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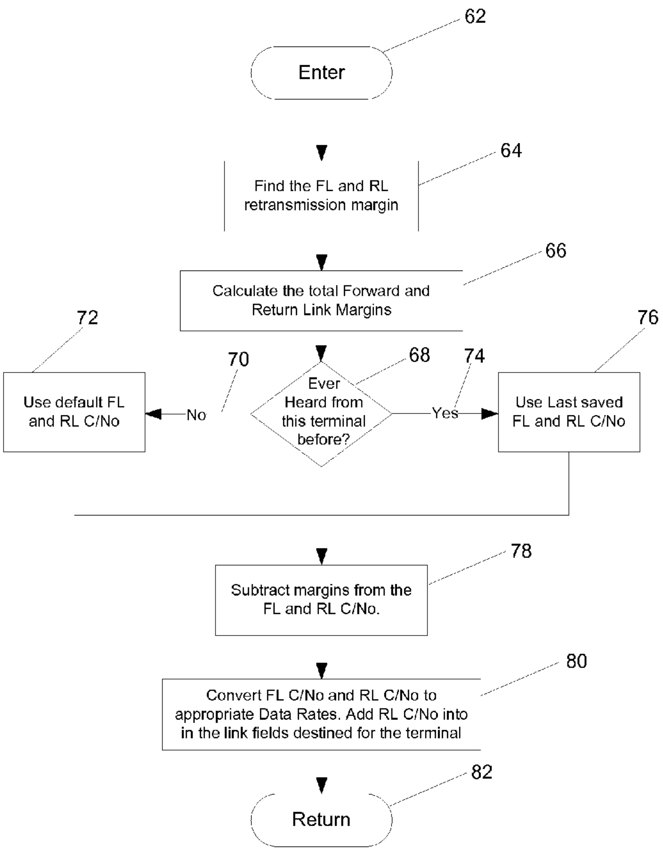
(54) Title: DATA RATE SELECTION IN A CONSTANT POWER VARIABLE DATA RATE TWO-WAY MOBILE SATELLITE COMMUNICATION LINK



(57) Abstract: A method an apparatus for selecting a forward link and return link data rate for a constant power, variable data rate two-way, mobile satellite communications link. The forward link and return link signal strength (in the form of carrier power to noise power spectral density ratio) is measured, cataloged, and the values are used for the data rate selection. In addition, a ping can be sent by the network operation center to the mobile unit and the response to the ping is used for updating the information of both forward link and return link signal strength, so the chance of wrong data rate selection can be reduced. Multiple re-transmission attempts combined with gradually increased re-transmission margin ensures the proper data rate decision can be eventually achieved even with occasionally inaccurate signal strength information.

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DATA RATE SELECTION IN A CONSTANT POWER VARIABLE DATA RATE TWO-WAY MOBILE SATELLITE COMMUNICATION LINK

Claim of Priority under 35 U.S.C. §119

[0001] The present Application for Patent claims priority to Provisional Application No. 60/839,506 entitled "A CONSTANT POWER, VARIABLE DATA RATE TWO-WAY, MOBILE SATELLITE COMMUNICATIONS LINK" filed August 22, 2006, and to Provisional Application No. 60/846,121 entitled "A CONSTANT POWER, VARIABLE DATA RATE TWO-WAY, MOBILE SATELLITE COMMUNICATIONS LINK" filed September 19, 2006, which were both assigned to the assignee hereof and hereby expressly incorporated by reference herein.

BACKGROUND

Field

[0002] The present invention relates generally to communication systems, and more specifically to a method and apparatus for selecting a forward link and return link data rate is a constant power, variable data rate two-way, mobile satellite communications link.

Background

[0003] There is therefore a need in the art for an efficient constant power, variable data rate two-way, mobile satellite communications link. Typical satellite communication links are designed with excess link margin in order to overcome occasional link degradations. The result is that during normal link conditions, the link is not efficiently used, i.e., power is wasted.

SUMMARY

[0004] The present system solves the shortcomings of the prior art. In the present system, the link margin is varied by adjusting the over the air data rate in order to limit the wasted power and at the same time to improve the over the air data rate useable by each mobile terminal.

[0005] A constant fixed power is transmitted by the earth station (both the fixed earth station network operation center and the mobile terminals). The modulation used in both links is such that the receiving terminal can accumulate the received power until enough energy is received to demodulate the signal correctly. The receiving terminal feeds back information to the transmitter including the signal strength it measures which determines at what data rate it can demodulate. The transmitter remembers this information so that next time it is to send data to the receiver, it uses this information to determine the data rate. In both links (network operations center to terminal and terminal to network operations center) the transmitters (and subsequently the receivers) are able to send (receive) multiple different data rates, thus minimizing the wasted link power while simultaneously keeping the transmitter power fixed.

[0006] The present invention contains novel features such as the network operations center and terminal measure the forward link (FL) and return link (RL) carrier power to noise power spectral density ratio (C/No), neither the network operations center nor terminal get constant feedback from the network operations center/terminal, the network operations center sends a short "ping message" to a terminal to get a current FL C/No reading if the terminal has not been heard from recently, the network operations center and terminal use data rate selection algorithms as a best guess to choose the packet data rate to minimize excess link margin for both the initial packet transmission and subsequent retransmissions and the network operations center and terminal change the modulation symbol rate (not the power level) to create the packet data rate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1 is a flow chart showing the FL message packet transmission;

[0008] Fig. 2 is a flow chart describing the method for determining the packet data rate;

[0009] Fig. 3 is an example of a table of FL data rates;

[00010] Fig. 4 is a flow chart of the preferred data rate determination for the RL message; and

[00011] Fig. 5 is an example of a RL data rate table.

DETAILED DESCRIPTION

[00012] The purpose of the presently disclosed embodiments, hereinafter referred to as the Millennium System, is to drastically increase bandwidth efficiency (and thereby drastically reduce transponder cost) and capacity of the communications link between a network operation center (NOC) or hub to a Millennium data module (MDM). The Millennium System will maintain compatibility with other systems, such as OmniTRACS®, and interfaces to the dispatch centers and resident applications.

[00013] The Millennium forward link consists of variable rate data frames that are directed to terminals based on their ability to receive. Terminals receiving a strong signal will be sent data frames at a higher rate, whereas terminals receiving a weaker signal will be sent frames at a lower data rate. The subsequent sections describe the rate selection algorithm.

[00014] Fig. 1 is a flow chart showing the FL message packet transmission. The NOC receives a customer originated message to be delivered **10** to a customer mobile terminal and segments it (if necessary) into one or more Protocol Data Units (PDUs). If the terminal has not been in communication with the NOC for $T_{RP\_PingThreshold}$ secs or longer and the message length is greater than or equal to $L_{RP\_PingThreshold}$ bytes, then the NOC sends a "Ping" **12** PDU to the mobile unit. If the Ping is sent **14** a Ping PDU is created and prepared for transmission **16** to the mobile unit. The forward link data rate used to send the Ping PDU is determined **18** as is the return data rate to be used by the terminal for the reply. The last known RL C/No from that terminal is also computed and inserted into the PDU. After the Ping is transmitted, the NOC waits a predetermined time for a response from the terminal **20**. Next a determination is made whether the NOC has received the Ping response from the mobile terminal **22**. If the predetermined time lapses and there is no response **24** from the terminal, the NOC resends the Ping **26** if the maximum number of attempts has not been reached **28**. The data rate to send the Ping is recomputed **18** and the process repeats until either the maximum number of attempts is reached **28** in which case the message delivery is deemed failed **30**, or the terminal responds.

[00015] When the NOC receives the Ping reply PDU **32**, it measures the RL C/No level of the received signal and stores it in its database for later use. The Ping reply PDU also contains the FL C/No level the terminal most recently measured. The NOC extracts that value and stores it in its database, also **34**. The NOC then prepares for transmission the original message PDU **36**. If a Ping is not necessary **40** or original message PDU in sent **36**, the NOC computes the FL data rate to use for transmitting the PDU using the most recently saved FL C/No levels. The NOC also computes the RL data rate to be used by the terminal for its acknowledgment reply **38**. The RL C/No to send to the terminal is also computed for it to use in its RL data rate selection algorithm. After the message PDU is transmitted, the NOC waits a predetermined time for a response from the terminal **42**. Next, the NOC determines whether an acknowledgement (Ack) has been received from the terminal **44**. If the predetermined time lapses and there is no response from the terminal **46**, the NOC resends the message PDU **48** if the maximum number of transmission attempts has not been reached **50**. If the maximum number of transmissions has been reached **52**, the message delivery is deemed a failed delivery **54**. The data rate used to retransmit the PDU is recomputed and the process repeats until either the maximum number of attempts is reached, or the terminal responds. If the NOC receives an acknowledgement from the terminal that it received the forward link message **56**, the NOC saves the measured RL C/No of that signal and the FL C/No that is contained in the received PDU **58**. After the acknowledgement is received, the NOC declares the message delivery to be successful and notifies the sender **60**.

[00016] Fig. 2 is a flow chart describing the method for determining the packet data rate procedure as indicated in steps **18** and **38** of Fig. 1. The first step is to initiate or enter into the system **62**. Using a look-up table with the transmission count as the index, the next step is to find the FL (M_{r_FL}) and RL (M_{r_RL}) retransmission margin value **64**. Calculate the total forward link (M_{total_FL}) and return link margin (M_{total_RL}) **66** values as:

$$M_{total\_FL} = M_{r\_FL} + M_{p\_FL} + M_{m\_FL} + M_{b\_FL}$$

Where: M_{r_FL} *is forward link re-transmission margin.*

M_{p_FL} *is forward link priority margin.*

M_{m_FL} *is forward link message type margin.*

M_{b_FL} *is forward link balance margin.*

$$M_{total\_RL} = M_{r\_RL} + M_{p\_RL} + M_{m\_RL} + M_{b\_RL}$$

Where: M_{r_RL} *is return link re-transmission margin.*
M_{p_RL} *is return link priority margin.*
M_{m_RL} *is return link message type margin.*
M_{b_RL} *is return link balance margin*

[00017] Next a determination is made whether the terminal has been heard from **68**. If the NOC has never received any packets from the mobile terminal before **70**, the NOC uses pre-determined, configurable values for default FL and RL C/N_0 values **72**. If the NOC has received packets from the mobile terminal before **74**, the NOC uses the last saved values for the FL and RL C/N_0 values for that terminal **76**. The NOC then subtracts the total forward link margin (M_{total_FL}) and total return link margin (M_{total_RL}) from the FL and RL C/N_0 values **78** to get estimated FL and RL C/N_0 values, as defined by:

$$\text{Estimated FL } C/N_0 = (\text{Last Known FL } C/N_0) - M_{total\_FL}$$
$$\text{Estimated RL } C/N_0 = (\text{Last Known RL } C/N_0) - M_{total\_RL}$$

[00018] Finally, the estimated FL and RL C/N_0 values are used to look-up FL and RL data rates to use for the packet. The RL data rate is used by the mobile terminal for the packet response. The NOC measured R/L C/N_0 is also sent to the terminal in the packet **80**, so that the terminal can make subsequent R/L data rate determinations wherein the systems returns **82** to the appropriate steps of Fig. 1.

[00019] An example of FL data rates for selection is shown in the table of Fig. 3. In this particular embodiment, the data rate table is configurable and can be expanded up to 31 FL data rates. This limitation is based on the available number of Walsh Codes, which are identified by the receiver to identify the data rates.

[00020] Fig. 4 is a flow chart showing the return link message packet transmission. As shown in Fig. 4, the mobile terminal receives a customer originated message to be sent or delivered to NOC **100** and segments it (if necessary) into one or more Protocol Data Units

(PDUs). The terminal calculates the margin **102** to use when determining the RL data rate as:

$$PDU\ Margin = M_p + M_m + M_b + M(i)_{retx}$$

Where:

M_p = *PDU priority margin*

M_m = *PDU type margin*

M_b = *Balance margin*

$M(i)_{retx}$ = *The ith retransmit schedule margin*

[00021] Depending on whether the terminal has received a PDU from the NOCl since it powered on **104**, the terminal takes one of two actions.

If the terminal has not received **106** any PDUs from the NOC since it powered on, the terminal uses the system default value of *FL_to_RL_CNo_Difference* it has received from the NOC in the broadcasted System Parameters message **108** in its next calculation. If the terminal has received **110** a PDU from the NOC since it powered on, the terminal uses the latest value of *FL_to_RL_CNo_Difference* **112** that it has previously computed using the RL_CNo feedback in the last PDU from the NOC in its next calculation.

The terminal then calculates an estimated RL C/No level **114** as:

$$Estimated\ RL\ C/N_0 = FL\ C/No - FL\_to\_RL\_CNo\_Difference - PDU\ Margin$$

Where:

FL C/No = The FL C/No the terminal is currently measuring

[00022] The terminal converts the estimated RL C/No to a data rate **116** to use when transmitting the PDU through a table look-up. The terminal creates the RL PDU and inserts the recently measured FL C/No into the PDU header **118** for the NOC to use in its FL data rate determination calculations. The PDU is transmitted and the terminal waits

for a response from the NOC **120**. The terminal also saves the recently measured FL C/No. The terminal waits a predetermined time for the NOC response **122**. Depending on whether a response is received, the terminal performs one of two actions. If the terminal does not receive **124** a response from the terminal and if the maximum number of transmit attempts has not been reached **126**, the terminal re-transmits or resends the PDU **128** after computing a new estimated RL C/No and PDU data rate. If the maximum number of transmission attempts has been reached **128**, the terminal drops the message **130**.

[00023] If the terminal has received the NOC's response **132**, it extracts the last RL C/No level **134** the NOC measured from the response message. The terminal uses that RL C/No level and the previously saved FL C/No to compute a new value of *FL_to_RL_CNo_Difference.* The terminal drops the message and considers it successfully delivered **136**.

[00024] An example of RL data rates for selection is shown in the table of Fig. 5. In this particular embodiment, the data rate table is configurable and can be expanded up to 16 RL data rates.

[00025] Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[00026] Those of skill would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular

application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

[00027] The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00028] The steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in Random Access Memory (RAM), flash memory, Read Only Memory (ROM), Electrically Programmable ROM (EPROM), Electrically Erasable Programmable ROM (EEPROM), registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

[00029] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic

principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein, but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

[00030] What is claimed is:

CLAIMS

1. A method for selecting a forward link and return link data rate for a mobile satellite communications link, the method comprising the steps of:

determining a forward link and return link retransmission margin value;

calculating a total forward link margin and total return link margin;

computing a last known forward link and return link carrier power to noise power spectral density ratios;

subtracting the total forward link margin from the computed forward link carrier power to noise power spectral density ratio to obtain an estimated forward link carrier power to noise power spectral density ratio;

subtracting the total return link margin from the computed return link carrier power to noise power spectral density ratio to obtain an estimated return link carrier power to noise power spectral density ratio; and

selecting the forward link and return link data rate from the estimated forward link carrier power to noise power spectral density ratio and estimated return link carrier power to noise power spectral density ratio.

2. The method of claim 1 wherein the step of determining a forward link and return link retransmission margin value comprises using a look-up table with a transmission count as an index.

3. The method of claim 1 wherein the step of computing a total forward link margin comprises summing the forward link re-transmission margin value, a forward link priority margin, a forward link message type margin and a forward link balance margin.

4. The method of claim 1 wherein the step of computing a total return link margin comprises summing the return link re-transmission margin value, a return link priority margin, a return link message type margin and a return link balance margin.

5. The method of claim 1 further comprising the step of sending a ping to a mobile unit for determining a forward link and return link data rate.

6. The method of claim 1 wherein the step of computing a last know total forward link margin and total return link margin comprises using a default value for the last known forward link and return link carrier power to noise power spectral density ratios.

7. The method of claim 1 wherein the step of selecting the forward link and return link data rate comprises using data rate look-up tables.

8. A computer readable medium having computer executable instructions for performing a method, the method comprising the steps of:

determining a forward link retransmission margin value for a mobile satellite communications link;

calculating a total forward link margin;

computing a last known forward link carrier power to noise power spectral density ratio;

subtracting the total forward link margin from the computed forward link carrier power to noise power spectral density ratio to obtain an estimated forward link carrier power to noise power spectral density ratio; and

selecting the forward link data rate from the estimated forward link carrier power to noise power spectral density ratio.

9. The method of claim 8 wherein the step of determining a forward link retransmission margin value comprises using a look-up table with a transmission count as an index.

10. The method of claim 8 wherein the step of computing a total forward link margin comprises summing the forward link re-transmission margin value, a forward link priority margin, a forward link message type margin and a forward link balance margin.

11. The method of claim 8 further comprising the step of sending a ping to a mobile unit for determining a forward link data rate.

12. The method of claim 8 wherein the step of computing a last know total forward link margin comprises using a default value for the last known forward link carrier power to noise power spectral density ratio.

13. The method of claim 8 wherein the step of selecting the forward link data rate comprises using a forward link data rate look-up table.

14. A computer readable medium having computer executable instructions for performing a method, the method comprising the steps of:

determining a return link retransmission margin value for a mobile satellite communications link;

calculating a total return link margin;

computing a last known return link carrier power to noise power spectral density ratio;

subtracting the total return link margin from the computed return link carrier power to noise power spectral density ratio to obtain an estimated return link carrier power to noise power spectral density ratio; and

selecting the return link data rate from the estimated return link carrier power to noise power spectral density ratio.

15. The method of claim 14 wherein the step of determining a return link retransmission margin value comprises using a look-up table with a transmission count as an index.

16. The method of claim 14 wherein the step of computing a total return link margin comprises summing the return link re-transmission margin value, a return link priority margin, a return link message type margin and a return link balance margin.

17. The method of claim 14 further comprising the step of sending a ping to a mobile unit for determining a return link data rate.

18. The method of claim 14 wherein the step of computing a last know total return link margin comprises using a default value for the last known return link carrier power to noise power spectral density ratio.

19. The method of claim 14 wherein the step of selecting the return link data rate comprises using a return link data rate look-up table.

20. A system for selecting a forward link and return link data rate for a mobile satellite communications link, the system comprising:

a means for determining a forward link and return link retransmission margin value;

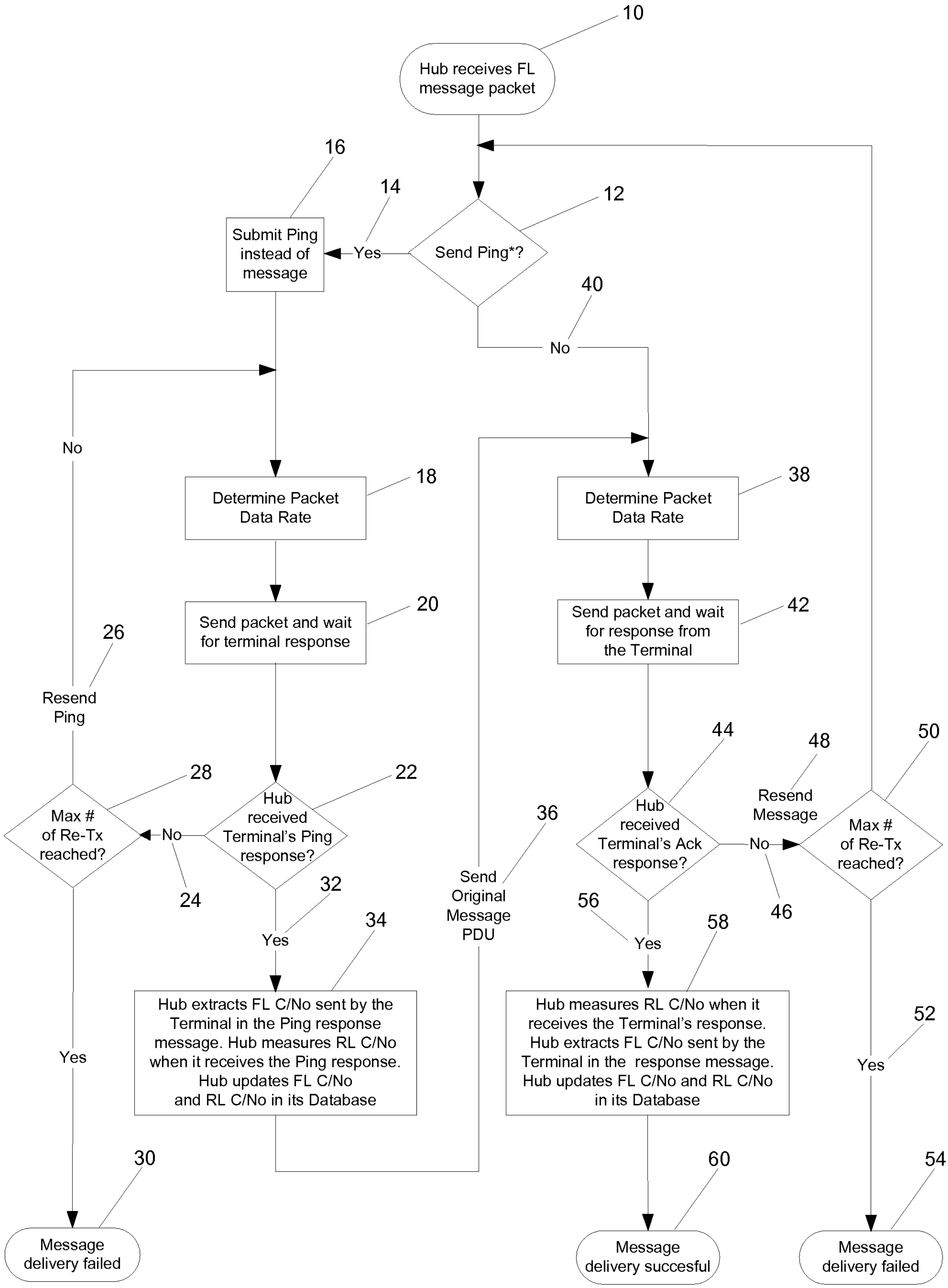
a means for calculating a total forward link margin and total return link margin;

a means for computing a last known forward link and return link carrier power to noise power spectral density ratios;

a means for subtracting the total forward link margin from the computed forward link carrier power to noise power spectral density ratio to obtain an estimated forward link carrier power to noise power spectral density ratio;

a means for subtracting the total return link margin from the computed return link carrier power to noise power spectral density ratio to obtain an estimated return link carrier power to noise power spectral density ratio; and

a means for selecting the forward link and return link data rate from the estimated forward link carrier power to noise power spectral density ratio and estimated return link carrier power to noise power spectral density ratio.



10
Hub receives FL message packet
16
14
12
Submit Ping instead of message
Yes
Send Ping*?
40
No
No
18
Determine Packet Data Rate
38
Determine Packet Data Rate
20
Send packet and wait for terminal response
42
Send packet and wait for response from the Terminal
26
Resend Ping
44
48
50
28
22
Resend Message
Max # of Re-Tx reached?
No
Hub received Terminal's Ping response?
36
Hub received Terminal's Ack response?
No
Max # of Re-Tx reached?
24
32
Send Original Message PDU
56
46
Yes
34
58
Yes
Hub extracts FL C/No sent by the Terminal in the Ping response message. Hub measures RL C/No when it receives the Ping response. Hub updates FL C/No and RL C/No in its Database
Hub measures RL C/No when it receives the Terminal's response. Hub extracts FL C/No sent by the Terminal in the response message. Hub updates FL C/No and RL C/No in its Database
52
Yes
Yes
30
60
54
Message delivery failed
Message delivery succesful
Message delivery failed

FIG. 1

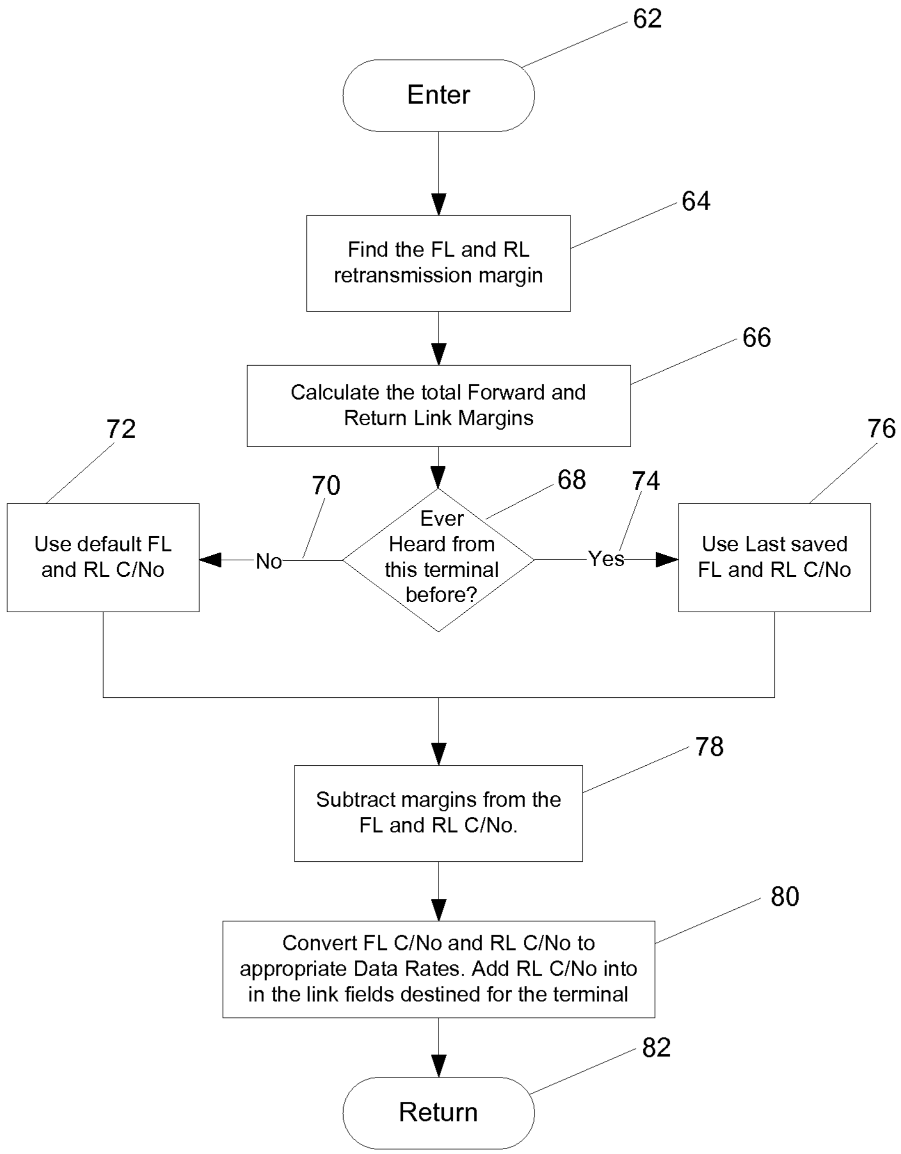

62
Enter
64
Find the FL and RL retransmission margin
66
Calculate the total Forward and Return Link Margins
72
70
68
74
76
Use default FL and RL C/No
No
Ever Heard from this terminal before?
Yes
Use Last saved FL and RL C/No
78
Subtract margins from the FL and RL C/No.
80
Convert FL C/No and RL C/No to appropriate Data Rates. Add RL C/No into in the link fields destined for the terminal
82
Return

FIG. 2

Index	Data rate (bits/second)	Minimum Required FL C/N_0 (dB)
0	12800	43.1
1	19200	44.8
2	25600	46.0
3	38400	47.7
4	51200	48.9
5	76800	50.7
6	102400	51.9
7	153600	53.6
8	204800	54.8
9	307200	56.6
10	409600	58.9
11	614400	59.6
12	921600	61.9
13	1228800	63.7

Fig. 3

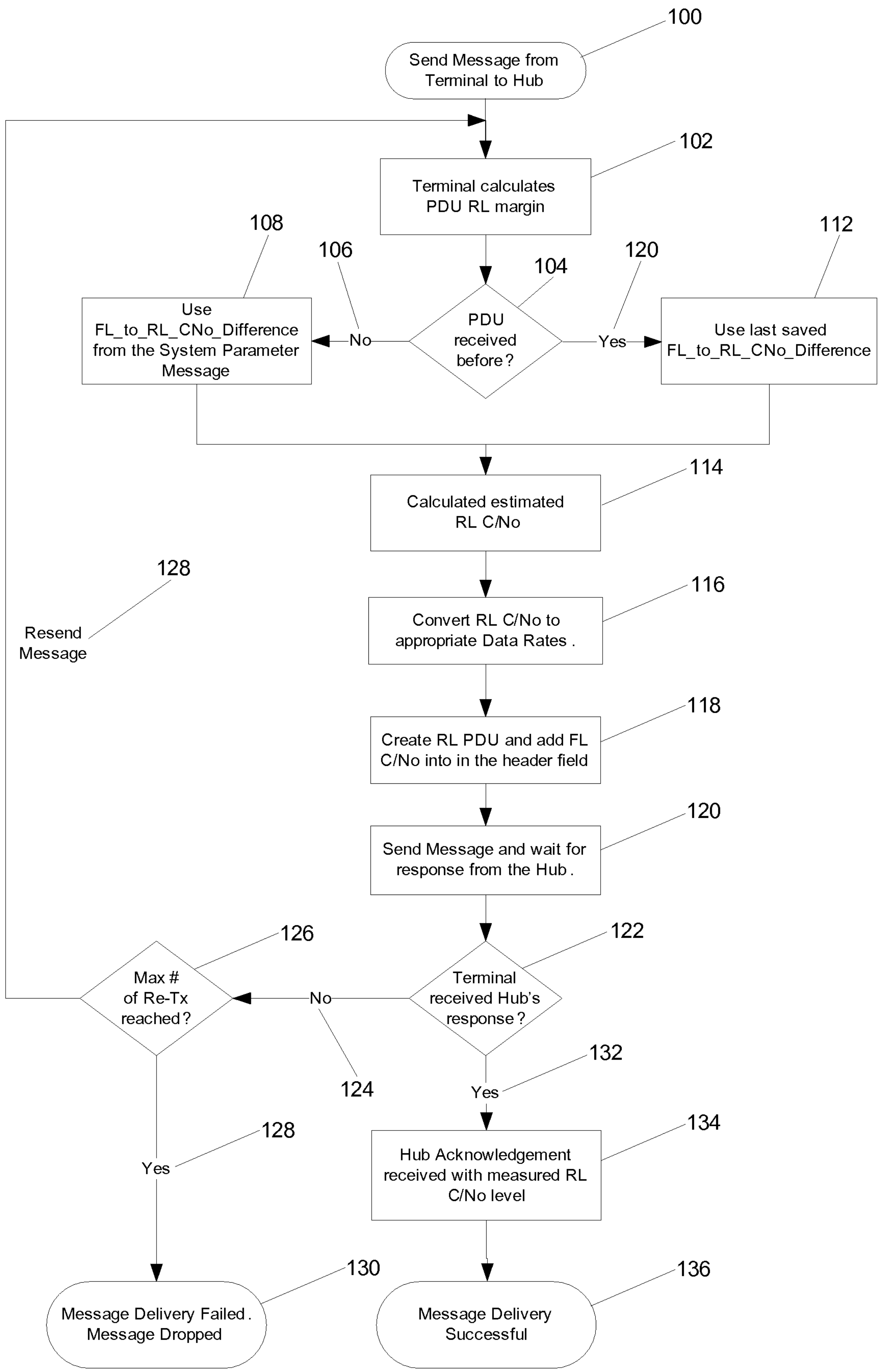

100
Send Message from Terminal to Hub
102
Terminal calculates PDU RL margin
108
106
104
120
112
Use FL_to_RL_CNo_Difference from the System Parameter Message
No
PDU received before?
Yes
Use last saved FL_to_RL_CNo_Difference
114
Calculated estimated RL C/No
128
Resend Message
116
Convert RL C/No to appropriate Data Rates.
118
Create RL PDU and add FL C/No into in the header field
120
Send Message and wait for response from the Hub.
126
122
Max # of Re-Tx reached?
No
Terminal received Hub's response?
124
132
Yes
134
128
Yes
Hub Acknowledgement received with measured RL C/No level
130
136
Message Delivery Failed. Message Dropped
Message Delivery Successful

FIG. 4

Index	Data rate (b/s)	Minimum Required RL C/N_0
0	50	25.5
1	75	26.6
2	100	27.5
3	150	28.8
4	200	29.8
5	300	31.2
6	400	32.3
7	600	33.8
8	800	35.0
9	1200	36.3
10	1600	37.5
11	2400	39.0
12	3200	40.2

Fig. 5