An audio device includes a first audio path with a loudspeaker for reproducing an audio signal, and a second audio path. The second audio path includes in series a band-pass filter for filtering an audio signal, a detector for detecting the amplitude of the band-pass filtered audio signal, a multiplier for multiplying a periodic signal by the amplitude of the band-pass filtered audio signal, and a vibration device for reproducing the multiplied periodic signal. The frequency of the periodic signal is substantially equal to the resonance frequency of the vibration device.
AUDIODEVICE FOR IMPROVED SOUND REPRODUCTION

FIELD OF THE INVENTION

The present invention relates to audio device comprising a first audio path comprising a loudspeaker for reproducing the higher frequency part of an audio signal, and a second audio path comprising a vibration device for reproducing the lower frequency part of the audio signal.

This invention may be used, for example, in mobile phones or in gaming devices.

BACKGROUND OF THE INVENTION

The U.S. Pat. No. 6,809,635 discloses a mobile telecommunications device which splits the demodulated audio communications into two paths. The first path comprises in series a low-pass filter, a first audio amplifier and a vibration motor. The second path comprises in series a high-pass filter, a second audio amplifier and a tweeter. The pass-band of the two filters may be chosen to change the sound quality of the audio communications which is reproduced. The output of the low-pass filter, which passes the lower frequency components in a substantially non-attenuated manner and substantially attenuates the higher frequency components is an input to the first audio amplifier having a relatively high gain for driving the vibration motor with sufficient input power to produce an acceptable output of audible sound which reproduces the lower frequency components present in the audio communications. The output of high-pass filter is an input to the second audio amplifier having a relatively lower gain than the gain of the first audio amplifier as a result of the higher efficiency of the tweeter in reproducing the higher frequency audible sound.

SUMMARY OF THE INVENTION

It is an object of the invention to propose an audio device which permit an improved sound reproduction compared with the one of the prior art.

To this end, the audio device in accordance with the invention is characterized in that it comprises:

- a band-pass filter for passing frequency components of the audio signal lying between a first frequency and a second frequency, said first frequency being lower than said second frequency, and for attenuating frequency components of the audio signal lower than said first frequency and higher than said second frequency,
- a detector for detecting an amplitude of the band-pass filtered audio signal,
- a multiplier for multiplying a periodic signal having a third frequency by the amplitude of the band-pass filtered audio signal,
- a vibration device for reproducing the multiplied periodic signal, wherein the third frequency is substantially equal to the resonance frequency of the vibration device.

Thanks to a processing device comprising in series the band-pass filter, the detector and the multiplier, the lower frequency part of the audio signal is reproduced in a very efficient and accurate manner.

The first audio path may comprise a high-pass filter for passing frequency components of the audio signal higher than the second frequency and for attenuating frequency components of the audio signal lower than said second frequency, the loudspeaker being adapted to reproduce the high-pass filtered audio signal. This first audio path may further comprise an amplifier for amplifying the audio signal, the loudspeaker being adapted to reproduce the amplified audio signal.

Beneficially, the detector is a peak detector or an envelope detector or a diode and the first frequency is substantially equal to 20Hz and the second frequency is substantially equal to 100 Hz.

The second audio path may comprise a generator for generating the periodic signal. It may also comprise a low-pass filter arranged between the detector and the multiplier, for passing frequency components of the detected band-pass filtered audio signal lower than the second frequency and for attenuating frequency components of the detected band-pass filtered audio signal higher than said second frequency. This second audio path may comprise a control path arranged between the vibration device and the generator, the generator being adapted to adjust the third frequency in dependence on parameters of the vibration device. It may also comprise an amplifier arranged between the multiplier and the vibration device.

The present invention also relates to a mobile phone comprising such an audio device.

These and other aspects of the invention will be apparent from and will be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in more detail, by way of example, with reference to the accompanying drawings, wherein:

FIG. 1 is a block diagram of the audio device in accordance with the invention;

FIG. 2 is a block diagram of the processing device in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, the audio device in accordance with the invention is depicted. The audio device may be incorporated in a portable apparatus which is, for example, a mobile phone. However, it will be apparent to a skilled person that this portable apparatus can be any other portable apparatus comprising an audio device such as, for example, a personal digital assistant PDA, a gaming device, etc.

The portable apparatus comprises an audio receiver (not represented), e.g. a radio frequency RF receiver in the example of a mobile phone, for receiving an input audio signal and for providing a demodulated output audio signal v1 in the same example.

The demodulated output audio signal v1 is then split into two paths. The first path comprising in series a processing device 11, which will be described in more detail hereinafter, a first audio amplifier 12, and a vibration device 13, e.g. a conventional transducer. Additionally, the vibration device 13 is utilized to perform its conventional function of producing a silent vibration alert when programmed to do so by the user of the mobile phone in response to incoming calls or messages v2. The first audio amplifier 11 has typically a relatively high gain for driving the vibration device 13 with sufficient input power to produce an acceptable output of audible sound.

The second path comprises in series a high-pass filter 14, a second audio amplifier 15 and a conventional loudspeaker 16. The high-pass filter 14 passes substantially the higher frequency components (e.g. above 100 Hz) in a substantially non-attenuated manner and substantially attenuates the lower frequency components (e.g. below 100 Hz). The sec-
ond audio amplifier 15 has a relatively lower gain than the
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gain of the first audio amplifier as a result of the higher
efficiency of the loudspeaker 16 in reproducing the higher
frequency audible sound.
The high-pass filter is not essential to a proper operation of
the audio device. It could be replaced by a band-pass filter or
there could even be no filter at all.
The portable apparatus may comprise a handset and a
headset. In this case, the vibration device 13 can be in
the hand set or in the headset or both. The same applies to
the loudspeaker. The handset and headset may be wired or wire-
less connected to each other.
The processing device in accordance with the invention is
schematically shown in FIG. 2. The processing device 11
comprises a band-pass filter 22, a detector 23 and a multiplier
24.
The band-pass filter 22 has a pass-band which corresponds
to the low frequency range, that is to say approximately 20
Hz-100 Hz. The band-pass filter 22 thus eliminates all fre-
quencies outside this low frequency range.
The detector 23 is adapted to detect the signal received
from the band-pass filter 22. The detector 23 is for example a
peak detector known per se, but may also be an envelope
detector known per se. In a very economical embodiment, the
detector may be constituted by a diode. The signal produced
by the detector 23 represents the amplitude of the combined
signals present within the low frequency range.
Multiplier 24 multiplies this signal by a periodic (e.g. sinu-
soidal) signal having a frequency f_c which is generated by a
generator 26. The generator frequency f_c is beneficially equal
to the resonance frequency f_0 of the vibration device.
The output signal of the multiplier 24 has a frequency f_c,
while its amplitude is dependant on the signals contained in
the low frequency range. Note that any signal contained in
the low frequency range will cause an output signal having a
frequency equal to f_c to be produced.
In addition, the processing device may comprise a low-
pass filter 25 arranged between the detector 23 and the mul-
tiplier 24, for attenuating the higher frequency components
(above 100 Hz). This low-pass filter serves to reduce any
undesired frequencies which may be generated by the detec-
tor 23.
The vibration device 13 is preferably driven at its reso-
nance frequency f_0. This results in a high sound level. As
will be clear from the above discussion, the processing device
produces sound output at the resonance frequency f_0 for all
audio signals falling within the low frequency range defined
by band-pass filter 22. This makes it possible to “adjust” low
audio frequencies to the properties of the vibration device in
order to reproduce them at a suitable sound level.
Optionally, a control path 28 may be present between the
vibration device 13 and the generator 26. This control path
allows the generator 26 to adjust the frequency f_c in depen-
dence on parameters of the vibration device such as its (in-
stantaneous) impedance, in particular since f_c may vary due,
for example, to temperature variations and/or deviations in
production parameters.
It should be noted that the above-mentioned embodiment
illustrates rather than limits the invention, and that those
skilled in the art will be capable of designing many alternative
embodiments without departing from the scope of the inven-
tion as defined by the appended claims.

by a user is the sum of the high frequency audio signal coming
from the loudspeaker and the low frequency audio signals
coming from the different vibration devices.

In the claims, any reference signs placed in parentheses
shall not be construed as limiting the claims. The word “com-
prising” and “comprises”, and the like, does not exclude the
presence of elements or steps other than those listed in any
claim or the specification as a whole. The singular reference
of an element does not exclude the plural reference of such
elements and vice-versa. The invention may be implemented
by means of hardware comprising several distinct elements,
and by means of a suitably programmed computer. In a device
claim enumerating several means, several of these means
may be embodied by one and the same item of hardware. The mere
fact that certain measures are recited in mutually different
dependent claims does not indicate that a combination of
these measures cannot be used to advantage.

The invention claimed is:
1. An audio device comprising a first audio path comprising
a loudspeaker for reproducing an audio signal, and a
second audio path comprising in series:
a band-pass filter for passing frequency components of
the audio signal lying between a first frequency and a second
frequency, said first frequency being lower than said
second frequency, and for attenuating frequency com-
ponents of the audio signal lower than said first fre-
quency and higher than said second frequency,
a detector for detecting an amplitude of the band-pass
filtered audio signal,
a multiplier for multiplying a periodic signal having a third
frequency by the amplitude of the band-pass filtered
audio signal,
a vibration device for reproducing the multiplied periodic
signal, wherein the third frequency is substantially equal
to a resonance frequency of the vibration device,
wherein the second audio path further comprises a genera-
tor for generating the periodic signal, and
wherein the second audio path further comprises a control
path arranged between the vibration device and the gen-
erator, the generator being adapted to adjust the third
frequency in dependence on parameters of the vibration
device.

2. The audio device as claimed in claim 1, wherein the first
audio path further comprises a high-pass filter for passing
frequency components of the audio signal higher than the
second frequency and for attenuating frequency components
of the audio signal lower than said second frequency, the
loudspeaker being adapted to reproduce the high-pass filtered
audio signal.

3. An audio device as claimed in claim 1, wherein the first
audio path further comprises an amplifier for amplifying
the audio signal, the loudspeaker being adapted to reproduce the
amplified audio signal.

4. The audio device as claimed in claim 1, wherein the
detector is a peak detector or an envelope detector or a diode.

5. The audio device as claimed in claim 1, wherein the
second audio path further comprises a low-pass filter
arranged between the detector and the multiplier, for passing
frequency components of the detected band-pass filtered
audio signal lower than the second frequency and attenuating
frequency components of the detected band-pass filtered
audio signal higher than said second frequency.

6. The audio device as claimed in claim 1, wherein the first
frequency is substantially equal to 20 Hz and the second
frequency is substantially equal to 100 Hz.
7. The audio device as claimed in claim 1, wherein the second audio path further comprises an amplifier arranged between the multiplier and the vibration device.

8. A mobile phone comprising an audio device, the audio device comprising a first audio path comprising a loudspeaker for reproducing an audio signal, and a second audio path comprising in series:

- a band-pass filter for passing frequency components of the audio signal lying between a first frequency and a second frequency, said first frequency being lower than said second frequency, and for attenuating frequency components of the audio signal lower than said first frequency and higher than said second frequency,

- a detector for detecting an amplitude of the band-pass filtered audio signal,

- a multiplier for multiplying a periodic signal having a third frequency by the amplitude of the band-pass filtered audio signal,

- a vibration device for reproducing the multiplied periodic signal, wherein the third frequency is substantially equal to a resonance frequency of the vibration device, wherein the second audio path further comprises a generator for generating the periodic signal, and wherein the second audio path further comprises a control path arranged between the vibration device and the generator, the generator being adapted to adjust the third frequency in dependence on parameters of the vibration device.