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(54) **Title:** SYSTEMS AND METHODS FOR PROCESSING A PLURALITY OF FREQUENCY SIGNALS WITH A WIDE BAND DIGITAL RECEIVER

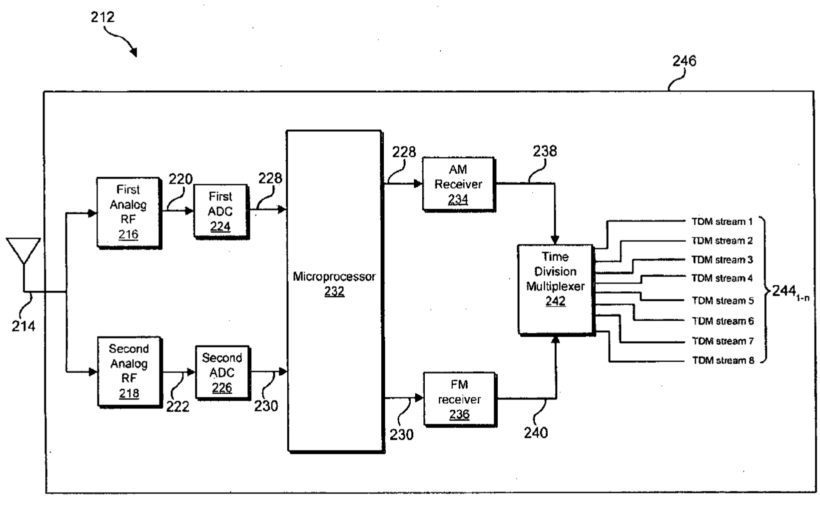

FIG. 2

(57) **Abstract:** A method for processing a plurality of individual frequency signals is described. A composite frequency signal is received. The composite signal comprises a plurality of individual frequency signals. The composite frequency signal is separated into the plurality of individual frequency signals. Each of the plurality of individual frequency signals are sequentially transmitted to a single channel demodulator. Each of the plurality of individual frequency signals is demodulated.

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SYSTEMS AND METHODS FOR PROCESSING A PLURALITY OF FREQUENCY SIGNALS WITH A WIDE BAND DIGITAL RECEIVER

RELATED APPLICATIONS

[0001] This application is related to and claims priority from U.S. Patent Application Serial No. 60/982649 filed October 25, 2007, for WIDE BAND DIGITAL RECEIVER, which is incorporated herein as if set out in full.

TECHNICAL FIELD

[0002] The present disclosure relates generally to radio frequency receivers. More specifically, the present disclosure relates to systems and methods for processing a plurality of frequency signals with a wide band digital receiver.

BACKGROUND

[0003] Broadcast systems generally include a broadcast source, a transmission medium, and a receiver. Greatly simplified, in the case of broadcast audio, generically referred to as radio or radio broadcast, the broadcast source typically modulates the audio signal onto a carrier signal using either amplitude or frequency modulation techniques (AM or FM, respectively). The modulated signal is transmitted from, for example, a tower or satellite through the air to a receiver. The receiver receives the radio transmission and demodulates the signal to extract the audio signal, which is played, for example, through speakers. Other broadcast systems transmit types of data other than broadcast audio and the extracted signal is generically referred to as an information or data signal.

[0004] Many broadcast sources exist. To inhibit multiple entities from broadcasting over the same radio frequency, in the United States, the Federal Communications Commission assigns the broadcast source the rights to broadcast at a specified signal strength in a specified frequency range. For example, FM radio stations typically broadcast between about 88 Megahertz (MHz) and 108 MHz. In other words, the radio station FM 97.3 refers to a radio station broadcasting a frequency modulated signal at 97.3 MHz. The strength of radio broadcasts decreases based on the distance from the broadcast source. Thus, the broadcast area of the particular station is geographically limited by where the signal can reach. Stronger signals cover more geographical area. Similarly, a radio station with the call signs 850 AM refers to a radio station broadcasting an AM signal at 850 kilohertz (kHz). Typically, AM stations broadcast from about 550 kHz to about 1700 kHz.

[0005] Recently, many broadcast sources have begun using satellite systems in which the content of the broadcast is transmitted from the broadcast source to a satellite and retransmitted from the satellite to the broadcast receiver. Satellite systems are similar to most radio frequency systems, but the broadcast to the satellite is up-converted to the appropriate radio frequency transmission band for satellites, which is currently allocated as the S-band (approximately 2.3 Gigahertz (GHz)). Moreover, the broadcast receivers typically down-convert the satellite transmission from the S-band to the appropriate baseband or intermediate frequency signal on reception.

[0006] A radio frequency antenna is capable of receiving multiple radio signals. Thus, a tuner is employed to filter the multiple radio signals to the specific or individual radio frequency signal at a particular frequency. For example, an FM radio receiver is capable of receiving all signals in the FM spectrum. The tuner, isolates a single channel, or frequency band, such that the output from the speakers is the radio broadcast at that particular frequency in the given area.

[0007] In some instances, it is often desirous to receive multiple radio broadcasts at the same time using a single device. Devices capable of receiving multiple broadcasts at the same or substantially the same time include, for example, mixing equipment, and computers, to name but two of many such devices. Conventionally, in order to receive multiple broadcasts at different radio frequencies, it has been required to have receivers with multiple tuners that would be appropriately tuned to receive the various broadcasts. Thus to receive three simultaneous broadcasts, such a receiver would require three tuners; six broadcasts would require six tuners, etc. As such, benefits would be realized by providing systems and methods for processing multiple frequency signals using a single tuner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 is a block diagram illustrating one embodiment of a broadcast system;

[0009] Figure 2 is a block diagram illustrating an embodiment of a receiver;

[0010] Figure 3 is a block diagram illustrating a further embodiment of an FM receiver;

[0011] Figure 4 is a block diagram illustrating one embodiment of an FM signal input module;

[0012] Figure 5 is a block diagram illustrating a further embodiment of a channelizer;

[0013] Figure 6 is a graph illustrating one embodiment of individual FM signals;

[0014] Figure 7 is a block diagram illustrating an embodiment of an M-band analysis filter bank based on the channelizer;

[0015] Figure 8 is a block diagram illustrating one embodiment of a single channel FM demodulator;

[0016] Figure 9 is a block diagram illustrating a further embodiment of an AM receiver;

[0017] Figure 10 is a block diagram illustrating one embodiment of an AM signal input module;

[0018] Figure 11 is a flow diagram illustrating one embodiment of a method for processing a plurality of individual frequency signals; and

[0019] Figure 12 illustrates various components that may be used in a computing device.

BRIEF SUMMARY OF THE TECHNOLOGY OF THE PRESENT APPLICATION

[0020] The technology of the present application provides systems, apparatuses, and methods to demultiplex a plurality of streams (channels) of multimedia data using a single digital multiplexer. Aspects of the technology of the present application include processing a plurality of individual frequency signals by first receiving a composite frequency signal, wherein the composite signal comprises a plurality of individual frequency signals. The composite signal is next separated into the plurality of individual frequency signals that are transmitted, sequentially, to a single channel demodulator. The single channel demodulator demodulates each of the plurality of individual frequency signals.

[0021] Other aspects of the technology of the present application includes a digital modulation device that is configured to receive a plurality of frequency multiplexed channels. The digital modulator comprises a computing device that is configured to process a plurality of individual frequency signals and has a processor and a memory in electronic communication with the processor. An antenna is configured to receive a composite frequency signal, wherein the composite signal comprises a plurality of individual frequency signals. The antenna is connected to a digital receiver, the receiver that includes a channelizer configured to separate the composite frequency signal into the plurality of individual frequency signals and a channel control module configured to sequentially transmit each of the plurality of individual frequency signals to a single channel demodulator. The single channel demodulator configured to demodulate each of the plurality of individual frequency signals. The processor memory includes instructions stored in the memory are executable by the digital modulation device to receive a plurality of multimedia channels. The plurality of multimedia channels are decoded. The decoded plurality of multimedia channels are modulated, digitally, into multimedia channels and transmitted simultaneously over a distribution infrastructure.

DETAILED DESCRIPTION

[0022] The present systems and methods will now be described with reference to the figures. Although described in the context of broadcast audio relating to frequency modulation (FM) and amplitude modulation (AM), the present systems and methods may be used for parallel reception of numerous types of radio frequency signals including, broadcast television signals, cellular telephone signals, and broadcast audio signals, to name but a few.

[0023] Moreover, the present systems and methods are explained with reference to exemplary embodiments. The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments. Additionally, unless otherwise provided, all embodiments provided herein should be considered exemplary.

[0024] Referring now to figure 1, a broadcast system 100 may include a broadcast source 102, an intermediate transceiver 110, and a receiver 112. The broadcast source 102 may be a radio or television provider, for example. In one embodiment, the source 102 may transmit one or more signals 104A, 104B to an intermediate transceiver 110. The signals 104A, 104B may be broadcast to the transceiver 110 through a transmission medium, such as air. The intermediate transceiver 110 may be a satellite 106, a broadcast tower 108, etc. In one embodiment, the transceiver 110 receives the signals 104A, 104B, processes the signals 104A, 104B, and transmits the signals 104A, 104B to a receiver 112. The transceiver 110 may transmit the signals 104A, 104B through a transmission medium, such as air. In one embodiment, the receiver 112 receives the signals 104A, 104B, processes the signals and provides the signals to an end user via an end device, which may be, for example, a conventional radio, television, MP3 player, computer processor, cellular telephone, or the like to name but a few examples.

[0025] Figure 2 is a block diagram illustrating one embodiment of a receiver 212. In the exemplary embodiment relating to broadcast audio, for example, the receiver 212 may include an AM receiver 234 and an FM receiver 236 to receive and process AM signals and FM signals, respectively. Alternatively, receiver 212 may provide only an AM receiver 234 or only an FM receiver 236 instead of providing both in a single device. In this exemplary embodiment, however, the AM receiver 234 and the FM receiver 236 may be mounted in a housing 246, or alternatively, mounted on a printed circuit board (PCB) (not shown). The housing may be, for example, a computing device, a radio, mixing equipment, a MP3 player, and the like to name but a few examples.

[0026] In one configuration, the receiver 212 includes an antenna 214 to receive FM signals and AM signals from the transceiver 110. The antenna 214 may be connected to a first analog radio frequency (RF) circuitry 216 and a second analog radio RF circuitry 218. The first and second analog RF circuitry 216, 218 may retrieve FM and AM signals from the antenna 214 and process the signals. The processed AM signal 220 and the processed FM signal 222 may be sampled by a first analog-to-digital converter (ADC) 224 and a second ADC 226, respectively.

[0027] In one example, the first ADC 224 outputs a sampled AM signal 228. The second ADC 226 may output a sampled FM signal 230. In one embodiment, the sampled signals 228, 230 may be preprocessed by a microprocessor 232. In another embodiment, the sampled signals 228, 230 are input to the AM receiver 234 and the FM receiver 236, respectively. The AM receiver 234 and the FM receiver 236 will be explained in further detail below.

[0028] In one embodiment, the AM receiver 234 outputs a demodulated AM signal 238 and the FM receiver 236 outputs a demodulated FM signal 240. The AM receiver 234 and the FM receiver 236 may each demodulate multiple AM signals 228 and FM signals 230, respectively. For example, in an exemplary embodiment regarding audio transmission, the AM receiver 234 and the FM receiver 236 may each demodulate one hundred twenty-eight AM and FM signals, respectively. The demodulated signals 238, 240 may be generically referred to as an information signal 238, 240 or an audio signal in the case of a radio broadcast.

[0029] In one configuration, the demodulated signals 238, 240 may be input to a time division multiplexer (TDM) 242 that multiplexes the demodulated signals 238, 240. The TDM 242 may output a plurality of audio streams $244_{1\text{-}n}$. As illustrated, the plurality of audio streams 244 may be eight audio streams, but more or less audio streams may be output from the TDM 242. In one embodiment, each of the plurality of audio streams 244 may be multiplexed between thirty-two different slots. Each slot may include sixteen bit information samples from the left (L) or right (R), in the case of audio samples.

[0030] Figure 3 is a block diagram illustrating a further embodiment of an FM receiver 336. A FM signal input module 350 may provide a digitized (*i.e.* sampled) FM signal 330 as input to the FM receiver 336. The input module 350 may include the antenna 214, the second analog RF circuitry 218, the second ADC 226, and the microprocessor 232. In one embodiment, the input module 350 may filter the signal. In addition, the second ADC 226 (not shown in figure 3) may sample the signal. Depending on the source of the FM signal, the module 350 may include a down-converter to down-convert the signal to the baseband frequency. Various sampling techniques may be implemented by the input module 350. Two sampling techniques are provided below.

[0031] A first method includes a relatively high sampling frequency, as will be explained with reference to figure 4. As shown in figure 4, assuming an analog signal input, an ADC 452 may input sampled FM modulated signal 454 to a down-converter 456. A down-converted FM signal 460 may be input to a down-sampler 462.

[0032] In one embodiment, the ADC 452 may sample the analog FM modulated signal using a sampling frequency in the Nyquist zone, such as a 243.2 Megahertz (MHz) sampling frequency. The down-converter 456 may down-convert the signal 454 using a down-convert frequency 458 of 97.9 MHz. Further, the down-sampler 462 may provide a 19 to 2 down-sampling ratio.

[0033] An antialiasing analog filter in the second analog RF circuitry 218 may suppress frequencies above a certain threshold. For example, the antialiasing analog filter suppresses frequencies that are greater than 135.3 MHz. As such, a transition bandwidth associated with the implementation of the first method previously described may be less than 30 MHz. Moreover, spectral components that are greater than 135.3 MHz after digital sampling may alias back into a spectrum between about 87.9 MHz and 107.9 MHz. In one embodiment, twelve bit ADCs are used for these sampling frequencies, which may limit the dynamic range of the input signal to about seventy-two decibels (dB).

[0034] A second method that may be used to obtain the sampled FM signal 454 may include a relatively lower sampling frequency. In this case, the ADC 452 may sample the analog FM modulated signal using a sampling frequency in the second Nyquist zone, such as a 128 MHz sampling frequency, which may allow for the use of sixteen bit ADCs 452. The down-converter 456 may down-convert the signal 454 using a down-convert frequency 458 of about 30.1 MHz. Further, the down-sampler 462 may provide a 5 to 1 down-sampling ratio. However, different down-converters and down-samplers may be used depending on the chosen analog RF solution. In one embodiment, the result of the anti-aliasing filter (not shown) may inhibit additional spectral replica between 20.1 MHz and 40.1 MHz (from aliasing) from being corrupted.

[0035] Figure 5 is a block diagram illustrating a further embodiment of a channelizer 552. As previously mentioned, the channelizer 552 may separate the sampled FM modulated signal 230 (which may have been down-converted or otherwise preprocessed) into a plurality of individual channels. In one embodiment, the channelizer 552 may separate the sampled signal 230 into one hundred twenty-eight individual channels. For example, as shown in Figure 6, in the case of a 128:1 channelizer, the sampled FM modulated signal 230 may be separated into one hundred twenty-eight channels 602a, 602b, 602c, 602d, 602e, etc. Each channel 602 may have a frequency span *W* 604 of about 200 kHz wide.

[0036] Returning to figure 5, the channelizer 552 may include a memory 502, one or more filters (which are illustrated as a first polyphase filter 504 and a second polyphase filter 506), and an inverse fast Fourier transform (IFFT) 508. The combination of the polyphase filters 504, 506 and the IFFT 508 may be referred to as a polyphase transform. In one embodiment, output 510 of the channelizer 552 may be a plurality of individual modulated FM signals 240. For example, the output 510 may be one hundred twenty-eight individual modulated FM signals 240.

[0037] The first and second polyphase filters 504, 506 may simulate individual low pass filters to tune the composite FM signal into one hundred twenty-eight separate FM signals. The filters 504, 506 may use in-phase components 512 and quadrature components 514 in order to tune the composite FM signal into separate FM signals.

[0038] In one embodiment, the channelizer 552 represents a uniform filter bank. For example, the memory 502 may store a plurality of banks 516. Each bank may include one or more coefficients 518. In one configuration, the memory 502 may store one hundred twenty-eight banks 516 with twelve coefficients 518 per bank.

[0039] Figure 7 is a block diagram illustrating an embodiment of an M-band analysis filter bank 700 based on the channelizer 552. The filter bank 700 facilitates the separation of a composite signal *x[n]* 704 into a plurality of separate signals 706. For example, the filter bank 700 may separate the composite signal 704 into one hundred twenty-eight individual signals *v0[n], v1[n], v2[n] . . . v127[n]* $706_{0\text{-}127}$.

[0040] In one embodiment, the filter bank 700 is designed to use the Remez algorithm as a polyphase structure with minimal in-band ripple. A plurality of sub-filters 702 may have pass-band ripple less than 0.08 dB and out-of-band suppression of a least 81 dB. In one example, the filter bank 700 includes one hundred twenty-eight sub-filters $702_{0\text{-}127}$. In order to avoid the flattening of the out-of-band characteristics of the filter, the last few samples of the filter in the time domain may be windowed to achieve a constant rate falling characteristic, such as can be accomplished out-of-band. A constant rate falling characteristic may be significant when the rate is changed with large ratios.

[0041] The input signal 704 may be filtered with each polyphase sub-filter 702 $e_i(n)$, where i = 0-127. After filtering, the filtered input signal may be further processed by an M-point discrete Fourier Transform (M-point DFT) 708. The output of the M-point DFT 708 may be a plurality of separate FM signals 706.

[0042] Referring back to figure 3, output from the channelizer 352 may be sent to a channel control module 354. In one embodiment, the channel control module 354 receives a block output of the plurality of signals from the channelizer 352, which in the case of a 128:1 channelizer is one hundred twenty-eight signals. Conventionally, each signal would be provided to its own demodulator. However, the present systems and methods use the channel control module 354 to allow a single channel FM demodulator 356 to demodulate each individual signal. As a result, resources needed to demodulate each signal are greatly reduced (*i.e.*, reduced number of demodulators). In addition, the size of the FM receiver 336 is also significantly reduced. In one embodiment, the FM receiver 336 is scalable as additional components are needed in the future and/or other components are not required.

[0043] Figure 8 is a block diagram illustrating one embodiment of a single channel FM demodulator 856. The illustrated demodulator 856 outputs an audio FM signal in stereo mode 840, 842. However, the demodulator 856 may output audio signals in mono mode or additional multimedia signals such as, for example, a video signal, an audio and video signal, or the like. The demodulator 856 may further output a Radio Data System (RDS) signal 838 or other conventional information data stream associated with the multimedia signals.

[0044] In one embodiment, an input signal 802 is provided. The input signal 802 may be an individual FM signal provided by the channel control module 354. The input signal 802 may be sampled at 200 kHz. The input signal 802 may be down-converted 806 with a signal provided by an automatic gain control (AGC) module 804. The signal provided by the AGC module 804 may be dependent on the input signal 802. The combined signal may be input to an FM differentiator 808 that flattens the amplitude of the combined signal. In one embodiment, a DC canceller module 810 may remove additional frequency offset from the combined signal. A plurality of low-pass filters (LPF) 812, band-pass filters (BPF) 814, 818, infinite impulse response (IIR) filters 834, 836, resamplers 828, 830, 832 and an extraction module 816 may be used to extract a left + right (L+R) signal, an L-R signal, and the RDS signal 838. The L+R signal and the L-R signal may be further processed to output a left signal (L) 840 and a right signal (R) 842, in the case of audio signals in stereo mode.

[0045] Figure 9 is a block diagram illustrating a further embodiment of an AM receiver 934. An AM signal input module 950 may provide a digitized (*i.e.* sampled) AM signal 928 as input to the AM receiver 934. The input module 950 may include the antenna 214, the first analog RF circuitry 216, the first ADC 224, and the microprocessor 232. In one embodiment, the input module 950 may filter the signal. In addition, the first ADC 224 (not shown) may sample the signal. Depending on the source of the AM signal, the module 950 may include a down-converter to down-convert the signal to the baseband frequency. Various sampling techniques may be implemented by the input module 950, similar to the two methods previously described in relation to the FM signal.

[0046] A first method includes a relatively high sampling frequency, as will be explained with reference to figure 10. As shown in figure 10, assuming an analog signal input, an ADC 1002 may input sampled AM modulated signal to a down-converter 1004. A down-converted AM signal may be input to a cascaded integrator-comb (CIC) filter 1006 and then input to a down-sampler 1008.

[0047] In one embodiment, the ADC 1002 may sample the analog AM modulated signal using a sampling frequency in the Nyquist zone, such as a 243.2 Megahertz (MHz) sampling frequency. The down-converter 1004 may down-convert the signal using a down-convert frequency of 1060 kHz. Further, the CIC 1006 may provide a 25 to 1 filtering ratio and the down-sampler 1008 may provide a 4 to 1 down-sampling ratio.

[0048] A second method that may be used to obtain the sampled AM signal may include a relatively lower sampling frequency. In this case, the ADC 1002 may sample the analog AM modulated signal using a sampling frequency in the second Nyquist zone, such as a 128 MHz sampling frequency. The down-converter 1004 may down-convert the signal using a down-convert frequency of about 1060 kHz. Further, the CIC 1006 may provide a 50 to 1 filtering ratio and the down-sampler 462 may provide a 19 to 5 down-sampling ratio.

[0049] In one embodiment, an antialiasing filter (not shown) in the first analog RF circuitry 216 is realized as a low pass filter for both the methods described above to acquire a sampled AM signal. This may be caused, in part, because the sampling frequency in both cases (*i.e.*, 243.2 MHz and 128 MHz) may be higher than the useful spectrum for AM radio signals.

[0050] In one embodiment, a sampled composite AM signal 928 is input to an AM channelizer 952. The channelizer 952 may separate the composite AM signal 928 into a plurality of individual AM signals. For example, the channelizer 952 may separate the composite AM signal 928 into one hundred twenty-eight signals, similar to that described above in relation to the FM channelizer 352. The plurality of individual AM signals may be input to an AM channel control module 954. As with the FM control module 354, the AM control module 954 provides each of the individual AM signals to an AM demodulator 956. In one embodiment, the demodulator 956 demodulates each of the individual AM signals and outputs an audio stream 958. The AM demodulator 956 may be a conventional single channel AM demodulator.

[0051] The above described AM and FM receivers 234, 236 may be characterized as receiving a composite RF signal (either AM or FM) from one or more broadcast sources. The composite RF signal may include a plurality of individual RF signals in which each individual RF signal may reside at a particular frequency. The composite RF signal may be input to a channelizer that separates the composite RF signal into the plurality of individual RF signals. A channel control module may receive the plurality of individual RF signals as a block input and sequentially transmit each of the plurality of individual RF signals to a single channel demodulator. The single channel demodulator may demodulate each of the plurality of individual RF signals into the respective information signal (or audio signal in the case of a radio broadcast). The information signals may be multiplexed as desired.

[0052] Figure 11 is a flow diagram illustrating one embodiment of a method 1100 for processing a plurality of individual frequency signals. The method 1100 may be implemented by a receiver 112 in a broadcast system. In one embodiment, a composite frequency signal is received 1102. The composite signal may include a plurality of individual frequency signals.

[0053] The composite frequency signal may be separated 1104 into the plurality of individual frequency signals. The separation of the composite frequency signal may be implemented by the channelizer 352, 952. In one embodiment, the plurality of individual frequency signals are multiplexed 1106 to a single channel demodulator. The method 1100 continues and each individual frequency signal may be demodulated 1108 into a corresponding information signal. In one embodiment, the composite frequency signal may be a radio frequency FM signal, a radio frequency AM signal, a television signal, an audio signal, or any other type of multimedia frequency signal.

[0054] Figure 12 illustrates various components that may be used in a computing device 1202. One or more computing devices 1202 may be used to implement the various systems and methods described herein. The illustrated components may be located within the same physical structure or in separate housings or structures. Thus, the term computer or computer system is used to mean one or more broadly defined computing devices 1202 unless it is expressly stated otherwise. Computing devices 1202 include the broad range of digital computers including microcontrollers, hand-held computers, personal computers, servers, mainframes, supercomputers, minicomputers, workstations, and any variation or related device thereof.

[0055] The computing device 1202 may include a processor 1204 which controls operation of the computing device 1202. The processor 1204 may also be referred to as a central processing unit (CPU). Memory 1206, which may include both read-only memory (ROM) and random access memory (RAM), provides instructions and data to the processor 1204. A portion of the memory 1206 may also include non-volatile random access memory (NVRAM). The processor 1204 typically performs logical and arithmetic operations based on program instructions stored within the memory 1206. The instructions in the memory 1206 may be executable to implement the methods described herein.

[0056] The computing device 1202 may also include a housing 1208 that may include a transmitter 1210 and a receiver 1212 to allow transmission and reception of data between the computing device 1202 and a remote location. The receiver 1212 may implement some or all of the methods described herein. The transmitter 1210 and receiver 1212 may be combined into a transceiver 1214. An antenna 1216 may be attached to the housing 1208 and electrically coupled to the transceiver 1214. The computing device 1202 may also include (not shown) multiple transmitters, multiple receivers, multiple transceivers and/or multiple antenna.

[0057] The computing device 1202 may also include a signal detector 1218 that may be used to detect and quantify the level of signals received by the transceiver 1214. The signal detector 1218 may detect such signals as total energy, pilot energy per pseudonoise (PN) chips, power spectral density, and other signals. The computing device 1202 may also include a digital signal processor (DSP) 1220 for use in processing signals.

[0058] The various components of the computing device 1202 may be coupled together by a bus system 1222 which may include a power bus, a control signal bus, and a status signal bus in addition to a data bus. However, for the sake of clarity, the various busses are illustrated in FIG. 12 as the bus system 1222. Figure 12 illustrates only one possible configuration of a computing device 1202. Various other architectures and components may be used.

[0059] As used herein, the term "determining" encompasses a wide variety of actions and, therefore, "determining" can include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" can include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, "determining" can include resolving, selecting, choosing, establishing and the like.

[0060] The phrase "based on" does not mean "based only on," unless expressly specified otherwise. In other words, the phrase "based on" describes both "based only on" and "based at least on."

[0061] The various illustrative logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array signal (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core or any other such configuration.

[0062] The steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor or in a combination of the two. A software module may reside in any form of storage medium that is known in the art. Some examples of storage media that may be used include RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM and so forth. A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs and across multiple storage media. An exemplary storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor.

[0063] The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is required for proper operation of the embodiment that is being described, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0064] The functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions on a computer-readable medium. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers.

[0065] Software or instructions may also be transmitted over a transmission medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of transmission medium.

[0066] Functions such as executing, processing, performing, running, determining, notifying, sending, receiving, storing, requesting, and/or other functions may include performing the function using a web service. Web services may include software systems designed to support interoperable machine-to-machine interaction over a computer network, such as the Internet. Web services may include various protocols and standards that may be used to exchange data between applications or systems. For example, the web services may include messaging specifications, security specifications, reliable messaging specifications, transaction specifications, metadata specifications, XML specifications, management specifications, and/or business process specifications. Commonly used specifications like SOAP, WSDL, XML, and/or other specifications may be used.

[0067] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the systems, methods, and apparatus described herein without departing from the scope of the claims.

What is claimed is:

1. A method for processing a plurality of individual frequency signals, comprising:

receiving a composite frequency signal, wherein the composite signal comprises a plurality of individual frequency signals;

separating the composite frequency signal into the plurality of individual frequency signals;

transmitting, sequentially, each of the plurality of individual frequency signals to a single channel demodulator; and

demodulating each of the plurality of individual frequency signals with the single channel demodulator.

2. The method of claim 1, wherein the composite frequency signal is a radio frequency (RF) signal.

3. The method of claim 2, wherein the RF signal is selected from the group consisting of: a frequency modulated (FM) signal, an amplitude modulated (AM) signal, a television signal, a cellular telephone signal, an audio signal.

4. The method of claim 1, further comprising demodulating each of the plurality of individual frequency signals to a plurality of corresponding information signals.

5. The method of claim 4, further comprising providing the plurality of information signals to a multiplexer.

6. The method of claim 5, wherein the multiplexer is a time division multiplexer (TDM).

7. The method of claim 4, further comprising outputting the plurality of information signals, wherein the plurality of information signals are selected from the group consisting of: a mono signal, a stereo signal, a stereo signal with radio data system (RDS) information.

8. The method of claim 1, further comprising sampling the composite frequency signal using a first frequency in the Nyquist zone, wherein the first frequency is 243.2 Megahertz (MHz).

9. The method of claim 8, further comprising sampling the composite frequency signal using a second frequency in the Nyquist zone, wherein the second frequency is 128 MHz.

10. The method of claim 1, wherein separating the composite frequency signal into a plurality of frequency signals comprises using an M-band analysis filter bank to separate the composite frequency signal.

11. A computing device that is configured to process a plurality of individual frequency signals, the computing device comprising:

a processor;

memory in electronic communication with the processor;

an antenna configured to receive a composite frequency signal, wherein the composite signal comprises a plurality of individual frequency signals;

a digital receiver, the receiver comprising:

a channelizer configured to separate the composite frequency signal into the plurality of individual frequency signals;

a channel control module configured to sequentially transmit each of the plurality of individual frequency signals to a single channel demodulator; and

the single channel demodulator configured to demodulate each of the plurality of individual frequency signals.

12. The device of claim 11, wherein the composite frequency signal is a radio frequency (RF) signal.

13. The device of claim 12, wherein the RF signal is selected from the group consisting of: a frequency modulated (FM) signal, an amplitude modulated (AM) signal, a television signal, a cellular telephone signal, an audio signal.

14. The device of claim 11, wherein the demodulator is further configured to demodulate each of the plurality of individual frequency signals to a plurality of corresponding information signals.

15. The device of claim 14, wherein the demodulator is further configured to provide the plurality of information signals to a multiplexer.

16. The device of claim 15, wherein the multiplexer is a time division multiplexer (TDM).

17. The device of claim 14, wherein the demodulator is further configured to output the plurality of information signals, wherein the plurality of information signals are selected from the group consisting of: a mono signal, a stereo signal, a stereo signal with radio data system (RDS) information.

18. The device of claim 11, wherein the receiver further comprises an analog-to-digital converter (ADC) configured to sample the composite frequency signal using a first frequency in the Nyquist zone, wherein the first frequency is 243.2 Megahertz (MHz).

19. The device of claim 18, wherein the ADC is further configured to sample the composite frequency signal using a second frequency in the Nyquist zone, wherein the second frequency is 128 MHz.

20. A computer-readable medium comprising executable instructions for:

receiving a composite frequency signal, wherein the composite signal comprises a plurality of individual frequency signals;

separating the composite frequency signal into the plurality of individual frequency signals;

transmitting, sequentially, each of the plurality of individual frequency signals to a single channel demodulator; and

demodulating each of the plurality of individual frequency signals.

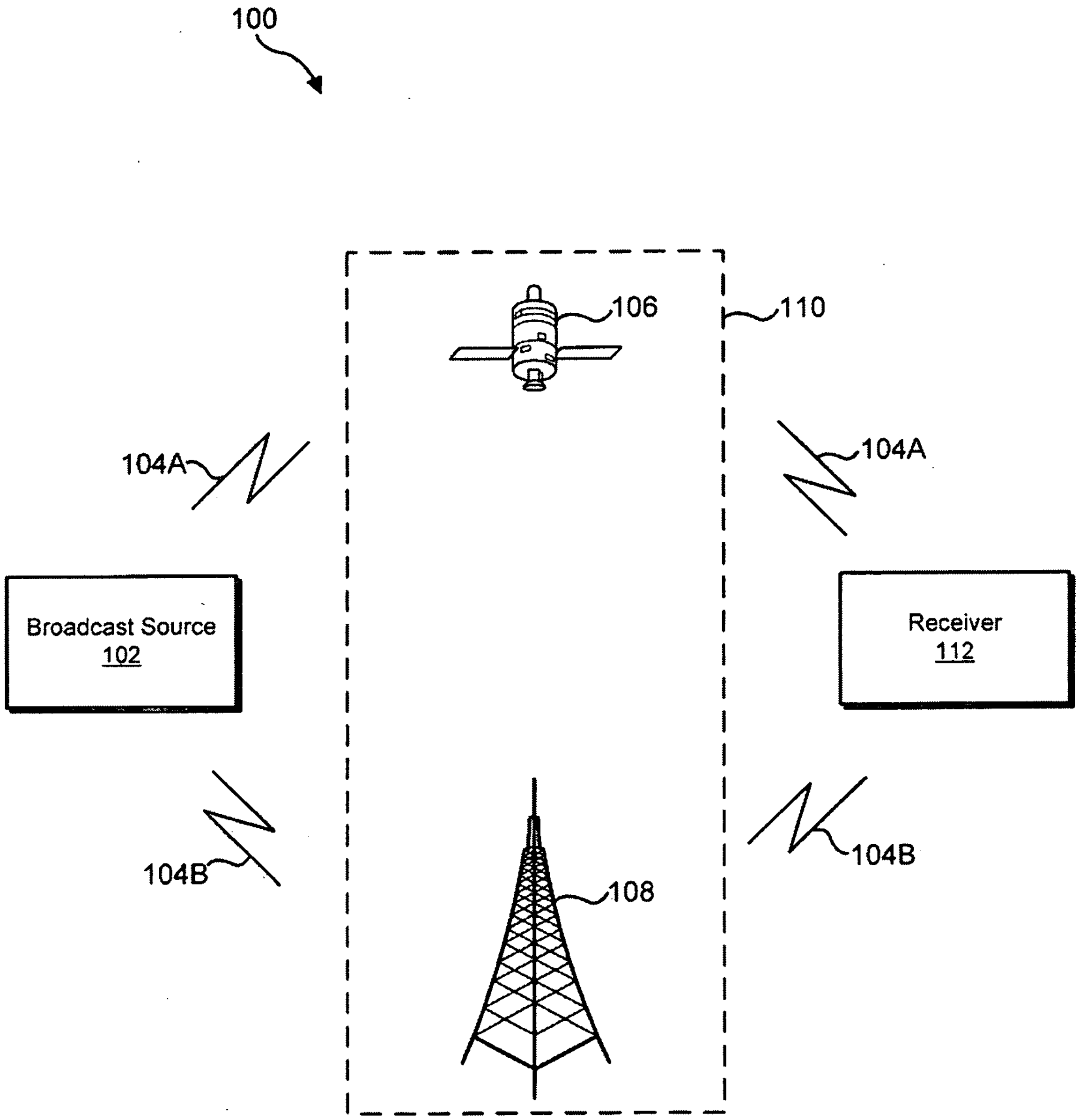

100
106
110
104A
104A
Broadcast Source
102
Receiver
112
104B
104B
108

FIG. 1

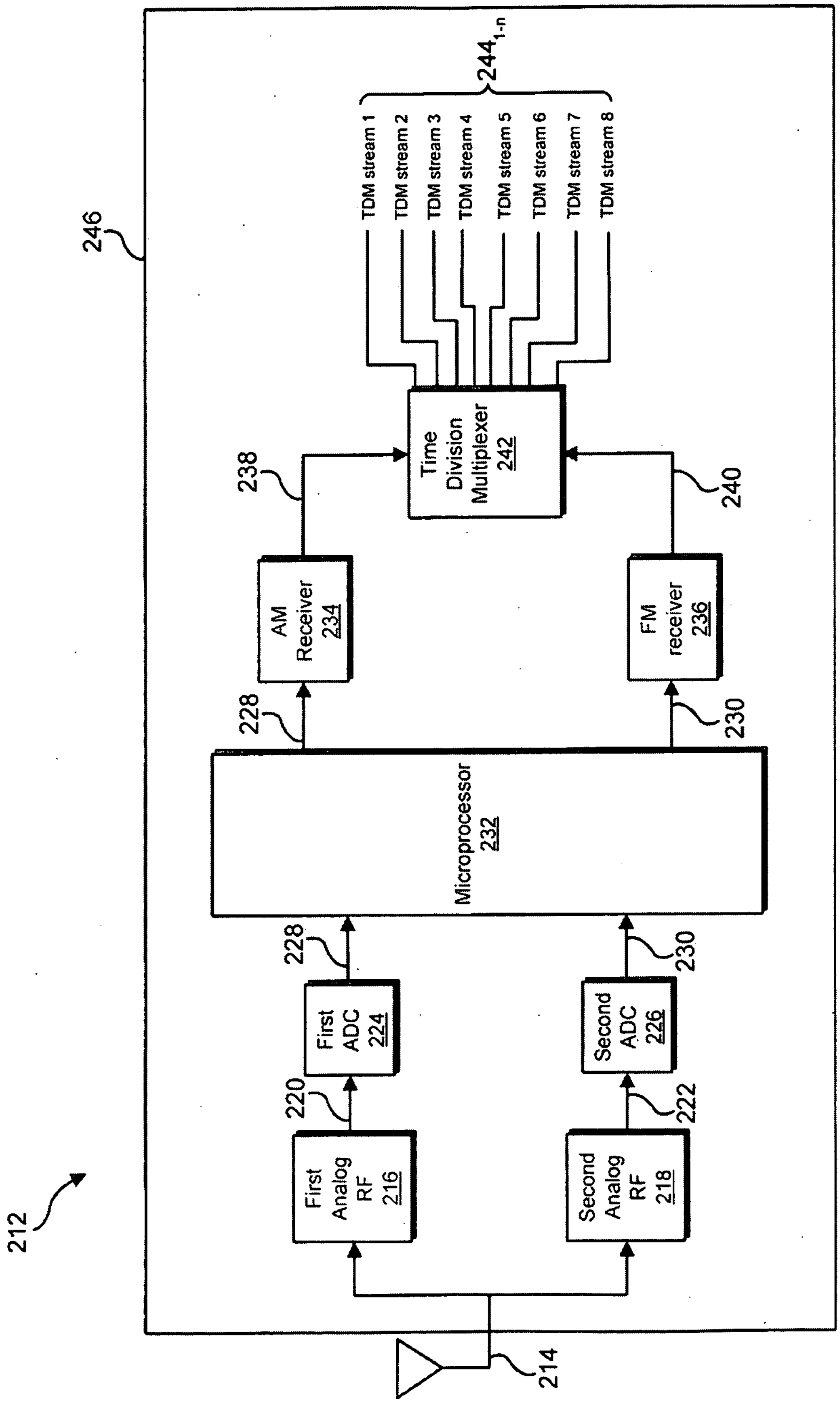

212
246
214
First Analog RF 216
Second Analog RF 218
220
222
First ADC 224
Second ADC 226
228
230
Microprocessor 232
228
230
AM Receiver 234
FM receiver 236
238
240
Time Division Multiplexer 242
TDM stream 1
TDM stream 2
TDM stream 3
TDM stream 4
TDM stream 5
TDM stream 6
TDM stream 7
TDM stream 8
244 1-n

FIG. 2

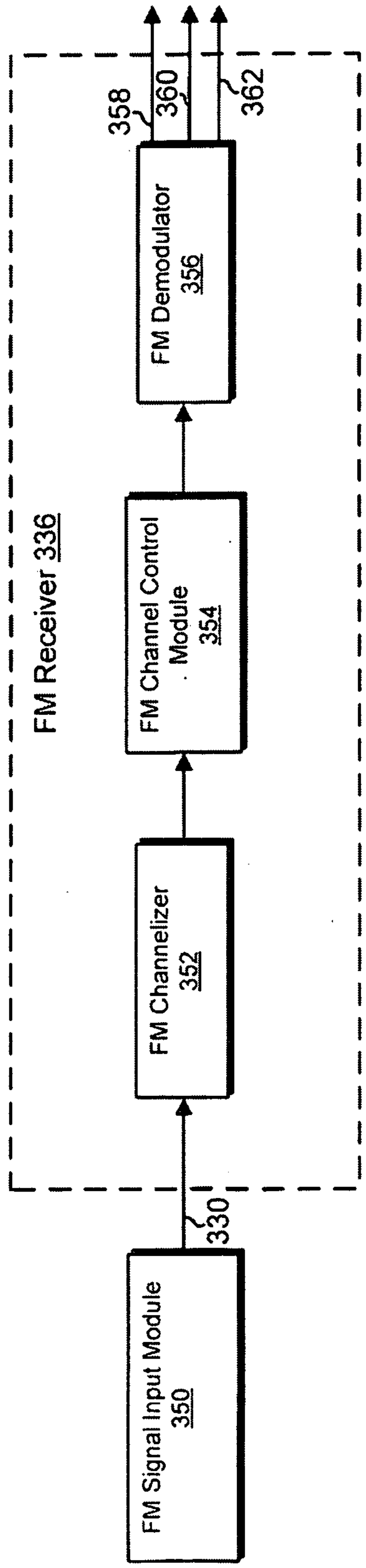

FM Receiver 336
FM Signal Input Module 350
330
FM Channelizer 352
FM Channel Control Module 354
FM Demodulator 356
358
360
362

FIG. 3

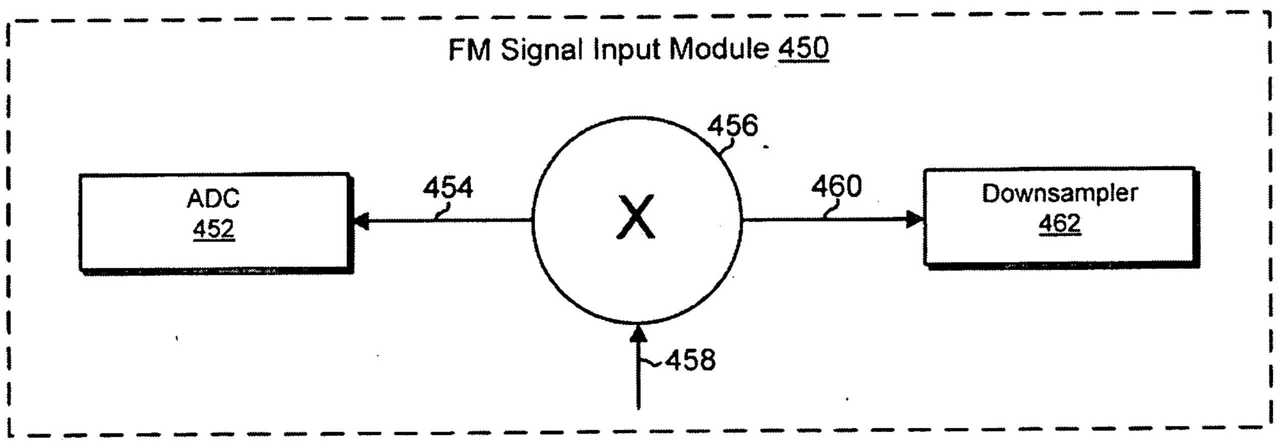

FM Signal Input Module 450
ADC
452
454
X
456
460
Downsampler
462
458

FIG. 4

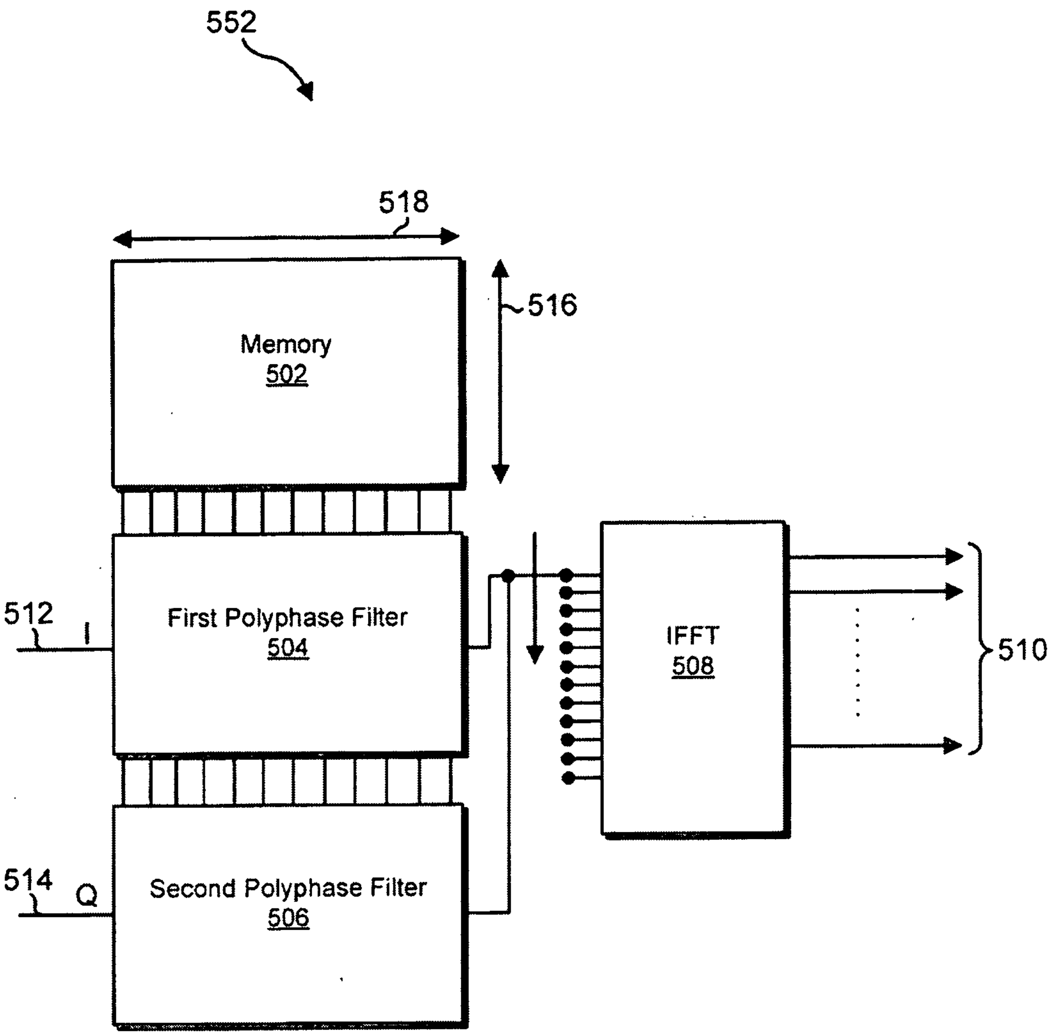

552
518
516
Memory
502
First Polyphase Filter
504
512
I
Second Polyphase Filter
506
514
Q
IFFT
508
510

FIG. 5

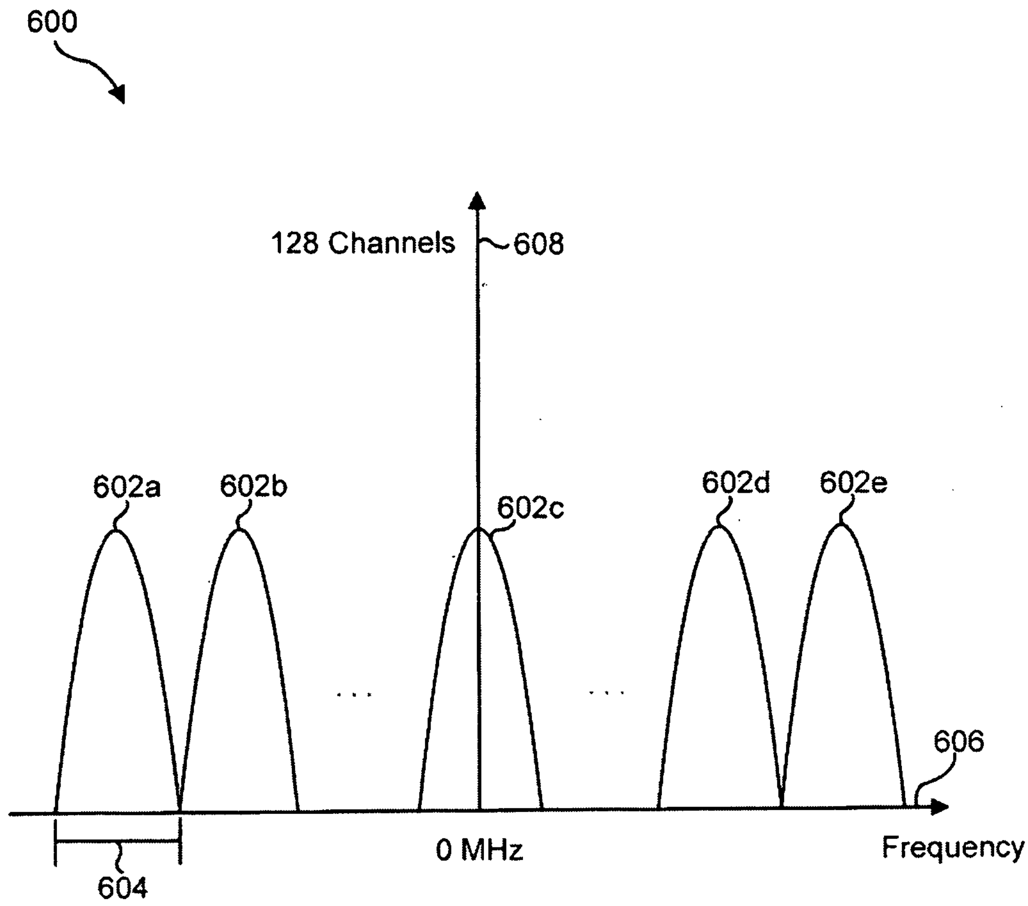

600
128 Channels
608
602a
602b
602c
602d
602e
606
0 MHz
Frequency
604

FIG. 6

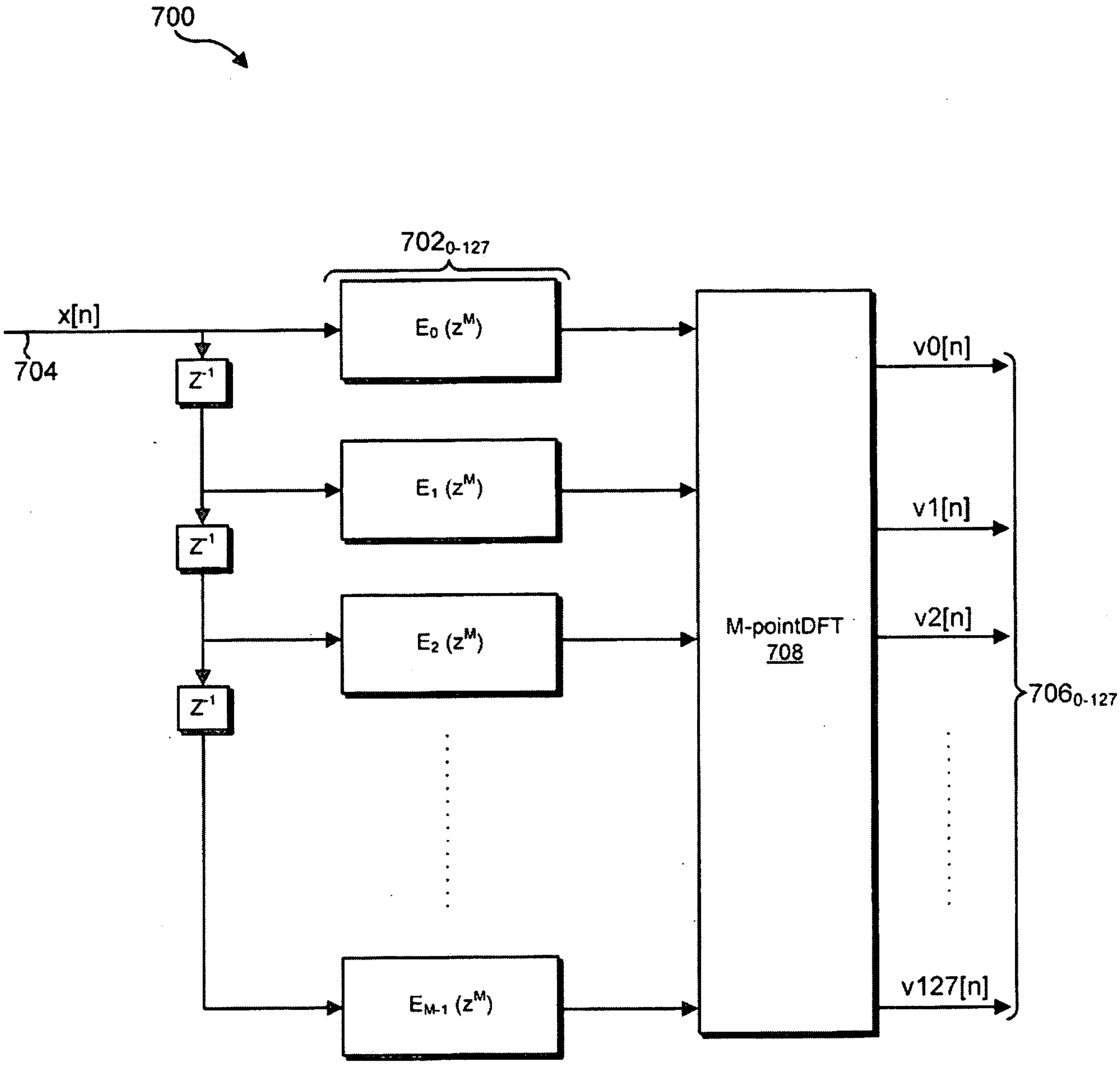

700
702 0-127
x[n]
704
E0 (z^M)
E1 (z^M)
E2 (z^M)
EM-1 (z^M)
Z^-1
Z^-1
Z^-1
M-pointDFT
708
v0[n]
v1[n]
v2[n]
v127[n]
706 0-127

FIG. 7

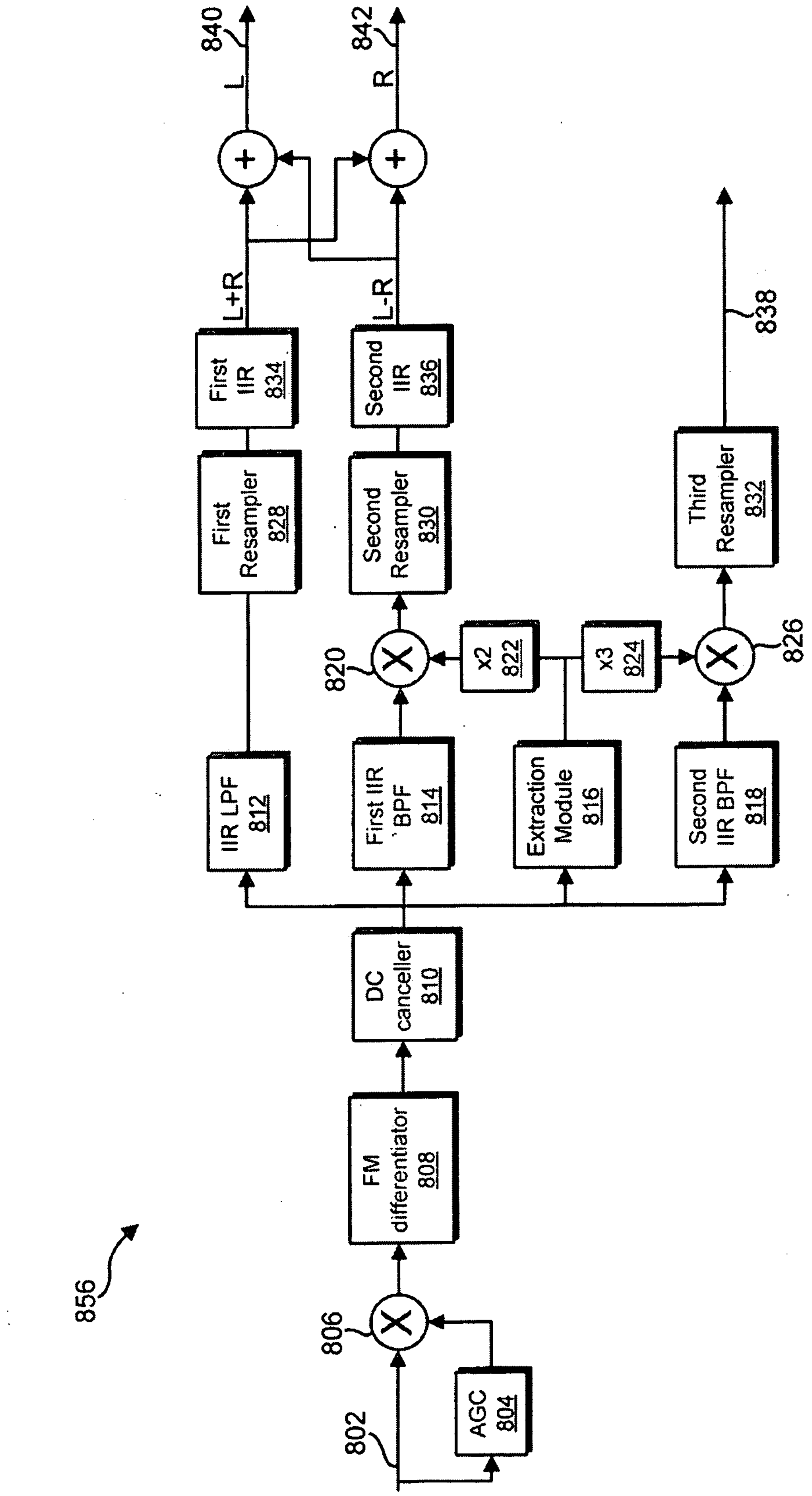
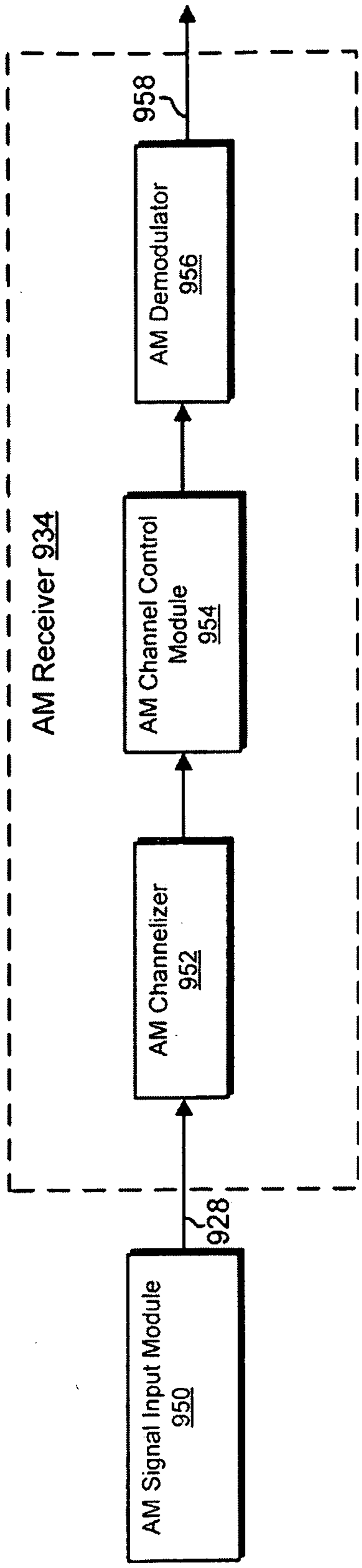

856
802
AGC
804
806
FM
differentiator
808
DC
canceller
810
IIR LPF
812
First IIR
BPF
814
Extraction
Module
816
Second
IIR BPF
818
820
x2
822
x3
824
826
First
Resampler
828
Second
Resampler
830
Third
Resampler
832
First
IIR
834
Second
IIR
836
L+R
L-R
L
840
R
842
838

FIG. 8


AM Receiver 934
AM Signal Input Module 950
928
AM Channelizer 952
AM Channel Control Module 954
AM Demodulator 956
958

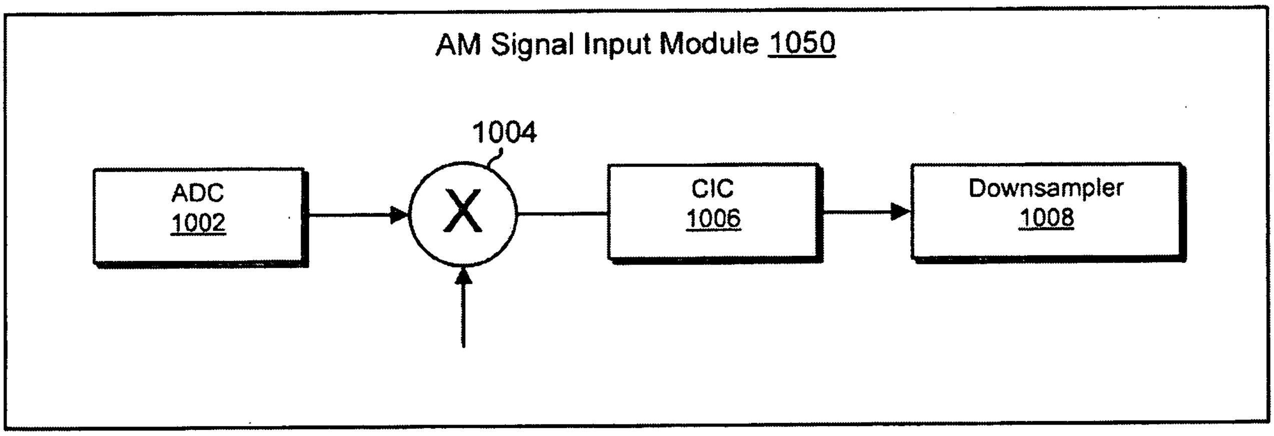

AM Signal Input Module 1050
1004
ADC
1002
X
CIC
1006
Downsampler
1008

FIG. 10

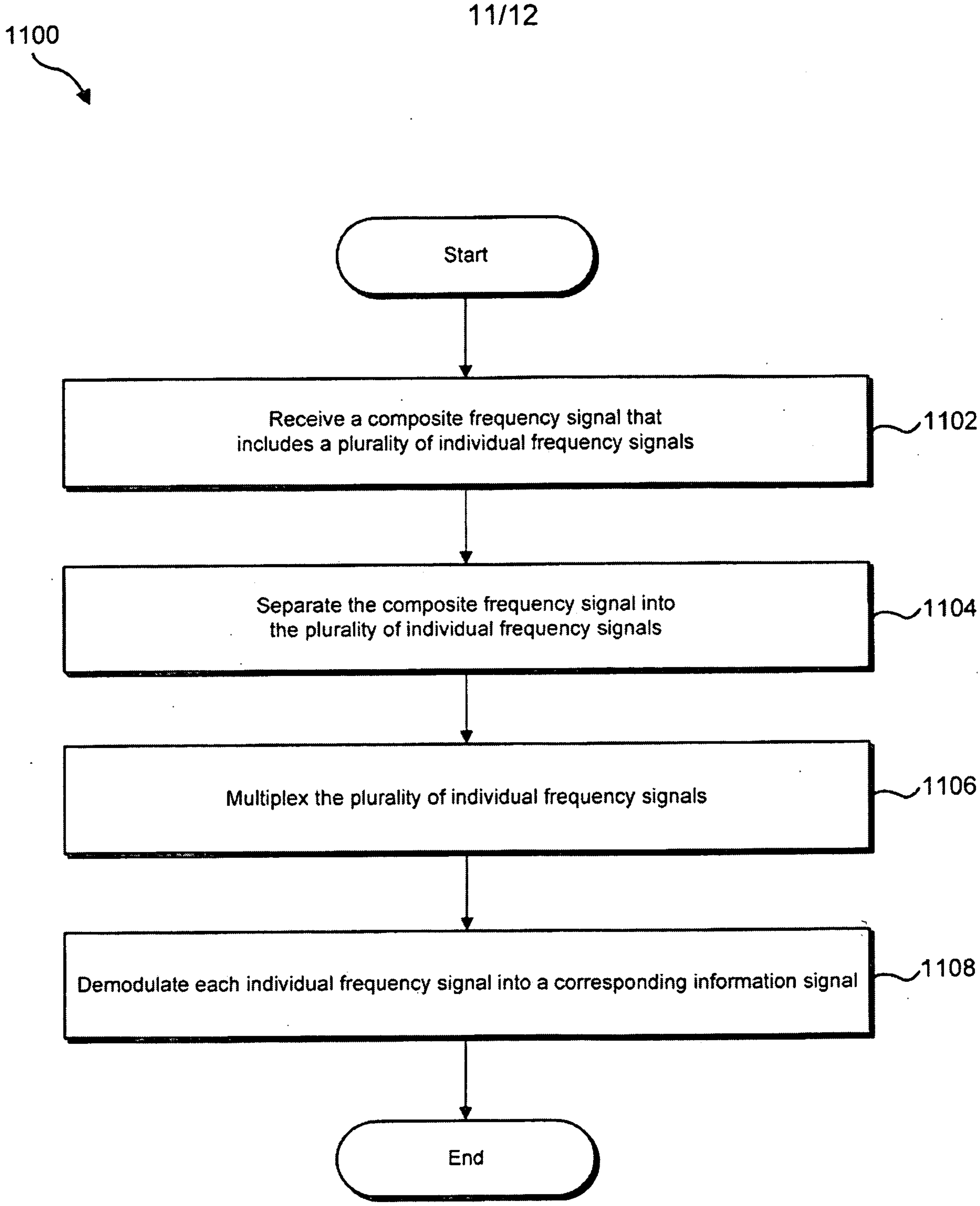

1100
Start
Receive a composite frequency signal that includes a plurality of individual frequency signals
1102
Separate the composite frequency signal into the plurality of individual frequency signals
1104
Multiplex the plurality of individual frequency signals
1106
Demodulate each individual frequency signal into a corresponding information signal
1108
End

FIG. 11

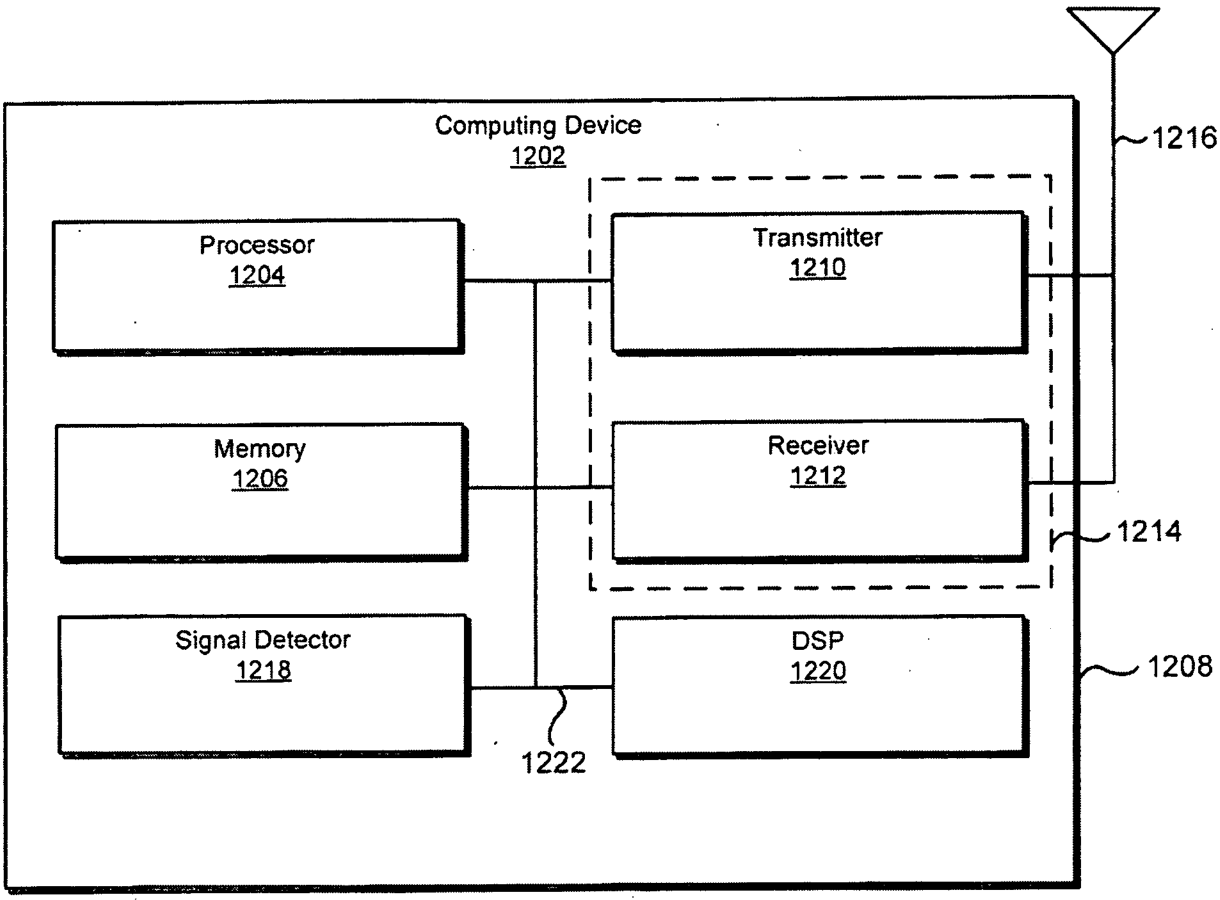

Computing Device
1202
Processor
1204
Memory
1206
Signal Detector
1218
Transmitter
1210
Receiver
1212
DSP
1220
1216
1214
1208
1222

FIG. 12

INTERNATIONAL SEARCH REPORT	International application No. PCT/US2008/080952

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H04J 1/00 (2008.04)
USPC - 370/343

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - H04J 1/00 (2008.04)
USPC - 455/427; 370/343; 375/324

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,838,732 A (CARNEY) 17 November 1998 (17.11.1998) entire document	1-20
Y	US 5,790,529 A (HABER) 04 August 1998 (04.08.1998) entire document	1-20
Y	US 2004/0252044 A1 (MATHIS et al) 16 December 2004 (16.12.2004) entire document	10

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2008	29 DEC 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774