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

(11) EP 1 113 702 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
04.07.2001 Bulletin 2001/27

(51) Int Cl.7: **H04R 1/40**

(21) Application number: **00310555.8**

(22) Date of filing: **29.11.2000**

(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: **31.12.1999 US 476045**

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(54) **Acoustic dipole radiator for portable electronic devices**

(57) A wearable acoustic dipole radiator accessory for portable electronic devices such as mobile phones, portable cassette players, MP3 players, portable radios, or any other suitable device. The acoustic dipole radiator has two loudspeakers that are acoustically connected by an interconnection cavity. The loudspeakers do not need to contact the user's ears. The interconnection cavity limits mutual interference between the front and backwaves of the loudspeakers. In one embodiment, the acoustic dipole radiator is implemented in a necklace. In another embodiment, the acoustic dipole radiator is implemented in a helmet. In yet another embodiment, the acoustic dipole radiator is implemented in a headset in which the loudspeakers do not contact the ears.

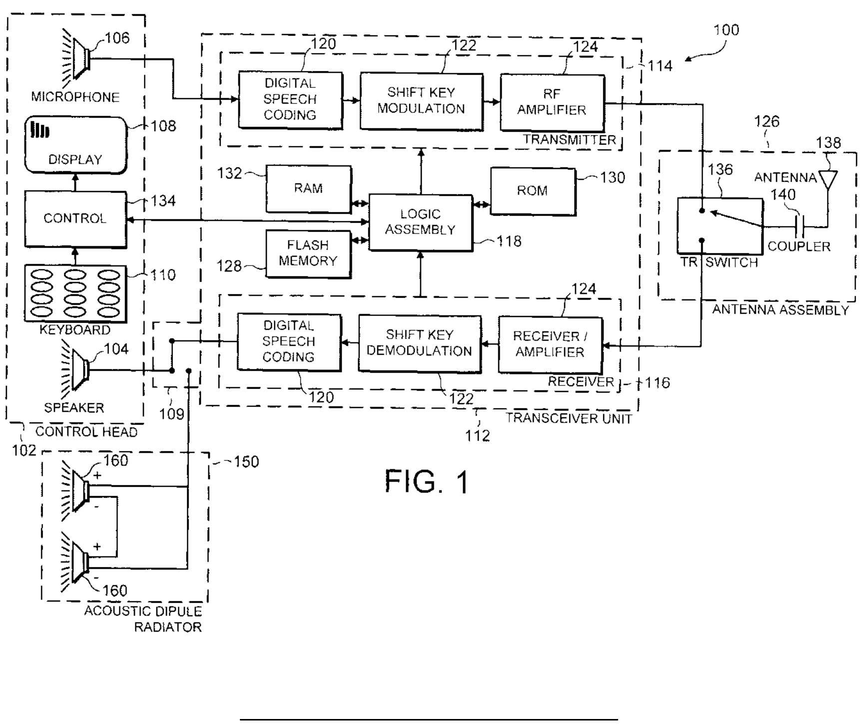

FIG. 1

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Description

[0001] This invention relates to accessories for portable electronics and, more particularly, to accessories with an acoustic dipole radiator.

[0002] It is difficult for a listener to determine the source of low-frequency sounds due to their relatively long wavelength. A listener is able to determine the source of a sound from several different acoustic cues. One of the important cues is the phase difference in a sound as it is heard at each ear. The listener's brain uses the phase difference between what the right ear hears and what the left ear hears to help locate the source of the sound. It is hard for the brain to determine the source of a low-frequency sound partially because there is very little phase difference between what is heard at each ear due to the length of the soundwave.

[0003] Most stereophonic sound recordings are made with a stereo high frequency recording and a monophonic low-frequency recording. The low frequencies can be recorded or reproduced in mono because users are unable to determine the source of low-frequency sounds. Thus the left and right channels of most stereo systems reproduce low-frequency sound that is in phase.

[0004] In general, the backwave from an unbaffled loudspeaker will cancel the frontwave. To overcome this problem, a baffle may separate the front of the speaker and the rear of the speaker so that the backwave will not cancel the frontwave. The first low frequency response peak occurs on the wavelength where the baffle radius is a half of the sound wavelength. This peak is at least partially due to the 180 degree phase ($\lambda/2$) difference between the frontwave and backwave as they diffract from the edge of the baffle. Depending upon the desired acoustic results, a designer may adjust the baffle dimensions to control the relationship between the front and backwaves. In general, the baffle should have a radius that is large enough, compared to the wavelength of the soundwave that the designer wishes to separate, to achieve the effect desired by the designer.

[0005] Low-frequency sounds present a special challenge because their wavelength is long enough that a very large baffle is required to stop the cancellation of the front and back waves. A solution familiar to most stereo system owners is the sealed box speaker. The backwave is contained within the speaker box and thus prevented from interfering with the frontwave. Unfortunately, the sealed box speaker also has increased acoustic loading on the backside that interferes with the backwards throw of the loudspeaker motor.

[0006] Another solution for low-frequency sound reproduction is the transmission line speaker. Instead of a sealed box, the transmission line speaker uses a long acoustic tube on the backside of the loudspeaker to separate the frontwave and backwave. Transmission line speakers are often used in movie theaters to reproduce low-frequency sounds. This type of speaker may have transmission lines that are longer than thirty feet (10 m) and therefore is not a good candidate for portable sound systems.

[0007] The headphone is a common speaker system for portable electronic devices. Headphones generally consist of two speakers that fit against the ears of the listener. The frontwave and backwave are separated because the headphone loudspeaker is sealed against the ear, which creates a baffle effect similar to a sealed box speaker. The headphone effect is even better than the sealed box scheme due to the fact that the ear is "sensing" the acoustic pressure on the "ear" side of the speaker cone. Thus there is no need for a big cavity; smaller is better, making the speaker cone coupling to the tympanic membrane tighter. If the headphone loudspeakers are not in contact with the ears, the sealed box (or sealed front cavity) effect is lost. Loss of the sealed box/cavity means that there is virtually no baffle, suggesting that the frontwave and backwave will interfere with each other at low frequencies.

[0008] Headphones are unsuited for some portable applications because they must be in physical contact with the ears. A situation for which headphones are not suited is when the listener must wear a helmet, such as a motorcycle or bicycle helmet. Additionally, headphones often become uncomfortable after wearing them for a long time.

[0009] In an embodiment of the invention, an acoustic tube connects two loudspeakers that are situated near each ear. The loudspeakers are electrically connected (in other words, fed) in a push-pull configuration such that the loudspeakers are driven with opposite polarity. Due to the push-pull configuration, the air in the acoustic tube loads the loudspeaker cones less than some other configurations. In other words, the diaphragms on the ends of the cavity are pushing/pulling air in the same direction because they are driven with the same monophonic audio signal but 180 degrees out of phase. When compared to a system where the speakers are driven in phase (pull-pull), the acoustic loading (impedance) of the air in the tube is reduced by the push-pull configuration.

[0010] An additional advantage is that, by driving the loudspeakers in different phase from the same monophonic source, low-frequency acoustic effects may be created where little or none were present before. In some variations of the embodiments discussed herein, the phase shift of the low-frequency signal to each loudspeaker can be varied to control the acoustic effect. The phase shifting can be done "softly" for the low-frequency tones only. "Softly" means that the transition frequency range from the non phase-shifted to phase-shifted is wide to minimize some audible interferences.

[0011] In another embodiment of the invention, the acoustic tube (aka cavity) is disposed within a necklace that is worn by a mobile station user. In some variations of this and the following embodiments, a microphone can be mounted on the tube near the acoustic null between the loudspeakers.

[0012] In another embodiment of the invention, the acoustic tube is contained within a helmet that is worn by a mobile station user.

[0013] One or more of the disclosed embodiments provides some of at least the following advantages: a portable speaker system that can be used in situations where headphones are uncomfortable or impractical; low-frequency sound effects from a monophonic source; good low-frequency sound reproduction in a portable form factor; and good separation of front and backwave.

[0014] In order that the invention may be more fully understood, embodiments thereof will now be described by way of example with reference to the accompanying drawings wherein:

> **Figure 1** is a block diagram of mobile station capable of implementing and/or using the embodiments of the invention;
> **Figure 2A** is a front view of a necklace embodiment of an acoustic dipole radiator;
> **Figure 2B** is a side view of the necklace shown in Figure 2A;
> **Figure 2C** illustrates the necklace when worn by a user;
> **Figure 3A** is a sectional view of a helmet embodiment of an acoustic dipole radiator; and
> **Figure 3B** illustrates the helmet when worn by a user..

[0015] The numerous innovative teachings of the present application will be described with particular reference to the presently preferred embodiment. However, it should be understood that this class of embodiments provides only a few examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do not necessarily delimit any of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others.

[0016] Various embodiments of the disclosed innovations will be described in the system context by use of a mobile station that can make use of the disclosed embodiments.

[0017] **Figure 1** is a block diagram of a mobile station **100** and acoustic dipole radiator **150.** The mobile station 100 includes, in this example, a control head **102** containing an audio interface, i.e. a speaker **104** and microphone **106**. The control head 102 is the user interface for the mobile station 100. The control head **102** generally includes a display assembly **108** allowing a user to see dialed digits, stored information, messages, calling status information, including signal strength, etc. The control head generally includes a keypad **110,** or other user control device, allowing a user to dial numbers, answer incoming calls, enter stored information, and perform other mobile station functions. The control head also has a controller unit **134** that interfaces with a logic control assembly **118** responsible, from the control unit perspective, for receiving commands from the keypad 110 or other control devices, and providing status information, alerts, and other information to the display assembly 108.

[0018] A transceiver unit **112** includes a transmitter unit **114**, receiver unit **116**, and the logic control assembly 118. The transmitter unit 114 converts low-level audio signals from the microphone 106 to digital coding using a codec (a data coder/decoder) **120**. The digitally encoded audio is represented by direct analog or coded digitally modulated shifts, for example, in the phase domain, using a modulator/demodulator **122.** Other data received from the logic control assembly 118, such as station parameters and control information, may also be encoded for transmission. The modulated signal is then amplified by RF amplifier **124** and transmitted via an antenna assembly **126**.

[0019] The antenna assembly 126 contains a TR (transmitter/receiver) switch or filter **136** to prevent interference due to simultaneous reception and transmission of a signal by the mobile station 100. The transceiver unit 112 is connected to the antenna assembly 126 through the TR switch 136. The antenna assembly contains at least one antenna **138** coupled to TR switch 136 by coupler 140

[0020] The receiver unit 116 that receives a transmitted signal via the antenna assembly 126. The signal is amplified by receiver/amplifier 124 and demodulated by demodulator 122. If the signal is an audio signal, it is decoded using the codec 120. The audio signal is then reproduced by the internal speaker 104 or the external acoustic dipole radiator 150. A headphone jack switch 109 connects either the acoustic dipole radiator 150 or the internal speaker 104 to the codec 120 in this embodiment but embodiments using a wireless link to radiator 150 may require user input (perhaps via keyboard or voice) to choose which to employ. Other signals are handled by the logic control assembly 118 after demodulation by demodulator 122.

[0021] The logic control assembly 118 comprises an application specific integrated circuit (or ASIC) combining many functions, such as a general purpose microprocessor, digital signal processor, and other functions, into one integrated circuit. The logic control assembly 118 coordinates the overall operation of the transmitter and receiver using control messages. The mobile station 100 may make use of the logic control assembly 118 to control scanning and evaluation of base stations. In the context of the present invention, the logic control assembly 118 may implement a variable phase shift in the monophonic low-frequency signal supplied to each loudspeaker **160** in the acoustic dipole radiator 150, thus allowing low-frequency sound reproduction from the acoustic dipole radiator 150. Note, however, that frequency dependent variable "soft" low frequency off-phasing would require a slightly different electrical connection to acoustic dipole radiator 150 because the electrical configuration shown is fixed for driving loudspeakers 160 in opposite polarity. Essentially, a separate electrical connection from codec 120 would have to be made to each loudspeaker 160 in order to implement a variable phase, vs. frequency, shift scheme. Also note that a functionally equivalent circuit to that shown in Figure 1 can be obtained by connecting each loudspeaker 160 in the acoustic dipole radiator 150 in parallel such that the positive terminal of the first loudspeaker is connected to the negative terminal of the second loudspeaker and the negative terminal of the first loudspeaker is connected to the positive terminal of the second loudspeaker.

[0022] The logic control assembly 118 can implement soft phase-shifting in many configurations. As an example; the frequencies over 400 Hz are not phase shifted (= 0 degree), the frequencies under 200 Hz are shifted 180 degrees. The band from 200 to 400 Hz is the transition band where the phase shift changes from 180 to 0 degree according some function vs frequency. This is one embodiment of soft phase-shifting. Soft phase-shifting is useful because "hard" phase-shifting (from 180 to 0 degree) vs frequency is extremely difficult to do instantaneously (with a transition band of 0 Hz). If the transition band is very narrow it generally means some undesired amplitude response and psychoacoustic effects.

[0023] Generally, the logic control assembly 118 operates from a program that is stored in flash memory **128** of the mobile station. The program stored in flash memory 128 may comprise any or all of the inventive methods disclosed below, including the variable phase shifting only the low-frequency audio signal. Flash memory 128 allows upgrading of operating software, software correction or addition of new features. Flash memory 128 is also used to hold user information such as speed dialing names and stored numbers. The various disclosed embodiments typically function from this or another section of the mobile station's memory.

[0024] In addition to flash memory 128, the mobile station 100 will typically contain read only memory (ROM) **130** for storing information that should not change, such as startup procedures, and random access memory (RAM) **132** to hold temporary information such as channel number and system identifier.

[0025] Figures 2A-C illustrate an acoustic dipole radiator necklace 200. Loudspeaker **210** and loudspeaker **220** are located at opposite ends of interconnection cavity **230**, under the user's ears. Interconnection cavity 230 and the user's head effectively create a baffle to separate the front and backwaves of loudspeakers 210 and 220. In this embodiment, loudspeaker 210 and 220 are driven with opposite polarity (i.e., 180 degrees out of phase). When driven in opposite polarity (or phase), one loudspeaker will be moving into the cavity 230 while the other loudspeaker is moving out, which causes the air in the interconnection cavity 230 to only slightly load loudspeakers 210 and 220. The acoustic dipole radiator necklace 200 has improved low-frequency response because there is little interference between the loudspeakers' frontwave and backwave. Also, when the loudspeakers are 180 degrees out of phase there is mutual cooperation between the soundwaves generated by each loudspeaker, i.e., one loudspeaker pulls while the other pushes, creating a bigger perceived sound. A microphone **240** may be mounted at or near an acoustic null point between loudspeakers 210 and 220. By mounting the microphone 240 at an acoustic null point, most of the speaker to microphone leakage is avoided. Microphone 240 would require an input to speech codec 120 similar to the one shown for microphone 106 in Figure 1. The acoustic dipole radiator necklace 200 may be supported around the user's neck by any suitable means. For example, a strap (not shown for clarity) may hook to the acoustic dipole radiator necklace 200 and hold it around the user's neck.

[0026] It should be clarified that the 'opposite phase' or "opposite polarity" terms are valid for monophonic signals only, the true stereo channels (L&R) have partially independent signals and phasing. Ordinary stereo recordings are monophonic in the low frequency range, for several reasons, some of which are explained in the background section, and thus opposite phasing can be implemented for that low frequency range.

[0027] **Figures 3A and 3B** shows an alternative embodiment of the invention, an acoustic dipole radiator helmet 300. Loudspeakers 310 and 320 are located on opposite sides of helmet 300, near the user's ears. Similar to the necklace shown in Figure 2, the helmet 300 has an interconnecting cavity **330** that runs between the backside of loudspeaker 310 and that of loudspeaker 320. A possible variation of the helmet 300 would have separate cavities for each loudspeaker rather than a common (shared) cavity. These separate cavities could be acoustic transmission lines.

[0028] As will be recognized by those skilled in the art, the innovative concepts described in the present application can be modified and varied over a tremendous range of applications, and accordingly the scope of patented subject matter is not limited by any of the specific exemplary teachings given.

[0029] For example, although Figure 1 shows a wire link between the mobile station and the acoustic dipole radiator, a wireless link can be used. Optical or low-power radio frequency (RF) are two possibilities for the wireless link.

[0030] For example, although Figure 1 shows the loudspeakers of the acoustic dipole radiator electrically connected for a monophonic input signal, the loudspeakers can be electrically connected for a stereophonic input signal as well. This would require a separate electrical input from codec 120 for each loudspeaker. The low-frequency sound may still be phase-shifted to provide the acoustic dipole effect in the stereo configuration.

[0031] For example, although loudspeakers 210 and

220 are shown in Figure 2 with their front roughly parallel to the plane running through the user's collarbones, loudspeakers 210 and 220 may be arranged with their front tilted inwards toward the user's head so that better use may be made of the loudspeaker's acoustic directivity pattern.

[0032] For example, although the interconnecting cavity in the helmet of Figure 3 has been discussed primarily as a sealed cavity between the loudspeakers, one skilled in the art understands that, instead of a sealed cavity shared by both loudspeakers, a separate acoustic transmission line for each loudspeaker could be constructed inside the helmet and ported near its respective loudspeaker to increase the low-frequency output of the acoustic dipole helmet.

[0033] For example, although the disclosed innovations have been discussed primarily in the context of use with a mobile station, one skilled in the art understands that many electronic devices may be used with the invention, such as AM/FM radio receivers, portable cassette players, MP3 players, portable CD players or any other suitable portable electronic device. Additionally, some devices such as AM/FM radio receivers, are small enough that they may be implemented within the necklace or helmet. The improved low-frequency response provided by the disclosed innovations is particularly advantageous with high fidelity equipment because hi-fi equipment needs a much better low frequency response than the typical mobile station (which usually has a low cut-off frequency around 300 Hz).

[0034] For example, although the embodiments have mainly been discussed with the backside of the loudspeaker enclosed by the cavity and the front side emitting into free space, one skilled in the art understands that either speaker could be turned around so that the frontside is enclosed by the cavity and the backside is emitting into free space.

[0035] For example, although not shown, one skilled in the art understands that embodiments that do not incorporate a receiver in the wearable audio accessory will have some means of accepting an input signal from an external receiver. Figure 1 shows a hardwire connection from the mobile station to the wearable accessory. Such hardwire connections generally are implemented with an audio jack (connector) or terminal disposed on/in the wearable accessory. For wireless connections to the wearable accessory, some type of receiver such as an infrared or RF receiver is required.

[0036] For example, although the invention has been discussed primarily in the context of a necklace and a helmet, other wearable accessories can use the disclosed inventions, such as, perhaps, a headset that does not allow the loudspeakers to form a sealed cavity with the ears.

Claims

1. A wearable acoustic dipole radiator, comprising:

a wearable assembly;
a first loudspeaker disposed within said wearable assembly, said first loudspeaker having a front and a back side;
a second loudspeaker disposed within said wearable assembly, said second loudspeaker having a front and a back side; and
an interconnecting cavity disposed within said wearable assembly, said interconnecting cavity joining one of said front or back side of said first loudspeaker to one of said front or back side of said second loudspeaker.

2. The wearable acoustic dipole radiator of Claim 1, wherein said wearable assembly comprises a helmet.

3. The wearable acoustic dipole radiator of Claim 1 wherein each of said first and second loudspeaker further has an input, and wherein said wearable acoustic dipole radiator further comprises a radio receiver disposed within said wearable assembly, said radio receiver having an output electrically connected to an input of said first loudspeaker and an input of said second loudspeaker.

4. The wearable acoustic dipole radiator of Claim 1,

wherein said first loudspeaker has a positive terminal for accepting an input signal and a negative terminal,
wherein said second loudspeaker has a positive terminal and a negative terminal for accepting an input signal; and
wherein said negative terminal of said first loudspeaker is electrically connected to said positive terminal of said second loudspeaker.

5. The wearable acoustic dipole radiator of Claim 1,

wherein said first loudspeaker has a negative terminal for accepting an input signal and a positive terminal,
wherein said second loudspeaker has a negative terminal for accepting an input signal and a positive terminal,
wherein said negative terminal of said first loudspeaker is electrically connected to said positive terminal of said second loudspeaker,
wherein said positive terminal of said first loudspeaker is electrically connected to said negative terminal of said second loudspeaker.

6. The wearable acoustic dipole radiator of Claim 1, further comprising:

an input connector for accepting a first signal and a second signal from an external electronic device;
wherein said second signal comprises a phase-shifted low-frequency portion of said first signal;
wherein said first loudspeaker further has an input that is electrically connected to accept said first signal, and wherein said second loudspeaker further has an input that is electrically connected to accept said second input signal.

7. The wearable acoustic dipole radiator of Claim 1, wherein said interconnecting cavity joins the backside of said first loudspeaker to the backside of said second loudspeaker.

8. The wearable acoustic dipole radiator of Claim 1, wherein said interconnecting cavity comprises an acoustic transmission line.

9. A wearable acoustic dipole radiator, comprising:

a wearable assembly;
a first loudspeaker disposed within said wearable assembly, said first loudspeaker having a front and a back side;
a second loudspeaker disposed within said wearable assembly, said second loudspeaker having a front and a back side;
a first cavity disposed within said wearable assembly, said first cavity enclosing one of said front or back side of said first loudspeaker; and
a second cavity disposed within said wearable assembly, said first cavity enclosing one of said front or back side of said second loudspeaker.

10. The wearable acoustic dipole radiator of Claim 9, wherein said wearable assembly comprises a helmet.

11. The wearable acoustic dipole radiator of Claim 9, wherein said first cavity comprises an acoustic transmission line.

12. The wearable acoustic dipole radiator of Claim 10, wherein said acoustic transmission line is ported to augment the acoustic output of said first loudspeaker.

13. The wearable acoustic dipole radiator of Claim 9,

wherein said first loudspeaker has a positive terminal for accepting an input signal and a negative terminal;
wherein said second loudspeaker has a positive terminal and a negative terminal for accepting an input signal; and
wherein said negative terminal of said first loudspeaker is electrically connected to said positive terminal of said second loudspeaker.

14. The wearable acoustic dipole radiator of Claim 9,

wherein said first loudspeaker has a negative terminal for accepting an input signal and a positive terminal,
wherein said second loudspeaker has a negative terminal for accepting an input signal and a positive terminal,
wherein said negative terminal of said first loudspeaker is electrically connected to said positive terminal of said second loudspeaker,
wherein said positive terminal of said first loudspeaker is electrically connected to said negative terminal of said second loudspeaker.

15. The wearable acoustic dipole radiator of Claim 9, further comprising:

an input connector for accepting a first signal and a second signal from an external electronic device;
wherein said second signal comprises a phase-shifted low-frequency portion of said first signal;
wherein said first loudspeaker further has an input that is electrically connected to accept said first signal, and wherein said second loudspeaker further has an input that is electrically connected to accept said second input signal.

16. The wearable acoustic dipole radiator of Claim 9, wherein said second cavity comprises an acoustic transmission line.

17. The wearable acoustic dipole radiator of Claim 16, wherein said acoustic transmission line is ported to augment the acoustic output of said second loudspeaker.

18. A wearable acoustic dipole radiator, comprising:

a necklace having a first end and a second end;
a first loudspeaker disposed at said first end of said necklace, said first loudspeaker having a front and back side;
a second loudspeaker disposed at said second end of said necklace, said second loudspeaker having a front and back side; and
an interconnecting cavity disposed within said necklace, said cavity running from said first end to said second end of said necklace and joining one of said front or back side of said first loud-

speaker to one of said front or back side of said second loudspeaker.

19. The wearable acoustic dipole radiator of Claim 18, further comprising a microphone disposed on the exterior of said necklace.

20. The wearable acoustic dipole radiator of Claim 19, wherein said microphone is disposed at an acoustic null point on the exterior of said necklace.

21. The wearable acoustic dipole radiator of Claim 18, wherein said interconnecting cavity joins the backside of said first loudspeaker to the backside of said second loudspeaker.

22. The wearable acoustic dipole radiator of Claim 18,

wherein said first loudspeaker has a positive terminal for accepting an input signal and a negative terminal;
wherein said second loudspeaker has a positive terminal and a negative terminal for accepting an input signal; and
wherein said negative terminal of said first loudspeaker is electrically connected to said positive terminal of said second loudspeaker.

23. The wearable acoustic dipole radiator of Claim 18,

wherein said first loudspeaker has a negative terminal for accepting an input signal and a positive terminal,
wherein said second loudspeaker has a negative terminal for accepting an input signal and a positive terminal,
wherein said negative terminal of said first loudspeaker is electrically connected to said positive terminal of said second loudspeaker,
wherein said positive terminal of said first loudspeaker is electrically connected to said negative terminal of said second loudspeaker.

24. The wearable acoustic dipole radiator of Claim 18, further comprising:

an input connector for accepting a first signal and a second signal from an external electronic device;
wherein said second signal comprises a phase-shifted low-frequency portion of said first signal;
wherein said first loudspeaker further has an input that is electrically connected to accept said first signal, and wherein said second loudspeaker further has an input that is electrically connected to accept said second input signal.

25. The wearable acoustic dipole radiator of Claim 18, further comprising a radio receiver disposed within said necklace, said radio receiver having an output for outputting an audio signal, said output connected to an input of said first loudspeaker and an input of said second loudspeaker.

26. A portable electronic system, comprising:

a portable electronic device having an audio output for outputting an audio signal; and
an acoustic dipole radiator having an input for accepting said audio signal from said portable electronic device;
wherein said acoustic dipole radiator is wearable by a user of said portable electronic device.

27. The system of Claim 26, wherein said portable electronic device comprises a mobile station.

28. The system of Claim 27, wherein said mobile station further comprises an electronic logic assembly for phase shifting low-frequency portions of said audio signal.

29. The system of Claim 26, wherein said audio signal is a stereo signal having at least a left and a right channel.

30. The system of Claim 26, wherein said left channel comprises a phase-shifted low-frequency portion of said right channel.

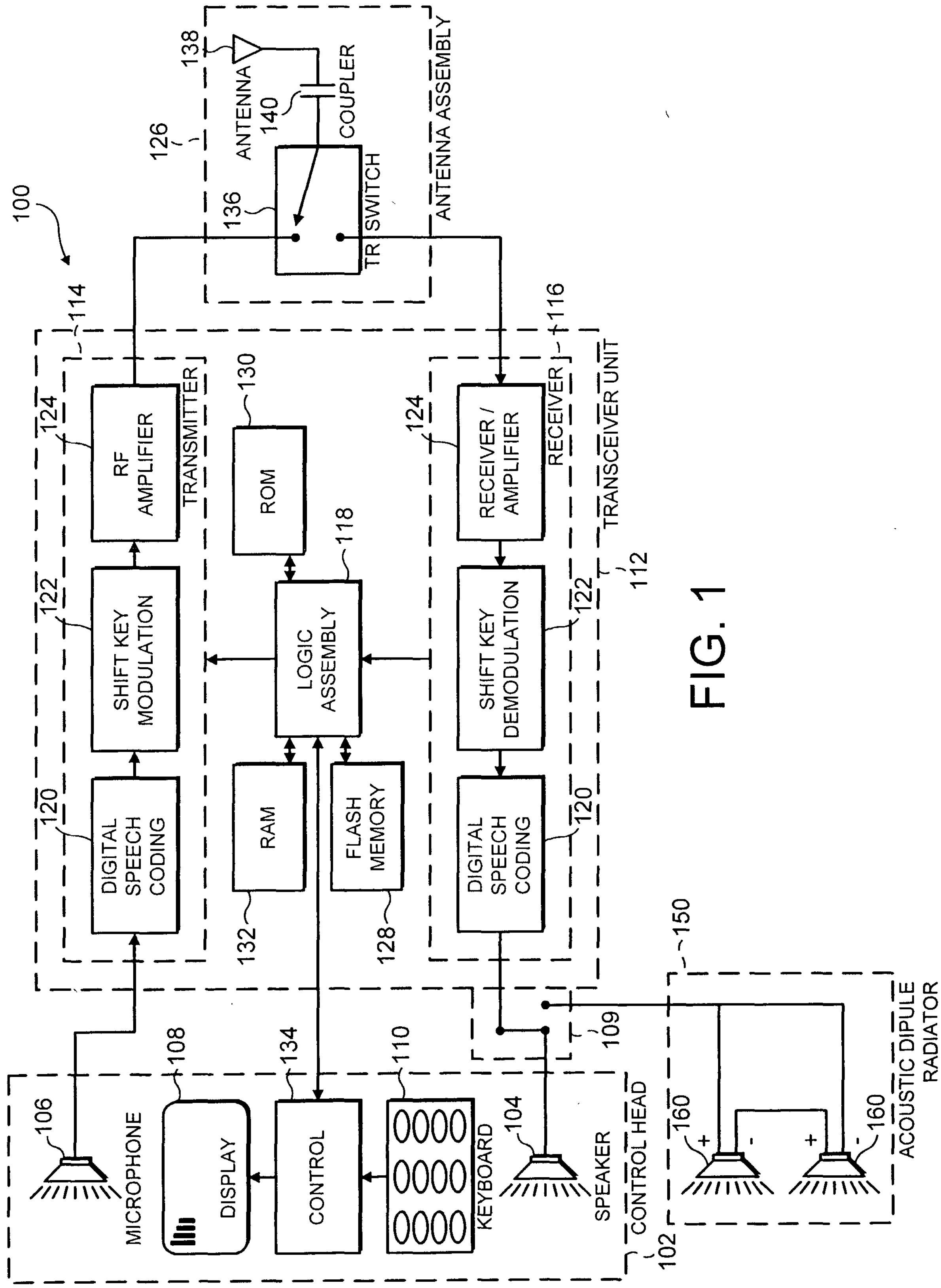
31. The system of Claim 26, wherein said acoustic dipole radiator further comprises:

a first loudspeaker, having a front and back side;
a second loudspeaker, having a front and back side; and
an interconnecting cavity joining one of said front or back side of said first loudspeaker to one of said front or back side of said second loudspeaker.

32. The system of Claim 31, wherein said first loudspeaker is configured to accept said audio signal.

33. The system of Claim 31, wherein said second loudspeaker is configured to accept said audio signal.

34. The system of Claim 31, wherein said first loudspeaker is configured to accept said audio signal in opposite polarity to said second loudspeaker.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ANTENNA ASSEMBLY
138
ANTENNA
140
COUPLER
126
136
TR SWITCH
114
116
TRANSMITTER
RF AMPLIFIER
124
SHIFT KEY MODULATION
122
DIGITAL SPEECH CODING
120
ROM
130
LOGIC ASSEMBLY
118
RAM
132
FLASH MEMORY
128
RECEIVER
RECEIVER / AMPLIFIER
124
SHIFT KEY DEMODULATION
122
DIGITAL SPEECH CODING
120
TRANSCEIVER UNIT
112
109
150
ACOUSTIC DIPULE RADIATOR
160
+
-
160
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MICROPHONE
108
DISPLAY
134
CONTROL
110
KEYBOARD
104
SPEAKER
CONTROL HEAD
102

FIG. 1

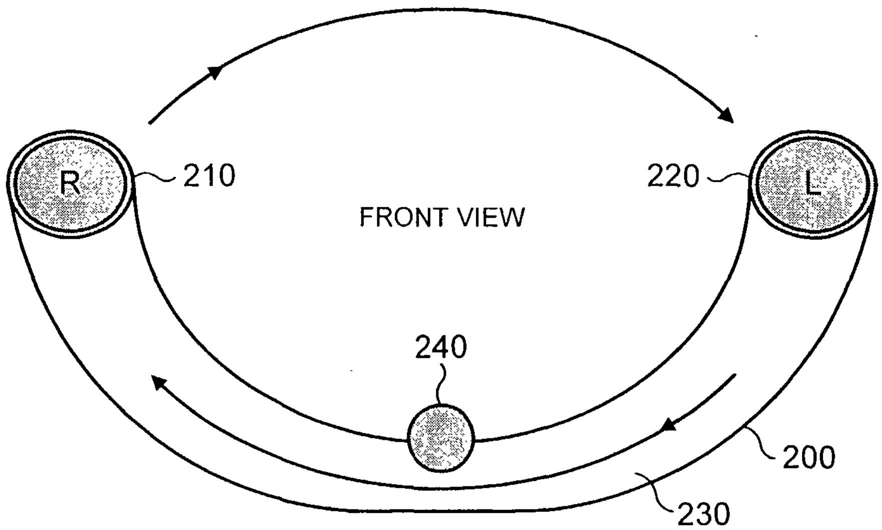

FIG. 2A

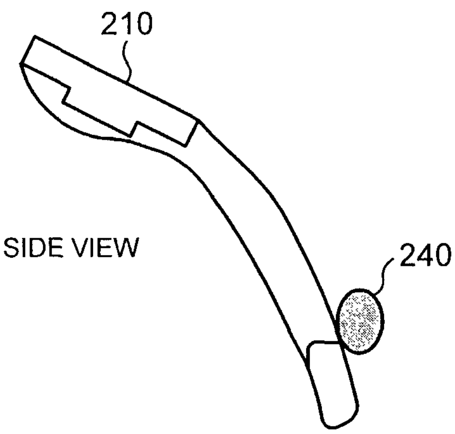

FIG. 2B

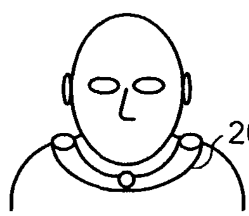

FIG. 2C

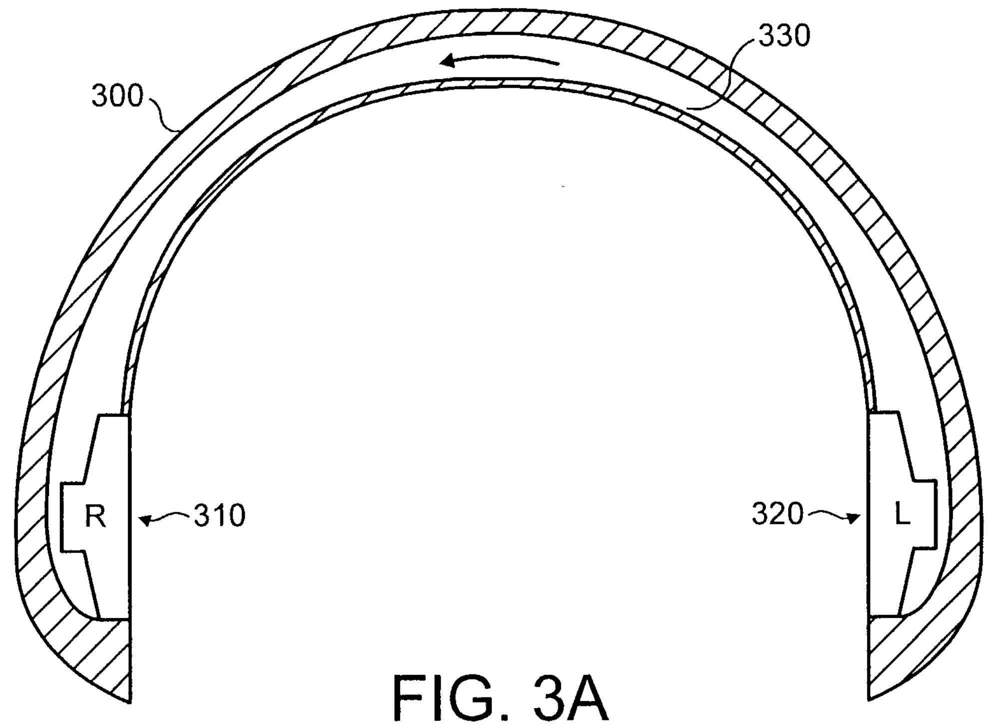

FIG. 3A

FIG. 3B