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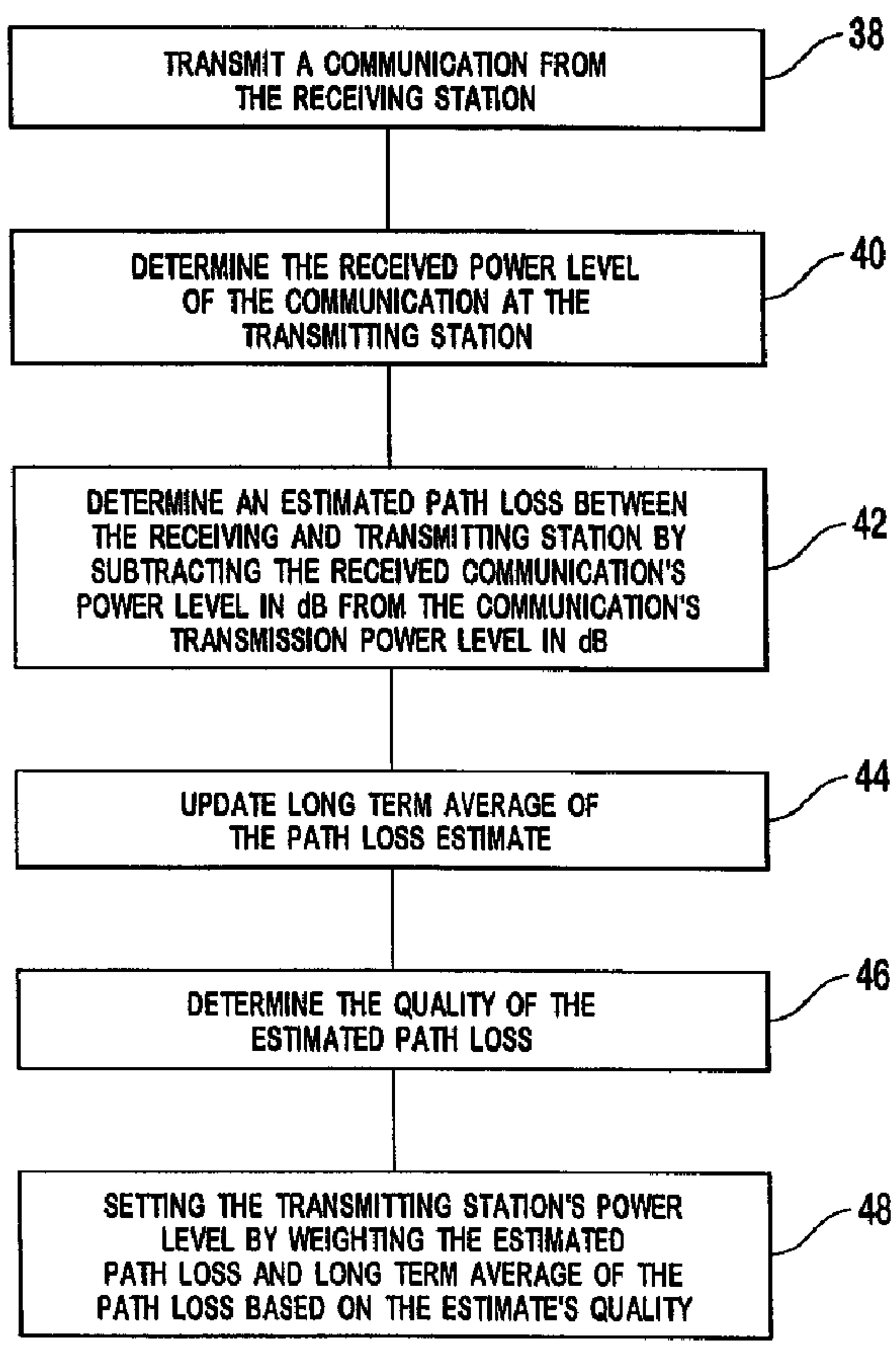
(54) Titre : COMMANDE EN BOUCLE OUVERTE PONDEREE INTEGREE DANS UN DUPLEX A REPARTITION DANS LE TEMPS D'UN SYSTEME DE COMMUNICATION

(54) Title: WEIGHTED OPEN LOOP POWER CONTROL IN A TIME DIVISION DUPLEX COMMUNICATION SYSTEM



(57) Abrégé/Abstract:
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(57) Abrégé(suite)/Abstract(continued):
communication and measures its received power level. Based on, in part, the received communication's power level and the communication's transmission power level, a path loss estimate is determined. A quality of the path loss estimate is also determined. The transmission power level for a communication from the second station to the first station is based on, in part, weighting the path loss estimate in response to the estimate's quality.

ABSTRACT

The invention controls transmission power levels in a spread spectrum time division duplex communication station. A first communication station transmits a communication to a second communication station. The second station receives the communication and measures its received power level. Based on, in part, the received communication's power level and the communication's transmission power level, a path loss estimate is determined. A quality of the path loss estimate is also determined. The transmission power level for a communication from the second station to the first station is based on, in part, weighting the path loss estimate in response to the estimate's quality.

TITLE OF THE INVENTION

WEIGHTED OPEN LOOP POWER CONTROL IN A TIME DIVISION DUPLEX COMMUNICATION SYSTEM

This application is a divisional of Canadian patent application Serial No. 2,491,179, which in turn is a divisional of Canadian patent application Serial No. 2,367,353 filed internationally on March 22, 2000, and entered into the National Phase in Canada on September 21, 2001.

BACKGROUND

This invention generally relates to spread spectrum time division duplex (TDD) communication systems. More particularly, the present invention relates to a system and method for controlling transmission power within TDD communication systems.

Figure 1 depicts a wireless spread spectrum time division duplex (TDD) communication system. The system has a plurality of base stations $\mathbf{30_1}$-$\mathbf{30_7}$. Each base station $\mathbf{30_1}$ communicates with user equipments (UEs) $\mathbf{32_1}$-$\mathbf{32_3}$ in its operating area. Communications transmitted from a base station $\mathbf{30_1}$ to a UE $\mathbf{32_1}$ are referred to as downlink communications and communications transmitted from a UE $\mathbf{32_1}$ to a base station $\mathbf{30_1}$ are referred to as uplink communications.

In addition to communicating over different frequency spectrums, spread spectrum TDD systems carry multiple communications over the same spectrum. The multiple signals are distinguished by their respective chip code sequences (codes). Also, to more efficiently use the spread spectrum, TDD systems as illustrated in **Figure 2** use repeating frames **34** divided into a number of time slots **36_1-36_n**,, such as fifteen time slots. In such systems, a communication is sent in selected time slots **36_1-36_n** using selected codes. Accordingly, one frame **34** is capable of carrying multiple communications distinguished by both time slot **36_1-36_n** and code. The use of a single code in a single time slot is referred to as a resource unit. Based on the bandwidth required to support a communication, one or multiple resource units are assigned to that communication.

Most TDD systems adaptively control transmission power levels. In a TDD system, many communications may share the same time slot and spectrum. When a UE **32_1** or base station **30_1** is receiving a specific communication, all the other communications using the same time slot and spectrum cause interference to the specific communication. Increasing the transmission power level of one communication degrades the signal quality of all other communications within that time slot and spectrum. However, reducing the transmission power level too far results in undesirable signal to noise ratios (SNRs) and bit error rates (BERs) at the receivers. To maintain both the signal quality of communications and low transmission power levels, transmission power control is used.

One approach using transmission power control in a code division multiple access (CDMA) communication system is described in U.S. Patent No. 5,056,109 (Gilhousen et al.). A transmitter sends a communication to a particular receiver. Upon reception, the received signal power is measured. The received signal power is compared to a desired received signal power.

Based on the comparison, a control bit is sent to the transmitter either increasing or decreasing transmission power by a fixed amount. Since the receiver sends a control signal to the transmitter to control the transmitter's power level, such power control techniques are commonly referred to as closed loop.

Under certain conditions, the performance of closed loop systems degrades. For instance, if communications sent between a UE **32_1** and a base station **30_1** are in a highly dynamic environment, such as due to the UE **32_1** moving, such systems may not be able to adapt fast enough to compensate for the changes. The update rate of closed loop power control in a typical TDD system is 100 cycles per second which is not sufficient for fast fading channels.

EPO 462 952 A discloses a method for regulating or adjusting transmission power for signals between a mobile station and a base station in a digital mobile telephony system. To determine the transmission power level, the mean values of the signal strength and signal transmission quality are determined. Based on the mean values, an anticipated signal strength and signal quality are calculated for a subsequent time period, assuming the transmission power is maintained unchanged. The transmission power level at the subsequent time period is adjusted based on the anticipated values.

WO 98 45962 A discloses a method for controlling a transmission power level of a mobile terminal in a satellite communication system. The power control method has both a closed-loop and an open-loop element. For the closed-loop element, the base station calculates the mobile terminal's power setting based on the strength of the signals received from the mobile terminal. The base station takes into account the propagation delays of the satellite system in the power setting determination. For the open-loop element, the strength of the received signal from the base station in each frame is compared to the strength of the signal received in the previous frame. The transmit power of the mobile terminal is adjusted inversely with the variations in the observed signal strength. Accordingly, there is a need for alternate approaches to maintain signal quality and low transmission power levels.

SUMMARY

The invention controls transmission power levels in a spread spectrum time division duplex communication station. A first communication station transmits a communication to a second communication station. The second station receives the communication and measures its received power level. Based on, in part, the received communication's power level and the communication's transmission power level, a path loss estimate is determined. The transmission power level for a communication from the second station to the first station is set based on, in part, weighting the path loss estimate and a long term pathloss estimate.

According to a first broad aspect of the invention, there is disclosed a User Equipment (UE) comprising: a receiver configured to receive a signal that includes a transmission power level parameter; a power measurement device configured to measure a power level of the received signal; an average pathloss estimation device configured to: determine an instantaneous pathloss, L, that is a difference in value of the transmission power level parameter and the measured power level of the received signal; output an average pathloss, L_0, based upon the determined L; a quality control device configured to: determine a quality of the L_o; apply a weighting factor α having a value between 0 and 1; and output a transmit power level adjustment; and a transmit power level determination device configured to determine a power level of a subsequent transmission signal from the UE based on the transmit power level adjustment.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a prior art TDD system.

Figure 2 illustrates time slots in repeating frames of a TDD system.

Figure 3 is a flow chart of weighted open loop power control.

Figure 4 is a diagram of components of two communication stations using weighted open loop power control.

Figure 5 depicts a graph of the performance of a weighted open loop, open loop and closed loop power control system for a UE moving at 30 kilometers per hour (km/h).

Figure 6 depicts a graph of the three systems' performance for a UE moving at 60 km/h.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments will be described with reference to the drawing figures where like numerals represent like elements throughout. Weighted open loop power control will be explained using the flow chart of **Figure 3** and the components of two simplified communication stations **110**,

112 as shown in **Figure 4**. For the following discussion, the communication station having its transmitter's power controlled is referred to as the transmitting station **112** and the communication station receiving power controlled communications is referred to as the receiving station **110**. Since weighted open loop power control may be used for uplink, downlink or both types of communications, the transmitter having its power controlled may be located at a base station **30_1**, UE **32_1** or both. Accordingly, if both uplink and downlink power control are used, the receiving and transmitting station's components are located at both the base station **30_1** and UE **32_1**. For use in estimating the path loss between the receiving and transmitting stations **110**, **112**, the receiving station **110** sends a communication to the transmitting station **112**. The communication may be sent on any one of various channels. Typically, in a TDD system, the channels used for estimating path loss are referred to as reference channels, although other channels may be used. If the receiving station **110** is a base station **30_1**, the communication is preferably sent over a downlink common channel or a Common Control Physical Channel (CCPCH).

Data to be communicated to the transmitting station **112** over the reference channel is referred to as reference channel data. The reference channel data is generated by a reference channel data generator **56**. The reference data is assigned one or multiple resource units based on the communication's bandwidth requirements. A spreading and training sequence insertion device **58** spreads the reference channel data and makes the spread reference data time-multiplexed with a training sequence in the appropriate time slots and codes of the assigned resource units. The resulting sequence is referred to as a communication burst. The communication burst is subsequently amplified by an amplifier **60**. The amplified communication burst may be summed by a sum device **62** with any other communication burst created through devices, such as a data generator **50**, spreading and training sequence insertion device **52** and amplifier **54**. The summed communication bursts are modulated by a modulator **64**. The modulated signal is passed through an isolator **66** and radiated by an antenna **78** as shown or, alternately, through an antenna array, step **38**. The radiated signal is passed through a wireless radio channel **80** to an antenna **82** of the transmitting station **112**. The type of modulation used for the transmitted communication can be any of the those known to those skilled in the art, such as direct phase shift keying (DPSK) or quadrature phase shift keying (QPSK).

The antenna **82** or, alternately, antenna array of the transmitting station **112** receives various radio frequency signals. The received signals are passed through an isolator **84** to a demodulator **86** to produce a baseband signal. The baseband signal is processed, such as by a channel estimation device **88** and a data estimation device **90**, in the time slots and with the appropriate codes assigned to the communication's burst. The channel estimation device **88** commonly uses the training sequence component in the baseband signal to provide channel information, such as channel impulse responses. The channel information is used by the data estimation device **90** and a power measurement device **92**. The power level of the processed communication corresponding to the reference channel, R_{TS}, is measured by the power measurement device **92** and sent to a pathloss estimation device **94**, **step 40**. The channel estimation device **88** is capable of separating the reference channel from all other channels. If an automatic gain control device or amplifier is used for processing the received signals, the measured power level is adjusted to correct for the gain of these devices at either the power measurement device **92** or the pathloss estimation device **94**.

To determine the path loss, L, the transmitting station **112** also requires the communication's transmitted power level, T_{RS}. The transmitted power level, T_{RS}, may be sent along with the communication's data or in a signaling channel. If the power level, T_{RS}, is sent along with the communication's data, the data estimation device **90** interprets the power level and sends the interpreted power level to the pathloss estimation device **94**. If the receiving station **110** is a base station **30_1**, preferably the transmitted power level, T_{RS}, is sent via the broadcast channel (BCH) from the base station **30_1**. By subtracting the received communication's power level, R_{TS} in dB, from the sent communication's transmitted power level, T_{RS} in dB, the pathloss estimation device **94** estimates the path loss, L, between the two stations **110**, **112**, **step 42**. Additionally, a long term average of the pathloss, L_0, is updated, **step 44**. In certain situations, instead of transmitting the transmitted power level, T_{RS}, the receiving station **110** may transmit a reference for the transmitted power level. In that case, the pathloss estimation device **94** provides reference levels for the path loss, L, and the long term average of the path loss, L_0.

Since TDD systems transmit downlink and uplink communications in the same frequency spectrum, the conditions these communications experience are similar. This phenomenon is referred to as reciprocity. Due to reciprocity, the path loss experienced for the downlink will also be experienced for the uplink and vice versa. By adding the estimated path loss to a desired received power level, a transmission power level for a communication from the transmitting station **112** to the receiving station **110** is determined. This power control technique is referred to as open loop power control.

Open loop systems have drawbacks. If a time delay exists between the estimated path loss and the transmitted communication, the path loss experienced by the transmitted communication may differ from the calculated loss. In TDD where communications are sent in differing time slots $\mathbf{36_1}$-$\mathbf{36_n}$, the time slot delay between received and transmitted communications may degrade the performance of an open loop power control system. To overcome these drawbacks, a quality measurement device **96** in a weighted open loop power controller **100** determines the quality of the estimated path loss, **step 46**. The quality measurement device **96** also weights the estimated path loss, L, and long term average of the pathloss, L_0, to set the transmit power level by transmit power calculation device **98**, **step 48**. As illustrated in **Figure 4**, the weighted open loop power controller **100** consists of the power measurement device **92**, pathloss estimation device **94**, quality measurement device **96**, and transmit power calculation device **98**.

The following is one of the preferred weighted open loop power control algorithms. The transmitting station's power level in decibels, P_{TS}, is determined using **Equation 1**.

$$P_{TS} = P_{RS} + \alpha(L-L_0) + L_0 + \text{CONSTANT VALUE} \qquad \textbf{Equation 1}$$

P_{RS} is the power level that the receiving station **110** desires to receive the transmitting station's communication in dB. P_{RS} is determined by the desired SIR, SIR_{TARGET}, at the receiving station **110** and the interference level, I_{RS}, at the receiving station **110**.

To determine the interference level, I_{RS}, at the receiving station, received communications from the transmitting station **112** are demodulated by a demodulator **68**. The resulting baseband signal is processed, such as by a channel estimation device **70** and a data estimator device **72** in the time slots and with the appropriate codes assigned the transmitting station's communications. The channel information produced by the channel estimation device **70** is used by an interference measurement device **74** to determine the interference level, I_{RS}. The channel information may also be used to control the transmit power level of the receiving station **110**. The channel information is input to a data estimation device **72** and a transmit power calculation device **76**. The data estimation produced by the data estimation device **72** is used with the channel information by the transmit power calculation device **76** to control the amplifier **54** which controls the receiving station's transmit power level.

P_{RS} is determined using **Equation 2**.

$$P_{RS} = SIR_{TARGET}+I_{RS} \qquad \textbf{Equation 2}$$

I_{RS} is either signaled or broadcasted from the receiving station **110** to the transmitting station **112**. For downlink power control, SIR_{TARGET} is known at the transmitting station **112**. For uplink power control, SIR_{TARGET} is signaled from the receiving station **110** to the transmitting station **112**. Using **Equation 2**, **Equation 1** is rewritten as either **Equations 3** or **4**.

$$P_{TS} = SIR_{TARGET}+I_{RS} + \alpha(L-L_0) + L_0 + \text{CONSTANT VALUE} \qquad \textbf{Equation 3}$$

$$P_{TS} = \alpha\, L+(1-\alpha)L_0+ I_{RS} + SIR_{TARGET}+ \text{CONSTANT VALUE} \qquad \textbf{Equation 4}$$

L is the path loss estimate in decibels, T_{RS} - R_{TS}, for the most recent time slot **36_1-36_n** that the path loss was estimated. The long term average of the pathloss, L_0, is a running average of the path loss estimates L. The CONSTANT VALUE is a correction term. The CONSTANT VALUE corrects for differences in the uplink and downlink channels, such as to compensate for differences in uplink and downlink gain. Additionally, the CONSTANT VALUE may provide correction if the transmit power reference level of the receiving station is transmitted, instead of the actual transmit power, T_{RS}. If the receiving station is a base station **30_1**, the CONSTANT VALUE is preferably sent via Layer 3 signaling. If the receiving station is a base station **30_1**, the CONSTANT VALUE is preferably sent via Layer 3 signaling.

The weighting value, α, determined by the quality measurement device **94**, is a measure of the quality of the estimated path loss and is, preferably, based on the number of time slots **36_1-36_n** between the time slot, n, of the last path loss estimate and the first time slot of the communication transmitted by the transmitting station **112**. The value of α is from zero to one. Generally, if the time difference between the time slots is small, the recent path loss estimate will be fairly accurate and α is set at a value close to one. By contrast, if the time difference is large, the path loss estimate may not be accurate and the long term average path loss measurement is most likely a better estimate for the path loss. Accordingly, α is set at a value closer to zero.

Equation 5 is one equation for determining α, although others may be used.

$$\alpha = 1 - (D - 1)/D_{max} \qquad \textbf{Equation 5}$$

The value, D, is the number of time slots **36_1-36_n** between the time slot of the last path loss estimate and the first time slot of the transmitted communication which will be referred to as the time slot delay. If the delay is one time slot, α is one. D_{max} is the maximal possible delay. A typical value for a frame having fifteen time slots is six. If the delay is D_{max} or greater, α approaches zero. Using the transmit power level, P_{TS}, determined by a transmit power calculation device **98**, the weighted open loop power controller **100** sets the transmit power of the transmitted communication, **step 48**.

Data to be transmitted in a communication from the transmitting station **112** is produced by a data generator **102**. The communication data is spread and time-multiplexed with a training sequence by the spreading and training sequence insertion device **104** in the appropriate time slots and codes of the assigned resource units. The spread signal is amplified by the amplifier **106** and modulated by the modulator **108** to radio frequency.

The weighted open loop power controller **100** controls the gain of the amplifier **106** to achieve the determined transmit power level, P_{TS}, for the communication. The communication is passed through the isolator **84** and radiated by the antenna **82**.

Figures 5 and **6** depict graphs **82**, **84** illustrating the performance of a weighted open loop system using **Equation 4**. **Equation 5** is used to calculate α. These graphs **82, 84** depict the results of simulations comparing the performance of a weighted open loop, an open loop and a closed loop system controlling the transmission power level of the transmitting station **112**. The simulations address the performance of these systems in a fast fading channel under steady-state conditions. In this example, the receiving station is a base station **30_1** and the transmitting station is a UE **32_1**. For the simulation, the UE **32_1** was a mobile station. The simulated base station **30_1** used two antenna diversity for reception with each antenna having a three finger RAKE receiver. The simulation approximated a realistic channel and SIR estimation based on a midamble sequence of burst type 1 field in the presence of additive white Gaussian noise (AWGN). The simulation used an International Telecommunication Union (ITU) Pedestrian B type channel and QPSK modulation. Interference levels were assumed to be accurately known with no uncertainty. Channel coding schemes were not considered. The CONSTANT VALUE and L_0 were set at 0 db.

For each of the power control techniques, **Figure 5**, graph **82** shows the energy for a transmitted complex symbol in decibels (Es/No) required to maintain a BER of 1% for various time slot delays, D, with the UE **32_1** moving at 30 kilometers per hour (km/h). As shown, at lower time slot delays, both weighted open loop and open loop outperform closed loop. For higher time slot delays, weighted open loop outperforms both open loop and closed loop. As shown in **Figure 6**, graph **84**, similar results occur if the UE **32_1** is traveling at 60 km/h.

WHAT IS CLAIMED IS:

1. A User Equipment (UE) comprising:

a receiver configured to receive a signal that includes a transmission power level parameter;

a power measurement device configured to measure a power level of the received signal;

an average pathloss estimation device configured to:

determine an instantaneous pathloss, L, that is a difference in value of the transmission power level parameter and the measured power level of the received signal;

output an average pathloss, L_o, based upon the determined L;

a quality control device configured to:

determine a quality of the L_o;

apply a weighting factor α having a value between 0 and 1; and

output a transmit power level adjustment; and

a transmit power level determination device configured to determine a power level of a subsequent transmission signal from the UE based on the transmit power level adjustment.

2. The UE of claim 1, wherein the receiver is configured to receive the signal over a signaling channel.

3. The UE of claim 2, wherein the signaling channel is a control channel.

4. The UE of claim 1, wherein the power level of the subsequent transmission is directly proportional to a sum of three factors: a first factor that is determined by multiplying the weighting factor α with the difference of L and L_0; a second factor that is L; and a third factor that is at least one other value received by the UE.

5. The UE of claim 1, wherein the subsequent transmission signal from the UE takes place over at least one time slot of a radio frame that is divided into a plurality of time slots.

6. The UE of claim 1 comprising an antenna configured to radiate the subsequent transmission signal.

7. The UE of claim 1 further comprising circuitry operatively coupled to the antenna to demodulate signals received by the antenna to produce a baseband signal.

8. The UE of claim 1 wherein the received signal and the subsequently transmitted signal are in a code division multiple access format.

9. The UE of claim 1, wherein the weighting factor α is directly proportional to:

a ratio of A/B wherein A is equal to a first slot number on which information is transmitted and B is equal to the maximum allowed delay as represented in slot numbers.

10. The UE of claim 1, wherein the weighting factor α is directly proportional to a ratio of a parameter (D) that is calculated as a difference between a time slot of a previous path loss estimate and a first time slot of data transmitted, and a maximum allowed delay (D_{max}) as represented in time slots.

11. The UE of claim 10, wherein for $D < D_{max}$, and $D \rightarrow D_{max}$, a difference between D and D_{max} is small, and the average pathloss estimation device is configured to determine the pathloss as an instantaneous pathloss L.

12. The UE of claim 10, wherein for $D < D_{max}$, and a difference between D and D_{max} is large, and the average pathloss estimation device is configured to determine the pathloss as a long term average pathloss L_o.

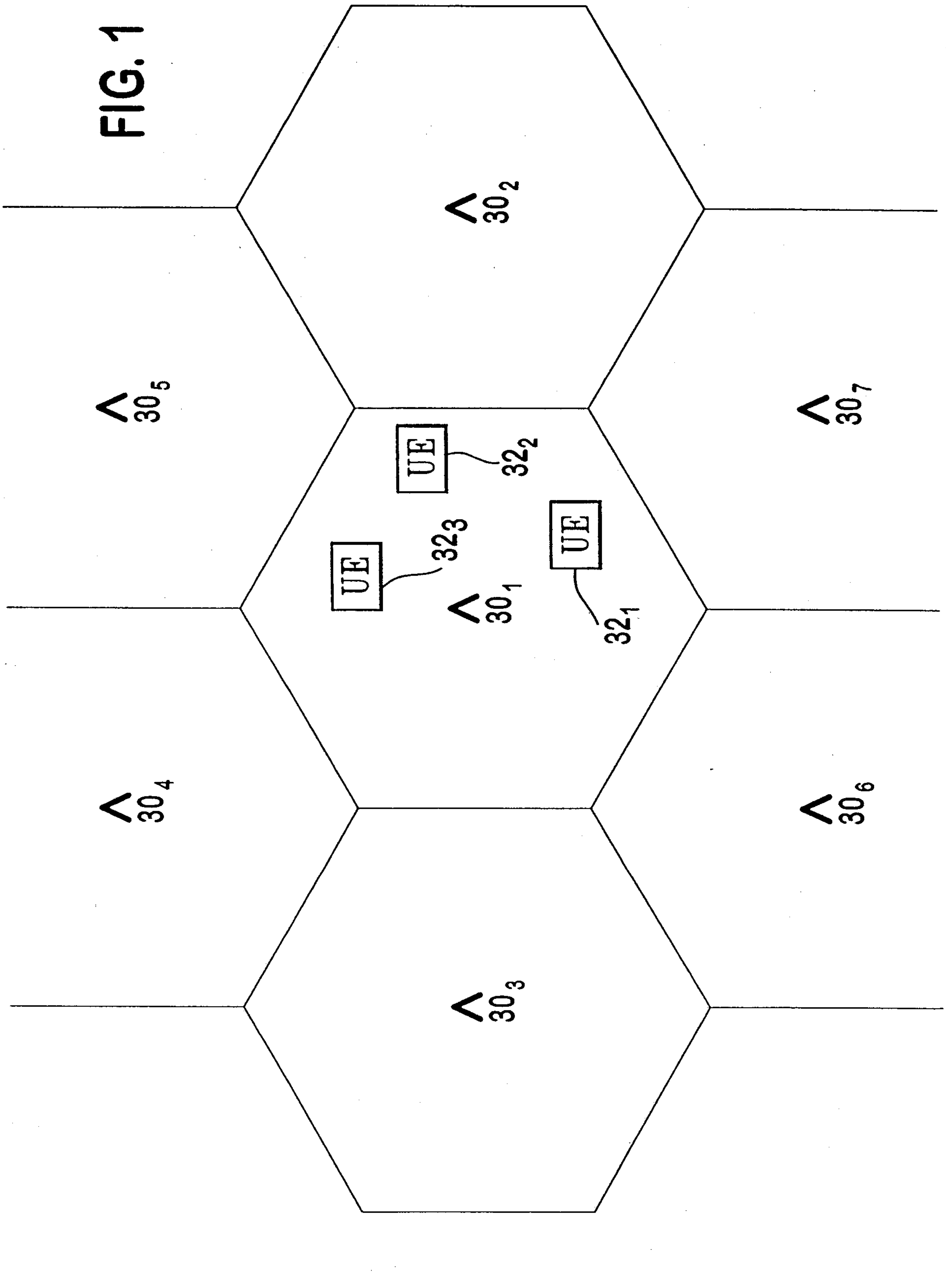
13. The UE of claim 10, wherein for $D > D_{max}$, the weighting factor is set to zero (0), and the average pathloss estimation device is configured to determine the pathloss as a long term average pathloss L_o.

14. The UE of claim 1, wherein the received signal is separated by time.

15. The UE of claim 1, wherein the received signal is separated by codes.

16. The UE of claim 1, wherein the received signal is separated by time and codes.

FIG. 1



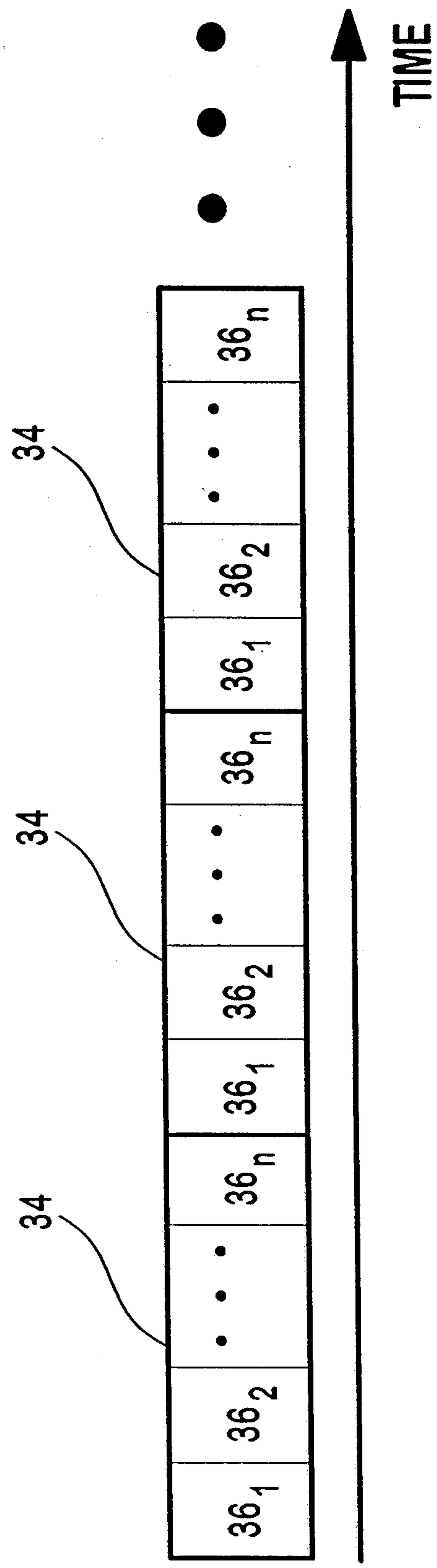
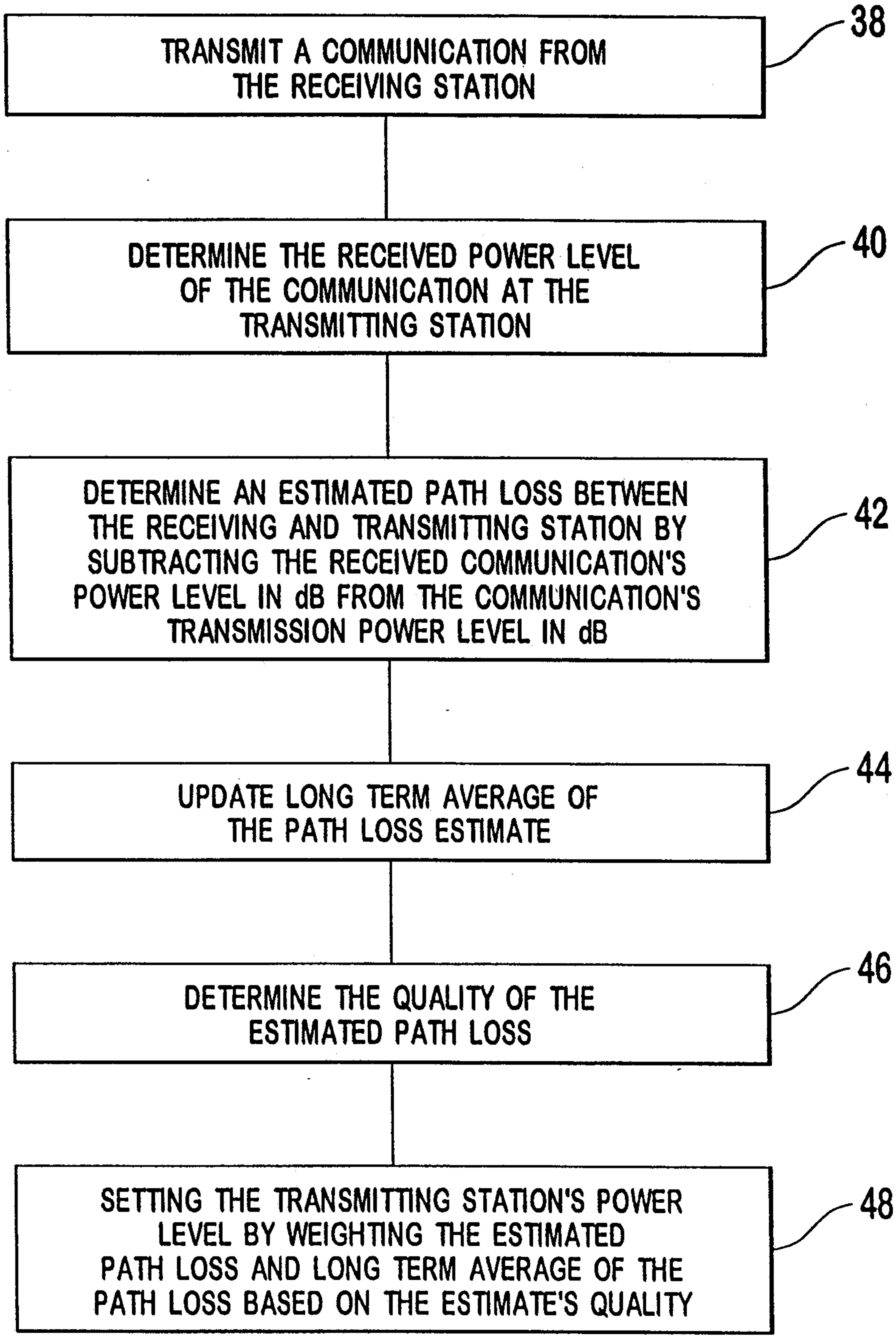


FIG. 2

FIG. 3


TRANSMIT A COMMUNICATION FROM THE RECEIVING STATION
38
DETERMINE THE RECEIVED POWER LEVEL OF THE COMMUNICATION AT THE TRANSMITTING STATION
40
DETERMINE AN ESTIMATED PATH LOSS BETWEEN THE RECEIVING AND TRANSMITTING STATION BY SUBTRACTING THE RECEIVED COMMUNICATION'S POWER LEVEL IN dB FROM THE COMMUNICATION'S TRANSMISSION POWER LEVEL IN dB
42
UPDATE LONG TERM AVERAGE OF THE PATH LOSS ESTIMATE
44
DETERMINE THE QUALITY OF THE ESTIMATED PATH LOSS
46
SETTING THE TRANSMITTING STATION'S POWER LEVEL BY WEIGHTING THE ESTIMATED PATH LOSS AND LONG TERM AVERAGE OF THE PATH LOSS BASED ON THE ESTIMATE'S QUALITY
48

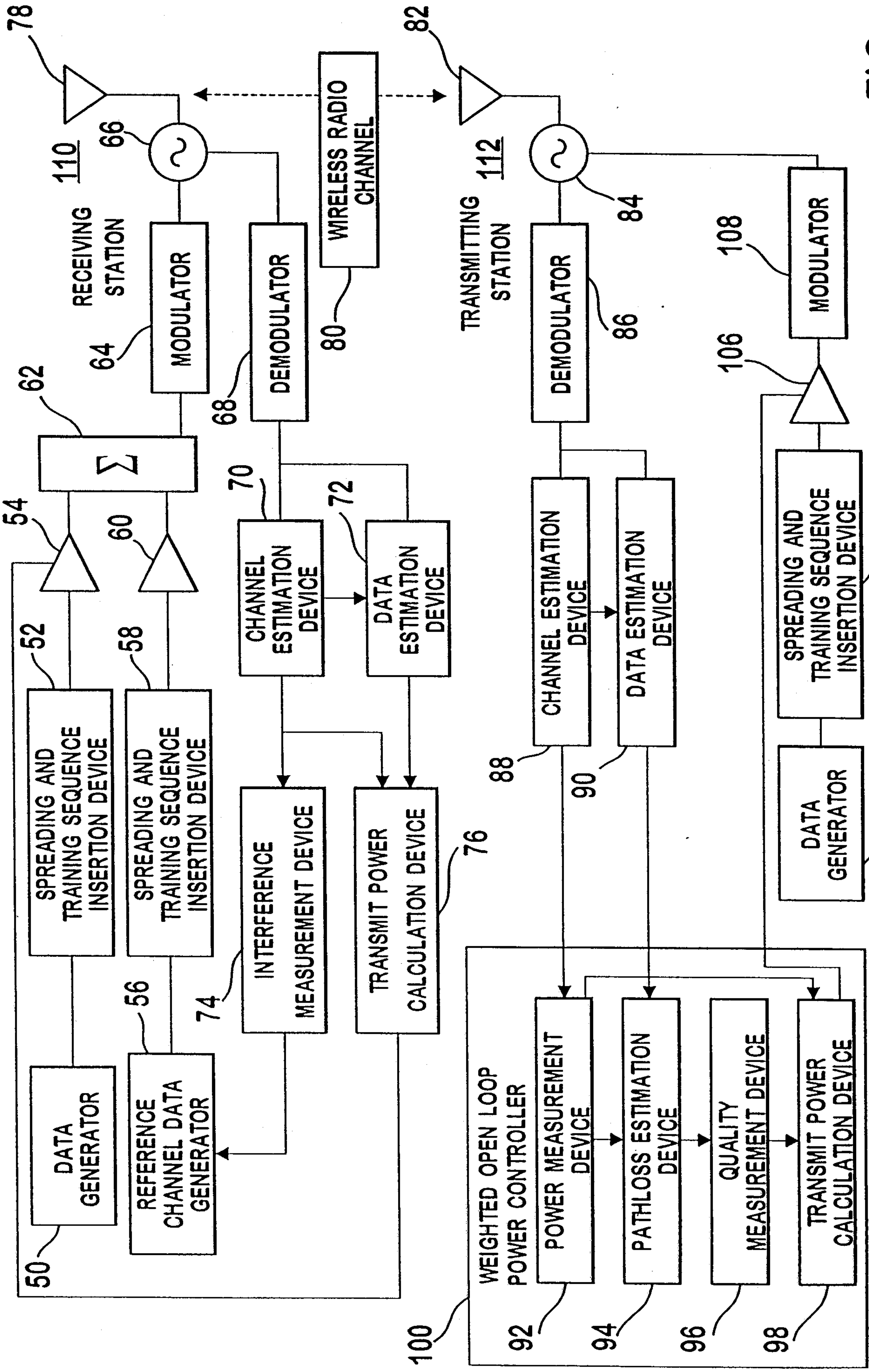
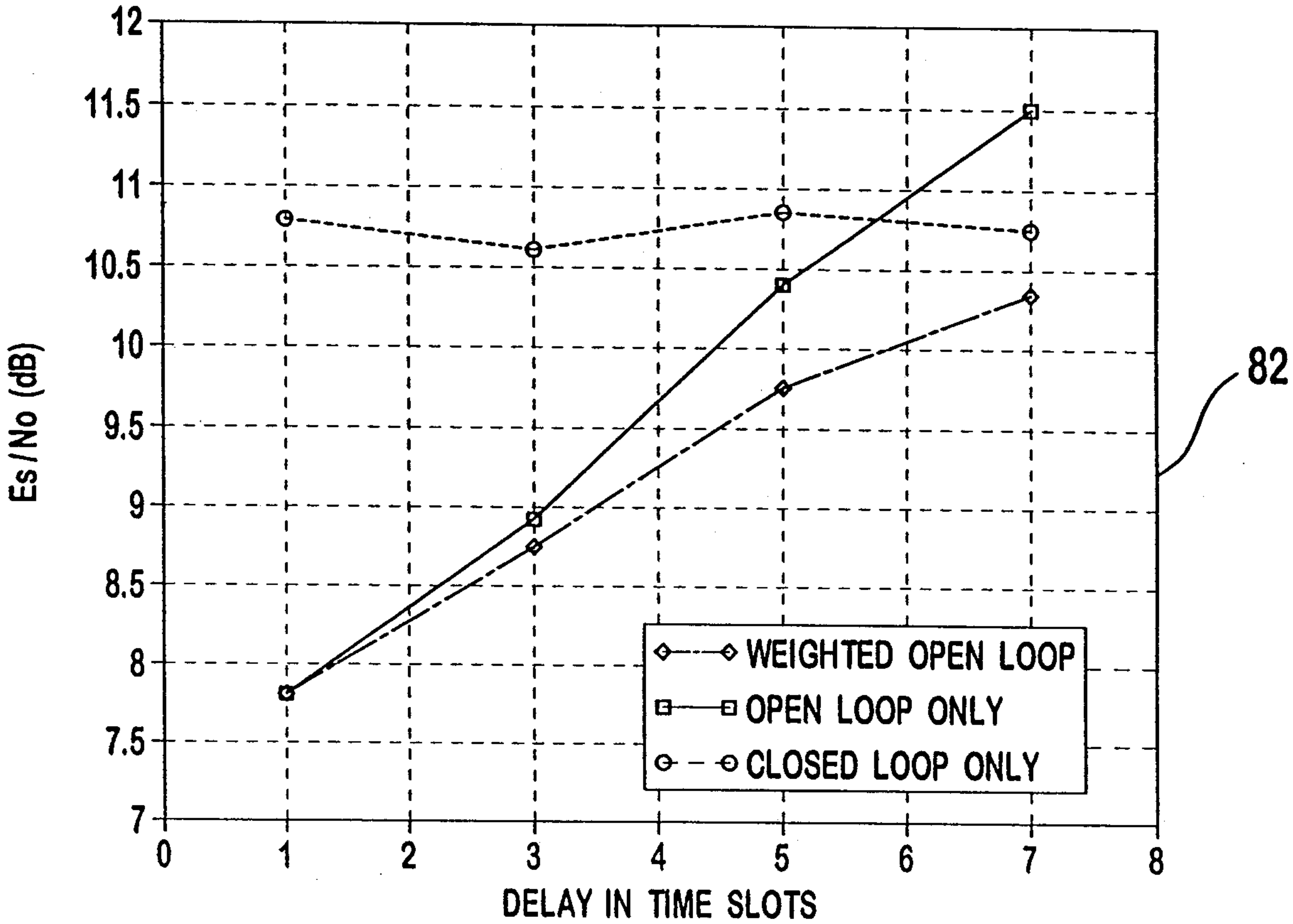

78
110
RECEIVING STATION
66
MODULATOR
64
DEMODULATOR
68
62
Σ
54
60
52
58
SPREADING AND TRAINING SEQUENCE INSERTION DEVICE
SPREADING AND TRAINING SEQUENCE INSERTION DEVICE
DATA GENERATOR
50
REFERENCE CHANNEL DATA GENERATOR
56
70
CHANNEL ESTIMATION DEVICE
72
DATA ESTIMATION DEVICE
INTERFERENCE MEASUREMENT DEVICE
74
TRANSMIT POWER CALCULATION DEVICE
76
WIRELESS RADIO CHANNEL
80
82
112
TRANSMITTING STATION
84
DEMODULATOR
86
CHANNEL ESTIMATION DEVICE
88
DATA ESTIMATION DEVICE
90
MODULATOR
108
106
SPREADING AND TRAINING SEQUENCE INSERTION DEVICE
104
DATA GENERATOR
102
WEIGHTED OPEN LOOP POWER CONTROLLER
100
POWER MEASUREMENT DEVICE
92
PATHLOSS ESTIMATION DEVICE
94
QUALITY MEASUREMENT DEVICE
96
TRANSMIT POWER CALCULATION DEVICE
98

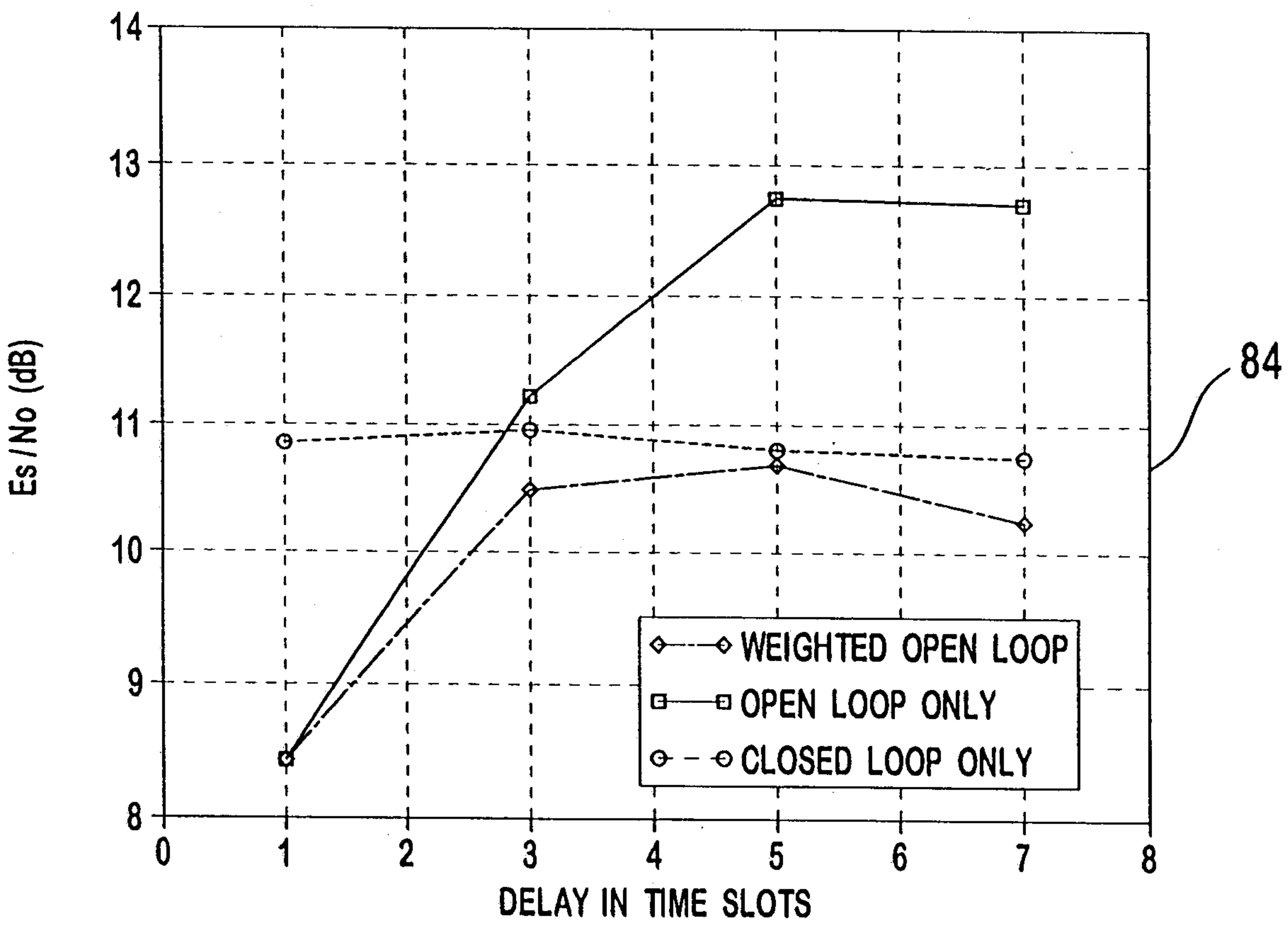
FIG. 4

FIG. 5

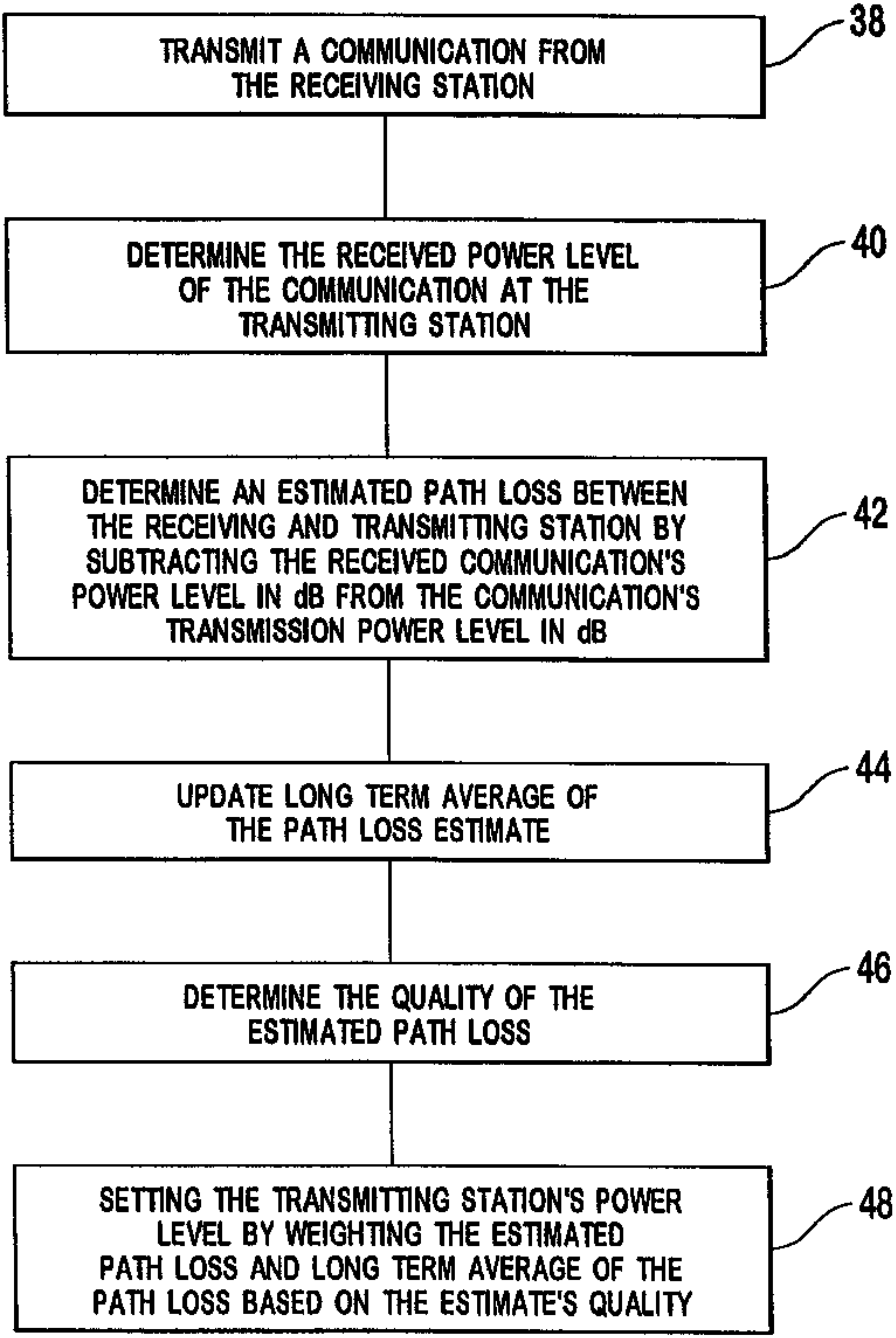


REQUIRED Es/No FOR BER=0.01 vs. DELAY AT 30 km/h

FIG. 6



REQUIRED Es/No FOR BER=0.01 vs. DELAY AT 60 km/h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