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(71) Applicant *(for all designated States except US)*: **TANDBERG TELECOM AS** [NO/NO]; Philip Pedersens vei 22, N-1366 Lysaker (NO).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **ENDSTAD, Gisle** [NO/NO]; Haugjordet 17, N-1366 Sandvika (NO). **GRAVERMOEN, Tore** [NO/NO]; Søndre Rød 8D, N-0752 Oslo (NO). **NIELSEN, Johan, Ludvig** [NO/NO]; Oberst Roeds vei 26, N-1152 Oslo (NO).

(74) Agents: **ONSAGERS AS** et al.; P.O. Box 6963 St. Olavs plass, N-0130 Oslo (NO).

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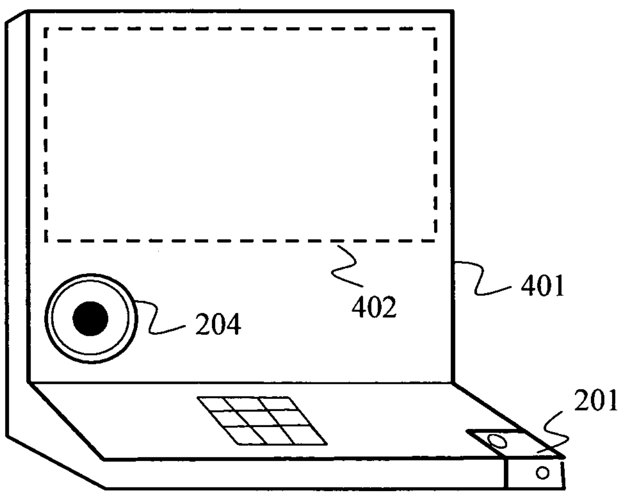

Fig. 4

(57) Abstract: The present invention discloses an inventive microphone assembly for desktop communication systems. It utilises the advantages of directional microphones in a desktop conferencing system without exposing the microphone for unfavourable mechanical or acoustic influence. This is achieved by building it into the footing in front of system, in a mechanically controlled and robust way. The microphone assembly according to the present invention maximize microphone sensitivity in the direction of a near end user while simultaneously minimize microphone sensitivity in the direc-tion of the loudspeaker.

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MICROPHONE DEVICE

Field of the Invention

The invention relates to a microphone assembly in a loud speaking conference end-point.

Background of the invention

A conventional video conferencing end-point includes a codec, a camera, a video display, a loudspeaker and a microphone, integrated in a chassis or a rack. In larger end-points for use in meeting and boardrooms, the audio equipment is installed separately. The microphone is often placed on the meeting table so as to bring the audio recorder to bring it closer to the audio source.

However, personal video conferencing end-points, also referred to as desktop terminals, are now becoming more common in offices as a substitute or supplement to larger end-points or to traditional telephony. Personal equipment is more portable, and is likely to be placed close to the user on a table. Thus, all the equipment belonging to one end-point, including the microphone is integrated in one device.

The microphone in a communication system should pick up voice from the user (called the near end user) with maximum quality and a suitable sensitivity. However, due to the fact that a desktop system is relatively small, and all parts (including microphone and speaker) are integrated in one device, the microphone must be positioned relatively close to the loudspeaker. This implies several audio problems, which will be discussed in the following.

Desktop telecommunication terminals (video conferencing systems, IP-phones, or any loud speaking integrated communication system) with integrated loudspeaker(s) and microphone(s), for hands-free operation (loud speaking mode) experience an effect referred to as feedback. Feedback is a result of the sound from the loudspeaker being picked up by the microphone. Feedback is highly unwanted in communication systems, for a number of reasons.

First of all, feedback causes an echo in the communication (a loop back of sound) where the user hears a delayed version of his/her own voice. Echo in a communication system can be very disturbing, especially with large delays. The subjective degrade in communication quality caused by the echo depends on several factors, including the level of echo, and the delay. Figure 1 illustrates the fundamental echo problem.

Secondly, feedback puts restraints on the maximum allowable output level on the loudspeaker, which may result in the near end user having difficulties hearing the far end user. As mentioned, desktop systems are often compact in size, meaning that the loudspeaker must be placed close to the microphone, and most often closer to the microphone than the distance between near end user and microphone. Hence, the sound level from the loudspeaker is often more powerful than the sound level (speech) from the near end user. If the sound level from the loudspeaker is too high, it might overload the microphone (acoustical overload) or the circuits (electrical overload), which leads to distortion of the microphone signal. Hence, the sound levels from the loudspeaker picked up by the microphone constraints the design of audio circuits, audio signal processing, and the allowed maximum level from the loudspeaker.

The loudspeaker signal can consist of far end talk, and sounds generated by the near end system, e.g. key tones, ringing tones and so on. The loudspeaker signal is picked up by the microphone and sent back to the far end. In general, the loudspeaker signal is unwanted in the microphone signal sent to the far end. The captured loudspeaker signal (referred to as echo) must be removed, or suppressed, from the microphone signal if the level and/or delay of the echo are large enough to cause significant disturbance in the communication. This is a well developed technology, and acoustic echo cancellation and/or echo suppression algorithms are incorporated in most digital IP based communication systems.

Therefore, the goal of the microphone and loudspeaker design of an integrated communication system with loud speaking hands-free mode is to allow for the best possible near end sound pick up (sound from near end user, e.g. speech), while simultaneously minimizing the acoustical feedback level from the loudspeaker(s) to the microphone(s). This allows for the best possible quality in the signal sent to the far end, and the level of the near end loudspeaker can also be maximized, to the benefit of the near end user. Echo cancellation and suppression algorithms will also benefit from a minimal acoustical feedback from the loudspeaker to the microphone, and the risk of overloading the microphone and the audio circuitry is reduced. Digital signal processing is often used to ensure that the microphone and audio circuits are not overloaded. The maximum loudspeaker signal is limited by known techniques in the field of dynamics processing.

The acoustical feedback can be reduced by increasing the distance from a loudspeaker to a microphone. However, the physical dimensions of the integrated system dictate the maximum distance. In addition, other considerations might require placing the microphone nearer the loudspeaker than the maximal possible distance. One example is if the comb filter effect, caused by a table reflection of speech, is to be avoided, the microphone needs to be placed very close to the table surface. This might not be the optimal placement with regards to acoustical feedback in an integrated desktop system.

Directional microphones can also be utilized to maximize microphone sensitivity in one or more directions, and minimize or reduce the sensitivity towards the loudspeaker, and are commonly used in telephony and conferencing equipment. E.g. the Polycom Soundstation™ series uses such microphones. However the physical properties of directional microphone elements require that sound waves must be able to reach both the front and the rear of the microphone. Hence, they are typically mounted in an open acoustical space in the product, typically beneath a perforated area of the mechanics, allowing free flow of air past the microphone. This is a space demanding and fragile mounting, and also not very flexible with regards to adjusting or optimizing the directional behavior of the microphone.

Further, directional microphones only effectively suppress sound when the sound enters from straight behind the microphone. This is difficult to obtain in a desktop system.

The requirements for sound quality are increasing as communication systems are using higher bandwidth audio. Also, acoustic echo and feedback control are critical issues for desktop systems. Microphone design, placement and assembly are therefore critical factors for the optimization of sound quality.

The present invention proposes a new way of incorporating a directional microphone element in a communication system, in a way that maximizes microphone sensitivity in the direction of a near end user, while simultaneously minimizing the sensitivity in the direction of the integrated loudspeaker, thus minimizing feedback. The utilization of a directional microphone will also reduce the ambient noise and reverberation pick-up.

Summary Of the invention

It is an object of the present invention to provide an arrangement and the use of such an arrangement that minimizes the drawbacks described above. The features defined in the independent claim enclosed characterize this system and the use of the system.

Brief description of the drawings

In order to make the invention more readily understandable, the discussion that follows will refer to the accompanying drawing.

Figure 1 illustrates the fundamental echo problem,

Figure 2 is the polar response of a typical unidirectional cardioid microphone element,

Figure 3 is a plot of the free field response of a unidirectional microphone,

Figure 4 is a schematic drawing of the microphone assembly according to the present invention in a desktop communication terminal,

Figure 5A and 5B illustrates the incident angle of sound from a loudspeaker and near end user,

Figure 6A and 6B is a schematic drawing of the microphone housing according to one embodiment of the invention,

Figure 7A and 7B is a top view of the microphone housing according to one embodiment of the invention,

Figure 8 is (omnidirectional and unidirectional) microphone response from a typical user position with the microphone assembly according to one embodiment of the present invention,

Figure 9 shows feedback response from internal loudspeaker to a calibrated unidirectional and omnidirectional microphone with the microphone assembly according to one embodiment of the present invention.

Preferred embodiment of the invention

In the following, the present invention will be discussed by describing a preferred embodiment, and by referring to the accompanying drawings. However, people skilled in the art will realize other applications and modifications within the scope of the invention as defined in the enclosed independent claims.

The present invention discloses an inventive microphone assembly for desktop telecommunication terminals. It utilises a conventional, off-the-shelf, directional electret condenser microphone element with a cardioid directivity pattern. This type of microphone has acoustical input ports at both the front and the rear of the element that together with its internal design gives it a directional behavior. The directional behavior of the microphone is modified by guiding sound to the front and the rear of the microphone in a controlled way to maximize sensitivity in the direction of the near end user and minimize the sensitivity in the direction of the integrated loudspeaker of the product. This is achieved by building it into the footing in front of the system, in a mechanically controlled and robust way, using a tuned acoustical waveguide. In this way, the time delay between sound received at the front and the rear of the directional microphone can be controlled to optimize sound quality.

Figure 2 shows a directional pattern **202** of a typical cardioid microphone **201**. A cardioid microphone **201** is a directional microphone and has a maximum sensitivity in the forward direction (0°), a minimum sensitivity in the backward direction (180°), and approximately half of the maximum sensitivity at 90°. This results from the geometry, internal design, and operating principle of the cardioid microphone element **201**. Directional microphones have acoustical input ports at both the front and the rear. The acoustical input ports are separated by an effective distance "d" which represents the distance that a sound wave must travel around the directional microphone in going from one acoustical input port to the other. Movements of a diaphragm inside the microphone are converted into voltages at the output of the microphone. The magnitude of the voltage output of the directional microphone is a function of the instantaneous difference in sound pressure on the opposite sides of diaphragm. As distance "d" becomes smaller and smaller, so too does the output voltage from the directional microphone. Velocity of sound in air at room temperature is 1128 feet per second, so that a f=2250 Hz audible signal has a wavelength of about 15 cm. Thus, even small separation distances provide sufficient phase difference between the acoustical input ports so that the directional microphone has a polar response pattern such as shown in figure 2. Therefore, the sensitivity of the microphone **201** varies depending on the angle of incidence of sound waves. Forward sound incidence (sound from a sound source **203** located in front of the microphone at 0°) leads to a delay of the sound arriving at the rear acoustical input port of the microphone relative to the sound arriving at the front acoustical input port. Correspondingly, incidence from the rear side of the microphone element leads to a delay of the sound to the front input port relative to the sound arriving at the rear input port of the microphone **201**.

Figure 3 shows a typical free field frequency response of a cardioid microphone, from front (0°) **301** and rear (180°) **302** sound incidence. As can be seen from the figure the frequency response of the sound signal incident at 0° is 15 dB stronger than the sound signal incident at 180°.

According to one embodiment of the present invention, a microphone assembly is disclosed which changes the acoustical distance of sound waves traveling to the rear acoustical input port of the microphone from one or more point sources, relative to free field, thereby modifying the directivity pattern of the microphone. The microphone assembly simultaneously optimizes the microphone response for maximum sensitivity in one direction, and minimizes the sensitivity in another direction, even if these directions are not being 180 degrees separated. (In the case of the unmodified cardioid microphone free field response, the directions of the maximum and minimum sensitivity are separated by 180 degrees.)

As mentioned in the background section, it is desirable to maximize the distance between the loudspeaker and the microphone. According to one embodiment of the present invention, the microphone is mounted in a lower corner of a desktop telecommunication terminal **401**, as shown in figure 4. The microphone **201** is placed very close to the desktop surface, or table top, in the front of the terminal in a mechanically controlled way to minimize comb filter effects. This is discussed in US application 11/239,042. The loudspeaker **204** is mounted on the opposite side of the terminal. Further, the loudspeaker **204** is preferably mounted on a surface located behind the microphone **201**, in such a way that the distance between the near end user and loudspeaker **204** is longer than the distance between the near end user and the microphone **201**. As can be seen in the figure, the maximum distance between a microphone **201** and a loudspeaker **204** in such a terminal **401** would be a diagonal separation as illustrated.

Figure 5A is a schematic drawing of the desktop communication terminal **401** in figure 4 and a near end user **203**, from a top view perspective. If the microphone **201** had been mounted unobstructed in this position (free field), of-centre (and very low) on the desktop terminal **401**, the incident angle **502** of the sound from a near end user **203** would be an area with reduced sensitivity for a cardioid microphone **201**. Further, the incident angle **501** of sound from the loudspeaker **204** is in an area with significantly reduced sensitivity for a directional microphone **201**, which again reduces feedback. However, as can be seen in the figure, the separation between the loudspeaker sound direction **501** and the user sound direction **502** is only approximately 90 degrees, which is far from an ideal 180 degree separation.

Figure 6 and 7 are schematic drawings of a housing **601** for a unidirectional microphone element **201** according to one embodiment of the present invention. The microphone **201** is to be encapsulated in a desktop foot supporting the desktop system on the table as discussed above. The microphone housing **601** may be a separate part to be integrated in the desktop foot, or the desktop foot itself may serve as the microphone housing **601**. An acoustic waveguide **602** extends from a first surface of the housing into a cavity **603** in the housing.

As indicated in figure 6A, 6B, 7A and 7B the cavity **603** extends from a front surface **605** of the housing, hence creating an opening in the housing for receiving a directional microphone **201**. The size and shape of the opening and cavity **603** should correspond to the size and shape of the microphone element. Alternatively the size of the opening and cavity **603** is slightly smaller than microphone element, so that when the microphone **201** is forced into the cavity **603**, the elastic properties of the housing material firmly hold the microphone element in the correct position and forms a seal around the sides of the microphone, preventing sound pressure at one acoustical input port to leak to the other acoustical input port. The acoustical waveguide allows sound waves from one or more point sources to reach the rear acoustical input port of the directional microphone.

The acoustical waveguide **602** extends from a top surface **606** of the housing **601** to a back surface **703** of the cavity. According to one embodiment of the invention, the channel is oblique both in the azimuth and elevation angle relative to the central axis of the cavity (said axis being parallel with the normal vector of the back surface). The acoustic waveguide is angled towards the loudspeaker, which is situated behind the microphone on the other side of the terminal. The length and direction of the acoustical waveguide **602** is dependent on the position of the loudspeaker relative to the microphone, and on a typical near end user **203** position relative to the microphone **201**, and serves as a sound guide for sound from one or more sound sources to the rear acoustical input port of the microphone **201**. This is discussed in more detail later.

As shown in figure 7B a protective cover **701** may be placed at least in front of the microphone housing **601** to protect the microphone **201** from impacts and from falling out of the housing **601**. One or more openings **702** are provided in the protective cover **701** to admit sound waves to the front acoustical input port of the microphone **201**.

When the housing **601** with the microphone **201** is mounted in a desktop system **401** the front acoustical input port of the microphone **201** is facing away from the system. According to one exemplary embodiment of the invention the front acoustical input port is facing forward, in the general direction of the near end user. However, the microphone may be tilted slightly towards the desktop (or table surface). The acoustical waveguide **602** guiding sound to the rear acoustical input port is designed to simultaneously minimize the microphone sensitivity in the direction of the internal loudspeaker, and maximize the microphone sensitivity in the direction of the user. This is achieved by making the acoustical waveguide **602** quite long, and angled slightly in the direction of the loudspeaker **204**. Since the waveguide is angled towards the loudspeaker, the acoustic distance between the loudspeaker and the rear acoustical input port is kept close to a free field acoustical distance. In this way, sound from the loudspeaker **204** will arrive at the rear input port of the microphone before arriving at the front input port of the microphone, thus giving a low sensitivity. Further, the additional distance the sound from the speaker needs to travel to traverse the corners of the microphone housing and the protective cover may increases the relative delay between sound reaching the rear and the front acoustical input port of the directional microphone, hence decreasing the sensitivity of the microphone for sound emanating from the loudspeaker even further.

From the typical user position, the opposite is true. The acoustical waveguide **602** is angled in direction of the loudspeaker, and simultaneously angled away from the near end user. The length and direction of the acoustical waveguide increase the acoustic distance between the near end user and the rear acoustical input port, relative to a free field acoustical distance. Sound from the user will arrive at the front input port of the microphone without delay, while the sound arriving at the rear input port of the microphone will experience delay, due to the configuration of the acoustical waveguide. The length and direction of the acoustical waveguide **602** increases the relative delay between sound reaching the rear and the front of the unidirectional microphone, hence increasing the sensitivity of the microphone for sound coming from the user (speech). In other words, the increased delay experienced by the microphone "moves" the direction of sound closer to 0° as illustrated by arrow **503** in figure 5B. This leads to a high sensitivity for sound from the user.

Figure 8 shows an example of achieved microphone response from a typical user position with the microphone assembly according to one embodiment of the present invention. The figure shows the response **802** of a calibrated unidirectional microphone mounted in the above described housing. The response **801** of a calibrated omni directional reference microphone in the same position is shown as a reference. It shows that a good sensitivity and frequency response from the user position is achieved.

Figure 9 shows feedback response **902** from internal loudspeaker to a calibrated unidirectional microphone, together with the feedback response **901** to a calibrated omni directional microphone in the same position. As can be seen from the figure a reduction in feedback up to 16 dB is achieved by the present invention for most frequencies in the voice frequency band.

Due to the length of the channel guiding sound to the back, the frequency response and directional properties will be somewhat different from the free field case. The long channel will cause a narrower frequency range of directional behavior. Figure 8 and 9 shows that a good directional behavior is achieved up to 2 kHz with our invention. In telephony, the usable voice frequency band **803** ranges from approximately 300 Hz to 3400 Hz. It is for this reason that the band of the frequencies between 300 and 3000 Hz is also referred to as "voice frequency". Therefore, even if an acoustical waveguide as disclosed according one embodiment of the present invention reduces the frequency range of directional behavior, the directional behavior is still strong in the "voice frequency" band.

Further, mechanical protection of the microphone element is secured by making the housing sturdy and rugged out of a relatively hard rubber material.

The cavity **603** for housing the microphone element should encapsulate the microphone element. A gap between the rear end of the microphone **201** and the back surface **703** of the cavity **603** would, together with the acoustical waveguide, create a resonant system, which will give a resonance peak in the frequency response at the resonance frequency. To control the resonance of the cavity, the distance between the microphone and the back surface should therefore be minimized to place the resonance frequency as high as possible. The diameter of the sound guide should be wide enough to give a relatively low resonance peak. This will ensure that the frequency response and directional behaviour is good.

A problem that may be more dominant when the microphone **201** is placed close to the tabletop, is the interfering structure borne noise and vibrations that may occur in the table material, originating from knocking and bumps in the table. To minimize pickup of sound and vibrations from the terminal assembly or the table surface, the microphone housing **601** is preferably made of a vibration damping material. The material of the housing **601** should be quite hard for rigidity and protection, and somewhat elastic to withstand varying stresses from the terminal **401** above it, and hold the microphone **201** in a fixed position. The housing **601** should cope with temporarily carrying the weight of the whole terminal **401** without the acoustic waveguide **602** permanently deforming or closing. The material should be non-porous so as to minimize sound absorption. Experience has shown that an elastomer cast with hardness of at least shore 35 is a working compromise.

The microphone housing **601** can be designed to be used as a foot that the desktop system rests on. This significantly reduces the degree of integration, thereby making an independent microphone module that can easily be re-used in new systems.

When the above aspects are considered, the following practical dimensions could be used according to one exemplary embodiment of the present invention: A acoustical waveguide width in the range of 1-4 mm, which matches sound entry holes in a typical unidirectional electret microphone element, a waveguide length in the range of 10-20 mm, and a protective cover thickness in the range of 0.5-5mm.

Further, when used as a foot for a system, some means of proper positioning and threading of signal cable to the electronics in the system must be devised.

An equalizer filter, analogue or digital, could counteract the high frequency peak and tailor the total response to the design goal of the application.

Any microphone element requiring sound wave entry from two directions direction could be used. A typical choice is a unidirectional cardioid electret condenser microphone. The size of the element is in principle not important.

The main advantage of the present invention is that the housing minimizes feedback from loudspeaker to microphone, while simultaneously maximizing microphone sensitivity towards the user for an off-the-shelf unidirectional microphone element, while keeping the microphone protected. This increases sound quality also for full audio band sound pickup.

Further, only one acoustic waveguide for sound entry is tuned to optimize the directivity pattern of the microphone element and simultaneously minimize feedback.

Patent claims

1. A desktop telecommunication terminal (401) comprising a loudspeaker (204) and microphone (201) mounted therein for enabling hands-free operation, wherein said microphone (204) is a directional microphone element having a front and rear acoustical input port,
characterized in that
said directional microphone element is encapsulated within a rigid housing (601), said housing comprising an acoustic waveguide (602) extending from the rear acoustical input port to a waveguide inlet in a first surface of the desktop telecommunication terminal (401), and with one or more openings in a second surface of the desktop telecommunication terminal admitting sound to the front acoustical input port,

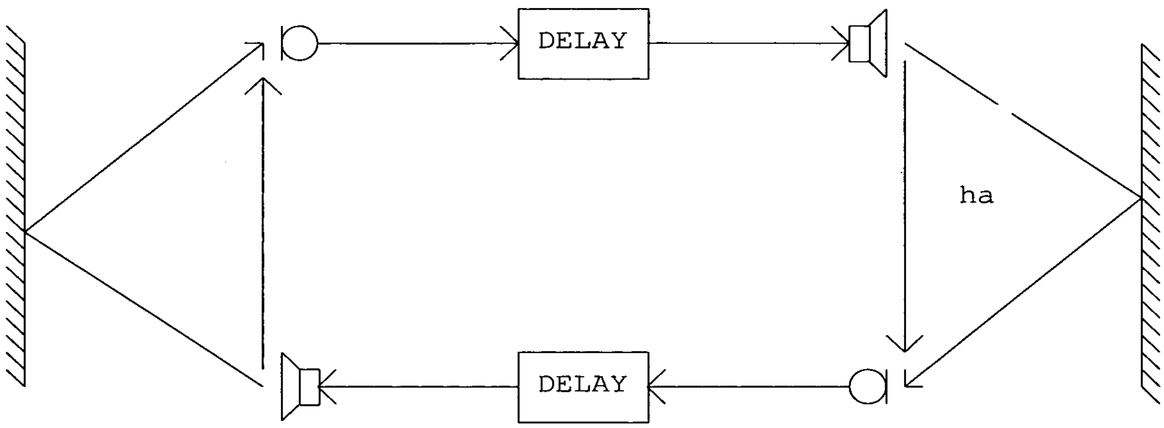
where the direction and length of said acoustic waveguide (602) is tuned to minimize the acoustical distance from the loudspeaker (604) to the rear acoustical input port while simultaneously increase the acoustical distance from the near end user to the rear acoustical input, relative to a free field acoustical distance, to maximize microphone sensitivity in the direction of a near end user while simultaneously minimize microphone sensitivity in the direction of the loudspeaker (204).

2. A desktop terminal according claim 1,
characterized in that said waveguide (602) is angled towards the loudspeaker (204) and simultaneously away from the near end user.

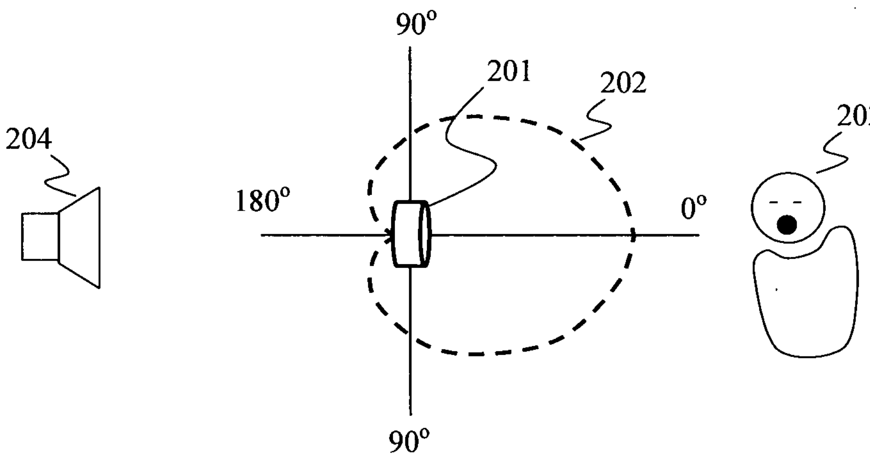
3. A desktop terminal according claim 1,
characterized in that the distance between a near end user and said microphone (201) is shorter than the distance between the near end user and said loudspeaker (204).

4. A desktop terminal according claim 1, where said microphone (201) is mounted in a lower corner of said terminal, and said microphone (201) and said loudspeaker (204) is positioned on opposite vertical halves of the terminal front.

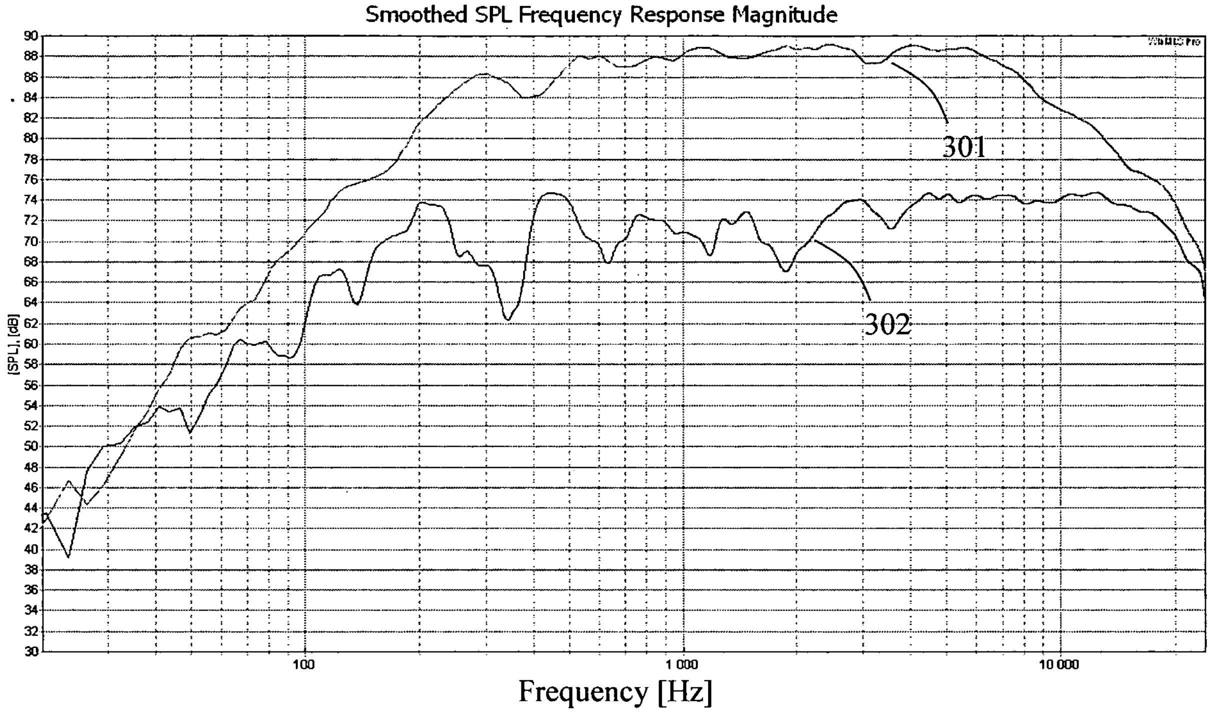
5. A desktop terminal according to one of the proceeding claims,
c h a r a c t e r i z e d i n that said microphone housing (601) is a desktop terminal foot.



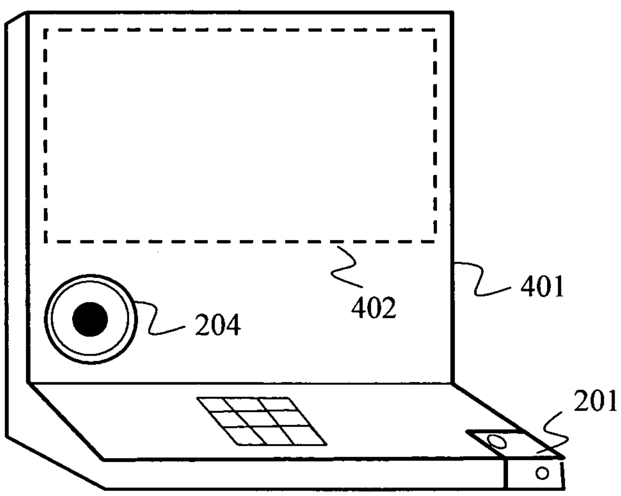
Figur 1



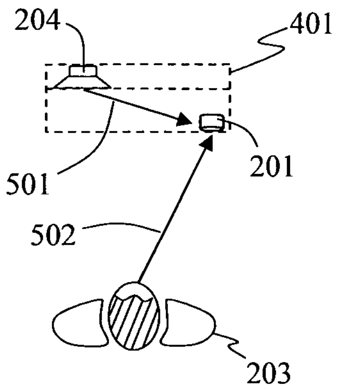
Figur 2



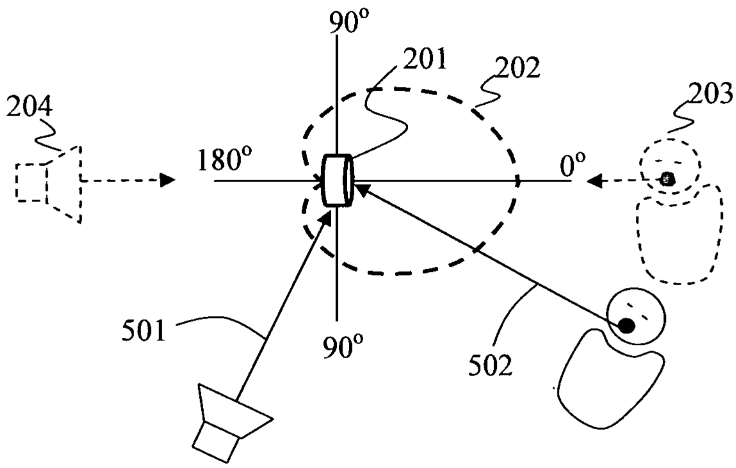
Figur 3



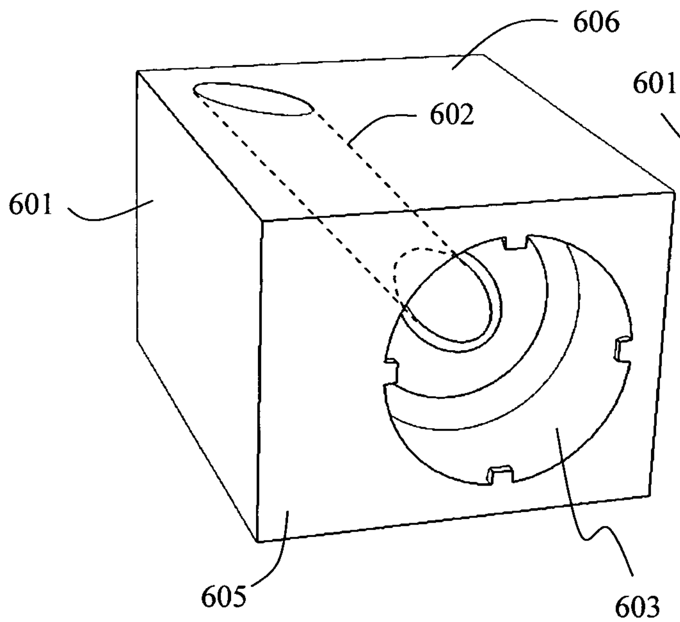
Figur 4



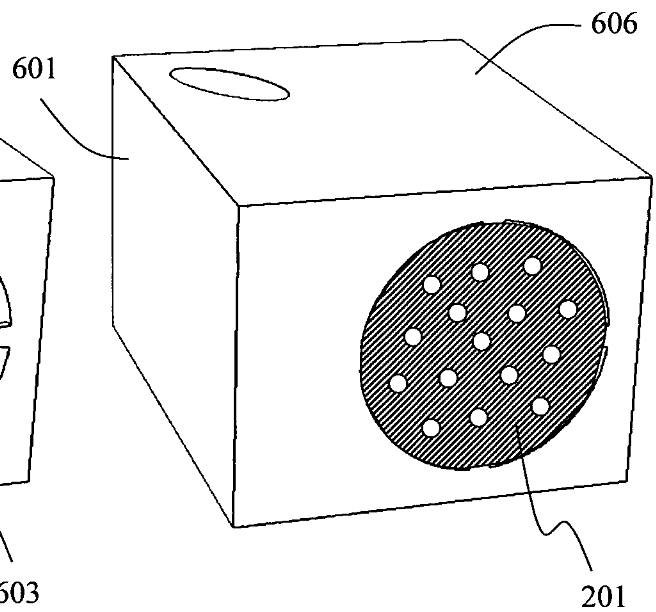
Figur 5A



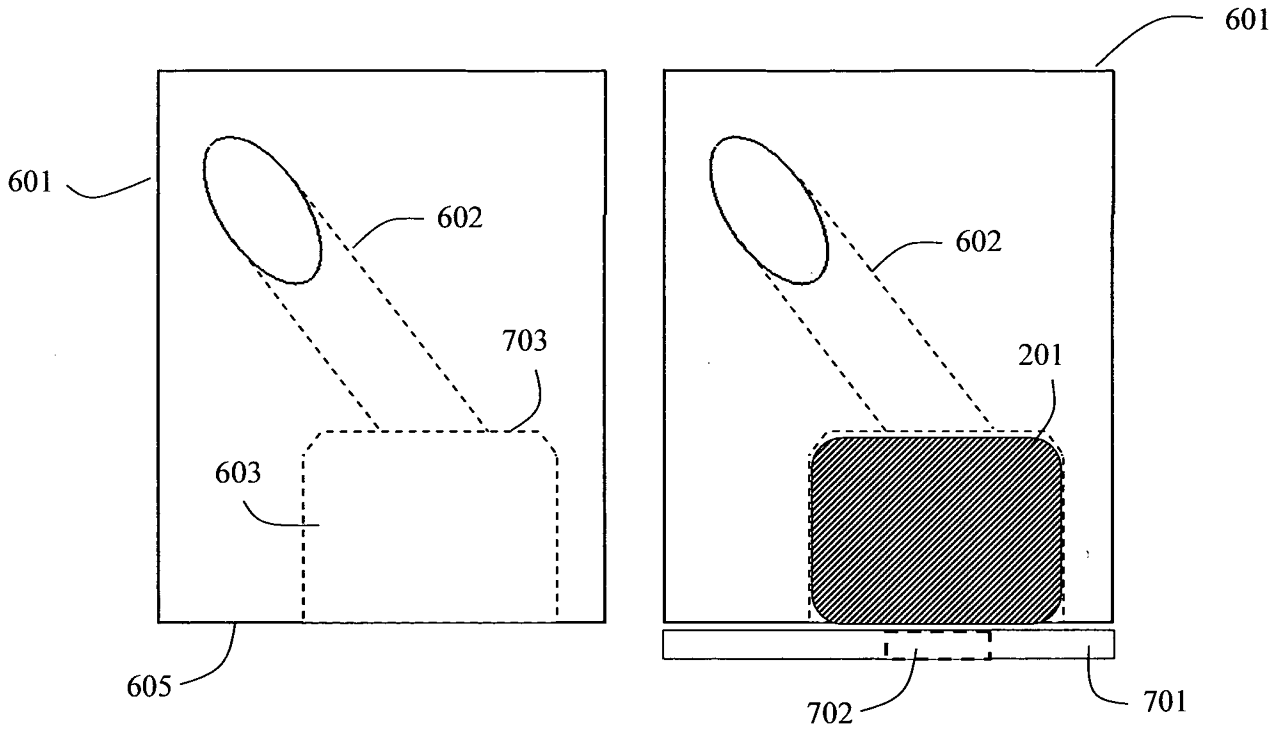
Figur 5B



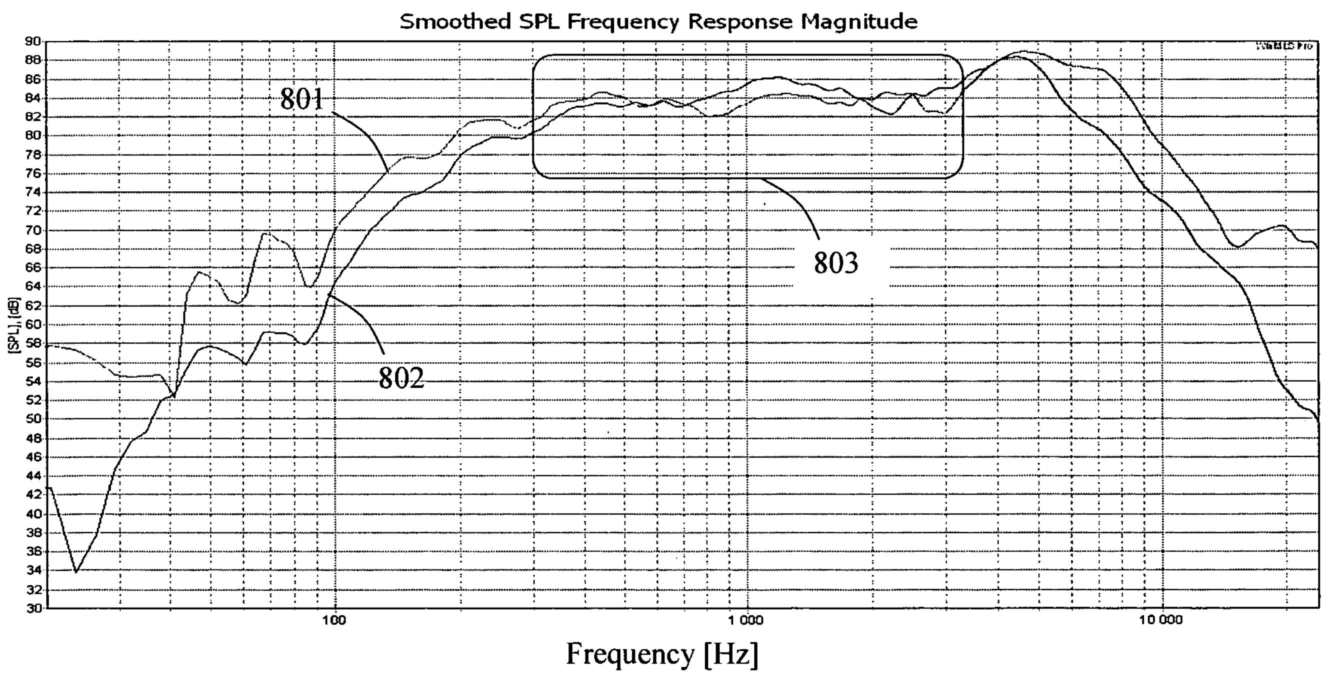
Figur 6A



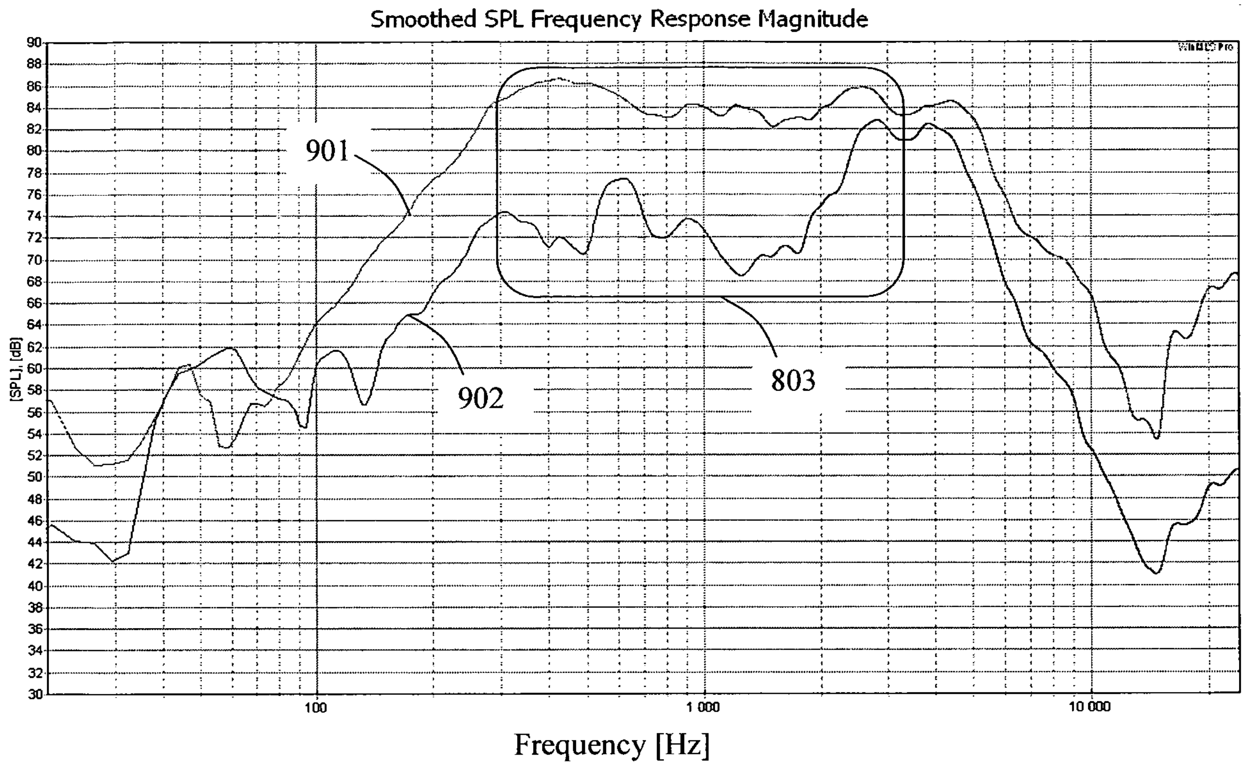
Figur 6B



Figur 7A Figur 7B



Figur 8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[SPL], [dB]
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52
50
48
46
44
42
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38
36
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100
1 000
10 000
901
902
803
Frequency [Hz]

Figur 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/NO2008/000341

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04R1/38 H04M1/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04R H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 121 426 A (BAUMHAUER JR JOHN C [US] ET AL) 9 June 1992 (1992-06-09) abstract column 2, line 38 - line 48; figure 20 column 9, line 4 - line 7 -----	1
A	US 3 715 500 A (SESSLER G ET AL) 6 February 1973 (1973-02-06) abstract; figures 2,4 -----	1,2
A	WO 92/04792 A (BRITISH TELECOMM [GB]) 19 March 1992 (1992-03-19) figures 1,2 abstract -----	1,2
A	DE 44 39 146 A1 (DEUTSCHE TELEKOM AG [DE]) 9 May 1996 (1996-05-09) figure 2 -----	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 December 2008	16/12/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Heiner, Christoph

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NO2008/000341

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