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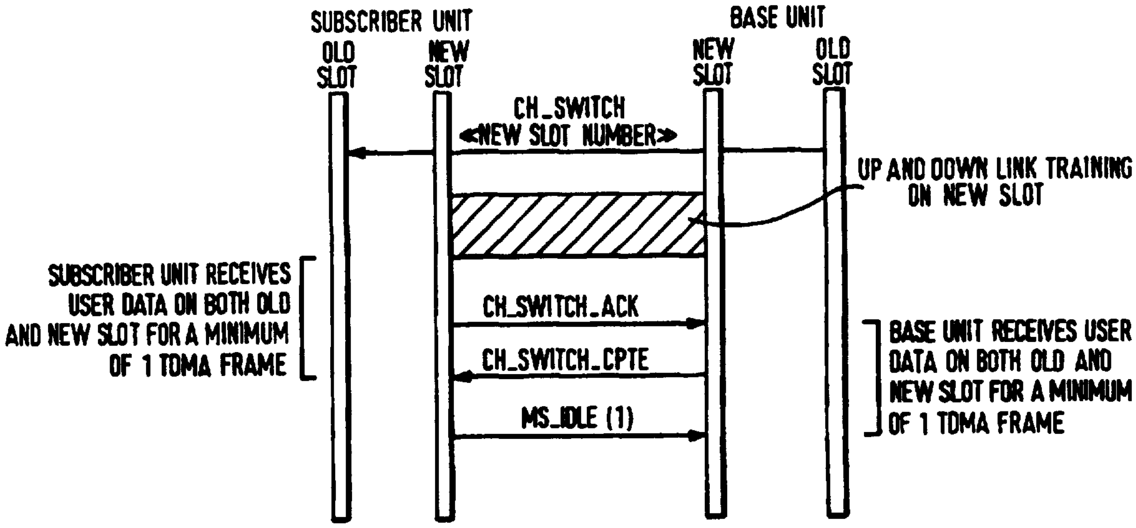

NOTES:
(1) RECEIPT OF THE MESSAGE CH_SWITCH_CPTE IS ACKNOWLEDGED BY THE SUBSCRIBER UNIT BY CEASING TO SEND THE MESSAGE CH_SWITCH_ACK. IN THE ABSENCE OF ANY OTHER VALID MESSAGE MS_IDLE SHALL BE SENT.

(57) Abstract

Switching a call sent in time slots within fixed length time frames from a first channel having an associated time slot to a second channel having an associated time slot in the frame involves transmitting in both slots for at least one frame. When correctly received in the second time slot, the first time slot can be released.

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Call Handoff in Digital Radio Telephony

This invention relates to transmitting a call in time slots within fixed length time frames, in particular, in time division multiplex/time division multiple access (TDM/TDMA) digital telephony.

In TDM/TDMA systems, such as those having a base station and subscriber units, a call is assigned to a physical channel, i.e. a predetermined time slot within each TDM/TDMA frame on a predetermined frequency. Sometimes it is desirable to change channels while the call is in progress. Accordingly, channels can be reallocated by a base station so as to free the channel currently being used. For example, channel switching is undertaken to reduce the chance that a new call will be unable to be set up due to a channel that satisfies appropriate power and range criteria not being available. For example, channel switching is also undertaken to move a call from a channel which is deteriorating in quality due to changing environmental conditions. For example, channel reallocation in this sense is usually termed "channel diversity".

The present invention is defined in the claims, to which reference should now be made.

The present invention preferably provides a method of switching a call from a first channel associated with a first TDM/TDMA time slot to a second channel associated with a second TDM/TDMA time slot in which for at least one frame, both first and second time slots are used for transmitting the call data. By using both time slots for at least one frame, it is possible to obtain a seamless channel switch, that is, without any loss of data. The first channel can be at the same or a different frequency to the second TDMA channel. Preferably, first and second channels of the same frequency use different time slots, but alternatively, first and second channels of different frequency may use the same time slot.

According to a first embodiment, the invention further provides a method of switching, in a TDM/TDMA system, from a first channel to a second channel, in which in at least one frame, a first sample of serial data is sent in the first channel, and a second sample of serial data overlapping the first sample is sent in the second channel, the overlap corresponding to serial data of at least one time slot period. According to a second embodiment, the invention provides a method of switching in a TDM/TDMA system, from a first channel to a second channel, in which in at least one frame, a data packet is replicated in both channels.

The invention also relates to a method of switching from a first TDM/TDMA slot for transmission to a second TDM/TDMA slot for transmission, in which transmission in both first and second slots from a base station to a subscriber unit is continued until reception by the subscriber unit of transmission in both first and second slots is acknowledged to the base station. The base station can then send a control signal to the subscriber unit operative to confirm that use of the first slot is discontinued.

The invention also relates to apparatus to implement these methods.

A preferred embodiment of the invention will now be described, by way of example, with reference to the drawings in which:

Figure 1 is a schematic diagram illustrating the system including a base station (BTE - Base Terminating Equipment) and subscriber unit (NTE - Network Terminating Equipment);

Figure 2 is a diagram illustrating frame structure and timing for a duplex link;

Figure 3 is a diagram illustrating the minimum time delay between transmission and reception of data using a TDMA system;

Figure 4 is a diagram illustrating the principles of seamless channel switching according to the invention;

Figure 5 is a diagram illustrating the exchange of control signals sent between a base station and subscriber unit during channel switching;

Figure 6 is a diagram illustrating a base channel switching according to the invention when transmitting data packets.

The Basic System

As shown in Figure 1, the preferred system is part of a telephone system in which the local wired loop from exchange to subscriber has been replaced by a full duplex radio link between a fixed base station and fixed subscriber unit. The preferred system includes the duplex radio link, and transmitters and receivers for implementing the necessary protocol. There are similarities between the preferred system and digital cellular mobile telephone systems such as GSM which are known in the art. This system uses a protocol based on a layered model, in particular the following layers: PHY (Physical), MAC (Medium Access Control), DLC (Data Link Control), NWK (Network).

One difference compared with GSM is that, in the preferred system, subscriber units are at fixed locations and there is no need for hand-off arrangements or other features relating to mobility. This means, for example, in the preferred system directional antennae and mains electricity can be used.

Each base station in the preferred system provides six duplex radio links at twelve frequencies chosen from the overall frequency allocation, so as to minimize interference between base stations nearby. The frame structure and timing for the duplex link is illustrated in Figure 2. Each duplex radio link comprises an up-link from a subscriber unit to a base station and, at a fixed frequency offset, a down-link from the base station to the subscriber unit. The down-links are TDM, and the up-links are TDMA. Modulation for all links is $\pi/4$ - DQPSK, and the basic frame structure for all links is ten slots per frame of 2560 bits i.e. 256 bits per slot. The bit rate is 512kbps. Down-links are continuously transmitted and incorporate a broadcast channel for essential system information. When there is no user information to be transmitted, the down-link transmissions continue to use the basic frame and slot structure and contain a suitable fill pattern.

For both up-link and down-link transmissions, there are two types of slot: normal slots which are used after call set-up, and pilot slots used during call set-up.

Each down-link normal slot comprises 24 bits of synchronisation information followed by 24 bits designated S-field which includes an 8 bit header, followed by 160 bits designated D-field. This is followed by 24 bits of Forward Error Correction and an 8 bit filler, followed by 12 bits of the broadcast channel. The broadcast channel consists of segments in each of the slots of a frame which together form the down-link common signalling channel which is transmitted by the base station, and contains control messages containing link information such as slot lists, multi-frame and super-frame information, connectionless messages and other information basic to the operation of the system.

During call set-up, each down-link pilot slot contains frequency correction data and a training sequence for receiver initialisation, with only a short S- field and no D- field information.

Up-link slots basically contain two different types of data packet. The first type of packet, called a pilot packet, is used before a connection is set up, for example, for an ALOHA call request and to allow adaptive time alignment. The other type of data packet, called a normal packet, is used when a call has been established and is a larger data packet, due to the use of adaptive time alignment.

Each up-link normal packet contains a data packet of 244 bits which is preceded and followed by a ramp of 4 bits duration. The ramps and the remaining bits left of the 256 bit slot provide a guard gap against interference from neighbouring slots due to timing errors. Each subscriber unit adjusts the timing of its slot transmissions to compensate for the time it takes signals to reach the base station. Each up-link normal data packet comprises 24 bits of synchronisation data followed by an S-field and D-field of the same number of bits as in each down-link normal slot.

Each up-link pilot slot contains a pilot data packet which is 192 bits long preceded and followed by 4 bit ramps defining an extended guard gap of 60 bits. This larger guard gap is necessary because there is no timing information available and without it propagation delays would cause neighbouring slots to interfere. The pilot packet comprises 64 bits of sync followed by 104 bits of S-field which starts with an 8 bit header and finishes with a 16 bit Cyclic Redundancy Check, 2 reserved bits, 14 FEC bits, and 8 tail bits. There is no D-field.

The S-fields in the above mentioned data packets can be used for two types of signalling. The first type is MAC signalling (MS) and is used for signalling between the MAC layer of the base station and the MAC layer of a subscriber unit whereby timing is important. The second type is called associated signalling, which can be slow or fast and is used for signalling between the base station and subscriber units in the DLC or NWK layers.

The D-field is the largest data field, and in the case of normal telephony contains digitised speech, but can also contain a non-speech data samples.

Provision is made in the preferred system for subscriber unit authentication using a challenge response protocol. General encryption is provided by combining the speech or data with a non-predictable sequence of cipher bits produced by a key stream generator which is synchronised to the transmitted super-frame number.

In addition, the transmitted signal is scrambled to remove dc components.

Channel Switching

As shown in Figure 3, data for transmission is a long sequence of serial digital data. A segment of this data, specifically a frame duration's worth of serial data, is compressed into a selected time slot within a frame. In Figure 1, time slot 0 has been selected by way of example. Upon reception of the data in the time slot, the data is decompressed as shown in the lower part of that figure, so that data is transmitted in a continuous (i.e. seamless manner).

As shown in Figure 3, it can be seen that the first digit A is received with a delay of the frame period minus one time slot. The last digit B of the data packet transmitted in time slot 0 similarly has a delay of the frame period minus one time slot. All digits between first and last experience this same delay. In practice, the delays will be slightly longer due to processing delays.

In seamless channel switching from one slot to another, both slots are used in the frame at which switching occurs. This results in some overlap of data dependent on the spacing between the two slots. Data is discarded to restore the normal seamless situation. Seamless channel switching from slot 0 to slot 9 is illustrated in Figure 4. Of course, switching between any two slots is possible.

As shown in Figure 4, both slots 0 and 9 are used for one frame. Each slot contains a sample of the serial data for transmission, the data sent in slot 9 basically follows on from the data sent in slot 0. However, there is an overlap which corresponds to one time slot period. Essentially, some of the serial data is sent in both slots 0 and 9 when switching between the two. At the receiver the data from both slots 0 and 9 is simply overlaid to reconstitute the original serial data stream, and replicated data is discarded, such that the reception of data is apparently seamless.

A new slot can be earlier in the frame than the old slot, as well as later in the frame as in the particular example illustrated in Figure 4.

Channels have an associated time slot in both uplink and downlink frames. such that switching is effected in both directions.

The messages sent between a base station and subscriber unit, to effect channel switching when system control information is being sent, are shown in Figure 5. Channel-Switch request is first sent from the base station to the subscriber unit and the usual training message sequence is effected for time alignment of transmissions. The transmission of data on the new channel is then enabled, and data is transmitted on both channels for a minimum of one frame. The subscriber unit then sends a Channel-Switch-Acknowledgement on the new channel and the base station responds by sending Channel-Switch- Complete signal on the down-link until the acknowledgement signal ceases i.e. is superseded by another message or MS-Idle. The old channel is then released.

Multi-bearer Channel Switching

Multi-bearer connections are those using more than one slot per frame so as to allow user data to be sent at a higher rate than normal. For example, the 64Kbps PCM service requires two slots per frame. No presumptions are made as to which two slots in the frame are appropriate for this connection; slots are allocated by the base dependent on traffic considerations and on the limitations of the subscriber unit.

When channel switching is effected in a multi-bearer connection, each channel to be switched is switched independently. The channel switching process reconstitutes the serial data on each channel without loss or duplication of data, and without introducing any unknown delays. The communications between the base station and a subscriber unit to switch a channel in a multi-bearer connection, are similar to those for channel switching a single bearer connection. Bearers in a multi-bearer connection can be switched in the same frame or in different frames. Of course, not all channels used in a multi-bearer connection need be switched.

Channel Switching Packet Data

When a call consisting of packetized data is switched between channels, the data packet transmitted in a first channel is replicated in a second channel in at least one frame, as shown in Figure 6, to ensure that the data is safely received during the switch over.

Reasons for Channel Switching

Channel switching is undertaken for any of several reasons. One reason is to switch to a frequency having better quality propagation between the subscriber unit and base station, or to minimise the risk of co-channel interference between neighbouring subscriber units. Switching is also useful so as to ensure that each of a number of subscriber units has at least one time slot/radio frequency setting available for communications of acceptable quality when there is moderately high traffic loading. Each subscriber unit can communicate with a base station on up to three different time slot/radio frequency settings. Where a first subscriber unit is using a slot which could be used by a second subscriber unit, and another slot is available to the first subscriber unit but not to the second subscriber unit, the transmission from the first unit can be switched so as to make that slot available to the second unit. Slot shuffling in this way reduces the chance of call attempts being blocked.

Waiting to handle a call set-up request until a channel switch is completed

If a channel switch is in progress at a particular subscriber unit when a further channel allocation request arrives, the request is held as "pending" until the channel-switch-complete message has been received. The released channel is then available for use in response to the request. In consequences, the chance that a call attempt will be blocked is reduced.

CLAIMS

1. A method of transmitting a call in selected time slots within fixed length time frames including switching the call being transmitted from a first channel associated with a first time slot to a second channel associated with a second time slot in which for at least one frame of time slots, both the first and the second time slots are used for transmitting the call data.

2. A method of transmitting a call according to claim 1, by radio.

3. A method of transmitting a call according to claim 2, in which each channel is defined by its associated time slot and carrier radio frequency.

4. A method of transmitting a call according to any preceding claim, in which the first channel is at the same radio carrier frequency as the second channel.

5. A method of transmitting a call according to any preceding claim, in which the first channel and the second channel use different time slots.

6. A method of transmitting a call according to claim 5, in which the second time slot is later in a frame than the first time slot.

7. A method of transmitting a call according to claim 5, in which the second time slot is earlier in a frame than the first time slot.

8. A method of transmitting a call according to any of claims 1 to 3, in which the first time slot and the second time slot are the same time slot within frames and are of different frequencies.

9. A method of transmitting a call according to any of claims 1 to 8, in which in at least one frame, a first sample of serial data is sent in the first channel, and a second sample of serial data overlapping the first sample is sent in the second channel, the overlap corresponding to serial data of at least one time slot period.

10. A method of transmitting a call according to any of claims 1 to 8, in which in said at least one frame, a data packet is replicated in both channels.

11. A method of transmitting a call according to any preceding claim, in which a call being transmitted shared between the first channel associated with the first time slot and a third channel associated with a third time slot is switched so as to be transmitted shared between the second channel associated with the second time slot and the third channel.

12. A method of transmitting a call to any preceding claim, in which a call being transmitted shared between a selected set of channels each of which is associated with a predetermined time slot is switched so as to be transmitted shared between a different selected set of channels each of which associated with a predetermined time slot.

13. A method of transmitting a call according to any preceding claim, in which each

channel is associated with a predetermined time slot in frames both from a base station to a subscriber unit and vice versa.

14. A method of transmitting a call according to any preceding claim, in which response to a call set-up request is postponed at least until the first channel has been released.

15. A transmitter for transmitting a call in time slots within fixed length time frames including switching means for switching a call being transmitted from a first channel associated with a first time slot to a second channel associated with a second time slot, in which for at least one frame of time slots, both the first and the second time slots are used for transmitting the call data.

16. A transmitter according to claim 15, comprising a base station operative to transmit time division multiplex (TDM) call data signals.

17. A transmitter according to claim 16, comprising a subscriber unit operative to transmit time division multiple access (TDMA) call data signals.

18. A transmitter according to claim 17, in which the subscriber unit is at a fixed location.

19. A method of receiving a call in selected time slots within fixed length time frames and switched from a first channel associated with a first time slot to a second

channel associated with a second time slot, in which for at least one frame of time slots, both the first and the second time slots are used for transmitting the call data such that there is an overlap in the data received in the first and second time slots, discarding the overlapping a data received in one of the first and the second channel to reconstitute the call data.

20. A receiver for a call in time slots within fixed length time frames and switched from a first received channel associated with a first time slot to a second received channel associated with a second time slot, in which for at least one frame, both the first and second time slots are used for transmitting the call data such that there is an overlap in the data received in the first and second time slots, the receiver including means to discard the overlapping data received on one of the first and the second channel and to reconstitute the call data.

21. A receiver according to claim 20, comprising a subscriber unit operative to receive time division multiplex (TDM) call data signals.

22. A receiver according to claim 20, comprising a base station operative to receive time division multiple access (TDMA) call data signals.

23. A method of switching a call sent in time slots within fixed length time frames from a first time slot to a second time slot, in which transmission in both first and second time slots is continued for at least one frame until reception by the receiver of transmissions in both first and second time slots in a frame is acknowledged to the

transmitter.

24. A method of switching according to claim 23, in which the receiver is a subscriber unit and the transmitter is a base station.

25. A method according to claim 23 or claim 24, in which the transmitter thereafter sends a control signal to the receiver to confirm that use of the first slot is discontinued.

26. A method of transmitting a call in time slots within fixed length time frames including switching from a first time slot to a second time slot, in which transmission in both first and second time slots is continued in at least one frame until reception is acknowledged.

27. A transmitter for a call in time slots within fixed length time frames including switching means for switching from a first time slot to a second time slot, in which transmission in both first and second time slots is continued in at least one frame until reception is acknowledged to the transmitter.

28. A receiver for a call in time slots within fixed length time frames switched from a first time slot to a second time slot, in which reception on the second time slot in a frame is acknowledged, and the receiver thereafter responds to a received control signal to cease reception on the first time slot in the frame.

FIG. 1

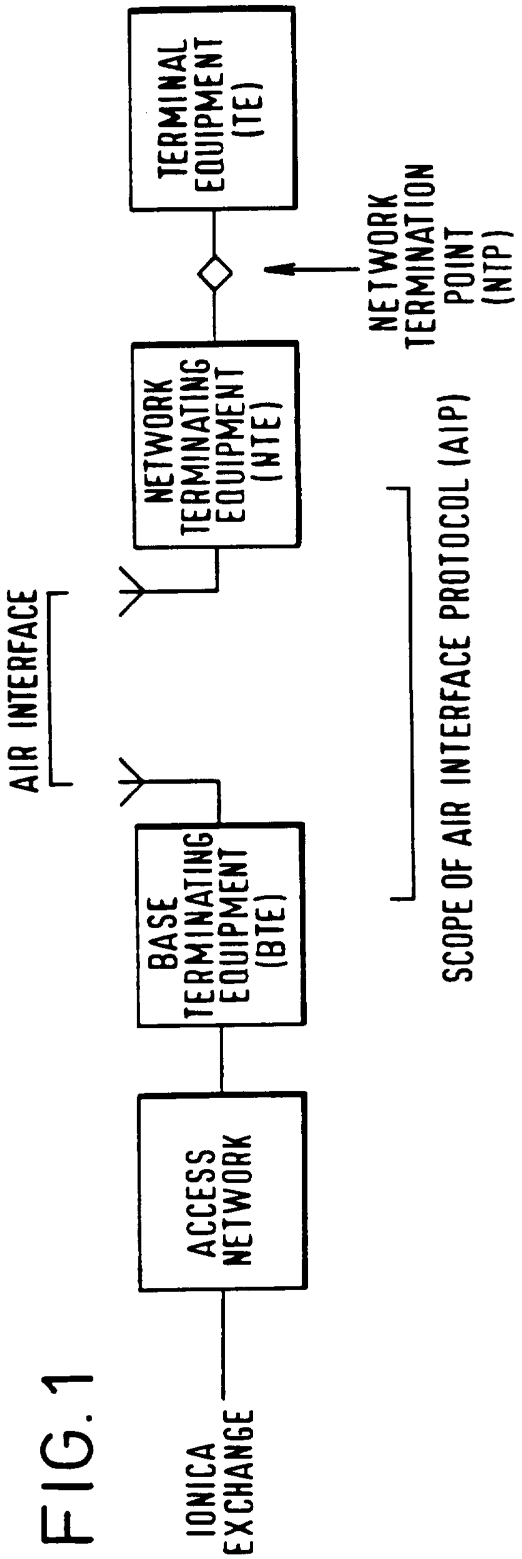

IONICA EXCHANGE
ACCESS NETWORK
BASE TERMINATING EQUIPMENT (BTE)
AIR INTERFACE
NETWORK TERMINATING EQUIPMENT (NTE)
NETWORK TERMINATION POINT (NTP)
TERMINAL EQUIPMENT (TE)
SCOPE OF AIR INTERFACE PROTOCOL (AIP)

FIG. 2

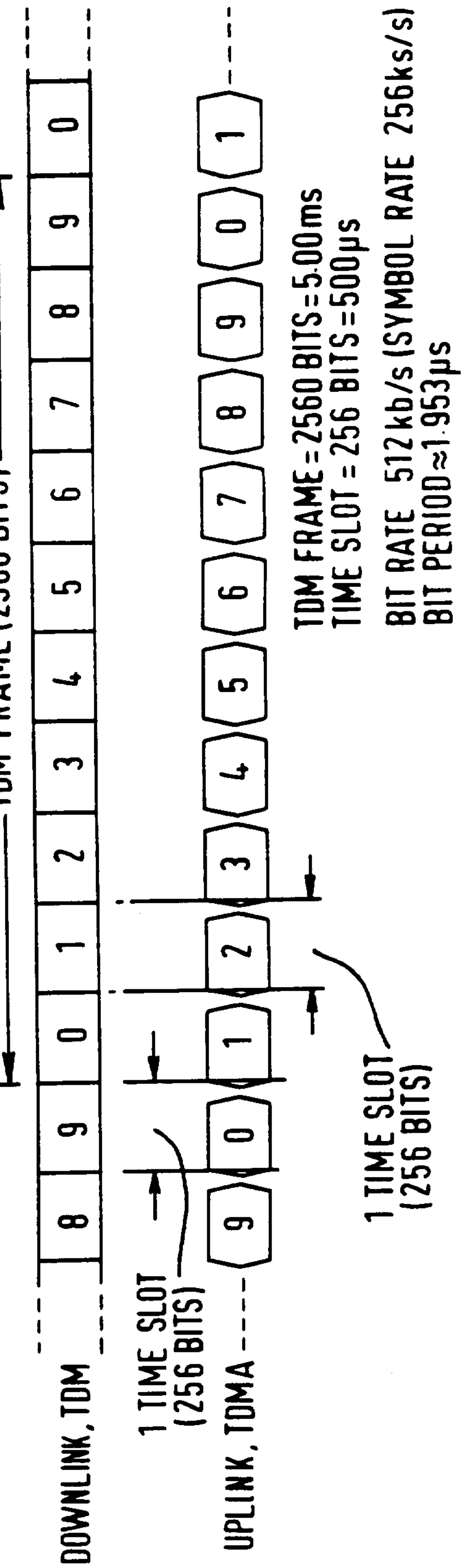

DOWNLINK, TDM
UPLINK, TDMA
TDM FRAME (2560 BITS)
8 9 0 1 2 3 4 5 6 7 8 9 0
9 0 1 2 3 4 5 6 7 8 9 0 1
1 TIME SLOT (256 BITS)
1 TIME SLOT (256 BITS)
TDM FRAME = 2560 BITS = 5.00ms
TIME SLOT = 256 BITS = 500μs
BIT RATE 512 kb/s (SYMBOL RATE 256ks/s)
BIT PERIOD≈1.953μs

FIG. 3

MINIMUM DELAY

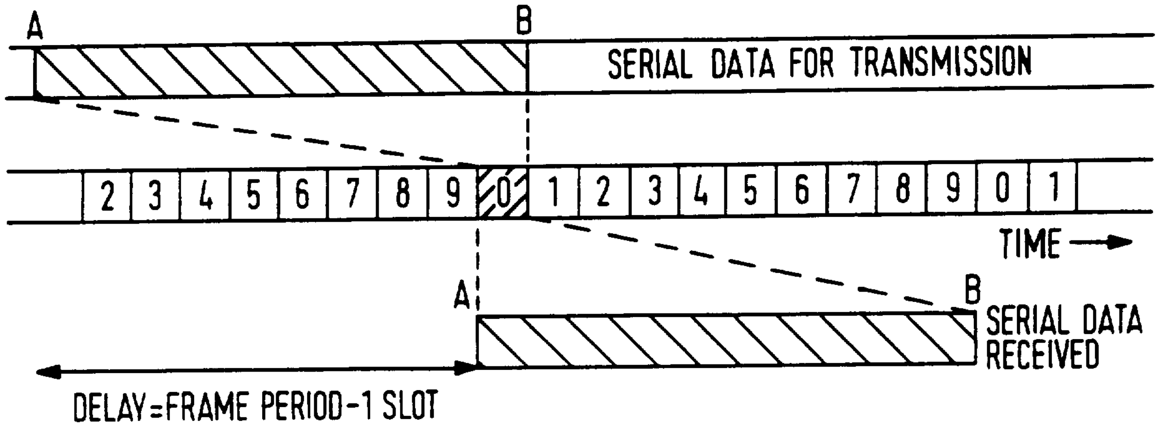
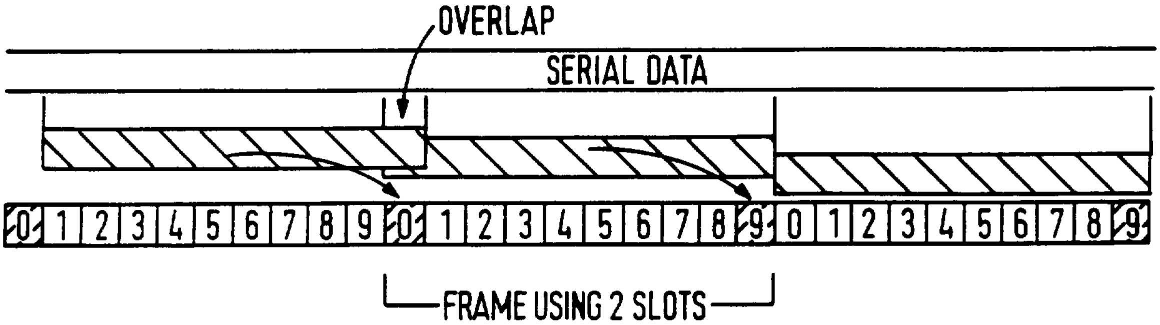


FIG. 4

SEAMLESS CHANNEL SWITCHING



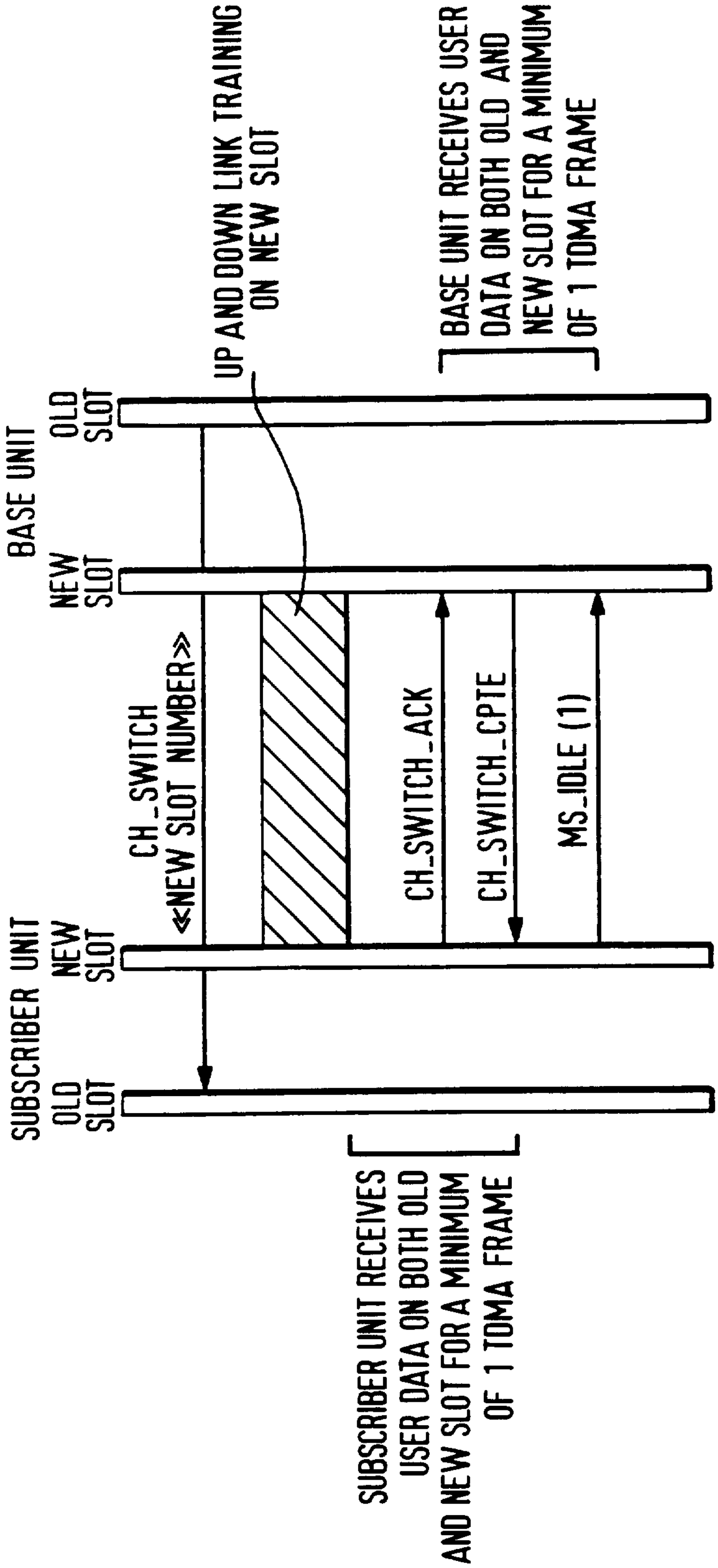


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FIG. 5

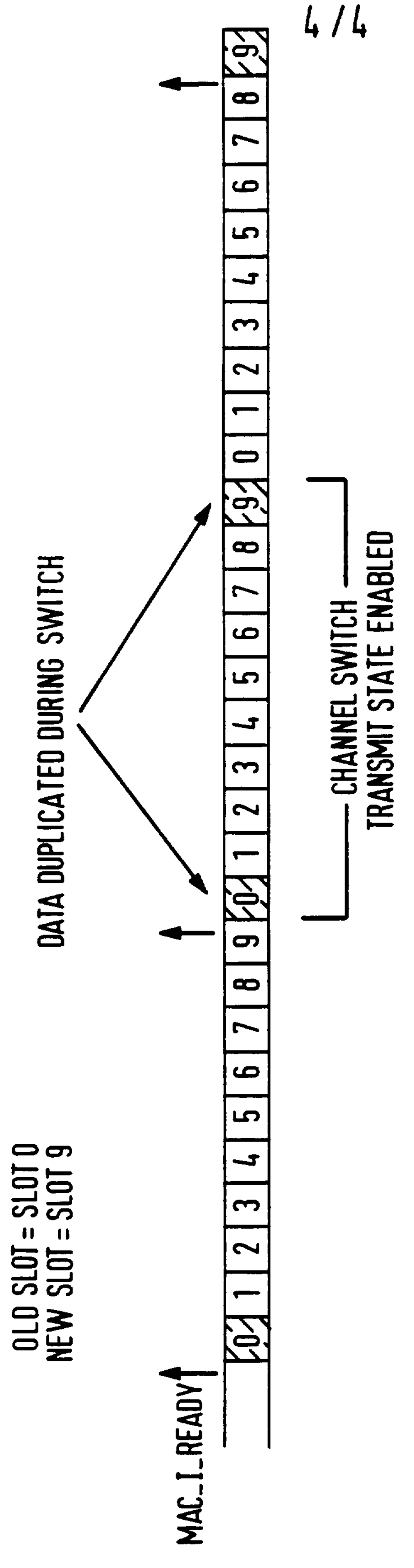

FIG. 6
CHANNEL SWITCHING