optional) Make sure the microphone is connected and correctly positioned.
5. Make sure the subject’s head is located correctly in the measurement volume. (Refer to “Figure 1-2” on page 3.)
6. Switch on SCU (1) and (if applicable) SCU (2).
7. If the system is integrated with an Optotrak System, switch on that system. (For details on integrating the Optotrak System with the Wave System, refer to Appendix A.)
8. On the host computer desktop, double click on the WaveFront  icon. The System Setup prompt appears.
9. Confirm that all SCU, SIU and sensors are connected as required for the experiment. Click “Connect” and wait approximately 20 seconds as the system connects to the host computer.

Note The system will periodically emit a series of “beeps” as it communicates with the host computer.

10. The WaveFront Setup wizard appears. Select one of the following two options:
    - **Load Experiment file** - Navigate to an existing experiment file (.wxp extension) and open it. Continue at step 12
    - **New Experiment** - Sets up a new experiment. The Experiment Setup dialog appears Continue at step 11.
11. In the Experiment Setup dialog (Figure 3-1) configure the following parameters:

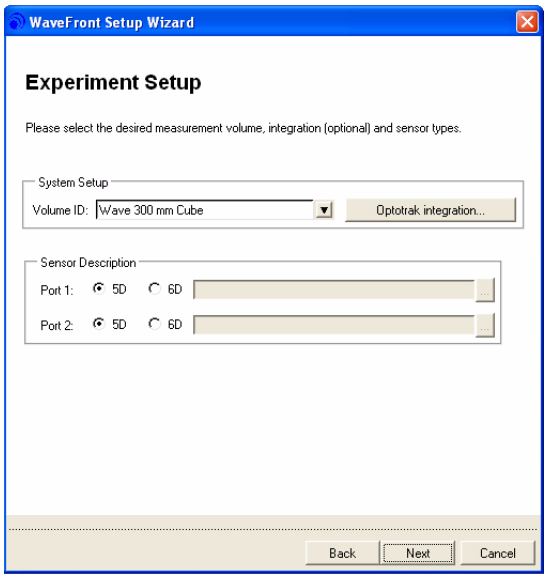

Figure 3-1 Experiment Setup Dialog

a) **Volume ID** - Set the volume option from the following options:

- Wave 300 mm Cube
- Wave 500 mm Cube
- Other 500 mm Cube

Note The “Other” option is reserved for specific applications and is not used with sensors supplied with the Wave System.

If you choose a volume that does match the sensor, the system will not track.

b) **Optotrak integration** - Click this option to open the “Optotrak Integration Setup” dialog. In that dialog, set the “Trigger Port” to match the RS-232 port that the Optotrak is connected to. Refer to "Setting up the Wave System" on page 10. The “Optotrak Integration” option is set to “Disabled” as default. To integrate the Optotrak System with the Wave System, refer to Appendix A.

c) **Sensor Description** - Select “5D” or “6D” as appropriate for the sensors on each port. Selecting “6D” activates the associated text box. Select the associated ellipsis and navigate to the appropriate SROM file for that sensor. (The reference sensor and palate probe SROM files are located in the program installation directory.)

The Port # list will display the number of Ports that have sensors attached. Typically this will be four ports for a basic system and eight ports for an extended system.

12. Click “Next”. The Session Setup dialog appears.
13. Type a Session Name and select the directory where the experiment data will be stored. The associated Data Location field will update to reflect the Session Name and directory settings. Click “Finish” to complete the setup procedure.

Note Do not alter the experiment parameters once they have been set. If the parameters are altered while an experiment is running the system prompts to save and then exits.

3.5 SMPTE Signal Test

It is important that you make sure that the SMPTE signal is not noisy or distorted. If you record data with a noisy or distorted SMPTE signal, the temporal synchronization between position and audio data may be incorrect or lost. Noisy or distorted SMPTE signals are caused by the microphone settings on the host computer, that records both the audio and SMPTE signal.

Before you start research data collection, perform a data collection for test purposes as detailed below and view the .wav file that will be placed in the **rawdata** directory of the test collection. It should look similar to Figure 3-2. If it has additional spikes or noise, you must correct it before you collect research data. Since the microphone settings vary on each host computer, it is not possible to identify which settings should be used. Refer to the documentation applicable to your host computer.

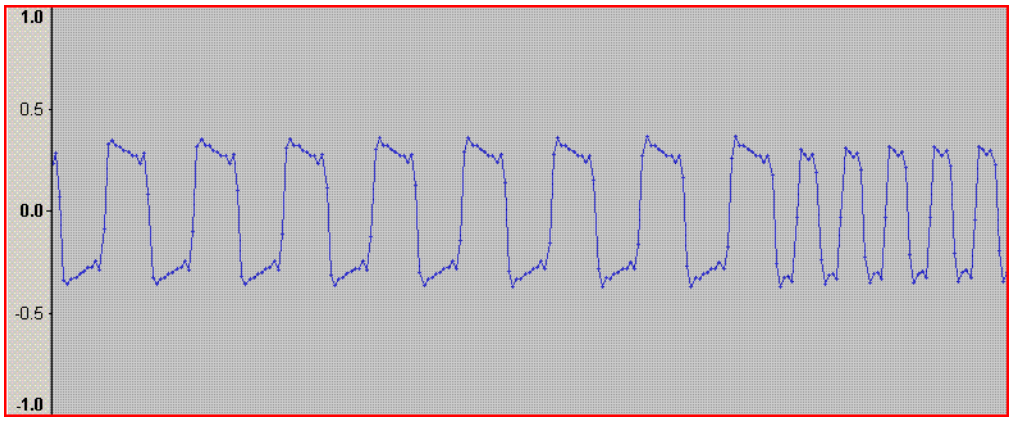

Figure 3-2 SMPTE Signal Example

3.6 Data Collection

Select “Finish” in Session Setup to activate data collection. Position data is collected continuously from each active sensor; it is displayed in real time in the spatial view, refer to “Figure 3-4” on page 21. The data is stored at the location specified during Session Setup, see page 17 (The data is not stored until the Record button is pressed. Audio will also be recorded and synchronised with the position data.)

Note Before you begin research data collection, make sure you have tested the SMPTE signal as detailed in "SMPTE Signal Test" on page 19.

For details on data format and retrieval see “Data Retrieval” on page 25.

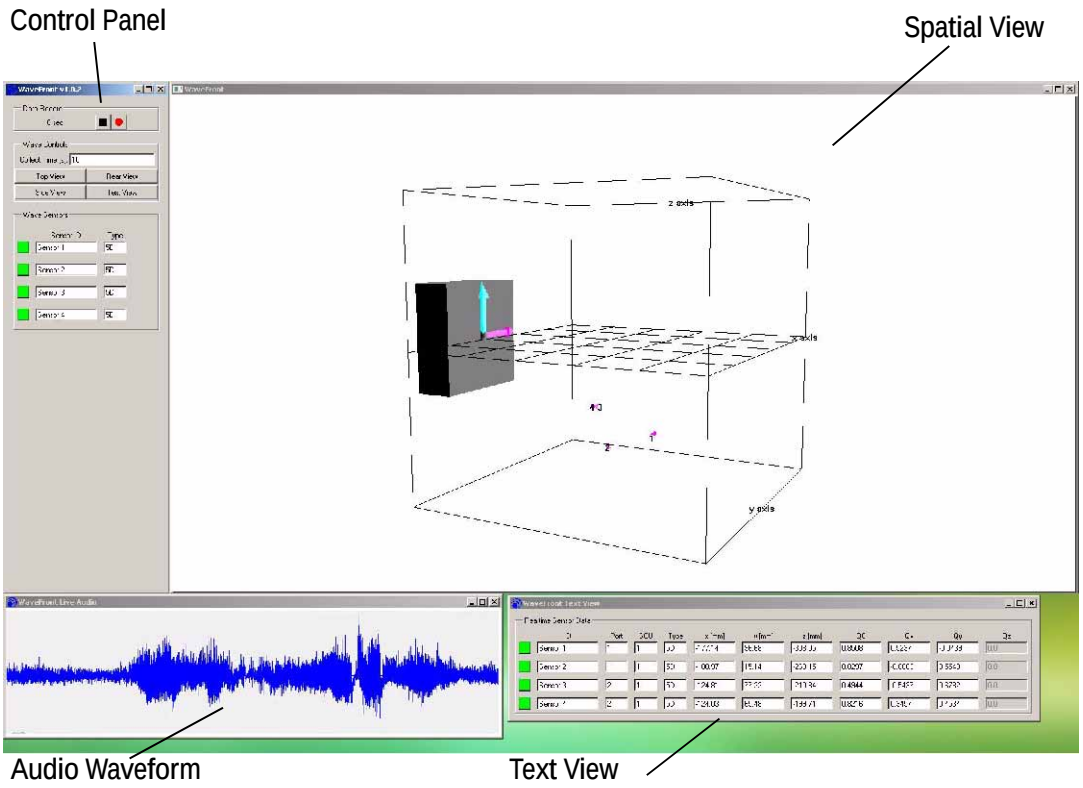

Figure 3-3 Data Collection View

The data collection view comprises three main panels:

- **Spatial View** - displays a real time spatial view of the volume, Field Generator and all the sensors.
- **Control Panel** - provides the means to monitor and control the following:
  - Data collection time
  - Recording controls
  - Data views
  - Sensor ID and status
- **Audio Waveform** - displays the audio waveform in real time and allows you to detect if the microphone is recording audio as expected. (The audio signal is only displayed when the Record button is pressed.)
- **Text View** - The text view displays real time sensor data and is detailed on page 24.

Each component of the view is described in detail in the following sections.

Spatial View

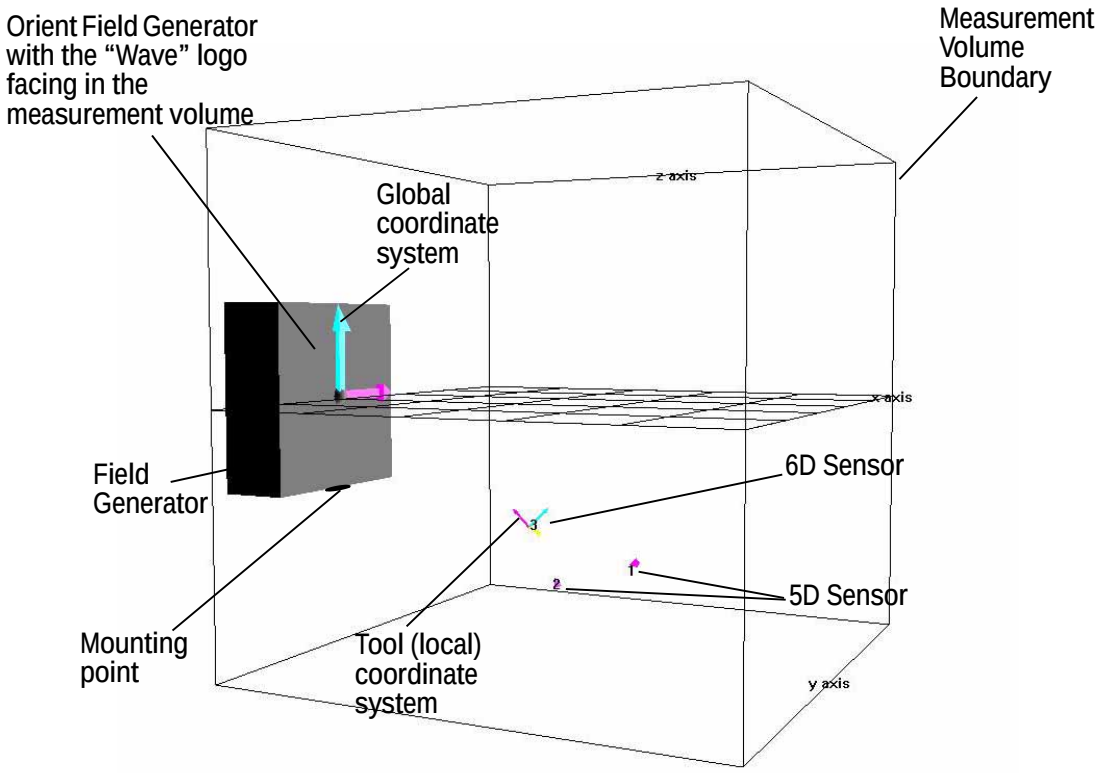

Figure 3-4 Spatial View

Note The spatial view in Figure 3-4 is shown as inverse from the actual application for clarity.

Use the spatial view to confirm the status and relative positions of the sensors in real time. The spatial view displays the volume boundaries in relation to the Field Generator. Each connected sensor is shown in real time as follows

- **5D Sensors** - are represented by pyramid shaped icons, where the pyramid point represents the “normals” direction.
- **6D Sensors (palate probe and reference sensor)** - are represented by a local (tool) coordinate system axis of:

  x = red
  y = green
  z = blue

Refer to Figure 3-5 for a visual representation of the reference sensor local coordinate system.

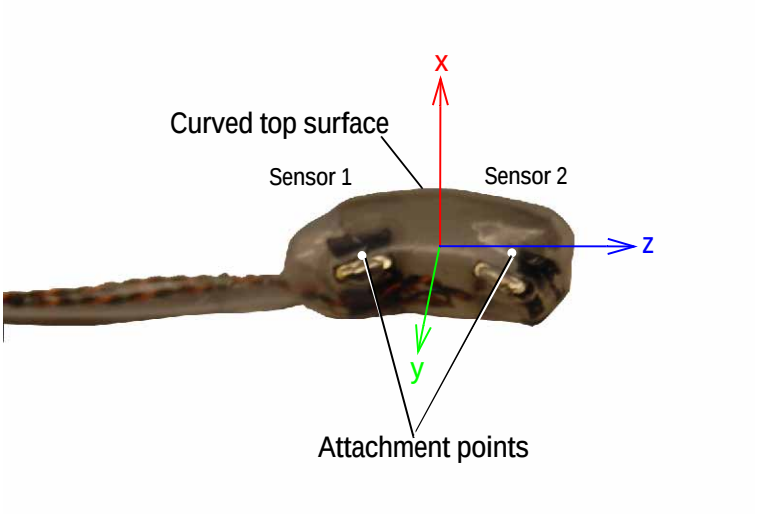

Figure 3-5 Reference Sensor Local Coordinate System

The sensor ID is displayed next to each sensor. A broken sensor will be blank. Manipulate the spatial view as follows:

- **Zoom** - Set the zoom level by either:

  Select the left and right mouse buttons simultaneously and move the mouse

  or

  Select the middle (scroll) mouse button and move the mouse.

- **Rotate** - To rotate the view, select the right mouse button and move the mouse.
- **Preset Views** - Set the view as required with the buttons on the Control Panel to Top, Rear or Side View. Refer to Figure 3-6.

Control Panel

Use the Control Panel (Figure 3-6) to set the options detailed below. Example A shows the control panel with 5D sensors only. Example B shows the control panel with both 5D and 6D sensors.

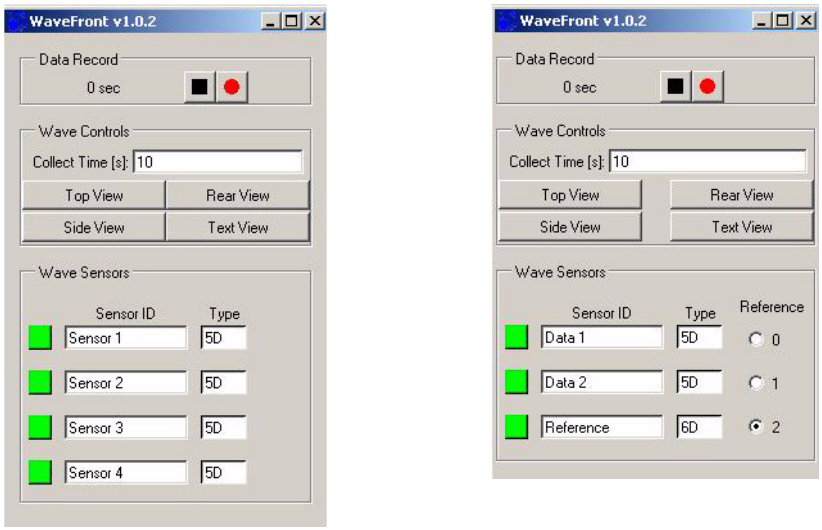

Figure 3-6 Control Panel

Data Record

Set the “Record” and “Stop” buttons as required to start and stop recording. Alternatively select the keys as follows

F4 to start recording

F5 to stop recording.

The associated time increments as you record and indicates the total recorded time.

Wave Controls

Set the “Collect Time” in seconds to the amount of time data is to be collected. The value must be more than 1 second with no upper limit.

Set the views as required. Selecting “Text View” activates the Text View panel, Figure 3-7.

Wave Sensors

The Wave Sensors panel displays the status, Sensor ID and Type of sensor as follows:

- **Status** -
  - **Green** - tracking
  - **Red** - not tracking
  - **Black** - not connected
- **Sensor ID** - Double click in this field to rename the Sensor as appropriate for the experiment. For example “Tongue 1”. Any change here will also appear in the text view and in the header of the data file, but not in the spatial view.
- **Type** - Shows either “5D” or “6D” as appropriate.

Note The control panel layout reflects whether or not 6D sensors are used in the experiment. Figure 3-6 (A) shows the layout when only 5D sensors are used. Figure 3-6 (B) shows the layout when 6D sensors are used. In the latter case an additional column provides the option to select a 6D sensor to use as a reference for all other measurements.

Audio Waveform

The audio waveform is an auto-scaled representation of the microphone input. It displays when recording is initiated on the Control Panel.

Text View

To display the Text View, select “Text View” in the Control Panel.

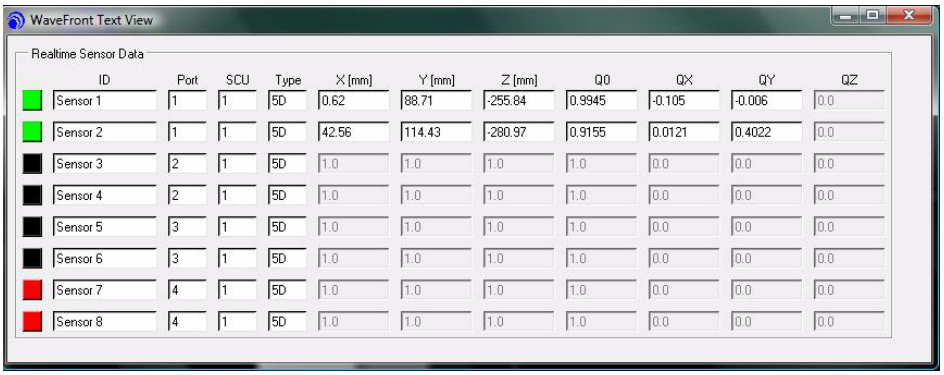

Figure 3-7 Text View

The Text View displays real time sensor data as follows:

- Sensor status
- Sensor ID
- The port and SCU (1 is SCU (1) and 2 is SCU (2)) to which the sensor is connected
- Sensor type
- Transformation data with rotation in quaternion format (x, y, z, Q0, Qx, Qy Qz)

3.7 Exit WaveFront and Save Experiment Data

To exit WaveFront click on the red “X” at the top right of either the Control Panel or the Spatial View. At the prompt enter a name and location for the experiment file (.exp). The experiment files saves the information as follows:

- Recording length
- Sensor IDs
- Volume ID
- Ports used

- Default recording directory
- SROM files

3.8 Data Retrieval

Collection data is stored at the location specified in “Session Setup” on page 17. The data is stored in the following formats:

- **.raw** - unformatted sensor position data files. This file is not meaningful to the system user, but may be requested by NDI technical support to aid in troubleshooting.
- **.wav** - raw audio file, consisting of two channels; one for the microphone signal and one for the SMPTE signal. (You can use this file to check the level of both microphone and SMPTE signals and make necessary adjustments of the stereo microphone input sensitivity, on the host computer. Refer to “SMPTE Signal Test” on page 19.) This file may be requested by NDI technical support to aid in troubleshooting.
- ***_sync.wav** - plain mono microphone audio signal, with SMPTE data removed.
- ***_sync.tsv** - Tab Separated Values data formatted to one frame of data per line, with the tab character as the delimiter. It also indicates the corresponding audio file sample number per each position data frame.

  If the SCU (1) audio signal is not provided to the host computer and the subsequent extraction of frame numbers from SMPTE signal fails, post processed files are not produced. Extraction and production of the _sync.tsv file takes approximately 50% of the data collection time. For example a data collection of 1 minute will take approximately 30 seconds to produce the _sync.tsv file.

The _sync.wav and _sync.tsv files are post processed files. The _sync.tsv file is formatted as follows:

- **Time** - the record time in seconds. This value is useful when searching for corresponding data in the _sync.wav file
- **MeasId** - the measurement number
- **WavId** - the Wave System frame number
- **Sensor n Id** - the sensor Id where n is the sensor name as set in the control panel
- **Sensor n Status** - the sensor port status where n is the sensor name as set in the control panel
- **X,Y,Z** - sensor position
- **Q0, Qx, Qy, Qz** - sensor rotation, in quaternion format

Note — In tsv files the Tab character key is used as the delimiter in the data.

4 Maintenance

User maintenance of the Wave System is limited to:

- cleaning
- replacing the SCU fuses

Warning! Apart from replacing the SCU fuses, there are no user serviceable parts in the Wave System. All servicing must be done by NDI. Unauthorised servicing may result in personal injury.

4.1 Cleaning

Warning! Do not immerse the Wave System in liquids, or allow fluid to enter the equipment in any way. Exposing the Wave System to liquids may result in equipment damage, produce a fire or shock hazard, and result in personal injury.

Switch off power to the system before cleaning it. Failure to do so may result in personal injury.

Caution! Do not use aerosol sprays near the equipment as these sprays can damage circuitry.

Do not use any solvent to clean the Wave System. Solvents may damage the finish and remove lettering.

Do not autoclave any Wave System component. Autoclaving may damage the system.

To clean the Wave System proceed as follows:

1. Wipe off dust with a dry, soft cloth.
2. Remove dirt or finger marks using a damp cloth and dry immediately with a clean cloth.

4.2 Replacing the System Control Unit Fuses

Warning! Do not change either fuse without first disconnecting the SCU from its power source. Failure to disconnect the system may result in personal injury.

1. Disconnect the SCU from the power supply.
2. Release the two fuse holder tabs simultaneously with the aid of a tool (such as a screwdriver), and pull upwards. The tabs are marked with arrows for identification.

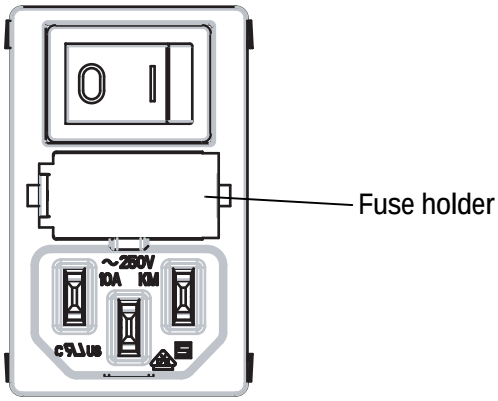

Figure 4-1 System Control Unit Power Entry Module

3. Remove the fuses from the fuse drawer and verify the filament is intact.
4. Replace the fuse(s) as required, with the correct type and rating (1.00 A, 250 V, Time Delay, 5 mm x 20 mm).
5. Press the fuse holder downwards, ensuring that it latches correctly.

5 Approvals and Classifications

5.1 Electrical Safety Approvals

Table 5-1 Electrical Safety Approvals

Standard	Title
UL 61010-1, 2nd Edition (2004)	Electrical Equipment, for Measurement, Control and Laboratory Use, Part 1: General requirements for safety
CAN/CSA C22.2 No. 61010-1 (R2004)	Electrical Equipment, for Measurement, Control and Laboratory Use, Part 1: General requirements for safety
IEC 61010-1, 2nd Edition (2001)	Electrical Equipment, for Measurement, Control and Laboratory Use

5.2 EMC/EMI Approvals

Table 5-2 EMC/EMI Approvals

Standard	Title
FCC CFR47, Part 15, Subpart B	Class A, Unintentional Radiators
CISPR11/EN55011	Class A, Industrial, Scientific and Medical Equipment
EN61326-1:2006	Electrical Equipment, for Measurement, Control and Laboratory Use - Collateral standard: Electromagnetic Compatibility

5.3 Classifications

Table 5-3 Classifications

Type	Classification
Electric Shock Protection	Class I - protectively earthed with power from supply mains.
Degree of Protection from Electric Shock	Type BF equipment. **Note: The system provides this level of protection, but the standard that the system is tested under does not test for this**
Degree of Protection Against Ingress of Liquids	Ordinary equipment.
Method of Sterilization or Disinfection	Not suitable for sterilization.
Flammable Atmosphere	Not suitable for use in the presence of a flammable anaesthetic mixture with air, oxygen, or nitrous oxide.
Mode of Operation	Continuous.

6 Electromagnetic Compatibility

6.1 ESD Precautionary Measures

Care should be taken to mitigate the production of electrostatic charges. These measures can include, but are not limited to, air conditioning, humidification, conductive floor coverings, attire, etc.

You should discharge any built-up static before connecting or disconnecting any cables marked with the electrostatic discharge (ESD) warning symbol shown here. To discharge any built up static, touch either the SCU metal enclosure or a large metallic object.

Avoid touching accessible pins on connectors marked with the ESD symbol. You should also use an anti-static mat and bond yourself to either the SCU metal enclosure or to earth by means of an anti-static wrist strap.

All staff using the Wave System should receive instructions on the ESD warning symbol and training in basic ESD precautionary procedures. This training should include an introduction to the physics of ESD, the voltage levels that can occur in normal circumstances, and the damage caused to electronic components on contact with an electrostatically charged operator. In addition, users should be provided with an explanation of the methods used to prevent the build-up of electrostatic charges.

6.2 Cables, Transducers and Accessories

The following table shows the cables, transducers and accessories that may be used with the Wave System and still maintain compliance to the emissions and immunity requirements of EN61326-1:2006

Table 6-1 Cables, Transducers and Accessories

Cable Name	NDI P/N	Type	Shielded	Notes
Host Cable	120056	RS-232 Cable, F/F	No	The SIU and Field Generator cables are attached to the respective component and hence the NDI P/N refers to the component part number, not the cable part number.
SIU Cable	8700555.000.002	-	N/A	
Field Generator Cable	610315	-	N/A	
Power Cord, AC	7500010	3- Conductor Medical Grade	No	

Do not use cables, transducers or accessories other than those listed in the table above, with the exception of those sold by NDI or by NDI-authorized manufacturers. To do so may result in increased emissions and/or decreased immunity of the Wave System.

6.3 Guidance and Manufacturer's Declaration - Electromagnetic Emissions

The Wave System is intended for use in the electromagnetic environment listed below. The customer or the user of the Wave System should assure that it is used in such an environment.

Table 6-2 Manufacturer's Declaration for Electromagnetic Emissions

Emissions Test	Compliance	Electromagnetic Environment Guidance
Radio Frequency (RF) emissions CISPR11	Group 1	The Wave System uses RF energy only for its internal function. Therefore, its RF emissions are very low and are not likely to cause any interference in nearby electronic equipment.
RF emissions CISPR11	Class A	The Wave System is suitable for use in all institutional establishments, and those directly connected to the public low-voltage power supply network that supplies power to buildings.
Harmonic emissions IEC61000-3-2	Class A	
Voltage fluctuations/flicker emissions IEC61000-3-3	Complies	

Warnings

Do not use the Wave System in the presence of other magnetic fields. To do so may lead to misleading or inaccurate transformations and possible personal injury.

Do not expose sensors to a high magnetic field, such as a Magnetic Resonance Imaging Machine, as they may become magnetized. Tracking with a magnetized sensor may result in incorrect transformations and possible personal injury.

6.4 Guidance and Manufacturer's Declaration - Electromagnetic Immunity

The Wave System is intended for use in the electromagnetic environment listed below. The customer and/or the user of the Wave System should ensure that it is used in such an environment.

Table 6-3 Electromagnetic Immunity

Immunity Test	IEC 61326 Test Level	Compliance Level	Electromagnetic Environment-Guidance
Electrostatic discharge (ESD)IEC 61000-4-2	±6kV contact ±8kV air	±6kV contact ±8kV air	Observe precautions when connecting or disconnecting cables at ports identified with the ESD warning symbol.
Electrical Fast Transient (EFT)/burst IEC 61000-4-4	±2kV for power supply lines ±1kV for I/O lines	±2kV for power supply lines ±1kV for I/O lines	
Surge IEC 61000-4-5	±1kV differential mode	±1kV differential mode	
	±2kV common mode	±2kV common mode	
	< 5% U_t for 0.5-cycle	< 5% U_t for 0.5-cycle	
Dips / Interruptions /Variations on power supply input IEC 61000-4-11	40% U_t for 5-cycles	40% U_t for 5-cycles	
	70% U_t for 25-cycles	70% U_t for 25-cycles	
	<5% U_t for 5-sec	<5% U_t for 5-sec	
Immunity Test	IEC 61326 Test Level	Compliance Level	Electromagnetic Environment-Guidance
Power frequency (50/60Hz) magnetic field IEC 61000-4-8	3A/m	3A/m	Ensure the ambient magnetic fields are low enough not to interfere with the operation of the Wave System. Portable and mobile RF communications equipment should be used no closer to any part of the Wave System, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter.

Table 6-3 Electromagnetic Immunity

Conducted RF IEC 61000-4-6	3Vrms 150 kHZ to 80 MHz	3Vrms 150 kHZ to 80 MHz	Recommended separation distance: $d = \left(\frac{3.5}{3}\right)\sqrt{P}$
Radiated RF IEC 61000-4-3	3 V/m 80 MHz to 2.5 GHz	3 V/m 200 MHz to 2.5 GHz 1 V/m 80 MHz to 200 MHz	$d = \left(\frac{3.5}{3}\right)\sqrt{P}$ 80 MHz to 800 MHz $d = \left(\frac{7}{3}\right)\sqrt{P}$ 800 MHz to 2.5 GHz where 'P' is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer and 'd' is the recommended separation distance in meters. Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey* should be less than the compliance level in each frequency range.** Interference may occur in the vicinity of equipment marked with the following symbol: 

* Field strengths from fixed transmitters, such as base stations for radio, cellular/cordless telephones, land mobile radios, amateur radio, AM and FM radio broadcast and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location in which the Wave System is used exceeds the applicable RF compliance level above, the Wave System should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the Wave System.

** Over the frequency range of 150 kHz to 80 MHz, field strengths should be less than 3V/m.

Note
1. U_t is the AC mains voltage prior to the application of the test level.
2. These guidelines may not apply to all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.
3. At 80 MHz and 800 MHz, the higher frequency range applies.

6.5 Recommended Separation Distances

The Wave System is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The customer and/or the user of the Wave System can help prevent electromagnetic interference by maintaining a minimum distance between portable and mobile RF

communications equipment (transmitters) and the Wave System as recommended below, according to the maximum output power of the communications equipment.

Table 6-4 Separation Distance - Communications Equipment and Wave System

Rated maximum output power of transmitter (watts)	Separation distance according to frequency of transmitter (meters)		
	150 kHz to 80 MHz d = (3.5 / 3) sqrt (P)	80 MHz to 800 MHz d = (3.5 / 3) sqrt (P)	800 MHz to 2.5 GHz d = (7 / 3) sqrt (P)
0.01	0.117 m	0.117 m	0.233 m
0.1	0.369 m	0.369 m	0.737 m
1.0	1.17 m	1.17 m	2.33 m
10	3.69 m	3.69 m	7.38 m
100	11.67 m	11.67 m	23.33 m

For transmitters rated at a maximum output power not listed above, the recommended separation distance d in metres (m) can be estimated using the equation applicable to the frequency of the transmitter, where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer.

Note
1. At 80 MHz and 800 MHz, the higher frequency range applies.
2. These guidelines may not apply to all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.

7 Technical Specifications

This section provides information on the technical specification of the system components.

7.1 Field Generator

Table 7-1 Field Generator Specifications

Dimensions (height x width x depth)	200 mm x 200 mm x 70 mm
Weight	2.8 kg

Table 7-2 Field Generator Operating Environmental Conditions

Atmospheric Pressure	70 to 106 kPa
Relative Humidity	30% to 75%
Temperature	+10 to +30 ^{o}C

Table 7-3 Field Generator Transportation and Storage Conditions

Atmospheric Pressure	50 to 106 kPa
Relative Humidity	10% to 90% non-condensing
Temperature	–10 to +50 ^{o}C

7.2 System Control Unit

Table 7-4 System Control Unit Specifications

Dimensions (height x width x depth)	88 mm x 235 mm x 295 mm
Weight	3.4 kg
Host Interface	RS-232
Maximum Data Rate	230400 baud
Mains Power: AC Input Requirements	100 -240 V ~ (Universal input) 50/60 Hz 1.0 A
Fuses	2 x T1.00, 250 V (time-delay, 5 mm x 20 mm 1.00 A, 250 V)
Maximum Number of Sensor Interface Units	Four

Table 7-5 System Control Unit Operating Environmental Conditions

Atmospheric Pressure	70 to 106 kPa
Relative Humidity	30% to 75%
Temperature	+10 to +30 ^{o}C

Table 7-6 System Control Unit Transportation and Storage Conditions

Atmospheric Pressure	50 to 106 kPa
Relative Humidity	10% to 90% non-condensing
Temperature	–10 to +50 ^{o}C

7.3 Sensor Interface Unit

Table 7-7 Sensor Interface Unit Specifications

Dimensions (height x width x depth)	32 mm x 50 mm x 90 mm
Weight	0.250 kg
Maximum Number of Sensors	Two

Table 7-8 Sensor Interface Unit Operating Environmental Conditions

Atmospheric Pressure	70 to 106 kPa
Relative Humidity	30% to 75%
Temperature	+10 to +30 ^{o}C

Table 7-9 Sensor Interface Unit Transportation and Storage Conditions

Atmospheric Pressure	50 to 106 kPa
Relative Humidity	10% to 90% non-condensing
Temperature	–10 to +50 ^{o}C

8 Equipment Symbols

The following table explains the symbols found on Wave System hardware:

Table 8-1 Equipment Symbols

Symbol	Meaning	Location
	Warning (to avoid personal injury, consult accompanying documentation)	SCU, SIU
	Power On	SCU (Switch)
	Power Off	SCU (Switch)
	Fuse	SCU
	Alternating current	SCU
	RS-232 serial communication port	SCU
	Field Generator cable port	SCU
	Sensor Interface Unit cable port	SCU, SIU
	External Synchronization port	SCU
	SMPTE port	SCU
	Tool cable port	SCU, SIU
	Type BF equipment	SCU

9 Declaration of Conformity

EC DECLARATION OF CONFORMITY

Manufacturer: NDI Europe GmbH
Address: Fritz-Reichle-Ring 2
D-78315 Radolfzell
Germany

Equipment Type: Electromagnetic Spatial Measurement System
Trade Name: Wave®

We, NDI, hereby declare that the product listed above adheres to the European Directives below and is in conformity with the Standards listed.

EEC Directive(s):

73/23/EEC - Low Voltage Directive (LVD)
2004/108/EC, Electromagnetic Compatibility Directive (EMC)

Safety: **Standard**
ANSI/UL61010-1 2nd Ed. 2004
CAN/CSA C22.2 No 61010-1:2004
IEC 61010-1:2001

EMC:

CISPR 11:2003 / EN55011:1998 + A1:1999 + A2:2002 Class A, FCC Part 15 Class A
EN61326-1:2006

EN 61000-3-2	2000:	Harmonic Current Emissions
EN 61000-3-3	2002:	Voltage Fluctuations & Flicker
EN 61000-4-2	2001:	ESD Immunity
EN 61000-4-3	2002:	Electric Field Immunity (controlled environment)
EN 61000-4-4	2004:	EFT/Burst Immunity
EN 61000-4-5	2001:	Surge Immunity
EN 61000-4-6	2003:	Conducted Immunity
EN 61000-4-8	1993 + A1:2000:	Magnetic Field Immunity
EN 61000-4-11	2004:	Dips, Interruptions, & Variations Immunity

Dated at Waterloo, Ontario, Canada this 31st day of July 2009.

NORTHERN DIGITAL INC.
per:

Jamie Fraser
President & CEO

FM-10134 Rev 001

Appendix A Optotrak System Integration

A.1 Introduction

This appendix provides details on integrating the Wave System with either an Optotrak Certus or a 3D Investigator System.

Note In this appendix, the term “Optotrak System” will be used throughout to refer to both the “Optotrak Certus System” and “3D Investigator System”.

The information provided in this appendix assumes a thorough understanding of how to use the Optotrak System and its accessories, including First Principles. For further information, refer to the documentation that was delivered with the Optotrak System.

Integrating the two systems places them into the same coordinate system and allows the Optotrak System to report in the Wave System coordinate system. At the same time, it allows the 3D, 6D or analog data from the Optotrak to be temporally synchronized with sensor position and orientation data from the Wave System.

The host computer requires an extra USB or regular RS-232 port to those detailed in "Host Computer Requirements" on page 2. This additional port is required for the external trigger to the Optotrak SCU.

A.2 Integration Setup

Components

Additional components are required to integrate the Optotrak System with the Wave System. The components are as follows:

- **Wave Reference Rigid Body** - Attached to the Field Generator and allows the Optotrak System to report in the Wave System coordinate system.
- **Synchronization Cable -** Interconnects the Optotrak and Wave System units and allows the synchronized start of data collection on both systems and frame by frame synchronization.

The components listed above are in addition to the standard Optotrak System and Wave System components. For standard Optotrak System components, refer to the documentation delivered with the system. For standard Wave System components, refer to page 10 of this guide.

Procedure

To integrate the Optotrak System with the Wave System, follow the procedure detailed below:

Figure A-1 Wave reference Rigid Body Attachment

1. Place the Optotrak SCU on a flat surface. Place the Wave SCU(s) on top of the Optotrak SCU. Make sure the ventilation ports on all units are not blocked.
2. Make sure that both the Wave System and Optotrak System are set up as required. Do not turn any system units on at this time. For Wave System set up instructions, refer to "Setting up the Wave System" on page 10. For Optotrak set up instructions, refer to the documentation that was delivered with the Optotrak System.

Note Make sure that the distance between the Optotrak markers (and associated wires) and Wave sensors, is at least 30 mm.

3. Interconnect the Optotrak System and Wave System using the Synchronization Cable as shown in Figure A-2. (If the Wave System incorporates only one SCU, there will be a connector on the Synchronization Cable that is not used.)
4. Connect the Wave reference rigid body RJ45 connectors into a Marker Strober.
5. Switch on the Optotrak System SCU and the Wave System SCUs and the associated host computers and powered peripherals. Allow both systems to initialise.

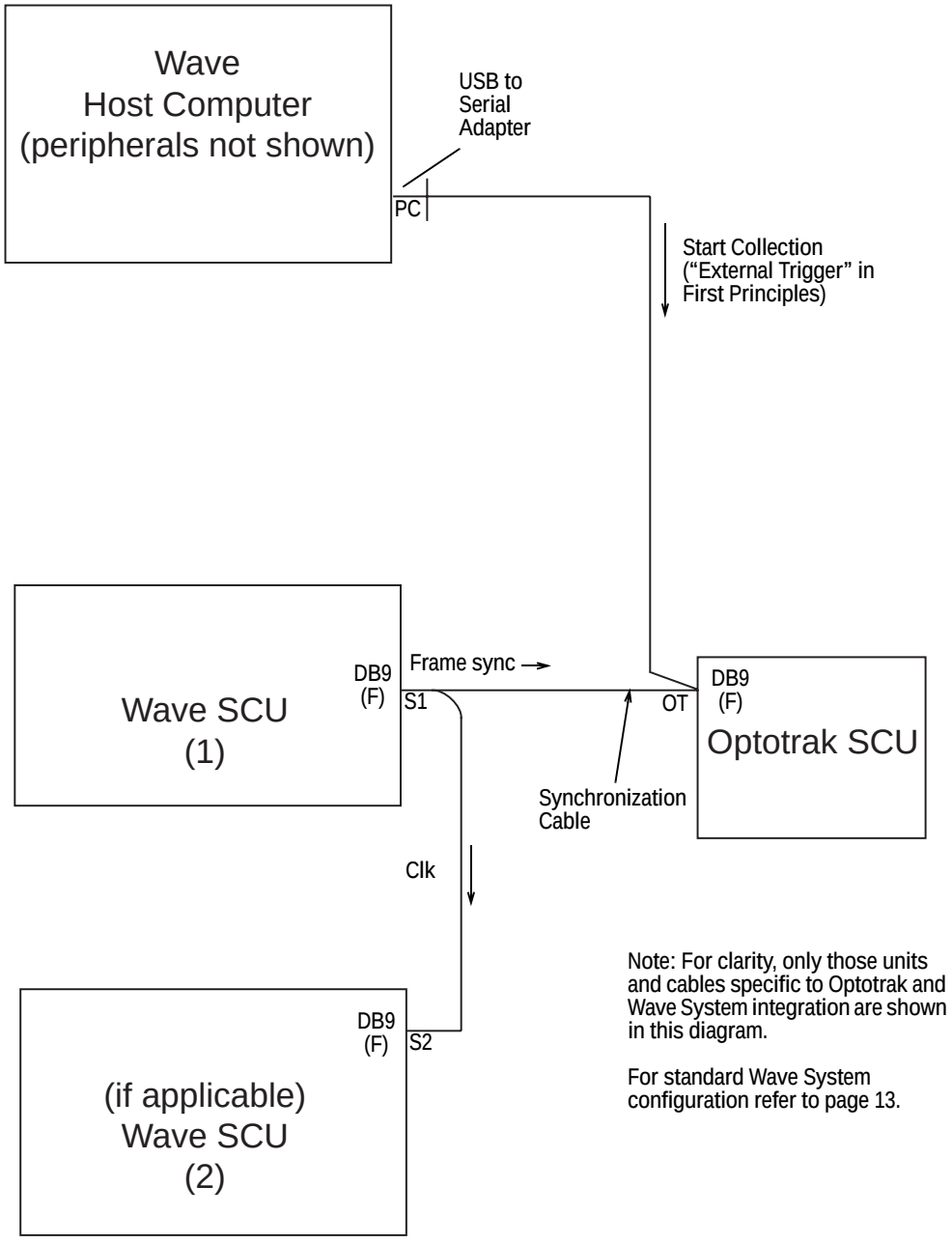

Figure A-2 Optotrak System Integration

A.3 Data Collection

To collect synchronized data from integrated systems, follow the procedure detailed below:

Note Make sure that the First Principles version is 1.1.10 or later. To check the version number, in First Principles, select Help>About. The latest version of First Principles is available for download at the NDI Support Site at: http://support.ndigital.com

1. In First Principles:
   a) In addition to the Optotrak experiment configuration, add the Wave reference rigid body .rig file (located WaveFront application installation directory).
   b) Change the Frame of Reference for all the experiment markers and rigid bodies to the WaveRef rigid body. (This ensures that they will all be reported relative to that rigid body, and therefore in the Wave coordinate system.)
   c) Two levels of synchronization are available between the Optotrak System and the Wave System:
      - **Start Collection and Frame synchronization** - This option forces the Optotrak System to match the frame frequency of the Wave System. In First Principles:
        - Set Frame Frequency to 100 Hz in the experiment
        - Set External Trigger, Automatic Re-arm and External Clock (in the Collection>Properties... menu)
      - **Start Collection Synchronization only** - This option allows the Optotrak System to run at frame rates higher than the Wave System (100 Hz), while still being synchronized at the beginning of collections. In First Principles:
        - Set Frame Frequency as required for the experiment
        - Set External Trigger and Automatic Re-arm (in the Collection>Properties... menu)
2. Make sure that both WaveFront and First Principles have their collection time set to the same value.
3. Start data collection as detailed in "Data Collection" on page 19. The Wave System will trigger First Principles to initiate the Optotrak System to record synchronized data.