FOMRI™ II Dual Channel MRI Microphone System

USER GUIDE

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Optoacoustics Ltd • Sound Solutions From Light Technology
www.optoacoustics.com
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The unique Optoacoustics™ FORMI II microphone system uses fiber-optic technology and an advanced set of noise-cancelling algorithms to reproduce high-quality speech from recordings within an Magnetic Resonance Imaging environment.

This guide explains how to set-up and begin working with the FORMI II microphone and its OptiMRI software system.

Overview

Magnetic Resonance Imaging is a safe and non-invasive method of obtaining valuable medical data. However, communicating with patients during an MRI scan is problematic. The MRI process produces high levels of acoustic noise, and traditional microphones distort MRI readings.

The Optoacoustics FORMI II microphone is a unique solution for recording speech during an MRI scan. Using a complex set of adaptive acoustic algorithms, it achieves high levels of noise reduction with no loss of speech quality and is ideal for use during high resolution EPI scans with 1.5T, 3T and 7T scanners.
Noise Reduction Technologies

The Optoacoustics FORMI II microphone achieves high levels of noise reduction by blending four complementary approaches:

- **Optical Microphone**
  
The system uses pressure gradient optical microphones. These microphones have low self noise, high bandwidth, a large dynamic range and a high directivity index of 4.8dB.

- **Orthogonal Recording**
  
The system uses two microphones, arranged in a unique orthogonal configuration. The microphones are phase and amplitude matched, and capture the input sound field at the same position in space.

- **Dual-Channel Adaptive Noise Reduction Software**
  
The OptiMRI software system uses noise reduction algorithms that have been specially optimized for the acoustic characteristics of an MRI environment, including varying dual-cycle time events, resonance frequencies and dynamic range. The software compares input from the two microphones, in order to more accurately estimate noise spectra and Voice Activity Detection (VAD).

- **Single Channel Speech Enhancement**
  
The software finally enhances the speech recording using OptoAcoustics' special single channel speech enhancement algorithm.

Features

The FORMI II system is specially designed to meet the needs of an MRI environment.
• No interference: the microphone contains no metal parts and uses no electrical signals, ensuring zero interference with MRI readings.

• Effective noise reduction: up to 40dB, compared to a conventional omnidirectional microphone.

• High quality speech reproduction: because the FORMI II microphone system reduces noise and ensures a high Signal-to-Noise Ratio, a large bandwidth and maintains a dynamic range, it can produce exceptional levels of speech reproduction.

• Real-time operation: input is processed immediately, producing virtually noise-free speech almost instantly (latency of less than 0.1sec).

• Post-processing functionality: speech signals can be fully analyzed and optimized after recording.

About this Guide

This User Guide explains how to set-up the FORMI II system, including the OptiMRI software package. It also explains the functionality of the system and some of the basic tasks that can be performed with it.
Before you begin to install the FORMI II microphone, check that you have all the components and that your computer meets the minimum system requirements for the OptiMRI software.

Unpacking the Equipment

The FORMI II microphone pack includes the following:

- The microphone, mounted on a flexible gooseneck boom with a 10m cable
- The MRI electro-optic unit
- Power adaptor (110V or 240V)
- HASP security dongle
- Sample microphone "pop-screens"
- Microphone mounting flange with Velcro strips
- Installation CD
- Warranty
- This user guide
Figure 1: The FORMI II System

Technical Specifications

Sound

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Response</td>
<td>100–4000Hz</td>
</tr>
<tr>
<td>Noise Reduction</td>
<td>15-40dB</td>
</tr>
<tr>
<td>(in comparison to a conventional omni-directional microphone)</td>
<td></td>
</tr>
<tr>
<td>Microphone Directivity</td>
<td>4.8dB</td>
</tr>
<tr>
<td>(of main and reference microphones)</td>
<td></td>
</tr>
<tr>
<td>Total Harmonic Distortion</td>
<td>&lt;1% at 94dB SPL</td>
</tr>
<tr>
<td>Maximum Ambient Sound Pressure Level</td>
<td>140dB</td>
</tr>
<tr>
<td>DSP Latency</td>
<td>10ms (optional)</td>
</tr>
</tbody>
</table>
Software

<table>
<thead>
<tr>
<th>Audio File Format</th>
<th>Mono 16bit WAV file, with 8kHz sample rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Time Playback Latency</td>
<td>96ms</td>
</tr>
</tbody>
</table>

Operating Conditions

<table>
<thead>
<tr>
<th>Supply Voltage</th>
<th>9–12V (DC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Consumption</td>
<td>2.5W</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>10–50°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>0–60°C</td>
</tr>
<tr>
<td>Humidity</td>
<td>Up to 95% relative humidity at 40°C</td>
</tr>
<tr>
<td>Fiber Optic Cable Length</td>
<td>10m</td>
</tr>
</tbody>
</table>

System Requirements

Optoacoustics recommend the following minimal requirements when running the OptiMRI software:

- Intel Pentium 4 800MHz processor
- 256M dynamic memory
- Microsoft Windows XP or Windows 2000 Pro (SP4)
- 5GB of unfragmented hard drive space

Note: The OptiMRI software system processes sound in a real-time environment. For best results, do not run any other processes on the computer while the software is running.

Installing the System

Before you use the microphone inside the MRI room, set-up the system fully and test it.
For more details, refer to "Testing the System" page 14.

Setting Up the MRI Electro-Optic Unit

The following steps explain how to set-up the Electro-Optic Unit and connect it to the FORMI II microphone.

Note: Do not install the software until the unit has been connected to the computer.

➢ TO SET-UP THE MRI ELECTRO-OPTIC UNIT

1. Attach the power cable to the back of the electro-optic unit.
2. Turn on the unit using the POWER switch on the front panel.
   The POWER switch turns blue.
3. Remove the black plastic covering caps from the MAIN and REF connectors at the back of the unit.

![Figure 2: Electro-Optic Unit MAIN and REF connectors](image)

WARNING: Always replace the black covering caps when the system is not in use.

4. The FORMI II microphone has four cables. Two of the cables have red (●) plastic covering caps.
   Remove the red covering caps.
5. Attach the cable marked "R" to the right-hand MAIN connector on the unit.
   Attach the cable marked "L" to the left-hand MAIN connector on the unit.

Chapter 2: Getting Started
6. The two remaining FORM I II microphone cables have **yellow** ( ) plastic covering caps.
   Remove the yellow covering caps.

7. Attach the cable marked "R" to the right-hand REF connector on the unit.
   Attach the cable marked "L" to the left-hand REF connector on the unit.

**Installing the Software**

The following steps explain how to set-up the OptiMRI software on a computer connected to the Electro-Optic Unit.

**Installing HASP Key Support**

The OptiMRI software is security protected using the HASP key system. The software will only operate after HASP support has been installed, and when a HASP key is connected to the computer.

➢ **To install HASP support**

1. Connect the HASP dongle to the parallel port of your PC.
2. Insert the CD into your computer’s CD drive.
3. Open My Computer and double-click on the CD drive icon.
4. Open the HASP folder and double-click on hdd32.exe.
   The HASP InstallShield window appears.
5. Click **Yes** and follow the on-screen instructions. When the installation is complete, click **Finish**.

![HASP Installation Complete](image)

**Figure 4: HASP Installation Complete**

### Installing OptiMRI

Before installing the software, attach the FORMI II microphone cables to the Electro-Optic Unit and turn the unit on.

- **To Install the OptiMRI Software**
  1. Connect the Electro-Optic Unit's DIGITAL OUT cable to the computer's USB port.
  2. Insert the CD into your computer's CD drive.
3. Open My Computer and double-click on the CD drive icon.

4. Copy the "optiMRI.exe" and the User Guide PDF files to a single convenient location on your computer. (For example, C:\Program Files\OptoAcoustics)

   Connect the HASP security key and then double-click this icon to run OptiMRI. Software preference and output files will be saved in the same folder as the .exe file.

5. The OptiMRI system is now installed and ready for use.

   **Note:** For easy access, place a shortcut link to the OptiMRI software on your desktop.

   To uninstall the software, simply delete "optiMRI.exe" from your computer.

**Configuring the System**

After the FORMI II microphone is properly set-up and you have installed the software, test the software and the FORMI II microphone together.

➢ To **Configure the OptiMRI Software**

   1. Open the folder containing the OptiMRI software.
      Double-click on the OptiMRI icon.
      The OptiMRI (Dual Channel) window opens.

   2. Select **Settings** on the toolbar.
      The OptiMRI Settings screen appears.
Figure 5: The OptiMRI Settings Screen.

3. Expand the (2) Process tree element and select (2.1) Live Process.

The Live Process settings screen appears.
4. Make the following selections:
   - In the "Mic. connected to:" box, select "USB Audio CODEC".
   - In the "Spk. connected to:" box, select the computer's sound card.

5. In the "Save to file" box, enter a root filename for sound files saved by OptiMRI.
   Select the "Add data/time to file-name" checkbox to append a date and time to every sound file saved by OptiMRI.
Testing the System

It is important to test the system before attempting to use the microphone in the MRI scanner room.

Follow the previous instructions in this section to set-up the FORMI II microphone in a simple office environment.

After the microphone has been set-up, the software has been installed, and the drivers have been configured, you can test the FORMI II system.

➢ To Test the System’s Basic Operations

1. Insert your HASP key into the computer and open the OptiMRI software.

2. Select Live on the toolbar. The OptiMRI Live Input screen appears.
3. Select the Pre-Main, Pre-Ref and Post-Proc options in the Output section of the screen.

Click the Start button at the bottom of the window to begin recording.

4. Attach a hygiene pop-screen to the FORMI II microphone and hold your mouth directly against the screen.

5. Speak directly into the microphone.

**Note:** For optimal results, the patient’s mouth must be as positioned as closely against the microphone’s pop-screen as possible.

The speech waveform shows in the OptiMRI View area. The recorded speech replays through the computer’s speakers.

6. Click one of the Play buttons to view the recorded sound in your selected sound editor.
If the computer cannot detect sound from the FORMI II microphone, review the previous sections in this chapter to confirm your set-up and installation options.

For further help, consult "Troubleshooting" on page 39 or contact Optoacoustics Technical Support.

**Using the Microphone within an MRI Scanner**

In order to gain optimal results from the FORMI II microphone system, the system must be prepared correctly.

**Note:** Optoacoustics recommend setting up, installing, configuring and testing the FORMI II microphone system in a lab before attempting to use it in the MRI scanner room.


**Connecting the System**

The connections between the MRI control room and scanner room and the positioning of the microphone inside the MRI scanner are important for the optimal operation of the system.

➢ **TO CONNECT BETWEEN THE MRI CONTROL ROOM AND SCANNER**

1. Carefully pass the fiber-optic cables from the Electro-Optic Unit and through the wave guide, into the MRI scanner room.

2. Position the Electro-Optic Unit and the computer running the OptiMRI software in the MRI control room.

**CAUTION:** The system will not function if there are breaks or sharp bends in the cables.
To prevent permanent damage, always handle the cables carefully and curve them gently around corners.
Fitting the Microphone

The FORMI II microphone uses a tongue-and-groove mounting system specially designed to fit MRI scanners, guaranteeing optimal positioning and high-quality sound reception.

➢ To Fit the Microphone:

1. Place the mounting flange around the front-most part of the MRI coil, with the tongue-and-groove mechanism facing you as shown in Figure 8.

Figure 8: Place the Flange on the Coil
2. Wrap the Velcro strips of the flange around the coil frame as shown in Figure 9.

![Figure 9: Attach the Velcro Strips](image)

3. Tighten and secure the Velcro strips around the coil frame, as shown in Figure 10.

Since the flange remains on the coil at all times, ensure that it will not block a patient’s head entering and exiting the coil.

![Figure 10: Secure the Flange](image)

4. Slide the microphone unit into the tongue-and-groove mount, as shown in Figure 11.
Adjust the gooseneck boom so that the microphone can swing out of the way while the patient's head is entering the coil.

Figure 11: Slide the Microphone into the Mount

The microphone and boom can be removed instantly in the case of emergency or between scans. The flange remains attached at all times.

5. When the patient is lying on the bed in the MRI scanner room, place the microphone's pop-shield directly against his or her lips, as in Figure 12.

For optimal results, ensure that the patient's mouth is as closely against the pop-shield as possible.
Figure 12: Position the Pop-Screen closely against the Patient's Mouth

**Note:** For hygiene reasons, insert a new disposable pop-shield in the microphone before each use.

The flange fits various types of MRI coil. Figure 13 shows examples of how the microphone can be mounted on some example coils.

Figure 13: Example Coil Mountings

**Operating the System**

Confirm the microphone is correctly positioned, with the pop-screen directly against the patient's mouth.
Before beginning the MRI scan, always confirm that the microphone can record a loud, clear sound signal in a noise-free environment.

➢ **TO RECORD A PATIENT’S SPEECH**

1. Start the MRI scan and wait until it has reached its normal volume.

2. In the OptiMRI software, select the Live screen by pressing **Live** on the toolbar.

   The Live sound processing screen appears.

   ![OptiMRI Live Input Screen](image)

   **Figure 14: The OptiMRI Live Input Screen**

3. Click **Power** in the Noise Reduction area of the screen to activate or deactivate noise reduction.

4. Click **Pre-Main**, **Pre-Ref** and **Post-Proc** in the Output area of the screen.
The software will record additional comparison tracks from the main channel, from the reference channel, and after sound reduction.

5. Confirm that the patient is silent and press the **Start** button at the bottom of the screen.

To reduce hard drive fragmentation, record many short sound files rather than a single large file. Hard drive fragmentation slows your system and could cause delays in processing sound from the microphone's two channels.

**Note:** For best results, always start recording when there is already background noise and before the patient begins speaking.

**Analyzing the Recordings**

The OptiMRI software records sound files of the microphone input before and after noise reduction. It can also record additional tracks from the main microphone channel only and from the reference microphone channel only.

These files are an important way to analyze results from the FORMI II microphone, both during the set-up and testing phase and during "in-the-field" use.

To view and analyze the files, open them in a sound editing application, such as Adobe Audition™ or Cool Edit™ (included on the OptiMRI Install CD).

**Note:** Optoacoustics recommend setting your operating system to open all .WAV files in your sound editing application by default.
Optional Audio Outputs

Sound recorded from the FORMI II microphone can also be reproduced directly from the Electro-Optic Unit, without the use of a computer.

The two RCA connectors marked ANALOG OUT at the front of the unit produce an analog sound signal that can be connected to any conventional sound system, such as a DAT machine.

Use the leftmost red MAIN connector to record input from the FORMI II microphone's main channel.

Use the rightmost black REF connector to record input from the FORMI II microphone's reference channel.

Figure 15: The ANALOG OUT Connectors
Using the OptiMRI Software

The OptiMRI system uses a series of advanced algorithms to reduce MRI scan noise. It can be applied in real-time or used to post-process data after it is recorded.

System Overview
The OptiMRI system operates via an intuitive and user-friendly graphical interface.

The OptiMRI User Interface
The main OptiMRI screen is used in both the Live and Post-Process modes.

Use the Live screen to process input in real-time. To prevent acoustic feedback in Live mode, listen to the computer output via headphones, keep the computer's speakers at a low volume or keep the computer's speakers at a distance from the microphone.

Use the Post-Process screen when processing saved files. It is only possible to post-process sound files produced from the FORMI II microphone and a set of files must share the same root name and end either "pre.wav" for main channel files, or "pre_ref.wav" for reference channel files.
Figure 16: Overview of the OptiMRI Interface

The following key gives an overview of the function in the OptiMRI software:

1. View Area
   Shows the current waveform and its status.

Click **View** to toggle between View Mode and Time Domain mode.
<table>
<thead>
<tr>
<th>#</th>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
</table>
| 2 | Output Selection | Sets the output files to be produced. Sets which outputs to produce.  
- **Speaker**: Outputs the processed sound to the computer's speakers, via the computer's sound card.  
- **Pre-Main**: Records a soundtrack from the microphone's main channel.  
- **Pre-Ref**: Records soundtrack from the microphone's reference channel.  
- **Post-Proc**: Records a post-noise reduction soundtrack.  
- **VAD**: Detects speech in the input sound. (Not available in this version)  
- **Trigger – L and R**: Produces a 2.8KHz pure tone for every "on" trigger detected in the left or right input, and zero reading for every "off" trigger. (Not available in this version)  
- **Rec. VAD Auto**: If selected, the system will detect speech in the recorded input.  
Click a **Play** button to open that input's waveform in your selected sound editor. |
| 3 | Volume | Click **Power** to toggle volume controls on and off.  
Click around the Gain knob to set the approximate level of noise reduction, in a -20 to +20dB range.  
For best general results, set the gain at 0dB. |
| 4 | Noise Reduction | Click **Power** to toggle Noise Reduction on and off.  
Click around the Reduction Level knob to set the approximate level of noise reduction.  
For best general results, set noise reduction at 15dB. |
Equalizer
Sets sound equalization for the recorded speech.

Click **Power** to toggle the Equalizer on and off. Six preset filters are available.

For best general results, reset all sliders to 0dB.

**Note:** Over-boosting an octave can damage overall speech quality.

---

**Menu Functions**

The following menu options are available:

<table>
<thead>
<tr>
<th><strong>File</strong></th>
<th><strong>Settings</strong></th>
<th><strong>Load</strong></th>
<th><strong>Save As</strong></th>
<th><strong>Exit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Settings</td>
<td>Load user settings and preferences.</td>
<td>Save user settings and preferences.</td>
<td>Exit the application.</td>
</tr>
</tbody>
</table>

**View**
Open the Settings, Live or Post-Process screens.

**Process**
Start or stop processing incoming sound.

**Help**
OptiMRI Help
Opens this user guide.

About
Release information.

---

**Setting Up the OptiMRI Software**

The OptiMRI software includes a comprehensive set of options and preferences, to meet a variety of needs and field requirements.

Settings can be saved and re-loaded, making it easy to maintain different settings for different test procedures or for multiple users.

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Using the OptiMRI Software
Automatically Saving Settings

By default, OptiMRI resets to its generic settings every time the program is closed.

The Presets element in the Settings screen allows users to automatically save their current settings when the program is closed. The settings are restored the next time the program is opened.

➢ To AUTOMATICALLY SAVE SETTINGS

1. Click **Settings** on the toolbar
   
The Settings screen appears.

2. Select the (1) **Presets** element from the tree view.
   
The Presets options are displayed.

![Figure 17: Presets Options in the Settings Screen](image)

3. Select the "Reload last settings on enter program" checkbox.
OptiMRI will save the current settings every time the program closes and restore them when the program is opened.

**Note:** To restore the factory defaults, click **Set default settings**.

Managing Sound Output Quality

OptiMRI allows users to select normalization levels, default equalizer settings, automatic notch filtering, and default noise reduction preferences.

➢ **To Set Sound Management Options**

1. Click **Settings** on the toolbar
   
The Settings screen appears.

2. Select the **(3) Normalize** element from the tree view.
   
The Normalize options are displayed.
Figure 18: Normalize Options in the Settings Screen

3. In the "Normalize Level" box, select the maximum level of normalization to apply to audio files.
   Before it is processed, the normalized file is saved in the same location as the pre-recorded source file.

4. Select the (4) **Equalizer** element from the tree view.
   The Equalizer options are displayed.
5. Select an Equalizer gain range. The range applies in both Live and Post-Process modes.

6. Select the (5) Filter element from the tree view.

The Filter options are displayed.
7. Select an automatic notch filter. The filter removes interference produced in the MRI control room by other electrical appliances.

**Note:** It is generally advisable to select the "Electrical Noise-Harmonics" option, which removes both fundamental resonance and harmonics.

8. Select the **(6) Noise Reduction** element from the tree view.

The Noise Reduction options are displayed.
9. Set the default noise reduction level.

If the recorded speech level is very low, select the "Whispering speech mode operation" checkbox to boost input signal thresholds.

Select the "Gain compensation" checkbox to prevent sound clipping in files produced by the software.

Choosing Display Preferences

The software color scheme and the range of statistics displayed is controlled by a set of preferences.

➢ To Define Display Preferences

1. Click Settings on the toolbar

   The Settings screen appears.

2. Select the (7) Statistics element from the tree view.
The Statistics options are displayed.

![Statistics Options in the Settings Screen](image)

Figure 22: Statistics Options in the Settings Screen

3. Select the "Show Statistics" checkbox to show statistics for average RMS power and peak amplitude (both in decibels).
   
   This setting applies in Live mode only.

4. Select the (6) Display element from the tree view.
   
   The Display options are displayed.
Figure 23: Display Options in the Settings Screen

5. Select a display color scheme from the "Display View" box.
Upgrades and Accessories

There are a selection of upgrades and accessories available for your new FORMI II microphone.

Contact Optoacoustics or your local dealer for more information.

OptiMRI DSP

The OptiMRI DSP is an optional add-on digital processing unit. It implements the OptiMRI software’s dual channel noise reduction and speech enhancement algorithms into a dedicated hardware system.

By using a dedicated hardware system, you ensure reduced latency while processing speech, and can work free from the operating constraints of a computer.

Figure 24: The OptiMRI DSP Unit
Replacement Pop-Screens

The FORMI II microphone pop-screens serve a dual purpose—they ensure that patients can position themselves in the best way possible to optimize sound reproduction from the microphone.

They also allow many patients to share the same mouth-to-receiver microphone in a hygienic and sanitary way.

![Replacement Pop Screens](image)

Figure 25: Replacement Pop Screens

Additional pop-screens are available in 100 piece bags.

Extension Cables

Indoor zip cord extension cables are available for the FORMI II microphone, in lengths between 10m and 50m.

All cables are Ø3.0 x 2m.
Troubleshooting

Some frequent problems that may occur while setting up the FORMI II microphone system are listed below.

For further help, please contact Optoacoustics technical support.

1. Problem
   The Electro-Optic Unit is switched on, but the switch is not illuminated.

   Cause
   There is no power to the unit, or the switch's LED is not working.

   Solution
   Check that the power cables are properly connected. If the LED is faulty, the system itself may be working normally.

2. Problem
   There is only one sound card listed in the "(2.1) Live" options element of OptiMRI's Settings screen. It is not a USB sound card.

   Cause
   The computer has not recognized the Electro-Optic Unit's USB connection as a sound card.

   Solution
   Close the program. Turn on the Electro-Optic Unit and connect its USB cable to the computer. Now, restart the program as normal.
3. **Problem**  
The input speech signal has a very low amplitude.

**Cause**  
FORMI II microphone was not placed directly against the patient's mouth.

**Solution**  
Re-align the microphone so that the patient is speaking directly into the mouth shield.

4. **Problem**  
There is a large latency-delay between the patient speaking into the microphone and the computer's playback.

**Cause**  
The computer cannot process and stream the sound fast enough.

**Solution**  
Ensure there is at least 5GB of defragmented hard drive space available.

Using the Windows Task Manager, close all background processes and assign the OptiMRI process "real-time" priority.

**Note:** For best results, use a computer with at least an 800MHz BUS speed.  
Optoacoustics recommend running OptiMRI under Windows 2000 or Windows XP.

5. **Problem**  
Bad sound quality.

**Cause**  
The algorithms are operating in a non-optimal mode.
Solution
Always record at least 2 seconds of noise before beginning to speak into the FORMI II microphone.

6. Problem
The software returns a floating point error and closes unexpectedly.

Cause
OptiMRI has not recognized the reference microphone.

Solution
Test each microphone, by trying both sets of cables in the MAIN input connectors on the rear of the Electro-optic converter unit.

7. Problem
Noise reduction is insufficient.

Cause
The microphone is positioned incorrectly, or OptiMRI has not recognized the voice signal.

Solution
Confirm that the microphone housing is open from both sides. Always record at least 2 seconds of noise before beginning to speak into the FORMI II microphone.
Microphone Characteristics

The FORMI II system uses two figure-of-eight orthogonally oriented optical microphones. The typical 3D spherical polarity of the dual-channel sensor is shown in the following diagram.

Figure 26: Typical Spherical Polarity of Dual-Channel Sensor

The diagram below shows the frequency response of the FORMI II microphone's main channel. The frequency response was measured at 0° and at 90° related to the front microphone direction (on-axis).

The diagram shows the frequency response of the microphone at a distance of 2.5cm and 30cm, 0.180 (on-axis) degrees and
90.270 (off-axis) degrees; generated signal 84dBspl of swept Sine wave.

All measurements were made in an anechoic chamber at a distance of 2.5cm (1") and at a far field distance of 30cm (12").

![Dual-Channel Microphone System; Relative Frequency Response](image)

*Figure 27: Frequency Response of the Dual Channel FORMI II Microphone*

**OptiMRI DSP Algorithms**

Optoacoustics' dual channel OptiMRI software system is a real-time speech enhancement application, for use with the FORMI II noise canceling optical microphone.

**Features and Benefits**

OptiMRI uses a state-of-the-art dual channel noise reduction algorithm that removes ambient acoustic sound from a speech signal. The algorithm is characterized by a high-level of original speech signal restoration with minimal residual artifacts.
Principles

The dual-channel OptiMRI is the integrated product of two algorithms. The first is a dual channel adaptive filter; the second is a single channel speech enhancement algorithm.

Both algorithms complement one another and have been adjusted to make optimal use of the specially designed dual channel microphone configuration. To this end, they allow for the microphone's frequency response, polar pattern, and the acoustic characteristics found within an MRI scanner.

Dual-Channel Adaptive Filter

The dual-adaptive filter subtracts the reference input from the noisy signal channel. It assumes the signal in the reference input is roughly similar to the interference in the noisy signal and contains only negligible residual of the desired signal. To achieve an optimal subtraction, the reference signal is modified by an adaptive filter, whose gains are learned continuously from the residual signal and the reference input. To prevent divergence of the filter when speech is present a speech detector is integrated in the algorithm.

Single Channel Speech Enhancement

The single channel speech enhancement performs its filtering in the spectral domain, by re-shaping the noisy signal spectrum. The input signal is partitioned to overlapping blocks, which are transformed to the spectral domain. The noisy spectrum of the system is corrected dynamically, based on the SNR in each spectral bend. To reach accurate correction factors, noise spectrum is estimated continuously also in speech segments. The noise estimator is aided by an accurate voice activity detector, which evaluates the speech likelihood in each signal block. The unseen speech signal is modeled based on the speech properties and "hints" seen in the noise signal. The modified spectrum is
transformed to the time domain to blocks of samples, which are sent out after performing Overlap–Add.

Properties
The OptMRI algorithms have the following properties:

- Fast adaptation to changing noisy conditions.
- Minimization of "musical notes", by gain calculation and smoothing, optimized for human hearing.
- No degradation of clean signals.