(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 152 637 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.11.2001 Bulletin 2001/45

(51) Int Cl.[7]: **H04R 3/00**

(21) Application number: **01201501.2**

(22) Date of filing: **25.04.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **04.05.2000 NL 1015111**

(71) Applicant: **Geluk, Ronald Jan, Ir.**
NL-2631 PL Nootdorp (NL)

(72) Inventors:
- **Geluk, Ronald Jan**
  2631 PL Nootdorp (NL)
- **de Klerk, Leendert**
  3295 PG s'-Gravendeel (NL)

(74) Representative:
Van kan, Johan Joseph Hubert, Ir. et al
Algemeen Octrooibureau
P.O. Box 645
5600 AP Eindhoven (NL)

(54) Microphone exhibiting frequency-dependent directivity

(57) A directional microphone comprising at least two converters and a circuit for processing electric signals delivered by said converters. The circuit delivers an output signal, wherein the directivity of the microphone increases as the frequency decreases over a limited frequency range. The limited frequency range falls entirely or at least partially within the frequency range of up to 1 kHz. Microphones comprising at least two converters exhibiting different degrees of directivity as well as microphones comprising at least two converters exhibiting the same degree of directivity can be used. In the case that at least two converters exhibiting the same degree of directivity are used, said converters are spaced a certain distance apart, and the signal from a first of said two converters is filtered through a low-pass filter, and the low-pass filtered signal is deducted from the signal from the second converter. The group delay time of the low-pass filter is substantially identical to the delay time of sound between said first and said second converter.

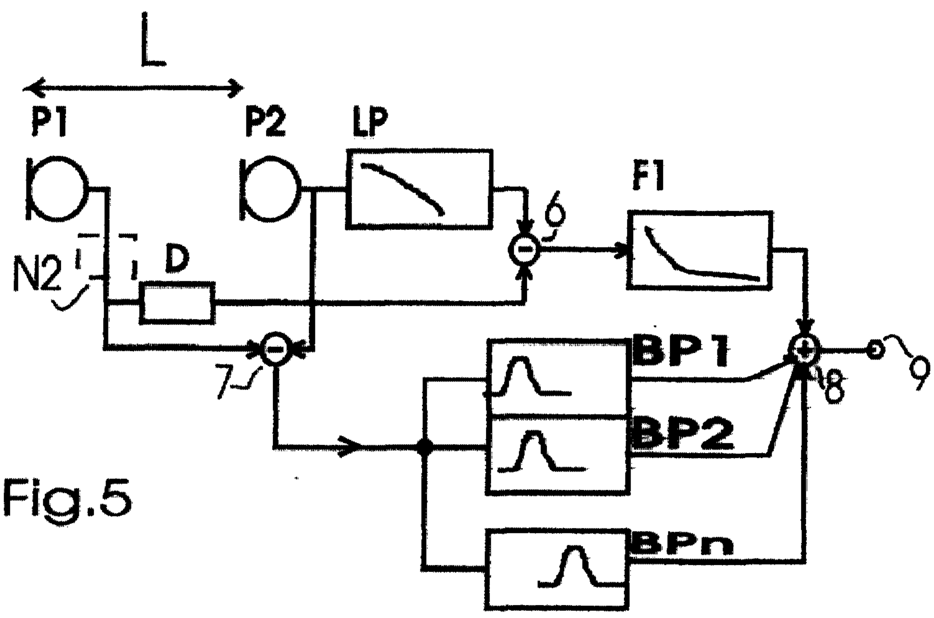


Fig.5

EP 1 152 637 A1

Description

[0001] The invention relates to a directional microphone comprising at least one converter for converting sound into an electric signal as well as a housing.

[0002] Microphones whose directivity increases as the frequency increases are well-known. This characteristic results from the physical properties of the converters or of the constructions in which they are mounted, such as directional tubes, hollow mirrors or rows of transducers. Furthermore, directional microphones are known which have been designed to exhibit frequency-independent directivity. Out of necessity, a small degree of directivity for low frequencies is often accepted so as to keep the dimensions of the microphone within practical bounds.

[0003] It is known that the reverberation time of acoustic rooms is longer in the case of low frequencies than in the case of high frequencies. For concert halls this is a desirable situation indeed, because to the ear the fading of wideband sound takes place evenly. The problem for which the invention provides a solution will now be explained in more detail with reference to Figures 1, 2 and 3, wherein:

Figure 1 shows the reverberation time of a room as a function of the frequency;
Figure 2 shows diagrams of spectral intensities; and
Figure 3 shows the desired frequency characteristics of a microphone according to the invention.

[0004] Figure 1 shows the trend of the reverberation time as a function of the frequency as it may occur in practice. The result of the slower fading of low-frequency sound is that, in the case of a continuous sound, the intensity thereof is also relatively higher than the intensity of the high-frequency portion of the continuous sound. For a microphone exhibiting a uniform sensitivity to frequency and direction, the diffuse sound causes an excess of low-frequency sound, therefore. In this connection, curve 1 of Figure 2 shows the spectral weighing of direct sound, curve 2 shows that of diffuse sound and curve 3 shows the spectral weighing of the electric signal being delivered by a conventional microphone. The excess of low-frequency spectrum in the microphone signal is disadvantageous when recording sound, because it is perceived as spectral colouration, and because low-frequency reverberation that is continued relatively long masks the perception of rapid intensity variations. A factor that plays a role thereby is that the masking effect that low-frequency sound has on high-frequency sound is greater than the other way round. Said spectral colouration and masking manifest themselves in that microphones combine direct sound and diffuse sound indiscriminately into a single signal. With the human ear this is different, since the human ear perceives direct sound and diffuse sound separately, as a result of which the intended colouration and masking are not perceived. In practice, microphones are placed closer to the source of sound than is desirable for other reasons, therefore, in order to prevent colouration and masking. Figure 3 shows the frequency transmissions that are desirable in this connection in forward direction (zero degrees), rearward direction (180 degrees) and for a diffuse sound field. The transmission for a diffuse sound field takes place in opposite sense to curve 2 in Figure 2, therefore.

[0005] The object of the invention is to provide a microphone which, in a room where there is reverberation, delivers an output signal whereof the curve 3 of Figure 2 is flat over the entire frequency range.

[0006] A microphone which is less affected by colouration and masking when used in a room where there is reverberation, is according to the invention characterized in that at least two converters are provided, which each deliver an electric signal, in that a circuit for processing said electric signals is provided, which circuit delivers an output signal, wherein the directivity of the microphone increases as the frequency decreases over a limited frequency range, and in that said limited frequency range falls entirely or at least partially within the frequency range of up to 1 kHz.

[0007] One preferred embodiment of a microphone according to the invention is characterized in that said at least two converters exhibit different degrees of directivity, in that said circuit is a frequency-dependent circuit, and in that said circuit, at frequencies of less than 1 kHz, transmits the signal from one or more converters exhibiting a greater degree of directivity more than the signal from one or more converters exhibiting a smaller degree of directivity.

[0008] Another embodiment of a microphone according to the invention is characterized in that at least two converters exhibiting the same degree of directivity are provided, in that said at least two converters are spaced a certain distance apart, in that said circuit comprises a low-pass filter for filtering the signal from a first of said two converters, and in that said circuit comprises a differential circuit, to which on the one hand the signal from a second of said at least two converters can be supplied, and to which on the other hand the filtered signal can be supplied. As a result, a difference signal is produced which equals the signal from the second of said at least two converters for high frequencies, and that a signal is obtained for low frequencies wherein directionality determined by the direction in which the two microphones are arranged one behind another has been obtained.

[0009] Preferably, such a microphone is characterized in that the group delay time of the low-pass filter is substantially identical to the group delay time of sound from the first of said at least two converters until the second of said at least two converters, at least over said limited frequency range.

[0010] As a result, sound coming from behind, that is, sound which reaches the first converter first, undergoes an additional attenuation, because the time which a sound wave needs to travel a distance from the second converter to the first is identical to the time which the signal from the first converter needs to reach the differential point via the low-pass filter. In this manner a second order high-pass effect is obtained for sound coming from behind, whilst the high-pass effect for sound coming from the front is of the first order type.

[0011] The invention will now be explained in more detail with reference to the drawings that have not been discussed so far, wherein:

Figure 4 shows a first embodiment of a microphone according to the invention;
Figure 5 shows a second embodiment of a microphone according to the invention; and
Figure 6 shows an embodiment of a microphone which is a combination of the embodiments that are shown in Figures 4 and 5.

[0012] Figure 4 shows an example of a first embodiment of a microphone according to the invention. This microphone includes a omnidirectional pressure converter P, a directional speed converter V, an adder 2 and a frequency-dependent network 3 comprising a capacitor C and a resistor R. The addition in adder 2 results in a new signal being produced, which signal corresponds to a microphone exhibiting a certain degree of directivity, hereinafter called a directional signal. As is known, the relation between the output signals from convertors V and P determines the directivity, which relation is selected so that the response is minimal for sound coming from behind, that is, sound coming from the direction in which the directional speed converter is least sensitive. The frequency-dependent network 3 is in fact a frequency-dependent voltage divider consisting of a resistor R and a capacitor C, and it transmits the aforesaid directional signal for low frequencies and the signal from the omnidirectional microphone for high frequencies. As a result, the output signal on output 4 corresponds to the signal from a microphone which exhibits a higher degree of directivity at low frequencies than at high frequencies. Speed converter V is disposed in the immediate vicinity of pressure converter P. Advantageously, a small-size speed converter is used, therefore, so that the sound field of pressure converter P will not be disturbed. Furthermore it is advantageous if the frequency transmissions of the two converters coincide, so that a uniform transmission is obtained in the frequency range in which they both contribute to approximately the same extent. A speed converter that can be suitably used in this connection is the "Microflown" speed microphone, which is marketed by Microflown Technologies B.V. at Zevenaar, Netherlands. It is known per se that speed microphones for proximate sound sources may have frequency-dependent transmission. For proximate sound sources it is therefore possible, as usual, to connect a frequency-dependent attenuator 5, indicated by a dashed line, between speed converter V and adder 2, or between adder 2 and resistor R or between the junction of resistor R and capacitor C and output 4.

[0013] Figure 5 shows an example of a second embodiment of a microphone according to the invention, which comprises two converters P1 and P2. P1 and P2 are converters which have the same directivity, both being pressure converters or both being speed converters, for example. Converters P1 and P2 are spaced a distance L apart. Due to the delay time of the sound over distance L, which delay time depends on the direction from which the sound originates with respect to the direction of the communication line between converters P1 and P2, the signals from P1 and P2 differ from each other. On the basis of the differences between the signals from P1 and P2, a microphone signal exhibiting the desired properties is generated. As a result of the fact that P1 and P2 are spaced a distance L apart, the sound field of P1 will not be disturbed by the proximity of P2, and vice versa. Furthermore it is possible to use identical converters for P1 and P2, so that the frequency transmission is identical. It is a well-known fact that the amplitude of the difference signal from two spaced-apart converters is not only directional, but that it drifts in accordance with a sinus function of the frequency which is undesirable for the present use. In order to prevent this undesirable effect, the signal from P2 is filtered through a low-pass filter LP. Then the difference signal is determined from the output signal of the low-pass filter LP and the output signal of converter P1. For high frequencies, this difference signal equals the signal from P1, and consequently the frequency transmission is uniform for high frequencies, without any directionality other than the directionality of converter P1. Preferably, the group delay time of the low-pass filter LP is identical to the delay time of the sound via the shortest route between P1 and P2. As a result, sound coming from behind, that is, sound that reaches converter P2 first, undergoes additional attenuation. Said attenuation is caused by the fact that the time which a sound wave needs to travel the distance between P2 and P1 is identical to the time which the signal from P2 needs to reach the differential point, differential circuit 6, via the low-pass filter. In this manner a second order high-pass effect is obtained for sound coming from behind, whilst the high-pass effect for sound coming from the front is of the first order type. If the group delay time of low-pass filter LP and the distance between converters P1 and P2 is such that the group delay time is longer than the delay time of the sound between the converters P1 and P2 via the shortest route therebetween, an additional delay line D is incorporated in the communication line between converter P1 and differential circuit 6. The delay effected by the delay line D is set so that the delay time of the sound over distance L plus the delay from a delay line D equals the group delay time through low-pass filter LP.

[0014] In the foregoing it has been assumed that sound coming from behind undergoes an additional attenuation. Sound from behind does not come exclusively from a direction straight behind the microphone, but it may come from may other directions. Each of said directions involves a specific time difference between the times at which a specific wave front reaches converter P2 first and subsequently converter P1. The more lateral the position of the source from which the sound in question originates, the shorter the time difference in question. It is possible, therefore, to opt for a direction of minimum response other than straight from behind by giving the signals that are being supplied to the differential circuit 6 a time difference other than zero, for example by selecting a low-pass filter having a different group delay time and/or by changing the setting of delay line D.

[0015] The output signal from differential circuit 6 has a first order high-pass transmission for sound from the front. This is corrected by means of low-over-high filter F1, which thus, in the main, transmits low frequencies more than higher frequencies, or, filter F1 exhibits a transmission characteristic which is substantially constant for higher frequencies and a transmission characteristic which increases as frequencies decrease, or a non-decreasing transmission characteristic, for lower frequencies.

[0016] If the transmission for sound from the front would be corrected by means of filter F1 in such a manner that a uniform transmission takes place, this would mean that the transmission for lateral sound will be less uniform, however. The output signal from filter F1 is now a signal which exhibits a directivity which increases as the frequency decreases, in any case in the entire low-frequency range for a direction from the front and from behind, and perhaps not in the entire low-frequency range for lateral directions.

[0017] Then non-uniformness for lateral sound of the output signal from filter F1 can be compensated in the following manner. Numeral 7 indicates a differential circuit by means of which the difference signal is determined from the signals from converters P1 and P2. The difference signal has no response for lateral sound, that is, for sound whose sound waves reach converters P1 and P2 simultaneously. For other directions, the output signal from differential circuit 7 increases as the sound comes from a direction that differs more from the exactly lateral direction. To that end, a band filter BP1, BP2, .. BPn is inserted from the output signal from differential circuit 7 for every frequency range in which the output signal from filter F1 is different from the uniform transmission, in such a manner that the signal on the output of filter F1 is compensated for every frequency band that is transmitted by the bandpass filters BP1-BPn, such that the sum for each frequency band arrives at a uniform transmission. To that end, the output signals from filter F1 and from bandpass filters BP1-BPn are combined in an adder 8 and delivered to the output 9 of the microphone.

[0018] It is also possible to combine the various bandpass filters BP1-BPn into a single filter after having determined their position and their form in the frequency domain. It is possible in this connection to make advantageous use of a digital filter whose transmission can be rendered precisely complementary to the non-uniformity that remains in the transmission in the output signal from filter F1. In that case the digital filter is a so-called digital multiple bandpass filter.

[0019] So far it has been assumed that the sound sources are located a relatively large distance away from converters P1 and P2. In the case that the a sound source is located closer to either one of the two converters, however, for example closer to P1, the output voltage of P1, whether or not frequency-dependent, will be higher than that of P2. An adjustable, whether or not frequency-dependent attenuator N2, illustrated in a dotted line, may be incorporated in the signal line of P1 in a well-known manner. The consequence of attenuator N2 being activated, however, is that the suppression of sources located further away decreases. After all, said suppression is based on the assumption that the output signals from converters P1 and P2 are identical. Instead of using an attenuator N2, it may be advantageous, therefore, to correct the frequency transmission for nearby sources with the adaptation of filters F1 and BP1-BPn, and to leave out the attenuator N2 or refrain from using it.

[0020] Figure 6, shows a combination of the first and the second embodiment of the invention, which will now be explained in more detail. Converters M2 and M3, combined with signal processor F, form a device as described with reference to Figure 5, wherein converter M2 corresponds to converter P1, converter M3 corresponds to converter P2 and the output signal from signal processor F corresponds to the output signal on output 9. M1 is a converter which exhibits less directivity than the combination of M2 and M3, and consequently it can be combined, in accordance with the principles that underlie the circuit as shown in Figure 4, with the circuit that is formed by converters M2, M3 and signal processor F. An advantageous aspect of this embodiment is that for converters M2 and M3 only the performance for low frequencies is relevant, whilst for M1 the performance for high frequencies is relevant. This is advantageous if it is desired to use speed converters wherein, as is well-known, it is not possible to combine into one converter the desired properties of a high-quality converter for high frequencies and a high quality converter for low frequencies. In the configuration of Figure 6, however, advantageous use can be made of a usual capacitive speed converter for M1 and of a so-called "Microflown" converter for M2 and M3.

[0021] In the above, a distinction has been made between the terms converter and microphone. This may have created the impression that the term converter is understood to mean exclusively the element which causes an electric signal to be generated thereacross as a result of the action of sound pressure. It is noted that within the framework of the above description and the appended claims, also an element which in ordinary terms is called a "microphone" is referred to as a converter. Accordingly, such a converter comprises an element which causes an electric signal to be generated thereacross as a result of the action of sound pressure as well as a handle housing therefor as well as a terminal for connection to an amplifier. The handle housing may furthermore accommodate a power supply and/or signal processing circuits other than the circuits to which the present invention relates. The electric signal to which the present invention relates will appear at said terminal.

[0022] A great many embodiments will be apparent to a person who has perused the above. Any and all such embodiments are considered to fall within the scope of the invention.

Claims

1. A directional microphone comprising at least one converter for converting sound into an electric signal as well as a housing, **characterized in that** at least two converters are provided, which each deliver an electric signal, **in that** a circuit for processing said electric signals is provided, which circuit delivers an output signal, wherein the directivity of the microphone increases as the frequency decreases over a limited frequency range, and **in that** said limited frequency range falls entirely or at least partially within the frequency range of up to 1 kHz.

2. A microphone according to claim 1, **characterized in that** said at least two converters exhibit different degrees of directivity.

3. A microphone according to claim 1, **characterized in that** said circuit is a frequency-dependent circuit, and **in that** said circuit, at frequencies of less than 1 kHz, transmits the signal from one or more converters exhibiting a greater degree of directivity more than the signal from one or more converters exhibiting a smaller degree of directivity.

4. A microphone according to claim 1, **characterized in that** at least two converters exhibiting the same degree of directivity are provided, **in that** said at least two converters are spaced a certain distance apart, **in that** said circuit comprises a low-pass filter for filtering the signal from a first of said two converters, and **in that** said circuit comprises a differential circuit, to which on the one hand the signal from a second of said at least two converters can be supplied, and to which on the other hand the filtered signal can be supplied.

5. A microphone according to claim 4, **characterized in that** the group delay time of the low-pass filter is substantially identical to the group delay time of sound from the first of said at least two converters until the second of said at least two converters, at least over said limited frequency range.

6. A microphone according to claim 4, **characterized in that** said circuit comprises a delay element for delaying the signal from the second of said at least two converters, and that the group delay time of the low-pass filter is substantially equal, at least over said limited frequency range, to the sum of the delay time of sound from the first of said at least two converters until the second of said at least two converters plus the delay time of the delay element.

7. A microphone according to claim 4, 5 or 6, **characterized in that** an output of the differential circuit is connected to an input of a low-over-high filter which exhibits a substantially constant transmission characteristic for higher frequencies and a transmission characteristic which increases as the frequency decreases for lower frequencies.

8. A microphone according to claim 7, **characterized in that** a second differential circuit is provided, a first input of which is connected to the first of said at least two converters, and a second input of which is connected to the second of said two converters, and **in that** an output of said second differential circuit is connected to an input of at least one bandpass filter, that a adder is provided, a first input of which is connected to an output of said low-over-high filter, and at least one second input of which is connected to an output of said at least one bandpass filter.

9. A microphone according to claim 8, **characterized in that** more than one bandpass filter is provided, and **in that** as many inputs of said adder are connected to the outputs of said bandpass filters.

10. A microphone according to claim 8, **characterized in that** said at least one bandpass filter is a digital, multiple bandpass filter.

11. A microphone according to claim 8, **characterized in that** said converter exhibiting a greater degree of directivity is a microphone according to any one of the claims 4 - 10.

Fig.1

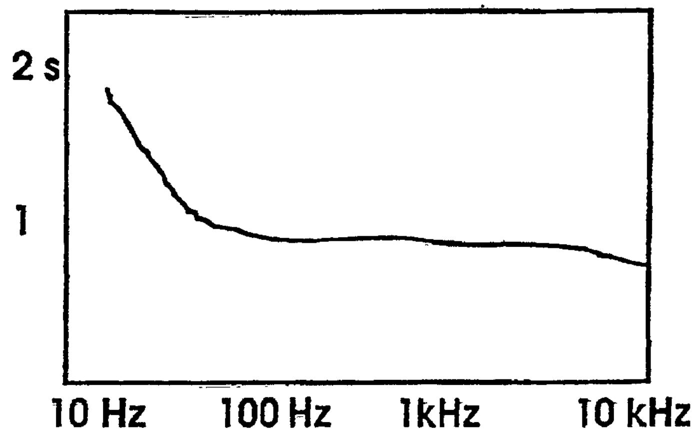


Fig.2

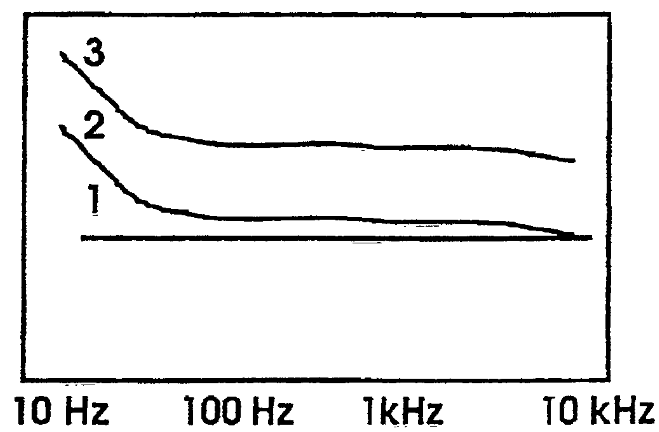
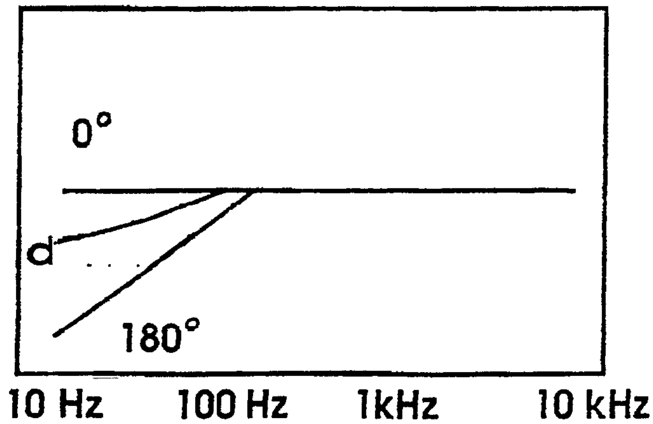


Fig.3



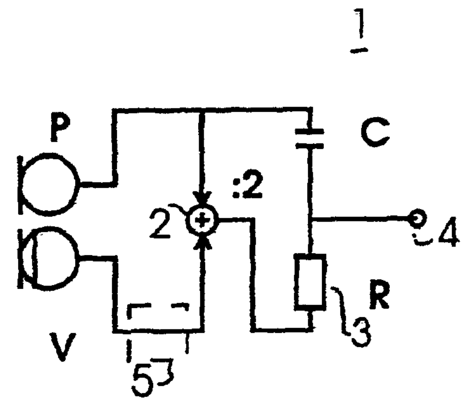


Fig.4

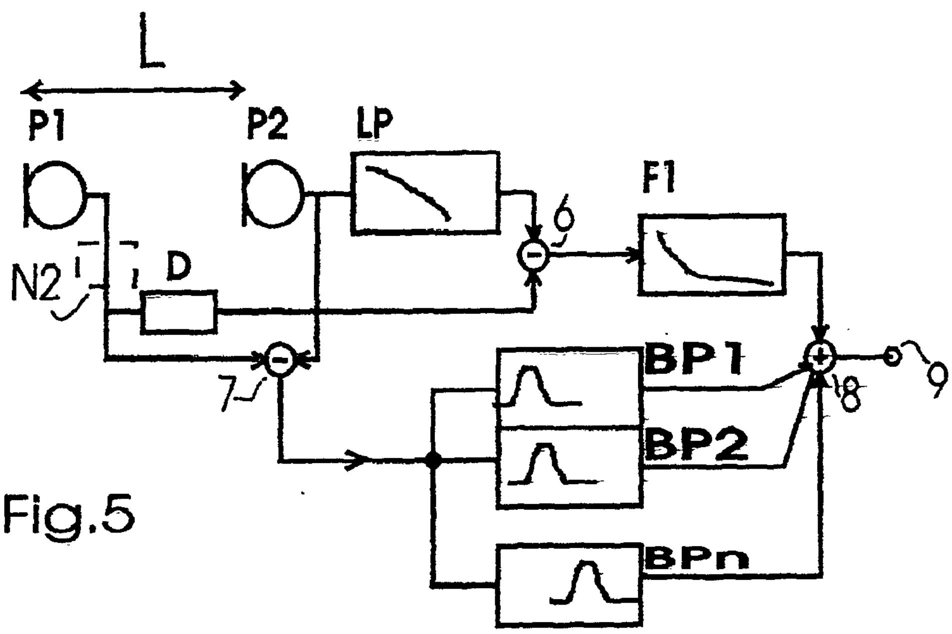


Fig.5

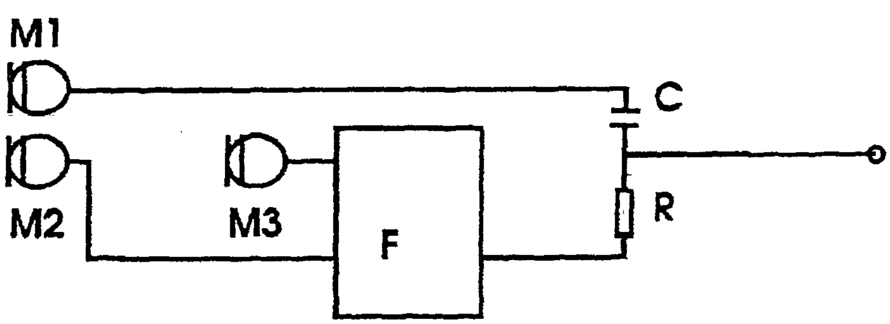


Fig.6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 20 1501

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	EP 0 430 513 A (MATSUSHITA ELECTRIC IND CO LTD) 5 June 1991 (1991-06-05) * column 3, line 4 - column 4, line 20; figures *	1-11	H04R3/00
A	EP 0 924 958 A (MICROTRONIC NEDERLAND BV) 23 June 1999 (1999-06-23) * column 2, line 7 - column 3, line 37; figures *	1-11	
A	DE 44 36 272 A (SCHALLTECHNIK DR ING SCHOEPS G) 18 April 1996 (1996-04-18) * column 3, line 50 - column 5, line 20; figures *	1-11	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			H04R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 August 2001	Gastaldi, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 20 1501

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

22-08-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0430513 A	05-06-1991	DE 69022688 D	02-11-1995
		DE 69022688 T	09-05-1996
		JP 3219798 A	27-09-1991
		KR 9406042 Y	01-09-1994
		US 5193117 A	09-03-1993
EP 0924958 A	23-06-1999	NL 1007858 C	22-06-1999
DE 4436272 A	18-04-1996	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82