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(54) Title: PULSE POSITION MODULATION WITH SPREAD SPECTRUM
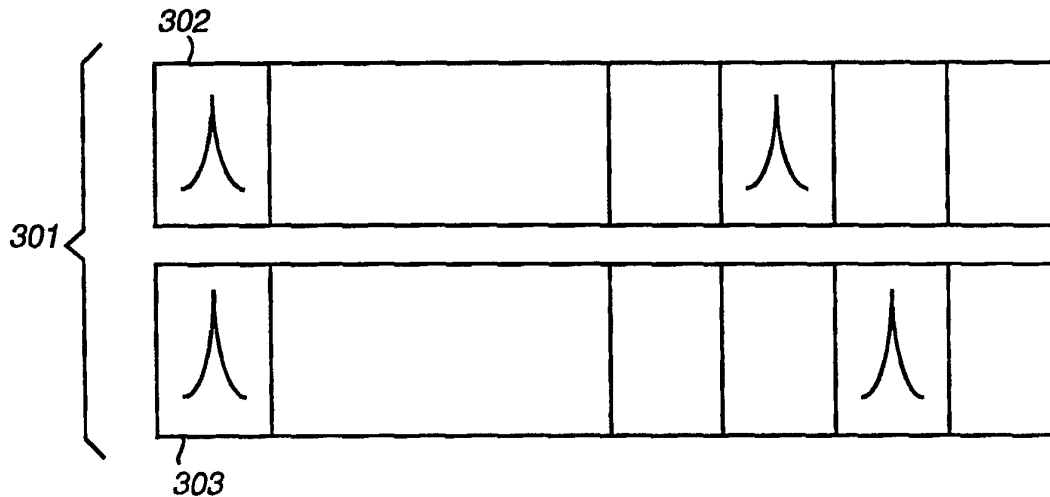
(57) Abstract

A method of pulse-position modulation in a spread-spectrum communication system which is capable of transmitting more than one bit per received and recognized chip sequence in a system in which an entire chip sequence is required to produce a correlation pulse. A framing pulse window (202) in which a framing pulse (204) may be received, and a plurality of data pulse windows (203) in which a data pulse (205) may (or may not) be received. The delay between the framing pulse window (202) and the first data pulse window (203) may comprise an entire chip-sequence duration, while the delay from one data pulse window to the next may be less. A method of pulse-position modulation with more than one spread-spectrum code (301, 302, 303). A second transmission medium (such as a second spread-spectrum code) on which a data pulse may (or may not) be received. Each possible choice, for the data pulse, of delay time and transmission code may represent a separate set of multiple data bits. A method of transmitting signals in a spread-spectrum communication system in which a spread-spectrum chip sequence may be interrupted with reduced noise. The system may ground the transmitter antenna at the end of a chip sequence when it is desired to delay transmission of the next chip sequence.

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DESCRIPTION

Pulse Position Modulation With Spread Spectrum

Background of the Invention

1. Field of the Invention

This invention relates to pulse-position modulation in
a spread-spectrum communication system.

5   2. Description of Related Art

In pulse-position modulation, a time delay between a
first pulse and a second pulse is used to encode data.
For example, a short time delay between the first and
second pulses may indicate a logical "0", while a long
10   time delay may indicate a logical "1". Successive time
delays between successive pulses may be used to encode a
stream of data bits. The receiver is able to determine
the encoded stream of data bits by measuring the time
delays between successive pulses.

15   In spread-spectrum modulation, a pseudo-random chip
sequence is used to encode data. The resulting encoded
signal is generally spread across a spectrum bandwidth
which substantially exceeds the data-transfer rate, hence
the term "spread-spectrum". The receiver produces a
20   correlation pulse in response to the received spread-
spectrum signal when it is able to match the chip sequence
to a sufficient degree. Spread-spectrum communication
often takes place in a noisy transmission environment.

One problem which has arisen in spread-spectrum
25   communication is distinguishing those pulses which are
produced by a true signal from those which are produced in
response to noise, echoing, or other causes. One solution
adopted by the assignee is to modulate each data bit with
the entire chip sequence. This method is advantageous in
30   reducing problems associated with synchronizing transmit-
ter and receiver. However, to achieve a high data trans-

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mission rate, it requires a high transmission rate for the
chip sequence.

Pulse-position modulation would appear well suited to
a high data rate. However, in spread-spectrum communica-
5   tion, precise timing of the incoming signal can be degrad-
ed due to the requirement of generating a correlation
pulse at the receiver. Moreover, in a system where each
data bit is modulated with the entire chip sequence,
delays between received pulses of less than the entire
10   chip sequence in length would be difficult.

Accordingly, it would be advantageous to transmit data
in a noisy environment, at a high data transmission rate,
in which true pulses are easily distinguished from false,
and in which synchronization between transmitter and
15   receiver is easily achieved.

Summary of the Invention

The invention provides for pulse-position modulation
in a spread-spectrum communication system. The invention
also provides a system which is capable of transmitting
20   more than one bit per received and recognized chip se-
quence in a system in which an entire chip sequence is
required to produce a correlation pulse. The system may
comprise a framing pulse window in which a framing pulse
may be received, and a plurality of data pulse windows in
25   which a data pulse may (or may not) be received. In a
preferred embodiment, the delay between the framing pulse
window and the first data pulse window may comprise an
entire chip-sequence duration, while the delay from one
data pulse window to the next may be less.

30   The invention also provides for pulse-position modula-
tion with more than one spread-spectrum code. The system
may comprise a second transmission medium (such as a
second spread-spectrum code) on which a data pulse may (or
may not) be received. In a preferred embodiment, each
35   possible choice, for the data pulse, of delay time and

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transmission code may represent a separate set of multiple
data bits.

The invention also provides for transmitting signals
in a spread-spectrum communication system, in which a
5   spread-spectrum chip sequence may be interrupted with
reduced noise. In a preferred embodiment, the system may
ground the transmitter antenna at the end of a chip
sequence when it is desired to delay transmission of the
next chip sequence.

10 Brief Description of the Drawings
        Figure 1 shows a block diagram of a spread-spectrum
communication transmitter and receiver.
        Figure 2 shows a timing diagram for pulse-position
modulation in a spread-spectrum communication system.
15   Figure 3 shows a timing diagram for pulse-position
modulation with more than one spread-spectrum code.
        Figure 4 shows a timing diagram of a transmitted
spread-spectrum signal when it is desired to delay trans-
mission of the next chip sequence.

20 Description of the Preferred Embodiment
        Figure 1 shows a block diagram of a spread-spectrum
communication transmitter and receiver.
        A spread-spectrum transmitter 101 may comprise an
input port 102 for input data 103, a chip sequence trans-
25 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
antenna 109, a chip sequence receiver generator 110, a
demodulator 111, and an output port 112 for output data
30 113. 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
essentially random to others not knowing the spreading
code upon which it is based. An extensive discussion of
35 spread-spectrum communication, spreading codes, and chip

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sequences, may be found in R. Dixon, SPREAD SPECTRUM
SYSTEMS (1984).

Framing Pulse Window And Data Pulse Windows

Figure 2 shows a timing diagram for pulse-position
5 modulation in a spread-spectrum communication system.

After spread-spectrum communication is established,
the transmitter 101 and the receiver 108 may agree upon a
timing window 201 for pulse-position modulation of data.
The timing window 201 may comprise a framing pulse window
10 202 at or near the beginning of the timing window 201, and
at least one data pulse window 203 following the framing
pulse window 202. In a preferred embodiment, the framing
pulse window 202 may comprise the time slot beginning with
the start of the timing window 201 and continuing for 651
15 nanoseconds thereafter. In a preferred embodiment, there
may be eight data pulse windows 203, each lasting 651
nanoseconds and each beginning at 5.208 microseconds, plus
a multiple of (0, 1, 2, 3, 4, 5, 6, or 7 times) 651
nanoseconds, after the beginning of the timing window 201
20 respectively.

To perform pulse-position modulation, the transmitter
101 may transmit a framing pulse 204 during the framing
pulse window 202. Because the framing pulse window 202
must occur at a known time, the receiver 108 may reject as
25 false all pulses which it detects outside the framing
pulse window 202. (Alternatively, it may treat such
pulses as indicating lack of synchronization.) After
receiving the framing pulse 204, the receiver 108 may look
for a data pulse 205 during one of the data pulse windows
30 203. Similarly, because the data pulse 205 must occur at
one of a set of known times, the receiver 108 may reject
as false all pulses which it detects outside the data
pulse windows 203.

In a preferred embodiment, the receiver 108 determines
35 during which of the data pulse windows 203 the data pulse
205 was received. When there are four data pulse windows

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203, there are four possibilities, and the choice of one
of those four possibilities by the transmitter 101 gives
two bits of information to the receiver 108. If the
receiver 108 does not detect the data pulse 205 during any
5 of the data pulse windows 203, it may reject the transmis-
sion as indicating an error.

In an alternative embodiment, the receiver 108 may
recognize its not receiving the data pulse 205 during any
of the data pulse windows 203 as an additional choice
10 available to the transmitter 101. For example, if there
is just one data pulse window 205, the presence or absence
of the data pulse 205 during the data pulse window 203
would involve a choice of one of those two possibilities,
and thus give the receiver 108 one bit of information. If
15 there are three data pulse windows 203, the choice of one
of those three possibilities, plus the fourth possibility
of not transmitting the data pulse 205 at all, would give
the receiver 108 two bits of information.

In a second alternative embodiment, the framing pulse
20 204 may be omitted. In such an embodiment, the receiver
108 may synchronize its operation with that of the trans-
mitter 101, so the receiver 108 may determine the start of
the framing pulse window 202 substantially simultaneously
(after allowing for transmission delays) with the trans-
25 mitter 101, and so the receiver 108 may determine the
timing of the data pulse windows 203 substantially simul-
taneously (after allowing for transmission delays) with
the transmitter 101.

In a preferred embodiment, the entire chip sequence
30 114 of 64 chips may be used to generate a correlation
pulse, and the correlation pulse may be adjusted in
duration increments of eight chips. At a transmission
rate of about 192 KHz, it takes about 5.208 microseconds
to transmit the entire chip sequence 114, so the offset
35 between the beginning of the framing pulse window 202 and
the beginning of the first data pulse window 203 is

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therefore 5.208 microseconds. However, if the chip
sequence 114 is not started immediately after the framing
pulse 202 is generated, the start time may be offset by
only a small amount. The offset between the successive
5 data pulse windows 203 is therefore only 651 nanoseconds.

More Than One Spread-Spectrum Code

Figure 3 shows a timing diagram for pulse-position
modulation with more than one spread-spectrum code.

The transmitter 101 and the receiver 108 may also
10 agree to use more than one transmission medium for pulse-
position modulation. In a preferred embodiment, the
transmitter 101 and the receiver 108 may agree upon a
plurality of spread-spectrum codes 301 for communication.
(To reduce false correlations, the plurality of spread-
15 spectrum codes 301 may be pairwise relatively orthogonal.)
Due to the nature of spread-spectrum communication, the
transmitter 101 may generate signals for each spread-
spectrum code essentially independently, and the receiver
108 may receive these signals essentially independently,
20 as if they were transmitted and received on separate
media.

To perform pulse-position modulation with more than
one spread-spectrum code 301, the transmitter 101 may
transmit the framing pulse 204 during the framing pulse
25 window 202 and with a first code 302. It is not necessary
to transmit the framing pulse 204 during the framing pulse
window 202 and with a second code 303, because the receiv-
er 108 may determine the time from only a single framing
pulse 204. After receiving the framing pulse 204, the
30 receiver 205 may look for the data pulse 205 during one of
the data pulse windows 203 on either the first code 302 or
the second code 303. (In a preferred embodiment, two
spread-spectrum codes 301 are used, but this disclosure
applies equally well to techniques which use more than two
35 spread-spectrum codes 301.)

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In a preferred embodiment, the receiver 108 determines during which of the data pulse windows 203, and on which of the spread-spectrum codes 301, the data pulse 205 was received. When there are four data pulse windows 203 and

5   two spread-spectrum codes 301, there are eight possibilities, and the choice of one of those eight possibilities by the transmitter 101 gives three bits of information to the receiver 108. If the receiver 108 does not detect the data pulse 205 during any of the data pulse windows 203,

10 on any of the spread-spectrum codes 301, it may reject the transmission as indicating an error.

In an alternative embodiment, the receiver 108 may recognize its not receiving the data pulse 205 during any of the data pulse windows 203, for any of the spread-

15 spectrum codes 301, as an additional choice available to the transmitter 101. The receiver would thus be able to interpret such an event similar to its treatment of failing to receive the data pulse 205 when using only one of the spread-spectrum codes 301.

20 In a second alternative embodiment, the receiver may recognize receiving the data pulse 205 separately for each of the spread-spectrum codes 301. Thus, after receiving the framing pulse 204 for the first spread-spectrum code 302, the receiver 108 may detect the data pulse 205 during

25 one of the data pulse windows 203 for the first spread-spectrum code 302 and during one of the data pulse windows 203 for the second spread-spectrum code 303. When there are four data pulse windows 203 and two spread-spectrum codes 301, there are sixteen possibilities, and the choice

30 of one of those sixteen possibilities by the transmitter 101 gives four bits of information to the receiver 108.

In a third alternative embodiment, more than one communication path may be used in place of the more than one spread-spectrum code 301. For example, transmission

35 noted above to be using the first code 302 may use spread-spectrum techniques, while transmission noted above to be

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using the second code 303 may be replaced with other techniques, e.g., one of the following:

- o   transmission using narrowband techniques;
- o   transmission using spread-spectrum techniques
5   using a different set of frequencies;
- o   transmission using spread-spectrum techniques using a different set of multiplexed time slots;
- o   transmission using spread-spectrum techniques over a different communication path (such as in
10   a packet switched network);
- o   transmission using another communication medium (such as wire, coaxial cable, or microwave trans-mission); or
- o   other transmission techniques which can be dis-
15   tinguished by the receiver 108.

In a preferred embodiment, the chip sequence 114 of the first code 302 may be 64 chips, and the chip sequence of the second code 303 may be the same 64 chips, in reverse order.

20 Minimizing Noise When Delaying Chip Sequence

Figure 4 shows a timing diagram of a transmitted spread-spectrum signal when it is desired to delay trans-mission of the next chip sequence.

The invention also provides for transmitting signals
25 in a spread-spectrum communication system in which a spread-spectrum chip sequence may be interrupted with reduced noise. In a preferred embodiment, the system may ground the transmitter antenna at the end of a chip sequence when it is desired to delay transmission of the
30 next chip sequence.

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

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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 art that these data could comprise both data and error-correcting codes, control information, or other signals, and that this would be within the scope and spirit of the invention.

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Claims

1.   A method of communication, comprising the step of transmitting a pulse-position modulated signal in a spread-spectrum communication system.

5   2.   A method of communication, comprising the steps of
         transmitting a first spread-spectrum pulse during a framing pulse window; and
         either transmitting or not transmitting a second
10   spread-spectrum pulse during a data pulse window, respon-sive to a data bit.

3.   A method of communication, comprising the steps of
         transmitting a first spread-spectrum pulse during
15   a framing pulse window;
         selecting one of a plurality of data pulse windows, responsive to at least one data bit; and
         transmitting a second spread-spectrum pulse during the selected data pulse window.

20   4.   A method of communication, comprising the steps of
         transmitting a first entire spread-spectrum chip sequence timed to end during a framing pulse window;
         selecting one of a plurality of data pulse
25   windows, responsive to at least one data bit; and
         transmitting a second entire spread-spectrum chip sequence timed to end during the selected data pulse window.

5.   A system for spread-spectrum communication,
30   comprising
         a framing pulse window, during which a spread-spectrum framing pulse may be received;

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a plurality of data pulse windows, during each of which a data pulse may be received or not received, a first one of said data pulse windows being offset from said framing pulse window by a predetermined time dura-

5   tion.

6.   A system as in claim 5, wherein said first one of said data pulse windows is offset from said framing pulse window by at least an entire spread-spectrum chip sequence.

10   7.   A   system   for   spread-spectrum   communication, comprising

a framing pulse window, during which a spread-spectrum framing pulse may be received;

a plurality of data pulse windows, during each of

15 which a data pulse may be received or not received;

each one of said plurality of data pulse windows being offset from said framing pulse window by a predetermined time duration specific to said one data pulse window.

20   8.   A system as in claim 7, wherein a first one of said plurality of data pulse windows is offset from said framing pulse window by at least an entire spread-spectrum chip sequence.

9.   A system as in claim 7, wherein said plurality of

25 data pulse windows comprises a first and a second data pulse window, and wherein said second data pulse window is offset from said first data pulse window by less than an entire spread-spectrum chip sequence.
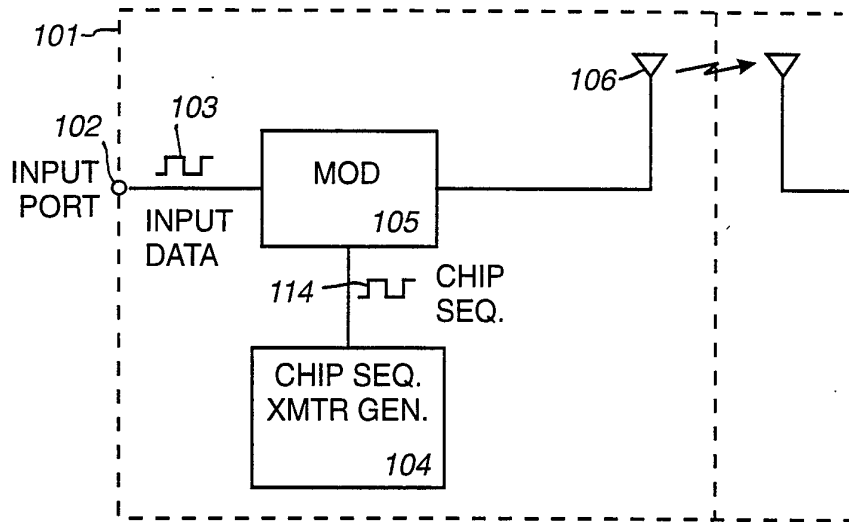
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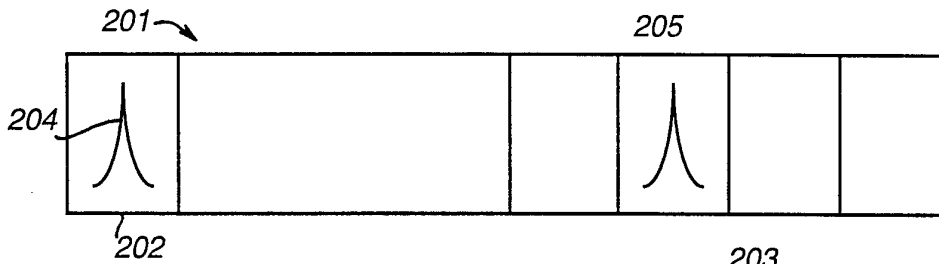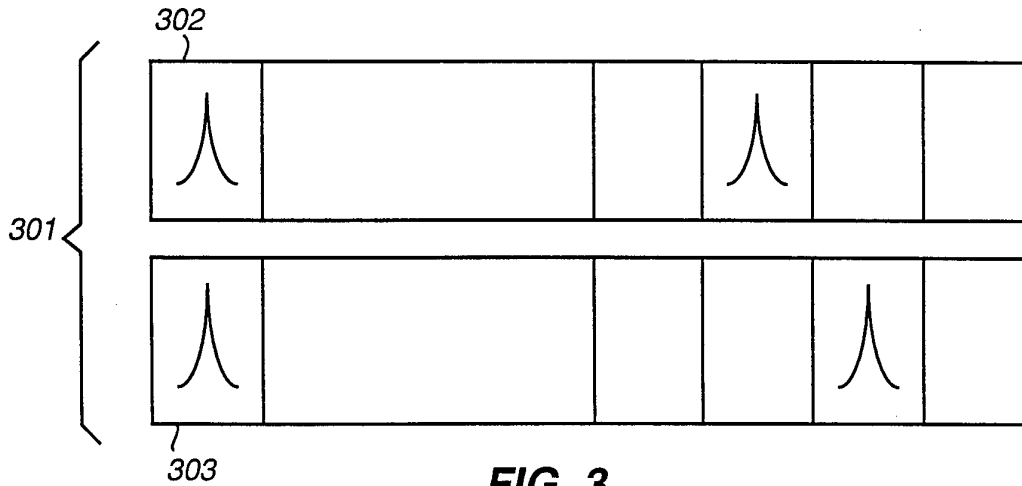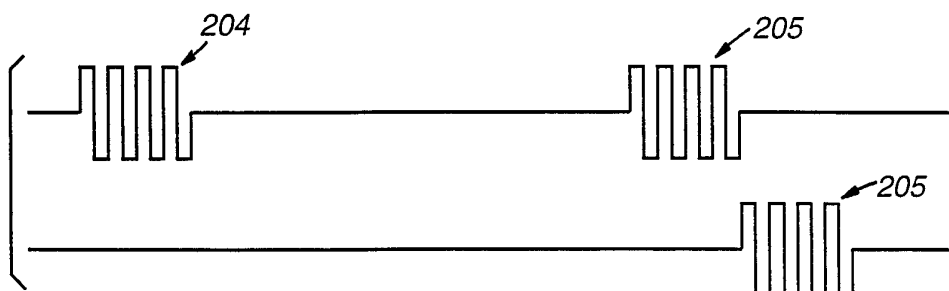
FIG. 1

FIG. 2

FIG. 3

FIG. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :HO4L 9/00
US CL :375/1
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

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.
Y	US, A, 5,157,686 (OMURA ET AL) 20 October 1992, See Fig. 1A.	1-9
Y	US, A, 5,166,952 (OMURA ET AL ET AL) 24 November 1992, See Fig. 1A.	1-9
A	US, A, 5,253,268 (OMURA ET AL) 12 October 1993, See Fig. 1A.	1-9

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

*	Special categories of cited documents:	"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
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"O"	document referring to an oral disclosure, use, exhibition or other means		
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Date of the actual completion of the international search	Date of mailing of the international search report
04 DECEMBER 1994	31 JAN 1995

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