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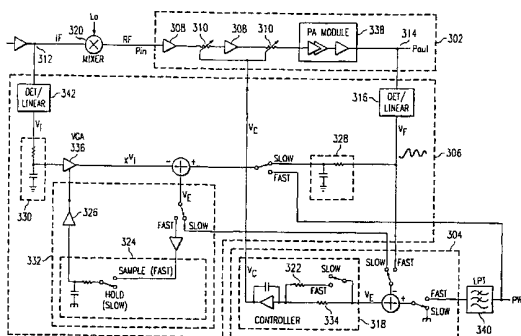
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- (54) Title: POWER CONTROL FOR NON-CONSTANT ENVELOPE MODULATION

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(54) Title: POWER CONTROL FOR NON-CONSTANT ENVELOPE MODULATION



(57) Abstract: A system and a method for handling power ramping and AM in wireless transmissions using NCE modulation schemes. A closed loop power control loop (304) with two modes is used for the power ramping and AM burst portions of a wireless transmission. During key-up (ramping) no AM transmission takes place. The power control loop (304) is in a conventional normal mode of operation during key-up, that is, it acts as a conventional power loop. Normal operation mode for the power control loop (304) is in a fast (high speed) closed loop. During ramping, the variable gain amplifier (or VGA) (336) of the AM Control Loop (306) is adjusted such that the baseband signal level matches the reference voltage used for ramping. Thus, prior to an AM burst transmission, the sampled IF voltage, xV , is made equal to the sampled output voltage of the power amplifier (302). When ramping up is complete and AM begins, the control voltage to the VGA (336) of the AM Control Loop (306) is held constant for the duration of the AM burst. During AM, the power control loop (304) is set to a slow control loop mode. Control of the power control loop (304) is achieved by comparing the power amplifier detector output with the calibrated baseband signal converted from IF.



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Power Control for
Non-Constant Envelope Modulation

Field of the Invention

5 This invention relates to power control of pulsed transmitters, more particularly, to power control in non-constant envelope modulation where amplitude modulation (AM) is also required.

Background of the Invention

10 One function of a power control loop in wireless applications is to control transient responses when ramping (keying) up or down. Another function of a power control loop is to control and maintain output power at a desired level. Minimizing transients and controlling loop speed are both important in the design of a power control loop for Time Division Multiple Access (or TDMA) type systems.

15 In a TDMA signaling format, a framed structure comprises a number of time slots (or channels). A wireless communications system using TDMA, for example, a Group Special Mobile (or GSM) system, transmits and receives information over each assigned slot or channel. Each channel of a frame is assigned to a different user with transmission (uplink) information on one frequency band and reception (downlink) information on a
20 separate frequency band communicated over each channel.

 Each channel is specified to ramp up to a required power level for burst transmissions and ramp down to a required power level in a predetermined amount of time. GSM specifications also require that the power at the start and end of a burst must be at a specified minimum level and that the transition from the minimum power level to
25 the final required power level must be completed in a specified time window. The time frame for ramping up and down is specified in order to reduce the generation of transient side bands and interference on adjacent channels.

 Figure 1 depicts a block diagram of a power control loop currently in use. A variable attenuator 102 controls the input of a power amplifier chain 104. The input to the
30 variable attenuator 102 is a modulated transmission signal, P_{in} . The output, P_{out} , of the power amplifier chain 104 is connected to an antenna for transmission. A control voltage, V_c , is applied to the variable attenuator 102 to control the attenuation of P_{in} . The control voltage, V_c , is adjusted to allow the power control loop to maintain required power levels (according to the wireless protocol specification) when ramping and during transmission
35 bursts.

The operation of the power control loop is divided into an open loop mode and a closed loop mode. The power control loop will run in open loop mode until the output of the power amplifier has reached a predetermined level, referred to as the switching point. At the switching point, a directional coupler 106 samples a portion of the output, P_{out} . The directional coupler 106 is connected to a linear detector 108. An error signal, V_e , is produced using the difference of a supplied reference signal, V_r , which is proportional to the required rate of ramping defined by the particular wireless specification being used and the output of the detector 108, V_f . An integrator 110 is used to produce the control voltage, V_c . The control voltage, V_c , is used to control the variable attenuator 102. The input to the variable attenuator 102 is used as a means to control power levels when ramping and during transmission bursts.

Figure 4A depicts a graph of the power output of a power amplifier controlled by a conventional power control loop. During key up, section A, the power output rises to the appropriate level. During transmission, section B, the power output is held steady by the power control loop. During key down, section C, the power output falls.

In $3\pi/8$ rotated 8-PSK, an example of a non-constant envelope (or "NCE") modulation scheme, a 3-bit quantized waveform, representing source data, is used as the argument of a complex exponential to generate a basic (non-rotated) PSK signal. This signal is then complex-multiplied by a $3\pi/8$ rotation per symbol term. The resulting modulating 8-PSK symbols excite a linear pulse shaping filter, such as a linearized Gaussian, Blackman, or other type of shaping filter. Thus the signal is both amplitude and phase modulated. Unlike phase modulation, $3\pi/8$ rotated 8-PSK and other forms of this type of modulation create an envelope that is not constant.

A disadvantage of conventional power control loops, when considering implementation of a NCE modulation system, is illustrated in Figure 4B. Figure 4B depicts a graph of the power output of a power amplifier transmitting an AM burst. As in Figure 4A, during key up, section A, the power output rises to the appropriate level. However, during transmission, section B, the power output fluctuates according to the amplitude of the signal being transmitted. During key down, section C, the power output falls. A conventional power controller would tend to level out the variations in power due to the AM burst. Such a situation is unacceptable for advanced wireless transmissions using AM. A known solution allowing a conventional power control loop to be used with amplitude modulation transmissions is to add a sample and hold circuit to the power control loop. Power levels are sampled during ramping and the level is held steady during an AM burst. However, Figure 4B illustrates a disadvantage of this approach when applied to advanced modulation schemes, such as NCE modulation schemes like $3\pi/8$ rotated 8-PSK, known

as gain tilt. Gain tilt can occur during a transmission burst. Figure 4B depicts the gain tilt effect, showing the expected gain level at the end of the burst and the actual gain level due to gain tilt at the end of a burst. The sample and hold circuitry of a conventional power controller works on an assumption that gain does not change during a burst and does not attempt to control gain tilt during the burst. This design can only be used if the transmission amplifier chain (txChain) is constant. Otherwise, a transient (or discontinuity) across the transmission spectrum results when the power control begins key down after the burst.

Additional general background, which helps to show the knowledge of those skilled in the art regarding the system context, and of variations and options for implementations, may be found in the following: Even-Or, Graphic Analysis of High speed NonLinear RF Leveling Loop, Microwave Journal pp. 67-80 (Dec. 1990); Keiser and Strange, Digital Telephony and Network Integration (1995); and Faulkenberry, An Introduction to Operational Amplifiers; both of which are hereby incorporated by reference.

Summary of the Invention

The disclosed embodiments of the present application provide a system and a method for handling power ramping and AM in wireless transmissions using NCE modulation schemes. A closed loop power control loop with two modes, differing in speed, is used for the power ramping and AM burst portions of a wireless transmission. During key-up (ramping) no AM transmission takes place. The power control loop is in a conventional normal mode of operation during key-up, that is, it acts as a conventional power loop. Normal operation mode for the power control loop is in a fast (high speed) closed loop. Also during ramping, the variable gain amplifier (or VGA) of the AM Control Loop is adjusted (either amplified or attenuated) such that the baseband signal level (converted from IF) matches the reference voltage used for ramping. Thus, prior to an AM burst transmission, the sampled IF voltage, xV_i is made equal to the sampled output voltage of the power amplifier. When ramping up is complete and AM begins, the control voltage to the VGA of the AM Control Loop is held constant for the duration of the AM burst (because the IF signal strength is steady at the burst). During AM, the power control loop is set to a slow control loop (slow speed) mode. Control of the power control loop in slow speed mode is achieved by the AM Control Loop comparing the power amplifier detector output with the calibrated baseband signal converted from IF. Thus, the AM burst is not flattened as would occur if a conventional power control loop were used. The power control loop returns to fast mode for key down.

The disclosed embodiments can provide several advantages. For example, the detector/linearizer does not require a wide dynamic range. The detector/linearizer in the disclosed embodiments is insensitive to the dynamic range of the detector/linearizer due to the use of the same low pass filters at the output of the baseband and V_f signals. This filter configuration also allows the disclosed embodiments to be insensitive to delay variations in the transmission chain. The closed loop design of the disclosed embodiments allows for correction of gain changes which will likely take place during the transmission time slot burst due to gain tilt.

Brief Description of the Drawings

The disclosed inventions will be described with reference to the accompanying drawings, which show important sample embodiments of the invention and which are incorporated in the specification hereof by reference, wherein:

Figure 1 depicts a block diagram of a power control loop currently in use.

Figure 2 depicts a block diagram of a base station that can make use of the disclosed embodiments.

Figure 3 depicts a block diagram of the presently preferred embodiment of the disclosed power control loop.

Figure 4A depicts a graph of the power output of a power amplifier controlled by a conventional power control loop.

Figure 4B depicts a graph of the power output of a power amplifier transmitting an AM burst.

Detailed Description of the Preferred Embodiments

The numerous innovative teachings of the present application will be described with particular reference to the presently preferred embodiment. However, it should be understood that this class of embodiments provides only a few examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do not necessarily delimit any of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others.

Figure 3 depicts a block diagram of the presently preferred embodiment of the disclosed power control loop for $3\pi/8$ rotated 8-PSK modulation. All AM on/off (slow/fast) switches are depicted in the on (slow) position. Three distinct sections 302, 304, and 306 comprising the transmitter of a base station are relevant to the disclosed embodiments. In the presently preferred embodiment, the power amplifier section 302 of a base station transmitter receives a radio frequency (RF) modulated transmission signal at Pin. The RF signal is an intermediate frequency (IF) transmission signal which has been

upconverted at a mixer, 320, to RF. An amplifier chain 308 with a power amplifier module 338 amplifies the signal from Pin. Two PIN diode attenuators 310 are connected between the amplifiers of the amplifier chain 308 to control the power output, Pout, of the power amplifier section 302. The output, Pout, of the power amplifier section 302 can be connected to an antenna for transmission. The PIN diode attenuators 310 are controlled by the output voltage, V_c , of the power control loop 304.

The power control loop 304 of the transmitter operates in two modes, a fast/high-speed mode (AM off) and a slow/low-speed mode (AM on). The power control loop 304 is in fast mode when AM is off. The fast mode of the dual mode power control loop allows the power control loop to quickly key-up prior to transmission of an AM burst.

In fast mode, the power control loop 304 acts as a conventional power control loop. The controller 318 of the power control loop 304 receives as input a voltage error signal, V_e , indicating the difference between a reference voltage, PWC, and V_f , the sampled voltage of Pout. The PWC is usually generated by an application specific integrated circuit (or ASIC). The waveform of the reference signal, PWC, during ramping is selected so that the switching transient spectrum is minimized. The waveform could be, for example, raise cosine, Blackman window, or any other desired waveform. For example, in the presently preferred embodiment, the voltage waveform of PWC is chosen to meet GSM specifications. The reference voltage, PWC, is passed through a low-pass filter, 340, to smooth the digital step signal for use in the power control loop 304. The delay which occurs between the ASIC reference signal peak and the key up of the power amplifier section 302 is used to allow the AM Control Loop 306 to settle, align the levels of V_i and V_f , prior to the AM transmission burst. The output voltage, V_f , is derived from a directional coupler 314 that samples the output power of the power amplifier 302. A detector/linearizer 316 converts the sample into voltage. Generally, the detector of the detector/linearizer 316 is designed using a detector diode. The output of the power amplifier, V_f , should follow the reference voltage, PWC. The power control loop 302 forces the power amplifier voltage to follow the reference voltage, PWC, so that they are substantially equal after ramping up (setting the power level). Ideally, the voltage error signal, V_e , should be 0. In the presently preferred embodiment, the controller 318 contains a resistor ladder with two resistors 334 and 322. In fast mode, both resistors 334 and 322 are connected in parallel. The controller 318 acts as an integrator for the voltage error signal, V_e . The output of the controller 318 is a control voltage, V_c . The control voltage V_c is used to control the PIN diode attenuators 310 and thus, the gain of the power amplifier section 302.

The power control loop 304 is in slow mode when AM is on. The slow mode of the dual mode power control loop allows the output power to remain at the desired power level (the power level just after ramp up) during the transmission of an AM burst. The slower mode of the power control loop also serves to eliminate transients which can, and usually do, occur after an AM burst due to changes in required power. In slow mode, the reference voltage is tied to ground (Gnd) instead of the reference voltage, PWC. The voltage error signal, V_e , is generated by the AM Control Loop 306. The voltage error signal, V_e , is the difference between the output signal, xV_i , of a variable gain amplifier 336 and output voltage, V_f . In the slow mode, only one resistor 334 of the controller 318 is used for integration of the voltage error signal, V_e .

The AM Control Loop 306 of the transmitter operates in two modes, AM off and AM on. In the presently preferred embodiment, when AM is off, the power control loop 304 is in fast mode. A voltage reference is derived from a directional coupler 312 that samples the baseband IF transmission signal. A detector/linearizer 342 of the same design as detector/linearizer 316 converts the sample into voltage. The voltage converted IF is passed through a low-pass filter 330 to smooth the sampled voltage output of the detector/linearizer 342. The VGA 336 of the AM control loop 306 receives the smoothed IF voltage sample as input. The gain controller 332 for the variable gain amplifier 336 uses the output of the VGA 336 to produce a control signal for the variable gain amplifier 336. With AM off, the error signal, V_e , is the difference between the VGA 336 output, xV_i and the unfiltered reference voltage, PWC. The error signal, V_e , is used by the gain controller 332 to produce the control signal for the VGA 336.

During fast mode, the power amplifier section is keying up, using PWC as a reference voltage, and the VGA 336 output, xV_i , is adjusted to amplify or attenuate the IF voltage level, V_i , to match PWC. The output of the VGA 336 is therefore said to have the same level as the reference voltage, PWC. In the presently preferred embodiment, the gain controller 332 samples V_e . The sampled signal is passed through a low-pass filter 324. An operational amplifier 326 is connected to receive the output of the low-pass filter 324. The output of the operational amplifier 326 is used as the gain control signal for the variable gain amplifier 336. A high-impedance buffer 344 is used to hold the voltage after xV_i and the reference voltage, PWC are substantially equal. Ideally, the impedance during a hold should be infinity to prevent loss of charge during the AM burst.

In the presently preferred embodiment, when AM is on, the power control loop 304 is controlled by the AM Control Loop 306. The AM Control Loop 306 places the power control loop 304 in slow mode. When AM is on, the error signal, V_e , of the AM Control

Loop 306 is calculated as the difference between the variable gain amplifier 336 output, xV_i and the output of the detector/linearizer 316, V_f , passed through a low-pass filter 328. Thus the power amplifier output, V_f , is controlled throughout the AM transmission burst. Without controlling the power amplifier output, V_f , a ripple in output could occur due to mismatched power levels. The low pass filters 328 and 330 are matched, allowing power control to be insensitive to the dynamic range of the detector/linearizers 316 and 342 and any delay and/or phase variations. This insensitivity results from the delay of the low pass filters 316 and 342 being longer than that of the power amplifier section 302. The modulation range of the AM burst can be 17db on top of a power level of 30db. Without the low pass filters 328 and 330, the dynamic range of the detector/linearizers 316 and 342 would need to be 47db. The low pass filters 328 and 330 smooth out the power level such that the detector/linearizers 316 and 342 do not require a wide dynamic range.

With AM on, the gain controller maintains the gain control of variable gain amplifier 336. That is, the gain control forces the VGA 336 to maintain the last level matching the reference voltage, PWC. Holding the gain of the VGA 336 at the last level of the baseband IF allows the gain level to be maintained despite gain tilt. While the IF level remains constant, the level of the output voltage, V_f , changes with the output power of the power amplifier section 302. The error signal, V_e , is used as input to the power control loop 304 to control the loop in slow mode. The control loop is used to attenuate or amplify the controlled IF voltage signal, xV_i before the comparison to ensure that the controlled IF voltage signal, xV_i and the power amplifier output voltage levels are the same.

System Context

Figure 2 depicts a block diagram of a part of a wireless communications base station 200 that can make use of the disclosed embodiments. The base station 200 receives transmission bursts via the air interfaces 210 which are filtered in an input filter 212. A transceiver 218 provides a high frequency receiver 220 and a high frequency transmitter 260. The signal from the input filter 212 is processed by the high frequency receiver 220 and then processed by digital signal processors in a transmitter/receiver module 230. The transceiver/receiver module 230 consists of a low frequency part for digital signal processing and a high frequency part for modulation and demodulation. These process signals are then provided to the Abis interface 240 via a transmission system 250. Signals from the Abis interface 240 are received at the transmission system 250 and then forwarded to the transmitter/receiver module 230. The signals are then processed and provided to the high frequency transmitter 260, filtered by the output filter 270 and sent out over the air interface 210. An operations and maintenance module 280

may be provided to administer the functionality of the base transceiver system and to provide clock distribution. The disclosed embodiments are generally incorporated in the high frequency transmitter 260.

5 Modifications and Variations

As will be recognized by those skilled in the art, the innovative concepts described in the present application can be modified and varied over a tremendous range of applications, and accordingly the scope of patented subject matter is not limited by any of the specific exemplary teachings given.

10 For example, the voltage control signal used to control the output of the power amplifier section 302 is described as controlling PIN diodes in the power amplifier section. However, power amplifier sections can be designed such that the control signal can directly control an amplifier, for example, a variable gain amplifier, or control the amplification in another way, for example, digital or analog input to a digital signal
15 processor (DSP).

For another example, the disclosed power control loop has been described in the context of $3\pi/8$ rotated 8-PSK modulation. However, the disclosed innovations can be used with other implementations of NCE modulation and other forms of modulated communication requiring power control. For example, other forms of amplitude modulation
20 communications may be able to make use of the disclosed innovations with slight or no modifications.

For another example, the disclosed power control loop can be implemented by a digital signal processor or in an application specific integrated circuit package.

9
Claims

What is claimed is:

- 1 1. A method of controlling power in non-constant envelope modulation,
2 comprising the steps of:
3 ramping up a power amplifier using a power control loop in a first mode;
4 emitting a modulated transmission while said power control loop is operated in a
5 second mode;
6 wherein the power output of said power amplifier is held steady during said emitting
7 step.

- 1 2. The method of Claim 1, wherein said power output exhibits reduced
2 transient response.

- 1 3. The method of Claim 1, wherein said first mode is a fast control loop.

- 1 4. The method of Claim 1, wherein said second mode is a slow control loop.

- 1 5. The method of Claim 1, wherein said second mode is controlled by an AM
2 Control Loop.

- 1 6. The method of Claim 1, wherein said modulated transmission is modulated
2 according to a non-constant envelope scheme.

- 1 7. The method of Claim 1, wherein said modulated transmission is a $3\pi/8$
2 rotated 8-PSK modulated transmission.

- 1 8. The method of Claim 1, wherein said modulated transmission is at least
2 amplitude modulated.

- 1 9. The method of Claim 1, wherein said modulated transmission is amplitude
2 and phase modulated.

1 10. The method of Claim 1, wherein said second mode is provided by
2 comparing a calibrated baseband signal to a voltage representing power amplifier
3 output.

1 11. The method of Claim 1, wherein said power control loop is a closed loop.

1 12. A method of controlling power in non-constant envelope modulation,
2 comprising the steps of:
3 operating a power control loop in a fast loop speed;
4 controlling the ramp up of a power amplifier with said power control loop in said fast
5 loop speed;
6 operating said power control loop in a slow loop speed; and
7 emitting a modulated transmission while said power control loop is operated in said
8 slow loop speed;
9 wherein control of said slow control loop is provided by comparing a baseband level
10 signal to a power output level signal.

1 13. The method of Claim 12 wherein said power control loop is a closed loop.

1 14. The method of Claim 12 wherein said slow loop speed is controlled by an
2 AM Control Loop.

1 15. The method of Claim 12 wherein said modulated is modulated according to
2 a non-constant envelope scheme.

1 16. The method of Claim 12 wherein said modulated transmission is a $3\pi/8$
2 rotated 8-PSK modulated transmission.

1 17. The method of Claim 12 wherein said modulated transmission is amplitude
2 and phase modulated.

1 18. The method of Claim 12, wherein said baseband level signal is obtained
2 during said controlling step using a variable gain amplifier and a feedback loop.

- 1 19. A power control loop non-constant envelope modulation, comprising:
2 a power control loop with at least two modes;
3 a power amplifier controlled by said power control loop; and
4 a modulation control loop controlling a mode of said power control loop;
5 wherein said power control loop is in a first mode during ramping and a second
6 mode during modulation transmission and the power output of said power
7 amplifier during said modulated transmission is held steady.
- 1 20. The power control loop of Claim 19, wherein said first mode is a fast control
2 loop.
- 1 21. The power control loop of Claim 19, wherein said modulation control loop is
2 an amplitude modulation control loop.
- 1 22. The power control loop of Claim 19, wherein said second mode is a slow
2 control loop.
- 1 23. The power control loop of Claim 19, wherein the power output of said power
2 amplifier exhibits reduced transient response.
- 1 24. The power control loop of Claim 19, wherein said second mode is controlled
2 by said modulation control loop.
- 1 25. The power control loop of Claim 19, wherein said modulated transmission is
2 modulated according to a non-constant envelope scheme.
- 1 26. The power control loop of Claim 19, wherein said modulated transmission is
2 a $3\pi/8$ rotated 8-PSK modulated transmission.
- 1 27. The power control loop of Claim 19, wherein said modulated transmission is
2 at least an amplitude modulated transmission.
- 1 28. The power control loop of Claim 19, wherein said modulated transmission is
2 a phase and amplitude modulated transmission.

1 29. The power control loop of Claim 19, wherein control of said second mode is
2 provided by comparing a baseband signal to a voltage representing power amplifier
3 output.

1 30. The power control loop of Claim 19, wherein said power control loop
2 operates in a closed loop.

1 31. A wireless communications base station, comprising:
2 a transceiver configured to emit and receive signals;
3 wherein a power amplifier of said transceiver is ramped using a power control loop
4 in a first mode and a modulated transmission is emitted while said power
5 control loop is operated in a second mode and the power output of said
6 power amplifier is held steady.

1 32. The wireless communications base station of Claim 31, wherein said first
2 mode is a fast control loop.

1 33. The wireless communications base station of Claim 31, wherein said
2 second mode is a slow control loop.

1 34. The wireless communications base station of Claim 31, wherein said
2 second mode is controlled by an AM Control Loop.

1 35. The wireless communications base station of Claim 31, wherein said
2 modulated transmission is modulated according to a non-constant envelope scheme.

1 36. The wireless communications base station of Claim 31, wherein said
2 modulated transmission is a $3\pi/8$ rotated 8-PSK modulated transmission.

1 37. The wireless communications base station of Claim 31, wherein said
2 modulated transmission is at least an amplitude modulated transmission.

1 38. The wireless communications base station of Claim 31, wherein said
2 modulated transmission is a phase and amplitude modulated transmission.

1 39. The wireless communications base station of Claim 31, wherein control of
2 said second mode is provided by comparing a baseband signal to a voltage
3 representing power amplifier output.

1 40. The wireless communications base station of Claim 31, wherein said power
2 control loop operates in a closed loop.

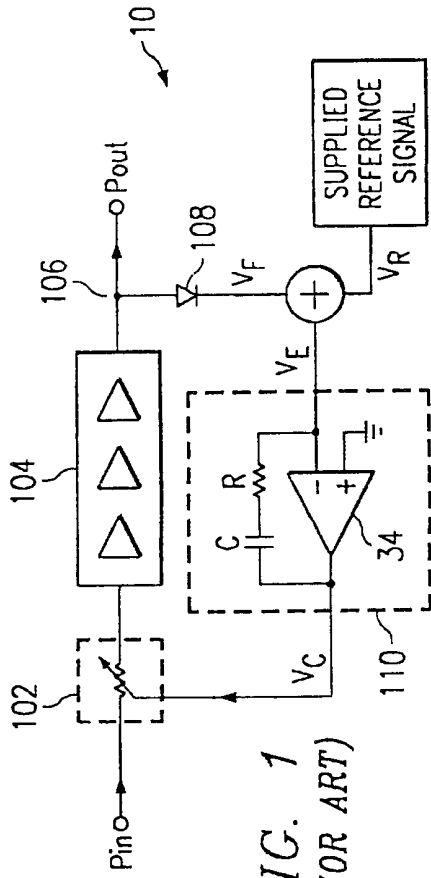


FIG. 1
(PRIOR ART)

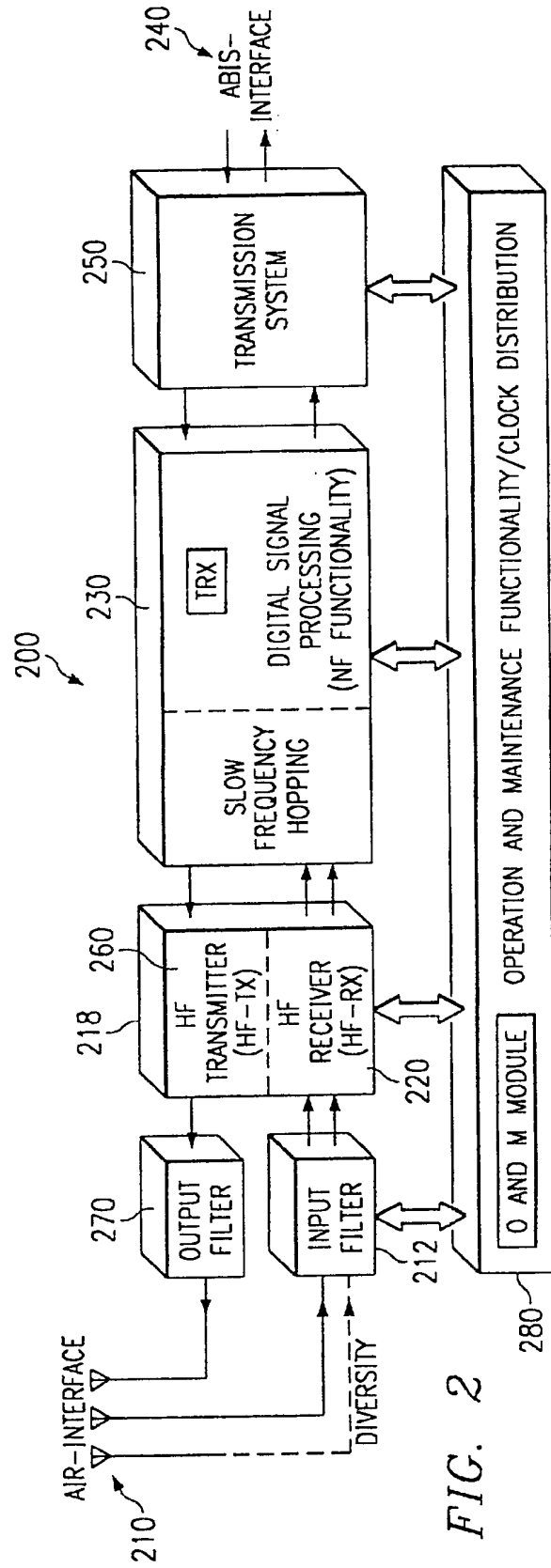


FIG. 2

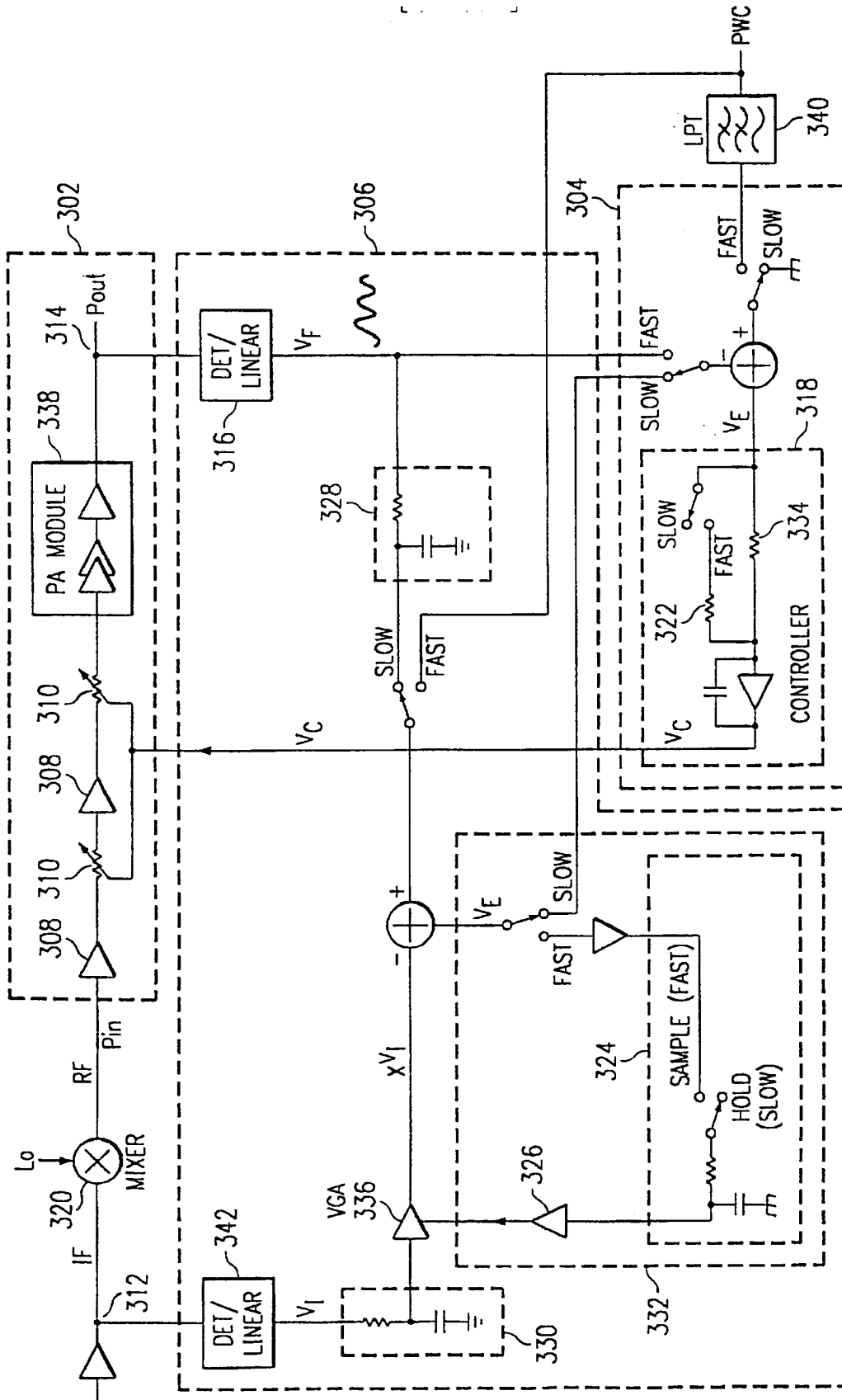


FIG. 3

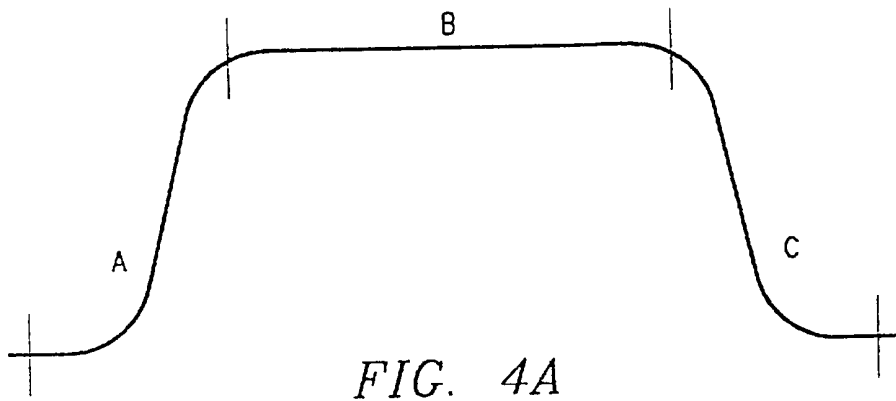


FIG. 4A

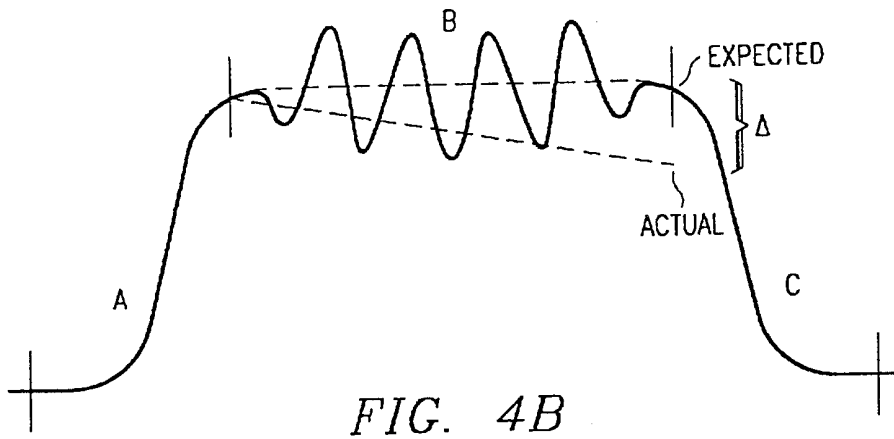


FIG. 4B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/18151

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H03G3/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 697 074 A (PAKONEN HANNU ET AL) 9 December 1997 (1997-12-09) the whole document	1-4, 11, 12, 19, 20, 22, 23, 31-33, 40
A	US 5 742 899 A (GRAHAM DAVID J ET AL) 21 April 1998 (1998-04-21) column 1, line 14 - line 37	1
A	PATENT ABSTRACTS OF JAPAN vol. 008, no. 256 (E-280), 22 November 1984 (1984-11-22) & JP 59 128806 A (OKI DENKI KOGYO KK), 25 July 1984 (1984-07-25) abstract	1

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Information on patent family members

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