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(54) SOUNDING SYSTEM

SOUNDSYSTEM

SYSTÈME AUDIO

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Description

Field of the Invention

[0001] The present application relates to a sounding system, and more particularly, to a sounding system capable of being performed efficiently.

Background of the Invention

[0002] Speaker driver is always the most difficult challenge for high-fidelity sound reproduction in the speaker industry. The physics of sound wave propagation teaches that, within the human audible frequency range, the sound pressures generated by accelerating a membrane of a conventional speaker driver may be expressed as $P \propto SF \cdot AR$, where SF is the membrane surface area and AR is the acceleration of the membrane. Namely, the sound pressure P is proportional to the product of the membrane surface area SF and the acceleration of the membrane AR. In addition, the membrane displacement DP may be expressed as $DP \propto 1/2 \cdot AR \cdot T^2 \propto 1/f^2$, where T and f are the period and the frequency of the sound wave respectively. The air volume movement $V_{A,CV}$ caused by the conventional speaker driver may then be expressed as $V_{A,CV} \propto SF \cdot DP$. For a specific speaker driver, where the membrane surface area is constant, the air movement $V_{A,CV}$ is proportional to $1/f^2$, i.e., $V_{A,CV} \propto 1/f^2$

[0003] To cover a full range of human audible frequency, e.g., from 20 Hz to 20 KHz, tweeter(s), mid-range driver(s) and woofer(s) have to be incorporated within a conventional speaker. All these additional components would occupy large space of the conventional speaker and will also raise its production cost. Hence, one of the design challenges for the conventional speaker is the impossibility to use a single driver to cover the full range of human audible frequency.

[0004] Another design challenge for producing high-fidelity sound by the conventional speaker is its enclosure. The speaker enclosure is often used to contain the back-radiating wave of the produced sound to avoid cancelation of the front radiating wave in certain frequencies where the corresponding wavelengths of the sound are significantly larger than the speaker dimensions. The speaker enclosure can also be used to help improve, or reshape, the low-frequency response, for example, in a bass-reflex (ported box) type enclosure where the resulting port resonance is used to invert the phase of back-radiating wave and achieves an in-phase adding effect with the front-radiating wave around the port-chamber resonance frequency. On the other hand, in an acoustic suspension (closed box) type enclosure, the enclosure functions as a spring which forms a resonance circuit with the vibrating membrane. With properly selected speaker driver and enclosure parameters, the combined enclosure-driver resonance peaking can be leveraged to boost the output of sound around the resonance frequency and therefore improve the performance of resulting speaker.

[0005] To overcome the design challenges of speaker driver and enclosure within the sound producing industry, a PAM-UPA sound producing scheme has been proposed. Furthermore, the PAM-UPA sound producing scheme taking "multipath channel effect" into consideration has been proposed. Conventionally, a sounding operation is needed to obtain a channel impulse response. The sounding operation is performed in a channel probing phase, which is separated from a transmission phase. It means that the listener/user has to wait until the channel probing phase is expired and then can hear the audio content, which degrades the user experience.

[0006] Therefore, it is necessary to improve the prior art such as US 6,807,281 which relates to a sounding system, the sounding system comprising a sound producing device and a sounding circuit.

Summary of the Invention

[0007] It is therefore a primary objective of the present application to provide a sounding system and a sounding method capable of being performed efficiently. The present invention provides a sounding system, configured to perform a sounding operation, the sounding system comprising a sound producing device, disposed at a sound producing location, receiving a sounding sequence, configured to produce a sounding pulse array according to the sounding sequence, wherein the sounding pulse array comprises a plurality of sounding pules, and each sounding pulse is corresponding to a sounding pulse waveform; and a sounding circuit, comprising a sensor, disposed at a sound constructing location, receiving a received sounding pulse array corresponding to the sounding pulse array, wherein the received sounding pulse array comprises a plurality of received sounding pulses; a filtering circuit, coupled to the sensor, configured to perform a filtering operation on the received sounding pulse array according to the sounding sequence and the sounding pulse waveform, and generate an overall filtering result; and a spike detection circuit, coupled to the filtering circuit, configured to perform a spike detection operation on the overall filtering result and obtain a channel impulse response corresponding to a channel between the sound producing location and the sound constructing location; wherein the sounding system is integrated into a sound producing system; wherein the sound producing system comprises the sound producing device disposed at the sound producing location; wherein the sound producing device produces a pulse array corresponding to an input audio signal, and the pulse array comprises a plurality of air pulses; wherein the pulse array is emitted from the sound producing location, propagates through the channel, such that a sound pressure level envelope corresponding to the input audio signal is constructed at the sound constructing location.

Brief Description of the Drawings

[0008]

FIG. 1 is a schematic diagram of a sound producing system according to an embodiment of the present application.

FIG. 2 is a schematic diagram of a first filter according to an embodiment of the present application.

FIG. 3 is a schematic diagram of a plurality of waveforms according to an embodiment of the present application.

FIG. 4 is a schematic diagram of a spike detection process according to an embodiment of the present application.

FIG. 5 is a schematic diagram of a plurality of waveforms according to an embodiment of the present application.

FIG. 6 is a schematic diagram of a sounding process according to an embodiment of the present application.

FIG. 7 is a schematic diagram of a sounding system according to an embodiment of the present application.

FIG. 8 is a schematic diagram of a filtering circuit according to an embodiment of the present application.

FIG. 9 is a schematic diagram of a sounding system according to an embodiment of the present application.

FIG. 10 is a schematic diagram of a sounding system according to an embodiment of the present application.

Detailed Description

[0009] In the present application, a signal or an impulse response b can be interchangeably expressed in continuous-time function a(*t*) or b(*t*) of time *t*. The term "coupled" in the present application is referred to either a direct or an indirect connection means. Further, the term "coupled" in the present application may refer to either a wireless connection means or a wireline connection means. For example, "a first circuit is coupled to a second circuit" may refer that "the first circuit is connected to the second circuit via a wireless connection means", or "the first circuit is connected to the second circuit via a wireline connection means".

[0010] FIG. 1 is a schematic diagram of a sound producing system 10 according to the invention The sound producing system 10 is similar to the sound producing system disclosed in the US Patent Application No. 16/551,685 filed by Applicant. The sound producing system 10 may be disposed in a walled-in environment e.g., an office, a living room, an exhibition hall, or inside a vehicle. The sound producing system 10 comprises a sound producing apparatus 12 and a sounding circuit 14. The sound producing apparatus 12 comprises a sound producing device (SPD) 120, a driving circuit 122 and a signal processing circuit 124. The sounding circuit 14 comprises a sensor 140, a filtering circuit 142 and a spike detection circuit 144. The SPD 120 is disposed at a sound producing location/point L_{SP}, and the sensor 140 is disposed at a sound constructing location/point L_{SC}. The sound constructing location L_{SC} is preferably near an ear of a listener.

[0011] The sound producing apparatus 12 is configured to perform a sound producing operation, in which the SPD 120 produces a pulse array PA, where the pulse array PA is generated corresponding to an input audio signal A, and comprises a plurality of air pulses P. The SPD 120 is driven by a driving signal d, generated by the driving circuit 122, to produce the pulse array PA or equivalently the plurality of air pulses P. The SPD 120, comprising a membrane 1201, can be realized by the air pulse generating elements or the sound producing devices disclosed in Application No. 16/125,761, No. 16/172,876, No. 16/161,097, No. 16/368,870 and No. 16/420,141, filed by Applicant, meaning that the SPD 120 may be a MEMS (micro electrical mechanical system) device. The plurality of air pulses P and the air pulse array PA, caused by the membrane vibration and produced by the SPD 120, would inherit the air pulse characteristics disclosed in US Application No. 16/125,761, in which the plurality of air pulses P has an air pulse rate (e.g., 40 KHz) higher than a maximum human audible frequency, and each one of the plurality of air pulses P generated by the SPD 120 would have non-zero offset in terms of sound pressure level (SPL), where the non-zero offset is a deviation from a zero SPL. In addition, the plurality of air pulses P generated by the SPD 120 is aperiodic over a plurality of pulse cycles. Details of the "non-zero SPL offset" and the "aperiodicity" properties may be referred to US Application No.16/125,761, and details of the device 120 may be referred to the applications listed in the above, which are not narrated herein for brevity.

[0012] The driving circuit 122 receives the input audio signal A and a channel-shaping signal g and generates the driving signal d. In an embodiment, the driving circuit 122 is configured to perform a (linear) convolution operation on the input audio signal A(*t*) and the channel-shaping signal g(*t*), so as to generate the driving signal d(*t*) as $d(t) = A(t) \otimes g(t)$, where $\otimes$ denotes the linear convolution operation and the linear convolution is represented as $A(t) \otimes g(t) = \int A(\tau) \cdot g(t-\tau) d\tau$, which is known by the art.

[0013] The signal processing circuit 124 is configured to perform a signal processing operation, e.g., a time reversing operation, on the estimated channel impulse response (CIR) h_S (or $h_S(t)$) of a multipath channel h, so as to generate the channel-shaping signal g. The multipath channel h is between the sound producing location L_{SP} and the sound constructing location L_{SC}, and comprises a plurality of channel paths h_0,...h_L. Mathematically, the channel impulse response h(*t*) of the channel h can be expressed as $h(t) = \Sigma_l h\_l \cdot \delta(t-\tau_l)$, where τ_l represents a sound wave propagation delay corresponding to the l-th channel path h_l between sound producing location L_{SP} and sound constructing location L_{SC}.

[0014] The signal processing circuit 124 would generate the channel-shaping signal g such that the channel-shaping signal g(t) is proportional to a time-reversed or a time-reversed-and-conjugated counterpart of the estimated CIR $h_S(t)$ of the channel h. That is, the channel-shaping signal g(t) reflects the feature/waveform of $h_S(-t)$ or $h_S^*(-t)$, regardless of translation in time, where $( )^*$ denotes a complex conjugate operation. Practically, the channel-shaping signal g(t) may be expressed as $g(t) = a \cdot h_S(T - t)$ or $g(t) = a \cdot h_S^*(T - t)$, where a is a constant. In an embodiment, T may be greater than or equal to the maximum propagation delay of the channel h. The operation of generating, e.g., $g(t) = a \cdot h_S(T - t)$, according to $h_S(t)$ is referred to as the time reversing operation.

[0015] The SPD 120 and the sounding circuit 14 form a sounding system 11, which can be viewed that the sounding system 11 is integrated in/into the sound producing system 10.The sounding system 11 or the sounding circuit 14 is configured to perform a sounding operation on the multipath channel h, i.e., to generate the estimated CIR h_S for the sound producing apparatus 12 or for the signal processing circuit 124, such that a time reversal transmission can be performed. Therefore, a sound pressure level (SPL) envelop of a received pulse array RPA, perceived at the sound constructing location L_{SC} and by the listener, is re-constructed or constructed as the input audio signal A(t) at the sound constructing location L_{SC}, given the estimated CIR h_S is provided by the sounding circuit 14 to the signal processing circuit 124. Details of the time reversal transmission can be referred to No. 16/551,685, which is not narrated herein for brevity.

[0016] Similar to No. 16/551,685, the device 120 is physically disposed at the sound producing location L_{SP} and the sensor 140 is physically disposed at the sound constructing location L_{SC}. The rest of the circuits, such as the filtering circuit 142, the spike detection circuit 144, the signal processing circuit 124 and the driving circuit 122, can be disposed at any location, not limited to the sound producing location L_{SP} and the sound constructing location L_{SC}, which are illustrated in dashed line in FIG. 1.

[0017] For the sounding operation, the pulse generating device 120 receives a sounding sequence SS, and is configured to produce a sounding pulse array SPA according to the sounding sequence SS. The sounding pulse array SPA comprises a plurality of sounding pulse SP, and each sounding pulse SP may have (or be corresponding to) a sounding pulse waveform UPW (which can be expressed as p(t)), where the sounding pulse waveform UPW may be determined by the hardware characteristic of the pulse generating device 120.

[0018] The plurality of sounding pules SP and/or the sounding pulse array SPA, corresponding the sounding sequence SS, is produced by the pulse generating device 120 and emitted from the sound producing location L_{SP}, propagates through the multipath channel h, and arrives at the sound constructing location L_{SC}, such that the sensor 140 would receive a received sounding pulse array RSPA corresponding to the sounding pulse array SPA, in terms of SPL. The received sounding pulse array RSPA comprises a plurality of received sounding pulses RSP. The sensor 140 would convert the received sounding pulse array RSPA in terms of SPL into electric signal. A signal component corresponding to the received sounding pulse array RSPA within an output of the sensor 140 is also called as the received sounding pulse array RSPA.

[0019] The sounding sequence SS is a pseudo random sequence or a low auto-correlation sequence, which implies that a correlation of the sounding sequence SS and a time-shifted version of the sounding sequence SS (called an auto-correlation of the sounding sequence SS in the present application) is low, i.e., less than a first threshold, where the first threshold may be 1% of an energy of the sounding sequence (SS).

[0020] Mathematically, supposed that the sounding sequence SS is expressed as SS[n] in discrete time sequence, and SS[n-k] represents the time-shifted version of the sounding sequence SS, where n and k denote time index and delay index, respectively. The sounding sequence SS satisfies that the correlation between SS[n] and SS[n-k], denoted as $< SS[n], SS[n-k]>$, is less than the first threshold. $<\cdot,\cdot>$ denotes a correlation operator, and a correlation between two sequences a_n and b_n may be defined as $< a_n, b_n > = \Sigma_n a_n \cdot b_n$ or $< a_n, b_n > = \Sigma_n a_n \cdot b_n^*$, where "$\cdot$" represents multiplication.

[0021] In an embodiment, the sounding sequence SS may be generated via a quality check process. The quality check process is to make sure that the auto-correlation of the sounding sequence SS is sufficiently low. For example, SS[n] may be expressed as $SS[n] = \Sigma_m s_m \cdot \delta[n-m]$ or $SS = \{s_0,...,s_m,...,s_{M-1}\}$, where s_m represents a sequence element here and $\delta[n]$ represents Dirac delta function, i.e., $\delta[n] = 1$ for n=0 and $\delta[n] = 0$ for $n \neq 0$, and M represents a sequence length. The sequence element s_m may be randomly generated starting from m = 0 until m = M-1. Once the sequence element s_m is randomly generated, the sequence $\{s_0,...,s_m\}$ would be performed the quality check process. If the quality check succeeds, then go ahead to generate the next sequence element s_{m+1}. Otherwise, if the quality check fails, the sequence element s_m is again re-generated (randomly). The sequence element s_m is kept re-generated until the sequence $\{s_0,... ,s_m\}$ passes the quality check. The sequence element s_m may be corresponding to a binary value, e.g., $s_m \in \{+1, -1\}$, or a ternary value, e.g., $s_m \in \{+1, 0, -1\}$. The quality check process is not limited. For example, the quality check may be determining whether "a time gap between two successive corresponding sounding pulses $\geq 16\mu s$ (microsecond)", "a number of successive sequence elements with same polarity ≤ 3", "a number of positive sequence element equals a number of negative sequence element ± 1", etc.

[0022] In an embodiment, the sounding sequence SS may comprise 2048 sequence elements corresponding to the set of {+1, -1}. The 2048 corresponding sounding pules SP, comprising 1024 positive sounding pulses SP and 1024 negative sounding pulses SP, are scattered/distributed over a time span of 32.768ms (millisecond), and a time gap between two peaks of two consecutive sounding pules SP is 16 μs.

[0023] In an embodiment, the sounding sequence SS may comprise 384 positive sequence elements with values corresponding to +1, 384 negative sequence elements with values corresponding to -1, and the rest sequence elements with values corresponding to 0. The corresponding 768 sounding pules SP are distributed pseudo randomly among 8192 (8K) possible time ticks, where the gap between successive time ticks is 4μs and the total time span of the 16k time-ticks is 32.768ms.

[0024] In an embodiment, the sounding sequence SS may be realized by the well-developed pseudo-noise (PN) sequence, which is widely exploited in CDMA (code divisional multiple access) communication systems or DSSS (direct-sequence spread spectrum) communication systems. The PN sequence is famous about its low auto-correlation and orthogonality between two distinct PN sequences, which can be easily generated by a low complexity linear-feedback shift register (LFSR). Details of the PN sequence are known by the art, which is not narrated herein.

[0025] The filtering circuit 142 is coupled to the sensor 140, configured to receive the received sounding pulse array RSPA as the electric signal, perform a filtering operation on the received sounding pulse array RSPA, and generate an overall filtering result FR. The filtering operation of the filtering circuit 142 is performed according to the low auto-correlation sounding sequence SS and also the sounding pulse waveform UPW.

[0026] In the embodiment illustrated in FIG. 1, the filtering circuit 142 may comprise a first filter 1421 and a second filter 1422. The first filter 1421 may be a finite impulse response (FIR) filter with integer coefficients. The first filter 1421 is configured to perform a sequence level filtering operation, and a first impulse response H1[n] of the first filter 1421 comprises a component which is proportional to a time-reversed or a time-reversed-and-conjugated version of the sounding sequence SS. For example, the first impulse response H1[n] can be mathematically expressed as H1[n] = SS[-n], H1[n] = SS[-n]*, H1[n] = SS[M-n] or H1[n] = SS[M-n]*.

[0027] FIG. 2 is a schematic diagram of the first filter 1421 according to an embodiment of the present application. In the embodiment illustrated in FIG. 2, the first filter 1421 has the same circuit topology as a typical FIR filter, comprising (M-1) delay elements D and a summing circuit SUM. The first filter 1421 has a plurality of first coefficients $c_0,...,c_M$, which would be corresponding to the sequence elements $s_0,...,s_M$. Note that, since the first coefficient $c_0,...,c_M$ may be in a set of {+1, -1} or in a set of {+1, 0, -1}, no multiplication/multiplicator is needed. Hence, the first filter 1421 may be realized by simplified FIR circuit which comprises no multiplier, but only delay elements and adders.

[0028] The second filter 1422 may be also a finite impulse response (FIR) filter with floating point filter coefficients, meaning that second filter coefficients of the second filter 1422 are in a floating point format. Compared to the first filter 1421, the second filter 1422 has much finer granularity in temporal delay and in coefficient amplitude. The second filter 1422 is configured to perform a waveform level filtering operation, and a second impulse response of the second filter 1422, expressed as H2(t), comprises a component which is proportional to a time-reversed or a time-reversed-and-conjugated version of the sounding pulse waveform UPW. For example, given that the sounding pulse waveform UPW is mathematically expressed as p(t) with finite duration T_{cycle}, the second impulse response H2(t) of the second filter 1422 can be expressed as H2(t) = p (-t), H2(t) = $p^*(-t)$, H2(t) = p(T_{cycle} -t) or H2(t) = p*(T_{cycle} -t).

[0029] T_{cycle} represents the pulse cycle of the sounding pulse waveform UPW, and a reciprocal of the pulse cycle T_{cycle} is higher than a maximum human audible frequency. For example, the pulse cycle T_{cycle} may be 25 μs, which is corresponding to a pulse rate of 40 KHz.

[0030] Note that, the filtering operation of the filtering circuit 142 may be regarded as a match-filtering operation, which matched to the component sounding pules SP that makes up the sounding sequence SS and the sounding pulse waveform corresponding to SP is UPW. That is, an impulse response H(t) of the filtering circuit 142 comprises a component which is proportional to a time-reversed or a time-reversed-and-conjugated version of the sounding pulse array SPA. For example, an overall impulse response H(t) of the filtering circuit 142 may be expressed as H(t) = SPA($M \cdot T_{cycle} - t$) or H(t) = SPA(-t), where SPA(t) is a mathematical expression of the sounding pulse array SPA, which may be expressed as SPA(t) = $\Sigma_m s_m \cdot p(t - m \cdot T_{cycle})$.

[0031] When the output signal of the sensor 140 comprises the component corresponding to the received sounding pulse array RSPA (or corresponding to the sounding sequence SS), a spike would appear in the overall filtering result FR of the filtering circuit 142, and the spike is corresponding to one channel path h_*l* within the multipath channel h. Practically, within the walled-in environment or through the multipath channel h, the overall filtering result FR of the filtering circuit 142 would comprise a plurality of spikes, which may be corresponding to the plurality of channel paths h_0,...h_L. If the output signal of the sensor 140 comprises no component corresponding to the sounding sequence SS, then no spike would appear in the overall filtering result FR, and the overall filtering result FR without spikes can be treated as noise.

[0032] FIG. 3 illustrates waveforms of the sounding sequence SS, the sounding pulse waveform UPW/p(t), the sounding pulse array SPA, the first impulse response H1[n] of the first filter 1421, the second impulse response

H2(t) of the second filter 1422, the overall filtering result FR output from the filtering circuit 142 and the estimated CIR h_S output from the spike detection circuit 144. In the embodiment illustrated in FIG. 3, the sounding sequence SS is SS = {s_0 = +1, s_1 = -1, s_2 =-1, s_3 = +1, s_4 = -1, s_5 =-1, s_6 = +1, s_7 = +1, s_8 =-1, s_9 = +1}. The sounding pulse array SPA is corresponding to the sounding sequence SS. The first impulse response H1[n] is the time-reversed version of the sounding sequence SS, and the second impulse response H2(t) is the time-reversed version of the sounding pulse waveform UPW. In this case, the overall filtering result FR would comprise a plurality of spikes. After spike detection, the estimated CIR h_S is obtained.

[0033] Note that, the pulse array PA generated according to the input audio signal A(*t*) comprising no component corresponding to the sounding sequence SS. The received pulse array RPA corresponding to the pulse array PA (or corresponding to the input audio signal A(*t*)) would be deconstructed or scrambled after passing through the filtering circuit 142. As a result, filtering result corresponding to the received pulse array RPA of the input audio signal A(*t*) would comprise no spike, and would be treated as noise and eliminated by the spike detection circuit 144. Therefore this portion of the (received) pulse array (R)PA would have no impact on the sounding operation. As a result, the sounding pulse array SPA can be superimposed on the pulse array PA and transmitted concurrently with the pulse array PA.

[0034] Different from the sounding operation of No. 16/551,685, in which only one sounding pulse is transmitted for each sounding operation, the sounding system 11 transmits the plurality of sounding pulses SP for each sounding operation, where the plurality of sounding pulses SP is generated according to the sounding sequence SS with low auto-correlation and low cross-correlation in multi-L_{SC} scenarios. Since the (received) pulse array (R)PA corresponding to the input audio signal A(*t*)) comprises no component related to the sounding sequence SS, the (received) pulse array (R)PA would have no impact on the sounding operation. In this case, the sound producing operation and the sounding operation can be performed concurrently.

[0035] Compared to No. 16/551,685, in which a channel probing phase separated from a transmission phase is needed, the listener does not have to wait until the channel probing phase is expired. When the sound producing system 10 and the sounding system 11 are adopted, the sounding operation can be performed while the listener listens to music or audio content (which is corresponding to the input audio signal A(*t*)).

[0036] Furthermore, the sound producing point L_{SP} and the sound constructing point L_{SC} do not have to be fixed location. Both of the sound producing point L_{SP} and the sound constructing point L_{SC} can be time varying. For example, the sound constructing point L_{SC} can vary/move as the listener walks around the environment.

[0037] Details of the spike detection operation performed by the spike detection circuit 144 are not limited. In an embodiment, the spike detection circuit 144 may execute a spike detection process 20. FIG. 4 is a schematic diagram of the spike detection process 20 according to an embodiment of the present application. As illustrated in FIG. 4, the spike detection process 20 comprises the following step:

Step 200: Start.

Step 202: Obtain a sample D_i.

Step 204: Obtain an observation time window W_i.

Step 206: Obtaining a maximum absolute-sample $\max_{j \in Wi} |D_j|$.

Step 208: Determine whether an absolute-sample $|D_i|$ is equal to the maximum absolute-sample $\max_{j \in Wi} |D_j|$. If yes, go to Step 210; otherwise, go to Step 202.

Step 210: Append the sample D_i and a time instant t_i into a list LST.

Step 212: Determine whether i is equal to a sample length SL. If yes, go to Step 214; otherwise, go to Step 202.

Step 214: Select a plurality of selected pairs from the plurality of pairs.

Step 216: Form the estimated CIR h_S according to the plurality of selected pairs.

Step 218: End.

[0038] In Step 200, the overall filtering result FR may be converted into or sampled as a plurality of samples $D_0, \ldots, D_{SL-1}$. For example, the sample D_i may be represented as $D_i = FR(t)|_{t=i \cdot TS+TOT}$, where TS represents a sample time interval, TOT represents an initial time at which FR(*t*) begins to be sampled, i.e., $D_0 = FR(t)|_{t=TOT}$, FR(*t*) is a continuous time function representing the overall filtering result FR, and SL represents a sample length of the samples $D_0, \ldots, D_{SL-1}$.

[0039] In Step 202, the spike detection circuit 144 sequentially obtains the sample D_i for i = 0,...,SL-1. Initially, the spike detection circuit 144 obtains the initial sample D_0 at the first/initial time executing Step 202. After that, at the i-th time the spike detection circuit 144 executes Step 202, the spike detection circuit 144 obtains the sample D_{i-1}.

[0040] In Step 204, the spike detection circuit 144 obtains an observation time window W_i. In an embodiment, the observation time window W_i may be represented by a set of time indices. For example, the observation time window W_i may be W_i = {0,...,i,...,i+r} for i < r, W_i= {i-r,...,i,...,i+r} for r < i ≤ SL-r-1, which is centered at the time index i, and W_i = {i-r,...,i,...,SL-1} for i > SL-r-1. The time index i is corresponding to the time instant (i·TS + TOT). The observation time window W_i has a specific window width (2·r+1), where a parameter r is configured to determine the window width.

[0041] In Step 206, the spike detection circuit 144 obtains a maximum absolute-sample $\max_{j\in Wi} | D_j |$. The maximum absolute-sample $\max_{j\in Wi} | D_j |$ satisfies that $\max_{j\in Wi} | D_j | \geq | D_j |$ for all j within the observation time window W_i. For example, given W_i ={i-r,...,i,...,i+r}, the maximum absolute-sample $\max_{j\in Wi} | D_j |$ is a maximum of a plurality of absolute-samples $| D_j |$ of a plurality of second samples $D_{i-r}, ..., D_{i+r}$ within the observation time window W_i. The absolute-sample $| D_j |$ among the plurality of absolute-samples $| D_{i-r} |, ..., | D_{i+r} |$ is an absolute value of the sample D_j among the plurality of second samples $D_{i-r}, ..., D_{i+r}$.

[0042] In Step 208, the spike detection circuit 144 determines whether the absolute-sample $| D_i |$ received at the current iteration is equal to the maximum absolute-sample $\max_{j\in Wi} | D_j |$. If yes, implying that the sample D_i is either a local maximum (representing a peak of a positive spike) or a local minimum (representing a peak of a negative spike), the spike detection circuit 144 would append the sample D_i and the time instant t_i corresponding to the time index i (e.g., t_i= i TS + TOT) of sample D_i as a pair (D_i, t_i) into the list LST (Step 210). If not, the spike detection circuit 144 goes to Step 202 to perform Steps 204 and 206 on the next sample D_{i+1}, with performing i = i+1.

[0043] In Step 212, the spike detection circuit 144 checks if the time index i is equal to SL-1, the sample length SL minus 1. When the time index i is equal to the sample length SL minus 1, it means that all samples $D_0, ..., D_{SL-1}$ have been performed and the spike detection circuit 144 would go to Step 214. Otherwise, the spike detection circuit 144 would again perform i=i+1 and go to Step 202.

[0044] Before entering Step 214, the list LST should comprise a plurality of pairs, denoted as PR pairs (D_p, t_p), where PR represents a number of pairs within the list LST. In Step 214, the spike detection circuit 144 selects the CL pairs ($D_{p,(S)}$, $t_{p,(S)}$) with the corresponding absolute-samples $| D_{p,(S)} |$ being the CL largest absolute-samples among all of the absolute-samples $| D_p |$ of the plurality of pairs (D_p, t_p). CL represents a number of channel path of the estimated CIR $h_S(t)$. In an embodiment, the spike detection circuit 144 may perform a sorting operation on all of the absolute-samples $| D_p |$ of all pairs (D_p, t_p) within the list LST in a descending order, select the CL largest absolute-samples $| D_{p,(S)} |$, and select the CL selected pairs ($D_{p,(S)}$, $t_{P,(S)}$). Note that, the absolute-sample $| D_{p,(S)} |$ is larger than an (or any) unselected absolute-sample $| D_{p,(R)} |$, i.e., $| D_{p,(S)} | > | D_{p,(R)} |$.

[0045] FIG. 5 is a schematic diagram of waveforms of the samples D_i (before the spike detection process 20 is performed) and the estimated CIR h_S (after the spike detection process 20 is performed). For brevity, FIG. 5 only illustrates the samples D_i for i=7,...,71. By performing the process 20, the samples D_7, D_9, D_{49}, D_{51}, D_{52}, D_{69}, D_{71} would be discarded by performing Step 208 as they are not local maximum, and the samples $D_{30}, ..., D_{37}$ would be discarded by performing Step 214 as they are not sufficiently significant. As a result, after performing Step 214, only pairs (D_8, t_8), (D_{50}, t_{50}) and (D_{70}, t_{70}) are selected as the selected pairs, the estimated CIR h_S can be formed (at least) by the selected pairs (D_8, t_8), (D_{50}, t_{50}) and (D_{70}, t_{70}).

[0046] Operations of the sounding system 11 can be summarized into a sounding process 30, which is illustrated in FIG. 6. The sounding process 30 comprises:

Step 300: Produce a sounding pulse array according to a sounding sequence, wherein a correlation of the sounding sequence and a time-shifted version of the sounding sequence is less than a first threshold.

Step 302: Receive a received sounding pulse array corresponding to the sounding pulse array.

Step 304: Perform a filtering operation on the received sounding pulse array according to the sounding sequence and the sounding pulse waveform, and generate an overall filtering result.

Step 306: Perform a spike detection operation on the overall filtering result and obtain a channel impulse response corresponding to a channel between a sound producing location and a sound constructing location.

[0047] Details of the sounding process 30 may be referred to the paragraphs stated in the above, which are not narrated for brevity.

[0048] The concept of the sounding system 11 can be extended to a multi-SPD multi-sensor sounding system. FIG. 7 is a schematic diagram of a sounding system 41 according to an embodiment of the present application. The sounding system 41 comprises a sounding circuit 44 and a plurality of SPDs 120_1,...,120_N, disposed at a plurality of sound producing locations $L_{SP,1}, ..., L_{SP,N}$, respectively. Each SPD 120_n can be realized by the SPD 120. In FIG. 7, the membrane within the SPD is omitted for brevity. The sounding circuit 44 comprises a plurality of sensors 140_1,...,140_M, disposed at a plurality of sound constructing locations $L_{SC,1}, ..., L_{SC,M}$, respectively. The sounding circuit 44 may also comprise a plurality of filtering circuits 142_1,..., 142_m and a plurality of spike detection circuits 144_1,...,144_M, which are coupled to the plurality of sensors 140_1,...,140_M, respectively. Between the sound producing locations $L_{SP,1}, ..., L_{SP,N}$ and the sound constructing locations $L_{SC,1}, ..., L_{SC,M}$, a plurality of channels $h_{1,1}, ..., h_{1,N}, ..., h_{m,1}, ..., h_{m,N}, h_{M,1}, ..., h_{M,N}$ is formed. Each channel $h_{m,n}$ is a multipath channel.

[0049] Each SPD 120_n receives a sounding sequence SS_n and produces a sounding pulse array SPA_n according to the sounding sequence SS_n. The plurality of SPDs 120 1,.. ,,120_N receives a plurality of sounding sequences $SS_1,...,SS_N$ and produces a plurality of sounding pulse arrays $SPA_1,..., SPA_N$, according to the plurality of sounding sequences $SS_1,...,SS_N$. The sounding sequences $SS_1,...,SS_N$ may have low cross-correlation, meaning that a correlation between a first sounding sequence SS_{n1} and a second sounding sequence SS_{n2} would be less than a second threshold. The second threshold may be, e.g., 1% of an energy of the sounding sequence. The sounding sequences $SS_1,...,SS_N$ may be realized by the PN sequence, where a plurality of PN sequences is mutually orthogonal.

[0050] Each sensor 140_m may receive an aggregated received sounding pulse array $RSPA_{(A),m}$. The aggregated received sounding pulse array $RSPA_{(A),m}$, received at the sensor 140_m, is an aggregation of the plurality of sounding pulse arrays $SPA_1,..., SPA_N$ due to the channels $h_{m,1},..., h_{m,N}$. That is, the aggregation is naturally performed by the channels $h_{m,1},..., h_{m,N}$. Specifically, the aggregated received sounding pulse array $RSPA_{(A),m}$ comprises a component which can be expressed as $h_{m,1} \cdot SPA_1 + ... + h_{m,N} \cdot SPA_N$.

[0051] The filtering circuit 142_m may perform a plurality of (overall) filtering operations on the aggregated received sounding pulse array $RSPA_{(A),m}$, and generate a plurality of overall filtering results $FR_{m,1},..., FR_{m,N}$. FIG. 8 is a schematic diagram of the filtering circuit 142_m according to an embodiment of the present application. The filtering circuit 142_m comprises a plurality of first filters 1421_m_1,..., 1421_m_N and a plurality of second filter filters 1422. Each first filter 1421_m_n, among the plurality of first filters 1421_m_1,..., 1421_m_N, may perform a sequence-level filtering operation (similar to the first filter 1421) on the aggregated received sounding pulse array $RSPA_{(A),m}$ according to the sounding sequence SS_1, and the corresponding second filter 1422 may perform a waveform-level filtering operation (similar to the second filter 1422) on an output of the first filter 1421_m_n according to the sounding pulse waveform UPW. Therefore, the filtering circuit 142_m can generate the plurality of overall filtering results $FR_{m,1},..., FR_{m,N}$. According to the plurality of overall filtering results $FR_{m,1},..., FR_{m,N}$, the spike detection circuit 144_m can generate estimated CIRs $h_{S,m,1},..., h_{S,m,N}$. In addition, the estimated CIRs $h_{S,1,1},..., h_{S,1,N}, ...,h_{S,m,1},..., h_{S,m,N}, h_{S,M,1},..., h_{S,M,N}$ the different sound producing locations and the difference sound constructing locations can be generated concurrently.

[0052] Note that, in the embodiment illustrated in FIG. 8, the plurality of the sequence-level filtering operations is performed parallelly, by the first filter filters 1421_m_1,..., 1421_m_N, which is not limited thereto. The sounding circuit may perform the plurality of the sequence-level filtering operations serially (or sequentially), which is also within the scope of the present application. In addition, the plurality of first filter filters 1421_m_1,..., 1421_m_N and the plurality of second filter filters 1422 are functionally distinguished, the plurality of first filters 1421_m_1,..., 1421_m_N and/or the plurality of second filter filters 1422 may be integrated in different realization.

[0053] In addition, since the sounding sequences $SS_1,...,SS_N$ have low cross-correlation with each other (or the sounding sequences $SS_1,...,SS_N$ are mutually orthogonal), the plurality of sounding pulse arrays $SPA_1,..., SPA_N$ would not interfere with each other when performing the sounding operation, the plurality of sounding pulse arrays $SPA_1,..., SPA_N$ can be transmitted concurrently.

[0054] In another perspective, FIG.7 can also be regarded as a portion of a sound producing system 40, where the driving circuit(s) and the signal processing circuit(s) of the sound producing system 40 are omitted, and only the SPDs 120_1,...,120_N and the sounding circuit 44 (with details therein) are illustrated. It can be regarded that the sounding system 41 is integrated into the sound producing system 40, in which the sound producing operation is performed.

[0055] For the sound producing operation, the SPDs 120_1,...,120_N receive a plurality of driving signals $d_1,..., d_N$ to produce a plurality of pulse arrays $PA_1,..., PA_N$, respectively. Since the plurality of pulse arrays $PA_1,..., PA_N$ would not affect the sounding operation, the sounding pulse array SPA_n for the sounding operation can be imposed on the pulse array PA_n for the sound producing operation. Thus, the pulse arrays $PA_1,..., PA_N$ and the sounding pulse arrays $SPA_1,..., SPA_N$ can be transmitted concurrently.

[0056] Note that, the sounding system 11 is a single-SPD single-sensor sounding system, and the sounding system 41 is a multi-SPD multi-sensor sounding system. Based on the rationale behind the sounding systems 11 and 41, the sounding system 41 can be degenerated to a single-SPD multi-sensor sounding system or a multi-SPD single-sensor sounding system.

[0057] For example, FIG. 9 is a schematic diagram of a sounding system 51 according to an embodiment of the present application. The sounding system 51 is similar to the sounding systems 11 and 41. Different from the sounding systems 11 and 41, the sounding system 51 is a single-SPD multi-sensor sounding system. Specifically, the sounding system 51 comprises a sounding circuit 54 and a SPD 520_n disposed at a sound producing location $L_{SP,n}$. The sounding circuit 54 comprises a plurality of sensors 540_1,...,540_M, a plurality of filtering circuits 542_1,..., 542_M and a plurality of spike detection circuits 544_1,...,544_M. The sensors 540_1,...,540_M are disposed at a plurality of sound constructing locations $L_{SC,1},..., L_{SC,M}$ and receives received sounding pulse array $RSPA_1,..., RSPA_M$, respectively. The filtering circuits 542_1,..., 542_M have similar structure as the filtering circuit 142, where the sequence level filtering operations of the filtering circuits 542_1,..., 542_M are performed according to the sounding sequence SS_n received by the SPD 520_n, such that the filtering circuits 542_1,..., 542_M produce overall filtering results $FR_{1,n}$,..., $FR_{M,n}$. The spike detection circuits 544_1,...,544_M have similar structure as the spike detection circuit 144. The spike detection circuits 544_1,...,544_M generates estimated CIRs $h_{S,1,n}$,..., $h_{S,M,n}$ according to the overall filtering results $FR_{1,n}$,..., $FR_{M,n}$. Hence, the sounding operation for the channels $h_{1,n}$,..., $h_{M,n}$ can be performed concurrently.

[0058] FIG. 10 is a schematic diagram of a sounding system 61 according to an embodiment of the present application. Different from the sounding systems 11 and 41, the sounding system 61 is a multi-SPD single-sensor sounding system. Operation details of the sounding system 61 are similar to which of the sounding systems 11 and 41, which is not narrated herein for brevity.

[0059] All of the sounding systems in the above can be integrated into the sound producing systems disclosed in No. 16/551,685.

[0060] In summary, the present application utilizes the sounding sequence with low auto-correlation to produce the sounding pulse array. The sounding pulse array for the sounding operation would not be affected by the pulse array, which is intended for the sound producing operation and generated according to the input audio signal. Thereby, the sounding pulse array for the sounding operation can be superimposed on the pulse array for the sound producing operation and transmit concurrently with the pulse array for the sound producing operation.

[0061] In addition, the present application utilizes the plurality of sounding sequences with low cross-correlation to produce the plurality of sounding pulse arrays from different SPDs, or from one SPD to multiple sound construction locations. In addition to the feature that the sounding pulse arrays (for the sounding operation) and the pulse arrays (for the sound producing operation) can be transmitted concurrently, the plurality of CIRs between the different sound producing locations and the difference sound constructing locations can be generated concurrently.

Claims

1. A sounding system (11), configured to perform a sounding operation, the sounding system (11) comprising:

a sound producing device (120), comprising a membrane (1201), disposed at a sound producing location (L_{SP}), receiving a sounding sequence (SS), configured to produce a sounding pulse array (SPA) according to the sounding sequence (SS), wherein the sounding pulse array (SPA) comprises a plurality of sounding pules (SP), and each sounding pulse (SP) is corresponding to a sounding pulse waveform (UPW);

characterized in that it further comprises a sounding circuit (14) configured to generate a channel impulse response (h_S) corresponding to a channel (h) between the sound producing location (L_{SP}) and a sound constructing location (L_{SC}), the sounding circuit (14) comprising:

a sensor (140), disposed at the sound constructing location (L_{SC}), receiving a received sounding pulse array (RSPA) corresponding to the sounding pulse array (SPA), wherein the received sounding pulse array (RSPA) comprises a plurality of received sounding pulses; and

a filtering circuit (142), coupled to the sensor (140), configured to generate an overall filtering result, wherein the sounding circuit (14) generates the channel impulse response (h_S) according to the overall filtering result;

wherein the sounding system (11) is integrated into a sound producing system (10);

wherein the sound producing system (10) comprises the sound producing device (120) disposed at the sound producing location (L_{SP});

wherein the sound producing device (120) produces a pulse array (PA) corresponding to an input audio signal (A), and the pulse array (PA) comprises a plurality of air pulses;

wherein the pulse array (PA) is generated according to the channel impulse response (h_S) and transmitted from the sound producing location (L_{SP}), and propagates through the channel (h), such that a sound pressure level envelope corresponding to the input audio signal (A) is constructed at the sound constructing location (L_{SC}).

2. The sounding system of claim 1, **characterised in that,**

a correlation of the sounding sequence and a time-shifted version of the sounding sequence is less than a first threshold, and the first threshold is 1% of an energy of the sounding sequence (SS); or

the sounding sequence (SS) comprises a plurality of sequence elements, a value of a sequence element is binary or ternary; or

a sounding pulse among the plurality of sounding pulses has a pulse cycle, and a reciprocal of the pulse cycle is higher than a maximum human audible frequency.

3. The sounding system of claim 1, **characterised in that,**

the filtering circuit (142) is configured to perform a filtering operation on the received sounding pulse array (RSPA) according to the sounding sequence (SS) and the sounding pulse waveform (UPW) ; or
the filtering circuit (142) comprises:

a first filter (1421), coupled to the sensor (140), configured to perform a first filtering operation according to the sounding sequence (SS); and
a second filter (1422), coupled to the first filter (1421), configured to perform a second filtering operation according to the sounding pulse waveform.

4. The sounding system of claim 3, **characterised in that,**

a first impulse response of the first filter (1421) comprises a component which is proportional to a time-reversed or a time-reversed-and-conjugated version of the sounding sequence (SS) ; or
the first filter (1421) comprises no multiplier but comprises a plurality of delay elements and a summing circuit; or
the first filter (1421) has a plurality of filter coefficients, the plurality of filter coefficients is in an integer format and in a set of {+1, -1} or {+1, 0, -1}; or
a second impulse response of the second filter (1422) comprises a component which is proportional to a time-reversed or a time-reversed-and-conjugated version of the sounding pulse waveform (UPW).

5. The sounding system of claim 1, **characterised in that,** the sounding circuit (14) comprises
a spike detection circuit (144), coupled to the filtering circuit (142), configured to perform a spike detection operation on the overall filtering result, so as to obtain the channel impulse response (h_S) corresponding to a channel (h) between the sound producing location (L_{SP}) and the sound constructing location (L_{SC}).

6. The sounding system of claim 5, **characterised in that,** the overall filtering result is represented by a plurality of samples, the spike detection circuit (144) is configured to perform the following steps, to perform the spike detection operation on the overall filtering result and obtain the channel impulse response (hs):

obtaining a first sample, where in the first sample is corresponding to a first time instant;
obtaining a first observation time window, wherein the first observation time window comprises the first time instant, and the first observation time window has a specific width;
obtaining a first maximum absolute-sample corresponding to the first observation time window, wherein the first maximum absolute-sample is a maximum of a plurality of absolute-samples of a plurality of second samples within the first observation time window, an absolute-sample among the plurality of absolute-samples is an absolute value of a second sample among the plurality of second samples;
determining whether a first absolute-sample is equal to the first maximum absolute-sample, wherein the first absolute-sample is an absolute value of the first sample;
appending the first sample and the first time instant into a list; and
obtaining the channel impulse response (h_S) according to the list.

7. The sounding system of claim 6, **characterised in that,** the list comprises a plurality of pairs, the plurality of pairs comprises a plurality of third samples and a plurality of third time instants corresponding to the plurality of third samples, the spike detection circuit (144) is further configured to perform the following steps, to perform the spike detection operation on the overall filtering result and obtain the channel impulse response (h_S):

selecting a plurality of selected pairs from the plurality of pairs, wherein a plurality of selected third absolute-samples is larger than a unselected third absolute-sample; and
forming the channel impulse response (h_S) according to the plurality of selected pairs.

8. The sounding system of claim 1, **characterised in that,** the sound producing system (10) comprises a sound producing apparatus (12), the sound producing apparatus (12) comprises:

a signal processing circuit (124), coupled to the spike detection circuit (144), configured to generate a channel-shaping signal (g) according to the channel impulse response (h_S);
a driving circuit (122), coupled to the signal processing circuit (124), receiving the channel-shaping signal (g) and an input audio signal (A), configured to generate a driving signal (d) according to the input audio signal (A) and the channel-shaping signal (g); and
the sound producing device (120), configured to produce the pulse array (PA) according to the driving signal (d).

9. The sounding system of claim 8, **characterised in that,**

an air pulse rate of the plurality of air pulses is higher than a maximum human audible frequency; or

the plurality of air pulses produces a non-zero offset in terms of sound pressure level, and the non-zero offset is a deviation from a zero sound pressure level; or

the signal processing circuit generates the channel-shaping signal (g) to be proportional to a time-reversed or a time-reversed-and-conjugated counterpart of the channel impulse response (h_S) of the channel between the sound producing location and the sound constructing location; or

the plurality of sounding pulses for the sounding operation and the plurality of air pulses corresponding to the input audio signal (A) are superimposed and transmitted concurrently.

10. The sounding system of claim 1, **characterised by,** further comprising:

a plurality of sound producing device (120_1,... 120 N), disposed at a plurality of sound producing locations, receiving a plurality of sounding sequences, configured to produce a plurality of sounding pulse arrays (SPA_1,..., SPA_N) according to the plurality of sounding sequences (SS_1,...,SS_N);

wherein the sensor (140_m) receives a received sounding pulse array ($RSPA_{(A),m}$), and the received sounding pulse array ($RSPA_{(A),m}$) is an aggregation of the plurality of sounding pulse arrays (SPA_1,..., SPA_N);

wherein the filtering circuit (142_m) perform a plurality of filtering operations on the received sounding pulse array ($RSPA_{(A),m}$) according to the plurality of sounding sequences (SS_1,...,SS_N) and the sounding pulse waveform (UPW), and generate a plurality of overall filtering results;

where the spike detection circuit (144_m) performs the spike detection operation on the plurality of overall filtering results and obtain a plurality of channel impulse responses ($h_{S,m,1}$,..., $h_{S,m,N}$) corresponding to a plurality of channels ($h_{m,1}$, . . ., $h_{m,N}$);

wherein the plurality of channels ($h_{m,1}$,..., $h_{m,N}$) is between the plurality of sound producing location ($L_{SP,1}$,..., $L_{SP,N}$) and the sound constructing location ($L_{SC,m}$).

11. The sounding system of claim 10, **characterised in that,**

the plurality of sound producing device (120_1,..., 120 N) produces a plurality of pulse arrays (PA_1,..., PA_N), the plurality of sounding pulse arrays (SPA_1,..., SPA_N) for the sounding operation and the plurality of pulse arrays (PA_1,..., PA_N) are transmitted concurrently; or

a correlation of a first sounding sequence and a second sounding sequence is less than 1% of an energy of the first sounding sequence.

12. The sounding system of claim 1, **characterised by,** further comprising:

a plurality of sound producing device (120_1,... 120 N), disposed at a plurality of sound producing location ($L_{SP,1}$,..., $L_{SP,N}$), receiving a plurality of sounding sequences (SS_1,...,SS_N), configured to produce a plurality of sounding pulse arrays (SPA_1,..., SPA_N) according to the plurality of sounding sequences (SS_1,... ,SS_N);

wherein the sounding circuit further comprises a plurality of sensors (140_1,...,140_M) disposed at a plurality of sound constructing locations ($L_{SC,1}$,..., $L_{SC,M}$), the plurality of sensors (140_1,...,140_M) receives a plurality of received sounding pulse arrays ($RSPA_{(A),1}$,..., $RSPA_{(A),M}$), the sounding circuit generates a plurality of channel impulse responses ($h_{S,m,n}$) corresponding to a plurality of channels ($h_{m,n}$) according to the plurality of received sounding pulse arrays ($RSPA_{(A),1}$,..., $RSPA_{(A),M}$), the plurality of channels ($h_{m,n}$) is between the plurality of sound producing location ($L_{SP,1}$,..., $L_{SP,N}$) and the plurality of sound constructing locations ($L_{SC,1}$,..., $L_{SC,M}$).

13. The sounding system of claim 1, **characterised in that,** the sounding circuit further comprises a plurality of sensors (540_1,...,540_M) disposed at a plurality of sound constructing locations ($L_{SC,1}$,..., $L_{SC,M}$), the plurality of sensors (540_1,...,540_M) receives a plurality of received sounding pulse array ($RSPA_1$,..., $RSPA_M$), the sounding circuit generates a plurality of channel impulse responses ($h_{S,1,n}$,..., $h_{S,M,n}$) corresponding to a plurality of channels ($h_{1,n}$,..., $h_{M,n}$), and the plurality of channels ($h_{1,n}$,..., $h_{M,n}$) is between the sound producing location ($L_{SP,n}$) and the plurality of sound constructing locations ($L_{SC,1}$,..., $L_{SC,M}$).

14. The sounding system of claim 13, **characterised in that,** the sounding system is integrated into a sound producing system.

Patentansprüche

1. Sound-System (11), welches ausgestaltet ist, einen Sound-Betrieb durchzuführen, worin das Sound-System (11) umfasst:

eine Sound-Erzeugungsvorrichtung (120), die eine Membran (1201) umfasst, die an einem Schall-Produktionsort (L_{SP}) angeordnet ist, die eine Sound-Sequenz (SS) empfängt, und die ausgestaltet ist, ein Sound-Impulsmuster (SPA) gemäß der Sound-Sequenz (SS) zu erzeugen, wobei das Sound-Impulsmuster (SPA) mehrere Sound-Impulse (SP) umfasst und jeder Sound-Impuls (SP) einer Sound-Impulswellenform (UPW) entspricht;
dadurch gekennzeichnet, dass es ferner umfasst:

eine Sound-Schaltung (14), die ausgestaltet ist, eine Kanalimpulsantwort (hs) zu erzeugen, die einem Kanal (h) zwischen dem Schall-Produktionsort (L_{SP}) und einer Sound-Erzeugungsstelle (Lsc) entspricht, wobei die Sound-Schaltung (14) umfasst:

einen Sensor (140), der an der Sound-Erzeugungsstelle (Lsc) angeordnet ist und ein Empfangs-Sound-Impulsmuster (RSPA) empfängt, das dem Sound-Impulsmuster (SPA) entspricht, wobei das Empfangs-Sound-Impulsmuster (RSPA) mehrere Empfangs-Sound-Impulse umfasst; und
eine Filterschaltung (142), die mit dem Sensor (140) gekoppelt und ausgestaltet ist, ein Gesamtfilterergebnis zu erzeugen, wobei die Sound-Schaltung (14) die Kanalimpulsantwort (hs) gemäß dem Gesamtfilterergebnis erzeugt;

wobei das Sound-System (11) in ein Sound-Erzeugungssystem (10) integriert ist;
wobei das Sound-Erzeugungssystem (10) die Sound-Erzeugungsvorrichtung (120) umfasst, die an dem Schall-Produktionsort (L_{SP}) angeordnet ist;
wobei die Sound-Erzeugungsvorrichtung (120) ein Impulsmuster (PA) erzeugt, das einem Eingangsaudiosignal (A) entspricht, und das Impulsmuster (PA) mehrere Luftimpulse umfasst;
wobei das Impulsmuster (PA) entsprechend der Kanalimpulsantwort (hs) erzeugt und von dem Schall-Produktionsort (L_{SP}) gesendet wird und sich durch den Kanal (h) ausbreitet, so dass eine Schalldruckpegelhüllkurve, die dem Eingangsaudiosignal (A) entspricht, an der Sound-Erzeugungsstelle (Lsc) aufgebaut wird.

2. Sound-System nach Anspruch 1, **dadurch gekennzeichnet, dass**

eine Korrelation der Sound-Sequenz und einer zeitverschobenen Version der Sound-Sequenz kleiner ist als ein erster Schwellenwert, und der erste Schwellenwert 1% einer Energie der Sound-Sequenz (SS) beträgt; oder
die Sound-Sequenz (SS) mehrere Sequenzelemente umfasst, und ein Wert eines Sequenzelements binär oder ternär ist; oder
ein Schallimpuls aus den mehreren Sound-Impulsen einen Impulszyklus aufweist, und ein Kehrwert des Impulszyklus höher ist als eine maximal für Menschen hörbare Frequenz.

3. Sound-System nach Anspruch 1, **dadurch gekennzeichnet, dass**

die Filterschaltung (142) ausgestaltet ist, eine Filteroperation an dem empfangenen Sound-Impulsmuster (RSPA) gemäß der Sound-Sequenz (SS) und der Sound-Impulswellenform (UPW) durchzuführen; oder
die Filterschaltung (142) umfasst:

einen ersten Filter (1421), der mit dem Sensor (140) gekoppelt und ausgestaltet ist, einen ersten Filtervorgang gemäß der Sound-Sequenz (SS) durchzuführen; und
einen zweiten Filter (1422), der mit dem ersten Filter (1421) gekoppelt und ausgestaltet ist, einen zweiten Filtervorgang gemäß der Sound-Impulswellenform durchzuführen.

4. Sound-System nach Anspruch 3, **dadurch gekennzeichnet, dass**

eine erste Impulsantwort des ersten Filters (1421) eine Komponente umfasst, die proportional zu einer zeitumgekehrten oder einer zeitumgekehrten und konjugierten Version der Sound-Sequenz (SS) ist; oder
der erste Filter (1421) keinen Vervielfacher, sondern mehrere Verzögerungselemente und eine Summierschaltung umfasst; oder
der erste Filter (1421) mehrere Filterkoeffizienten aufweist, wobei mehrere Filterkoeffizienten in einem ganzzahligen Format und in einer Menge von {+1, -1} oder {+1, 0, -1} vorliegen; oder
eine zweite Impulsantwort des zweiten Filters (1422) eine Komponente umfasst, die proportional zu einer zeitumgekehrten oder einer zeitumgekehrten und konjugierten Version der Sound-Impulswellenform (UPW) ist.

5. Sound-System nach Anspruch 1, **dadurch gekennzeichnet, dass** die Sound-Schaltung (14) umfasst: eine Spike-Erfassungsschaltung (144), die mit der Filterschaltung (142) gekoppelt und ausgestaltet ist, einen Spike-Erfassungsvorgang an dem Gesamtfilterergebnis durchzuführen, um die Kanalimpulsantwort (hs) zu erhalten, die einem Kanal (h) zwischen dem Schall-Produktionsort (L_{SP}) und der Sound-Erzeugungsstelle (L_{SC}) entspricht.

6. Sound-System nach Anspruch 5, **dadurch gekennzeichnet, dass** das Gesamtfilterergebnis durch mehrere Messwerte dargestellt wird, wobei die Spike-Erfassungsschaltung (144) ausgestaltet ist, um den Spike-Erfassungsvorgang an dem Gesamtfilterergebnis durchzuführen und die Kanalimpulsantwort (hs) zu erhalten, die Schritte durchzuführen:

Gewinnen eines ersten Messwertes, wobei der erste Messwert einem ersten Zeitmoment entspricht;
Erhalten eines ersten Betrachtungszeitfensters, wobei das erste Betrachtungszeitfenster den ersten Zeitpunkt umfasst und das erste Betrachtungszeitfenster eine bestimmte Breite hat;
Erhalten eines ersten maximalen absoluten Messwertes, der dem ersten Betrachtungszeitfenster entspricht, wobei der erste maximale absolute Messwert ein Maximum mehrerer absoluter Messwerte mehrerer zweiter Messwerte innerhalb des ersten Betrachtungszeitfensters ist, wobei ein absoluter Messwert unter den mehreren absoluten Messwerten ein absoluter Wert eines zweiten Messwertes unter den mehreren zweiten Messwerten ist;
Bestimmen, ob ein erster absolute Messwert gleich dem ersten maximalen absoluten Messwert ist, wobei der erste absolute Messwert ein absoluter Wert des ersten Messwertes ist;
Eintragen des ersten Messwertes und des ersten Zeitpunkts in eine Liste; und
Erhalten der Kanalimpulsantwort (hs) gemäß der Liste.

7. Sound-System nach Anspruch 6, **dadurch gekennzeichnet, dass** die Liste mehrere Paare umfasst, wobei die mehreren Paare mehrere dritte Messwerte und mehrere dritte Zeitpunkte umfasst, die den mehreren dritten Messwerten entsprechen, wobei die Spike-Erfassungsschaltung (144) ferner ausgestaltet ist, um den Spike-Erfassungsvorgang an dem Gesamtfilterergebnis durchzuführen und die Kanalimpulsantwort (hs) zu erhalten, die Schritte durchzuführen:

Auswählen mehrerer ausgewählter Paare aus den mehreren Paaren, wobei mehrere ausgewählte dritte absolute Messwerte größer sind als ein nicht ausgewählter dritter absoluter Messwert; und
Bilden der Kanalimpulsantwort (hs) entsprechend den mehreren ausgewählten Paaren.

8. Sound-System nach Anspruch 1, **dadurch gekennzeichnet, dass** das Sound-Erzeugungssystem (10) eine Sound-Erzeugungsvorrichtung (12) umfasst, wobei die Sound-Erzeugungsvorrichtung (12) umfasst:

eine Signalverarbeitungsschaltung (124), die mit der Spike-Erfassungsschaltung (144) gekoppelt und ausgestaltet ist, ein kanalformendes Signal (g) entsprechend der Kanalimpulsantwort (hs) zu erzeugen;
eine Treiberschaltung (122), die mit der Signalverarbeitungsschaltung (124) gekoppelt ist, und die das Kanalformungssignal (g) und ein Eingangsaudiosignal (A) empfängt und ausgestaltet ist, ein Treibersignal (d) entsprechend dem Eingangsaudiosignal (A) und dem Kanalformungssignal (g) zu erzeugen; und
die Sound-Erzeugungsvorrichtung (120), die ausgestaltet ist, das Impulsmuster (PA) gemäß dem Treibersignal (d) zu erzeugen.

9. Sound-System nach Anspruch 8, **dadurch gekennzeichnet, dass**

eine Luftimpulsrate der mehreren Luftimpulse höher ist als eine maximal für Menschen hörbare Frequenz; oder
die mehreren Luftimpulse einen Offset ungleich Null in Bezug auf den Schalldruckpegel erzeugen, und der Offset ungleich Null eine Abweichung von einem Null-Schalldruckpegel ist; oder
die Signalverarbeitungsschaltung das kanalformende Signal (g) erzeugt, das proportional zu einem zeitumgekehrten oder einem zeitumgekehrten und konjugierten Gegenstück der Kanalimpulsantwort (hs) des Kanals zwischen dem Schall-Produktionsort (L_{SP}) und der Sound-Erzeugungsstelle (L_{SC}) ist; oder
die mehreren Sound-Impulse für den Sound-Betrieb und die mehreren Luftimpulse, die dem Eingangsaudiosignal (A) entsprechen, überlagert und gleichzeitig übertragen werden.

10. Sound-System nach Anspruch 1, **dadurch gekennzeichnet, dass** es ferner umfasst:

mehrere Sound-Erzeugungsvorrichtungen (120_1,...120_N), die an mehreren Schall-Produktionsorten angeordnet sind und mehrere Schallsequenzen empfangen, die ausgestaltet sind, mehrere Schall-Impulsmuster (SPA_1,..., SPA_N) entsprechend den mehreren Schallsequenzen (SS_1,..., SS_N) zu erzeugen;
wobei der Sensor (140_m) ein empfangenes Sound-Impulsmuster ($RSPA_{(A),m}$) empfängt und das empfangene Sound-Impulsmuster

($RSPA_{(A),m}$) eine Aggregation der mehreren Sound-Impulsmuster (SPA_1, ..., SPA_N) ist;
wobei die Filterschaltung (142_m) mehrere Filteroperationen an dem empfangenen Sound-Impulsmuster ($RSPA_{(A),m}$) gemäß der Mehreren Sound-Sequenzen (SS_1, ..., SS_N) und der Sound-Impulswellenform (UPW) durchführt und mehrere Gesamtfilterergebnisse erzeugt;
wobei die Spike-Erfassungsschaltung (144_m) den Spike-Erfassungsvorgang an den mehreren Gesamtfilterergebnissen durchführt und mehrere Kanalimpulsantworten ($h_{S,m,1}$, ..., $h_{S,m,N}$) entsprechend mehrerer Kanäle ($h_{m,1}$, ..., $h_{m,N}$) erhält;
wobei die mehreren Kanälen ($h_{m,1}$, ..., $h_{m,N}$) zwischen den mehreren Schall-Produktionsorten ($L_{SP,1}$, ..., $L_{SP,N}$) und der Sound-Erzeugungsstelle ($L_{SC,m}$) liegen.

11. Sound-System nach Anspruch 10, **dadurch gekennzeichnet, dass**

die mehreren Sound-Erzeugungsvorrichtungen (120_1, ..., 120_N) mehrere Impulsmuster (PA_1, ..., PA_N) erzeugen, und darin, dass die mehreren Sound-Impulsmuster (SPA_1, ..., SPA_N) für den Sound-Betrieb und die mehreren Impulsmuster (PA_1, ..., PA_N) gleichzeitig übertragen werden; oder
eine Korrelation einer ersten Sound-Sequenz und einer zweiten Sound-Sequenz weniger als 1% einer Energie der ersten Sound-Sequenz beträgt.

12. Sound-System nach Anspruch 1, **dadurch gekennzeichnet, dass** es ferner umfasst:

mehrere Sound-Erzeugungsvorrichtungen (120_1,...120_N), die an mehreren Schallerzeugungsorten ($L_{SP,1}$,..., $L_{SP,N}$) angeordnet sind, die mehrere Schallsequenzen (SS_1,..., SS_N) empfangen, und ausgestaltet sind, mehrere Sound-Impulsmuster (SPA_1,..., SPA_N) entsprechend den mehreren Schallsequenzen (SS_1,..., SS_N) zu erzeugen;
worin die Sound-Schaltung ferner mehrere Sensoren (140_1, ..., 140_M) umfasst, die an mehreren Schallerzeugungsorten ($L_{SC,1}$, ..., $L_{SC,M}$) angeordnet sind, wobei die mehreren Sensoren (140_1, ..., 140_M) mehrere Empfangs-Sound-Impulsmuster ($RSPA_{(A),1}$, ... , $RSPA_{(A),M}$) empfangen, die Sound-Schaltung mehrere Kanalimpulsantworten ($h_{S,m,n}$) erzeugt, die mehreren Kanälen ($h_{m,n}$) gemäß den mehreren Empfangs-Sound-Impulsmustern ($RSPA_{(A),1}$,... , $RSPA_{(A),M}$) entsprechen, wobei die mehreren Kanäle ($h_{m,n}$) zwischen den mehreren Schall-Produktionsorten ($L_{SP,1}$,..., $L_{SP,N}$) und den mehreren Sound-Erzeugungsstellen ($L_{SC,1}$,..., $L_{SC,M}$) liegen.

13. Sound-System nach Anspruch 1, **dadurch gekennzeichnet, dass** die Sound-Schaltung ferner mehrere Sensoren (540_1, ..., 540_M) umfasst, die an mehreren Sound-Erzeugungsstellen ($L_{SC,1}$, ..., $L_{SC,M}$) angeordnet sind, wobei die mehreren Sensoren (540_1, ..., 540_M) mehrere Empfangs-Sound-Impulsmuster ($RSPA_1$, ... , $RSPA_M$) empfangen, die Sound-Schaltung mehrere Kanalimpulsantworten ($h_{s,1,n}$,..., $h_{S,M,n}$) erzeugt, die mehreren Kanälen ($h_{1,n}$, ..., $h_{M,n}$) entsprechen, und die mehreren Kanäle ($h_{1,n}$,..., $h_{M,n}$) zwischen dem Schall-Produktionsort ($L_{SP,n}$) und den mehreren Sound-Erzeugungsstellen ($L_{SC,1}$,..., $L_{SC,M}$) liegen.

14. Sound-System nach Anspruch 13, **dadurch gekennzeichnet, dass** das Sound-System in ein Sound-Erzeugungssystem integriert ist.

Revendications

1. Système de sonorisation (11), configuré pour effectuer une opération de sonorisation, le système de sonorisation (11) comprenant:

un dispositif de production de son (120), comprenant une membrane (1201), disposée à un emplacement de production de son (L_{SP}), recevant une séquence de sonorisation (SS), configurée pour produire un réseau d'impulsions de sonorisation (SPA) selon la séquence de sonorisation (SS), dans lequel le réseau d'impulsions de sonorisation (SPA) comprend une pluralité d'impulsions de sonorisation (SP), et chaque impulsion de sonorisation (SP) correspond à une forme d'onde d'impulsion de sonorisation (UPW);
caractérisé en ce qu'il comprend en outre
un circuit de sonorisation (14), configuré pour générer une réponse impulsionnelle de canal (h_S) correspondant à un canal (h) entre l'emplacement de production de son (L_{SP}) et un emplacement de construction de son (Lsc), le circuit de sonorisation (14) comprenant:

un capteur (140), disposé à l'emplacement de construction de son (Lsc), recevant un réseau d'impulsions de sonorisation reçues ($_{RSPA}$) correspondant au réseau d'impulsions de sonorisation (SPA), dans lequel le réseau d'impulsions de sonorisation reçues (RSPA) comprend une pluralité d'impulsions de sonorisation reçues; et
un circuit de filtrage (142), couplé au capteur (140), configuré pour générer un résul-

tat de filtrage global, dans lequel le circuit de sonorisation (14) génère la réponse impulsionnelle de canal (hs) selon le résultat de filtrage global;
dans lequel le système de sonorisation (11) est intégré dans un système de production de son (10);
dans lequel le système de production de son (10) comprend le dispositif de production de son (120) disposé à l'emplacement de production de son (L_{SP});
dans lequel le dispositif de production de son (120) produit un réseau d'impulsions (PA) correspondant à un signal audio d'entrée (A), et le réseau d'impulsions (PA) comprend une pluralité d'impulsions d'air;
dans lequel le réseau d'impulsions (PA) est généré selon la réponse impulsionnelle de canal (hs) et transmis depuis l'emplacement de production de son (L_{SP}), et se propage à travers le canal (h), de sorte qu'une enveloppe de niveau de pression sonore correspondant au signal audio d'entrée (A) est construite à l'emplacement de construction de son (Lsc).

2. Système de sonorisation selon la revendication 1, **caractérisé en ce que**,

une corrélation de la séquence de sonorisation et d'une version décalée dans le temps de la séquence de sonorisation est inférieure à un premier seuil, et le premier seuil est de 1% d'une énergie de la séquence de sonorisation (SS); ou
la séquence de sonorisation (SS) comprend une pluralité d'éléments de séquence, une valeur d'un élément de séquence est binaire ou ternaire; ou
une impulsion sonore parmi la pluralité d'impulsions sonores a un cycle d'impulsion, et une réciproque du cycle d'impulsion est supérieure à une fréquence maximale audible par l'homme.

3. Système de sonorisation selon la revendication 1, **caractérisé en ce que**,

le circuit de filtrage (142) est configuré pour effectuer une opération de filtrage sur le réseau d'impulsions de sonorisation reçues (RSPA) selon la séquence de sonorisation (SS) et la forme d'onde d'impulsion de sonorisation (UPW); ou
le circuit de filtrage (142) comprend:

un premier filtre (1421), couplé au capteur (140), configuré pour effectuer une première opération de filtrage selon la séquence de sonorisation (SS); et
un deuxième filtre (1422), couplé au premier filtre (1421), configuré pour effectuer une deuxième opération de filtrage selon la forme d'onde d'impulsion de sonorisation.

4. Système de sonorisation selon la revendication 3, **caractérisé en ce que**,

une première réponse impulsionnelle du premier filtre (1421) comprend une composante qui est proportionnelle à une version inversée dans le temps ou inversée dans le temps et conjuguée de la séquence de sonorisation (SS); ou
le premier filtre (1421) ne comprend pas de multiplicateur mais comprend une pluralité d'éléments de retard et un circuit de sommation; ou
le premier filtre (1421) a une pluralité de coefficients de filtre, la pluralité de coefficients de filtre est dans un format entier et dans un ensemble de {+1, -1} ou {+1, 0, -1}; ou
une deuxième réponse impulsionnelle du deuxième filtre (1422) comprend une composante qui est proportionnelle à une version inversée dans le temps ou inversée dans le temps et conjuguée de la forme d'onde d'impulsion de sonorisation (UPW).

5. Système de sonorisation selon la revendication 1, **caractérisé en ce que**, le circuit de sonorisation (14) comprend:
un circuit de détection de crête (144), couplé au circuit de filtrage (142), configuré pour effectuer une opération de détection de crête sur le résultat de filtrage global, de manière à obtenir la réponse impulsionnelle de canal (hs) correspondant à un canal (h) entre l'emplacement de production de son (L_{SP}) et l'emplacement de construction de son (L_{SC}).

6. Système de sonorisation selon la revendication 5, **caractérisé en ce que**, le résultat global de filtrage est représenté par une pluralité d'échantillons, le circuit de détection de pointes (144) est configuré pour exécuter les étapes suivantes, pour exécuter l'opération de détection de pointes sur le résultat global de filtrage et obtenir la réponse impulsionnelle de canal (hs):

obtenir un premier échantillon, dans lequel le premier échantillon correspond à un premier instant;
obtenir une première fenêtre temporelle d'observation, dans laquelle la première fenêtre temporelle d'observation comprend le premier instant temporel, et la première fenêtre temporelle d'observation a une largeur spécifique;
obtenir un premier échantillon absolu maximum correspondant à la première fenêtre de temps d'observation, dans lequel le premier échantillon absolu maximum est un maximum d'une

pluralité d'échantillons absolus d'une pluralité de seconds échantillons dans la première fenêtre de temps d'observation, un échantillon absolu parmi la pluralité d'échantillons absolus est une valeur absolue d'un second échantillon parmi la pluralité de seconds échantillons;
déterminer si un premier échantillon absolu est égal au premier échantillon absolu maximum, dans lequel le premier échantillon absolu est une valeur absolue du premier échantillon;
ajouter le premier échantillon et le premier instant dans une liste; et
obtenir la réponse impulsionnelle de canal (hs) en fonction de la liste.

7. Système de sonorisation selon la revendication 6, **caractérisé en ce que**, la liste comprend une pluralité de paires, la pluralité de paires comprend une pluralité de troisièmes échantillons et une pluralité de troisièmes instants correspondant à la pluralité de troisièmes échantillons, le circuit de détection de pointes (144) est en outre configuré pour exécuter les étapes suivantes, pour exécuter l'opération de détection de pointes sur le résultat de filtrage global et obtenir la réponse impulsionnelle de canal (hs):

sélectionner une pluralité de paires sélectionnées parmi la pluralité de paires, dans laquelle une pluralité de troisièmes échantillons absolus sélectionnés est plus grande qu'un troisième échantillon absolu non sélectionné; et
former la réponse impulsionnelle de canal (hs) en fonction de la pluralité de paires sélectionnées.

8. Système de sonorisation selon la revendication 1, **caractérisé en ce que**, le système de production de son (10) comprend un appareil de production de son (12), l'appareil de production de son (12) comprend:

un circuit de traitement de signal (124), couplé au circuit de détection de pointes (144), configuré pour générer un signal de mise en forme de canal (g) selon la réponse impulsionnelle de canal (hs);
un circuit d'attaque (122), couplé au circuit de traitement de signal (124), recevant le signal de mise en forme de canal (g) et un signal audio d'entrée (A), configuré pour générer un signal d'attaque (d) selon le signal audio d'entrée (A) et le signal de mise en forme de canal (g); et
le dispositif de production de son (120), configuré pour produire le réseau d'impulsions (PA) selon le signal de commande (d).

9. Système de sonorisation selon la revendication 8, **caractérisé en ce que**,

une fréquence d'impulsions d'air de la pluralité d'impulsions d'air est supérieure à une fréquence maximale audible par l'homme; ou
la pluralité d'impulsions d'air produit un décalage non nul en termes de niveau de pression acoustique, et le décalage non nul est un écart par rapport à un niveau de pression acoustique nul; ou
le circuit de traitement de signal génère le signal de mise en forme de canal (g) pour qu'il soit proportionnel à une contrepartie inversée dans le temps ou inversée dans le temps et conjuguée de la réponse impulsionnelle de canal (hs) du canal entre l'emplacement de production de son et l'emplacement de construction de son; ou
la pluralité d'impulsions de sonorisation pour l'opération de sonorisation et la pluralité d'impulsions d'air correspondant au signal audio d'entrée (A) sont superposées et transmises simultanément.

10. Système de sonorisation de la revendication 1, **caractérisé en ce qu'**il comprend en outre:

une pluralité de dispositifs de production de son (120_1, ... 120_N), disposés à une pluralité d'emplacements de production de son, recevant une pluralité de séquences de sonorisation, configurés pour produire une pluralité de réseaux d'impulsions de sonorisation (SPA_1, ..., SPA_N) selon la pluralité de séquences de sonorisation (SS_1, ..., SS_N);
dans lequel le capteur (140_m) reçoit un réseau d'impulsions de sonorisation reçu ($RSPA_{(A),m}$), et le réseau d'impulsions de sonorisation reçu ($RSPA_{(A),m}$) est une agrégation de la pluralité de réseaux d'impulsions de sonorisation (SPA_1,..., SPA_N);
dans lequel le circuit de filtrage (142_m) effectue une pluralité d'opérations de filtrage sur le réseau d'impulsions de sonorisation reçues ($RSPA_{(A),m}$) selon la pluralité de séquences de sonorisation (SS_1,..., SS_N) et la forme d'onde d'impulsion de sonorisation (UPW), et génère une pluralité de résultats de filtrage globaux;
où le circuit de détection de pointes (144_m) effectue l'opération de détection de pointes sur la pluralité de résultats de filtrage globaux et obtient une pluralité de réponses impulsionnelles de canal ($h_{S,m,1}$,..., $h_{S,m,N}$) correspondant à une pluralité de canaux ($h_{m,1}$,..., $h_{m,N}$);
dans lequel la pluralité de canaux ($h_{m,1}$,..., $h_{m,N}$) est entre la pluralité d'emplacements de production de son ($L_{SP,1}$,..., $L_{SP,N}$) et l'emplacement de construction de son ($L_{SC,m}$).

11. Système de sonorisation selon la revendication 10, **caractérisé en ce que**, la pluralité de dispositifs de production de son (120_1, ..., 120_N) produit une pluralité de réseaux d'impulsions (PA_1, ..., PA_N), la pluralité de réseaux d'impulsions de sonorisation (SPA_1, ..., SPA_N) pour l'opération de sonorisation et la pluralité de réseaux d'impulsions (PA_1, ..., PA_N) sont transmis simultanément; ou une corrélation d'une première séquence de sonorisation et d'une deuxième séquence de sonorisation est inférieure à 1% d'une énergie de la première séquence de sonorisation.

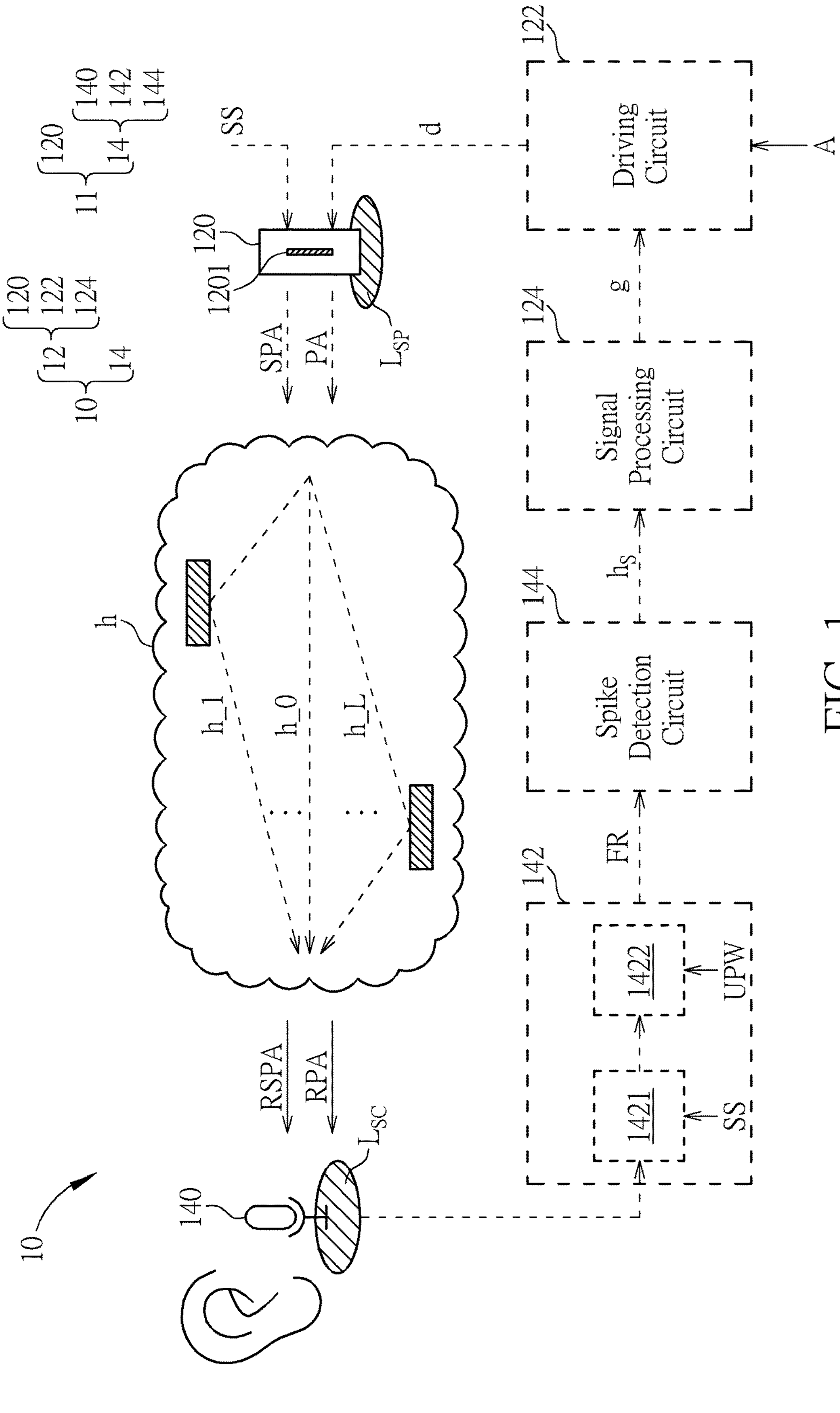
12. Système de sonorisation selon la revendication 1, **caractérisé en ce qu'**il comprend en outre:

une pluralité de dispositifs de production de son (120_1, ... 120_N), disposés à une pluralité d'emplacements de production de son ($L_{SP,1}$, ..., $L_{SP,N}$), recevant une pluralité de séquences de sonorisation (SS_1, ..., SS_N), configurés pour produire une pluralité de réseaux d'impulsions de sonorisation (SPA_1, ..., SPA_N) selon la pluralité de séquences de sonorisation (SS_1, ..., SS_N);

dans lequel le circuit de sonorisation comprend en outre une pluralité de capteurs (140_1,..., 140_M) disposés à une pluralité d'emplacements de construction de son ($L_{SC,1}$,..., $L_{SC,M}$), la pluralité de capteurs (140_1,..., 140_M) reçoit une pluralité de réseaux d'impulsions de sonorisation reçus ($RSPA_{(A),1}$,.... , $RSPA_{(A),M}$), le circuit de sonorisation génère une pluralité de réponses impulsionnelles de canal ($h_{S,m,n}$) correspondant à une pluralité de canaux ($h_{m,n}$) selon la pluralité de réseaux d'impulsions de sonorisation reçus ($RSPA_{(A),1}$,.... $RSPA_{(A),1}$,..., $RSPA_{(A),M}$), la pluralité de canaux ($h_{m,n}$) se situe entre la pluralité d'emplacements de production de son ($L_{SP,1}$,..., $L_{SP,N}$) et la pluralité d'emplacements de construction de son ($L_{SC,1}$,..., $L_{SC,M}$).

13. Système de sonorisation selon la revendication 1, **caractérisé en ce que** le circuit de sonorisation comprend en outre une pluralité de capteurs (540_1,..., 540_M) disposés à une pluralité d'emplacements de construction de son ($L_{SC,1}$,..., $L_{SC,M}$), la pluralité de capteurs (540_1,..., 540_M) reçoit une pluralité de réseaux d'impulsions de sonorisation reçues ($RSPA_1$,..., $RSPA_M$), les impulsions de sonorisation reçues étant des impulsions d'une durée de 10 minutes. $RSPA_M$), le circuit de sonorisation génère une pluralité de réponses impulsionnelles de canal ($h_{S,1,n}$,..., $h_{S,M,n}$) correspondant à une pluralité de canaux ($h_{1,n}$,..., $h_{M,n}$), et la pluralité de canaux ($h_{1,n}$,..., $h_{M,n}$) est entre l'emplacement de production de son ($L_{SP,n}$) et la pluralité d'emplacements de construction de son ($L_{SC,1}$,..., $L_{SC,M}$).

14. Système de sonorisation selon la revendication 13, **caractérisé en ce que** le système de sonorisation est intégré dans un système de production de son.



10
12
14
120
122
124
11
120
14
140
142
144
SS
d
120
1201
SPA
PA
L_{SP}
h
h_1
h_0
h_L
RSPA
RPA
L_{SC}
140
10
Driving Circuit
A
122
Signal Processing Circuit
124
g
Spike Detection Circuit
144
h_S
FR
142
1422
1421
UPW
SS

FIG. 1

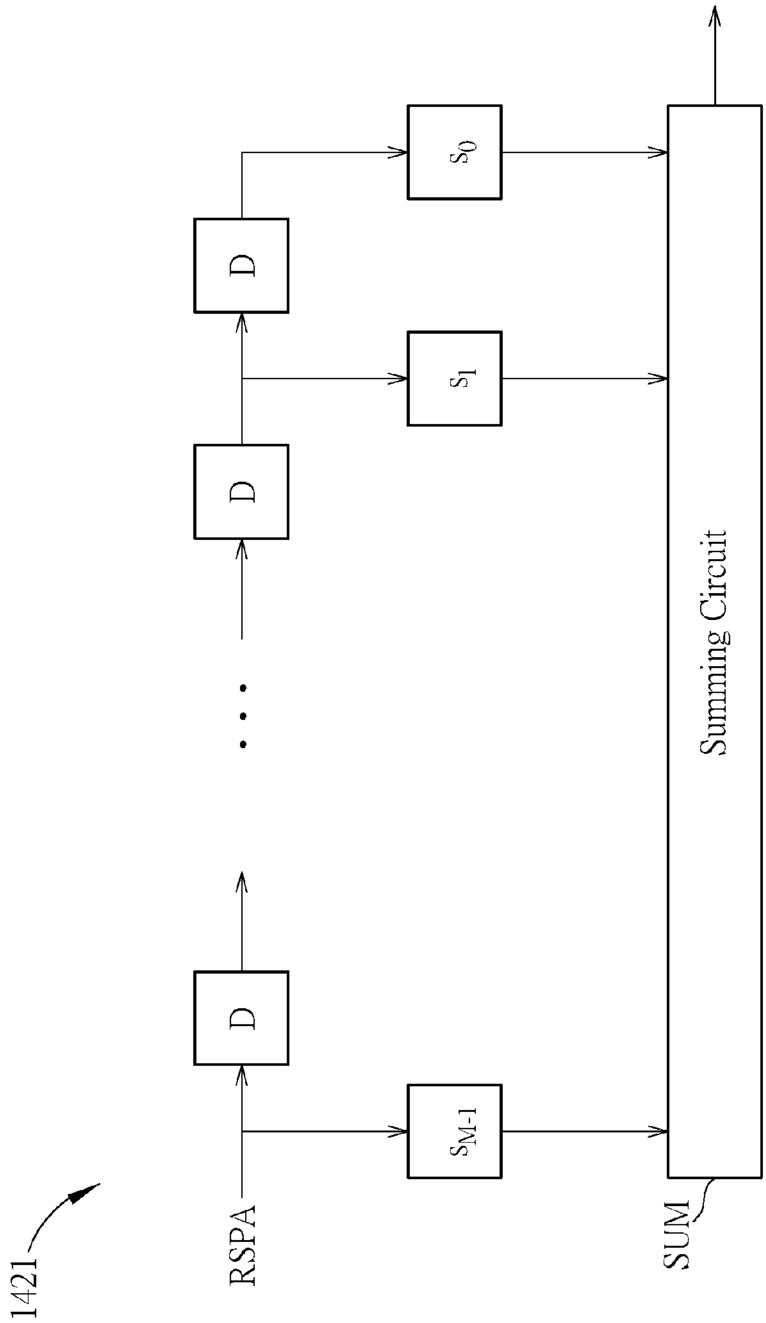


FIG. 2

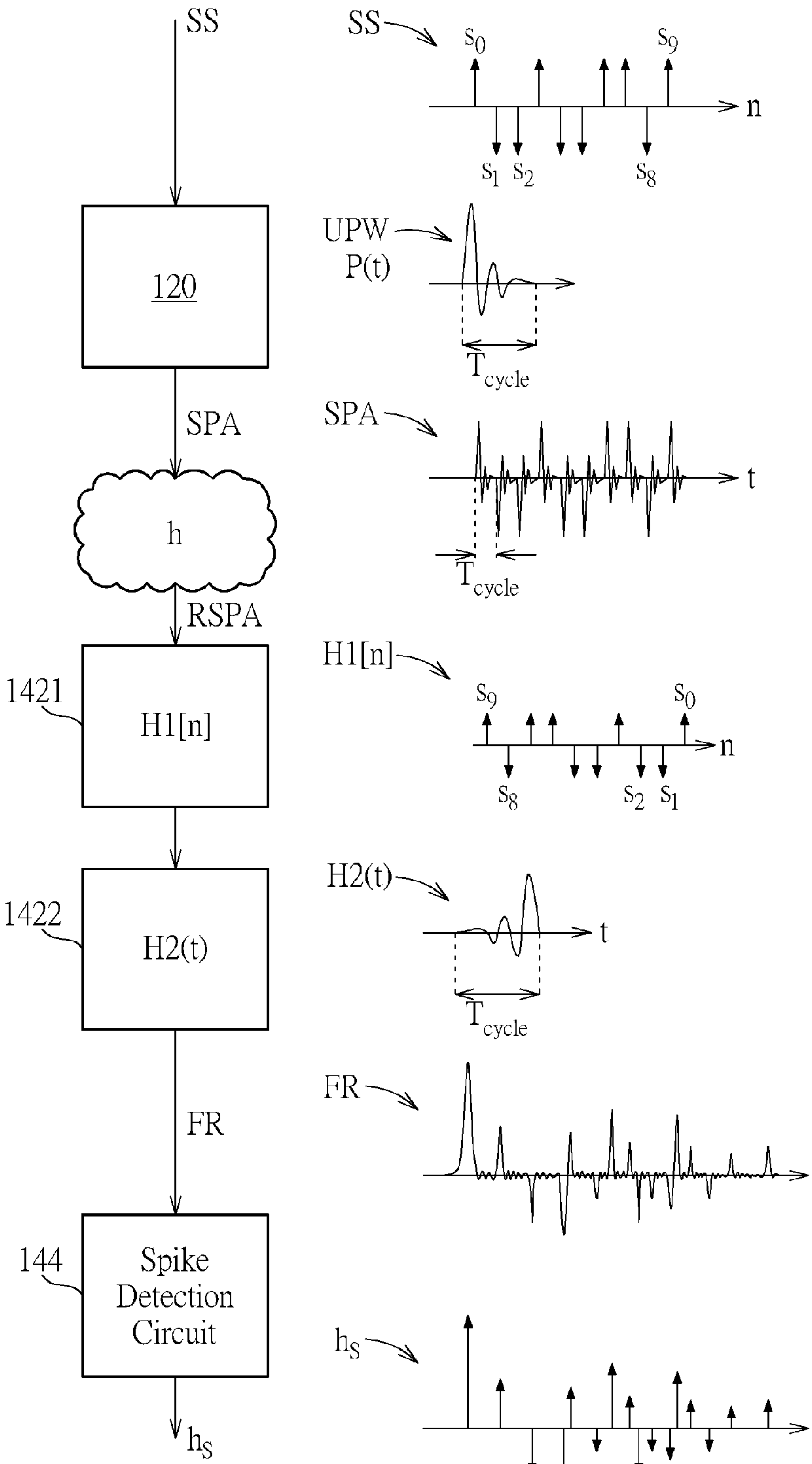

SS
120
SPA
h
RSPA
1421
H1[n]
1422
H2(t)
FR
144
Spike Detection Circuit
hS
SS
s0
s9
n
s1 s2
s8
UPW
P(t)
Tcycle
SPA
t
Tcycle
H1[n]
s9
s0
n
s8
s2 s1
H2(t)
t
Tcycle
FR
hS

FIG. 3

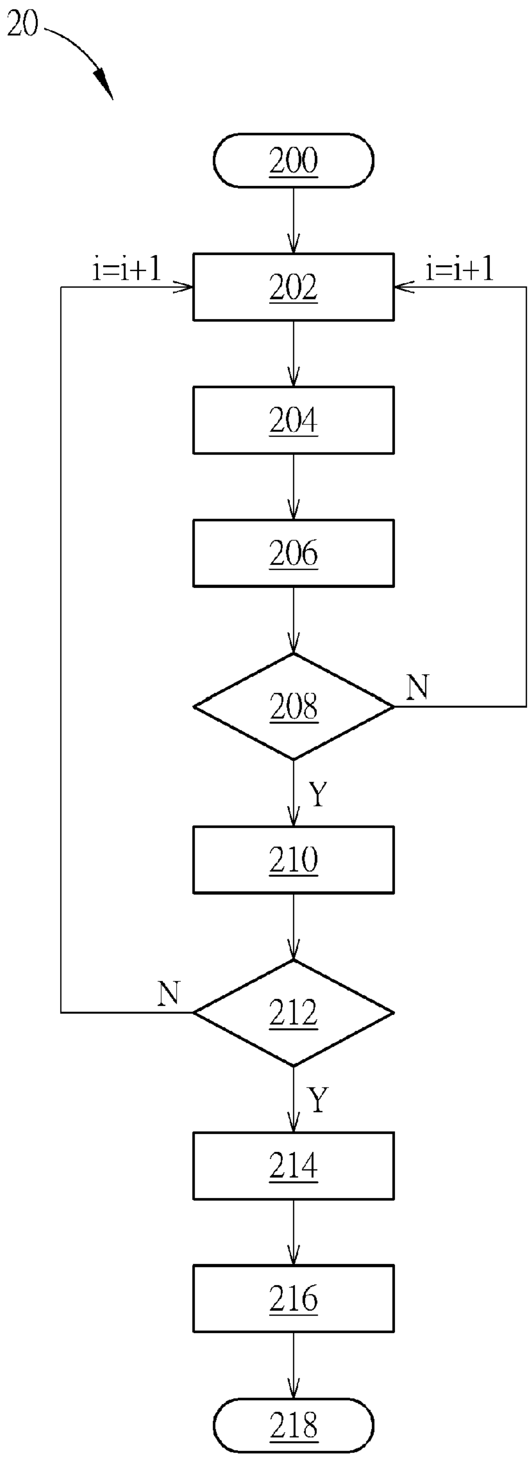


FIG. 4

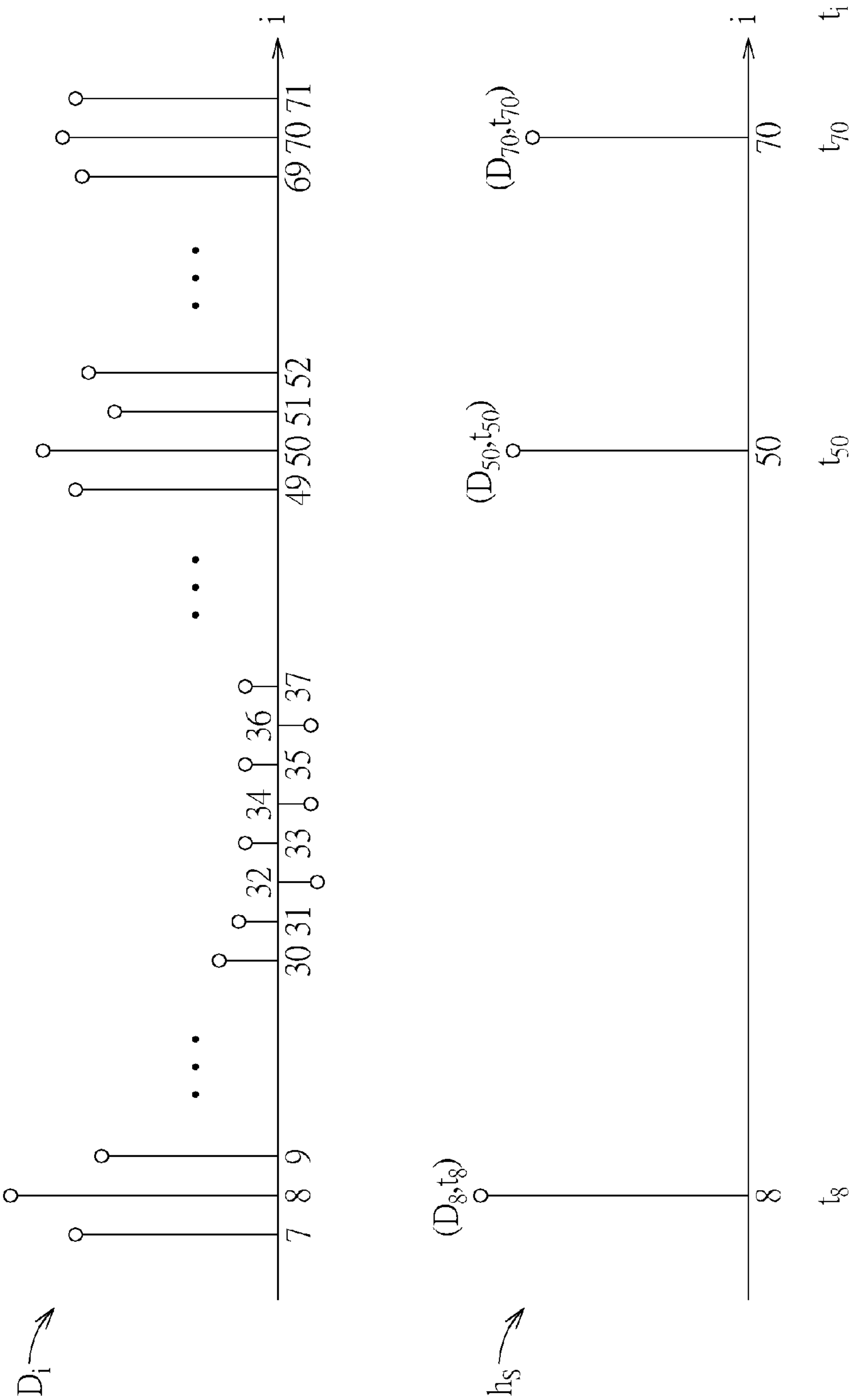

D_i
h_S
i
t_i
7 8 9
30 31 32 33 34 35 36 37
49 50 51 52
69 70 71
(D_8, t_8)
(D_{50}, t_{50})
(D_{70}, t_{70})
8
50
70
t_8
t_{50}
t_{70}

FIG. 5

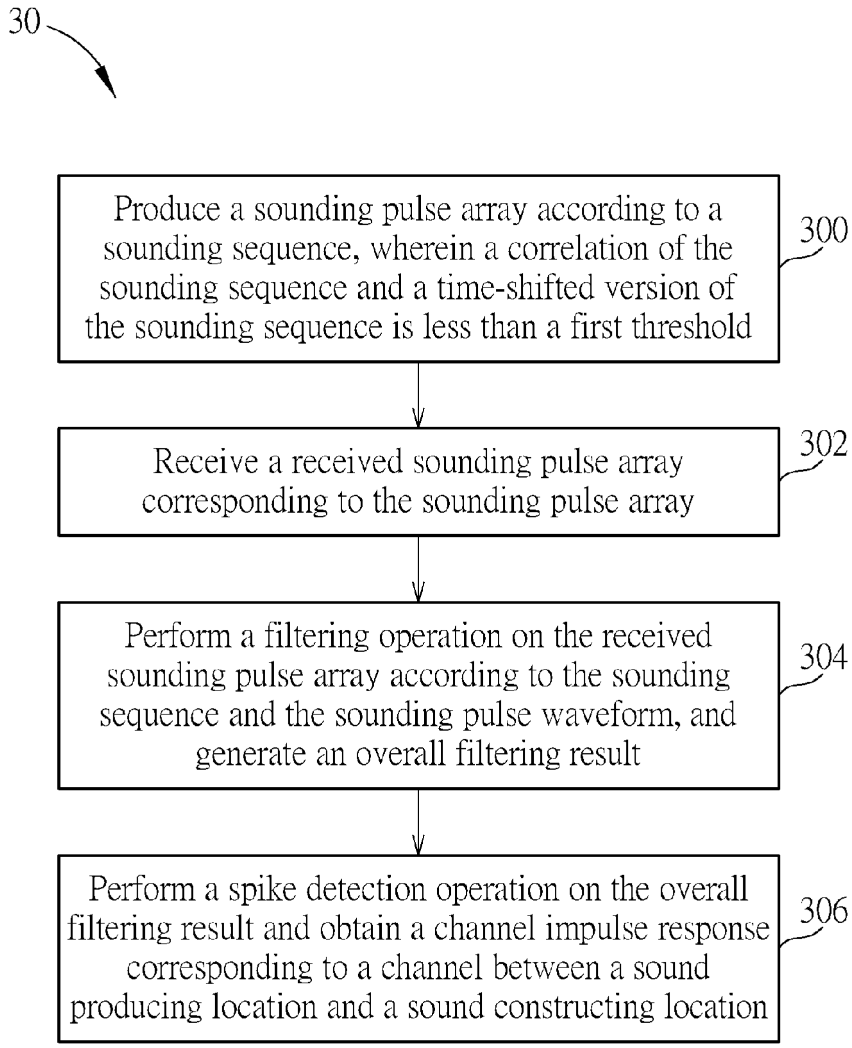

30
Produce a sounding pulse array according to a sounding sequence, wherein a correlation of the sounding sequence and a time-shifted version of the sounding sequence is less than a first threshold
300
Receive a received sounding pulse array corresponding to the sounding pulse array
302
Perform a filtering operation on the received sounding pulse array according to the sounding sequence and the sounding pulse waveform, and generate an overall filtering result
304
Perform a spike detection operation on the overall filtering result and obtain a channel impulse response corresponding to a channel between a sound producing location and a sound constructing location
306

FIG. 6

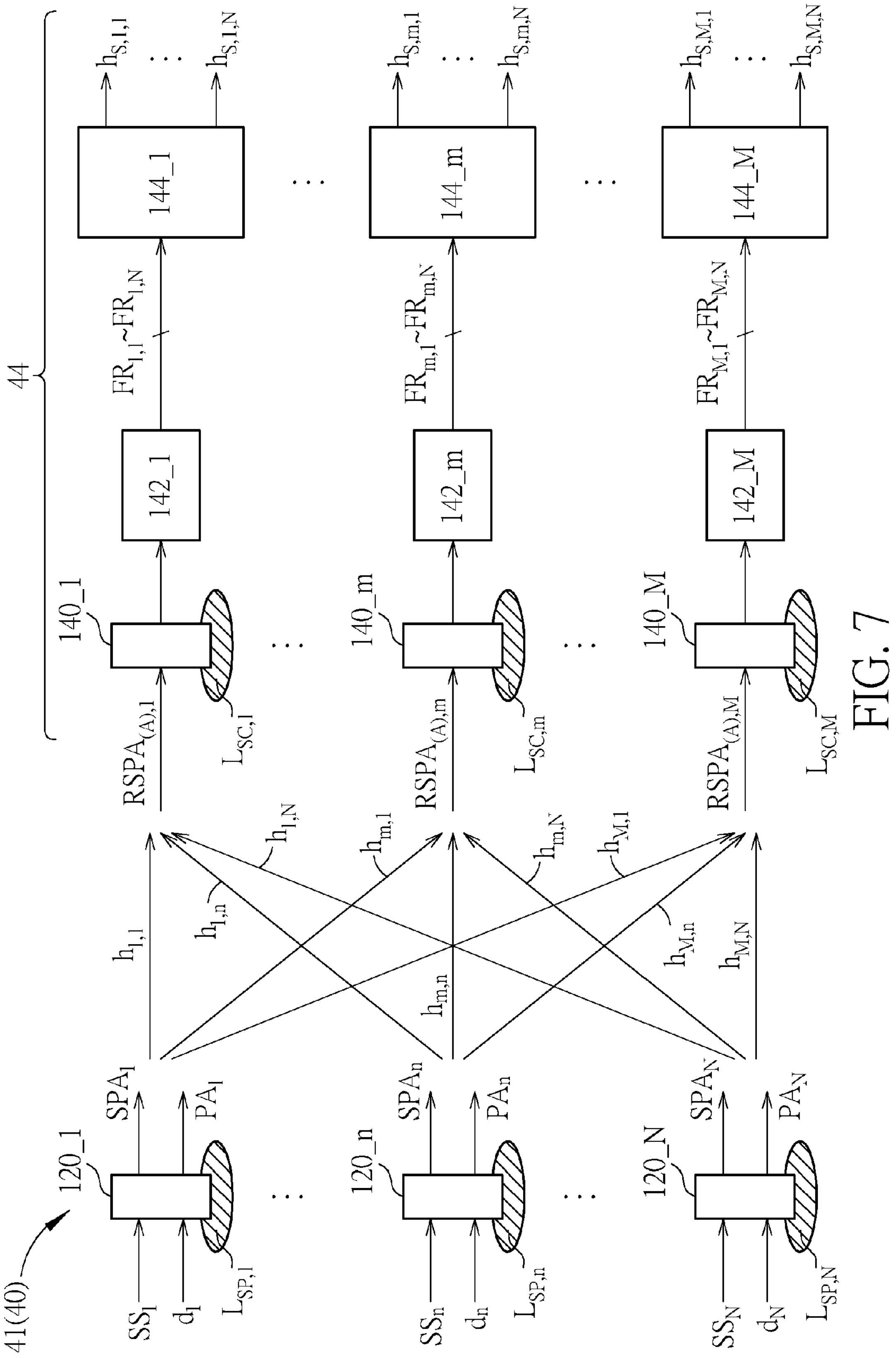

41(40)
120_1
120_n
120_N
SS1
d1
LSP,1
SPA1
PA1
h1,1
h1,n
h1,N
hm,1
hm,n
hm,N
hM,1
hM,n
hM,N
RSPA(A),1
RSPA(A),m
RSPA(A),M
140_1
140_m
140_M
LSC,1
LSC,m
LSC,M
142_1
142_m
142_M
FR1,1~FR1,N
FRm,1~FRm,N
FRM,1~FRM,N
144_1
144_m
144_M
hS,1,1
hS,1,N
hS,m,1
hS,m,N
hS,M,1
hS,M,N
44

FIG. 7

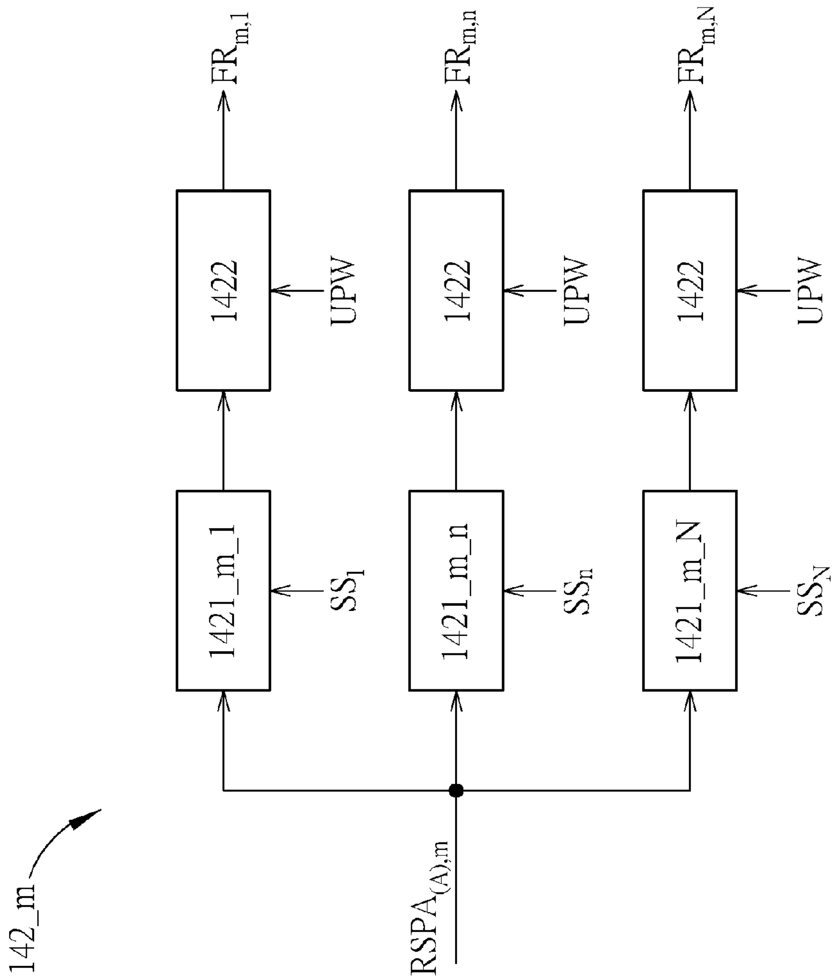

142_m
RSPA$_{(A),m}$
1421_m_1
1421_m_n
1421_m_N
SS$_1$
SS$_n$
SS$_N$
1422
1422
1422
UPW
UPW
UPW
FR$_{m,1}$
FR$_{m,n}$
FR$_{m,N}$

FIG. 8

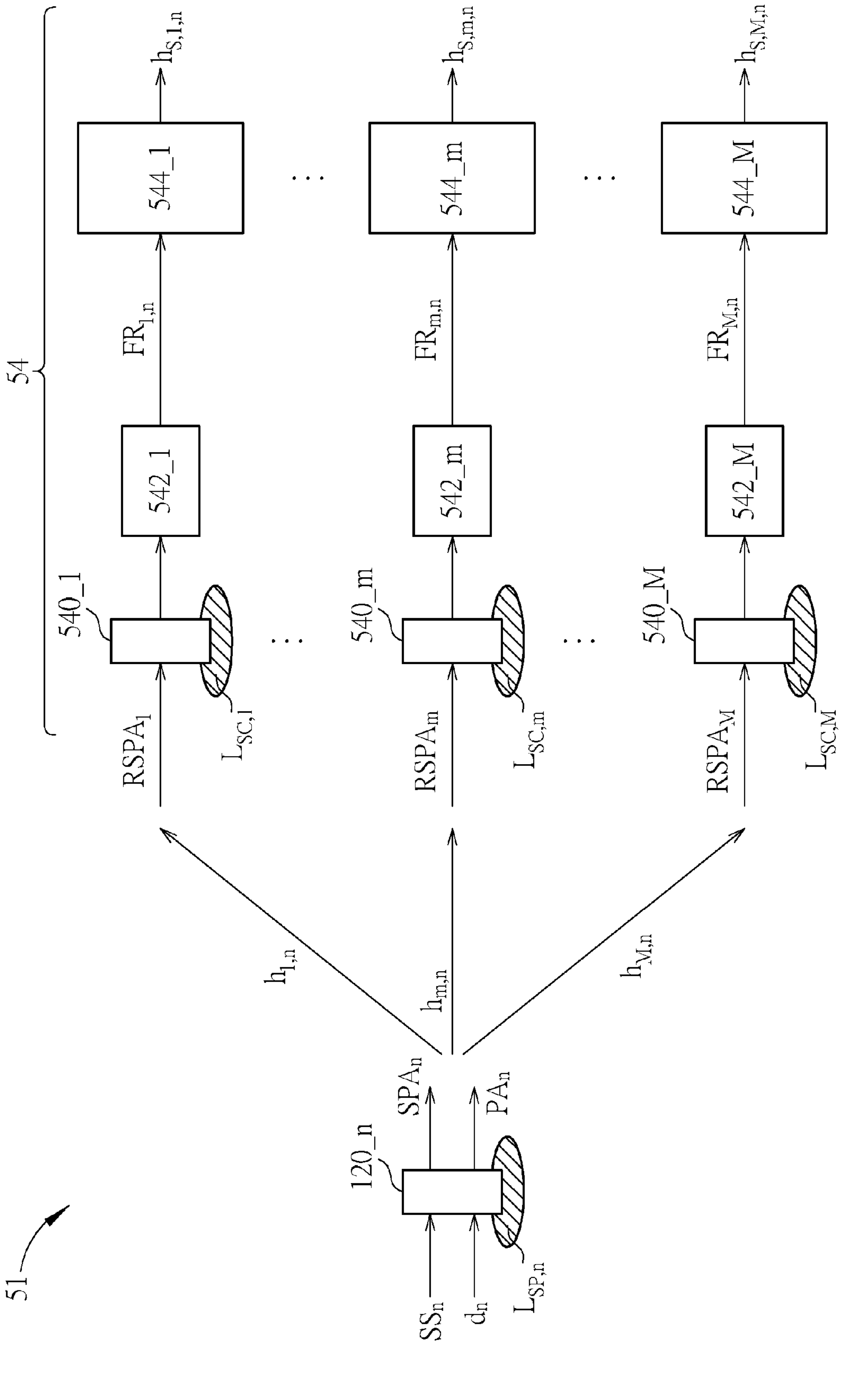

51
120_n
SSn
dn
LSP,n
SPAn
PAn
h1,n
hm,n
hM,n
RSPA1
RSPAm
RSPAM
LSC,1
LSC,m
LSC,M
540_1
540_m
540_M
542_1
542_m
542_M
FR1,n
FRm,n
FRM,n
544_1
544_m
544_M
hS,1,n
hS,m,n
hS,M,n
54

FIG. 9

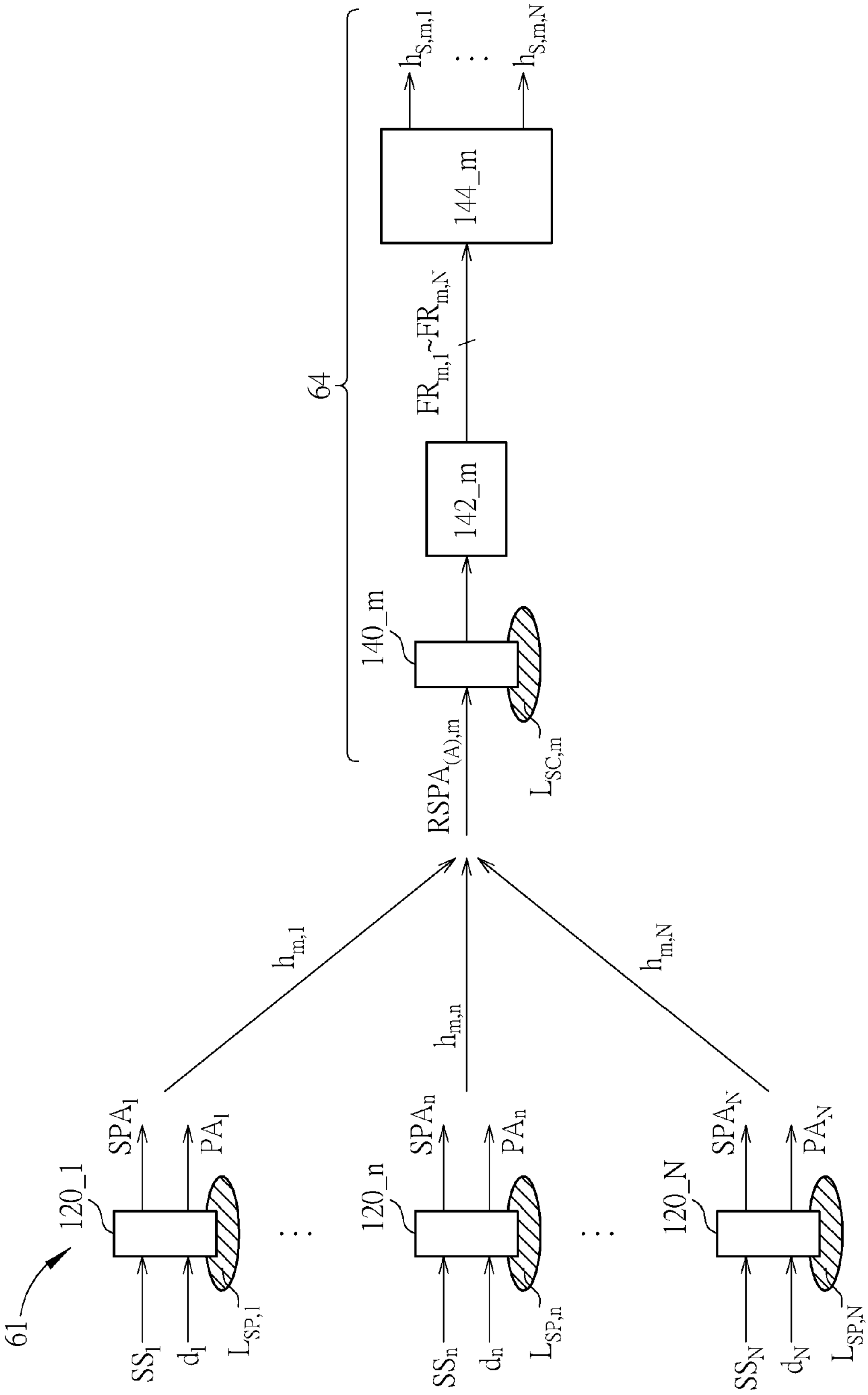

61
120_1
120_n
120_N
SS_1
d_1
$L_{SP,1}$
SPA_1
PA_1
SS_n
d_n
$L_{SP,n}$
SPA_n
PA_n
SS_N
d_N
$L_{SP,N}$
SPA_N
PA_N
$h_{m,1}$
$h_{m,n}$
$h_{m,N}$
$RSPA_{(A),m}$
$L_{SC,m}$
140_m
142_m
$FR_{m,1}$~$FR_{m,N}$
144_m
$h_{S,m,1}$
$h_{S,m,N}$
64

FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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