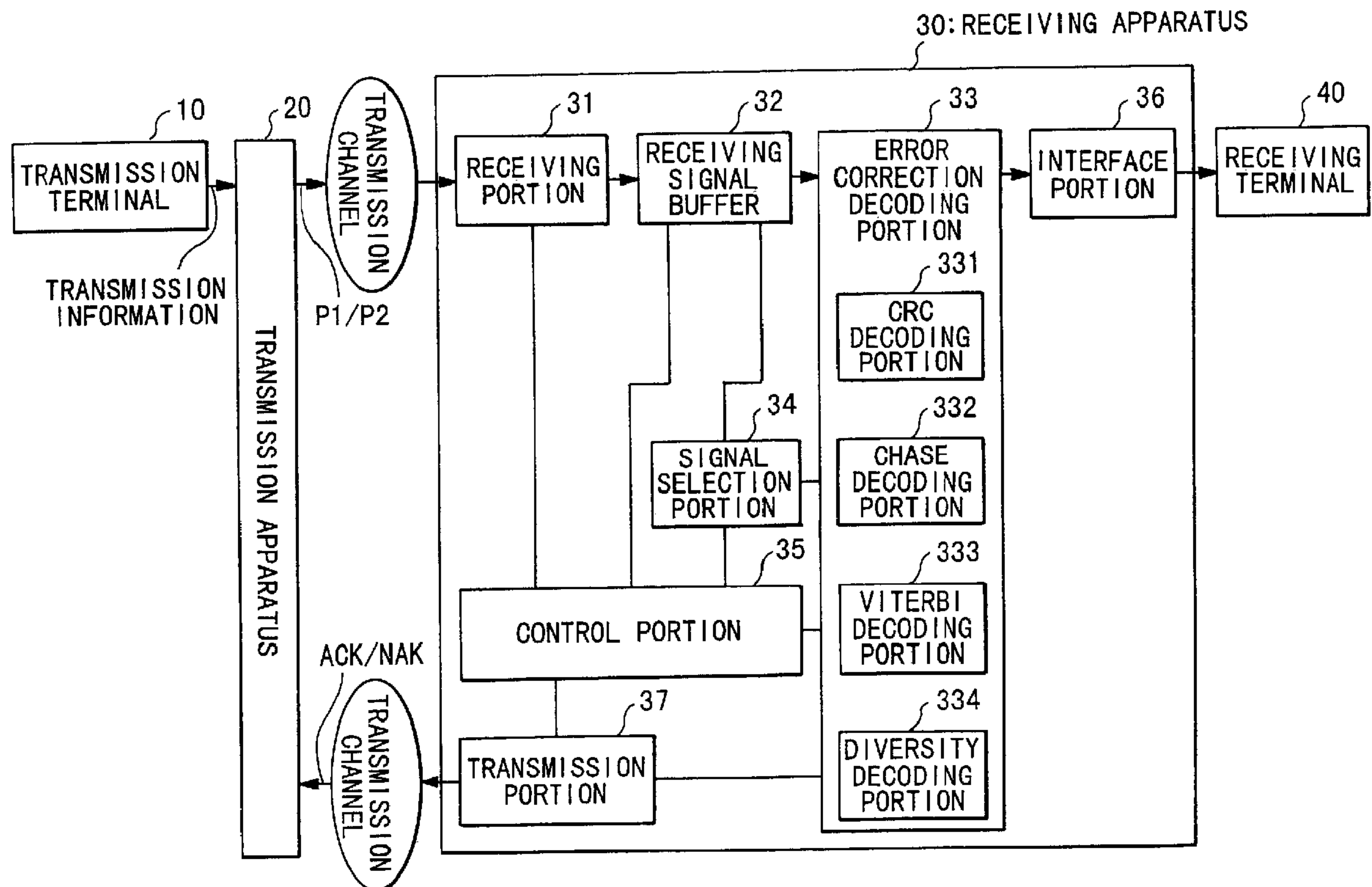




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(54) Titre : METHODE ET DISPOSITIF DE CORRECTION DES ERREURS POUR LES COMMUNICATIONS NUMERIQUES
 (54) Title: ERROR CONTROL METHOD AND ERROR CONTROL DEVICE FOR DIGITAL COMMUNICATION



(57) Abrégé/Abstract:

In an error control device, an error correction decoding portion 33 selects a bit position which has low reliability from the received signal by means of a predetermined bit number, generates error patterns by assuming that the errors exist at the bit position, and carries out Chase decoding for the received signals on the basis of each error pattern in Chase decoding portion 332. Chase decoding portion 332 calculates the reliability of each error pattern by using the reliability of each bit in the received signal.

ABSTRACT OF THE DISCLOSURE

In an error control device, an error correction decoding portion 33 selects a bit position which has low reliability from the received signal by means of a predetermined bit number, generates error patterns by assuming that the errors exist at the bit position, and carries out Chase decoding for the received signals on the basis of each error pattern in Chase decoding portion 332. Chase decoding portion 332 calculates the reliability of each error pattern by using the reliability of each bit in the received signal.

ERROR CONTROL METHOD AND ERROR CONTROL DEVICE
FOR DIGITAL COMMUNICATION

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an error control method and an error control device for digital communication which employ retransmission control such as ARQ (Automatic Repeat Request), and in particular relates to an error control method and an error control device for digital communication which use hybrid ARQ which carries out code combining.

Background

In conventional retransmission control using a code combining technique, all received signals are used in a decoding. The technique of retransmission control is disclosed, for example, in IEEE Trans. Commun. vol. 33, pp, 385-393, May, 1985. Retransmission control methods using code combining techniques are classified into methods which add only an error detecting code to the first signal transmitted without providing a redundancy for error correction, and methods which provide a redundancy for error correction to the first signal transmitted.

In retransmission control using the code combining technique, when signals having an extremely large number of errors are included in the received signals, multiple retransmission is necessary and all the received signals are used in the technique. Furthermore, in the method which adds an error detecting code only to the first transmitted signal without providing a redundancy for error correction, the first signal received can be decoded only if it is received error-free. However, if there is an error in even one bit, then this signal cannot be decoded. On the other hand, in the method which

provides a redundancy for error correction to the first transmitted signal, the throughput is improved in the case where the transmission channel has a poor quality. However, in the case where the transmission channel has a sufficient quality, the throughput plateaus.

If Chase decoding is used on retransmission control using a code combining technique, it is possible to correct errors using only an error detecting code. However, many combinations must be calculated in order to carry out Chase decoding, such that the number of calculations becomes erroneous.

SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to provide an error control method and an error control device for digital communication, that are able to decode with high efficiency, and are able to obtain a maximum throughput even if the transmission channel has a low quality.

In accordance with one aspect of the present invention, there is provided an error control method for digital communication which corrects errors which occur in the transmission of signals, comprising the steps of: receiving a first signal; in the case that an error is detected in said first signal received in said receiving step, implementing a modified Chase decoding generating a plurality of error patterns assuming that each of a predetermined number of bits is wrong, decoding said first signal sequentially using said plurality of error patterns in an order of highest to lowest possibility of successful decoding, and terminating the process upon the first error pattern that allows successful decoding; in the case that said modified Chase decoding fails, requesting the transmission of a second signal; in the case that an error is detected in said second signal after receiving said second signal, repeating said modified Chase decoding using said second signal; and in the case that said modified Chase decoding fails in said repeating step,

implementing Viterbi decoding using said first and said second received signals that said modified Chase decoding has failed to decode.

In accordance with another aspect of the present invention, there is provided an error control device which corrects errors which occur in the transmission of signals, comprising: a receiver for receiving signals; decoding means, in the case that an error is detected in a signal received in said receiver, for implementing a modified Chase decoding generating a plurality of error patterns assuming that each of a predetermined number of bits is wrong, decoding said signal sequentially using said plurality of error patterns in an order of highest to lowest possibility of successful decoding, and terminating the process upon the first error pattern that allows successful decoding; signal transmission requesting means, in the case that said modified Chase decoding fails, for requesting the transmission of a further signal; repeating means, in the case that an error is detected in said another signal after receiving said further signal, for repeating said modified Chase decoding using said further signal; and a Viterbi decoder, in the case that said modified Chase decoding fails in said repeating step, for implementing Viterbi decoding using a plurality of received signals that said modified Chase decoding has failed to decode.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages of the present invention will be apparent from the following description, reference being made to the accompanying drawings wherein preferred embodiments of the present invention are clearly shown.

Fig. 1 is a block diagram showing a structural example of a receiving apparatus according to an embodiment of the present invention;

Fig. 2 is a chart diagram explaining the operation of a transmission apparatus and a receiving apparatus; and

Fig. 3 is a flowchart showing the Chase decoding method of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An explanation will now be made of preferred embodiments of the present invention with reference to figures.

Fig. 1 is a block diagram showing a structural example of a receiving apparatus according to an embodiment of the present invention.

Fig. 2 is a chart diagram explaining the operation of a transmission apparatus and a receiving apparatus. Transmission apparatus 20 receives transmission information from transmission terminal 10, and then adds an error detecting code (CRC code) to the transmission information. A signal series with added CRC code is expressed as I. Next, transmission apparatus 20 carries out a convolutional encoding to the signal series including CRC bits at a rate of 1/2. The generator polynomials are expressed as (G1, G2). Furthermore, a signal encoded with G1 is expressed as P1, and a signal encoded with G2 is expressed as P2. Transmission apparatus 20 transmits the transmission signal P1 first.

Receiving apparatus 30 receives signal P1 in which errors are overlapped thereto on the transmission channel. The overlapping error pattern is expressed as E1, and the receiving signal is expressed as R1. Therefore, receiving signal R1 becomes a value ($R1=P1+E1$) which is the sum of transmission signal P1 and a modulo-2 of error pattern E1. Receiver 31 of receiving apparatus 30 receives receiving signal R1, and then converts receiving signal R1

to a base band signal, and outputs the base band signal to receiving signal buffer 32. Control portion 35 detects receiving signal R1, and then instructs an execution of a CRC decoding procedure to error correction decoding portion 33. Error correction decoding portion 33 receives the base band signal from receiving buffer 32, and carries out CRC decoding in CRC decoding portion 331 (Fig. 2 (S1)). If CRC decoding portion 331 can decode the base band signal, receiving apparatus 30 outputs a decoded signal to receiving terminal 40 through interface portion 36, and transmits a receipt acknowledgment signal ACK to transmission apparatus 20 through transmission portion 37, completing the receiving procedure. On the other hand, if CRC decoding portion 331 cannot decode the base band signal because of errors, receiving apparatus 30 carries out Chase decoding by Chase decoding portion 332.

Fig. 3 is a flowchart showing the Chase decoding method of the present invention. Chase decoding portion 332 checks whether errors exist in the receiving signal or not (S20). When errors exist in the receiving signal, Chase decoding portion 332 searches the reliability of each bit of the receiving signal, and selects t bits which have the lowest degree of reliability. It is assumed that errors were generated in all or a portion of these t bits, and that errors were not generated in the remainder of the bits. There are $2^t - 1$ ($^$ expresses the power of the number) error patterns in t bits. Next, Chase decoding portion 332 calculates the sum of the reliabilities of the bits in which error is indicated by the error patterns, and carries out CRC check (check using cyclic redundancy code) in the order that selects the untried pattern for which the sum of the reliabilities is lowest (S22).

When CRC check is successful (S24), error correction decoding portion 33 completes the Chase decoding procedure. Next, when Chase check is completed, error correction decoding portion 33 transmits receipt acknowledgment signal ACK to transmission apparatus 20, and completes the receiving procedure (S26). On the other hand, when CRC decoding fails, error correction decoding portion 33 judges whether or not there is a combination which has not been tested (S28). Furthermore, when CRC check for all combinations fails, and all attempts are completed (S28), error correction decoding portion 33 transmits retransmission request signal NAK to transmission apparatus 20 (S30). On the other hand, when all attempts have not been completed, error correction decoding portion 33 generates the pattern of the next attempt by reversing the appropriate bits (S32), and returning to step S24.

When transmission apparatus 20 receives retransmission request signal NAK, it transmits transmission signal P2. Afterward, transmission apparatus 20 alternately transmits transmission signals P1 and P2 whenever it receives retransmission request signal NAK. When receiving apparatus 30 receives receiving signal R2 with the value equivalent to that obtained by adding transmission signal P2 and error pattern E2 ($R2=P2+E2$), CRC decoding portion 331 begins by carrying out CRC decoding (S3). At this time, if CRC decoding portion 331 cannot decode, then receiving apparatus 30 carries out Chase decoding by using Chase decoding portion 332 (S4). Furthermore, if Chase decoding by Chase decoding portion 332 also fails, receiving apparatus 30 carries out Viterbi decoding using R1 and R2 in Viterbi decoding portion 333 (S5). If Viterbi decoding by Viterbi decoding portion 333 fails, then receiving apparatus 30 transmits retransmission request signal NAK.

Next, receiving apparatus 30 receives receiving signal R3 which is obtained by adding transmission signal P1 and error pattern E3 ($R3=P1+E3$), and carries out CRC decoding (S6). If CRC decoding fails, then receiving apparatus 30 carries out Chase decoding (S7). If Chase decoding also fails, receiving apparatus 30 carries out Viterbi decoding using R1, R2 and R3 (S8). If Viterbi decoding fails, then receiving apparatus 30 carries out Viterbi decoding using R2 and R3 (S9). If this decoding also fails, receiving apparatus 30 carries out diversity decoding in diversity decoding portion 334(S10) using R1 and R3.

Chase decoding is also used during diversity decoding. For example, when R1 and R3 are received, diversity decoding portion 334 obtains a signal RD which is decoded by diversity decoding on the basis of a selection diversity or maximum rate synthetic diversity for each bit of R1 and R3. Next, diversity decoding portion 334 carries out Chase decoding on signal RD.

If all decoding fails, then receiving apparatus 30 transmits retransmission request signal NAK. Then, receiving apparatus 30 carries out CRC decoding and Chase decoding whenever it receives a signal, and then carries out Viterbi decoding and diversity decoding when CRC and Chase decoding fails by combining the received signals in a predetermined order. Signal selecting portion 34 decides the combination of the received signals to be decoded.

Next, an explanation will be made of the combination order of the received signals when carrying out Viterbi decoding and diversity decoding. In this example, it is assumed that there are N number of received signal series R1, R2, ..., Rn ($n=2k$); that the received signal series R1, R3, ..., R $2k-1$ is the received signal when P1 is transmitted; and that received signal series R2, R4, ..., R $2k$ is the received signal when P2 is transmitted. In this example, it is also assumed that the reliability of received signal Rn is rn. The reliability rn can be expressed, for example, as the sum of the receiving levels of each bit in received signal Rn.

First, Viterbi decoding is carried out using all received signals. Next, Viterbi decoding is carried out using (N-1) received signals by excluding one received signal from the N received signals. There are N combinations for (N-1) number of signals. Thus, signal selecting portion 34 decides the selection order by using reliability rn. Signal selecting portion 34 selects (N-1) signals by sequentially excluding received signals Rn starting with the signal which has the smallest reliability rn. However, it is also possible for signal selecting portion 34 to select (N-1) signals by sequentially excluding signals beginning with the oldest received signals.

When Viterbi decoding using all combinations of (N-1) signals fails, Viterbi decoding is carried out using (N-2) signals. First, (N-2) signals are selected by excluding the two signals which have the smallest reliability rn. Then, $rn+rn'$ ($1 \leq n, n' \leq N, n < n'$) is calculated, and (N-2) signals are

selected by excluding signals R_n and R_n' in the order of smallest r_n+r_n' , and Viterbi decoding is carried out using the selected signals.

Additionally, it is noted here that the reliability may also be calculated for all the signal combinations. For example, the reliability of received signal $R_a \times R_b \times R_c \times \dots \times R_x$ is $r_a+r_b+r_c+\dots+r_x$. In this case, the reliabilities for all signal combinations are calculated, and then Viterbi decoding is carried out by sequentially selecting the combinations in the order of highest to lowest reliability.

Then, diversity decoding is carried out on the received signal which corresponds to P1 in the selected combination. Next, diversity decoding is carried out on the received signal which corresponds to P2. Finally, Viterbi decoding is carried out by using the two signals which are obtained by each diversity decoding.

(Other Embodiment)

In this example, the number of received signals which correspond to P1 is n_1 , and the number of received signals which correspond to P2 is n_2 . If n_1 is larger than n_2 ($n_1 > n_2$), diversity decoding is carried out for $(n_1 - n_2 + 1)$ signals having low reliability from among the received signals which correspond to P1. When this signal and the received signals which corresponds to the remaining P1 are combined, signals which corresponds to n_2 number of P1 are obtained. As a result, Viterbi decoding can be carried out using a total $2 \times n_2$ number of signals.

This invention may be practiced or embodied in still other ways without departing from the spirit or essential character thereof. Therefore, the preferred embodiments described herein are illustrative and not restrictive, the scope of the invention being indicated by the appended claims and all variations which come within the meaning of the claims are intended to be embraced therein.

Claims:

1. An error control method for digital communication which corrects errors which occur in the transmission of signals, comprising the steps of:

receiving a first signal;

in the case that an error is detected in said first signal received in said receiving step, implementing a modified Chase decoding generating a plurality of error patterns assuming that each of a predetermined number of bits is wrong, decoding said first signal sequentially using said plurality of error patterns in an order of highest to lowest possibility of successful decoding, and terminating the process upon the first error pattern that allows successful decoding;

in the case that said modified Chase decoding fails, requesting the transmission of a second signal;

in the case that an error is detected in said second signal after receiving said second signal, repeating said modified Chase decoding using said second signal; and

in the case that said modified Chase decoding fails in said repeating step, implementing Viterbi decoding using said first and said second received signals that said modified Chase decoding has failed to decode.

2. An error control method as claimed in Claim 1,

wherein said transmitted second signal is generated by a method different from a method that has generated said first signal.

3. An error control method as claimed in Claim 1, further comprising the steps of:

in the case that said Viterbi decoding fails, requesting transmission of a third signal;

in the case that an error is detected in said third signal after receiving said third signal, repeating said modified Chase decoding using said third signal;

in the case that said modified Chase decoding fails in said repeating step, implementing Viterbi decoding using said first, said second, and said third received signals that said modified Chase decoding has failed to decode;

further applying the above steps to further received signals until successful decoding is achieved.

4. An error control method as claimed in Claim 3,
wherein said Viterbi decoding is implemented using all of said first, said second, said third and said further received signals.
5. An error control method as claimed in Claim 3,
wherein said Viterbi decoding is implemented using a portion of said first, said second, said third or said further received signals, said portion comprising all except one of said first, said second, said third or said further received signals, the signal having lowest reliability not being used.
6. An error control method as claimed in Claim 5,
wherein said portion of received signals used in said Viterbi decoding is selected in an order of highest to lowest reliability.
7. An error control method as claimed in Claim 3, further comprising the step of:
implementing diversity decoding using said portion of said first, said second, said third or said further received signals that said modified Chase decoding has failed to decode.

8. An error control method as claimed in Claim 7,
wherein said portion of signals used for said diversity decoding are generated by the same method.
9. An error control device which corrects errors which occur in the transmission of signals, comprising:
a receiver for receiving signals;
decoding means, in the case that an error is detected in a signal received in said receiver, for implementing a modified Chase decoding generating a plurality of error patterns assuming that each of a predetermined number of bits is wrong, decoding said signal sequentially using said plurality of error patterns in an order of highest to lowest possibility of successful decoding, and terminating the process upon the first error pattern that allows successful decoding;
signal transmission requesting means, in the case that said modified Chase decoding fails, for requesting the transmission of a further signal;
repeating means, in the case that an error is detected in said another signal after receiving said further signal, for repeating said modified Chase decoding using said further signal; and
a Viterbi decoder, in the case that said modified Chase decoding fails in said repeating step, for implementing Viterbi decoding using a plurality of received signals that said modified Chase decoding has failed to decode.
10. An error control device as claimed in Claim 9, further comprising:
signal transmission requesting means, in the case that said Viterbi decoding fails, for requesting the transmission of a third signal;

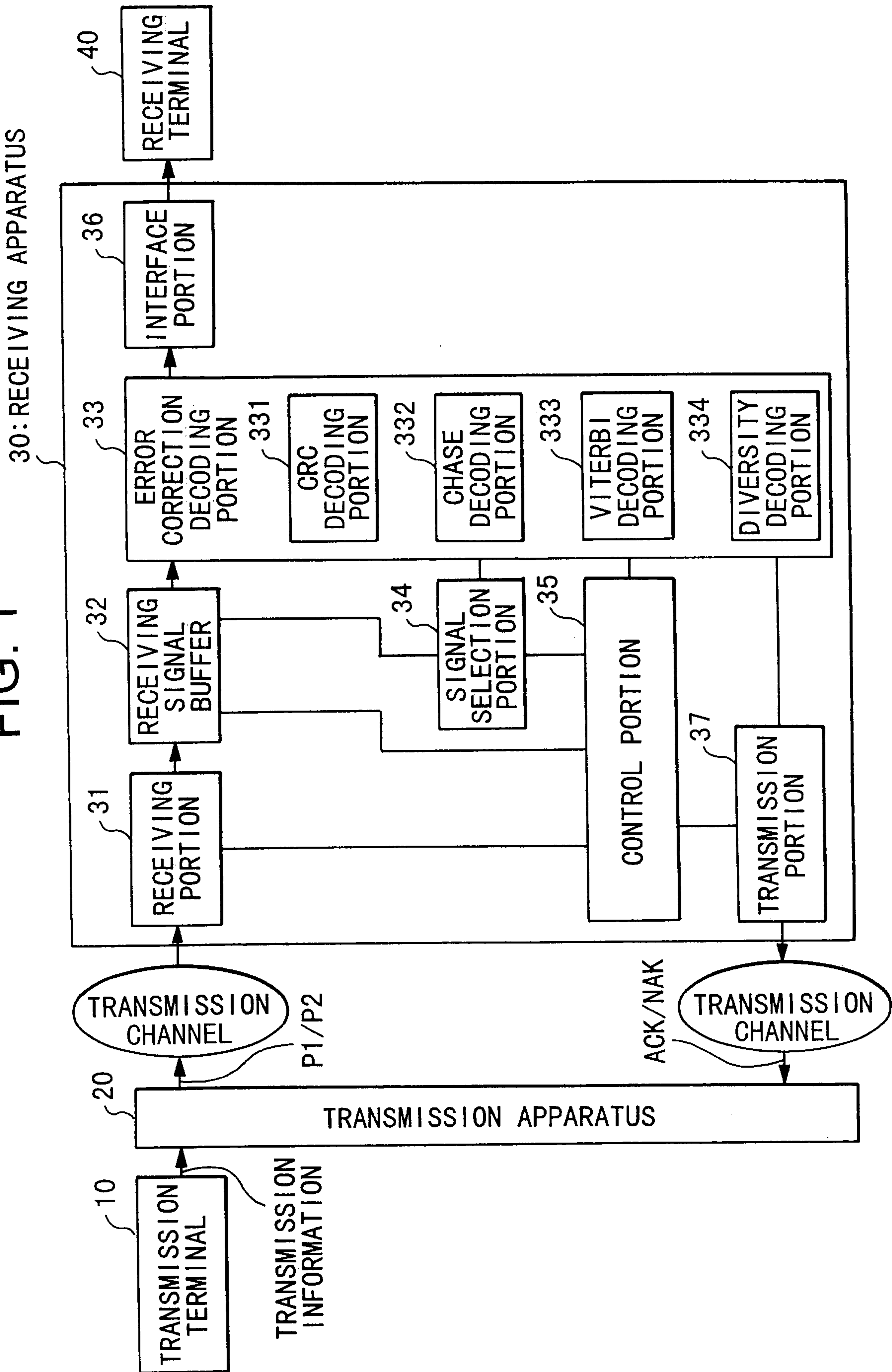
in the case that an error is detected in said third signal after receiving said third signal, repeating means for repeating said modified Chase decoding using said third signal;

in the case that said modified Chase decoding performed by said repeating means fails, a Viterbi decoder for implementing Viterbi decoding using received signals that said modified Chase decoding has failed to decode;

means for further applying the above steps to further received signals until successful decoding is achieved.

11. An error control device as claimed in Claim 10,
wherein said Viterbi decoder further comprises signal selecting means, for selecting signals to be decoded in an order of highest to lowest reliability.
12. An error control device as claimed in Claim 10, further comprising:
a diversity decoder, in the case that said Viterbi decoding fails, for implementing diversity decoding using a portion of received signals that said modified Chase decoding has failed to decode.

FIG. 1



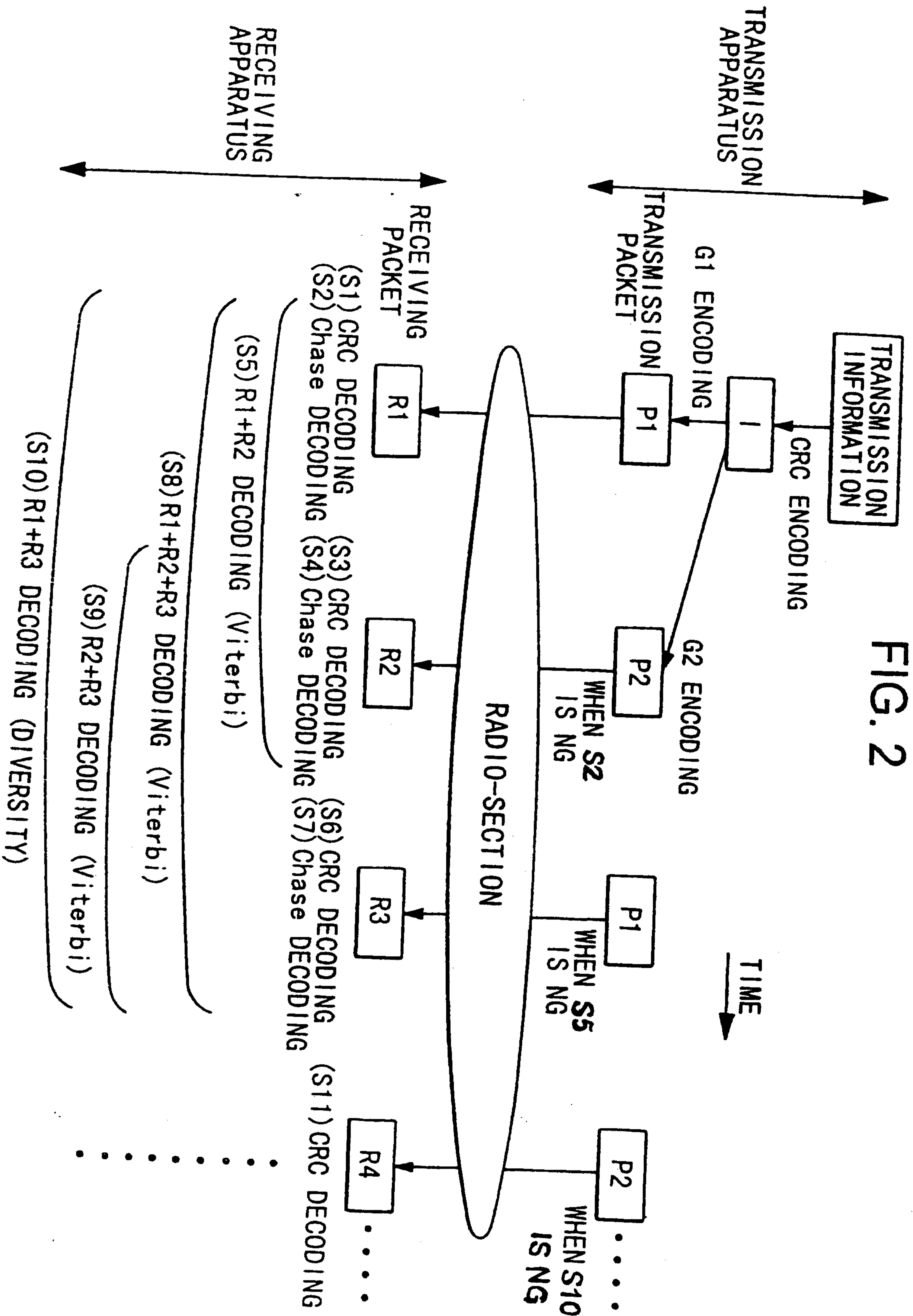


FIG. 2

FIG. 3

