



(51) International Patent Classification:

H04L 27/18 (2006.01) *H04B 1/69* (2011.01)
H03M 7/00 (2006.01) *H04J 13/00* (2011.01)

(21) International Application Number:

PCT/CA2015/000340

(22) International Filing Date:

26 May 2015 (26.05.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/002,978 26 May 2014 (26.05.2014) US

(71) Applicant: **POLYVALOR, LIMITED PARTNERSHIP**
[CA/CA]; 3535 Queen-Mary Road, Suite 220, Montreal,
Quebec H3V 1H8 (CA).

(72) Inventors: **NIKFAL, Babak**; 101 Place Charles Lemoyne,
Apt. 322, Longueuil, Quebec, J4K 2T3 Canada (CA).
CALOZ, Christophe; 4750 MacMahon, Montréal, QC
H4B 2B4 (CA). **SALEM, Mohamed, Ahmed**; 4261 Rue
de la Roche, Apt. 5, Montreal Quebec, H2J 3H8 Canada
(CA).

(74) Agent: **IP DELTA PLUS INC.**; 2965 Place Cherry, Saint-
Laurent, Quebec H4R 3A5 (CA).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG,
MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM,
PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,
SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: A METHOD AND APPARATUS FOR ENCODING DATA USING INSTANTANEOUS FREQUENCY DISPERSION

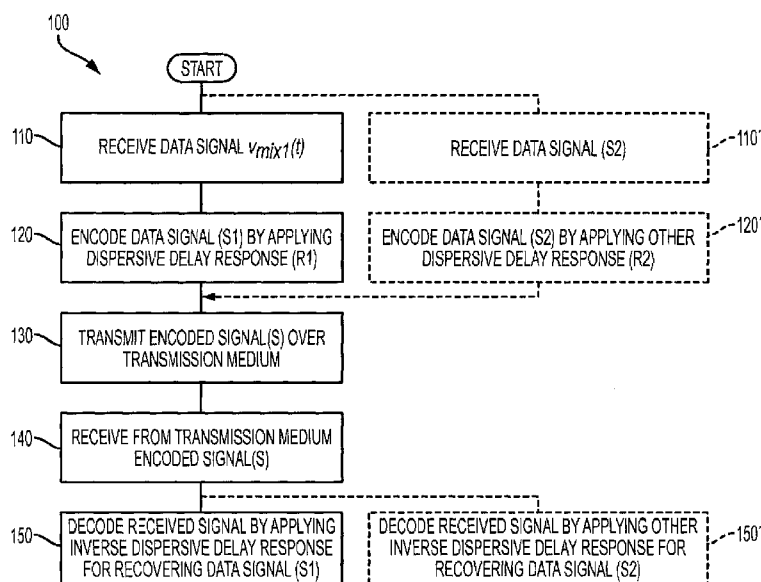


FIG. 1

(57) Abstract: The present disclosure relates to a method of encoding a data signal, a transmitter and a receiver. The method receives the data signal and encodes the data signal by applying a dispersive delay response to the data signal thereby generating an encoded data signal. The transmitter comprises at least one phaser for applying a dispersive delay response to the signal thereby generating an encoded data signal. The receiver comprises at least one phaser for decoding the received encoded data signal by applying an inverse dispersive delay response to the received encoded data signal.



Published:

— with international search report (Art. 21(3))

A METHOD AND APPARATUS FOR ENCODING DATA USING INSTANTANEOUS FREQUENCY DISPERSION

TECHNICAL FIELD

[0001] The present disclosure relates to encoding of data for transmission over Multiple Access medium. More specifically, the present disclosure relates to a method and apparatus for encoding data using instantaneous frequency dispersion.

BACKGROUND

[0002] Multiple Access (MA) is a communication method that allows several terminals connected to a multi-point transmission medium (e.g. cable, air or optical fiber) to transmit and receive data via multiple communication channels. The main MA methods are Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Space Division Multiple Access (SDMA).

[0003] Chirp Spread Spectrum (CSS) is a technique developed within the Institute of Electrical and Electronics Engineers (IEEE) Computer Society standard 802.15.4a. CSS resorts to chirping techniques to encode information. However, CSS is currently only applicable to precision ranging and does not provide encoding of data that could be used in the context of Multiple Access.

[0004] Therefore, there is a need for a new data encoding method and apparatus using dispersive techniques to encode information for providing Multiple Access communications.

SUMMARY

[0005] In accordance with a first aspect, the present disclosure relates to a method of encoding a data signal. The method comprises receiving the data

signal, and encoding the data signal by applying a dispersive delay response to the data signal thereby generating an encoded data signal.

[0006] In accordance with a second aspect, the present disclosure relates to a transmitter for encoding a data signal. The transmitter comprises at least one phaser for applying a dispersive delay response to the signal thereby generating an encoded data signal.

[0007] In another aspect, the present disclosure relates to a receiver for decoding a received encoded data signal. The receiver comprises at least one phaser for decoding the received encoded data signal by applying an inverse dispersive delay response to the received encoded data signal, thereby decoding the received encoded data signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of the disclosure will be described by way of example only with reference to the accompanying drawings, in which:

[0009] Figure 1 illustrates a method for encoding a data;

[0010] Figure 2 illustrates a transmitter and receiver for encoding and decoding a data signal;

[0011] Figure 3 shows transmitters and receivers for encoding and decoding multiple data signals;

[0012] Figures 4A and 4B illustrate signals respectively transmitted and received by the transmitters and receivers of Figure 3;

[0013] Figure 5 illustrates Chebyshev polynomials of multiple orders for use in the transmitter and receiver of Figure 2; and

[0014] Figure 6 illustrates use of the transmitter and receiver of Figures 2 and 3 in a multi-transmitter / multi-receiver environment.

DETAILED DESCRIPTION

[0015] The foregoing and other features will become more apparent upon reading of the following non-restrictive description of illustrative embodiments thereof, given by way of example only with reference to the accompanying drawings. Like numerals represent like features on the various drawings.

[0016] Various aspects of the present disclosure generally address one or more of the problems related to encoding and decoding data signals.

[0017] The following terminology is used throughout the present specification:

[0018] Multiple Access (MA): communication method allowing several terminals connected to a multi-point transmission medium (e.g. cable, air or optical fiber) to transmit and receive data via plural communication channels and thereby share available bandwidth.

[0019] Chirping: concept of instantaneous frequency increase (positive chirping) or instantaneous frequency decrease (negative chirping) of a signal over time.

[0020] Phaser: electromagnetic (electric or optic) component delaying the different spectral components of a signal over time.

[0021] Dispersion Coded Multiple Access (DCMA): Multiple Access method using phasing (or dispersive) techniques.

[0022] The present method, transmitter and receiver provide a new and simple encoding/decoding technique. Encoding is performed by applying a dispersive delay response to the data signal, and decoding is performed by

applying an inverse dispersive delay response to the encoded signal, thereby recovering the data signal. Various types and combinations of dispersive delay responses may be applied to the data signal, which provides countless encoding options and thereby an unlimited number of channels. Complementary dispersive delay response provides correct signal recovery while further spreading the signals from other channels, hence reducing the interference.

[0023] Referring now concurrently to Figures 1 and 2, a method 100 and transmitter 200 / receiver 300 for encoding/decoding a data signal and transmitting/receiving the encoded data signal are represented. The method 100 comprises steps implemented by the transmitter 200 for encoding the data signal before transmission over a transmission medium 230, and steps implemented by the receiver 300 for decoding the encoded signal received from the transmission medium 230.

[0024] The method 100 comprises receiving 110 a data signal $v_{mix1}(t)$ (represented as reference 210 in Figure 2). The data signal 210 may be generated by the transmitter 200 (as illustrated in Figure 2). Alternatively, the signal 210 may be generated by another component (not represented in Figure 2) and received at the transmitter 200 for encoding. For example, generating the data signal 210 may include the following steps: receiving a binary data signal 202, generating a wide-band Gaussian-type pulse 204 for the received binary data signal 202, and multiplexing the wide-band Gaussian pulse 204 with a carrier frequency f_0 to generate the data signal 210.

[0025] The method 100 also comprises encoding 120 the data signal 210 by applying a dispersive delay response $\tau_1(\omega)$ 216 to the data signal 210. The resulting signal is an encoded signal $v_{tr1}(t)$ 220. The dispersive delay response 216 is applied by an encoder (phaser) 215 in the transmitter 200.

[0026] The group delay is defined as the derivative of the phase with respect to angular frequency, i.e. $\tau_1(\omega)$, and is a measure of the dispersion

introduced by group differences for different frequencies. Applying the dispersive delay response 216 to the data signal 210 thus consists in applying a delay varying as a function of angular frequency to the data signal 210, thus spreading in time and encoding the data signal 210. This operation may be performed in any of the following manner taken solely or in combination: spreading with positive chirping, spreading with negative chirping, alternately changing the phase of the instantaneous frequency of the data signal 210 over time throughout a fixed frequency interval. Dispersion is introduced by the encoder 215, which consists of a phaser, which generally exhibits a delay versus frequency response that corresponds to a Chebyshev function.

[0027] The method 100 further comprises transmitting 130 the encoded signal 220 over the transmission medium 230. The transmission medium 230 may consist of any type of electromagnetic or optical signal communication media, such as for example: cable, twisted-pair wire, an optical fiber, a microwave waveguide, wirelessly by means of antennas, etc. The transmission 130 is performed by a component of the transmitter 200 (not represented in Figure 2), which depends on the transmission medium 230 (e.g. electrical connector for an electrical cable, optical connector for an optical fiber, antenna for wireless).

[0028] The method further comprises receiving 140 from the transmission medium 230 the encoded signal at a receiver 300. The received signal 320 represented in Figure 2 only comprises the encoded signal 220. However, the received signal 320 may also comprise additional encoded signal(s) combined with the encoded signal 220, as will be illustrated later in the description. Furthermore, as known to those skilled in the art, the received signal 320 may be affected by known negative transmission conditions, such as fading, interference, path loss, etc. As the received signal 320 may be affected by such negative transmission conditions, a reference numeral distinct than the encoded signal 220 transmitted on the transmission medium 230 is used for the received signal 320.

[0029] The method further comprises decoding 150 the received signal 320 at the receiver 300 by applying an inverse dispersive delay response 316 to the received signal 320. The decoding is performed by a decoder 315 in the receiver 300. Thus, the decoding 150 inverts the dispersive delay response applied to the data signal 210 by the transmitter, so as to recover the data signal 210, i.e. decoding the received signal. Inverse is used to mean compensating, e.g. if 1, 2 and 3 GHz were delayed by 1, 2 and 3 ns at the transmitter, respectively, then the corresponding receiver will delay 1, 2 and 3 GHz by 3, 2 and 1 ns (opposite sequence), respectively. In this way, the total delay for three frequencies will be $1+3=2+3=3+1=4$ ns, leading to a constant overall delay, and therefore a simple time shift (without distortion) of the original signal. Alternately, in the case of a Chebyshev phaser with order > 1 , a non-monotonic (i.e., neither purely increasing nor purely decreasing) sequence of delays in frequency is applied to reverse the applied sequence of delays at the transmitter. The decoder 315 thus receives the received signal 320, and inverts the dispersive delay response 316 effect to recover the decoded signal 310. In the case that the data signal 210 was encoded by a phase such as a Chebyshev phase, the decoder 315 is an inverse Chebyshev phaser, i.e. a phaser which inverts the dispersive delay response 316.

[0030] Thus applying the dispersive delay response 216 to the data signal 210 consists in encoding in instantaneous frequency and spreading in time the data signal 210 as a function of angular frequency, while inverting the dispersive delay response 316 on the received signal 320 consists in decoding by compressing in time as a function of angular frequency the received signal 320 for recovering the data signal 210. As a simple example, if the data signal 210 is spread with positive chirping, the received signal 320 is compressed with a corresponding negative chirping. Alternatively, if the data signal 210 is spread with negative chirping, the received signal 320 is compressed with a corresponding positive chirping.

[0031] Receiving 140 the encoded signal is performed by a component of the receiver 300 (not represented in Figure 2), which depends on the transmission medium 230 (e.g. electrical connector for an electrical cable, optical connector for an optical fiber, antenna for wireless).

[0032] Figures 1 and 2 illustrate a particular method for generating the data signal 210, which is illustrative only and is not intended to be in any way limiting. Other embodiments will readily suggest themselves to such persons with ordinary skill in the art having the benefit of the present disclosure. Those skilled in the art will understand that the data signal 202 is not a signal square impulse, but rather a series of square impulses, also known as a data stream. The data stream 202 is transformed into a smoother pulse train 204 by the wide-band Gaussian pulse generator (essentially a low-pass filter) 203. The smoother pulse train 204 is converted into a modulated pulse train corresponding to the data signal 210 by a mixer 205 or a multiplexer having a local oscillator frequency f_0 .

[0033] The transmitter 200 represented in Figure 2 comprises a single encoder 215 for encoding a single data signal 210 by applying the dispersive delay response 216 to the single data signal 210, the present method and transmitter are not limited to a single encoder 215.

[0034] Although the present encoder and decoder may rely on phasers and filters, those skilled in the art will recognize that the frequency and phase response of phasers and filters are very different. In a phaser, the linear chirp response is a particular case of the positive and negative Chebyshev function with order 1. Chebyshev phasers of order 2, 3, 4 (and minus those) are phasers with more complicated group delay responses. Generally, filters impose a flat group delay response versus frequency, which inhibits any possible analog signal processing. Phasers do the opposite of filters, i.e. they keep the magnitude response constant (all pass) if possible, and the phase as dispersive as possible, allowing the group delay to be dependent on frequency when within certain ranges of operation of course.

[0035] Turning now to Figure 3, the transmitter 200 may comprise a plurality of encoders (for example 215 and 215') for encoding a plurality of data signals 210 and 210' by applying different dispersive delay responses 216 and 216' to each of the data signals 210 and 210'. A plurality of encoded signals 220 and 220' are generated by the plurality of encoders 215 and 215' and transmitted over the transmission medium 230. The receiver 300 receives a signal 320 comprising a combination of the encoded signals 220 and 220' propagated over the transmission medium 230. The receiver 300 may comprise a plurality of decoders 315 and 315' for decoding the received signal 320. Each decoder 315 and 315' applies an inverse dispersive delay response 316 and 316' to the received signal 320. The inverse dispersive delay responses 316 and 316' correspond (i.e. inversely) to the dispersive delay responses 216 and 216' for recovering the corresponding data signals 210 and 210'. The dispersive delay responses (e.g. 216 and 216') of the encoders (e.g. 215 and 215') need to have inverse dispersion delay responses in order for the decoders (e.g. 315 and 315') to recover the data signals (e.g. 210 and 210'). The receiver 300 may be capable of decoding all the encoded signals 220 and 220' generated by the transmitter 200. In this case, for each encoder 215 and 215' in the transmitter 200, the receiver 300 comprises a decoder 315 and 315'. Alternatively, the receiver 300 is designed to decode only one of the encoded signals 220 and 220' generated by the transmitter 200. In this case, the receiver 300 comprises a decoder (315 or 315') for applying the inverse dispersive delay response corresponding to one of the encoders 215 and 215' generating the encoded signal (220 or 220') to be decoded. Additionally, several receivers 300 may be used in parallel. Each receiver 300 may be capable of decoding all the encoded signals 220 and 220' generated by the transmitter 200. Alternatively, each receiver 300 may be capable of decoding only one or some of the encoded signals 220 or 220' generated by the transmitter 200. Although Figure 3 shows two encoders 215 and 215' and two decoders 315 and 315', the present invention is not limited to such a configuration, and several more encoders and decoders could be used

concurrently.

[0036] Although not shown on Figures 2 and 3, the transmitter 200 and receiver 300 may both combine the functionalities of a transmitter and a receiver so as to allow two-ways encoded communication as previously discussed.

[0037] Referring now again to Figure 3, the signal 320 received by the receiver 300 comprises a combination of the encoded signals (e.g. 220 and 220'). The inverse dispersive delay response 316 applied by the decoder 315 compresses in time and hence increases in amplitude the component 311 of the received signal 320 corresponding to the encoded signal 220. At the same time, the inverse dispersive delay response 316 applied by the decoder 315 spreads in time and hence decreases in amplitude the component 311' of the received signal 320 corresponding to the encoded signal 220'. Consequently, the component 311' becomes negligible in comparison to the component 311 and the data signal 210 can be recovered.

[0038] Similarly, the inverse dispersive delay response 316' applied by the decoder 315' compresses in time and increases in amplitude the component 311' of the received signal 320 corresponding to the encoded signal 220'. At the same time, the inverse dispersive delay response 316' applied by the decoder 315' spreads in time and decreases in amplitude the component 311 of the received signal 320 corresponding to the encoded signal 220. Consequently, the component 311 becomes negligible in comparison to the component 311' and the data signal 210' can be recovered.

[0039] Thus applying the inverse dispersive delay response results in each decoder compressing in time and increasing in amplitude the component of the received signal 320 corresponding to the encoded signal that needs to be recovered, and spreading in time and decreasing in amplitude the other components of the received signal 320 corresponding to the other encoded signals.

[0040] The encoders (e.g. 215 and 215') of the transmitter 200 and / or the decoders (e.g. 315 and 315') of the receiver 300 may be implemented by phasers, each phaser having a specific response of dispersive delay response. The transmitter 200 may have an array of phasers implementing specific dispersive delay responses, and the receiver 300 may have an array of phasers implementing inverse dispersive delay responses. Each phaser at the receiver 300 operates at substantially the same specific frequency than its inverse phaser on the transmitter 200.

[0041] In a particular aspect, the encoding (i.e. the dispersive delay response) and decoding (i.e. the inverse dispersive delay response) may be implemented by a Chebyshev polynomial function of order n , with n being an integer greater or equal to 1.

[0042] The present encoding/decoding technique by application of a dispersive delay response and application of an inverse dispersive delay response can be further generalized to any combination of encoders 215 and 215' applying any type of relevant dispersive delay responses 216 and 216' (not necessarily a Chebyshev polynomial function type) and decoders 315 and 315' applying inverse dispersive delay responses 316 and 316'. However, Chebyshev polynomial functions (phasers) provide optimal response, since each channel experiences maximal dispersion and exactly the same spreading upon transmission. With Chebyshev phasers, all the channels are exactly on an equal footing. Moreover, employing Chebyshev polynomial functions (phasers) leads to codes that are optimally distributed in terms of diversity.

[0043] For illustration purposes only, the bi-channel DCMA transmission system of Figure 3 uses phasers 215, 215', 315 and 315' with dispersive delay responses 216, 216', 316 and 316' implemented by first-order Chebyshev polynomials (linear dispersive delay responses). On the transmitting side, the data signals 210 and 210' are expanded in time and their peak values are decreased respectively by the transmitting phasers 215 and 215', since (assuming negligible

loss) the total energy of each data signal 210 and 210' is conserved. More specifically, the pulses of the data signal 210 are spread out with positive chirping (increasing the instantaneous frequency) while the pulses of the data signal 210' are spread out with negative chirping (decreasing the instantaneous frequency). On the receiving side, the received signal 320 propagates through the receiving phasers 315 (applying a negative chirping complementary to phaser 215) and 315' (applying a positive chirping complementary to phaser 215'). The received signal comprises the encoded signals 220 and 220' generated by the transmitting phasers 215 and 215'.

[0044] In the phaser 315, the part of the received signal 320 corresponding to the positively chirped signal 220 experiences perfect group delay compensation (equalization) and therefore gets compressed in time and magnified in amplitude to its original shape and magnitude 330. The part corresponding to the negatively chirped signal 220' is further spread out in time and lowered in amplitude 331, since it gets down-chirped another time. As a result, the component 330 corresponding to the transmitted data signal 210 largely emerges above the component 331 corresponding to the transmitted data signal 210'. Thus, the phaser 315 recovers the transmitted data signal 310.

[0045] The converse applies to the phaser 315'. The part of the received signal 320 corresponding to the negatively chirped signal 220' experiences perfect group delay compensation (equalization) and therefore gets compressed in time and magnified in amplitude to its original shape and magnitude 330'. The part corresponding to the positively chirped signal 220 is further spread out in time and lowered in amplitude 331', since it gets up-chirped another time. As a result, the component 330' corresponding to the transmitted data signal 210' largely emerges above the component 331' corresponding to the transmitted data signal 210. Thus, the phaser 315' recovers the transmitted data signal 310'.

[0046] The magnitude ratio of the desired component 330 (or 330') to the undesired component 331 (or 331') corresponds to the square of the magnitude of

the group delay slopes involved. The data signals 210 and 210' can be directly recovered by using comparators, with a threshold placed between the reshaped desired component (330 or 331') maxima and the double spread undesired component (331 or 331') maxima.

[0047] Referring now concurrently to Figures 4A and 4B, in addition to Figure 3, signals transmitted by the transmitter 200 and recovered by the receiver 300 are illustrated.

[0048] Figure 4A represents exemplary data signals 210 and 210' before encoding by the phasers 215 and 215' of transmitter 200. Signal 210 consists in a pulse train conveying the following bit stream: 1-1-0-0-1-1-1-1. Signal 210' consists in a pulse train conveying the following bit stream: 1-1-1-1-1-0-0-0.

[0049] Figure 4B represents the components 331 and 332 obtained after decoding by the phaser 315 of receiver 200 of the combined encoded signals 220 and 220'. Figure 4B also represents the components 331' and 332' obtained after decoding by the phaser 315' of receiver 200 of the combined encoded signals 220 and 220'.

[0050] The original pulse train conveying the bit stream 1-1-0-0-1-1-1-1 corresponding to data signal 210 is recovered from amplified component 331. The undesired component 332 corresponding to the data signal 210' is minimized in amplitude and thus eliminated using a proper threshold as previously mentioned.

[0051] The original pulse train conveying the bit stream 1-1-1-1-1-0-0-0 corresponding to data signal 210' is recovered from amplified component 331'. The undesired component 332' corresponding to the data signal 210 is minimized in amplitude and thus eliminated using the proper threshold.

[0052] The bi-channel DCMA system illustrated in Figure 3 can be generalized to the case of $N > 2$ communication channels by using for example Chebyshev dispersive delay responses specified by Chebyshev polynomial functions of different orders.

[0053] Chebyshev polynomial functions of orders 1 to 5 are illustrated in Figures 5; more specifically order 1 by reference number 510, order 2 by reference number 520, order 3 by reference number 530, order 4 by reference number 540 and order 5 by reference number 550.

[0054] Chebyshev polynomials are defined as follows (where n is the order):

$$T_0(x) = 1$$

$$T_1(x) = x$$

$$T_{n+1}(x) = 2x T_n(x) - T_{n-1}(x)$$

[0055] Chebyshev polynomial functions $T_n(x)$ have the property of minimal maximal absolute values in the interval $[-1, +1]$ for x , where they oscillate between -1 and $+1$ for $T_n(x)$ (as illustrated in Figure 5 for orders 1 to 5). To design a phaser with a Chebyshev polynomial of order n , the independent variable interval x is mapped to the operational bandwidth of the phaser and the Chebyshev amplitude $T_n(x)$ to the dispersive delay response of the phaser, to which an offset is added since delays are always positive in such phasers. This results in a set of N (theoretically unlimited) possible dispersive delay response pairs (a phaser with a specific dispersive delay response on a transmitter and a phaser with a complementary dispersive delay response on a receiver) that can be used to encode N different communication channels sharing the same transmission medium.

[0056] When several Chebyshev polynomials of different orders are used to implement the plurality of phasers for encoding a plurality of communication channels, the operational frequency for each is mapped to the interval $[-1, +1]$ for each Chebyshev polynomial of order n .

[0057] Figure 3 corresponds to the case $N = 2$ (two communication channels), using only an order 1 Chebyshev polynomial with two compensating

dispersive delay responses $T_1(w) = T_1(w) + \tau_0 = w$ and $T_2(w) = -T_1(w) + \tau_0 = -w$ in the transmitters and receivers, where w is the bandwidth normalized frequency. As illustrated in Figure 3, the dispersive delay response $T_1(w)$ is used by phaser 215 in the transmitter 200 and phaser 315' in the receiver 300; while the dispersive delay response $T_2(w)$ is used by phaser 215' in the transmitter 200 and phaser 315 in the receiver 300.

[0058] In the case $N = 4$ (four communication channels), Chebyshev polynomials of order 1 and 2 can be used, with the following additional dispersive delay responses (for the Chebyshev polynomial of order 2) $T_3(w) = T_2(w) + \tau_0 = 2w^2 - 1 + \tau_0$ and $T_4(w) = -T_2(w) + \tau_0 = -2w^2 + 1 + \tau_0$.

[0059] It should be noted that all the communication channels are exactly on an equal footing as far as time spreading and thus signal-to-noise ratio are concerned, thanks to the fact that the sum of a pair of Chebyshev polynomials has the same bounds, leading to the same interval $[T_{\min}, T_{\max}]$ and hence to the same time expansion $T = T_{\max} - T_{\min}$ (the only differences are the different distribution of temporal frequencies over T).

[0060] Referring now to Figure 6, an application of DCMA for a wireless scenario involving multiple transmitting and receiving terminals is illustrated.

[0061] At a given time, four transmitting terminals (610, 620, 630 and 640) are active and one receiving terminal (650) is listening to a message transmitted by one of the transmitting terminals (for example 610).

[0062] The four active transmitting terminals are coding transmitted data pulse trains using phasers with dispersive delay responses of orders +5 for 610 (Chebyshev polynomial of order 5 with positive chirping), -3 for 620 (Chebyshev polynomial of order 3 with negative chirping), +7 for 640 (Chebyshev polynomial of order 7 with positive chirping) and +2 for 640 (Chebyshev polynomial of order 2 with positive chirping).

[0063] The receiving terminal 650 aims at decoding the signal from

transmitting terminal 610. For this purpose, it uses a phaser with the same Chebyshev dispersive delay response but with an opposite slope -5 (Chebyshev polynomial of order 5 with negative sign). This exactly equalizes, and hence maximizes, the peak of the signal 700 received from terminal 610; while spreading out by exactly the same amount (Chebyshev functions property) and hence minimizing the signals 710 received from the other terminals 620, 630 and 640.

[0064] The benefits of implementing DCMA are multiple: resistance to multipath fading caused by dispersion, and increased capacity of the communication medium by allowing communication of several encoded signals on one channel. In addition, implementing DCMA using phasers yields further advantages: simplicity, low-cost, low-power consumption (purely passive) and high-speed (following from the analog and real-time nature of the phasers).

[0065] Furthermore, the present method, transmitter and receiver further provide a very important additional advantage: the present encoding/decoding technique, transmitter and receiver (encoder and decoder) enhance the signal to Gaussian noise. Increasing the signal to noise ratio is always desirable in a wireless communication system, and the higher the signal to noise ratio, the better and more robust the communication between the transmitter and receiver. Thus the present method, encoder and decoder further provide immunity against noise and multipath fading.

[0066] Although the present disclosure has been described hereinabove by way of non-restrictive, illustrative embodiments thereof, these embodiments may be modified at will within the scope of the appended claims without departing from the spirit and nature of the present disclosure.

WHAT IS CLAIMED IS:

1. A method of encoding a data signal, the method comprising:
receiving the data signal; and
encoding the data signal by applying a dispersive delay response to the data signal thereby generating an encoded data signal.
2. The method of claim 1, wherein applying the dispersive delay response consists in spreading the data signal in time.
3. The method of claim 2, wherein spreading the data signal in time is performed by applying a specific phase to each instantaneous frequency of the data signal.
4. The method of claim 3, wherein spreading the data signal in time is performed by applying negative chirping to decrease an instantaneous frequency of the data signal.
5. The method of claim 1 further comprising: transmitting the encoded signal over a transmission medium.
6. The method of claim 5 wherein the transmission medium is an electromagnetic signal communication media, including any of the following: a cable, an optical fiber, a wireless communication medium, a microwave waveguide, or a twisted-pair wire.
7. The method of claim 1, comprising:
receiving a plurality of data signals;
encoding each one of the data signal by applying a different dispersive delay response.

8. The method of claim 1, wherein the dispersive delay response is applied by a phaser having a specific response of group delay versus frequency.
9. The method of claim 8, wherein the specific response of group delay versus frequency is specified by a Chebyshev polynomial of order n , with n being an integer greater or equal to 1 and the data signal frequency band is mapped to the interval -1 to +1 of the Chebyshev polynomial.
10. A transmitter for encoding a data signal, the transmitter comprising:
 - a phaser for applying a dispersive delay response to the signal thereby generating an encoded data signal.
11. The transmitter of claim 11, wherein the dispersive delay response is specified by a Chebyshev polynomial of order n , with n being an integer greater or equal to 1 and the data signal frequency band is mapped to the interval -1 to +1 of the Chebyshev polynomial.
12. The transmitter of claim 11, comprising a plurality of phasers for encoding a plurality of data signals, each phaser applying a specific dispersive delay response to one of the plurality of data signals.
13. A receiver for decoding a received encoded data signal, the receiver comprising:
 - at least one phaser for decoding the received encoded data signal by applying an inverse dispersive delay response to the received encoded data signal.
14. The receiver of claim 13, wherein the inverse dispersive delay response is specified by a Chebyshev polynomial of order n , with n being an integer greater or equal to 1 and the data signal frequency band is mapped to the interval -1 to +1 of the Chebyshev polynomial.
15. The receiver of claim 14, comprising a plurality of phasers for decoding the multiple received encoded data signal, each phaser applying a specific

inverse dispersive delay response to the received encoded data signals for recovering a specific data signal.

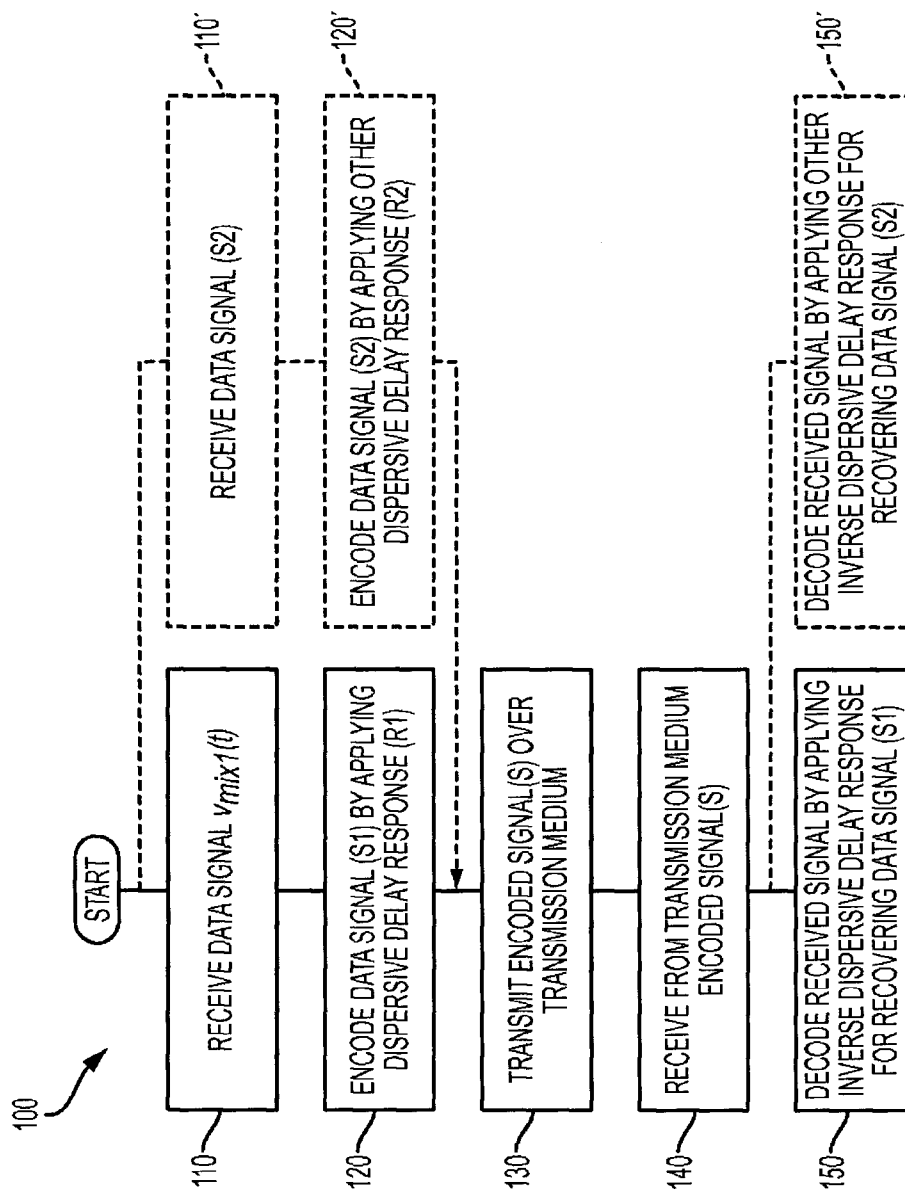


FIG. 1

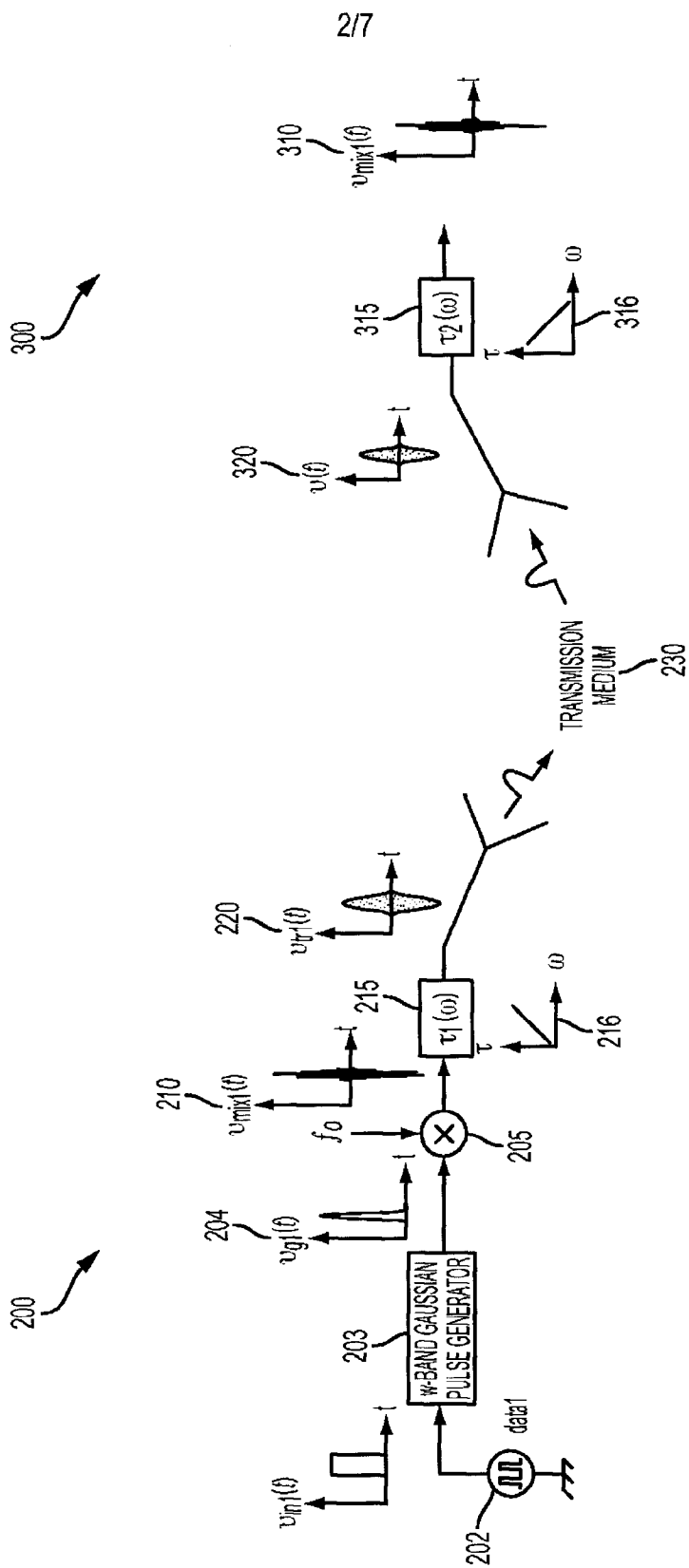


FIG. 2

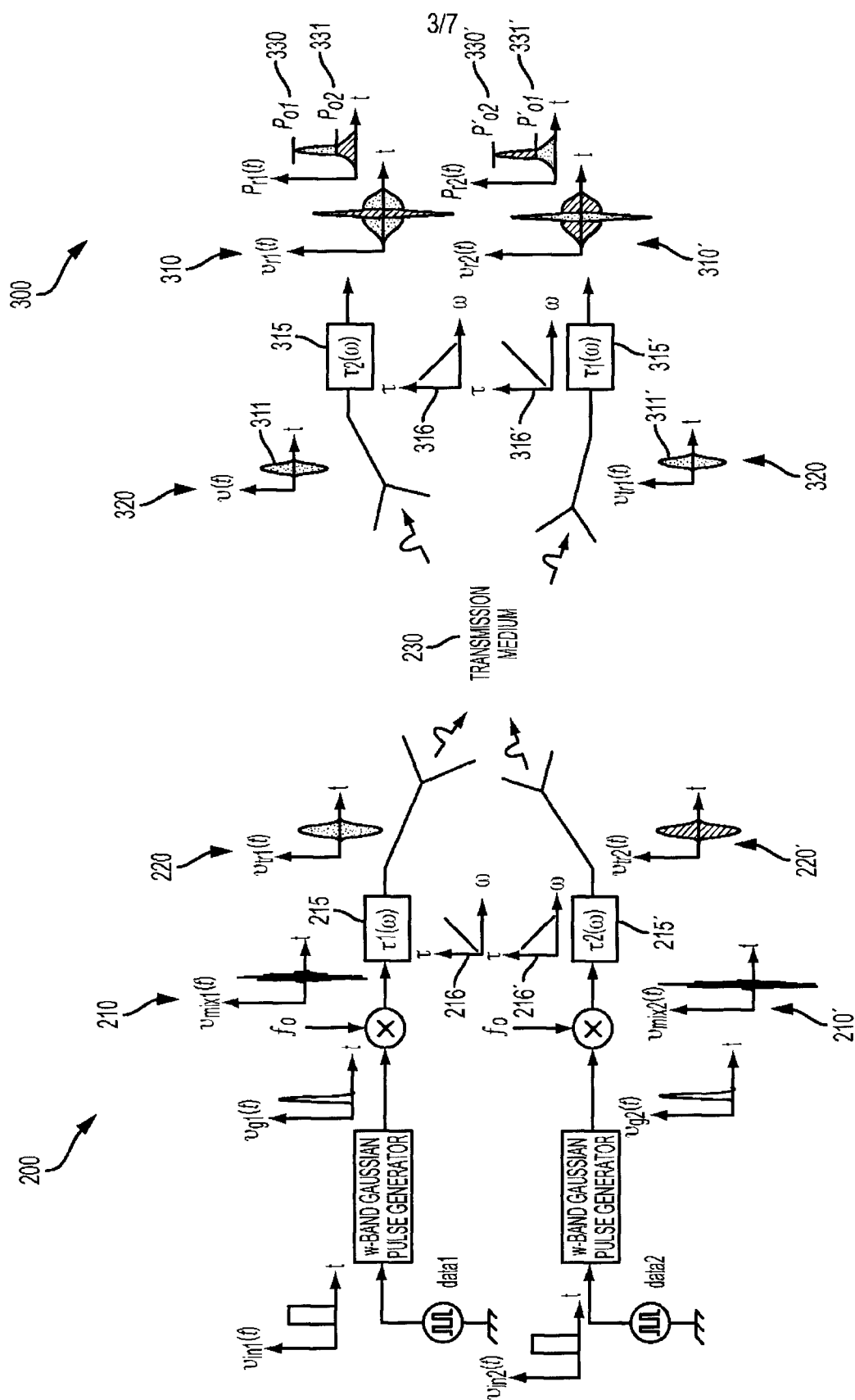


FIG. 3

4/7

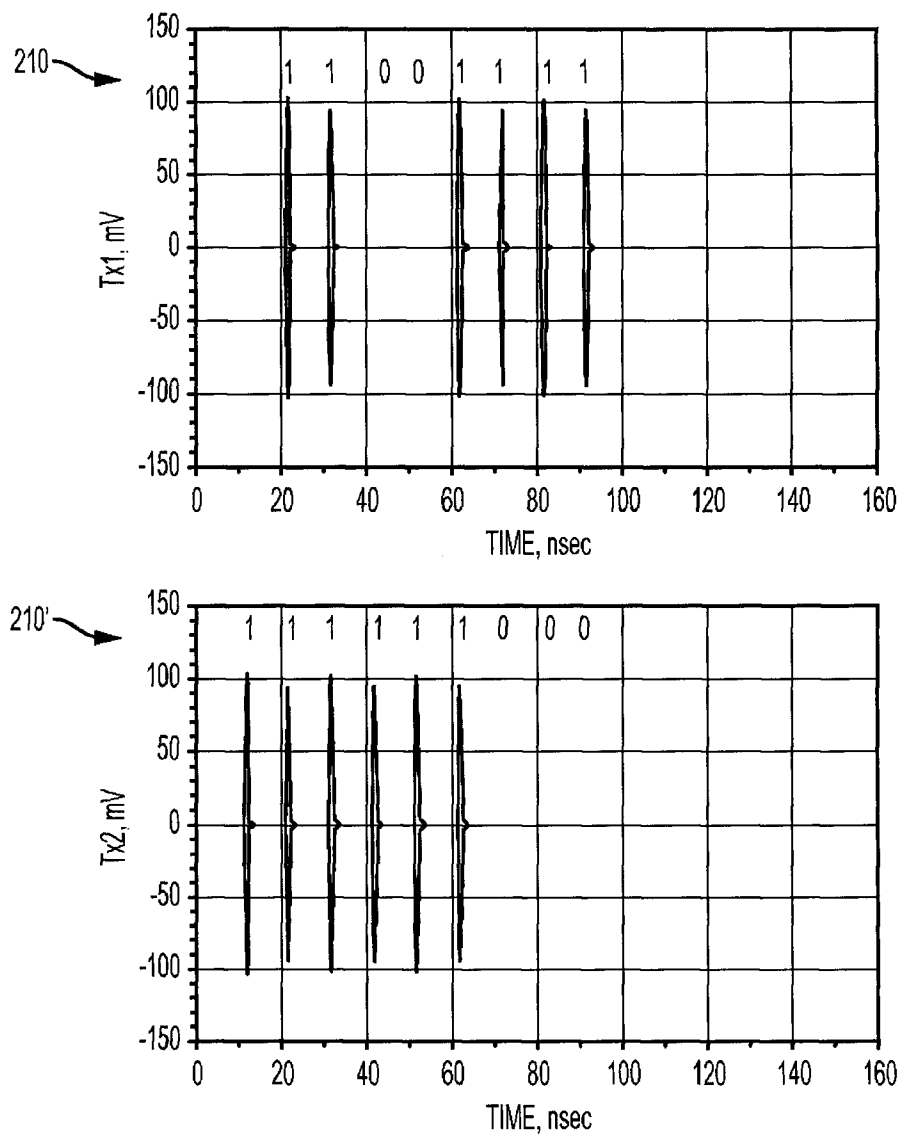


FIG. 4A

5/7

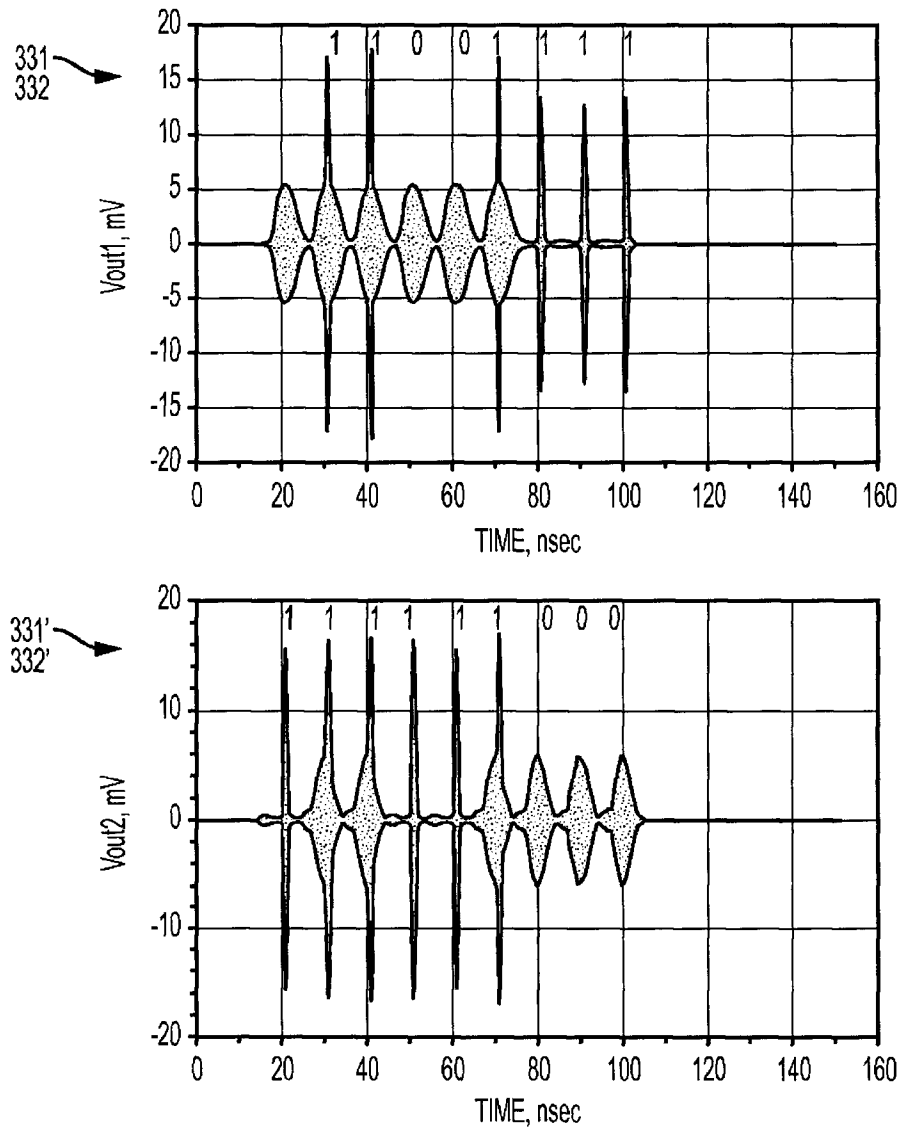


FIG. 4B

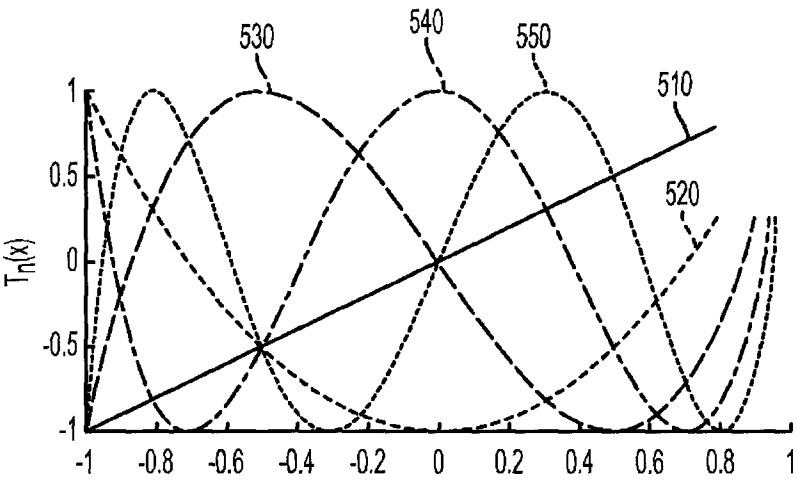


FIG. 5

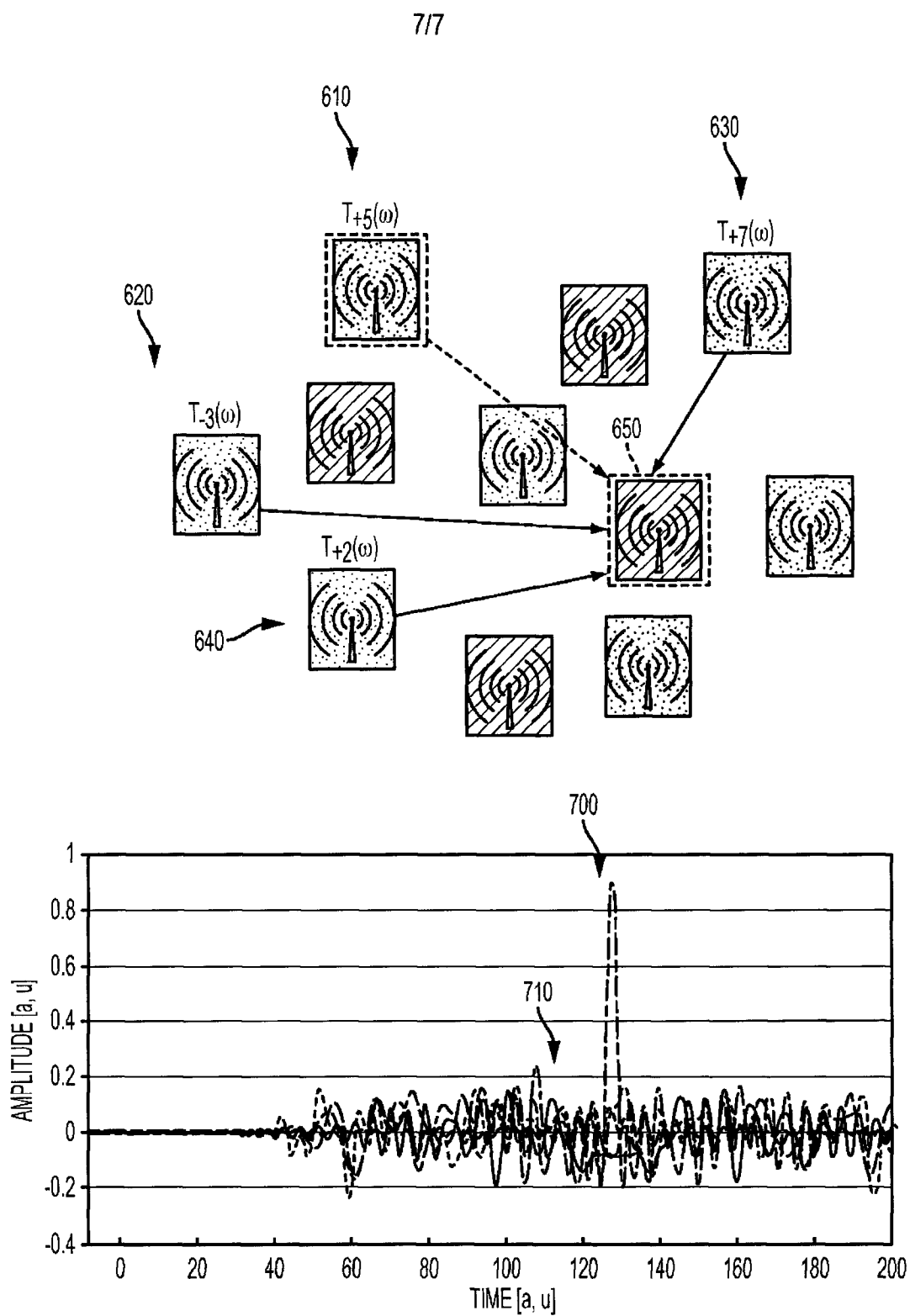


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2015/000340

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **H04L 27/18** (2006.01), **H03M 7/00** (2006.01), **H04B 1/69** (2011.01), **H04J 13/00** (2011.01)

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)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Orbit, Google, IEEEExplore; Keywords: : DISPER+ DELAY+ ENCOD+ INVER+ OPPOS+ CHEBYSHEV POLYNO+ INTERVAL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Caloz et al., "Analog signal processing", IEEE Microwave Magazine, September 2013, pp. 87-103	1-6, 8-11, 14
X	Abielmona, et al., "Compressive receiver using a CRLH-based dispersive delay line for analog signal processing", IEEE Microwave Theory and Techniques, IEEE Transactions on (Volume: 57, Issue: 11), November 2009, pp. 2617-2626.	13

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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search
30 June 2015 (30-06-2015)Date of mailing of the international search report
31 July 2015 (31-07-2015)Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 001-819-953-2476

Authorized officer

Simon Chau (819) 576-2143