

1 **Title of the invention**

2 **Burst Mode Preamble**

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4 **Inventor**

5 **Lawrence Ebringer**

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7 **Cross-References**

8 This application claims the benefit of U.S. Provisional Application No. 60/005,444 filed on
9 October 12, 1995, entitled "Preamble for Burst Mode Reception." of which Lawrence Ebringer is the
10 inventor. with attorney docket number NP2008.

11

12 **Background**

13 Burst mode transmitters generally need to transmit a training sequence or preamble prior to
14 the transmission of data so that a burst mode receiver can obtain the correct clock sample phase and
15 carrier phase to recover the data. There is a need for a short preamble which contains the maximum
16 amount of information regarding the burst and which can effectively be used by a number of different
17 types of burst mode receivers to detect the presence of the burst and to recover clock sample phase and
18 carrier phase.

19

20 **Summary of the Invention**

21 In a burst mode communications system having a burst mode transmitter using Quadrature
22 Phase Shift Keying modulation, bursts containing a preamble and data are transmitted by first
23 transmitting a pulse of one to three symbols in length, waiting during a dead time of one to three
24 symbols in length during which time no symbols are transmitted, transmitting a Barker sequence of at
25 least seven bits in length in both the I and Q channels, and transmitting the data.

26 To reduce the effect of the noise on the Barker sequence, the sequence can be reversed and
27 inverted in the I and Q channels such that the I channel contains a Barker sequence and the Q channel
28 contains the same Barker sequence in reverse order and multiplied by minus 1.

1 An advantage of the present invention is that many different types of burst mode receivers can
2 be used to detect the burst and recover the transmitted data based on a short preamble.

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Brief Description of the Drawings

5 Fig. 1 represents a shared media with multiple burst mode transmitters and a single burst
6 mode receiver.

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8 Fig. 2 illustrates a Fiber-to-the-Curb (FTTC) network with a coaxial drop cables to the
9 residence which provides connectivity to a number of devices in the residence and over the shared
10 media formed by the coaxial drop cable, splitter, and in-home coaxial wiring.

11 Fig. 3 illustrates a spectrum of forward and return signals on the coaxial drop in a FTTC
12 network.

13 Fig. 4 illustrates the format of a burst transmission.

14 Fig. 5 illustrates a table representing the symbol values in the preamble.

15

Description of Preferred Embodiments

1. Introduction

17 The general form of a burst mode communications system is illustrated in Fig. 1, and is
18 formed when multiple burst mode transmitters 110 transmit signals over a shared media 100 which are
19 received by a burst mode receiver 120. The shared media can be of a multitude of forms including free
20 space, twisted pair copper cable in a bus configuration, a passive optical network, or a shared coaxial
21 cable network comprised of coaxial cable and splitters. Examples of applications using shared media
22 include local area networks, cellular phone systems, and bi-directional cable TV systems.

23 Fig. 2 illustrates a Fiber to the Curb (FTTC) network with a subscriber coaxial cable network
24 which forms a shared media. In the FTTC network illustrated, a Host Digital Terminal (HDT) 230 is
25 connected to the Public Switched Telecommunications Network (PSTN) 210 as well as an
26 Asynchronous Transfer Mode (ATM) network 220, and to one or more Optical Network Units (ONUs)
27 240 via optical fiber 260. A Broadband Interface Unit (BIU) 250 in ONU 240 contains transmit and
28 receive circuits for sending signals to devices in a residence 290.

1 The devices in the residence 290 are connected to BIU 250 via a subscriber coaxial cable
2 network, which when used herein, is defined as a network comprised of a coaxial drop cable 270,
3 splitter 280, and in-home coaxial wiring 272 which connects and individual residence 290 to the BIU
4 250. Use of the term subscriber indicates that the customer in the residence is a subscriber or potential
5 subscriber to the services provided over the FTTC telecommunications network. The subscriber
6 coaxial cable network forms a shared media since it allows all devices connected to it to access the BIU
7 250 with no active switching.

8 As shown in Fig. 3, examples of the types of devices which can be present in the residence
9 290 include a telephone 294 connected to a Premise Interface Device (PID) 296, a computer containing
10 a Network Interface Card 292 and a television 299 with a settop 298. The computer containing a NIC
11 card 292, PID 296, and settop 298 can, via the in-home coaxial wiring 272, splitter 280, and coaxial
12 drop cable 270, all transmit signals to the BIU 250.

13 II. Burst mode communications in a FTTC system

14 In the FTTC system digital signals are used to carry voice, video, and data signals to the
15 devices. Asynchronous Transfer Mode (ATM) protocols and formats can be used to carry the signals.
16 The system requires bi-directional communications between the devices in the residence 290 and the
17 ONU 240, and information is transmitted in the return direction, for example, from the devices to the
18 ONU 240 for changing channels on the television 299, carrying out voice conversation on the
19 telephone 294, or using network services on the computer with NIC card 292. The system provides for
20 the transport of ATM cells in the return direction as well as the forward (ONU to devices) direction.

21 The shared media formed by the subscriber coaxial network suggests that the devices use a
22 multiple access protocol to transmit to the BIU 250 in the ONU 240. A number of multiple access
23 protocols can be used including Frequency Division Multiple Access (FDMA), Code Division Multiple
24 Access (CDMA) and Time Division Multiple Access (TDMA). When a TDMA protocol is used the
25 devices will be assigned opportunities for the transmissions to the BIU 250, and, when ATM protocols
26 are used, will transmit one or more cells in the opportunities.

27 Although signals can be transmitted on the subscriber coaxial cable network in baseband form
28 when the splitter 280 has the appropriate low frequency characteristics, it is generally more appropriate

1 to transmit signals in both the forward and return direction on passband signals which are centered
2 about some non-zero frequency.

3 Fig. 3 illustrates a possible spectrum of forward and return signals on a subscriber coaxial
4 network, with a FTTC forward carrier 310, and a FTTC return carrier 320. In one embodiment of an
5 FTTC system, the forward transmission takes place on a FTTC forward carrier 310 at a frequency of
6 19.44 MHz, with a data rate of 51.84 Mb/s using 16 Quadrature Amplitude Modulation (16QAM).
7 Transmissions in the return direction can take place on a FTTC return carrier 320 at a frequency of
8 38.88 MHz, with a data rate of 19.44 Mb/s using Quadrature Phase Shift Keying (QPSK). An
9 advantage of this embodiment is that the spectrum of TV signals above 50 MHz is not disturbed by
10 these transmissions, if such an analog signal is present on the subscriber coaxial network. However,
11 this embodiment is given as an example only, and various frequencies, data rates and modulation
12 formats could be used to practice the invention. It should also be noted that techniques which are
13 commonly referred to as Carrierless Amplitude Phase (CAP) modulation are subsequent to generation
14 of the signal, equivalent to QPSK and QAM modulation formats.

15 III. Preamble for burst mode communications

16 Fig. 4 illustrates the structure of a burst for burst mode transmission. It can be received using
17 a number of methods, and consists of a preamble 402 followed by data 404. The preamble has a pulse
18 420, a dead time 430, and a Barker sequence 440.

19 The Barker sequence is used in a preferred embodiment of the invention because it has low
20 crosscorrelation and high autocorrelation properties. In the preferred embodiment, the transmitter
21 utilizes Quadrature Phase Shift Keying (QPSK) modulation in which binary symbols are modulated on
22 to orthogonal carriers, referred to as the I and Q channels. The carriers can be thought of as having
23 different frequencies in the sense that the complex representation of the orthogonal carriers are
24 different even when the real value of the frequency is the same. The Barker sequence, consisting of 1-
25 13 bits, can be transmitted in the preamble on both carriers.

26 Because noise on the orthogonal carriers can be correlated, there can be a correspondence
27 between errors in the detected signal at the burst mode receiver. To reduce the probability that noise
28 events on both carriers make the Barker sequence less detectable on each channel, the order of the

1 Barker sequence can be reversed in one channel with respect to the other channel. To further reduce
 2 the effect of correlated noise events, the Barker sequences in the I and Q channels can be inverted with
 3 respect to each other as well as transmitted in different transmission sequences in the I and Q channels.
 4 As an example, the Barker sequence can be transmitted from beginning to end in the I channel, and in
 5 inverted form from end to beginning in the Q channel.

6 Fig. 5 illustrates the preamble sequence of an embodiment which is comprised of a binary '1'
 7 in both the I and Q channels, followed by a dead time of two symbols during which time no signal is
 8 transmitted, followed by a Barker sequence of 13 bits in the I channel, and the same Barker sequence
 9 reversed and inverted in the Q channel.

10 One skilled in the art will recognize that a Barker sequence may be modified without
 11 substantially altering its cross-correlation or autocorrelation properties. It is also recognized that a
 12 Barker sequence may comprise more than one Barker codeword, and in one embodiment a 13 bit
 13 Barker codeword is repeated twice to form the Barker sequence. In a preferred embodiment of the
 14 preamble, the initial pulse and dead time are followed by a 13 bit Barker codeword which is
 15 subsequently followed by a binary sequences which are different for the I channel and the Q channel.
 16 In a preferred embodiment the preamble is

17 $I = 1\ 0\ 0\ 1\ 1\ 1\ 1\ 1\ -1\ -1\ 1\ 1\ -1\ 1\ -1\ 1\ 1\ 1\ 1\ 1\ 1\ 1$

18 $Q = 1\ 0\ 0\ -1\ 1\ -1\ 1\ -1\ -1\ 1\ 1\ -1\ -1\ -1\ -1\ 1\ 1\ 1\ -1\ 1\ -1\ -1$

19 The number of ones in the pulse 420 can vary with a single occurrence of a one being the
 20 obvious minimum for being able to detect the presence of a pulse in a receiver. More than a single '1'
 21 can be transmitted but may cause unnecessary lengthening of the preamble. By transmitting a one in
 22 both the I and Q channels it is possible to use a power measurement at the receiver to detect the
 23 presence of the pulse. Since carrier recovery has not typically occurred when the pulse arrives, only a
 24 power measurement is possible, and the use of a one in both the I and Q channel allows a noncoherent
 25 power measurement to be used to detect the pulse.

26 The dead time 430 is provided to prevent precursors which may be formed in the filtering of
 27 the Barker sequence 440 in a burst mode receiver 120 from interfering with the reception and detection
 28 of the pulse 420, and visa versa.

1 Data is subsequently transmitted in the form of binary symbols modulated onto the orthogonal
2 carriers using QPSK modulation.

3 In another aspect, the invention comprises a burst mode transmitter for use in a burst mode
4 communications system. The burst mode transmitter is capable of generating bursts for transmission to
5 a burst mode receiver. The burst mode transmitter circuitry for producing burst signals in general are
6 known in the art. The bursts of the present invention comprise a preamble and data which are coded
7 into binary symbols and modulated onto a first carrier frequency and a second carrier frequency
8 wherein said second carrier frequency is orthogonal to said first carrier frequency as described above.
9 The preamble consists of a sequence of a data pulse followed by a Barker sequence. The data pulse
10 and Barker sequence are separated by a transmission time period equivalent to the transmission period
11 of at least one, preferably two, binary symbols.

12 The burst mode signal is transmitted over a shared media, and received by a burst mode
13 receiver which uses the preamble to determine the presence of a burst and to determine the correct
14 carrier frequency, carrier phase, symbol clock frequency and symbol clock phase in order to correctly
15 recover the symbols transmitted, and thus the information contained within the burst.

16 As an example of a method of recovering a burst mode signal is the use of a cross-coupled
17 fractionally spaced equalizer structure which is preceded by an initiator circuit which detects the
18 presence of pulse 420 and uses the Barker sequence 440 for adjustment of the taps of the equalizer for
19 clock and carrier phase recovery.

20 Reception of the burst mode signal can be accomplished by converting a received analog
21 signal to a digital signal and downconverting the digital signal to a baseband signal having an I channel
22 and a Q channel with at least two samples per symbol. The presence of a burst is determined by
23 examining the squared values of at least three samples and determining, through the use of at least one
24 threshold, if a burst is present, and if so, which of the samples is nearest to the center of a
25 predetermined symbol in the preamble.

26 The signals in the I and Q channels are passed through digital filters which have taps which
27 can be adjusted to minimize an error signal which is produced by a subsequent decision circuit which
28 performs thresholding of the filtered samples and makes determinations of the symbol values and
29 correlates the recovered symbols with a stored version of the predetermined preamble during training

1 mode, or with the samples prior to thresholding during normal operation mode. The correlation
2 produces an error signal which during the training mode represents the initial error while the filters are
3 being adjusted to obtain the proper symbol sampling phase and minimize the carrier phase offset, and
4 which during normal mode of operation represents the drift in the symbol sampling and carrier phases.
5 Minimizing this error signal during the training phase results in symbol sampling phase recovery and
6 carrier phase acquisition, and during the normal mode of operation resulting in a tracking of the
7 symbol and carrier phases.

8 The preceding description of a method and receiver architecture for burst mode reception is
9 given as an example only, and alternative architectures for burst mode receivers are possible.

10 Although the present invention has been described in considerable detail with reference to
11 certain preferred versions thereof, other versions are possible. The goal of the invention as a method
12 and apparatus for the transmission of burst mode data remains the same however. An application of the
13 invention is the transmission of data transmitted from a burst mode device located in a residence 290,
14 an example of which is a settop 298 connected to a television 299, to a BIU 250 in an ONU 240 of a
15 FTTC system. In this application a subscriber may perform a channel change operation or other video
16 related function through the remote control of a settop. This information is transmitted in the form of a
17 burst from the settop 298 to the BIU 250, to the ONU 240, and to the HDT 230, which may effect the
18 change or request another network element of the ATM network 220 to effect the change. The ability
19 to transmit bursts from the settop 298 and be correctly received by a burst mode receiver is essential to
20 correctly interpret the subscriber commands. Therefore the spirit and scope of the appended claims
21 should not be limited to the description of the preferred versions contained herein.



1 What is claimed is:

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3 1. In a burst mode communications system having bursts containing a predetermined
4 preamble and data which are coded into binary symbols and modulated onto a first carrier
5 frequency and a second carrier frequency wherein said second carrier frequency is
6 orthogonal to said first carrier frequency, a method for transmitting said burst comprising:

7 a) transmitting at least one symbol indicating a binary one on said first carrier
8 frequency and at least one symbol indicating a binary one on said second carrier
9 frequency;

10 b) subsequently waiting a period of at least one symbol during which time no
11 symbols are transmitted; and

12 c) subsequently transmitting a binary Barker sequence with a length of at least
13 seven bits and having a beginning and an end on said first carrier frequency and
14 simultaneously transmitting said binary Barker sequence with a length of at least
15 seven bits and having said beginning and said end on said second carrier
16 frequency;

17 d) subsequently transmitting said data in the form of binary symbols modulated
18 onto said first carrier and said second carrier.

19

20 2. The method of claim 1, wherein said Barker sequence has a length of at least
21 thirteen bits.

22

23 3. The method of claim 1, wherein said Barker sequence is transmitted from said
24 beginning to said end on said first carrier frequency and is simultaneously transmitted
25 from said end to said beginning on said second carrier frequency.

26

27 4. The method of claim 2, wherein said Barker sequence is transmitted from said
28 beginning to said end on said first carrier frequency and is simultaneously transmitted
29 from said end to said beginning on said second carrier frequency.



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5. The method of claim 1, wherein said Barker sequence is transmitted from said beginning to said end on said first carrier frequency and is simultaneously transmitted from said end to said beginning and inverted in sign on said second carrier frequency.

6. The method of claim 2, wherein said Barker sequence is transmitted from said beginning to said end on said first carrier frequency and is simultaneously transmitted from said end to said beginning and inverted in sign on said second carrier frequency.

7. A burst mode communications system comprising a burst mode transmitter, a burst mode receiver, and a transmission medium between said burst mode transmitter and said burst mode receiver, wherein bursts are transmitted from said burst mode transmitter to said burst mode receiver and said bursts comprise a preamble and data which are coded into binary symbols and modulated onto a first carrier frequency and a second carrier frequency wherein said second carrier frequency is orthogonal to said first carrier frequency, and wherein said preamble comprises a sequence of a data pulse followed by a Barker sequence, said data pulse and Barker sequence being separated by a transmission time period equivalent to the transmission period of at least one binary symbol.

8. The burst mode communications system of claim 7, wherein the Barker sequence has a length of at least thirteen bits.

9. The burst mode communications system of claim 8, wherein the Barker sequence comprises a thirteen bit codeword.

10. A burst mode preamble for use in a burst mode communications system having bursts containing data which are coded into binary symbols and modulated onto a first carrier frequency and a second carrier frequency wherein said second carrier frequency is orthogonal to said first carrier frequency, said burst mode preamble comprising a



1 sequence of a data pulse followed by a Barker sequence, said data pulse and Barker
2 sequence being separated by a transmission time period equivalent to the transmission
3 period of at least one binary symbol.

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5 11. The burst mode preamble of claim 10, wherein the Barker sequence has a length
6 of at least thirteen bits.

7

8 12. The burst mode preamble of claim 11, wherein the Barker sequence comprises a
9 thirteen bit codeword.

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11 13. A burst mode transmitter for use in a burst mode communications system, said
12 burst mode transmitter comprising a means for generating bursts for transmission to a
13 burst mode receiver, said bursts comprising a preamble and data which are coded into
14 binary symbols and modulated onto a first carrier frequency and a second carrier
15 frequency wherein said second carrier frequency is orthogonal to said first carrier
16 frequency, and wherein said preamble comprises a sequence of a data pulse followed by a
17 Barker sequence, said data pulse and Barker sequence being separated by a transmission
18 time period equivalent to the transmission period of at least one binary symbol.

19

20 14. A burst mode transmitter of claim 13, wherein the Barker sequence has a length
21 of at least thirteen bits.

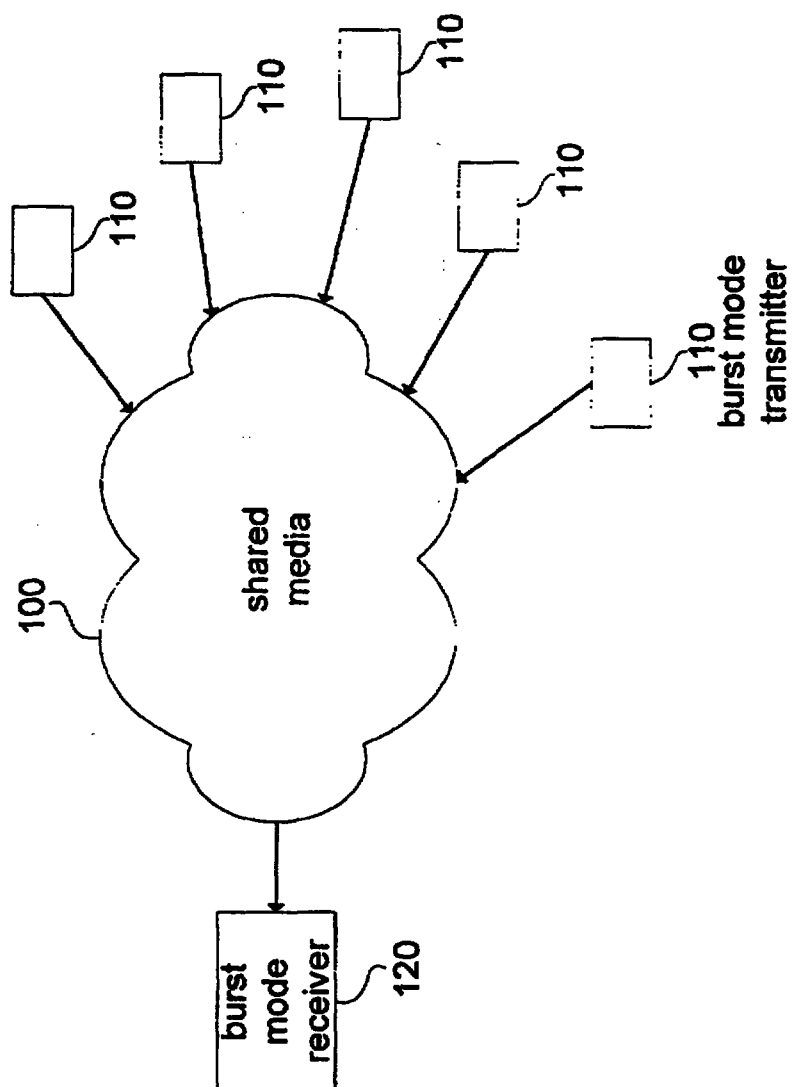
22

23 15. A burst mode transmitter of claim 14, wherein the Barker sequence comprises a
24 thirteen bit codeword.

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**FIG. 1**

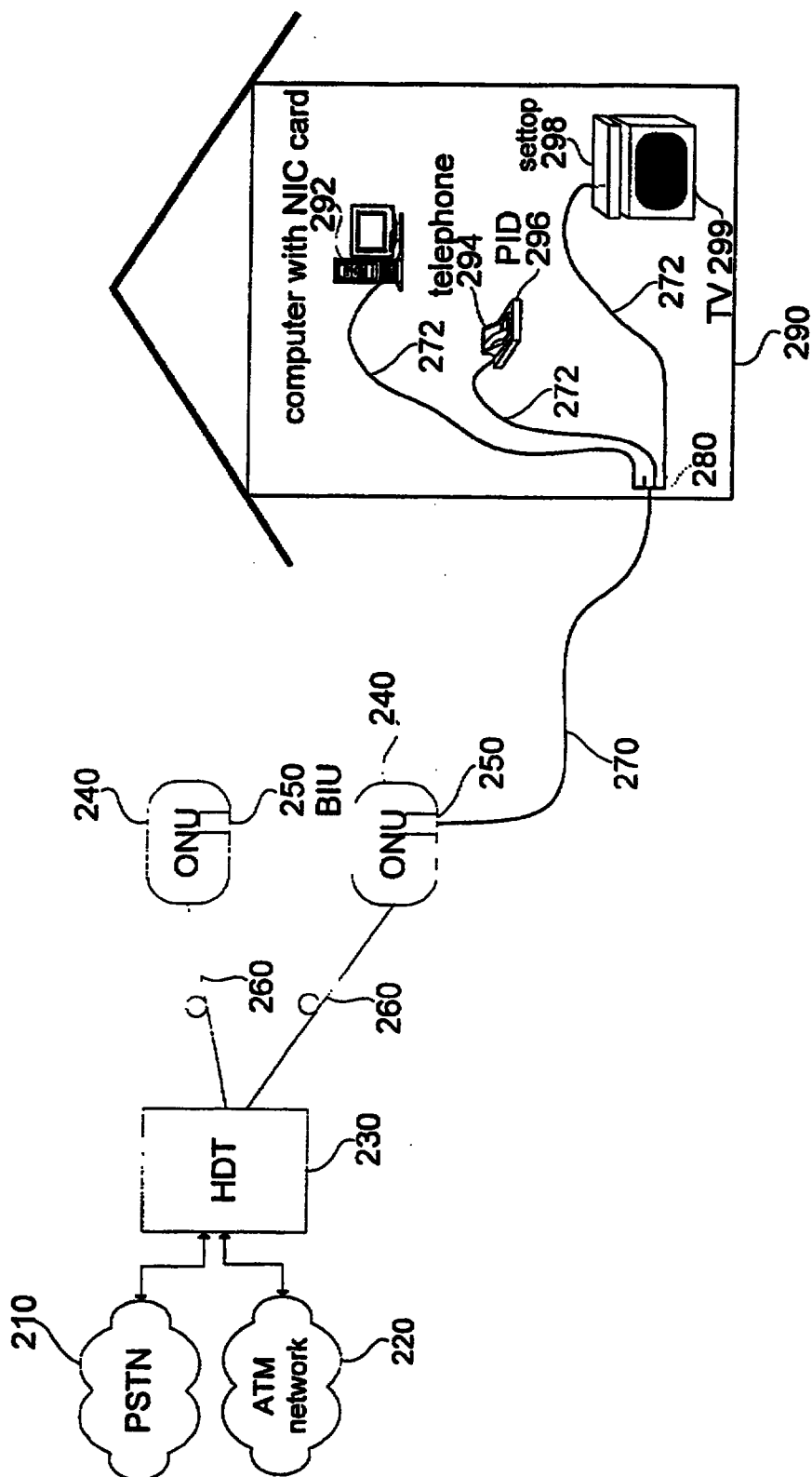


FIG. 2

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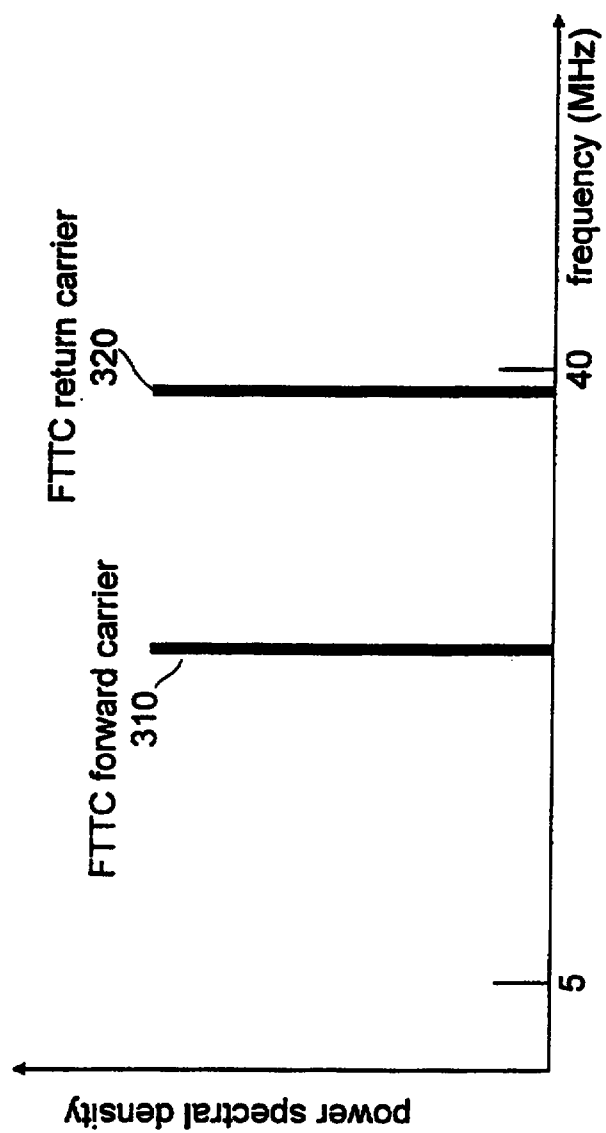


FIG. 3

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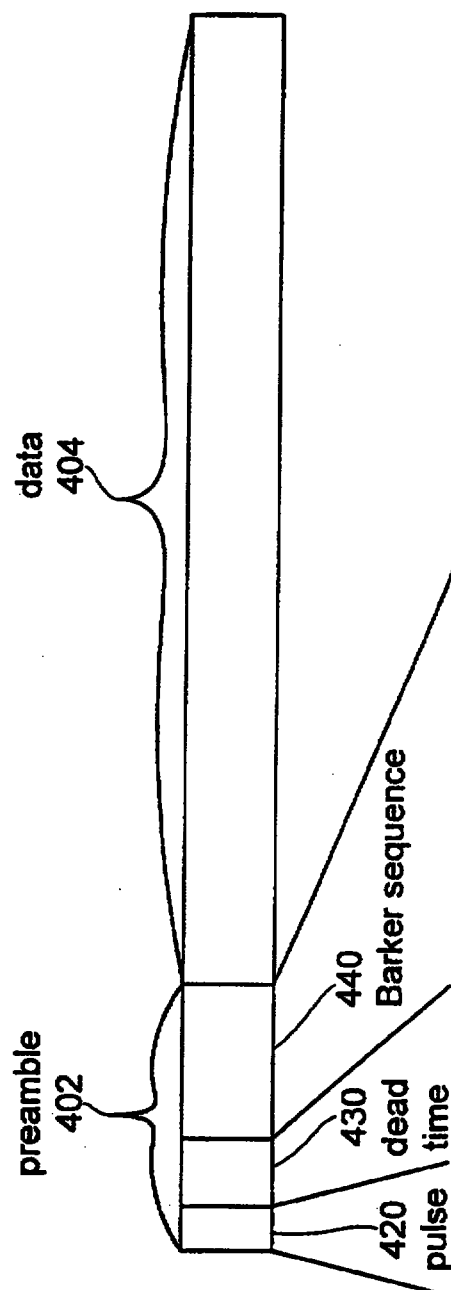


FIG. 4

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TABLE I
I AND Q VALUES IN PREAMBLE

I	Q
1	1
0	0
0	0
1	-1
1	1
1	-1
1	1
1	-1
-1	-1
-1	1
1	1
1	-1
-1	-1
1	-1
-1	-1
1	-1

FIG. 5

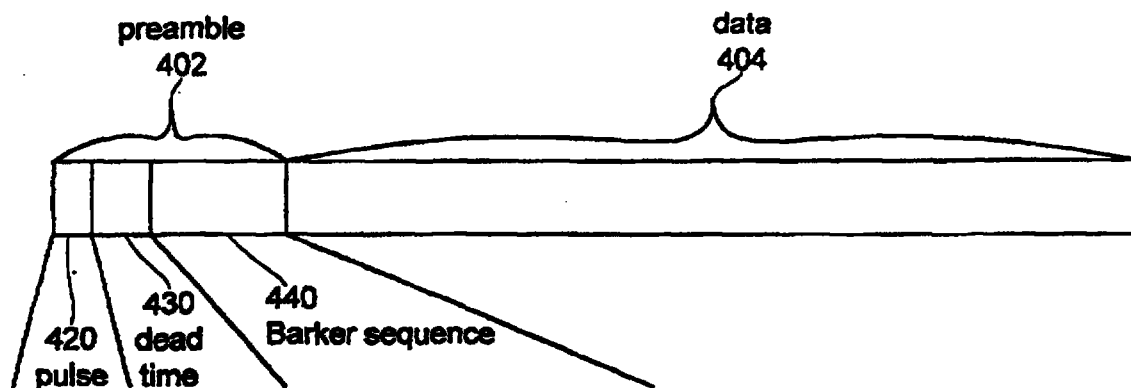
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International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : H04L 27/28, 23/02, H04K 1/10, H04J 13/00		A1	(11) International Publication Number: WO 97/14241
			(43) International Publication Date: 17 April 1997 (17.04.97)
(21) International Application Number: PCT/US96/17070		(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 11 October 1996 (11.10.96)			
(30) Priority Data: 60/005,444 12 October 1995 (12.10.95) US			
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Published
With international search report.

(54) Title: BURST MODE PREAMBLE



(57) Abstract

In a burst mode communications system (figs. 1 and 2), bursts of information with a known preamble (402), fig. 4 are transmitted from a burst mode transmitter and are received by a burst mode receiver which uses the preamble to determine the presence of a burst and to determine the correct carrier frequency, carrier phase, symbol clock frequency and symbol clock phase in order to correctly recover the symbols transmitted, and thus the information contained within the burst. The present invention involves a method of burst transmission using a preamble (402) which contains an initial pulse (420) and a Barker sequence (440) following the initial pulse separated by a dead time (430) period equal to the transmission time of at least one symbol. The preamble can be transmitted on orthogonal carriers (fig. 5) and the order to the Barker sequence (440) can be reversed and multiplied by minus one on one of the carrier to reduce the probability that noise events on both carriers make the Barker sequence less detectable on each channel.