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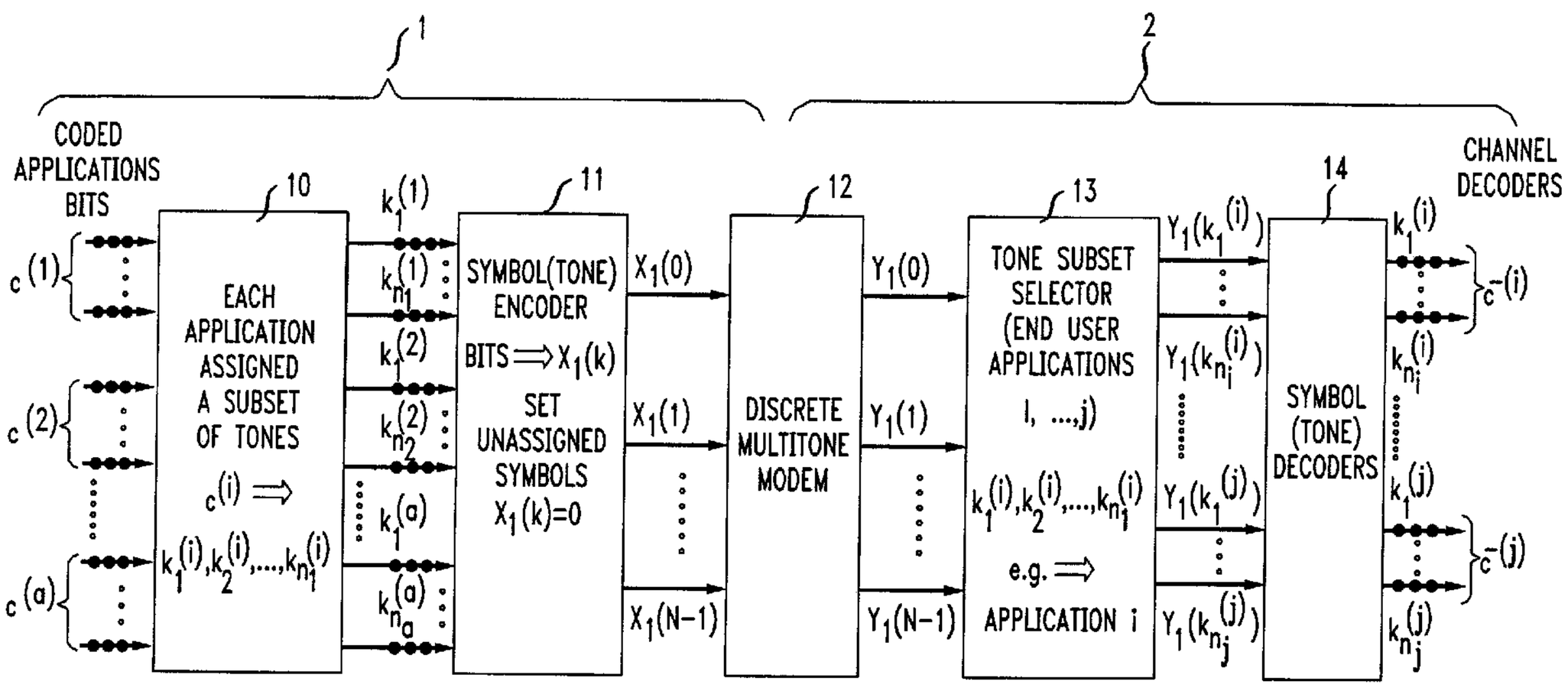
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(54) Titre : METHODE DE SEGMENTATION EN PLUSIEURS TONALITES DE COMMUNICATIONS A ACCES MULTIPLE

(54) Title: METHOD FOR MULTITONE DIVISION MULTIPLE ACCESS COMMUNICATIONS



(57) Abrégé/Abstract:
A method for multiple users accessing a common channel in which coded application bits are generated and transmitted for a plurality of applications for a plurality of users. A plurality of tones are assigned to the coded application bits for each application. The coded application bits for each application are encoded into multitone symbols at a transmitter using the plurality of tones assigned to the coded application bits. The multitone symbols for each application are synchronized for transmission on a common channel. At a receiver, the multitone symbols for each application are received from the common channel and tone decoded into the coded application bits for each application using the plurality of tones assigned to the coded application bits. The coded application bits are then decoded for each application.

ABSTRACT

A method for multiple users accessing a common channel in which coded application bits are generated and transmitted for a plurality of applications for a plurality of users. A plurality of tones are assigned to the coded application bits for each application. The coded application bits for each application are encoded into multitone symbols at a transmitter using the plurality of tones assigned to the coded application bits. The multitone symbols for each application are synchronized for transmission on a common channel. At a receiver, the multitone symbols for each application are received from the common channel and tone decoded into the coded application bits for each application using the plurality of tones assigned to the coded application bits. The coded application bits are then decoded for each application.

Method For Multitone Division Multiple Access Communications

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of telecommunications. More particularly, the present invention relates to a method for multi-user telecommunications.

2. Description of the Related Art

Currently, there are three major non-random multiple access techniques for multi-user communications: FDMA, TDMA and CDMA. In multimedia transmissions, i.e., applications having different data rates, none of these three multiple access techniques is effective in terms of throughput efficiency, hardware implementation, or signal quality. For instance, to accommodate a high bit rate data type, an FDMA approach assigns several frequency subbands that are separated by frequency guardbands and are realized by distinct carriers, resulting in spectral and hardware inefficiency. Similarly, a TDMA approach uses several time slots that are separated by time guardbands and requires accurate timing at both the transmitter and receiver. TDMA leads to throughput loss and intersymbol interference caused by channel distortion, multipath spread, and mistiming. Lastly, a CDMA approach breakdowns the high-rate bit stream to several lower rate bit streams for achieving a sufficiently large processing gain. Each low-rate stream requires spreading and despreading processing. The breakdown to several low-rate streams is also necessary if dynamic assignment of any data types to a CDMA channel is to be achieved. Further, the performance of a CDMA rake receiver degrades considerably in the presence of intersymbol interference.

What is needed is a multiple access technique for multi-user communications that is resistant to intersymbol interference occurring in high-speed

transmission, accommodates multiple user data rates, while keeping hardware implementation simple.

SUMMARY OF THE INVENTION

The present invention provides a multiple access technique for multi-user communications that is resistant to intersymbol interference occurring in high-speed transmission, accommodates multiple user data rates, and keeps hardware implementation simple. In that regard, the present invention provides a new multiple access method for multi-user communications that allows transmission of multiple user data rates over a common channel and has an implementation complexity comparable to that for systems providing single user data rates. Intersymbol interference arising from channel impairments, such as channel distortion and multipath propagation, as well as from transmitter and receiver baseband filtering, is avoided without using channel equalization. For wireless applications having space diversity reception, frequency selective fading is also overcome. The present invention avoids inter-user interference for both point-to-multipoint and multipoint-to-point communications, while greatly relaxing the timing accuracy requirement at a receiver when compared to other multiple access techniques such as CDMA and TDMA.

The advantages of the present invention are provided by a method for multiple users accessing a common channel. Coded application bits are generated for a plurality of applications for a plurality of users. A plurality of tones, which are preferably a subset of available tones, are assigned to the coded application bits for each application. The coded application bits for each application are encoded into multitone symbols at a transmitter using the plurality of tones assigned to the coded application bits. The multitone symbols for each application are synchronized for transmission on a common channel. At a receiver, the multitone symbols for each application are received from the common channel and tone decoded into the coded application bits for each

application using the plurality of tones assigned to the coded application bits. The coded application bits are then decoded for each application.

BRIEF DESCRIPTION OF THE DRAWING

The present invention is illustrated by way of example and not limitation in the accompanying figures in which like reference numerals indicate similar elements and in which:

Figure 1 shows a block diagram of the basic functional elements for a transmitter and a receiver for a downlink (point-to-multipoint) according to the present invention;

Figure 2 shows a block diagram of the basic functional elements of an FFT-based multitone DPSK modem configured as a transmitter according to the present invention;

Figure 3 shows a block diagram of the basic functional elements of an FFT-based multitone DPSK modem configured as a receiver according to the present invention; and

Figure 4 shows a block diagram of the basic functional elements for a transmitter and a receiver for an uplink (multipoint-to-point) according to the present invention.

DETAILED DESCRIPTION

The present invention provides a multiple access method for multi-user communications. The approach of the present invention, referred to as Multitone Division Multiple Access (MDMA), is effective for transmitting multiple data types of different rates, in resisting intersymbol interference, and in maximizing channel throughput. For single or multiple data rate transmissions, the approach of the present invention does not increase system hardware complexity, nor decrease channel

throughput in comparison to FDMA, TDMA, and CDMA approaches. MDMA is resistant to intersymbol interference without using channel equalization, as is required by FDMA, TDMA and CDMA approaches. Furthermore, in realizing inter-user interference free communications for multipoint-to-point links, such as an uplink in a satellite or cellular system, the present invention imposes no stringent transmitter and receiver timing accuracy, as is the case for TDMA and CDMA approaches.

The present invention uses multitone modulation and assigns different application data to different tones. The multitone modulation technique not only serves as a modulation scheme, but also provides a multiple access mechanism. In particular, coded bits for various applications which are originated from, or destined to, a plurality of users are mapped over distinct sets of tones that are assigned to the respective applications at the time the calls are initialized. The bits are encoded into symbols (tones) for discrete multitone modulation, and the reverse demodulation process is performed for recovering received tones and the information bits. Unassigned symbols are set to zero.

For downlink (point-to-multipoint) transmission, a user receiver selects the tones assigned for the applications intended for the user receiver after discrete multitone demodulation so that only the information bits belonging to that user are decoded. For uplink (multipoint-to-point) transmission, the transmission is synchronized among all the users associated with a particular receiver. The demodulated symbols are aligned with associated applications and users so that the decoded bits can be identified properly for further processing. The synchronization accuracy may be greatly relaxed by appropriately designing the multitone modem.

Figure 1 shows a block diagram of the basic functional elements for a transmitter 1 and a receiver 2 for an MDMA downlink (point-to-multipoint). Multiple data streams $c^{(1)}$ through $c^{(a)}$ representing different applications and different users are assigned to distinct subsets of the tones at 10. A subset of tones may comprise the entire

set of available tones, and is established during the setup process for a call. With this pre-assignment of tones, encoding of the channel coded data bits into multitone symbols proceeds at 11. Symbols that are not associated with any applications are set to zero.

The encoded tones for the multiple data streams are then processed by block 12, which represents modulation and transmission of the multiple data streams by transmitter 1, and reception and demodulation of the data streams at receiver 2. Figures 2 and 3 show functional details of an FFT-based multitone DPSK modem system that is suitable for block 12. Following multitone demodulation at receiver 2, the recovered symbols are selected for symbol and channel decoding, if and only if, the symbols are associated with applications at receiver 2. The symbols are properly identified with an application and decoded.

Figure 2 shows a block diagram of the basic functional elements of an FFT-based multitone DPSK modem according to the invention that is configured as a transmitter for a single bit stream. In Figure 2, a sequence of (trellis) coded information bits 20 are input to an MPSK mapper 21. MPSK mapper 21 maps groups of data bits onto MPSK constellation points. In particular, the coded information bits are segmented into frames of M bits. (In this case, the number of constellation points (M) and the number of bits (M) per frame coincidently use the same symbol M. For purposes of the present invention, the number of constellation points M can be different from the number of bits M per frame.) Each frame of M bits is then parsed into N groups, where the k-th group is assigned m(k) bits, and $M = m(0) + m(1) + \ldots + m(N-1)$. Each group is separately mapped into a differential phase $\Delta\phi_l(k)$, where $k = 0, 1, \ldots, N-1$, according to the chosen PSK constellation.

A differential phase encoder 22 operates on two consecutive frames in a well-known manner to generate an absolute phase $\phi_l(k)$. The absolute phase $\phi_l(k)$ is then used by a symbol (tone) encoder 23 for generating a complex symbol $X_l(k)$, or a discrete tone, on the complex signal plane. A complex symbol $X_l(k)$ equals $\bar{X}_l(k)\exp[j\phi_l(k)]$.

The amplitude $X_i(k)$ is chosen for maximizing the overall channel capacity or for achieving desired signal-to-noise ratios across the tones. Next, N complex symbols within each frame pass through a serial-to-parallel (S/P) converter 24 and are applied to the input of an inverse discrete Fourier transform (IDFT) discrete multitone modulator 25. The N complex symbols within each frame are inverse discrete Fourier transformed into N (complex) samples in the time domain via an FFT.

The N parallel samples in each frame are converted to a serial sequence by a parallel-to-serial (P/S) converter 26, which also adds a cyclic prefix and suffix to each frame and further converts the enlarged complex sample sequence into two real data sequences by separating each complex sample into a real part and an imaginary part (R/I). The length of the cyclic suffix is one or two samples, while the length of the cyclic prefix is the length of the cyclic suffix plus the unit-sample response of the overall digital channel including the transmitting and receiving filters as well as the transport medium between the transmitting and receiving filters. The one or two samples added for both prefix and suffix allows for a large timing offset in synchronization and sampling at the receiver, while the other samples appended to the prefix enables interframe free interference, and thus intersymbol-free interference, over a time dispersive channel.

The two real sequences are then passed through two identical lowpass filters 27a and 27b for digital-to-analog (D/A) conversion. Two baseband signals are thus generated, and subsequently they modulate two quadrature carriers at mixers 28a and 28b. After quadrature multiplexing, appropriate power amplification and bandpass filtering at 29, successive (extended) frames are transmitted. The modem of Figure 2 processes multiple bit streams that have each been associated with distinct tone sets in a similar fashion.

Figure 3 shows a block diagram of the basic functional elements of an FFT-based multitone DPSK modem configured as a receiver according to the present

invention. A received RF signal 30 is bandpass filtered, power amplified and split into two components at 31 for non-coherent quadrature demodulation (i.e., frequency down-conversion) at mixers 32a and 32b and lowpass filters 33a and 33b. The resulting quadrature baseband components are sampled in parallel by analog-to-digital (A/D) converters 34a and 34b. The output of A/D converters 34a and 34b are input to an S/P & R/I converter 35, where the two real sample sequences are converted to a complex sample sequence by treating each pair of the real samples as the real part and the imaginary part (R/I) of a complex sample. The samples at the two ends of the extended frame that are associated with the added prefix and suffix are discarded here, and the resulting N complex samples within each frame are further organized into a parallel format by an serial-to-parallel (S/P) converter.

The N parallel complex numbers within each frame are then discrete Fourier transformed via an FFT by discrete multitone demodulator 36 to yield N complex symbols. The N complex symbols are the transmitted tones weighted by the exponential of the locally generated and received carrier phase difference and the frequency response of the overall channel at the corresponding tones, and further corrupted by noise. The N complex symbols pass through a parallel-to-serial (P/S) converter 37, having a serial output that is sent to a frame delay device 38 and a differential phase comparator 39. The output of frame delay device 38 is the input delayed by one frame. Differential phases between the corresponding symbols of two consecutive frames are evaluated by differential phase comparator 39 in a well-known manner without having to determine the received carrier phase or the channel frequency response. The extracted differential phase values are mapped back to coded bits by an MPSK demapper 40 for subsequent channel decoding (not shown). Alternatively, the MPSK demapper and the channel decoder, such as a Viterbi decoder, may be combined for soft-decision decoding.

Figure 4 shows a block diagram of the basic functional elements for a

transmitter 3 and a receiver 4 for an MDMA uplink (multipoint-to-point). The architecture for an uplink is similar to that for the downlink (Figure 1). In particular, each application accessing the uplink is assigned a distinct set of multitone symbols so that messages generated by each application are distinguishable from messages generated by other applications. The unused symbols are again set to zero. All transmissions are frame synchronized with respect to the receiver for avoiding inter-user interference when more than one other user 15 accesses the channel. Synchronization errors of one or even two sample intervals will not cause substantial transmission errors to the present invention where one or two cyclic samples are added to the prefix and suffix of the multitone modulated sample sequences for each frame prior to transmission, as previously mentioned. All the recovered symbols at the receiver after multitone demodulation are identified with the respective applications and users, followed by symbol and channel decoding.

While the present invention has been described in connection with the illustrated embodiments, it will be appreciated and understood that modifications may be made without departing from the true spirit and scope of the invention.

CLAIMS:

1. A method for multiple users to communicate using a common communications channel, comprising the steps of:

generating coded application bits for a plurality of applications;

assigning a plurality of tones to the coded application bits for each application;

encoding the coded application bits for each application into multitone symbols at a transmitter using the plurality of tones assigned to the respective coded application bits;

transforming the multitone symbols into complex time-domain samples using an inverse discrete Fourier transform; and

transmitting the complex time-domain samples transformed from the multitone symbols for each application on a common channel using a discrete multitone modem.

2. The method according to claim 1, wherein the plurality of tones assigned to the coded bits of an application is a subset of available tones.

3. The method according to claim 1, wherein the step of generating coded application bits is done for a plurality of users; and

the step of transmitting the complex time-domain samples on the common channel includes the step of synchronizing transmissions among the plurality of users with respect to a destination receiver.

4. The method according to claim 3, wherein the common channel is a multipoint-to-point uplink channel.

5. The method according to claim 1, further comprising the steps of:

receiving the complex time-domain samples for each application from the common channel using the discrete multitone modem;

transforming the complex time-domain samples to multitone symbols using a discrete Fourier transform;

decoding the multitone symbols for each application into coded application bits for each application at a receiver using the plurality of tones assigned to the coded application bits; and

decoding the coded application bits for each application.

6. The method according to claim 5, wherein the step of generating decoded application bits is done for a plurality of users.

7. A method for multiple users to receive communications using a common communication channel, comprising the steps of:

receiving complex time-domain samples transformed from multitone symbols for each of a plurality of applications from a common channel using a discrete multitone modem at a receiver, the multitone symbols for each application being a plurality of coded application bits encoded using a plurality of tones assigned to each plurality of coded application bits;

transforming the complex time-domain samples to multitone symbols using a discrete Fourier transform;

decoding the multitone symbols for each application into coded application bits for each application at the receiver using the plurality of tones assigned to the coded application bits; and

decoding the coded application bits for each application.

8. The method according to claim 7, wherein the step of decoding the coded application bits is done for a plurality of users.

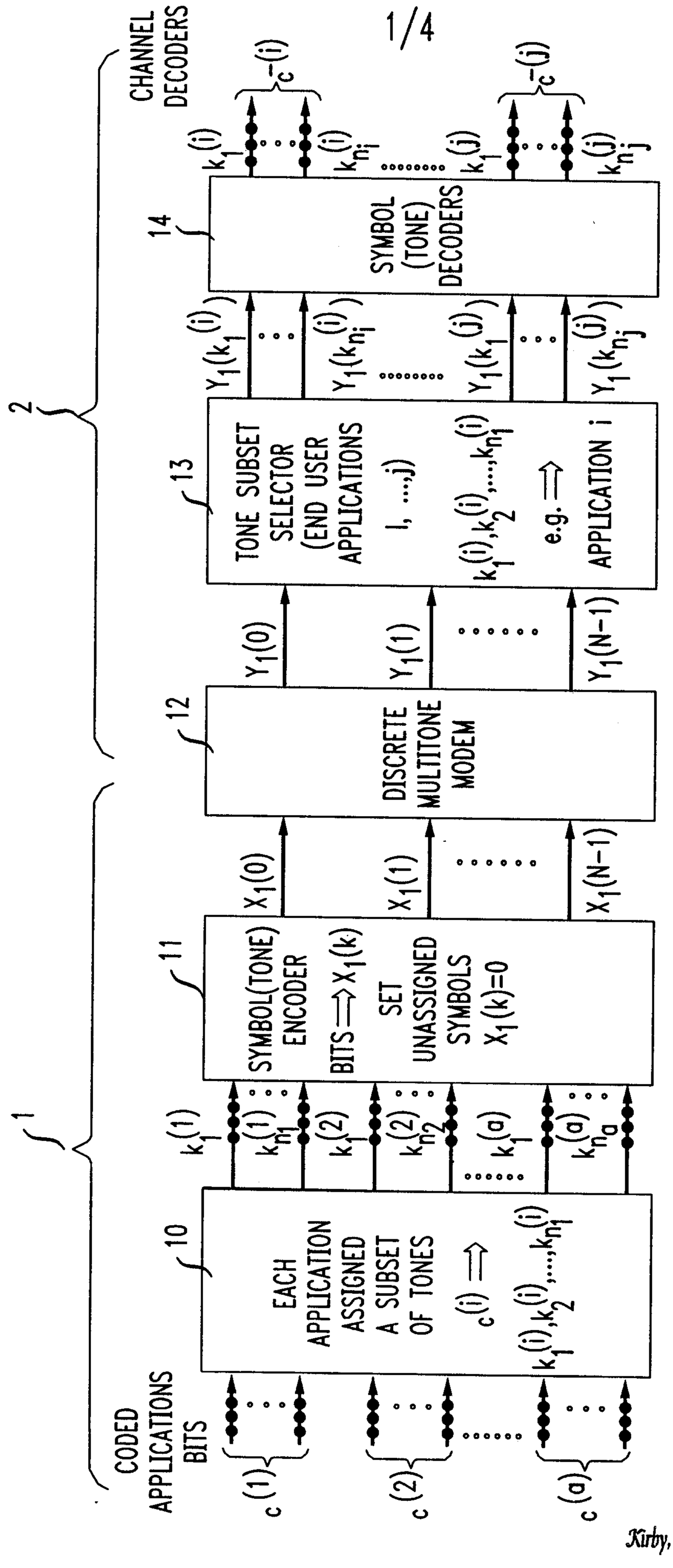
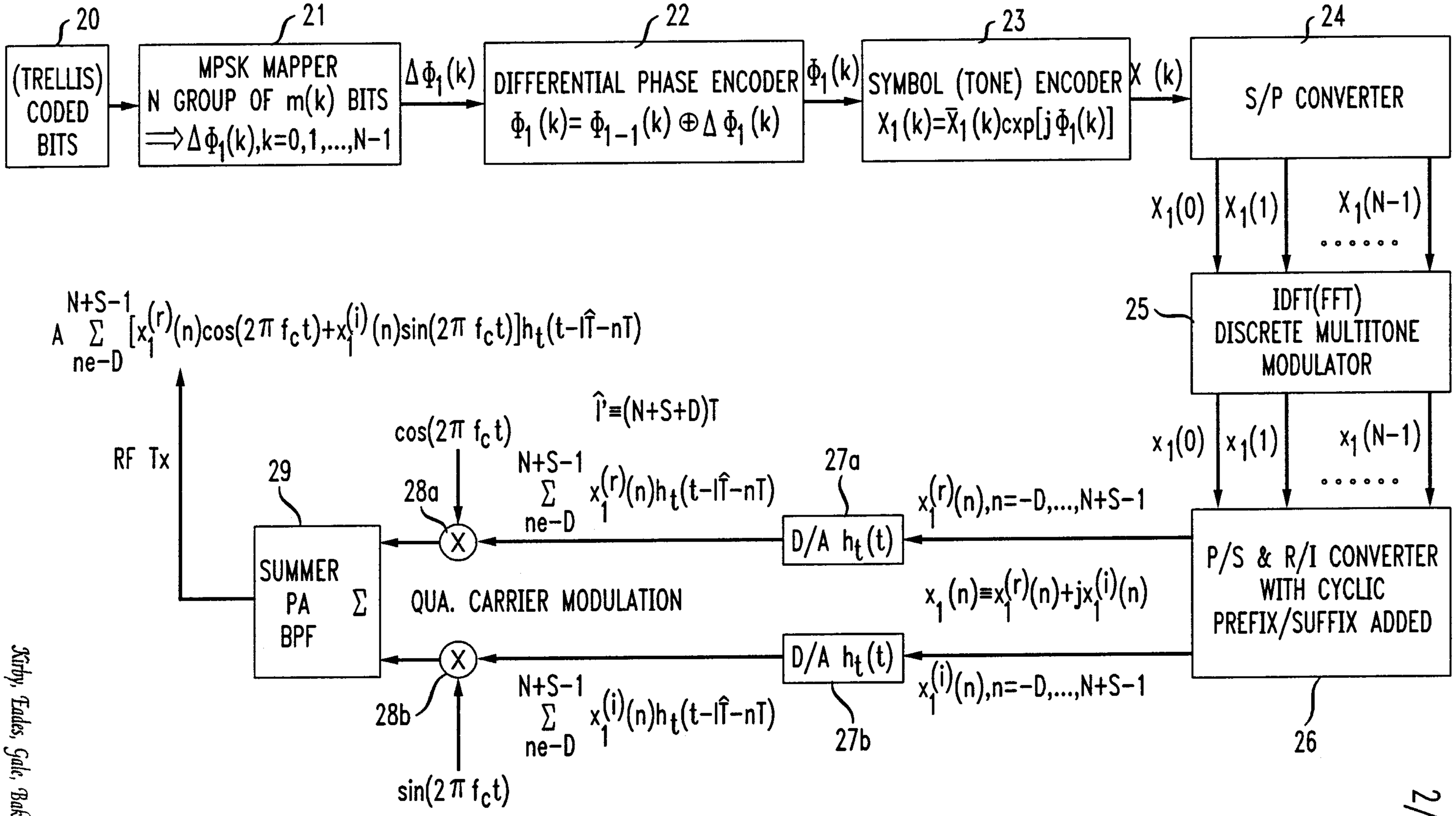

CODED APPLICATIONS BITS
EACH APPLICATION ASSIGNED A SUBSET OF TONES
SYMBOL(TONE) ENCODER
SET UNASSIGNED SYMBOLS
DISCRETE MULTITONE MODEM
TONE SUBSET SELECTOR (END USER APPLICATIONS
SYMBOL (TONE) DECODERS
CHANNEL DECODERS
APPLICATION i
e.g.
1
2
10
11
12
13
14

FIG. 1

FIG. 2

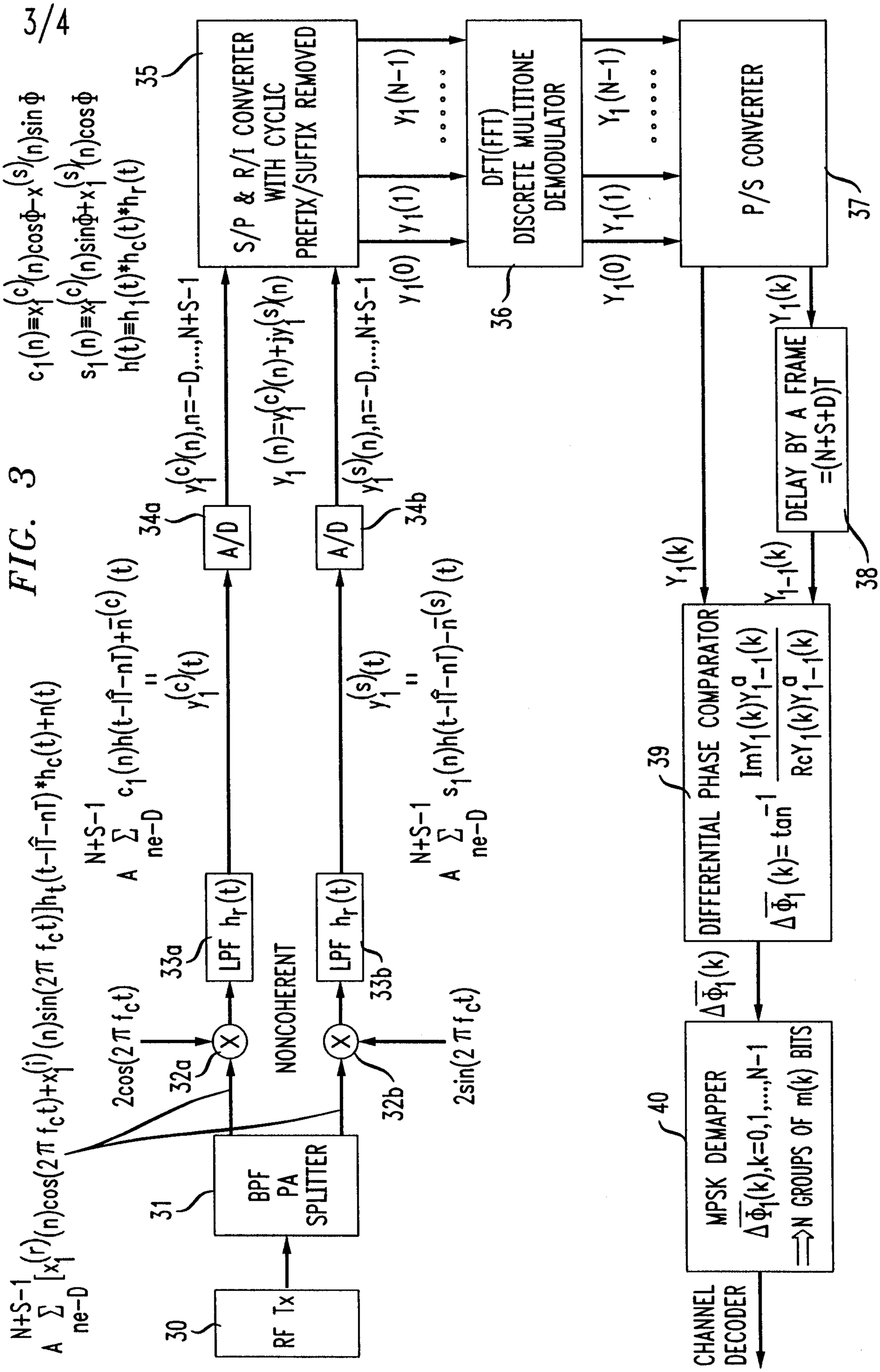


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FIG. 3



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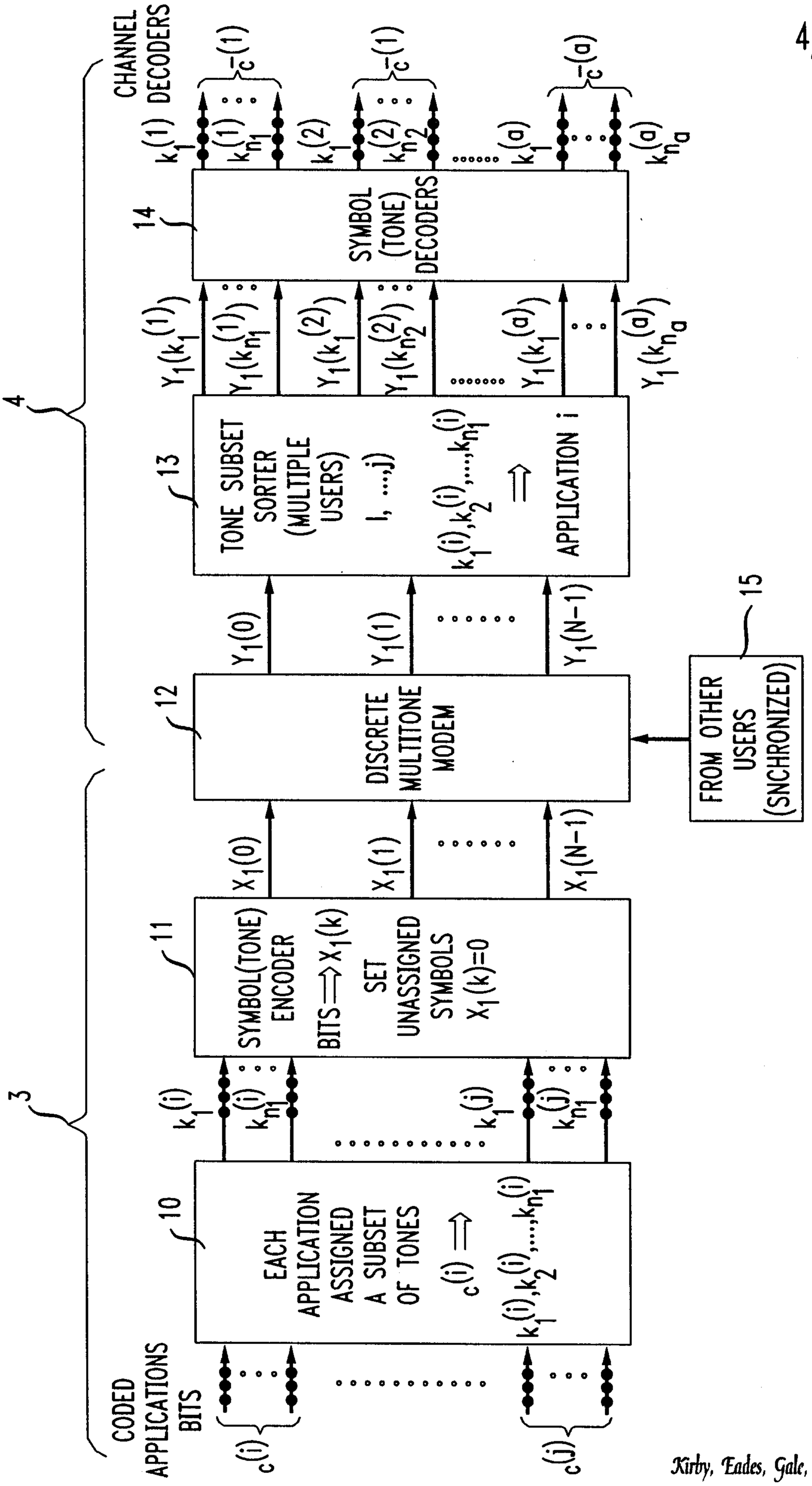
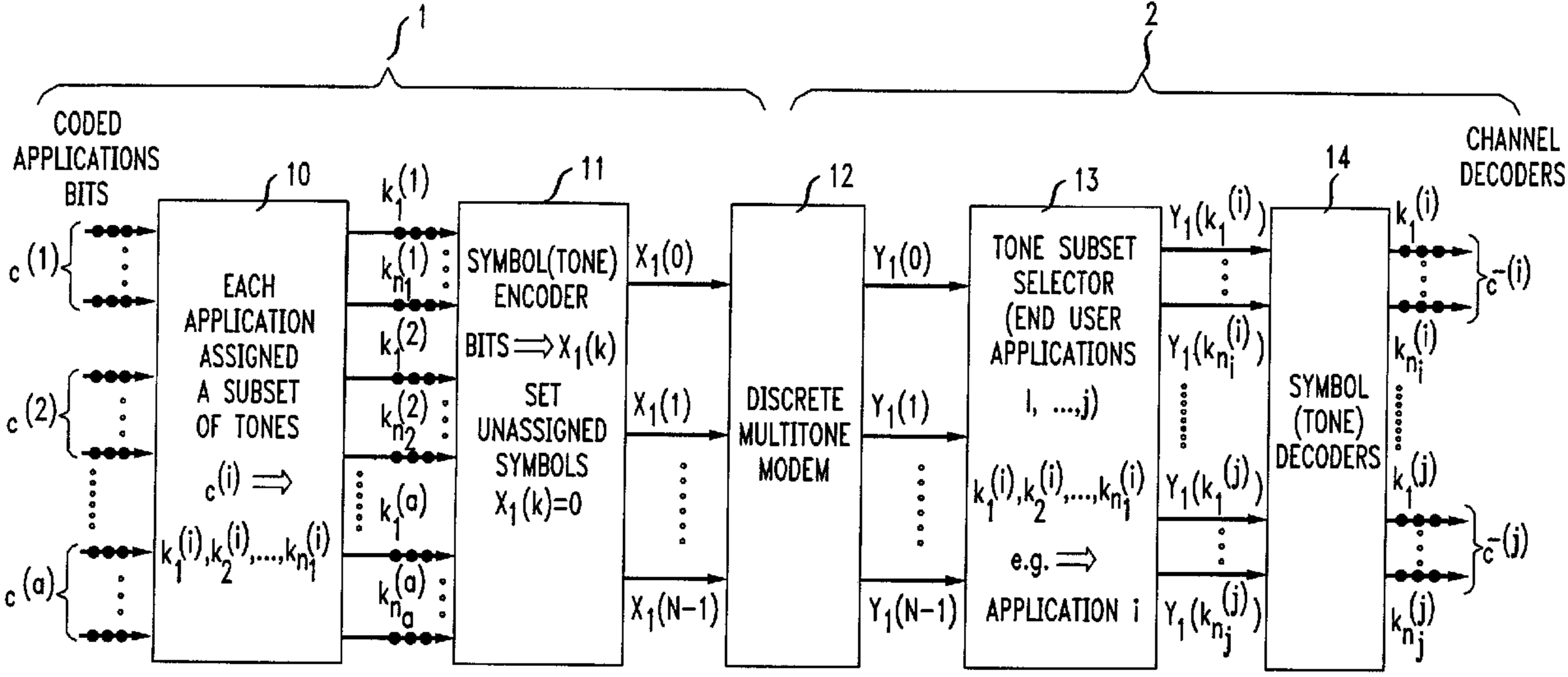


FIG. 4

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1
2
CODED APPLICATIONS BITS
10
EACH APPLICATION ASSIGNED A SUBSET OF TONES
$c^{(i)} \Longrightarrow$
$k_1^{(i)}, k_2^{(i)}, \ldots, k_{n_1}^{(i)}$
$c^{(1)}$
$c^{(2)}$
$c^{(a)}$
$k_1^{(1)}$
$k_{n_1}^{(1)}$
$k_1^{(2)}$
$k_{n_2}^{(2)}$
$k_1^{(a)}$
$k_{n_a}^{(a)}$
11
SYMBOL(TONE) ENCODER
BITS $\Longrightarrow X_1(k)$
SET UNASSIGNED SYMBOLS $X_1(k)=0$
$X_1(0)$
$X_1(1)$
$X_1(N-1)$
12
DISCRETE MULTITONE MODEM
$Y_1(0)$
$Y_1(1)$
$Y_1(N-1)$
13
TONE SUBSET SELECTOR (END USER APPLICATIONS 1, ...,j)
$k_1^{(i)}, k_2^{(i)}, \ldots, k_{n_1}^{(i)}$
e.g. $\Longrightarrow$
APPLICATION i
$Y_1(k_1^{(i)})$
$Y_1(k_{n_i}^{(i)})$
$Y_1(k_1^{(j)})$
$Y_1(k_{n_j}^{(j)})$
14
SYMBOL (TONE) DECODERS
$k_1^{(i)}$
$k_{n_i}^{(i)}$
$k_1^{(j)}$
$k_{n_j}^{(j)}$
CHANNEL DECODERS
$\bar{c}^{(i)}$
$\bar{c}^{(j)}$