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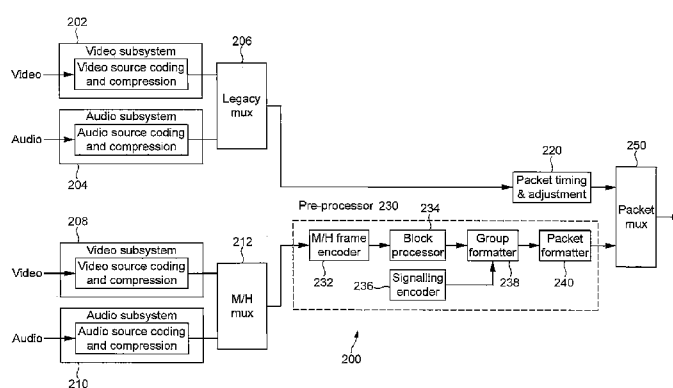


FIG. 2

(57) Abstract: Communications systems often use networks including separately located transmitters and excitors for signal transmission as part of a single frequency network. A method is described that includes receiving (610) a broadcast signal stream containing a data packet and a synchronization timing packet, the synchronization timing packet containing signal transmission delay parameters provided to at least two transmitters, identifying (630) a synchronization interval in the broadcast signal stream, and determining (640) a transmission time for the data packet in the broadcast signal stream based on the signal transmission delay parameters and a time position of the packet with respect to the synchronization interval. An apparatus includes a multiplexer (110) that generates a transport stream containing a data packet and a synchronization timing packet, an exciter (118a-n), that identifies a synchronization interval in the broadcast signal stream and an antenna (120a-n), transmits a broadcast signal based on the synchronization timing packet and the synchronization interval.



APPARATUS AND METHOD FOR TRANSMITTING A SIGNAL IN A SINGLE FREQUENCY NETWORK

REFERENCE TO RELATED PROVISIONAL APPLICATION

This application claims the benefit under 35 U.S.C. § 119 of provisional application 61/369, 922 filed in the United States on August 2, 2010.

TECHNICAL FIELD OF THE INVENTION

The present disclosure generally relates to broadcast systems and signal processing in a network that operates using multiple transmitters and more particularly to an apparatus and method for processing and transmitting a broadcast signal in a single frequency network that uses multiple transmitters.

BACKGROUND OF THE INVENTION

Television broadcast systems throughout the world have migrated from the delivery of analog audio and video signals to the delivery of digital audio and video signals using modern digital communications systems. For example, in the United States, the Advanced Television Standards Committee (ATSC) developed a standard called "ATSC Standard: Digital Television Standard A/53" (the A/53 standard). The A/53 standard defines how data for digital television broadcasts should be encoded and decoded. In addition, the U.S. Federal Communications Commission (FCC) has allocated portions of the electromagnetic spectrum for television broadcasts. The FCC assigns a contiguous 6 Megahertz (MHz) channel within the allocated portion to a broadcaster for transmission of terrestrial (i.e., not cable or satellite) digital television broadcasts. Each 6 MHz channel has a channel capacity of approximately 19 megabit (Mb)/second based on the encoding and modulation format in the A/53 standard. Furthermore, the FCC has mandated that transmissions of terrestrial digital television data through the 6 MHz channel must comply with the A/53 standard.

Digital broadcast signal transmission standards, such as the A/53 standard, define how source data (e.g., digital audio and video data) should be processed and modulated into a signal that is transmitted through the channel. The processing adds redundant information to the source data so that a receiver that receives the signal from the channel may recover the source data, even if the channel adds noise and multi-path interference to the transmitted signal. The redundant information added to the source data reduces the effective data rate at which the source data is transmitted but increases the potential for successful recovery of the source data from the transmitted signal.

The A/53 standard development process was focused on high definition television (HDTV) and fixed reception. The system was designed to maximize video bit rate for the large high resolution television screens that were already beginning to enter the market. However, transmissions broadcast under the ATSC A/53, or legacy encoding and transmission, standard are not easily received in difficult reception environments and therefore present difficulties for mobile, handheld, and portable receivers.

Recognizing this fact, in 2007, the ATSC announced the launch of a process to develop a standard that would enable broadcasters to deliver television content and data to mobile and handheld devices via their digital broadcast signal, commonly known as ATSC mobile/handheld (M/H) or A/153 (the A/153 standard). Additions and changes to the legacy transmission format include an additional encoding scheme for the M/H portion of the stream to introduce further data redundancy. The additional encoding has been adapted to better perform with advanced receivers in mobile, handheld and pedestrian devices while still remaining backward compatible with the legacy A/53 standard. The proposed changes also allow operation of existing ATSC services in the same radio frequency (RF) channel without an adverse impact on existing receiving equipment. The proposed changes also encompass use of single frequency networks (SFNs) for broadcasting mobile content.

In SFNs, two or more transmitters with either contiguous or overlapping geographic coverage send the same program content simultaneously on the same frequency. Most broadcast signal formats, including the 8 vestigial sideband (VSB) modulation used by ATSC A/53 allows SFN transmissions. To improve reception due to irregular transmission channel characteristics, such as the interference created by multiple transmitters, ATSC M/H provides for including additional training sequences.

An additional standard, ATSC A/110, defines a method to synchronize the ATSC modulator as part of each transmitter. The A/110 standard sets up synchronization based on a uniform time base. A signal multiplexer and each of the transmitters is synchronized by a global positioning system (GPS) time and frequency reference. The multiplexer operates as a network adapter and inserts time stamps along with a set of timing offset values into the broadcast transport stream. Each exciter circuit at the transmitters analyzes the time stamp and offsets and based on its own unique processing delay calculations, delays the transport stream before it is modulated and transmitted. Eventually, all transmitters in the SFN generate and transmit a synchronized signal.

However, synchronization of broadcast transmission SFN systems often have additional shortcomings. For instance, the timing reference and timing information packet in the ATSC A/110 standard used for establishing the synchronization within the broadcast data stream structure includes variability as to its final location within the transmitted data stream. This variability is often due to downstream processing in the exciter, such as the encoding and modulation processing for ATSC A/53, after the timing reference and packet are inserted. The variability results in an additional set of computations or maintenance of a look-up table of values for adjusting the timing after identification of the location of the timing reference. A simpler approach to synchronization that reduces the variability of location of the timing reference is desirable.

SUMMARY

An apparatus and method for transmitting a signal in single frequency network are provided. In one embodiment a method is described that includes
5 receiving a broadcast signal stream containing a data packet and a synchronization timing packet, the synchronization timing packet containing signal transmission delay parameters provided to at least two transmitters, identifying a synchronization interval in the broadcast signal stream, and determining a transmission time for the data packet in the broadcast signal stream based on the signal transmission delay
10 parameters and a time position of the data packet with respect to the synchronization interval.

In another embodiment, an apparatus is described that includes a multiplexer that generates a transport stream containing a data packet and a synchronization
15 timing packet, the synchronization timing packet containing signal transmission delay parameters provided to at least two transmitters, an exciter coupled to the multiplexer, the exciter (118a-n) identifying a synchronization interval in the broadcast signal stream and determining a transmission time for the data packet in the broadcast signal stream based on the signal transmission delay parameters and
20 a time position of the data packet with respect to the synchronization interval, and an antenna, coupled to the exciter, the antenna transmitting a broadcast signal including the synchronization interval and the data packet.

BRIEF DESCRIPTION OF THE DRAWINGS

These, and other aspects, features and advantages of the present disclosure will be described or become apparent from the following detailed description of the preferred embodiments, which is to be read in connection with the accompanying
30 drawings.

In the drawings, wherein like reference numerals denote similar elements throughout the views:

FIG. 1 is a block diagram of an embodiment of a Single Frequency Network System according to aspects of the present disclosure.

5 FIG. 2 is a block diagram of an embodiment of a multiplexer in accordance with aspects of the present disclosure.

FIG. 3 is a block diagram an embodiment of an exciter in accordance with aspects of the present disclosure.

10 FIG. 4 is a timing diagram for emission synchronization of a packet in the signal stream used in an SFN in accordance with the present disclosure.

FIG. 5 is another timing diagram for emission synchronization of a packet in the signal stream used in an SFN in accordance with the present disclosure.

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FIG. 6 is a flowchart of an embodiment of a process illustrating an exemplary process for synchronizing a plurality of exciters in a network in accordance with aspects of the present disclosure.

20 It should be understood that the drawing(s) are for purposes of illustrating the concepts of the disclosure and is not necessarily the only possible configuration for illustrating the disclosure.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

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It should be understood that the elements shown in the figures may be implemented in various forms of hardware, software or combinations thereof. Preferably, these elements are implemented in a combination of hardware and software on one or more appropriately programmed general-purpose devices, which
30 may include a processor, memory and input/output interfaces. Herein, the phrase "coupled" is defined to mean directly connected to or indirectly connected with through one or more intermediate components. Such intermediate components may include both hardware and software based components.

The present description illustrates the principles of the present disclosure. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the disclosure and are included within its spirit and scope.

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All examples and conditional language recited herein are intended for educational purposes to aid the reader in understanding the principles of the disclosure and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions.

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Moreover, all statements herein reciting principles, aspects, and embodiments of the disclosure, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

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Thus, for example, it will be appreciated by those skilled in the art that the block diagrams presented herein represent conceptual views of illustrative circuitry embodying the principles of the disclosure. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudocode, and the like represent various processes which may be substantially represented in computer readable media and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

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The functions of the various elements shown in the figures may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly

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include, without limitation, digital signal processor (DSP) hardware, read only memory (ROM) for storing software, random access memory (RAM), and nonvolatile storage.

5 Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically
10 understood from the context.

In the claims hereof, any element expressed as a means for performing a specified function is intended to encompass any way of performing that function including, for example, a) a combination of circuit elements that performs that
15 function or b) software in any form, including, therefore, firmware, microcode or the like, combined with appropriate circuitry for executing that software to perform the function. The disclosure as defined by such claims resides in the fact that the functionalities provided by the various recited means are combined and brought together in the manner which the claims call for. It is thus regarded that any means
20 that can provide those functionalities are equivalent to those shown herein.

The present disclosure is directed at a method and apparatus for operating an emission, or transmission, time synchronization system used in an SFN broadcast
25 system that employs multiple broadcast sources and locations, each transmitting the same content at the same time. In particular, a set of timing offset or delay parameters are identified and determined. These parameters are provided in a timing information data packet to each of the transmitters and identify a delay needed for the received transport stream at each transmitter to be synchronously
30 transmitted as a broadcast. Each transmitter uses the parameters along with its own specific processing delay time to determine a time point to begin modulation processing in order to transmit the broadcast signal at the proper time. Rather than use the timing packet as a timing reference due to its variable position within the

transport stream, the particular embodiments use a separate synchronization point, such as an established Cadence Sync Point, or the first packet that is in the transport stream following the Data Frame Sync or the Field Sync provided as part

of the original ATSC A/53 formatted transmission signal, as the reference packet. Timing interval and delay calculations are based on the time for that reference packet in relation to the position of the timing information packet in the provided transport stream.

Choosing this first packet after data frame or field sync in A/53 transport stream offers at least the advantage of not requiring a variable delay calculation at each transmitter that is independent of the provided timing information due to the operation of encoding and processing, such as interleaving in each transmitter. This first packet does not change in relative location to the remainder of the transmitted signal during encoding and processing. Choosing a different packet, such as the timing information packet as permitted under the A/110 specification, results in including further processing in each transmitter, such as including a table of values and further calculation, in order to adjust the processing time for each particular implementation in order to maintain emission timing for each particular implementation.

Referring now to FIG. 1, an exemplary broadcast system 100 used as part of an SFN according to aspects of the present disclosure is shown. Broadcast system 100 includes a multiplexer 110 that connects to a plurality of exciters 118a-n. Each exciter 118a-n also connects to antennas 120a-n. Each exciter and antenna pair are usually located at, and identified as, a broadcast transmitter site. The connection between multiplexer 110 and each exciter 118a-n is typically a remote connection and may be made through a wired or wireless connection system and may utilize both private and available public communications systems, such as public land line telephony, satellite, terrestrial wireless, or internet communications. It is also important to note that broadcast system 100 may also be referred to as a Studio-to-Transmitter Link (STL) system, with the multiplexer 110 located at the studio portion, the exciters 118a-n and antennas 120a-n located at the transmitter portion, and the connection between them representing the link portion.

Multiplexer 110 receives one or more bitstreams of content (e.g., audio, video, and data). Multiplexer 110 processes each of the content streams to produce a multiplexed broadcast stream at its output. Multiplexer 110 may include circuitry for producing a broadcast stream in one or more broadcast transport stream formats and may further be able to process incoming content into more than one format simultaneously. In one embodiment, multiplexer 110 includes circuitry for processing an audio and video input according to the ATSC A/53 standard and additionally processing the same audio and video content, as well as a second set of audio and video content according to the ATSC A/153 standard. Further, Multiplexer 110 combines these processed transport streams into a single multiplexed broadcast transport stream as dictated by the ATSC A/153 standard.

Multiplexer 110 also includes control circuitry for identifying, generating, and inserting ancillary information into the data streams as needed. For instance, the control circuitry may receive an external timing reference signal from an external timing source, such as a GPS receiving device. An example of a timing reference signal from a GPS receiving device is known as a one pulse per second (1 PPS) signal. Multiplexer 110 uses this timing signal to generate timing reference information and insert this timing reference information into the process content stream prior to outputting from multiplexer 110. In one embodiment, the timing reference information generated by circuitry in multiplexer 110 includes pointers to the last and next cadence sync (CS) point and various timing offset values included in one or more transmission control packets. This control circuitry establishes and controls the specific structure for each content processing subsystem as well the combined data structure for the system if necessary. Further aspects of multiplexers, such as multiplexer 110, will be described in detail below.

The multiplexed broadcast transport stream from multiplexer 110 is provided to each of the exciters 118a-n at the broadcast transmitter sites. Each exciter 118a-n further encodes and modulates the stream onto a radio frequency carrier to produce a transmission signal. In addition, each exciter 118a-n uses the timing control information to adjust the signal processing and timing to synchronize the emission of the signal between each of the broadcast transmitter sites. The

transmission signals produced by each exciter 118a-n are provided to antennas 120a-n for transmission over the radio frequency airwaves. Further aspects of exciters, such as exciters 118a-n, will be described in detail below.

5 Broadcast system 100 represents one common configuration for an SFN. However, alternative configurations are possible. For example, in another configuration, the multiplexer and one exciter and antenna may be co-located, while the remaining exciters and antennas are remotely located. In this configuration, often referred to as a translator SFN, co-located exciter and antenna serve as the
10 main transmitter while each remote exciter and antenna serve as translator or repeater transmitter. The main transmitter communicates with the translator transmitters over the broadcast transmission channel. The translator transmitter sites include reception equipment and equipment to re-transmit the received broadcast, either on the same or a different broadcast channel frequency. Similar
15 synchronization requirements may be placed on this configuration as well as other configurations of an SFN.

As mentioned above, it is important in an SFN that the transmitters transmit the same signal to the receivers and that the signal transmission be synchronized.
20 SFN synchronization specifications, such as ATSC A/110, define a method to synchronize each exciter 118a-n. In such an SFN, the multiplexer 110 and exciters 118a-n used are synchronized by the same GPS reference received by both the multiplexer 110 and exciters 118a-n. The multiplexer 110 operates as a network adapter and inserts time stamps and other timing information in the transport stream.
25 Each exciter 118a-n of the transmitters analyzes the time stamps and timing information along with the received GPS reference and delays the transport stream before it is modulated and transmitted. Eventually, all broadcast transmitter sites in the SFN generate a synchronized signal.

30 Referring now to FIG. 2, a block diagram of an embodiment of a multiplexer 200 according to aspects of the present disclosure is shown. Except as described below, the operating principles of multiplexer 200 are similar to multiplexer 110 described in FIG. 1. Multiplexer 200 may be included as part of the studio side

portion of the STL. As described below, multiplexer 200 operates on broadcast signals according to the ATSC standards A/53, A/153, and A/110. However, it should be noted that similar structures and functionality for operating on signals according to standards or formats other than those described are possible and easily
5 recognized and understood by one skilled in the art.

In multiplexer 200, video and audio content, delivered as signal streams, for use in the A/53 or legacy broadcast portion of a multiplexed transport stream is provided to the video subsystem 202 and audio subsystem 204 respectively. The
10 video subsystem 202 and audio subsystem 204 each connect to legacy mux 206. Similarly, video and audio content for the M/H portion of the multiplexed transport stream is provided to video subsystem 208 and audio subsystem 210, both of which further connect to M/H mux 212. The legacy mux 206 connects to packet timing and adjustment block 220. The M/H mux 212 connects to the pre-processor 230. Both
15 the packet timing and adjustment block 220 and pre-processor 230 connect to packet mux 240. The output of packet mux 240 is a multiplexed broadcast transport stream and provided as the output of multiplexer 200. Within pre-processor 230, the input signal is provided to M/H frame encoder 232. Frame encoder 232 connects to block processor 234. The output of the block processor 234 connects to group
20 formatter 238. A signaling encoder 206 also connects to group formatter 238. The output of group formatter 238 connects to packet formatter 240 and provided as the output signal for pre-processor 230.

At a high level, the function of the multiplexer 200 is to combine the two types
25 of streams, the main service data and the M/H service data, into one stream of MPEG transport stream packets. For compatibility with legacy 8-VSB receivers, the M/H service data is encapsulated in special MPEG-2 transport stream packets, designated as M/H Encapsulation (MHE) packets, in pre-processor 230. The pre-processor 230 can accommodate encapsulated service data that is in any desired
30 format. For example, services carried in MPEG transport streams such as like MPEG-2 video/audio, MPEG-4 video/audio, other data, or services carried by IP packets may be processed.

The video subsystem 202 and audio subsystem 204, along with the video subsystem 208 and audio subsystem 210, provide source coding and signal compression respectively for video and audio content provided as inputs. It is important to note that each of the video subsystems and audio subsystems may process the received signals using the same or different coding or compression algorithms. For example, video subsystem 202 may encode the received video stream using the Motion Picture Entertainment Group (MPEG) standard MPEG-2 format while the Video subsystem 208 may encode the received video stream using the Advanced Video Content (AVC) standard format. Further, each of the respective video and audio subsystems may operate on the same video and audio content streams or may operate on separate streams. Still further, any of the subsystems may be capable of operating on more than one content stream simultaneously. Alternatively, in a different embodiment, one or more additional video and/or audio subsystem may be added to multiplexer 200.

Legacy mux 206 combines the separate compressed audio and video streams from video subsystem 202 and audio subsystem 204 to create a single legacy transport stream. Legacy mux 206 may also add any necessary packet framing and identification, such as cadence points or VSB sync points (frame or field), to the stream to facilitate separation of the signals in a receiving device. Similarly, M/H mux 212 performs a similar operation with the compressed signal streams from video subsystem 208 and audio subsystem 210 to create a single M/H service data structure.

The legacy stream from legacy mux 206 is processed by packet timing and adjustment module 220. and then transmitted to packet multiplexer 214. Packet timing and adjustment module 220 adjusts the main service multiplex data to compensate for temporal displacements at the combining point so that the emitted signal complies with the MPEG and ATSC standards to protect legacy receivers. Packet timing and adjustment module 220 adjusts the timing of individual portions, or packets, of the legacy stream to allow for the further multiplexing of the M/H stream. Packet timing and adjustment module 220 also changes the time reference or program clock reference (PCR) for the stream. This program clock reference is

used in receivers for proper recovery of the legacy broadcast stream, as dictated by the ATSC A/53 standard.

5 The M/H service data structure from M/H mux 212 is processed by the components within pre-processor 230. Pre-processor 230 rearranges the M/H service data structure into an M/H data packet structure to enhance the robustness of the M/H data for reception. Forward error correction is performed in MH frame encoder 232 and block processor 234. Training sequences are added by signaling encoder 236 and group formatter 238. Packet formatter 240 subsequently
10 encapsulates the processed enhanced data into M/H transport stream packets and formats the M/H packets as a Group of 118 consecutive packets of 207 bytes (or segments) to be inserted in the adjusted legacy transport stream.

15 It is important to note that the format processing for the M/H signal is different from the processing for the legacy signal. The legacy signal compliant with A/53 is intended as a continuous type signal formatted as a conventional transport stream of packets and is primarily synchronously provided. In contrast, the M/H signal compliant with A/153 is formatted and encapsulated as an internet protocol (IP) signal that may be delivered synchronously or asynchronously. The M/H signal is
20 positioned at specific locations within an existing legacy signal stream. As a result, in addition to separate error correction coding in block processor 234, separate framing and formatting is performed in the M/H frame encoder 232, group formatter 238, and packet formatter 240 along with separate identification information inserted by signaling encoder 236. Trellis identification and formatting is provided to enable
25 the broadcast signal to be compliant with A/153 as well as with SFN operation under A/110.

Time-division multiplexing of main and M/H data introduces changes to the time of emission of the legacy transport stream packets compared to the timing that
30 would occur with no M/H data packets present. The temporally adjusted legacy transport data from packet timing and adjustment block 220 and the processed M/H packet data from the pre-processor 230 are multiplexed, or combined, together in

packet mux 250. At the packet mux 250, each M/H Group of packet data is inserted in an M/H Slot, consisting of 156 data packets, or half the size of an ATSC data field. M/H Slots may or may not contain M/H Groups. If an M/H Group is inserted in a particular Slot, then 118 packets are M/H packets and 38 packets are legacy transport data packets. If no M/H Group is inserted in a Slot, then all 156 packets are main service data packets. The allocation of M/H Groups to M/H Slots may be a function of the relative rates between the M/H data and the main service data.

Packet mux 250 also includes circuitry for processing the timing information needed for establishing emission synchronization in an SFN. Packet mux 250 may include a processor or microcontroller and memory. The processor receives the synchronization identification information and calculates the necessary parameters, such as delays and offsets, for establishing synchronization in a plurality of exciters at transmission sites, such as exciters 118a-n described in FIG. 1. Packet mux 250 also includes circuitry for inserting the parameters, as part of a timing control packet (TCP). In one embodiment, packet mux 250 generates and inserts a packet identified as the DTxP according to the A/110 standard.

It is important to note that in some configurations for a multiplexer, such as multiplexer 200, the circuitry for establishing emission synchronization, as well as any additional circuitry or processing specifically used for SFN processing may be included in a separate block, often referred to as a distributed transmission adaptor (DTA). Typically, the DTA is added to existing multiplexers that were not configured for SFN operation. The DTA typically connects to the output of the final stream multiplexer, such as packet mux 250 and provides the final transport stream to the link portion of the STL.

In some synchronization specifications, such as ATSC A/110, the TCP or DTxP contains delay parameters provided to each of the exciters at the transmission locations. In A/110, these delay parameters are identified as a maximum delay and an offset delay. The maximum delay is the same for all exciters and accounts for

delay in the delivery of the stream to the exciters. The offset delay may be different for each exciter and accounts for network design variations. However, none of these delay parameters take into account the potential variable timing and location of the DTxP. Further, the A/110 specification does not include transmitting additional delay parameters or information related to the variable location of the DTxP. The location of the DTxP is only identified by its packet number, which is conveyed as part of the transport stream. By using a fixed synchronization point in the transport stream, such as the cadence sync point for the A/53 signal, and determining an additional offset for the relation of the cadence sync point location and the DTxP location in the transport stream, synchronization at the transmitter locations can be improved and simplified.

Turning now to FIG. 3, a block diagram of an embodiment of an exciter 300 using aspects of the present disclosure is shown. Except as described below, exciter 300 operates in a manner similar to exciters 118a-n described in FIG. 1. Exciter 300 may be included as part of the transmitter side portion of the STL. As described below, exciter 300 operates on broadcast signals according to the ATSC standards A/53, A/153, and A/110. However, it should be noted that similar structures and functionality for operating on signals according to standards or formats other than those described are possible and easily recognized and understood by one skilled in the art.

In exciter 300, a broadcast type signal stream, such as the multiplexed broadcast transport stream, is provided to the input of post-processor 302. The output of post-processor 302 is connected to sync mux 351. Sync mux 351 also receives input signals identified as Field sync and Segment Sync. The output of sync mux 351 connects to pilot inserter 353. The output of pilot inserter 353 connects to pre-equalizer filter 355. The output of pre-equalizer filter 355 connects to 8-VSB modulator 357. The output of 8-VSB modulator 357 connects to RF upconverter 359. The output of RF upconverter is a broadcast signal and is provided to an antenna, such as one of antennas 120a-n described in figure 1, and transmitted. Post-processor 302 further contains additional blocks. The input to post-processor 302 is provided to modified data randomizer 330. The output of

modified data randomizer 330 is connected to a systematic/non-systematic Reed Solomon (RS) encoder 332. The output of the systematic/non-systematic RS encoder is connected to data interleaver 334. One output of the data interleaver 334 is connected to parity replacer 336, while a second output is connected as one input to non-systematic RS encoder 340. The output of non-systematic RS encoder 340 is connected as a second input to parity replacer 336. The output of parity replacer 336 is connected to modified trellis encoder 342, which provides an output for post-processor 302. A second output from modified trellis encoder 342 is connected to a second input of non-systematic RS encoder 340.

The broadcast transport stream from the output of a multiplexer, such as multiplexer 200 described in FIG. 2, and communicated across an STL link connection is provided to post-processor 302. Post-processor 302 further encodes and processes the broadcast transport data stream, and is capable of recognizing, separating, and separately processing and encoding the legacy data portion and the M/H data portion of the broadcast transport data stream. Post-processor 302 processes and encodes the legacy transport data using the 8-VSB encoding based on the A/53 standard. The encoding includes data randomizing in modified data randomizer 330, RS encoding in systematic/non-systematic RS encoder 332, data interleaving in data interleaving 334, and trellis encoding in modified trellis encoder 342.

Post-processor 302 includes a buffer memory for storing and retrieving portions of the received multiplexed stream. This buffer memory may be a separate block (not shown) in post-processor 302. Alternatively, the buffer memory may be included as part of data randomizer 330 as an input circuit. The buffer memory may be any number of forms of memory, but preferably would be implemented as either static or dynamic RAM and may further be optimized for first-in-first-out (FIFO) operation. The buffer memory permits a time delay of the received multiplexed stream as necessary to establish synchronization of the broadcast stream across the SFN. Aspect of the delay and synchronization will be described in further detail below.

Post-processor 302 also manipulates the pre-processed M/H packet data in the broadcast transport stream to ensure compatibility with ATSC 8-VSB receivers. The M/H packet data in the combined stream is processed differently from the legacy transport data in post-processor 302. The M/H packet data bypasses the modified data randomizer 330 and is not randomized. The pre-processed M/H service data is encoded as non-systematic data in systematic/non-systematic RS encoder 332 and interleaved, as a block of data containing 52 bytes, in data interleaver 334. Data interleaver 334 corresponds to the A/53 ATSC convolutional interleaver and equally applies to M/H and legacy transport data. Additional operations are also performed on the pre-processed M/H packet data in order to properly initialize the trellis encoder memories used with modified trellis encoder 342 at the start of each training sequence included in the pre-processed M/H service data.

Systematic/non-systematic RS encoder 332 performs the RS encoding process of the $(N, K, t) = (207, 187, 10)$ code at the data output of modified randomizer 330. The systematic/non-systematic RS encoder 332 is a modified version of a standard ATSC RS encoder for the same RS code but reflects the modifications implied by the M/H Group data format table included as part of the A/153 standard. The non-systematic RS encoding of the M/H packet data allows for the placing the M/H data within the broadcast transport stream such that any further trellis encoding processing may be done without disrupting reception by legacy receivers.

As described in the ATSC M/H standard A/153, the systematic/non-systematic RS encoder 332 performs an RS encoding process with a $(N, K, t) = (207, 187, 10)$ code on the data output by the data randomizer, which will have been randomized or bypassed by the data randomizer. The RS parity generator polynomial and the primitive field generator are identical to those of the legacy ATSC 8-VSB system.

In operation of systematic/non-systematic RS encoder 154, if the inputted data corresponds to a main service data packet, the RS encoder shall perform the

same systematic RS encoding process as in the legacy ATSC 8-VSB system, adding 20 bytes of RS forward error correction (FEC) parity data at the end of each set of 187 information-byte packets, therefore creating a 207-coded byte packet or segment. However, if the inputted data corresponds to an M/H service data packet, the RS encoder performs only a non-systematic RS encoding process.

Modified trellis encoder 342 operates in a manner similar to a conventional trellis encoder used in the ATSC A/53 broadcast standard. In operation, 12 interleaved rate 2/3 trellis encoders with differential pre-coding perform the encoding. However, the inclusion the M/H data creates for the additional need to initialize the encoder memories just prior to each M/H training sequence, for the purpose of obtaining known training sequences used for receiving the ATSC M/H signal. As a result, the RS parity data calculated prior to the trellis initialization for the M/H signal will now contains errors prior to transmission. Hence, modified trellis Encoder 342 supplies the changed initialization byte to the non-systematic RS encoder 340. Non-systematic RS encoder 340, together with pre-interleaved data and control signals provided by data interleaver 334, calculates the new parity bytes to replace the erroneous parity bytes due to trellis initialization. These calculated parity bytes are provided to parity replacer 336 in order replace the original parity bytes computed by systematic/non-systematic RS encoder 332 and are further provided back to modified trellis encoder 342.

It is important to note that it may be possible to combine the systematic/non-systematic encoder 154 and non-systematic encoder 160 and eliminate the separate encoding blocks. In one embodiment, non-systematic RS encoder 160 may be replaced by a memory and a processing block that multiplies the trellis encoded data by a stored weight value and replaces the data bytes in the MH service data portion of the combined data stream in order to initialize the trellis encoded data stream during the MH service data portion.

The final output of modified trellis encoder 342 is provided to sync mux 351 and the remaining blocks in FIG. 3. These remaining blocks in FIG. 3 are identical to blocks used in a signal transmission system for broadcasting a signal using the

ATSC A/53 standard. Sync mux 351 adds the ATSC A/53 synchronization, known as field and segment synchronization signals, to the data stream. Pilot inserter 353 inserts a small in-phase pilot to the data signal with the same frequency as the suppressed-carrier frequency. The pre-equalizer filter 355 filters the signal to compensate in advance for known system distortions and facilitate the reception. In some embodiments, pre-equalizer filter 355 may not be included or alternatively may be switched out of operation depending operational conditions. The 8-VSB modulator 357 modulates the 8-level trellis encoded composite data signal (including pilot and sync) in accordance with the A/53 specification, based on VSB modulation and a linear phase raised cosine Nyquist filter response in the concatenated transmitter and receiver and an intermediate frequency (IF) frequency of 44 MHz. Finally RF up-Converter 359 up-converts the 8-VSB signal to the proper RF channel frequency to be broadcast via an antenna.

It is important to note that all or a portion of post processor 302 may be included in either the multiplexer as part of the studio portion of the STL or in each of the exciters as part of the transmitter portion of the STL, as described here. For example, modified data randomizer 330 may be included as part of the multiplexer, such as connected to the output of packet mux 250 in the multiplexer described in FIG. 2. Other partition configurations and arrangements may also be possible.

As described above, one problem associated with operating multiple transmitters in a single frequency network involves the proper timing of the emission or transmission time for the signal at each of the transmission sites. System developers, such as the drafters of the A/110b specification have recognized this problem, and have included provisions in the signal and control system for adjusting the timing of the emission time for each transmission site. The present embodiments further address problems in synchronization introduced by the additional processing occurring in each of the exciters, such as the encoding and modulation described in exciter 300. Aspects of emission synchronization and adjustment of broadcast emission time for each transmission site, including aspects of the present disclosure, will be described in further detail below.

Turning now to FIG. 4, an exemplary timing diagram 400 showing the relationship between the emission time and a predefined data reference pointer, position, or packet in a broadcast signal transmitted over an SFN is shown. The timing diagram 400 represents an allotted time interval for emission of a TCP, also referred to as the DTxP, based on an initial time reference and the creation or arrival of the TCP or DTxP at the input of a transport stream processing block within a multiplexer, such as the packet timing and adjustment block 220 described in FIG. 2. The DTxP is one of the packets used as part of the timing information provided as part of the signal form format for the A/110 standard. From this timing diagram, calculations are possible for each transmitter to permit synchronized emission of the DTxP. Synchronized emission of all remaining packets is then governed by synchronization of this packet as well as any additional initialization and synchronization of branching type error correction processes, such as trellis state processing performed as part of the pre-processor 230 in FIG. 2 and post-processor 302 in FIG. 3.

Timing diagram 400 includes an initial time reference 410, identified as the 1PPS signal provided through the GPS reference on a time scale 401. A time span 415, identified as the synchronization time stamp (STS), represents a first known time delay and is common to all transmitters since it occurs in the multiplexer. The STS identifies a first offset time span associated with the reference time signal, such as the 1PPS. In one embodiment, the STS refers to the number of specified clock intervals between the leading edge of the last 1 PPS of the common time reference and the occurrence in the transport stream of the first bit of the MPEG-2 packet sync byte in the header of the DTxP at the output of the pre-processor, such as pre-processor 230 in FIG. 2. In other words, time span 415 represents the time from the last 1PPS to the release of a DTxP, identified as time point 420, in the multiplexer, as part of the data packet timing and processing.

A time span 425, identified as Trans delay (transport delay), represents a second time delay and is equal to the time delay through the remaining processing in the multiplexer (common to all transmitters) to a time point 430, identified as DTxP arrival. A time span 435, identified as the Tx delay represents the time allotted for

the delay required between the exit of the DTxP from the multiplexer and the input or arrival at the exciter of that packet to the data randomizer, such as data randomizer 330 in FIG. 3.

5 Tx Delay identifies the delay through the link connection of the STL and is not typically common to all transmitters. However, a worst case delay value is used in order to provide a single common delay parameter. A time point 440 at the end of the time span 435, identified as DTxP modulation, indicates a point at which the DTxP packet enters the transmitter portion of the STL, such as post-processor 302 in FIG. 3. In one embodiment, the DTxP modulation time is the time of arrival at
10 data randomizer of bit 1 of MPEG -2 packet sync in header of the DTxP in order for the packet to be synchronously emitted.

A time span 445, identified as the transmitter and antenna delay (TAD), is a time delay associated with the transmitter and antenna portion of the STL. In other
15 words, time span 445 as the TAD represents the processing time for a packet arriving at time point 440 in the exciter, such as exciter 300, to be transmitted synchronously at a time point 450, identified as the Ref Emission time. This time span 445 is specific to each exciter device and is generally further determined by each exciter. For instance, for a particular exciter the TAD includes the total delay
20 from the input to the data randomizer, at which point the transmitter output timing is measured and controlled, to the output of the antenna connected to the exciter. In particular, with respect to an A/53 broadcast signal, TAD equals the time from the entry of the first bit of a DTxP word into the Data Randomizer to the appearance at the antenna output of the leading edge (zero crossing of the full symbol range
25 transition) of the segment sync of the corresponding Data Frame Sync data segment (i.e., the segment sync that occurs at the start of the corresponding Data Frame Sync data segment). The TAD compensation is performed through a calculation carried out by the exciter, subtracting TAD from OD, using a calculated value of TAD determined for that exciter.

30 The time point 450, the Ref Emission time, indicates the nominal emission time for the DTxP, given all of the time delays and spans described above. However, at least one additional variable time span may be included. Time span

455, identified as offset delay (OD), provides a variable emission point in order to account for variations in the transmission environment. The OD is a value that is set as a parameter for each exciter so as to allow adjustment of the emission timing of transmitter sites with respect to one another.

- 5 The OD value is specified as either a positive or negative offset, a digital value covering a range from approximately -3.5 ms to 3.5 ms and providing a range of possible emission time on each side of the Ref Emission time point 450. As a result, the actual emission time for the DTxP packet for each individual transmitter may range from an early emission time 452 to a late emission time 454.

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Finally, one or more of these time spans, representing delay time offsets, may be combined in order to simplify the number of variables sent. According to the A/110 standard, a delay value shown as time span 465, and identified as Max Delay, along with the delay value associated with the offset delay time span 455 is sent in a timing information packet. Offset value MaxDelay, time span 465, includes the time delays for trans delay 425, Tx Delay 435, and TAD 445. As a result, a simplified calculation, based on certain assumptions which will be described below, may be performed to determine the emission time of the DTxP packet, based on the release time of the DTxP packet (time point 420) as:

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$$\text{DTxP emission} = \text{DTxP arrival} + \text{MaxDelay} - \text{Offset Delay}(n), \quad (1)$$

where n represents each different exciter in the SFN

In addition, since the both the multiplexer and exciter use the same time reference, such as the GPS source, the actual emission time based on a common time reference would include the additional delay value for the STS (time span 415). In specifications, such as A/110, the STS value is computed in the multiplexer and provided as a start value for each exciter in the SFN. It is important to note that in some synchronization specifications the STS may not be provided as part of the TCP or DTxP. Instead, the STS and the DTxP arrival time may be computed at the multiplexer side as well as at each exciter on the transmitter side of the STL.

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Although the emission time for a packet, such as the DTxP is determined by

the equation above, each exciter may typically determine a processing starting time for the particular packet. In this case, the processing start time, identified as time 440, DTxP modulation is computed as:

$$\text{DTxP modulation} = \text{DTxP emission} - \text{TAD}(n), \quad (2)$$

where n represents each different exciter in the SFN

It is important to note that some synchronization specifications may limit the number of delay parameters provided a timing information packet or TCP. For instance, the A/110 specification provides that only two time delay parameters are provided in the DTxP communicated between the multiplexer or studio portion of the STL and each exciter or transmitter portion of the STL. These values are the parameter max delay, or MD and the parameter offset delay, or OD. As described above, OD is specific to each exciter and based on factors such as network architecture. As a result, the OD values for each exciter may be the same or different. An additional value, the transmitter antenna delay parameter, TAD, is also specific to each exciter, and is maintained and/or computed in each exciter. Typically, each exciter may maintain its own initial TAD value being predetermined, for instance by the exciter manufacturer. However, the final TAD must include other variable factors, such as the TCP or DTxP location in the final transmitted stream relative to its location prior to processing.

As a result, the calculations above lack some efficiency in that they include information that may be inherent in the particular implementation of the broadcast equipment. These additional dependencies may not always be completely and readily available or identifiable, making the complete SFN implementation more difficult. For instance, the emission time must account for the DTxP (TCP) packet point, and to do so may require a mechanism to include an estimate of the DTxP or TCP time of arrival in the emission time calculation as part of a final TAD computation. In many cases, the actual location of the DTxP or TCP packet within the multiplexed broadcast stream may only be known after additional processing.

For instance, error correction systems employing interleaving, such as is used in data interleaver 334 described in FIG. 3, change the relative location of packets of data. As a result, the final location of the TCP or DTxP packet is not completely known until after this interleaving process.

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However, since the use of the DTxP for timing is necessary to be compliant with A/110, a different reference packet for emission time can improve the issues and performance of emission synchronization. The reference packet immediately following the CSP or the segment sync, also being the first packet of a VSB frame has the property that it is unaffected by the interleaver. In other words, the CSP, and more particularly the first packet from the CSP, experiences no delay as result of processing in the interleaver, such as interleaver 334 described in FIG. 3. As a result, calculations made prior to the interleaving process remain valid following the interleaver processing. Further, following 8-VSB encoding the first bits in this first packet are included in the first symbol transmitted for the VSB frame. One approach is to have each exciter perform additional calculations using an alternate reference packet from the reference packet that the delay parameters are established for. In this case, a reference or synchronization point, such as the CSP identified in the A/53 standard, may improve the operational efficiency of the exciter. As a result, using the CSP as emission timing reference, exciter only needs to manage the delay parameters provided by the multiplexer, the exciter dependent delay and, if necessary, a single computation of the STS value based in part on the difference in time between the DTxP and CSP.

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An alternative approach to addressing this problem is additional signal processing in the multiplexer to identify the initial location of a specific synchronization point, such as the CSP, with respect to the TCP or DTxP packet within the transport stream, prior to delivery to each exciter. Time delay parameters may then be calculated, and determined relative to the specific synchronization point in the multiplexer, rather than the TCP or DTxP packet.

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Turning now to FIG 5, another exemplary timing diagram 500 illustrating a relationship between the emission time of a data packet in a broadcast signal

transmitted over an SFN is shown. Timing diagram 500 is similar to timing diagram 400 but further illustrates a relationship between a synchronization packet represented by signal stream synchronization packet or location, such as the CSP, identified as the first packet following the data frame or field sync in an ATSC A/53 transport stream, and the designated timing information control packet, such as a TCP or DTxP.

Timing diagram 500 represents an allotted time delay interval for emission of the synchronization point or CSP and the creation or arrival of the TCP or DTxP at the input of a transport stream processing block within a multiplexer, such as the packet timing and adjustment block 220 described in FIG. 2. Timing diagram 500 further includes a time delay interval identified as the difference in location between the TCP or DTxP and the synchronization point, or CSP. From this timing diagram, calculations are possible for each transmitter to permit synchronized emission of the synchronization point or CSP using information supplied in the TCP or DTxP. Synchronized emission of all remaining packets is then governed by synchronization of this packet and only the delay associated with processing the stream in an exciter, such as exciter 300 described in FIG. 2, and not on any additional processing for identifying the location of TCP or DTxP in the transmitted signal stream due to error correction or interleaving.

Timing diagram 500 includes an initial time reference 510, identified as the 1PPS signal provided through the GPS reference on a time scale 501. A time span 515, identified as the DTxP STS, represents the known time delay the time from the last 1PPs to the release of a DTxP, identified as time point 520. A second initial time span 512, identified as DTxP loc is the time period between arrival of the next synchronization point, or CSP in the signal stream and the last DTxP release. In one embodiment, the time span 512 is measured in numbers of packets referenced to the stream and given by the following:

$$\text{DTxP loc} = 624 - \text{packet_num}(\text{DTxP}), \quad (3)$$

where packet_num(DTxP) is the location in the signal transport stream of the DTxP packet relative to the synchronization packet or CSP.

Time span 512 is a variable time span based on the predictable location of the synchronization point or CSP with the transport stream and the initial variable location of the DTxP.

5 However, the initial variable location of the DTxP is known and established in the multiplexer, such as multiplexer 200, and can be easily determined and provided as a delay parameter (e.g., included in the STS) as part of the timing information for each exciter. The time span 512 is included along with time span 515 to form a time span 518, identified as the CSP STS. The CSP STS, like the STS time span 415
10 described in FIG. 4, identifies the time location of a particular packet or time point in the stream. In this case, CSP STS time span 518 represents the CSP release in the multiplexer, identified as time point 521. The creation of the CSP STS time span 518 as a replacement for STS time span 415 described in FIG. 4 allows for inclusion of this offset delay as part of the timing information already provided, such as the
15 timing information provided as part of A/110. It is important to note that time span 518 may span a time past a subsequent of the 1PPS time marker. In this case, the calculation of the CSP STS, as described above, may be altered to use this subsequent 1PPS occurrence as a starting time reference. Such a determination may occur if the time difference of the DTxP release and the CSP release is greater
20 than the interval for the 1PPS signal.

A time span 525, identified as Trans delay (transport delay), represents a second time delay and is equal to the time delay through the remaining processing in the multiplexer (common to all transmitters) to a time point 530, identified as CSP
25 arrival. A time span 535, identified as the Tx delay represents the time allotted for the delay required between the exit of the CSP from the multiplexer and the input or arrival at the exciter of that packet to the data randomizer, such as data randomizer 330 in FIG. 3. Tx Delay identifies the delay through the link connection of the STL and is not typically common to all transmitters. However, a worst case delay value is
30 used in order to provide a single common delay parameter. A time point 540 at the end of the time span 535, identified as CSP modulation, indicates a point at which the CSP packet enters the transmitter portion of the STL, such as post-processor 302 in FIG. 3. In one embodiment, the CSP modulation time is the time of arrival at

data randomizer of bit 1 of MPEG -2 packet sync in header of the CSP in order for the packet to be synchronously emitted.

A time span 545, identified as the transmitter and antenna delay (TAD), is a time delay associated with the transmitter and antenna portion of the STL.

In other words, time span 545 as the TAD represents the processing time for a packet (e.g., the packet following the CSP) arriving at time point 540 in the exciter, such as exciter 300, to be transmitted synchronously at a time point 550, identified as the Ref Emission time. This time span 545 is specific to each exciter device and is generally further determined by each exciter. For instance, for a particular exciter the TAD includes the total delay from the input to the data randomizer, at which point the transmitter output timing is measured and controlled, to the output of the antenna connected to the exciter. In particular, with respect to an A/53 broadcast signal, TAD equals the time from the entry of the first bit of the word immediately following the CSP into the Data Randomizer to the appearance at the antenna output of the leading edge (zero crossing of the full symbol range transition) of the segment sync of the corresponding Data Frame Sync data segment (i.e., the segment sync that occurs at the start of the corresponding Data Frame Sync data segment). The TAD compensation is performed through a calculation carried out by the exciter, subtracting TAD from OD, using a stored value of TAD determined for that exciter. It is important to note that by using a packet having a fixed location relative to the signal stream, such as described here, not additional compensation or calculations associated with the TAD parameter value are needed in the exciter.

The time point 550, the Ref Emission time, indicates the nominal emission time for the CSP, given all of the time delays and spans described above. However, at least one additional variable time span may be included. Time span 455, identified as offset delay (OD), provides a variable emission point in order to account for variations in the transmission environment. The OD is a value that is set as a parameter for each exciter so as to allow adjustment of the emission timing of transmitter sites with respect to one another. The OD value is specified as either a positive or negative offset, a digital value covering a range from approximately -3.5 ms to 3.5 ms and providing a range of possible emission time on each side of the Ref Emission time point 450.

As a result, the actual emission time for the CSP packet for each individual transmitter may range from an early emission time 452 to a late emission time 454.

As described, above, one or more of the time delays shown in timing diagram 500 may be combined.

In one embodiment, a Max Delay parameter representing all of the delays from point 521 (CSP release) to Ref Emission 550 and an offset delay parameter are provided in the DTxP packet according to the A/110 standard. A representative equation, including a set of constants related to the common time reference and the signaling period for the A/53 signal, along with the original STS (identified as DTxP STS in FIG. 5), is given by:

$$\text{CSP Emission time} = (((\text{DTxP loc}) * 188 * 8 * 10.762238\text{e}6) / 19.392658\text{e}6)) + \text{DTxP STS} + \text{Max Delay} + \text{Offset Delay}, \quad (4)$$

where DTxP loc is computed in equation (3)

As described above in FIG. 4, each exciter may typically determine a processing starting time for the particular packet. In this case, the processing start time, identified as time 540, CSP modulation is computed as:

$$\text{CSP modulation} = \text{CSP emission} - \text{TAD}(n), \quad (5)$$

where n represents each different exciter in the SFN.

It is important to note that unlike the computation in FIG. 4, the TAD value in the above equation only includes time delays associated specifically with the equipment used in the exciter. The TAD value does not further depend on a determination of delay associated with the variable location of the TCP or DTxP used as the timing reference packet.

Turning now to FIG 6, a flowchart of an embodiment of a process 600 for establishing the emission time of packets in a signal stream for transmitters in an SFN is shown. The steps in process 600 are described primarily in conjunction with the operation of multiplexer 110 and each of the exciters 118a-n described in FIG. 1.

However, some or all of the steps in process 600 may also apply to the operation of multiplexer 200 described in FIG. 2 and exciter 300 described in FIG. 3. Furthermore, one or more specific embodiments may be described in the steps of process 600 with respect to operations on broadcast signals according to the ATSC standards A/53, A/153, and A/110. However, it should be noted that one or more of the steps of process 600 may equally apply to similar structures and functionality for operating on signals according to standards or formats other than those described are possible and easily recognized and understood by one skilled in the art. Further, it is important to note that one or more of the steps may be combined or may be performed simultaneously in a parallel process that may occur in either multiplexer 110 or exciters 118a-n or both.

At step 610, one or more content signal streams are received at the input of multiplexer 110. The content signal streams may include audio content, video content, and/or data content. In one embodiment, two or more separate content signal streams separately containing audio content and video content are received. Other embodiments may include more or fewer content signal streams where one or more streams include combined audio, video, or data content. At step 620, the one or more content signal streams are processed to produce a multiplexed transport stream. The processing step 620 is performed in multiplexer 110 and may include encoding or compression of the content and may further include multiplexing of separate encoded streams to form a transport stream. In one embodiment, the content signal streams are encoded using either MPEG-2 or AVC encoding and multiplexed according to the formatting in A/153 and A/53.

Next, at step 630, a synchronization interval is identified. The identification at step 630 is performed in multiplexer 110 and includes receiving a time reference, such as the GPS signal (i.e., 1PPS) and any other timing control information in multiplexer 110. Additionally, at step 630, a synchronization interval associated specifically with the signal stream may be identified. For example, in ATSC A/53, the cadence sync point, also identified as the first packet that is in the broadcast transport stream following either the Frame Sync or the Field Sync, may be identified and used part of the synchronization interval. The use of the cadence sync point, or

CSP, has advantages over the use of other packets as a synchronization interval in that the cadence sync point is unaffected by certain processing that is performed as part of the encoding and modulation of the broadcast signal, as has been described above.

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At step 640, using the identified synchronization interval at step 630, a final transmission time value for synchronization, along with one or more transmission or emission synchronization time offset delay values are determined or calculated. These delay values are determined according to the operational conditions for the SFN and include parameters such as those shown and calculated in timing diagram 10 400 described in FIG. 4 and timing diagram 500 described in FIG. 5. Also, at step 640, some of these offset delay values are inserted into the transport stream in a timing control information packet or TCP. In one embodiment, the offset delay values are included in a DTxP packet according to the A/110 standard.

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It is important to note that the offset delay values at step 640 may be determined based on the location of a defined packet in the transport stream. In one embodiment, the packet immediately following a signal synchronization segment, identified as the CSP in A/53, is used as the reference packet as part of the 20 synchronization interval described at step 630. Information is also determined with respect to the time and location of this reference packet to the timing control information packet or TCP that includes the calculated offset delay values.

Further, some of the parameters described at step 640 may be determined or 25 calculated in multiplexer 110 and provided, at step 650, by multiplexer 110 over a communication link to each of exciters 118a-n. Each of the exciters uses these parameters in determining emission time as well as a time point for beginning modulation processing as described below. Alternatively, one or more parameters may be determined in each of exciters 118a-n for use in determining a time point for 30 modulation processing.

Next, at step 660, using the parameters provided from multiplexer 110 at step 650, the modulation processing start time is determined in each exciter 118a-n.

The modulation processing start time may be referenced to the reference packet or a time or location in the transport, such as the CSP described above. Each exciter will determine an individual processing start time using the location of CSP along with the parameters from multiplexer 110 and an additional delay value equal to the processing time needed in the exciter, identified as the transmitter and antenna delay or TAD.

Last, at step 670, based on the properly delayed and adjusted starting time for exciter processing occurring at step 660, the broadcast stream is transmitted. The transmission at step 670 includes encoding and modulation processing occurring in each exciter 118a-n. More particularly, the transmission at step 670 includes error correction encoding, interleaving, and modulation according to the ATSC A/53 standard in processing blocks such as those described for exciter 300 in FIG. 3. Based on the calculations and steps described above, each exciter 118a-n will deliver the broadcast stream, or more particularly the reference packet, to the antenna for emission or transmission at the time as designated by the synchronization timing.

The disclosed embodiments describe the operation of an SFN broadcast system using aspects of the existing broadcast transmission, such as ATSC A/53 and A/153. More specifically, the embodiments relate to a method and apparatus for the determination and calculation of the synchronized emission time of a broadcast signal relative to synchronization point or CSP in the transport stream. The embodiments eliminate the need to manage arrival time or timestamping of a transmission control packet containing delay information due to its variable final time location in the transmission stream.

Although embodiments which incorporate the teachings of the present disclosure have been shown and described in detail herein, those skilled in the art can readily devise many other varied embodiments that still incorporate these teachings. Having described preferred embodiments of an apparatus and method for transmitting a signal in a single frequency network (which are intended to be illustrative and not limiting), it is noted that modifications and variations can be made

by persons skilled in the art in light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments of the disclosure disclosed which are within the scope of the disclosure as outlined by the appended claims.

WHAT IS CLAIMED IS:

1. A method (600) comprising the steps of:
 - receiving (610) a broadcast signal stream containing a data packet and a synchronization timing packet, the synchronization timing packet containing signal transmission delay parameters provided to at least two transmitters;
 - identifying (630) a synchronization interval in the broadcast signal stream; and
 - determining (640) a transmission time for the data packet in the broadcast signal stream based on the signal transmission delay parameters and a time position of the data packet with respect to the synchronization interval.
2. The method (600) as in claim 1, wherein the step of determining (640) further includes
 - calculating a difference between the time position of the synchronization interval and the time position of the synchronization timing packet in the broadcast signal stream.
3. The method (600) as in claim 1, further comprising:
 - transmitting (670) the broadcast signal stream including the synchronization interval and the data packet.
4. The method (600) as in claim 3, wherein the step of transmitting (670) further includes encoding the broadcast signal stream to create a broadcast transmission signal.
5. The method (600) as in claim 4, wherein the synchronization interval is chosen such that the time position of the synchronization interval in the broadcast transmission signal is unaffected by the encoding step.

6. The method (600) as in claim 4, wherein the time position of the synchronization timing packet in the broadcast signal stream is different than the time position of the synchronization timing packet in the broadcast transmission signal.
7. The method (600) as in claim 4, wherein the step of transmitting (670) further includes computing (660) a start time for encoding the data packet in the broadcast signal stream.
8. The method (600) as in claim 1, wherein the synchronization timing packet includes delay parameters that are referenced to a time reference common between the at least two transmitters.
9. The method (600) as in claim 1, wherein the broadcast signal stream is a transport stream compliant with at least one of the Advanced Television Systems Committee A/53 standard and Advanced Television Systems Committee A/153 standard.
10. The method (600) as in claim 1, wherein the synchronization timing packet includes delay parameters that are included in a distributed transmission packet as part of the Advanced Television Systems Committee A/110 standard.
11. The method (600) as in claim 1, wherein the at least two transmitters operate as part of a single frequency network.
12. The method as in claim 1, wherein the data packet is in a time position immediately following the synchronization interval.
13. An apparatus (100) comprising:
 - a multiplexer (110) that generates a transport stream containing a data packet and a synchronization timing packet, the synchronization timing packet containing signal transmission delay parameters provided to at least two transmitters;

an exciter (118a-n), coupled to the multiplexer (110), the exciter (118a-n) identifying a synchronization interval in the broadcast signal stream and determining a transmission time for the data packet in the broadcast signal stream based on the signal transmission delay parameters and a time position of the data packet with respect to the synchronization interval;

an antenna (120a-n), coupled to the exciter (118a-n), the antenna (120a-n) transmitting a broadcast signal including the synchronization interval and the data packet.

14. The apparatus (100) of claim 13, wherein the exciter (118a-n) further calculates a difference between the time position of the synchronization interval and the time position of the synchronization timing packet in the broadcast signal stream.

15. The apparatus (100) of claim 13, wherein the antenna (120a-n) transmits the broadcast signal at a time synchronized with at least one different antenna based on the determination of the transmit time by the exciter (118a-n).

16. The apparatus (100) of claim 13, wherein the exciter (118a-n) further encodes the transport stream to create the broadcast signal.

17. The apparatus (100) of claim 16, wherein the synchronization interval is chosen such that the time position of the synchronization interval in the broadcast signal is unaffected by the encoding step.

18. The apparatus (100) of claim 16, wherein the time position of the synchronization timing packet is different between the broadcast signal and the transport signal.

19. The apparatus (100) of claim 13, wherein the exciter (118a-n) further computes a start time for encoding the data packet.

20. The apparatus (100) of claim 13, wherein the synchronization timing packet includes delay parameters that are referenced to a time reference common between the multiplexer (110) and the exciter (118a-n).

21. The apparatus (100) of claim 13, wherein the transport stream is compliant with at least one of the Advanced Television Systems Committee ATSC A/53 standard and Advanced Television Systems Committee ATSC A/153 standard.

22. The apparatus (100) of claim 13, wherein the synchronization timing packet includes delay parameters that are included in a distributed transmission packet as part of the Advanced Television Systems Committee A/110 standard.

23. The apparatus (100) of claim 13, wherein the apparatus (100) operates as part of a single frequency network.

24. An apparatus for transmitting a synchronized signal in a single frequency network, the apparatus comprising:

means for receiving (610) a broadcast signal stream containing a data packet and a synchronization timing packet, the synchronization timing packet containing signal transmission delay parameters provided to at least two transmitters;

means for identifying (630) a synchronization interval in the broadcast signal stream; and

means for determining (640) a transmission time for the data packet in the broadcast signal stream based on the signal transmission delay parameters and a position in time of the data packet with respect to the synchronization interval.

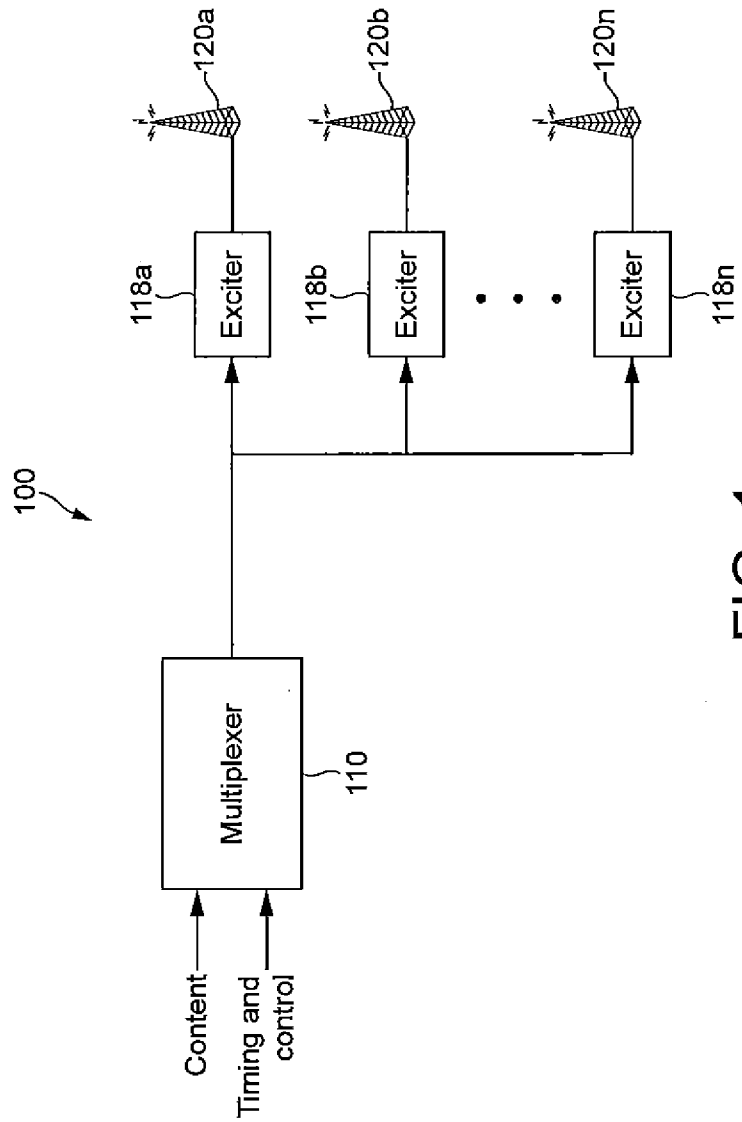


FIG. 1

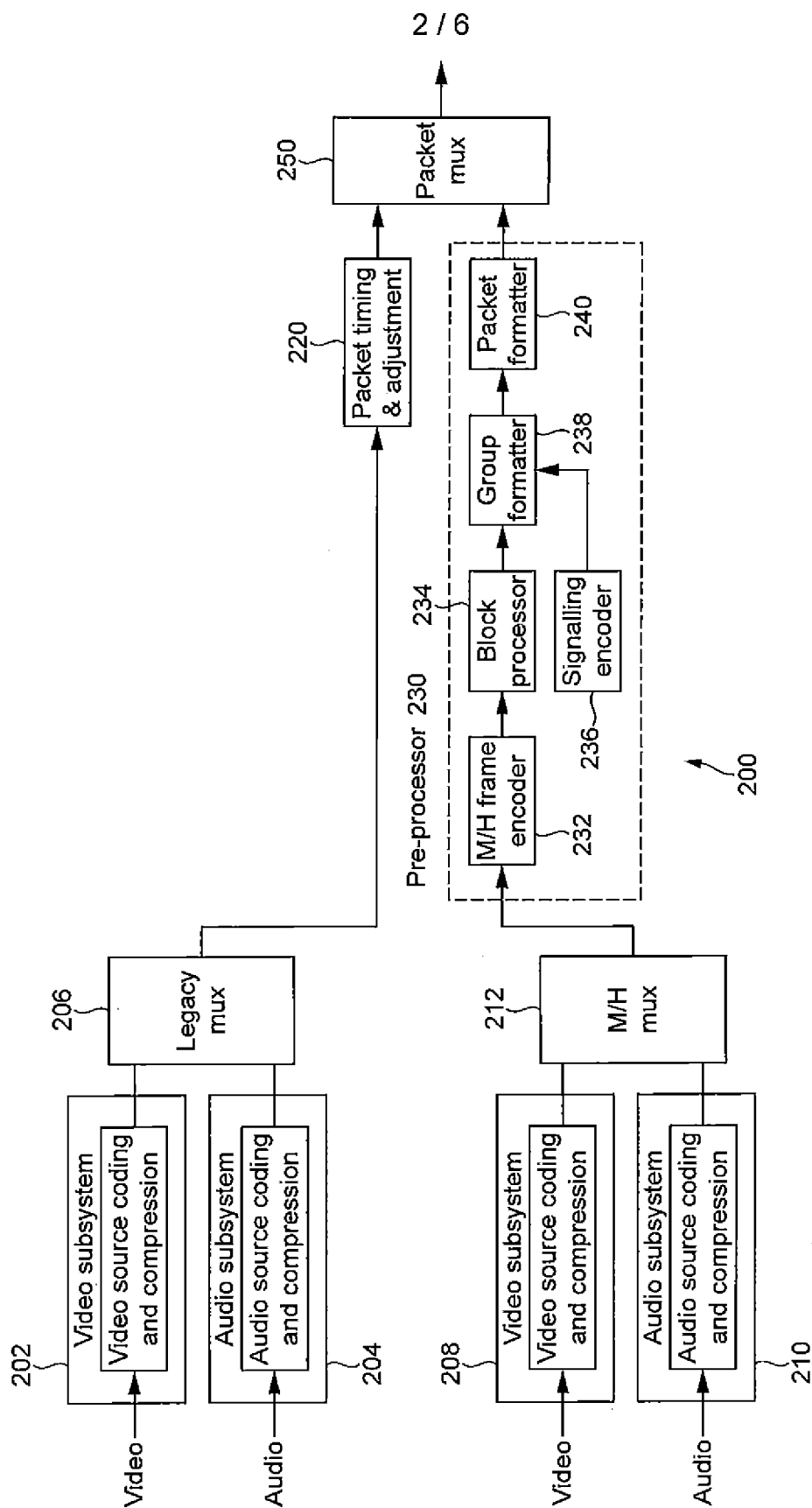


FIG. 2

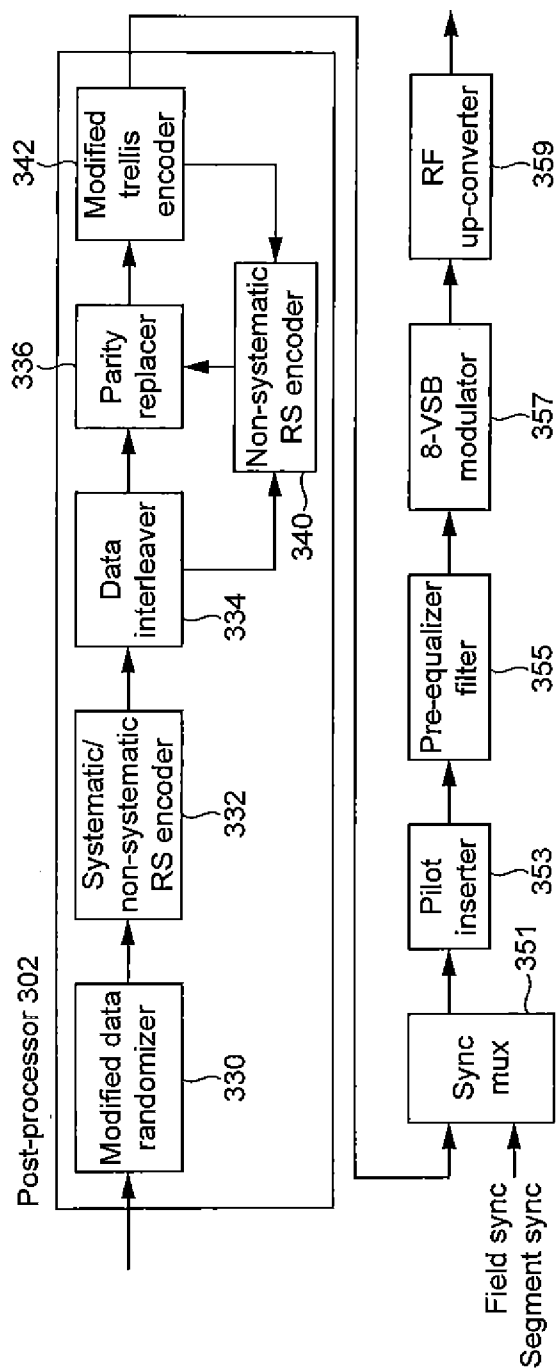


FIG. 3

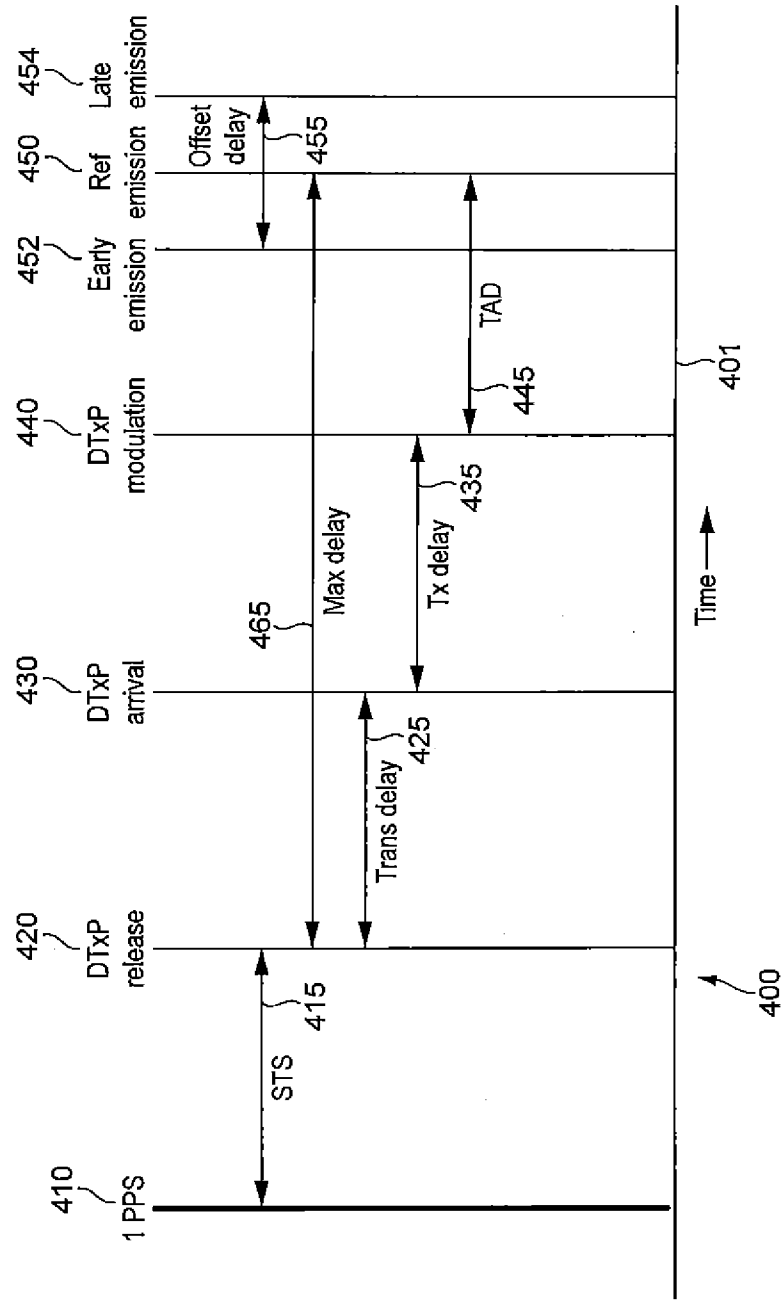


FIG. 4

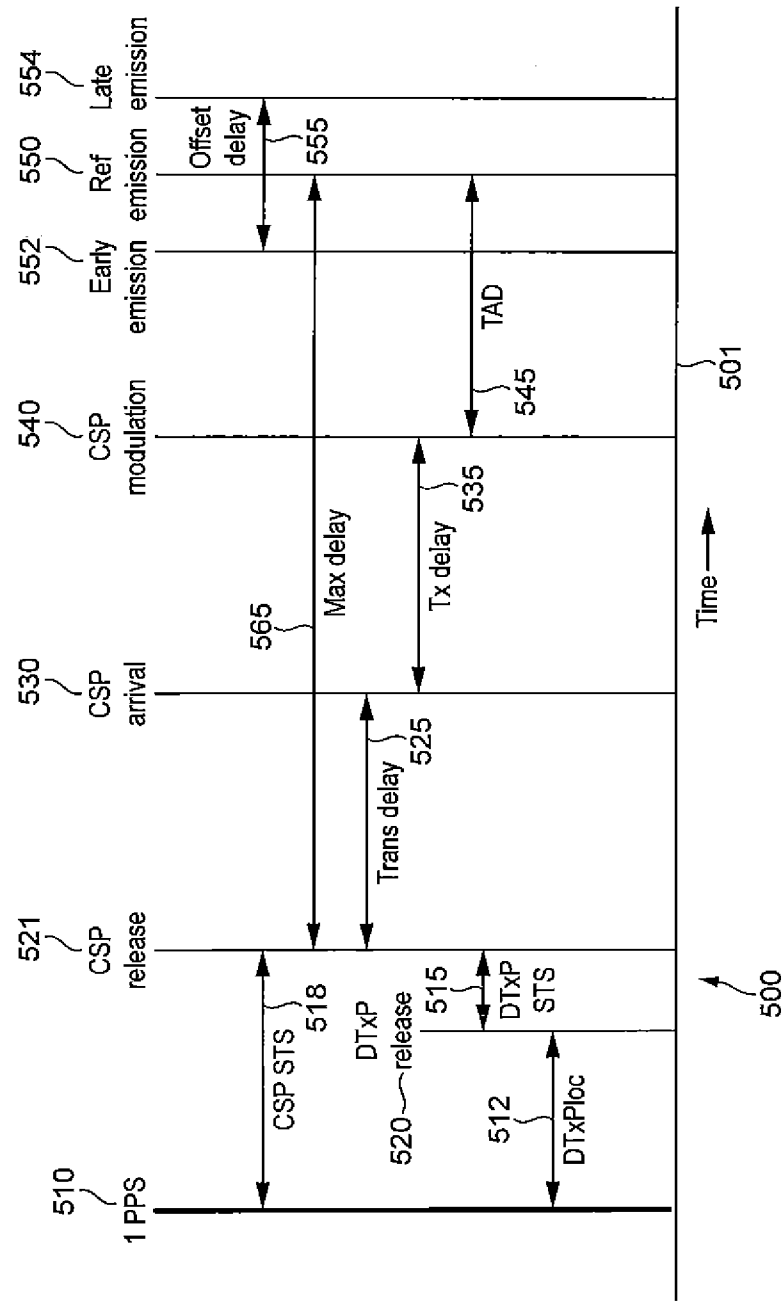


FIG. 5

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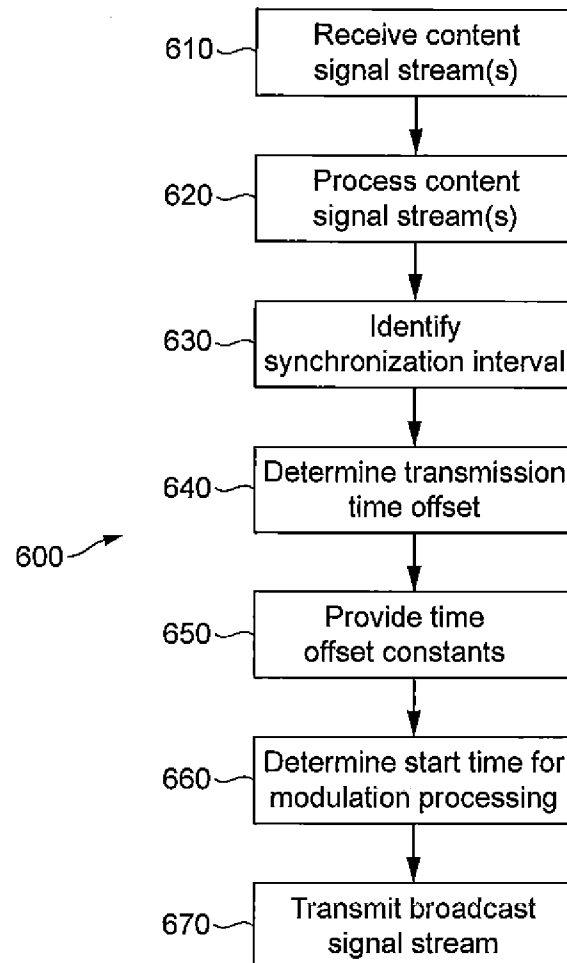


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/046219

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04H20/67 H04H20/18 H04B7/26
ADD.

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)

H04H H04N H04B H04W H04J

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 practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/244865 A1 (SIMON MICHAEL [US]) 2 November 2006 (2006-11-02) paragraph [0056] paragraph [0059] paragraphs [0061] - [0063] paragraphs [0066] - [0069] paragraph [0071] paragraphs [0079] - [0088] figures 2,5,7,11,12	1-24
A	----- US 2006/159193 A1 (MATTSSON ANDERS S [US] ET AL) 20 July 2006 (2006-07-20) the whole document	1-24
A	----- US 2010/111109 A1 (HERZOG NORMAN [DE] ET AL) 6 May 2010 (2010-05-06) the whole document ----- -/-	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

28 November 2011

Date of mailing of the international search report

05/12/2011

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/046219

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/323729 A1 (SIMON MICHAEL [US] ET AL) 31 December 2009 (2009-12-31) the whole document -----	1-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/046219

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US 2009323729	A1	31-12-2009	US 2009323729 A1 31-12-2009 US 2011188521 A1 04-08-2011