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(54) **SYSTEM FOR DYNAMIC ADAPTATION OF DATA/CHANNEL CODING IN WIRELESS COMMUNICATIONS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(51) **Int. Cl.**[7] **H04Q 7/20**

(52) **U.S. Cl.** **455/67.3**; 455/63; 455/501; 455/226.3; 375/227

(58) **Field of Search** 455/67.3, 67.7, 455/63, 501, 423, 9, 560, 226.3, 517, 466, 422, 426, 67.1; 375/227, 225, 222

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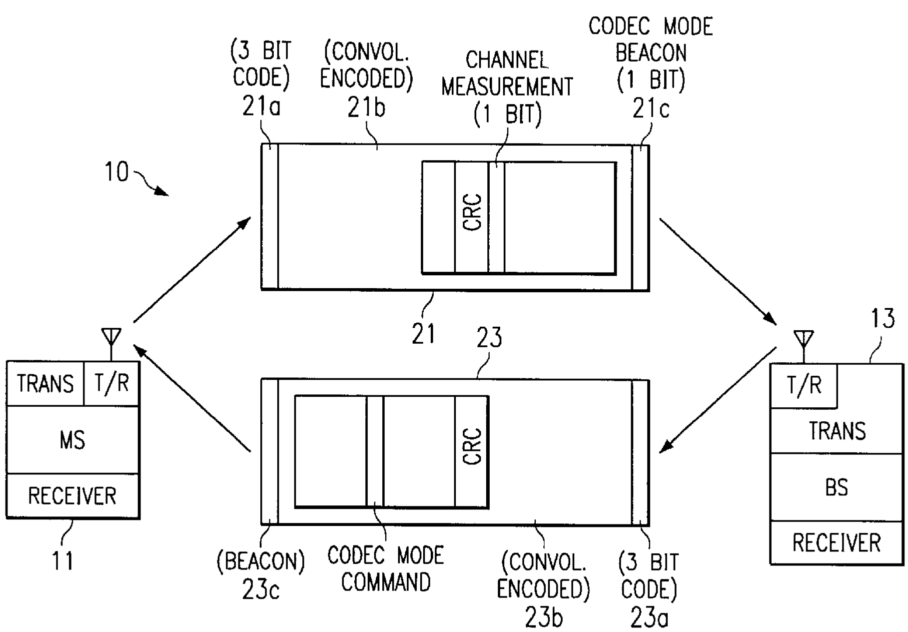
(57) **ABSTRACT**

A system for dynamic adaptation of wireless communication between a Mobile Station **(11)** and a Base Station **(13)** wherein the transmitted frame from the Mobile Station includes a convolutionally coded portion containing a down-link measurement bit and a repetition code identifying the codec mode of the frame. The transmitted frame from the Base Station **(13)** includes a codec mode command signal for the Mobile Station **(11)** in the convolutionally encoded portion and the repetition code identify the codec mode of the down-link frame. The Base Station **(13)** includes means for analyzing the quality of the up-link frame and means from the received down-link measurement bit for determining the down-link quality.

4 Claims, 2 Drawing Sheets



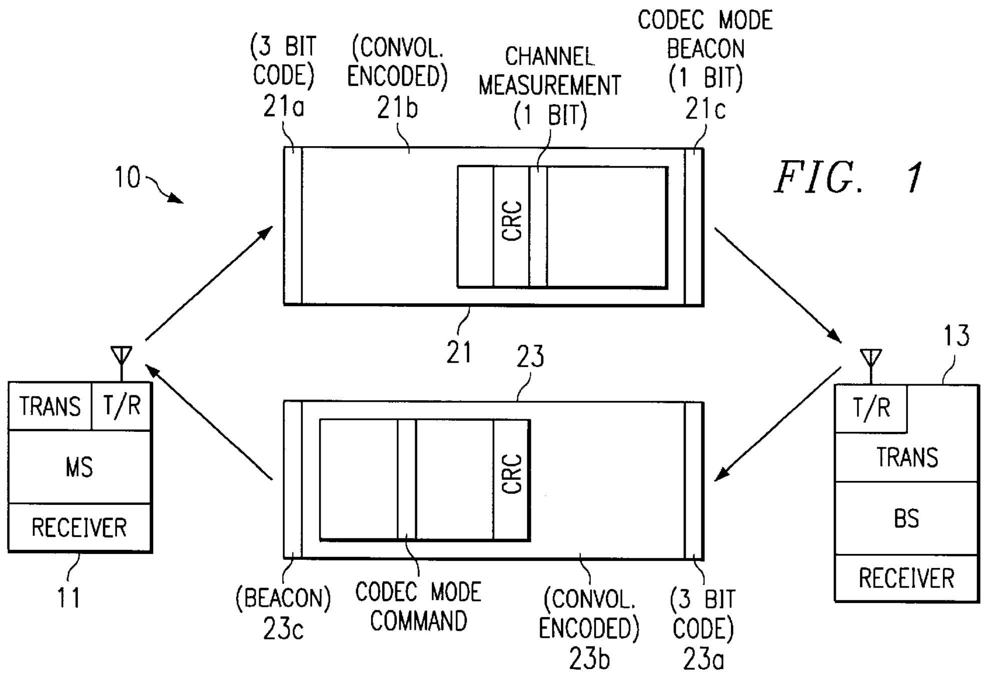

(3 BIT
CODE)
21a
(CONVOL.
ENCODED)
21b
CHANNEL
MEASUREMENT
(1 BIT)
CODEC MODE
BEACON
(1 BIT)
21c
10
CRC
21
23
13
TRANS
T/R
MS
RECEIVER
11
CRC
T/R
TRANS
BS
RECEIVER
(BEACON)
23c
CODEC MODE
COMMAND
(CONVOL.
ENCODED)
23b
(3 BIT
CODE)
23a

FIG. 1

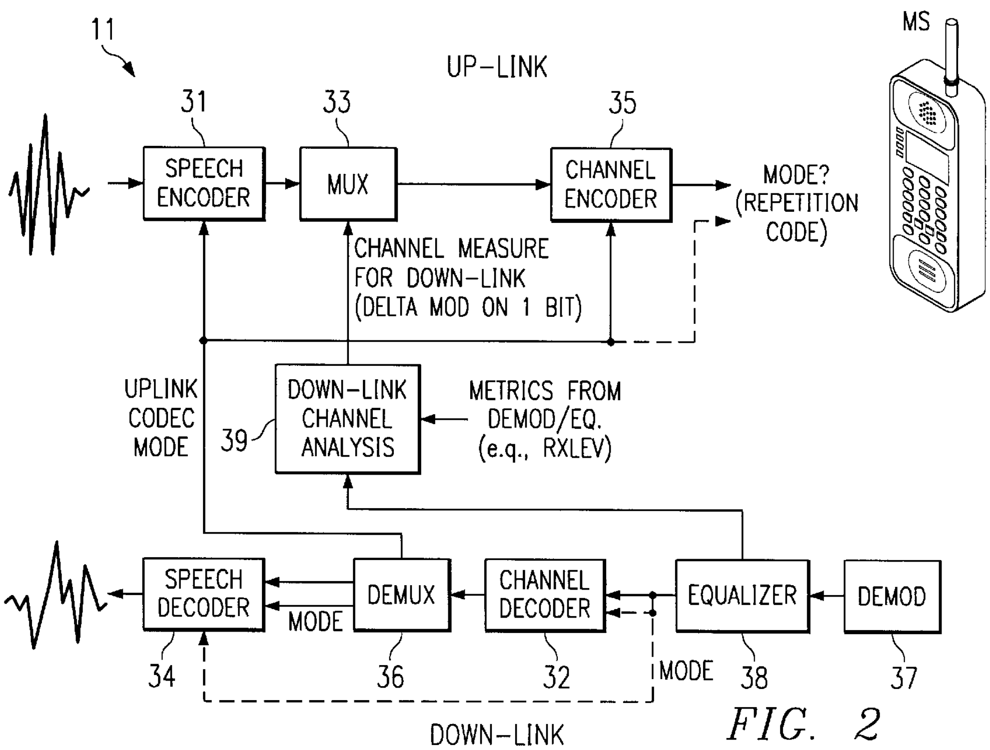

11
UP-LINK
MS
31
33
35
SPEECH
ENCODER
MUX
CHANNEL
ENCODER
MODE?
(REPETITION
CODE)
CHANNEL MEASURE
FOR DOWN-LINK
(DELTA MOD ON 1 BIT)
UPLINK
CODEC
MODE
39
DOWN-LINK
CHANNEL
ANALYSIS
METRICS FROM
DEMOD/EQ.
(e.q., RXLEV)
SPEECH
DECODER
DEMUX
CHANNEL
DECODER
EQUALIZER
DEMOD
MODE
MODE
34
36
32
38
37
DOWN-LINK

FIG. 2

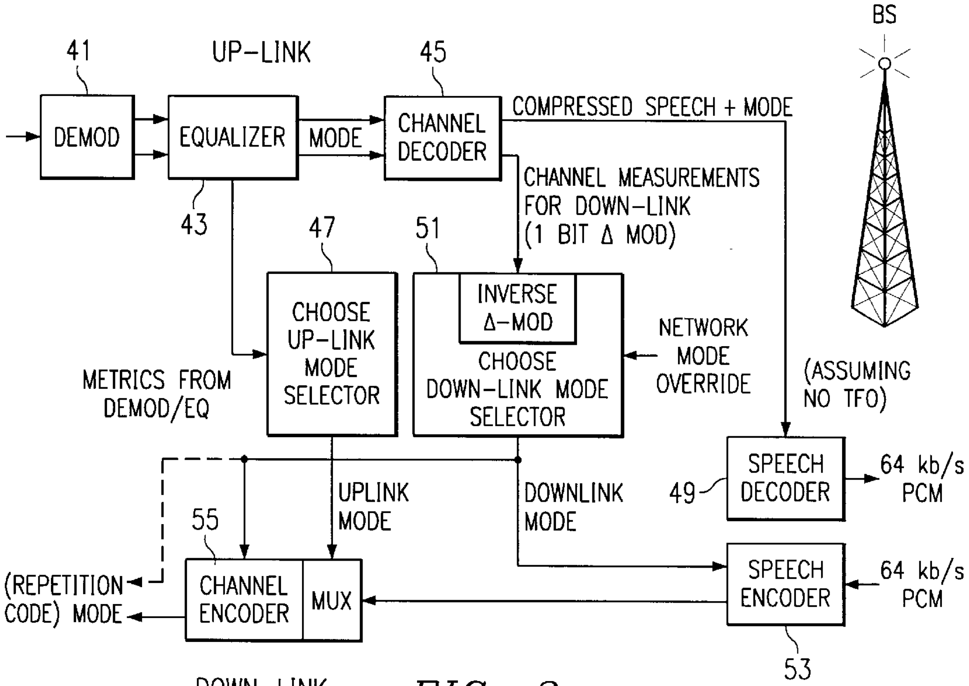

BS
41
UP-LINK
45
DEMOD
EQUALIZER
MODE
CHANNEL DECODER
COMPRESSED SPEECH + MODE
CHANNEL MEASUREMENTS FOR DOWN-LINK (1 BIT Δ MOD)
43
47
51
CHOOSE UP-LINK MODE SELECTOR
INVERSE Δ-MOD
CHOOSE DOWN-LINK MODE SELECTOR
NETWORK MODE OVERRIDE
(ASSUMING NO TFO)
METRICS FROM DEMOD/EQ
SPEECH DECODER
49
64 kb/s PCM
55
UPLINK MODE
DOWNLINK MODE
(REPETITION CODE) MODE
CHANNEL ENCODER
MUX
SPEECH ENCODER
64 kb/s PCM
53
DOWN-LINK

FIG. 3

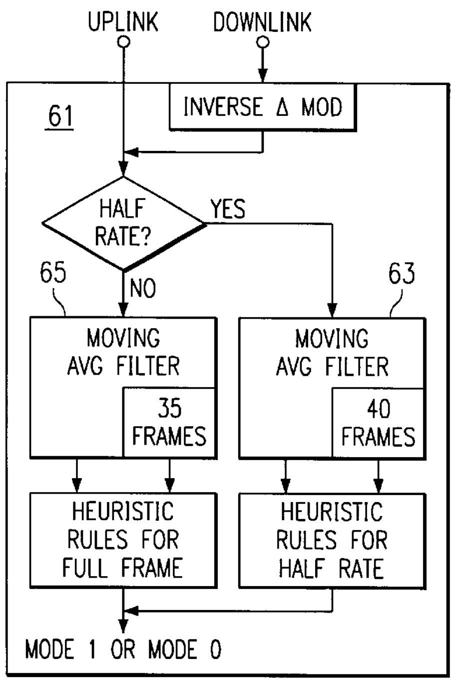

UPLINK
DOWNLINK
61
INVERSE Δ MOD
HALF RATE?
YES
NO
65
63
MOVING AVG FILTER
35 FRAMES
MOVING AVG FILTER
40 FRAMES
HEURISTIC RULES FOR FULL FRAME
HEURISTIC RULES FOR HALF RATE
MODE 1 OR MODE 0

FIG. 4

SYSTEM FOR DYNAMIC ADAPTATION OF DATA/CHANNEL CODING IN WIRELESS COMMUNICATIONS

This application claims priority under 35 USC §119(e)(1) of provisional application No. 60/086,217, filed May 21, 1998.

TECHNICAL FIELD OF THE INVENTION

This invention relates to wireless communications and more particularly to a system for dynamic adaptation of data/channel coding.

BACKGROUND OF THE INVENTION

Transmission of digitally encoded speech over wireless channels in a cellular environment usually requires the use of error control techniques to combat the noisy nature of such channels. In cellular applications, however, the characteristics of the channel are highly non-stationary, that is, periods of relatively error-free signal alternate with periods of strongly deteriorated signal. The traditional solution to this problem is to allocate to error detection and correction enough bandwidth to deal with the "average channel", sacrificing optimality for the two extreme cases of good and bad channels.

This static approach is clearly not optimal: in good channel conditions most of the resources employed by error control are redundant, and could be better used to increase the speech quality, while in bad channels, error control should be reinforced by using resources made available by a lower bit rate speech codec. Moreover, the cellular channel is quite bipolar, that is, oscillates in time between good and bad channels, passing only a fraction of the time of a call in the "average channel" condition for which the static solution was designed. Unequal Error Protection is used in most cellular standards. In Unequal Error Protection, speech bits are divided into classes of decreasing perceptual importance and each class is encoded with appropriate rates of protection including no protection. Although the Unequal Error Protection approach used in most cellular standards somewhat mitigates the flaw of using the "average channel" approach, a better solution is desirable.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, a system is presented that allows one station to communicate with a second station. The station monitors the quality of the channels connecting them and adapts their data and error control rates accordingly.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is an overall block diagram of the system in accordance with one embodiment of the present invention;

FIG. **2** is a block diagram of the mobile station;

FIG. **3** is a block diagram of the base station; and

FIG. **4** is a block diagram of the mode selector in the base station.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE PRESENT INVENTION

In the present invention, a system for dynamic adaptation of speech/channel coding to the varying conditions of wireless channels in a cellular environment is presented. In an adaptive system, the ratio between speech bits and error control bits changes as a function of the condition of the channel.

In the present invention, there is more error control and less speech bits in bad channels, and more speech bits and less error control in good channels, where error control is less needed.

In accordance with the present invention, the up-link and down-link codec modes are dynamically changed to account for the estimated error rates on the up-link and down-link. To implement an adaptive system and, more specifically, one that is in accordance to the requirements of the new Global System for Mobile Communications (GSM) Adaptive Multi-Rate (AMR) system as specified by European Telecommunication Standards Institute (ETSI), we also need to send in-band information and a mode indicator.

In a preferred embodiment of the present invention, the adaptation control is located in the Base Station (BS).

Dynamic switching requires the transmission of two different kinds of in-band information: a channel measurement of the quality of the down-link channel, sent via the up-link, that is, from Mobile Station (MS) **11** to Base Station (BS) **13**; and a codec command sent via the down-link, that is from Base Station (BS) **13** to Mobile Station (MS) **11** (see FIG. **1**). The former describes how good the down-link channel is, the latter is the codec mode that the Mobile Station (MS) **11** encoder is asked to use.

The objective is to send this information accurately and frequently enough to make the adaptation mechanism work effectively, but using as few bits as possible, to minimize overhead.

We have chosen to send the in-band information for both directions in every frame (20 ms), using a single bit. This in-band information bit is placed in Class **0**, to achieve maximum protection. Class **0** is the most channel protected subset of information bits.

One substantial problem of an adaptive system is that the channel decoder has to know which mode had been used to encode the frame before it can successfully decode it. Several solutions have been considered, the simplest to understand and implement being that of attaching a header to the convolutionally encoded frame as presented herein. Prior to channel decoding, the header is decoded and the mode extracted, allowing the decoding of the rest of the frame. A specific implementation of this approach is a repetition code with a novel decoding scheme.

A relatively simple solution to the mode indicator problem is to code the mode with a 3-bit repetition code: Mode 0 is represented by the codeword '000', while Mode 1 by '111'. Such codeword is sent together with the convolutionally encoded data and represents a header that the channel decoder reads in order to determine how to decode the convolutionally encoded part of the frame. Traditional majority-vote decoding of a 3-bit repetition code would not perform well enough in the kind of channels we are dealing with, where the bit error rate can be 19% or more. Using more bits, however, would diminish the number of bits available for speech or for error control. In order to minimize the overhead, applicants, in accordance with one embodiment, decode the repetition code taking advantage of the characteristics of the information represented by the sequence of modes, a slowly varying, highly correlated sequence of just two modes. With such decoding, which is referred herein as "unanimous decoding", the mode is changed only if a unanimous codeword is received, i.e., '000' or '111'. Such codewords can only be the result of no errors or three errors on the channel. All the remaining codewords, caused by all the possible combinations of 1 and 2 errors, are ignored, leaving the mode unchanged. Erroneous decoding is still possible, it will happen every time that we have three errors, but it can be shown that it is a relatively rare occurrence even in very bad channels, and anyway it results, because of the CRC protection (parity discussed later), in a frame repeat, which often goes unheard. On the other hand, unanimous decoding could slow down a mode change, since it is based on the assumption that a mode change is unlikely, but it can be shown that the probability of making the transition to the right mode within three frames is very high even in bad channels. In short, a traditional repetition code decoded in a novel way allows good performance in a time-varying channel with a minimum amount of overhead (3 channel bits). If even higher switching performance is needed, the system can be straightforwardly extended to use 4 or more bits.

Referring to the system **10** of FIG. **1**, a cellular Mobile Station (MS) **11** comprising a transmitter, a receiver, an antenna and transmit/receive control switch (TR) transmits a packet frame **21** to a Base Station (BS) **13**. The packet frame **21** is made of three parts or subsets. The first and main part or subset **21***b* is the speech bits, parity bits, and in-band information all convolutionally encoded. A second part or subset **21***a* is the 3-bit codec mode header discussed above. The third part or subset **21***c* is a 1-bit codec mode beacon (explained later). The Base Station **13** includes a transmitter, a receiver, and an antenna system for transmit and receive. The Base Station **13** determines the best speech and channel coding combinations for both the up-link and the down-link. It then creates a frame **23** using the appropriate mode for the down-link. The frame **23** is made of the same three parts: the subset of the convolutionally encoded section **23***b*, the codec header **23***a* and codec mode beacon **23***c*. The convolutionally encoded subset **23***b* includes a codec mode command for the up-link as part of the in-band information. The Base Station (BS) **13** receives the frequencies of the channel used by the Mobile Station (MS) **11** and the Mobile Station (MS) receives the frequencies of the channel used by the Base Station (BS) **13**. The system **10** can change the source and channel bit rates to adapt to the quality of the channels. The present invention does this in accordance with the constraints and requirements for the new Global System for Mobile Communications (GSM) Adaptive Multi-Rate (AMR) system as specified by European Telecommunication Standards Institute (ETSI).

In the new GSM AMR, there are two channel modes, full rate or half rate. In the full rate, there are 456 bits per frame at an overall bit rate of 22.8K bits per second. In the half rate, there are 228 bits per frame at an overall bit rate of 11.4K bits per second. Within each of the two channel modes (full rate or half rate) there are in the present embodiment two different speech/error control combinations. These are the codec modes. With the full rate there are two options. For a bad channel, the codec mode is Mode 0 and the source coding rate for speech is 7.45 Kb/sec. For the good channel, the codec mode is Mode 1 and the source coding rate for speech is 11.85 Kb/sec. The rest of the bits are used for in-band signaling, channel coding, codec mode header and codec mode beacon. The channel coding adds redundancy to correct for bit errors. For the half rate there are two options. For a bad channel, the codec mode is Mode 0 and the source coding rate is 5.15 Kb/sec. For the good channel, the codec mode is Mode 1 and the source coding rate is 7.45 Kb/sec.

Referring to FIG. **2**, there is illustrated the Mobile Station (MS) **11** according to one embodiment of the present invention. The up-link input speech is sampled/digitized and encoded with the up-link codec mode in encoder **31**. The speech/data bits are multiplexed with a down-link channel measurement bit from down-link analyzer **39** in multiplexer **33** and the multiplexed speech bits and channel measurement bit output is applied to the channel encoder **35**. The channel encoder is operated at the codec up-link mode received via the down-link from the Base Station **13**.

Speech bits are divided into classes of decreasing perceptual importance. Each class is then encoded with convolutional codes of appropriate rate (including, possibly, rate 1, i.e., no protection). The first class, Class **0**, includes the most important bits. On the up-link frame, the bits are protected by a Cyclic Redundancy Code (CRC) parity check. A CRC parity check is computed over the bits of Class **0** to detect any error at the receiver. At the receiver, the received CRC is compared to the CRC computed over the received bits: if they are equal, all bits in Class **0** are assumed to be correct. The down-link channel measurement bit (1 bit) is part of Class **0** and therefore has the CRC protection. With no convolutional encoding and no error detection, we have the codec mode identifier (repetition code) **21***a*. This identifier **21***a* is sent as header information and for the example is the repetition code discussed above. We also have the codec mode beacon (1-bit channel) **21***c* described later. Everything else is channel coded which in this case means that a convolution code with different levels of redundancy for every bit of information is used. This is what the Mobile Station (MS) **11** is transmitting. The channel encoded information **21***b*, the codec mode header **21***a* and beacon bit **21***c* are sent in the frame **21**. They are modulated on the RF carrier of the mobile transmitter.

Referring to FIG. **3**, the Base Station (BS) **13** antenna system picks up the radiated packet frame signal and down converts to the base band signal which is detected at demodulator **41** and the analog signal is sampled back to digital bits, for example, in maximum likelihood equalizer **43**. The receiver recognizes the header **21***b* 3-bit (repetition code for example) code and knows the codec mode to use for the frame. The equalizer **43** makes a decision as to whether a logic 1 or zero and passes the result to the channel decoder **45**. The reliability of the received bits is reflected by their soft values, a number, for example, between −127 and +127 that is directly proportional to the probability of error. If the bits are strongly **1**, the value is close to +127. If the bits are strongly **0**, the value is close to −127. All the intermediate values reflect a lesser degree of confidence. This level of confidence is used to choose the up-link mode at up-link mode select **47**.

A suitable moving average of the soft-values is a good estimator of the current Carrier to Interference (C/I) Ratio of the channel, a parameter which is directly connected to the amount of errors introduced by the channel. The aim of the mode selector, for both up- and down-link, is to follow the C/I profile faithfully and quickly enough to allow a good mode adaptation between the two available modes.

Two different sets of thresholds have been chosen for the specific case of the GSM half- and full-rate channel modes. For the half-rate case, the absolute values of the soft-bits for the current frame are averaged together and the resulting value is then fed to a moving average filter **63** of memory size **40** (See FIG. **4**). The filter **63** averages over 40 frames. The output of the filter, called "average value", is then used to estimate the current C/I value and consequently the most suitable mode to be used for the up-link. The mode is chosen according to a number of heuristic rules:

If average value <120, change to mode 0 (the mode with greater error control protection);

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