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Topchy et al.

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(54) **METHODS AND APPARATUS TO FINGERPRINT AN AUDIO SIGNAL**

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(52) **U.S. Cl.**
CPC ***G10L 25/51*** (2013.01); ***G11B 27/28*** (2013.01)

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CPC G10L 25/51; G10L 25/48; G10L 25/54; G10L 19/018; G10L 25/18
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,363,345 B1 3/2002 Marash et al.
9,202,472 B1 * 12/2015 Sharifi G10L 19/018
9,299,350 B1 * 3/2016 Dumont G10L 21/055
9,299,364 B1 3/2016 Pereira et al.
9,390,719 B1 7/2016 Roblek et al.
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2006505821 2/2006
JP 2016518663 6/2016
(Continued)

OTHER PUBLICATIONS

L. Ondel, X. Anguera and J. Luque, "MASK+: Data-driven regions selection for acoustic fingerprinting," 2015 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2015, pp. 335-339, doi: 10.1109/ICASSP.2015.7177986. (Year: 2015).*

(Continued)

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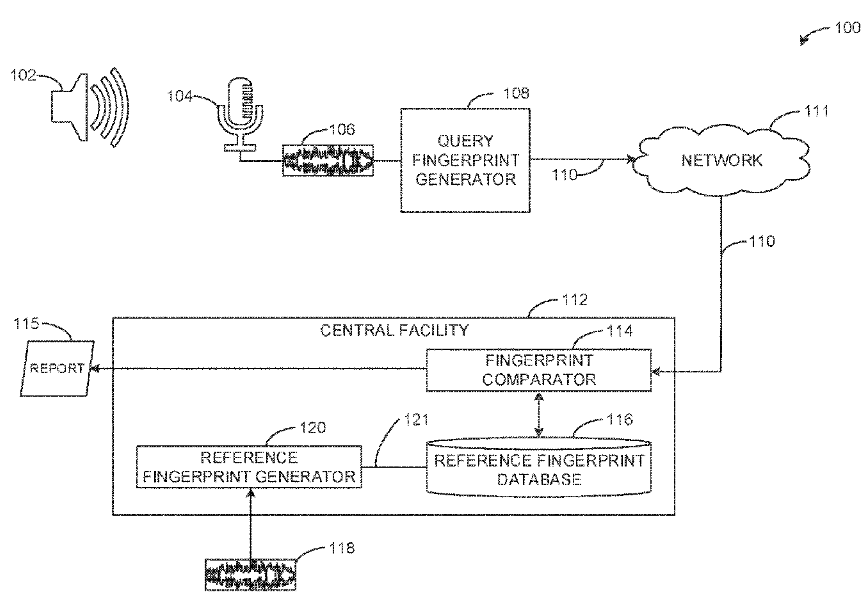
(57) **ABSTRACT**

Methods, apparatus, systems, and articles of manufacture to fingerprint an audio signal. An example apparatus disclosed herein includes an audio segmenter to divide an audio signal into a plurality of audio segments, a bin normalizer to normalize the second audio segment to thereby create a first normalized audio segment, a subfingerprint generator to generate a first subfingerprint from the first normalized audio segment, the first subfingerprint including a first portion corresponding to a location of an energy extremum in the normalized second audio segment, a portion strength evaluator to determine a likelihood of the first portion to change, and a portion replacer to, in response to determining the likelihood does not satisfy a threshold, replace the first portion with a second portion to thereby generate a second subfingerprint.

17 Claims, 11 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

10,866,989	B1	12/2020	Chandler et al.	
2003/0086341	A1	5/2003	Wells et al.	
2006/0020958	A1	1/2006	Allamanche et al.	
2008/0215651	A1	9/2008	Sawada et al.	
2009/0052784	A1	2/2009	Covell et al.	
2011/0035035	A1	2/2011	Khan et al.	
2011/0064244	A1	3/2011	Eisenberg et al.	
2011/0261257	A1	10/2011	Terry et al.	
2011/0307085	A1*	12/2011	Selby	G10L 25/18 700/94
2012/0103166	A1	5/2012	Shibuya et al.	
2013/0279704	A1	10/2013	Crockett	
2013/0279740	A1*	10/2013	Bauer	G06F 16/285 382/100
2014/0114456	A1	4/2014	Stavropoulos et al.	
2014/0180674	A1	6/2014	Neuhauser et al.	
2014/0310006	A1	10/2014	Anguera Miro et al.	
2016/0148620	A1	5/2016	Bilobrov	
2016/0247512	A1	8/2016	Duong et al.	
2017/0365276	A1	12/2017	Greene	
2019/0130032	A1	5/2019	Donier et al.	
2019/0139557	A1	5/2019	Hodgson et al.	
2020/0082835	A1	3/2020	Coover et al.	
2021/0157838	A1	5/2021	Berrian et al.	

FOREIGN PATENT DOCUMENTS

JP	2020527255 A	*	9/2020	G10L 25/54
KR	20130055115		5/2013	
KR	20170027648		3/2017	
KR	20180135464		12/2018	
TW	201640492 A	*	11/2016	G06F 16/61

OTHER PUBLICATIONS

X. Anguera, A. Garzon and T. Adamek, "MASK: Robust Local Features for Audio Fingerprinting," 2012 IEEE International Conference on Multimedia and Expo, 2012, pp. 455-460, doi: 10.1109/ICME.2012.137. (Year: 2012).*

S. Yao, B. Niu and J. Liu, "Audio Identification by Sampling Sub-fingerprints and Counting Matches," in IEEE Transactions on Multimedia, vol. 19, No. 9, pp. 1984-1995, Sep. 2017, doi: 10.1109/TMM.2017.2723846. (Year: 2017).*

Haitsma, Kalker "A Highly Robust Audio Fingerprinting System" Retrieved from https://ismir2002.ismir.net/proceedings/02-FP04-2.pdf (Year: 2002).*

B. Coover and J. Han, "A Power Mask based audio fingerprint," 2014 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2014, pp. 1394-1398, doi: 10.1109/ICASSP.2014.6853826 (Year: 2014).*

International Searching Authority, "Written Opinion of the International Searching Authority", issued in connection with International Patent Application No. PCT/US2022/015442 dated May 18, 2022, 3 pages.

International Searching Authority, "International Search Report", issued in connection with International Patent Application No. PCT/US2022/015442 dated May 18, 2022, 4 pages.

Canadian Intellectual Property Office, "Examination Report", issued in connection with Canadian Patent Application No. 3,111,800 dated Mar. 7, 2022, 4 pages.

IP Australia, "Examination Report No. 1", issued in connection with Australian Patent Application No. 2019335404 dated Jan. 27, 2022, 3 pages.

International Searching Authority, "Written Opinion of the International Searching Authority", issued in connection with International Patent Application No. PCT/US2020/061077 dated Mar. 5, 2021, 3 pages.

International Searching Authority, "International Search Report", issued in connection with International Patent Application No. PCT/US2020/061077 dated Mar. 5, 2021, 3 pages.

International Searching Authority, "International Preliminary Report on Patentability", issued in connection with International Patent Application No. PCT/US2019/049953 dated Mar. 9, 2021, 7 pages.

European Patent Office, "Communication Pursuant to Rules 161(2) and 162 EPC", issued in connection with European Patent Application No. 19857365.1 dated Apr. 14, 2021, 3 pages.

French Patent Office, "Notice of Decision to Grant", issued in connection with French Patent Application No. 18 58041 dated Feb. 12, 2021, 2 pages, (English Summary Included).

French Patent Office, "Office Action", issued in connection with French Patent Application No. 18 58041 dated Jan. 21, 2019, 12 pages (English Summary Included).

European Patent Office, "Communication of European Publication No. and Information on the Application of Article 67(3) EPC", issued in connection with European Patent Application No. 20891501.7 dated Sep. 7, 2022, 1 page.

Wooram Son, "Sub-Fingerprint Masking for a Robust Audio Fingerprinting System in a Real-noise Environment for Portable Consumer Devices", 2010, 2 pages.

International Searching Authority, "International Search Report", issued in connection with International Patent Application No. PCT/US2019/049953 dated Dec. 23, 2019, 3 pages.

International Searching Authority, "Written Opinion of the International Searching Authority", issued in connection with International Patent Application No. PCT/US2019/049953 dated Dec. 23, 2019, 5 pages.

Japanese Patent Office, "Notice of Reasons for Rejection", issued in connection with Japanese Patent Application No. 21-5165-XY dated Apr. 26, 2022, 6 pages, (English Translation Included).

European Patent Office, "Extended European Search Report", issued in connection with European Patent Application No. 19857365.1 dated Jun. 7, 2022, 8 pages.

European Patent Office, "Communication Pursuant to Rules 161(2) and 162 EPC", issued in connection with European Patent Application No. 20891501.7 dated Jul. 5, 2022, 3 pages.

IP Australia, "Notice of Acceptance for Patent Application", issued in connection with Australian Patent Application No. 2019335404 dated Aug. 10, 2022, 3 pages.

European Patent Office, "Communication Pursuant to Rules 70(2) and 70a(2) EPC", issued in connection with European Patent Application No. 19857365.1 dated Jun. 24, 2022, 1 page.

International Searching Authority, "International Preliminaiy Report on Patentability", issued in connection with International Patent Application No. PCT/US2020/061077 dated May 17, 2022, 4 pages.

United States Patent and Trademark Office, "Non-Final Office Action", issued in connection with U.S. Appl. No. 16/453,654 dated Apr. 29, 2021, 10 pages.

International Searching Authority, "International Preliminaiy Report on Patentability", issued in connection with PCT/US2019/049953 dated Mar. 9, 2021, 7 pages.

United States Patent and Trademark Office, "Non-Final Office Action", issued in connection with U.S. Appl. No. 16/696,874 dated Jun. 24, 2022, 22 pages.

United States Patent and Trademark Office, "Advisary Action", issued in connection with U.S. Appl. No. 16/453,654 dated Feb. 8, 2022, 3 pages.

United States Patent and Trademark Office, "Non-Final Office Action", issued in connection with U.S. Appl. No. 16/453,654 dated May 26, 2022, 10 pages.

* cited by examiner

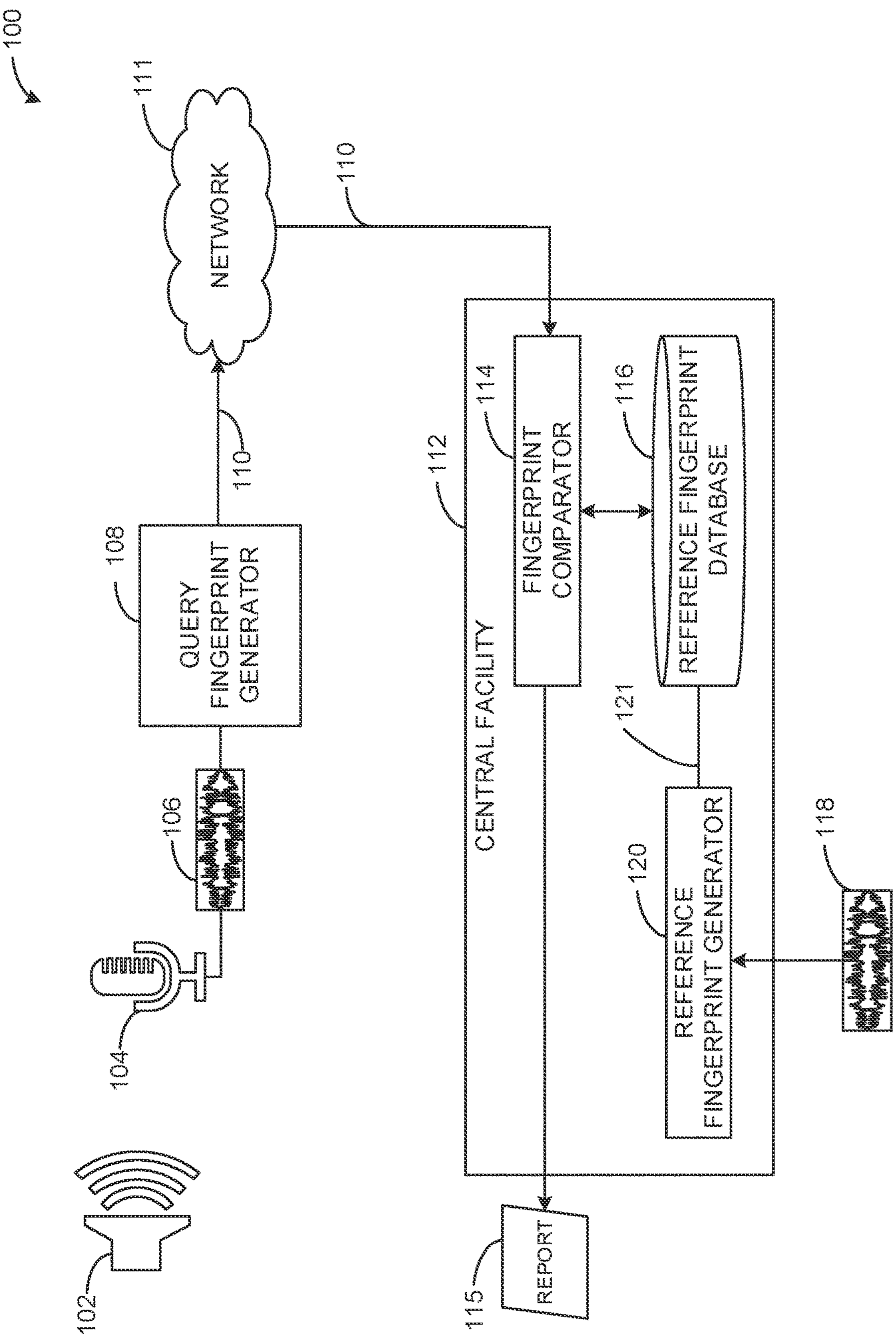

100
111
NETWORK
110
108
QUERY FINGERPRINT GENERATOR
110
106
104
102
112
CENTRAL FACILITY
114
FINGERPRINT COMPARATOR
116
REFERENCE FINGERPRINT DATABASE
121
120
REFERENCE FINGERPRINT GENERATOR
118
115
REPORT

FIG. 1

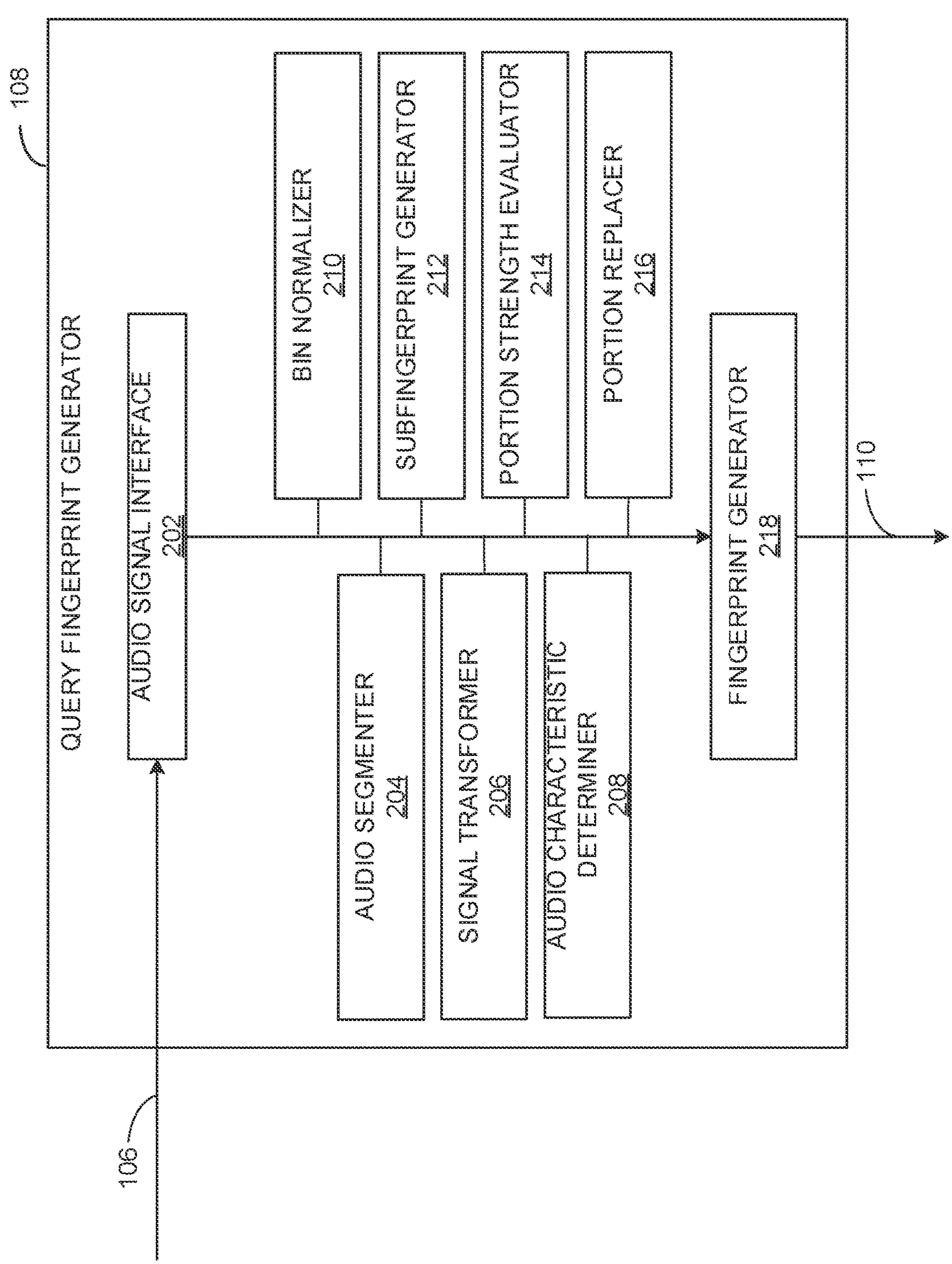

108
QUERY FINGERPRINT GENERATOR
AUDIO SIGNAL INTERFACE 202
BIN NORMALIZER 210
SUBFINGERPRINT GENERATOR 212
PORTION STRENGTH EVALUATOR 214
PORTION REPLACER 216
AUDIO SEGMENTER 204
SIGNAL TRANSFORMER 206
AUDIO CHARACTERISTIC DETERMINER 208
FINGERPRINT GENERATOR 218
110
106

FIG. 2

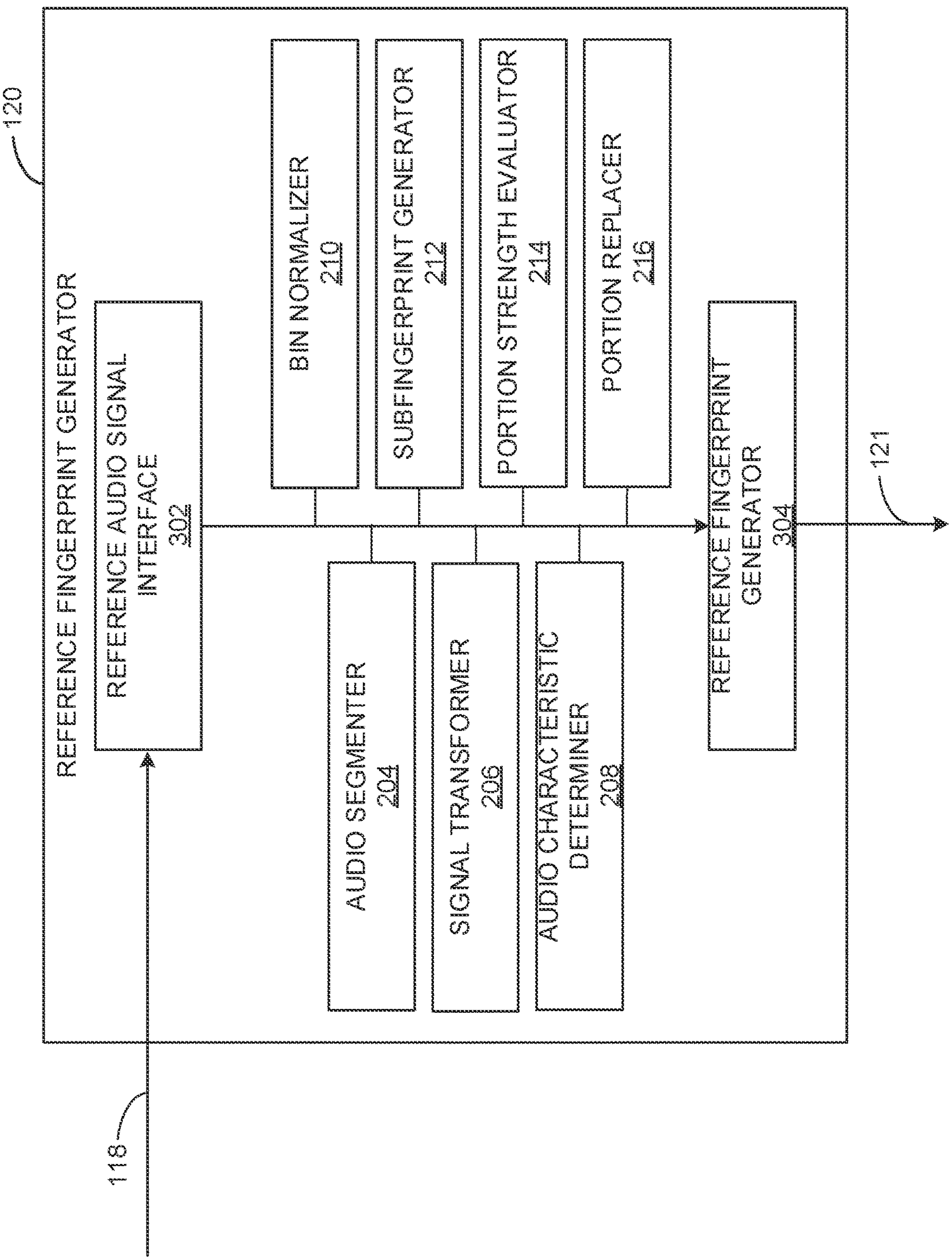

120
REFERENCE FINGERPRINT GENERATOR
REFERENCE AUDIO SIGNAL INTERFACE
302
BIN NORMALIZER
210
SUBFINGERPRINT GENERATOR
212
PORTION STRENGTH EVALUATOR
214
PORTION REPLACER
216
AUDIO SEGMENTER
204
SIGNAL TRANSFORMER
206
AUDIO CHARACTERISTIC DETERMINER
208
REFERENCE FINGERPRINT GENERATOR
304
121
118

FIG. 3

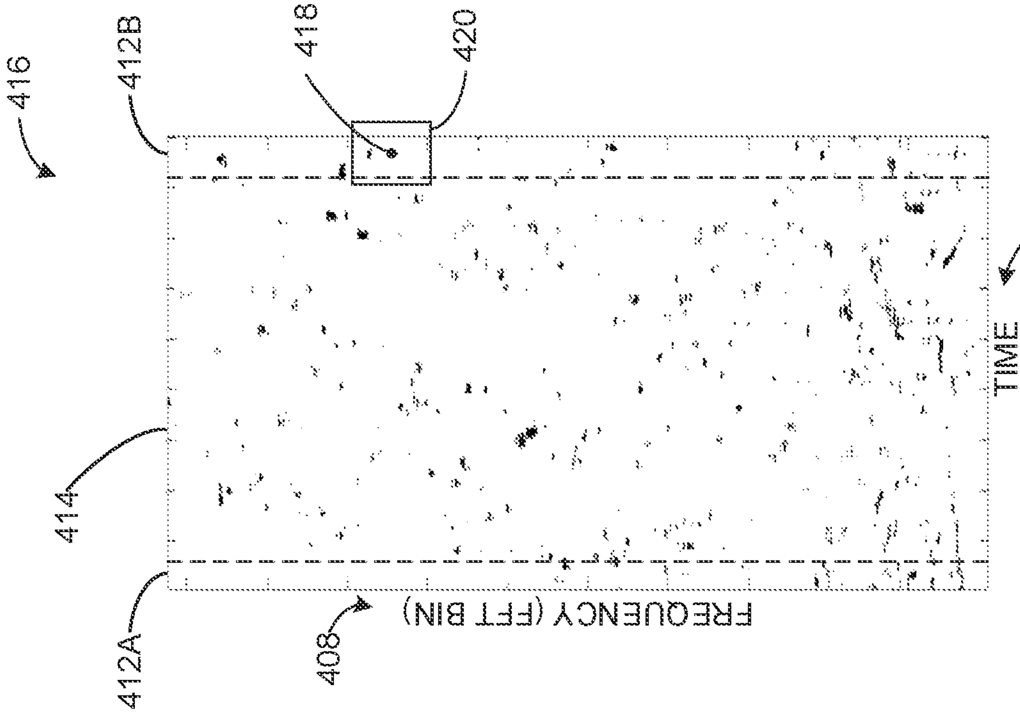

416
412B
418
420
414
412A
408
FREQUENCY (FFT BIN)
TIME
410

FIG. 4B

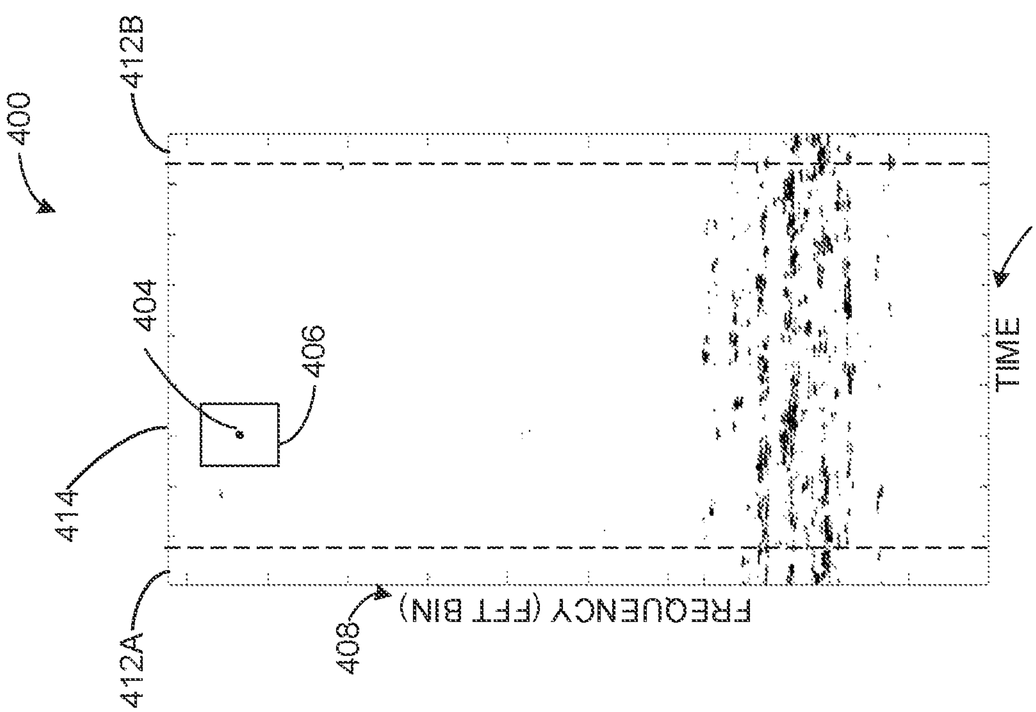

400
412B
404
406
414
412A
408
FREQUENCY (FFT BIN)
TIME
410

FIG. 4A

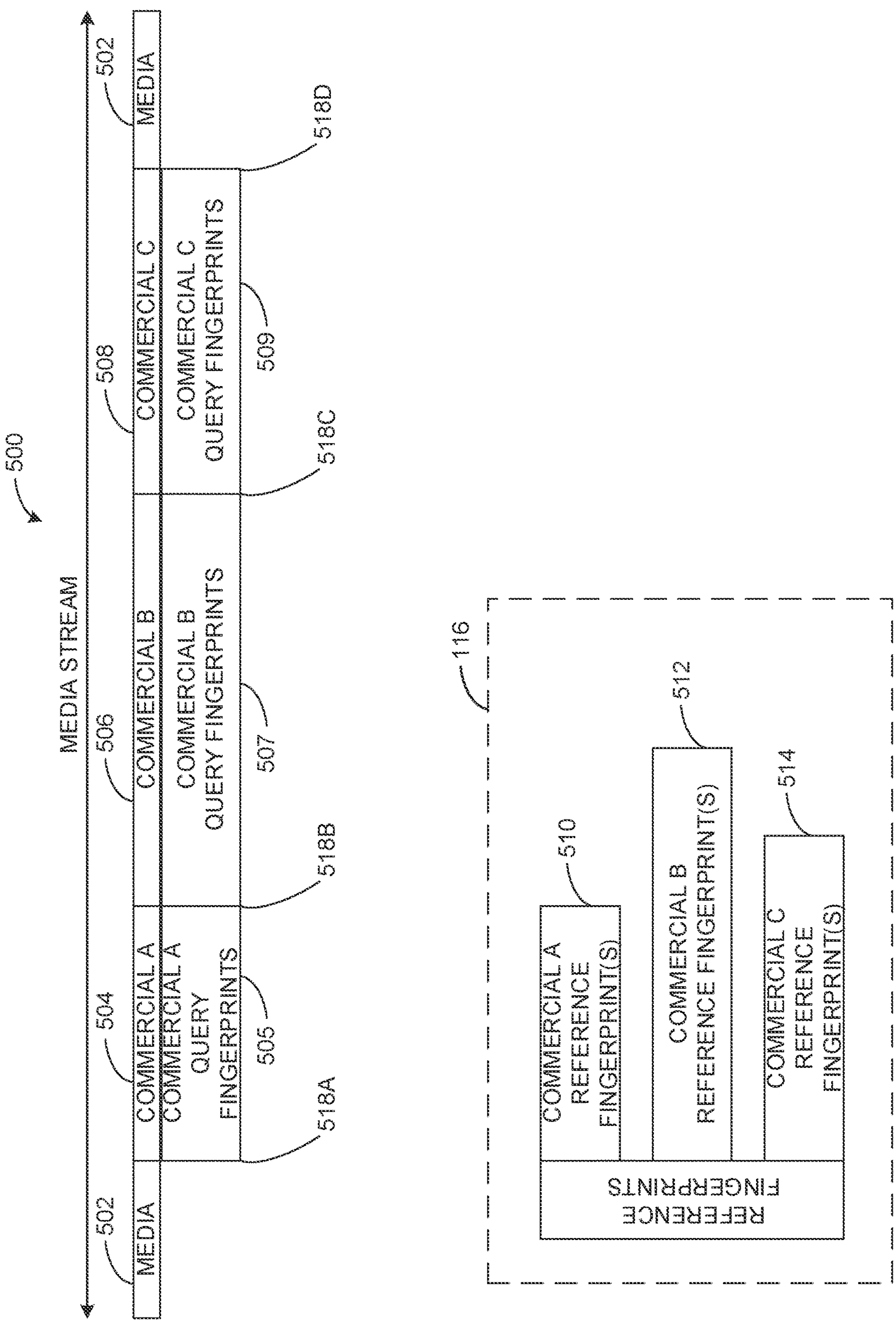
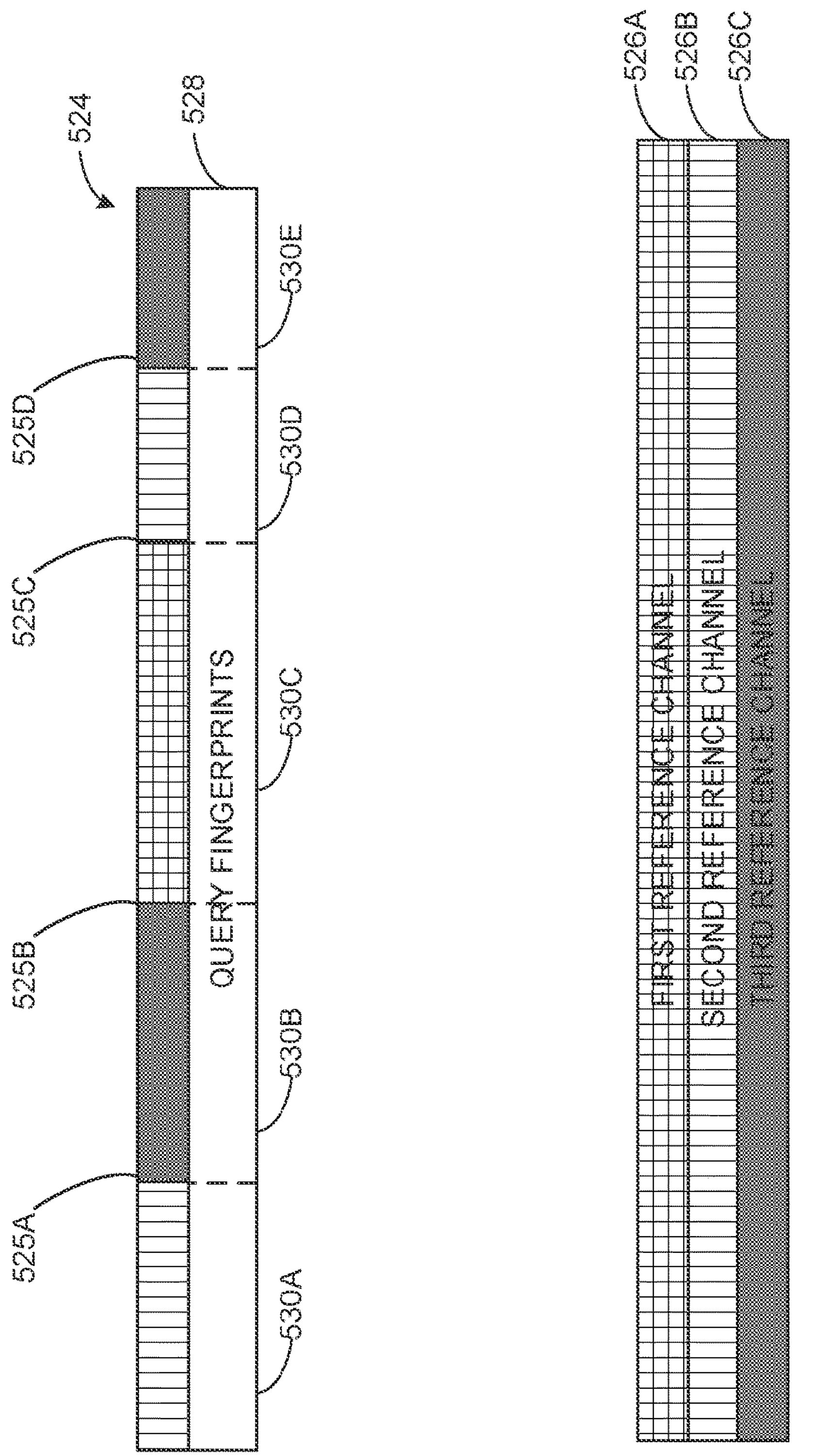

500
MEDIA STREAM
MEDIA
502
COMMERCIAL A
504
COMMERCIAL A QUERY FINGERPRINTS
505
COMMERCIAL B
506
COMMERCIAL B QUERY FINGERPRINTS
507
COMMERCIAL C
508
COMMERCIAL C QUERY FINGERPRINTS
509
518A
518B
518C
518D
116
REFERENCE FINGERPRINTS
COMMERCIAL A REFERENCE FINGERPRINT(S)
510
COMMERCIAL B REFERENCE FINGERPRINT(S)
512
COMMERCIAL C REFERENCE FINGERPRINT(S)
514

FIG. 5A



524
528
525A
525B
525C
525D
530A
530B
530C
530D
530E
QUERY FINGERPRINTS
526A
526B
526C
FIRST REFERENCE CHANNEL
SECOND REFERENCE CHANNEL
THIRD REFERENCE CHANNEL

FIG. 5B

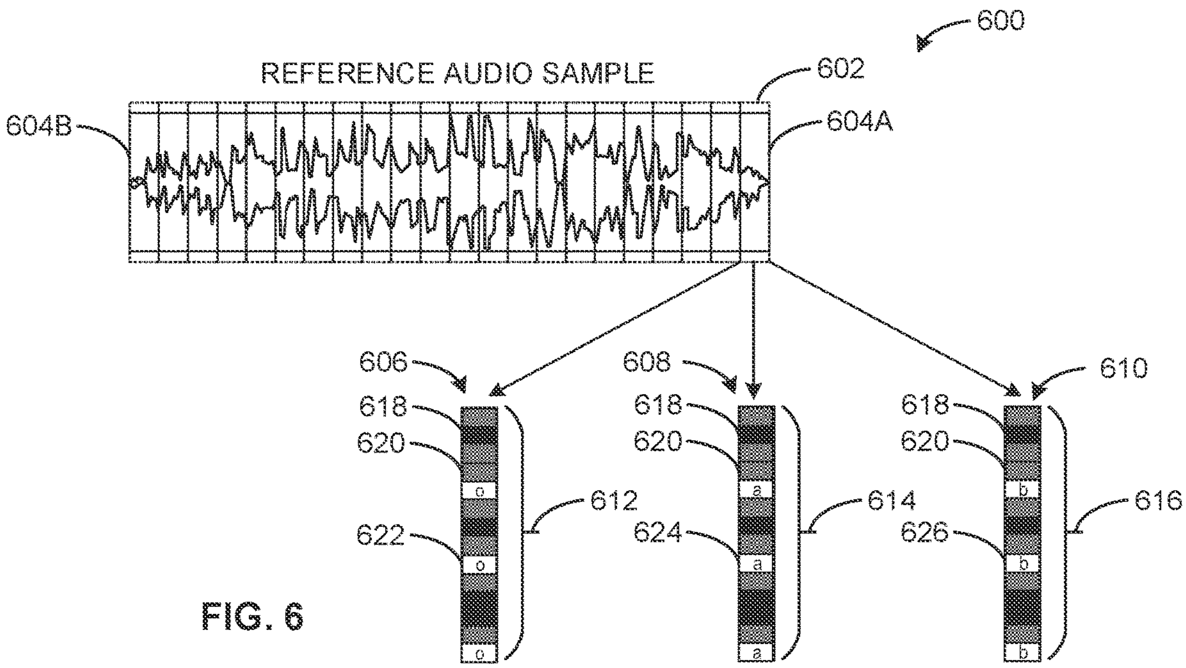

600
REFERENCE AUDIO SAMPLE
602
604B
604A
606
608
610
618
620
o
622
612
a
624
614
b
626
616

FIG. 6

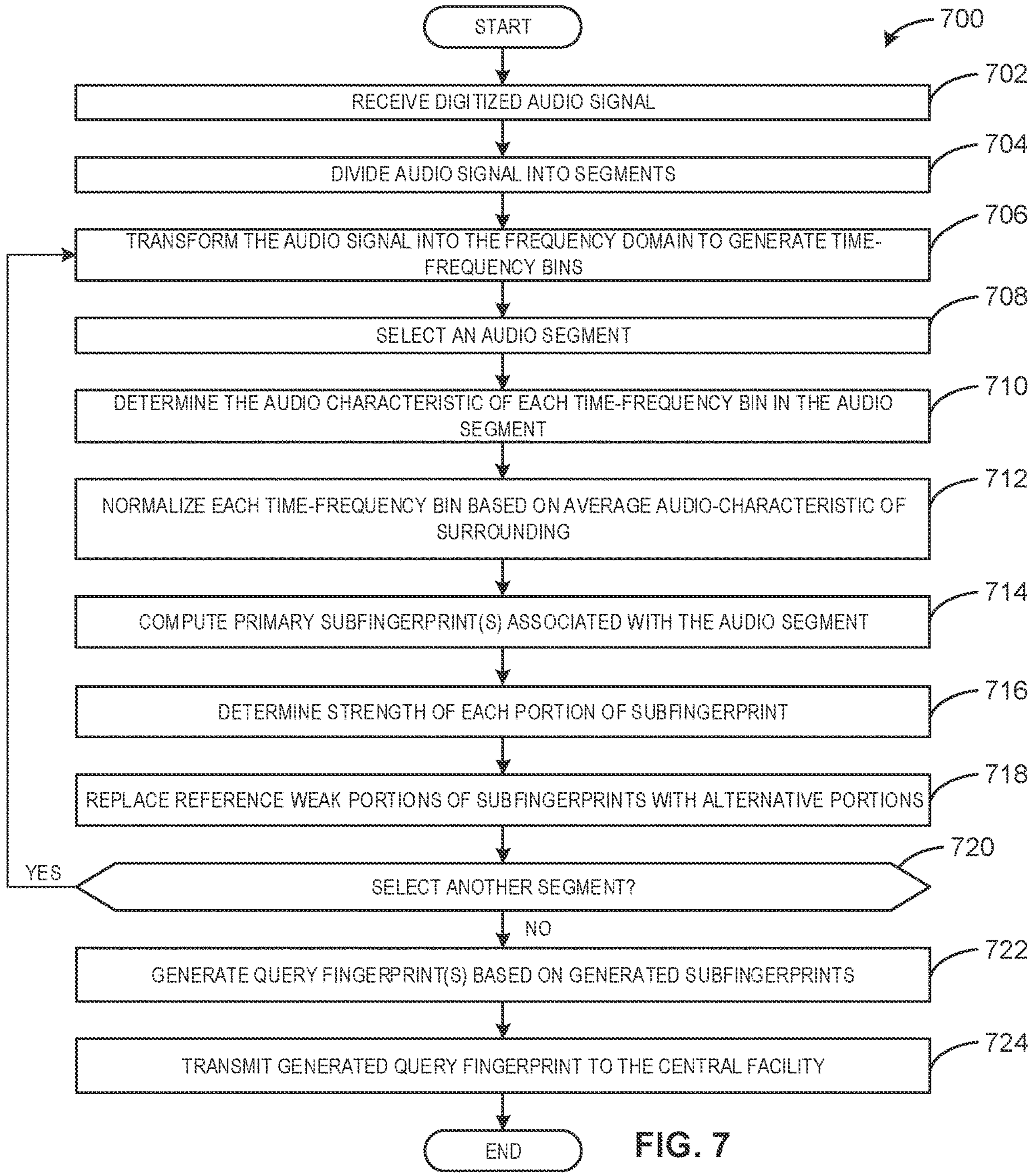

START
700
RECEIVE DIGITIZED AUDIO SIGNAL
702
DIVIDE AUDIO SIGNAL INTO SEGMENTS
704
TRANSFORM THE AUDIO SIGNAL INTO THE FREQUENCY DOMAIN TO GENERATE TIME-FREQUENCY BINS
706
SELECT AN AUDIO SEGMENT
708
DETERMINE THE AUDIO CHARACTERISTIC OF EACH TIME-FREQUENCY BIN IN THE AUDIO SEGMENT
710
NORMALIZE EACH TIME-FREQUENCY BIN BASED ON AVERAGE AUDIO-CHARACTERISTIC OF SURROUNDING
712
COMPUTE PRIMARY SUBFINGERPRINT(S) ASSOCIATED WITH THE AUDIO SEGMENT
714
DETERMINE STRENGTH OF EACH PORTION OF SUBFINGERPRINT
716
REPLACE REFERENCE WEAK PORTIONS OF SUBFINGERPRINTS WITH ALTERNATIVE PORTIONS
718
SELECT ANOTHER SEGMENT?
720
YES
NO
GENERATE QUERY FINGERPRINT(S) BASED ON GENERATED SUBFINGERPRINTS
722
TRANSMIT GENERATED QUERY FINGERPRINT TO THE CENTRAL FACILITY
724
END

FIG. 7

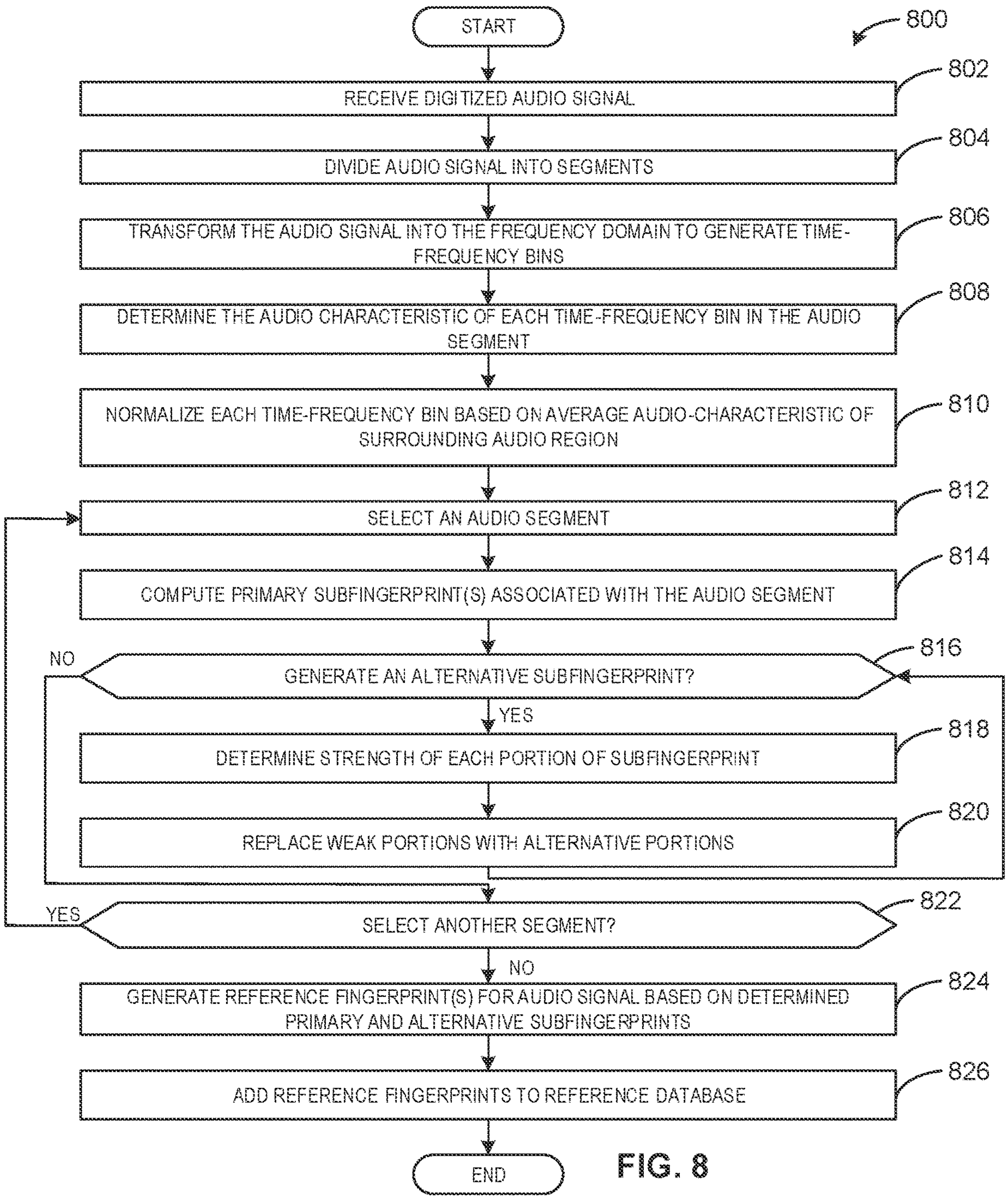

800
START
RECEIVE DIGITIZED AUDIO SIGNAL
802
DIVIDE AUDIO SIGNAL INTO SEGMENTS
804
TRANSFORM THE AUDIO SIGNAL INTO THE FREQUENCY DOMAIN TO GENERATE TIME-FREQUENCY BINS
806
DETERMINE THE AUDIO CHARACTERISTIC OF EACH TIME-FREQUENCY BIN IN THE AUDIO SEGMENT
808
NORMALIZE EACH TIME-FREQUENCY BIN BASED ON AVERAGE AUDIO-CHARACTERISTIC OF SURROUNDING AUDIO REGION
810
SELECT AN AUDIO SEGMENT
812
COMPUTE PRIMARY SUBFINGERPRINT(S) ASSOCIATED WITH THE AUDIO SEGMENT
814
GENERATE AN ALTERNATIVE SUBFINGERPRINT?
816
NO
YES
DETERMINE STRENGTH OF EACH PORTION OF SUBFINGERPRINT
818
REPLACE WEAK PORTIONS WITH ALTERNATIVE PORTIONS
820
SELECT ANOTHER SEGMENT?
822
YES
NO
GENERATE REFERENCE FINGERPRINT(S) FOR AUDIO SIGNAL BASED ON DETERMINED PRIMARY AND ALTERNATIVE SUBFINGERPRINTS
824
ADD REFERENCE FINGERPRINTS TO REFERENCE DATABASE
826
END

FIG. 8

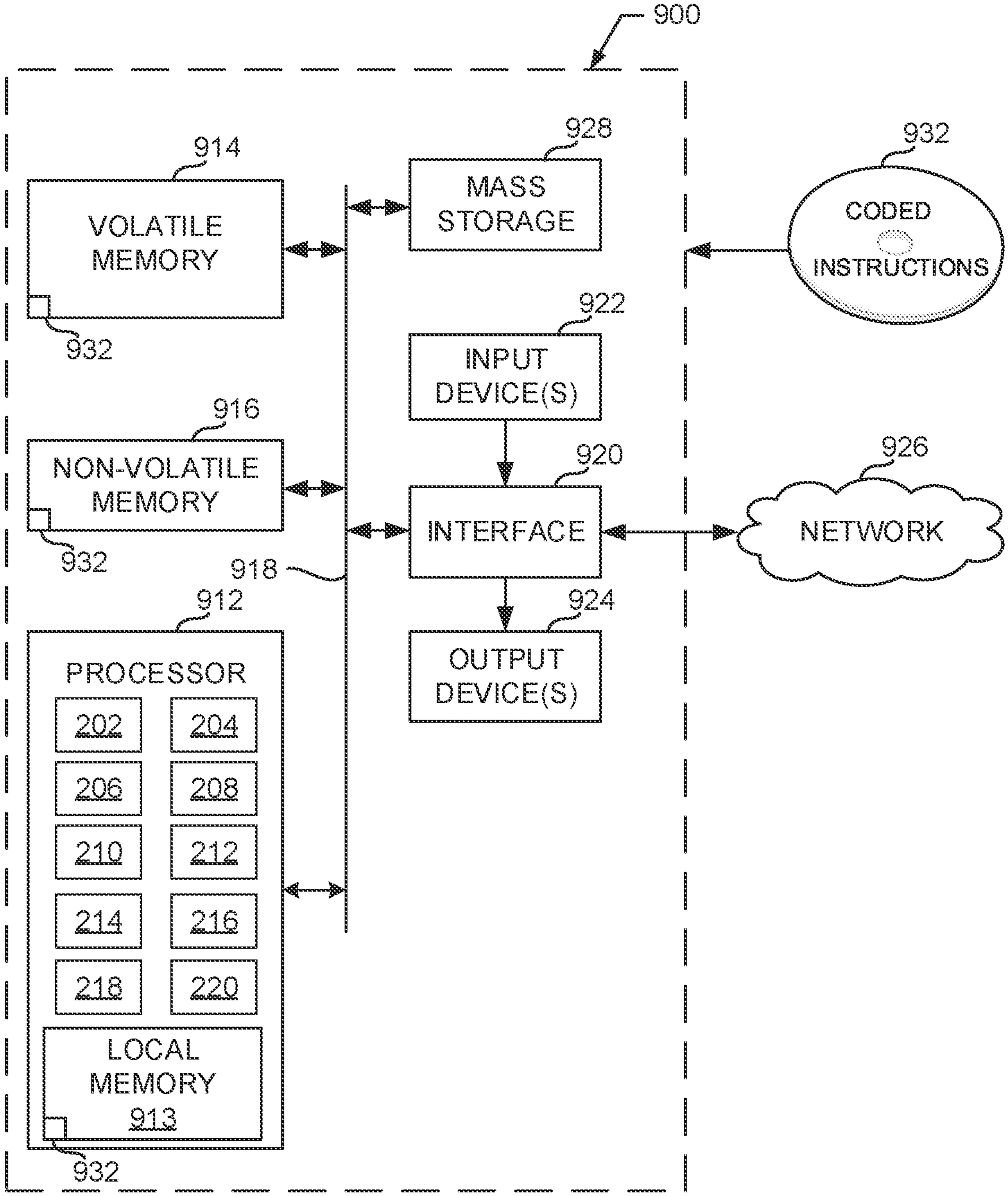

900
914
VOLATILE MEMORY
932
916
NON-VOLATILE MEMORY
932
918
912
PROCESSOR
202
204
206
208
210
212
214
216
218
220
LOCAL MEMORY 913
932
928
MASS STORAGE
922
INPUT DEVICE(S)
920
INTERFACE
924
OUTPUT DEVICE(S)
932
CODED INSTRUCTIONS
926
NETWORK

FIG. 9

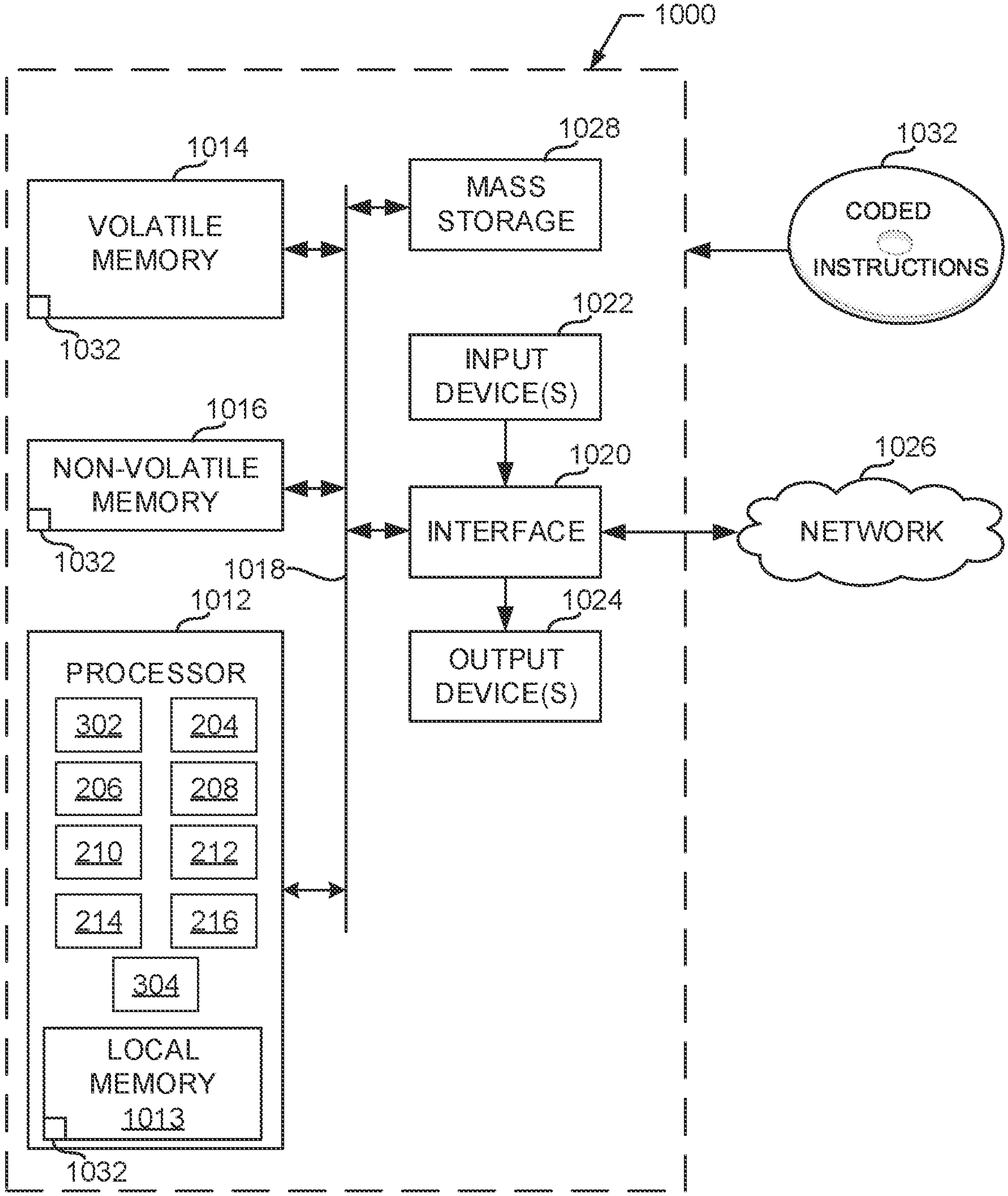

1000
1014
VOLATILE MEMORY
1032
1028
MASS STORAGE
1032
CODED INSTRUCTIONS
1022
INPUT DEVICE(S)
1016
NON-VOLATILE MEMORY
1032
1020
INTERFACE
1026
NETWORK
1018
1012
1024
OUTPUT DEVICE(S)
PROCESSOR
302
204
206
208
210
212
214
216
304
LOCAL MEMORY
1013
1032

FIG. 10

METHODS AND APPARATUS TO FINGERPRINT AN AUDIO SIGNAL

FIELD OF THE DISCLOSURE

This disclosure relates generally to audio signal processing, and, more particularly, to methods and apparatus to fingerprint an audio signal.

BACKGROUND

Audio information (e.g., sounds, speech, music, etc.) can be represented as digital data (e.g., electronic, optical, etc.). Captured audio (e.g., via a microphone) can be digitized, stored electronically, processed, and/or cataloged. One way of cataloging audio information is by generating an audio fingerprint. Audio fingerprints are digital summaries of audio information created by sampling a portion of the audio signal. Audio fingerprints have historically been used to identify audio and/or verify audio authenticity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an example system in which the teachings of this disclosure may be implemented.

FIG. **2** is an example implementation of the query fingerprint generator of FIG. **1**.

FIG. **3** is an example implementation of the reference fingerprint generator of FIG. **1**.

FIG. **4**A depicts an example unprocessed spectrogram generated by the example signal transformer of FIG. **2**.

FIG. **4**B depicts an example of a normalized spectrogram generated by the signal normalizer of FIG. **2** from the unprocessed spectrogram of FIG. **4**A.

FIG. **5**A is the content of an audio signal including commercials that can be processed by the system of FIG. **1**.

FIG. **5**B is the content of an audio signal including multiple channel changes that can be processed by the system of FIG. **1**.

FIG. **6** is an illustration showing the generation of alternative reference fingerprints output by the reference fingerprint generator of FIGS. **1** and **3**.

FIG. **7** is a flowchart representative of machine-readable instructions that may be executed to implement the query fingerprint generator of FIGS. **1** and **2**.

FIG. **8** is a flowchart representative of machine-readable instructions that may be executed to implement the reference fingerprint generator of FIGS. **1** and **3**.

FIG. **9** is a block diagram of an example processing platform structured to execute the instructions of FIG. **7** to implement the reference fingerprint generator of FIGS. **1** and/or **3**.

FIG. **10** is a block diagram of an example processing platform structured to execute the instructions of FIG. **8** to implement the query fingerprint generator of FIGS. **1** and/or **3**.

The figures are not to scale. Instead, the thickness of the layers or regions may be enlarged in the drawings. In general, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts.

Unless specifically stated otherwise, descriptors such as "first," "second," "third," etc. are used herein without imputing or otherwise indicating any meaning of priority, physical order, arrangement in a list, and/or ordering in any way, but are merely used as labels and/or arbitrary names to distinguish elements for ease of understanding the disclosed examples. In some examples, the descriptor "first" may be used to refer to an element in the detailed description, while the same element may be referred to in a claim with a different descriptor such as "second" or "third." In such instances, it should be understood that such descriptors are used merely for identifying those elements distinctly that might, for example, otherwise share a same name.

DETAILED DESCRIPTION

Fingerprint or signature-based media monitoring techniques generally utilize one or more inherent characteristics of the monitored media during a monitoring time interval to generate a substantially unique proxy for the media. Such a proxy is referred to as a signature or fingerprint, and can take any form (e.g., a series of digital values, a waveform, etc.) representative of any aspect(s) of the media signal(s) (e.g., the audio and/or video signals forming the media presentation being monitored). A signature can be a series of sub-signatures collected in series over a time interval. The term "fingerprint" and "signature" are used interchangeably herein and are defined herein to mean a proxy for identifying media that is generated from one or more inherent characteristics of the media.

Signature-based media monitoring generally involves determining (e.g., generating and/or collecting) signature(s) representative of a media signal (e.g., an audio signal and/or a video signal) output by a monitored media device and comparing the monitored media signature(s) to one or more reference signatures corresponding to known (e.g., reference) media sources. Various comparison criteria, such as a cross-correlation value, a Hamming distance, etc., can be evaluated to determine whether a monitored signature matches a particular reference signature.

When a match between the monitored signature and one of the reference signatures is found, the monitored media can be identified as corresponding to the particular reference media represented by the reference signature that matched with the monitored media signature. Because attributes, such as an identifier of the media, a presentation time, a broadcast channel, etc., are collected for the reference signature, these attributes can then be associated with the monitored media whose monitored signature matched the reference signature. Example systems for identifying media based on codes and/or signatures are long known and were first disclosed in Thomas, U.S. Pat. No. 5,481,294, which is hereby incorporated by reference in its entirety.

Historically, audio fingerprinting technology has used the loudest parts (e.g., the parts with the most energy, etc.) of an audio signal to create fingerprints in a time segment. In some examples, the loudest parts of an audio signal can be associated with noise (e.g., unwanted audio) and not from the audio of interest. In some examples, fingerprints generated using historic audio fingerprint technology would be generated based on the background noise and not of the audio of interest, which reduces the usefulness of the generated fingerprint. Additionally, fingerprints of music generated using these historic audio fingerprint technologies often are not generated information from all parts of the audio spectrum that can be used for signature matching because the bass spectrum of audio tends to be louder than other frequencies spectra in the audio (e.g., treble ranges, etc.). Some example methods, apparatus, systems, and articles of manufacture to overcome the above-noted deficiencies by generating fingerprints using mean normalization and are disclosed in U.S. patent application Ser. No. 16/453,654, which is hereby incorporated by reference in its entirety.

Audio signaturing technologies, like the technologie(s) disclosed in U.S. patent application Ser. No. 16/453,654, use characteristics of temporal adjacent audio spectra characteristics to normalize specific aspects of the audio signal. The normalized audio spectra are then used to generate audio fingerprints. That is, the fingerprint of a specific portion of an audio signal is based upon a temporal window of the audio signal around that specific portion (e.g., a six second audio window, etc.). This non-local dependence can cause adverse effects on query fingerprint generation and reference fingerprint generation due to boundary/edge effects. For example, if the audio signal includes multiple audio sources (e.g., multiple commercials during an audio signal associated with a commercial break, an audio signal including a song transition, an audio signal including a channel change, etc.), the fingerprint of one audio source may generated based partially on the audio characteristics of the adjacent sources.

Method and apparatus disclosed herein overcome the above noted-deficiencies by determining the relative strength of the portions of the subfingerprints of a fingerprint. In some examples disclosed herein, each portion of a subfingerprint can be characterized based on how dependent the value of that portion is on the variations in the surrounding audio signal region. In such examples disclosed herein, weak portions of a subfingerprint correspond to portions of a subfingerprint that frequently change due to noise or surrounding characteristics of the audio signal. In such examples disclosed herein, strong portions of a subfingerprint correspond to portions of a subfingerprint that infrequently change due to noise or surrounding characteristics of the audio signal. In some examples disclosed herein, during reference fingerprint generation, alternative fingerprints can be generated based on the identified weak subfingerprint portions based on the probability of their occurrences. In some examples disclosed herein, during the generation of a query fingerprint, modified query fingerprints can be generated by changing the weak portions of the query fingerprint. In some examples disclosed herein, weak portions of the subfingerprint can be excluded during fingerprint matching.

FIG. **1** is an example system **100** in which the teachings of this disclosure can be implemented. The example system **100** includes an example audio source **102**, an example microphone **104** that captures sound from the audio source **102** and converts the captured sound into an example audio signal **106**. An example query fingerprint generator **108** receives the audio signal **106** and generates one or more example query fingerprint(s) **110**, which is transmitted over an example network **111** to an example central facility **112**. The central facility **112** includes an example fingerprint comparator **114**, which matches the example query fingerprint(s) **110** to fingerprints of an example reference fingerprint database **116** to generate an example media identification report **115**. The example reference fingerprint database **116** includes reference fingerprints generated by a reference fingerprint generator **120**. In the illustrated example of FIG. **1**, the reference fingerprint generator **120** generates reference fingerprints based on a reference audio signal **118**.

The example audio source **102** emits an audible sound. The example audio source can be a speaker (e.g., an electroacoustic transducer, etc.), a live performance, a conversation, and/or any other suitable source of audio. The example audio source **102** can include desired audio (e.g., the audio to be fingerprinted, etc.) and can also include undesired audio (e.g., background noise, etc.). In the illustrated example, the audio source **102** is a speaker. In other examples, the audio source **102** can be any other suitable audio source (e.g., a person, etc.).

The example microphone **104** is a transducer that converts the sound emitted by the audio source **102** into the audio signal **106**. In some examples, the microphone **104** can be a component of a computer, a mobile device (a smartphone, a tablet, etc.), a navigation device, or a wearable device (e.g., a smartwatch, etc.). In some examples, the microphone can include an analog-to digital converter to digitize the audio signal **106**. In other examples, the query fingerprint generator **108** can digitize the audio signal **106**.

The example audio signal **106** is a digitized representation of the sound emitted by the audio source **102**. In some examples, the audio signal **106** can be saved on a computer before being processed by the query fingerprint generator **108**. In some examples, the audio signal **106** can be transferred over a network (e.g., the network **111**, etc.) to the example query fingerprint generator **108**. Additionally or alternatively, any other suitable method can be used to generate the audio (e.g., digital synthesis, etc.).

The example query fingerprint generator **108** converts the example audio signal **106** into the example query fingerprint(s) **110**. In some examples, the query fingerprint generator **108** can convert some or all of the audio signal **106** into the frequency domain. In some examples, the query fingerprint generator **108** divides the audio signal into time-frequency bins. In some examples, the audio characteristic is the energy of the audio signal. In other examples, any other suitable audio characteristic can be determined and used to normalize each time-frequency bin (e.g., the entropy of the audio signal, etc.). In some examples, the query fingerprint generator **108** identifies the weak portions of the query fingerprint(s) **110** and modifies the query fingerprint(s) **110** to replace the identified weak portions. Additionally or alternatively, any suitable means can be used to generate the query fingerprint(s) **110**. In some examples, some or all of the components of the query fingerprint generator **108** can be implemented by a mobile device (e.g., a mobile device associated with the microphone **104**, etc.). In other examples, the query fingerprint generator **108** can be implemented by any other suitable device(s). An example implementation of the query fingerprint generator **108** is described below in conjunction with FIG. **2**.

The example query fingerprint(s) **110** are a condensed digital summary of the audio signal **106** that can be used to identify and/or verify the audio signal **106**. For example, the query fingerprint(s) **110** can be generated by sampling portions of the audio signal **106** and processing those portions. In some examples, the query fingerprint(s) **110** is composed of a plurality of subfingerprints, which correspond to distinct samples of the audio signal **106**. In some examples, the query fingerprint(s) **110** is associated with a period of time (e.g., six seconds, 48 seconds, etc.) of audio signal **106**. In some examples, the query fingerprint(s) **110** can include samples of the highest energy portions of the audio signal **106**. In some examples, the query fingerprint(s) **110** can be used to identify the audio signal **106** (e.g., determine what song is being played, etc.). In some examples, the query fingerprint(s) **110** can be used to verify the authenticity of the audio signal **106**.

The example network **111** is a network that allows the query fingerprint(s) **110** to be transmitted to the central facility **112** and fingerprint comparator **114**. For example, the network **111** is a local area network (LAN), a wide area network (WAN), etc. In some examples, the network **111** is the Internet. In some examples, the network **111** is a wired connection. In some examples, the network **111** is absent. In such examples, the query fingerprint(s) **110** can be transmitted to the central facility **112** by any other suitable means (e.g., a physical storage device, etc.). Additionally or alternatively, the query fingerprint generator **108**, the reference fingerprint generator **120**, and/or the fingerprint comparator **114** can be implemented by or at the same device (e.g., a server at the central facility **112** of media monitoring entity, etc.).

The central facility **112** is a facility operated to analyze reference fingerprints, associated with an interested party to analyze, identify, and categorize audio signals (e.g., a media monitoring entity, a media provider, etc.). In some examples, the central facility **112** can be include and/or be implemented by a server. In some examples, the central facility **112** can be implemented by a cloud service, a distributed system at several locations, and/or any other suitable means. In the illustrated example of FIG. **1**, the central facility **112** includes the fingerprint comparator **114**, the reference fingerprint database **116**, and the reference fingerprint generator **120**. In other examples, the fingerprint comparator **114**, the reference fingerprint database **116**, and the reference fingerprint generator **120** can be implemented at any other suitable location (e.g., at a user device, at a third party location, etc.).

The example fingerprint comparator **114** receives and processes the query fingerprint(s) **110**. For example, the fingerprint comparator **114** can match the query fingerprint(s) **110** to one or more reference fingerprint(s) stored in the reference fingerprint database **116**. In some examples, the fingerprint comparator **114** can determine the query fingerprint(s) **110** matches none of the reference fingerprints stored in the reference fingerprint database **116**. In such examples, the fingerprint comparator **114** returns a result indicating the media associated with the reference fingerprint could not be identified. In some examples, one of the query fingerprint(s) **110** can be compared to multiple reference fingerprints associated with one reference audio signal. In such examples, a match with any of the reference fingerprints indicates the query fingerprint(s) **110** is associated with the same media as the reference audio signal **118**. Additionally or alternatively, multiple query fingerprint(s) **110** can be compared with the reference fingerprint(s) **121**. In some such examples, a match with any of the reference fingerprints indicates the query fingerprint(s) **110** is associated with the same media as the reference audio signal **118**.

The reference fingerprint database **116** stores a plurality of reference fingerprint(s) corresponding to one or more pre-identified pieces of media. The reference fingerprint database **116** can be implemented by a volatile memory (e.g., a Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS Dynamic Random Access Memory (RDRAM), etc.) and/or a non-volatile memory (e.g., flash memory). The reference fingerprint database **116** can additionally or alternatively be implemented by one or more double data rate (DDR) memories, such as DDR, DDR2, DDR3, DDR4, mobile DDR (mDDR), etc. The reference fingerprint database **116** can additionally or alternatively be implemented by one or more mass storage devices such as hard disk drive(s), compact disk drive(s), digital versatile disk drive(s), solid-state disk drive(s), etc. In the illustrated example of FIG. **1**, the reference fingerprint database **116** is illustrated as a single database. In other examples, the reference fingerprint database **116** can be implemented by any number and/or type(s) of databases. Furthermore, the reference fingerprint(s) stored in the reference fingerprint database **116** may be in any data format. (e.g., an 8 bit integer number, a 32 bit floating point number, etc.).

The reference audio signal **118** is a digitized representation of the sound emitted. In some examples, the reference audio signal **118** is audio captured by a microphone in a manner similar to the audio signal **106**. In other examples, the reference audio signal can be already digitized audio received (e.g., extracted, etc.) from a storage medium (e.g., a hard disk, a compact disk (CD), a record, a cassette, etc.) and/or another type of media (e.g., the audio of a movie, the audio of television program, the audio of streaming media, etc.). In some examples, the reference audio signal **118** is provided to the central facility **112** by an interested party (e.g., a publisher of the audio, etc.). In such examples, the reference audio signal **118** can be transferred over a network to the reference fingerprint generator **120**.

The reference fingerprint generator **120** converts the example reference audio signal **118** into the example reference fingerprint **121**. For example, the reference fingerprint generator **120** can convert the reference audio signal **118** into the reference fingerprint(s) **121** in a manner similar to that of the query fingerprint generator **108**. In other examples, the reference fingerprint generator **120** can convert the reference audio signature by any other suitable means. An example implementation of the reference fingerprint generator **120** is described below in conjunction with FIG. **3**.

The reference fingerprint(s) **121** is/are a condensed digital summary of the reference audio signal **118** that can be used to identifies the reference audio signal **118**. The reference fingerprint(s) **121** generally have the same structure as the query fingerprint(s) **110**. For example, the reference fingerprint(s) **121** is composed of a plurality of subfingerprints, which correspond to distinct samples of the reference audio signal **118**. As such, the query fingerprint(s) **110** can be compared to the reference fingerprint(s) **121**. In some examples, the reference fingerprint(s) **121** can be formatted differently than the query fingerprint(s) **110**. For example, the reference fingerprint(s) **121** can be generated at a higher fidelity and/or at a different sample rate than the query fingerprint(s) **110**.

FIG. **2** is an example implementation of the example query fingerprint generator **108** of FIG. **1**. The example query fingerprint generator **108** includes an example audio signal interface **202**, an example audio segmenter **204**, an example signal transformer **206**, an example audio characteristic determiner **208**, an example bin normalizer **210**, an example subfingerprint generator **212**, an example portion strength evaluator **214**, an example portion replacer **216**, and an example fingerprint generator **218**.

The example audio signal interface **202** receives the digitized audio signal from the microphone **104**. In some examples, the audio signal interface **202** can request the digitized audio signal from the microphone **104** periodically. In other examples, the audio signal interface **202** can receive the audio signal **106** from the microphone **104** as soon as the audio is detected. In some examples when the microphone **104** is absent, the audio signal interface **202** can request the digitized audio signal **106** from a database. In some examples, the audio signal interface **202** can include an analog-to-digital converter to convert the audio received by the microphone **104** into the audio signal **106**.

The example audio segmenter **204** divides the audio signal **106** into audio segments (e.g., frames, periods, etc.).

For example, the audio segmenter can divide the audio signal **106** into discrete audio segments corresponding to unique portions of the audio signal **106**. In some examples, the audio segmenter **204** determines which portions of the audio signal **106** correspond to each of the generated audio segments. In some examples, the audio segmenter **204** can generate segments of any suitable size.

The example signal transformer **206** transforms portions of the audio signal of the digitized audio signal **106** into the frequency domain. For example, the signal transformer **206** performs a fast Fourier transform (FFT) on an audio signal **106** to transform the audio signal **106** into the frequency domain. In other examples, the signal transformer **206** can use any suitable technique to transform the audio signal **106** (e.g., discrete Fourier transforms, a sliding time window Fourier transform, a wavelet transform, a discrete Hadamard transform, a discrete Walsh Hadamard, a discrete cosine transform, etc.). In some examples, each time-frequency bin has an associated magnitude (e.g., the magnitude of the transformed signal in that time-frequency bin, etc.). In some examples, the signal transformer **206** can be implemented by one or more band-pass filters (BPFs). In some examples, the output of the example signal transformer **206** can be represented by a spectrogram. In some examples, the signal transformer **206** works concurrently with the audio segmenter **204**. An example output of the signal transformer **206** is discussed below in conjunction with FIG. **4**A.

The example audio characteristic determiner **208** determines the audio characteristic(s) of a portion of the audio signal **106** (e.g., an audio region associated with a time-frequency bin, etc.). The audio characteristic determiner **208** can determine the audio characteristics of a group of time-frequency bins (e.g., the energy of the portion of the audio signal **106** corresponding to each time-frequency bin in a group of time-frequency bins, the entropy of the portion of the audio signal **106** corresponding to each time-frequency bin in a group of time-frequency bins, etc.). For example, the audio characteristic determiner **208** can determine the mean energy (e.g., average power, etc.) of one or more of the audio regions associated with an audio region (e.g., the mean of the magnitudes squared of the transformed signal corresponding to the time-frequency bins in the region, etc.) adjacent to a selected time-frequency bin. In other examples, the audio characteristic determiner **208** can determine the mean entropy of one or more of the audio regions associated with an audio region (e.g., the mean of the magnitudes of the time-frequency bins in the region, etc.) adjacent to a selected time-frequency bin. In other examples, the audio characteristic determiner **208** can determine the mean energy and/or mean entropy by any other suitable means. Additionally or alternatively, the audio characteristic determiner **208** can determine other characteristics of a portion of the audio signal (e.g., the mode energy, the median energy, the mode power, the median energy, the mean energy, the mean amplitude, etc.).

The example bin normalizer **210** normalizes one or more time-frequency bins by an associated audio characteristic of the surrounding audio region. For example, the bin normalizer **210** can normalize a time-frequency bin by a mean energy of the surrounding audio region. In other examples, the bin normalizer **210** normalizes some of the audio signal frequency bins by an associated audio characteristic of the surrounding audio region. For example, the bin normalizer **210** can normalize each time-frequency bin using the mean energy associated with the audio region surrounding that time-frequency bin. In some examples, the output of the bin normalizer **210** (e.g., a normalized time-frequency bin, etc.) can be represented as a spectrogram.

The example subfingerprint generator **212** generates subfingerprints associated with an audio sample(s) and/or audio segment at a sample rate. In some examples, the subfingerprint generator **212** generates a subfingerprint of a sample after the bin normalizer **214** has normalized the energy value of each time-frequency bin in an audio segment. In some examples, the subfingerprint generator **212** generates the subfingerprint associated with a sample based on the energy extrema of the normalized time-frequency bins within the sample. In some examples, the subfingerprint generator **212** selects a group of time-frequency bins (e.g., one bin, five bins, 20 bins, etc.) with the highest normalized energy values in a sample to generate a subfingerprint. In such examples, each portion of the subfingerprints generated by subfingerprint generator **212** is associated with a location of a particular energy extremum in the normalized spectrogram generated by the bin normalizer **210**.

The example portion strength evaluator **214** evaluates the strength of each portion of the subfingerprints generated by the subfingerprint generator **212**. For example, the portion strength evaluator **214** can repeat the subfingerprint generation process (e.g., the process executed by the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, etc.) but overlaying the audio signal with randomly generated noise (e.g., white noise, artificially generated background audio, etc.). In some examples, because the subfingerprints associated with each audio sample depend on audio characteristics of adjacent samples, the portion strength evaluator **214** can determine the strength of the portions of a subfingerprint by changing the audio characteristics of adjacent audio samples. For example, for subfingerprints associated with temporal ends of the audio signal **106** (e.g., the beginning of the audio signal, the end of the audio signal), the portion strength evaluator **214** can append different audio (e.g., white noise, artificially generated background audio, other media, etc.). Additionally or alternatively, the portion strength evaluator **214** can, for some or all samples of the audio signal, replace the adjacent audio samples with different audio (e.g., white noise, artificially generated background audio, different media, etc.).

Based on how the portions of subfingerprints change, the portion strength evaluator **214** can label portions of a subfingerprint as "weak," "strong," or "neutral." As used herein, a weak portion of a subfingerprint frequently changes based on audio overlays or adjacent feature testing. As used herein, a strong portion of a subfingerprint does not frequently change based on audio overlays or adjacent feature testing. As used herein, a neutral portion of a subfingerprint is portion of the subfingerprint that is neither strong nor weak portions. In some examples, the portion strength evaluator **214** determines the strength of a portion of subfingerprint based on one or more strength threshold. In such examples, the portion strength evaluator **214** can conduct a plurality of trials (e.g., multiple noise overlays, multiple sample replacements, etc.) and count the number of times a given portion of subfingerprint changes. In some examples, if a portion changes more than a weak strength threshold is identified as a weak portion. In some examples, if a portion changes less than a strong strength threshold, the portion is identified as a strong portion. In some examples, if a portion satisfies neither the weak nor strong thresholds, the portion is identified as a neutral.

The example portion replacer **216** replaces portions of the generated subfingerprint generator **212** identified as weak by the portion strength evaluator **214**. For example, the portion replacer **216** can replace weak portions of generated subfingerprints with random audio. In such examples, the portion replacer **216** can replace some or all of the identified weak portions with a random portion. For example, the portion replacer **216** can replace the weak portions with audio generated during the operation of the portion strength evaluator **214**. In other examples, the portion replacer **216** can replace the identified weak portions with any other suitable portion.

The example fingerprint generator **218** generates a fingerprint based on the subfingerprints generated by the subfingerprint generator **212** and/or the portion replacer **216**. For example, the fingerprint generator **218** can generate the query fingerprint(s) **110** based on the subfingerprints (e.g., query subfingerprints, etc.) generated by the subfingerprint generator **212**. For example, the fingerprint generator **218** can concatenate the subfingerprints associated with each audio segment into the query fingerprint(s) **110**. In some examples, the fingerprint generator **218** can generate a fingerprint including the subfingerprints in which the weak portions have been replaced by the portion replacer **216**. In some examples, the fingerprint generator **218** can generate multiple query fingerprints based on the portions of the subfingerprints. In such examples, the fingerprint generator **218** can generate fingerprints including different subfingerprints of which the weak portions have been replaced. In some examples, the portion replacer **216** can be omitted. In such examples, the fingerprint generator **218** can generate multiple fingerprints based on different audio overlays and/or audio sample appendages.

While an example manner of implementing the query fingerprint generator **108** of FIG. **1** is illustrated in FIG. **2**, one or more of the elements, processes and/or devices illustrated in FIG. **2** may be combined, divided, re-arranged, omitted, eliminated and/or implemented in any other way. Further, the example audio signal interface **202**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, an example fingerprint generator **218**, and/or, more generally, the example query fingerprint generator **108** of FIG. **2** may be implemented by hardware, software, firmware and/or any combination of hardware, software and/or firmware. Thus, for example, any of the example audio signal interface **202**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, an example fingerprint generator **218**, and/or, more generally, the example query fingerprint generator **108** could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), programmable controller(s), graphics processing unit(s) (GPU(s)), digital signal processor(s) (DSP(s)), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)) and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example audio signal interface **202**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, an example fingerprint generator **218**, is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc. including the software and/or firmware. Further still, the example query fingerprint generator **108** of FIG. **2** may include one or more elements, processes and/or devices in addition to, or instead of, those illustrated in FIG. **2**, and/or may include more than one of any or all of the illustrated elements, processes, and devices. As used herein, the phrase "in communication," including variations thereof, encompasses direct communication and/or indirect communication through one or more intermediary components, and does not require direct physical (e.g., wired) communication and/or constant communication, but rather additionally includes selective communication at periodic intervals, scheduled intervals, aperiodic intervals, and/or one-time events.

FIG. **3** is an example implementation of the reference fingerprint generator **120** of FIG. **1**. In the illustrated example of FIG. **3**, the reference fingerprint generator **120** includes an example reference audio signal interface **302** and an example reference fingerprint generator **304**. In the illustrated example of FIG. **3**, the reference fingerprint generator **120** includes the example audio segmenter **204** of FIG. **2**, the example signal transformer **206** of FIG. **2**, the example audio characteristic determiner **208** of FIG. **2**, the example bin normalizer **210** of FIG. **2**, the example subfingerprint generator **212** of FIG. **2**, the example portion strength evaluator **214**, and the portion replacer **216** of FIG. **2**. Unless stated otherwise, the audio segmenter **204** of FIG. **3**, the signal transformer **206** of FIG. **3**, the example audio characteristic determiner **208** of FIG. **3**, the example bin normalizer **210** of FIG. **3**, the example subfingerprint generator **212** of FIG. **3**, the example portion strength evaluator **214**, and the portion replacer **216** of FIG. **3** function substantially as the counterparts described in conjunction with FIG. **2** unless stated otherwise.

The example reference audio signal interface **302** receives the reference audio signal **118**. In some examples, the reference audio signal interface **302** receives a digitized reference audio signal **118** (e.g., actual audio captured by a microphone, transferred over a network, etc.). In some examples, the reference audio signal interface **302** can be implemented by audio processing hardware (e.g., a CD-player, a record player, etc.) In some examples when the microphone **104** is absent, the audio signal interface **202** can request the reference audio signal **118** from a database. In some examples, the audio signal interface **202** can include an analog-to-digital converter to convert the audio into the reference audio signal **118**.

The example reference fingerprint generator **304** generates a fingerprint based on the subfingerprints. For example, the reference fingerprint generator **304** can generate the reference fingerprint(s) **121** based on the subfingerprints (e.g., reference subfingerprints, etc.) generated by the subfingerprint generator **212**. For example, the fingerprint generator **218** can concatenate the subfingerprints associated with each audio segment into the query fingerprint(s) **110**. In some examples, the fingerprint generator **218** can generate multiple reference fingerprints based on the portions of the subfingerprints. For example, the reference fingerprint generator **304** can generate two or more reference fingerprint(s) **121**. In such examples, the reference fingerprint generator **304** can store multiple reference fingerprints in the reference fingerprint database **116**. During matching, a generated query fingerprint (e.g., the query fingerprint(s) **110** of FIG. **1**) can be compared to each of the related reference fingerprint(s) **121**.

While an example manner of implementing the reference fingerprint generator **120** of FIG. **1** is illustrated in FIG. **3**, one or more of the elements, processes and/or devices illustrated in FIG. **3** may be combined, divided, re-arranged, omitted, eliminated and/or implemented in any other way. Further, the example reference audio signal interface **302**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, the example reference fingerprint generator **304**, and/or, more generally, the example reference fingerprint generator **120** of FIG. **3** may be implemented by hardware, software, firmware and/or any combination of hardware, software and/or firmware. Thus, for example, any of the example reference audio signal interface **302**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, the example reference fingerprint generator **304** and/or, more generally, the example reference fingerprint generator **120** could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), programmable controller(s), graphics processing unit(s) (GPU(s)), digital signal processor(s) (DSP(s)), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)) and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example reference audio signal interface **302**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, the example reference fingerprint generator **304**, is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc. including the software and/or firmware. Further still, the example reference fingerprint generator **120** of FIG. **3** may include one or more elements, processes and/or devices in addition to, or instead of, those illustrated in FIG. **4**, and/or may include more than one of any or all of the illustrated elements, processes, and devices. As used herein, the phrase "in communication," including variations thereof, encompasses direct communication and/or indirect communication through one or more intermediary components, and does not require direct physical (e.g., wired) communication and/or constant communication, but rather additionally includes selective communication at periodic intervals, scheduled intervals, aperiodic intervals, and/or one-time events.

FIG. **4**A depicts an example unprocessed spectrogram **400** generated by the example signal transformer **206** of FIG. **2**. In the illustrated example of FIG. **4**A, the example unprocessed spectrogram **400** includes an example first time-frequency bin **404** surrounded by an example first audio region **406**. The example unprocessed spectrogram **400** of FIG. **4**A includes an example vertical axis **408** denoting frequency bins and an example horizontal axis **410** denoting time bins. In the illustrated example of FIG. **4**A, the spectrogram **400** is divided into example first edge region **412**A, an example second edge region **412**B, and a center region **414**. The example unprocessed spectrogram **400** further includes an example second time-frequency bin **418** surrounded by an example second audio region **420**.

The example first audio region **406** from which the normalization audio characteristic is derived by the audio characteristic determiner **208** and used by the bin normalizer **210** to normalize the first time-frequency bins **404**. In the illustrated example, each time-frequency bin of the unprocessed spectrogram **400** is normalized to generate a normalized spectrogram. In other examples, any suitable number of the time-frequency bins of the unprocessed spectrogram **400** can be normalized to generate a normalized spectrogram. An example normalized spectrogram generated by the bin normalizer **210** of FIGS. **2** and **3** is depicted in FIG. **4**C.

The example vertical axis **408** has frequency bin units generated by a fast Fourier Transform (FFT) and has a length of 1024 FFT bins. In other examples, the example vertical axis **308** can be measured by any other suitable techniques of measuring frequency (e.g., Hertz, another transformation algorithm, etc.). In some examples, the vertical axis **408** encompasses the entire frequency range of the audio signal **106** and/or reference audio signal **118**. In other examples, the vertical axis **408** can encompass a portion of the audio signal **106** and/or the reference audio signal **118**.

In the illustrated examples, the example horizontal axis **410** represents a time period of the unprocessed spectrogram **400** that has a total length of 11.5 seconds. In the illustrated example, horizontal axis **410** has sixty-four milliseconds (ms) intervals as units. In other examples, the horizontal axis **410** can be measured in any other suitable units (e.g., 1 second, etc.). For example, the horizontal axis **410** encompasses the complete duration of the audio. In other examples, the horizontal axis **410** can encompass a portion of the duration of the audio signal **106**. In the illustrated example, each time-frequency bin of the spectrograms **300**, **302** has a size of 64 ms by 1 FFT bin.

In the illustrated example of FIG. **4**A, the first time-frequency bin **404** is associated with an intersection of a frequency bin and a time bin of the unprocessed spectrogram **400** and a portion of the audio signal **106** or reference audio signal **118** associated with the intersection. The example first audio region **406** includes the time-frequency bins within a pre-defined distance away from the example first time-frequency bin **404**. For example, the audio characteristic determiner **208** can determine the vertical length of the first audio region **406** (e.g., the length of the audio region **306**A along the vertical axis **408**, etc.) based on a set number of FFT bins (e.g., 5 bins, 11 bins, etc.). Similarly, the audio characteristic determiner **208** can determine the horizontal length of the first audio region **406** (e.g., the length of the first audio region **406** along the horizontal axis **410**, etc.). In the illustrated example, the first audio region **406** is a square. Alternatively, the first audio region **406** can be any suitable size and shape and can contain any suitable combination of time-frequency bins (e.g., any suitable group of time-frequency bins, etc.) within the unprocessed spectrogram **400**. The example audio characteristic determiner **208** can then determine an audio characteristic of time-frequency bins contained within the first audio region **406** (e.g., mean energy, etc.). Using the determined audio characteristic, the bin normalizer **210** of FIGS. **2** and/or **3** can normalize an associated value of the first time-frequency bin **404** (e.g., the energy of first time-frequency bin **404** can be normalized by the mean energy of each time-frequency bin within the first audio region **406**).

FIG. **4**B depicts an example of a normalized spectrogram **416** generated by the bin normalizer **210** of FIGS. **2** and/or **3** from the unprocessed spectrogram **400** of FIG. **4**A by normalizing a plurality of the time-frequency bins of the unprocessed spectrogram **400** of FIG. **4**A. The normalized spectrogram **416** includes the vertical axis **408** of FIG. **4**A denoting frequency bins and the horizontal axis **410** of FIG. **4**A denoting time bins. The spectrogram **416** is divided into the edge regions **412**A, **412**B, and the center region **414**.

For example, some or all of the time-frequency bins of the unprocessed spectrogram **400** can be normalized in a manner similar to how the first time-frequency bin **404**A was normalized. The normalization of the audio signal **106** and subsequent generation of the query fingerprint(s) **110** is described below in conjunction with FIG. **7**. The normalization and subsequent generation of the reference fingerprint(s) **121** of the reference audio signal **118** is described below in conjunction with FIG. **8**. The resulting frequency bins depicted FIG. **4**B have now been normalized by the local mean energy within the local area around the region. As a result, the darker regions are areas that have the most energy in their respective local area. This allows the fingerprint to incorporate relevant audio features even in areas that are low in energy relative to the usual louder bass frequency area.

The spectrograms **400**, **416** of FIGS. **4**A-**4**B are divided into the example edge regions **412**A, **412**B, and the example center region **414**. The example edge regions **412**A, **412**B are the portions of the spectrograms **400**, **416** that the audio regions (e.g., the second audio region **420** of FIG. **4**A, etc.) associated with the time-frequency bins (e.g., the second time-frequency bin **418** of FIG. **4**A, etc.) extends outside the edges of the spectrograms **400**, **416**. If the audio signal **106** is a discrete signal (e.g., the temporal entirety of the audio signal **106** is represented in the spectrogram **400**, etc.), the audio characteristic determiner **208** and bin normalizer **210** can ignore the portion of the audio region **420** without defined characteristics (e.g., there is no portion of the spectrogram associated with that portion of the region, etc.). In other examples, if the audio signal **106** is discrete, the audio characteristic determiner **208** and bin normalizer **210** can account for the undefined region by any other suitable method. If the audio signal **106** is not a discrete signal (e.g., is part of a continuous stream of audio, etc.), the audio characteristic determiner **208** may be capturing audio signal characteristics not associated with the audio signal **106**. For example, if the audio signal **106** is a portion of an audio stream associated with a commercial, when the bin normalizer **210** normalizes the time-frequency bins in the first edge region **412**A (e.g., the audio from the beginning of the commercial, etc.), each of those time-frequency bins is normalized by a value partially based on the audio characteristics of the audio immediately proceeding media (e.g., the television program, the radio program, a different commercial, etc.). Accordingly, the values of the time-frequency bins in the edge regions **412**A, **412**B of the normalized spectrogram **416** can vary based on the adjacent audio despite the audio signal **106** being the same. This variance in the normalized spectrogram **416** results in variance in audio fingerprints generated therefrom, which decreases the likelihood of a positive match with reference fingerprints identifying the media associated with the audio signal **106**.

FIG. **5**A is the content of an example media stream **500** including example media **502**, an example first commercial **504**, an example second commercial **506**, and example third commercial **508** that can be processed by the system **100** of FIG. **1**. The example commercials **504**, **506**, **508** have been processed by the query fingerprint generator **108** of FIGS. **1** and/or **2** to generate corresponding an example first query fingerprint **505**, an example second query fingerprint **507**, and an example third query fingerprint **509**, respectively. The example commercials also have an example reference fingerprint **510**, an example second reference fingerprint **512**, and an example third reference fingerprint **514**, respectively, stored in the reference fingerprint database **116**. The example media stream includes an example first content change point **518**A between the media **502** (e.g., media airing in a television broadcast, etc.) and the first commercial **504**, an example second content change point **518**B between the first commercial **504** and the second commercial **506**, a third content change point **518**C, and an example fourth content change point **518**D.

The media stream **500** is a stream of audio and/or video content that includes audio. The media stream **500** can be associated with a radio broadcast, a television broadcast, streaming media, and/or any other type of media presentation. The media stream **500** includes different media content arranged continuously. In the illustrated example of FIG. **5**A, the media stream **500** includes the example media **502** and the example commercials **504**, **506**, **508**. In other examples, the media stream **500** can include different commercials and/or repeated instances of the same commercial (e.g., multiple instances of the first commercial **504**, etc.). The media **502** can include any suitable content associated with the media stream (e.g., music, television programming, etc.).

The commercials **504**, **506**, **508** are relatively short pieces of media used to advertise various products, services, and/or other things of potential issues to consumers of the media **502**. The commercials **504**, **506**, **508** are of different lengths are relatively short (e.g., less than a minute long, etc.). In the illustrated example of FIG. **5**A, the query fingerprints **505**, **507**, **509** were generated using the query fingerprint generator **108** by analyzing the audio associated with the media stream **500**. In other examples, the query fingerprints **505**, **507**, **509** can be generated by any other suitable means.

The example reference fingerprints **510**, **512**, **514** are reference fingerprints stored in the reference fingerprint database **116**. In the illustrated example of FIG. **5**A, the reference fingerprints **510**, **512**, **514** were generated from the commercials **504**, **506**, **508**, respectively, (e.g., provides by the advertisers, retrieved from a database, etc.) and not from media stream **500**. The reference fingerprints **510**, **512**, **514** were generated using the reference fingerprint generator **120**. In other examples, the reference fingerprints **510**, **512**, **514** can be generated by any other suitable means.

The content change points **518**A, **518**B, **518**C, **518**D represent the portions of the media stream where the media content changes. That is, the first content change point **518**A represents the transition point between the media **502** and the beginning of the first commercial **504**, the second content change point **518**B represents the transition point between the end of the first commercial **504** and the beginning of the second commercial **506**, the third content change point **518**C represents the transition point between the end of the second commercial **506** and the beginning of the third commercial **508**, and the fourth content change point **518**D represents the transition point between the end of the third commercial **508** and the media **502**. Because each subfingerprint of the query fingerprints **505**, **507**, **509** is generated by normalizing local audio characteristics (e.g., energy extrema, etc.), the subfingerprints of the query fingerprints **505**, **507**, **509** associated with the portions of the commercials **504**, **506**, **508**, respectively, near the content change points **518**A, **518**B, **518**C, **518**D are normalized partly by audio characteristics of adjacent media. For example, the subfingerprints of the first query fingerprint **505** near the first content change point **518**A are calculated partly based on the audio characteristics of the media **502**, the subfingerprints of the second query fingerprint **507** near the first content change point **518**A are partly calculated based the audio characteristics of the first commercial **504**, etc. Accordingly, the subfingerprints of the query fingerprints **505**, **507**, **509** associated with the portions of the commercials **504**, **506**, **508** near the content change points **518**A, **518**B, **518**C, **518**D may not match the corresponding subfingerprints of the reference fingerprints **510**, **512**, **514** despite being generated from the commercials **504**, **506**, **508**.

The arrangement of commercials (e.g., the commercials **504**, **506**, **508**, etc.) displayed during broadcasts is variable. That is, the media preceding and proceeding the first commercial **504**, the second commercial **506**, and/or the third commercial **508** can vary depending on the time of broadcast and the broadcasting channel and can be decided by the content provider. As such, the subfingerprints of the generated query fingerprints from the commercials **504**, **506**, **508** can change depending on the media immediately proceeding and preceding each of the commercials **504**, **506**, **508**. As such, the likelihood of successfully matching the query fingerprints **505**, **507**, **509** to the reference fingerprints **510**, **512**, **514** can be inhibited.

FIG. **5**B is the content of an example audio signal **524** including example tuning events **525**A, **525**B, **525**C, **525**D that can be processed by the system **100** of FIG. **1**. In the illustrated example of FIG. **5**B, the audio signal **524** includes media associated with an example first channel **526**A, an example second channel **526**B, and an example third channel **526**C. The audio signal **524** is processed to generated example query fingerprints **528** (e.g., by the system **100** of FIG. **1**, etc.) composed of an example first query fingerprint portion **530**A, an example second query fingerprint portion **530**B, an example third query fingerprint portion **530**C, and example fourth query fingerprint portion **530**D, which are delineated by the tuning events **525**A, **525**B, **525**C, **525**D.

The audio signal **524** is composed of media from multiple channels **526**A, **526**B, **526**C. For example, the audio signal **524** can be generated by a user changing (e.g., tuning, etc.) a media device (e.g., a television, a radio, a portable audio device, etc.) between multiple channels. In some examples, the multiple channels **526**A, **526**B, **526**C represent different media broadcasts (e.g., a broadcast from a new channel, a broadcast from a specific sports channel, a specific radio station, etc.). In other examples, the multiple channels **526**A, **526**B, **526**C are different specific pieces of media (e.g., a first movie, a second movie, a third movie, etc.). In some examples, the reference fingerprints corresponding to the media of the channels **526**A, **526**B, **526**C are generated by directly processing the unbroken stream (e.g., without tuning events, etc.) of the multiple channels **526**A, **526**B, **526**C. Each time the user switches between the channels **526**A, **526**B, **526**C, one of the tuning events **525**A, **525**B, **525**C, **525**D occurs. For example, at the example first tuning event **525**A, the media associated with the audio signal **524** switches from the second channel **526**B to the third channel **526**C. While the illustrated example of FIG. **5**B is only described with reference to three channels and four tuning events, other examples can include any suitable number of channels and tuning events.

The example query fingerprint portions **530**A, **530**B, **530**C, **530**D, **530**E of the query fingerprints **528** corresponds to the portions of the audio signal **524** delineated by the tuning events **525**A, **525**B, **525**C, **525**D. The first query fingerprint portion **530**A corresponds to the portion of the audio signal **524** before the first tuning event **525**A. The second query fingerprint portion **530**B corresponds to the portion of the audio signal between the first tuning event **525**A and the second tuning event **525**B. The third query fingerprint portion **530**C corresponds to the portion of the audio signal **524** between the second tuning event **525**B and the third turning event **525**C. The fourth query fingerprint portion **530**D corresponds to the portion of the audio signal **524** between the third tuning event **525**C and the fourth tuning event **525**D. The subfingerprints of the first query fingerprint portion **530**A and fourth query fingerprint portion **530**D can be used to identify the media associated with the second channel **526**B. The subfingerprints of the second query fingerprint portion **530**B and the fifth query finger portion **530**BE can be used to identify the media associated with the third channel **526**C. The subfingerprints of the third query fingerprint portion **530**C can be used to identify the media associated with the first channel **526**A.

Because each subfingerprint of the query fingerprints **528** is generated by normalizing local audio characteristics (e.g., energy extrema, etc.), the subfingerprints of the query fingerprints **528** near the tuning events **525**A, **525**B, **525**C, **525**D (e.g., near the beginning or end of each of the query fingerprint portions **530**A, **530**B, **530**C, **530**D, **530**E, etc.) are normalized partly by audio characteristics of media on channels not corresponding to the actual channel associated with the query fingerprint portions **530**A, **530**B, **530**C, **530**D, **530**E. For example, the subfingerprints of the query fingerprint portions **530**A near the first turning event **525**B are normalized partly by the audio characteristics of media associated with the third channel **526**C, despite the first query fingerprint portions **530**A identifying the media on the second channel **526**B. Accordingly, the subfingerprints of the query fingerprints **528** associated with the portions of the audio signal **524** near the tuning events **525**A, **525**B, **525**C, **525**D may not match the corresponding subfingerprints of the reference fingerprints identifying the media of the audio channels **526**A, **526**B, **526**C despite being generated from the same reference media.

The location of tuning events (e.g., the tuning events **525**A, **525**B, **525**C, **525**D, etc.) in an audio signal are generated by the media consumption of a user. As such, the audio signal **524** is user-determined and not directly identifiable by a monitoring entity. That is, the location of tuning events **525**A, **525**B, **525**C, **525**D can be difficult to identify based on the generated query fingerprints (e.g., the query fingerprints **528**, etc.). The subfingerprints of the generated query fingerprints **528** from the audio signal **524** can change based on the location of the tuning events. As such, the likelihood of successfully matching the query fingerprints **528** to the corresponding reference fingerprints can be inhibited.

FIG. **6** is an illustration showing an example generation **600** of alternative subfingerprints output by the query fingerprint generator **108** and/or the reference fingerprint generator **120** of FIGS. **1**, **2**, and/or **3**. In the illustrated example of FIG. **6**, an example audio signal **602** divided into signal portions including an example first audio signal portion **604**A and an example second audio signal portion **604**B. In the illustrated example of FIG. **6**, the audio signal portion **604**A is processed (e.g., by the query fingerprint generator **108**, by the reference fingerprint generator **120**, etc.) to generate an example primary subfingerprint **606**, an example first secondary subfingerprint **608**, and an example second secondary subfingerprint **610** having an example first subfingerprint portions **612**, an example second subfingerprint portions **614**, and an example third subfingerprint portions **616**. Each of the primary subfingerprints **606** and first secondary subfingerprint **608**, and the second secondary subfingerprint **610** is composed of strong portions (illustrated as black rectangles), neutral portions (illustrated as dot-shaded rectangles), and weak portions (illustrated as white rectangles, etc.). While the illustrated example of FIG. **6** only includes the first secondary subfingerprint **608** and the second secondary subfingerprint **610**, in other examples additional subfingerprints can be generated.

The example primary subfingerprint **606** includes (e.g., is composed of, etc.) the example first subfingerprints portions **612**. The first subfingerprint portions **612** correspond to the specific time-frequency bins of the first audio signal portion **604**A that are energy extrema selected (e.g., by the subfingerprint generator **212** of FIGS. **2** and/or **3**, etc.) after the audio signal portion **604**A has been normalized. In some examples, each of the first subfingerprint portions **612** is a data structure (e.g., a bit, a byte, etc.) corresponding to the location of the time-frequency bin of the spectrogram selected to form part of the primary subfingerprint **606**. In the illustrated example of FIG. **6**, the portion strength evaluator **214** of FIGS. **2** and/or **3** has analyzed each of the first subfingerprint portions **612** to determine the strength of each portion of the first subfingerprints portions **612**. For example, the portion strength evaluator **214** can overlay white noise onto the audio signal portion **604**A and regenerate the subfingerprint. Additionally or alternatively, the portion strength evaluator **214** can append different audio (e.g., white noise, different media, etc.) before or after the audio signal portion **604**A. In such examples, the portion strength evaluator **214** can determine which of the first subfingerprint portions **612** are more likely to change in response to different adjacent audio and/or noise (e.g., comparing the percent of changes to a threshold, comparing the number of changes to a threshold, etc.),

In the illustrated example of FIG. **6**, the portion strength evaluator **214** has identified some of the subfingerprint portions **612** as strong fingerprints, including an example strong subfingerprint portion **618**, some of the subfingerprint portions **612** as neutral fingerprints, including an example neutral subfingerprint **620**, and some of the subfingerprint portions **612** as weak subfingerprint portions, including an example weak subfingerprint portion **622**. In the illustrated example of FIG. **6**, the portion replacer **216** replaces the identified weak portions of the subfingerprint portions **612** with alternative subfingerprint portions. In the illustrated example of FIG. **6**, the portion replacer **216** has replaced the weak subfingerprint portion **622** with an example first alternative portion **624** to generate the first secondary subfingerprint **608**. The portion replacer **216** has replaced the weak subfingerprint portion **622** with an example second alternative portion **626** to generate the second secondary subfingerprint **610**. Additionally or alternatively, the portion replacer **216** can replace additional portions of the subfingerprint portions **612** to generate the secondary fingerprints **608**, **610**. In some examples, the portion replacer **216** can generate additional secondary fingerprints.

If the primary subfingerprint **606**, the first secondary subfingerprint **608**, and the second secondary subfingerprint **610** are generated by the query fingerprint generator **108**, each of the primary subfingerprint **606**, the first secondary subfingerprint **608**, and the second secondary subfingerprint **610** can be used to generate a fingerprint for the audio signal **602**, which can then be compared by the fingerprint comparator **114** to stored reference fingerprints in the reference fingerprint database **116** to identify the audio signal **602**. In some examples, the other portions of the audio signal **602** can be similarly processed by the query fingerprint generator **108** to generate alternative subfingerprints for each of those other portions. In other examples, only the boundary segments of the audio signal **602** (e.g., the audio signal portions **604**A, **604**B) can be processed by query fingerprint generator **108** to generate alternative fingerprints including various combinations of the generated subfingerprints.

If the primary subfingerprint **606**, the first secondary subfingerprint **608**, and the second secondary subfingerprint **610** are generated by the reference fingerprint generator **120**, each of the primary subfingerprint **606**, the first secondary subfingerprint **608**, and the second secondary subfingerprint **610** can be used to generate a fingerprint for the audio signal **602**, which can then be compared by the fingerprint comparator **114** to received query fingerprints. In some examples, the other portions of the audio signal **602** can be similarly processed by the reference fingerprint generator **120** to generate alternative subfingerprints for each of those other portions. In other examples, only the boundary segments of the audio signal **602** (e.g., the audio signal portions **604**A, **604**B) can be processed by reference fingerprint generator **120** to generate alternative fingerprints including various combinations of the generated subfingerprints. In such examples, each of the alternative fingerprints is stored in the database **116** and can be used to generate the alternative reference. As such employment of the system **100** of FIG. **1** can be used to minimize the matching difficulties arising from the tuning events of FIG. **5**B and the channel change events of FIG. **5**A.

A flowchart representative of example hardware logic, machine readable instructions, hardware implemented state machines, and/or any combination thereof for implementing the query fingerprint generator **108** of FIG. **2** is shown in FIG. **7**. The machine readable instructions may be one or more executable programs or portion(s) of an executable program for execution by a computer processor and/or processor circuitry, such as the processor **912** shown in the example processor platform **900** discussed below in connection with FIG. **9**. The program may be embodied in software stored on a non-transitory computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a DVD, a Blu-ray disk, or a memory associated with the processor **912**, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor **912** and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowchart illustrated in FIG. **9**, many other methods of implementing the example query fingerprint generator **108** may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined. Additionally or alternatively, any or all of the blocks may be implemented by one or more hardware circuits (e.g., discrete and/or integrated analog and/or digital circuitry, an FPGA, an ASIC, a comparator, an operational-amplifier (op-amp), a logic circuit, etc.) structured to perform the corresponding operation without executing software or firmware. The processor circuitry may be distributed in different network locations and/or local to one or more devices (e.g., a multi-core processor in a single machine, multiple processors distributed across a server rack, etc).

The process **700** of FIG. **7** includes block **702**. At block **702**, the audio signal interface **202** receives the reference audio signal **118**. In some examples, the reference audio signal interface **302** receives a digitized reference audio signal **118** (e.g., actual audio captured by a microphone, transferred over a network, etc.). In other examples, the audio signal interface **202** can request the reference audio signal **118** from a database. In some examples, the audio signal interface **202** can include an analog-to-digital converter to convert the audio into the reference audio signal **118**.

At block **704**, the audio segmenter **204** divides the reference audio signal **118** into segments. For example, the audio segmenter **204** can divide the reference audio signal **118** into temporal segments corresponding to a length of the reference audio signal **118** associated with a sample (e.g., the period of the reference audio signal **118** corresponding to a subfingerprint, etc.). In some examples, the audio segmenter **204** can segment the reference audio signal **118** into audio segments into corresponding to the length of a time bin (e.g., a frame, etc.).

At block **706**, the signal transformer **206** transforms the reference audio signal **118** into the frequency domain to generate time-frequency bins. For example, the signal transformer **206** can transform the portion of the reference audio signal **118** corresponding to the audio segment using a Fast Fourier Transform (FFT). In other examples, the signal transformer **206** can use any other suitable means of transforming the reference audio signal **118** (e.g., discrete Fourier transform, a sliding time window Fourier transform, a wavelet transform, a discrete Hadamard transform, a discrete Walsh Hadamard, a discrete cosine transform, etc.). In some examples, the time-frequency bins generated by the signal transformer **206** and corresponding to the selected audio segment are associated with the intersection of each frequency bin of the reference audio signal **118** and the time bin(s) associated with the audio segment. In some examples, each time-frequency bin generated by the audio segmenter **204** has an associated magnitude value (e.g., a magnitude of the FFT coefficient of the reference audio signal **118** associated with that time-frequency bin, etc.).

At block **708**, the audio segmenter **204** selects an audio segment. For example, the audio segmenter **204** can select a first audio segment (e.g., the audio segment corresponding to the beginning of the reference audio signal **118**, etc.). In some examples, the audio segmenter **204** can select an audio segment temporally immediately adjacent to a previously selected audio segment. In other examples, the audio segmenter **204** can select an audio segment based on any suitable characteristic. In some examples, the audio segmenter **204** windows the first segment.

At block **710**, the audio characteristic determiner **208** determines the audio characteristic of each time-frequency bin in the audio segment. For example, the audio characteristic determiner **208** can determine the magnitude of each time-frequency bin in the audio segment. In such examples, the audio characteristic determiner **208** can calculate the energy and/or the entropy associated with each time-frequency bin. In other examples, the audio characteristic determiner **208** can determine any other suitable audio characteristic(s) (e.g., amplitude, power, etc.).

At block **712**, the bin normalizer **210** normalizes each time-frequency bin based on an average audio-characteristic of the surrounding audio region. For example, the bin normalizer **210** can normalize an example time-frequency bin (e.g., the first time-frequency bin **404**, etc.) based on the average audio characteristic of the surrounding region (e.g., the first region **406**, etc.) as determined during the execution of block **710**. In some examples, the bin normalizer generates a normalized spectrogram (e.g., the normalized spectrogram **416** of FIG. **4**B, etc.) by normalizing each of the time-frequency bins of the audio segment.

At block **714**, the subfingerprint generator **212** computes the primary subfingerprint(s) associated with the audio segment. For example, the subfingerprint generator **212** can generate a subfingerprint based on the normalized values of the time-frequency bins of the previous segment(s) analyzed at block **712**. In some examples, the subfingerprint generator **212** generates a subfingerprint by selecting energy and/or entropy extrema (e.g., five extrema, 20 extrema, etc.) in the previous segment(s). In such examples, the subfingerprint generated by the subfingerprint generator **212** includes portions (e.g., bits, etc.) corresponding to each one of the selected extrema. In such examples, each portion of a generated subfingerprint corresponds to the location of an energy extremum. In some examples, the subfingerprint generator **212** does not generate a subfingerprint (e.g., the previous audio segment is not being used to subfingerprint due to down-sampling, etc.). In such examples, blocks **716-820** are not executed for this selected segment.

At block **716**, the portion strength evaluator **214** determines the strength of each portion of the generated subfingerprint. For example, the portion strength evaluator **214** can repeat the subfingerprint generator process (e.g., the execution of blocks **710-714**, etc.) but overlaying the audio signal with random noise (e.g., white noise, artificially generated background audio, etc.). In some examples, because the subfingerprints associated with each audio sample depend on audio characteristics of adjacent samples, the portion strength evaluator **214** can determine the strength of portions of a subfingerprint by changing the audio characteristics of adjacent audio samples. In some such examples, the portion strength evaluator **214** can replace adjacent audio segments with different audio segments and/or append different audio on the audio segment being analyzed. Additionally or alternatively, the portion strength evaluator **214** can, for some or all samples of the audio signal, replace the adjacent audio samples with different audio (e.g., white noise, artificially generated background audio, different media, etc.). Based on the frequency of the portions of the generated subfingerprints change, the portion strength evaluator **214** can determine the strength of each portion as "weak," "strong," or "neutral." In some examples, the portion strength evaluator **214** can compare the frequency of change to a threshold.

At block **718**, the portion replacer **216** replaces reference weak portions of subfingerprints with alternative portions. For example, the portion replacer **216** can replace weak portions of generated subfingerprints with random audio. In such examples, the portion replacer **216** can replace some or all of the identified weak portions with a random portion. For example, the portion replacer **216** can replace the weak portions with audio generated during the operation of the portion strength evaluator **214**. In other examples, the portion replace **216** can replace the identified weak portions with any other suitable portion.

At block **720**, the audio segmenter **204** determines if another segment is to be selected. For example, the audio segmenter **204** can determine if there are additional audio segments of the reference audio signal **118** that have yet to be analyzed. If another segment is to be selected by the audio segmenter **204**, the process **700** returns to block **706**. If another segment is not to be selected by the audio segmenter **204**, the process **700** advances to block **722**.

At block **722**, the fingerprint generator **218** generates fingerprint(s) based on generated subfingerprint(s). For example, the fingerprint generator **218** can generate the query fingerprint(s) **110** based on the subfingerprints generated by the subfingerprint generator **212**. For example, the fingerprint generator **218** can concatenate the subfingerprints associated with each audio segment into the query fingerprint(s) **110**. In some examples, the fingerprint generator **218** can generate a fingerprint including the subfingerprints in which the weak portions have been replaced by the portion replacer **216**. In some examples, the fingerprint generator **218** can generate multiple query fingerprints based on the portions of the subfingerprints. In such examples, the fingerprint generator **218** can generate fingerprints including different subfingerprints of which the weak portions have been replaced. In some examples, the portion replacer **216** can be omitted. In some such examples, the fingerprint generator **218** can generate multiple fingerprints based on different audio overlays and/or audio sample appendages. In some such examples, the fingerprint generator **218** can cause the identified weak portions to be included from the query fingerprint **110** when the query fingerprint **110** is compared to reference fingerprints by the fingerprint comparator **114**.

At block **724**, the fingerprint generator **218** transmits generated query fingerprint(s) **110** to the central facility **112**. For example, the fingerprint generator **218** can transmit the generated query fingerprint via the network **111**. In other examples, the fingerprint generator **218** can transmit the generated query fingerprint(s) **110** via a wired connection and/or any other suitable connection. The process **700** ends.

A flowchart representative of example hardware logic, machine readable instructions, hardware implemented state machines, and/or any combination thereof for implementing the reference fingerprint generator **120** of FIG. **3** is shown in FIG. **8**. The machine readable instructions may be one or more executable programs or portion(s) of an executable program for execution by a computer processor and/or processor circuitry, such as the processor **1012** shown in the example processor platform **900** discussed below in connection with FIG. **10**. The program may be embodied in software stored on a non-transitory computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a DVD, a Blu-ray disk, or a memory associated with the processor **1012**, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor **1012** and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowchart illustrated in FIG. **10**, many other methods of implementing the example reference fingerprint generator **120** may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined. Additionally or alternatively, any or all of the blocks may be implemented by one or more hardware circuits (e.g., discrete and/or integrated analog and/or digital circuitry, an FPGA, an ASIC, a comparator, an operational-amplifier (op-amp), a logic circuit, etc.) structured to perform the corresponding operation without executing software or firmware. The processor circuitry may be distributed in different network locations and/or local to one or more devices (e.g., a multi-core processor in a single machine, multiple processors distributed across a server rack, etc.).

The process **800** of FIG. **8** includes block **802**. At block **802**, the reference audio signal interface **302** receives the digitized audio signal **106**. For example, the reference audio signal interface **302** can receive audio (e.g., emitted by the audio source **102** of FIG. **1**, etc.) captured by the microphone **104**. In this example, the microphone can include an analog to digital converter to convert the audio into a digitized audio signal **106**. In other examples, the reference audio signal interface **302** can receive audio stored in a database (e.g., the volatile memory **1014** of FIG. **10**, the non-volatile memory **1016** of FIG. **10**, the mass storage **1028** of FIG. **10**, etc.). In other examples, the digitized audio signal **106** can be transmitted to the reference audio signal interface **302** over a network **111**. Additionally or alternatively, the reference audio signal interface **302** can receive the audio signal **106** by any other suitable means.

At block **804**, the audio segmenter **204** divides audio signal **106** into segments. For example, the audio segmenter **204** can divide the audio signal **106** into temporal segments corresponding to a length of the audio signal **106** associated with a sample (e.g., the period of the audio signal **106** corresponding to a subfingerprint, etc.). In some examples, the audio segmenter **204** can segment the audio signal **106** into audio segments corresponding to the length of a time bin (e.g., a frame, etc.).

At block **806**, the signal transformer **206** transforms the audio signal into the frequency domain to generate time-frequency bins. For example, the signal transformer **206** can transform the portion of the audio signal **106** corresponding to the audio segment using a Fast Fourier Transform (FFT). In other examples, the signal transformer **206** can use any other suitable means of transforming the audio signal **106** (e.g., discrete Fourier transform, a sliding time window Fourier transform, a wavelet transform, a discrete Hadamard transform, a discrete Walsh Hadamard, a discrete cosine transform, etc.). In some examples, the time-frequency bins generated by the signal transformer **206** and corresponding to the selected audio segment are associated with the intersection of each frequency bin of the audio signal **106** and the time bin(s) associated with the audio segment. In some examples, each time-frequency bin generated by the audio segmenter **204** has an associated magnitude value (e.g., a magnitude of the FFT coefficient of the audio signal **106** associated with that time-frequency bin, etc.).

At block **808**, the audio characteristic determiner **208** determines the audio characteristic of each time-frequency bin in the audio segment. For example, the audio characteristic determiner **208** can determine the magnitude of each time-frequency bin in the audio segment. In such examples, the audio characteristic determiner **208** can calculate the energy and/or the entropy associated with each time-frequency bin. In other examples, the audio characteristic determiner **208** can determine any other suitable audio characteristic(s) (e.g., amplitude, power, etc.).

At block **810**, the bin normalizer **210** normalizes each time-frequency bin based on an average audio-characteristic of the surrounding audio region. For example, the bin normalizer **210** normalizes each time-frequency bin based on an average audio-characteristic of surrounding audio region. For example, the bin normalizer **210** can normalize an example time-frequency bin (e.g., the first time-frequency bin **404**, etc.) based on the average audio characteristic of the surrounding region (e.g., the first region **406**, etc.) as determined during the execution of block **710**. In some examples, the bin normalizer generates a normalized spectrogram (e.g., the normalized spectrogram **416** of FIG. 4B, etc.) by normalizing each of the time-frequency bins of audio segment.

At block **812**, the audio segmenter **204** selects an audio segment. For example, the audio segmenter **204** can select a first audio segment (e.g., the audio segment corresponding to the beginning of the audio signal **106**, etc.). In some examples, the audio segmenter **204** can select an audio segment temporally immediately adjacent to a previously selected audio segment. In other examples, the audio segmenter **204** can select an audio segment based on any suitable characteristic. In some examples, the audio segmenter windows the first segment.

At block **814**, the subfingerprint generator **212** computes primary subfingerprint(s) associated with the audio segment. For example, the subfingerprint generator **212** can generate a subfingerprint based on the normalized values of the time-frequency bins of the previous segment(s) analyzed at block **812**. In some examples, the subfingerprint generator **212** generates a subfingerprint by selecting energy and/or entropy extrema (e.g., five extrema, 20 extrema, etc.) in the previous segment(s). In such examples, the subfingerprint generated by the subfingerprint generator **212** includes portions (e.g., bits, etc.) corresponding to each one of the selected extrema. In such examples, each portion of a generated subfingerprint corresponds to the location of an energy extremum. In some examples, the subfingerprint generator **212** does not generate a subfingerprint (e.g., the previous audio segment is not being used to subfingerprint due to down-sampling, etc.). In such examples, blocks **816-720** are not executed for this selected segment.

At block **816**, the subfingerprint generator **212** determines if an alternative subfingerprint is to be generated. For example, the subfingerprint generator **212** can determine if a user has requested an alternative subfingerprint be generated. Additionally or alternatively, the subfingerprint generator **212** can determine if an alternative fingerprint is to be generated by any other suitable means. If an alternative subfingerprint is to be generated, the process **800** advances to block **818**. If an alternative subfingerprint is not to be generated, the process **800** advances to block **722**.

At block **818**, the portion strength evaluator **214** determines the strength of each portion of subfingerprint. For example, the portion strength evaluator **214** can repeat the subfingerprint generator process (e.g., the execution of blocks **806-814**, etc.) but overlaying the audio signal with random noise (e.g., white noise, artificially generated background audio, etc.). In some examples, because the subfingerprints associated with each audio sample depend on audio characteristics of adjacent samples, the portion strength evaluator **214** can determine the strength of portions of a subfingerprint by changing the audio characteristics of adjacent audio samples. In some such examples, the portion strength evaluator **214** can replace adjacent audio segments with different audio segments and/or append different audio on the audio segment being analyzed. Additionally or alternatively, the portion strength evaluator **214** can, for some or all samples of the audio signal, replace the adjacent audio samples with different audio (e.g., white noise, artificially generated background audio, different media, etc.). Based on the frequency of the portions of the generated subfingerprints change, the portion strength evaluator **214** can determine the strength of each portion as "weak," "strong," or "neutral." In some examples, the portion strength evaluator **214** can compare the frequency of change to a threshold.

At block **820**, the portion replacer **216** replaces weak portions with alternative portions. For example, the portion replacer **216** can replace weak portions of generated subfingerprints with random audio. In such examples, the portion replacer **216** can replace some or all of the identified weak portions with a random portion. For example, the portion replacer **216** can replace the weak portions with audio generated during the operation of the portion strength evaluator **214**. In other examples, the portion replacer **216** can replace the identified weak portions with any other suitable portion.

At block **822**, the audio segmenter **204** determines if another segment is to be selected. For example, the audio segmenter **204** can determine if there are additional audio segments of the audio signal **106** that have yet to be analyzed. If another segment is to be selected by the audio segmenter **204**, the process **800** returns to block **812**. If another segment is not to be selected by the audio segmenter **204**, the process **800** advances to block **824**.

At block **824**, the reference fingerprint generator **304** generates reference fingerprint(s) **121** for audio signal based on determined primary and alternative subfingerprints. For example, the reference fingerprint generator **304** can generate the reference fingerprint(s) **121** based on the subfingerprints generated by the subfingerprint generator **212**. For example, the reference fingerprint generator **304** can concatenate the subfingerprints associated with each audio segment into the reference fingerprint(s) **118**. In some examples, the reference fingerprint generator **304** can generate a fingerprint including the subfingerprints in which the weak portions have been replaced by the portion replacer **216**. In some examples, the reference fingerprint generator **304** can generate multiple query fingerprints based on the portions of the subfingerprints. In such examples, the reference fingerprint generator **304** can generate fingerprints including different subfingerprints of which the weak portions have been replaced. In some examples, the portion replacer **216** can be omitted. In some such examples, the reference fingerprint generator **304** can generate multiple fingerprints based on different audio overlays and/or audio sample appendages. In some such examples, the reference fingerprint generator **304** can cause the identified weak portions to be included from the query fingerprint **110** when the reference fingerprint **121** is compared to reference fingerprints by the fingerprint comparator **114**.

At block **826**, the fingerprint generator **218** adds the generated reference fingerprint(s) **121** to the reference fingerprint database **116**. For example, the fingerprint generator **218** can transmit and/or transmit the generated reference fingerprint(s) **121** to the reference fingerprint database **116** via a wireless network. In other examples, the fingerprint generator **218** can transfer the generated reference fingerprint(s) to the reference fingerprint database **116** via a wired connection and/or any other suitable means. The process **800** then ends.

The machine readable instructions described herein may be stored in one or more of a compressed format, an encrypted format, a fragmented format, a compiled format, an executable format, a packaged format, etc. Machine readable instructions as described herein may be stored as data or a data structure (e.g., portions of instructions, code, representations of code, etc.) that may be utilized to create, manufacture, and/or produce machine executable instructions. For example, the machine readable instructions may be fragmented and stored on one or more storage devices and/or computing devices (e.g., servers) located at the same or different locations of a network or collection of networks (e.g., in the cloud, in edge devices, etc.). The machine readable instructions may require one or more of installation, modification, adaptation, updating, combining, supplementing, configuring, decryption, decompression, unpacking, distribution, reassignment, compilation, etc. in order to make them directly readable, interpretable, and/or executable by a computing device and/or other machine. For example, the machine readable instructions may be stored in multiple parts, which are individually compressed, encrypted, and stored on separate computing devices, wherein the parts when decrypted, decompressed, and combined form a set of executable instructions that implement one or more functions that may together form a program such as that described herein.

In another example, the machine readable instructions may be stored in a state in which they may be read by processor circuitry, but require addition of a library (e.g., a dynamic link library (DLL)), a software development kit (SDK), an application programming interface (API), etc. in order to execute the instructions on a particular computing device or other device. In another example, the machine readable instructions may need to be configured (e.g., settings stored, data input, network addresses recorded, etc.) before the machine readable instructions and/or the corresponding program(s) can be executed in whole or in part. Thus, machine readable media, as used herein, may include machine readable instructions and/or program(s) regardless of the particular format or state of the machine readable instructions and/or program(s) when stored or otherwise at rest or in transit.

The machine readable instructions described herein can be represented by any past, present, or future instruction language, scripting language, programming language, etc. For example, the machine readable instructions may be represented using any of the following languages: C, C++, Java, C#, Perl, Python, JavaScript, HyperText Markup Language (HTML), Structured Query Language (SQL), Swift, etc.

As mentioned above, the example processes of FIGS. **7** and **8** may be implemented using executable instructions (e.g., computer and/or machine readable instructions) stored on a non-transitory computer and/or machine readable medium such as a hard disk drive, a flash memory, a read-only memory, a compact disk, a digital versatile disk, a cache, a random-access memory and/or any other storage device or storage disk in which information is stored for any duration (e.g., for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media.

"Including" and "comprising" (and all forms and tenses thereof) are used herein to be open ended terms. Thus, whenever a claim employs any form of "include" or "comprise" (e.g., comprises, includes, comprising, including, having, etc.) as a preamble or within a claim recitation of any kind, it is to be understood that additional elements, terms, etc. may be present without falling outside the scope of the corresponding claim or recitation. As used herein, when the phrase "at least" is used as the transition term in, for example, a preamble of a claim, it is open-ended in the same manner as the term "comprising" and "including" are open ended. The term "and/or" when used, for example, in a form such as A, B, and/or C refers to any combination or subset of A, B, C such as (1) A alone, (2) B alone, (3) C alone, (4) A with B, (5) A with C, (6) B with C, and (7) A with B and with C. As used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. As used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B.

As used herein, singular references (e.g., "a," "an," "first," "second," etc.) do not exclude a plurality. The term "a" or "an" entity, as used herein, refers to one or more of that entity. The terms "a" (or "an"), "one or more," and "at least one" can be used interchangeably herein. Furthermore, although individually listed, a plurality of means, elements or method actions may be implemented by, e.g., a single unit or processor. Additionally, although individual features may be included in different examples or claims, these may possibly be combined, and the inclusion in different examples or claims does not imply that a combination of features is not feasible and/or advantageous.

FIG. **9** is a block diagram of an example processor platform **1000** structured to execute the instructions of FIG. **7** to implement the query fingerprint generator **108** of FIG. **2**. The processor platform **900** can be, for example, a server, a personal computer, a workstation, a self-learning machine (e.g., a neural network), a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPad™), a personal digital assistant (PDA), an Internet appliance, a DVD player, a CD player, a digital video recorder, a Blu-ray player, a gaming console, a personal video recorder, a set top box, a headset or other wearable device, or any other type of computing device.

The processor platform **900** of the illustrated example includes a processor **912**. The processor **912** of the illustrated example is hardware. For example, the processor **912** can be implemented by one or more integrated circuits, logic circuits, microprocessors, GPUs, DSPs, or controllers from any desired family or manufacturer. The hardware processor may be a semiconductor based (e.g., silicon based) device. In this example, the processor implements the example audio signal interface **202**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, and the example fingerprint generator **218**.

The processor **912** of the illustrated example includes a local memory **913** (e.g., a cache). The processor **912** of the illustrated example is in communication with a main memory including a volatile memory **914** and a non-volatile memory **916** via a bus **918**. The volatile memory **914** may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS® Dynamic Random Access Memory (RDRAM®) and/or any other type of random access memory device. The non-volatile memory **916** may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory **914**, **916** is controlled by a memory controller.

The processor platform **900** of the illustrated example also includes an interface circuit **920**. The interface circuit **920** may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), a Bluetooth® interface, a near field communication (NFC) interface, and/or a PCI express interface.

In the illustrated example, one or more input devices **922** are connected to the interface circuit **920**. The input device(s) **922** permit(s) a user to enter data and/or commands into the processor **912**. The input device(s) can be implemented by, for example, an audio sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

One or more output devices **924** are also connected to the interface circuit **920** of the illustrated example. The output devices **924** can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display (LCD), a cathode ray tube display (CRT), an in-place switching (IPS) display, a touchscreen, etc.), a tactile output device, a printer and/or speaker. The interface circuit **920** of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip and/or a graphics driver processor.

The interface circuit **920** of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem, a residential gateway, a wireless access point, and/or a network interface to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network **926**. The communication can be via, for example, an Ethernet connection, a digital subscriber line (DSL) connection, a telephone line connection, a coaxial cable system, a satellite system, a line-of-site wireless system, a cellular telephone system, etc.

The processor platform **900** of the illustrated example also includes one or more mass storage devices **928** for storing software and/or data. Examples of such mass storage devices **928** include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, redundant array of independent disks (RAID) systems, and digital versatile disk (DVD) drives.

The machine executable instructions **932** of FIG. **7** may be stored in the mass storage device **928**, in the volatile memory **914**, in the non-volatile memory **916**, and/or on a removable non-transitory computer readable storage medium such as a CD or DVD.

FIG. **10** is a block diagram of an example processor platform **1000** structured to execute the instructions of FIG. **8** to implement the reference fingerprint generator **120** of FIG. **9**. The processor platform **1000** can be, for example, a server, a personal computer, a workstation, a self-learning machine (e.g., a neural network), a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPad'), a personal digital assistant (PDA), an Internet appliance, a DVD player, a CD player, a digital video recorder, a Blu-ray player, a gaming console, a personal video recorder, a set top box, a headset or other wearable device, or any other type of computing device.

The processor platform **1000** of the illustrated example includes a processor **1012**. The processor **1012** of the illustrated example is hardware. For example, the processor **1012** can be implemented by one or more integrated circuits, logic circuits, microprocessors, GPUs, DSPs, or controllers from any desired family or manufacturer. The hardware processor may be a semiconductor based (e.g., silicon based) device. In this example, the processor implements the audio signal interface **202**, the example audio signal interface **202**, the example audio segmenter **204**, the example signal transformer **206**, the example audio characteristic determiner **208**, the example bin normalizer **210**, the example subfingerprint generator **212**, the example portion strength evaluator **214**, the example portion replacer **216**, and the reference fingerprint generator **304**.

The processor **1012** of the illustrated example includes a local memory **1013** (e.g., a cache). The processor **1012** of the illustrated example is in communication with a main memory including a volatile memory **1014** and a non-volatile memory **1016** via a bus **1018**. The volatile memory **1014** may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS® Dynamic Random Access Memory (RDRAM®) and/or any other type of random access memory device. The non-volatile memory **1016** may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory **1014**, **1016** is controlled by a memory controller.

The processor platform **1000** of the illustrated example also includes an interface circuit **1020**. The interface circuit **1020** may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), a Bluetooth® interface, a near field communication (NFC) interface, and/or a PCI express interface.

In the illustrated example, one or more input devices **1022** are connected to the interface circuit **1020**. The input device(s) **1022** permit(s) a user to enter data and/or commands into the processor **1012**. The input device(s) can be implemented by, for example, an audio sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

One or more output devices **1024** are also connected to the interface circuit **1020** of the illustrated example. The output devices **1024** can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display (LCD), a cathode ray tube display (CRT), an in-place switching (IPS) display, a touchscreen, etc.), a tactile output device, a printer and/or speaker. The interface circuit **1020** of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip and/or a graphics driver processor.

The interface circuit **1020** of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem, a residential gateway, a wireless access point, and/or a network interface to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network **1026**. The communication can be via, for example, an Ethernet connection, a digital subscriber line (DSL) connection, a telephone line connection, a coaxial cable system, a satellite system, a line-of-site wireless system, a cellular telephone system, etc.

The processor platform **1000** of the illustrated example also includes one or more mass storage devices **1028** for storing software and/or data. Examples of such mass storage devices **1028** include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, redundant array of independent disks (RAID) systems, and digital versatile disk (DVD) drives.

The machine executable instructions **1032** of FIG. may be stored in the mass storage device **1028**, in the volatile memory **1014**, in the non-volatile memory **1016**, and/or on a removable non-transitory computer readable storage medium such as a CD or DVD.

Although certain example methods, apparatus and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.

Example methods, apparatus, systems, and articles of manufacture to fingerprint an audio signal are disclosed herein. Further examples and combinations thereof include the following: Example 1 includes an apparatus comprising an audio segmenter to divide an audio signal into a plurality of audio segments including a first audio segment, a second audio segment temporally after and adjacent to the first audio segment, and a third audio segment temporally after and adjacent to the second audio segment, a bin normalizer to normalize the second audio segment to thereby create a first normalized audio segment, the normalization based on first audio characteristics of the first audio segment, second audio characteristics of the second audio segment, and third audio characteristics the third audio segment, a subfingerprint generator to generate a first subfingerprint from the first normalized audio segment, the first subfingerprint including a first portion corresponding to a location of an energy extremum in the normalized second audio segment, a portion strength evaluator to determine a likelihood of the first portion to change based on changes to at least one of the first audio characteristics, the second audio characteristics, or the third audio characteristics, and a portion replacer to, in response to determining the likelihood does not satisfy a threshold, replace the first portion with a second portion to thereby generate a second subfingerprint.

Example 2 includes the apparatus of example 1, wherein the portion replacer is to, in response to determining the likelihood does not satisfy a strength threshold, exclude the first portion when matching query subfingerprints to the first subfingerprint.

Example 3 includes the apparatus of example 1, further including a signal transformer to transform the audio signal into a frequency domain to thereby generate a first group of time-frequency bins corresponding to the first audio segment, a second group of time-frequency bins corresponding to the second audio segment, and a third group of time-frequency bins corresponding to the third audio segment, and wherein the normalizing of the second audio segment includes normalizing a time-frequency bin of the second group of time-frequency bins based on a surrounding region of time-frequency bins, the surrounding region of time-frequency bins including ones of the first group of time-frequency bins and ones of the second group of time-frequency bins.

Example 4 includes the apparatus of example 1, wherein the portion strength evaluator determines the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics by replacing the first audio segment with a fourth audio segment, normalizing the second audio segment to thereby create a second normalized audio segment based on second audio characteristics of the fourth audio segment and the third audio segment, generating a second subfingerprint from the normalized second audio segment, and determining if the second subfingerprint includes the first portion.

Example 5 includes the apparatus of example 4, wherein the portion strength evaluator determines the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes replacing the third audio segment with a fifth audio segment, normalizing the second audio segment to thereby create a third normalized audio segment based on third audio characteristics of the first audio segment and the fifth audio segment, generating a third subfingerprint from the third normalized audio segment, and determining if the second subfingerprint includes the first portion.

Example 6 includes the apparatus of example 5, wherein at least one of the fourth audio segment or the fifth audio segment is randomly generated noise audio.

Example 7 includes the apparatus of example 4, further including a fingerprint generator to store the first subfingerprint and the second subfingerprint to enable matching query subfingerprints to at least one of the first subfingerprint or the second subfingerprint to thereby identify the audio signal.

Example 8 includes a method comprising dividing an audio signal into a plurality of audio segments including a first audio segment, a second audio segment temporally after and adjacent to the first audio segment, and a third audio segment temporally after and adjacent to the second audio segment, normalizing the second audio segment to thereby create a first normalized audio segment, the normalization based on first audio characteristics of the first audio segment, second audio characteristics of the second audio segment, and third audio characteristics the third audio segment, generating a first subfingerprint from the first normalized audio segment, the first subfingerprint including a first portion corresponding to a location of an energy extremum in the normalized second audio segment, determining a likelihood of the first portion to change based on changes to at least one of the first audio characteristics, the second audio characteristics, or the third audio characteristics, and in response to determining the likelihood does not satisfy a threshold, replacing the first portion with a second portion to thereby generate a second subfingerprint.

Example 9 includes the method of example 8, further including, in response to determining the likelihood does not satisfy a strength threshold, excluding the first portion when matching query subfingerprints to the first subfingerprint.

Example 10 includes the method of example 8, further including transforming the audio signal into a frequency domain to thereby generate a first group of time-frequency bins corresponding to the first audio segment, a second group of time-frequency bins corresponding to the second audio segment, and a third group of time-frequency bins corresponding to the third audio segment, and wherein the normalizing the second audio segment includes normalizing a time-frequency bin of the second group of time-frequency bins based on a surrounding region of time-frequency bins, the surrounding region of time-frequency bins including ones of the first group of time-frequency bins and ones of the second group of time-frequency bins.

Example 11 includes the method of example 8, wherein the determination of the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes replacing the first audio segment with a fourth audio segment, normalizing the second audio segment to thereby create a second normalized audio segment based on second audio characteristics of the fourth audio segment and the third audio segment, generating a second subfingerprint from the normalized second audio segment, and determining if the second subfingerprint includes the first portion.

Example 12 includes the method of example 11, wherein the determination of the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes replacing the third audio segment with a fifth audio segment, normalizing the second audio segment to thereby create a third normalized audio segment based on third audio characteristics of the first audio segment and the fifth audio segment, generating a third subfingerprint from the third normalized audio segment, and determining if the second subfingerprint includes the first portion.

Example 13 includes the method of example 11, further including storing the first subfingerprint and the second subfingerprint to enable matching query subfingerprints to at least one of the first subfingerprint or the second subfingerprint to thereby identify the audio signal.

Example 14 includes a non-transitory computer readable medium comprising instructions which, when executed, cause a processor to divide an audio signal into a plurality of audio segments including a first audio segment, a second audio segment temporally after and adjacent to the first audio segment, and a third audio segment temporally after and adjacent to the second audio segment, normalize the second audio segment to thereby create a first normalized audio segment, the normalization based on first audio characteristics of the first audio segment, second audio characteristics of the second audio segment, and third audio characteristics the third audio segment, generate a first subfingerprint from the first normalized audio segment, the first subfingerprint including a first portion corresponding to a location of an energy extremum in the normalized second audio segment, determine a likelihood of the first portion to change based on changes to at least one of the first audio characteristics, the second audio characteristics, or the third audio characteristics, and in response to determining the likelihood does not satisfy a threshold, replace the first portion with a second portion to thereby generate a second subfingerprint.

Example 15 includes the non-transitory computer readable medium of example 14, wherein the instructions further cause the processor to, in response to determining the likelihood does not satisfy a strength threshold, excluding the first portion when matching query subfingerprints to the first subfingerprint.

Example 16 includes the non-transitory computer readable medium of example 14, wherein the instructions further cause the processor to transform the audio signal into a frequency domain to thereby generate a first group of time-frequency bins corresponding to the first audio segment, a second group of time-frequency bins corresponding to the second audio segment, and a third group of time-frequency bins corresponding to the third audio segment, and wherein the normalizing the second audio segment includes normalizing a time-frequency bin of the second group of time-frequency bins based on a surrounding region of time-frequency bins, the surrounding region of time-frequency bins including ones of the first group of time-frequency bins and ones of the second group of time-frequency bins.

Example 17 includes the non-transitory computer readable medium of example 14, wherein the determination of the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes replacing the first audio segment with a fourth audio segment, normalizing the second audio segment to thereby create a second normalized audio segment based on second audio characteristics of the fourth audio segment and the third audio segment, generating a second subfingerprint from the normalized second audio segment, and determining if the second subfingerprint includes the first portion.

Example 18 includes the non-transitory computer readable medium of example 17, wherein the determination of the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes replacing the third audio segment with a fifth audio segment, normalizing the second audio segment to thereby create a third normalized audio segment based on third audio characteristics of the first audio segment and the fifth audio segment, generating a third subfingerprint from the third normalized audio segment, and determining if the second subfingerprint includes the first portion.

Example 19 includes the non-transitory computer readable medium of example 18, wherein at least one of the fourth audio segment or the fifth audio segment is randomly generated noise audio.

Example 20 includes the non-transitory computer readable medium of example 18, wherein the instructions further cause the processor to store the first subfingerprint and the second subfingerprint to enable matching query subfingerprints to at least one of the first subfingerprint or the second subfingerprint to thereby identify the audio signal. The following claims are hereby incorporated into this Detailed Description by this reference, with each claim standing on its own as a separate embodiment of the present disclosure.

What is claimed is:

1. An apparatus comprising:

an audio segmenter to divide an audio signal into a plurality of audio segments including a first audio segment, a second audio segment temporally after and adjacent to the first audio segment, a third audio segment temporally after and adjacent to the second audio segment, and a fourth audio segment;

a bin normalizer to normalize the second audio segment to thereby create a first normalized audio segment based on first audio characteristics of the first audio segment, second audio characteristics of the second audio segment, and third audio characteristics the third audio segment and a second normalized audio segment based on fourth audio characteristics of the fourth audio segment and at least one of the first audio characteristics of the first audio segment, the second audio characteristics of the second audio segment, and the third audio characteristics the third audio segment;

a subfingerprint generator to generate a first subfingerprint from the first normalized audio segment, the first subfingerprint including a first portion corresponding to a location of an energy extremum in the normalized second audio segment, and a second subfingerprint from the second normalized audio segment;

a portion strength evaluator to determine a likelihood of the first portion to change based on changes to at least one of the first audio characteristics, the second audio characteristics, or the third audio characteristics; and

a portion replacer to, in response to determining the likelihood does not satisfy a threshold, replace the first portion with a second portion and determine if the second subfingerprint includes the first portion.

2. The apparatus of claim **1**, wherein the portion replacer is to, in response to determining the likelihood does not satisfy a strength threshold, exclude the first portion when matching query subfingerprints to the first subfingerprint.

3. The apparatus of claim **1**, further including

a signal transformer to transform the audio signal into a frequency domain to thereby generate a first group of time-frequency bins corresponding to the first audio segment, a second group of time-frequency bins corresponding to the second audio segment, and a third group of time-frequency bins corresponding to the third audio segment; and

wherein the normalizing of the second audio segment includes normalizing a time-frequency bin of the second group of time-frequency bins based on a surrounding region of time-frequency bins, the surrounding region of time-frequency bins including ones of the first group of time-frequency bins and ones of the second group of time-frequency bins.

4. The apparatus of claim **1**, wherein the portion strength evaluator determines the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes:

replacing the third audio segment with a fifth audio segment;

normalizing the second audio segment to thereby create a third normalized audio segment based on third audio characteristics of the first audio segment and the fifth audio segment;

generating a third subfingerprint from the third normalized audio segment; and

determining if the second subfingerprint includes the first portion.

5. The apparatus of claim **4**, wherein at least one of the fourth audio segment or the fifth audio segment is randomly generated noise audio.

6. The apparatus of claim **1**, further including a fingerprint generator to store the first subfingerprint and the second subfingerprint to enable matching query subfingerprints to at least one of the first subfingerprint or the second subfingerprint to thereby identify the audio signal.

7. A method comprising:

dividing an audio signal into a plurality of audio segments including a first audio segment, a second audio segment temporally after and adjacent to the first audio segment, a third audio segment temporally after and adjacent to the second audio segment, and a fourth audio segment;

normalizing the second audio segment to thereby create a first normalized audio segment based on first audio characteristics of the first audio segment, second audio characteristics of the second audio segment, and third audio characteristics the third audio segment and a second normalized audio segment based on fourth audio characteristics of the fourth audio segment and at least one of the first audio characteristics of the first audio segment, the second audio characteristics of the second audio segment, and the third audio characteristics the third audio segment;

generating a first subfingerprint from the first normalized audio segment, the first subfingerprint including a first portion corresponding to a location of an energy extremum in the normalized second audio segment, and a second subfingerprint from the second normalized audio segment;

determining a likelihood of the first portion to change based on changes to at least one of the first audio characteristics, the second audio characteristics, or the third audio characteristics; and

in response to determining the likelihood does not satisfy a threshold, replacing the first portion with a second portion and determine if the second subfingerprint includes the first portion.

8. The method of claim **7**, further including, in response to determining the likelihood does not satisfy a strength threshold, excluding the first portion when matching query subfingerprints to the first subfingerprint.

9. The method of claim **7**, further including:

transforming the audio signal into a frequency domain to thereby generate a first group of time-frequency bins corresponding to the first audio segment, a second group of time-frequency bins corresponding to the second audio segment, and a third group of time-frequency bins corresponding to the third audio segment; and

wherein the normalizing the second audio segment includes normalizing a time-frequency bin of the second group of time-frequency bins based on a surrounding region of time-frequency bins, the surrounding region of time-frequency bins including ones of the first group of time-frequency bins and ones of the second group of time-frequency bins.

10. The method of claim **7**, wherein the determination of the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes:

replacing the third audio segment with a fifth audio segment;

normalizing the second audio segment to thereby create a third normalized audio segment based on third audio characteristics of the first audio segment and the fifth audio segment;

generating a third subfingerprint from the third normalized audio segment; and

determining if the second subfingerprint includes the first portion.

11. The method of claim **7**, further including storing the first subfingerprint and the second subfingerprint to enable matching query subfingerprints to at least one of the first subfingerprint or the second subfingerprint to thereby identify the audio signal.

12. A non-transitory computer readable medium comprising instructions which, when executed, cause a processor to:

divide an audio signal into a plurality of audio segments including a first audio segment, a second audio segment temporally after and adjacent to the first audio segment, a third audio segment temporally after and adjacent to the second audio segment, and a fourth audio segment;

normalize the second audio segment to thereby create a first normalized audio segment based on first audio characteristics of the first audio segment, second audio characteristics of the second audio segment, and third audio characteristics the third audio segment and a second normalized audio segment based on fourth audio characteristics of the fourth audio segment and at least one of the first audio characteristics of the first audio segment, the second audio characteristics of the second audio segment, and the third audio characteristics the third audio segment;

generate a first subfingerprint from the first normalized audio segment, the first subfingerprint including a first portion corresponding to a location of an energy extremum in the normalized second audio segment, and a second subfingerprint from the second normalized audio segment;

determine a likelihood of the first portion to change based on changes to at least one of the first audio characteristics, the second audio characteristics, or the third audio characteristics; and

in response to determining the likelihood does not satisfy a threshold, replace the first portion with a second portion and determine if the second subfingerprint includes the first portion.

13. The non-transitory computer readable medium of claim 12, wherein the instructions further cause the processor to, in response to determining the likelihood does not satisfy a strength threshold, excluding the first portion when matching query subfingerprints to the first subfingerprint.

14. The non-transitory computer readable medium of claim 12, wherein the instructions further cause the processor to:

transform the audio signal into a frequency domain to thereby generate a first group of time-frequency bins corresponding to the first audio segment, a second group of time-frequency bins corresponding to the second audio segment, and a third group of time-frequency bins corresponding to the third audio segment; and

wherein the normalizing the second audio segment includes normalizing a time-frequency bin of the second group of time-frequency bins based on a surrounding region of time-frequency bins, the surrounding region of time-frequency bins including ones of the first group of time-frequency bins and ones of the second group of time-frequency bins.

15. The non-transitory computer readable medium of claim 12, wherein the determination of the likelihood based on changes to at least one of the first audio characteristics, the second audio characteristics or the third audio characteristics includes:

replacing the third audio segment with a fifth audio segment;

normalizing the second audio segment to thereby create a third normalized audio segment based on third audio characteristics of the first audio segment and the fifth audio segment;

generating a third subfingerprint from the third normalized audio segment; and

determining if the second subfingerprint includes the first portion.

16. The non-transitory computer readable medium of claim 15, wherein at least one of the fourth audio segment or the fifth audio segment is randomly generated noise audio.

17. The non-transitory computer readable medium of claim 15, wherein the instructions further cause the processor to store the first subfingerprint and the second subfingerprint to enable matching query subfingerprints to at least one of the first subfingerprint or the second subfingerprint to thereby identify the audio signal.

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