G.R.A.S.
SOUND & VIBRATION

Instruction Manual

Vector Intensity Probe Type 50VI-1
(Wide-band Intensity Probe Type 50VI-3)

G.R.A.S.
Sound & Vibration

Skovlytoften 33, 2840 Holte, Denmark Tel. +45 45 66 40 46 Fax +45 45 66 40 47

Revision 6 June 2014

CONTENTS

1. Introduction and Description

The G.R.A.S. Vector Intensity Probe Type 50VI - 1 (Fig. 1.1) is a 3-D sound-intensity probe. The probe head is based on the proven design of the G.R.A.S. Sound-intensity Probe Type 50AI.

The first generation of sound intensity probes was designed and developed using available standard microphones and preamplifiers; resulting in a number of compromises regarding size, acoustical performance and durability. In the new generation of sound-intensity probes, all components have been made specifically for sound intensity applications. Each small ¼-inch diameter and 40 mm long microphone preamplifier is housed in a robust, stainless steel casing which enables novel probe designs which reduce disturbances to the sound field otherwise brought about by the effects of shadows and diffraction. Furthermore, its symmetry enables reliable calibrations as described in the proposed standard (ISO/DIS 9614-2) for sound power measurements using sound-intensity measurements.

Fig. 1.1 The Vector Intensity Probe Type 50VI - 1

The Vector Intensity Probe Type 50VI - 1 includes spacers for 25 mm and 50 mm for covering the frequency range from 80 Hz to 6.3 kHz. The probe handle has an input for three pairs of probe microphones designated **X**, **Y** and **Z**.

The output of the probe handle is via the 24-pin LEMO connector mounted on the base. This is for use with the 10 m cable AA0030, included with the Type 50VI - 1, which connects the Type 50VI - 1 either:

- directly with the G.R.A.S. Power Module Type 12AC which provides power and polarization voltages for each pair of probe microphones.

  or

- adapter cable AC0017, also included with the Type 50VI - 1, which splits into six 7-pin LEMO connectors for use with alternative (less dedicated) power modules with standard 7-pin LEMO microphone connectors.

1.2 Main Components for Type 50VI-1

The main components of the Vector Intensity Probe Type 50VI - 1 are:

- 3 × Type 40AI; Sound Intensity Microphone Pair (see Fig. 1.3). Do not mix up the pairs.
- 6 × Type 26AA; Microphone Preamplifiers (see Fig. 1.4).
- AL0004; Light-weight Tripod.
- RA0004; 3-dimensional solid spacer (25 mm) (see Fig. 1.5).
- RA0005; 3-dimensional solid spacer (50 mm) (see Fig. 1.5).
- RA0003; Straight adapter for ½-inch microphone and ¼-inch preamplifier.
- 5 × RA0001; Right-angled adapter for ½-inch microphone and ¼-inch preamplifier. Three are marked accordingly X, Y and Z.
- Handle.
- 10 m cable AA0030 (for direct use with G.R.A.S. Power Module Type 12AC).
- Cable adapter AC0017 (for splitting the six preamplifier channels in the AA0030 into six separate short leads each terminating in a 7-pin LEMO connector). Can also be used without AA0030 since it plugs directly into Type 50VI - 1

The Type 50VI - 1 is delivered in a carrying case similar to the one shown in Fig. 1.2, complete with microphones, preamplifiers, standard accessories and a handle.

Fig. 1.2 The type of carrying case delivered with the Type 50VI - 1

1.2.1 Microphones

The microphones are delivered as matched pairs (Fig. 1.3) and are high sensitivity, free-field ½-inch condenser microphones with a uniquely-designed pressure equalization system that ensures extremely well defined phase characteristics. **It is most important not to mix up the pairs**. The microphones and preamplifiers are mounted on the top of the telescopic arm of the Handle. To cover the full frequency range from 60 Hz to 5.6 kHz, the Type 50VI - 1 is delivered with two 3-D solid spacers (Fig. 1.5) for spacing the matched microphones at 25 mm or 50 mm.

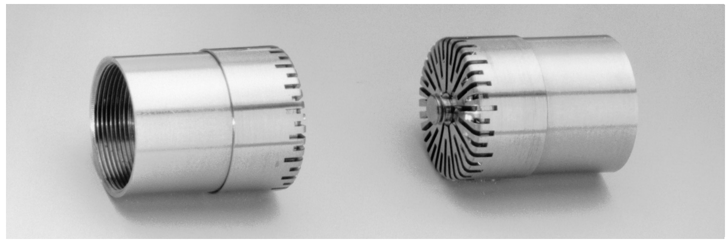

Fig. 1.3 Showing a pair of phase-matched ½-inch microphone cartridges Type 40AI. Three pairs are supplied with the Type 50VI - 1. Do not mix up the pairs

1.2.2 Preamplifiers

The small ¼-inch diameter and 40mm long microphone preamplifiers (Fig. 1.4) are housed in robust, stainless steel casings which enable novel probe designs that reduce disturbances to the sound field otherwise brought about by the effects of shadows and diffraction. Symmetry of design enables reliable calibrations as described in the proposed standard (ISO/DIS 9614-2) for sound power measurements using sound-intensity measurements.

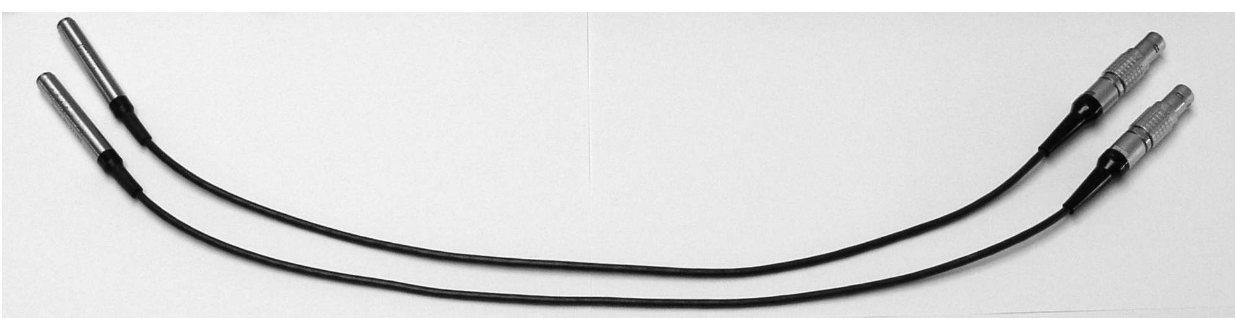

Fig. 1.4 A Pair of ¼-inch Preamplifiers Type 26AA. Three pairs are supplied with the Type 50VI - 1

Fig. 1.5 Showing the two spacers supplied with the Type 50VI-1

1.3 Main Components for Type 50VI-3

The main components of the Vector Intensity Probe Type 50VI - 1 are:

- 3 × Type 40AI; Sound Intensity Microphone Pair (see Fig. 1.3). Do not mix up the pairs.
- 6 × Type 26AA; Microphone Preamplifiers (see Fig. 1.4).
- AL0004; Light-weight Tripod.
- RA0004; 3-dimensional solid spacer (25 mm) (see Fig. 1.5).
- RA0005; 3-dimensional solid spacer (50 mm) (see Fig. 1.5).
- RA0003; Straight adapter for ½-inch microphone and ¼-inch preamplifier.
- 5 × RA0001; Right-angled adapter for ½-inch microphone and ¼-inch preamplifier. Three are marked accordingly X, Y and Z.
- Handle.
- 10 m cable AA0030 (for direct use with G.R.A.S. Power Module Type 12AC).
- Cable adapter AC0017 (for splitting the six preamplifier channels in the AA0030 into six separate short leads each terminating in a 7-pin LEMO connector). Can also be used without AA0030 since it plugs directly into Type 50VI - 1

The Type 50VI - 1 is delivered in a carrying case similar to the one shown in Fig. 1.2, complete with microphones, preamplifiers, standard accessories and a handle.

2. Input Channels (Type 50VI-1)

There are six input channels (A,B,C,D,E and F) for the six microphone preamplifiers used with the three pairs of intensity probes. The channels for each intensity probe are marked on the handle as:

- **A X B**
- **C Y D**
- **E Z F**

See example visible in Fig. 2.1.

2.1 X - Y - Z Axes

A sound intensity vector can be measured via its three components along the *X, Y* and *Z* axes. For the Type 50VI - 1, the positive components in each of these directions are as defined in the following (see also Fig. 2.2).

2.1.1 A X B Channels

A and B refer to the two channels of the probe along the *X*-axis. Positive sound intensity along the *X*-axis occurs when sound travels in the direction from channel A to channel B.

2.1.2 C Y D Channels

C and D refer to the two channels of the probe along the *Y*-axis. Positive sound intensity along the *Y*-axis occurs when sound travels in the direction from channel C to channel D.

2.1.3 E Z F Channels

E and F refer to the two channels of the probe along the *Z*-axis. Positive sound intensity along the *Z*-axis occurs when sound travels in the direction from channel E to channel F.

2.2 Data Processing

Measurement data from the channels of each probe can be fed to a suitable anlyser or a computer in order to determine the resultant intensity vector in both magnitude and direction.

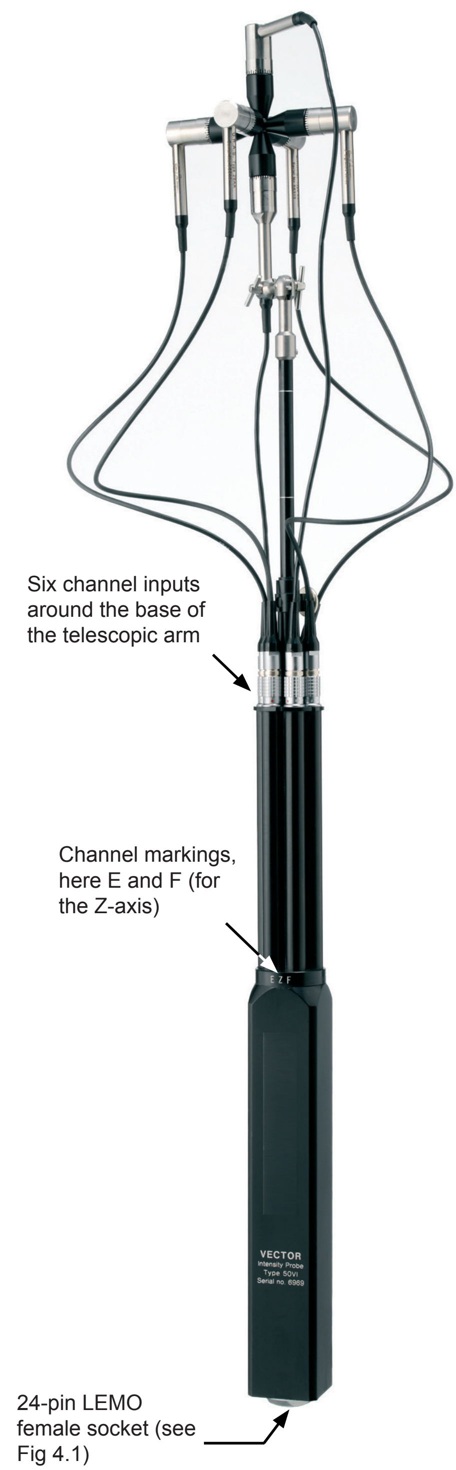

Fig. 2.1 Channel markings (here for the Z-axis) and the location of the 24-pin LEMO socket

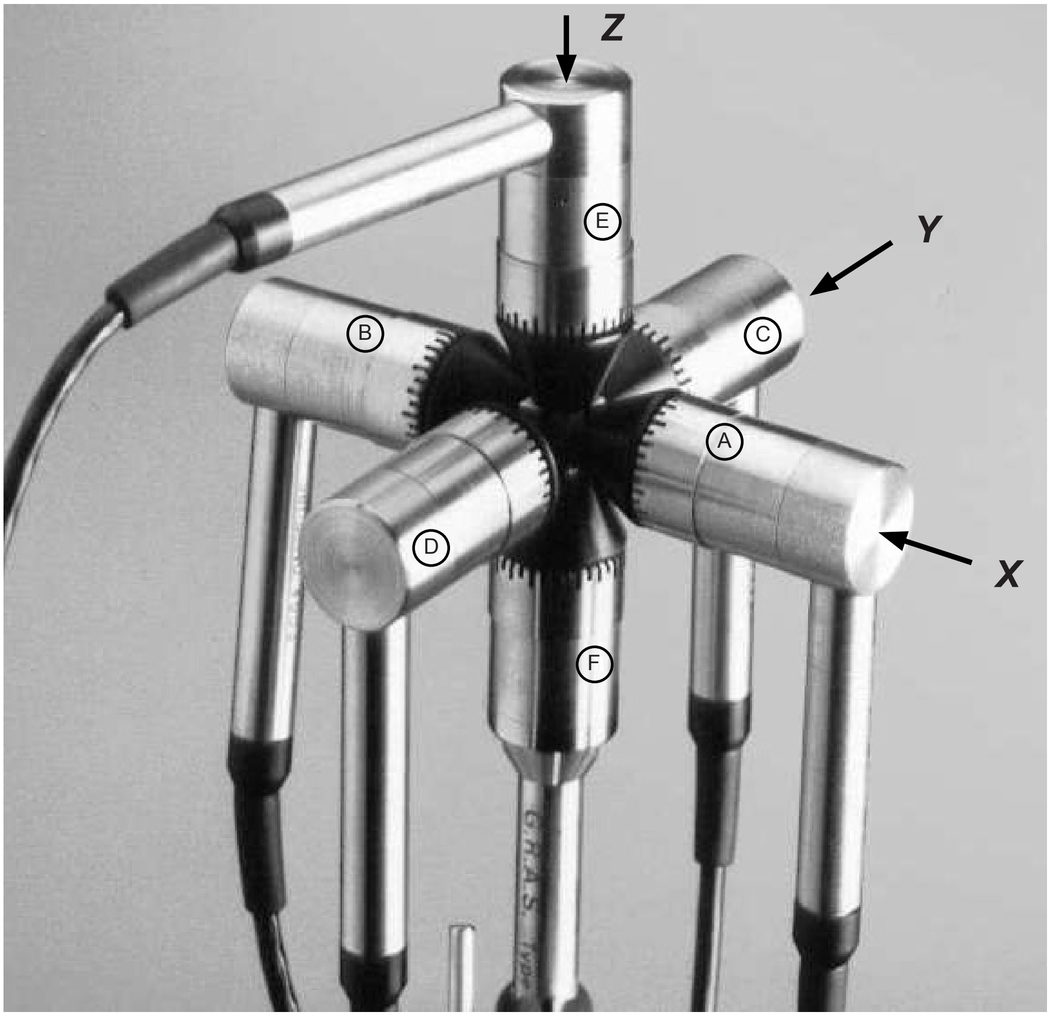

Fig. 2.2 Showing the channels (A,B,C,D,E and F), and the positive directions of the X-Y-Z axes for each pair of probe microphones

3. Input Channels (Type 50VI-3)

There are six input channels (A,B,C,D,E and F) for the six microphone preamplifiers used with the three pairs of intensity probes. The channels for each intensity probe are marked on the handle as:

- **A X B**
- **C Y D**
- **E Z F**

See example visible in Fig. 2.1.

3.1 X - Y - Z Axes

Type 50VI-3 is a wide-band intensity probe with two sets of intensity microphones covering each their respective frequency area. This probe only measures along the *X* axes. For the Type 50VI - 3, the positive components in this direction is as defined in the following.

3.1.1 A X B Channels

A and B refer to the two channels for low-frequency detection in the area from 80 Hz to 1 kHz. Positive sound intensity along the *X*-axis occurs when sound travels in the direction from channel A to channel B.

3.1.2 C Y D Channels

C and D refer to the two channels for high-frequency detection in th area from 200 Hz to 10 kHz. Positive sound intensity along the *X*-axis occurs when sound travels in the direction from channel C to channel D.

3.1.3 E Z F Channels

These channels are not used for Type 50VI-3.

3.2 Data Processing

Measurement data from the channels of each probe can be fed to a suitable anlyser or a computer in order to determine the resultant intensity vector in both magnitude and direction.

4. Output Socket

The outputs of the three pairs of intensity probes (six preamplifiers) is via the 24-pin LEMO output socket at the base of the handle of the Type 50VI - 1 & 3 (see Fig. 2.1) are shown in Fig. 4.1.

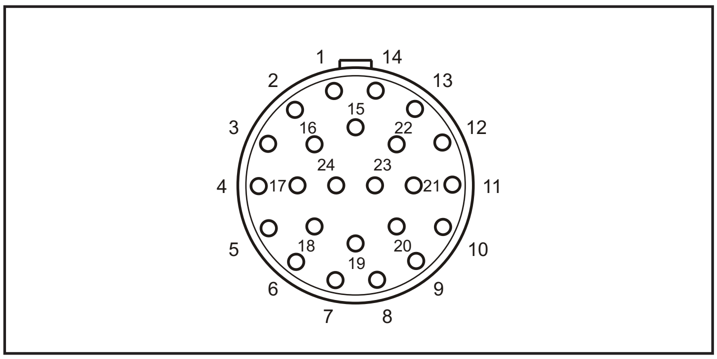

Fig. 4.1 External view of the pin numbers of the 24-pin LEMO female socket ECG.3B.324 at the base of the Type 50VI - 1 & 3 (see also Table. 4.1)

Pin No.	Function	Pin No.	Function
1	Signal **A**	13	120 V Preamp. supply **C + D**
2	Signal Gnd. **A**	14	Preamp. supply Gnd. **C + D**
3	200 V Pol. Volt. **A + B**	15	Signal **E**
4	Signal **B**	16	Signal Gnd. **E**
5	Signal Gnd. **B**	17	200 V Pol. Volt. **E + F**
6	120 V Preamp. supply **A + B**	18	Signal **F**
7	Preamp. supply Gnd. **A + B**	19	Signal Gnd. **F**
8	Signal **C**	20	120 V Preamp. supply **E + F**
9	Signal Gnd. **C**	21	Preamp. supply Gnd. **E + F**
10	200 V Pol. Volt. **C + D**	22	not used
11	Signal **D**	23	not used
12	Signal Gnd. **D**	24	not used

Table. 4.1 Pin numbers (see Fig. 4.1) and their functions for the socket at the base of the Type 50VI - 1 & 3

4.1 Use with External Equipment

Use the included Cable Adapter AC0017 (which plugs directly into the base of the Type 50VI - 1 & 3) for splitting the six (or four) preamplifier channels into six (or four) separate short leads (marked accordingly wth channel designations A, B, C, D, E and F) each terminating in a 7-pin LEMO connector.

Each 7-pin LEMO connector can then be plugged directly into a suitable preamplifier supply wired up as shown in (Fig. 4.1.1).

Cable Adapter AC0017 can also be used with the 10 m cable AA0030 (also included).

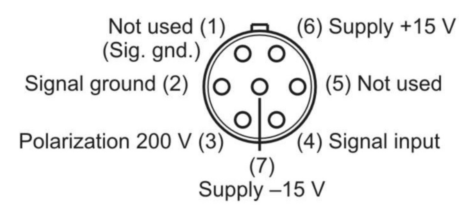

Fig. 4.1.1 7-pin LEMO female socket 1B (external view)

4.2 Use with Power Module Type 12AC

The Power Module Type 12AC (Fig. 4.2) is designed specifically for the Type 50VI - 1 and will provide it with all necessary voltages for powering all six preamplifiers and polarizing all six microphones. It also provides BNC outputs for each channel marked accordigly for the *X*, *Y* and *Z* axes of the Type 50VI - 1.

Connect the Type 50VI - 1 to the Power Module Type 12AC via the 10 m cable AA0030 (included). The Type 12AC has a corresponding 24-pin LEMO input socket marked **Probe Input**.

Fig. 4.2 Power Module Type 12AC, designed specifically for the Type 50VI - 1

5. Handling and Assembling the Probe

5.1 The Microphones

The Microphones Type 40AI (Fig. 1.3) are a pair of special free-field microphones with extremely well-controlled phase characteristics. They are delivered as a matched pair each with individual calibration data as well as data on differences between their phase responses.

These microphones have a unique pressure equalisation system which ensures a well defined lower-limiting frequency and an extremely low sensitivity to sound pressures at the pressure equalisation channels. Therefore, they can be calibrated in single-port phase calibrators such as the G.R.A.S. Intensity Calibrator Type 51AB.

5.2 Probe Design

The design of the Sound-intensity Probe minimises acoustic reflections and the influence of diffraction.

Microphones are supplied as pairs (Type 40AI) Spacers are included and six preamplifier adapters (five right-angled and one straight).

The distances between microphones and preamplifiers have been kept to a minimum in order to avoid problems with any stray capacitance and sensitivity to vibration. While amplitude characteristics are little influenced, the phase characteristics of a Sound-intensity Probe can be critically affected by even very small vibrations in the conductors carrying the raw signals from the microphones. Therefore, the ¼-inch preamplifiers are mounted in rigid contact with the ½-inch microphones via short adapters (right-angled and/or straight). This also eliminates problems with non-matching capacitances between microphones and preamplifiers, which could give rise to phase problems.

5.3 Physical Strength

From a physical point of view, a Sound-intensity Probe should be robust and easy to assemble and dismantle. Typically, there are two points in a Sound-intensity Probe which can be identified as critical for physical strength and are the most likely to suffer damage and are the most difficult to repair. These points are the threads on microphones and preamplifiers as well as on the microphones' protection grids. The connections between microphones and preamplifiers are very delicate and carry both microphone signals and microphone polarisation voltages. Therefore, the preamplifier threads are supported by stainless steel ½-inch to ¼-inch adapters. There is also a protective guard within the ¼-inch housing of each preamplifier. In addition, the microphones' protection grids are made of stainless steel to withstand rough physical treatment since a buckled or damaged protection grid will almost invariably damage a microphone's diaphragm beyond repair.

5.4 Assembling the Type 50VI-1 Probe

The probe head should be assembled so that the orientation of its co-ordinate system is as defined by the Sound-intensity Probe. The following procedure will result in the co-ordinate system shown as in Fig. 2.2. Refer also to Fig. 5.5.

Note that each pair of intensity microphones is phase matched for accurate intensity measurements. Therefore, keep them together in their original pairs for each of the intensity measurement axes.

Mount the three pairs of phase-matched intensity microphones and the preamplifiers on the five right-angled adapters and the one straight adapter as shown in Fig. 5.1. Note the placing of three of the right-angled adaptors engraved with direction indicating arrows corresponding to the positive **x**, **y** and **z** directions.

Note also the single microphone (Fig. 5.1 a) which does not have a push-fit adapter (Fig. 5.2) screwed onto the threaded stud of its protection grid, whereas the other five do.

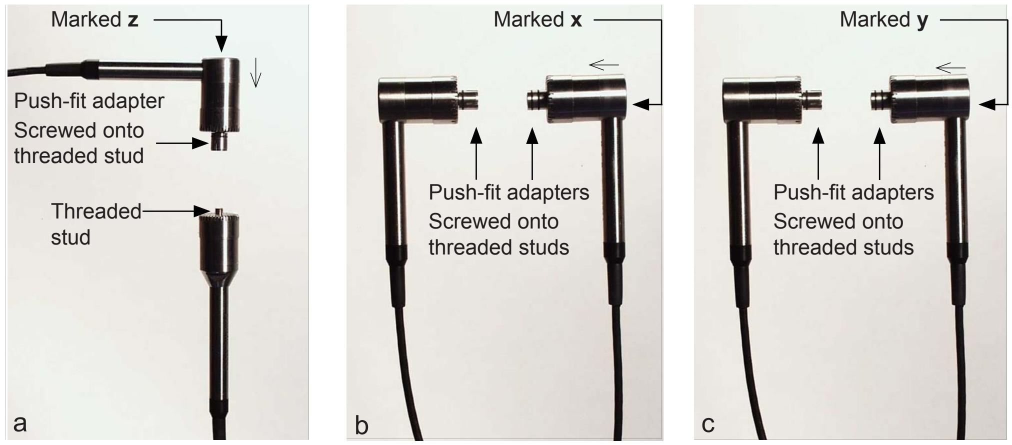

Fig. 5.1 Assembly of microphones, adapters and preamplifiers.
Note: each picture shows a unique pair of phase-matched microphones Type 40AI. Do not mix up the pairs. A close up of a push-fit adapter is shown in Fig. 5.2.
*a) One right-angled preamlifier adapter indicating postive **z** direction, plus one straight preamlifier adapter.*
*b) Two right-angled preamlifier adapters, one indicating postive **x** direction.*
*c) Two right-angled preamlifier adapters, one indicating postive **y** direction.*

Fig. 5.2 Push-fit adapter (5.5 mm dia.)

The single microphone without a push-fit adapter must be mounted on the straight preamplifier adapter. The remaining five microphones must be mounted on right-angled adapters.

Depending on the required frequency range, choose a spacer (Fig. 1.5):

- RA0004 (25 mm) will cover the frequency range from 80 Hz to 4 kHz
- RA0005 (50 mm) will cover the frequency range from 40 Hz to 1.25 kHz

Identify the threaded insert on the spacer (Fig. 5.3 a) and screw this onto the microphone with the threaded grid stud (Fig. 5.3 b). Push-fit the other microphone of this pair on the opposite side of the spacer, Fig. 5.3c.

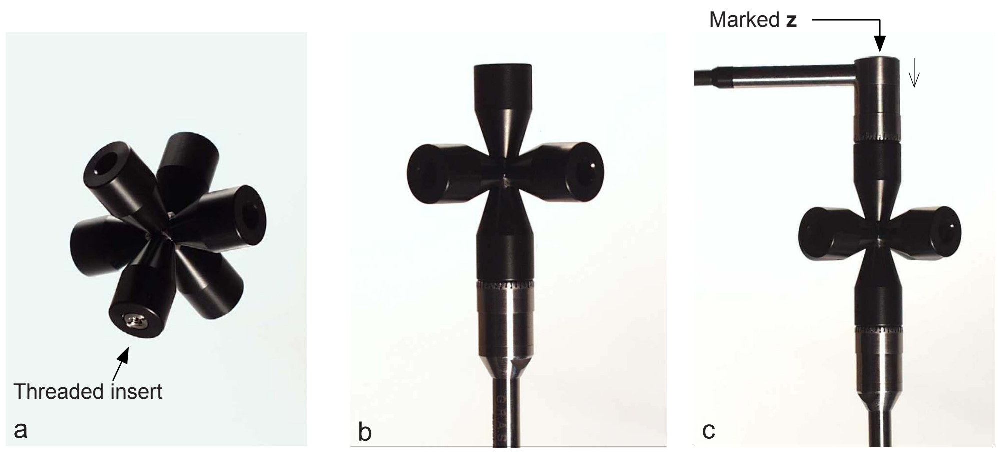

Fig. 5.3 Mounting the microphones of the Z-axis (see Fig. 5.1a) on the spacer.
a) Identify threaded insert.
b) Screw onto the microphone with the exposed threaded stud.
c) Push-fit the other microphone on the opposite side.

Push-fit the x-direction microphones on the spacer as shown in Fig. 5.4 a and finally the y-direction microphones to give a complete probe head as shown in Fig. 2.2. Mount the assembled probe head on the telescopic arm of the probe handle as shown in Fig. 5.4 b.

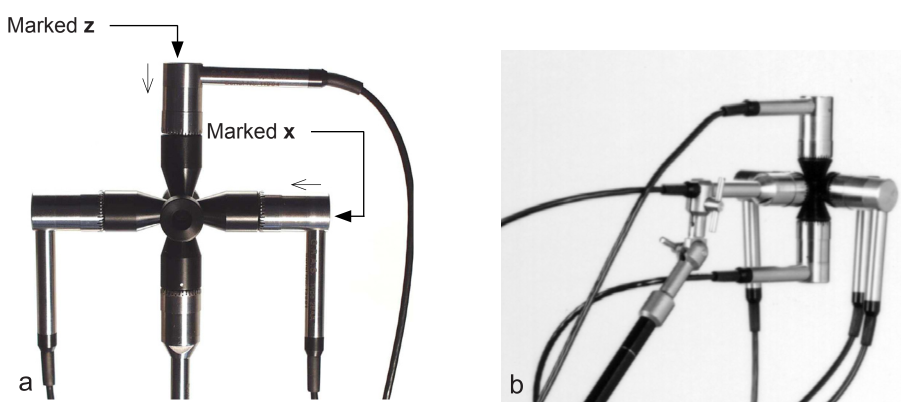

Fig. 5.4 Mounting the microphones of the X-axis (see Fig. 5.3 b) and Y-axis (see Fig. 5.3 c) on the spacer.
a) X-axis. The Y-axis points towards the reader
b) The assembled probe.

5.5 Channel Connections on the Probe Handle

The 4-pin LEMO connectors of the six preamplifiers should be connected to the six corresponding channel inputs around the base of the telescopic arm as shown in Fig. 2.1. Make sure these channel connections comply with the information given in section 2.2.

5.6 Using Windscreen AM0365

A spherical windscreen (AM0365) is available from G.R.A.S. which can be used whenever making outdoor measurements or when making indoor measurements in the presence of bulk air movements. Use it only when measurements are influenced by wind. It gives good protection at windspeeds greater than 0.5 m/s and can reduce pressure fluctuations caused by turbulence by as much as 20 dB with this technique of intensity measurements.

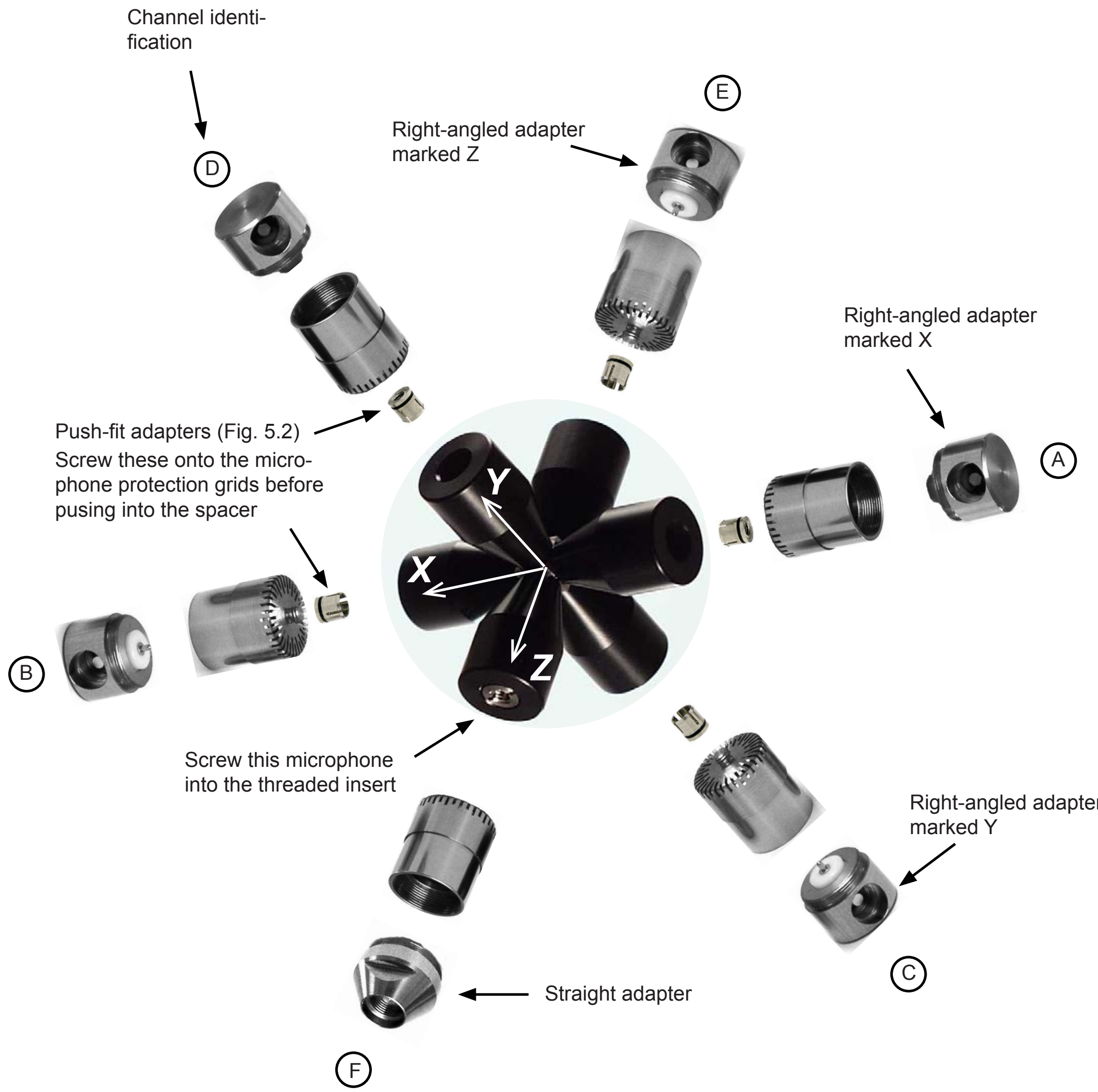

Fig. 5.5   Exploded view of probe assembly (for clarity preamplifiers not shown).
Notes:
Channel F is the only one which uses the threaded insert and a straight adapter. The rest use the push-fit inserts and right-angled adapters.

5.7 Assembling the Type 50VI-3 Probe

The probe head should be assembled according to Fig. 5.7.

Note that each pair of intensity microphones and preamplifiers is phase matched for accurate intensity measurements. Therefore, keep them together in their original pairs for each of the frequency areas.

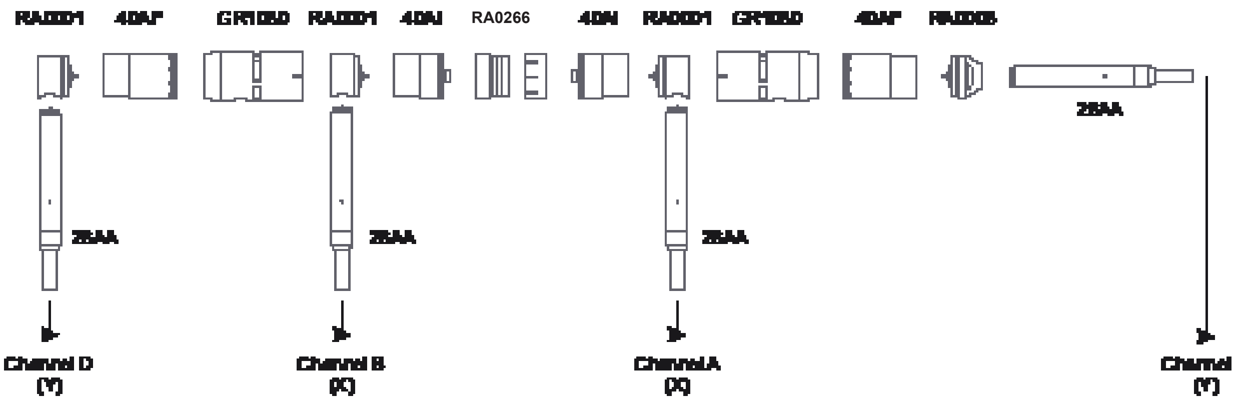

Fig. 5.5 Exploded view of Type 50VI-3 Probe assembly.

Notes:

The two 40AI are paired intensity microphones as well as the two 40AI and should remain in that configuration!*

6. Specifications

Sound-intensity microphones:

Type 50VI-1:	
3 matched pairs ½-inch mics.	Type 40AI
Type 50VI-3:	
2 matched pairs ½-inch mics.	Type 40AI

3-dimensional spacers:

Type 50VI-1:	
25 mm spacer	RA0004
50 mm spacer	RA0005
Type 50VI-3:	
12 mm spacer	RA0266

See Fig. 6.1 for working frequency ranges

Preamplifiers:

3 (2) Pairs ¼-inch	Type 26AA Set

with 4-pin LEMO connectors type FGG OB

Frequency response and phase matching:

IEC 1043 Class 1

Handle:

Has Six 4-pin LEMO sockets at the top for the preamplifiers. These are internally connected to the 24-pin LEMO socket at the base of the handle. The cable AC0017 connects directly into the base socket.

The X-Y-Z axes for each pair of preamplifiers are clearly marked on the handle.

Operating Temperature Range:

+5°C to +40°C

Weight:

0.45kg (1lb)

Accessories included:

(In addition to the preamplifiers, microphones and spacers described above)

10 m Cable	AA0030 (with 24-pin LEMO connectors) [1]
Cable adapter	AC0017 [2]
Tripod	AL0004

Accessories available:

6-channel Power Module	Type 12AC
Windscreen	AM0365

[1] For direct use with G.R.A.S. Power Module Type 12AC.

[2] For splitting the six preamplifier channels in the AA0030 into six separate short cables each terminating in a 7-pin LEMO connector.

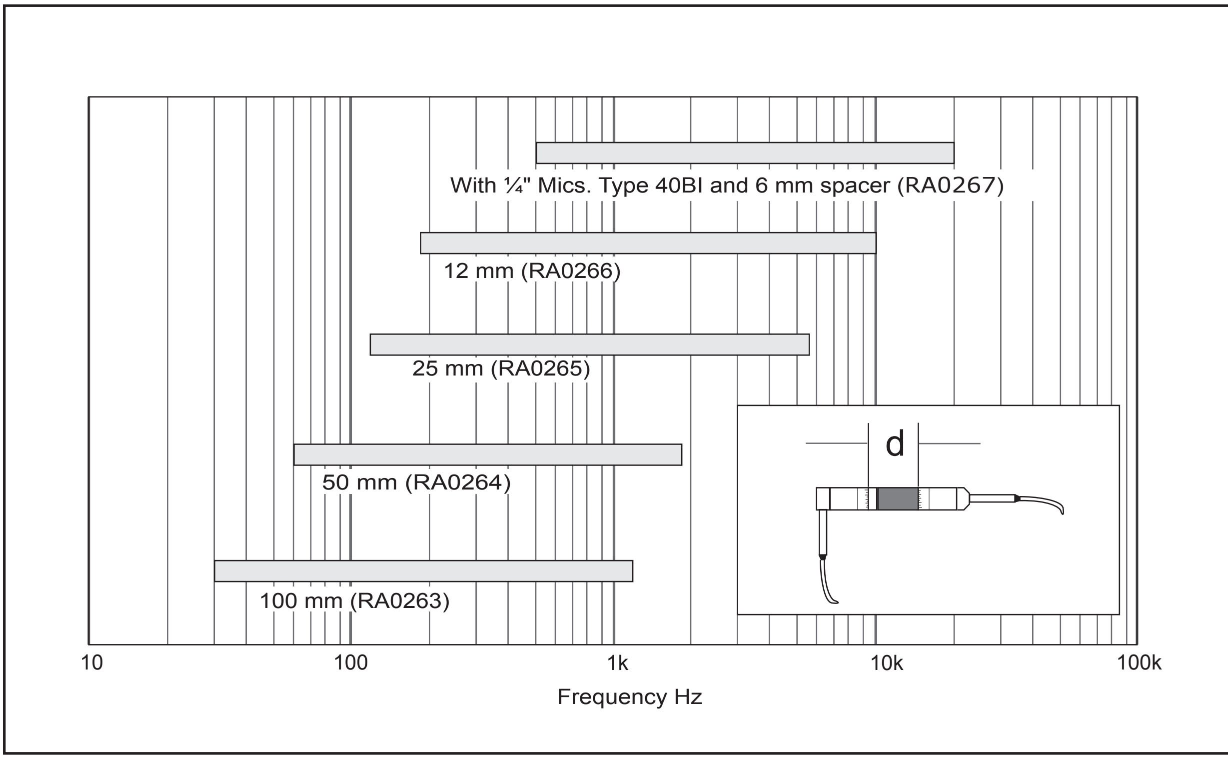

Fig. 6.1 *Working frequency ranges covered by the various spacer lengths. The top bar is for the case when a Type 50VX is equipped with a pair of ¼-inch intensity microphones (Type 40BI) and a 6 mm spacer (note the extended high-frequency range)*

A. Appendix

Theory

Power is the rate at which work is done by one system on another. In Fig. A.2, system **A** acts on system **B** with a force F_i which gives **B** a resulting velocity v_i. The power P_i transmitted from **A** to **B** is given by:

$$P_i = F_i \cdot v_i$$

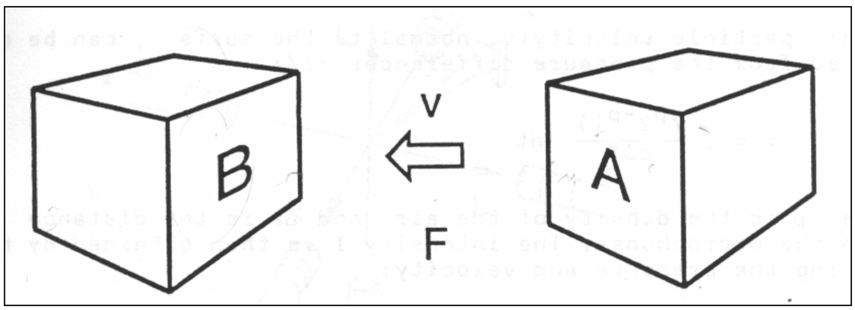

*Fig. A.2 Transmission of power from system **A** to system **B***

In acoustics there is normally no real division between the two systems **A** and **B**, but a division may be defined as an imaginary surface in space (see Fig. A.3). The power transmitted from the air on the one side of this surface to the air on the other side is:

$$P = F \cdot v = S \cdot p \cdot v$$

Where S is the area of the surface, p is the pressure on the surface and v the resulting particle velocity. The intensity I is the power per unit area, i.e.:

$$I = \frac{P}{S} = p \cdot v$$

In practice, the intensity is measured with a two-microphone intensity probe. These two microphones measure the pressures on just either side of the imaginary surface S (Fig. A.3), and the pressure in the plane of this imaginary surface is calculated as the mean of these two pressures, i.e.:

$$p = \frac{p_1 + p_2}{2}$$

Using the pressure difference, the particle velocity v of unit volume of air normal to the surface can be derived from the following:

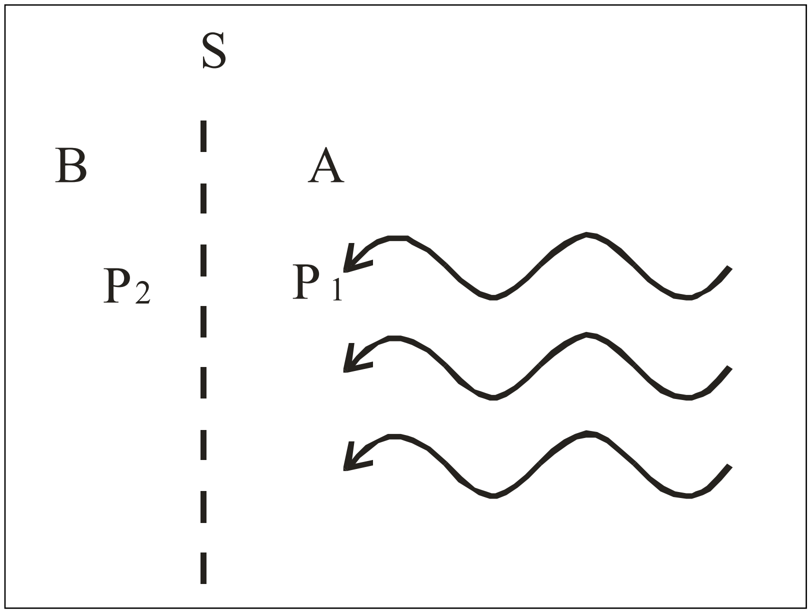

Fig. A.3   Transmission of power from system ***A*** *to system* ***B*** *across an imaginary surface S*

$$v = \int \frac{p_2 - p_1}{\rho \cdot \Delta r} dt$$

Where ρ is the density of the air and Δ_r is the distance between the microphones. The intensity *I* is then obtained by multiplying the pressure by the velocity:

$$I = p \cdot v = \frac{p_1 + p_2}{2} \int \frac{p_2 - p_1}{\rho \cdot \Delta r} dt$$

This is the intensity along the axis of the probe or, in other words, one of the components of an intensity vector *I* along the axis of the probe. The intensity vector *I* describes the resulting direction and magnitude of the acoustic energy flow. The intensity vector *I* can be measured by measuring the intensity in three mutually perpendicular directions, see Fig. A.4. The intensities I_x, I_y and I_z are the component intensities in the three directions ***x***, ***y*** and ***z***, and the resultant intensity vector is given by:

$$\vec{I} = I_x \cdot \vec{x} + I_y \cdot \vec{y} + I_z \cdot \vec{z}$$

As can be seen, the co-ordinate system is defined by the orientation of the three pairs of microphones in the vector probe. Thus, the components of the intensity vector **I** depend on the orientation of the probe.

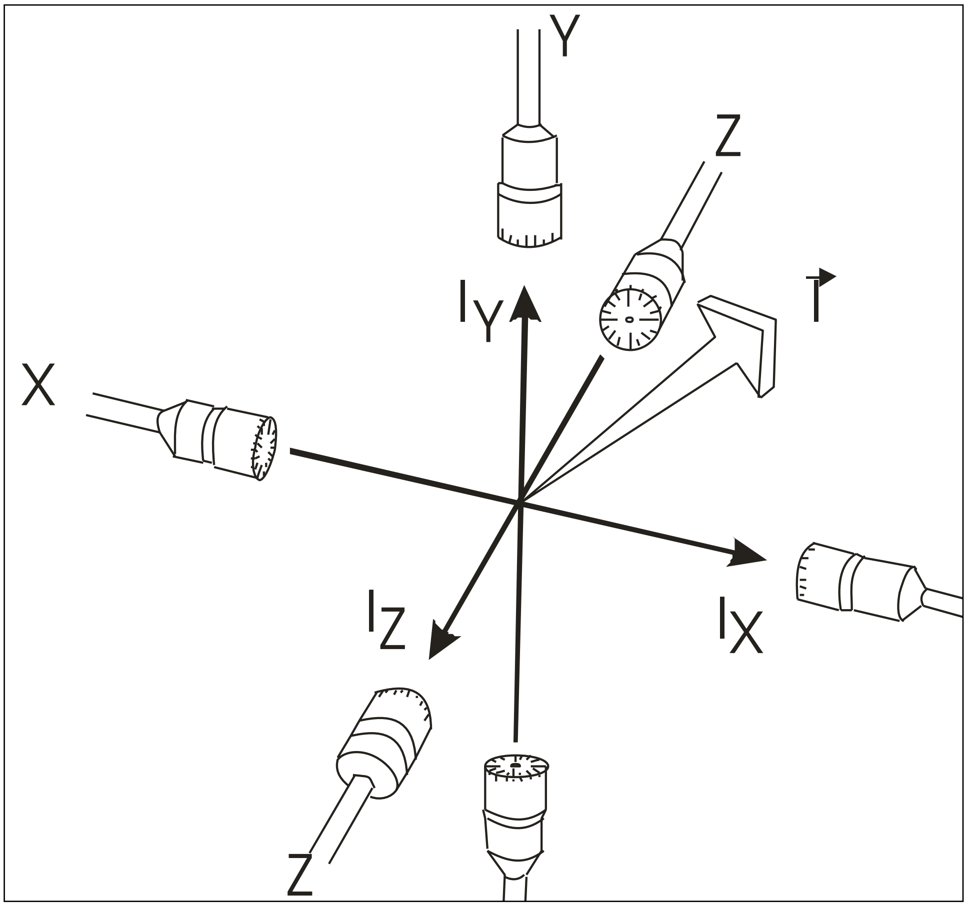

*Fig. A.4   The three mutually orthogonal components (I_X, I_Y and I_Z) of the resultant intensity vector **I***