

PATENT SPECIFICATION (11)

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(54) ACTIVE ATTENUATION OF RECURRING VIBRATIONS

(71) We, GEORGE BRIAN BARRIE CHAPLIN, (RODERICK ALAN SMITH and ROBERT GEORGE BEARCROFT, all British subjects) of the Department of Electrical Engineering Science, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of or apparatus for the reduction of unwanted vibrations received at a selected location from a source (point or distributed). The invention concerns application of the technique broadly known as "active attenuation" in which the unwanted vibration is at least partially cancelled at the said location by a nulling vibration specially generated (e.g. by a waveform generator) and fed into the location.

This invention is concerned with methods of active attenuation where some anticipatory information as to the vibration to be attenuated is available and thus has particular reference to the reduction of vibrations from a source of recurring vibrations (such as an internal combustion engine).

In the specification of U.S. Patent 3,071,752 there is described apparatus for reducing the disturbing effect of recurring noise from a machine on sonar equipment which uses a recording of the recurring noise driven by the machine to generate cancellation signals which can be fed into the sonar equipment to at least partly null the background noise from the machine. The recording can be on a magnetic tape or disc powered by a drive shaft of the machine and the specification suggests that if the characteristic sound of the machine is different in different speed ranges, a unique recording for each speed range can be made and means provided to switch recordings as the machine speeds up or slows down.

The arrangement described in this U.S. specification has significant drawbacks. It would be very difficult to ensure accurate synchronisation of the recording and the machine under widely different operating

conditions and the quality of the recording will deteriorate with time. Further the noise output of the machine will be affected by many parameters requiring a vast number of different recordings (and means to select which one is required at any given time) if all possible changes and conditions are to be accounted for.

Yet again there must be a physical link between the noise-generating machine and the rest of the equipment and such a link may not be possible or at least not desirable.

This invention relates to an improved method of reducing, from a source of recurring vibration (e.g. noise), the amplitude of unwanted vibrations at a selected location which derives from the source merely a triggering signal.

Because the nature of the primary wave generated by the source is similar on each occasion of its generation, information as to when the source is generating the primary wave is enough to enable a nulling secondary wave to be generated and fed to the selected location.

According to one aspect the present invention relates to a method of reducing the amplitude of vibrations received at a selected location from a source of recurring vibration, which method comprises feeding to said location a secondary vibration which at least partially nulls the vibrations from the source at the said location and is characterised in that the secondary vibration is a synthesised waveform generated by a waveform generator fed with a triggering signal derived from the source to accurately relate the generation of the secondary vibration to that of the vibration to be cancelled.

In a simple embodiment of method according to the invention, a sound generating system is preset to transmit a nulling pulse which will coact with the characteristic sound of one explosion from a diesel exhaust or one impact of a pneumatic road drill at a particular location spaced from the source of the sound, and the system is "fired" (with the appropriate preset delay) to generate a nulling pulse each time a trigger signal is received from the source

25 MAR 1987

that a burst of primary sound is being emitted. Where the primary sound bursts are, to an appreciable measure, identical each time, a preset system can easily and cheaply provide a significant reduction in sound level at the location.

Suitably, however, the waveform generator is arranged to adapt its output on the basis of success achieved in cancelling the unwanted vibrations from the source. Using an adaptive technique it is immaterial what form the secondary vibration takes initially, since periodically when a burst of unwanted vibration is generated by the source, a new adaptation can be tried and if the system is programmed to seek out the more successful secondary vibration, it is only a matter of time before the correct secondary vibration is found to effect the desired degree of cancellation. The adaptive technique may employ a microphone located at the said location to sense the quality of the contemporary nulling action and a simple memory can be used to determine whether, following a change in the secondary vibration, the nulling action has improved.

The electrical triggering signal to time the generation of the secondary vibration can be derived from a microphone disposed close to the source or, in the case where the source is rotating or reciprocating machinery, the triggering signal may be derived from a motional transducer mounted on the machinery itself. Where the source of the vibrations to be nulled is itself an electrical transducer, a part of the signal driving that transducer can be picked off and used as the triggering signal for the purposes of the method of this invention.

According to a further aspect of the present invention apparatus for reducing the vibration received at a selected location from a source of recurring primary vibration comprises a synthesising generator, means for deriving from the generator a secondary vibration which at least partially nulls the primary vibration in the said location and an electrical transducer located at or closely adjacent to the source for feeding a signal to the generator to trigger the generation of the synthesised secondary vibration in time with the generation of the primary vibration.

The invention will now be described by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic illustration of the broad principles behind the method and apparatus of the invention,

Figure 2 is a block diagram illustrating one embodiment of waveform generator as shown in Figure 1,

Figure 3 is an embodiment in accordance with the invention suitable for a particular characteristic noise,

Figure 4 shows the details of a preferred arrangement for cancellation of noise from a distributed repetitive source such as an engine,

Figure 5 shows an arrangement for nulling the sound entering a location from two different sources, one a source of repetitive sound, and the other a source of purely random sound,

Figure 6 is a schematic representation of one embodiment of the invention used to provide a quiet area adjacent to a typewriter,

Figure 7 shows a practical set-up used to demonstrate the method of the invention,

Figures 8 and 9 show experimental results obtained with the set-up of Figure 7, and

Figures 10 and 11 show details of the set-up of Figure 7 in greater detail.

Referring to Figure 1, a source 1 of recurring sound is provided with an electrical transducer 2 which generates a trigger signal that synchronises with the bursts of sound energy from the source. A loudspeaker 3 located in a protected area 4 (shown by the dashed line) is energised from a waveform generator 5 to which the trigger signal is fed. Within the area 4 the sound from the loudspeaker 3 (at least to some extent) nulls the sound reaching that area from the source 1. In its simplest embodiment the integers 2, 3 and 5 are sufficient to achieve an acceptable reduction of sound in the area 4, the waveform generator 5 being preset to give an optimum cancelling signal.

Better performance can be obtained with a more sophisticated system which incorporates further integers shown dotted in Figure 1. These are a sensing microphone 6 within the area 4 which feeds its output signal via a power measuring device 7 to the output of an adaptation unit 8 being used to modify the performance of the waveform generator 5.

One example of an application in which a simple system such as that shown in Figure 1 could be employed, would be an area adjacent to an IC engine, the transducer 2 sensing each burst of sound from the engine (e.g. each firing stroke) and with an appropriate time-lag to allow for the sound to reach the area 4, generating a cancelling pulse of preset amplitude and waveform to at least partially null the effect of the sound on somebody within the area 4. Since to a large extent every pulse of sound from the source 1 is the same as every other pulse of sound, the signal necessary to null it in the area 4 is the same in each case and all that matters is the synchronisation of the primary and nulling sounds within the area 4.

The transducer 2 can take many forms such as, for example, a pressure sensitive electrical transducer on the exhaust of the

engine, a vibration-sensitive electrical transducer on the casing of the engine, motion-sensing means on some moving part of the engine or an electrical signal derived directly from the ignition or fuel injection systems.

The system shown in Figure 1, by including the integers 6, 7 and 8, does allow for the performance of the equipment to be self-improving, the feedback loop defined by the integers 6, 7 and 8 acting to minimise the power output from the unit 7. The more sophisticated system shown in Figure 1 can be used for circumstances where although the same sound recurs time after time, the amplitude and/or waveform of the sound in each burst can be expected to vary in the long term.

One form of generator 5 and adaptation unit 8 which could be used in the system of Figure 1 is illustrated in Figure 2.

The synchronisation signal from the transducer 2 can be assumed to be at a repetitive frequency f . A frequency multiplier 9a (e.g. incorporating a phase locked loop) feeds a frequency which is an integer multiple of the frequency f to a frequency divider chain 9b which sequentially addresses locations of the memory 9c. This waveform memory 9c stores a plurality of samples each having a unique address in the memory 9c. The samples represent portions of a precursor of the required waveform to be generated and are presented sequentially to a digital analogue converter 9d to generate the actual waveform to be fed to the loudspeaker 3. It is because each of the samples must be presented once per repetition of the acoustic waveform to generate the required secondary wave that the need arises for a frequency multiplier, the degree of multiplication depending on the number of samples (in a typical case 32). The samples stored in the memory 9c can be derived in a variety of different ways but since the memory is modified by the unit 8 to minimise the output from the unit 7 it is not generally too important what the starting samples are, since eventually if each burst of recurring primary sound energy is like each other burst, the correct samples will appear in the memory 9c and the pattern of samples one starts with merely affects how long it takes to produce the correct cancelling signal.

The adaptation unit 8 (which can be a conventional microprocessor) can address the memory 9c (at intervals determined by the programme built into the microprocessor) to update the values stored in each section of the memory and conventional techniques can be used for this. Preferably a time delay is built into the updating mechanism to ensure that any alleged improvement is a genuine (and thus a lasting one) one before the memory is updated.

Figure 3 shows an arrangement which can be used to cancel sound which has a constant wave shape at any given repetition rate but whose repetition rate alters considerably over a short time scale and whose wave shape is affected by the repetition rate. In the arrangement shown in Figure 3 the wave shapes for three different bands of frequencies are stored in three different memory blocks 9cⁱ, 9cⁱⁱ and 9cⁱⁱⁱ, and a sensing circuit 10 selects the appropriate memory location for the current frequency of operation. The waveform adjusting automaton 8 can act to adjust the wave shape in each block of memory and will be effective at any given time on the memory block corresponding to the current frequency of operation. If desired, the choice of memory from which the adaptive waveform is drawn can be based on parameters other than frequency such as the loading of an internal combustion engine, the degree of throttle opening and/or the speed depending on the nature of the sensing unit 10.

Equipment such as shown in Figure 3 could be used to reduce the ambient sound level within the operating cab of a machine where the machine can operate in a variety of different modes with each of which a characteristic noise is associated. In such circumstances a substantial reduction in noise level is acceptable even when this is far short of 100 per cent cancellation so that the adaptive technique provided by integers 6, 7 and 8 may not be necessary and if it is provided need not be of sophisticated design.

Figure 4 schematically illustrates a situation where an extended area surrounding a source of repetitive noise needs to be protected, a plurality of sensing microphones M1—M4 being located at locations spaced apart across the protected area. A plurality of loudspeakers for generating the necessary nulling signals (L1 . . . L4) is disposed adjacent to the source. A single trigger signal can be derived from a transducer 2 on the source and fed to all the waveform generators (5₁ . . . 5₄) to synchronise the generation of the nulling signals for the individual loudspeakers.

A power sensing circuit (7₁ . . . 7₄) is provided for each microphone but a common adaptation circuit 8 can be provided for all of the generators 5₁ . . . 5₄.

With the arrangement shown the adaptation will proceed until the total output from all the circuits 7₁ . . . 7₄ is at a minimum.

Figure 5 illustrates an arrangement in which noise from a repetitive source 15 and noise from a random source 16 flowing into a protected area 17 are both nulled from a single loudspeaker 18. The trigger signal from the source 15 is fed to a waveform generator 19 and the random signal from the source 16 is picked up by an upstream

microphone 20 and fed to a unit 21 where it is convolved with an appropriate programme in the manner described in the specification of U.K. Patent No. 1555760 (27412/75). An adder 22 combines the output signals from 19 and 21 and acts as the driver for the loudspeaker 18. A sensing microphone 23 is used to modify the performance of either or both the generator 19 or the unit 21 to achieve improved cancellation.

To null the noise from a typewriter 34 (see Figure 6), a waveform generator 35 is triggered to emit a nulling sound in the desired direction from a loudspeaker 36 whenever a key on the typewriter has been pressed. This provides a quiet zone for a reader 37. In the simplest system a single preset waveform is used for all the keys. In a somewhat more sophisticated system, the typewriter keys are classified in groups on the basis of the sound each makes, and a slightly different secondary wave is generated for each different group of keys, an arrangement, such as that shown in Figure 3 without the integers 6, 7 and 8 being employed in this case.

However to allow for the effect of different typists, different paper, different mountings of the machine and the effects of wear and tear on the noise output of a machine an adaptive technique using a microprocessor 8 is much preferred.

In the case of producing "quiet areas" adjacent to a road drill or pile driver similar principles would apply.

EXAMPLE

The invention will be further described by the following Example.

A loudspeaker 40 (see Figure 7) simulating a source of repetitive noise was installed in a room 41 which was not acoustically damped. A second loudspeaker 42 was then mounted in close proximity to the loudspeaker 40 and a microphone 43 was placed about 4 metres from the pair of loudspeakers to measure the residual, uncanceled noise. The loudspeaker 40 was driven by a source 46 and the microphone 43 fed its output to a sound level metering unit 45. A microprocessor 44 programmed to monitor the power and repetition rate (but not the waveshape) of the noise picked up by the microphone 43 was used to generate a waveform, consisting of 32 discrete samples and this waveform was applied to the loudspeaker 42 to reduce the noise power at the microphone 43 to a minimum. The microprocessor 44 initially supplied a digitally generated waveform of arbitrary shape and amplitude to the noise reducing loudspeaker 42 and was synchronised to the source 46 by a line 47. The waveform was divided into 32 time slots, and each slot was

varied in turn in amplitude. If the variation of a particular time slot produced a reduction in the power output of the microphone 43, it was incorporated in the waveform but if it did not, it was rejected.

Referring to Figures 8a-8c the oscillograms show the output from the microphone 43 and the input to the loudspeaker 42 for three instants of time after a 65 Hz complex waveform had been applied to the noise source 40. In Figure 8(a), at $t=0$, no cancellation is taking place and so the residual waveform shows the full effect of the noise source and the acoustic characteristics of the room 41 at the microphone 43. Figure 8(b) shows that after 3 minutes the cancellation waveform has partially adapted itself and reduced the noise source to below half power, whilst Figure 8(c) shows virtually complete cancellation after 30 minutes, leaving only a ripple due to the finite number of samples. It should be noted that the cancellation waveform of Figure 8(c) differs from the residual sound waveform of Figure 8(a) because the system automatically takes into account the characteristics of the transducers and the room. A plot of the residual noise power against time for the first 15 minutes is shown in Figure 9 and from this it can be seen that a reduction in signal strength of 15dB was obtained inside five minutes.

A response time of 5 minutes is too long for many applications, but a more efficient algorithm and the storing of information relating to various operating conditions and the possible use of waveshape information in addition to power information from the microphone permit the response time to be reduced to at most a few seconds.

Figure 10 shows how the output of the microphone 43 is used to generate the cancelling waveform fed to the loudspeaker 42. A microprocessor and random access memory 50 (types MCS 6502 and M.6810) is connected to a peripheral interface adapter 51 (type M.6820) which under programme control, pulses a sample line to a "better-or worse" circuit 52 which includes a sample and hold circuit 52a using a CD 4016 transmission gate and a CA 3130 amplifier and a comparator 52b. The input to the circuit 52 is from the microphone 43 via an amplifier and precision rectifier 54 constructed using conventional techniques and 741 type operational amplifiers.

The microprocessor type MCS 6502 is configured in an individualised system (functionally very similar to a board sold under the Trade Mark "KIM" by MOS Technology Inc) and has facilities for programme loading from keys or domestic audio tape or teletype, a couple of kilobytes of random access storage for programme and data, and a potential of 65 kilobytes of storage. A

décimal decoder-driver (type 7442) is used for address decoding and this selects device types when particular areas of memory are addressed. The unit 50 controls a waveform generator 55 that feeds the loudspeaker 42 via a power amplifier 56.

Figure 11 shows the waveform generator 55 in greater detail. It consists of a small random access memory (part of a M 6510) which can be connected to the unit 50 via a switch 55a or to a chain of type 7493 counters 55c and a resistive digital to analogue converter 55d.

When generating a waveform for the loudspeaker 42, the address for the RAM 55b is provided by the counters 55c, resulting in the presentation of the contents of successive locations in the RAM 55b to the digital to analogue converter 55d in successive time intervals.

While the processor unit 50 is modifying the shared RAM 55b, the RAM 55b is temporarily disconnected from the counters 55c and the converter 55d by the switch 55a and is connected to the processor unit 50 as a conventional memory. The switching function of the switch 55a is performed on the address bus by type 74157 gates (not shown) and on the data bus by type CD4066 gates (not shown).

The source 46 (see Figure 7) is connected to the counters 55c as shown dotted in Figure 11.

WHAT WE CLAIM IS:—

1. A method of reducing the amplitude of vibrations received at a selected location from a source of recurring vibration, which method comprises feeding to said location a secondary vibration which at least partially nulls the vibrations from the source at the said location and is characterised in that the secondary vibration is a synthesised waveform generated by a waveform generator fed with a triggering signal derived from the source to accurately relate the generation of the secondary vibration to that of the vibration to be cancelled.

2. A method as claimed in claim 1, in which the waveform generator is arranged to adapt its output waveform on the basis of success achieved in cancelling the unwanted vibrations from the source.

3. A method as claimed in claim 2, in which periodically when a burst of unwanted vibration is generated by the source, a new adaptation is tried, the waveform generator generating the secondary vibration being programmed to seek out the more successful secondary vibration following each such adaptation.

4. A method as claimed in either of claims 2 or 3, in which the adaptive technique employs a microphone located at the said location to sense the quality of the con-

temporary nulling action and a memory is used to determine whether, following a change in the secondary vibration, the nulling action has improved.

5. A method as claimed in any preceding claim, in which the electrical trigger signal used to time the generation of the secondary vibration is derived from a transducer disposed close to the source.

6. A method as claimed in claim 5, in which the source is rotating or reciprocating machinery, and the triggering signal is derived from a motional transducer mounted on the machinery itself.

7. A method as claimed in any of claims 1 to 4, in which the source of the vibrations to be nulled is itself an electrical transducer and a part of the signal driving that transducer is picked off and used as the triggering signal.

8. A method of reducing the amplitude of sound vibrations received at a selected location from a source of recurring noise, which method comprises feeding to said location a secondary sound vibration which at least partially nulls the sound vibrations from the source at the said location and is characterised in that the secondary sound vibration is obtained from a waveform generator which is triggered to generate its output by a timing signal derived from the source, the generator for the secondary sound vibration being such that its output waveform is obtained by sequentially combining a series of component part waveforms each stored in a memory and deriving the output waveform by a successive series of approximations, each successive approximation being made by altering at least one of the individual component parts and adopting an alteration of a component part by updating that part in the memory or rejecting that part alteration on the basis of whether or not that part alteration improved the degree of cancellation of the unwanted sound vibration from the source at the selected location.

9. A method as claimed in claim 8, in which a microphone is located at the selected location to sense the quality of the contemporary cancelling action and a microprocessor is used to determine whether, following a change in the output waveform of the generator, the cancelling action has improved.

10. A method of reducing the amplitude of vibrations received at a selected location from a source of recurring noise substantially as hereinbefore described with reference to, and as illustrated in, Figures 1 and 2 of the accompanying drawings.

11. A method of reducing the amplitude of vibrations received at a selected location from a source of recurring noise substantially as hereinbefore described with refer-

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décimal decoder-driver (type 7442) is used for address decoding and this selects device types when particular areas of memory are addressed. The unit 50 controls a waveform generator 55 that feeds the loudspeaker 42 via a power amplifier 56.

Figure 11 shows the waveform generator 55 in greater detail. It consists of a small random access memory (part of a M 6510) which can be connected to the unit 50 via a switch 55a or to a chain of type 7493 counters 55c and a resistive digital to analogue converter 55d.

When generating a waveform for the loudspeaker 42, the address for the RAM 55b is provided by the counters 55c, resulting in the presentation of the contents of successive locations in the RAM 55b to the digital to analogue converter 55d in successive time intervals.

While the processor unit 50 is modifying the shared RAM 55b, the RAM 55b is temporarily disconnected from the counters 55c and the converter 55d by the switch 55a and is connected to the processor unit 50 as a conventional memory. The switching function of the switch 55a is performed on the address bus by type 74157 gates (not shown) and on the data bus by type CD4066 gates (not shown).

The source 46 (see Figure 7) is connected to the counters 55c as shown dotted in Figure 11.

WHAT WE CLAIM IS:—

1. A method of reducing the amplitude of vibrations received at a selected location from a source of recurring vibration, which method comprises feeding to said location a secondary vibration which at least partially nulls the vibrations from the source at the said location and is characterised in that the secondary vibration is a synthesised waveform generated by a waveform generator fed with a triggering signal derived from the source to accurately relate the generation of the secondary vibration to that of the vibration to be cancelled.

2. A method as claimed in claim 1, in which the waveform generator is arranged to adapt its output waveform on the basis of success achieved in cancelling the unwanted vibrations from the source.

3. A method as claimed in claim 2, in which periodically when a burst of unwanted vibration is generated by the source, a new adaptation is tried, the waveform generator generating the secondary vibration being programmed to seek out the more successful secondary vibration following each such adaptation.

4. A method as claimed in either of claims 2 or 3, in which the adaptive technique employs a microphone located at the said location to sense the quality of the con-

temporary nulling action and a memory is used to determine whether, following a change in the secondary vibration, the nulling action has improved.

5. A method as claimed in any preceding claim, in which the electrical trigger signal used to time the generation of the secondary vibration is derived from a transducer disposed close to the source.

6. A method as claimed in claim 5, in which the source is rotating or reciprocating machinery, and the triggering signal is derived from a motionial transducer mounted on the machinery itself.

7. A method as claimed in any of claims 1 to 4, in which the source of the vibrations to be nulls is itself an electrical transducer and a part of the signal driving that transducer is picked off and used as the triggering signal.

8. A method of reducing the amplitude of sound vibrations received at a selected location from a source of recurring noise, which method comprises feeding to said location a secondary sound vibration which at least partially nulls the sound vibrations from the source at the said location and is characterized in that the secondary sound vibration is obtained from a waveform generator which is triggered to generate its output by a timing signal derived from the source, the generator for the secondary sound vibration being such that its output waveform is obtained by sequentially combining a series of component part waveforms each stored in a memory and deriving the output waveform by a successive series of approximations, each successive approximation being made by altering at least one of the individual component parts and adopting an alteration of a component part by updating that part in the memory or rejecting that part alteration on the basis of whether or not that part alteration improved the degree of cancellation of the unwanted sound vibration from the source at the selected location.

9. A method as claimed in claim 8, in which a microphone is located at the selected location to sense the quality of the contemporary cancelling action and a microprocessor is used to determine whether, following a change in the output waveform of the generator, the cancelling action has improved.

10. A method of reducing the amplitude of vibrations received at a selected location from a source of recurring noise substantially as hereinbefore described with reference to, and as illustrated in, Figures 1 and 2 of the accompanying drawings.

11. A method of reducing the amplitude of vibrations received at a selected location from a source of recurring noise substantially as hereinbefore described with refer-



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- ence to, and as illustrated in, Figures 3, 4, 5 and 6 of the accompanying drawings.
12. A method of reducing the amplitude of vibrations received at a selected location from a source of recurring noise substantially as hereinbefore described with reference to, and as illustrated in, Figures 7 to 11 of the accompanying drawings.
13. Apparatus for reducing the vibration received at a selected location from a source of recurring primary vibration comprising a synthesising generator, means for deriving from the generator a secondary vibration which at least partially nulls the primary vibration in the said location and an electrical transducer located at or closely adjacent to the source for feeding a signal to the generator to trigger the generation of the synthesised secondary vibration in time with the generation of the primary vibration.
14. Apparatus as claimed in claim 13, in which the waveform generator includes adaptive means modifying the secondary vibration to minimise the output from a microphone or other vibration-sensing transducer in the said location.
15. Apparatus as claimed in claim 14, in which the adaptive means includes a microprocessor updating a memory adapted to store a plurality of waveform samples, each at a unique address.
16. Apparatus as claimed in claim 13, in which precursors for a plurality of different secondary vibrations are stored in a memory and means is provided for calling for the generation of the secondary vibration associated with a particular memory on the basis of the operating mode of the source.
17. Apparatus for reducing the noise received at a selected location from a source

of recurring primary sound waves comprising a waveform generator, a loudspeaker for deriving from the generator a secondary sound wave which at least partially nulls the primary sound wave in the said location and an electrical transducer located at or closely adjacent to the source for feeding a timing signal to the generator to trigger the generation of the secondary wave in timed relation with the generation of the primary wave and a microphone in the said location to sense the residual noise left after interference of the primary and secondary sound waves in the said location, the generator including a memory in which are stored a plurality of electrical component signals, each representing a part of the full signal fed to the loudspeaker, each of said component signals being at a unique address in the memory, and a microprocessor connected to said memory and the output of said microphone to periodically modify at least some of said component signals to effect a reduction in the said residual noise.

18. Apparatus for producing a quiet area in the vicinity of a machine substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

19. Apparatus for producing a quiet area in the vicinity of a machine substantially as hereinbefore described with reference to Figures 3, 4, 5 or 6 of the accompanying drawings.

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By a direction given under Section 30 of the Patents Act 1977 this application proceeded in the name of **GEORGE BRIAN BARRIE CHAPLIN**, a British Subject of The Department of Electrical Engineering Science, University of Essex, Wivenhoe Park, Colchester CO4 3SQ.

THE PATENT OFFICE

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