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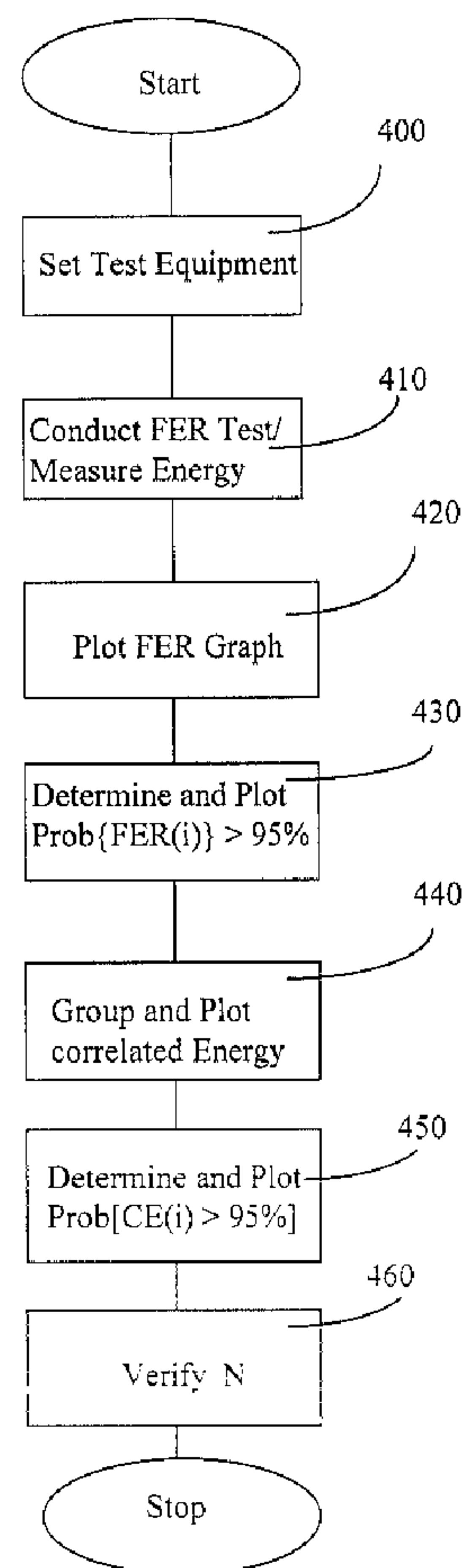
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(54) Titre : METHODE FAISANT APPEL AU RAPPORT S/B POUR REDUIRE LE TEMPS D'ESSAI EN USINE

(54) Title: METHOD OF USING SNR TO REDUCE FACTORY TEST TIME



(57) Abrégé/Abstract:

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(57) **Abrégé(suite)/Abstract(continued):**

wireless receiver is the minimum received power, measured at the mobile station antenna connector, at which the frame error rate (FER) does not exceed 0.5% with 95% confidence. In order to reduce the test time of FER test method, the relation between correlated energy (or E_c/I_o) and FER is determined using simulated traffic and the correlated energy (or E_c/I_o) measurement is then used as the test parameter on like models to achieve the same or superior test confidence with significantly reduced test time.

ABSTRACT

The application relates to wireless networks and more particularly to a method of reducing
5 factory test time of receiver sensitivity in a Code Division Multiple Access (CDMA)
wireless device. Under TIA/EIA/-98E, the radio frequency (RF) sensitivity of a CDMA
wireless receiver is the minimum received power, measured at the mobile station antenna
connector, at which the frame error rate (FER) does not exceed 0.5% with 95%
confidence. In order to reduce the test time of FER test method, the relation between
10 correlated energy (or E_c/I_o) and FER is determined using simulated traffic and the
correlated energy (or E_c/I_o) measurement is then used as the test parameter on like models
to achieve the same or superior test confidence with significantly reduced test time.

METHOD OF USING SNR TO REDUCE FACTORY TEST TIME

[0001] The application relates to wireless networks and more particularly to a method of reducing factory test time of receiver sensitivity of a wireless device, such as a Code
5 Division Multiple Access (CDMA) wireless device.

[0002] As shown in Figure 1, the delivery end of a typical mobile communication system 100 is divided into a number of cells 110 or geographical coverage areas, within each of which is a base station 120. Alternately, base station 120 for a number of cells 110 is co-
10 located at the intersection of those cells and directional antennas are used to provide coverage over the area of each adjacent cell. Each base station 120 contains radio transmission and reception equipment for communicating with a wireless device 130, such as mobile phone, laptop, personal digital assistant (PDA) or the like, located within the associated cell 110. The coverage area of a given cell 110 is dependent upon a number of
15 factors such as transmit/receive capabilities of the base station 120 and/or wireless device 130, the antenna (not shown) of base station 120, and the topology of the area. Specific radio frequencies are allocated with each cell 110. In a CDMA wireless network, the same frequency is reused in every cell. Each base station 120 connects to a backbone infrastructure (not shown) which perform a variety of functions such as the set up and tear
20 down of call and the handoff of calls from one base station 120 to another.

[0003] Figure 2 depicts a representative CDMA receiver block 200 for wireless device 130. Antenna 210 receives radio frequency signal 220 from base station 120 and converts it into a current on a conductor. The signal is very weak from absorption so, after passing
25 through duplexer 230 (which simply permits a single antenna system to be used for both transmitting and receiving) the signal is amplified in low noise amplifier (LNA) 240. The signal is then passed through filter 250 to eliminate out-of-band noise and interference. In order to recover the original information signal from the modulated radio frequency signal 220, the signal is sent through mixer 260 which is fed by local oscillator (LO) 270 at the
30 same frequency as the one in the transmitter (not shown) of base station 120 if, as shown in Figure 2, zero intermediate frequency (IF) technology is used. Alternatively, there may be more than one mixer 260 to mix the received signal 220 down to at least one non-zero intermediate frequency and then down to a baseband signal by multiple steps. Out of the

mixer 260 come two frequency signals (sum and difference). One of the frequencies is the intermediate frequency, the other is eliminated by filter 280. The resulting signal is amplified by amplifier 290, and passed through analog to digital converter 300 for digital processing in baseband processor 310 which may comprise a RAKE receiver. As those skilled in the art will appreciate, wireless device 130 is a transceiver in that it incorporates both transmitter (Tx) and receiver (Rx) functionality (e.g. the power amplifier (PA) associated with the transmitter is shown in Figure 2). As will also be appreciated, the signal processing system of wireless device 130 may be comprised of multiple analog and mixed signal integrated circuit (IC) chips (such as amplifiers, filters, A/D and D/A converters), digital IC chips (such as memory, digital signal processors (DSP), and microprocessors) and many passive discrete components.

[0004] Quality assurance measures at the factory level ensure that wireless device 130 operates satisfactorily. Various standards have been developed against which wireless device 130 is measured. One such standard is a Telecommunications Industry Association/Electronic Industries Association standard, TIA/EIA/-98E, which defines recommended minimum performance standards for cdma2000 spread spectrum mobile stations. More specifically, a test is established in this standard for receiver sensitivity and dynamic range. The radio frequency (RF) sensitivity of a cdma2000 mobile station receiver is the minimum received power, measured at the mobile station antenna connector, at which the frame error rate (FER) does not exceed 0.5% with 95% confidence. In CDMA systems, the frame is the basic physical channel data packet, typically having a 20ms transmission time that consists of information on the traffic channel (voice or data). Because the link between base station and handset is established on a frame-by-frame basis the performance of a CDMA mobile phone is evaluated in terms of its FER. Regarding receiver sensitivity, two sources of interference are purely additive white Gaussian noise (AWGN): the receiver's input-referred thermal noise power spectral density (N_o) and the transmitter's thermal noise power spectral density (N_{Tx}) in the receiver frequency band (see Figure 2). A typical sensitivity and dynamic range test setup using FER is shown in Figure 3A while the associated test parameters as defined in TIA/EIA/-98E are shown in Figure 3B. A sensitivity test (test 1) ensures the receiver's ability to receive weak signals, and a dynamic range test (test 2) ensures the receiver's ability to receive a strong signal. In Figure 3A, the base station 120 is simulated using a piece of test equipment 320, such as

the Agilent 8960 wireless communications test set, which feeds a test signal to an antenna port of a device under test (DUT) 330. As highlighted in Figure 3B, a typical test, at 9600 bps (RC 1 and 3) or 14400 bps (RC 2) data rate, consists of setting the test parameters of Test 1 or Test 2, and counting the number of frames transmitted at the base station and
5 comparing it to the number of erroneous frames received at the mobile station.

[0005] One of the problems with the TIA/EIA/-98E receiver sensitivity test is that the test time is too long for mass production, being physically restricted by the arrival rate of the frames at DUT 330. In an attempt to reduce the test time, the maximum number of frames
10 for the sensitivity test is limited to no more than 1000 (which may not always achieve the required 95% confidence level), but this method still takes up to 80 seconds for four channels at two bands. As will be appreciated, for thousands of units, the test time and associated cost in man hours may become prohibitive.

15 SUMMARY

[0006] In order to overcome the deficiencies of the FER test method, there is provided an improved receiver sensitivity test. For a given model of CDMA wireless device the relation between correlated energy or SNR and FER is determined using simulated traffic
20 and the correlated energy or SNR measurements are then used as the test parameters on like models to achieve the same or superior test confidence with significantly reduced test time. Because the test is conducted over a time-invariant AWGN, and given the fact that the digital signal processing is identical to all DUT 330 of the same type, the frame error rate is only dependent on the correlated energy or SNR at the output of A/D 300 feeding to
25 the baseband processor 310. Baseband processor 310 of a CDMA wireless device 130 includes an E_c/I_o estimator (energy per chip to interference density ratio, which is a kind of expression of SNR often used in a CDMA based system), which is borrowed for the factory test. The E_c/I_o estimate is determined by a RAKE finger energy estimator (producing an output related to correlated "energy") found in baseband processor 310, and
30 some further processing which translates the estimated correlated energy to E_c/I_o . Both E_c/I_o and the correlated energy are monotonic functions of frame error rate under a given channel condition, so either can be used. Since the estimator reported correlated energy (or E_c/I_o) contains a certain degree of random fluctuations, its distribution and nonlinear

relation with frame error rate is characterized for a given model of wireless device, to determine a set of factory test criteria that achieves a test confidence level equal or superior to the TIA/EIA/-98E receiver sensitivity test. Once the characterization is carried out, each wireless device 130 is evaluated against the established pass/fail correlated
5 energy or E_c/I_o threshold.

[0007] In accordance with a first embodiment, there is provided a method of testing receiver sensitivity in a radio frequency (RF) device comprising: (a) selecting a new test quantity to replace a known receiver sensitivity test parameter; (b) determining the
10 relationship between the known receiver sensitivity test parameter and the new test quantity; (c) determining a new test criteria based on the new test quantity using the determined relationship and a known test criteria based on the known receiver sensitivity test parameter, and which known test criteria is in accordance with a defined standard; and
15 (d) conducting a receiver sensitivity test using the new test quantity and the new test criteria.

[0008] Preferably, the new test quantity is taken from the group comprising signal to noise ratio, signal to interference ratio, energy per chip to interference density ratio (E_c/I_o), energy per bit to interference density ratio (E_b/I_o), energy per symbol to interference
20 density ratio (E_s/I_o), energy per chip to noise density ratio (E_c/N_o), energy per bit to noise density ratio (E_b/N_o), energy per symbol to noise density ratio (E_s/N_o), carrier power to noise density ratio (C/N_o), correlated energy, correlated amplitude, symbol error rate and bit error rate.

[0009] In accordance with a second embodiment, there is provided a system for testing receiver sensitivity in a radio frequency (RF) device comprising: (a) a wireless communications test set (320); (b) a device under test (DUT) (330) communicating with the wireless communications test set (320), wherein a simulated traffic signal is forwarded from the wireless communications test set (320) to the DUT (330), and wherein the
25 communications test set comprises means for selecting a new test quantity to replace a
30 known receiver sensitivity test parameter; means for determining the relationship between said known receiver sensitivity test parameter and said new test quantity; means for

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determining a new test criteria based on said new test quantity using the determined relationship and a known test criteria based on the known receiver sensitivity test parameter, and which known test criteria is in accordance with a defined standard; and means for conducting a receiver sensitivity test using said new test quantity and said new test criteria.

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[00010] Preferably, the DUT comprises a baseband processor (310), and wherein the baseband processor comprises a channel estimator for estimating a new test quantity associated with the simulated traffic signal.

5 [00011] More preferably, the wireless communications test set (320) is connected via a coaxial cable to an antenna or radiating coupler positioned in a shielded enclosure housing the DUT (330), and wherein the DUT (330) receives the simulated traffic signal via a wireless transmission from the antenna or radiating coupler, and wherein path loss
10 associated with the wireless transmission, the coaxial cable, or the antenna or radiating coupler, is corrected by the wireless communications test set (320).

[00012] The advantage of the described test method is now readily apparent. Using the improved testing methodology, the test time using the correlated energy or SNR technique can be reduced significantly. Test time using the FER method can span 48 to 80 seconds
15 per device for one confidence level while using the correlated energy or SNR method can reduce the test time to a range of 10 to 22 seconds at the same confidence level.

[00013] Further features and advantages of the invention will be apparent from the detailed description which follows together with the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

[00014] A better understanding of the invention will be obtained by considering the detailed description below, with reference to the following drawings in which:

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Figure 1 depicts a typical mobile communication system;

Figure 2 depicts a representative receiver block diagram for a wireless device;

Figure 3A depicts a standard FER hardware test setup for sensitivity and dynamic range tests;

30 Figure 3B depicts a table showing the test parameters associated with a standard FER test according to TIA/EIA/-98E receiver sensitivity and dynamic range test;

Figure 4 depicts the steps in the characterization process whereby the relationship of correlated energy to FER is established;

- Figure 5 depicts an energy estimator settle time chart;
- Figures 6A and 6B depict a plot of FER(i) v. FERave and correlated energy v. FERave along with a plot of the 95% confidence line;
- Figures 7A to 7E depict exemplary plots of correlated energy v. FER for sample sizes N=
- 5 5, 10, 20, 40 and 80;
- Figure 8 depicts a table listing iteration criteria used in testing a wireless device using correlated energy;
- Figures 9A and 9B depict the steps for testing a wireless device using correlated energy; and
- 10 Figure 10 depicts the steps for an alternate test on a wireless device using correlated energy.

DESCRIPTION

- 15 [00015] The first step in the testing methodology, is the energy or SNR and FER characterization. As those in the art will appreciate, one of the main advantages of CDMA systems is the capability of using signals that arrive in the receivers with different time delays. This phenomenon is called multipath. As discussed in the background section, CDMA wireless devices may use RAKE receivers located in baseband processor 310. A
- 20 RAKE receiver uses several baseband correlators to individually process several signal multipath components. Each correlator in a RAKE receiver is called a RAKE-receiver finger. One of the receivers (fingers) usually is a dedicated channel searcher which obtains course estimates of the time and amplitude of arrival of the strongest multipath components of the wireless device signal. This information is then fed to the other fingers.
- 25 Each finger then demodulates the signal corresponding to a strong multipath. The results are then combined together to make the signal stronger. The square of the amplitude at the correlator output is generally referred to as the correlated energy. Baseband processor 310 also includes a function which can map the correlator output energy to a signal to interference ratio, E_c/I_o , expressed in dB. For the purposes of the present description, the
- 30 test methodology will be described using the correlated energy, although E_c/I_o could also be used and is meant to be included within the scope of the present application.

[00016] Prior to taking correlated energy readings it is necessary to determine the settling time for the correlated energy readings produced by the estimator i.e. to ensure that an erroneous transient reading is not inadvertently taken. This is accomplished by performing a test call at an arbitrarily chosen strong received signal strength (I_{or}) e.g. -60_{dBm} . An automated program is then used to set I_{or} to have a step decrease to a weak level around the device sensitivity, e.g. -105_{dBm} and an extended diagnostic monitor (XDM), a software tool well known to those skilled in the art, is used to read the correlated energy values. The frequency of reading by XDM should be chosen to be fast enough to get good time response samples e.g. five readings per second and an exemplary resulting time response for a sample device under test are shown in Figure 5. Each point on the graph is a distinct reading of energy. The results reveal that a wait time of about 1.5 seconds is sufficient to allow for settling of the energy signal.

[00017] Figure 4 is a flow chart depicting the steps in the characterization process; this preparation step must be performed before the wireless device test can be conducted. The process generates a set of test parameters and criteria to be used in the test. For the characterization, two alternate objectives can be used. The first is to make the test method as reliable as an existing FER-based test in terms of false alarm rate (i.e. a good device mistakenly reported as bad), and missed detection rate (i.e. a bad device is mistakenly reported as good). The second is to make the new test compliant with the standard, which only controls the missed detection rate lower than 5% (i.e. 1–95%) and does not really care about the false alarm rate. The following describes the former embodiment and then describes the latter.

[00018] At step 400, the wireless communications test set (which simulates base station 120) is configured to the same receiver sensitivity test setting as detailed in TIA/EIA/-98E (see Fig. 3B) and I_{or} is set, for example, in 0.5 dB steps in a FER range that covers 0.1% ~ 1%. At step 410, device under test (DUT) 330 is then tested by, at each of a number of received signal strength (I_{or}) levels: (a) measuring the FER using the max number of frames that is used in factory e.g. 1000 frames; (b) repeating the measurement for a large number of times e.g. 20 times; (c) recording each individual FER(i) and also calculating the average FER of all the measured frames of the repeated measurement (denoted as FERave); and (d) simultaneously measuring and recording a large sample of correlated

energy values for each Ior setting. At step 420, a scatter diagram of FER(i) vs. FERave is then plotted. At step 430, the 95% probability point is determined (i.e. an FER(i) value of P at which $\text{Prob}[\text{FER}(i) > P] = 95\%$, and similarly an FER(i) value of Q at which $\text{Prob}[\text{FER}(i) < Q] = 95\%$). In the calculation, if the sample size of FER(i) is not

5 significantly large, such as 20 measurements, the variance of the 20 samples is used and Gaussian distribution is assumed to calculate the P and Q. The 95% confidence lines are then plotted on the graph by interpolating all of the P points, and all of the Q points respectively. A graph for a sample device is given in Figure 6A. As will be appreciated by those in the art, if a measurement of 1000 frames gets a raw FER(i) reading of X, most

10 likely the a true FER is between B and A, and the worst case with 95% confidence is A. When A is FER of 0.5%, find the range between A and B. This range will help determine the number of averages needed in new tests for achieving a sufficiently low false alarm rate. B is the point on the line of 95% on the other side i.e., the $\text{Prob}[\text{FER}(i) < Q] = 95\%$.

15 [00019] At step 440, the measured correlated energy samples are grouped by N=5 and the average value of each N-sample group is plotted as scatter diagram. An exemplary graph for a sample device is given in Figure 6B. At step 450, the 95% probability point of the scatters is located, similar to step 430, i.e., $\text{Prob}[\text{correlated energy}(i) > P] = 95\%$ and on the other side $\text{Prob}[\text{FER}(i) < Q] = 95\%$. The point A'=0.5% is located and the range

20 between A' and B' is obtained. If the range B'-A' is larger than that B-A obtained in step 430, N is increased and steps 440 and 450 are repeated. Otherwise N is decreased and steps 440 and 450 are repeated. At step 460, the N value determined at step 450 is verified for a number of sample devices. The N value determined at step 450 is used to measure the average correlated energy a number of times on each of a number of sample devices

25 (good and bad) and each of a few channels on each band of the supported bands. The corresponding FER around 0.5% is also measured with a large number of frames (e.g. 5000 or more). The overall 95% confidence result is then determined to check for consistency and the pass/fail criteria (X and X' from Figures 6A and 6B), for the 0.5% FER with 95% confidence. For the purpose of compliance with the TIA/EIA/-98E

30 standard and without taking into account the false alarm rate, N can be any value and only X' need be determined for the test.

[00020] An alternate embodiment using variable N can also be used. To determine N, after the determined settling time of the test Ior, a continuous series of individual correlated energy samples are taken. The mean of N adjacent samples is calculated and plotted. The exemplary results for a device under test are shown in Figures 7A to 7E for N=5, 10, 20, 40, and 80. These values of N are chosen to simplify the processing of data in the test stage. Each point on the graphs depicted in Figures 7A to 7E is the scatter diagram of mean values of N adjacent readings. As N increases, the 95% confidence interval becomes narrower. Using a test limit of FER = 0.5%, taken from the plot of N=5 (Figure 7A), the corresponding correlated energy threshold value is determined to be 1385. Thus, a mean correlated energy above 1385, would indicate an FER <0.5%. It is obviously most desirable to use the lowest value of N to decrease test time i.e. N=5. However, it may not always be possible to determine a pass with N=5, as the false alarm rate may be too high. If a pass is not determined within N=5 samples, then N can be doubled until a maximum value of N=80 is reached. The maximum value of N is determined by the maximum test time allowed in manufacturing and the sampling rate for reading the energy values. If the mean of 80 energy readings is smaller than 1333, a fail is registered.

[00021] Having completed the characterization step to determine the correlated energy pass/fail thresholds, the actual test of the sample device can be conducted. Figure 8 depicts a table highlighting the number of correlated energy readings taken over a given time and the associated pass criterion for each iteration of the test for a sample device under test. The pass criterion are derived from Figures 7A to 7E. Figures 9A and 9B depict a flow chart highlighting the steps in a generic test. In Figure 9A, at step 500 a test call is setup on the test channel to generate simulated traffic. At step 510, the test Ior is set. At step 520, the tester waits the correlated energy estimator settling time (e.g. 1.5 seconds). At step 530, the first iteration is performed. N samples of correlated energy are taken within, for example, one second (where N is preferably greater than or equal to 5). The average of the N samples is then taken. If the calculated average is greater than the pass criterion established for the number of N samples (see Figure 7A and 8) then, at step 540 the device under test is passed. If the calculated average is below the pass criterion, then proceed to iteration two at step 550. In the second iteration, an additional N correlated energy samples are taken and the average of these samples is calculated. The average from the

first iteration and the second iteration are added together and divided by two to form an overall average of $2N$ samples. If the new average is greater than the pass criterion established for the number of $2N$ samples (see Figure 7B and 8) then, at step 560, the device under test is passed. If the calculated average is below the pass criterion, then

5 proceed to iteration three at step 570 in Figure 9B. The steps associated with second iteration are repeated with $2N$ additional correlated energy samples and the calculated average is compared to the $4N$ pass criteria. If the new average is greater than the pass criterion established for the number of $4N$ samples (see Figure 7C and 8) then, at step 580, the device under test is passed. If the calculated average is below the pass criterion, then

10 proceed to iteration four at step 590. $4N$ additional correlated energy samples are taken and the calculated average is compared to the $8N$ pass criteria. If the new average is greater than the pass criterion established for the number of $8N$ samples (see Figure 7D and 8) then, at step 600, the device under test is passed. If the calculated average is below the pass criterion, then proceed to iteration five at step 610. $8N$ additional correlated

15 energy samples are taken and the calculated average is compared to the $16N$ pass criteria. If the new average is greater than the pass criterion established for the number of $16N$ samples (see Figure 7E and 8) then, at step 620, the device under test is passed. If the calculated average is below the pass criterion, then, at step 630, the device under test is failed and testing begins on another device. Depending on the number of iterations a

20 device has to be tested, some devices may take less time to finish testing than other devices. Overall, the average test time of many devices is significantly reduced. The number of iterations may not have to be five. The test which has been described serves only as an example.

25 [00022] Figure 10 depicts an alternate test in accordance with the present application. At step 700 a test call is setup on the test channel. At step 710, the test Ior is set. At step 720, the tester waits the correlated energy estimator settling time (e.g. 1.5 seconds). At step 730, the first iteration is performed. N samples of correlated energy are taken within, for example, one second (where N is preferably greater than or equal to 5). The average of

30 the N samples is then taken. If the calculated average is greater than the upper pass criterion established for the number of N samples (see Figure 7A, upper limit for 0.5% FER and 95% confidence) then, at step 740 the device under test is passed. If the calculated average is below the lower fail criterion (see Figure 7A, lower limit for 0.5%

FER and 95% confidence) then the device under test is failed at step 750. If the calculated average is between the upper and lower limit, then proceed to step 760. In the second iteration, 3N additional correlated energy samples are taken and the average of these samples is calculated. The average from the first iteration is weighted by $\frac{1}{4}$ and the second iteration is weighted by $\frac{3}{4}$ and then the two weighted values are added together to form an overall average of 4N samples. If the newly calculated average is less than the 4N fail criteria then, at step 770 the device under test is failed. If the newly calculated average is greater than the 4N pass criteria then, at step 780 the device under test is passed. The described 4N pass criteria represents the 50% confidence midpoint between the upper and lower limits for 95% confidence (see Figure 7C). Similarly, the test can be performed using a different number of iterations. The test described is only by way of example. As will be appreciated, if the test only allows two possible resulting decisions: Pass or Fail, the threshold has to be the mid point and for some devices the confidence of such decision has to be 50%. Alternately, the pass confidence can be 95% and the fail confidence can be as low as 5%, in which case the threshold used is the upper 95% point. In yet another embodiment, the resulting decision can be one of three: Pass, Fail or Uncertain, in which case to determine a device "Pass", the average must be higher than the upper 95% point, to determine a device "Fail" the average must be lower than the lower 95% point, and to determine a device "Uncertain", the average must be between the upper and lower 95% thresholds. In this case, both "Pass" and "Fail" decisions have a confidence of 95%.

[00023] As will be appreciated by those in the art, wireless communications test set 320 which simulates base station 120 may be hard wired directly to DUT 330 via coaxial cable to an RF connector or the coaxial cable could be hard wired to a transmitting antenna or a radiating coupler located within a shielded box or an RF anechoic chamber where DUT 330 is also located. DUT 330 may be simply a printed circuit board integral to a wireless device with the sensitivity test being conducted by feeding a test signal into an antenna port integral to the printed circuit board. It will also be appreciated that path loss introduced by the coaxial cables and/or antenna/couplers/propagation involved in the test set up is accounted for in the tests when setting the Ior value.

[00024] Although various exemplary embodiments of the invention have been disclosed, it should be apparent to those skilled in the art that various changes and modifications can

be made which will achieve some of the advantages of the improved testing methodology without departing from the true scope of the application. More specifically, any physical quantity obtained in the baseband processing which has a monotonic relationship with signal to interference ratio can be used to conduct the receiver sensitivity test e.g. symbol error rate (SER), bit error rate (BER), carrier power to noise density ratio (C/N_0), energy per symbol to interference density ratio (E_s/I_0), energy per bit to interference density ratio (E_b/I_0), energy per chip to noise density ratio (E_c/N_0), energy per bit to noise density ratio (E_b/N_0), energy per symbol to noise density ratio (E_s/N_0) etc. Also, the measurement replaced by a physical quantity (e.g. signal to interference ratio or correlated energy) in a test may not have to be FER. Other examples include packet error rate (PER) or BER after forward error correction. All such alternate embodiments are meant to be included within the scope of the invention. Additionally, the air interface is not limited to cdma2000. There are other examples including UMTS, GSM/GPRS, 802.11, etc to which the present invention can be applied. Finally, this test had been described in relation to a mobile device. The test is more universally applicable to any RF communication device where receiver sensitivity testing is required (e.g. for base station 120 in Figure 1) where a relationship between the existing test parameter and correlated energy or SNR can be determined to establish new thresholds against which the receiver's sensitivity can be evaluated.

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[00025] A person understanding this invention may now conceive of alternative structures and embodiments or variations of the above all of which are intended to fall within the scope of the invention as defined in the claims that follow.

CLAIMS:

1. A wireless communications test set for testing receiver sensitivity in a radio frequency (RF) device, the test set comprising:

a selection module for selecting a new test quantity obtained in baseband processing of a traffic signal received by the device and having a predetermined and monotonic relationship with the frame error rate, packet error rate or bit error rate after forward error correction of the traffic signal received by the device;

a test module for conducting a receiver sensitivity test on the radio frequency device using a simulated traffic signal, the new test quantity, and a new test criteria;

wherein the new test criteria is determined from a respective known frame error rate, packet error rate or bit error rate after forward error correction criteria and the predetermined monotonic relationship between the new test quantity and the respective frame error rate, packet error rate or bit error rate after forward error correction of a traffic signal received by the device.

2. A test set according to claim 1, wherein the new test quantity is selected from the group comprising: signal to noise ratio (SNR), signal to interference ratio (E_c/I_o), energy per chip to interference density ratio (E_c/I_o), energy per bit to interference density ratio (E_b/I_o), energy per symbol to interference density ratio (E_s/I_o), energy per chip to noise density ratio (E_c/N_o), energy per bit to noise density ratio (E_b/N_o), energy per symbol to noise density ratio (E_s/N_o), carrier power to noise density ratio (C/N_o), correlated energy, correlated amplitude, symbol error rate, bit error rate before forward error correction.

3. A test set according to claim 1 or 2, wherein the known frame error rate criteria is a frame error rate of 0.5% with 95% confidence.

4. A test set according to any one of claims 1 to 3, further comprising a relationship determination module for determining the predetermined relationship between the test quantity and the respective frame error rate, packet error rate or bit error rate after forward error correction of a traffic signal received by the device using a simulated traffic signal.

5. A system for testing receiver sensitivity in a radio frequency (RF) device comprising:
a wireless communications test set according to any one of claims 1 to 4;

a device under test (DUT), the device under test being arranged to communicate with the wireless communications test set and to receive the simulated traffic signal from the wireless communications test set;

wherein the RF device is any of a wireless device or a base station operating within a wireless network.

6. The system of claim 5, wherein an RF receiver of the RF device is arranged on a printed circuit board integral to the wireless device, and wherein the wireless communications test set is arranged to conduct the receiver sensitivity test by feeding the simulated traffic signal into an antenna port integral to the printed circuit board.

7. The system of claim 5 or 6 wherein the DUT comprises a baseband processor, and wherein the baseband processor comprises a channel estimator for estimating the new test quantity associated with the simulated traffic signal.

8. The system of claim 7 wherein the baseband processor further comprises a function for translating a correlated energy value to a signal to noise ratio (SNR) or energy per chip to interference density ratio (E_c/I_o).

9. The system of any one of claims 5 to 8 wherein the wireless communications test set is connected via a coaxial cable to an antenna or radiating coupler positioned in a shielded enclosure housing the DUT, and wherein the DUT is arranged to receive the simulated traffic signal via a wireless transmission from the antenna or radiating coupler, and wherein the wireless communications test set is arranged to correct path loss associated with the wireless transmission, the coaxial cable, or the antenna or radiating coupler.

10. A method of testing receiver sensitivity in a radio frequency (RF) device comprising:
selecting a new test quantity obtained in baseband processing of a traffic signal received by the device and having a monotonic and predetermined relationship with the frame error rate, packet error rate or bit error rate after forward error correction of the traffic signal received by the device;

conducting a receiver sensitivity test on the radio frequency device using a simulated traffic signal, the new test quantity, and a new test criteria;
wherein the new test criteria is determined from a respective known frame error rate, packet error rate or bit error rate after forward error correction criteria and the predetermined monotonic

relationship between the new test quantity and the respective frame error rate, packet error rate or bit error rate after forward error correction of a traffic signal received by the device.

11. The method of claim 10 wherein the new test quantity is read from a baseband processor associated with the RF device.

12. The method of claim 10 or 11 wherein the new test criteria corresponds with a known frame error rate criteria of 0.5% with 95% confidence.

13. The method of any one of claims 10 to 12, wherein the new test quantity comprises any of signal to noise ratio, signal to interference ratio, energy per chip to interference density ratio (E_c/I_o), energy per bit to interference density ratio (E_b/I_o), energy per symbol to interference density ratio (E_s/I_o), energy per chip to noise density ratio (E_c/N_o), energy per bit to noise density ratio (E_b/N_o), energy per symbol to noise density ratio (E_s/N_o), carrier power to noise density ratio (C/N_o), correlated energy, correlated amplitude, symbol error rate and/or bit error rate before forward error correction.

14. The method of any one of claims 10 to 13, further comprising determining the predetermined relationship between the test quantity and the respective frame error rate, packet error rate or bit error rate after forward error correction of a traffic signal received by the device using a simulated traffic signal.

15. The method of claim 14, wherein the step of determining the predetermined relationship comprises:

- obtaining a plurality of the frame error rate measurements and corresponding values of the new test quantity at each of a plurality of received signal strengths;

- calculating at each of the plurality of received signal strength levels an average value of the plurality of the frame error rate measurements;

- plotting the averages of N-sample groups of the corresponding values of the new test quantity versus the calculated average values of the plurality of the frame error rate measurements and determining targeted confidence level probability points from the plot;

- interpolating between the targeted confidence level probability points for different ones of the plurality of received signal strength levels; and

- determining a pass/fail threshold for the new test quantity which corresponds to a pass/fail criteria associated with the known frame error rate criteria.

16. The method of any one of claims 10 to 15 wherein the step of conducting a receiver sensitivity test comprises:
- waiting a defined settling time;
 - obtaining N samples of the new test quantity;
 - calculating the average of the N samples;
 - if the calculated average is greater than a specified N new test quantity threshold, passing the wireless device,
 - else, if the calculated average is less than the specified N new test quantity threshold, obtaining a multiple number of N additional samples and repeating the steps of calculating the average of the N samples and passing the wireless device; and
 - after a predefined number of iterations, failing the RF device if the new test quantity threshold has not been met.
17. The method of any one of claims 10 to 15 wherein the step of conducting a receiver sensitivity test comprises:
- waiting a defined settling time;
 - obtaining N samples of the new test quantity;
 - calculating the average of the N samples;
 - if the calculated average is greater than an upper limit associated with a specified N test quantity threshold, passing the wireless device,
 - else, if the calculated average is less than the upper limit associated with the N new test quantity threshold but greater than a lower limit associated with the N test quantity threshold, obtaining 3N additional samples and repeating the steps of calculating the average of the N samples and passing the wireless device wherein a calculated 4N average is obtained by assigning the N samples a weighted average of $\frac{1}{4}$ and the 3N samples a weighted average of $\frac{3}{4}$; and
 - if the 4N calculated average is less than a specified 4N new test quantity threshold, failing the RF device.
18. The method of claim 14 wherein the new test quantity is correlated energy, and wherein the determining the predetermined relationship comprises:
- obtaining a plurality of FER measurements and corresponding correlated energy values at each of a plurality of received signal strengths;
 - calculating an average value of the plurality of FER measurements obtained at each of the plurality of received signal strengths;

plotting the plurality of FER measurements versus the calculated FER averages and determining the 95% probability point from the plot;

plotting the averages of N-sample groups of the corresponding correlated energy values versus the calculated FER averages and determining the 95% probability points from the plot;

interpolating between the 95% probability points for different ones of the plurality of received signal strength levels; and

determining a correlated energy threshold for 0.5% FER with 95% confidence.

19. The method of claim 18 wherein the step of conducting a receiver sensitivity test comprises:

waiting a defined settling time;

obtaining N samples of the correlated energy;

calculating the average of the N samples;

if the calculated average is greater than a specified N correlated energy threshold, passing the wireless device; and

else, if the calculated average is less than the specified N correlated energy threshold, obtaining a multiple number of N additional samples and repeating the steps of calculating the average of the N samples and passing the wireless device; and

after a predefined number of iterations, failing the RF device if the correlated energy threshold has not been met.

20. The method of claim 18 wherein the step of conducting a receiver sensitivity test comprises:

waiting a defined settling time;

obtaining N samples of the correlated energy;

calculating the average of the N samples;

if the calculated average is greater than an upper limit associated with a specified N correlated energy threshold passing the wireless device; and

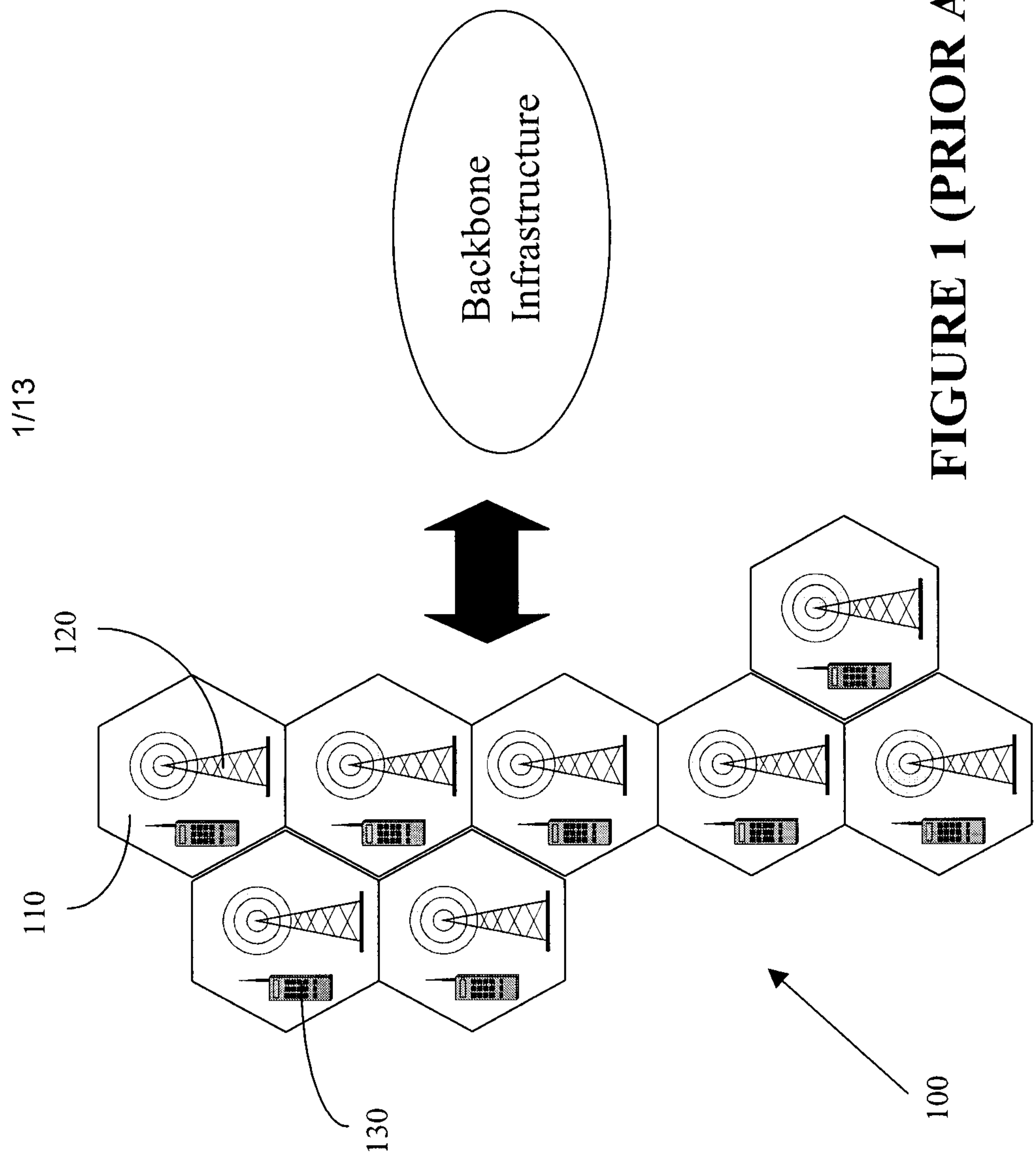
else if the calculated average is less than the upper limit associated with the specified N correlated energy threshold but greater than a lower limit associated with the specified N correlated energy threshold, obtaining 3N additional samples and repeating the steps of calculating the average of the N samples and passing the wireless device wherein a calculated 4N average is obtained by assigning the N samples a weighted average of $\frac{1}{4}$ and the 3N samples a weighted average of $\frac{3}{4}$; and

if the $4N$ calculated average is less than a specified $4N$ correlated energy threshold, failing the RF device.

21. The method of any one of claims 18 to 20, wherein the step of obtaining a plurality of FER measurements and corresponding correlated energy values further comprises the step of translating the correlated energy values to corresponding signal to noise ratio (SNR) or E_c/I_o values, and wherein the steps of passing and/or failing the wireless device are performed using the mapped SNR or E_c/I_o values.

22. The method of claim 20, wherein the step of obtaining N samples of the correlated energy further comprises the step of translating the correlated energy values to corresponding signal to noise ratio (SNR) or E_c/I_o values, and wherein the steps of calculating the average of the N samples and passing and/or failing the wireless device are performed using the mapped SNR or E_c/I_o values.

23. A machine readable medium comprising program code means executable by a processor of the wireless communications test set of any one of claims 1 to 4 for implementing the method of any one of claims 10 to 22.



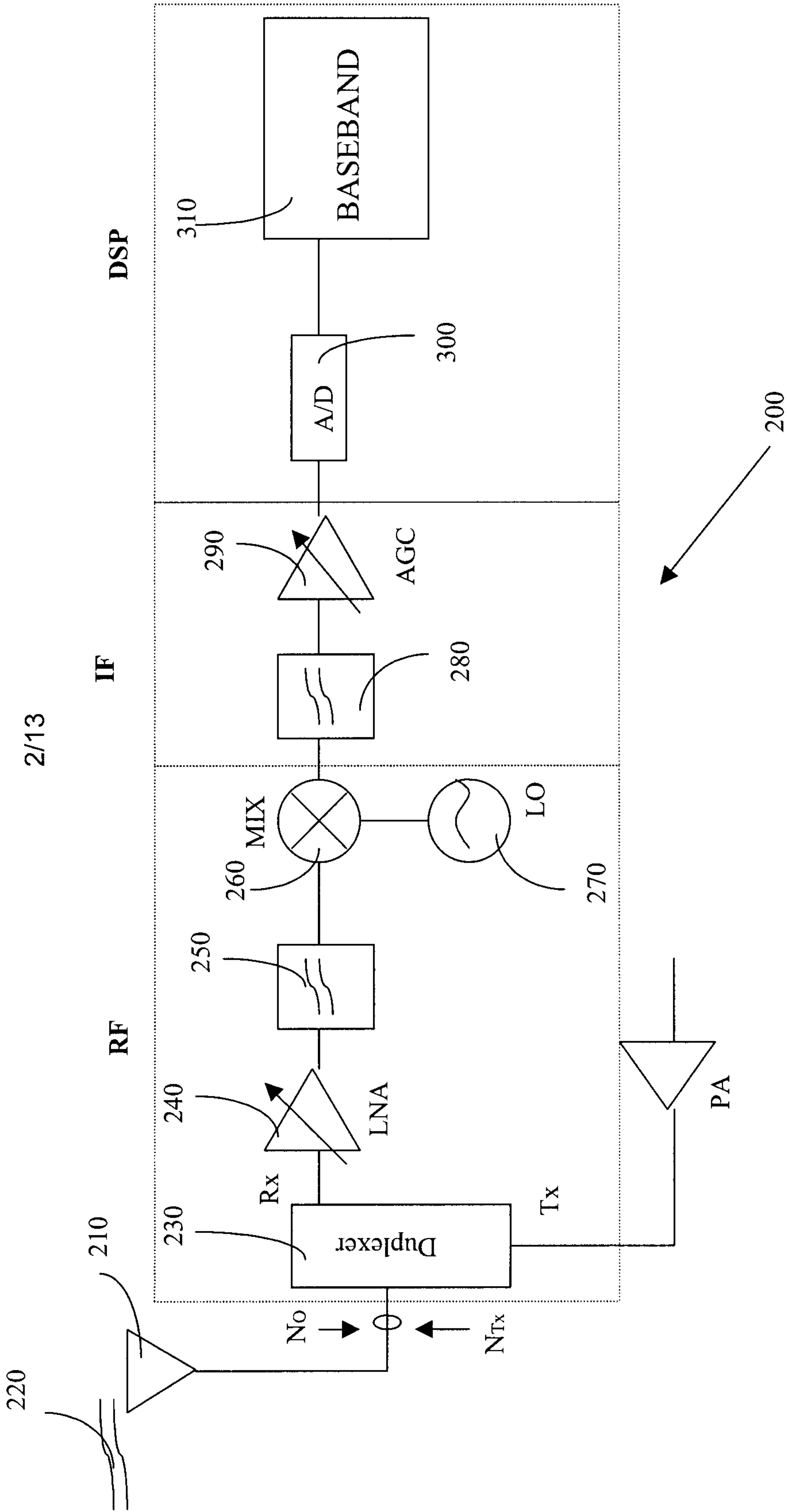


FIGURE 2 (PRIOR ART)

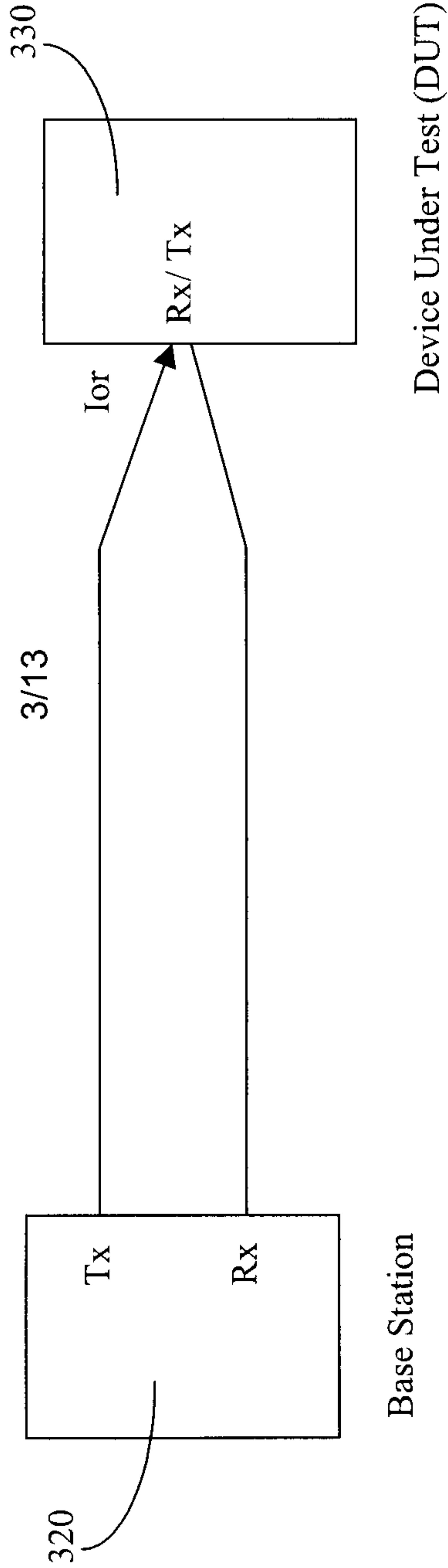
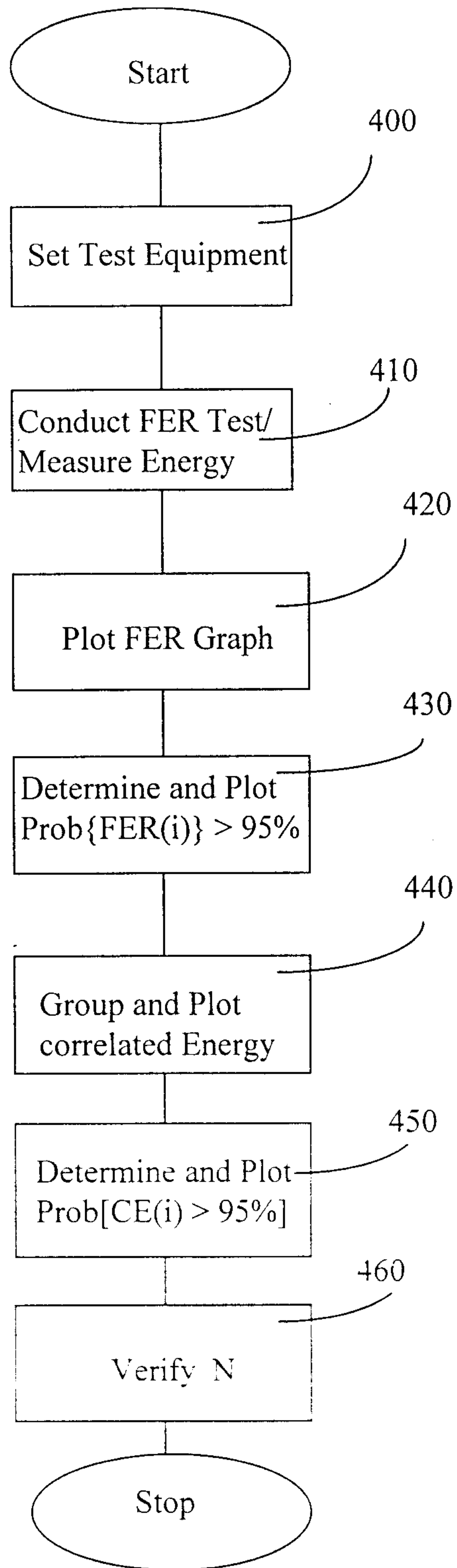


FIGURE 3A (PRIOR ART)

PARAMETER	UNITS	TEST 1	TEST 2
Ior	dBm/1.23 MHz	-104	-25
(Pilot Ec)/ Ior	dB	-7	
(Traffic Ec)/ Ior	dB	-15.6 (RC 1 and 3) -12.3 (RC 2) -20.6 (RC 7)	

FIGURE 3B (PRIOR ART)

**FIGURE 4**

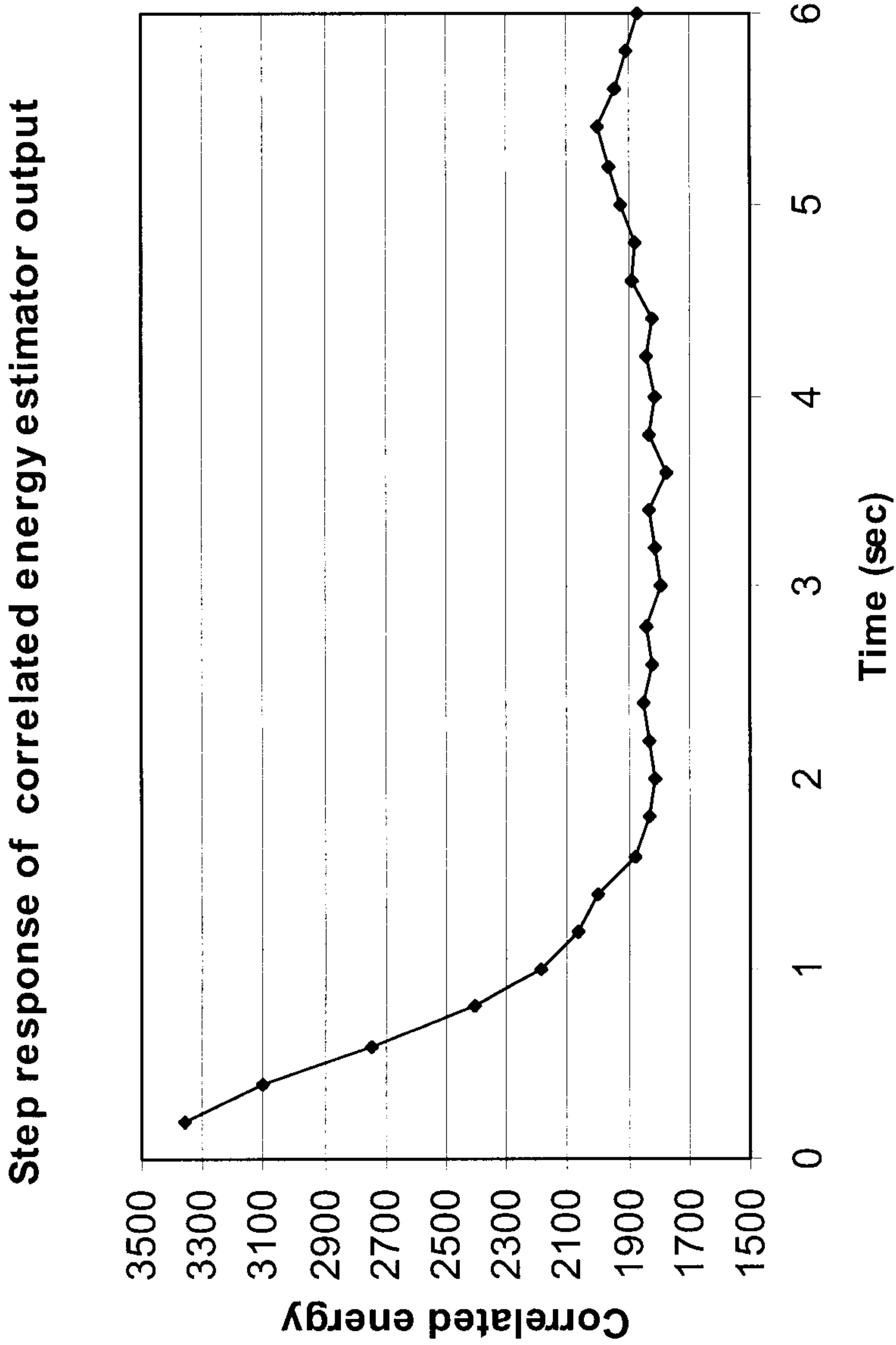


FIGURE 5

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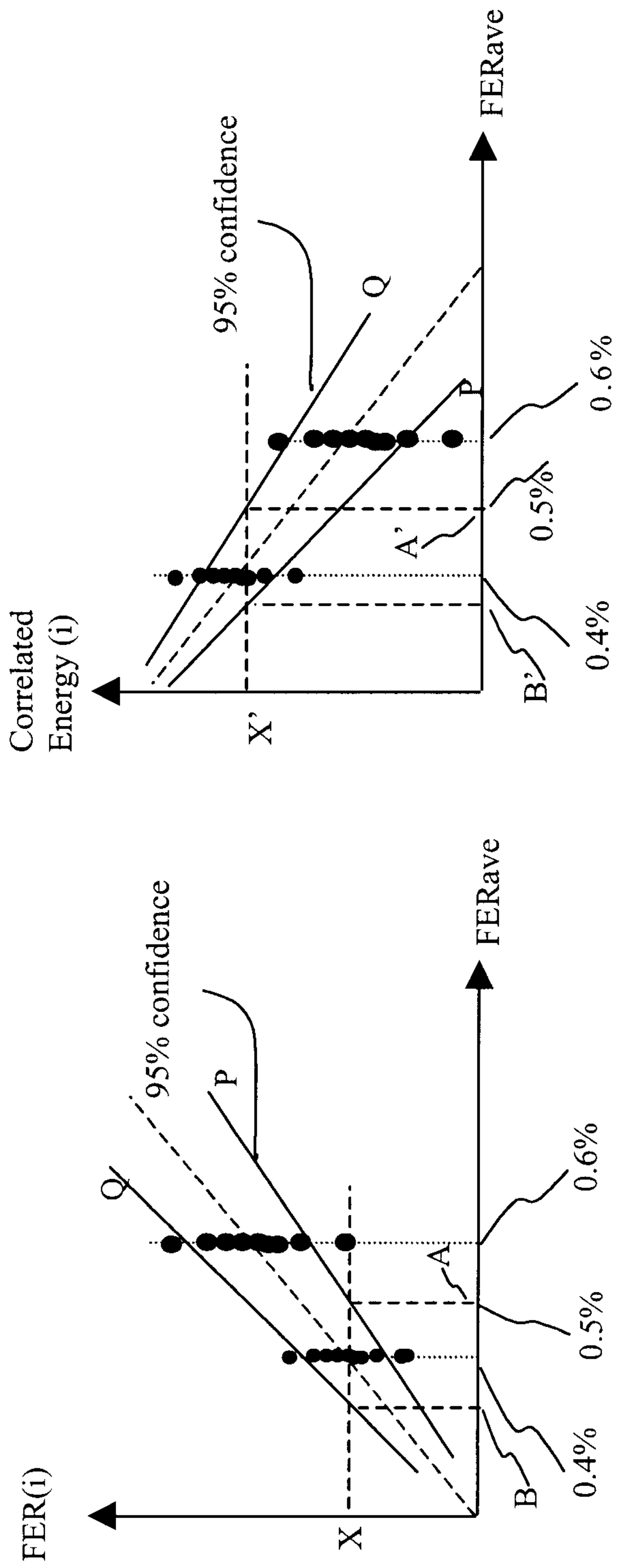


FIGURE 6A

FIGURE 6B

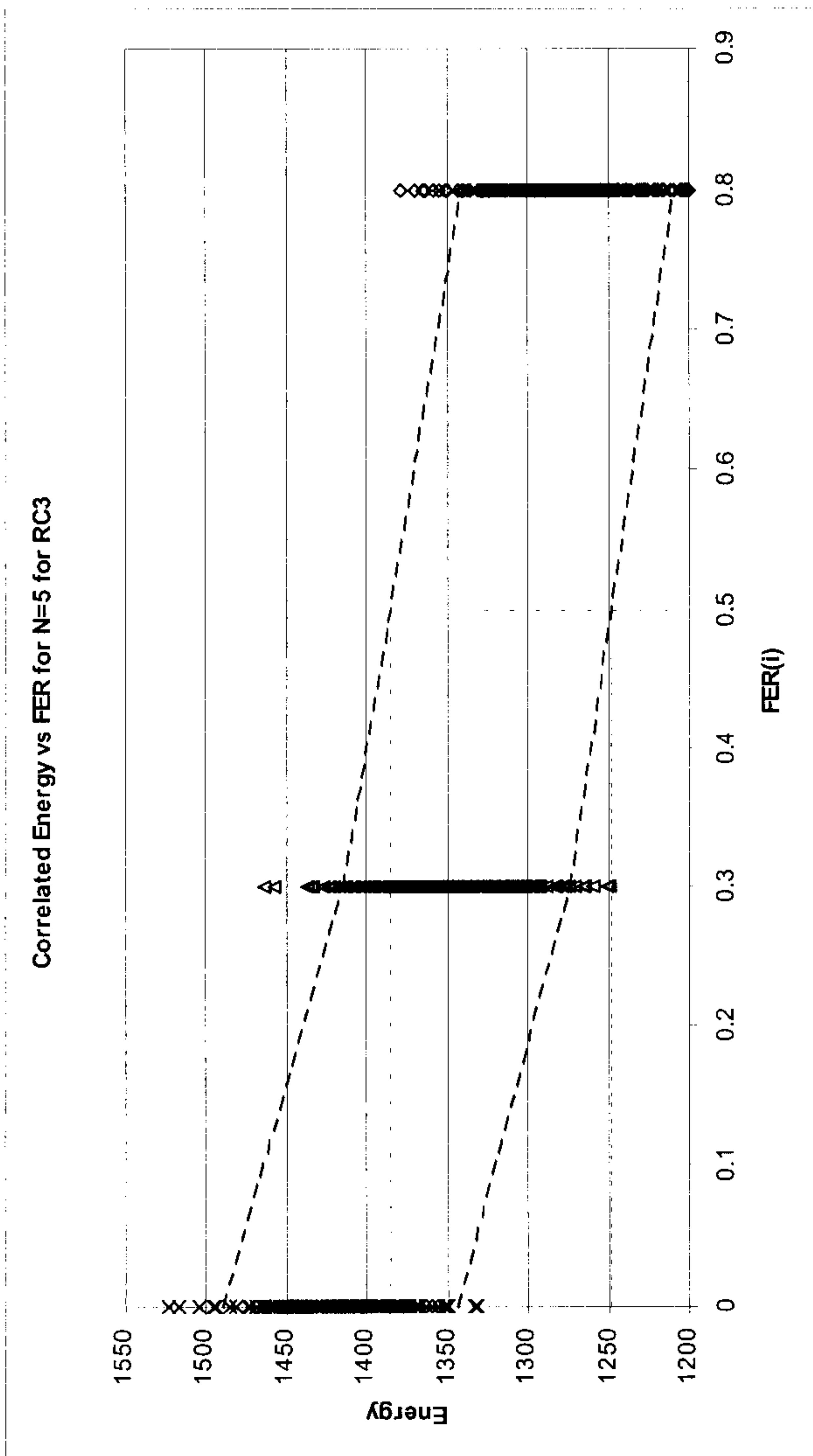


FIGURE 7A

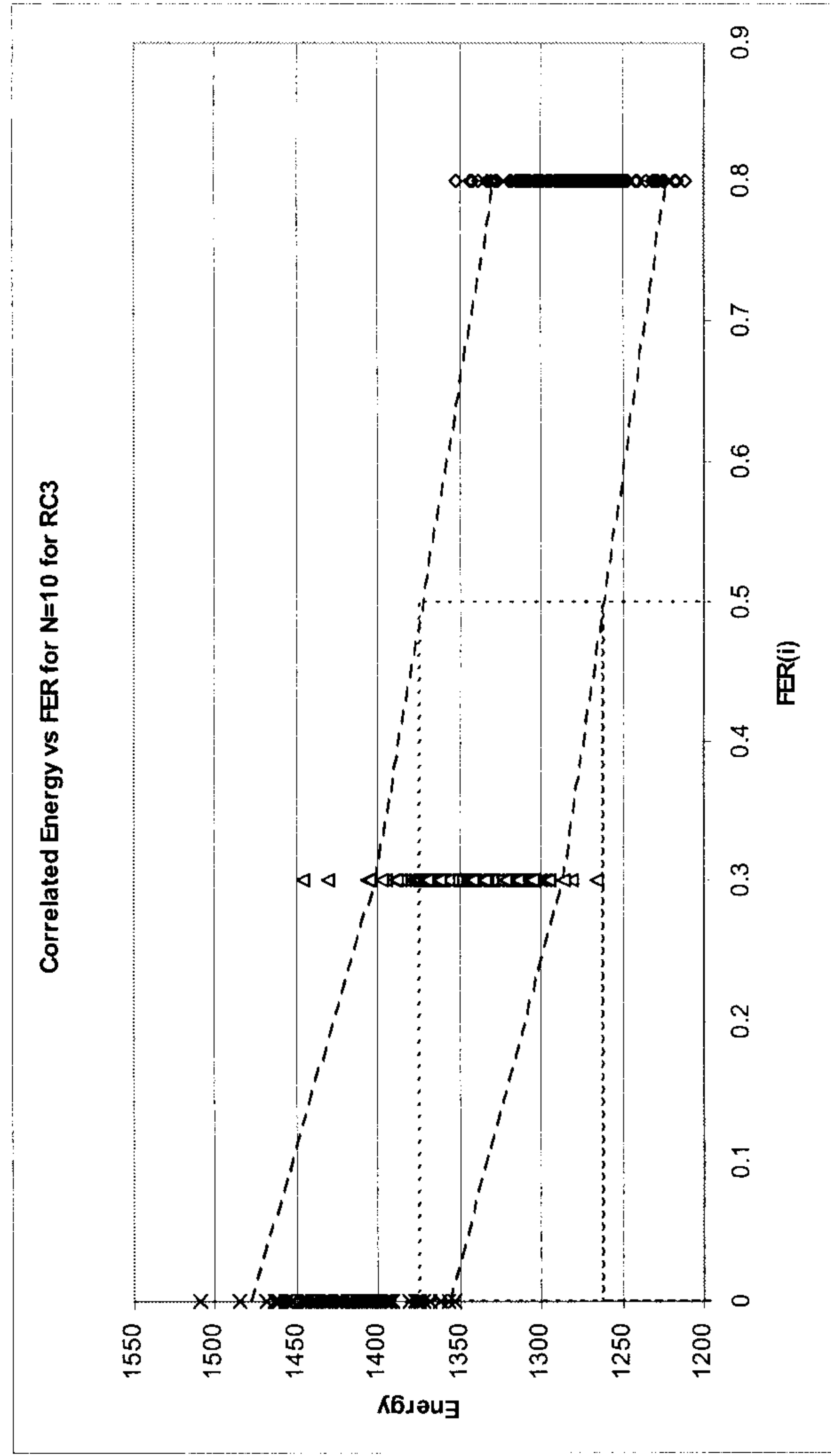


FIGURE 7B

Correlated Energy vs FER for N=20 for RC3

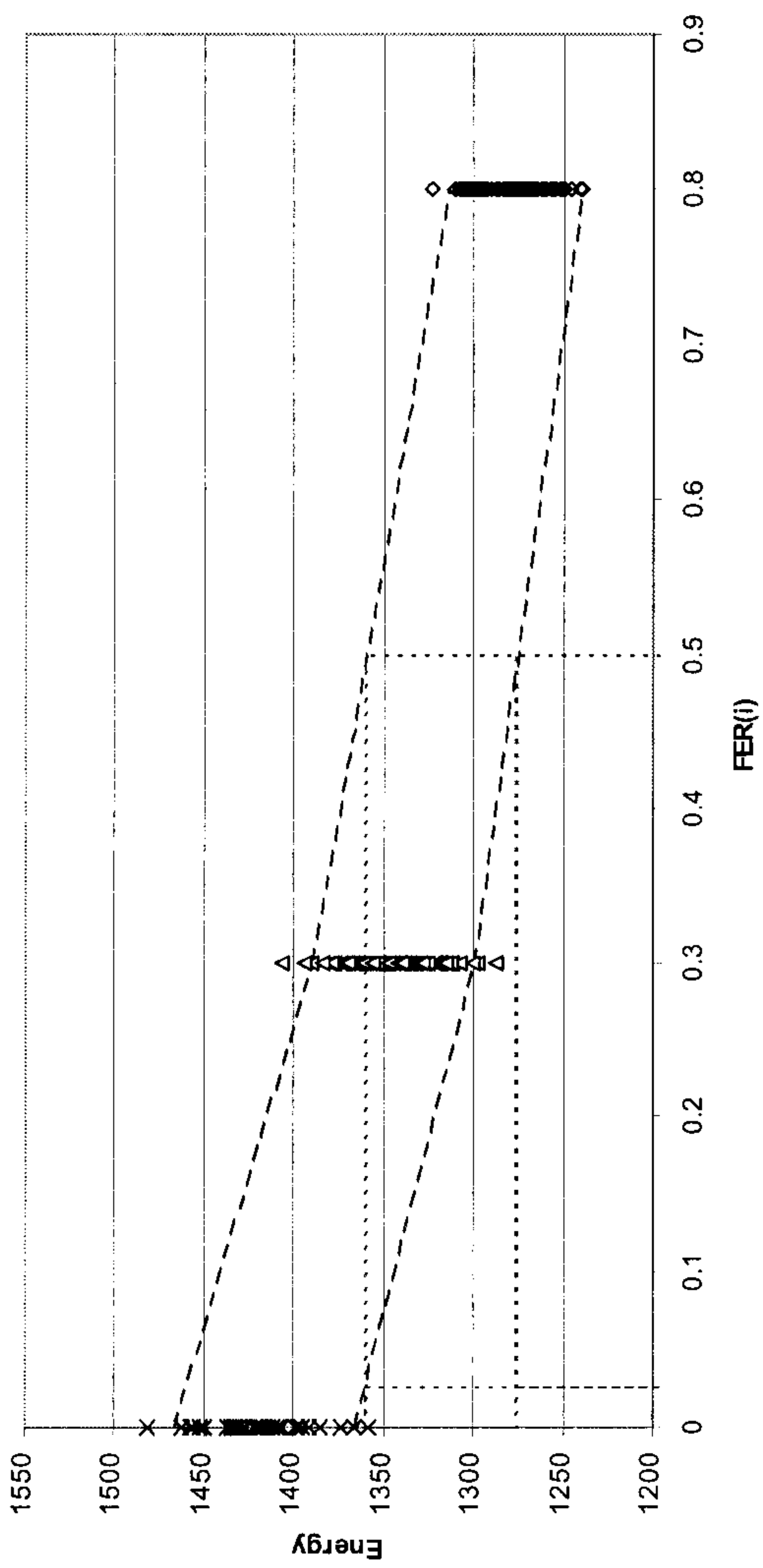


FIGURE 7C

Correlated Energy vs FER for N=40 for RC3

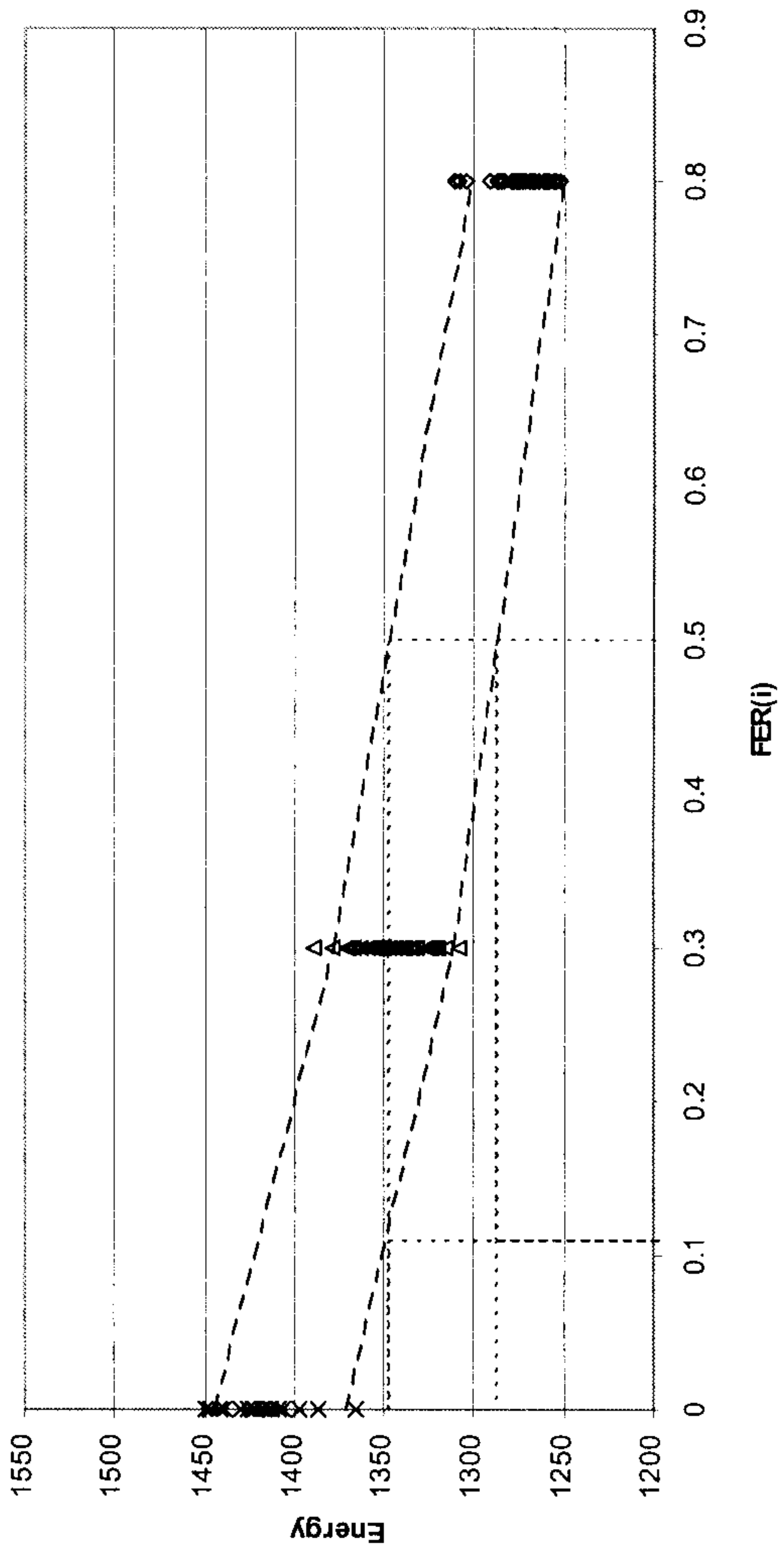


FIGURE 7D

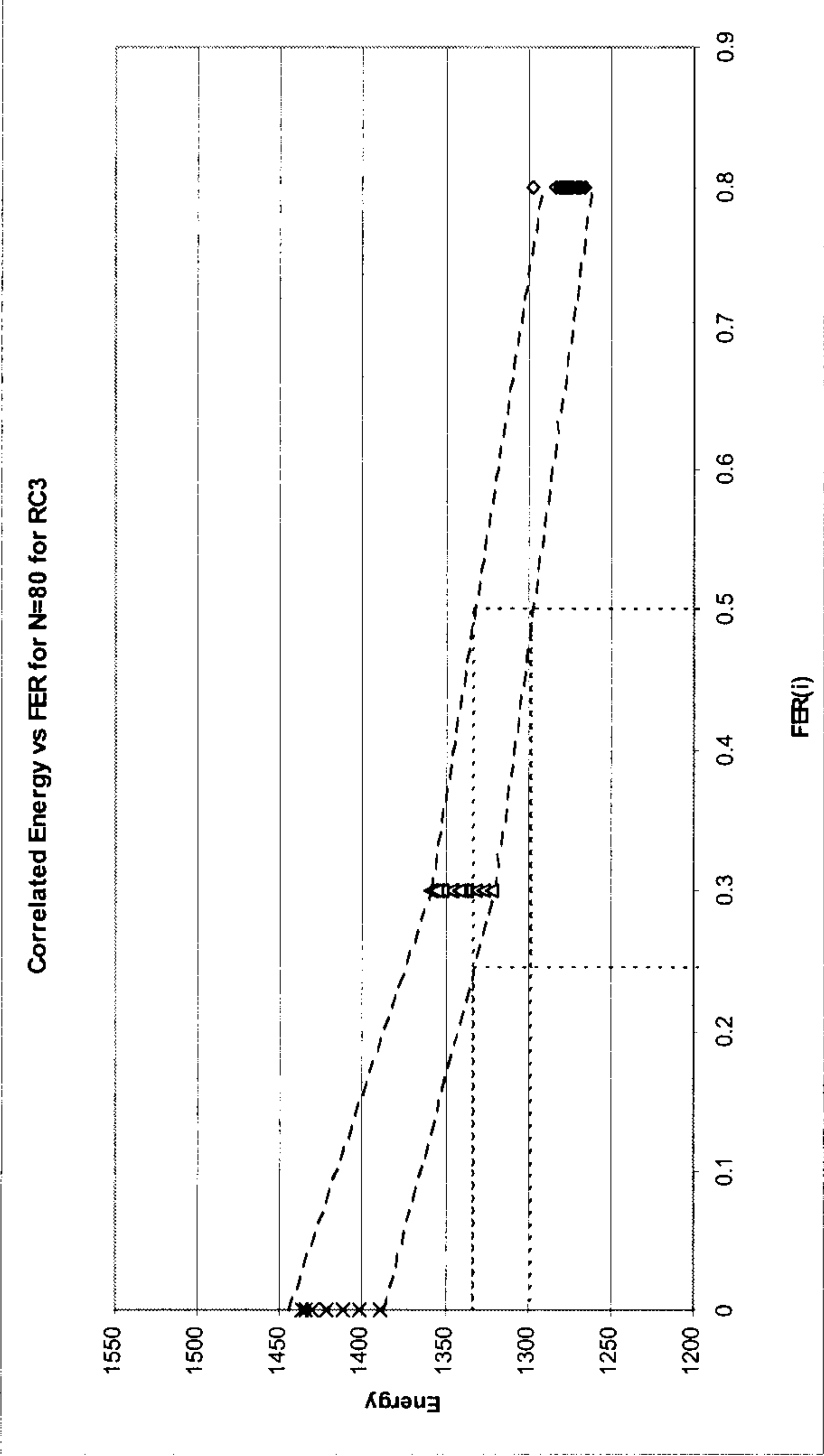
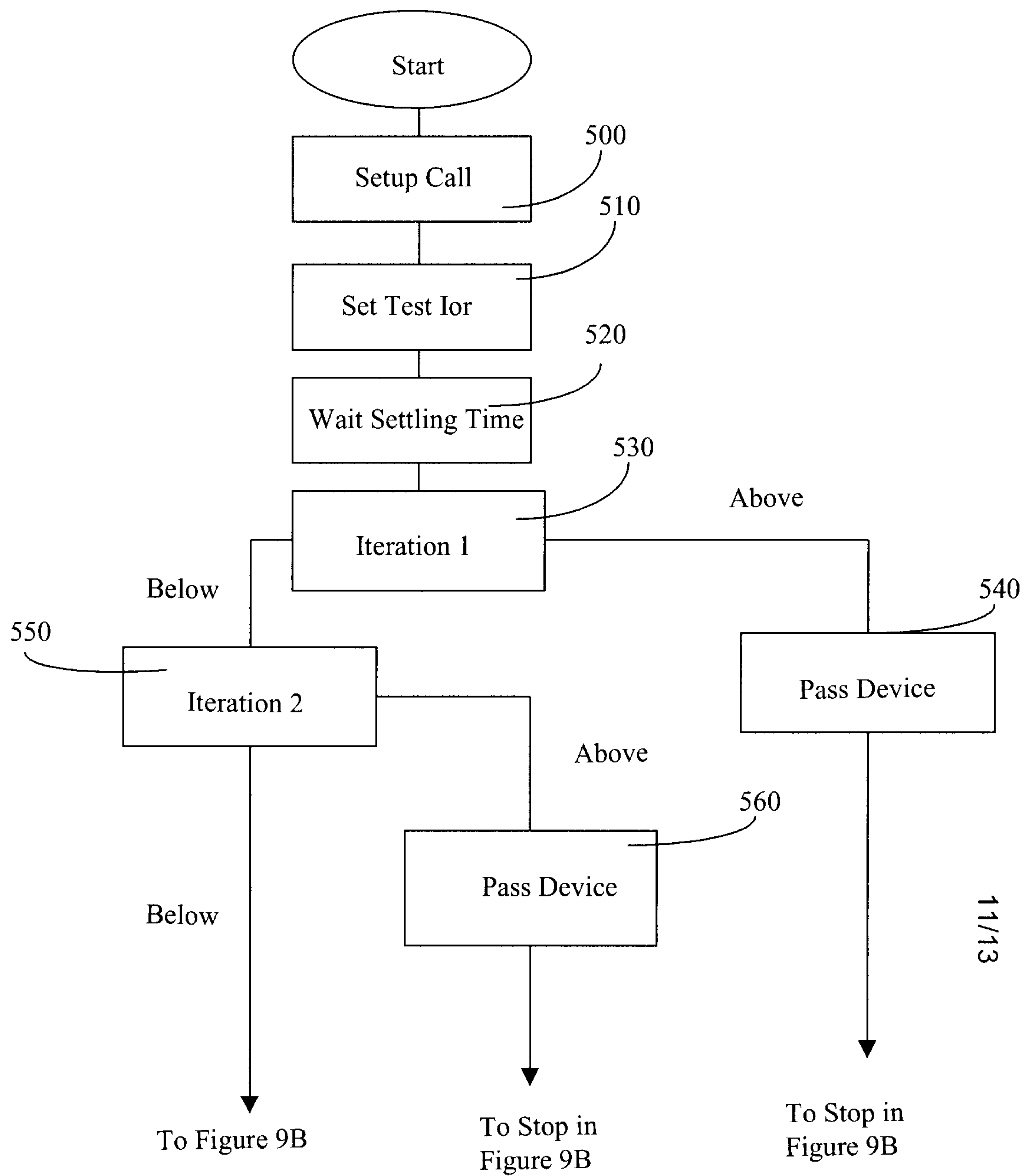


FIGURE 7E

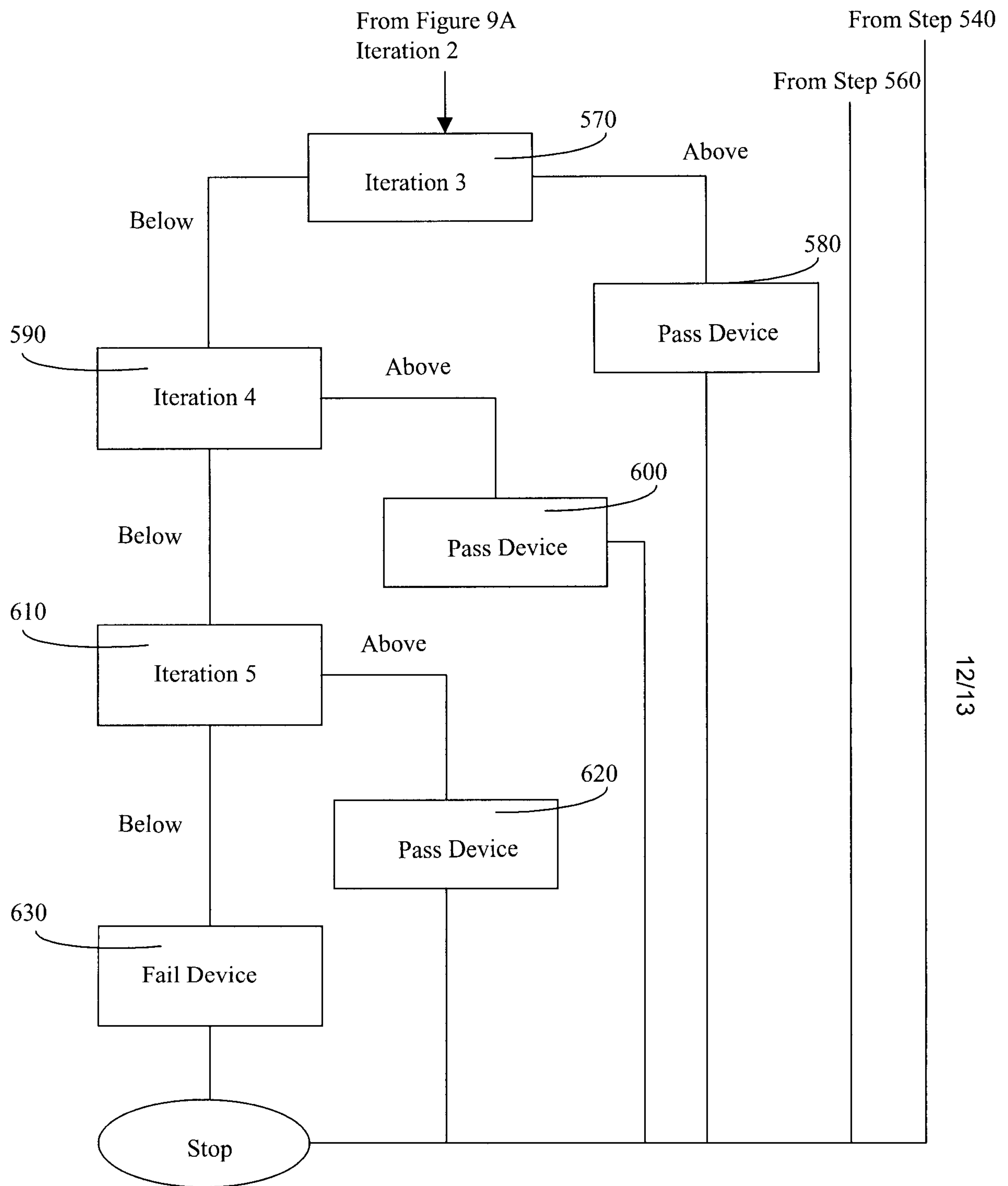
Iteration	Samples taken	Total number of Energy Readings	Incremental test time	Total Test Time (including settling time)	Pass Criterion
0	-	-	1.5 sec (energy settling time)	1.5 sec	-
1	N_1	N_1	1	2.5 sec	$E_{ave} \geq 1385$
2	N_1	$2N_1$	1	3.5 sec	$E_{ave} \geq 1375$
3	$2N_1$	$4N_1$	2	5.5 sec	$E_{ave} \geq 1360$
4	$4N_1$	$8N_1$	4	9.5 sec	$E_{ave} \geq 1348$
5	$8N_1$	$16N_1$	8	17.5 sec	$E_{ave} \geq 1333$

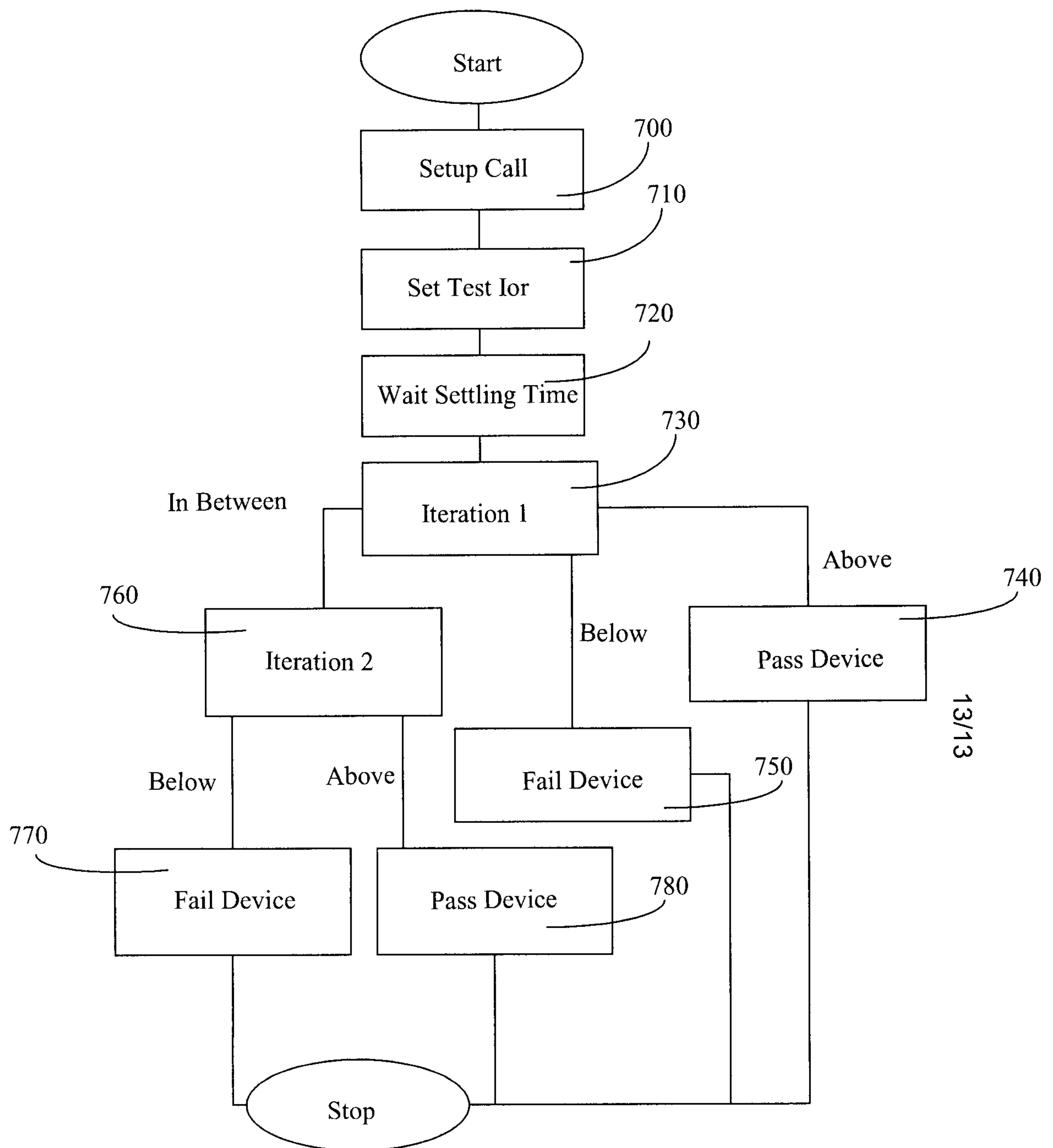
FIGURE 8



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FIGURE 9A

**FIGURE 9B**

**FIGURE 10**

