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(54) **LOUDSPEAKER TESTING AND PROTECTION**

(57) The present invention provides a method (500) of testing and protecting a loudspeaker in an audio device under test, which comprises the loudspeaker. The method at least comprises adjusting (501) an output volume of the device under test to be initially substantially less than a maximum possible volume of the audio device, applying (502) an audio test signal to the audio device, emitting a sound from the loudspeaker in response to the audio test signal, receiving the sound from the loudspeaker with a test microphone, outputting an electrical signal from the microphone in response to the sound, and analysing (503) the electrical signal to measure a level of distortion in the sound emitted by the loudspeaker. If the measured level of distortion is found to be less than or equal to a maximum acceptable level of distortion, the method then comprises incrementally increasing (504) the output volume of the audio device and repeating the process of emitting a sound from the loudspeaker, receiving the sound with the microphone, outputting an electrical signal from the microphone and analysing (503) the electrical signal, until the measured level of distortion is greater than the maximum acceptable level of distortion. Then the method comprises stopping (505) the audio test signal, and determining (506) whether the output volume of the audio device is less than a least acceptable value of the maximum volume of the audio device. If so, the method comprises rejecting (507) the loudspeaker as out of specification. If not, the method comprises setting (508) the maximum volume of the audio device to be equal to the output volume of the audio device when the measured level of distortion was last less than or equal to the maximum acceptable level of distortion. The method ensures that the maximum volume of the audio

device is set at a level below that at which damage to the loudspeaker can occur, whilst also ensuring that the maximum volume of the audio device is set to be more than a least acceptable value, by rejecting loudspeakers that are out of specification. The present invention also provides an audio testing system for carrying out such a method, and an audio device comprising at least one loudspeaker, which has been tested according to such a method.

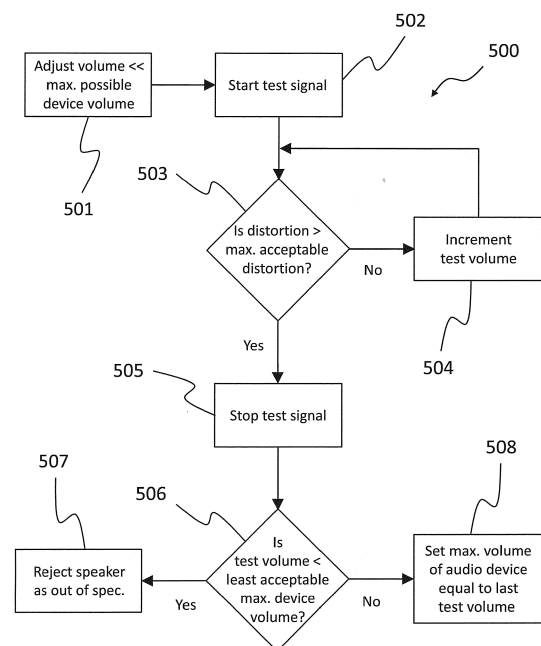


Fig. 5

Description

[0001] The present invention relates to an audio testing system according to claim 1, a method of testing a loudspeaker according to claim 6, and an audio device according to claim 15.

Background of the Invention

[0002] It is known that peaks in sound power output levels are the most common reason for irreversible damage to loudspeakers in audio devices. Such peaks can move the diaphragm of a loudspeaker suddenly and strongly by sufficiently much that the loudspeaker will be unable to return to its normal rest position, or such that the diaphragm's suspension becomes torn or otherwise damaged. A loudspeaker's departure from its normal rest position during operation is sometimes known as the loudspeaker's excursion, and the limit beyond which such damage to the loudspeaker can occur is therefore known as the excursion limit. Several different techniques are known in the prior art for trying to prevent loudspeakers from exceeding their excursion limit, in order to protect them against such irreversible damage.

[0003] One known technique is to monitor the amplitude of an audio signal input to a loudspeaker of an audio device and to use an equalizer of the audio device to reduce the gain of low-frequency components of the input audio signal if the amplitude of the signal is found to be above a predetermined level. This reduces the risk of high-amplitude, low-frequency components causing the loudspeaker to exceed its excursion limit, damaging the loudspeaker. However, the disadvantage of this approach is that the maximum sound output level is not monitored or controlled, so that even if the gain of the input signal is reduced, the output level may still exceed that at which damage to the loudspeaker can occur.

[0004] Another approach, as described, for example, in US 4,583,245, is not to reduce the amplification of high-amplitude, low-frequency components of an input audio signal, but to reroute them away from one loudspeaker of an audio device which risks being damaged by them to another loudspeaker of the device which is better able to cope with them, such as from a tweeter to a woofer. This is also done by monitoring the level of the input audio signal, but by changing the frequency of a boundary at which the frequency components are sent to each of the two loudspeakers (called the "crossover" frequency), if a loudspeaker overload condition is found to exist. Thus according to this technique, the crossover frequency is temporarily increased to route high-amplitude, low-frequency components to the woofer, rather than to the tweeter, when the amplitude of the input signal is found to be above a predetermined level. However, since the sound output level is manually adjusted, the adjustment of the crossover frequency can also be incorrect. Moreover, since the sound output level is again not monitored, there remains a risk that damage to the tweeter in such an audio device can still occur as there is no peak level control on the loudspeaker's sound output level.

Object of the Invention

[0005] It is therefore an object of the invention to provide an audio testing system, a method of testing a loudspeaker, and an audio device.

Description of the Invention

[0006] The object of the invention is solved by an audio testing system according to claim 1. The audio testing system at least comprises an audio device under test, at least one microphone, an audio analyser, a signal feedback line from the audio analyser to the device under test, and means for adjusting and setting a maximum volume of the device under test. The device under test comprises at least one loudspeaker configured to receive an audio test signal and to emit a sound in response to the audio test signal. The at least one microphone is configured to receive the sound from the at least one loudspeaker and to output an electrical signal in response thereto. The audio analyser is configured to receive the electrical signal from the at least one microphone and to analyse the electrical signal.

[0007] The audio device under test may be any device comprising at least one loudspeaker, such as a television, a mobile phone, a portable audio device, a tablet, laptop or desktop computer, a hi-fi equipment component or system, a home cinema system, an in-car entertainment system, and so on. The at least one microphone is preferably one or more standardized, high-fidelity test microphones.

[0008] This solution is beneficial because the actual output sound level of the loudspeaker in the audio device under test can be monitored by the audio analyser during testing and controlled by the means for adjusting and setting the maximum volume of the device under test, thereby guaranteeing that the maximum desirable output sound level of the loudspeaker cannot be exceeded during normal operation of the device subsequent to its testing and after the maximum volume of the device under test has been set.

[0009] Advantageous embodiments of the invention may be configured according to any claim and/or part of the following description.

[0010] In one possible embodiment, the audio device under test may comprise at least one digital signal input and be

separate from the audio analyser. By a digital signal input is meant an input suitable for receiving an electrical signal in digital form. Examples of such audio devices include tablet computers, mobile phones, in-car entertainment systems and the like, which although they may, in some cases, comprise their own microphone for receiving a sound input, do not generally also have a socket suitable for receiving an analogue audio input in the form of an electrical signal, to which one or more standardized, high-fidelity test microphones can be connected. In such a case, the audio analyser is a separate component of the audio testing system from the audio device under test, and the signal feedback line from the audio analyser to the device under test is supplied in digital form to the digital signal input of the device under test.

[0011] In an alternative possible embodiment, the audio device under test may instead comprise the audio analyser and at least one analogue audio signal input connected thereto. Examples of such audio devices include hi-fi equipment, televisions and home cinema systems, which although they may or may not comprise their own microphone for receiving a sound input, generally do have a socket for receiving an analogue audio signal, to which one or more standardized, high-fidelity test microphones may also be connected. Such audio devices generally also comprise an analogue-to-digital converter connected to such a socket, which is configured to convert any input analogue audio signal into digital form and which may also be used as an audio analyser.

[0012] In one possible embodiment of the audio testing system, the means for adjusting and setting a maximum volume of the device under test may comprise a software module of the device under test. The software module may comprise at least one of audio signal processing software and firmware of the device under test. This embodiment may be more convenient for devices such as mobile phones, televisions, and tablet, laptop or desktop computers.

[0013] In an alternative possible embodiment of the audio testing system, the means for adjusting and setting a maximum volume of the device under test may comprises a hardware component of the device under test, such as a loudspeaker protection circuit. This alternative embodiment may be more convenient for devices such as hi-fi equipment, in-car entertainment systems, and home cinema systems.

[0014] The present invention also relates to a method of testing a loudspeaker according to claim 6. The method at least comprises adjusting an output volume of an audio device under test, wherein the device under test comprises at least one loudspeaker, such that the output volume of the audio device is initially substantially less than a maximum possible volume of the audio device. The method then comprises applying an audio test signal to the audio device, emitting a sound from the at least one loudspeaker in response to the audio test signal, receiving the sound from the at least one loudspeaker with at least one microphone, outputting an electrical signal from the microphone in response to the sound, and analysing the electrical signal to measure a level of distortion in the sound emitted by the loudspeaker. If the measured level of distortion is less than or equal to a maximum acceptable level of distortion, the method then comprises incrementally increasing the output volume of the audio device and repeating the process of emitting a sound from the at least one loudspeaker, receiving the sound with the at least one microphone, outputting an electrical signal from the microphone and analysing the electrical signal, until the measured level of distortion is greater than the maximum acceptable level of distortion. The method then comprises stopping the audio test signal, and determining whether the output volume of the audio device is less than a least acceptable value of the maximum volume of the audio device. If the output volume of the audio device is less than a least acceptable value of the maximum volume of the audio device, then the at least one loudspeaker is rejected as out of specification. On the other hand, if the output volume of the audio device is not less than the least acceptable value of the maximum volume of the audio device, then the maximum volume of the audio device is set to be equal to the output volume of the audio device when the measured level of distortion was last less than or equal to the maximum acceptable level of distortion.

[0015] This solution is beneficial because it guarantees that the maximum volume of the audio device can be set at a level below that at which damage to the loudspeaker starts to occur, as indicated by when the maximum acceptable level of distortion is reached, whilst also ensuring that the maximum volume of the audio device is also set to be more than a least acceptable value, by rejecting loudspeakers that are out of specification.

[0016] The method may be carried out in an anechoic chamber, using one or more standardized, high-fidelity test microphones, carefully placed in relation to the at least one loudspeaker of the audio device under test according to a standardized test protocol, in such a manner as is well established for testing loudspeakers. Since, in general, distortion in the audio testing system due to the at least one loudspeaker of the audio device under test will usually be significantly greater than any distortion due to the at least one microphone and other electronic or software components of the system, such other sources of distortion may safely be ignored when the electrical signal is analysed.

[0017] Preferably, the output volume of the audio device under test is initially adjusted to be less than about three-quarters of the maximum possible output volume of the audio device, more preferably about two-thirds of the maximum possible output volume of the audio device, and most preferably, around about one-half of the maximum possible output volume of the audio device. So, for example, if the audio device under test has a maximum possible output volume of 10 sound watts, the output volume of the device under test is preferably initially adjusted to be less than 7.5 sound watts, more preferably less than 6.7 sound watts, and most preferably, around about 5 sound watts. Initially adjusting the output volume of the device under test in this way has the advantage of reducing the risk of accidentally damaging the at least one loudspeaker during testing.

[0018] Preferably, the output volume of the audio device under test is incrementally increased each time from the initial output volume by less than about 5%, and more preferably by only from about 1% to about 4%, of the maximum possible output volume of the audio device. Thus, for example, if the audio device under test has a maximum possible output volume of 10 sound watts and its output volume is initially adjusted to be about 6 sound watts, the output volume can preferably be incrementally increased firstly to 6.25 sound watts, then to 6.5 sound watts, then to 6.75 sound watts, and so on, until the level of distortion is measured to be greater than the maximum acceptable level of distortion. Incrementally increasing the output volume of the audio device under test in this way also has the advantage of reducing the risk of accidentally damaging the at least one loudspeaker during testing.

[0019] Preferably, the audio test signal comprises a plurality of peaks in power output at different frequencies. This is beneficial because it is typically peaks in power output which are responsible for damaging loudspeakers. Thus by providing a plurality of peaks in power output at different frequencies, the at least one loudspeaker may be tested in such a way as to protect it from being damaged during use after testing across a range of frequencies corresponding to the different frequencies of the peaks in power output.

[0020] If so, the method preferably comprises applying the plurality of peaks in power output to the device under test sequentially at the same output volume of the audio device as each other. This is beneficial because it makes it easier for the audio analyser to detect harmonics of each of the plurality of peaks in power output without being masked by or interference from other ones of the plurality of peaks in power output at different frequencies.

[0021] In one possible embodiment, the method comprises generating the audio test signal and analysing the electrical signal outside the audio device under test. This embodiment of the method is beneficial because it is best suited to testing the at least one loudspeaker of audio devices which do not have a socket for receiving an analogue audio input in the form of an electrical signal, such as tablet computers, mobile phones, in-car entertainment systems and the like, but which may nonetheless be tested with a separate audio analyser for generating the audio test signal and analysing the electrical signal from the at least one microphone.

[0022] In another possible alternative embodiment, the method comprises generating the audio test signal and analysing the electrical signal in the audio device under test itself. This embodiment of the method is beneficial because it is best suited to testing the at least one loudspeaker of audio devices which have a socket for receiving an analogue audio signal, as well as an analogue-to-digital converter to convert an input analogue audio signal into digital form, such as hi-fi equipment, televisions and home cinema systems. In such a case, the analogue-to-digital converter can be used as an audio analyser to allow the audio device under test to analyse the performance of its own at least one loudspeaker.

[0023] In any case, the distortion which is measured is preferably total harmonic distortion (THD). This is beneficial because it allows the use of a THD analyser having a notch filter, the frequency of which may be varied to correspond to the frequency of a peak in power output of the audio test signal.

[0024] If the at least one loudspeaker is rejected as being out of specification, the method preferably further comprises removing the rejected loudspeaker from the device under test, replacing the removed loudspeaker with another loudspeaker, and repeating the same method of testing on the device under test. This solution is beneficial because it allows the device under test to be corrected and provided with a replacement loudspeaker which is within specification.

[0025] The present invention further relates to an audio device comprising at least one loudspeaker, wherein the loudspeaker has been tested according to the method described herein, and the maximum volume of the audio device has been adjusted as a result of the test.

[0026] The present invention further relates to a computer program product or a program code or system for executing one or more than one of the herein described methods.

[0027] Further features, goals and advantages of the present invention will now be described in association with the accompanying drawings, in which exemplary components of the invention are illustrated. Components of the devices and methods according to the invention, which are at least essentially equivalent to each other with respect to their function can be marked by the same reference numerals, wherein such components do not have to be marked or described in all of the drawings.

[0028] In the following description, the invention is described by way of example only with respect to the accompanying drawings.

Brief Description of the Drawings

[0029]

Figs. 1A, 1B and 1C are respective schematic circuit diagrams of a loudspeaker protection circuit of the prior art, and the application thereof in two-speaker and three-speaker audio systems;

Fig. 2 is a schematic diagram of a first embodiment of an audio testing system;

Fig. 3 is schematic diagram of a second embodiment of an audio testing system;

Fig. 4 is a graph plotting power against frequency, schematically representing an audio test signal; and

Fig. 5 is a schematic flow diagram of a method of testing an audio device.

Detailed Description of the Drawings

[0030] Figs. 1A, 1B and 1C respectively show a prior art loudspeaker protection circuit and its application in two-speaker and three-speaker audio systems, as described in US 4,583,245. Referring firstly to Fig. 1A, the loudspeaker protection circuit comprises an input amplifier 10, to which an audio input signal is applied. The amplified signal is passed from there to a high-pass/low-pass filter section 12, from where low-frequency components of the signal are routed via a first output amplifier 14 to a low-pass output and high-frequency components are routed via a second output amplifier 16 to a high-pass output. A high-pass sense input line 19 is monitored by an excursion limit sense circuit 18. If an overload condition of the audio input signal to input amplifier 10 is detected on the high-pass sense input line 19, the excursion limit sense circuit 18 switches the crossover frequency of the high-pass/low-pass filter section 12 via a switch 20 and a line 22 connected to the high-pass/low-pass filter section 12, such that high amplitude low-frequency components of the audio input signal originally intended for the high-pass output amplifier 16 are rerouted to the low-pass output amplifier 14 instead. Figs. 1B and 1C schematically show the application of the same principles to two-speaker (tweeter and woofer) and three-speaker (tweeter, mid-range and woofer) loudspeaker systems, respectively. In Fig. 1B, the unit labelled "2-way crossover" corresponds to the contents of Fig. 1A just described above. In Fig. 1C, the two units 9a, 9b, both labelled "2-way crossover", each correspond to the contents of Fig. 1A described above.

[0031] Fig. 2 schematically shows a first embodiment of an audio testing system 200. The audio testing system 200 comprises an audio device 100 under test, a microphone 120, an audio analyser 130, a signal feedback line 140 from the audio analyser 130 to the device 100 under test, and means for adjusting and setting a maximum volume of the device under test (not visible in Fig. 2). The device under test 100 comprises two loudspeakers 102a, 102b for providing left and right channels of stereo sound, each of which is configured to receive an audio test signal and to emit a sound in response to the audio test signal. The microphone 120 is a standardized, high-fidelity test microphone and is positioned in relation to the loudspeaker 102a according to a standardized test protocol, 1 metre distant from and axially aligned with the loudspeaker 102a. Thus the microphone 120 is configured to receive the sound from the loudspeaker 102a and to output an electrical signal in response thereto. The audio analyser 130 is configured to receive the electrical signal from the microphone 120 and to analyse the electrical signal.

[0032] The device under test 100 does not have an analogue audio input suitable for receiving an analogue signal directly from the standardized, high-fidelity test microphone 120. It does, however, have a digital signal input 103. Examples of such audio devices include tablet computers, mobile phones, in-car entertainment systems and the like. Thus the audio analyser 130 is a separate component of the audio testing system 200 from the audio device 100 under test, and the signal feedback line 140 from the audio analyser 130 to the device 100 under test is supplied in digital form to the digital signal input 103 of the device 100.

[0033] During operation of the audio testing system 200, the audio test signal is generated in the audio analyser 130 and is supplied from there, via the signal feedback line 140 to the device 100 under test. The audio test signal is initially supplied only to the channel of the audio device 100, which corresponds to the loudspeaker 102a, for testing loudspeaker 102a. After loudspeaker 102a has been tested, the microphone 120 is re-positioned according to the same test protocol in front of the other loudspeaker 102b, for testing loudspeaker 102b. The audio test signal comprises a plurality of peaks in power output at different frequencies, which are sequentially applied at the same output volume of the audio device 100 as each other. The device 100 under test causes the loudspeaker 102a to emit a sound in response to the audio test signal. The microphone 120 picks up the sound generated by the loudspeaker 102a and outputs an (analogue) electrical signal in response thereto, which is supplied back to the audio analyser 130 for analysis. The audio analyser 130 measures a level of distortion in the sound emitted by the loudspeaker 102a, which is total harmonic distortion. Thus the audio analyser 130 looks for harmonics of the fundamental frequency of each of the plurality of peaks in power output of the audio test signal which are sequentially applied to the device 100 under test, and uses these to calculate the total harmonic distortion. The method of testing the loudspeaker 102a with the audio testing system 200 will be described in greater detail below, in relation to Fig. 5.

[0034] Fig. 3 schematically shows a second embodiment of an audio testing system 300. The audio testing system 300 comprises an audio device 101 under test, a pair of microphones 120a, 120b, a signal feedback line 140a, 140b from each respective one of the pair of microphones 120a, 120b to the device 101 under test, and means for adjusting and setting a maximum volume of the device under test (not visible in Fig. 3). In this case, and in contrast to the audio testing system 200 shown in Fig. 2, the audio device 101 under test comprises an audio analyser (also not visible in Fig. 3), as well as a pair of analogue audio signal inputs 104a, 104b. Examples of such audio devices include hi-fi

equipment, televisions and home cinema systems. Each of the pair of analogue audio signal inputs 104a, 104b is configured to receive a respective one of the pair of signal feedback lines 140a, 140b from the microphones 120a, 120b and is connected to the audio analyser of the device 101 under test.

[0035] The device under test 101 also comprises two loudspeakers 102a, 102b for providing left and right channels of stereo sound, each of which is configured to receive an audio test signal and to emit a sound in response to the audio test signal. The pair of microphones 120a, 120b are both standardized, high-fidelity test microphones and are respectively positioned in relation to the loudspeakers 102a, 102b according to a standardized test protocol, 1 metre distant from and axially aligned with the respective loudspeaker 102a, 102b. Thus the microphones 120a, 120b are configured to receive the sound from the loudspeakers 102a, 102b and to output an electrical signal in response thereto. The audio analyser of the device 101 under test is configured to receive the (analogue) electrical signal from each of the microphones 120a, 120b and to analyse these electrical signals.

[0036] During operation of the audio testing system 200, the audio test signal is generated in the device 101 under test and is supplied to both of the loudspeakers 102a, 102b. The audio test signal is supplied alternately to the left and right channel loudspeakers, so that both of the loudspeakers 102a, 102b can be tested at the same time, without the sound emitted by one of the loudspeakers 102a, 102b masking or interfering with the sound emitted by the other of the two loudspeakers. The microphones 120a, 120b pick up the sound generated by the loudspeakers 102a, 102b and output an (analogue) electrical signal in response thereto, which is supplied back to the audio analyser of the device 101 under test for analysis. The audio analyser measures a level of distortion in the sound emitted by the loudspeakers 102a, 102b, which is total harmonic distortion. Thus the audio analyser looks for harmonics of the fundamental frequency of each of the plurality of peaks in power output of the audio test signal, which are sequentially applied to the device 100 under test, and uses these to calculate the total harmonic distortion. The method of testing the loudspeakers 102a, 102b with the audio testing system 300 will be described in greater detail below, in relation to Fig. 5.

[0037] Fig. 4 schematically shows an example of an audio test signal, which may be used in the audio testing systems 200, 300 of Figs. 2 and 3. As may be seen in Fig. 4, the audio test signal comprises a plurality of peaks 400 in power output at different frequencies. In this example, each peak 400 increases in power from a fundamental frequency and then decreases smoothly at higher frequencies over a narrow waveband. Thus the shape of each peak is well defined and their harmonics can be easily identified by analysis of the electrical signal received from one of the test microphones. Since the fundamental frequencies of the peaks 400 are simple multiples of each other, the peaks 400 are applied sequentially to avoid the harmonics from being masked.

[0038] Fig. 5 shows a method 500 of testing a loudspeaker of an audio device, which may be carried out using either one of the audio testing system 200, 300 shown in Figs. 2 and 3. At box 501, the method 500 firstly comprises adjusting an output volume of the audio device under test, such that the output volume of the audio device is initially substantially less than a maximum possible volume of the audio device. So, for example, if the device under test has a maximum possible volume of 20 sound watts, the output volume of the device may initially be adjusted to be only 10 sound watts. This significantly reduces the risk of one or more of the peaks 400 in power output of the audio test signal damaging the loudspeaker during testing.

[0039] At box 502, the method then comprises applying the audio test signal to the device under test, so that a sound is emitted from the loudspeaker in response to the audio test signal and that the sound is received from the loudspeaker by a test microphone, which outputs an electrical signal in response to the sound, for analysis. At box 503, the electrical signal is analysed and the level of distortion in the sound emitted by the loudspeaker is measured. If the level of distortion is found to be less than or equal to a maximum acceptable level of distortion, the method then comprises, at box 504, incrementally increasing the output volume of the audio device. The output volume of the device under test may be incrementally increased by less than about 5% of the maximum possible output volume of the audio device. So, for example, if the device under test has a maximum possible volume of 20 sound watts, the output volume of the device may be increased by only 1 sound watt. Again, this significantly reduces the risk of one or more of the peaks 400 in power output of the audio test signal damaging the loudspeaker during testing.

[0040] Once the output volume of the device under test has been incrementally increased in this way, the method then comprises repeating the process of applying the audio test signal to the device under test, so that a sound is emitted from the loudspeaker, receiving the sound with the microphone, outputting an electrical signal from the microphone and analysing the electrical signal. This process is repeated, incrementally increasing the output volume of the audio device each time, until the measured level of distortion is found to be greater than a maximum acceptable level of distortion. The audio test signal is then stopped in box 505 to avoid damaging the loudspeaker. So, for example, if the maximum acceptable level of distortion has previously been selected to be 3% THD, and the device under test has a maximum possible volume of 20 sound watts, if the output volume of the device under test has been incrementally increased by 1 sound watt at a time until it reaches 17 sound watts, when the measured level of distortion is found to be 3.2% THD, then the audio test signal will be stopped at an output volume of 17 sound watts.

[0041] In box 506, the method then comprises determining whether the output volume of the audio device is less than a least acceptable value of the maximum volume of the audio device. If the output volume of the audio device is found

to be less than a least acceptable value of the maximum volume of the audio device, then in box 507, the loudspeaker is rejected as being out of specification. On the other hand, if the output volume of the audio device is found to be not less than the least acceptable value of the maximum volume of the audio device, then in box 508, the maximum volume of the audio device is set to be equal to the output volume of the audio device when the measured level of distortion was last less than or equal to the maximum acceptable level of distortion during the test.

[0042] So, for example, if a least acceptable value of the maximum volume of the audio device had previously been selected to be 18 sound watts, whereas the audio test signal has been stopped at an output volume of 17 sound watts, then the loudspeaker will be rejected as being out of specification. If, on the other hand, the least acceptable value of the maximum volume of the audio device had previously been selected to be only 15 sound watts and the audio test signal has been stopped at an output volume of 17 sound watts, then the maximum volume of the audio device will be set to be equal to 16 sound watts, which was the last value of the output volume of the audio device during the test at which the measured level of distortion was less than the 3% THD, which had previously been selected as the maximum acceptable level of distortion.

[0043] In box 508, setting the maximum volume of the device under test to be equal to the output volume of the device when the measured level of distortion was last less than or equal to the maximum acceptable level of distortion during the test can be achieved in one of several different ways. In one possible embodiment, the maximum volume of the device under test can be adjusted using a software module of the device under test. This can most easily be done in the case of devices such as laptop or tablet computers and mobile phones. So, for example, a laptop computer may start with a maximum possible volume, before testing, of 2 sound watts, but may be restricted as a result of testing to emit sounds with a volume no greater than 1.8 sound watts by means of a suitably programmed software module of the device. In an alternative possible embodiment, the maximum volume of the device under test can instead be adjusted using a hardware component of the device under test, such as a rheostat or a loudspeaker protection circuit having passive components of suitably chosen values, for example. This can most easily be done in the case of devices like hi-fi equipment, televisions and home cinema systems. Thus, for example, a home cinema system may start with a maximum possible volume, before testing, of 30 sound watts, but may be restricted as a result of testing to emit sounds with a volume no greater than 28 sound watts by means of a suitably designed loudspeaker protection circuit.

[0044] In this way, the one or more loudspeakers which have been subjected to such testing can be protecting during their subsequent usage against damage by never having to handle a peak power output which would result in a distortion exceeding the previously selected maximum acceptable level of distortion.

[0045] On the other hand, if a loudspeaker is rejected as a result of testing for being out of specification, the rejected loudspeaker can be removed from the device under test, replaced with another loudspeaker, and the same method of testing can be repeated on the device until a loudspeaker which is in specification has been found and the maximum volume of the device has been adjusted accordingly.

[0046] The present invention also encompasses an audio device comprising at least one loudspeaker which has been tested according to such a method as described above, and wherein the maximum volume of the audio device has been adjusted as a result of the test.

[0047] In summary, therefore, the present invention provides a method of testing and protecting a loudspeaker in an audio device under test which comprises the loudspeaker. The method at least comprises adjusting an output volume of the device under test to be initially substantially less than a maximum possible volume of the audio device, applying an audio test signal to the audio device, emitting a sound from the loudspeaker in response to the audio test signal, receiving the sound from the loudspeaker with a test microphone, outputting an electrical signal from the microphone in response to the sound, and analysing the electrical signal to measure a level of distortion in the sound emitted by the loudspeaker. If the measured level of distortion is found to be less than or equal to a maximum acceptable level of distortion, the method then comprises incrementally increasing the output volume of the audio device and repeating the process of emitting a sound from the loudspeaker, receiving the sound with the microphone, outputting an electrical signal from the microphone and analysing the electrical signal, until the measured level of distortion is greater than the maximum acceptable level of distortion. Then the method comprises stopping the audio test signal, and determining whether the output volume of the audio device is less than a least acceptable value of the maximum volume of the audio device. If so, the method comprises rejecting the loudspeaker as out of specification. If not, the method comprises setting the maximum volume of the audio device to be equal to the output volume of the audio device when the measured level of distortion was last less than or equal to the maximum acceptable level of distortion. The method ensures that the maximum volume of the audio device is set at a level below that at which damage to the loudspeaker can occur, whilst also ensuring that the maximum volume of the audio device is set to be more than a least acceptable value, by rejecting loudspeakers that are out of specification. The present invention also provides an audio testing system for carrying out such a method, and an audio device comprising at least one loudspeaker, which has been tested according to such a method.

Reference Numerals:

100	Device under test without analogue audio input	500	Loudspeaker testing method
5 101	Device under test with analogue audio input	501	Adjust volume of device under test to be very much less than maximum possible device volume
102a, 102b	Loudspeakers	502	Start test signal
		503	Measure distortion
10 103	Digital signal input	504	Incrementally increase test volume
104a, 104b	Analogue audio signal input	505	Stop test signal
120, 120a, 120b	Test microphones	506	Compare test volume to least acceptable value of maximum device volume
		507	Reject loudspeaker
15 130	Audio analyser	508	Set maximum volume of audio device
140, 140a, 140b	Signal feedback line to device under test		
200, 300	Audio testing systems		
400	Audio test signal peaks		
20			

Claims

- 25 1. An audio testing system (200, 300) at least comprising:
an audio device (100, 101) under test, wherein the device under test comprises at least one loudspeaker (102a, 102b) configured to receive an audio test signal and to emit a sound in response to the audio test signal;
at least one microphone (120, 120a, 120b) configured to receive the sound from the at least one loudspeaker (102a, 102b) and to output an electrical signal in response thereto;
30 an audio analyser (130) configured to receive the electrical signal from the at least one microphone (120, 120a, 120b) and to analyse the electrical signal;
a signal feedback line (140, 140a, 140b) from the audio analyser (130) to the device under test; and
means for adjusting and setting a maximum volume of the device under test.
- 35 2. An audio testing system (200) according to claim 1, wherein the audio device (100) under test is separate from the audio analyser (130) and comprises at least one digital signal input (103) for receiving the signal feedback line (140) from the audio analyser.
- 40 3. An audio testing system (300) according to claim 1, wherein the audio device (101) under test comprises the audio analyser (130) and at least one analogue audio signal input (104a, 104b) connected thereto.
4. An audio testing system according to any one of claims 1 to 3, wherein the means for adjusting and setting a maximum volume of the device under test comprises a software module of the device under test.
- 45 5. An audio testing system according to any one of claims 1 to 3, wherein the means for adjusting and setting a maximum volume of the device under test comprises a hardware component of the device under test.
6. A method (500) of testing a loudspeaker, the method at least comprising:
50 adjusting (501) an output volume of an audio device (100, 101) under test, wherein the device under test comprises at least one loudspeaker (102a, 102b), to be initially substantially less than a maximum possible volume of the audio device;
applying (502) an audio test signal to the audio device;
emitting a sound from the at least one loudspeaker (102a, 102b) in response to the audio test signal;
55 receiving the sound from the at least one loudspeaker (102a, 102b) with at least one microphone (120, 120a, 120b);
outputting an electrical signal from the microphone (120, 120a, 120b) in response to the sound;

analysing (503) the electrical signal to measure a level of distortion in the sound emitted by the loudspeaker; and if the measured level of distortion is less than or equal to a maximum acceptable level of distortion, incrementally increasing (504) the output volume of the audio device and repeating the process of emitting a sound from the at least one loudspeaker, receiving the sound with the at least one microphone, outputting an electrical signal from the microphone and analysing (503) the electrical signal, until the measured level of distortion is greater than the maximum acceptable level of distortion; then stopping (505) the audio test signal; and determining (506) whether the output volume of the audio device is less than a least acceptable value of the maximum volume of the audio device; and if so, rejecting (507) the at least one loudspeaker as out of specification; whereas if not, setting (508) the maximum volume of the audio device to be equal to the output volume of the audio device when the measured level of distortion was last less than or equal to the maximum acceptable level of distortion.

7. A method according to claim 6, wherein the output volume of the audio device (100, 101) under test is initially adjusted (501) to be less than two-thirds of the maximum possible output volume of the audio device.
8. A method according to claim 6 or claim 7, wherein the output volume of the audio device under test (100, 101) is incrementally increased (504) each time by less than about 5% of the maximum possible output volume of the audio device.
9. A method according to any one of claims 6 to 8, wherein the audio test signal comprises a plurality of peaks (400) in power output at different frequencies.
10. A method according to claim 9, comprising applying the plurality of peaks (400) in power output to the device (100, 101) under test sequentially at the same output volume of the audio device as each other.
11. A method according to any one of claims 7 to 10, comprising generating the audio test signal and analysing (503) the electrical signal outside the audio device (100) under test.
12. A method according to any one of claims 7 to 10, comprising generating the audio test signal and analysing (503) the electrical signal in the audio device (101) under test.
13. A method according to any one of claims 7 to 12, wherein the distortion measured is total harmonic distortion.
14. A method according to any one of claims 7 to 13, further comprising, if the at least one loudspeaker is rejected (507) as out of specification:
 - removing the rejected loudspeaker from the device (100, 101) under test;
 - replacing the removed loudspeaker with another loudspeaker; and
 - repeating the same method of testing on the device (100, 101) under test.
15. An audio device (100, 101) comprising at least one loudspeaker (102a, 102b), wherein the loudspeaker has been tested according to the method of any one of claims 7 to 14, and the maximum volume of the audio device has been adjusted as a result of the test.

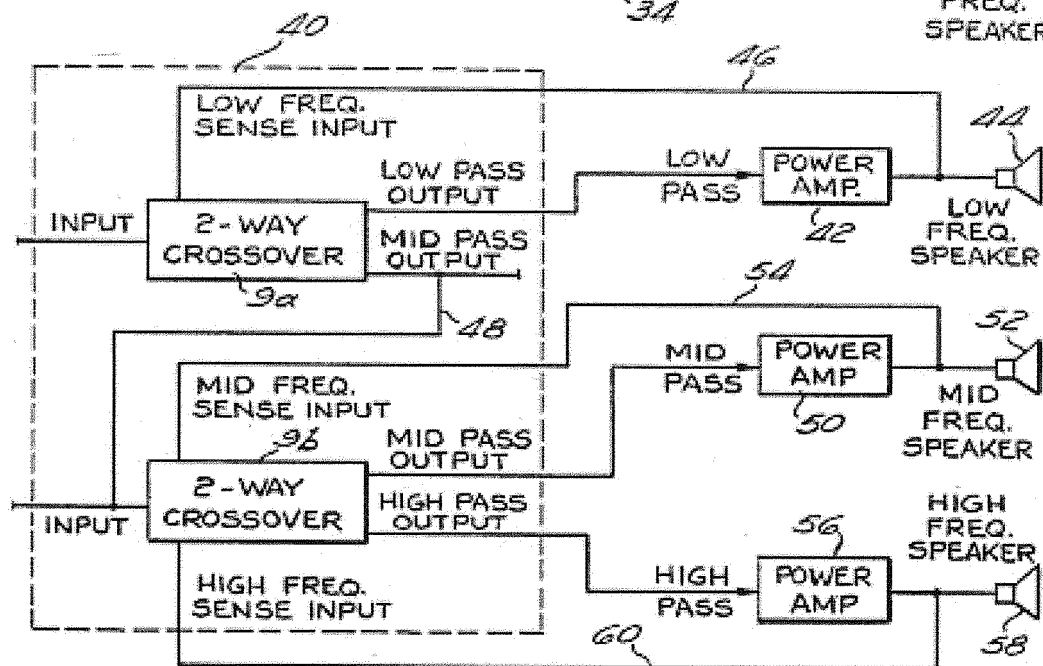
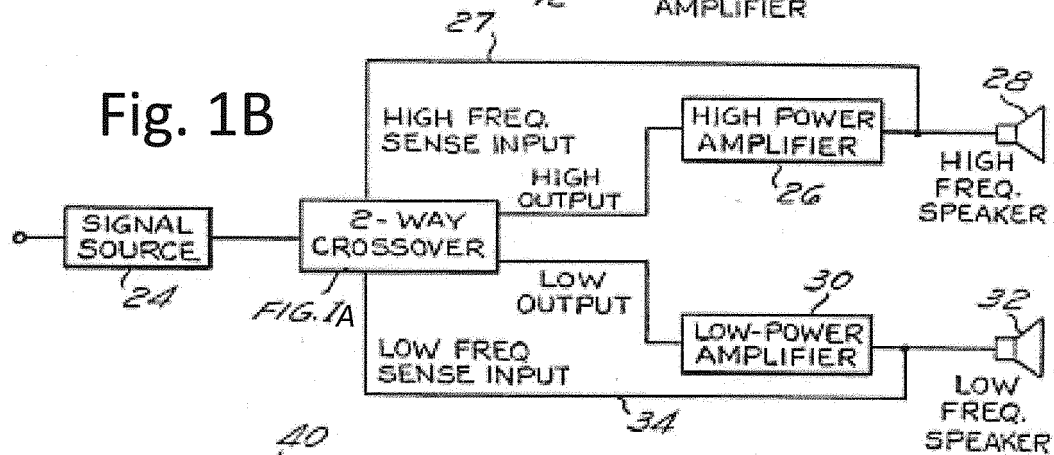
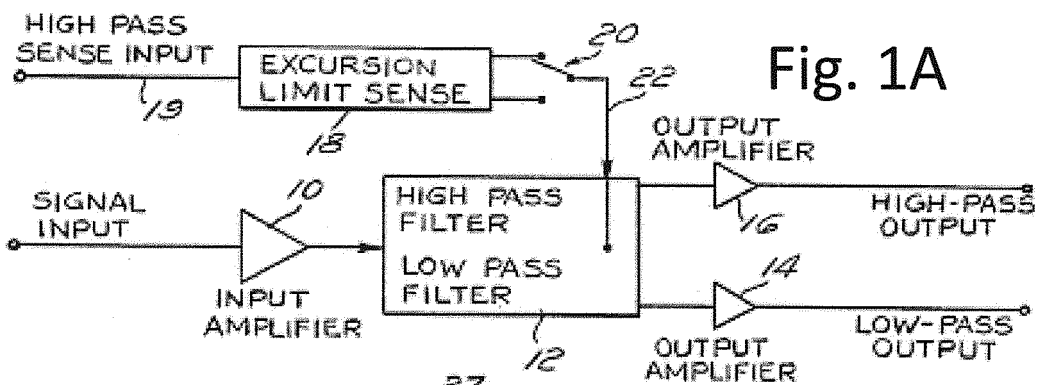


Fig. 1C

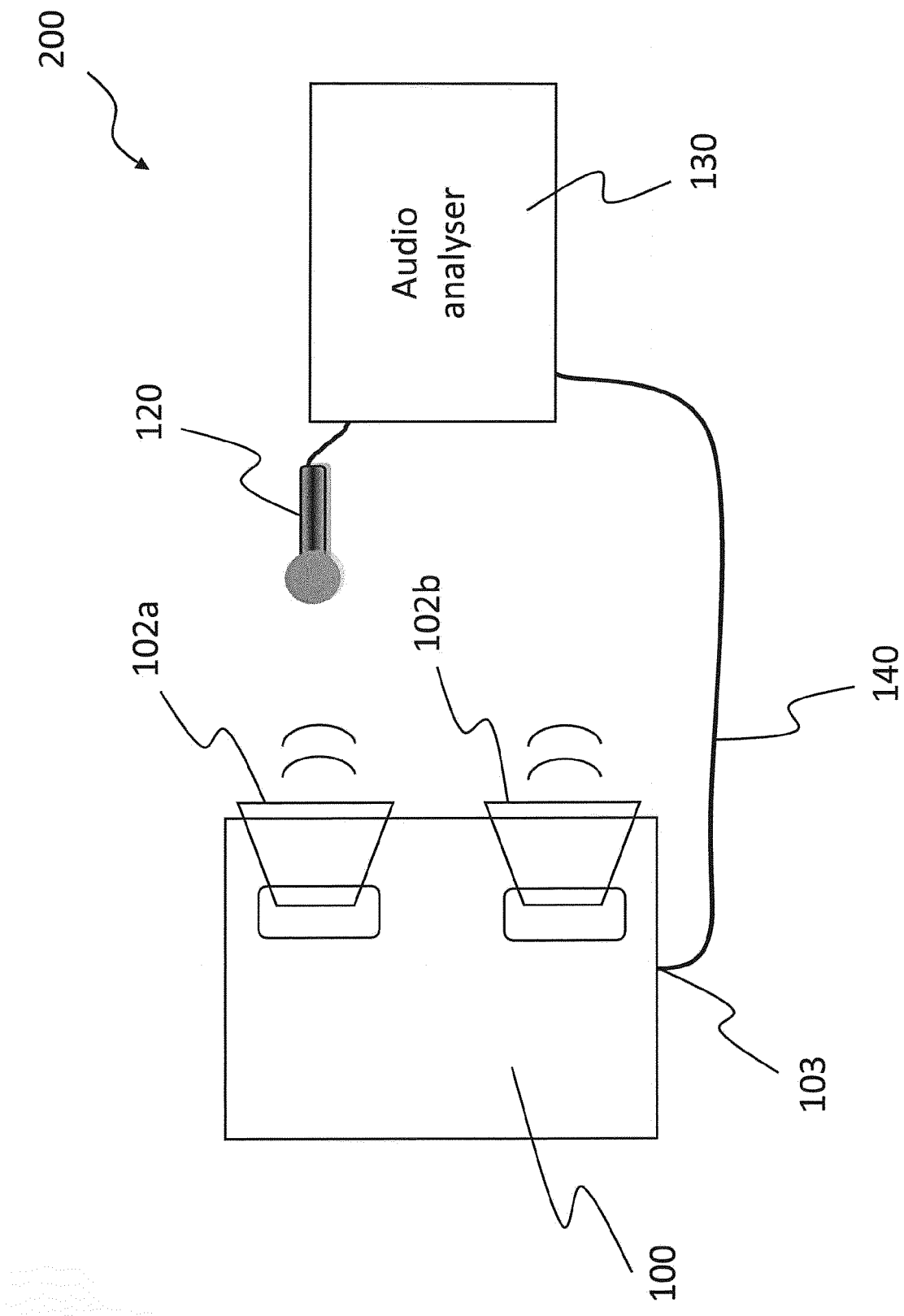


Fig. 2

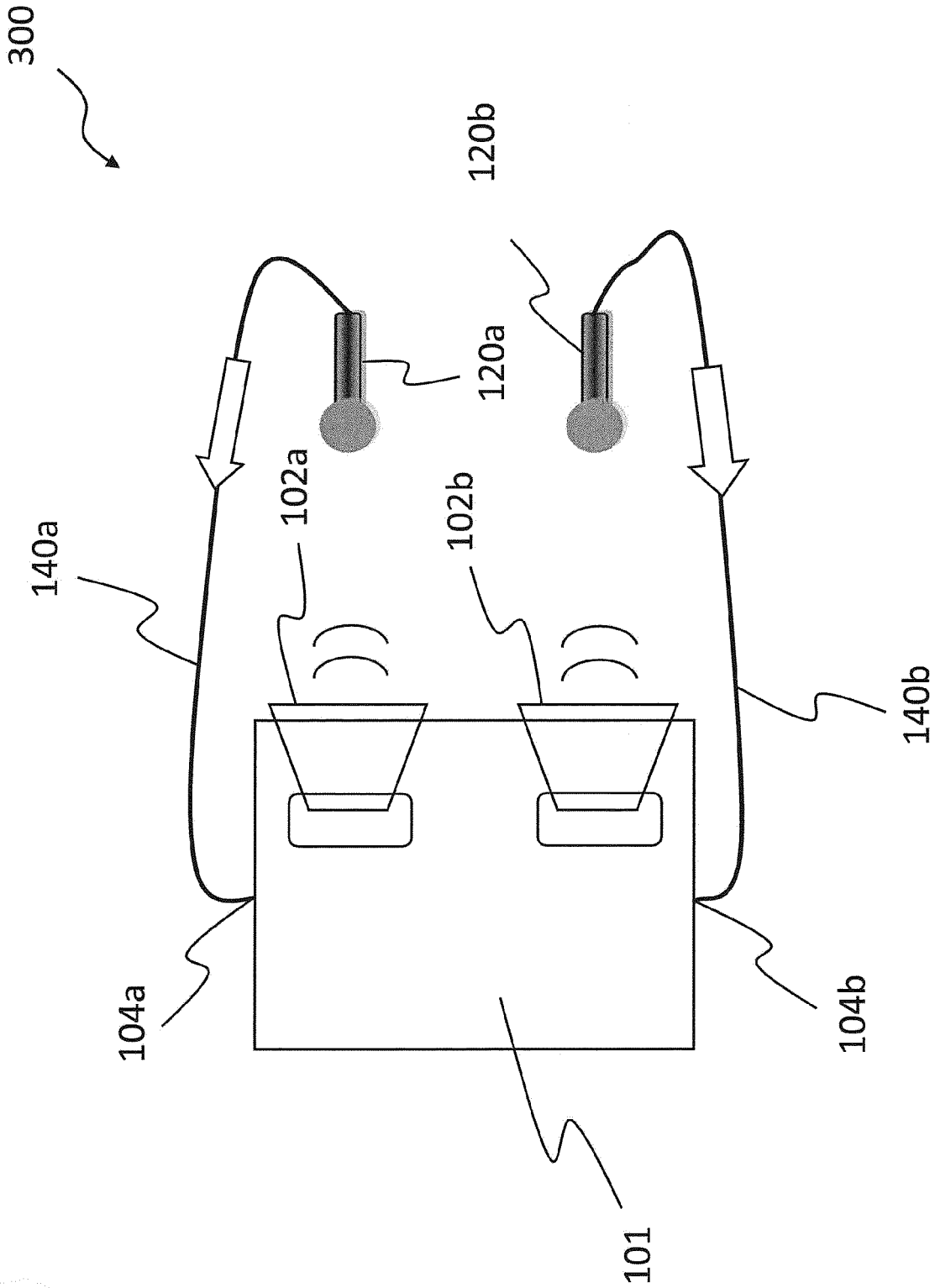


Fig. 3

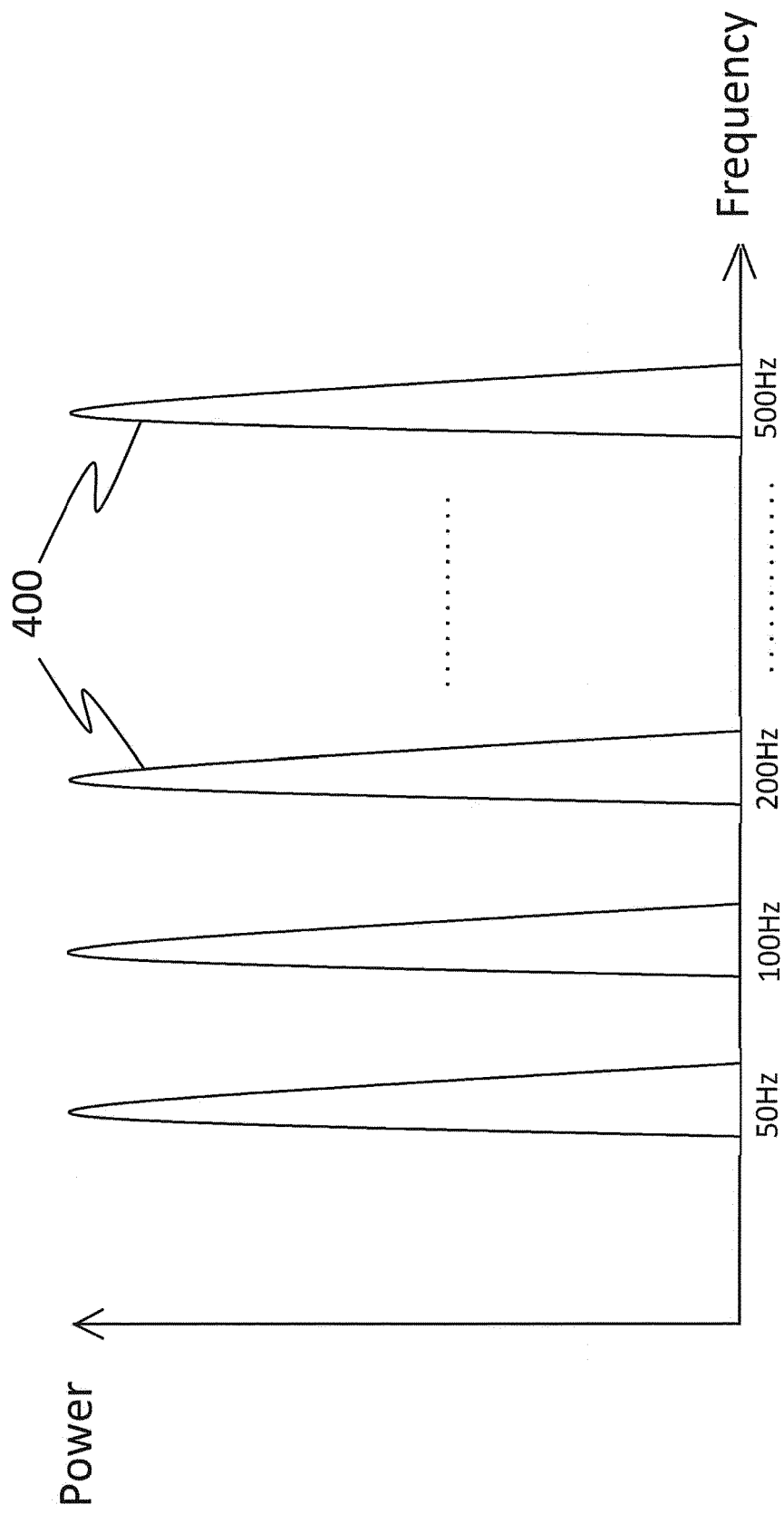


Fig. 4

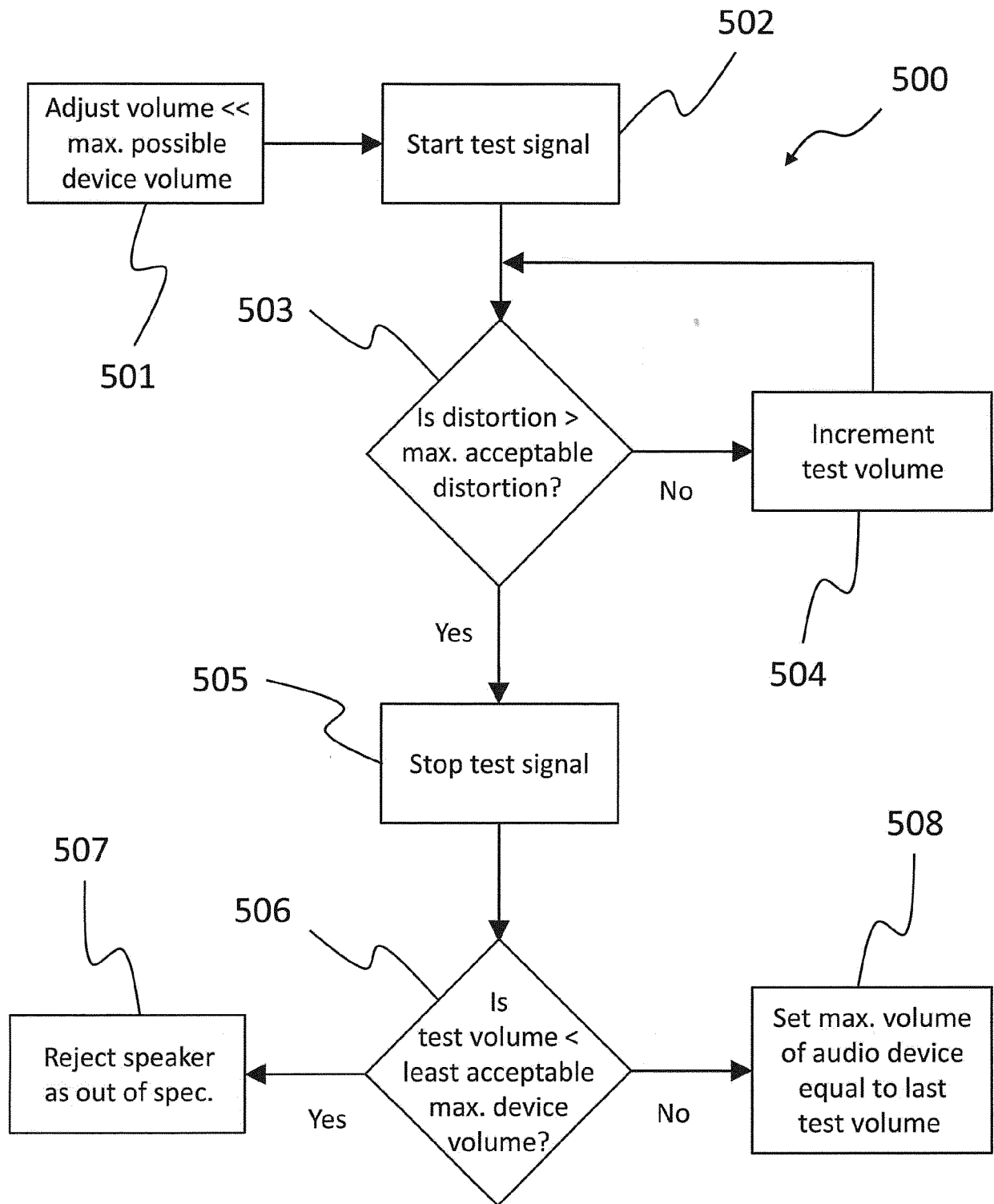


Fig. 5



EUROPEAN SEARCH REPORT

Application Number
EP 17 15 8924

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Place of search		Date of completion of the search	Examiner
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