AVOIDING EAVESDROPPING IN ELECTRONIC DEVICES

FIELD OF TECHNOLOGY

[0001] This disclosure relates generally to communication and, more particularly, to avoiding eavesdropping in electronic devices.

BACKGROUND

[0002] Communicating personal and/or confidential matters over telephone is a usual practice and always has a security risk associated therewith, as people in the vicinity can overhear and thus eavesdrop on a conversation. The issue of eavesdropping can be of significant importance in places where information security is paramount (e.g. military). With the advent of mobile phones, there is a higher risk of eavesdropping since the calls might now be received in non-secure locations (e.g., public places). Also, talking in public places, (e.g.: theatre or public transport) is considered as bad manners. Current state of the art lacks suitable technical methods to overcome the problem of eavesdropping. People try speaking in lower volumes, moving to a place where others are not there etc, but these are not proper solutions to this issue. A common technique used for sound cancellation includes active cancellation technique.

[0003] The active cancellation technique is however limited to cancellation of periodic signals and thus does not support cancellation of voice signals as there is a non-negligible time delay between the noise being registered at a reference microphone and a control signal being produced at a control microphone. The delays can be due to digital control system delays (e.g., filtering, sampling, calculation etc), loudspeaker drive delays, and the like. Overall approximate time delay for an average active noise cancellation system is around 6 milliseconds (ms). However, in 6ms a sound wave would have travelled close to 2 meters in air, implying that for a causal control system, one or more sound sources must be separated by at least 2 meters. But for good active cancellation, the approximate distance between the control microphone and the source should be in the range of centimeters, thereby rendering the conventional active cancellation technique to be unsuitable for tackling the problem of eavesdropping.

SUMMARY

[0004] The method and attenuation device disclosed herein addresses the above stated need for attenuation of voice signals to avoid eavesdropping in electronic devices (e.g., a mobile phone). In one aspect, a voice signal generated by a user, to be transmitted to a receiver, may be attenuated through an attenuation device, so that any person in the vicinity of the user is unable to hear the generated voice signal, while allowing the voice signal to pass unchanged to the receiver. The attenuation is performed through a modified active noise cancellation technique. One or more passive cancellation techniques may also be performed in conjunction with the modified active cancellation techniques. The attenuation device can be a part of the electronic device or can be a separate device.

[0005] The active noise cancellation techniques known in the art do not support cancellation of voice signals due to circuit and hardware delay in generation of one or more cancellation signals, however in the method disclosed herein, one or more subsequent voice signals are predicted and one or more cancellation signals are generated based on the prediction, to attenuate the voice signals. The cancellation is performed only for the voice signals generated by the user, while not affecting other signals in the vicinity of the user, by performing a selective attenuation.

[0006] In one aspect of the method disclosed herein, one or more subsequent signals of a first auditory signal (e.g., a voice signal of a user) may be predicted through a prediction unit of an attenuation device. One or more second auditory signals (e.g., subsequent voice signals of the user) may be attenuated based on the predicted subsequent signal through the attenuation device. The subsequent signals may be predicted to overcome any effect of circuit delay and /or randomness of the auditory signals on the attenuation. The attenuation device may be positioned in a vicinity of a source of the second auditory signal (e.g., vocal tract of the user). The subsequent signals may be attenuated through an active cancellation. In addition, one or more auditory signals (e.g., noise signals) received from one or more other sources in the vicinity of the source of the second auditory signal may be selectively attenuated through the attenuation device.

[0007] The audibility and /or reception of the second auditory signals may be reduced beyond the region of the attenuation device due to the attenuation. The second auditory signals may be rendered inaudible to one or more other users in the vicinity of the user, due to the attenuation, thereby avoiding eavesdropping in the vicinity of the source of the second auditory signal. One or more passive cancellation techniques may also be used in combination with the active cancellation to optimize the attenuation.

[0008] In addition, a passive cancellation may be implemented in the vicinity of the electronic device to attenuate the second auditory signals generated by the user. Further, the passive cancellation may be implemented through a passive filter positioned in the vicinity of the electronic device and/or the user (e.g., close to the vocal tract of the user). The attenuation may lead to reduction in audibility and /or reception of the auditory signals beyond the passive filter due to attenuation. The auditory signals may be rendered inaudible to one or more other users in the vicinity of the user, due to the attenuation, thereby avoiding eavesdropping of the auditory signals. The passive cancellation may be implemented in addition to and in conjunction with the active cancellation.

[0009] The attenuation device disclosed herein may include one or more acoustic to electric transducers (e.g., a microphones) configured to generate at least one reference signal based on one or more auditory signals (e.g., voice signals, noise signals) received at the acoustic to electric transducers. The attenuation device may also include a prediction unit configured to predict at least one subsequent signal of at least one first auditory signal (e.g., a voice signal).

[0010] The prediction unit may also be configured to generate at least one predicted signal based on the prediction using at least one of the generated reference signal and /or an error signal. The error signal may be generated through an error transducer coupled to the attenuation device. The attenuation device may also include a control unit to generate at least one cancellation signal based on at least one of the predicted signal and /or the error signal. The control unit may include at least one control source to generate at least one control signal to attenuate at least one second auditory signal through an active cancellation using the cancellation signal.

[0011] The methods and system disclosed herein may be implemented in any means for achieving various embodiments, and may be executed in a form of a machine-readable medium embodying a set of instructions that, when executed by a machine, cause the machine to perform any of the operations disclosed herein. Other features will be apparent from the accompanying drawings and from the detailed description that follows.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

[0012] Example embodiments are illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

[0013] Figure 1 is a schematic view of an attenuation device configured to avoid eavesdropping in one or more electronic devices, in accordance with one or more embodiments.

[0014] Figure 2 is a schematic view of the attenuation device of **Figure 1** including multiple acoustic to electric transducers, in accordance with one or more embodiments.

[0015] Figure 3 is an example scenario illustrating avoiding eavesdropping in a mobile device of a user through an attenuation device, in accordance with one or more embodiments.

[0016] Figure 4 is a process flow illustrating a method to avoid eavesdropping in electronic devices, in accordance with one or more embodiments.

[0017] Other features of the present embodiments will be apparent from accompanying Drawings and from the Detailed Description that follows.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Example embodiments, as described below, may be used to provide a method, an apparatus and /or an attenuation device to avoid eavesdropping in electronic devices. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the various embodiments. It may be evident, however, to one skilled in the art that the various embodiments may be practiced without these specific details.

[0019] Figure 1 is a schematic view of an attenuation device 100 configured to avoid eavesdropping in one or more electronic devices. Examples of the electronic devices may include, but are not limited to, electronic communication devices (e.g., cellular phones), landline telephones, multimedia players, personal digital assistants, and the like. In order to avoid eavesdropping in the electronic devices, an auditory signal (e.g., a voice signal generated by the user of the electronic device) that needs to be transmitted to a recipient through the electronic device may be rendered inaudible and non receptive in the vicinity of the source of the auditory signal (e.g., vocal tract of the user) while allowing it to pass unchanged to the receiver. For example, while a user of a cellular phone converses with a friend through the cellular phone, the voice signals of the user may be transmitted to a receiving device of the friend through a transmitter of the cellular phone of the user but the voice signals may be rendered inaudible to any other person standing close to the user.

[0020] In one or more embodiments, the attenuation device 100 described herein may enable avoiding eavesdropping of one or more auditory signals. In one or more embodiments, the attenuation device 100 may include one or more acoustic to electric transducers 102 (e.g., the acoustic to electric transducer 102). The acoustic to electric transducers 102 (e.g., microphones) may be configured to generate one or more reference signals based on one or more auditory signals received from a source of a auditory signal 104.

[0021] The auditory signal (e.g., a first auditory signal, a second auditory signal), may be, for example a voice signal. In order to avoid eavesdropping, the voice signals may need to be attenuated in the vicinity of the source of the voice signals. The attenuation device 100 may also include a prediction unit 106 configured to predict at least one subsequent signal of at least one first auditory signal. The prediction unit 106 may also be configured to generate the predicted subsequent signal based on the prediction using the generated reference signal and /or an error signal. For purposes of illustration, the detailed description refers to a first auditory signal and a second auditory signal; however the scope of the method, the attenuation device, and /or the apparatus disclosed herein is not limited to a single auditory signal but may be extended to include an almost unlimited number of auditory signals.

[0022] In one or more embodiments, the prediction unit 106 may be configured to model a source of the first auditory signal (e.g., vocal tract of a user of the electronic device, a random signal generating device, and the like) to predict the subsequent signals. Modeling the source of the first auditory signal may include creating a circuitry with one or more characteristics identical to the source of the first auditory signal. The characteristics may include, for example, a transfer function. In one or more embodiments, the prediction unit 106 may be configured to use one or more speech coding techniques to model the source of the first auditory signal and /or to predict the subsequent signal.

[0023] The prediction unit 106 may include one or more predictive filters to model the source of the first auditory signal. The predictive filter may include, but is not limited to, a filter based on a vocoder technology. Examples of the predictive filters may include, but is not limited to a code excited linear prediction filter, an algebraic code excited linear predictive filter (CELP), a modified CELP, and the like. In one or more embodiments, the prediction may be performed using the predictive filter based on one or more linear prediction coding techniques similar to the ones used in a low delay CELPs or the vocoder technology. The attenuation device may be positioned at a predetermined distance from a source of the second auditory signal to enable attenuation of the second auditory signal. Examples of the source of the second auditory signal may include, but is not limited to, a vocal tract of a user of the electronic device, an audio signal generating device, and the like.

[0024] In one or more embodiments, the second auditory signal may be generated by the user subsequently, after a time gap, after generating the first auditory signal. The time gap may be, for example, 10 milliseconds. The attenuation device 100 may be suitably positioned at the predetermined distance from the source of the second auditory signal. The predetermined distance is preferably less than 1/5th the wavelength of the auditory signal. An extent of attenuation is determined by the predetermined distance, for example, positioning the attenuation device 100 at 1/10th the wavelength of the auditory signal may lead to a 10dB attenuation of the second auditory signal.

[0025] The attenuation device 100 may also include a control unit 108 to generate at least one cancellation signal based on the predicted signal and /or the error signal. The generated cancellation signal may attenuate /or cancel the second auditory signal. The subsequent signal is predicted so as to overcome a circuit delay if any of the control unit 108 causing a delay in generating the cancellation signal. For example, consider an instance where the control unit 108 can generate the cancellation signal only 8ms after receiving the first auditory signal due to circuit delay. The cancellation signal does not attenuate the first auditory signal due to the first auditory signal travelling a distance of 8ms times the speed of sound away. The attenuation device 100 disclosed herein enables prediction of a subsequent signal expected to be received from the source of the first auditory signal 8ms later, through the prediction unit 106, such that the predicted signal may be used to determine the cancellation signal. In one or more embodiments, the prediction unit 106 may have an inherent delay (d2), and the attenuation device may have a basic circuit delay (d1) and therefore the prediction unit 106 may cause a net delay (d1+d2) during prediction. The prediction unit 106 may be configured to predict the subsequent signal taking into account the net delay of the prediction unit 106.

[0026] The cancellation signal corresponding to the predicted signal may be outputted from the control unit 108 only 8ms later due to the circuit delay. However, since the cancellation signal is determined so as to be complementary to the predicted signal, the determined cancellation signal may be capable of attenuating a second auditory signal generated 8ms later from the source of the first auditory signal or any other source. The attenuation may be performed through an active cancellation. Those skilled in the art with access to the present teachings will recognize that the term "active cancellation" refers to reduction of a signal level by cancelling unwanted waves (e.g., acoustic waves) with a second set of electronically generated acoustic waves complimentary to the unwanted waves. The active cancellation may be a global cancellation and/ or a local cancellation. In one or more embodiments, the control unit 108 may include a control source 110 (e.g., a loudspeaker) to generate one or more control signals. The control signals may be used to generate the cancellation signals to attenuate one or more second auditory signals through the active cancellation. In one or more embodiments, the control source 110 may be external to the control unit 108. In one or more embodiments, multiple control sources may be coupled to the attenuation device 100. The attenuation device 100 may include an error transducer 112 operatively coupled to the control unit 108 to generate the error signal. In one or more embodiments, the error signal may be generated based on an attenuated signal obtained from the control unit 108.

[0027] In one or more embodiments, the attenuation device 100 may include multiple acoustic to electric transducers to prevent external noise signals from affecting the auditory signals. The multiple acoustic to electric transducers may be configured to generate multiple reference signals based on multiple auditory signals. **Figure 2** is a schematic view of the attenuation device of **Figure 1** with multiple acoustic to electric transducers (e.g., acoustic to electric transducer 102_A, and acoustic to electric transducer 102_N). The attenuation device 100 may also include a monitoring unit 201 operatively coupled to the acoustic to electric transducers 102_A and 102_N to monitor a time of arrival of each of the auditory signals (e.g., x_1 and x_N) at the acoustic to electric transducers 102_A and 102_N respectively and / or to communicate the time of arrival to the control source 110 to control attenuation of the auditory signal. The monitoring unit 201 may be operatively coupled to the control source 110. Based on the communicated time of arrival, the control unit 108 may select one or more of the auditory signals to generate cancellation signal for.

[0028] The selection may be based on the whether the time of arrival exceeds a predetermined value. Based on the time of arrival, the distance of the source of each of the auditory signals (e.g., source of the auditory signal X_1, 104_A and source of the auditory signal X_N, 104_N), from the control unit 108 may be computed. In one or more embodiments, the control unit 108 may select one or more auditory signals originating from the sources at close proximity to the control unit 108. The control unit 108 may generate control signals for the selected auditory signals and may prevent generation of control signals for the rest of the auditory signals. In one or more embodiments, the attenuation device 100 may further include an interface (e.g., a universal serial bus port) to couple the attenuation device 100 to the electronic device. In one or more embodiments, the attenuation device 100 may be embedded in the electronic device. The attenuation device 100 may be internally or externally coupled to the electronic device.

[0029] **Figure 3** is an example scenario illustrating avoiding eavesdropping in a mobile device 304 of a user 302 through an attenuation device 100, in accordance with one or more embodiments. The attenuation device 100 coupled to the mobile device 304. The user 302 of the mobile device 304 may call a recipient through the mobile device 304. The user 302 may generate one or more random voice signals while speaking to the recipient. The attenuation device 100 may be positioned at a predetermined distance (d) from the vocal tract 306 of the user 302, the vocal tract 306 constituting a source of the random voice signals. The predetermined distance (d) may be one fifth the wavelength of the auditory signal. Based on the reference voice signal, the voice signals generated while the user 302 speaks may be predicted through a prediction unit within the attenuation device 100. If the reference voice signal is generated at an n^{th} millisecond, then the random voice signals expected to be generated ten milliseconds later (at n+10 milliseconds) may be predicted through the prediction unit. A control unit 108 within the attenuation device 100 may generate a cancellation signal based on the random voice signal predicted at the $(n+10)^{th}$ millisecond. When the user 302 begins to speak, the generated cancellation signals may interfere with the random voice signal generated at $(n+10)^{th}$ millisecond by the user 302 and the interference may cause attenuation of the random voice signal.

[0030] The attenuation may be a 30 dB (decibel) attenuation rendering the random voice signal to be nearly inaudible to a person 308 standing close to the user 302 as illustrated in **Figure 2.** So the person 308, in spite of standing close to the user 302, may not be able to hear the conversation between the user 302 and the recipient clearly, thereby avoiding eavesdropping with respect to the user 302. The random voice signal may be retrieved from the attenuated signal to be transferred to the transmitter of the mobile device, thereby rendering the random voice signal of the user 302, to be audible to the recipient while avoiding eavesdropping.

[0031] Figure 4 is a process flow detailing the operations involved in a method to avoid eavesdropping in electronic devices, in accordance with one or more embodiments. In one or more embodiments, operation 402 may involve predicting at least one subsequent signal of at least one first auditory signal (e.g., a voice signal of a user) through a prediction unit of an attenuation device. For example, given a auditory signal generated by a source of the auditory signal at an instant of time t milliseconds, a new auditory signal; generated 10 milliseconds after t milliseconds (at (10+t) ms) by the source of the auditory signal may be predicted through the prediction unit.

[0032] The prediction may be, for example, a linear prediction. The attenuation device may be positioned in a vicinity of a source of the first auditory signal (e.g., vocal cord of a user, a signal source, a distributed signal source, and the like). For example, the attenuation device may be coupled to a microphone of a cellular phone of the user. In one or more embodiments, the source of the first auditory signal may be modeled to predict the subsequent signal. In one or more embodiments, modeling the source of the first auditory signal may include creating a circuitry with one or more characteristics identical to the source of the first auditory signal.

[0033] The characteristics may include, for example, a transfer function. In one or more embodiments, one or more speech coding techniques may be used to model the source of the first auditory signal and /or to predict the subsequent signal. In one or more embodiments, one or more predictive filters may be used to model the source of the first auditory signal. Examples of the predictive filters may include, but is not limited to a code excited linear prediction filter, an algebraic code excited linear predictive filter (CELP), a modified CELP filter, and the like. In one or more embodiments, the prediction may be performed using the predictive filter based on one or more linear prediction coding techniques similar to the ones used in a low delay CELPs or the vocoder technology.

[0034] In one or more embodiments, operation 404 may involve attenuating at least one second auditory signal based on the predicted subsequent signal, through an attenuation device in the vicinity of a source of the second auditory signal. In one or more embodiments, the attenuation device may be positioned at a distance within a fraction of a wavelength of the second auditory signal, from the source of the second auditory signal. In a preferred embodiment, the distance is within one fifth the wavelength of the second auditory signal and /or the first auditory signal. In some other embodiments, the attenuation device may be positioned at a distance equal to multiple of the wavelength of the second auditory signal. In one or more embodiments, the first auditory signal and /or the second auditory signal may be for example, a voice signal.

[0035] The attenuation may be for example, about 30 decibel attenuation. In one or more embodiments, during attenuation at least one reference signal may be generated through at least one acoustic to electric transducer coupled to the attenuation device. The predicted subsequent signal may be generated based on the generated reference signal and/or an error signal. Further, one or more cancellation signals may be generated based on the generated predicted subsequent signal and /or the error signal.

[0036] In one or more embodiments, the error signal may be generated based on the attenuated signal through an error microphone in the attenuation device. In one or more embodiments, the generated cancellation signal may attenuate the second auditory signal through an active cancellation. The active cancellation may include, but is not limited to global cancellation, local cancellation, and the like. In one or more embodiments, attenuation of at least one auditory signal may be prevented at the attenuation unit. The auditory signal may be, for example, a noise signal. To prevent attenuation, a time of arrival of the auditory signals at one or more of the multiple acoustic to electric transducers may be determined.

[0037] The time of arrival of each auditory signal (e.g., external noise signals received from one or more sources in the vicinity of the attenuation device) from among the auditory signals may be compared at each of the acoustic to electric transducers. Based on the comparison at least one auditory signal may be selected. In one or more embodiments, the selection may be based on a distance of a source of the auditory signal from a control unit within the attenuation device. The distance may be computed based on the time of arrival. At least one auditory signal may be selected if the distance is beyond a predetermined distance, that is, the auditory signal may be attenuated only if the source of the auditory signal is in close proximity to the control unit.

[0038] The attenuation of the selected auditory signal may be prevented at the attenuation device, by preventing generation of cancellation signals for the selected auditory signals. The predetermined distance may be preset based on requirements of a specific application of the method. In one or more embodiments, the second auditory signal may be retrieved from the attenuated signal and may be transferred to a transmitter of an electronic device so as to be audible to a recipient through the electronic device. In one or more embodiments, a passive cancellation may be implemented in the vicinity of the source of the first auditory signal and /or the source of the second auditory signal.

[0039] In one or more embodiments, a combination of the passive cancellation and the active cancellation may be implemented to attenuate the auditory signals. One or more passive filters may be positioned in the vicinity of the source of the first auditory signal and /or the source of the second auditory signal to implement passive cancellation. The first auditory signal and /or the second auditory signal may be attenuated through the passive cancellation. Examples of the passive filters may include, but are not limited to, ear plugs, foam coverings, and the like. The passive cancellation may be high for high frequency auditory signals. The attenuation may reduce an audibility and /or reception of the second auditory signal in the vicinity of and / or beyond a region of the attenuation device owing to the attenuation. Examples of the passive cancellation may include, but is not limited to, positioning the passive filter in the vicinity of the source of the auditory signal, deflecting and absorbing sound waves, employing earplugs made of foam, installing foam in interior linings of cars or rooms, and also creating huge and thick barriers in a path of the auditory signal. In one or more embodiments, a first characteristic impedance of the source of the auditory signal may be matched with a second characteristic impendence of the passive filter to attenuate the auditory signal through the passive filter. For example, considering vocal tract of the user as a waveguide, the characteristic impedance of the vocal cord of the user is determined and matched with a characteristic impendence of a foam (passive filter) covering of a microphone of the user, to attenuate one or more voice signals generated by the user arriving at the microphone.

[0040] The foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention disclosed herein. While the invention has been described with reference to various embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Further, although the invention has been described herein with reference to particular means, materials and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims. Those skilled in the art, having the benefit of the teachings of this specification, may affect numerous modifications thereto and changes may be made without departing from the scope and spirit of the invention in its aspects.