(51) International Patent Classification ⁶ : H04B 1/69	A1	(11) International Publication Number: WO 95/12924
		(43) International Publication Date: 11 May 1995 (11.05.95)

(54) Title: SPREAD SPECTRUM SPECTRAL DENSITY TECHNIQUES
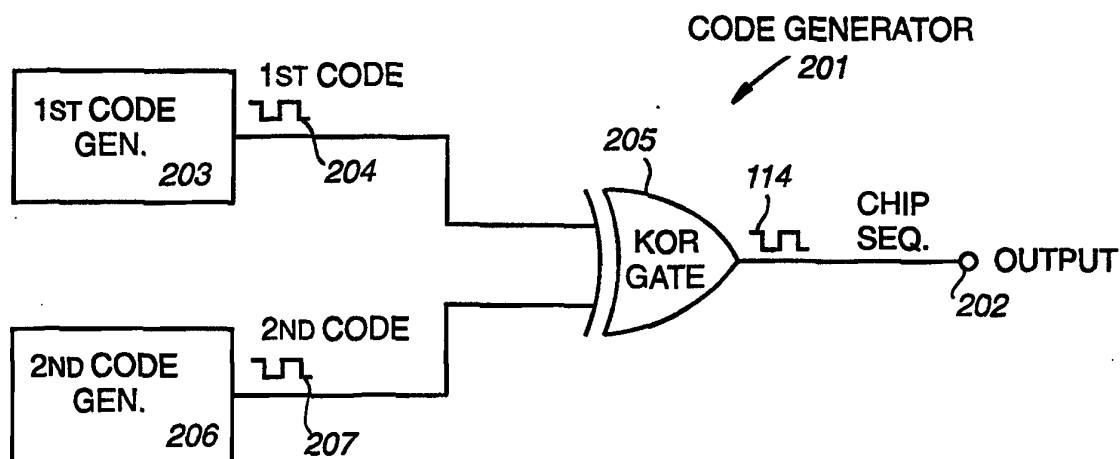
(57) Abstract

A spread-spectrum communication system in which the energy output is more smoothly distributed than the length of the pseudo-random code would otherwise indicate. A spread-spectrum communication system in which the code sequence is pseudo-randomly inverted (205) on data-bit boundaries, so that the code sequence (204) appears longer, for energy spreading, that it otherwise would appear.

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DESCRIPTION

Spread Spectrum Spectral Density Techniques

Background of the Invention
1. Field of the Invention
    This invention relates to spectral density techniques
for use with spread-spectrum modulation.

 5 2. Description of Related Art
        In direct-sequence spread-spectrum communication, a
data stream may be modulated with a pseudo-random code, so
that the energy of the modulated signal is spread over a
bandwidth which is larger than the bandwidth of the data
10 stream. Present regulations, for communication in a band
    of electromagnetic spectrum in which spread-spectrum
    communication is allowed, generally require all parts of
    the modulated signal to be no more than +8 db power over
    the signal average, measured over a 3 KHZ resolution
15 bandwidth. In a spread-spectrum system which uses rela-
    tively short pseudo-random codes, the modulated signal may
    at times not be sufficiently random to meet the regulatory
    requirement. Accordingly, it would be advantageous to
    generate a spread-spectrum signal using relatively short
20 pseudo-random codes which meets the regulatory require-
    ment.

    Summary of the Invention
        The invention provides a spread-spectrum communication
    system in which the energy output is more smoothly dis-
25 tributed than the length of the pseudo-random code would
    otherwise indicate. In particular, the invention provides
    a spread-spectrum communication system in which the code
    sequence is pseudo-randomly inverted on data-bit bound-
    aries, so that the code sequence appears longer, for
30 energy spreading, than it otherwise would appear.

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Brief Description of the Drawings

        Figure 1 shows a block diagram of a spread-spectrum
communication transmitter and receiver.

        Figure 2 shows a block diagram for a pseudo-random
5   code generator for use in a spread-spectrum communication
system.

Description of the Preferred Embodiment

        Figure 1 shows a block diagram of a spread-spectrum
communication transmitter and receiver.

10   A spread-spectrum transmitter 101 may comprise an
input port 102 for input data 103, a chip sequence trans-
mitter generator 104, a modulator 105, and a transmitting
antenna 106 for transmitting a spread-spectrum signal 107.
A spread-spectrum receiver 108 may comprise a receiver
15 antenna 109, a chip sequence receiver generator 110, a
demodulator 111, and an output port 112 for output data
113.   In a preferred embodiment, a single chip sequence
114 is identically generated by both the transmitter
generator 104 and the receiver generator 110, and appears
20 essentially random to others not knowing the spreading
code upon which it is based. An extensive discussion of
spread-spectrum communication, spreading codes, and chip
sequences, may be found in R. Dixon, SPREAD SPECTRUM
SYSTEMS (1984).

25   Figure 2 shows a block diagram for a pseudo-random
code generator for use in a spread-spectrum communication
system.

        The transmitter generator 104 and the receiver genera-
tor 110 may comprise a code generator 201, having an
30 output 202 for the chip sequence 114.   In a preferred
embodiment, the chip sequence 114 may comprise a 63-chip
maximal-length pseudo-random chip sequence, which is
pseudo-randomly inverted by XOR-ing with a second chip
sequence at each data bit boundary.

35   The code generator 201 comprises a first generator 203
which generates a first code 204. In a preferred embodi-

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ment, the first code 204 may comprise a 63-chip linear
maximal-length code. An output from the first generator
203 is coupled to a first input of an XOR gate 205. A
second generator 206 is clocked at the same rate as the
5   data stream, and generates a second code 207, which is
coupled to a second input of the XOR gate 205. The output
of the XOR gate 205 is coupled to the output 202 for the
code generator 201.

The code generator 201 thus generates a complete
10   sequence of the first code 204 for each data bit, but
pseudo-randomly inverts the first code 204 by XOR-ing it
with the second code 207 at each data bit boundary (i.e.,
each full data bit is modulated either with the full
length of the first code 204 or with the full length of
15   the inverse of the first code 204).

It will be clear to those of ordinary skill in the
art, after perusal of this application, that the effect of
pseudo-randomly inverting the first code 204 at each data
bit boundary is to more smoothly distribute the energy of
20   the modulated signal over the bandwidth it occupies. In
a preferred embodiment, the first code 204 is $2^N - 1$ chips
long, e.g., 63 chips long, the second code 207 is $2^P - 1$
chips long, e.g., 63 chips long, and the modulated signal
has about 4 to 7 db maximum power over the signal average,
25   measured in a 3 KHz resolution bandwidth.

Alternative Embodiments

While preferred embodiments are disclosed herein, many
variations are possible which remain within the concept
and scope of the invention, and these variations would
30   become clear to one of ordinary skill in the art after
perusal of the specification, drawings and claims herein.

For example, information which is transmitted from
transmitter to receiver is referred to herein as "data",
but it would be clear to those of ordinary skill in the
35   art that these data could comprise both data and error-
correcting codes, control information, or other signals,

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and that this would be within the scope and spirit of the
invention.

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Claims

1.   A method, comprising the steps of
receiving a plurality of data bits;
generating a pseudo-random chip sequence and an
5   inverse of said pseudo-random chip sequence;
pseudo-randomly selecting one or the other of
said pseudo-random chip sequence or its inverse;
generating a new chip sequence in response to
said selection; and
10   modulating each one of said plurality of data
bits with said new chip sequence.

2.   A method as in claim 1, wherein said step of
pseudo-randomly selecting comprises the steps of
generating a second pseudo-random chip sequence,
15   said second pseudo-random chip sequence comprising one
chip for each data bit; and
generating said new chip sequence in response to
a boolean operation performed on said original pseudo-
random chip sequence and said second pseudo-random chip
20   sequence.

3.   A method, comprising the steps of
receiving a plurality of data bits;
receiving a pseudo-random chip sequence; and
generating a spread-spectrum signal in response
25   to said plurality of data bits and said pseudo-random chip
sequence, said spread-spectrum signal having a smoother
spectral energy density than that of a spread-spectrum
signal generated by direct-sequence modulation of said
plurality of data bits with said pseudo-random chip
30   sequence.

4.   A method as in claim 3, wherein said pseudo-
random chip sequence is a 63-chip maximal length code.

5.   A method, comprising the steps of

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receiving a plurality of data bits;

receiving a pseudo-random chip sequence; and

generating a spread-spectrum signal in response
to said plurality of data bits and a transformation of
5   said pseudo-random chip sequence, said spread-spectrum
signal having a smoother spectral energy density than that
of a spread-spectrum signal generated by direct-sequence
modulation of said plurality of data bits with said
pseudo-random chip sequence.

10   6.   A method as in claim 5, wherein said pseudo-
random chip sequence is a 63-chip maximal length code.

7.   A method as in claim 5, wherein said transforma-
tion of said pseudo-random chip sequence is an inverse of
said pseudo-random chip sequence.

15   8.   A method, comprising the steps of

receiving a plurality of data bits;

generating a first pseudo-random chip sequence at
a rate of more than one chip per bit;

generating a second pseudo-random chip sequence
20   at a rate of no more than one chip per bit;

generating a signal in response to said first and
second pseudo-random chip sequences; and

spread-spectrum modulating said plurality of data
bits with said signal.

25   9.   A method as in claim 8, wherein said step of
generating a signal comprises XOR-ing said first and
second pseudo-random chip sequences.

10.   A method as in claim 8, wherein said first
pseudo-random chip sequence is a 63-bit maximal length
30   code.

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11. A method as in claim 8, wherein said second pseudo-random chip sequence has a rate of exactly one chip per bit.

12. A code generator for use in a spread spectrum communication system comprising:
        a first pseudo-noise generator having as an output a first chip sequence,
        a second pseudo-noise generator having as an output a second chip sequence,
        an XOR gate, said XOR gate having as inputs said first chip sequence and said second chip sequence, and having as an output either said first chip sequence or an inverse of said first chip sequence in response to said second chip sequence.

13. The code generator of claim 12 further comprising a modulator comprising a first and second input, said output of said XOR gate coupled to said first input, and a data signal coupled to said second input.

14. The code generator of claim 13 wherein said data signal comprises a series of data bits clocked at a predefined rate, and said second chip sequence comprises a series of chips, wherein said second chip sequence is clocked at said predefined rate.

15. The code generator of claim 13 wherein a signal output from said modulator is coupled to a transmitter, and said transmitter transmits said modulator signal over a communication channel.

16. A method of generating a spread spectrum signal comprising the steps of
        receiving a plurality of data bits;
        generating a first pseudo-random chip sequence,

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generating at selected intervals either a second pseudo-random chip sequence or an inverse of said second pseudo-random chip sequence in response to said first pseudo-random chip sequence, and forming a modulation
5   signal thereby;
        modulating each one of said plurality of data bits with said modulation signal.

        17.   A method as in claim 16, wherein said selected intervals correspond to boundaries of said data bits.

10   18.   A spread spectrum code generator comprising:
        a   first   pseudo-noise   generator   capable   of outputting a first chip sequence,
        a   second   pseudo-noise   generator   capable   of outputting a second chip sequence,
15   means   for   selecting   either   said   first   chip sequence or an inverse of said first chip sequence in response to said second chip sequence, and generating an output signal thereby.

        19.   A spread spectrum code generator as in claim 18,
20 wherein said means for selecting comprises and XOR gate having as inputs said first chip sequence and said second chip sequence.

        20.   A spread spectrum code generator as in claim 18 wherein said output signal is modulated with a data signal
25 comprising data bits clocked at a predefined rate, and said second chip sequence has a chip rate equal to said predefined rate.
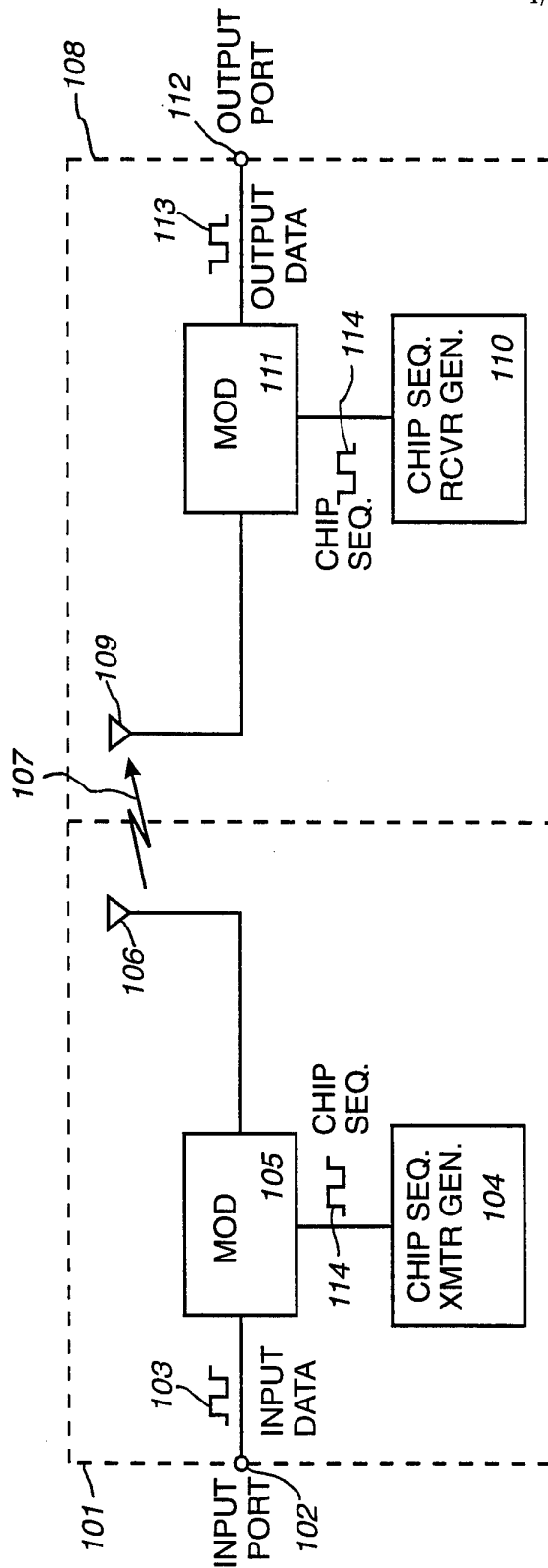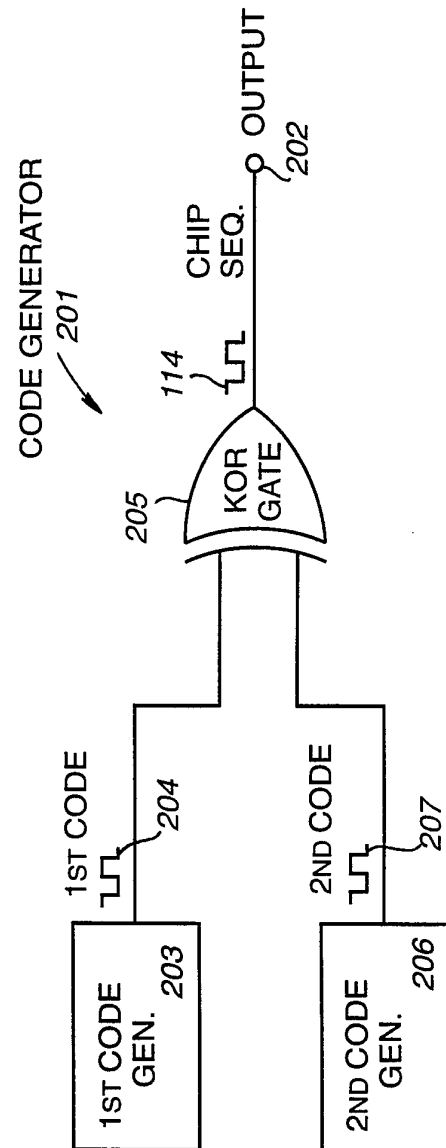
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FIG. 1

FIG. 2

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 1/69
US CL :375/1; 380/46

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)

U.S. : 375/1; 380/46

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 practicable, 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	US, A, 5,150,377 (VANNUCCI) 22 September 1992	1-20
A	US, A, 4,774,715 (MESSENGER) 27 September 1988	1-20

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:
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"E"	earlier document published on or after the international filing date
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"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	Date of mailing of the international search report
01 FEBRUARY 1995	28 FEB 1995

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Form PCT/ISA/210 (second sheet)(July 1992)*