



US00RE46740E

(19) **United States**
(12) **Reissued Patent**
Lee et al.

(10) **Patent Number:** US RE46,740 E
(45) **Date of Reissued Patent:** Feb. 27, 2018

(54) **DIGITAL BROADCASTING SYSTEM AND METHOD OF PROCESSING DATA IN THE DIGITAL BROADCASTING SYSTEM**

(58) **Field of Classification Search**
CPC H03M 13/27; H03M 13/2909; H03M 13/1915; H03M 13/2936; H03M 13/2945;
(Continued)

(71) Applicant: **LG ELECTRONICS INC.**, Seoul (KR)

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(73) Assignee: **LG ELECTRONICS INC.**, Seoul (KR)

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(Continued)

(21) Appl. No.: **14/668,771**

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(22) Filed: **Mar. 25, 2015**

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Related U.S. Patent Documents

Reissue of:

(64) Patent No.: **8,406,256**
Issued: **Mar. 26, 2013**
Appl. No.: **12/396,066**
Filed: **Mar. 2, 2009**

Primary Examiner — Majid A Banankhah
(74) *Attorney, Agent, or Firm* — Dentons US LLP

U.S. Applications:

(60) Provisional application No. 61/033,432, filed on Mar. 4, 2008.

(57) **ABSTRACT**

A transmitting system and a method for processing data are disclosed herein. The transmitting system includes a service multiplexer and at least one transmitter located in a remote position from the service multiplexer. Herein, the service multiplexer generates an RS frame having the size of N (row)×187 (column) bytes including at least one type of mobile service data, packetizes the RS frame into a plurality of mobile service data packets, and multiplexes the packetized mobile service data packets with a main service data packet at a predetermined data rate, thereby transmitting the multiplexed data packets. Herein, each mobile service data packet is configured of a TS header and a data region, and the data region is configured of at least one of a payload region and an adaptation field region.

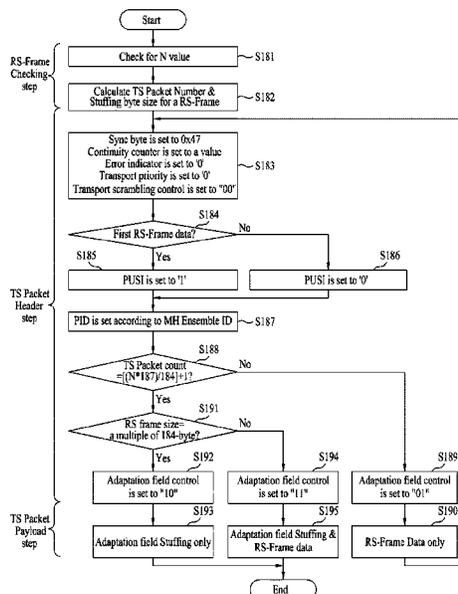
(30) **Foreign Application Priority Data**

Feb. 25, 2009 (KR) 10-2009-0015936

(51) **Int. Cl.**
H04J 3/00 (2006.01)
H04J 3/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H03M 13/27** (2013.01); **H03M 13/2909** (2013.01); **H03M 13/2915** (2013.01);
(Continued)

19 Claims, 49 Drawing Sheets



US RE46,740 E

- (51) **Int. Cl.**
H03M 13/27 (2006.01)
H03M 13/35 (2006.01)
H03M 13/29 (2006.01)
H03M 13/15 (2006.01)
H03M 13/23 (2006.01)
H03M 13/09 (2006.01)
- (52) **U.S. Cl.**
CPC ... *H03M 13/2936* (2013.01); *H03M 13/2945*
(2013.01); *H03M 13/356* (2013.01); *H03M*
13/09 (2013.01); *H03M 13/15* (2013.01);
H03M 13/23 (2013.01)
- (58) **Field of Classification Search**
CPC H03M 13/356; H03M 13/09; H03M 13/15;
H03M 13/23
USPC 370/476, 535; 714/758, 762, 784;
725/62
See application file for complete search history.

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FIG. 1

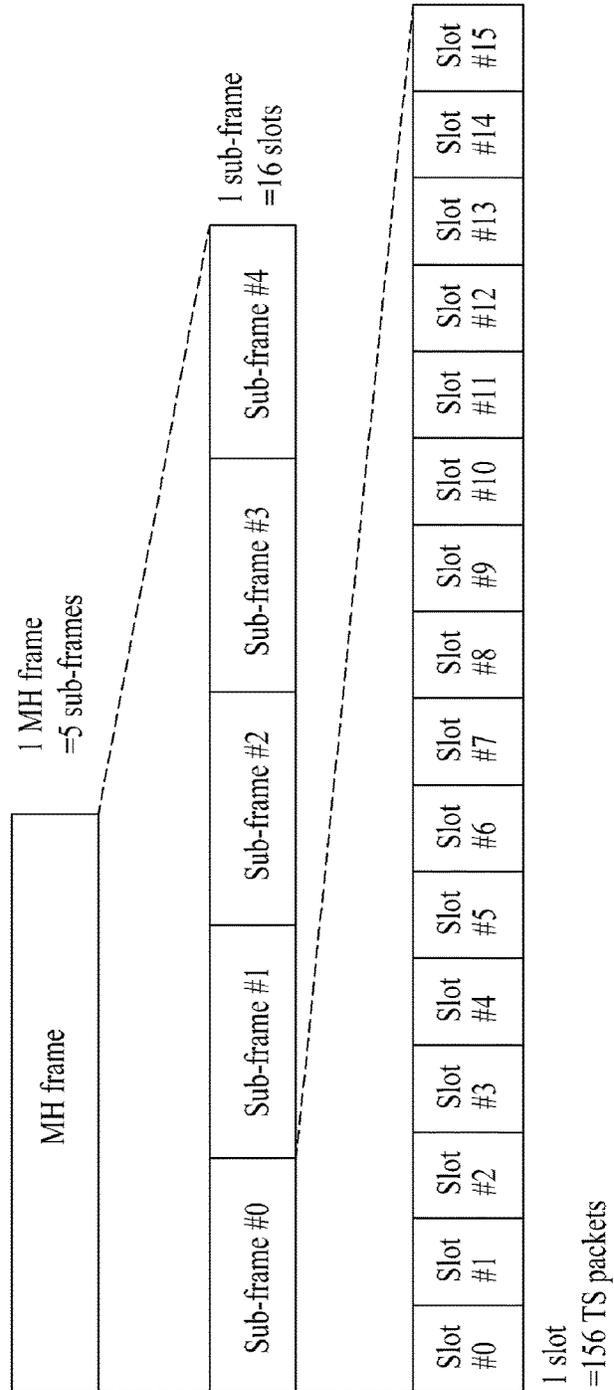


FIG. 2

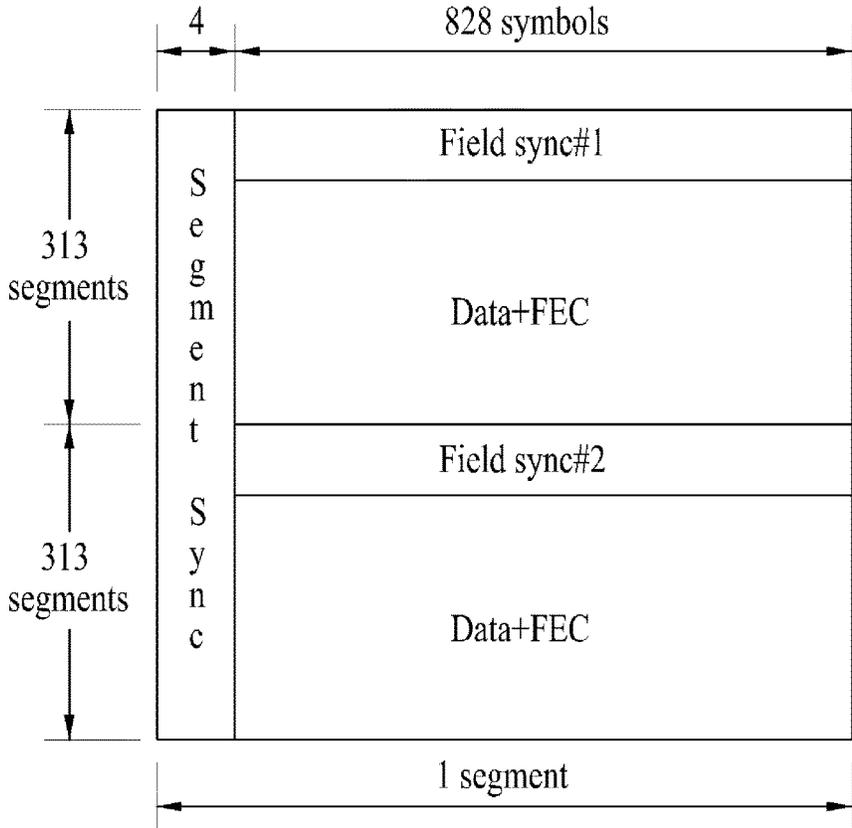


FIG. 3

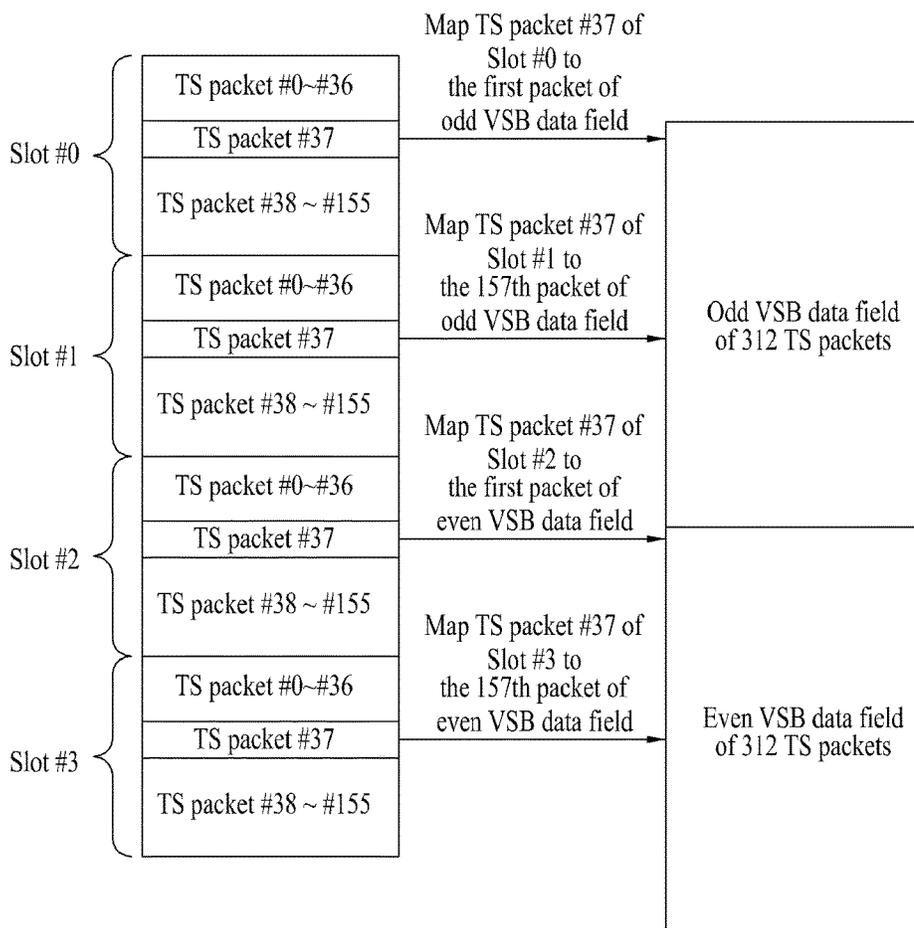


FIG. 4

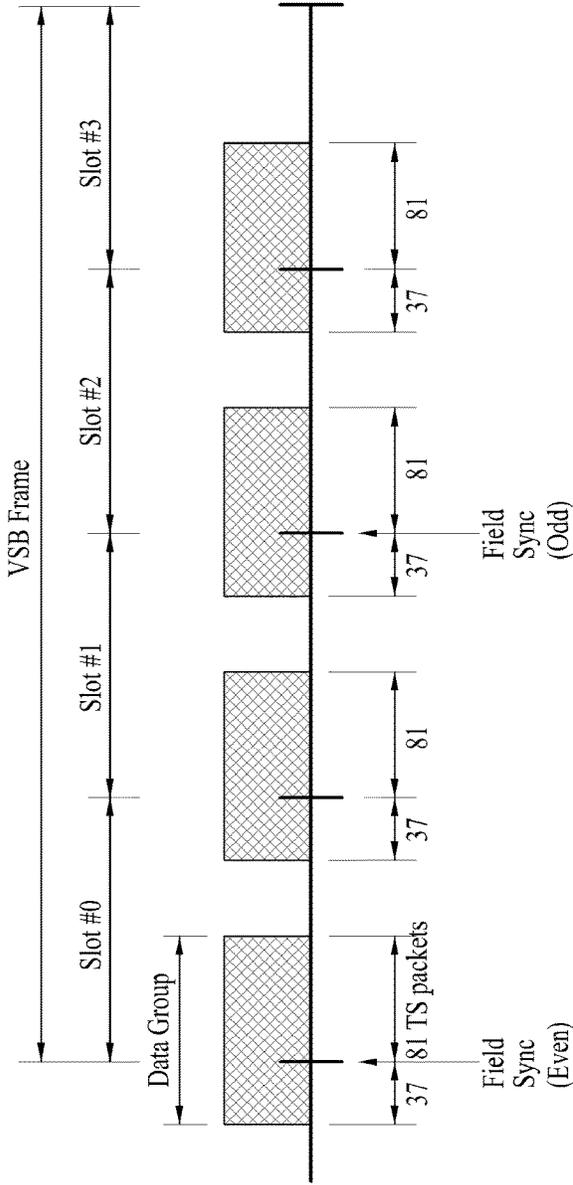


FIG. 5

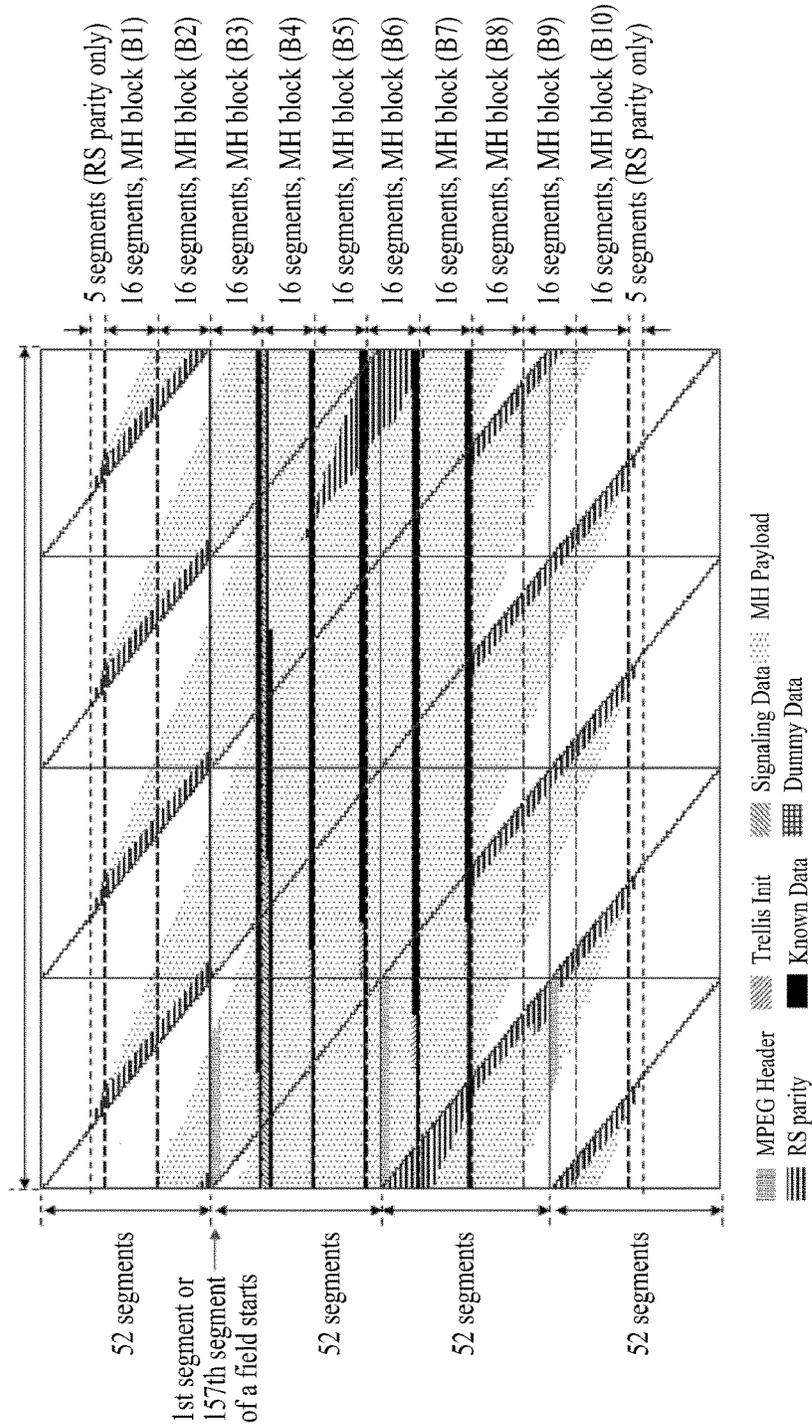


FIG. 6

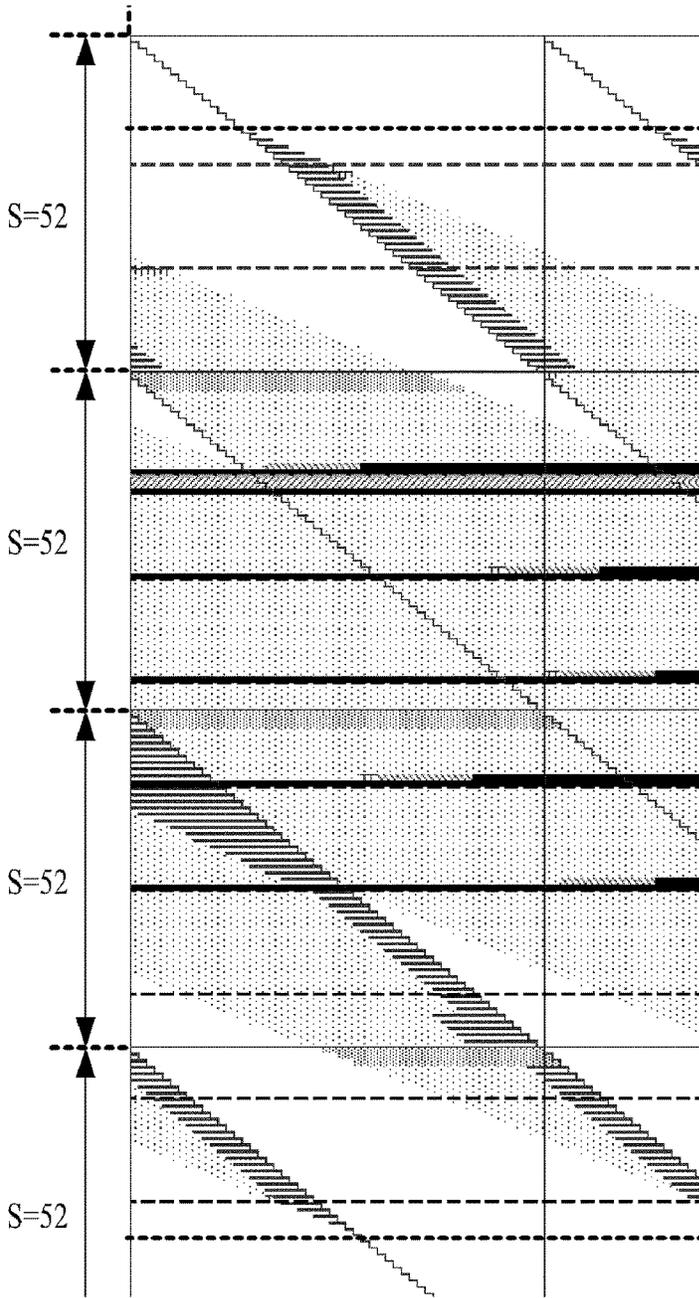


FIG. 7

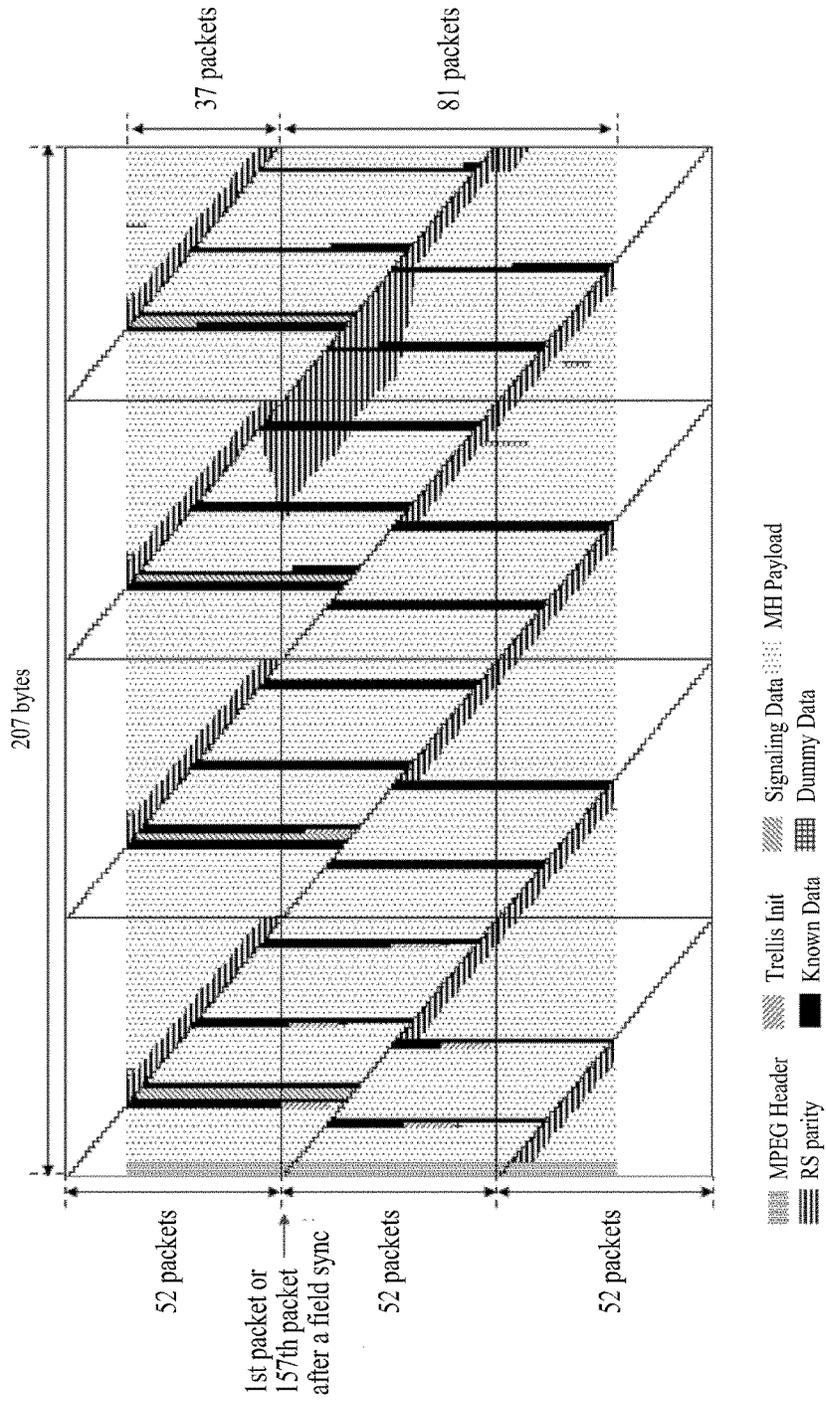


FIG. 8

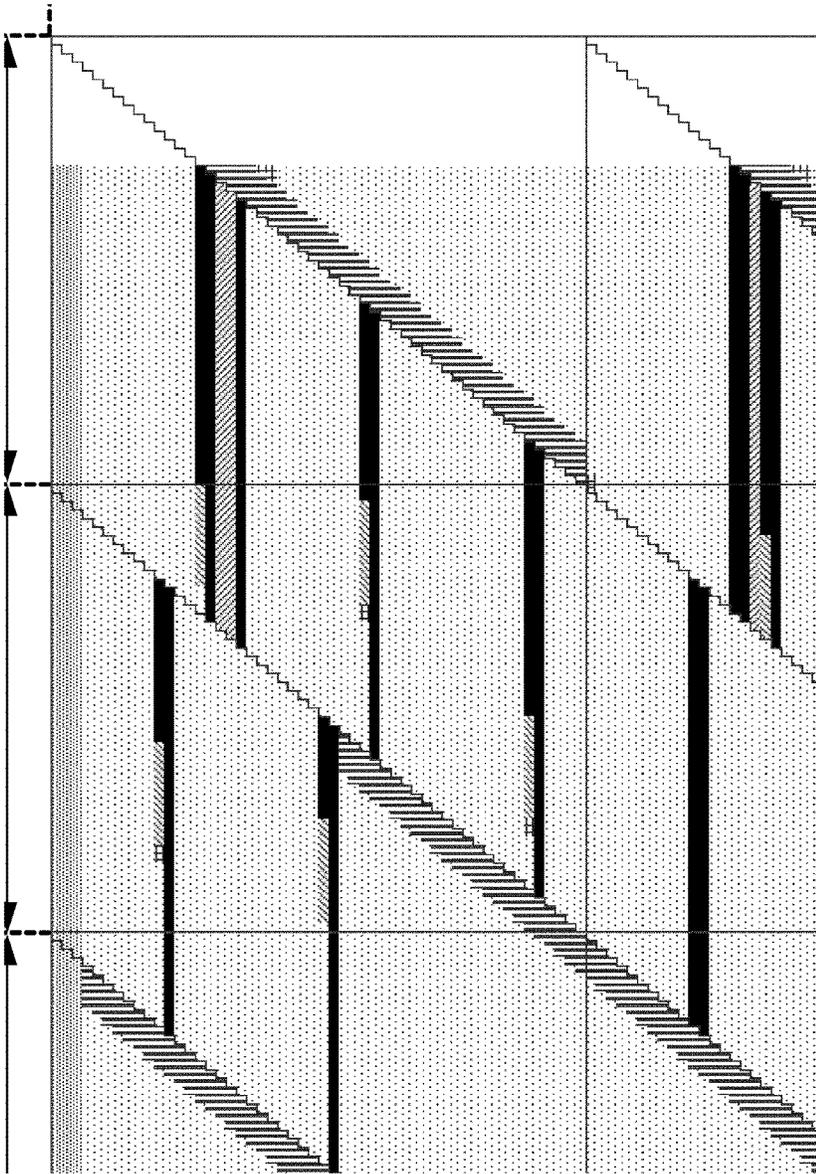


FIG. 9

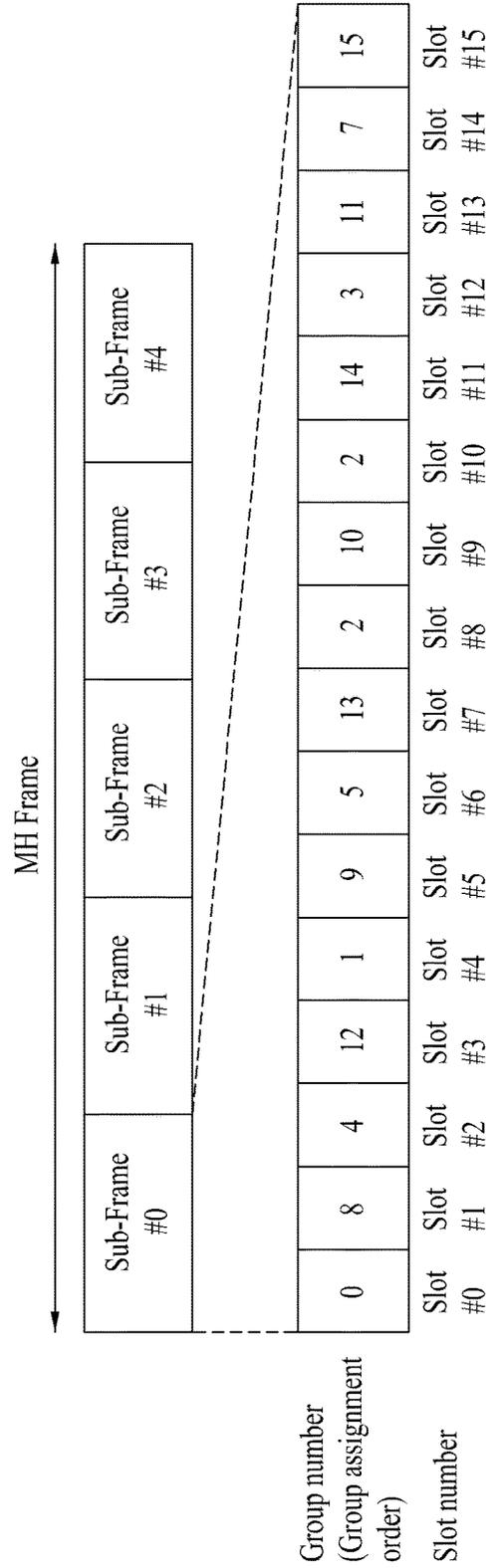


FIG. 10

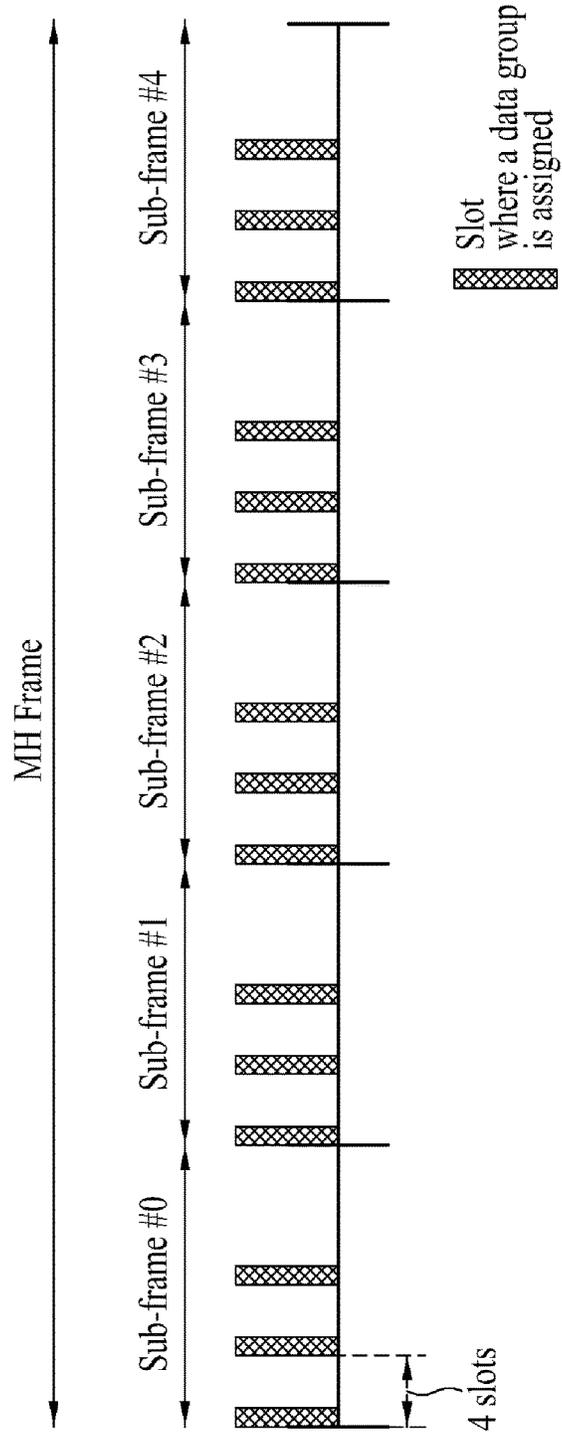


FIG. 11

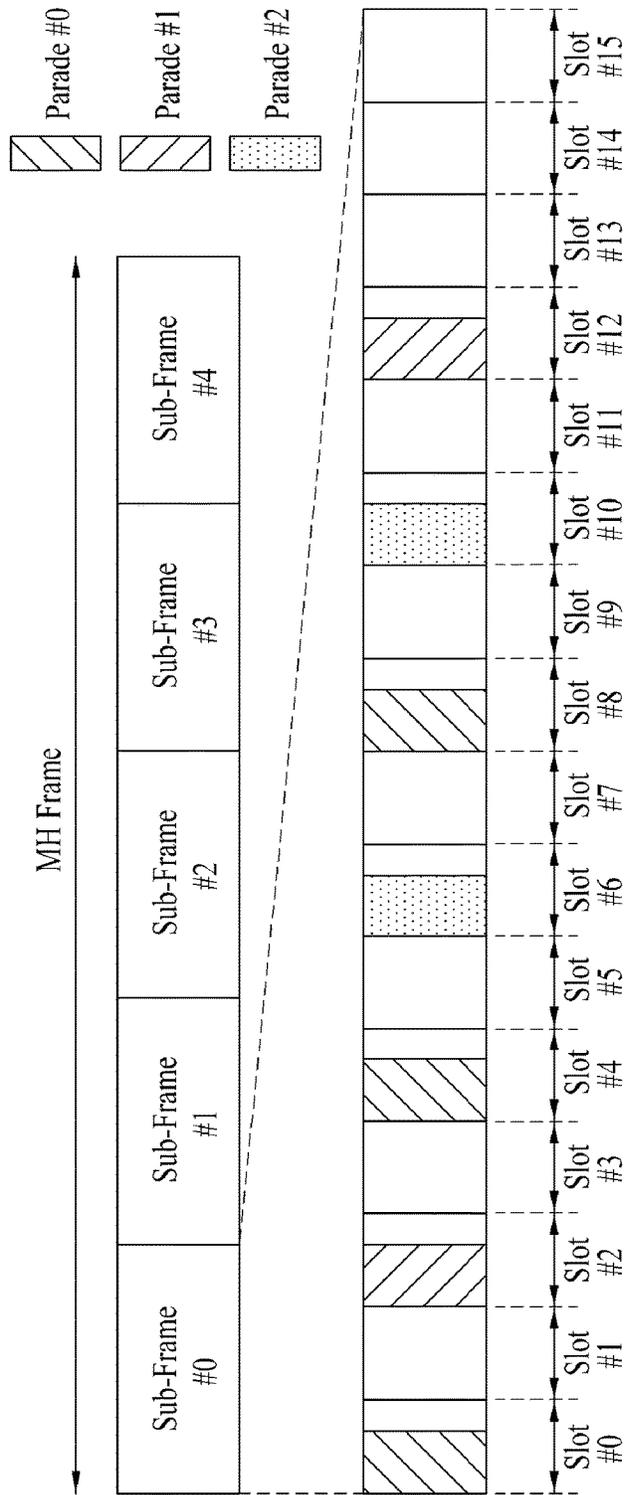


FIG. 12

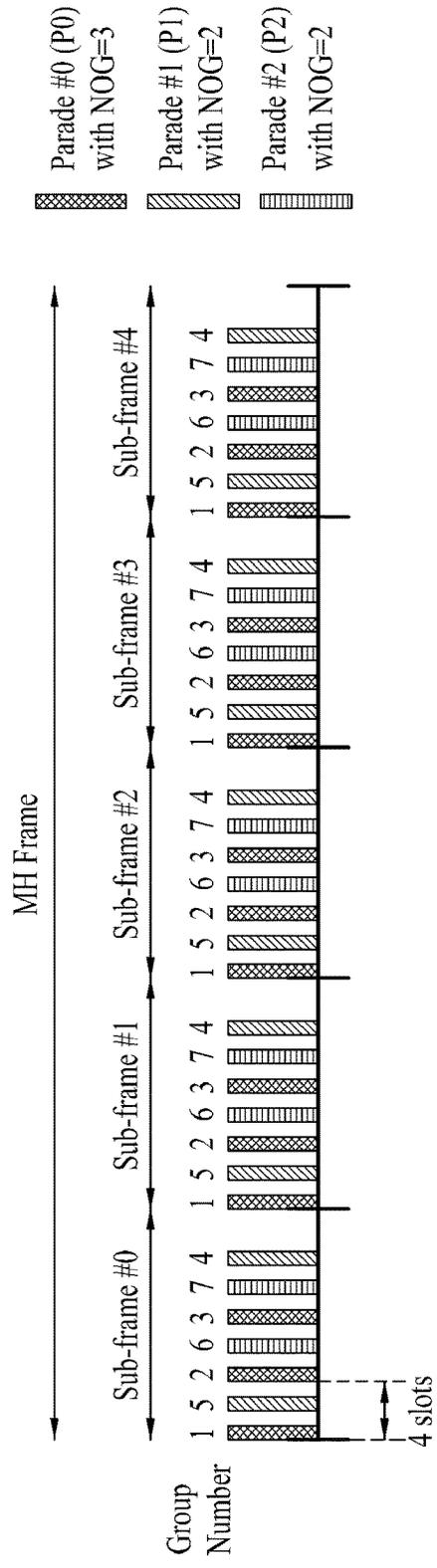


FIG. 13

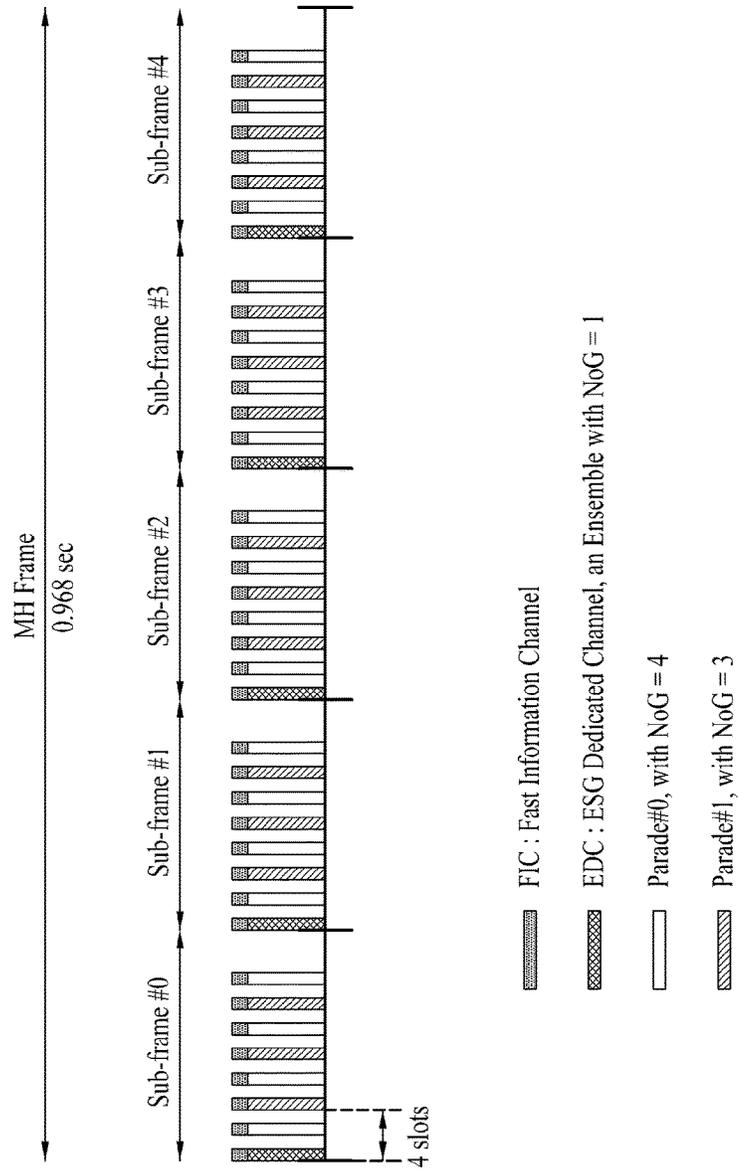


FIG. 14

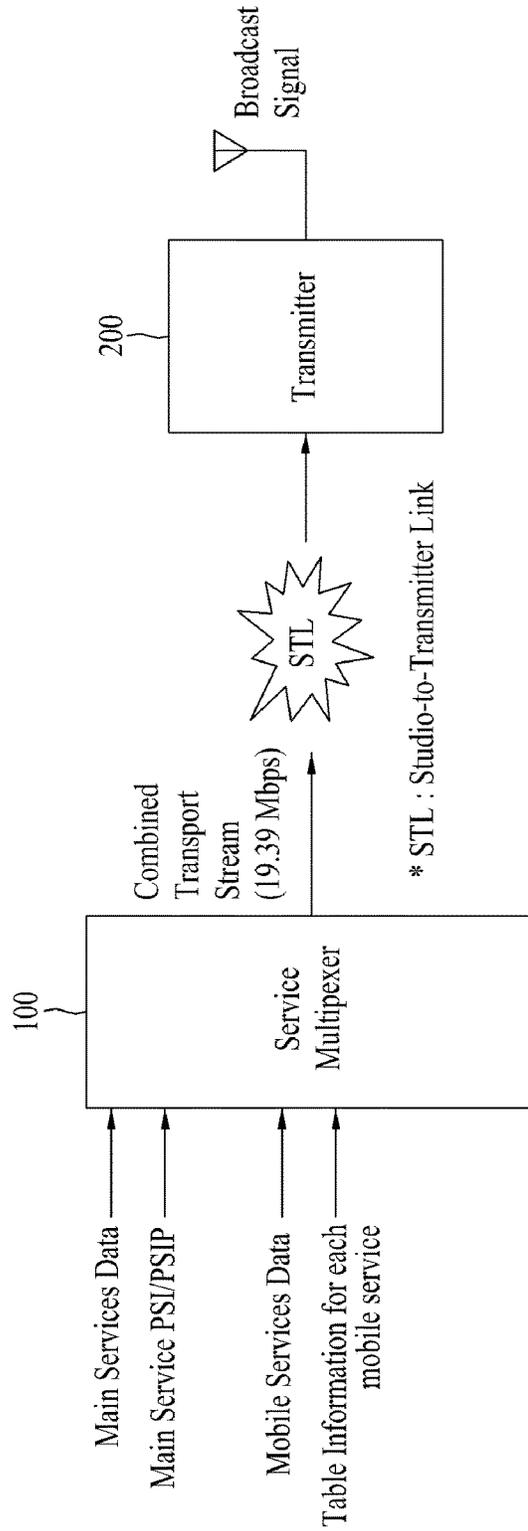


FIG. 15

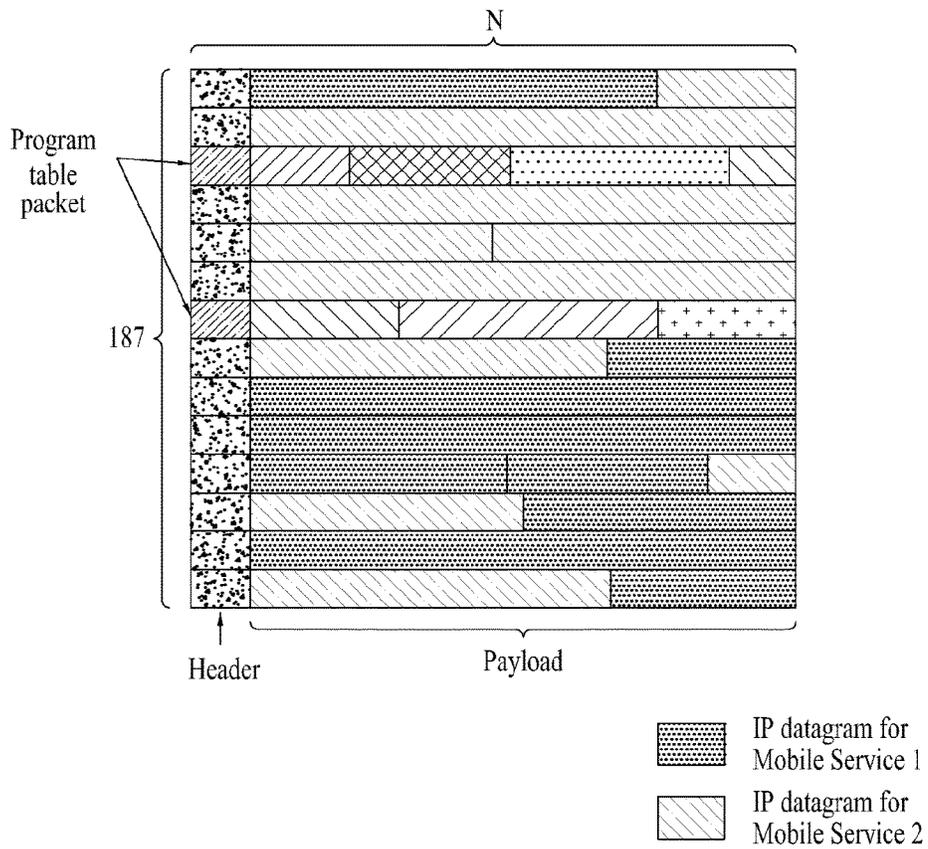


FIG. 16

Type Indicator (3)	Error Indicator (1)	Stuff Indicator (1)	Pointer Field (11)	Payload (N-2) bytes
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FIG. 17

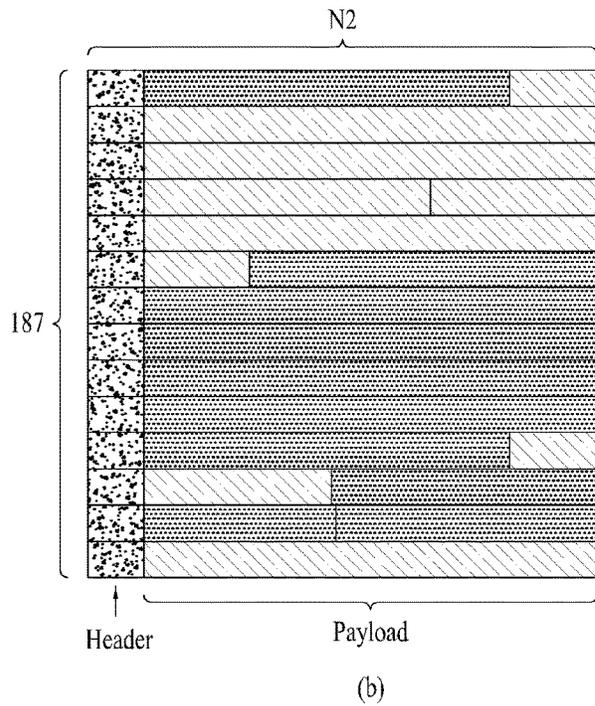
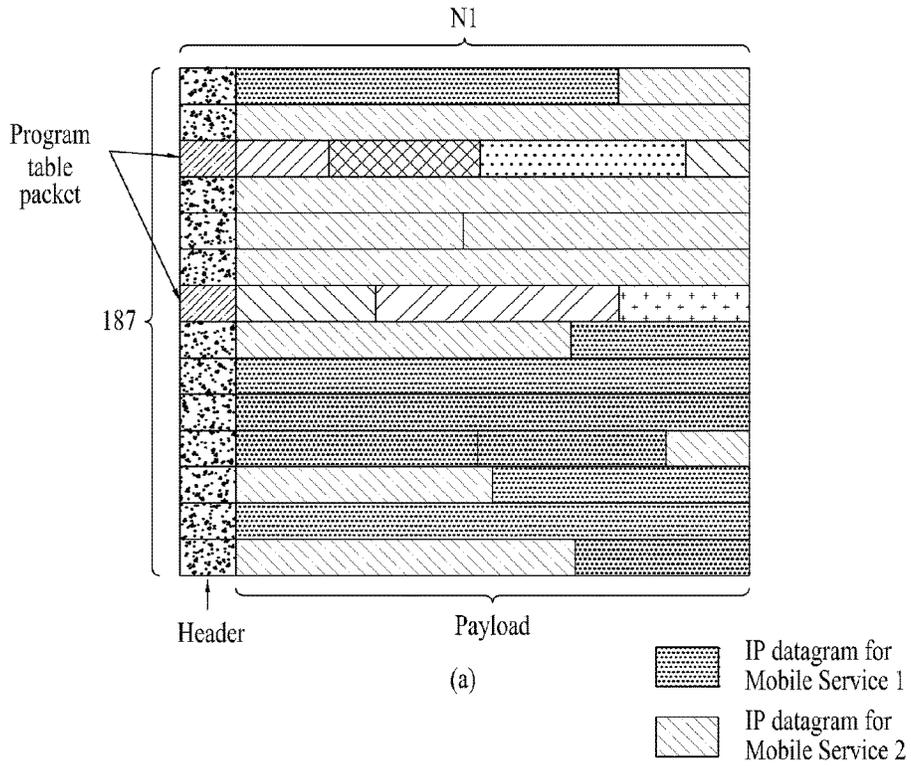


FIG. 18

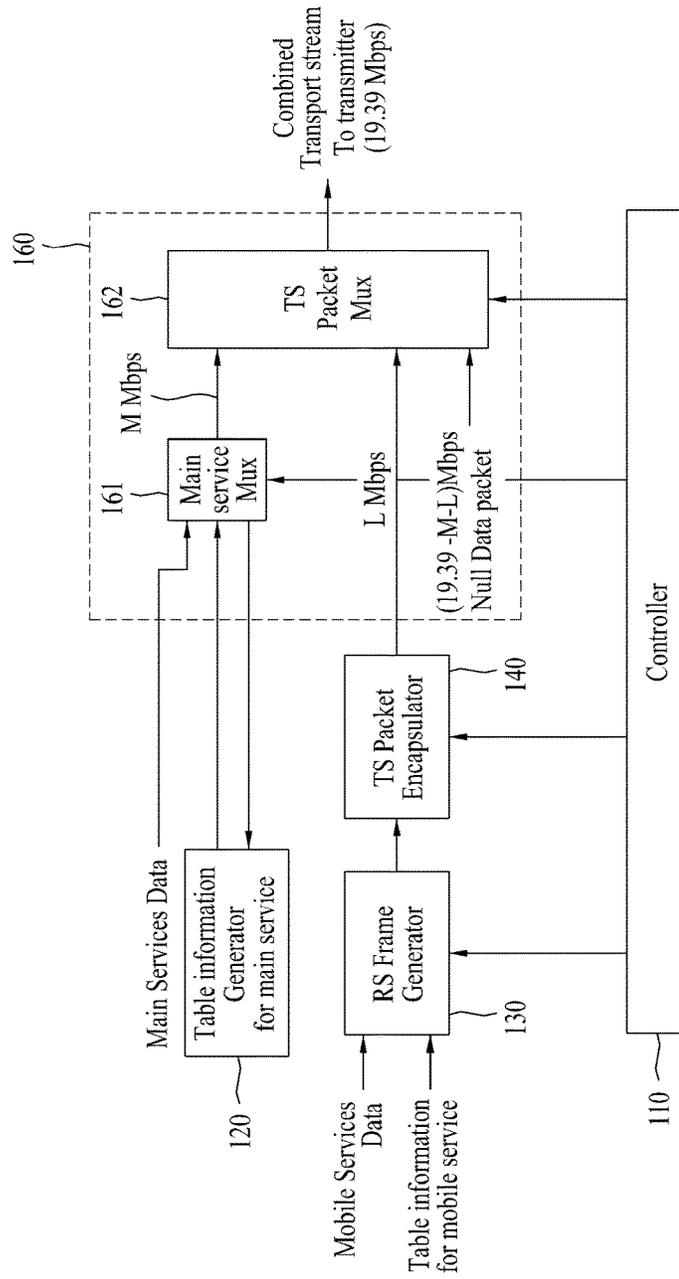


FIG. 19

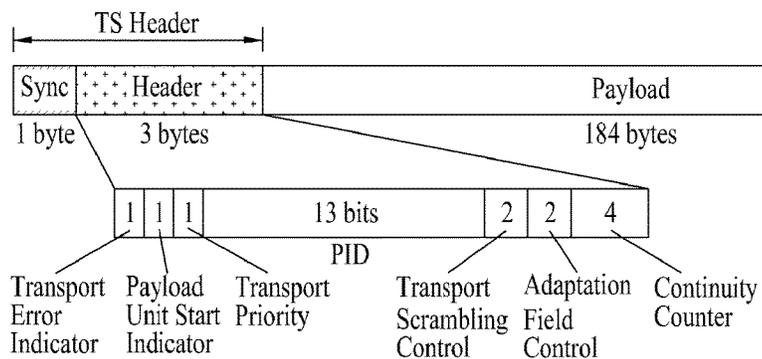


FIG. 20

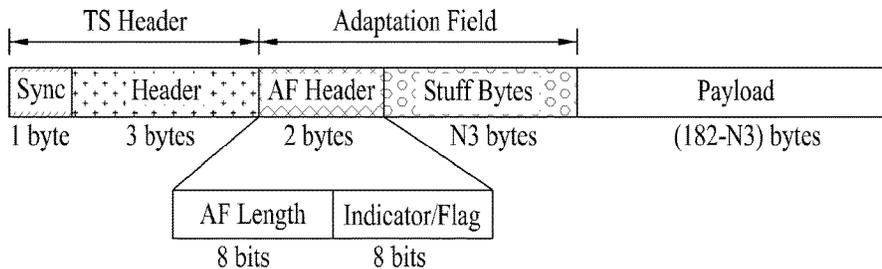


FIG. 21

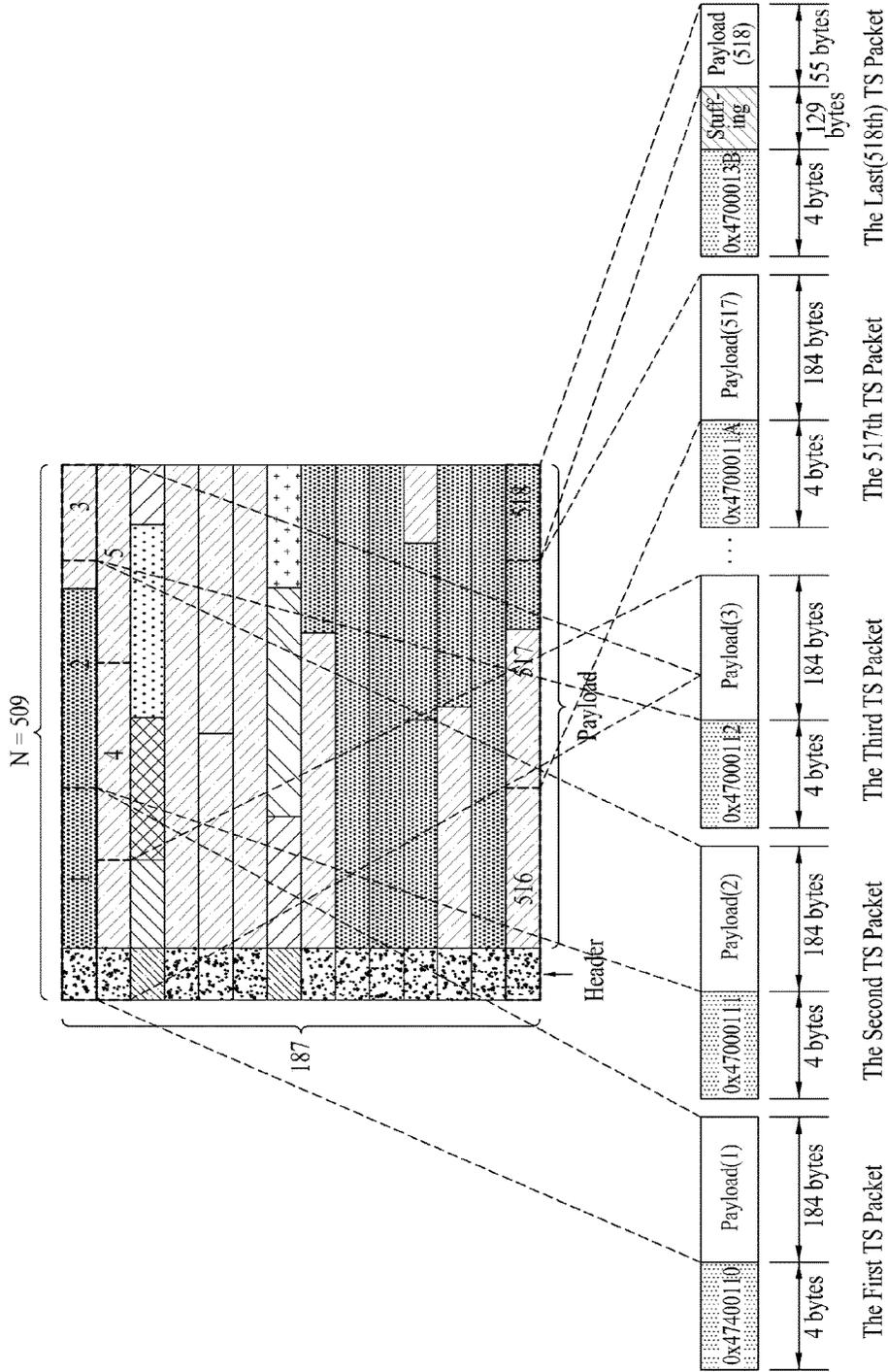


FIG. 22

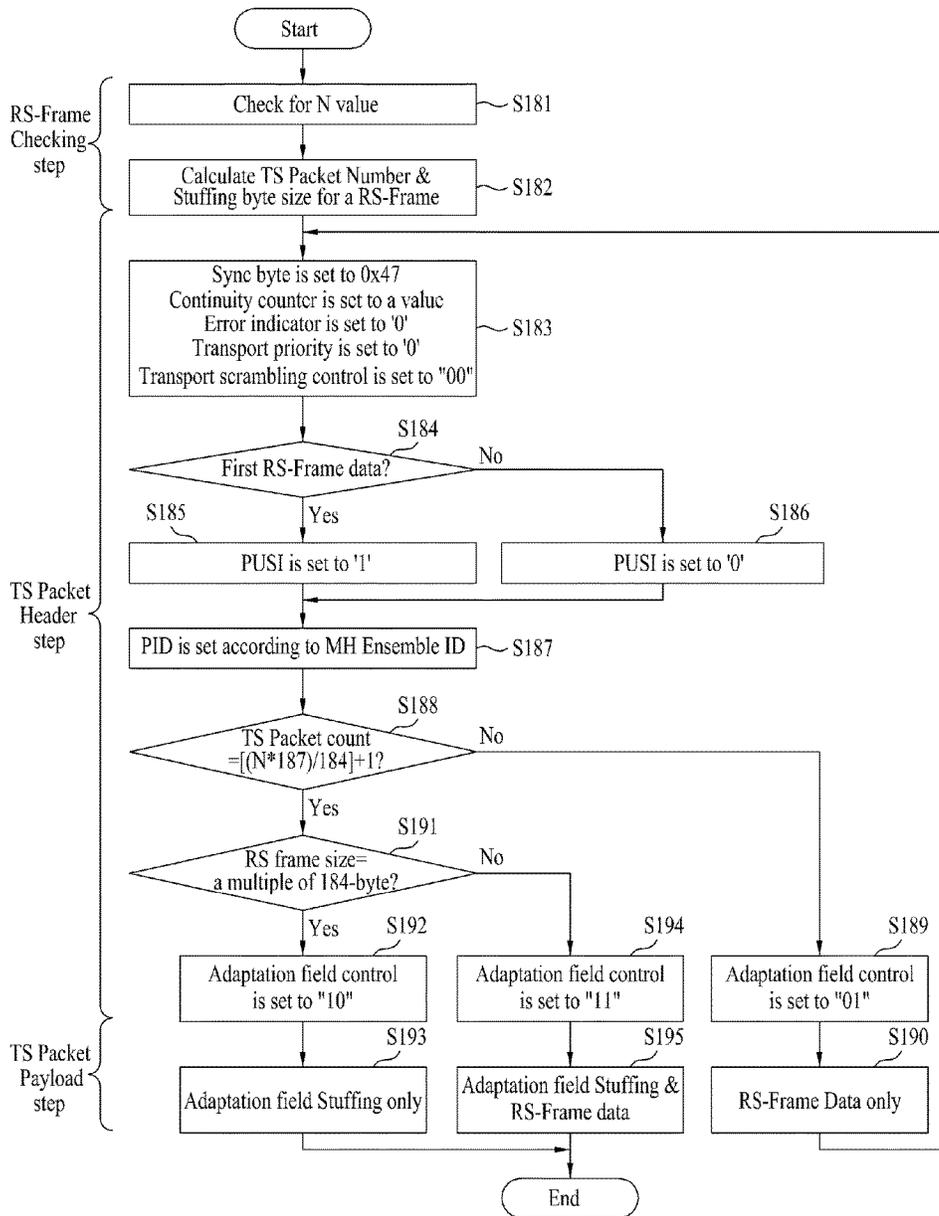


FIG. 23

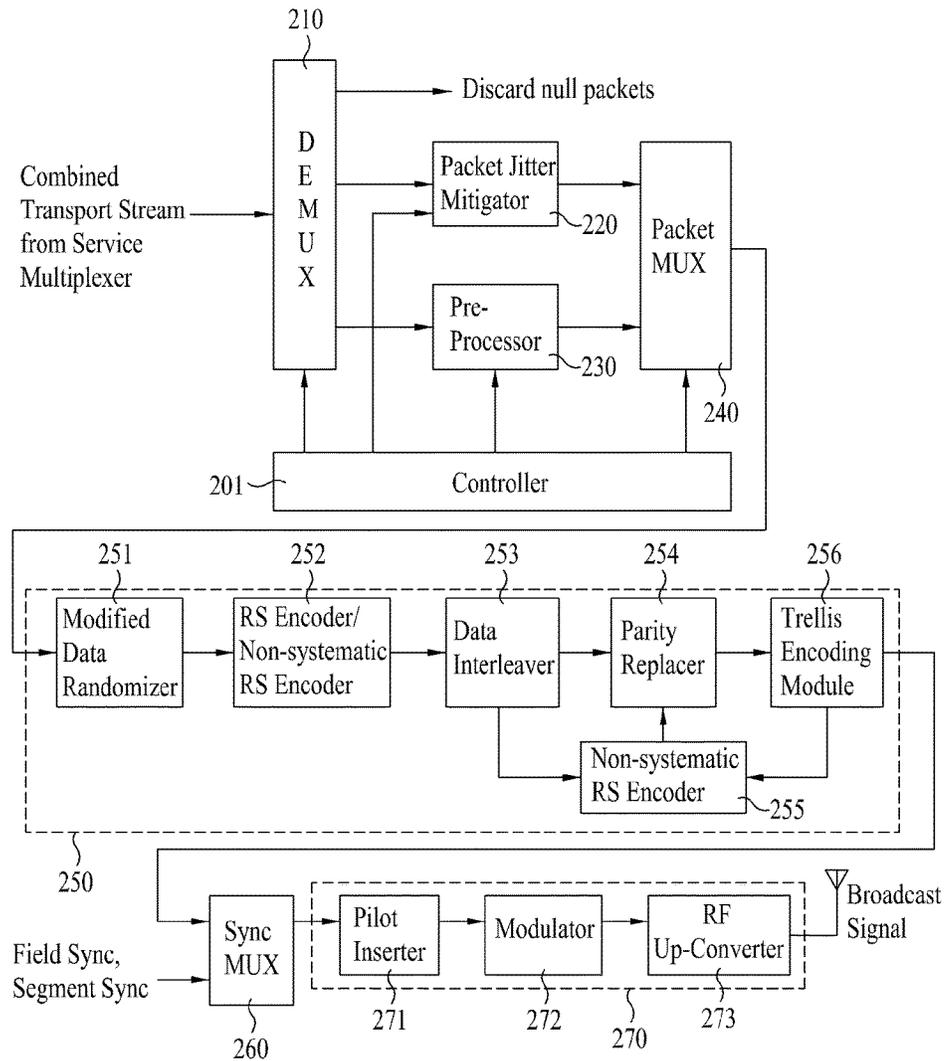


FIG. 24

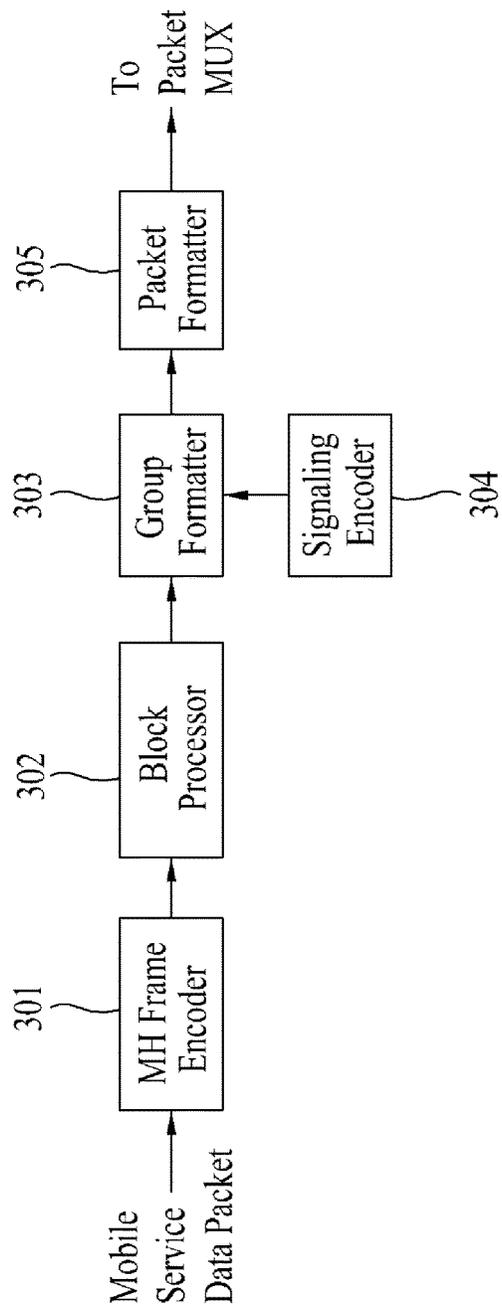


FIG. 25

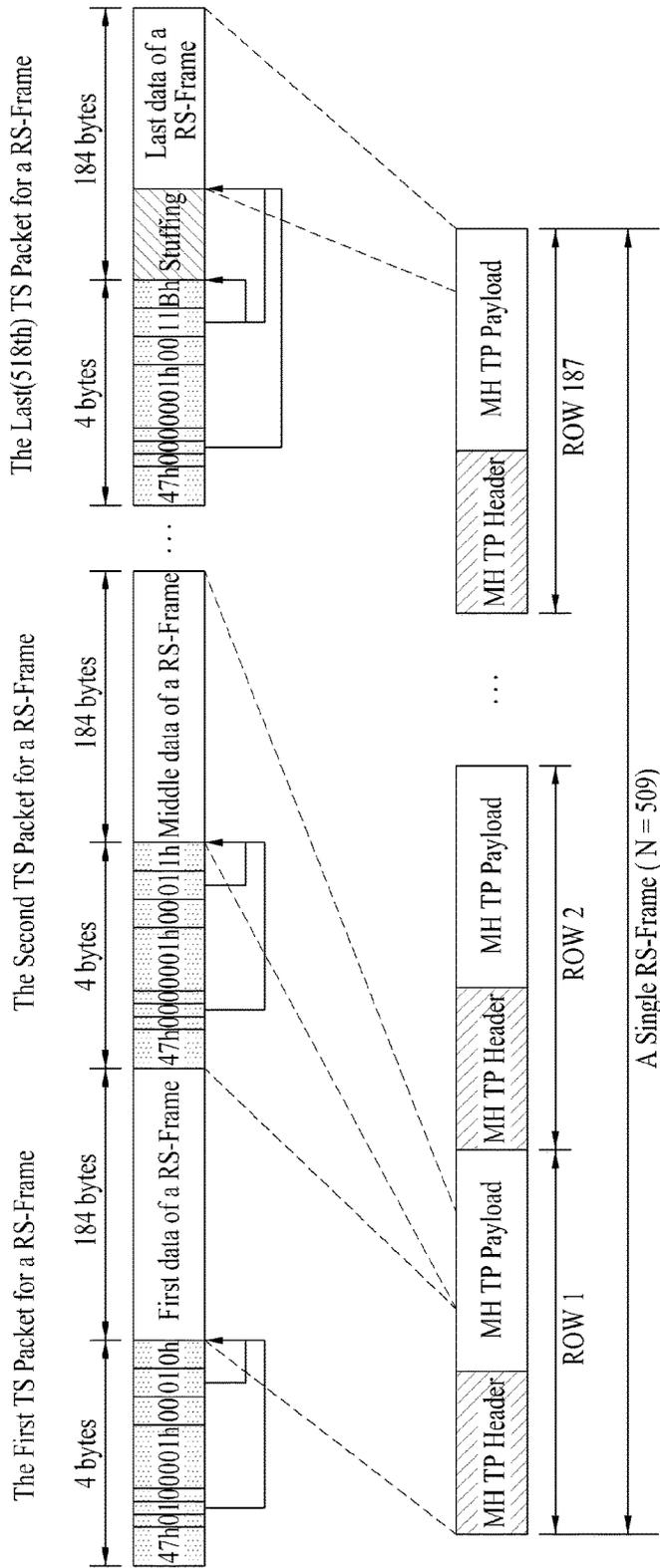


FIG. 26

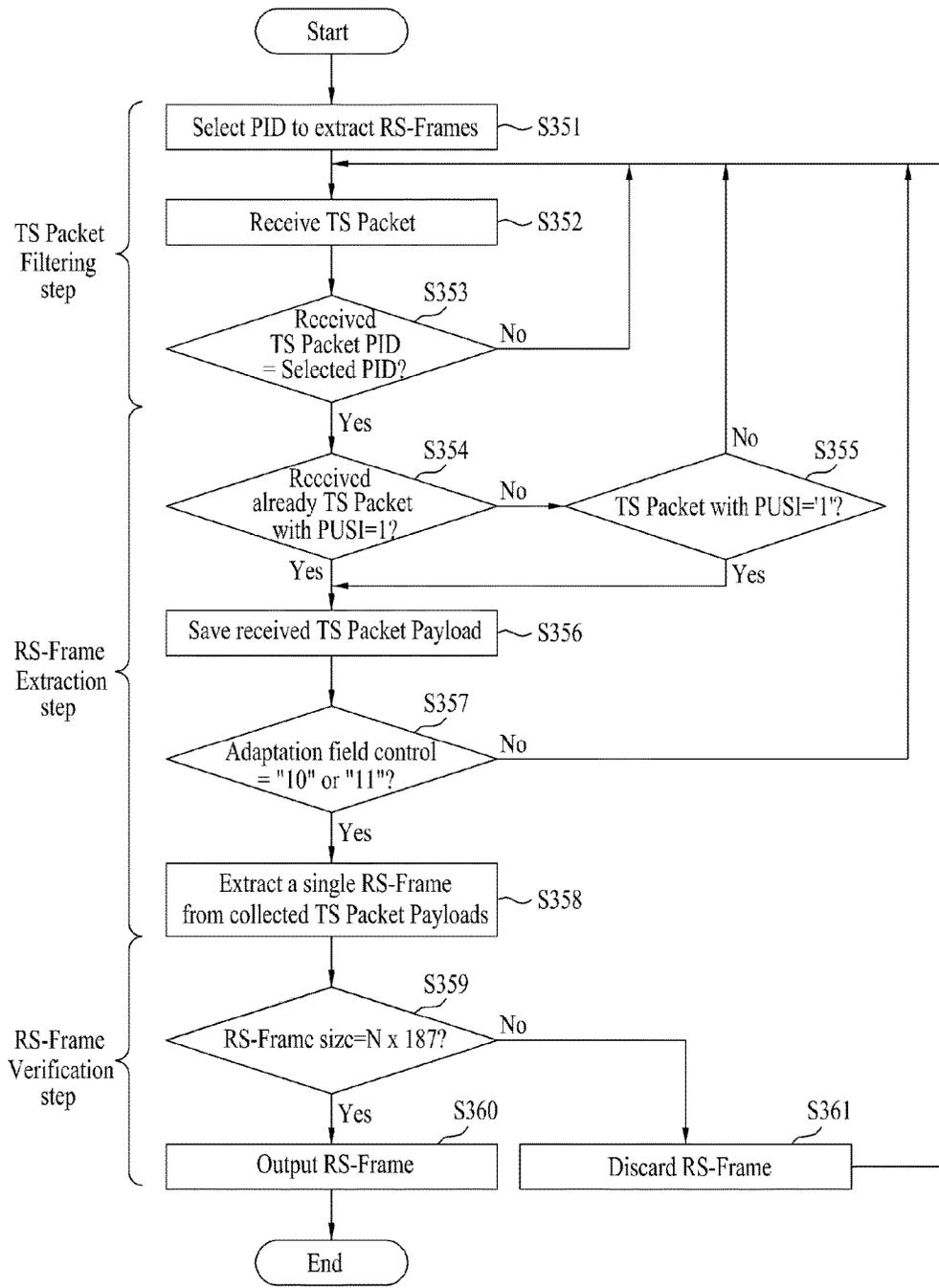


FIG. 27

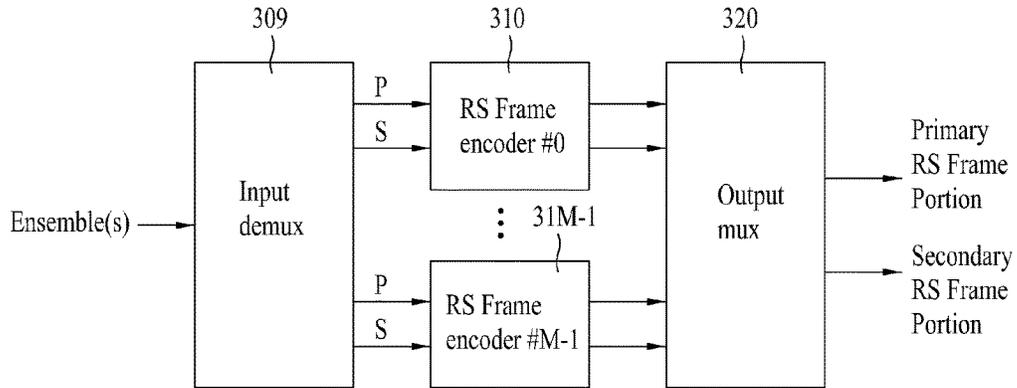


FIG. 28

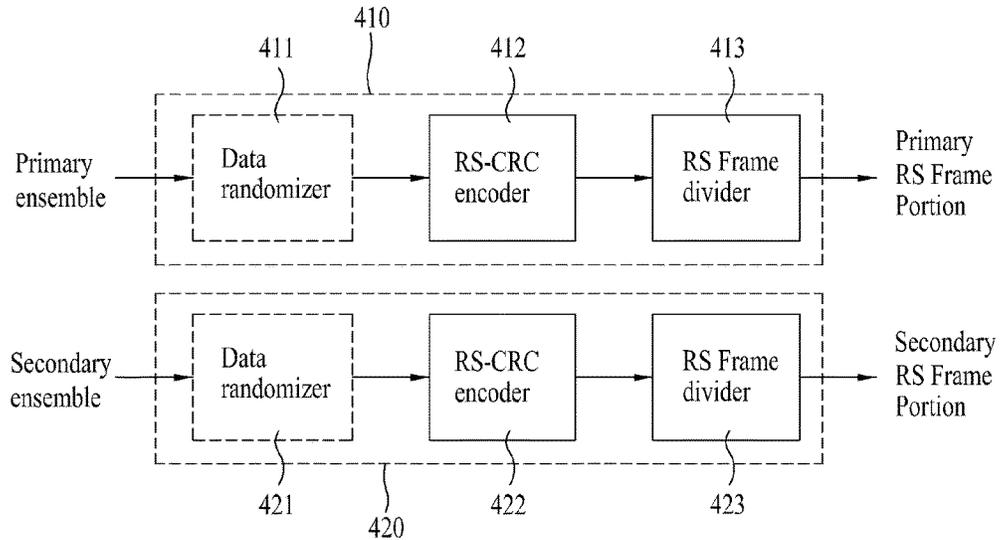


FIG. 29

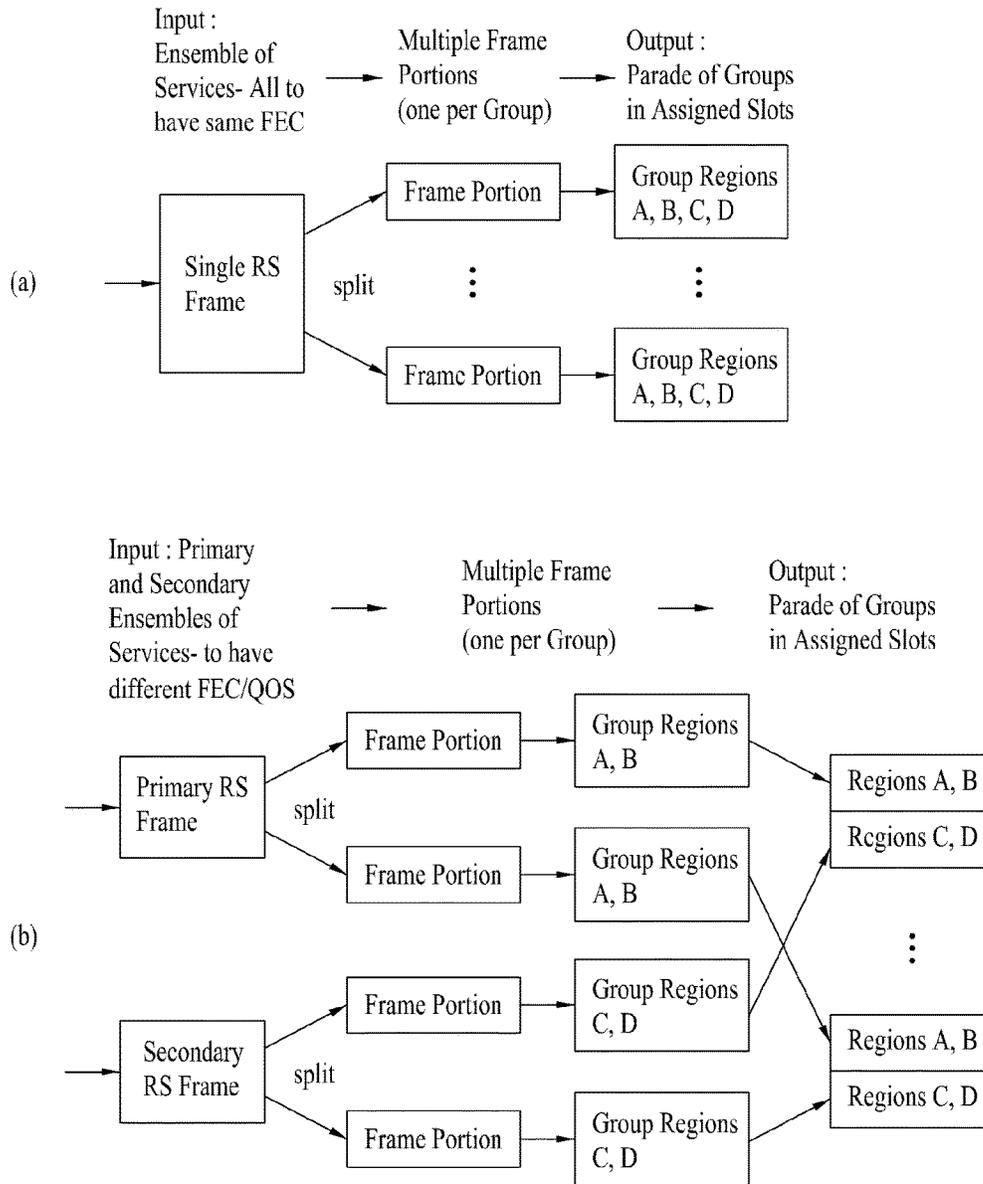


FIG. 30

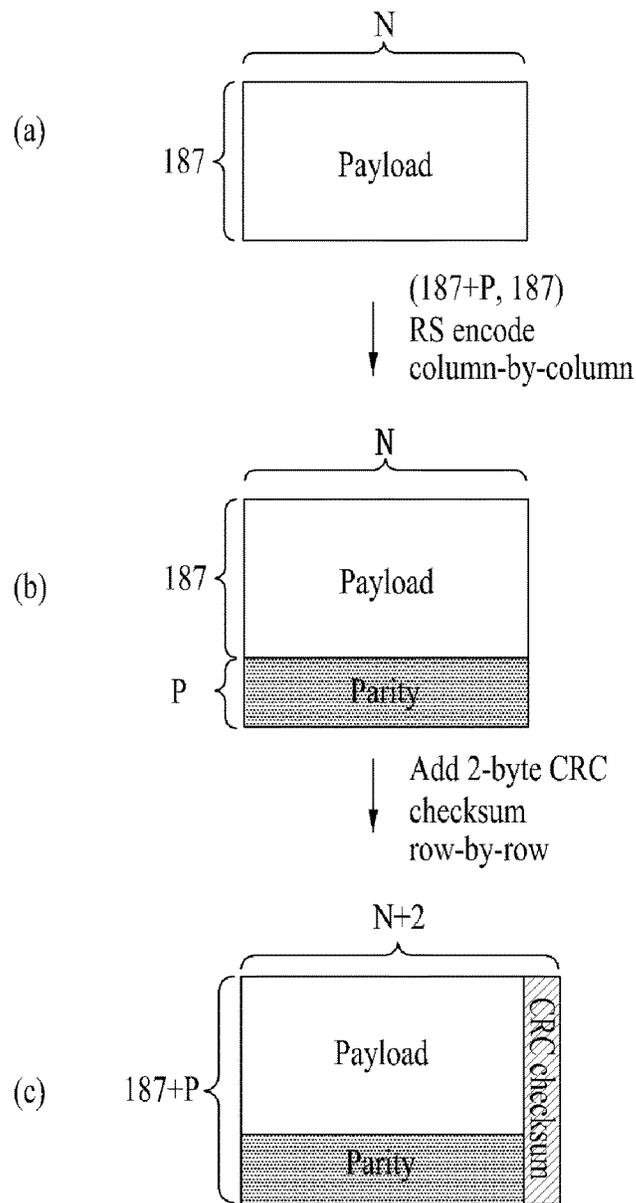


FIG. 31

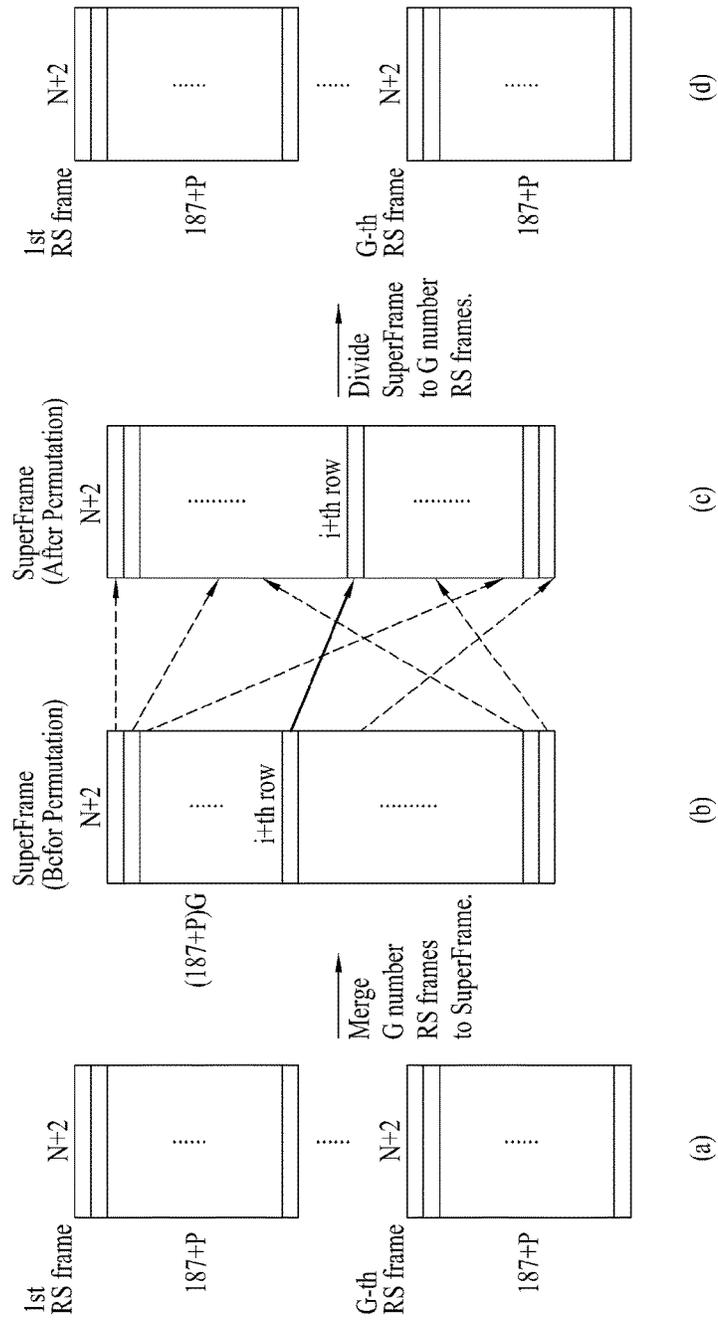


FIG. 32

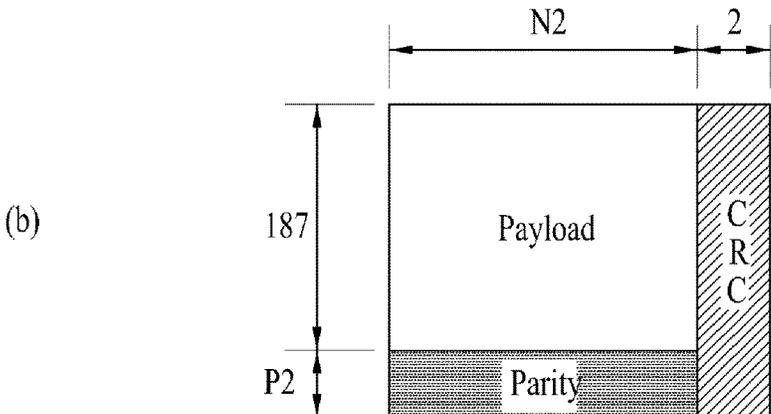
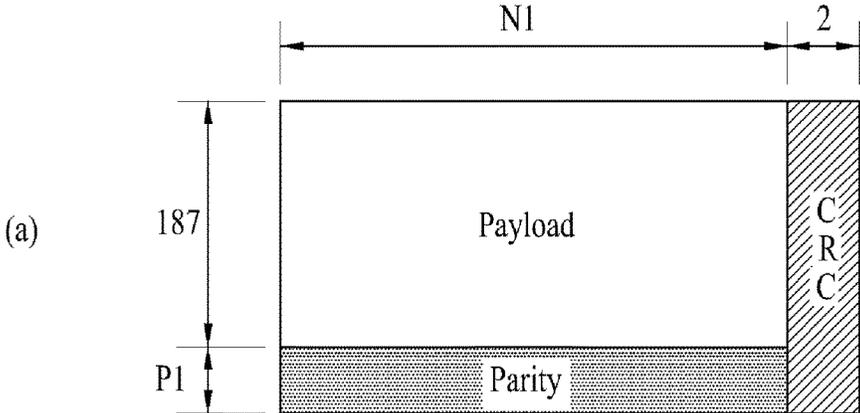


FIG. 33

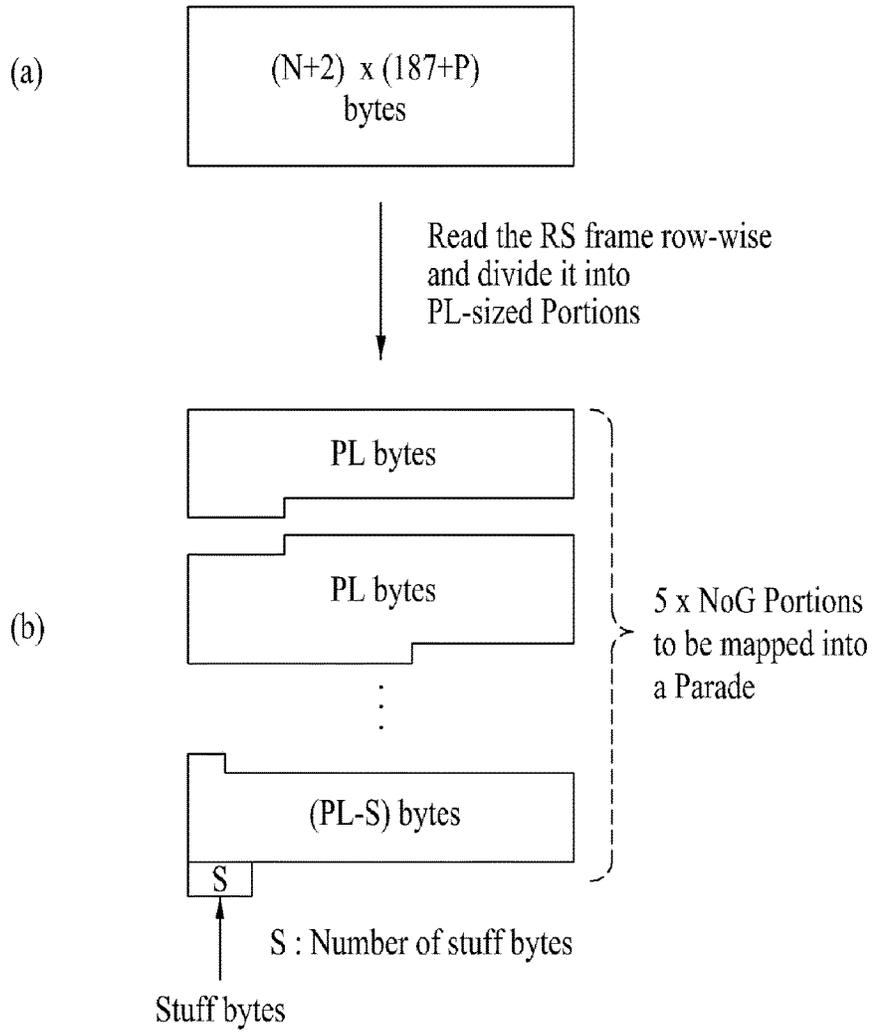


FIG. 34

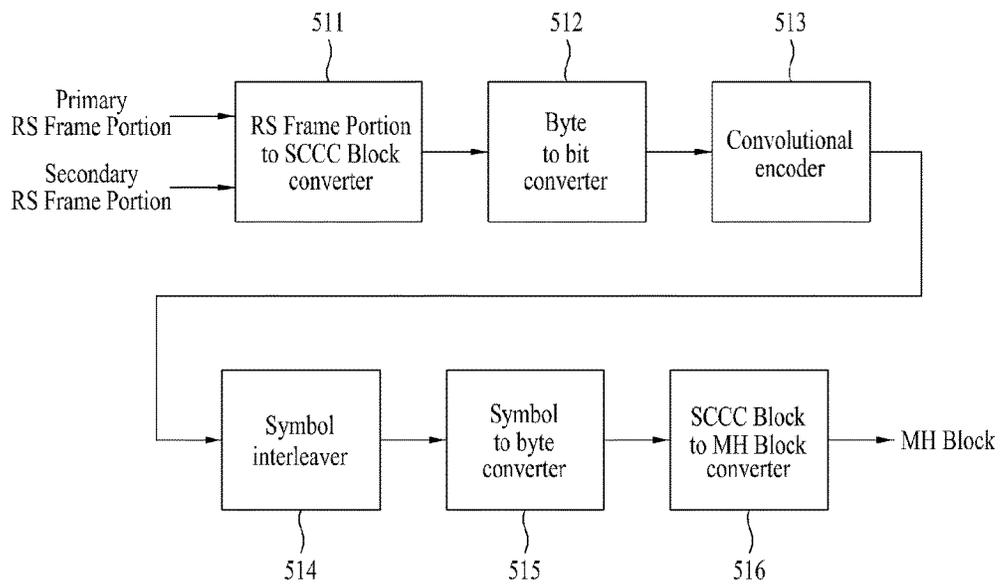


FIG. 35

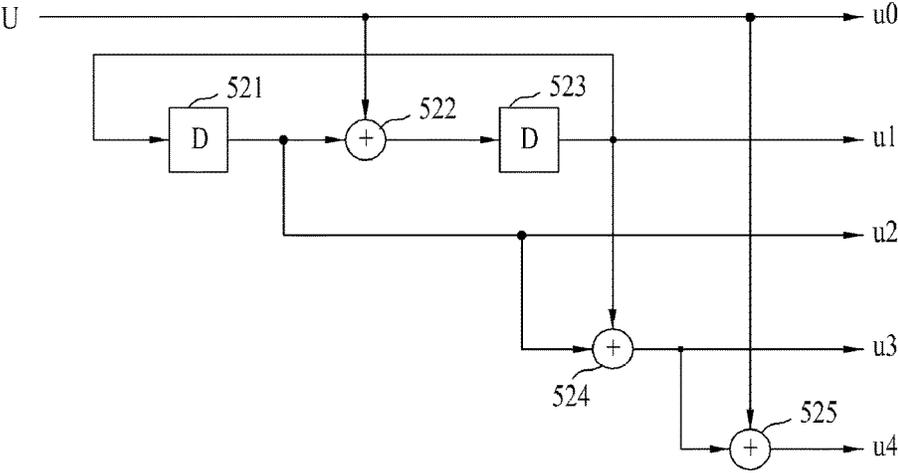


FIG. 36

i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	...	2110	2111
P'(i)	0	89	267	534	890	1335	1869	2492	3204	4005	799	1778	2846	4003	1153	2488	...	2809	2272
P(i)	0	89	267	534	890	1335	1869	799	1778	1153	1329	526	79	2037	253	874	...	444	2048

FIG. 37

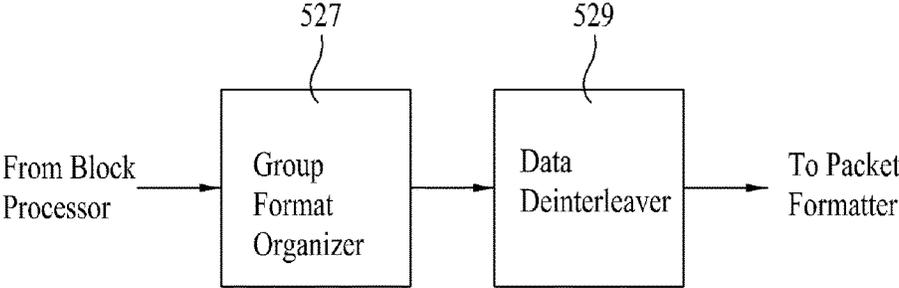
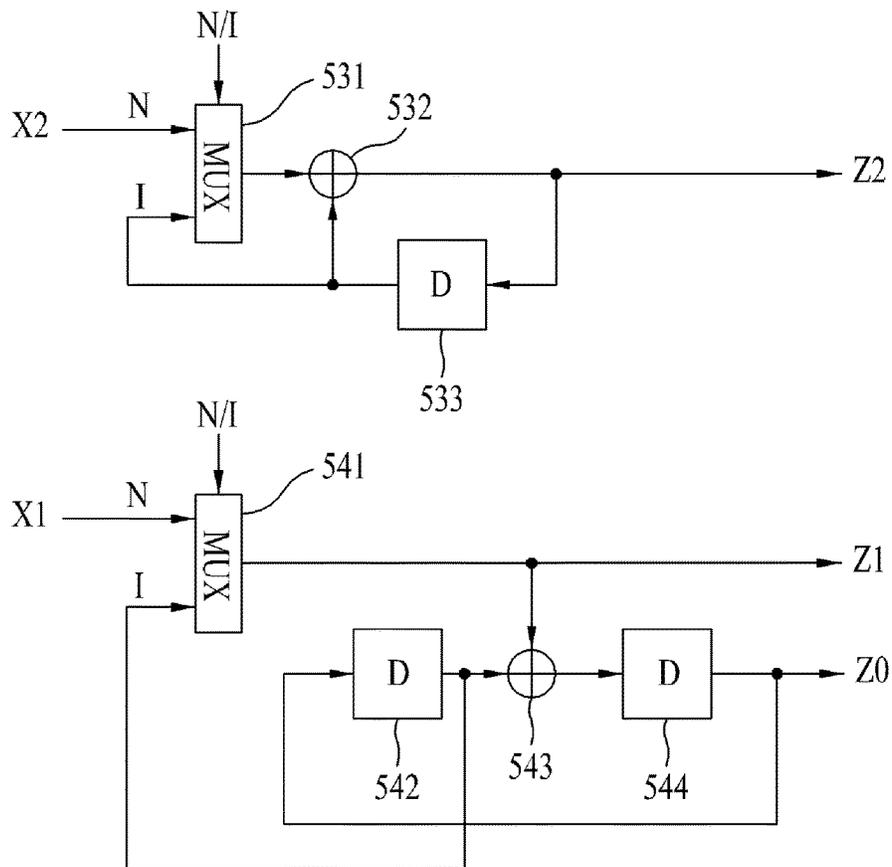


FIG. 38



N : Normal mode, I : Initialization mode

FIG. 39

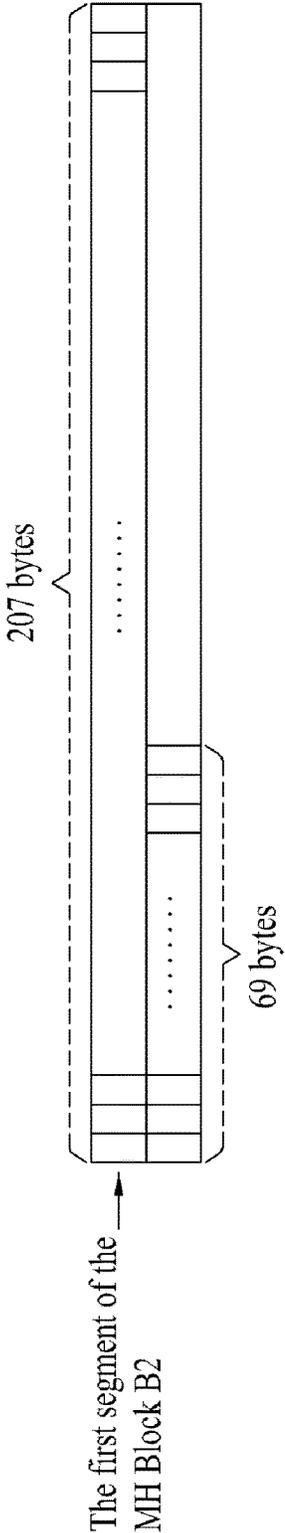


FIG. 40

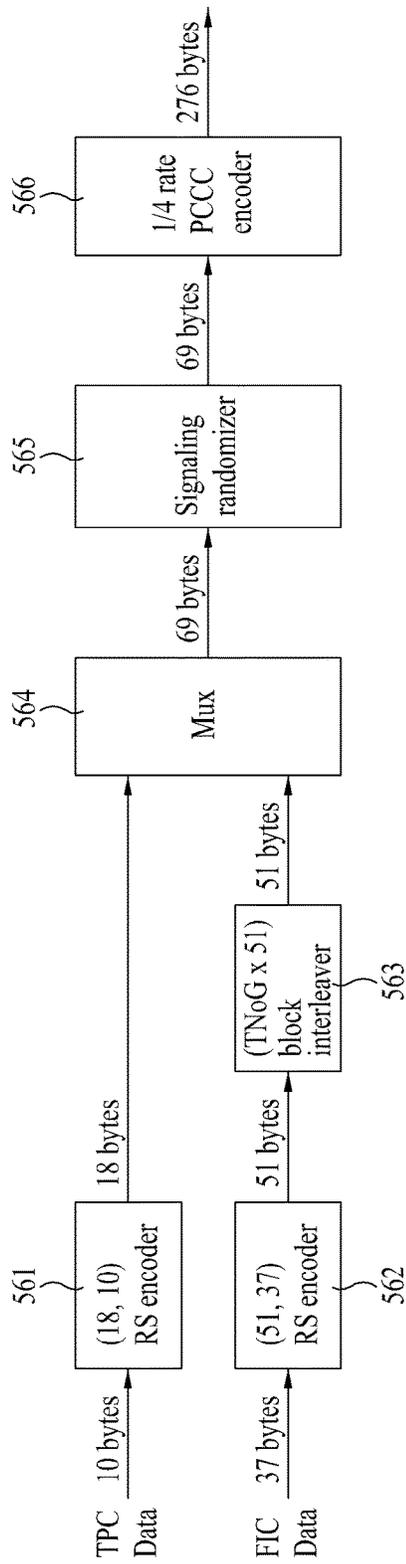


FIG. 41

Syntax	No. of bits	Format
TPC_data {		
Sub-Frame_number	3	uimsbf
Slot_number	4	uimsbf
Parade_id	7	uimsbf
starting_Group_number	4	uimsbf
number_of_Groups	3	uimsbf
Parade_repetition_cycle	3	uimsbf
RS_Frame_mode	2	bslbf
RS_code_mode_primary	2	bslbf
RS_code_mode_secondary	2	bslbf
SCCC_Block_mode	2	bslbf
SCCC_outer_code_mode_A	2	bslbf
SCCC_outer_code_mode_B	2	bslbf
SCCC_outer_code_mode_C	2	bslbf
SCCC_outer_code_mode_D	2	bslbf
FIC_version	5	uimsbf
Parade_continuity_counter	4	uimsbf
TNoG	5	uimsbf
reserved	26	bslbf
}		

FIG. 42

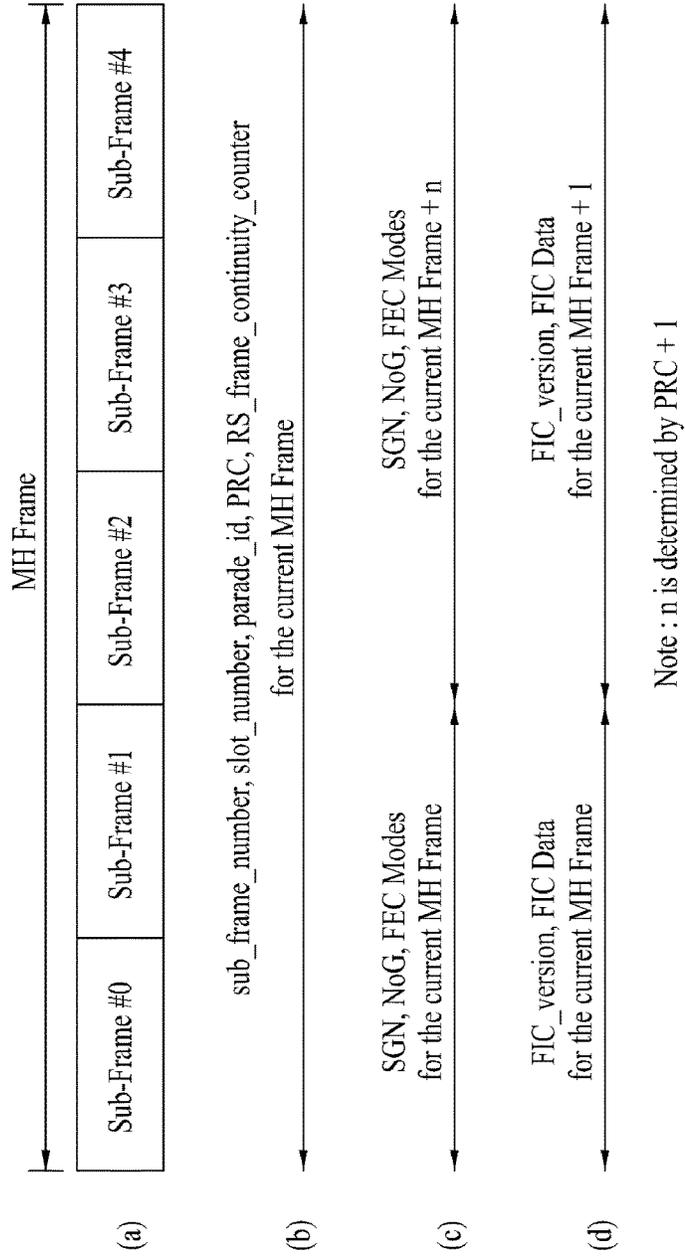


FIG. 43

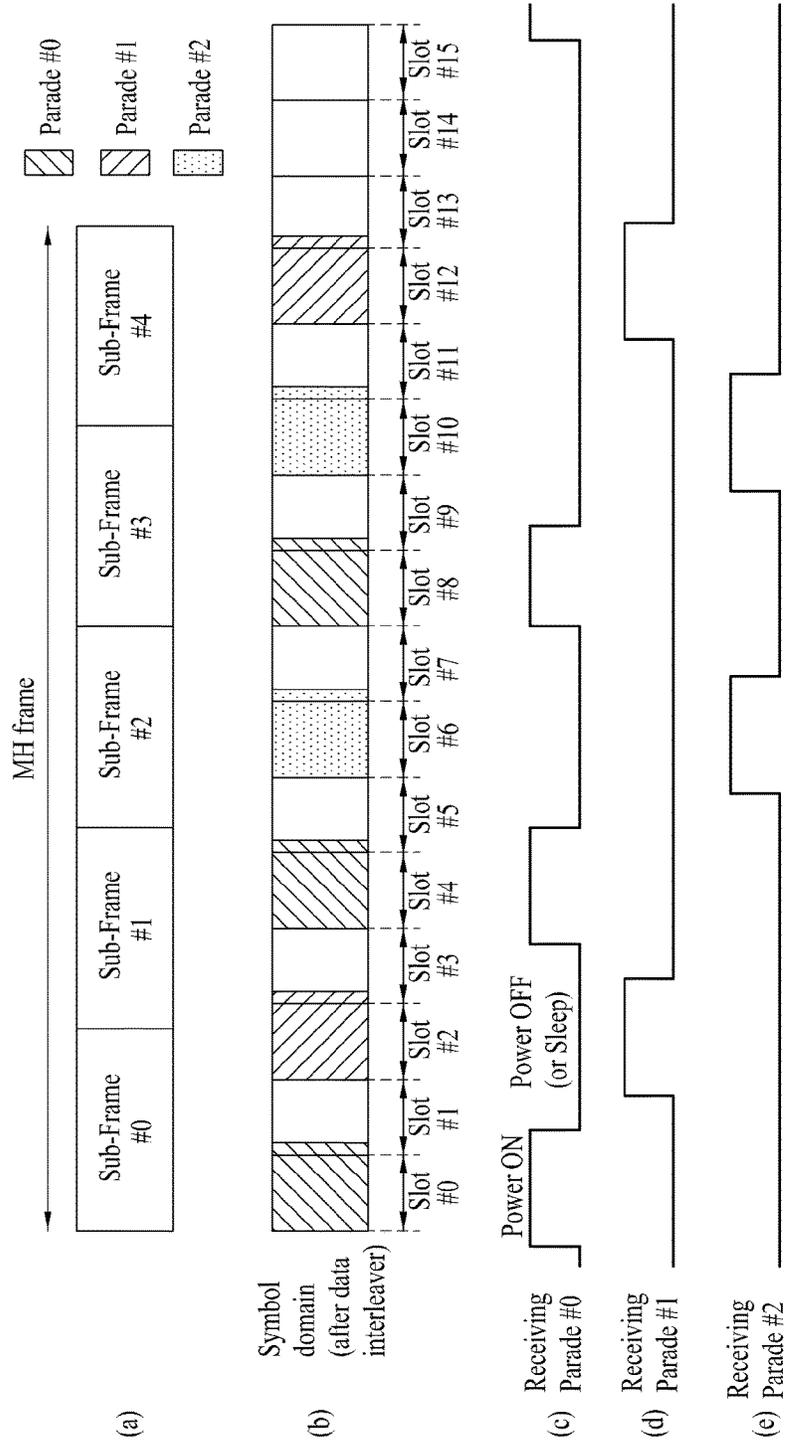


FIG. 44

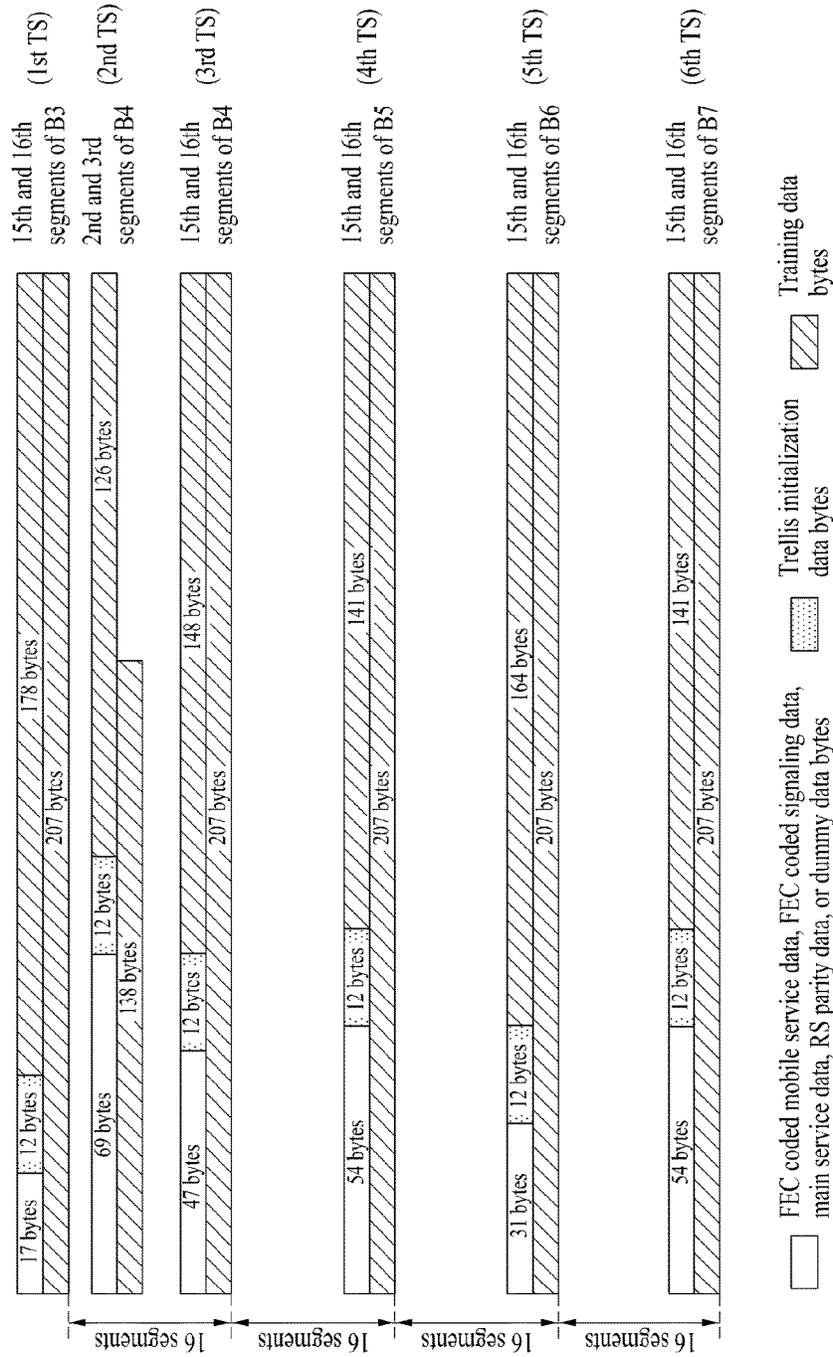


FIG. 45

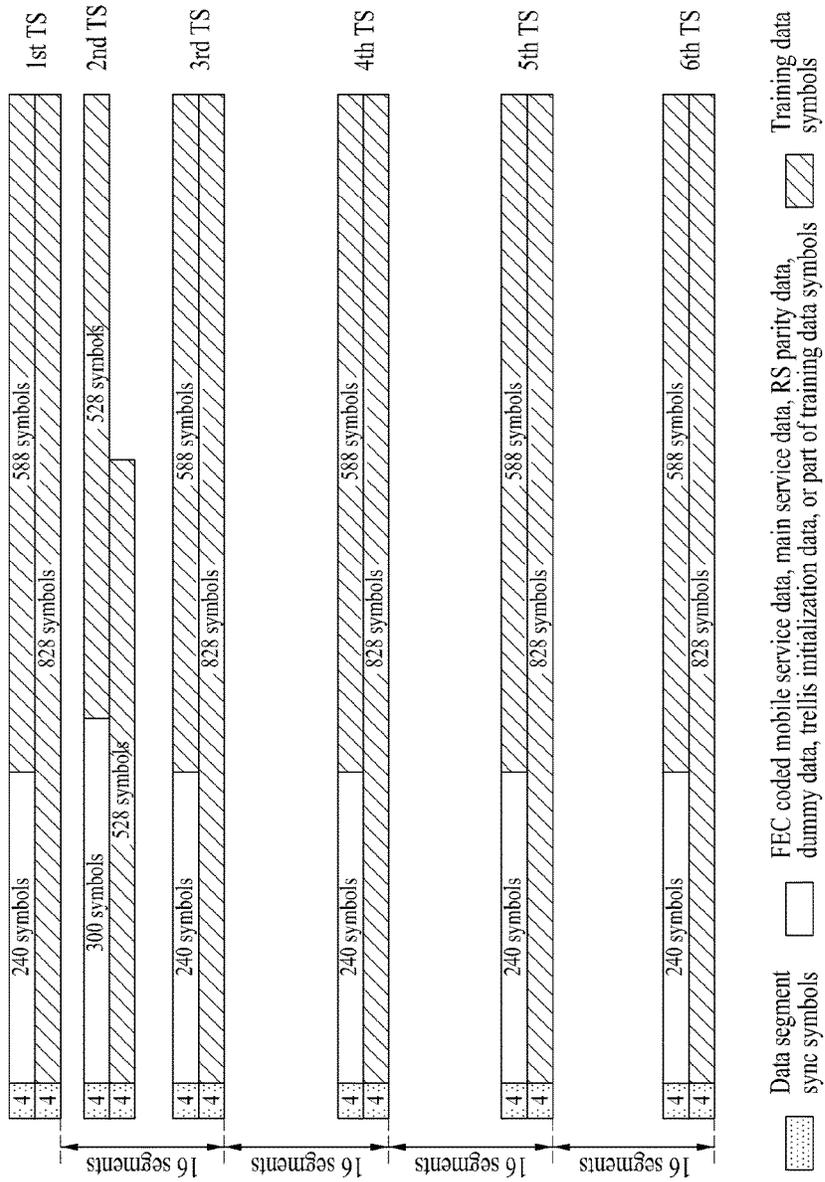


FIG. 46

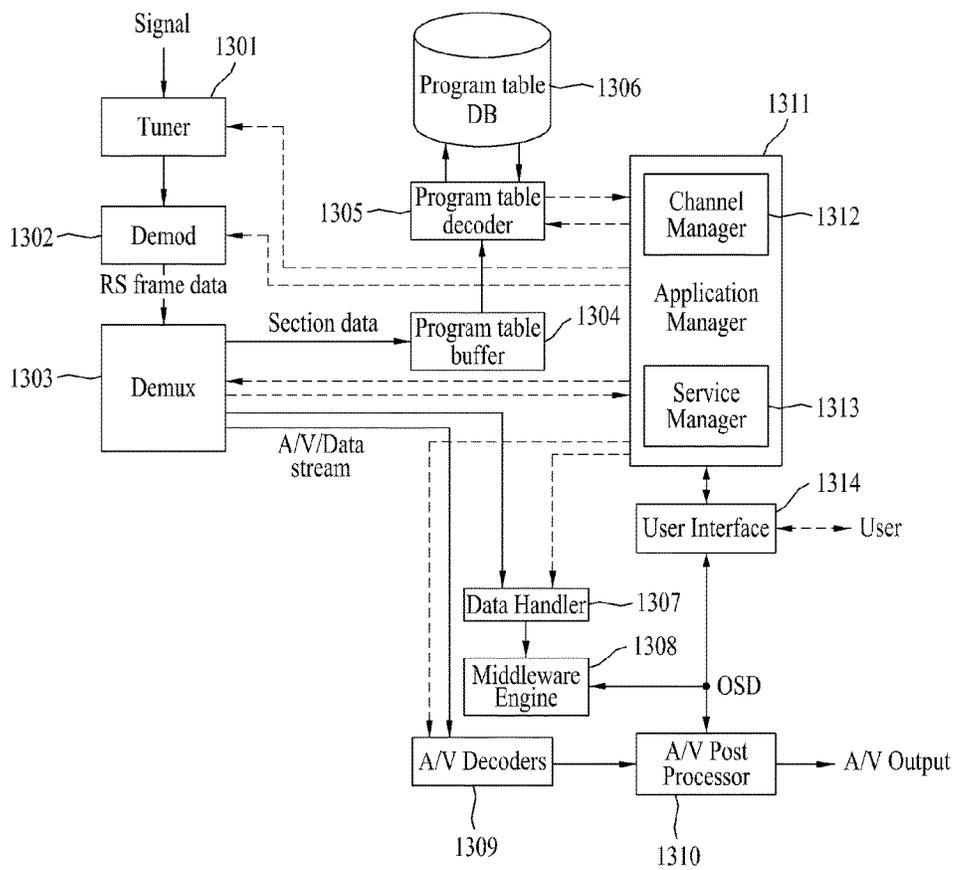


FIG. 47

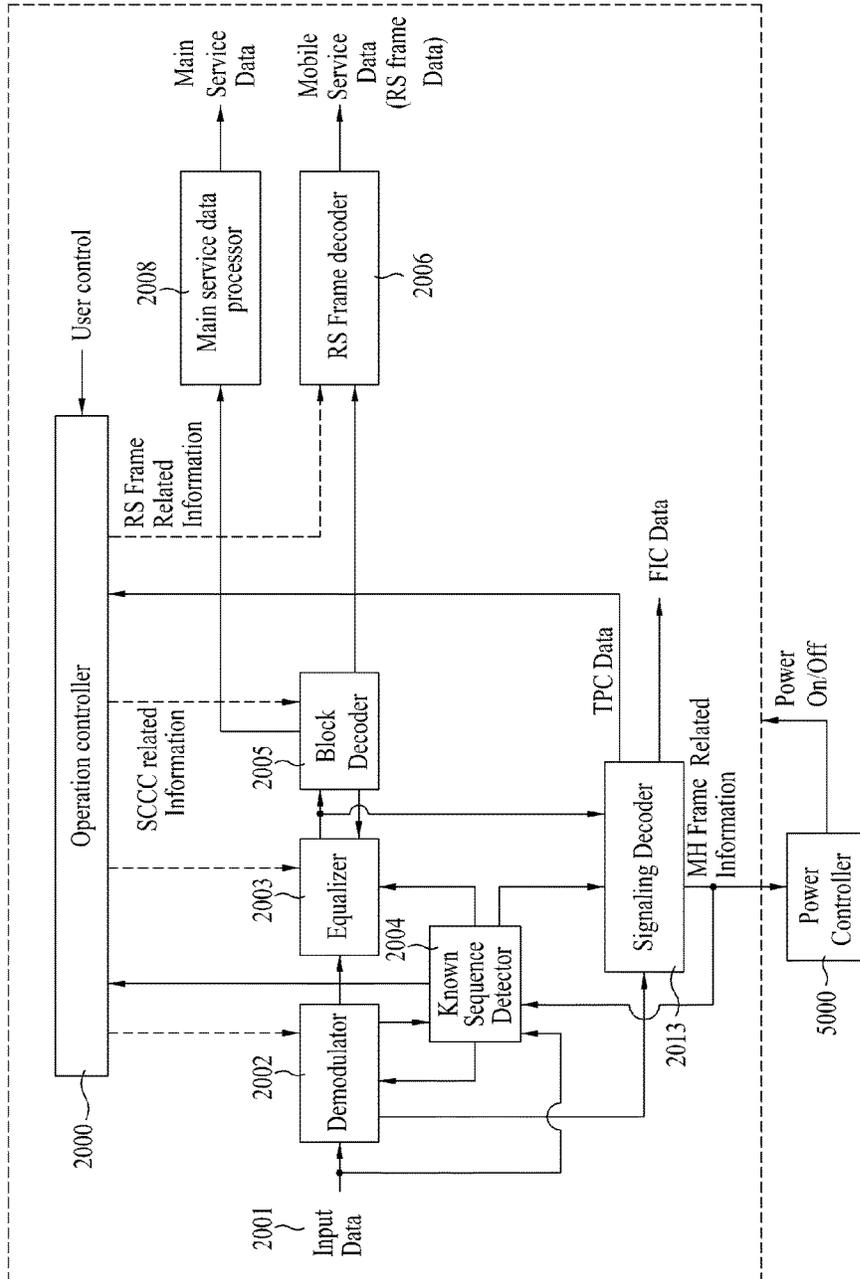


FIG. 4B

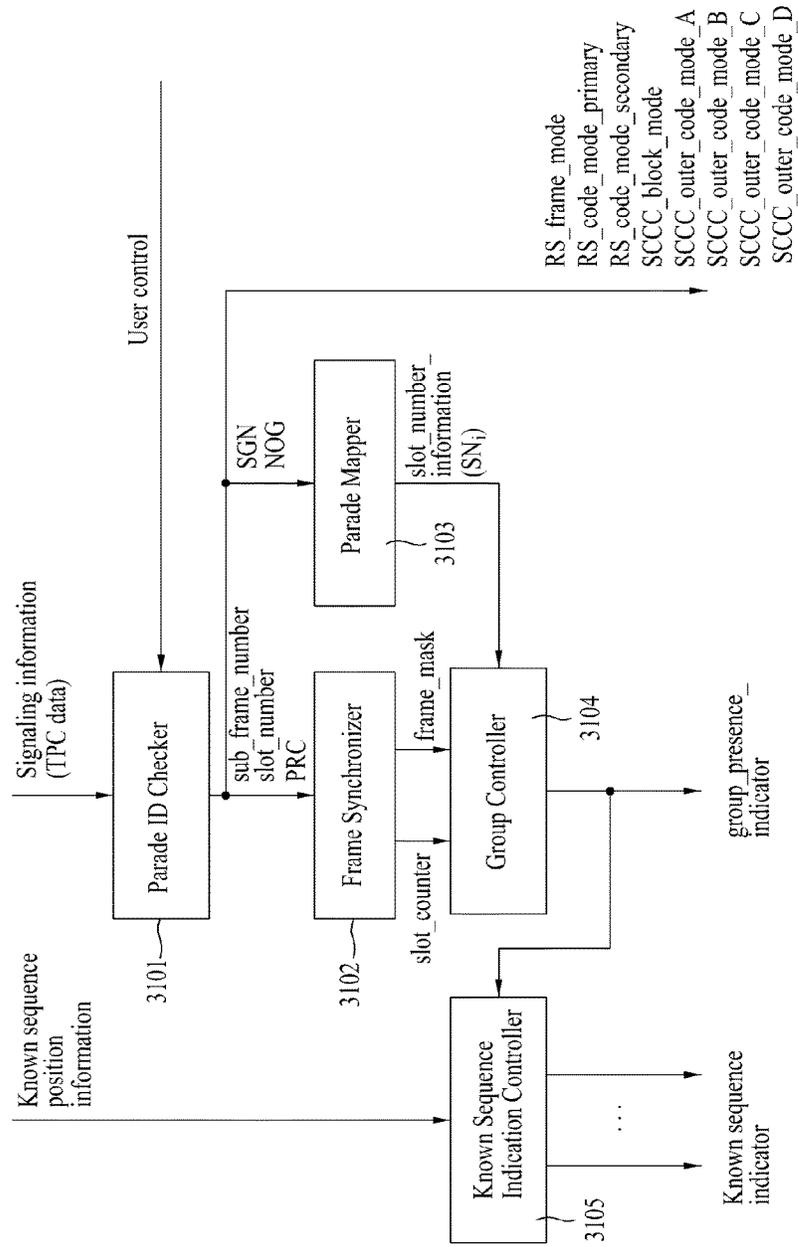


FIG. 49

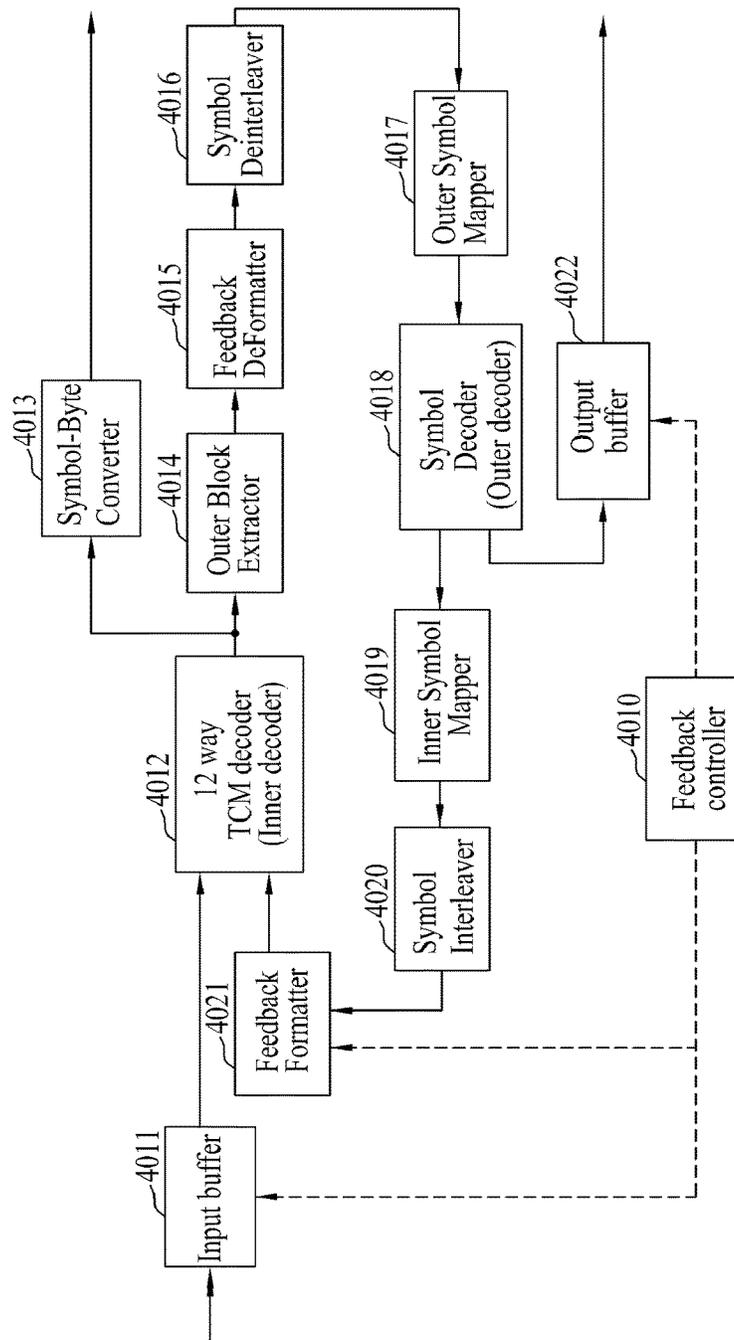


FIG. 50

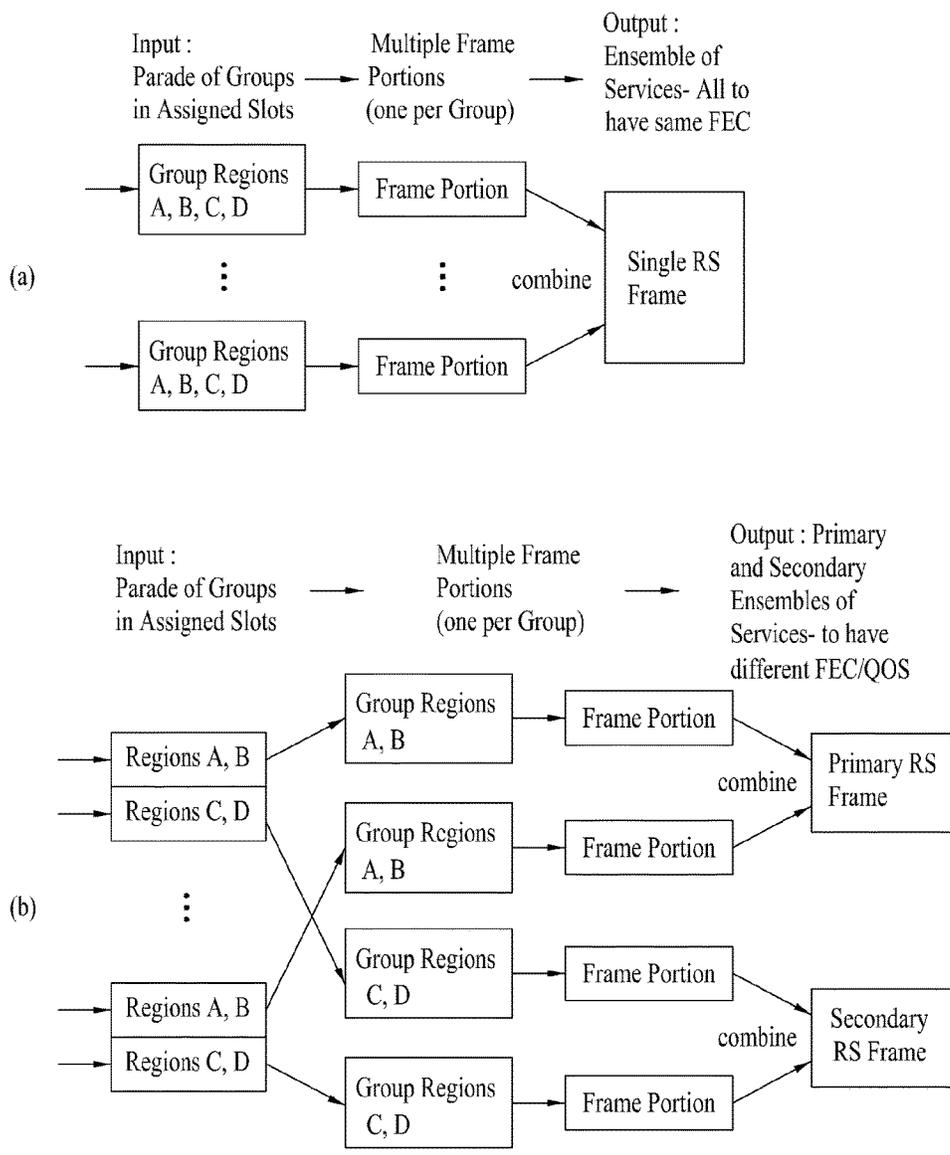


FIG. 51

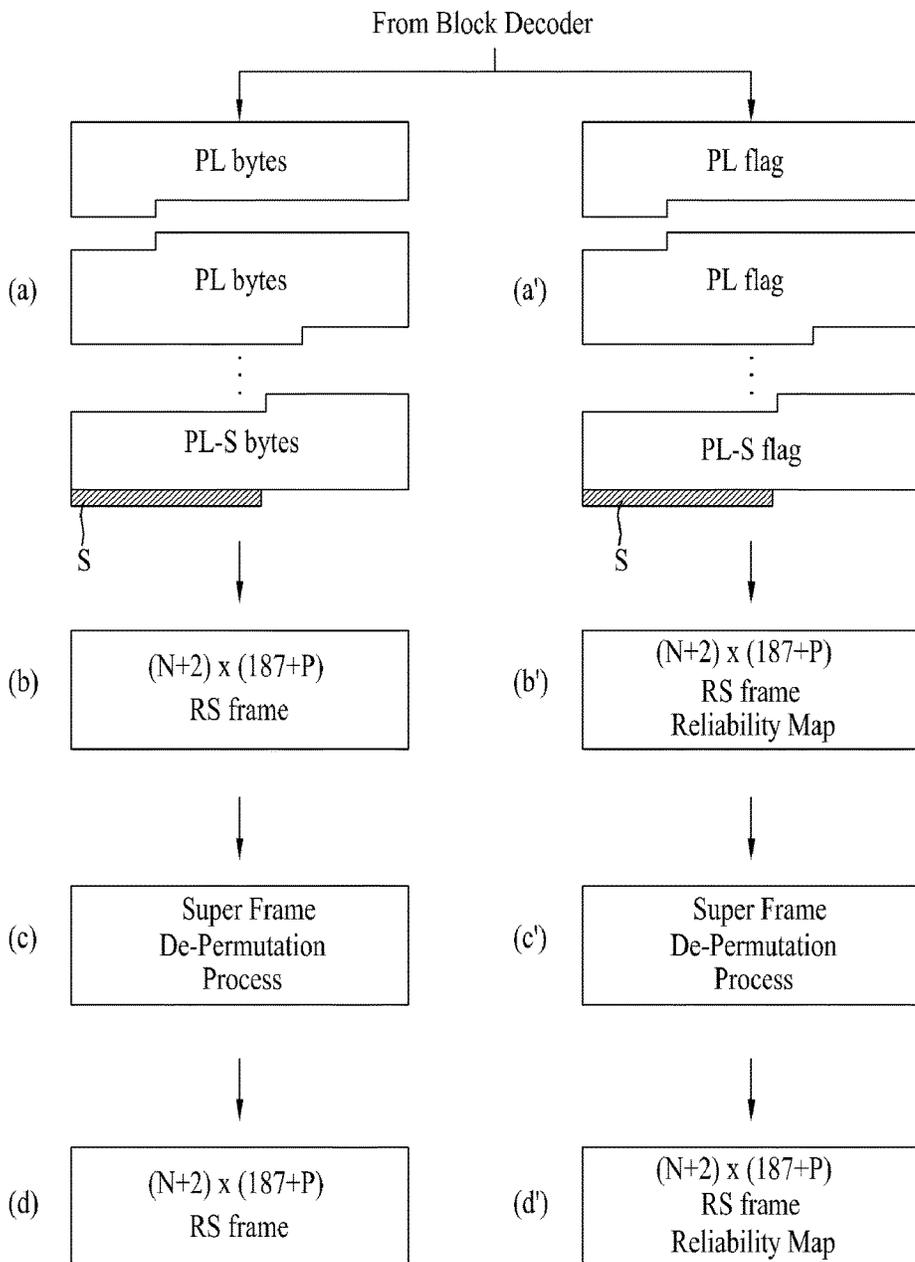
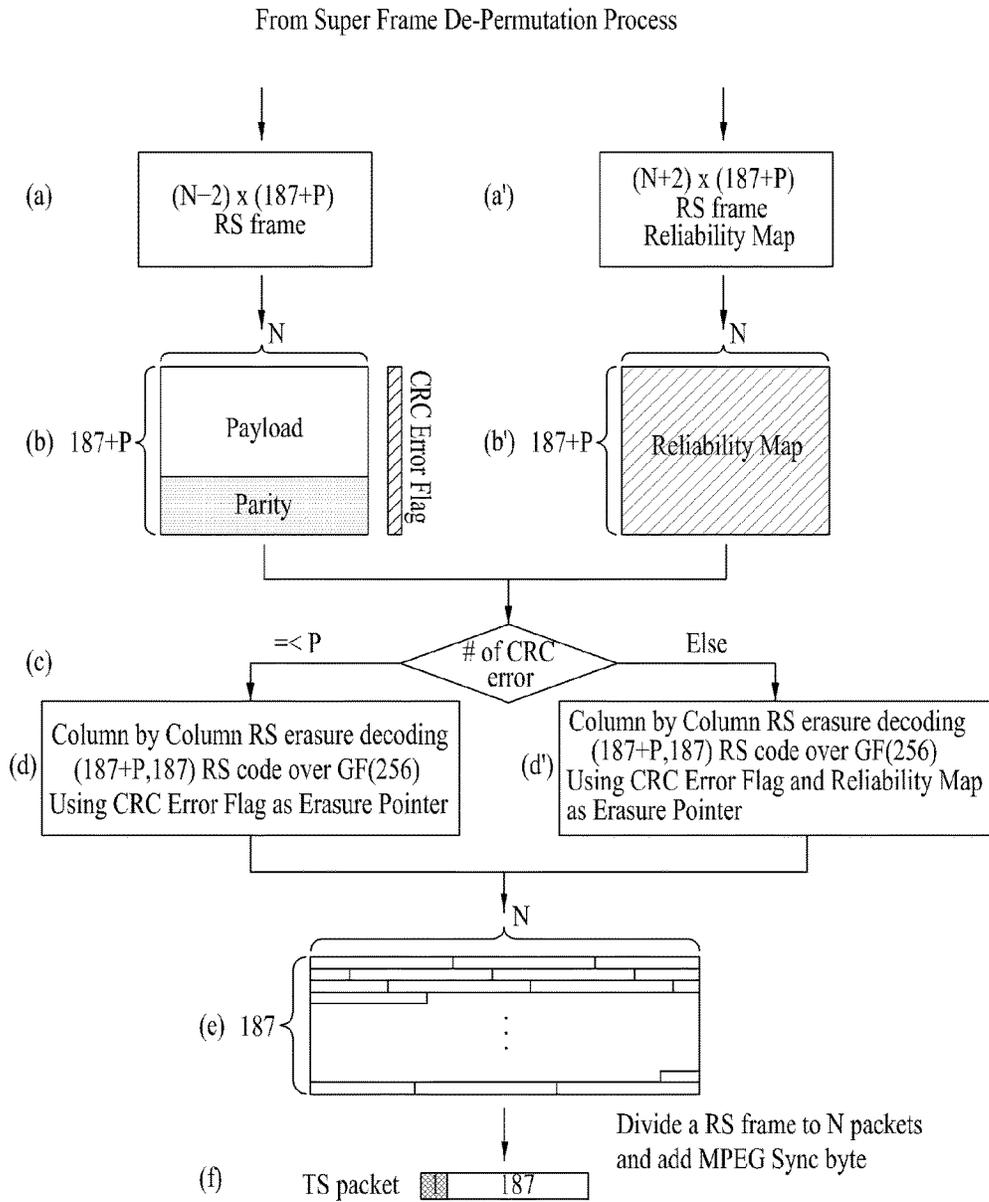


FIG. 52



**DIGITAL BROADCASTING SYSTEM AND
METHOD OF PROCESSING DATA IN THE
DIGITAL BROADCASTING SYSTEM**

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

*CROSS-REFERENCE TO RELATED
APPLICATIONS*

This application [claims the benefit of U.S. Provisional Application No. 61/033,432, filed on Mar. 4, 2008, which is hereby incorporated by reference as if fully set forth herein. And this application] *is a reissue of U.S. Pat. No. 8,406,256, which issued on Mar. 26, 2013, from U.S. application Ser. No. 12/396,066, filed on Mar. 2, 2009, which claims the benefit of earlier filing date and right of priority to Korean Application No. 10-2009-0015936, filed on Feb. 25, 2009, [which is hereby incorporated by reference] and also claims the benefit of U.S. Provisional Application Ser. No. 61/033,432, filed on Mar. 4, 2008, the contents of which are hereby incorporated by reference herein in their entirety.*

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a digital broadcasting system for transmitting and receiving digital broadcast signal, and more particularly, to a transmitting system for processing and transmitting digital broadcast signal, and a receiving system for receiving and processing digital broadcast signal and, a method of processing data in the transmitting system and the receiving system.

2. Discussion of the Related Art

The Vestigial Sideband (VSB) transmission mode, which is adopted as the standard for digital broadcasting in North America and the Republic of Korea, is a system using a single carrier method. Therefore, the receiving performance of the digital broadcast receiving system may be deteriorated in a poor channel environment. Particularly, since resistance to changes in channels and noise is more highly required when using portable and/or mobile broadcast receivers, the receiving performance may be even more deteriorated when transmitting mobile service data by the VSB transmission mode.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a digital broadcasting system and a data processing method that substantially obviate one or more problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide a digital broadcasting system and a data processing method that are highly resistant to channel changes and noise.

Another object of the present invention is to provide a digital broadcasting system and a data processing method that can enhance the receiving performance of the receiving system by performing additional encoding on mobile service data and by transmitting the processed data to the receiving system.

A further object of the present invention is to provide a digital broadcasting system and a data processing method that can also enhance the receiving performance of the receiving system by inserting known data already known in accordance with a pre-agreement between the receiving system and the transmitting system in a predetermined region within a data region.

A further object of the present invention is to provide a digital broadcasting system and a data processing method that can packetize data of a Reed-Solomon (RS) frame for mobile services from a service multiplexer within a transmitting system into a plurality of transport stream (TS) packets, and transmit the packetized TS packets to a transmitter, thereby enabling the transmitting system to maintain compatibility with the conventional system.

Additional advantages, objects, and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention. The objectives and other advantages of the invention may be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these objects and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, a digital broadcast transmitting system may include a service multiplexer and a transmitter. The service multiplexer may multiplex mobile service data and main service data at a predetermined data rate and may transmit the multiplexed data to the transmitter. The transmitter may perform additional encoding on the mobile service data being transmitted from the service multiplexer. The transmitter may also group a plurality of additionally encoded mobile service data packets so as to form a data group. The transmitter may multiplex mobile service data packets including mobile service data and main service data packets including main service data and may transmit the multiplexed data packets to a receiving system.

Herein, the data group may be divided into a plurality of regions depending upon a degree of interference of the main service data. Also, a long known data sequence may be periodically inserted in regions without interference of the main service data. Also, a receiving system according to an embodiment of the present invention may be used for demodulating and channel equalizing the known data sequence.

In another aspect of the present invention, a transmitting system may include a service multiplexer and at least one transmitter located in a remote position from the service multiplexer. Herein, the service multiplexer generates an RS frame having the size of N (row)×187 (column) bytes including at least one type of mobile service data, packetizes the RS frame into a plurality of mobile service data packets, and multiplexes the packetized mobile service data packets with a main service data packet at a predetermined data rate, thereby transmitting the multiplexed data packets. Herein, each mobile service data packet is configured of a TS header and a data region, and the data region is configured of at least one of a payload region and an adaptation field region.

The transmitter recovers the RS frame from the mobile service data packets based upon the TS header of each mobile service data packet transmitted from the service multiplexer, and performs error correction encoding and block encoding on data of the recovered RS frame, thereby transmitting the processed RS frame data to a receiving system.

Herein, the service multiplexer sets, among the plurality of mobile service data packets, a payload unit start indicator (PUSI) field value of the TS header included in the mobile service data packet including the first data byte of the RS frame data to '1', and wherein the service multiplexer sets the PUSI field value of the TS header included in each of the remaining mobile service data packets to '0'. Also, the service multiplexer may set an ensemble identifier corresponding to the RS frame as a packet identifier (PID) of the TS header included in each of the plurality of mobile service data packets.

Herein, the transmitter may extract data included in the payload region of each mobile service data packet having an ensemble identifier corresponding to the RS frame, which is to be recovered, as a respective packet identifier (PID) value, thereby recovering the RS frame.

In another aspect of the present invention, in a method for processing data in a transmitting system including a service multiplexer and at least one transmitter located in a remote position from the service multiplexer, the method includes generating a Reed-Solomon (RS) frame having the size of N (row) \times 187 (column) bytes including at least one type of mobile service data, packetizing the RS frame into a plurality of mobile service data packets, wherein each mobile service data packet is configured of a TS header and a data region, and wherein the data region is configured of at least one of a payload region and an adaptation field region, and multiplexing the packetized mobile service data packets with a main service data packet at a predetermined data rate, thereby transmitting the multiplexed data packets to each transmitter.

Herein, the method may further include recovering the RS frame from the plurality of mobile service data packets based upon the TS header of each mobile service data packet transmitted from the service multiplexer, and performing error correction encoding and block encoding on data of the recovered RS frame, thereby transmitting the processed RS frame data to a receiving system.

It is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this application, illustrate embodiment(s) of the invention and together with the description serve to explain the principle of the invention. In the drawings:

FIG. 1 illustrates a structure of a MH frame for transmitting and receiving mobile service data according to the present invention;

FIG. 2 illustrates an exemplary structure of a VSB frame;

FIG. 3 illustrates a mapping example of the positions to which the first 4 slots of a sub-frame are assigned with respect to a VSB frame in a space region;

FIG. 4 illustrates a mapping example of the positions to which the first 4 slots of a sub-frame are assigned with respect to a VSB frame in a time region;

FIG. 5 illustrates an alignment of data after being data interleaved and identified;

FIG. 6 illustrates an enlarged portion of the data group shown in FIG. 5 for a better understanding of the present invention;

FIG. 7 illustrates an alignment of data before being data interleaved and identified;

FIG. 8 illustrates an enlarged portion of the data group shown in FIG. 7 for a better understanding of the present invention;

FIG. 9 illustrates an exemplary assignment order of data groups being assigned to one of 5 sub-frames according to the present invention;

FIG. 10 illustrates an example of assigning a single parade to an MH frame according to the present invention;

FIG. 11 illustrates an example of assigning 3 parades to an MH frame according to the present invention;

FIG. 12 illustrates an example of expanding the assignment process of 3 parades to 5 sub-frames within an MH frame;

FIG. 13 illustrates a data transmission structure according to an embodiment of the present invention, wherein signaling data are included in a data group so as to be transmitted;

FIG. 14 illustrates a block diagram showing a general structure of a transmitting system according to an embodiment of the present invention;

FIG. 15 is a diagram illustrating an example of RS frame according to the present invention;

FIG. 16 is a diagram illustrating a structure of an MH header within an MH service data packet according to the present invention;

FIG. 17(a) and FIG. 17(b) are diagrams illustrating another example of RS frame according to the present invention; and

FIG. 18 illustrates a block diagram showing an example of a service multiplexer of FIG. 14;

FIG. 19 illustrates a structure of a transport stream packet that does not include an adaptation field;

FIG. 20 illustrates a structure of a transport stream packet that includes an adaptation field;

FIG. 21 is a diagram illustrating an example of packetizing an RS frame into TS packets according to the present invention;

FIG. 22 is a flowchart illustrating an example of TS-packetizing an RS frame according to the present invention;

FIG. 23 illustrates a block diagram showing an embodiment of a transmitter of FIG. 14;

FIG. 24 illustrates a block diagram showing an example of a pre-processor of FIG. 23;

FIG. 25 is a diagram illustrating an example of recovering an RS frame from mobile service data packets according to the present invention;

FIG. 26 is a flowchart illustrating an example of recovering an RS frame from mobile service data packets according to the present invention;

FIG. 27 illustrates a conceptual block diagram of the MH frame encoder of FIG. 24;

FIG. 28 illustrates a detailed block diagram of an RS frame encoder of FIG. 27;

FIG. 29(a) and FIG. 29(b) illustrate a process of one or two RS frame being divided into several portions, based upon an RS frame mode value, and a process of each portion being assigned to a corresponding region within the respective data group;

FIG. 30(a) to FIG. 30(c) illustrate error correction encoding and error detection encoding processes according to an embodiment of the present invention;

FIG. 31(a) to FIG. 31(d) illustrate an example of performing a row permutation (or interleaving) process in super frame units according to the present invention;

FIG. 32(a) and FIG. 32(b) illustrate an example which a parade consists of two RS frames

FIG. 33(a) and FIG. 33(b) illustrate an exemplary process of dividing an RS frame for configuring a data group according to the present invention;

FIG. 34 illustrates a block diagram of a block processor according to an embodiment of the present invention;

FIG. 35 illustrates a detailed block diagram of a convolution encoder of the block processor;

FIG. 36 illustrates a symbol interleaver of the block processor;

FIG. 37 illustrates a block diagram of a group formatter according to an embodiment of the present invention;

FIG. 38 illustrates a block diagram of a trellis encoder according to an embodiment of the present invention;

FIG. 39 illustrates an example of assigning signaling information area according to an embodiment of the present invention;

FIG. 40 illustrates a detailed block diagram of a signaling encoder according to the present invention;

FIG. 41 illustrates an example of a syntax structure of TPC data according to the present invention;

FIG. 42 illustrates an example of a transmission scenario of the TPC data and the FIC data level according to the present invention;

FIG. 43 illustrates an example of power saving of in a receiver when transmitting 3 parades to an MH frame level according to the present invention;

FIG. 44 illustrates an example of a training sequence at the byte level according to the present invention;

FIG. 45 illustrates an example of a training sequence at the symbol according to the present invention;

FIG. 46 illustrates a block diagram of a receiving system according to an embodiment of the present invention;

FIG. 47 is a block diagram showing an example of a demodulating unit in the receiving system;

FIG. 48 is a block diagram showing an example of an operation controller of FIG. 47;

FIG. 49 illustrates a block diagram of a block decoder according to an embodiment of the present invention;

FIG. 50(a) and FIG. 50(b) illustrate an exemplary process of configuring one or two RS frame by collecting a plurality of portions according to the present invention; and

FIG. 51 and FIG. 52 illustrate process steps of error correction decoding according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. In addition, although the terms used in the present invention are selected from generally known and used terms, some of the terms mentioned in the description of the present invention have been selected by the applicant at his or her discretion, the detailed meanings of which are described in relevant parts of the description herein. Furthermore, it is required that the present invention is understood, not simply by the actual terms used but by the meaning of each term lying within.

Among the terms used in the description of the present invention, main service data correspond to data that can be received by a fixed receiving system and may include audio/video (A/V) data. More specifically, the main service data may include A/V data of high definition (HD) or

standard definition (SD) levels and may also include diverse data types required for data broadcasting. Also, the known data correspond to data pre-known in accordance with a pre-arranged agreement between the receiving system and the transmitting system.

Additionally, among the terms used in the present invention, "MH" corresponds to the initials of "mobile" and "handheld" and represents the opposite concept of a fixed-type system. Furthermore, the MH service data may include at least one of mobile service data and handheld service data, and will also be referred to as "mobile service data" for simplicity. Herein, the mobile service data not only correspond to MH service data but may also include any type of service data with mobile or portable characteristics. Therefore, the mobile service data according to the present invention are not limited only to the MH service data.

The above-described mobile service data may correspond to data having information, such as program execution files, stock information, and so on, and may also correspond to A/V data. Most particularly, the mobile service data may correspond to A/V data having lower resolution and lower data rate as compared to the main service data. For example, if an A/V codec that is used for a conventional main service corresponds to a MPEG-2 codec, a MPEG-4 advanced video coding (AVC) or scalable video coding (SVC) having better image compression efficiency may be used as the A/V codec for the mobile service. Furthermore, any type of data may be transmitted as the mobile service data. For example, transport protocol expert group (TPEG) data for broadcasting real-time transportation information may be transmitted as the main service data.

Also, a data service using the mobile service data may include weather forecast services, traffic information services, stock information services, viewer participation quiz programs, real-time polls and surveys, interactive education broadcast programs, gaming services, services providing information on synopsis, character, background music, and filming sites of soap operas or series, services providing information on past match scores and player profiles and achievements, and services providing information on product information and programs classified by service, medium, time, and theme enabling purchase orders to be processed. Herein, the present invention is not limited only to the services mentioned above.

In the present invention, the transmitting system provides backward compatibility in the main service data so as to be received by the conventional receiving system. Herein, the main service data and the mobile service data are multiplexed to the same physical channel and then transmitted.

Furthermore, the transmitting system according to the present invention performs additional encoding on the mobile service data and inserts the data already known by the receiving system and transmitting system (e.g., known data), thereby transmitting the processed data.

Therefore, when using the transmitting system according to the present invention, the receiving system may receive the mobile service data during a mobile state and may also receive the mobile service data with stability despite various distortion and noise occurring within the channel.

MH Frame Structure

In the embodiment of the present invention, the mobile service data are first multiplexed with main service data in MH frame units and, then, modulated in a VSB mode and transmitted to the receiving system.

At this point, one MH frame consists of K1 number of sub-frames, wherein one sub-frame includes K2 number of slots. Also, each slot may be configured of K3 number of

data packets. In the embodiment of the present invention, K1 will be set to 5, K2 will be set to 16, and K3 will be set to 156 (i.e., K1=5, K2=16, and K3=156). The values for K1, K2, and K3 presented in this embodiment either correspond to values according to a preferred embodiment or are merely exemplary. Therefore, the above-mentioned values will not limit the scope of the present invention.

FIG. 1 illustrates a structure of a MH frame for transmitting and receiving mobile service data according to the present invention. In the example shown in FIG. 1, one MH frame consists of 5 sub-frames, wherein each sub-frame includes 16 slots. In this case, the MH frame according to the present invention includes 5 sub-frames and 80 slots. Also, in a packet level, one slot is configured of 156 data packets (i.e., transport stream packets), and in a symbol level, one slot is configured of 156 data segments. Herein, the size of one slot corresponds to one half ($\frac{1}{2}$) of a VSB field. More specifically, since one 207-byte data packet has the same amount of data as a data segment, a data packet prior to being interleaved may also be used as a data segment.

At this point, two VSB fields are grouped to form a VSB frame.

FIG. 2 illustrates an exemplary structure of a VSB frame, wherein one VSB frame consists of 2 VSB fields (i.e., an odd field and an even field). Herein, each VSB field includes a field synchronization segment and 312 data segments.

The slot corresponds to a basic time period for multiplexing the mobile service data and the main service data. Herein, one slot may either include the mobile service data or be configured only of the main service data.

If one MH frame is transmitted during one slot, the first 118 data packets within the slot correspond to a data group. And, the remaining 38 data packets become the main service data packets. In another example, when no data group exists in a slot, the corresponding slot is configured of 156 main service data packets.

Meanwhile, when the slots are assigned to a VSB frame, an offset exists for each assigned position.

FIG. 3 illustrates a mapping example of the positions to which the first 4 slots of a sub-frame are assigned with respect to a VSB frame in a space region. And, FIG. 4 illustrates a mapping example of the positions to which the first 4 slots of a sub-frame are assigned with respect to a VSB frame in a time region.

Referring to FIG. 3 and FIG. 4, a 38th data packet (TS packet #137) of a 1st slot (Slot #0) is mapped to the 1st data packet of an odd VSB field. A 38th data packet (TS packet #137) of a 2nd slot (Slot #1) is mapped to the 157th data packet of an odd VSB field. Also, a 38th data packet (TS packet #137) of a 3rd slot (Slot #2) is mapped to the 1st data packet of an even VSB field. And, a 38th data packet (TS packet #137) of a 4th slot (Slot #3) is mapped to the 157th data packet of an even VSB field. Similarly, the remaining 12 slots within the corresponding sub-frame are mapped in the subsequent VSB frames using the same method.

Meanwhile, one data group may be divided into at least one or more hierarchical regions. And, depending upon the characteristics of each hierarchical region, the type of mobile service data being inserted in each region may vary. For example, the data group within each region may be divided (or categorized) based upon the receiving performance.

In an example given in the present invention, a data group is divided into regions A, B, C, and D in a data configuration after data interleaving.

FIG. 5 illustrates an alignment of data after being data interleaved and identified. FIG. 6 illustrates an enlarged

portion of the data group shown in FIG. 5 for a better understanding of the present invention. FIG. 7 illustrates an alignment of data before being data interleaved and identified. And, FIG. 8 illustrates an enlarged portion of the data group shown in FIG. 7 for a better understanding of the present invention. More specifically, a data structure identical to that shown in FIG. 5 is transmitted to a receiving system. In other words, one data packet is data-interleaved so as to be scattered to a plurality of data segments, thereby being transmitted to the receiving system. FIG. 5 illustrates an example of one data group being scattered to 170 data segments. At this point, since one 207-byte packet has the same amount of data as one data segment, the packet that is not yet processed with data-interleaving may be used as the data segment.

FIG. 5 shows an example of dividing a data group prior to being data-interleaved into 10 MH blocks (i.e., MH block 1 (B1) to MH block 10 (B10)). In this example, each MH block has the length of 16 segments. Referring to FIG. 5, only the RS parity data are allocated to portions of the first 5 segments of the MH block 1 (B1) and the last 5 segments of the MH block 10 (B10). The RS parity data are excluded in regions A to D of the data group. More specifically, when it is assumed that one data group is divided into regions A, B, C, and D, each MH block may be included in any one of region A to region D depending upon the characteristic of each MH block within the data group.

Herein, the data group is divided into a plurality of regions to be used for different purposes. More specifically, a region of the main service data having no interference or a very low interference level may be considered to have a more resistant (or stronger) receiving performance as compared to regions having higher interference levels. Additionally, when using a system inserting and transmitting known data in the data group, wherein the known data are known based upon an agreement between the transmitting system and the receiving system, and when consecutively long known data are to be periodically inserted in the mobile service data, the known data having a predetermined length may be periodically inserted in the region having no interference from the main service data (i.e., a region wherein the main service data are not mixed). However, due to interference from the main service data, it is difficult to periodically insert known data and also to insert consecutively long known data to a region having interference from the main service data.

Referring to FIG. 5, MH block 4 (B4) to MH block 7 (B7) correspond to regions without interference of the main service data. MH block 4 (B4) to MH block 7 (B7) within the data group shown in FIG. 5 correspond to a region where no interference from the main service data occurs. In this example, a long known data sequence is inserted at both the beginning and end of each MH block. In the description of the present invention, the region including MH block 4 (B4) to MH block 7 (B7) will be referred to as "region A (=B4+B5+B6+B7)". As described above, when the data group includes region A having a long known data sequence inserted at both the beginning and end of each MH block, the receiving system is capable of performing equalization by using the channel information that can be obtained from the known data. Therefore, the strongest equalizing performance may be yielded (or obtained) from one of region A to region D.

In the example of the data group shown in FIG. 5, MH block 3 (B3) and MH block 8 (B8) correspond to a region having little interference from the main service data. Herein, a long known data sequence is inserted in only one side of

each MH block B3 and B8. More specifically, due to the interference from the main service data, a long known data sequence is inserted at the end of MH block 3 (B3), and another long known data sequence is inserted at the beginning of MH block 8 (B8). In the present invention, the region including MH block 3 (B3) and MH block 8 (B8) will be referred to as "region B(=B3+B8)". As described above, when the data group includes region B having a long known data sequence inserted at only one side (beginning or end) of each MH block, the receiving system is capable of performing equalization by using the channel information that can be obtained from the known data. Therefore, a stronger equalizing performance as compared to region C/D may be yielded (or obtained).

Referring to FIG. 5, MH block 2 (B2) and MH block 9 (B9) correspond to a region having more interference from the main service data as compared to region B. A long known data sequence cannot be inserted in any side of MH block 2 (B2) and MH block 9 (B9). Herein, the region including MH block 2 (B2) and MH block 9 (B9) will be referred to as "region C(=B2+B9)". Finally, in the example shown in FIG. 5, MH block 1 (B1) and MH block 10 (B10) correspond to a region having more interference from the main service data as compared to region C. Similarly, a long known data sequence cannot be inserted in any side of MH block 1 (B1) and MH block 10 (B10).

Herein, the region including MH block 1 (B1) and MH block 10 (B10) will be referred to as "region D(=B1+B10)". Since region C/D is spaced further apart from the known data sequence, when the channel environment undergoes frequent and abrupt changes, the receiving performance of region C/D may be deteriorated.

FIG. 7 illustrates a data structure prior to data interleaving. More specifically, FIG. 7 illustrates an example of 118 data packets being allocated to a data group. FIG. 7 shows an example of a data group consisting of 118 data packets, wherein, based upon a reference packet (e.g., a 1st packet (or data segment) or 157th packet (or data segment) after a field synchronization signal), when allocating data packets to a VSB frame, 37 packets are included before the reference packet and 81 packets (including the reference packet) are included afterwards.

In other words, with reference to FIG. 5, a field synchronization signal is placed (or assigned) between MH block 2 (B2) and MH block 3 (B3). Accordingly, this indicates that the slot has an off-set of 37 data packets with respect to the corresponding VSB field.

The size of the data groups, number of hierarchical regions within the data group, the size of each region, the number of MH blocks included in each region, the size of each MH block, and so on described above are merely exemplary. Therefore, the present invention will not be limited to the examples described above.

FIG. 9 illustrates an exemplary assignment order of data groups being assigned to one of 5 sub-frames, wherein the 5 sub-frames configure an MH frame. For example, the method of assigning data groups may be identically applied to all MH frames or differently applied to each MH frame. Furthermore, the method of assigning data groups may be identically applied to all sub-frames or differently applied to each sub-frame. At this point, when it is assumed that the data groups are assigned using the same method in all sub-frames of the corresponding MH frame, the total number of data groups being assigned to an MH frame is equal to a multiple of '5'.

According to the embodiment of the present invention, a plurality of consecutive data groups is assigned to be spaced

as far apart from one another as possible within the MH frame. Thus, the system can be capable of responding promptly and effectively to any burst error that may occur within a sub-frame.

For example, when it is assumed that 3 data groups are assigned to a sub-frame, the data groups are assigned to a 1st slot (Slot #0), a 5th slot (Slot #4), and a 9th slot (Slot #8) in the sub-frame, respectively. FIG. 9 illustrates an example of assigning 16 data groups in one sub-frame using the above-described pattern (or rule). In other words, each data group is serially assigned to 16 slots corresponding to the following numbers: 0, 8, 4, 12, 1, 9, 5, 13, 2, 10, 6, 14, 3, 11, 7, and 15. Equation 1 below shows the above-described rule (or pattern) for assigning data groups in a sub-frame.

$$j=(4i+0) \bmod 16 \quad \text{Equation 1}$$

$$0=0 \text{ if } i<4,$$

$$0=2 \text{ else if } i<8,$$

Herein,

$$0=1 \text{ else if } i<12,$$

$$0=3 \text{ else.}$$

Herein, j indicates the slot number within a sub-frame. The value of j may range from 0 to 15 (i.e., $0 \leq j \leq 15$). Also, value of i indicates the data group number. The value of i may range from 0 to 15 (i.e., $0 \leq i \leq 15$).

In the present invention, a collection of data groups included in a MH frame will be referred to as a "parade". Based upon the RS frame mode, the parade transmits data of at least one specific RS frame.

The mobile service data within one RS frame may be assigned either to all of regions A/B/C/D within the corresponding data group, or to at least one of regions A/B/C/D. In the embodiment of the present invention, the mobile service data within one RS frame may be assigned either to all of regions A/B/C/D, or to at least one of regions A/B and regions C/D. If the mobile service data are assigned to the latter case (i.e., one of regions A/B and regions C/D), the RS frame being assigned to regions A/B and the RS frame being assigned to regions C/D within the corresponding data group are different from one another.

In the description of the present invention, the RS frame being assigned to regions A/B within the corresponding data group will be referred to as a "primary RS frame", and the RS frame being assigned to regions C/D within the corresponding data group will be referred to as a "secondary RS frame", for simplicity. Also, the primary RS frame and the secondary RS frame form (or configure) one parade. More specifically, when the mobile service data within one RS frame are assigned either to all of regions A/B/C/D within the corresponding data group, one parade transmits one RS frame. In this case, also the RS frame will be referred to as a "primary RS frame". Conversely, when the mobile service data within one RS frame are assigned either to at least one of regions A/B and regions C/D, one parade may transmit up to 2 RS frames.

More specifically, the RS frame mode indicates whether a parade transmits one RS frame, or whether the parade transmits two RS frames. Table 1 below shows an example of the RS frame mode.

TABLE 1

RS frame mode (2 bits)	Description
00	There is only one primary RS frame for all group regions
01	There are two separate RS frames. Primary RS frame for group regions A and B Secondary RS frame for group regions C and D
10	Reserved
11	Reserved

Table 1 illustrates an example of allocating 2 bits in order to indicate the RS frame mode. For example, referring to Table 1, when the RS frame mode value is equal to '00', this indicates that one parade transmits one RS frame. And, when the RS frame mode value is equal to '01', this indicates that one parade transmits two RS frames, i.e., the primary RS frame and the secondary RS frame. More specifically, when the RS frame mode value is equal to '01', data of the primary RS frame for regions A/B are assigned and transmitted to regions A/B of the corresponding data group. Similarly, data of the secondary RS frame for regions C/D are assigned and transmitted to regions C/D of the corresponding data group.

As described in the assignment of data groups, the parades are also assigned to be spaced as far apart from one another as possible within the sub-frame. Thus, the system can be capable of responding promptly and effectively to any burst error that may occur within a sub-frame.

Furthermore, the method of assigning parades may be identically applied to all sub-frames or differently applied to each sub-frame. According to the embodiment of the present invention, the parades may be assigned differently for each MH frame and identically for all sub-frames within an MH frame. More specifically, the MH frame structure may vary by MH frame units. Thus, an ensemble rate may be adjusted on a more frequent and flexible basis.

FIG. 10 illustrates an example of multiple data groups of a single parade being assigned (or allocated) to an MH frame. More specifically, FIG. 10 illustrates an example of a plurality of data groups included in a single parade, wherein the number of data groups included in a sub-frame is equal to '3', being allocated to an MH frame. Referring to FIG. 10, 3 data groups are sequentially assigned to a sub-frame at a cycle period of 4 slots. Accordingly, when this process is equally performed in the 5 sub-frames included in the corresponding MH frame, 15 data groups are assigned to a single MH frame. Herein, the 15 data groups correspond to data groups included in a parade. Therefore, since one sub-frame is configured of 4 VSB frame, and since 3 data groups are included in a sub-frame, the data group of the corresponding parade is not assigned to one of the 4 VSB frames within a sub-frame.

For example, when it is assumed that one parade transmits one RS frame, and that a RS frame encoder located in a later block performs RS-encoding on the corresponding RS frame, thereby adding 24 bytes of parity data to the corresponding RS frame and transmitting the processed RS frame, the parity data occupy approximately 11.37% ($=24/(187+24) \times 100$) of the total code word length. Meanwhile, when one sub-frame includes 3 data groups, and when the data groups included in the parade are assigned, as shown in FIG. 10, a total of 15 data groups form an RS frame. Accordingly, even when an error occurs in an entire data group due to a burst noise within a channel, the percentile is merely 6.67% ($=1/15 \times 100$). Therefore, the receiving system may correct all errors by performing an erasure RS decoding process. More specifically, when the erasure RS decoding is

performed, a number of channel errors corresponding to the number of RS parity bytes may be corrected. By doing so, the receiving system may correct the error of at least one data group within one parade. Thus, the minimum burst noise length correctable by a RS frame is over 1 VSB frame.

Meanwhile, when data groups of a parade are assigned as described above, either main service data may be assigned between each data group, or data groups corresponding to different parades may be assigned between each data group. More specifically, data groups corresponding to multiple parades may be assigned to one MH frame.

Basically, the method of assigning data groups corresponding to multiple parades is very similar to the method of assigning data groups corresponding to a single parade. In other words, data groups included in other parades that are to be assigned to an MH frame are also respectively assigned according to a cycle period of 4 slots.

At this point, data groups of a different parade may be sequentially assigned to the respective slots in a circular method. Herein, the data groups are assigned to slots starting from the ones to which data groups of the previous parade have not yet been assigned.

For example, when it is assumed that data groups corresponding to a parade are assigned as shown in FIG. 10, data groups corresponding to the next parade may be assigned to a sub-frame starting either from the 12th slot of a sub-frame. However, this is merely exemplary. In another example, the data groups of the next parade may also be sequentially assigned to a different slot within a sub-frame at a cycle period of 4 slots starting from the 3rd slot.

FIG. 11 illustrates an example of transmitting 3 parades (Parade #0, Parade #1, and Parade #2) to an MH frame. More specifically, FIG. 11 illustrates an example of transmitting parades included in one of 5 sub-frames, wherein the 5 sub-frames configure one MH frame.

When the 1st parade (Parade #0) includes 3 data groups for each sub-frame, the positions of each data groups within the sub-frames may be obtained by substituting values '0' to '2' for i in Equation 1. More specifically, the data groups of the 1st parade (Parade #0) are sequentially assigned to the 1st, 5th, and 9th slots (Slot #0, Slot #4, and Slot #8) within the sub-frame. Also, when the 2nd parade includes 2 data groups for each sub-frame, the positions of each data groups within the sub-frames may be obtained by substituting values '3' and '4' for i in Equation 1.

More specifically, the data groups of the 2nd parade (Parade #1) are sequentially assigned to the 2nd and 12th slots (Slot #3 and Slot #11) within the sub-frame.

Finally, when the 3rd parade includes 2 data groups for each sub-frame, the positions of each data groups within the sub-frames may be obtained by substituting values '5' and '6' for i in Equation 1. More specifically, the data groups of the 3rd parade (Parade #2) are sequentially assigned to the 7th and 11th slots (Slot #6 and Slot #10) within the sub-frame.

As described above, data groups of multiple parades may be assigned to a single MH frame, and, in each sub-frame, the data groups are serially allocated to a group space having 4 slots from left to right. Therefore, a number of groups of one parade per sub-frame (NOG) may correspond to any one integer from '1' to '8'. Herein, since one MH frame includes 5 sub-frames, the total number of data groups within a parade that can be allocated to an MH frame may correspond to any one multiple of '5' ranging from '5' to '40'.

FIG. 12 illustrates an example of expanding the assignment process of 3 parades, shown in FIGS. 11, to 5 sub-frames within an MH frame.

FIG. 13 illustrates a data transmission structure according to an embodiment of the present invention, wherein signaling data are included in a data group so as to be transmitted.

As described above, an MH frame is divided into 5 sub-frames. Data groups corresponding to a plurality of parades co-exist in each sub-frame. Herein, the data groups corresponding to each parade are grouped by MH frame units, thereby configuring a single parade.

The data structure shown in FIG. 13 includes 3 parades, one ESG dedicated channel (EDC) parade (i.e., parade with NoG=1), and 2 service parades (i.e., parade with NoG=4 and parade with NoG=3). Also, a predetermined portion of each data group (i.e., 37 bytes/data group) is used for delivering (or sending) FIC information associated with mobile service data, wherein the FIC information is separately encoded from the RS-encoding process. The FIC region assigned to each data group consists of one FIC segments.

Meanwhile, the concept of an MH ensemble is applied in the embodiment of the present invention, thereby defining a collection (or group) of services. Each MH ensemble carries the same QoS and is coded with the same FEC code. Also, each MH ensemble has the same unique identifier (i.e., ensemble ID) and corresponds to consecutive RS frames.

As shown in FIG. 13, the FIC segment corresponding to each data group described service information of an MH ensemble to which the corresponding data group belongs.

Furthermore, FIG. 13 illustrates a structure further including a separate EDC parade apart from the service parade and wherein electronic service guide (ESG) data are transmitted in the 1st slot of each sub-frame.

FIG. 14 illustrates a block diagram showing a general structure of a digital broadcast transmitting system according to an embodiment of the present invention.

Herein, the digital broadcast transmitting includes a service multiplexer 100 and a transmitter 200. Herein, the service multiplexer 100 is located in the studio of each broadcast station, and the transmitter 200 is located in a site placed at a predetermined distance from the studio. The transmitter 200 may be located in a plurality of different locations. Also, for example, the plurality of transmitters may share the same frequency. And, in this case, the plurality of transmitters receives the same signal. This corresponds to data transmission using Single Frequency Network (SFN). Accordingly, in the receiving system, a channel equalizer may compensate signal distortion, which is caused by a reflected wave, so as to recover the original signal. In another example, the plurality of transmitters may have different frequencies with respect to the same channel. This corresponds to data transmission using Multi Frequency Network (MFN).

A variety of methods may be used for data communication each of the transmitters, which are located in remote positions, and the service multiplexer. For example, an interface standard such as a synchronous serial interface for transport of MPEG-2 data (SMPTE-310M). In the SMPTE-310M interface standard, a constant data rate is decided as an output data rate of the service multiplexer. For example, in case of the 8VSB mode, the output data rate is 19.39 Mbps, and, in case of the 16VSB mode, the output data rate is 38.78 Mbps. Furthermore, in the conventional 8VSB mode transmitting system, a transport stream (TS) packet having a data rate of approximately 19.39 Mbps may be transmitted through a single physical channel. Also, in the transmitting system according to the present invention provided with backward compatibility with the conventional transmitting system, additional encoding is performed on the mobile service data. Thereafter, the additionally encoded

mobile service data are multiplexed with the main service data to a TS packet form, which is then transmitted. At this point, the data rate of the multiplexed TS packet is approximately 19.39 Mbps.

At this point, the service multiplexer 100 receives at least one type of main service data and table information (e.g., PSI/PSIP table data) for each main service and encapsulates the received data into a transport stream (TS) packet.

Also, the service multiplexer 100 generates an RS frame included at least one type of mobile service data, thereby encapsulating the generated RS frame into a plurality of transport stream (TS) packets.

The RS frame generated from the service multiplexer 100 may further include table information for the corresponding mobile service.

And, the service multiplexer 100 multiplexes the encapsulated TS packets for main service and the encapsulated TS packets for mobile service based upon a predetermined multiplexing rule, thereby outputting the multiplexed TS packets to the transmitter 200.

At this point, the RS frame generated from the service multiplexer 100 has the size of N (row)×187 (column), as shown in FIG. 15. Herein, N represents the length of a row (i.e., number of columns), and 187 corresponds to the length of a column (i.e., number of rows).

In the present invention, each row configured of N bytes will be referred to as an MH service data packet for simplicity. The MH service data packet may be configured of a 2-byte MH header and a (N-2)-byte MH payload. Herein, the assigning 2 bytes to the MH header region is merely exemplary. The above-described configuration may be altered by the system designer and will, therefore, not be limited only to the example presented in the description of the present invention.

The RS frame is generated by collecting (or gathering) table information and/or mobile service data collectively corresponding to a size of (N-2) (row)×187 (column) bytes. According to an embodiment of the present invention, the mobile service data has the form of an IP datagram. Herein, the RS frame may include table information and IP datagram corresponding to at least one mobile service. For example, IP datagram and table information of two different types of mobile service data, such as news service (e.g., IP datagram for mobile service 1) and stock information service (e.g., IP datagram for mobile service 2), may be included in a single RS frame.

More specifically, either table information of a section structure or an IP datagram of a mobile service data may be assigned to an MH payload within an MH service data packet configuring the RS frame. Alternatively, either an IP datagram of table information or an IP datagram of a mobile service data may be assigned to an MH payload within an MH service data packet configuring the RS frame.

At this point, the size of the MH service data packet including the MH header may not be equal to N bytes.

In this case, stuffing bytes may be assigned to the surplus (or remaining) payload region within the corresponding MH service data packet. For example, after assigning program table information to an MH service data packet, when the length of the corresponding MH service data packet including the MH header is equal to (N-20) bytes, stuffing bytes may be assigned to the remaining 20-byte region.

The RS frame may be assigned to at least one of regions A/B/C/D within a data group by the transmitter. In the description of the present invention, when the RS frame is assigned to regions A/B/C/D within the data group, or when the RS frame is assigned to regions A/B, the RS frame will

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be referred to as a primary RS frame. Alternatively, when the RS frame is assigned to regions C/D, the RS frame will be referred to as a secondary RS frame.

FIG. 16 is a diagram illustrating examples of fields allocated to the MH header region within the MH service data packet according to the present invention. Examples of the fields include type_indicator field, error_indicator field, stuff_indicator field, and pointer field.

The type_indicator field can allocate 3 bits, for example, and represents a type of data allocated to payload within the corresponding MH service data packet. In other words, the type_indicator field indicates whether data of the payload is IP datagram or program table information. At this time, each data type constitutes one logical channel. In the logical channel which transmits the IP datagram, several mobile services are multiplexed and then transmitted. Each mobile service undergoes demultiplexing in the IP layer.

The error_indicator field can allocate 1 bit, for example, and represents whether the corresponding MH service data packet has an error. For example, if the error_indicator field has a value of 0, it means that there is no error in the corresponding MH service data packet. If the error_indicator field has a value of 1, it means that there may be an error in the corresponding MH service data packet.

The stuff_indicator field can allocate 1 bit, for example, and represents whether stuffing byte exists in payload of the corresponding MH service data packet. For example, if the stuff_indicator field has a value of 0, it means that there is no stuffing byte in the corresponding MH service data packet. If the stuff_indicator field has a value of 1, it means that stuffing byte exists in the corresponding MH service data packet.

The pointer field can allocate 11 bits, for example, and represents position information where new data (i.e., new signaling information or new IP datagram) starts in the corresponding MH service data packet.

For example, if IP datagram for mobile service 1 and IP datagram for mobile service 2 are allocated to the first MH service data packet within the RS frame as illustrated in FIG. 15, the pointer field value represents the start position of the IP datagram for mobile service 2 within the MH service data packet.

Also, if there is no new data in the corresponding MH service data packet, the corresponding field value is expressed as a maximum value exemplarily. According to the embodiment of the present invention, since 11 bits are allocated to the pointer field, if 2047 is expressed as the pointer field value, it means that there is no new data in the packet. The point where the pointer field value is 0 can be varied depending on the type_indicator field value and the stuff_indicator field value.

It is to be understood that the order, the position, and the meaning of the fields allocated to the header within the MH service data packet illustrated in FIG. 16 are exemplarily illustrated for understanding of the present invention. Since the order, the position and the meaning of the fields allocated to the header within the MH service data packet and the number of additionally allocated fields can easily be modified by those skilled in the art, the present invention will not be limited to the above example.

FIG. 17(a) and FIG. 17(b) illustrate another examples of RS frame according to the present invention. FIG. 17(a) illustrates an example of primary RS frame to be allocated to regions A/B within the data group, and FIG. 17(b) illustrates an example of secondary RS frame to be allocated to regions C/D within the data group.

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In FIG. 17(a) and FIG. 17(b), a column length (i.e., the number of rows) of the RS frame to be allocated to the regions A/B and a column length (i.e., the number of rows) of the RS frame to be allocated to the regions C/D are 187 equally. However, row lengths (i.e., the number of columns) may be different from each other.

According to the embodiment of the present invention, when the row length of the primary RS frame to be allocated to the regions A/B within the data group is N1 bytes and the row length of the secondary RS frame to be allocated to the regions C/D within the data group is N2 bytes, a condition of N1>N2 is satisfied. In this case, N1 and N2 can be varied depending on the transmission parameter or a region of the data group, to which the corresponding RS frame will be transmitted.

For convenience of the description, each row of the N1 and N2 bytes will be referred to as the MH service data packet. The MH service data packet within the RS frame to be allocated to the regions A/B within the data group can be comprised of MH header of 2 bytes and payload of N1-2 bytes. Also, the MH service data packet within the RS frame to be allocated to the regions C/D within the data group can be comprised of MH header of 2 bytes and payload of N2-2 bytes.

In the present invention, the primary RS frame for the regions A/B within the data group and the secondary RS frame for the regions C/D within the data group can include at least one of program table information and IP datagram. Also, one RS frame can include IP datagram corresponding to one or more mobile services.

Corresponding parts of FIG. 15 can be applied to the other parts, which are not described in FIG. 17(a) and FIG. 17(b).

Meanwhile, the value of N, which corresponds to the number of columns within an RS frame, can be decided according to Equation 2.

N = floor((5 * NoG * PL) / (187 + P)) - 2 Equation 2

Herein, NoG indicates the number of data groups assigned to a sub-frame. PL represents the number of SCCC payload data bytes assigned to a data group. And, P signifies the number of RS parity data bytes added to each column of the RS frame. Finally, [X] is the greatest integer that is equal to or smaller than X.

More specifically, in Equation 2, PL corresponds to the length of an RS frame portion. The value of PL is equivalent to the number of SCCC payload data bytes that are assigned to the corresponding data group. Herein, the value of PL may vary depending upon the RS frame mode, SCCC block mode, and SCCC outer code mode. Table 2 to Table 5 below respectively show examples of PL values, which vary in accordance with the RS frame mode, SCCC block mode, and SCCC outer code mode. The SCCC block mode and the SCCC outer code mode will be described in detail in a later process.

TABLE 2

Table with 5 columns: Region A, Region B, Region C, Region D, PL. Rows show values for SCCC outer code mode.

TABLE 2-continued

SCCC outer code mode				
for Region A	for Region B	for Region C	for Region D	PL
00	00	01	00	8886
00	00	01	01	8634
00	01	00	00	8403
00	01	00	01	8151
00	01	01	00	7665
00	01	01	01	7413
01	00	00	00	7023
01	00	00	01	6771
01	00	01	00	6285
01	00	01	01	6033
01	01	00	00	5802
01	01	00	01	5550
01	01	01	00	5064
01	01	01	01	4812
Others				Reserved

Table 2 shows an example of the PL values for each data group within an RS frame, wherein each PL value varies depending upon the SCCC outer code mode, when the RS frame mode value is equal to '00', and when the SCCC block mode value is equal to '00'. For example, when it is assumed that each SCCC outer code mode value of regions A/B/C/D within the data group is equal to '00' (i.e., the block processor 302 of a later block performs encoding at a coding rate of 1/2), the PL value within each data group of the corresponding RS frame may be equal to 9624 bytes. More specifically, 9624 bytes of mobile service data within one RS frame may be assigned to regions A/B/C/D of the corresponding data group.

TABLE 3

SCCC outer code mode	PL
00	9624
01	4812
Others	Reserved

Table 3 shows an example of the PL values for each data group within an RS frame, wherein each PL value varies depending upon the SCCC outer code mode, when the RS frame mode value is equal to '00', and when the SCCC block mode value is equal to '01'.

TABLE 4

SCCC outer code mode		
for Region A	for Region B	PL
00	00	7644
00	01	6423
01	00	5043
01	01	3822
Others		Reserved

Table 4 shows an example of the PL values for each data group within a primary RS frame, wherein each PL value varies depending upon the SCCC outer code mode, when the RS frame mode value is equal to '01', and when the SCCC block mode value is equal to '00'. For example, when each SCCC outer code mode value of regions A/B is equal to '00', 7644 bytes of mobile service data within a primary RS frame may be assigned to regions A/B of the corresponding data group.

TABLE 5

SCCC outer code mode			
	for Region C	for Region D	PL
5	00	00	1980
	00	01	1728
	01	00	1242
	01	01	990
10	Others		Reserved

Table 5 shows an example of the PL values for each data group within a secondary RS frame, wherein each PL value varies depending upon the SCCC outer code mode, when the RS frame mode value is equal to '01', and when the SCCC block mode value is equal to '00'. For example, when each SCCC outer code mode value of regions C/D is equal to '00', 1980 bytes of mobile service data within a secondary RS frame may be assigned to regions C/D of the corresponding data group.

Service Multiplexer
 FIG. 18 illustrates a block diagram showing an example of the service multiplexer. The service multiplexer includes a controller 110 for controlling the overall operations of the service multiplexer, a table information generator 120 for the main service, a RS frame generator 130, a TS packet encapsulator 140, and a transport multiplexer 160.

The transport multiplexer 160 may include a main service multiplexer 161 and a transport stream (TS) packet multiplexer 162.

At this point, when data is transmitted from the service multiplexer 100 to the transmitter 200 using an interface standard, such as a synchronous serial interface for transport of MPEG-2 data (SMPTE-310M), the format of the data is defined to be in an MPEG-2 TS packet format. Therefore, when the data being outputted from the service multiplexer 100 does not correspond to a TS packet format, the data cannot be transmitted by using the SMPTE-310M. Herein, the MPEG-2 TS packet is also referred to as a TS packet.

The present invention is devised to transmit data of an RS frame for mobile services from a service multiplexer to a transmitter using SMPTE-310M. In order to do so, in the embodiment of the present invention, the data of the RS frame is MPEG-2 TS-packetized.

Referring to FIG. 18, at least one type of compression-encoded main service data and table data generated from the table information generator 120 for the main services are inputted to the main service multiplexer 161 of the transport multiplexer 160. According to the embodiment of the present invention, the table information generator 120 generates PSI/PSIP table data, which is configured in the form of an MPEG-2 private section. The main service multiplexer 161 respectively encapsulates each of the main service data and the PSI/PSIP table data, which are being inputted, to MPEG-2 TS packet formats, thereby multiplexing the encapsulated TS packets and outputting the multiplexed packets to the TS packet multiplexer 162. Herein, the data packet being outputted from the main service multiplexer 162 will hereinafter be referred to as a main service data packet for simplicity.

The RS frame generator 130 generates an RS frame in any one of the formats shown in FIG. 15, FIG. 17A, and FIG. 17B, thereby outputting the generated RS frame to the TS packet encapsulator 140. The TS packet encapsulator 140 TS-packetizes the RS frame generated by the RS frame generator 130, thereby outputting the TS packet to the TS packet multiplexer 162.

According to an embodiment of the present invention, a process of TS-packetizing the RS frame generated, as shown in FIG. 15, will now be described in detail.

The TS packet has a fixed length of 188 bytes. The TS packet broadly consists of a TS header (also referred to as an MPEG header), which corresponds to an information region, and a payload, which corresponding to a data region. Herein, depending upon whether or not an adaptation field is included in the TS packet, the payload has a variable length ranging from 0 to 184 bytes. If the adaptation field is not included in the TS packet, the payload of the corresponding TS packet has a fixed length of 184 bytes.

FIG. 19 illustrates a TS packet structure that does not include the adaptation field, wherein the TS packet consists of a 4-byte TS header and a 184-byte payload. In the 4-byte TS header, 1 byte corresponds to a synchronization byte being assigned with a value of '0x47(=01000111)', in case of an MPEG-2 TS packet. The remaining 3 bytes consists of a 1-bit transport error indicator field, a 1-bit payload unit start indicator field, a 1-bit transport priority field, a 13-bit PID field, a 2-bit transport scrambling control field, a 2-bit adaptation field control field, and a 4-bit continuity counter field. Herein, whether or not an adaptation field is included in the TS packet can be known through the adaptation field control field.

More specifically, referring to FIG. 19, the transport error indicator field indicates the value of '1', when a problem occurs in a transport layer, e.g., when a packet is lost during the transport.

The payload unit start indicator (hereinafter referred to as PUSI) field indicates the beginning of the TS packet. In other words, among a plurality of TS packets, only the PUSI field value of the starting TS packet is indicated as '1', and the PUSI field value for each of the remaining TS packets is indicated as '0'.

The transport priority field decides the priority level of a transmission medium having a PID included therein, when more than one transmission media having the same PID exist in the TS transmission path. Herein, the TS packet having the transport priority field value is set to '1', the corresponding TS packet has the highest priority level as compared to the remaining TS packets.

The PID field is an identifier that can identify the corresponding TS packet.

The transport scrambling control field indicates whether or not the corresponding TS packet has been scrambled.

The adaptation field control field indicates whether or not an adaptation field is included in the corresponding TS packet. For example, when the value of the adaptation field control field is equal to either '10' or '11', this indicates that an adaptation field is included in the corresponding TS packet. At this point, when the value of the adaptation field control field is equal to '10', this indicates that a payload does not exist in the corresponding TS packet. And, when the value of the adaptation field control field is equal to '11', this indicates that the length of the payload region varies depending upon the length of the adaptation field. Alternatively, when the value of the adaptation field control field is equal to '01', this indicates that an adaptation field is not included in the corresponding TS packet. Furthermore, the value '00' is not used in the adaptation field control field.

The continuity counter field is used in TS packets having the same PID, and the continuity counter field increases by 1 for each packet. However, when the adaptation field control field value is equal to '00' or '10', the continuity counter field value should not be increased.

FIG. 20 illustrates a TS packet structure including an adaptation field. More specifically, FIG. 20 illustrates the structure of the TS packet shown in FIG. 19 further including an adaptation field. The adaptation field is configured of a 2-byte adaptation field (AF) header and N3 bytes of stuff bytes. The AF header is configured of an 8-bit AF length field and an 8-bit indicator flag field, so as to indicate the length of the corresponding adaptation field. The length of the payload within the TS packet is equal to 182-N3 (wherein N3 corresponds to the stuff byte length). For example, when the stuff byte length is equal to 182 bytes in the corresponding TS packet, a payload region does not exist. Alternatively, if the stuff byte length is equal to 20 bytes, then the length of the payload region is equal to 162 bytes.

The TS packet encapsulator 140 divides the RS frame, which is generated from the RS frame generator 130, into a 184-byte payload. Herein, a 4-byte TS header (also referred to as an MPEG header) is added to each payload, thereby being encapsulated into a 188-byte TS packet.

At this point, the number of TS packets required for TS-packetizing one RS frame can be calculated by using Equation 3 below.

$$\text{number of TS packets} = \lfloor (N \times 187) / 184 \rfloor + 1 \quad \text{Equation 3}$$

In Equation 3, $\lfloor X \rfloor$ represents a maximum integer not larger than X, and N indicates a number of columns in the corresponding RS frame.

More specifically, in order to know how many TS packets are generated from the RS frame, the size of the RS frame should be known. The size of the RS frame varies depending upon the value of N, which corresponds to the number of columns included in the corresponding RS frame. The value N may be obtained by applying Equation 2.

Also, when one RS frame is TS-packetized, a first TS packet and a last TS packet should be known, so that the transmitter 200 can recover the original RS frame. Therefore, the present invention uses the TS header added to each payload, in order to indicate the number of TS packets being packetized from a single RS frame, a first (or starting) TS packet, a last TS packet, and information that can identify (or distinguish) the RS frame.

More specifically, a PID of the TS header of all TS packets that are being encapsulated from the RS frame is set to have a value corresponding to an ensemble identifier (ID). For example, if the ensemble identifier (ID) corresponding to the RS frame is '0x01', the PID of the TS header in all TS packets that are encapsulated from the RS frame is set to '0x0001h' (i.e., 0000000000001 bit). However, this is merely exemplary, and, therefore, any value that can identify a TS packet packetized from the RS frame may be assigned.

Additionally, in the RS frame, a PUSI field value assigned TS header of a TS packet packetized for the first time is set to '1', and the PUSI field value of each of the remaining TS packets is set to '0'.

More specifically, when the PUSI field value of a TS packet is set to '1', this indicates that the first byte of the payload included in the corresponding TS packet includes the first data byte among the data within a single RS frame. Therefore, when a plurality of TS packets is grouped (or collected) so as to be recovered to the original state by the transmitter 200, the transmitter 200 may find the TS packet having the PUSI value set to '1' and may use the continuity of a continuity counter field value to find the next TS packets. Then, when the transmitter 200 adds the found TS packets, the original RS frame may be recovered. If the PUSI value is set to '0', this indicates that the corresponding

TS packet corresponds to a middle portion or end portion of the respective RS frame and not the beginning portion.

Furthermore, the size of an RS frame may correspond to a multiple of 184 bytes (i.e., $(N \times 187) \bmod 184 = 0$) or may not correspond to a multiple of 184 bytes (i.e., $0 \leq (N \times 187) \bmod 184 \leq 183$). More specifically, when the size of an RS frame does not correspond to a multiple of 184 bytes, this indicates that, among the data of an RS frame, the size of a set of data that is to be TS-packetized last is smaller than the size of a payload (i.e., 184 bytes) included in the TS packet.

In the present invention, the method of TS-packetizing the last data of the RS frame varies depending upon whether the size of the corresponding RS frame is equal to a multiple of 184 bytes, or depending upon whether the size of the corresponding RS frame is not equal to a multiple of 184 bytes.

First of all, when the size of the RS frame corresponds to a multiple of 184 bytes (i.e., $(N \times 187) \bmod 184 = 0$), the last data of the RS frame is already inserted in the payload of the previous TS packet, thereby transmitted to the transmitter **200**. In this case, according to the embodiment of the present invention, the last data of the RS frame uses the last TS packet to notify the transmitter **200** that the transmission by the previous TS packet has been completed. Therefore, in the last TS packet, an adaptation field control field of the TS header is set to '10', and the entire payload region of the corresponding TS packet is stuffed by using the adaptation field. More specifically, when the adaptation field control field of the TS header is set to '10', a payload region does not exist in the corresponding TS packet. As described above, the last TS packet having all 182 bytes stuffed, with the exception of the TS header and the AF header, is used to notify (or indicate) that all data of a single RS frame have been transmitted.

For example, when the number of TS packets calculated by using Equation 3 is equal to '10', the last data of the corresponding RS frame is inserted in the payload of the 9th TS packet, no data of the corresponding RS frame is transmitted to the 10th TS packet. However, the 10th TS packet is used for the purpose of notifying that all data of the corresponding RS frame have been transmitted. At this point, with the exception of the last TS packet, the value of the adaptation field control field for each TS packet is set to '01'.

According to another embodiment of the present invention, when the size of the RS frame does not correspond to a multiple of 184 bytes (i.e., $0 \leq (N \times 187) \bmod 184 \leq 183$), the last data of the RS frame is included in the payload of the last TS packet and then transmitted. At this point, since the RS frame data that is to be inserted in the payload of the last TS packet is smaller than 184 bytes, adequate stuffing is required in the remaining region of the corresponding TS packet.

According to the embodiment of the present invention, the value of the adaptation field control field included in the TS header of the last TS packet is set to '11', and the adaptation field is used to stuff the remaining portion of the last TS packet, thereby inserting the last data of the RS frame. For example, when the RS frame data that is to be transmitted to the last TS packet corresponds to 162 bytes, 20 bytes of stuffing data are inserted after a 2-byte AF header of the last TS packet. Thereafter, 162 bytes of the RS frame data are added immediately after the 20-byte stuffing data. At this point, with the exception of the last TS packet, the value of the adaptation field control field for each TS packet is set to '01'.

FIG. **21** illustrates an example of TS-packetizing an RS frame, when the value of N is equal to 509. When the value **509** is substituted for the value of N in Equation 3, the number of TS packets being packetized from the corresponding RS frame is equal to 518, and the size of the corresponding RS frame is not equal to a multiple of 184 bytes. In this case, this indicates that the last 55 data bytes in the corresponding RS frame are transmitted to the 518th TS packet.

As shown in FIG. **21**, the value of the TS header corresponding to the first TS packet, wherein the first data of the RS frame is to be included, is equal to 0x47000110h. This is because the PUSI field value of the first TS packet is set to '1b', the synchronization byte field value to '01000111b' (i.e., 0x47h), the PID field value to '000000000001b', and the adaptation field control field value to '01b'. Furthermore, it is assumed that each of the transport error indicator field value and the transport priority field value is set to '0b', that the transport scrambling control field is set to '0b', and that the continuity counter field value is set to '0000b' (i.e., 0x0h).

Conversely, the value of the TS header corresponding to the last TS packet, wherein the last data of the RS frame is to be included, is equal to 0x4700013Bh. This is because the PUSI field value of the last TS packet is set to '0b', the synchronization byte field value to '0x47h', the PID field value to '000000000001b', and the adaptation field control field value to '11b'. Furthermore, it is assumed that each of the transport error indicator field value and the transport priority field value is set to '0b', that the transport scrambling control field is set to '00b', and that the continuity counter field value is set to a random (or arbitrary) value (e.g., 0xBh) so that the last TS packet can have a continuity with the previous TS packet. Then, the region following the TS header of the last TS packet is divided into a 129-byte adaptation field region and a 55-byte payload region. Among the 129 bytes of the adaptation field region, 2 bytes are assigned to the AF header so as to indicate the length of the adaptation field, and the remaining 127 bytes of the adaptation field region are stuffed. More specifically, referring to FIG. **21**, the region marked as 'stuffing' corresponds to the adaptation field.

FIG. **22** illustrates a flow chart showing an exemplary process of TS-packetizing the RS frame according to the present invention.

In order to obtain the size of the RS frame, an N value is calculated by using Equation 2 (**S181**). Then, by applying the calculated N value to Equation 3, the number of TS packets that are to be packetized from the RS frame is calculated (**S812**). In step **812**, when the size of the RS frame does not correspond to a multiple of 184 bytes, the number of stuffing bytes that are to stuff the last TS packet is also calculated. Subsequently, the RS frame is divided into 184-byte units, and 4-byte TS header is assigned to each 184-byte unit (**S183** to **S195**).

At this point, when the size of the corresponding RS frame is a multiple of 184, the RS frame is divided into a plurality of 184-byte units, wherein the number of 184-byte units corresponds to the total number of TS packets obtained in step **182** subtracting '1'. In this case, the adaptation field control field value of the TS header included in the last TS packet is set to '10', and the 182 bytes following the 2-byte AF header are filled with 182 bytes of stuffing data.

Meanwhile, when the size of the corresponding RS frame is not equal to a multiple of 184, the RS frame is divided into a plurality of 184-byte units, wherein the number of 184-byte units corresponds to the total number of TS packets

obtained in step **182** subtracting '1'. Accordingly, data having a size smaller than 184 bytes remain in the RS frame, and the corresponding data is included in the last TS packet. In this case, the adaptation field control field value of the TS header included in the last TS packet is set to '11', and the adaptation field is used to fill the remaining portion of the RS frame is filled with stuffing data. For example, when the data of the RS frame that is to be included in the last TS packet corresponds to 55 bytes, the remaining 127 bytes excluding the 2-byte AF header within the adaptation field are filled with stuffing data, and the next 55 bytes are filled with the RS frame data.

More specifically, when the RS frame is divided into 184-byte units, each field value of the TS header that is to be added to each 184-byte unit varies depending upon the position of the respective TS packet. And, each time the RS frame is divided into 184-byte units is counted. In the description of the present invention, the count value will be referred to as a TS packet count value. The maximum TS packet count value corresponds to $\lfloor (N \times 187) / 184 \rfloor + 1$, and the TS packet count is reset when the TS-packetizing of the corresponding RS frame is completed. Settings for the field value of the TS header being added to each 184-byte unit will now be described in detail.

More specifically, in step **183**, the synchronization byte field value of the corresponding TS packet is set to '0x47h', and the continuity counter field value is set to a random value so that the corresponding TS packet can have a continuity with the previous TS packet. Then, each of the transport error indicator field value and the transport priority field value is set to '0b', and the transport scrambling control field value is set to '00b'. Thereafter, it is verified whether the data that is to be included in the TS packet includes the first 184 bytes of the respective RS frame (**S184**).

When it is verified that the data that is to be included in the TS packet contains the first 184 bytes of the RS frame, the PUSI field value of the TS packet is set to '1b' (**S185**). However, when the data that is to be included in the TS packet does not contain the first 184 bytes of the RS frame, the PUSI field value of the TS packet is set to '0b' (**S186**). Subsequently, the PID field value of the TS packet sets an ensemble identifier corresponding to the respective RS frame. For example, when the ensemble identifier is '0x01h', the PID value becomes '0x0001h' (i.e., 0000000000001b).

After performing step **187**, it is verified whether the TS packet count value is equal to the number of TS packets (i.e., $\lfloor (N \times 187) / 184 \rfloor + 1$) calculated in step **182** (**S188**). This is because the method of TS-packetizing the last data of the RS frame varies depending upon whether or not the size of the corresponding RS frame is a multiple of 184. More specifically, in step **188**, when the TS packet count value is not equal to the number of TS packets, the adaptation field control field value within the TS header of the corresponding TS packet is set to '01' (**S189**). And, the payload region is filled with the 184-byte RS frame data (**S190**). Herein, step **189** and step **190** correspond to the packetizing process before the last TS packet.

In step **188**, when the TS packet count value is equal to the number of TS packets, it is verified whether or not the size of the corresponding RS frame is a multiple of 184 (**S191**). More specifically, in case of the last TS packet, it is verified whether the size of the corresponding RS frame is a multiple of 184. Then, when it is verified that the size of the RS frame is a multiple of 184, in step **191**, the adaptation field control field value in the TS header of the last TS packet is set to '10' (**S192**), and the region corresponding to 182 bytes subse-

quent to the 2-byte AF header within the adaptation field is filled with stuffing data (**S193**).

Furthermore, when it is verified that the size of the RS frame is not a multiple of 184, in step **191**, among the RS frame data, data having a size smaller than 184 bytes should be included in the last TS packet. For this, the value of the adaptation field control field of the TS header included in the last TS header is set to '11' (**S194**), and the remaining portion of the last TS packet excluding the last data size of the RS frame is filled with stuffing data by using the adaptation field (**S195**). For example, if the RS frame data that is to be included in the last TS packet is 55 bytes, the remaining 127 bytes excluding the 2-byte AF header within the adaptation field are filled with stuffing data, and the next 55 bytes are filled with RS frame data.

Referring to the flow chart shown in FIG. **22**, it can be known that in order to TS-packetize a series of continuous RS frames, an RS frame checking step is performed only once at the beginning, and then a TS packet header step and a TS packet payload step are serially performed.

As described above, the RS frame is encapsulated to a plurality of TS packets from the TS packet encapsulator **140**, and the encapsulated TS packets are outputted to the TS packet multiplexer **162** of the transport multiplexer **160**. Hereinafter, the TS packets being outputted from the TS packet encapsulator **140** will be referred to as mobile service data packets for simplicity.

At this point, for the transmitter **200** to identify and process the main service data packet and mobile service data packet, identification information is required. According to an embodiment of the present invention, the identification process is performed by using the packet identifier (PID) assigned to the main service data packet and the mobile service data packet.

According to another embodiment of the present invention, by modifying the synchronization bytes within the header of the mobile service data packet, the identification process may be performed by using the synchronization byte value of the corresponding service data packet. For example, by directly outputting the synchronization byte of the main service data packet without changing its value (e.g., 0x47), which is provided (or defined) in the ISO/IEC 13818-1, and by modifying and outputting the synchronization byte of the mobile service data packet, the main service data packet and the mobile service data packet can be distinguished (or identified).

Alternatively, by modifying and outputting the synchronization byte of the main service data packet, and by outputting the synchronization byte of the mobile service data packet without modification, the main service data packet and the mobile service data packet can also be distinguished. The synchronization byte may be modified by using a plurality of methods. For example, the synchronization byte may be modified by performing bitwise inversion or by performing partial inversion on a selection of data bits.

As described above, any information that can identify (or distinguish) the main service data packet and the mobile service data packet may be used as the identification information. Therefore, the present invention will not be limited only to the examples given herein.

Meanwhile, the transport multiplexer used in the existing digital broadcasting system can be used as the transport multiplexer **160**. Namely, in order to multiplex the mobile service data with the main service data and transmit them, a data rate of the main service is limited to a data rate of M Mbps, and L Mbps corresponding to the other data rate is

allocated to the mobile service output from the TS packet encapsulator **140**. In this case, the existing transport multiplexer can be used as it is without any change. Then, the TS packet multiplexer **162** multiplexes the main service data packets output from the main service multiplexer **161** at a data rate of M Mbps with the mobile service data packets output from the TS packet encapsulator **140** at a data rate of L Mbps and transmits the multiplexed data packets to the transmitter.

However, there may be a case where the output data rate of the TS packet multiplexer **162** does not reach 19.39 Mbps even though the output data rate L Mbps of the TS packet encapsulator **140** and the output data rate M Mbps of the main service multiplexer **161** are added to each other.

In this case, the TS packet multiplexer **162** receives null data packets of a data rate of (19.39-M-L) Mbps, multiplexes the null data packets with the main service data packets and the mobile service data packets, and output the multiplexed data packets. In this case, the identification information is included in the null data packets so that the transmitter can identify the null data packets. In this case, the output data rate of the TS packet multiplexer **162** can be adjusted to 19.39 Mbps.

In other words, since the mobile service data are extended by additional encoding in the transmitter, even though the TS packet encapsulator **140** obtains data of L Mbps by packetizing RS frame into TS packets, if the data rate of L Mbps is added to the output data rate of the main service multiplexer **161**, the output data rate of the TS packet multiplexer **162** may be smaller than 19.39 Mbps. In this case, the null data packets are added to the service data packets by the difference so that the output data rate of the TS packet multiplexer **162** is adjusted to 19.39 Mbps.

At this point, the transmitter **200** discards the null data packets transmitted from the service multiplexer **100** instead of transmitting the null data packets.

Further, in order to allow the transmitter **200** to discard the null data packets transmitted from the service multiplexer **100** instead of transmitting them, identification information for identifying the null data packet is required. Herein, the identification information may use values pre-decided in accordance with an agreement between the transmitting system and the receiving system. For example, the value of the synchronization byte within the header of the null data packet may be modified so as to be used as the identification information. Alternatively, a transport_error_indicator flag may also be used as the identification information.

In the description of the present invention, an example of using the transport_error_indicator flag as the identification information will be given to describe an embodiment of the present invention. In this case, the transport_error_indicator flag of the null data packet is set to '1', and the transport_error_indicator flag of the remaining data packets are reset to '0', so as to identify the null data packet. In the present invention, any type of identification information for identifying the null data packets may be used. Therefore, the scope of the present invention is not limited only to the examples set forth in the description of the present invention.

The controller **110** controls the RS frame generation of the RS frame generator **130**, the TS packetization of TS packet encapsulator **140**, the multiplexing processed performed by the main service multiplexer **161** and the TS packet multiplexer **162** of the transport multiplexer **160**, and also controls the null data packet generation.

Transmitter

FIG. 23 illustrates a block diagram showing an example of the transmitter **200** according to an embodiment of the

present invention. Herein, the transmitter **200** includes a controller **201**, a demultiplexer **210**, a packet jitter mitigator **220**, a pre-processor **230**, a packet multiplexer **240**, a post-processor **250**, a synchronization (sync) multiplexer **260**, and a transmission unit **270**.

Herein, when a data packet is received from the service multiplexer **100**, the demultiplexer **210** should identify whether the received data packet corresponds to a main service data packet, a mobile service data packet, or a null data packet.

For example, the demultiplexer **210** uses the PID within the received data packet so as to identify the main service data packet and the mobile service data packet. Then, the demultiplexer **210** uses a transport_error_indicator field to identify the null data packet.

The main service data packet identified by the demultiplexer **210** is outputted to the packet jitter mitigator **220**, the mobile service data packet is outputted to the pre-processor **230**, and the null data packet is discarded.

The pre-processor **230** groups a plurality of mobile service data packets demultiplexed and outputted from the demultiplexer **210**, thereby recovering the original RS frame. The RS frame refers to the TS header of each mobile service data packet, so as to perform the recovery process. At this point, the TS header of the mobile service data packet is removed, and the payload of each mobile service data is grouped to recover the RS frame. Thereafter, additional encoding is performed in the recovered RS frame unit. Furthermore, the pre-processor **230** perform a data group configuring process so that a corresponding data can be positioned in a specific position of a transmission frame depending upon the usage of the data that are to be transmitted. Then, known data, mobile service data, RS parity data, MPEG header, and so on are assigned to predetermined regions within the data group. This is to enable the mobile service data to swiftly and strongly respond to noise and channel changes.

Pre-Processor in the Transmitter

FIG. 24 illustrates a block view showing the structure of a pre-processor **230** according to an embodiment of the present invention. Herein, the pre-processor **230** includes an MH frame encoder **301**, a block processor **302**, a group formatter **303**, a signaling encoder **304**, and a packet formatter **305**. In the pre-processor **230** having the above-described structure, the MH frame encoder **301** groups a plurality of mobile service data packets being inputted through the demultiplexer **210**, so as to recover the original RS frame. Thereafter, an encoding process for error correction is performed in the recovered RS frame unit.

FIG. 25 illustrates an exemplary process of recovering the RS frame from a plurality of mobile service data packets, when the value of N is equal to 509.

Referring to FIG. 25, it is assumed that the value assigned to the TS header in each mobile service data packet is the same as the value assigned to the TS header of each TS packet in the TS-packetizing process shown in FIG. 21. First of all, mobile service data packets, which are set to have PID field values identical to ensemble identifier (ID) values corresponding to the RS frame that is to be recovered, are extracted and stored. According to an embodiment of the present invention, the PID field value of each TS header is set to have the same value as the ensemble identifier.

Then, among the extracted mobile service data packets, when data included in payload region of each mobile service packets from the mobile service data packet having the PUSI field value of the respective TS header set to '1' to the mobile service data packet having the adaptation field con-

trol field of the respective TS header set to '10' or '11' are sequentially grouped, one RS frame is recovered. At this point, since the adaptation field region of the mobile service data packet having its adaptation field control field value set to '10' or '11' does not correspond to a payload region, the stuffing data being inserted in the adaptation field region are not used as the RS frame data. Furthermore, when the RS frame recovery is completed, the TS header of each mobile service data packet that has transmitted the RS frame data is also removed. Then, the TS header of each mobile service data packet configuring the RS frame is assigned with the same PID value, i.e., each of the corresponding TS headers is given an ensemble identifier corresponding to the RS frame.

More specifically, when the PUSI field value in the TS header of a mobile service data packet is set to '1', this indicates the payload of the corresponding mobile service data packet includes the 1st data byte among the data of an RS frame. As described above, by using the PUSI field value of the TS header, the system may know from which mobile service data packet, among the extracted mobile service data packets, the 1st data byte of an RS frame begins. At this point, the adaptation field control field value should be set to '01'. More specifically, an adaptation field region does not exist in the corresponding mobile service data packet.

Among the extracted mobile service data packets, the mobile service data packet having the PUSI field value of the TS header set to '1' is found (or located). Then, by using the continuity of the continuity counter field values, the mobile service data packets following the primarily located mobile service data packet are sequentially located. At this point, the PUSI field value of the TS header in the next mobile service data packets should be set to '0', and the PID value of the next mobile service data packets should be identical to the PID values of the mobile service data packets, which have the PUSI field value set to '1'. Furthermore, the adaptation field control field value should be set to '01'.

This process is performed until the mobile service data packet having the respective adaptation field control field value set to '10' or '11' is located. Thus, mobile service data packets corresponding to a single RS frame are all located (or found). More specifically, when the mobile service data packet has the adaptation field control field value of '10' or '11', this indicates that the corresponding mobile service data packet is the last mobile service data packet of the corresponding RS frame.

At this point, when the adaptation field control field value of a mobile service data packet is set to '10', this indicates that the corresponding mobile service data does not include a payload region and that the remaining 182 bytes of the adaptation field excluding the AF header are filled with stuffing data. More specifically, the last data of the RS frame is already inserted in the payload of the previous mobile service data packet and received. Therefore, when the mobile service data packet having its adaptation field control field value set to '10' is extracted, the MH frame encoder 301 may be informed that the last data of the RS frame, which is to be recovered, has already been received by the previous mobile service data packet.

Additionally, when the adaptation field control field value of a mobile service data packet is set to '11', an adaptation field region and a payload region are both included in the respective mobile service data packet. Herein, the last data of the corresponding RS frame is included in the payload region. At this point, the last data of the RS frame, which is to be inserted in the payload of the corresponding mobile service data packet, is smaller than 184 bytes. And, the

remaining data bytes from the 182 bytes excluding the last data of the RS frame are filled with stuffing data in the adaptation field region.

As described above, when the data included in the payload region starting from the extracted (or located) starting mobile service data packet to the extracted (or located) last mobile service data packet are sequentially grouped, a single RS frame can be recovered. Also, when comparing the recovered RS frame size to the RS frame size based upon the N value, the system can verify whether or not a complete RS frame has been recovered.

FIG. 26 illustrates a flow chart showing the process of recovering an RS frame from a plurality of mobile service data packets according to an embodiment of the present invention.

Firstly, an ensemble identifier corresponding to an RS frame that is to be recovered is selected as the PID field value (S351). Then, when the mobile service data packet is received (S352), it is verified whether or not the PID field value of the received mobile service data packet is identical to the selected PID field value (S353). If it is determined in step 353 that the PIDs are not identical to each other, this indicates that the respective mobile service data packet does not correspond to a desired (or requested) mobile service data packet. Therefore, the process step returns to step 352 so as to receive another mobile service data packet.

Thereafter, if it is determined that the PIDs are identical to each other, it is determined whether or not a mobile service data packet having the PUSI field value of the TS header set to '1' has already been received (S354). More specifically, if the PUSI field value of the TS header in the mobile service data packet is set to '1', this indicates that the payload of the corresponding mobile service data packet includes the 1st data byte among the data of the RS frame that is to be recovered.

In step 354, when a mobile service data packet having the PUSI field value of the TS header set to '1' has already been received, the process step moves on to step 356. In step 356, the received mobile service data packet is stored. At this point, the PUSI field value of the TS header corresponding to the stored mobile service data packet is set to '0'. Furthermore, the adaptation field control field value is set to any one of '01', '10', and '11'. Alternatively, in step 354, when a mobile service data packet having the PUSI field value of the TS header set to '1' has not yet been received, the process step moves on to step 355, thereby verifying whether or not the PUSI field value of the TS header included in the currently received mobile service data packet is equal to '1'.

In the step 355, when it is determined that the PUSI field value of the TS header included in the currently received mobile service data packet is not equal to '1', this indicates that the currently received mobile service data packet does not correspond to a desired (or requested) mobile service data packet. Therefore, the process step returns to step 352 so as to receive another mobile service data packet.

Conversely, in step 355, when it is determined that the PUSI field value of the TS header included in the currently received mobile service data packet is equal to '1', this indicates that the currently received mobile service data packet includes the 1st data byte among the data of the RS frame that is to be recovered. Therefore, the received mobile service data packet is stored (S356). At this point, the adaptation field control field value is set to '01'.

In step 356, when the received mobile service data is stored, it is verified whether or not the adaptation field control field value of the TS header included in the received

mobile service data packet is set to '10' or '11' (S357). Namely, it is verified whether or not the received mobile service data is the last mobile service data configuring the RS frame that is to be recovered.

In step 357, when the adaptation field control field value is not equal to '10' or '11', this indicates that the stored mobile service data packet does not correspond to the last mobile service data packet. Therefore, the process step returns to step 352 so as to further receive mobile service data packets.

Alternatively, in step 357, when the adaptation field control field value is equal to '10' or '11', this indicates that all mobile service data packets starting from the 1st mobile service data packet to the last mobile service data packet of the RS frame that is to be recovered are stored. Accordingly, when the data inserted in the payload of each of the stored mobile service data packets are grouped, an RS frame can be recovered (S358).

At this point, a step verifying whether or not the RS frame has been properly recovered may be further included.

More specifically, it is determined whether or not the size of the RS frame recovered in step 358 is equal to $N \times 187$ bytes (S359). If the size of the recovered RS frame is equal to $N \times 187$ bytes, this indicates that the recovery of the RS frame has been properly performed. Therefore, an error correction encoding process is performed on the recovered RS frame (S360).

However, if the size of the recovered RS frame is not equal to $N \times 187$ bytes, this indicates that the RS frame recovery process has not been properly performed. Therefore, the recovered RS frame is discarded (or deleted) (S361).

Referring to the flow chart of FIG. 26, the MH frame encoder 301 first inputs initial PID settings and, then, repeatedly performs the remaining process steps, thereby being able to sequentially recover RS frames having the same ensemble from the received mobile service data packets.

At this point, the MH frame encoder 301 may include at least one RS frame encoder. More specifically, the number of RS frame encoders that are provided in parallel may be equal to the number of parades within the MH frame. As described above, the MH frame corresponds to a basic time cycle for transmitted at least one parade. Herein, each parade is configured of one or two RS frames.

FIG. 27 is a conceptual block diagram showing an example of the MH frame encoder 301. The MH frame encoder 301 may include an input demultiplexer (DEMUX) 309, M number of RS frame encoders 310 to 31M-1, and an output multiplexer (MUX) 320. Herein, M represent the number of parades included in one MH frame. The input demultiplexer 309 output the inputted mobile service data packet to a corresponding RS frame encoder among M number of RS frame encoders in ensemble units.

For example, the demultiplexer 309 may decide an output path of the mobile service data packet based upon the TS header of the inputted mobile service data packet. At this point, the ensemble may be mapped to the RS frame encoder or a parade. For example, when one parade is configured of one RS frame, each ensemble, RS frame, and parade may be mapped to be in a 1:1:1 (or one-to-one-to-one) correspondence.

According to an embodiment of the present invention, each RS frame encoder groups a plurality of mobile service data packets, each having the corresponding ensemble identifier as the respective PID field value, so as to configure an RS frame and, then, to perform an error correction encoding

process in RS frame units. Also, each RS frame encoder divides the error-correction-encoded RS frame into a plurality of portions, in order to assign the error-correction-encoded RS frame data to a plurality of data groups.

Based upon the RS frame mode of Table 1, data within one RS frame may be assigned either to all of regions A/B/C/D within multiple data groups, or to at least one of regions A/B and regions C/D within multiple data groups.

When the RS frame mode value is equal to '01', i.e., when the data of the primary RS frame are assigned to regions A/B of the corresponding data group and data of the secondary RS frame are assigned to regions C/D of the corresponding data group, each RS frame encoder configures a primary RS frame and a secondary RS frame for each parade. Conversely, when the RS frame mode value is equal to '00', when the data of the primary RS frame are assigned to all of regions A/B/C/D, each RS frame encoder configures a RS frame (i.e., a primary RS frame) for each parade.

Also, each RS frame encoder divides each RS frame into several portions. Each portion of the RS frame is equivalent to a data amount that can be transmitted by a data group. The output multiplexer (MUX) 320 multiplexes portions within M number of RS frame encoders 310 to 310M-1 and then outputted to the block processor 302. For example, if one parade transmits two RS frames, portions of primary RS frames within M number of RS frame encoders 310 to 310M-1 are multiplexed and outputted. Thereafter, portions of secondary RS frames within M number of RS frame encoders 310 to 310M-1 are multiplexed and transmitted.

The input demultiplexer (DEMUX) 309 and the output multiplexer (MUX) 320 operate based upon the control of the controller 201. The controller 201 may provide necessary (or required) FEC modes to each RS frame encoder. The FEC mode includes the RS code mode, which will be described in detail in a later process.

FIG. 28 illustrates a detailed block diagram of an RS frame encoder among a plurality of RS frame encoders within an MH frame encoder.

The primary encoder 410 includes a data randomizer 411, an RS-CRC encoder 412, and an RS frame divider 413. Herein, the data randomizer 411 may be omitted from the primary encoder 410.

The secondary encoder 420 may also include a data randomizer 421, an RS-CRC encoder 422, and an RS frame divider 423. Similarly, the data randomizer 421 may also be omitted from the secondary encoder 420.

According to an embodiment of the present invention, each of the data randomizers 411 and 421 are omitted from the primary encoder 410 and the secondary encoder 420. However, according to another embodiment of the present invention, if the data randomizers 411 and 421 are not omitted, the RS frame is recovered from the randomized mobile service data packets.

More specifically, when a randomizing process is performed on a mobile service data packet by the data randomizer 411 of the primary encoder 410, a randomizing process on the respective mobile service data packet that is to be performed by the data randomizer 251 of the post-processor 250 may be omitted.

The data randomizer 411 may discard the synchronization byte within the mobile service data packet, thereby performing the randomizing process. Alternatively, the randomizing process may also be performed without having to discard the synchronization byte. Such modification or variation may be selected by the system designer. According to an embodiment of the present invention, when performing the randomizing process, the randomizing process may be per-

formed without discarding the synchronization byte within the corresponding mobile service data packet.

The RS-CRC encoder 412 configures (or recovers) an RS frame corresponding to a primary ensemble from the input mobile service data packets. Then, the RS-CRC encoder 412 uses at least one of a Reed-Solomon (RS) code and a cyclic redundancy check (CRC) code in RS frame units, so as to perform forward error correction (FEC) encoding on the recovered RS frame, thereby outputting the processed RS frame to the RS frame divider 413. More specifically, the RS-CRC encoder 412 groups (or gathers) data that are inserted in the payload of each mobile service data packet, so as to configure an RS frame. Then, the RS-CRC encoder 412 performs at least one of an error correction encoding process and an error detection encoding process in RS frame units. Accordingly, robustness may be provided to the mobile service data, thereby scattering group error that may occur during changes in a frequency environment, thereby enabling the mobile service data to respond to the frequency environment, which is extremely vulnerable and liable to frequent changes.

Also, the RS-CRC encoder 412 groups a plurality of RS frame so as to create a super frame, thereby performing a row permutation process in super frame units. The row permutation process may also be referred to as a "row interleaving process". Hereinafter, the process will be referred to as "row permutation" for simplicity. In the present invention, the row permutation process may be omitted.

More specifically, when the RS-CRC encoder 412 performs the process of permuting each row of the super frame in accordance with a pre-determined rule, the position of the rows within the super frame before and after the row permutation process is changed. If the row permutation process is performed by super frame units, and even though the section having a plurality of errors occurring therein becomes very long, and even though the number of errors included in the RS frame, which is to be decoded, exceeds the extent of being able to be corrected, the errors become dispersed within the entire super frame. Thus, the decoding ability is even more enhanced as compared to a single RS frame.

At this point, as an example of the present invention, RS-encoding is applied for the error correction encoding process, and a cyclic redundancy check (CRC) encoding is applied for the error detection process in the RS-CRC encoder 412. When performing the RS-encoding, parity data that are used for the error correction are generated. And, when performing the CRC encoding, CRC data that are used for the error detection are generated.

The CRC data generated by CRC encoding may be used for indicating whether or not the mobile service data have been damaged by the errors while being transmitted through the channel. In the present invention, a variety of error detection coding methods other than the CRC encoding method may be used, or the error correction coding method may be used to enhance the overall error correction ability of the receiving system.

Herein, the RS-CRC encoder 412 refers to a pre-determined transmission parameter provided by the controller so as to perform operations including RS frame configuration, RS encoding, CRC encoding, super frame configuration, and row permutation in super frame units.

FIG. 29 illustrates a process of one or two RS frame being divided into several portions, based upon an RS frame mode value, and a process of each portion being assigned to a corresponding region within the respective data group.

According to an embodiment of the present invention, the data assignment within the data group performs in the group formatter 303.

More specifically, FIG. 29(a) shows an example of the RS frame mode value being equal to '00'. Herein, only the primary encoder 410 of FIG. 28 operates, thereby forming one RS frame for one parade. Then, the RS frame is divided into several portions, and the data of each portion are assigned to regions A/B/C/D within the respective data group.

FIG. 29(b) shows an example of the RS frame mode value being equal to '01'. Herein, both the primary encoder 410 and the secondary encoder 420 of FIG. 28 operate, thereby forming two RS frames for one parade, i.e., one primary RS frame and one secondary RS frame. Then, the primary RS frame is divided into several portions, and the secondary RS frame is divided into several portions. At this point, the data of each portion of the primary RS frame are assigned to regions A/B within the respective data group. And, the data of each portion of the secondary RS frame are assigned to regions C/D within the respective data group.

Detailed Description of the RS Frame

FIG. 30(a) illustrates an example of an RS frame being generated from the RS-CRC encoder 412 according to the present invention.

When the RS frame is created, as shown in FIG. 30(a), the RS-CRC encoder 412 performs a (Nc,Kc)-RS encoding process on each column, so as to generate Nc-Kc(=P) number of parity bytes. Then, the RS-CRC encoder 412 adds the newly generated P number of parity bytes after the very last byte of the corresponding column, thereby creating a column of (187+P) bytes. Herein, as shown in FIG. 30(a), Kc is equal to 187 (i.e., Kc=187), and Nc is equal to 187+P (i.e., Nc=187+P). Herein, the value of P may vary depending upon the RS code mode. Table 6 below shows an example of an RS code mode, as one of the RS encoding information.

TABLE 6

RS code mode	RS code	Number of Parity Bytes (P)
00	(211, 187)	24
01	(223, 187)	36
10	(235, 187)	48
11	Reserved	Reserved

Table 6 shows an example of 2 bits being assigned in order to indicate the RS code mode. The RS code mode represents the number of parity bytes corresponding to the RS frame.

For example, when the RS code mode value is equal to '10', (235,187)-RS-encoding is performed on the RS frame of FIG. 30(a), so as to generate 48 parity data bytes. Thereafter, the 48 parity bytes are added after the last data byte of the corresponding column, thereby creating a column of 235 data bytes.

When the RS frame mode value is equal to '00' in Table 1 (i.e., when the RS frame mode indicates a single RS frame), only the RS code mode of the corresponding RS frame is indicated. However, when the RS frame mode value is equal to '01' in Table 1 (i.e., when the RS frame mode indicates multiple RS frames), the RS code mode corresponding to a primary RS frame and a secondary RS frame. More specifically, it is preferable that the RS code mode is independently applied to the primary RS frame and the secondary RS frame.

When such RS encoding process is performed on all N number of columns, a RS frame having the size of N (row) \times (187+P) (column) bytes may be created, as shown in FIG. 30(b).

Each row of the RS frame is configured of N bytes. However, depending upon channel conditions between the transmitting system and the receiving system, error may be included in the RS frame. When errors occur as described above, CRC data (or CRC code or CRC checksum) may be used on each row unit in order to verify whether error exists in each row unit.

The RS-CRC encoder 412 may perform CRC encoding on the mobile service data being RS encoded so as to create (or generate) the CRC data. The CRC data being generated by CRC encoding may be used to indicate whether the mobile service data have been damaged while being transmitted through the channel.

The present invention may also use different error detection encoding methods other than the CRC encoding method. Alternatively, the present invention may use the error correction encoding method to enhance the overall error correction ability of the receiving system.

FIG. 30(c) illustrates an example of using a 2-byte (i.e., 16-bit) CRC checksum as the CRC data. Herein, a 2-byte CRC checksum is generated for N number of bytes of each row, thereby adding the 2-byte CRC checksum at the end of the N number of bytes. Thus, each row is expanded to (N+2) number of bytes. Equation 4 below corresponds to an exemplary equation for generating a 2-byte CRC checksum for each row being configured of N number of bytes.

$$g(x)=x^{16}+x^{12}+x^5+1 \quad \text{Equation 4}$$

The process of adding a 2-byte checksum in each row is only exemplary. Therefore, the present invention is not limited only to the example proposed in the description set forth herein. As described above, when the process of RS encoding and CRC encoding are completed, the (N \times 187)-byte RS frame is expanded to a (N+2) \times (187+P)-byte RS frame. Based upon an error correction scenario of a RS frame expanded as described above, the data bytes within the RS frame are transmitted through a channel in a row direction. At this point, when a large number of errors occur during a limited period of transmission time, errors also occur in a row direction within the RS frame being processed with a decoding process in the receiving system. However, in the perspective of RS encoding performed in a column direction, the errors are shown as being scattered. Therefore, error correction may be performed more effectively. At this point, a method of increasing the number of parity data bytes (P) may be used in order to perform a more intense error correction process. However, using this method may lead to a decrease in transmission efficiency. Therefore, a mutually advantageous method is required. Furthermore, when performing the decoding process, an erasure decoding process may be used to enhance the error correction performance.

Additionally, the RS-CRC encoder 412 according to the present invention also performs a row permutation (or interleaving) process in super frame units in order to further enhance the error correction performance when error correction the RS frame.

FIG. 31(a) to FIG. 31(d) illustrates an example of performing a row permutation process in super frame units according to the present invention. More specifically, G number of RS frames RS-CRC-encoded is grouped to form a super frame, as shown in FIG. 31(a). At this point, since

each RS frame is formed of (N+2) \times (187+P) number of bytes, one super frame is configured to have the size of (N+2) \times (187+P) \times G bytes.

When a row permutation process permuting each row of the super frame configured as described above is performed based upon a pre-determined permutation rule, the positions of the rows prior to and after being permuted (or interleaved) within the super frame may be altered. More specifically, the i^{th} row of the super frame prior to the interleaving process, as shown in FIG. 31(b), is positioned in the j^{th} row of the same super frame after the row permutation process, as shown in FIG. 31(c). The above-described relation between i and j can be easily understood with reference to a permutation rule as shown in Equation 5 below.

$$j=G(i \bmod (187+P))+[i/(187+P)] \quad \text{Equation 5}$$

$$i=(187+P)(j \bmod G)+[j/G]$$

where $0 \leq i, j \leq (187+P)G-1$; or

where $0 \leq i, j \leq (187+P)G$

Herein, each row of the super frame is configured of (N+2) number of data bytes even after being row-permuted in super frame units.

When all row permutation processes in super frame units are completed, the super frame is once again divided into G number of row-permuted RS frames, as shown in FIG. 31(d), and then provided to the RS frame divider 413. Herein, the number of RS parity bytes and the number of columns should be equally provided in each of the RS frames, which configure a super frame. As described in the error correction scenario of a RS frame, in case of the super frame, a section having a large number of error occurring therein is so long that, even when one RS frame that is to be decoded includes an excessive number of errors (i.e., to an extent that the errors cannot be corrected), such errors are scattered throughout the entire super frame. Therefore, in comparison with a single RS frame, the decoding performance of the super frame is more enhanced.

The above description of the present invention corresponds to the processes of forming (or creating) and encoding an RS frame, when a data group is divided into regions A/B/C/D, and when data of an RS frame are assigned to all of regions A/B/C/D within the corresponding data group. More specifically, the above description corresponds to an embodiment of the present invention, wherein one RS frame is transmitted using one parade. In this embodiment, the secondary encoder 420 does not operate (or is not active).

Meanwhile, 2 RS frames are transmitting using one parade, the data of the primary RS frame may be assigned to regions A/B within the data group and be transmitted, and the data of the secondary RS frame may be assigned to regions C/D within the data group and be transmitted. At this point, the primary encoder 410 receives the mobile service data packets that are to be assigned to regions A/B within the data group, so as to form the primary RS frame, thereby performing RS-encoding and CRC-encoding. Similarly, the secondary encoder 420 receives the mobile service data packets that are to be assigned to regions C/D within the data group, so as to form the secondary RS frame, thereby performing RS-encoding and CRC-encoding. More specifically, the primary RS frame and the secondary RS frame are created independently.

FIG. 32 illustrates examples of receiving the mobile service data packets that are to be assigned to regions A/B within the data group, so as to form the primary RS frame, and receives the mobile service data packets that are to be assigned to regions C/D within the data group, so as to form

the secondary RS frame, thereby performing error correction encoding and error detection encoding on each of the first and secondary RS frames.

More specifically, FIG. 32(a) illustrates an example of the RS-CRC encoder 412 of the primary encoder 410 receiving mobile service data packets of the primary ensemble that are to be assigned to regions A/B within the corresponding data group, so as to create an RS frame having the size of $N1$ (row) \times 187 (column). Then, in this example, the primary encoder 410 performs RS-encoding on each column of the RS frame created as described above, thereby adding $P1$ number of parity data bytes in each column. Finally, the primary encoder 410 performs CRC-encoding on each row, thereby adding a 2-byte checksum in each row.

FIG. 32(b) illustrates an example of the RS-CRC encoder 422 of the secondary encoder 420 receiving mobile service data packets of the secondary ensemble that are to be assigned to regions C/D within the corresponding data group, so as to create an RS frame having the size of $N2$ (row) \times 187 (column). Then, in this example, the secondary encoder 420 performs RS-encoding on each column of the RS frame created as described above, thereby adding $P2$ number of parity data bytes in each column. Finally, the secondary encoder 420 performs CRC-encoding on each row, thereby adding a 2-byte checksum in each row.

At this point, each of the RS-CRC encoders 412 and 422 may refer to a pre-determined transmission parameter provided by the controller 201 and/or a transmission parameter provided from external such as the service multiplexer 100, the RS-CRC encoders 412 and 422 may be informed of RS frame information (including RS frame mode information), RS encoding information (including RS code mode), SCCC information (including SCCC block mode information and SCCC outer code mode information), data group information, and region information within a data group. The RS-CRC encoders 412 and 422 may refer to the transmission parameters for the purpose of RS frame configuration, error correction encoding, error detection encoding. Furthermore, the transmission parameters should also be transmitted to the receiving system so that the receiving system can perform a normal decoding process. At this point, as an example of the present invention, the transmission parameter is transmitted through transmission parameter channel (TPC) to a receiving system. The TPC will be described in detail in a later.

The data of the primary RS frame, which is encoded by RS frame units and row-permuted by super frame units from the RS-CRC encoder 412 of the primary encoder 410, are outputted to the RS frame divider 413. If the secondary encoder 420 also operates in the embodiment of the present invention, the data of the secondary RS frame, which is encoded by RS frame units and row-permuted by super frame units from the RS-CRC encoder 422 of the secondary encoder 420, are outputted to the RS frame divider 423. The RS frame divider 413 of the primary encoder 410 divides the primary RS frame into several portions, which are then outputted to the output multiplexer (MUX) 320. Each portion of the primary RS frame is equivalent to a data amount that can be transmitted by one data group. Similarly, the RS frame divider 423 of the secondary encoder 420 divides the secondary RS frame into several portions, which are then outputted to the output multiplexer (MUX) 320.

Hereinafter, the RS frame divider 413 of the primary RS encoder 410 will now be described in detail. Also, in order to simplify the description of the present invention, it is assumed that an RS frame having the size of N (row) \times 187 (column), as shown in FIG. 30(a) to FIG. 30(c), that P

number of parity data bytes are added to each column by RS-encoding the RS frame, and that a 2-byte checksum is added to each row by CRC-encoding the RS frame. Accordingly, the RS frame divider 413 divides (or partitions) the encoded RS frame having the size of $(N+2)$ (row) \times 187 (column) into several portions, each having the size of PL (wherein PL corresponds to the length of the RS frame portion).

At this point, as shown in Table 2 to Table 5, the value of PL may vary depending upon the RS frame mode, SCCC block mode, and SCCC outer coder mode. Also, the total number of data bytes of the RS-encoded and CRC-encoded RS frame is equal to or smaller than $5\times NoG\times PL$. In this case, the RS frame is divided (or partitioned) into $((5\times NoG)-1)$ number of portions each having the size of PL and one portion having a size equal to smaller than PL . More specifically, with the exception of the last portion of the RS frame, each of the remaining portions of the RS frame has an equal size of PL . If the size of the last portion is smaller than PL , a stuffing byte (or dummy byte) may be inserted in order to fill (or replace) the lacking number of data bytes, thereby enabling the last portion of the RS frame to also be equal to PL . Each portion of an RS frame corresponds to the amount of data that are to be SCCC-encoded and mapped into a single data group of a parade.

FIG. 33(a) and FIG. 33(b) respectively illustrate examples of adding S number of stuffing bytes, when an RS frame having the size of $(N+2)$ (row) \times (187+ P)(column) is divided into $5\times NoG$ number of portions, each having the size of PL . More specifically, the RS-encoded and CRC-encoded RS frame, shown in FIG. 33(a), is divided into several portions, as shown in FIG. 33(b). The number of divided portions at the RS frame is equal to $(5\times NoG)$. Particularly, the first $((5\times NoG)-1)$ number of portions each has the size of PL , and the last portion of the RS frame may be equal to or smaller than PL . If the size of the last portion is smaller than PL , a stuffing byte (or dummy byte) may be inserted in order to fill (or replace) the lacking number of data bytes, as shown in Equation 6 below, thereby enabling the last portion of the RS frame to also be equal to PL .

$$S=(5\times NoG\times PL)-((N+2)\times(187+P)) \quad \text{Equation 6}$$

Herein, each portion including data having the size of PL passes through the output multiplexer 320 of the MH frame encoder 301, which is then outputted to the block processor 302.

At this point, the mapping order of the RS frame portions to a parade of data groups is not identical with the group assignment order defined in Equation 1. When given the group positions of a parade in an MH frame, the SCCC-encoded RS frame portions will be mapped in a time order (i.e., in a left-to-right direction).

For example, as shown in FIG. 11, data groups of the 2nd parade (Parade #1) are first assigned (or allocated) to the 13th slot (Slot #12) and then assigned to the 3rd slot (Slot #2). However, when the data are actually placed in the assigned slots, the data are placed in a time sequence (or time order, i.e., in a left-to-right direction). More specifically, the 1st data group of Parade #1 is placed in Slot #2, and the 2nd data group of Parade #1 is placed in Slot #12.

Block Processor

Meanwhile, the block processor 302 performs an SCCC outer encoding process on the output of the MH frame encoder 301. More specifically, the block processor 302 receives the data of each error correction encoded portion. Then, the block processor 302 encodes the data once again at a coding rate of $1/H$ (wherein H is an integer equal to or

greater than 2 (i.e., $H \geq 2$)), thereby outputting the 1/H-rate encoded data to the group formatter 303. According to the embodiment of the present invention, the input data are encoded either at a coding rate of $1/2$ (also referred to as “ $1/2$ -rate encoding”) or at a coding rate of $1/4$ (also referred to as “ $1/4$ -rate encoding”). The data of each portion outputted from the MH frame encoder 301 may include at least one of pure mobile service data, RS parity data, CRC data, and stuffing data. However, in a broader meaning, the data included in each portion may correspond to data for mobile services. Therefore, the data included in each portion will all be considered as mobile service data and described accordingly.

The group formatter 303 inserts the mobile service data SCCC-outer-encoded and outputted from the block processor 302 in the corresponding region within the data group, which is formed in accordance with a pre-defined rule. Also, in association with the data deinterleaving process, the group formatter 303 inserts various place holders (or known data place holders) in the corresponding region within the data group. Thereafter, the group formatter 303 deinterleaves the data within the data group and the place holders.

According to the present invention, with reference to data after being data-interleaved, as shown in FIG. 5, a data groups is configured of 10 MH blocks (B1 to B10) and divided into 4 regions (A, B, C, and D). Also, as shown in FIG. 5, when it is assumed that the data group is divided into a plurality of hierarchical regions, as described above, the block processor 302 may encode the mobile service data, which are to be inserted to each region based upon the characteristic of each hierarchical region, at different coding rates. For example, the block processor 302 may encode the mobile service data, which are to be inserted in region A/B within the corresponding data group, at a coding rate of $1/2$. Then, the group formatter 303 may insert the $1/2$ -rate encoded mobile service data to region A/B. Also, the block processor 302 may encode the mobile service data, which are to be inserted in region C/D within the corresponding data group, at a coding rate of $1/4$ having higher (or stronger) error correction ability than the $1/2$ -coding rate. Thereafter, the group formatter 303 may insert the $1/2$ -rate encoded mobile service data to region C/D. In another example, the block processor 302 may encode the mobile service data, which are to be inserted in region C/D, at a coding rate having higher error correction ability than the $1/4$ -coding rate. Then, the group formatter 303 may either insert the encoded mobile service data to region C/D, as described above, or leave the data in a reserved region for future usage.

According to another embodiment of the present invention, the block processor 302 may perform a 1/H-rate encoding process in SCCC block units. Herein, the SCCC block includes at least one MH block. At this point, when 1/H-rate encoding is performed in MH block units, the MH blocks (B1 to B10) and the SCCC block (SCB1 to SCB10) become identical to one another (i.e., $SCB1=B1$, $SCB2=B2$, $SCB3=B3$, $SCB4=B4$, $SCB5=B5$, $SCB6=B6$, $SCB7=B7$, $SCB8=B8$, $SCB9=B9$, and $SCB10=B10$). For example, the MH block 1 (B1) may be encoded at the coding rate of $1/2$, the MH block 2 (B2) may be encoded at the coding rate of $1/4$, and the MH block 3 (B3) may be encoded at the coding rate of $1/2$. The coding rates are applied respectively to the remaining MH blocks.

Alternatively, a plurality of MH blocks within regions A, B, C, and D may be grouped into one SCCC block, thereby being encoded at a coding rate of 1/H in SCCC block units. Accordingly, the receiving performance of region C/D may be enhanced. For example, MH block 1 (B1) to MH block

5 (B5) may be grouped into one SCCC block and then encoded at a coding rate of $1/2$. Thereafter, the group formatter 303 may insert the $1/2$ -rate encoded mobile service data to a section starting from MH block 1 (B1) to MH block 5 (B5). Furthermore, MH block 6 (B6) to MH block 10 (B10) may be grouped into one SCCC block and then encoded at a coding rate of $1/4$. Thereafter, the group formatter 303 may insert the $1/4$ -rate encoded mobile service data to another section starting from MH block 6 (B6) to MH block 10 (B10). In this case, one data group may consist of two SCCC blocks.

According to another embodiment of the present invention, one SCCC block may be formed by grouping two MH blocks. For example, MH block 1 (B1) and MH block 6 (B6) may be grouped into one SCCC block (SCB1). Similarly, MH block 2 (B2) and MH block 7 (B7) may be grouped into another SCCC block (SCB2). Also, MH block 3 (B3) and MH block 8 (B8) may be grouped into another SCCC block (SCB3). And, MH block 4 (B4) and MH block 9 (B9) may be grouped into another SCCC block (SCB4). Furthermore, MH block 5 (B5) and MH block 10 (B10) may be grouped into another SCCC block (SCB5). In the above-described example, the data group may consist of 10 MH blocks and 5 SCCC blocks. Accordingly, in a data (or signal) receiving environment undergoing frequent and severe channel changes, the receiving performance of regions C and D, which is relatively more deteriorated than the receiving performance of region A, may be reinforced. Furthermore, since the number of mobile service data symbols increases more and more from region A to region D, the error correction encoding performance becomes more and more deteriorated. Therefore, when grouping a plurality of MH block to form one SCCC block, such deterioration in the error correction encoding performance may be reduced.

As described-above, when the block processor 302 performs encoding at a 1/H-coding rate, information associated with SCCC should be transmitted to the receiving system in order to accurately recover the mobile service data. Table 7 below shows an example of a SCCC block mode, which indicating the relation between an MH block and an SCCC block, among diverse SCCC block information.

TABLE 7

SCB	SCCC Block Mode			
	00	01	10	11
	Description			
	One MH Block per SCCC Block SCB input, MH Block	Two MH Blocks per SCCC Block SCB input, MH Blocks	Reserved	Reserved
SCB1	B1	B1 + B6		
SCB2	B2	B2 + B7		
SCB3	B3	B3 + B8		
SCB4	B4	B4 + B9		
SCB5	B5	B5 + B10		
SCB6	B6	—		
SCB7	B7	—		
SCB8	B8	—		
SCB9	B9	—		
SCB10	B10	—		

More specifically, Table 4 shows an example of 2 bits being allocated in order to indicate the SCCC block mode. For example, when the SCCC block mode value is equal to ‘00’, this indicates that the SCCC block and the MH block are identical to one another. Also, when the SCCC block

mode value is equal to '01', this indicates that each SCCC block is configured of 2 MH blocks.

As described above, if one data group is configured of 2 SCCC blocks, although it is not indicated in Table 7, this information may also be indicated as the SCCC block mode. For example, when the SCCC block mode value is equal to '10', this indicates that each SCCC block is configured of 5 MH blocks and that one data group is configured of 2 SCCC blocks. Herein, the number of MH blocks included in an SCCC block and the position of each MH block may vary depending upon the settings made by the system designer. Therefore, the present invention will not be limited to the examples given herein. Accordingly, the SCCC mode information may also be expanded.

An example of a coding rate information of the SCCC block, i.e., SCCC outer code mode, is shown in Table 8 below.

TABLE 8

SCCC outer code mode (2 bits)	Description
00	Outer code rate of SCCC block is 1/2 rate
01	Outer code rate of SCCC block is 1/4 rate
10	Reserved
11	Reserved

More specifically, Table 8 shows an example of 2 bits being allocated in order to indicate the coding rate information of the SCCC block. For example, when the SCCC outer code mode value is equal to '00', this indicates that the coding rate of the corresponding SCCC block is 1/2. And, when the SCCC outer code mode value is equal to '01', this indicates that the coding rate of the corresponding SCCC block is 1/4.

If the SCCC block mode value of Table 7 indicates '00', the SCCC outer code mode may indicate the coding rate of each MH block with respect to each MH block. In this case, since it is assumed that one data group includes 10 MH blocks and that 2 bits are allocated for each SCCC block mode, a total of 20 bits are required for indicating the SCCC block modes of the 10 MH modes. In another example, when the SCCC block mode value of Table 7 indicates '00', the SCCC outer code mode may indicate the coding rate of each region with respect to each region within the data group. In this case, since it is assumed that one data group includes 4 regions (i.e., regions A, B, C, and D) and that 2 bits are allocated for each SCCC block mode, a total of 8 bits are required for indicating the SCCC block modes of the 4 regions. In another example, when the SCCC block mode value of Table 7 is equal to '01', each of the regions A, B, C, and D within the data group has the same SCCC outer code mode.

Meanwhile, an example of an SCCC output block length (SOBL) for each SCCC block, when the SCCC block mode value is equal to '00', is shown in Table 9 below.

TABLE 9

SCCC Block	SOBL	SIBL	
		1/2 rate	1/4 rate
SCB1 (B1)	528	264	132
SCB2 (B2)	1536	768	384
SCB3 (B3)	2376	1188	594
SCB4 (B4)	2388	1194	597
SCB5 (B5)	2772	1386	693

TABLE 9-continued

SCCC Block	SOBL	SIBL	
		1/2 rate	1/4 rate
SCB6 (B6)	2472	1236	618
SCB7 (B7)	2772	1386	693
SCB8 (B8)	2508	1254	627
SCB9 (B9)	1416	708	354
SCB10 (B10)	480	240	120

More specifically, when given the SCCC output block length (SOBL) for each SCCC block, an SCCC input block length (SIBL) for each corresponding SCCC block may be decided based upon the outer coding rate of each SCCC block. The SOBL is equivalent to the number of SCCC output (or outer-encoded) bytes for each SCCC block. And, the SIBL is equivalent to the number of SCCC input (or payload) bytes for each SCCC block. Table 10 below shows an example of the SOBL and SIBL for each SCCC block, when the SCCC block mode value is equal to '01'.

TABLE 10

SCCC Block	SOBL	SIBL	
		1/2 rate	1/4 rate
SCB1 (B1 + B6)	528	264	132
SCB2 (B2 + B7)	1536	768	384
SCB3 (B3 + B8)	2376	1188	594
SCB4 (B4 + B9)	2388	1194	597
SCB5 (B5 + B10)	2772	1386	693

In order to do so, as shown in FIG. 34, the block processor 302 includes a RS frame portion-SCCC block converter 511, a byte-bit converter 512, a convolution encoder 513, a symbol interleaver 514, a symbol-byte converter 515, and an SCCC block-MH block converter 516. The convolutional encoder 513 and the symbol interleaver 514 are virtually concatenated with the trellis encoding module in the post-processor in order to configure an SCCC block. More specifically, the RS frame portion-SCCC block converter 511 divides the RS frame portions, which are being inputted, into multiple SCCC blocks using the SIBL of Table 9 and Table 10 based upon the RS code mode, SCCC block mode, and SCCC outer code mode. Herein, the MH frame encoder 301 may output only primary RS frame portions or both primary RS frame portions and secondary RS frame portions in accordance with the RS frame mode.

When the RS Frame mode is set to '00', a portion of the primary RS Frame equal to the amount of data, which are to be SCCC outer encoded and mapped to 10 MH blocks (B1 to B10) of a data group, will be provided to the block processor 302. When the SCCC block mode value is equal to '00', then the primary RS frame portion will be split into 10 SCCC Blocks according to Table 9. Alternatively, when the SCCC block mode value is equal to '01', then the primary RS frame will be split into 5 SCCC blocks according to Table 10.

When the RS frame mode value is equal to '01', then the block processor 302 may receive two RS frame portions. The RS frame mode value of '01' will not be used with the SCCC block mode value of '01'. The first portion from the primary RS frame will be SCCC-outer-encoded as SCCC Blocks SCB3, SCB4, SCBS, SCB6, SCB7, and SCB8 by the block processor 302. The SCCC Blocks SCB3 and SCB8 will be mapped to region B and the SCCC blocks SCB4, SCBS, SCB6, and SCB7 shall be mapped to region A by the

group formatter 303. The second portion from the secondary RS frame will also be SCCC-outer-encoded, as SCB1, SCB2, SCB9, and SCB10, by the block processor 302. The group formatter 303 will map the SCCC blocks SCB1 and SCB10 to region D as the MH blocks B1 and B10, respectively. Similarly, the SCCC blocks SCB2 and SCB9 will be mapped to region C as the MH blocks B2 and B9.

The byte-bit converter 512 identifies the mobile service data bytes of each SCCC block outputted from the RS frame portion-SCCC block converter 511 as data bits, which are then outputted to the convolution encoder 513. The convolution encoder 513 performs one of 1/2-rate encoding and 1/4-rate encoding on the inputted mobile service data bits.

FIG. 35 illustrates a detailed block diagram of the convolution encoder 513. The convolution encoder 513 includes two delay units 521 and 523 and three adders 522, 524, and 525. Herein, the convolution encoder 513 encodes an input data bit U and outputs the coded bit U to 5 bits (u0 to u4). At this point, the input data bit U is directly outputted as uppermost bit u0 and simultaneously encoded as lower bit u1u2u3u4 and then outputted. More specifically, the input data bit U is directly outputted as the uppermost bit u0 and simultaneously outputted to the first and third adders 522 and 525.

The first adder 522 adds the input data bit U and the output bit of the first delay unit 521 and, then, outputs the added bit to the second delay unit 523. Then, the data bit delayed by a pre-determined time (e.g., by 1 clock) in the second delay unit 523 is outputted as a lower bit u1 and simultaneously fed-back to the first delay unit 521. The first delay unit 521 delays the data bit fed-back from the second delay unit 523 by a pre-determined time (e.g., by 1 clock). Then, the first delay unit 521 outputs the delayed data bit as a lower bit u2 and, at the same time, outputs the fed-back data to the first adder 522 and the second adder 524. The second adder 524 adds the data bits outputted from the first and second delay units 521 and 523 and outputs the added data bits as a lower bit u3. The third adder 525 adds the input data bit U and the output of the second delay unit 523 and outputs the added data bit as a lower bit u4.

At this point, the first and second delay units 521 and 523 are reset to '0', at the starting point of each SCCC block. The convolution encoder 513 of FIG. 35 may be used as a 1/2-rate encoder or a 1/4-rate encoder. More specifically, when a portion of the output bit of the convolution encoder 513, shown in FIG. 35, is selected and outputted, the convolution encoder 513 may be used as one of a 1/2-rate encoder and a 1/4-rate encoder. Table 11 below shown an example of output symbols of the convolution encoder 513.

TABLE 11

Region	1/2 rate	1/4 rate	
		SCCC block mode = '00'	SCCC block mode = '01'
A, B	(u0, u1)	(u0, u2), (u1, u3)	(u0, u2), (u1, u4)
C, D		(u0, u1), (u3, u4)	

For example, at the 1/2-coding rate, 1 output symbol (i.e., u0 and u1 bits) may be selected and outputted. And, at the 1/4-coding rate, depending upon the SCCC block mode, 2 output symbols (i.e., 4 bits) may be selected and outputted. For example, when the SCCC block mode value is equal to '01', and when an output symbol configured of u0 and u2

and another output symbol configured of u1 and u4 are selected and outputted, a 1/4-rate coding result may be obtained.

The mobile service data encoded at the coding rate of 1/2 or 1/4 by the convolution encoder 513 are outputted to the symbol interleaver 514. The symbol interleaver 514 performs block interleaving, in symbol units, on the output data symbol of the convolution encoder 513. More specifically, the symbol interleaver 514 is a type of block interleaver. Any interleaver performing structural rearrangement (or realignment) may be applied as the symbol interleaver 514 of the block processor. However, in the present invention, a variable length symbol interleaver that can be applied even when a plurality of lengths is provided for the symbol, so that its order may be rearranged, may also be used.

FIG. 36 illustrates a symbol interleaver according to an embodiment of the present invention. Particularly, FIG. 36 illustrates an example of the symbol interleaver when B=2112 and L=4096. Herein, B indicates a block length in symbols that are outputted for symbol interleaving from the convolution encoder 513. And, L represents a block length in symbols that are actually interleaved by the symbol interleaver 514. At this point, the block length in symbols B inputted to the symbol interleaver 514 is equivalent to 4xSOBL. More specifically, since one symbol is configured of 2 bits, the value of B may be set to be equal to 4xSOBL.

In the present invention, when performing the symbol-interleaving process, the conditions of L=2^m (wherein m is an integer) and of L≥B should be satisfied. If there is a difference in value between B and L, (L-B) number of null (or dummy) symbols is added, thereby creating an interleaving pattern, as shown in P' (i) of FIG. 36. Therefore, B becomes a block size of the actual symbols that are inputted to the symbol interleaver 514 in order to be interleaved. L becomes an interleaving unit when the interleaving process is performed by an interleaving pattern created from the symbol interleaver 514.

Equation 7 shown below describes the process of sequentially receiving B number of symbols, the order of which is to be rearranged, and obtaining an L value satisfying the conditions of L=2^m (wherein m is an integer) and of L≥B, thereby creating the interleaving so as to realign (or rearrange) the symbol order.

In relation to all places, wherein 0≤i≤B-1,

$$P'(i) = \{89 \times i \times (i+1) / 2\} \text{ mod } L \tag{Equation 7}$$

Herein, L≥B, L=2^m, wherein m is an integer.

As shown in P' (i) of FIG. 36, the order of B number of input symbols and (L-B) number of null symbols is rearranged by using the above-mentioned Equation 7. Then, as shown in P(i) of FIG. 36, the null byte places are removed, so as to rearrange the order. Starting with the lowest value of i, the P(i) are shifted to the left in order to fill the empty entry locations. Thereafter, the symbols of the aligned interleaving pattern P(i) are outputted to the symbol-byte converter 515 in order. Herein, the symbol-byte converter 515 converts to bytes the mobile service data symbols, having the rearranging of the symbol order completed and then outputted in accordance with the rearranged order, and thereafter outputs the converted bytes to the SCCC block-MH block converter 516. The SCCC block-MH block converter 516 converts the symbol-interleaved SCCC blocks to MH blocks, which are then outputted to the group formatter 303.

If the SCCC block mode value is equal to '00', the SCCC block is mapped at a one-to-one (1:1) correspondence with each MH block within the data group. In another example,

if the SCCC block mode value is equal to '01', each SCCC block is mapped with two MH blocks within the data group. For example, the SCCC block SCB1 is mapped with (B1, B6), the SCCC block SCB2 is mapped with (B2, B7), the SCCC block SCB3 is mapped with (B3, B8), the SCCC block SCB4 is mapped with (B4, B9), and the SCCC block SCB5 is mapped with (B5, B10). The MH block that is outputted from the SCCC block-MH block converter 516 is configured of mobile service data and FEC redundancy. In the present invention, the mobile service data as well as the FEC redundancy of the MH block will be collectively considered as mobile service data.

Group Formatter

The group formatter 303 inserts data of MH blocks outputted from the block processor 302 to the corresponding MH blocks within the data group, which is formed in accordance with a pre-defined rule. Also, in association with the data-deinterleaving process, the group formatter 303 inserts various place holders (or known data place holders) in the corresponding region within the data group. More specifically, apart from the encoded mobile service data outputted from the block processor 302, the group formatter 303 also inserts MPEG header place holders, non-systematic RS parity place holders, main service data place holders, which are associated with the data deinterleaving in a later process, as shown in FIG. 5.

Herein, the main service data place holders are inserted because the mobile service data bytes and the main service data bytes are alternately mixed with one another in regions B to D based upon the input of the data deinterleaver, as shown in FIG. 5. For example, based upon the data outputted after data deinterleaving, the place holder for the MPEG header may be allocated at the very beginning of each packet. Also, in order to configure an intended group format, dummy bytes may also be inserted. Furthermore, the group formatter 303 inserts place holders for initializing the trellis encoding module 256 in the corresponding regions. For example, the initialization data place holders may be inserted in the beginning of the known data sequence. Additionally, the group formatter 303 may also insert signaling information, which are encoded and outputted from the signaling encoder 304, in corresponding regions within the data group. At this point, reference may be made to the signaling information when the group formatter 303 inserts each data type and respective place holders in the data group. The process of encoding the signaling information and inserting the encoded signaling information to the data group will be described in detail in a later process.

After inserting each data type and respective place holders in the data group, the group formatter 303 may deinterleave the data and respective place holders, which have been inserted in the data group, as an inverse process of the data interleaver, thereby outputting the deinterleaved data and respective place holders to the packet formatter 305. More specifically, when the data and respective place holders within the data group, which is configured (or structured) as shown in FIG. 5, are deinterleaved by the group formatter 303 and outputted to the packet formatter 305, the structure of the data group may be identical to the structure shown in FIG. 7. In order to do so, the group formatter 303 may include a group format organizer 527, and a data deinterleaver 529, as shown in FIG. 37. The group format organizer 527 inserts data and respective place holders in the corresponding regions within the data group, as described above. And, the data deinterleaver 529 deinterleaves the inserted data and respective place holders as an inverse process of the data interleaver.

The packet formatter 305 removes the main service data place holders and the RS parity place holders that were allocated for the deinterleaving process from the deinterleaved data being inputted. Then, the packet formatter 305 groups the remaining portion and inserts the 3-byte MPEG header place holder in an MPEG header having a null packet PID (or an unused PID from the main service data packet). Furthermore, the packet formatter 305 adds a synchronization data byte at the beginning of each 187-byte data packet. Also, when the group formatter 303 inserts known data place holders, the packet formatter 303 may insert actual known data in the known data place holders, or may directly output the known data place holders without any modification in order to make replacement insertion in a later process. Thereafter, the packet formatter 305 identifies the data within the packet-formatted data group, as described above, as a 188-byte unit mobile service data packet (i.e., MPEG TS packet), which is then provided to the packet multiplexer 240.

Based upon the control of the controller 201, the packet multiplexer 240 multiplexes the data group packet-formatted and outputted from the packet formatter 306 and the main service data packet outputted from the packet jitter mitigator 220. Then, the packet multiplexer 240 outputs the multiplexed data packets to the data randomizer 251 of the post-processor 250. More specifically, the controller 201 controls the time-multiplexing of the packet multiplexer 240. If the packet multiplexer 240 receives 118 mobile service data packets from the packet formatter 305, 37 mobile service data packets are placed before a place for inserting VSB field synchronization. Then, the remaining 81 mobile service data packets are placed after the place for inserting VSB field synchronization. The multiplexing method may be adjusted by diverse variables of the system design. The multiplexing method and multiplexing rule of the packet multiplexer 240 will be described in more detail in a later process.

Also, since a data group including mobile service data in-between the data bytes of the main service data is multiplexed (or allocated) during the packet multiplexing process, the shifting of the chronological position (or place) of the main service data packet becomes relative. Also, a system object decoder (i.e., MPEG decoder) for processing the main service data of the receiving system, receives and decodes only the main service data and recognizes the mobile service data packet as a null data packet.

Therefore, when the system object decoder of the receiving system receives a main service data packet that is multiplexed with the data group, a packet jitter occurs.

At this point, since a multiple-level buffer for the video data exists in the system object decoder and the size of the buffer is relatively large, the packet jitter generated from the packet multiplexer 240 does not cause any serious problem in case of the video data. However, since the size of the buffer for the audio data in the object decoder is relatively small, the packet jitter may cause considerable problem. More specifically, due to the packet jitter, an overflow or underflow may occur in the buffer for the main service data of the receiving system (e.g., the buffer for the audio data). Therefore, the packet jitter mitigator 220 re-adjusts the relative position of the main service data packet so that the overflow or underflow does not occur in the system object decoder.

In the present invention, examples of repositioning places for the audio data packets within the main service data in order to minimize the influence on the operations of the audio buffer will be described in detail. The packet jitter

mitigator **220** repositions the audio data packets in the main service data section so that the audio data packets of the main service data can be as equally and uniformly aligned and positioned as possible. Additionally, when the positions of the main service data packets are relatively re-adjusted, associated program clock reference (PCR) values may also be modified accordingly. The PCR value corresponds to a time reference value for synchronizing the time of the MPEG decoder. Herein, the PCR value is inserted in a specific region of a TS packet and then transmitted.

In the example of the present invention, the packet jitter mitigator **220** also performs the operation of modifying the PCR value. The output of the packet jitter mitigator **220** is inputted to the packet multiplexer **240**. As described above, the packet multiplexer **240** multiplexes the main service data packet outputted from the packet jitter mitigator **220** with the mobile service data packet outputted from the pre-processor **230** into a burst structure in accordance with a pre-determined multiplexing rule. Then, the packet multiplexer **240** outputs the multiplexed data packets to the data randomizer **251** of the post-processor **250**.

If the inputted data correspond to the main service data packet, the data randomizer **251** performs the same randomizing process as that of the conventional randomizer. More specifically, the synchronization byte within the main service data packet is deleted. Then, the remaining 187 data bytes are randomized by using a pseudo random byte generated from the data randomizer **251**. Thereafter, the randomized data are outputted to the RS encoder/non-systematic RS encoder **252**.

On the other hand, if the inputted data correspond to the mobile service data packet, the data randomizer **251** may randomize only a portion of the data packet. For example, if it is assumed that a randomizing process has already been performed in advance on the mobile service data packet by the pre-processor **230**, the data randomizer **251** deletes the synchronization byte from the 4-byte MPEG header included in the mobile service data packet and, then, performs the randomizing process only on the remaining 3 data bytes of the MPEG header. Thereafter, the randomized data bytes are outputted to the RS encoder/non-systematic RS encoder **252**. More specifically, the randomizing process is not performed on the remaining portion of the mobile service data excluding the MPEG header. In other words, the remaining portion of the mobile service data packet is directly outputted to the RS encoder/non-systematic RS encoder **252** without being randomized. Also, the data randomizer **251** may or may not perform a randomizing process on the known data (or known data place holders) and the initialization data place holders included in the mobile service data packet.

The RS encoder/non-systematic RS encoder **252** performs an RS encoding process on the data being randomized by the data randomizer **251** or on the data bypassing the data randomizer **251**, so as to add 20 bytes of RS parity data. Thereafter, the processed data are outputted to the data interleaver **253**. Herein, if the inputted data correspond to the main service data packet, the RS encoder/non-systematic RS encoder **252** performs the same systematic RS encoding process as that of the conventional broadcasting system, thereby adding the 20-byte RS parity data at the end of the 187-byte data. Alternatively, if the inputted data correspond to the mobile service data packet, the RS encoder/non-systematic RS encoder **252** performs a non-systematic RS encoding process. At this point, the 20-byte RS parity data

obtained from the non-systematic RS encoding process are inserted in a pre-decided parity byte place within the mobile service data packet.

The data interleaver **253** corresponds to a byte unit convolutional interleaver. The output of the data interleaver **253** is inputted to the parity replacer **254** and to the non-systematic RS encoder **255**. Meanwhile, a process of initializing a memory within the trellis encoding module **256** is primarily required in order to decide the output data of the trellis encoding module **256**, which is located after the parity replacer **254**, as the known data pre-defined according to an agreement between the receiving system and the transmitting system. More specifically, the memory of the trellis encoding module **256** should first be initialized before the received known data sequence is trellis-encoded. At this point, the beginning portion of the known data sequence that is received corresponds to the initialization data place holder and not to the actual known data. Herein, the initialization data place holder has been included in the data by the group formatter within the pre-processor **230** in an earlier process. Therefore, the process of generating initialization data and replacing the initialization data place holder of the corresponding memory with the generated initialization data are required to be performed immediately before the inputted known data sequence is trellis-encoded.

Additionally, a value of the trellis memory initialization data is decided and generated based upon a memory status of the trellis encoding module **256**. Further, due to the newly replaced initialization data, a process of newly calculating the RS parity and replacing the RS parity, which is outputted from the data interleaver **253**, with the newly calculated RS parity is required. Therefore, the non-systematic RS encoder **255** receives the mobile service data packet including the initialization data place holders, which are to be replaced with the actual initialization data, from the data interleaver **253** and also receives the initialization data from the trellis encoding module **256**.

Among the inputted mobile service data packet, the initialization data place holders are replaced with the initialization data, and the RS parity data that are added to the mobile service data packet are removed and processed with non-systematic RS encoding. Thereafter, the new RS parity obtained by performing the non-systematic RS encoding process is outputted to the parity replacer **255**. Accordingly, the parity replacer **255** selects the output of the data interleaver **253** as the data within the mobile service data packet, and the parity replacer **255** selects the output of the non-systematic RS encoder **255** as the RS parity. The selected data are then outputted to the trellis encoding module **256**.

Meanwhile, if the main service data packet is inputted or if the mobile service data packet, which does not include any initialization data place holders that are to be replaced, is inputted, the parity replacer **254** selects the data and RS parity that are outputted from the data interleaver **253**. Then, the parity replacer **254** directly outputs the selected data to the trellis encoding module **256** without any modification. The trellis encoding module **256** converts the byte-unit data to symbol units and performs a 12-way interleaving process so as to trellis-encode the received data. Thereafter, the processed data are outputted to the synchronization multiplexer **260**.

FIG. 38 illustrates a detailed diagram of one of 12 trellis encoders included in the trellis encoding module **256**. Herein, the trellis encoder includes first and second multiplexers **531** and **541**, first and second adders **532** and **542**, and first to third memories **533**, **542**, and **544**. More specifically, the first to third memories **533**, **542**, and **544** are

initialized by a set of trellis initialization data inserted in an initialization data place holder by the parity replacer 254 and, then, outputted. More specifically, when the first two 2-bit symbols, which are converted from each trellis initialization data byte, are inputted, the input bits of the trellis encoder will be replaced by the memory values of the trellis encoder, as shown in FIG. 38.

Since 2 symbols (i.e., 4 bits) are required for trellis initialization, the last 2 symbols (i.e., 4 bits) from the trellis initialization bytes are not used for trellis initialization and are considered as a symbol from a known data byte and processed accordingly. When the trellis encoder is in the initialization mode, the input comes from an internal trellis status (or state) and not from the parity replacer 254. When the trellis encoder is in the normal mode, the input symbol provided from the parity replacer 254 will be processed. The trellis encoder provides the converted (or modified) input data for trellis initialization to the non-systematic RS encoder 255.

More specifically, when a selection signal designates a normal mode, the first multiplexer 531 selects an upper bit X2 of the input symbol. And, when a selection signal designates an initialization mode, the first multiplexer 531 selects the output of the first memory 533 and outputs the selected output data to the first adder 532. The first adder 532 adds the output of the first multiplexer 531 and the output of the first memory 533, thereby outputting the added result to the first memory 533 and, at the same time, as a most significant (or uppermost) bit Z2. The first memory 533 delays the output data of the first adder 532 by 1 clock, thereby outputting the delayed data to the first multiplexer 531 and the first adder 532.

Meanwhile, when a selection signal designates a normal mode, the second multiplexer 541 selects a lower bit X1 of the input symbol. And, when a selection signal designates an initialization mode, the second multiplexer 541 selects the output of the second memory 542, thereby outputting the selected result to the second adder 543 and, at the same time, as a lower bit Z1. The second adder 543 adds the output of the second multiplexer 541 and the output of the second memory 542, thereby outputting the added result to the third memory 544. The third memory 544 delays the output data of the second adder 543 by 1 clock, thereby outputting the delayed data to the second memory 542 and, at the same time, as a least significant (or lowermost) bit Z0. The second memory 542 delays the output data of the third memory 544 by 1 clock, thereby outputting the delayed data to the second adder 543 and the second multiplexer 541.

The synchronization multiplexer 260 inserts a field synchronization signal and a segment synchronization signal to the data outputted from the trellis encoding module 256 and, then, outputs the processed data to the pilot inserter 271 of the transmission unit 270. Herein, the data having a pilot inserted therein by the pilot inserter 271 are modulated by the modulator 272 in accordance with a pre-determined modulating method (e.g., a VSB method). Thereafter, the modulated data are transmitted to each receiving system through the radio frequency (RF) up-converter 273.

Multiplexing Method of Packet Multiplexer

Data of the error correction encoded and 1/H-rate encoded primary RS frame (i.e., when the RS frame mode value is equal to '00') or primary/secondary RS frame (i.e., when the RS frame mode value is equal to '01'), are divided into a plurality of data groups by the group formatter 303. Then, the divided data portions are assigned to at least one of regions A to D of each data group or to an MH block among the MH blocks B1 to B10, thereby being deinterleaved.

Then, the deinterleaved data group passes through the packet formatter 305, thereby being multiplexed with the main service data by the packet multiplexer 240 based upon a de-decided multiplexing rule. The packet multiplexer 240 multiplexes a plurality of consecutive data groups, so that the data groups are assigned to be spaced as far apart from one another as possible within the sub-frame. For example, when it is assumed that 3 data groups are assigned to a sub-frame, the data groups are assigned to a 1st slot (Slot #0), a 5th slot (Slot #4), and a 9th slot (Slot #8) in the sub-frame, respectively.

As described-above, in the assignment of the plurality of consecutive data groups, a plurality of parades are multiplexed and outputted so as to be spaced as far apart from one another as possible within a sub-frame. For example, the method of assigning data groups and the method of assigning parades may be identically applied to all sub-frames for each MH frame or differently applied to each MH frame.

FIG. 10 illustrates an example of a plurality of data groups included in a single parade, wherein the number of data groups included in a sub-frame is equal to '3', and wherein the data groups are assigned to an MH frame by the packet multiplexer 240. Referring to FIG. 10, 3 data groups are sequentially assigned to a sub-frame at a cycle period of 4 slots. Accordingly, when this process is equally performed in the 5 sub-frames included in the corresponding MH frame, 15 data groups are assigned to a single MH frame. Herein, the 15 data groups correspond to data groups included in a parade.

When data groups of a parade are assigned as shown in FIG. 10, the packet multiplexer 240 may either assign main service data to each data group, or assign data groups corresponding to different parades between each data group. More specifically, the packet multiplexer 240 may assign data groups corresponding to multiple parades to one MH frame. Basically, the method of assigning data groups corresponding to multiple parades is very similar to the method of assigning data groups corresponding to a single parade. In other words, the packet multiplexer 240 may assign data groups included in other parades to an MH frame according to a cycle period of 4 slots. At this point, data groups of a different parade may be sequentially assigned to the respective slots in a circular method. Herein, the data groups are assigned to slots starting from the ones to which data groups of the previous parade have not yet been assigned. For example, when it is assumed that data groups corresponding to a parade are assigned as shown in FIG. 10, data groups corresponding to the next parade may be assigned to a sub-frame starting either from the 12th slot of a sub-frame.

FIG. 11 illustrates an example of assigning and transmitting 3 parades (Parade #0, Parade #1, and Parade #2) to an MH frame. For example, when the 1st parade (Parade #0) includes 3 data groups for each sub-frame, the packet multiplexer 240 may obtain the positions of each data groups within the sub-frames by substituting values '0' to '2' for *i* in Equation 1. More specifically, the data groups of the 1st parade (Parade #0) are sequentially assigned to the 1st, 5th, and 9th slots (Slot #0, Slot #4, and Slot #8) within the sub-frame. Also, when the 2nd parade includes 2 data groups for each sub-frame, the packet multiplexer 240 may obtain the positions of each data groups within the sub-frames by substituting values '3' and '4' for *i* in Equation 1. More specifically, the data groups of the 2nd parade (Parade #1) are sequentially assigned to the 2nd and 12th slots (Slot #3 and Slot #11) within the sub-frame. Finally, when the 3rd parade includes 2 data groups for each sub-frame, the packet multiplexer 240 may obtain the positions of each data

groups within the sub-frames by substituting values '5' and '6' for i in Equation 1. More specifically, the data groups of the 3rd parade (Parade #2) are sequentially assigned and outputted to the 7th and 11th slots (Slot #6 and Slot #10) within the sub-frame.

As described above, the packet multiplexer 240 may multiplex and output data groups of multiple parades to a single MH frame, and, in each sub-frame, the multiplexing process of the data groups may be performed serially with a group space of 4 slots from left to right. Therefore, a number of groups of one parade per sub-frame (NOG) may correspond to any one integer from '1' to '8'. Herein, since one MH frame includes 5 sub-frames, the total number of data groups within a parade that can be allocated to an MH frame may correspond to any one multiple of '5' ranging from '5' to '40'.

Processing Signaling Information

The present invention assigns signaling information areas for inserting signaling information to some areas within each data group. FIG. 39 illustrates an example of assigning signaling information areas for inserting signaling information starting from the 1st segment of the 4th MH block (B4) to a portion of the 2nd segment. More specifically, 276 (=207+69) bytes of the 4th MH block (B4) in each data group are assigned as the signaling information area. In other words, the signaling information area consists of 207 bytes of the 1st segment and the first 69 bytes of the 2nd segment of the 4th MH block (B4). For example, the 1st segment of the 4th MH block (B4) corresponds to the 17th or 173rd segment of a VSB field.

The signaling information that is to be inserted in the signaling information area is FEC-encoded by the signaling encoder 304, thereby inputted to the group formatter 303.

The group formatter 303 inserts the signaling information, which is FEC-encoded and outputted by the signaling encoder 304, in the signaling information area within the data group. Herein, the signaling information may be identified by two different types of signaling channels: a transmission parameter channel (TPC) and a fast information channel (FIC). Herein, the TPC information corresponds to signaling information including transmission parameters, such as RS frame-associated information, SCCC-associated information, and MH frame-associated information. However, the signaling information presented herein is merely exemplary. And, since the adding or deleting of signaling information included in the TPC may be easily adjusted and modified by one skilled in the art, the present invention will, therefore, not be limited to the examples set forth herein. Furthermore, the FIC is provided to enable a fast service acquisition of data receivers, and the FIC includes cross layer information between the physical layer and the upper layer(s).

FIG. 40 illustrates a detailed block diagram of the signaling encoder 304 according to the present invention. Referring to FIG. 40, the signaling encoder 304 includes a TPC encoder 561, an FIC encoder 562, a block interleaver 563, a multiplexer 564, a signaling randomizer 565, and a PCCC encoder 566. The TPC encoder 561 receives 10-bytes of TPC data and performs (18,10)-RS encoding on the 10-bytes of TPC data, thereby adding 8 bytes of parity data to the 10 bytes of TPC data. The 18 bytes of RS-encoded TPC data are outputted to the multiplexer 564. The FIC encoder 562 receives 37-bytes of FIC data and performs (51,37)-RS encoding on the 37-bytes of FIC data, thereby adding 14 bytes of parity data to the 37 bytes of FIC data.

Thereafter, the 51 bytes of RS-encoded FIC data are inputted to the block interleaver 563, thereby being interleaved in predetermined block units.

Herein, the block interleaver 563 corresponds to a variable length block interleaver. The block interleaver 563 interleaves the FIC data within each sub-frame in TNOG (column)×51 (row) block units and then outputs the interleaved data to the multiplexer 564. Herein, the TNOG corresponds to the total number of data groups being assigned to all sub-frames within an MH frame. The block interleaver 563 is synchronized with the first set of FIC data in each sub-frame. The block interleaver 563 writes 51 bytes of incoming (or inputted) RS codewords in a row direction (i.e., row-by-row) and left-to-right and up-to-down directions and reads 51 bytes of RS codewords in a column direction (i.e., column-by-column) and left-to-right and up-to-down directions, thereby outputting the RS codewords.

The multiplexer 564 multiplexes the RS-encoded TPC data from the TPC encoder 561 and the block-interleaved FIC data from the block interleaver 563 along a time axis. Then, the multiplexer 564 outputs 69 bytes of the multiplexed data to the signaling randomizer 565. The signaling randomizer 565 randomizes the multiplexed data and outputs the randomized data to the PCCC encoder 566. The signaling randomizer 565 may use the same generator polynomial of the randomizer used for mobile service data. Also, initialization occurs in each data group. The PCCC encoder 566 corresponds to an inner encoder performing PCCC-encoding on the randomized data (i.e., signaling information data). The PCCC encoder 566 may include 6 even component encoders and 6 odd component encoders.

FIG. 41 illustrates an example of a syntax structure of TPC data being inputted to the TPC encoder 561. The TPC data are inserted in the signaling information area of each data group and then transmitted. The TPC data may include a sub-frame_number field, a slot_number field, a parade_id field, a starting_group_number (SGN) field, a number_of_groups (NoG) field, a parade_repetition_cycle (PRC) field, an RS_frame_mode field, an RS_code_mode_primary field, an RS_code_mode_secondary field, an SCCC_block_mode field, an SCCC_outer_code_mode_A field, an SCCC_outer_code_mode_B field, an SCCC_outer_code_mode_C field, an SCCC_outer_code_mode_D field, an FIC_version field, a parade_continuity_counter field, and a TNOG field.

The Sub-Frame_number field corresponds to the current Sub-Frame number within the MH frame, which is transmitted for MH frame synchronization. The value of the Sub-Frame_number field may range from 0 to 4. The Slot_number field indicates the current slot number within the sub-frame, which is transmitted for MH frame synchronization. Also, the value of the Sub-Frame_number field may range from 0 to 15. The Parade_id field identifies the parade to which this group belongs. The value of this field may be any 7-bit value. Each parade in a MH transmission shall have a unique Parade_id field.

Communication of the Parade_id between the physical layer and the management layer may be performed by means of an Ensemble_id field formed by adding one bit to the left of the Parade_id field. If the Ensemble_id field is used for the primary Ensemble delivered through this parade, the added MSB shall be equal to '0'. Otherwise, if the Ensemble_id field is used for the secondary ensemble, the added MSB shall be equal to '1'. Assignment of the Parade_id values may occur at a convenient level of the system, usually in the management layer. The starting_group_number (SGN) field shall be the first Slot_number for a parade to which this group belongs, as determined by Equation 1 (i.e.,

after the Slot numbers for all preceding parades have been calculated). The SGN and NoG shall be used according to Equation 1 to obtain the slot numbers to be allocated to a parade within the sub-frame.

The number_of_Groups (NoG) field shall be the number of groups in a sub-frame assigned to the parade to which this group belongs, minus 1, e.g., NoG=0 implies that one group is allocated (or assigned) to this parade in a sub-frame. The value of NoG may range from 0 to 7. This limits the amount of data that a parade may take from the main (legacy) service data, and consequently the maximum data that can be carried by one parade. The slot numbers assigned to the corresponding Parade can be calculated from SGN and NoG, using Equation 1. By taking each parade in sequence, the specific slots for each parade will be determined, and consequently the SGN for each succeeding parade. For example, if for a specific parade SGN=3 and NoG=3 (010b for 3-bit field of NoG), substituting i=3, 4, and 5 in Equation 1 provides slot numbers 12, 2, and 6.

The Parade_repetition_cycle (PRC) field corresponds to the cycle time over which the parade is transmitted, minus 1, specified in units of MH frames, as described in Table 12.

TABLE 12

PRC	Description
000	This parade shall be transmitted once every MH frame.
001	This parade shall be transmitted once every 2 MH frames.
010	This parade shall be transmitted once every 3 MH frames.
011	This parade shall be transmitted once every 4 MH frames.
100	This parade shall be transmitted once every 5 MH frames.
101	This parade shall be transmitted once every 6 MH frames.
110	This parade shall be transmitted once every 7 MH frames.
111	Reserved

For example, if PRC field value is equal to '001', this indicates that the parade shall be transmitted once every 2 MH frame.

The RS_Frame_mode field shall be as defined in Table 1. The RS_Frame_mode field represents that one parade transmits one RS frame or two RS frames.

The RS_code_mode_primary field shall be the RS code mode for the primary RS frame. Herein, the RS_code_mode_primary field is defined in Table 6.

The RS_code_mode_secondary field shall be the RS code mode for the secondary RS frame. Herein, the RS_code_mode_secondary field is defined in Table 6.

The SCCC_Block_mode field represents how MH blocks within a data group are assigned to SCCC block. The SCCC_Block_mode field shall be as defined in Table 7.

The SCCC_outer_code_mode_A field corresponds to the SCCC outer code mode for Region A within a data group. The SCCC outer code mode is defined in Table 8.

The SCCC_outer_code_mode_B field corresponds to the SCCC outer code mode for Region B within the data group. The SCCC_outer_code_mode_C field corresponds to the SCCC outer code mode for Region C within the data group. And, the SCCC_outer_code_mode_D field corresponds to the SCCC outer code mode for Region D within the data group.

The FIC_version field represents a version of FIC data.

The Parade_continuity_counter field counter may increase from 0 to 15 and then repeat its cycle. This counter shall increment by 1 every (PRC+1) MH frames. For example, as shown in Table 12, PRC=011 (decimal 3) implies that Parade_continuity_counter increases every fourth MH frame.

The TNOG field may be identical for all sub-frames in an MH Frame.

However, the information included in the TPC data presented herein is merely exemplary. And, since the adding or deleting of information included in the TPC may be easily adjusted and modified by one skilled in the art, the present invention will, therefore, not be limited to the examples set forth herein.

Since the TPC data (excluding the Sub-Frame_number field and the Slot_number field) for each parade do not change their values during an MH frame, the same information is repeatedly transmitted through all MH groups belonging to the corresponding parade during an MH frame. This allows very robust and reliable reception of the TPC data. Because the Sub-Frame_number and the Slot_number are increasing counter values, they also are robust due to the transmission of regularly expected values.

Furthermore, the FIC data is provided to enable a fast service acquisition of data receivers, and the FIC information includes cross layer information between the physical layer and the upper layer(s).

FIG. 42 illustrates an example of a transmission scenario of the TPC data and the FIC data. The values of the Sub-Frame_number field, Slot_number field, Parade_id field, Parade_repetition_cycle field, and Parade_continuity_counter field may correspond to the current MH frame throughout the 5 sub-frames within a specific MH frame. Some of TPC parameters and FIC data are signaled in advance.

The SGN, NoG and all FEC modes may have values corresponding to the current MH frame in the first two sub-frames. The SGN, NoG and all FEC modes may have values corresponding to the frame in which the parade next appears throughout the 3rd, 4th and 5th sub-frames of the current MH frame. This enables the MH receivers to receive (or acquire) the transmission parameters in advance very reliably.

For example, when Parade_repetition_cycle='000', the values of the 3rd, 4th and 5th sub-frames of the current MH frame correspond to the next MH frame. Also, when Parade_repetition_cycle='011', the values of the 3rd, 4th, and 5th sub-frames of the current MH frame correspond to the 4th MH frame and beyond.

The FIC_version field and the FIC_data field may have values that apply to the current MH Frame during the 1st sub-frame and the 2nd sub-frame, and they shall have values corresponding to the MH frame immediately following the current MH frame during the 3rd, 4th, and 5th sub-frames of the current MH frame.

Meanwhile, the receiving system may turn the power on only during a slot to which the data group of the designated (or desired) parade is assigned, and the receiving system may turn the power off during the remaining slots, thereby reducing power consumption of the receiving system. Such characteristic is particularly useful in portable or mobile receivers, which require low power consumption. For example, it is assumed that data groups of a 1st parade with NOG=3, a 2nd parade with NOG=2, and a 3rd parade with NOG=3 are assigned to one MH frame, as shown in FIG. 43. It is also assumed that the user has selected a mobile service included in the 1st parade using the keypad provided on the remote controller or terminal. In this case, the receiving system turns the power on only during a slot that data groups of the 1st parade is assigned, as shown in FIG. 43, and turns the power off during the remaining slots, thereby reducing power consumption, as described above. At this point, the power is required to be turned on briefly earlier than the slot

to which the actual designated data group is assigned (or allocated). This is to enable the tuner or demodulator to converge in advance.

Assignment of Known Data (or Training Signal)

In addition to the payload data, the MH transmission system inserts long and regularly spaced training sequences into each group. The regularity is an especially useful feature since it provides the greatest possible benefit for a given number of training symbols in high-Doppler rate conditions. The length of the training sequences is also chosen to allow fast acquisition of the channel during bursted power-saving operation of the demodulator. Each group contains 6 training sequences. The training sequences are specified before trellis-encoding. The training sequences are then trellis-encoded and these trellis-encoded sequences also are known sequences. This is because the trellis encoder memories are initialized to pre-determined values at the beginning of each sequence. The form of the 6 training sequences at the byte level (before trellis-encoding) is shown in FIG. 44. This is the arrangement of the training sequence at the group formatter 303.

The 1st training sequence is located at the last 2 segments of the 3rd MH block (B3). The 2nd training sequence may be inserted at the 2nd and 3rd segments of the 4th MH block (B4). The 2nd training sequence is next to the signaling area, as shown in FIG. 5. Then, the 3rd training sequence, the 4th training sequence, the 5th training sequence, and the 6th training sequence may be placed at the last 2 segments of the 4th, 5th, 6th, and 7th MH blocks (B4, B5, B6, and B7), respectively. As shown in FIG. 44, the 1st training sequence, the 3rd training sequence, the 4th training sequence, the 5th training sequence, and the 6th training sequence are spaced 16 segments apart from one another. Referring to FIG. 44, the dotted area indicates trellis initialization data bytes, the lined area indicates training data bytes, and the white area includes other bytes such as the FEC-coded MH service data bytes, FEC-coded signaling data, main service data bytes, RS parity data bytes (for backwards compatibility with legacy ATSC receivers) and/or dummy data bytes.

FIG. 45 illustrates the training sequences (at the symbol level) after trellis-encoding by the trellis encoder. Referring to FIG. 45, the dotted area indicates data segment sync symbols, the lined area indicates training data symbols, and the white area includes other symbols, such as FEC-coded mobile service data symbols, FEC-coded signaling data, main service data symbols, RS parity data symbols (for backwards compatibility with legacy ATSC receivers), dummy data symbols, trellis initialization data symbols, and/or the first part of the training sequence data symbols. Due to the intra-segment interleaving of the trellis encoder, various types of data symbols will be mixed in the white area.

After the trellis-encoding process, the last 1416 (=588+828) symbols of the 1st training sequence, the 3rd training sequence, the 4th training sequence, the 5th training sequence, and the 6th training sequence commonly share the same data pattern. Including the data segment synchronization symbols in the middle of and after each sequence, the total length of each common training pattern is 1424 symbols. The 2nd training sequence has a first 528-symbol sequence and a second 528-symbol sequence that have the same data pattern. More specifically, the 528-symbol sequence is repeated after the 4-symbol data segment synchronization signal. At the end of each training sequence, the memory contents of the twelve modified trellis encoders shall be set to zero (0).

Receiving System

FIG. 46 is a block diagram illustrating a receiving system according to an embodiment of the present invention.

The receiving system of FIG. 46 includes a tuner 1301, a demodulating unit 1302, a demultiplexer 1303, a program table buffer 1304, a program table decoder 1305, a program table storage unit 1306, a data handler 1307, a middleware engine 1308, an A/V decoder 1309, an A/V post-processor 1310, an application manager 1311, and a user interface 1314. The application manager 1311 may include a channel manager 1312 and a service manager 1313.

In FIG. 46, solid lines indicate data flows and dotted lines indicate control flows.

The tuner 1301 tunes to a frequency of a specific channel through any of an antenna, a cable, or a satellite and down-converts the frequency to an Intermediate Frequency (IF) signal and outputs the IF signal to the demodulating unit 1302. Here, the tuner 1301 is controlled by the channel manager 1312 in the application manager 1311 and reports the result and strength of a broadcast signal of the tuned channel to the channel manager 1312. Data received through the frequency of the specific channel includes main service data, mobile service data, a transmission parameter, and program table information for decoding the main service data and the mobile service data.

The demodulating unit 1302 performs VSB demodulation, channel equalization, etc., on the signal output from the tuner 1301 and identifies and separately outputs main service data and mobile service data. The demodulating unit 1302 will be described in detail in a later.

On the other hand, the transmitter can transmit signaling information (or TPC information) including transmission parameters by inserting the signaling information into at least one of a field synchronization region, a known data region, and a mobile service data region. Accordingly, the demodulating unit 1302 can extract the transmission parameters from the field synchronization region, the known data region, and the mobile service data region.

The transmission parameters may include sub-frame information, slot information, parade-related information (for example, a parade_id, a parade repeat period, etc.), information of data groups in a sub-frame, RS frame mode information, RS code mode information, SCCC block mode information, SCCC outer code mode information, FIC version information, etc.

The demodulating unit 1302 performs block decoding, RS frame decoding, etc., using the extracted transmission parameters. For example, the demodulating unit 1302 performs block decoding of each region in a data group with reference to SCCC-related information (for example, SCCC block mode information or an SCCC outer code mode) included in the transmission parameters and performs RS frame decoding of each region included in the data group with reference to RS-related information (for example, an RS code mode).

In the embodiment of the present invention, an RS frame including mobile service data demodulated by the demodulating unit 1302 is input to the demultiplexer 1303.

That is, data inputted to the demultiplexer 1303 has an RS frame data format as shown in FIG. 17(a) or FIG. 17(b).

More specifically, the RS frame decoder of the demodulating unit 1302 performs the reverse of the encoding process performed at the RS frame encoder of the transmission system to correct errors in the RS frame and then outputs the error-corrected RS frame to a data derandomizer. The data derandomizer then performs derandomizing on the error-corrected RS frame through the reverse of the random-

izing process performed at the transmission system to obtain an RS frame as shown in FIG. 17(a) or FIG. 17(b).

The demultiplexer 1303 may receive RS frames of all parades and may also receive only an RS frame of a parade including a mobile service that the user desires to receive through power supply control. For example, when RS frames of all parades are received, the demultiplexer 1303 can demultiplex a parade including a mobile service that the user desires to receive using a parade_id.

One parade carries one or two RS frames and one ensemble is mapped to one RS frame. Therefore, when one parade carries two RS frames, the demultiplexer 1303 needs to identify an RS frame carrying an ensemble including mobile service data to be decoded from a parade containing a mobile service that the user desires to receive. That is, when a received single parade or a parade demultiplexed from a plurality of parades carries a primary ensemble and a secondary ensemble, the demultiplexer 1303 selects one of the primary and secondary ensembles.

In an embodiment, the demultiplexer 1303 can demultiplex an RS frame carrying an ensemble including mobile service data to be decoded using an ensemble_id created by adding one bit to a left position of the parade_id.

The demultiplexer 1303 refers to the MH header of the MH service data packet within the RS frame corresponding to the ensemble including the mobile service data that are to be decoded, thereby identifying when the corresponding MH service data packet is the program table information or the IP datagram of the mobile service data. Alternatively, when the program table information and the mobile service data are both configured in the form of IP datagrams, the demultiplexer 1303 may use the IP address in order to identify the IP datagram of the program table information and the mobile service data.

Herein, the identified program table information is outputted to the program table buffer 1304. And, audio/video/data streams are separated from the IP datagram of mobile service data that are to be selected among the IP datagrams of the identified mobile service data, thereby being respectively outputted to the A/V decoder 1309 and/or the data handler 1307.

According to an embodiment of the present invention, when the stuff_indicator field within the MH header of the MH service data packet indicates that stuffing bytes are inserted in the payload of the corresponding MH service data packet, the demultiplexer 1303 removes the stuffing bytes from the payload of the corresponding MH service data packet. Then, the demultiplexer 1303 identifies the program table information and the mobile service data. Thereafter, the demultiplexer 1303 identifies A/V/D streams from the identified mobile service data.

The program table buffer 1304 temporarily stores the section-type program table information and then outputs the section-type program table information to the program table decoder 1305.

The program table decoder 1305 identifies tables using a table_id and a section_length in the program table information and parses sections of the identified tables and produces and stores a database of the parsed results in the program table storage unit 1306. For example, the program table decoder 1305 collects sections having the same table identifier (table_id) to construct a table. The program table decoder 1305 then parses the table and produces and stores a database of the parsed results in the program table storage unit 1306.

The A/V decoder 1309 decodes the audio and video streams outputted from the demultiplexer 1303 using audio

and video decoding algorithms, respectively. The decoded audio and video data is outputted to the A/V post-processor 1310.

Here, at least one of an AC-3 decoding algorithm, an MPEG 2 audio decoding algorithm, an MPEG 4 audio decoding algorithm, an AAC decoding algorithm, an AAC+ decoding algorithm, an HE AAC decoding algorithm, an AAC SBR decoding algorithm, an MPEG surround decoding algorithm, and a BSAC decoding algorithm can be used as the audio decoding algorithm and at least one of an MPEG 2 video decoding algorithm, an MPEG 4 video decoding algorithm, an H.264 decoding algorithm, an SVC decoding algorithm, and a VC-1 decoding algorithm can be used as the video decoding algorithm.

The data handler 8507 processes data stream packets required for data broadcasting among data stream packets separated (or identified) by the demultiplexer 1303 and provides the processed data stream packets to the middleware engine 1310 to allow the middleware engine 1310 to be multiplexed them with A/V data. In an embodiment, the middleware engine 1310 is a Java middleware engine.

The application manager 1311 receives a key input from the TV viewer and displays a Graphical User Interface (GUI) on the TV screen in response to a viewer request through a User Interface (UI). The application manager 1311 also writes and reads information regarding overall GUI control of the TV, user requests, and TV system states to and from a memory (for example, NVRAM or flash memory). In addition, the application manager 1311 can receive parade-related information (for example, a parade_id) from the demodulating unit 1302 to control the demultiplexer 1303 to select an RS frame of a parade including a required mobile service. The application manager 1311 can also receive an ensemble_id to control the demultiplexer 1303 to select an RS frame of an ensemble including mobile service data to be decoded from the parade. The application manager 1311 also controls the channel manager 1312 to perform channel-related operations (for example, channel map management and program table decoder operations).

The channel manager 1312 manages physical and logical channel maps and controls the tuner 1301 and the program table decoder 1305 to respond to a channel-related request of the viewer. The channel manager also requests that the program table decoder 1305 parse a channel-related table of a channel to be tuned and receives the parsing results from the program table decoder 1305.

Demodulating Unit Within Receiving System

FIG. 47 illustrates an example of a demodulating unit in a digital broadcast receiving system according to the present invention. The demodulating unit of FIG. 47 uses known data information, which is inserted in the mobile service data section and, then, transmitted by the transmitting system, so as to perform carrier synchronization recovery, frame synchronization recovery, and channel equalization, thereby enhancing the receiving performance. Also the demodulating unit may turn the power on only during a slot to which the data group of the designated (or desired) parade is assigned, thereby reducing power consumption of the receiving system.

Referring to FIG. 47, the demodulating unit includes an operation controller 2000, a demodulator 2002, an equalizer 2003, a known sequence detector 2004, a block decoder 2005, and a RS frame decoder 2006. The demodulating unit may further include a main service data processor 2008. The main service data processor 2008 may include a data deinterleaver, a RS decoder, and a data derandomizer. The demodulating unit may further include a signaling decoder 2013.

The receiving system also may further include a power controller **5000** for controlling power supply of the demodulating unit.

More specifically, a frequency of a particular channel tuned by a tuner down converts to an intermediate frequency (IF) signal. Then, the down-converted data **2001** outputs the down-converted IF signal to the demodulator **2002** and the known sequence detector **2004**. At this point, the down-converted data **2001** is inputted to the demodulator **2002** and the known sequence detector **2004** via analog/digital converter ADC (not shown). The ADC converts pass-band analog IF signal into pass-band digital IF signal.

The demodulator **2002** performs self gain control, carrier recovery, and timing recovery processes on the inputted pass-band digital IF signal, thereby modifying the IF signal to a base-band signal. Then, the demodulator **2002** outputs the newly created base-band signal to the equalizer **2003** and the known sequence detector **2004**.

The equalizer **2003** compensates the distortion of the channel included in the demodulated signal and then outputs the error-compensated signal to the block decoder **2005**.

At this point, the known sequence detector **2004** detects the known sequence position information inserted by the transmitting end from the input/output data of the demodulator **2002** (i.e., the data prior to the demodulation process or the data after the demodulation process). Thereafter, the position information along with the symbol sequence of the known data, which are generated from the detected position, is outputted to the operation controller **2000**, the demodulator **2002**, the equalizer **2003**, and the signaling decoder **2013**. Also, the known sequence detector **2004** outputs a set of information to the block decoder **2005**. This set of information is used to allow the block decoder **2005** of the receiving system to identify the mobile service data that are processed with additional encoding from the transmitting system and the main service data that are not processed with additional encoding.

In addition, although the connection status is not shown in FIG. **47**, the information detected from the known sequence detector **2004** may be used throughout the entire receiving system and may also be used in the RS frame decoder **2006**.

The data demodulated in the demodulator **2002** or the data equalized in the channel equalizer **2003** is inputted to the signaling decoder **2013**. The known data position information detected in the known sequence detector **2004** is inputted to the signaling decoder **2013**.

The signaling decoder **2013** extracts and decodes signaling information (e.g., TPC information), which inserted and transmitted by the transmitting end, from the inputted data, the decoded signaling information provides to blocks requiring the signaling information.

More specifically, the signaling decoder **2013** extracts and decodes TPC data, which inserted and transmitted by the transmitting end, from the equalized data, and then the decoded TPC data outputs to the operation controller **2000**, the known sequence detector **2004**, and the power controller **5000**. For example, the TPC data is inserted in a signaling information region of each data group, and then is transmitted to a receiving system.

Herein, the TPC data may include RS frame-associated information, SCCC-associated information, MH frame-associated information, and so on, as shown in FIG. **41**. The RS frame-associated information may include RS frame mode information and RS code mode information. The SCCC-associated information may include SCCC block mode information and SCCC outer code mode information. The MH frame-associated information may include sub-

frame count information, slot count information, parade_id information, SGN information, NoG information, and so on.

At this point, the signaling decoder **2013** can know the signaling information region within a data group by using the known data information being outputted from the known sequence detector **2004**. Namely, the 1st known sequence (or training sequence) is located at the last 2 segments of the 3rd MH block (B3) within the data group. The 2nd training sequence may be inserted at the 2nd and 3rd segments of the 4th MH block (B4). The 2nd known sequence is located at between 2nd and 3rd segments of the 4th MH block (B4) within the data group. Since the 2nd known sequence is inserted and received next to the signaling information area, the signaling decoder **2013** may extract and decode signaling information included in the signaling information region from the data being outputted in the demodulator **2002** or the channel equalizer **2003**.

The power controller **5000** is inputted the MH frame-associated information from the signaling decoder **2013**, and controls power of the tuner and the demodulating unit. Alternatively, the power controller **5000** is inputted a power control information from the operation controller **2000**, and controls power of the tuner and the demodulating unit.

According to the embodiment of the present invention, the power controller **5000** turns the power on only during a slot to which a slot of the parade including user-selected mobile service is assigned. The power controller **5000** then turns the power off during the remaining slots.

For example, it is assumed that data groups of a 1st parade with NOG=3, a 2nd parade with NOG=2, and a 3rd parade with NOG=3 are assigned to one MH frame, as shown in FIG. **43**. It is also assumed that the user has selected a mobile service included in the 1st parade using the keypad provided on the remote controller or terminal. In this case, the power controller **5000** turns the power on only during a slot that data groups of the 1st parade is assigned, as shown in FIG. **43**, and turns the power off during the remaining slots, thereby reducing power consumption.

The demodulator **2002** uses the known data symbol sequence during the timing and/or carrier recovery, thereby enhancing the demodulating performance. Similarly, the equalizer **2003** uses the known data so as to enhance the equalizing performance. Moreover, the decoding result of the block decoder **2005** may be fed-back to the equalizer **2003**, thereby enhancing the equalizing performance.

Demodulator and Known Sequence Detector

At this point, the transmitting system may receive a data frame (or VSB frame) including a data group which known data sequence (or training sequence) is periodically inserted therein, as shown in FIG. **5**. Herein, the data group is divided into regions A to D, as shown in FIG. **5**. More specifically, in the example of the present invention, each region A, B, C, and D are further divided into MH blocks B4 to B7, MH blocks B3 and B8, MH blocks B2 and B9, MH blocks B1 and B10, respectively.

Referring to FIG. **44** and FIG. **45**, known data sequence having the same pattern are included in each known data section that is being periodically inserted. Herein, the length of the known data sequence having identical data patterns may be either equal to or different from the length of the entire (or total) known data sequence of the corresponding known data section (or block). If the two lengths are different from one another, the length of the entire known data sequence should be longer than the length of the known data sequence having identical data patterns. In this case, the same known data sequences are included in the entire known data sequence.

Accordingly, when the known data sequence is periodically inserted in mobile service data as described above, the channel equalizer included in the receiving system used the inserted known data as a training sequence, so as to be used either for an accurate decision value or for estimating a channel impulse response.

Meanwhile, when known data sequence having the same pattern is periodically inserted, each known data sequence may be used as a guard interval in a channel equalizer according to the present invention. Herein, the guard interval prevents interference that occurs between blocks due to a multiple path channel. This is because the known data sequence located behind a mobile service data section (i.e., data block) may be considered as being copied in front of the mobile service data section.

The above-described structure is referred to as a cyclic prefix. This structure provides circular convolution in a time domain between a data block transmitted from the transmitting system and a channel impulse response. Accordingly, this facilitates the channel equalizer of the receiving system to perform channel equalization in a frequency domain by using a fast fourier transform (FFT) and an inverse fast fourier transform (IFFT).

More specifically, when viewed in the frequency domain, the data block received by the receiving system is expressed as a multiplication of the data block and the channel impulse response. Therefore, when performing the channel equalization, by multiplying the inverse of the channel in the frequency domain, the channel equalization may be performed more easily.

The known sequence detector **2004** detects the position of the known data being periodically inserted and transmitted as described above. At the same time, the known sequence detector **2004** may also estimate initial frequency offset during the process of detecting known data. In this case, the demodulator **2002** may estimate with more accuracy carrier frequency offset from the information on the known data position information and initial frequency offset estimation value, thereby compensating the estimated carrier frequency offset.

Meanwhile, when known data is transmitted, as shown in FIG. 5, the known sequence detector **2004** detects a position of second known data region by using known data of the second known data region that the same pattern is repeated twice.

At this point, since the known sequence detector **2004** is well-informed of the data group structure, when the position of the second known data region is detected, the known sequence detector **2004** can estimate positions of the first, third, fourth, fifth, and sixth known data regions of a corresponding data group by counting symbols or segments based upon the second known data region position. If the corresponding data group is a data group including field synchronization segment, the known sequence detector **2004** can estimate the position of the field synchronization segment of the corresponding data group, which is positioned chronologically before the second known data region, by counting symbols or segments based upon the second known data region position. Also, the known sequence detector **2004** may estimate the known data position information and the field synchronization position information from the parade including mobile service selected by a user based on the MH frame-associated information outputted from the signaling decoder **2013**.

At least one of the estimated known data position information and field synchronization information is provided to

the demodulator **2002**, the channel equalizer **2003**, the signaling decoder **2013**, and the operation controller **2000**.

Also, the known sequence detector **2004** may estimate initial frequency offset by using known data inserted in the second known data region (i.e., ACQ known data region). In this case, the demodulator **2002** may estimate with more accuracy carrier frequency offset from the information on the known data position information and initial frequency offset estimation value, thereby compensating the estimated carrier frequency offset.

Channel Equalizer

The demodulated data using the known data in the demodulator **2002** is inputted to the channel equalizer **2003**. The demodulated data is inputted to the known sequence detector **2004**.

The equalizer **2003** may perform channel equalization by using a plurality of methods. An example of estimating a channel impulse response (CIR) so as to perform channel equalization will be given in the description of the present invention.

Most particularly, an example of estimating the CIR in accordance with each region within the data group, which is hierarchically divided and transmitted from the transmitting system, and applying each CIR differently will also be described herein. Furthermore, by using the known data, the place and contents of which is known in accordance with an agreement between the transmitting system and the receiving system, and/or the field synchronization data, so as to estimate the CIR, the present invention may be able to perform channel equalization with more stability.

Herein, the data group that is inputted for the equalization process is divided into regions A to D, as shown in FIG. 5. More specifically, in the example of the present invention, each region A, B, C, and D are further divided into MH blocks B4 to B7, MH blocks B3 and B8, MH blocks B2 and B9, MH blocks B1 and B10, respectively.

More specifically, a data group can be assigned and transmitted a maximum the number of 4 in a VSB frame in the transmitting system. In this case, all data group do not include field synchronization data. In the present invention, the data group including the field synchronization data performs channel-equalization using the field synchronization data and known data. And the data group not including the field synchronization data performs channel-equalization using the known data. For example, the data of the MH block B3 including the field synchronization data performs channel-equalization using the CIR calculated from the field synchronization data area and the CIR calculated from the first known data area. Also, the data of the MH blocks B1 and B2 performs channel-equalization using the CIR calculated from the field synchronization data area and the CIR calculated from the first known data area. Meanwhile, the data of the MH blocks B1 to B3 not including the field synchronization data performs channel-equalization using CIRs calculated from the first known data area and the third known data area.

As described above, the present invention uses the CIR estimated from the field synchronization data and the known data sequences in order to perform channel equalization on data within the data group. At this point, each of the estimated CIRs may be directly used in accordance with the characteristics of each region within the data group. Alternatively, a plurality of the estimated CIRs may also be either interpolated or extrapolated so as to create a new CIR, which is then used for the channel equalization process.

Herein, when a value $F(Q)$ of a function $F(x)$ at a particular point Q and a value $F(S)$ of the function $F(x)$ at

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another particular point S are known, interpolation refers to estimating a function value of a point within the section between points Q and S. Linear interpolation corresponds to the simplest form among a wide range of interpolation operations. The linear interpolation described herein is merely exemplary among a wide range of possible interpolation methods. And, therefore, the present invention is not limited only to the examples set forth herein.

Alternatively, when a value $F(Q)$ of a function $F(x)$ at a particular point Q and a value $F(S)$ of the function $F(x)$ at another particular point S are known, extrapolation refers to estimating a function value of a point outside of the section between points Q and S. Linear extrapolation is the simplest form among a wide range of extrapolation operations. Similarly, the linear extrapolation described herein is merely exemplary among a wide range of possible extrapolation methods. And, therefore, the present invention is not limited only to the examples set forth herein.

Operation Controller

The operation controller **2000** receives the known data position information and the transmission parameter information and then forwards MH frame time information, a presence or non-presence of a data group of a selected parade, position information of known data within the data group, power control information and the like to each block of the demodulating unit. The operation controller **2000**, as shown in FIG. 47, controls operations of the demodulator **2002**, the channel equalizer **2003**, the block decoder **2005** and the RS frame decoder **2006**. And, the operation controller **2000** is able to overall operations of the demodulating unit (not shown in the drawing). Moreover, the operation controller **2000** can be implemented with the separate block or can be included within a prescribed one of the blocks of the demodulating unit shown in FIG. 47.

FIG. 48 is an overall block diagram of an operation controller **2000**.

Referring to FIG. 48, the operation controller **2000** can include a parade ID checker **3101**, a frame synchronizer **3102**, a parade mapper **3103**, a group controller **3104** and a known sequence indication controller **3105**.

The operation controller **2000** receives known data position information from the known sequence detector **2004** and receives transmission parameter information from the signaling decoder **2013**. The operation controller **2000** then generates a control signal necessary for a demodulating unit of a receiving system. For instance, the known data position information detected by the known sequence detector **2004** is inputted to the known sequence indication controller **3105**. And, the transmission parameter information (i.e., TPC data) decoded by the signaling decoder **2013** is inputted to the parade ID checker **3101**.

The parade ID checker **3101** compares a parade ID (parade ID selected by a user) contained in the user control signal to a parade ID inputted from the signaling decoder **2013**. If the two parade IDs are not identical to each other, the parade ID checker stands by until a next transmission parameter is inputted from the signaling decoder **2013**.

If the two parade IDs are identical to each other, the parade ID checker **3101** outputs the transmission parameter information to the blocks within the operation controller **2000** and the overall system.

If it is checked that the parade ID in the transmission parameter information inputted to the parade ID checker **3101** is identical to the parade ID selected by a user, the parade ID checker **3101** outputs starting_group_number (SGN) and number_of_groups (NOG) to the parade mapper **3103**, outputs sub_frame_number, slot_number and para-

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de_repetition_cycle PRC) to the frame synchronizer **3102**, outputs SCCC_block_mode, SCCC_outer_code_mode_A, SCCC_outer_code_mode_B, SCCC_outer_code_mode_C and SCCC_outer_code_mode_D to the block decoder **2005**, and outputs RS_frame_mode, RS_code_mode_primary and Rs_code_mode_secondary to the RS frame decoder **2006**.

The parade mapper **3103** receives the SGN and the NOG from the parade ID checker as inputs, decides a data group is carried by which one of sixteen slots within a Sub-frame, and then outputs the corresponding information. Data group number transmitted every sub-frame is set to an integer consecutive between SGN and (SGN+NOG-1). For instance, if SGN=3 and NOG=4, four groups, of which group numbers are 3, 4, 5 and 6, are transmitted for the corresponding sub-frames, respectively. The parade mapper finds a slot number j for transmitting a data group according to Equation 1 with a group number i obtained from SGN and NOG.

In the above example, in case of SGN=3 and NOG=4, if they are inserted in Equation 1, slot numbers of groups transmitted according to the above formula sequentially become 12, 2, 6 and 10.

The parade mapper **3103** then outputs the found slot number information.

For example of outputting slot numbers, a method of using a bit vector having 16 bits is available.

A bit vector SNi (i=0~15) can be set to 1 if there exists a group transmitted for an i^{th} slot. A bit vector SNi (i=0~15) can be set to 0 if a group transmitted for an i^{th} slot does not exist. And, this bit vector can be outputted as slot number information.

The frame synchronizer **3102** receives the sub_frame_number, slot-number and PRC from the parade ID checker and then sends slot_counter and frame_mask signals as outputs. The slot_counter is the signal indicating a slot_number at a current timing point at which a receiver is operating. And, the frame_mask is the signal indicating whether a corresponding parade is transmitted for a current frame. The frame synchronizer **3102** performs a process for initializing slot_counter, sub_frame_number and frame_counter in receiving signaling information initially. A counter value of a current timing point is generated from adding a delayed slot number L according to a time taken to decode signaling from demodulation together with the signaling information inputted in this process. After completion of the initialization process, slot_counter is updated every single slot period, updates sub_frame_counter every period of the slot_counter value, and updates frame_counter every period of the sub_frame_counter. By referring to the frame_counter information and the PRC information, a frame_mask signal is generated. For example, if a corresponding parade is being transmitted for a current frame, '1' is outputted as the frame_mask. Otherwise, it is able to output '0'.

The group controller **3104** receives the slot number information from the parade mapper **3103**. The group controller **3104** receives the slot_counter and frame_mask information from the frame synchronizer **3102**. The group controller **3104** then outputs group_presence_indicator indicating whether an MH group is being transmitted. For instance, if the slot number information inputted from the parade mapper **3103** corresponds to 12, 2, 6 and 10, when the frame_mask information inputted from the frame synchronizer **3102** is 1 and the slot_counter inputted from the frame synchronizer **3102** includes 2, 6, 10 and 12, '1' is outputted as the group_presence_indicator. Otherwise, it is able to output 0.

The known sequence indication controller **3105** outputs position information of another known data, group start position information and the like with position information of specific inputted known data. In this case, since the known data are present at a previously appointed position within the data group, if position data of one of a plurality of known data sequences, it is able to know data position information of another known sequence, data group start position information and the like. The known sequence indication controller **3105** can output known data and data group position information necessary for the demodulating unit of the receiving system using the group_presence_indicator information only if the data group is transmitted. Alternatively, the known sequence detector **2004** can perform operations of the known sequence indication controller **3105**.

Block Decoder

Meanwhile, if the data being inputted to the block decoder **2005**, after being channel-equalized by the equalizer **2003**, correspond to the data having both block encoding and trellis encoding performed thereon (i.e., the data within the RS frame, the signaling information data, etc.) by the transmitting system, trellis decoding and block decoding processes are performed on the inputted data as inverse processes of the transmitting system. Alternatively, if the data being inputted to the block decoder **2005** correspond to the data having only trellis encoding performed thereon (i.e., the main service data), and not the block encoding, only the trellis decoding process is performed on the inputted data as the inverse process of the transmitting system.

The trellis decoded and block decoded data by the block decoder **2005** are then outputted to the RS frame decoder **2006**. More specifically, the block decoder **2005** removes the known data, data used for trellis initialization, and signaling information data, MPEG header, which have been inserted in the data group, and the RS parity data, which have been added by the RS encoder/non-systematic RS encoder or non-systematic RS encoder of the transmitting system. Then, the block decoder **2005** outputs the processed data to the RS frame decoder **2006**. Herein, the removal of the data may be performed before the block decoding process, or may be performed during or after the block decoding process.

Meanwhile, the data trellis-decoded by the block decoder **2005** are outputted to the data deinterleaver of the main service data processor **2008**. At this point, the data being trellis-decoded by the block decoder **2005** and outputted to the data deinterleaver may not only include the main service data but may also include the data within the RS frame and the signaling information. Furthermore, the RS parity data that are added by the transmitting system after the pre-processor **230** may also be included in the data being outputted to the data deinterleaver.

According to another embodiment of the present invention, data that are not processed with block decoding and only processed with trellis encoding by the transmitting system may directly bypass the block decoder **2005** so as to be outputted to the data deinterleaver. In this case, a trellis decoder should be provided before the data deinterleaver. More specifically, if the inputted data correspond to the data having only trellis encoding performed thereon and not block encoding, the block decoder **2005** performs Viterbi (or trellis) decoding on the inputted data so as to output a hard decision value or to perform a hard-decision on a soft decision value, thereby outputting the result.

Meanwhile, if the inputted data correspond to the data having both block encoding process and trellis encoding

process performed thereon, the block decoder **2005** outputs a soft decision value with respect to the inputted data.

In other words, if the inputted data correspond to data being processed with block encoding by the block processor **302** and being processed with trellis encoding by the trellis encoding module **256**, in the transmitting system, the block decoder **2005** performs a decoding process and a trellis decoding process on the inputted data as inverse processes of the transmitting system. At this point, the RS frame encoder of the pre-processor included in the transmitting system may be viewed as an outer (or external) encoder. And, the trellis encoder may be viewed as an inner (or internal) encoder. When decoding such concatenated codes, in order to allow the block decoder **2005** to maximize its performance of decoding externally encoded data, the decoder of the internal code should output a soft decision value.

FIG. **49** illustrates a detailed block diagram of the block decoder **2005** according to an embodiment of the present invention. Referring to FIG. **49**, the block decoder **2005** includes a feedback controller **4010**, an input buffer **4011**, a trellis decoding unit (or 12-way trellis coded modulation (TCM) decoder or inner decoder) **4012**, a symbol-byte converter **4013**, an outer block extractor **4014**, a feedback deformatter **4015**, a symbol deinterleaver **4016**, an outer symbol mapper **4017**, a symbol decoder **4018**, an inner symbol mapper **4019**, a symbol interleaver **4020**, a feedback formatter **4021**, and an output buffer **4022**. Herein, just as in the transmitting system, the trellis decoding unit **4012** may be viewed as an inner (or internal) decoder. And, the symbol decoder **4018** may be viewed as an outer (or external) decoder.

The input buffer **4011** temporarily stores the mobile service data symbols being channel-equalized and outputted from the equalizer **2003**. (Herein, the mobile service data symbols may include symbols corresponding to the signaling information, RS parity data symbols and CRC data symbols added during the encoding process of the RS frame.) Thereafter, the input buffer **4011** repeatedly outputs the stored symbols for M number of times to the trellis decoding unit **4012** in a turbo block (TDL) size required for the turbo decoding process.

The turbo decoding length (TDL) may also be referred to as a turbo block. Herein, a TDL should include at least one SCCC block size. Therefore, as defined in FIG. **5**, when it is assumed that one MH block is a 16-segment unit, and that a combination of 10 MH blocks form one SCCC block, a TDL should be equal to or larger than the maximum possible combination size. For example, when it is assumed that 2 MH blocks form one SCCC block, the TDL may be equal to or larger than 32 segments (i.e., $828 \times 32 = 26496$ symbols). Herein, M indicates a number of repetitions for turbo-decoding pre-decided by the feed-back controller **4010**.

Also, M represents a number of repetitions of the turbo decoding process, the number being predetermined by the feedback controller **4010**.

Additionally, among the values of symbols being channel-equalized and outputted from the equalizer **2003**, the input symbol values corresponding to a section having no mobile service data symbols (including RS parity data symbols during RS frame encoding and CRC data symbols) included therein, bypass the input buffer **4011** without being stored. More specifically, since trellis-encoding is performed on input symbol values of a section wherein SCCC block-encoding has not been performed, the input buffer **4011** inputs the inputted symbol values of the corresponding section directly to the trellis encoding module **4012** without

performing any storage, repetition, and output processes. The storage, repetition, and output processes of the input buffer **4011** are controlled by the feedback controller **4010**. Herein, the feedback controller **4010** refers to SCCC-associated information (e.g., SCCC block mode and SCCC outer code mode), which are outputted from the signaling decoder **2013** or the operation controller **2000**, in order to control the storage and output processes of the input buffer **4011**.

The trellis decoding unit **4012** includes a 12-way TCM decoder. Herein, the trellis decoding unit **4012** performs 12-way trellis decoding as inverse processes of the 12-way trellis encoder.

More specifically, the trellis decoding unit **4012** receives a number of output symbols of the input buffer **4011** and soft-decision values of the feedback formatter **4021** equivalent to each TDL, so as to perform the TCM decoding process.

At this point, based upon the control of the feedback controller **4010**, the soft-decision values outputted from the feedback formatter **4021** are matched with a number of mobile service data symbol places so as to be in a one-to-one (1:1) correspondence. Herein, the number of mobile service data symbol places is equivalent to the TDL being outputted from the input buffer **4011**.

More specifically, the mobile service data being outputted from the input buffer **4011** are matched with the turbo decoded data being inputted, so that each respective data place can correspond with one another. Thereafter, the matched data are outputted to the trellis decoding unit **4012**. For example, if the turbo decoded data correspond to the third symbol within the turbo block, the corresponding symbol (or data) is matched with the third symbol included in the turbo block, which is outputted from the input buffer **4011**. Subsequently, the matched symbol (or data) is outputted to the trellis decoding unit **4012**.

In order to do so, while the regressive turbo decoding is in process, the feedback controller **4010** controls the input buffer **4011** so that the input buffer **4011** stores the corresponding turbo block data. Also, by delaying data (or symbols), the soft decision value (e.g., LLR) of the symbol outputted from the symbol interleaver **4020** and the symbol of the input buffer **4011** corresponding to the same place (or position) within the block of the output symbol are matched with one another to be in a one-to-one correspondence. Thereafter, the matched symbols are controlled so that they can be inputted to the TCM decoder through the respective path. This process is repeated for a predetermined number of turbo decoding cycle periods. Then, the data of the next turbo block are outputted from the input buffer **4011**, thereby repeating the turbo decoding process.

The output of the trellis decoding unit **4012** signifies a degree of reliability of the transmission bits configuring each symbol. For example, in the transmitting system, since the input data of the trellis encoding module correspond to two bits as one symbol, a log likelihood ratio (LLR) between the likelihood of a bit having the value of '1' and the likelihood of the bit having the value of '0' may be respectively outputted (in bit units) to the upper bit and the lower bit. Herein, the log likelihood ratio corresponds to a log value for the ratio between the likelihood of a bit having the value of '1' and the likelihood of the bit having the value of '0'. Alternatively, a LLR for the likelihood of 2 bits (i.e., one symbol) being equal to "00", "01", "10", and "11" may be respectively outputted (in symbol units) to all 4 combinations of bits (i.e., 00, 01, 10, 11). Consequently, this becomes the soft decision value that indicates the degree of reliability of the transmission bits configuring each symbol. A maxi-

mum a posteriori probability (MAP) or a soft-out Viterbi algorithm (SOVA) may be used as a decoding algorithm of each TCM decoder within the trellis decoding unit **4012**.

The output of the trellis decoding unit **4012** is inputted to the symbol-byte converter **4013** and the outer block extractor **4014**.

The symbol-byte converter **4013** performs a hard-decision process of the soft decision value that is trellis decoded and outputted from the trellis decoding unit **4012**. Thereafter, the symbol-byte converter **4013** groups 4 symbols into byte units, which are then outputted to the data deinterleaver of the main service data processor **2008** of FIG. **47**. More specifically, the symbol-byte converter **4013** performs hard-decision in bit units on the soft decision value of the symbol outputted from the trellis decoding unit **4012**. Therefore, the data processed with hard-decision and outputted in bit units from the symbol-byte converter **4013** not only include main service data, but may also include mobile service data, known data, RS parity data, and MPEG headers.

Among the soft decision values of TDL size of the trellis decoding unit **4012**, the outer block extractor **4014** identifies the soft decision values of B size of corresponding to the mobile service data symbols (wherein symbols corresponding to signaling information, RS parity data symbols that are added during the encoding of the RS frame, and CRC data symbols are included) and outputs the identified soft decision values to the feedback deformatter **4015**.

The feedback deformatter **4015** changes the processing order of the soft decision values corresponding to the mobile service data symbols. This is an inverse process of an initial change in the processing order of the mobile service data symbols, which are generated during an intermediate step, wherein the output symbols outputted from the block processor **302** of the transmitting system are being inputted to the trellis encoding module **256** (e.g., when the symbols pass through the group formatter, the data deinterleaver, the packet formatter, and the data interleaver). Thereafter, the feedback deformatter **2015** performs reordering of the process order of soft decision values corresponding to the mobile service data symbols and, then, outputs the processed mobile service data symbols to the symbol deinterleaver **4016**.

This is because a plurality of blocks exist between the block processor **302** and the trellis encoding module **256**, and because, due to these blocks, the order of the mobile service data symbols being outputted from the block processor **302** and the order of the mobile service data symbols being inputted to the trellis encoding module **256** are not identical to one another. Therefore, the feedback deformatter **4015** reorders (or rearranges) the order of the mobile service data symbols being outputted from the outer block extractor **4014**, so that the order of the mobile service data symbols being inputted to the symbol deinterleaver **4016** matches the order of the mobile service data symbols outputted from the block processor **302** of the transmitting system. The reordering process may be embodied as one of software, middleware, and hardware.

The symbol deinterleaver **4016** performs deinterleaving on the mobile service data symbols having their processing orders changed and outputted from the feedback deformatter **4015**, as an inverse process of the symbol interleaving process of the symbol interleaver **514** included in the transmitting system. The size of the block used by the symbol deinterleaver **4016** during the deinterleaving process is identical to interleaving size of an actual symbol (i.e., B) of the symbol interleaver **514**, which is included in the transmitting system. This is because the turbo decoding

process is performed between the trellis decoding unit **4012** and the symbol decoder **4018**. Both the input and output of the symbol deinterleaver **4016** correspond to soft decision values, and the deinterleaved soft decision values are outputted to the outer symbol mapper **4017**.

The operations of the outer symbol mapper **4017** may vary depending upon the structure and coding rate of the convolution encoder **513** included in the transmitting system. For example, when data are $\frac{1}{2}$ -rate encoded by the convolution encoder **513** and then transmitted, the outer symbol mapper **4017** directly outputs the input data without modification. In another example, when data are $\frac{1}{4}$ -rate encoded by the convolution encoder **513** and then transmitted, the outer symbol mapper **4017** converts the input data so that it can match the input data format of the symbol decoder **4018**. For this, the outer symbol mapper **4017** may be inputted SCCC-associated information (i.e., SCCC block mode and SCCC outer code mode) from the signaling decoder **2013**. Then, the outer symbol mapper **4017** outputs the converted data to the symbol decoder **4018**.

The symbol decoder **4018** (i.e., the outer decoder) receives the data outputted from the outer symbol mapper **4017** and performs symbol decoding as an inverse process of the convolution encoder **513** included in the transmitting system. At this point, two different soft decision values are outputted from the symbol decoder **4018**. One of the outputted soft decision values corresponds to a soft decision value matching the output symbol of the convolution encoder **513** (hereinafter referred to as a “first decision value”). The other one of the outputted soft decision values corresponds to a soft decision value matching the input bit of the convolution encoder **513** (hereinafter referred to as a “second decision value”).

More specifically, the first decision value represents a degree of reliability the output symbol (i.e., 2 bits) of the convolution encoder **513**. Herein, the first soft decision value may output (in bit units) a LLR between the likelihood of 1 bit being equal to ‘1’ and the likelihood of 1 bit being equal to ‘0’ with respect to each of the upper bit and lower bit, which configures a symbol. Alternatively, the first soft decision value may also output (in symbol units) a LLR for the likelihood of 2 bits being equal to “00”, “01”, “10”, and “11” with respect to all possible combinations. The first soft decision value is fed-back to the trellis decoding unit **4012** through the inner symbol mapper **4019**, the symbol interleaver **4020**, and the feedback formatter **4021**. On the other hand, the second soft decision value indicates a degree of reliability the input bit of the convolution encoder **513** included in the transmitting system. Herein, the second soft decision value is represented as the LLR between the likelihood of 1 bit being equal to ‘1’ and the likelihood of 1 bit being equal to ‘0’. Thereafter, the second soft decision value is outputted to the outer buffer **4022**. In this case, a maximum a posteriori probability (MAP) or a soft-out Viterbi algorithm (SOVA) may be used as the decoding algorithm of the symbol decoder **4018**.

The first soft decision value that is outputted from the symbol decoder **4018** is inputted to the inner symbol mapper **4019**. The inner symbol mapper **4019** converts the first soft decision value to a data format corresponding the input data of the trellis decoding unit **4012**. Thereafter, the inner symbol mapper **4019** outputs the converted soft decision value to the symbol interleaver **4020**. The operations of the inner symbol mapper **4019** may also vary depending upon the structure and coding rate of the convolution encoder **513** included in the transmitting system.

The symbol interleaver **4020** performs symbol interleaving, as shown in FIG. **36**, on the first soft decision value that is outputted from the inner symbol mapper **4019**. Then, the symbol interleaver **4020** outputs the symbol-interleaved first soft decision value to the feedback formatter **4021**. Herein, the output of the symbol interleaver **4020** also corresponds to a soft decision value.

With respect to the changed processing order of the soft decision values corresponding to the symbols that are generated during an intermediate step, wherein the output symbols outputted from the block processor **302** of the transmitting system are being inputted to the trellis encoding module (e.g., when the symbols pass through the group formatter, the data deinterleaver, the packet formatter, the RS encoder, and the data interleaver), the feedback formatter **4021** alters (or changes) the order of the output values outputted from the symbol interleaver **4020**. Subsequently, the feedback formatter **4020** outputs values to the trellis decoding unit **4012** in the changed order. The reordering process of the feedback formatter **4021** may configure at least one of software, hardware, and middleware.

The soft decision values outputted from the symbol interleaver **4020** are matched with the positions of mobile service data symbols each having the size of TDL, which are outputted from the input buffer **4011**, so as to be in a one-to-one correspondence. Thereafter, the soft decision values matched with the respective symbol position are inputted to the trellis decoding unit **4012**. At this point, since the main service data symbols or the RS parity data symbols and known data symbols of the main service data do not correspond to the mobile service data symbols, the feedback formatter **4021** inserts null data in the corresponding positions, thereby outputting the processed data to the trellis decoding unit **4012**. Additionally, each time the symbols having the size of TDL are turbo decoded, no value is fed-back by the symbol interleaver **4020** starting from the beginning of the first decoding process. Therefore, the feedback formatter **4021** is controlled by the feedback controller **4010**, thereby inserting null data into all symbol positions including a mobile service data symbol. Then, the processed data are outputted to the trellis decoding unit **4012**.

The output buffer **4022** receives the second soft decision value from the symbol decoder **4018** based upon the control of the feedback controller **4010**. Then, the output buffer **4022** temporarily stores the received second soft decision value. Thereafter, the output buffer **4022** outputs the second soft decision value to the RS frame decoder **2006**. For example, the output buffer **4022** overwrites the second soft decision value of the symbol decoder **4018** until the turbo decoding process is performed for M number of times. Then, once all M number of turbo decoding processes is performed for a single TDL, the corresponding second soft decision value is outputted to the RS frame decoder **2006**.

The feedback controller **4010** controls the number of turbo decoding and turbo decoding repetition processes of the overall block decoder, shown in FIG. **49**. More specifically, once the turbo decoding process has been repeated for a predetermined number of times, the second soft decision value of the symbol decoder **4018** is outputted to the RS frame decoder **2006** through the output buffer **4022**. Thus, the block decoding process of a turbo block is completed. In the description of the present invention, this process is referred to as a regressive turbo decoding process for simplicity.

At this point, the number of regressive turbo decoding rounds between the trellis decoding unit **4012** and the

symbol decoder **4018** may be defined while taking into account hardware complexity and error correction performance. Accordingly, if the number of rounds increases, the error correction performance may be enhanced. However, this may lead to a disadvantageous of the hardware becoming more complicated (or complex).

Meanwhile, the main service data processor **2008** corresponds to block required for receiving the main service data. Therefore, the above-mentioned blocks may not be necessary (or required) in the structure of a digital broadcast receiving system for receiving mobile service data only.

The data deinterleaver of the main service data processor **2008** performs an inverse process of the data interleaver included in the transmitting system. In other words, the data deinterleaver deinterleaves the main service data outputted from the block decoder **2005** and outputs the deinterleaved main service data to the RS decoder. The data being inputted to the data deinterleaver include main service data, as well as mobile service data, known data, RS parity data, and an MPEG header. At this point, among the inputted data, only the main service data and the RS parity data added to the main service data packet may be outputted to the RS decoder. Also, all data outputted after the data derandomizer may all be removed with the exception for the main service data. In the embodiment of the present invention, only the main service data and the RS parity data added to the main service data packet are inputted to the RS decoder.

The RS decoder performs a systematic RS decoding process on the deinterleaved data and outputs the processed data to the data derandomizer.

The data derandomizer receives the output of the RS decoder and generates a pseudo random data byte identical to that of the randomizer included in the digital broadcast transmitting system. Thereafter, the data derandomizer performs a bitwise exclusive OR (XOR) operation on the generated pseudo random data byte, thereby inserting the MPEG synchronization bytes to the beginning of each packet so as to output the data in 188-byte main service data packet units.

RS Frame Decoder

The data outputted from the block decoder **2005** are in portion units. More specifically, in the transmitting system, the RS frame is divided into several portions, and the mobile service data of each portion are assigned either to regions A/B/C/D within the data group or to any one of regions A/B and regions C/D, thereby being transmitted to the receiving system. Therefore, the RS frame decoder **2006** groups several portions included in a parade so as to form an RS frame. Alternatively, the RS frame decoder **2006** may also group several portions included in a parade so as to form two RS frames. Thereafter, error correction decoding is performed in RS frame units.

For example, when the RS frame mode value is equal to '00', then one parade transmits one RS frame. At this point, one RS frame is divided into several portions, and the mobile service data of each portion are assigned to regions A/B/C/D of the corresponding data group, thereby being transmitted. In this case, the RS frame decoder **2006** extracts mobile service data from regions A/B/C/D of the corresponding data group, as shown in FIG. 50(a). Subsequently, the RS frame decoder **2006** may perform the process of forming (or creating) a portion on a plurality of data group within a parade, thereby forming several portions. Then, the several portions of mobile service data may be grouped to form an RS frame. Herein, if stuffing bytes are added to the last portion, the RS frame may be formed after removing the stuffing byte.

In another example, when the RS frame mode value is equal to '01', then one parade transmits two RS frames (i.e., a primary RS frame and a secondary RS frame). At this point, a primary RS frame is divided into several primary portions, and the mobile service data of each primary portion are assigned to regions A/B of the corresponding data group, thereby being transmitted. Also, a secondary RS frame is divided into several secondary portions, and the mobile service data of each secondary portion are assigned to regions C/D of the corresponding data group, thereby being transmitted.

In this case, the RS frame decoder **2006** extracts mobile service data from regions A/B of the corresponding data group, as shown in FIG. 50(b). Subsequently, the RS frame decoder **2006** may perform the process of forming (or creating) a primary portion on a plurality of data group within a parade, thereby forming several primary portions. Then, the several primary portions of mobile service data may be grouped to form a primary RS frame. Herein, if stuffing bytes are added to the last primary portion, the primary RS frame may be formed after removing the stuffing byte. Also, the RS frame decoder **2006** extracts mobile service data from regions C/D of the corresponding data group. Subsequently, the RS frame decoder **2006** may perform the process of forming (or creating) a secondary portion on a plurality of data group within a parade, thereby forming several secondary portions. Then, the several secondary portions of mobile service data may be grouped to form a secondary RS frame. Herein, if stuffing bytes are added to the last secondary portion, the secondary RS frame may be formed after removing the stuffing byte.

More specifically, the RS frame decoder **2006** receives the RS-encoded and/or CRC-encoded mobile service data of each portion from the block decoder **2005**. Then, the RS frame decoder **2006** groups several portions, which are inputted based upon RS frame-associated information outputted from the signaling decoder **2013** or the operation controller **2000**, thereby performing error correction. By referring to the RS frame mode value included in the RS frame-associated information, the RS frame decoder **2006** may form an RS frame and may also be informed of the number of RS code parity data bytes and the code size. Herein, the RS code is used to configure (or form) the RS frame. The RS frame decoder **2006** also refers to the RS frame-associated information in order to perform an inverse process of the RS frame encoder, which is included in the transmitting system, thereby correcting the errors within the RS frame. Thereafter, the RS frame decoder **2006** adds 1 MPEG synchronization data byte to the error-correction mobile service data packet. In an earlier process, the 1 MPEG synchronization data byte was removed from the mobile service data packet during the RS frame encoding process. Finally, the RS frame decoder **2006** performs a derandomizing process on the processed mobile service data packet.

FIG. 51 illustrates, when the RS frame mode value is equal to '00', an exemplary process of grouping several portion being transmitted to a parade, thereby forming an RS frame and an RS frame reliability map, and an exemplary process of performing a row de-permutation process in super frame units as an inverse process of the transmitting system, thereby re-distinguishing (or identifying) the row-de-permuted RS frame and RS frame reliability map. More specifically, the RS frame decoder **2006** receives and groups a plurality of mobile service data bytes, so as to form an RS frame. According to the present invention, in transmitting system, the mobile service data correspond to data RS-

encoded in RS frame units and also correspond to data row-permuted in super frame units. At this point, the mobile service data may already be error correction encoded (e.g., CRC-encoded). Alternatively, the error correction encoding process may be omitted.

It is assumed that, in the transmitting system, an RS frame having the size of $(N+2) \times (187+P)$ bytes is divided into M number of portions, and that the M number of mobile service data portions are assigned and transmitted to regions A/B/C/D in M number of data groups, respectively. In this case, in the receiving system, each mobile service data portion is grouped, as shown in FIG. 51(a), thereby forming an RS frame having the size of $(N+2) \times (187+P)$ bytes. At this point, when stuffing bytes (S) are added to at least one portion included in the corresponding RS frame and then transmitted, the stuffing bytes are removed, thereby configuring an RS frame and an RS frame reliability map. For example, as shown in FIG. 33, when S number of stuffing bytes are added to the corresponding portion, the S number of stuffing bytes are removed, thereby configuring the RS frame and the RS frame reliability map.

Herein, when it is assumed that the block decoder 2005 outputs a soft decision value for the decoding result, the RS frame decoder 2006 may decide the '0' and '1' of the corresponding bit by using the codes of the soft decision value. 8 bits that are each decided as described above are grouped to create 1 data byte. If the above-described process is performed on all soft decision values of several portions (or data groups) included in a parade, the RS frame having the size of $(N+2) \times (187+P)$ bytes may be configured.

Additionally, the present invention uses the soft decision value not only to configure the RS frame but also to configure a reliability map.

Herein, the reliability map indicates the reliability of the corresponding data byte, which is configured by grouping 8 bits, the 8 bits being decided by the codes of the soft decision value.

For example, when the absolute value of the soft decision value exceeds a pre-determined threshold value, the value of the corresponding bit, which is decided by the code of the corresponding soft decision value, is determined to be reliable. Conversely, when the absolute value of the soft decision value does not exceed the pre-determined threshold value, the value of the corresponding bit is determined to be unreliable. Thereafter, if even a single bit among the 8 bits, which are decided by the codes of the soft decision value and group to configure one data byte, is determined to be unreliable, the corresponding data byte is marked on the reliability map as an unreliable data byte.

Herein, determining the reliability of one data byte is only exemplary. More specifically, when a plurality of data bytes (e.g., at least 4 data bytes) are determined to be unreliable, the corresponding data bytes may also be marked as unreliable data bytes within the reliability map. Conversely, when all of the data bits within the one data byte are determined to be reliable (i.e., when the absolute value of the soft decision values of all 8 bits included in the one data byte exceed the predetermined threshold value), the corresponding data byte is marked to be a reliable data byte on the reliability map. Similarly, when a plurality of data bytes (e.g., at least 4 data bytes) are determined to be reliable, the corresponding data bytes may also be marked as reliable data bytes within the reliability map. The numbers proposed in the above-described example are merely exemplary and, therefore, do not limit the scope or spirit of the present invention.

The process of configuring the RS frame and the process of configuring the reliability map both using the soft decision value may be performed at the same time. Herein, the reliability information within the reliability map is in a one-to-one correspondence with each byte within the RS frame. For example, if a RS frame has the size of $(N+2) \times (187+P)$ bytes, the reliability map is also configured to have the size of $(N+2) \times (187+P)$ bytes. FIG. 51(a') and FIG. 51(b') respectively illustrate the process steps of configuring the reliability map according to the present invention.

At this point, the RS frame of FIG. 51(b) and the RS frame reliability map of FIG. 51(b') are interleaved in super frame units. Therefore, the RS frame and the RS frame reliability maps are grouped to create a super frame and a super frame reliability map. Subsequently, as shown in FIG. 51(c) and FIG. 51(c'), a de-permutation (or deinterleaving) process is performed in super frame units on the RS frame and the RS frame reliability maps, as an inverse process of the transmitting system. Then, when the de-permutation process is performed in super frame units, the processed data are divided into de-permuted (or deinterleaved) RS frames having the size of $(N+2) \times (187+P)$ bytes and de-permuted RS frame reliability maps having the size of $(N+2) \times (187+P)$ bytes, as shown in FIG. 51(d) and FIG. 51(d'). Subsequently, the RS frame reliability map is used on the divided RS frames so as to perform error correction.

FIG. 52 illustrates example of the error correction processed according to embodiments of the present invention. FIG. 52 illustrates an example of performing an error correction process when the transmitting system has performed both RS encoding and CRC encoding processes on the RS frame.

As shown in FIG. 52(a) and FIG. 52(a'), when the RS frame having the size of $(N+2) \times (187+P)$ bytes and the RS frame reliability map having the size of $(N+2) \times (187+P)$ bytes are created, a CRC syndrome checking process is performed on the created RS frame, thereby verifying whether any error has occurred in each row. Subsequently, as shown in FIG. 52(b), a 2-byte checksum is removed to configure an RS frame having the size of $N \times (187+P)$ bytes. Herein, the presence (or existence) of an error is indicated on an error flag corresponding to each row. Similarly, since the portion of the reliability map corresponding to the CRC checksum has hardly any applicability, this portion is removed so that only $N \times (187+P)$ number of the reliability information bytes remain, as shown in FIG. 52(b').

After performing the CRC syndrome checking process, as described above, a RS decoding process is performed in a column direction. Herein, a RS erasure correction process may be performed in accordance with the number of CRC error flags. More specifically, as shown in FIG. 52(c), the CRC error flag corresponding to each row within the RS frame is verified. Thereafter, the RS frame decoder 2006 determines whether the number of rows having a CRC error occurring therein is equal to or smaller than the maximum number of errors on which the RS erasure correction may be performed, when performing the RS decoding process in a column direction. The maximum number of errors corresponds to P number of parity bytes inserted when performing the RS encoding process. In the embodiment of the present invention, it is assumed that 48 parity bytes have been added to each column (i.e., $P=48$).

If the number of rows having the CRC errors occurring therein is smaller than or equal to the maximum number of errors (i.e., 48 errors according to this embodiment) that can be corrected by the RS erasure decoding process, a (235, 187)-RS erasure decoding process is performed in a column

direction on the RS frame having $(187+P)$ number of N-byte rows (i.e., 235 N-byte rows), as shown in FIG. 52(d). Thereafter, as shown in FIG. 52(e), the 48-byte parity data that have been added at the end of each column are removed. Conversely, however, if the number of rows having the CRC errors occurring therein is greater than the maximum number of errors (i.e., 48 errors) that can be corrected by the RS erasure decoding process, the RS erasure decoding process cannot be performed. In this case, the error may be corrected by performing a general RS decoding process. In addition, the reliability map, which has been created based upon the soft decision value along with the RS frame, may be used to further enhance the error correction ability (or performance) of the present invention.

More specifically, the RS frame decoder 2006 compares the absolute value of the soft decision value of the block decoder 2005 with the pre-determined threshold value, so as to determine the reliability of the bit value decided by the code of the corresponding soft decision value. Also, 8 bits, each being determined by the code of the soft decision value, are grouped to form one data byte. Accordingly, the reliability information on this one data byte is indicated on the reliability map. Therefore, as shown in FIG. 52(c), even though a particular row is determined to have an error occurring therein based upon a CRC syndrome checking process on the particular row, the present invention does not assume that all bytes included in the row have errors occurring therein. The present invention refers to the reliability information of the reliability map and sets only the bytes that have been determined to be unreliable as erroneous bytes. In other words, with disregard to whether or not a CRC error exists within the corresponding row, only the bytes that are determined to be unreliable based upon the reliability map are set as erasure points.

According to another method, when it is determined that CRC errors are included in the corresponding row, based upon the result of the CRC syndrome checking result, only the bytes that are determined by the reliability map to be unreliable are set as errors. More specifically, only the bytes corresponding to the row that is determined to have errors included therein and being determined to be unreliable based upon the reliability information, are set as the erasure points. Thereafter, if the number of error points for each column is smaller than or equal to the maximum number of errors (i.e., 48 errors) that can be corrected by the RS erasure decoding process, an RS erasure decoding process is performed on the corresponding column. Conversely, if the number of error points for each column is greater than the maximum number of errors (i.e., 48 errors) that can be corrected by the RS erasure decoding process, a general decoding process is performed on the corresponding column.

More specifically, if the number of rows having CRC errors included therein is greater than the maximum number of errors (i.e., 48 errors) that can be corrected by the RS erasure decoding process, either an RS erasure decoding process or a general RS decoding process is performed on a column that is decided based upon the reliability information of the reliability map, in accordance with the number of erasure points within the corresponding column. For example, it is assumed that the number of rows having CRC errors included therein within the RS frame is greater than 48. And, it is also assumed that the number of erasure points decided based upon the reliability information of the reliability map is indicated as 40 erasure points in the first column and as 50 erasure points in the second column. In this case, a $(235,187)$ -RS erasure decoding process is performed on the first column. Alternatively, a $(235,187)$ -RS

decoding process is performed on the second column. When error correction decoding is performed on all column directions within the RS frame by using the above-described process, the 48-byte parity data which were added at the end of each column are removed, as shown in FIG. 52(e).

As described above, even though the total number of CRC errors corresponding to each row within the RS frame is greater than the maximum number of errors that can be corrected by the RS erasure decoding process, when the number of bytes determined to have a low reliability level, based upon the reliability information on the reliability map within a particular column, while performing error correction decoding on the particular column. Herein, the difference between the general RS decoding process and the RS erasure decoding process is the number of errors that can be corrected. More specifically, when performing the general RS decoding process, the number of errors corresponding to half of the number of parity bytes (i.e., $(\text{number of parity bytes})/2$) that are inserted during the RS encoding process may be error corrected (e.g., 24 errors may be corrected). Alternatively, when performing the RS erasure decoding process, the number of errors corresponding to the number of parity bytes that are inserted during the RS encoding process may be error corrected (e.g., 48 errors may be corrected).

After performing the error correction decoding process, as described above, a RS frame configured of 187 N-byte rows (or packet) may be obtained as shown in FIG. 52(e). The RS frame having the size of $N \times 187$ bytes is outputted by the order of N number of 187-byte units. At this point, 1 MPEG synchronization byte, which had been removed by the transmitting system, is added to each 187-byte packet, as shown in FIG. 52(f). Therefore, a 188-byte unit mobile service data packet is outputted.

At this point, the RS frame decoded mobile service data is performed a derandomizing process, which corresponds to the inverse process of the randomizer included in the transmitting system and then the derandomized data are outputted, thereby obtaining the mobile service data transmitted from the transmitting system. In the present invention, the RS frame decoder 2006 may perform the data derandomizing function.

An RS frame decoder may be configured of M number of RS frame decoders provided in parallel, wherein the number of RS frame encoders is equal to the number of parades ($=M$) within an MH frame, a multiplexer for multiplexing each portion and being provided to each input end of the M number of RS frame decoders, and a demultiplexer for demultiplexing each portion and being provided to each output end of the M number of RS frame decoders.

As described above, the present invention has the following advantages. Herein, the present invention is robust (or strong) against any error that may occur when transmitting mobile broadcast service data through a channel. And, the present invention is also highly compatible to the conventional system.

Moreover, the service multiplexer packetizes the RS frame for mobile service into a plurality of MPEG-2 TS packets, which are then transmitted to each transmitter. Thereafter, each transmitter groups a plurality of MPEG-2 TS packets so as to recover an RS frame, thereby using the conventional interface standard between the service multiplexer and the transmitter without modification.

Additionally, the present invention may also receive the mobile broadcast service data without any error occurring, even in channels having severe ghost effect and noise.

Furthermore, by inserting known data in a specific position within a data region and by transmitting the processed data, the receiving performance of a receiving system may be enhanced even in channel environments (or conditions) undergoing frequent channel changes.

The present invention is even more effective when applied to mobile and portable receivers, which are also liable to frequent change in channels, and which require strength (or robustness) against intense noise.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the spirit or scope of the inventions. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A transmitting system comprising:

a service multiplexer configured to packetize a Reed-Solomon (RS) frame payload having a size of N (a column size of the RS frame payload) $\times 187$ (a row size of the RS frame payload) bytes including mobile service data into a plurality of mobile service data packets and to transmit the plurality of mobile service data packets, wherein each of the plurality of mobile service data packets is configured from a transport stream (TS) header and a data region, the data region including at least a payload region or an adaptation field region; and a transmitter configured to

form the RS frame payload from the plurality of mobile service data packets based upon the TS header of each of the plurality of mobile service data packets transmitted from the service multiplexer; and

pre-process the mobile service data of the RS frame payload,

wherein a number of the plurality of mobile service data packets being packetized from the RS frame payload is determined as

$\lfloor (N \times 187) / 184 \rfloor + 1$, and

wherein $\lfloor X \rfloor$ represents a maximum integer not larger than X and N indicates a number of columns in the corresponding RS frame payload,

wherein the service multiplexer is further configured to: set a payload unit start indicator (PUSI) field value of the TS header included in a mobile service data packet of the plurality of mobile service data packets that include a first data byte of the RS frame payload to '1'; and

set the PUSI field value of the TS header included in remaining mobile service data packets of the plurality of data packets to '0'.

2. The transmitting system of claim 1, wherein the service multiplexer is further configured to set an ensemble identifier corresponding to the RS frame payload as a packet identifier (PID) of the TS header included in each of the plurality of mobile service data packets.

3. The transmitting system of claim 1 wherein the service multiplexer is further configured to:

configure $\lfloor (N \times 187) / 184 \rfloor$ mobile service data packets of the plurality of data packets by dividing the RS frame payload into 184-byte units, each including a 4-byte TS header and a payload region including data of each of the 184-byte unit and configure a $\lfloor (N \times 187) / 184 \rfloor + 1^{th}$ mobile service data packet that includes the 4-byte TS header and a 184-byte adaptation field region including stuffing data, when the size of the RS frame payload corresponds to a multiple of 184 bytes.

4. The transmitting system of claim 1, wherein the service multiplexer is further configured to:

configure $\lfloor (N \times 187) / 184 \rfloor$ mobile service data packets of the plurality of data packets by dividing the RS frame payload into 184-byte units, each including a 4-byte TS header and a payload region including data of each of the 184-byte units and configure a $\lfloor (N \times 187) / 184 \rfloor + 1^{th}$ mobile service data packet of the plurality of data packets that includes a 4-byte TS header, a (184-N4)-byte adaptation field region including stuffing data, and a payload region including N4 bytes of non-packetized data bytes among the RS frame payload, when the size of the RS frame payload does not correspond to a multiple of 184 bytes, wherein N4 represents a number of non-packetized data bytes among the RS frame payload.

5. The transmitting system of claim 2, wherein the transmitter is further configured to:

extract the mobile service data included in the payload region of each of the plurality of mobile service data packets having the PID that correspond to the RS frame payload; and

form the RS frame payload based on the extracted mobile service data.

6. The transmitting system of claim 5, wherein the transmitter is further configured to:

select a first of the plurality of mobile service data packets of the RS frame payload based upon the PUSI field value of the TS header; and

select a last of the plurality of mobile service data packet of the RS frame payload based upon an adaptation field control field value of the TS header.

7. The transmitting system of claim 1, wherein the transmitter comprises:

an RS frame encoder configured to RS encode and Cyclic Redundancy Check (CRC) encode the mobile service data of the RS frame payload in order to build one or two RS frames per parade depending on RS frame mode information that indicates a single frame mode or a dual frame mode;

a block processor configured to encode data in the one or two RS frames at a code rate of $1/H$, wherein $H > 1$;

a signaling encoder configured to encode signaling data; and

a group formatter configured to form data groups including the encoded data in the one or two RS frames and insert known data sequences and the encoded signaling data into each of the data groups.

8. The transmitting system of claim 7, wherein the signaling encoder comprises:

a first RS encoder configured to RS encode transmission parameter channel (TPC) data in the signaling data;

a second RS encoder configured to RS encode fast information channel (FIC) data in the signaling data;

an interleaver configured to interleave the RS-encoded FIC data;

a multiplexer configured to multiplex the RS-encoded TPC data and the interleaved FIC data; and

a Parallel Concatenated Convolutional Code (PCCC) encoder configured to PCCC encode the multiplexed data,

wherein the TPC data include the RS frame mode information and a parade identifier for identifying the parade, and

wherein the FIC data include cross layer information between a physical layer and an upper layer for rapid service acquisition.

9. A method of processing broadcast data in a transmitting system including a service multiplexer and a transmitter, the method comprising:

packetizing, by the service multiplexer, a Reed-Solomon (RS) frame payload having a size of N (a column size of the RS frame payload) $\times 187$ (a row size of the RS frame payload) bytes including mobile service data into a plurality of mobile service data packets;

transmitting, by the service multiplexer, the plurality of mobile service data

packets to the transmitter, wherein each of the plurality of mobile service data packets is configured from a transport stream (TS) header and a data region, the data region including at least a payload region or an adaptation field region;

forming, by the transmitter, the RS frame payload from the plurality of mobile service data packets based upon the TS header of each of the plurality of mobile service data packets transmitted from the service multiplexer; and

pre-processing, by the transmitter, the mobile service data of the RS frame payload,

wherein a number of the plurality of mobile service data packets being packetized from the RS frame payload is determined as $\lfloor (N \times 187) / 184 \rfloor + 1$, and

wherein $\lfloor X \rfloor$ represents a maximum integer not larger than X and N indicates a number of columns in the corresponding RS frame payload,

setting a payload unit start indicator (PUSI) field value of the TS header included in a mobile service data packet of the plurality of mobile service data packets that include a first data byte of the RS frame payload to '1'; and

setting the PUSI field value of the TS header included in remaining mobile service data packets of the plurality of data packets to '0'.

10. The method of claim 9, further comprising setting an ensemble identifier corresponding to the RS frame payload as a packet identifier (PID) of the TS header included in each of the plurality of mobile service data packets.

11. The method of claim 9, further comprising:

configuring $\lfloor (N \times 187) / 184 \rfloor$ mobile service data packets of the plurality of mobile service data packets by dividing the RS frame payload into 184-byte units, each including a 4-byte TS header and a payload region including data of each of the 184-byte units and configuring a $\lfloor (N \times 187) / 184 \rfloor + 1^{th}$ mobile service data packet of the plurality of mobile service data packets to include that includes a 4-byte TS header and a 184-byte adaptation field region including stuffing data, when the size of the RS frame payload corresponds to a multiple of 184 bytes.

12. The method of claim 9, further comprising:

configuring $\lfloor (N \times 187) / 184 \rfloor$ mobile service data packets of the plurality of mobile service data packets by dividing the RS frame payload into 184-byte units, each including a 4-byte TS header and a payload region including data of each of the 184-byte units and configuring a $\lfloor (N \times 187) / 184 \rfloor + 1^{th}$ mobile service data packet of the plurality of mobile service data packets that includes a 4-byte TS header, a $(184 - N_4)$ -byte adaptation field region including stuffing data, and a payload region including N_4 bytes of non-packetized data bytes among the RS frame payload, when the size of the RS frame payload does not correspond to a multiple of 184 bytes, wherein N_4 represents a number of non-packetized data bytes among the RS frame payload.

13. The method of claim 9, further comprising:

extracting the mobile service data included in the payload region of each of the plurality of mobile service data packets having the ensemble identifier corresponding to the RS frame payload, and

forming the RS frame payload based on the extracted mobile service data.

14. The method of claim 9, wherein pre-processing the mobile service data comprises:

RS encoding and Cyclic Redundancy Check (CRC) encoding the mobile service data of the RS frame payload in order to build one or two RS frames per parade depending on RS frame mode information that indicates a single frame mode or a dual frame mode; encoding data in the one or two RS frames at a code rate of $1/H$, wherein $H > 1$;

encoding signaling data; and

forming data groups including the encoded data in the one or two RS frames; and

inserting known data sequences and the encoded signaling data into each of the data groups.

15. The method of claim 14, wherein encoding signaling data comprises:

RS encoding transmission parameter channel (TPC) data in the signaling data;

RS encoding fast information channel (FIC) data in the signaling data,

interleaving the RS-encoded FIC data;

multiplexing the RS-encoded TPC data and the interleaved FIC data; and

Parallel Concatenated Convolutional Code (PCCC) encoding the multiplexed data;

wherein the TPC data includes the RS frame mode information and a parade identifier for identifying the parade, and

wherein the FIC data includes cross layer information between a physical layer and an upper layer for rapid service acquisition.

16. A method of processing a broadcast signal in a transmitting system, the method comprising:

forward error correction (FEC) encoding at least broadcast service data for a broadcast service or table information for the broadcast service, thereby outputting an FEC frame;

permuting data of the FEC frame;

block interleaving the permuted data;

convolutional interleaving the block-interleaved data;

FEC encoding transmission parameter data; and

transmitting a transmission frame including the convolutional interleaved data and the FEC-encoded transmission parameter data,

wherein the transmission frame is composed of multiple sub-frames that are concatenated in time,

wherein the transmission parameter data include sub-frame information related to the sub-frames,

wherein the FEC frame corresponds to one of a first FEC frame and a second FEC frame, and

wherein a length of the first FEC frame differs from that of the second FEC frame.

17. A transmitting system for processing a broadcast signal, the transmitting system comprising:

a first encoder to FEC encode at least broadcast service data for a broadcast service or table information for the broadcast service, thereby outputting an FEC frame and permute data of the FEC frame;

a first interleaver to block interleave the permuted data;
 a second interleaver to convolutional interleave the
 block-interleaved data;
 a second encoder to FEC encode transmission parameter
 data; and 5
 a transmitting unit to transmit a transmission frame
 including the convolutional interleaved data and the
 FEC-encoded transmission data,
 wherein the transmission frame is composed of multiple
 sub-frames that are concatenated in time, 10
 wherein the transmission parameter data include sub-
 frame information related to the sub-frames,
 wherein the FEC frame corresponds to one of a first FEC
 frame and a second FEC frame, and
 wherein a length of the first FEC frame differs from that 15
 of the second FEC frame.

18. The method of claim 16, wherein:
 the FEC frame includes at least one data packet having a
 header and a payload,
 the header includes stuffing indication information for 20
 indicating whether stuffing data are included in the
 data packet, and
 the payload includes the broadcast service data.

19. The transmitting system of claim 17, wherein:
 the FEC frame includes at least one data packet having a 25
 header and a payload,
 the header includes stuffing indication information for
 indicating whether stuffing data are included in the
 data packet, and
 the payload includes the broadcast service data. 30

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