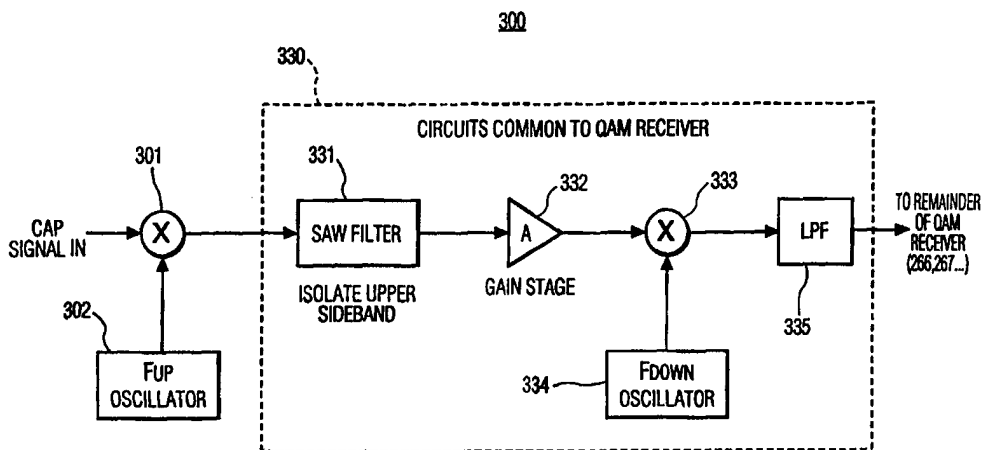




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(54) Title: RECEIVER SIGNAL PROCESSING SYSTEM FOR CAP SIGNALS



(57) Abstract

A CAP signal is processed by a QAM demodulator network (fig. 2, 250). The QAM network causes the CAP signal to rotate about its center frequency, which rotation is removed prior to conveying the CAP signal to utilization networks. In an analog implementation (fig. 3), the CAP signal is frequency up-converted to be centered at $f_{ad}/4$ so that the QAM processor can use the usual 1, 0, -1, 0 demodulation sequence to bring the CAP signal to baseband. Alternatively, using digital techniques (fig. 4), frequency upconverting is not needed and the 1, 0, -1, 0 demodulation sequence is replaced with a Numerically Controlled Oscillator (406) and full multiplier to allow the QAM processor the bring the CAP signal to baseband.

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Receiver Signal Processing System for CAP Signals

The present invention relates to a digital signal processing system, and in particular to a receiver for processing carrierless AM/PM (CAP) signals.

CAP transceivers are used to transmit and receive modulated signals over a transmission medium, such as an asymmetric digital subscriber line (ADSL) application. CAP is a bandwidth-efficient two-dimensional pass band line code in which the symbol data is organized in I and Q pairs. In this system, the I and Q data are filtered with orthogonal I and Q band pass filters having a common pass band. CAP is primarily intended for use in relatively simple communication links, where there is only one frequency division per channel. With CAP, all processing is done in the pass band of the filters, which eliminates the need for a carrier tracking loop (CTL), at the expense of tighter symbol timing constraints due to the frequencies of the pulses transmitted, which are higher than those of many other modulation schemes. CAP systems are described in detail in Werner, J.J., *Tutorial on Carrierless AM/PM*, June 23, 1992 (UTP Development Forum, ANSI X3T9.5 TP/PMD Working Group).

Many end users do not have CAP transceivers capable of receiving such CAP signals. For example, many consumers have existing cable set-top transceiver devices which are not compatible with CAP. Because of the often prohibitive cost of installing new CAP receivers compatible with CAP signals, it is desirable to modify existing receivers to be able to receive CAP signals.

In accordance with the principles of the present invention, a method for processing a CAP signal to facilitate its demodulation to baseband involves the steps of processing the CAP signal by a QAM demodulator network, and removing rotation of the CAP signal about its center frequency caused by QAM demodulator processing.

In the Drawings:

Fig. 1 is a block diagram of a CAP transceiver system;

Fig. 2 is a block diagram of a QAM transceiver system;

Fig. 3 is a block diagram of a portion of a modified QAM receiver modified in accordance with an embodiment of the present invention;

Fig. 4 is a block diagram of a portion of a second modified QAM receiver modified in accordance with a second embodiment of the present invention; and

Fig. 5 is a block diagram of a modified carrier tracking loop of the QAM receiver of Figs. 4 or 5, in accordance with the present invention.

Symbol Constellations

In the present invention, a QAM receiver is modified to receive CAP signals. In either a CAP or QAM system, a transmitted data symbol is represented by both "I" and "Q" quadrature components. Each symbol may comprise several bits, and the number of bits/symbol dictates the type of QAM (or CAP) system, i.e., 16-QAM, 32-QAM, and so forth. In a 16-QAM system, for example, 16 possible 4-bit symbols exist, each of which is mapped (assigned) to a prescribed coordinate in a four-quadrant grid-like constellation using a look-up table (e.g., a ROM). A prescribed number of symbols occupy assigned areas in each quadrant. In a 32-QAM (or 32-CAP) system, each quadrant of the constellation contains eight symbols at prescribed coordinates with respect to quadrature I and Q axes.

CAP Transceiver System

Referring now to Fig. 1, there is shown a block diagram of a CAP transceiver system 100, containing CAP transmitter 110, CAP receiver 150, and transmission channel 120. CAP transmitter 110 comprises symbol generator 111, in-phase filter 112, quadrature filter 113, and summing node 115, which is coupled to transmission channel 120. CAP receiver 150 comprises in-phase filter 152, quadrature filter 153, and timing recovery mechanism 154, each coupled to transmission channel 120, sampling device 155, which is coupled to symbol to data mapper 157. In one embodiment, transmission channel 120 is a standard telephone twisted pair wire.

Symbol generator 111 receives an input data signal Data In, and maps each input data value to be transmitted to a symbol pair or pair of coordinates I_{xs} and Q_{xs} of a corresponding constellation point on a complex signal constellation having real I (in-phase) and imaginary Q (quadrature) axes. I_{xs} and Q_{xs} are spaced by $L-1$ zeros, where L is the

number of samples per symbol. Filters 112 and 113 are orthogonal pulse shaping filters having a common pass band. Filters 112 and 113 receive symbols $I_{xs}(n)$ and $Q_{xs}(n)$, and generate signals $I_x(n)$ and $Q_x(n)$, respectively, where n is the sample index, and $I_x(n) = P_i \cdot I_{xs}(n)$, and $Q_x(n) = P_q \cdot Q_{xs}(n)$. The pulse shaping filter functions P_i , P_q of filters 112, 113 are derived by frequency shifting a common M tap root raised cosine filter, P , to F_c , where F_c is the center or carrier frequency of the pulse shaping filter functions P_i and P_q of filters 112 and 113. Thus, $P_{ik} = P_k \cdot \cos((2 \cdot \pi \cdot F_c \cdot k) / (F_s \cdot \text{sps}))$, and $P_{qk} = P_k \cdot \sin((2 \cdot \pi \cdot F_c \cdot k) / (F_s \cdot \text{sps}))$, for $k = -(M/2), -(M/2)+1, \dots, (M/2)-1$, where the value sps represents the number of samples per symbol used in the filter, F_s is the symbol rate, and k is an index variable. Thus, unlike in QAM transmitters, as discussed below with reference to Fig. 2, the input symbol data $I_{xs}(n)$ and $Q_{xs}(n)$ are not rotated; rather, the input symbol data are only filtered by the root raised cosine orthogonal bandpass filters 112, 113. This generates a CAP signal which resembles, in some respects, a QAM signal, except the transmitted data is not spinning or rotating at carrier frequency F_c as it would be in a QAM system.

The summed signal $I_x(n) + Q_x(n)$ output by summing node 115 is transmitted over transmission channel 120. As will be appreciated, the summed signal $I_x(n) + Q_x(n)$ is typically passed through a digital-to-analog converter (DAC) and interpolating low-pass filter (not shown) before being transmitted over transmission channel 120. Further, in an alternative embodiment, summing node 115 may subtract, rather than add, the signals $I_x(n)$ and $Q_x(n)$.

The signal $I_x(n) + Q_x(n)$ is received by P_i and P_q filters 152, 153 of CAP receiver 150, which are related in phase and magnitude response to filters 112, 113 of CAP transmitter 110. CAP receiver 150 has a structure that is similar to the structure of CAP transmitter 110 in that it has a parallel arrangement of in-phase and quadrature filters. Filters 152, 153 generate signals $I_x(n)$ and $Q_x(n)$, which are provided to sampling device 155. Timing recovery means 154 recovers the timing of the transmitted data, and supplies timing data to sampling device 155 to properly sample signals $I_x(n)$ and $Q_x(n)$, to generate $I_{xs}(n)$ and $Q_{xs}(n)$, which are used by symbol to data mapper 157 to provide the coordinates of the corresponding constellation point and thus to provide the data represented by the constellation point.

QAM Transceiver System

Referring now to Fig. 2, there is shown a block diagram of a QAM transceiver system 200, containing QAM transmitter 210 and QAM receiver 250. QAM transmitter 210 comprises symbol generator 211, baseband pulse shaping filter 212, baseband pulse shaping filter 213, multipliers 216 and 217, and summing node 215, which is coupled to QAM receiver 250 via a transmission channel (not shown). QAM receiver 250 comprises multipliers 266, 267, baseband pulse shaping filters 252, 253, timing recovery mechanism 254, sampling device 255, complex multiplier 261, carrier tracking loop (CTL) 262, and symbol to data mapper 257.

In QAM transmitter 210, the entire signal is modulated to frequency F_c , as opposed to frequency shifting the filters as is done with CAP system 100. Consequently, the pulse shaping filter functions P of filters 212, 213 are invoked at baseband, and the upconverted signal rotates at rate F_c . At QAM receiver 250, the process is reversed to restore the mapped, modulated, and transmitted data. QAM systems are discussed in Werner, *Tutorial on Carrierless AM/PM*, referenced above, and in Edward A. Lee & David G. Messerschmitt, *Digital Communication*, 2d ed. (Boston: Kluwer Academic Publishers, 1994), pages 20 et seq., 202 et seq., and 220 et seq.

In QAM transceiver system 200, symbol generator 211 receives an input data signal Data In, and maps each input data value to be transmitted to a pair of coordinates I_{xs} and Q_{xs} of a corresponding constellation point, as in the CAP system 100 of Fig. 1. The $I_{xs}(n)$ and $Q_{xs}(n)$ symbols generated by symbol generator 211 are passed through baseband pulse shaping filters 212, 213, respectively, to produce band-limited I and Q values. These band-limited I and Q values are multiplied by a carrier and a version of that carrier shifted in phase by 90 degrees by modulators 216, 217, respectively. The combination of these modulations causes the I and Q values to rotate in the complex plane about the carrier frequency, as will be understood by those skilled in the art. Modulator 216 multiplies the band limited I value by $\cos(2\pi \cdot F_c \cdot k \cdot T)$, and modulator 217 multiplies the band limited Q value by $\sin(2\pi \cdot F_c \cdot k \cdot T)$, where F_c is the center frequency of baseband pulse shaping filters 212, 213, k is an index variable, and $1/T$ is the symbol rate. A QAM signal can thus be seen to consist of two independently modulated carrier signals with a $\pi/2$ or 90 degree relative phase shift. Filters 212, 213 and filters

252, 253 are square-root raised-cosine (SQRC) filters. The cascade of filters 212 and 252, and of filters 213 and 253, each form a so-called "Nyquist filter," which achieves minimal inter-symbol interference according to Nyquist's theory.

5 The resulting modulated signal streams are added by summing node 215 to form the QAM signal, which is thus seen to provide separate double-sideband modulation of the I and Q signals superimposed in the frequency domain. Typically, an upconverter (not shown) translates the low-frequency QAM signal to the transmission channel of interest, e.g. a
10 VHF or UHF channel. Also, the QAM signal is typically passed through a DAC and interpolating low-pass filter (not shown) before being transmitted over the transmission channel.

The QAM signal is received by a tuner portion (not shown) of QAM receiver 250, which filters the selected channel and reduces the
15 frequency of the received signal down to an intermediate frequency (IF), the output of which is applied to multipliers 266 and 267. The components of QAM receiver 250 generally perform inverse functions to their counterpart components in QAM transmitter 210. For example, receiver 250 also contains SQRC I and Q filters 252, 253, which are
20 "matched" to the transmit pulse shape. The QAM signal received by QAM receiver 250 is converted down to baseband by multiplying the received signal by multipliers 266, 267. This also causes the QAM signal to be largely derotated. Any residual rotation and phase error is removed by CTL 262. Next, filters 252, 253 generate signals $I_r(n)$ and $Q_r(n)$, which
25 are provided to sampling device 255. Sampling device converts the received analog signal to digital by sampling. Timing recovery mechanism 254 recovers the timing of the transmitted data, and supplies timing data to sampling device 255 to enable sampling device 255 properly to sample signals $I_r(n)$ and $Q_r(n)$, which in turn generates $I_{rs}(n)$
30 and $Q_{rs}(n)$.

Signals $I_{rs}(n)$ and $Q_{rs}(n)$ are then applied to complex multiplier 261, which receives a tracking signal from CTL 262 to remove residual rotation and constellation phase error left over after the multiplication of multipliers 266, 267. CTL 262 receives the data out signal and applies
35 the tracking signal to complex multiplier 261, as will be appreciated by those skilled in the art. The outputs of complex multiplier 261 are applied to symbol to data mapper 257 to provide the coordinates of the corresponding constellation point and thus to provide the data

represented by the constellation point. In an alternative embodiment, the received QAM signal is converted to digital by an analog-to-digital converter ADC before being applied to multipliers 266 and 267. In this case, sampling device 255 is replaced by an interpolator, as will be appreciated by those skilled in the art.

Receiving CAP Signal with QAM Receiver

As will be appreciated by those skilled in the art, QAM system 200 contains a control loop not found in CAP system 100. In a QAM system, both the carrier frequency, F_c , and the symbol timing clock must be phase and frequency locked to the transmitter. In a CAP system, only the symbol timing information must be locked. In a standard QAM receiver, the QAM receiver is designed to demodulate a QAM signal having a center frequency F_c of $\frac{1}{4}$ the ADC sample rate F_{ad} of sampling device 255, i.e., $F_c = F_{ad}/4$. This allows the use of a 1,0,-1,0 sequence to demodulate the received QAM signal with multipliers 266, 267. In such a sequence, the cosine and sine signals transmitted to multipliers 266, 267 of QAM receiver 250 may simply be a 1,0,-1,0 sequence, which allows the use of simple multiplexer devices to be used to perform the functions of multipliers 266, 267. The relationship $F_c = F_{ad}/4$ is advantageously used with sinusoidal (sine/cosine) multiplier functions associated with the 1, 0, -1, 0 sequence. However, other relationships between F_c and F_{ad} could also be used in accordance with the requirements of a particular system. Alternatively, if an ADC is used at the input of multipliers 266, 267, multipliers 266, 267 are digital multipliers or mixers of a digital demodulator comprising a numerically controlled oscillator (NCO).

In the present invention, one of two modifications is made to a QAM receiver to enable the QAM receiver to receive a CAP signal. To center a CAP signal at the frequency F_c at which the QAM receiver can use the 1,0,-1,0 sequence for demodulation, the CAP signal may be converted up and down in the analog frequency domain. Alternatively, where a digital demodulator is used, the digital demodulator may be modified to accept center frequencies other than $F_{ad}/4$, so that the CAP signal need not be converted up and down in the analog frequency domain before being applied to the input of the modified QAM receiver. Accordingly, in one embodiment of the present invention using analog techniques, as discussed below with reference to Fig. 3, a received CAP signal is shifted to being centered at $F_{ad}/4$, so that the standard 1,0,-1,0 demodulator system in the QAM demodulator can bring the signal to complex

baseband. In a second embodiment using digital techniques, as discussed below with reference to Fig. 4, the 1,0,-1,0 demodulation of a digital demodulator is changed to incorporate a full multiplier and NCO to allow the QAM receiver to shift the input CAP signal to baseband. To remove
5 the rotation left after a CAP signal is received by a QAM receiver by either of these techniques, the CTL is also modified to remove this rotation, as discussed with respect to Fig. 5.

Modified QAM Receiver: Analog Technique

Referring now to Fig. 3, there is shown a block diagram of a portion
10 300 of a modified QAM receiver, which is modified in accordance with the analog technique described above to be able to receive CAP signals transmitted by a CAP transmitter such as CAP transmitter 110 of Fig. 1. In QAM receiver portion 300, an Fup oscillator 302 and mixer 301 are added to the input stage of a standard QAM receiver. The output of mixer
15 301 is applied to the input of tuner stage 330, which utilizes components common to a standard QAM receiver tuner. Tuner stage 330 comprises a surface acoustic wave (SAW) filter 331, a gain stage 332, a multiplier 333, and Fdown oscillator 334, and low pass filter 335.

In QAM receiver portion 300, an input CAP signal is applied to
20 multiplier 301, which upconverts the CAP signal up to a higher frequency. With typical bits rates, such as DAVIC (Digital Audio Visual Integrated Circuit Council) bit rates C and D, a filter with a sharpness similar to that of a SAW filter is required to separate the upper sideband of the converted signal from the lower sideband. Thus, the output of multiplier
25 301 is applied to the input of SAW filter 331 of stage 330. The frequency Fup generated by oscillator 302 is selected to put the upper sideband of the upconverted signal generated by mixer 301 in the passband of SAW filter 331. Within stage 330, Fdown oscillator 334 is selected to center the signal at $F_c = F_{ad}/4$, or $\frac{1}{4}$ the ADC sample rate of sampling device 255.

30 The output of stage 330 is applied to the remainder of a QAM receiver, which is identical to QAM receiver 250 of Fig. 2, except for a modification to the CTL derotator, discussed with reference to Fig. 5. In particular, the output of stage 330 is applied to the input of multipliers
35 multipliers 266, 267, the demodulated CAP signal is rotating about its center frequency F_c , unlike a QAM signal, which would be largely derotated at this point of QAM receiver 250. Accordingly, in order to

derotate the symbols received, the CTL needs to be modified to provide an F_c derotator. Thus, with the embodiment illustrated in Fig. 3, the CTL derotator is also modified, as discussed below with respect to Fig. 5.

Modified QAM Receiver: Digital Technique

5 Referring now to Fig. 4, there is shown a block diagram of a digital CAP to QAM interface portion 400 of a second modified QAM receiver, which is modified in accordance with the digital technique described above to be able to receive CAP signals transmitted by a CAP transmitter such as CAP transmitter 110 of Fig. 1. In QAM interface portion 400, the
10 1,0,-1,0 digital demodulator of a standard QAM receiver is replaced with the digital CAP to QAM interface 400 of Fig. 4, at the intermediate frequency (IF) input of the QAM receiver. Interface 400 incorporates a full multiplier (eg., a complex multiplier) and NCO to allow the QAM receiver to shift the input CAP signal to baseband. With appropriate gain
15 adjustment, the CAP signal can thus be applied directly to the ADC 401, without having to be upconverted as done in QAM receiver portion 300.

Interface 400 comprises ADC 401, coupled to inputs of multipliers or mixers 402 and 403. These multipliers replace the function of multipliers 266 and 267 of QAM receiver 250 of Fig. 2. The outputs of
20 multipliers 402 and 403 are applied to filters 252 and 253, the output of which is applied to sampling device 255, which is an interpolator in this embodiment, since analog-to-digital conversion has already been performed. An NCO that provides center frequency F_c of the received CAP signal is also applied to inputs of multipliers 402 and 403. This
25 replaces the simpler 1,0,-1,0 sequence that is used when the input signal has a frequency of $F_{ad}/4$. Full multipliers 402 and 403 are also used in this embodiment, rather than simpler multipliers possible when the NCO generates the simpler 1,0,-1,0 sinusoidal sequence.

30 With this embodiment, the CTL derotator is also modified, as discussed below with respect to Fig. 5.

Modified CTL Derotator of QAM Receiver for Analog and Digital Techniques

Carrier tracking is an integral part of the QAM demodulation performed by a QAM receiver such as QAM receiver 250. A CAP system
35 avoids this problem by not rotating data on a carrier frequency. However, it has been determined that, if a QAM receiver is to demodulate

a CAP signal and frequency conversions are part of the signal processing performed, then it is likely that carrier tracking will be needed, since the frequency converters will rotate the data. Fortunately, when the static center frequency is added to the CTL NCO, the offsets introduced by conversion tuning errors are comparable to those that exist with a QAM system and can be corrected in the standard manner.

Referring now to Fig. 5, there is shown a block diagram of a modified CTL 500, which replaces CTL 262 of QAM receiver 250, in accordance with the present invention. This modification is necessary since the CAP symbols are rotated at F_c when they are converted to baseband by multipliers 266 and 267 (for Fig. 3) or multipliers 402 and 403 (for Fig. 4). When a CAP signal is received by a QAM receiver, the CAP signal is not rotating as a QAM signal would be. However, the QAM receiver will bring the received CAP signal down to baseband by multiplying it by a carrier which is the center frequency of the CAP signal, which causes the signal to rotate about F_c . Thus, to recover the data, the CAP symbols must have the F_c rotation removed from them. The center frequency can be removed only after all baseband signal processing, since adding back the center frequency to remove the rotation would shift the signal out of baseband. This requires that center frequency derotation be performed when the signal is converted to 1 sample per symbol for equalization or slicing. Accordingly, the derotation of the data must occur after pulse shaping filters 252 and 253 of a QAM receiver such as QAM receiver 250.

Accordingly, in the present invention, derotation is performed by CTL 500. This permits the CTL to track out errors caused by the conversions, as well as recover the original symbol data. The modified CTL comprises a CTL phase error detector 501, which generates a CTL phase error, CTL loop filter 502, adder 510, and NCO 511. Phase error detector 513 generates a CTL phase error by receiving the Data Out signal, as will be appreciated. CTL loop filter 502 generates a signal indicating the frequency and phase error of the processed signal. In standard CTLs, the output of CTL loop filter 502 would be applied directly to the input of NCO 511, which would generate the correct sinusoidal signals to control the multiplication of complex multiplier 261, so as to reduce the error. This is normally used to eliminate the residual rotation and phase error discussed previously. In the present invention, adder 510 and signal F_c are added to allow CTL 500 to also remove the rotation caused by a CAP

signal rotating about frequency F_c . When a processor or user determines that a QAM signal is being received, the F_c signal can be switched to zero, so that zero is added to the error signal output by CTL loop filter 502, to mimic the operation of a normal CTL in a QAM receiver when a QAM
5 signal is received.

The F_c switching can be accomplished in various ways. For example, signal F_c could be provided from a switched source which provides either signal F_c or a zero value to adder 510 in response to a control signal from a sensor network which identifies the presence or absence of a CAP
10 signal. For example, a viewer may select a video program from a menu display. Mapping associated with the selection and with the provider of the selected source material would provide an identifier signal indicating that the selected material will be conveyed by CAP or QAM format. The identifier would be sensed eg., by a comparator, to develop the control
15 signal.

As will be appreciated, in alternative embodiments, the modified QAM receivers and components of the present invention may be implemented partially or completely in digital signal processing software on a processor. An analog system may or may not need an NCO. A fixed
20 NCO is suitable for generating the 1, 0, -1, 0 demodulation sequence mentioned previously.

CLAIMS

1. A receiver for processing a CAP signal, comprising:
first means (266,267;402,403) for causing the CAP signal to rotate
5 about the center frequency of the CAP signal; and
second means (500) for removing the rotation of the CAP signal
about the center frequency.
2. The receiver of claim 1, wherein the first means comprises a
10 1,0,-1,0 sequence demodulator, wherein the receiver has an analog-to-
digital sample rate, the receiver further comprising:
means for converting the center frequency of the CAP signal to a
frequency related to the analog-to-digital sample rate of the receiver
before the CAP signal is applied to the 1,0,-1,0 sequence demodulator.
15
3. The receiver of claim 2, wherein the converting means further
comprises:
- (1) a passband filter coupled to the 1,0,-1,0 sequence
demodulator;
 - 20 (2) a first translator for converting the center frequency of
the CAP signal to the passband frequency before the CAP signal is applied
to the filter; and
 - (3) a second translator for converting the frequency of the
CAP signal after being filtered by the filter to one-quarter of the analog-
25 to-digital sample rate of the receiver.
4. The receiver of claim 1, wherein
the first means comprises an analog-to-digital converter for
converting the CAP signal from analog to digital and a digital demodulator
30 comprising a full multiplier and numerically controlled oscillator (NCO)
adapted to shift the CAP signal to baseband.
5. The receiver of claim 1, further comprising
a carrier tracking loop (CTL) associated with the second means.

6. The receiver of claim 5, wherein
the CTL comprises a CTL loop filter having an output, an adder
having first and second inputs, the first input of the adder coupled to the
output of the CTL loop filter, and a CTL oscillator having an input coupled
5 to the output of the adder, wherein the second input of the adder is
coupled to a derotation signal, wherein the derotation signal has a
nonzero value sufficient to cause the CTL to remove the rotation of the
CAP signal about the center frequency.

10 7. The receiver of claim 1,
wherein the first means comprises a means for converting
the CAP signal to baseband.

15 8. The receiver of claim 1, wherein
the first means comprises a means for multiplying the CAP signal
by a carrier signal having a carrier frequency equal to the center
frequency of the CAP signal.

20 9. The receiver of claim 1, wherein
the first means comprises a means for demodulating QAM signals,
whereby the CAP signal rotates about the center frequency after being
processed by the means for demodulating.

25 10. A method for receiving a CAP signal in a receiver, comprising
the steps of:

(a) causing the CAP signal to rotate about the center frequency of
the CAP signal; and

(b) removing the rotation of the CAP signal about the center
frequency.

30 11. The method of claim 10, wherein
step (a) comprises the step of demodulating the CAP signal with a
1,0,-1,0 sequence demodulator, wherein the receiver has an analog-to-
digital sample rate, the method further comprising the step of:

35 (c) converting the center frequency of the CAP signal to a frequency
related to the analog-to-digital sample rate of the receiver before
demodulating the CAP signal with the 1,0,-1,0 sequence demodulator.

12. The method of claim 11, wherein step (c) further comprises:

(1) converting the center frequency of the CAP signal to a passband frequency of a passband filter;

(2) filtering the CAP signal with the filter after step (c)(1); and

5 (3) converting the frequency of the CAP signal after step (c)(2) to one-quarter of the analog-to-digital sample rate of the receiver.

13. The method of claim 10, wherein

10 step (a) comprises the steps of converting the CAP signal from analog to digital, and shifting the CAP signal to baseband with a digital demodulator comprising a full multiplier and NCO.

14. The method of claim 10, wherein

15 step (b) is performed by a CTL of the receiver.

15. The method of claim 14, wherein

20 the CTL comprises a CTL loop filter having an output, an adder having first and second inputs, the first input of the adder coupled to the output of the CTL loop filter, and a CTL oscillator having an input coupled to the output of the adder, wherein the second input of the adder is coupled to a derotation signal, wherein the derotation signal has a nonzero value sufficient to cause the CTL to remove the rotation of the CAP signal about the center frequency.

25 16. The method of claim 10, wherein

step (a) comprises the step of converting the CAP signal to baseband.

17. The method of claim 10, wherein

30 step (a) comprises the step of multiplying the CAP signal by a carrier signal having a carrier frequency equal to the center frequency of the CAP signal.

18. The method of claim 10, wherein

35 step (a) comprises the step of demodulating the CAP signal with a means for demodulating QAM signals, whereby the CAP signal rotates about the center frequency after the demodulation.

19. A method of processing a CAP signal normally not subject to rotation about a center frequency, comprising the steps of

(a) processing the CAP signal by means of a QAM demodulator network; and

5 (b) removing rotation of the CAP signal about its center frequency caused by QAM demodulator processing in step (a).

20. A method according to claim 19, further including the steps of
10 coupling the CAP signal to a carrier recovery network associated with the QAM demodulator network;

generating a reference signal at the center frequency of the CAP signal;

applying the reference signal to the carrier recovery network in the presence of a CAP signal to be processed; and

15 inhibiting the reference signal in the absence of a CAP signal to be processed.

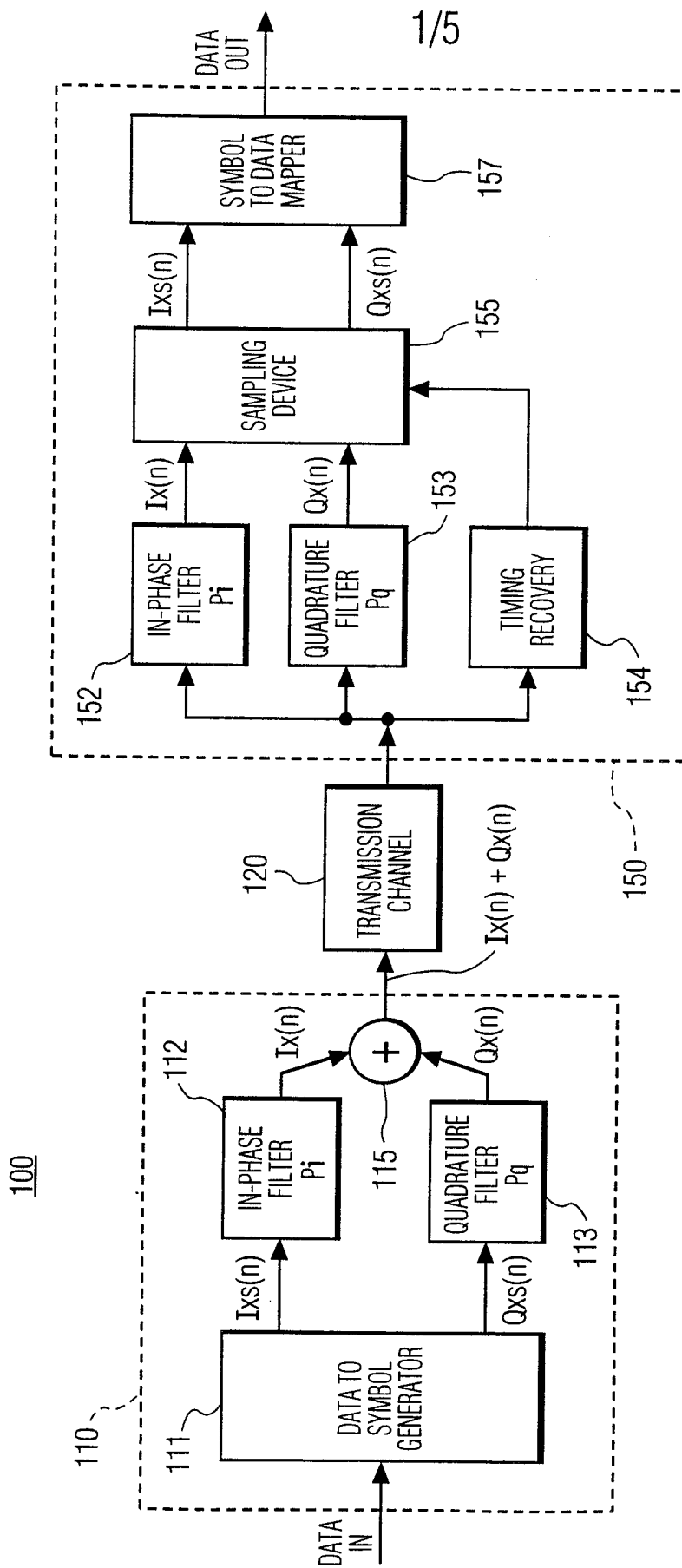


FIG. 1
PRIOR ART

200

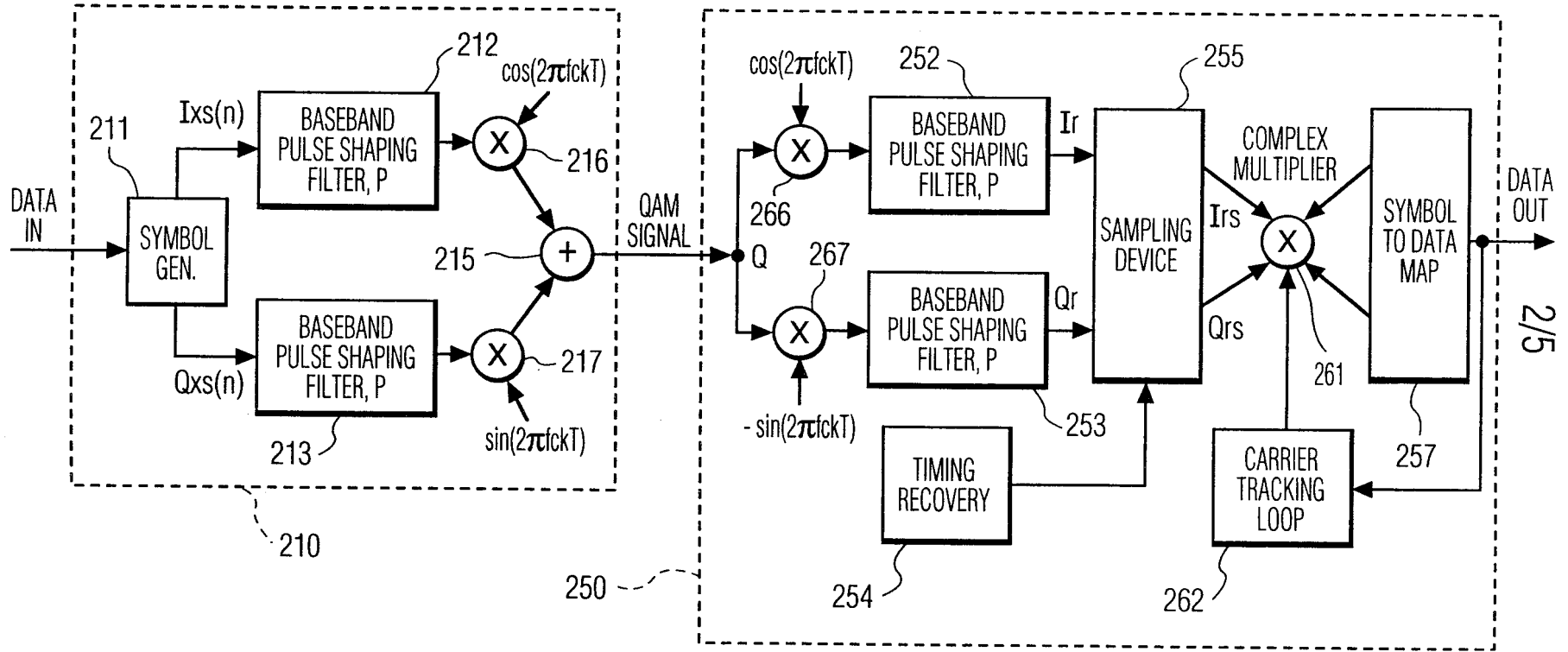


FIG. 2

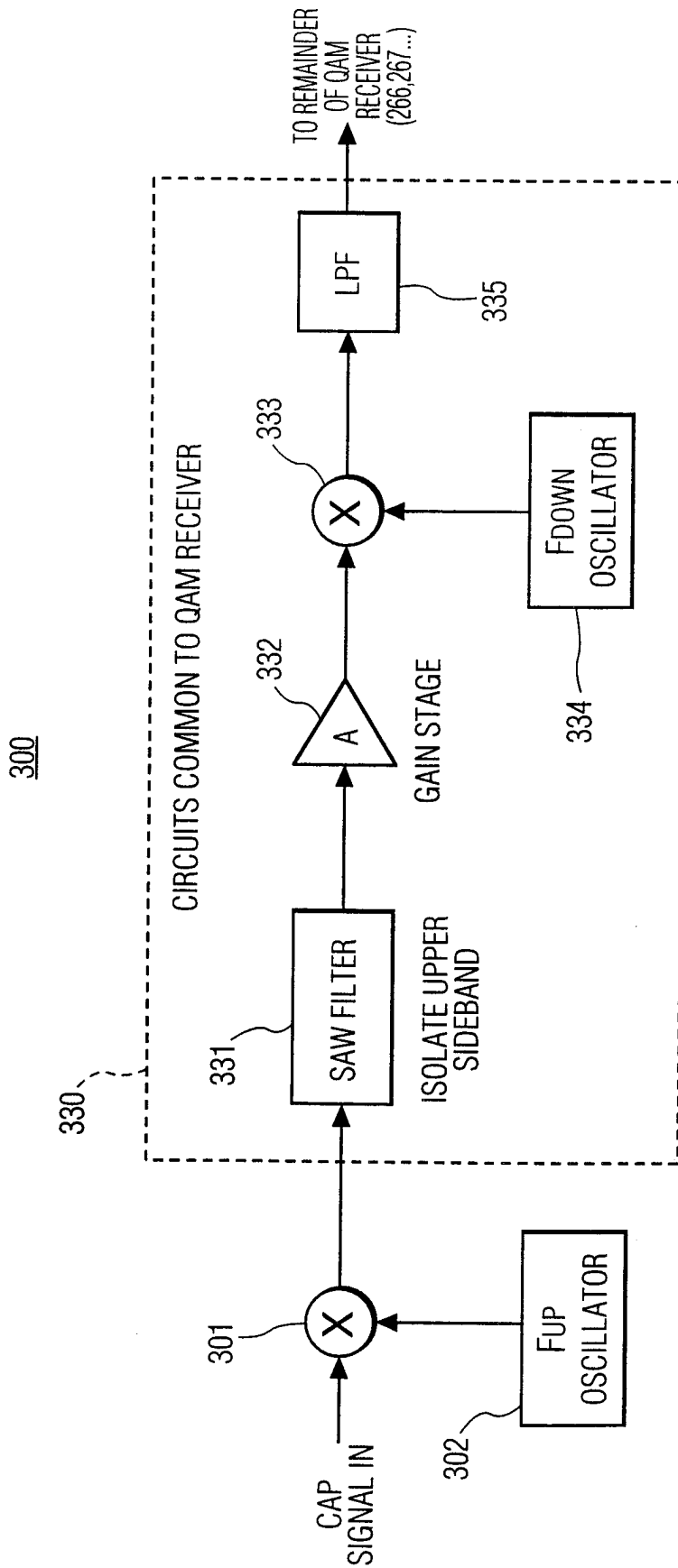


FIG. 3

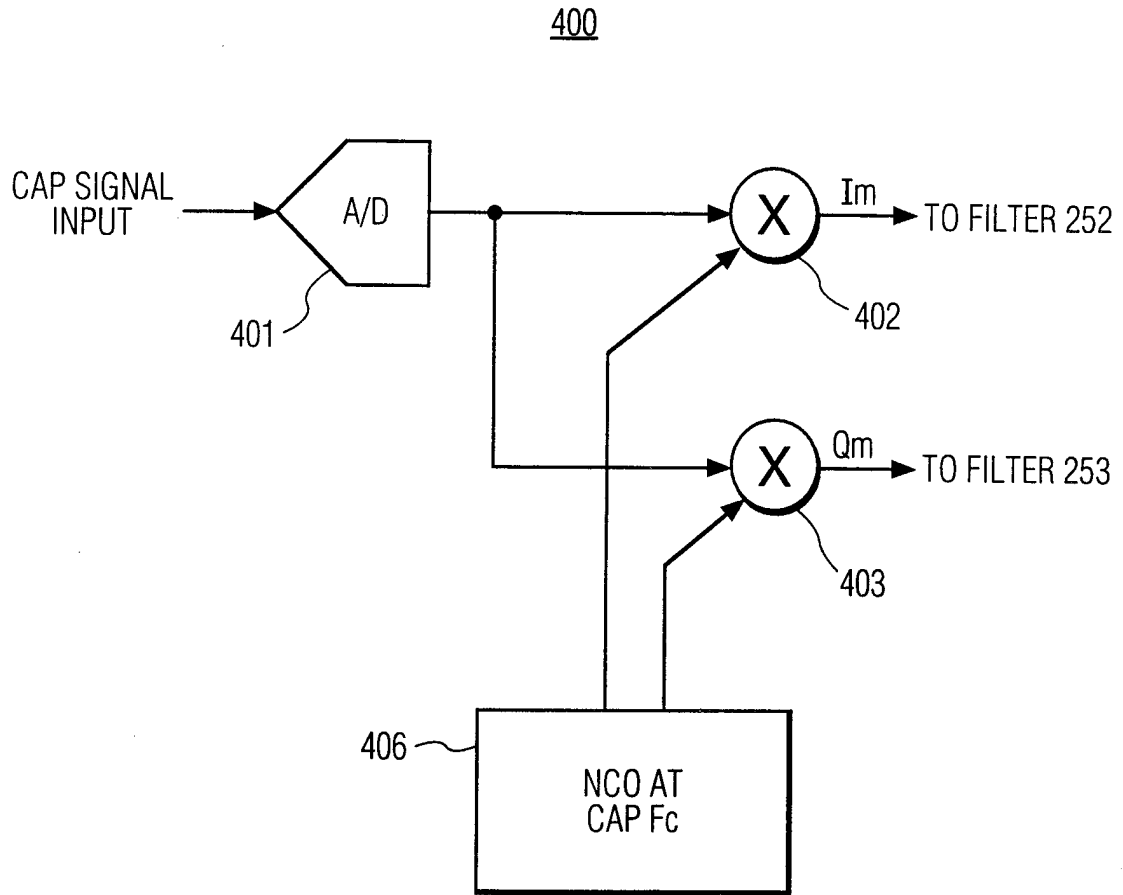


FIG. 4

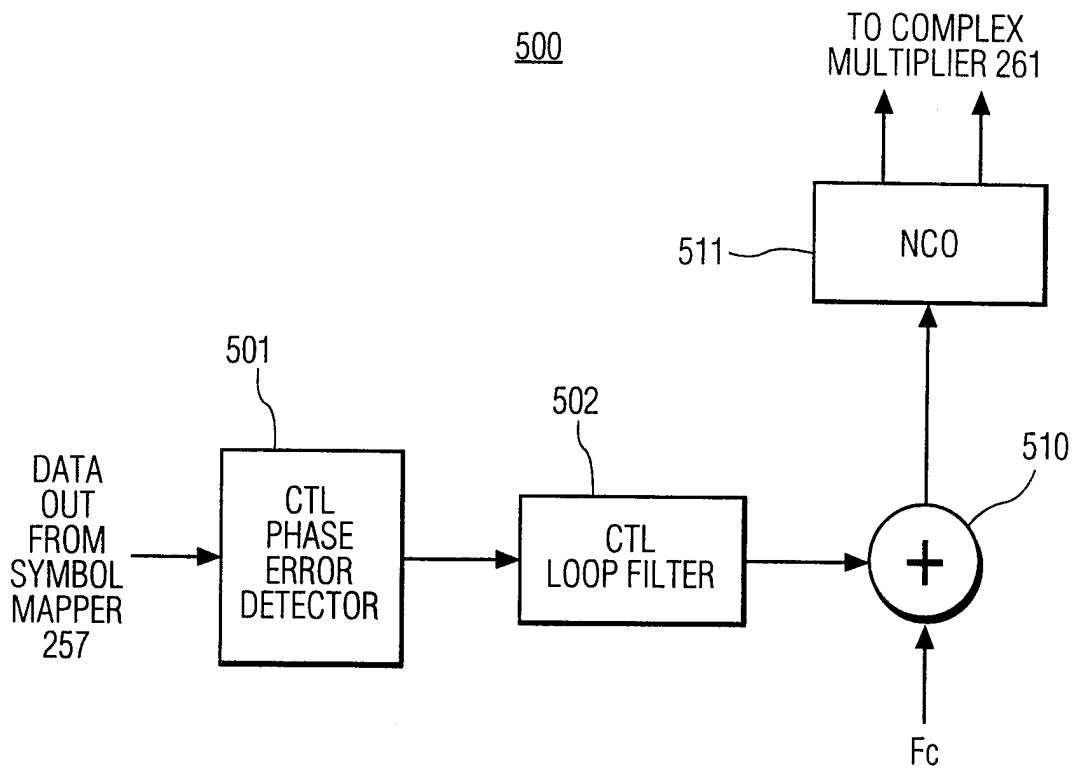


FIG. 5

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 97/17829

A. CLASSIFICATION OF SUBJECT MATTER IPC 6 H04L27/38				
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 6 H04L				
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)				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
A	IM G -H ET AL: "51.84 MB/S 16-CAP ATM LAN STANDARD" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, vol. 13, no. 4, 1 May 1995, pages 620-632, XP000501258 see page 624, left-hand column, paragraph 2 --- -/--	1, 10		
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.				
° Special categories of cited documents :				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;"> "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; border: none; vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family			
Date of the actual completion of the international search <div style="text-align: center; font-size: 1.2em;">27 January 1998</div>		Date of mailing of the international search report <div style="text-align: center; font-size: 1.2em;">05/02/1998</div>		
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer <div style="text-align: center; font-size: 1.2em;">Goulding, C</div>		

2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/17829

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>WOODWARD S L ET AL: "A PASSIVE-OPTICAL NETWORK EMPLOYING UP CONVERTED 16-CAP SIGNALS"</p> <p>IEEE PHOTONICS TECHNOLOGY LETTERS, vol. 8, no. 9, September 1996, pages 1249-1251, XP000624890</p> <p>see abstract</p> <p>see page 1250, right-hand column, paragraph 2 - page 1251, left-hand column, paragraph 1</p> <p style="text-align: center;">-----</p>	1, 10