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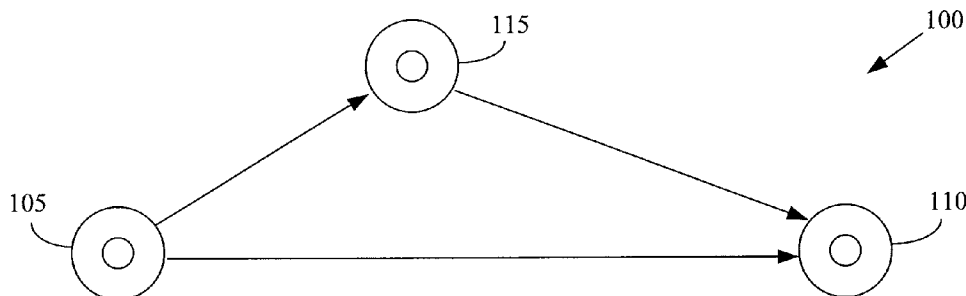


Figure 1

(57) Abstract: The present invention provides a method of relaying soft information for cooperative diversity. One embodiment of the method may include providing soft information to a destination node over a first air interface. The soft information is formed based on encoded information received from a source node over a second interface. The soft information is also suitable as input to a decoder at the destination node. Another embodiment of the method may include receiving soft information from at least one relay node over a first air interface. The soft information is formed based on encoded information received at the relay node(s) from a source node over at least one second interface. The soft information is also suitable as input to a decoder.

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METHOD OF RELAYING SOFT INFORMATION FOR COOPERATIVE DIVERSITY IN A WIRELESS COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates generally to communication systems, and, more particularly, to wireless communication systems.

2. DESCRIPTION OF THE RELATED ART

In a conventional wireless communication system, mobile units and base stations communicate by exchanging information over a wireless communication link or air interface. The base stations may then connect to a network, such as the Internet, over a wired and/or wireless backhaul connection. The backhaul connection may be a direct wired connection to a network entity such as a radio network controller. Alternatively, the backhaul connection may include a number of wireless communication links, or legs, between base stations in the network. For example, the wireless backhaul connection in multi-hop cellular networks, wireless mesh backhaul networks, and ad hoc networks is formed over air interfaces between base stations in these networks. Although networks that use a mesh of wireless communication links to form backhaul connections have a number of advantages, such as flexibility and scalability, over conventional hierarchical networks, these networks also have a number of disadvantages. For example, signal fading caused by multipath propagation of signals over the legs of the wireless backhaul connection may cause severe channel impairment that may limit the capacity of the wireless backhaul connection.

The capacity, reliability, and/or channel quality associated with an air interface may be improved utilizing multiple-input-multiple-output (MIMO) technologies. For example, the channel impairment caused by signal fading can be mitigated using the spatial diversity that is achieved by transmitting the same information from multiple antennas that are separated far enough to experience independent fading channels. The performance of a wireless backhaul connection may therefore be improved by implementing MIMO techniques in the base stations and/or mobile units. However, it is not always practical to deploy multiple antennas in every base station and/or mobile unit. For example, consumers often express a preference for compact mobile units, which may not include space for multiple antennas that are separated by a sufficient distance. For another example, service providers may prefer to deploy relatively small, inexpensive, and/or portable base stations and therefore may prefer to deploy base stations that only include a single antenna.

Spatial diversity can be achieved in networks formed of base stations and/or mobile units that include a single antenna by forming a virtual antenna array from multiple base stations and/or mobile units. The virtual antenna array of a destination node in the wireless communication system includes the antenna at the destination node as well as antennas at one or more other nodes. Information transmitted by a source node may then be received by the antenna at the destination node and the antennas at the other nodes. The intermediate nodes may then forward or relay the received information to the destination node, which may cooperatively combine the information received directly from the source node with the information received from the intermediate nodes. The combined information may then be decoded.

Figure 1 conceptually illustrates a one-relay network 100. In the one-relay network 100 shown in Figure 1, a source terminal 105 transmits a message to a destination terminal 110 via a direct transmission. The message transmitted by the source terminal 105 is also received by a relay terminal 115, which transmits or relays the message to the destination terminal 110 in the next available timeslot. The destination terminal 110 therefore receives identical information via two paths or antennas separated in the space domain, which may be combined to provide spatial diversity. The relay concept can be extended to multiple-relay networks. Figure 2 conceptually illustrates a two-relay network 200. In the two-relay network 200 shown in Figure 2, a source terminal 205 transmits a message to a destination terminal 210 via a direct transmission. The message transmitted by the source terminal 205 is also received by relay terminals 215, 220. The relay terminal 215 transmits or relays the message to the destination terminal 210 and the relay terminal 220 in the next available timeslot. The relay terminal 220 combines the information received from the source terminal 205 and the relay terminal 215 and relays this information to the destination terminal 210. The destination terminal 210 therefore receives identical information via four paths separated in the space domain, which may be combined to provide spatial diversity.

Figure 3 conceptually illustrates a first conventional relaying technique. In the illustrated technique, a source node 300 modulates and encodes a bit stream 305 and transmits the encoded information over the air interface to a destination node 310, which receives the (noisy) encoded bits 315. The encoded information is also transmitted to a relay node 320, which receives a copy of the (noisy) encoded bits 325. The relay node 320 demodulates and decodes the encoded bits 325 to form a decoded bit stream 330. Thus, all redundancy introduced by encoding at the source is removed at the relay node 320. The relay

node 320 then modulates and encodes the decoded bits 300. The modulation and encoding format can be adapted to the quality of the link to the destination node 310. The relay node 320 transmits the encoded bit stream to the destination node 310, which receives the (noisy) encoded bits 335. The destination node 310 combines the bits 315, 335 to achieve spatial diversity. The illustrated technique is conventionally referred to as a "decode-and-forward" technique because each relay node 320 decodes the received information before relaying it to the destination node 310.

The main shortcoming of the decode-and-forward approach is the fact the transmissions over each leg must be decoded separately, *e.g.*, the transmissions are combined at the destination node 310 using hard combining techniques. No soft combining is possible at the destination node 310. Consequently, if none of the individual links (from any relay node 320 or from the source node 300) can be decoded correctly, then the whole block is in error and cannot be recovered. This means that the space diversity cannot be exploited fully. Another disadvantage of full decoding used in the decode-and-forward approach is the highly involved signal processing that must be performed at each relay node 320 to demodulate, decode, modulate, and code the relayed signal.

Figure 4 conceptually illustrates a second conventional relaying technique. In the illustrated technique, a source node 400 modulates and encodes a bit stream 405 and transmits the encoded information over the air interface to a destination node 410, which receives the (noisy) encoded bits 415. The encoded information is also transmitted to a relay node 420, which receives a copy of the (noisy) encoded bits 425. The relay node 420 amplifies the encoded bits 425 by a factor β to form an amplified bit stream 430. Since

neither decoding nor demodulation is performed at the relay node 420, and all the coding and modulation is done at the source node 400, the coding and modulation is not adapted to the link conditions between the relay node 420 and the destination node 410. The relay node 420 then transmits the amplified bit stream to the destination node 410, which receives the (noisy) encoded bits 435. The destination node 410 combines the bits 415, 435 to achieve spatial diversity. The illustrated technique is conventionally referred to as an "amplify-and-forward" technique because each relay node 420 amplifies the received information before relaying it to the destination node 410.

The amplify-and-forward approach has a number of drawbacks. First, the information to be transmitted from the relay node 420 to the destination node 410 is in no way adapted to the corresponding mobile radio channel. For example, if transmission between the source node 400 and the relay node 420 has an available bandwidth of 10 MHz and the forwarding channel from the relay node 420 to the destination node 410 has an available bandwidth of only 5 MHz. In this case, the forwarded information is encoded and modulated for the larger bandwidth, which is not optimal for information transmitted over the smaller bandwidth forwarding channel. This situation might occur if UMTS-LTE is applied at nodes enabling flexible bandwidth allocations. Second, the amplify-and-forward approach suffers high SINR deterioration due to the amplification of the noise in the received encoded bits 425. As a result, the amplify-and-forward approach shows low performance at low SINRs.

In another alternative approach, the relay nodes can also transmit quantized and compressed versions of the channel output to the destination node while exploiting statistical dependence in the source coding between this output and the channel output at the destination

node. This method is referred to as a “compress-and-forward” approach. However, compress-and-forward approaches require tremendous signal processing effort at the relay node and are therefore considered difficult or impossible to implement in an actual wireless communication system. Furthermore, no practical source coding strategies are known that exploit the statistical dependencies of the different channel outputs.

SUMMARY OF THE INVENTION

The present invention is directed to addressing the effects of one or more of the problems set forth above. The following presents a simplified summary of the invention in order to provide a basic understanding of some aspects of the invention. This summary is not an exhaustive overview of the invention. It is not intended to identify key or critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is discussed later.

In one embodiment of the present invention, a method is provided for relaying soft information for cooperative diversity. One embodiment of the method may include providing soft information to a destination node over a first air interface. The soft information is formed based on encoded information received from a source node over a second interface. The soft information is also suitable as input to a decoder at the destination node. Another embodiment of the method may include receiving soft information from at least one relay node over a first air interface. The soft information is formed based on encoded information received at the relay node(s) from a source node over at least one second interface. The soft information is also suitable as input to a decoder.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

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Figure 1 conceptually illustrates a conventional one-relay network;

Figure 2 conceptually illustrates a conventional two-relay network;

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Figure 3 conceptually illustrates a first conventional relaying technique;

Figure 4 conceptually illustrates a second conventional relaying technique;

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Figure 5 conceptually illustrates one exemplary embodiment of a wireless communication system, in accordance with the present invention;

Figure 6 conceptually illustrates a first exemplary embodiment of a method of relaying soft information, in accordance with the present invention; and

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Figure 7 conceptually illustrates a second exemplary embodiment of a method of relaying soft information, in accordance with the present invention.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are

herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions should be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

Portions of the present invention and corresponding detailed description are presented in terms of software, or algorithms and symbolic representations of operations on data bits within a computer memory. These descriptions and representations are the ones by which those of ordinary skill in the art effectively convey the substance of their work to others of ordinary skill in the art. An algorithm, as the term is used here, and as it is used generally, is conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of optical, electrical, or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven

convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise, or as is apparent from the discussion, terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical, electronic quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

Note also that the software implemented aspects of the invention are typically encoded on some form of program storage medium or implemented over some type of transmission medium. The program storage medium may be magnetic (e.g., a floppy disk or a hard drive) or optical (e.g., a compact disk read only memory, or "CD ROM"), and may be read only or random access. Similarly, the transmission medium may be twisted wire pairs, coaxial cable, optical fiber, or some other suitable transmission medium known to the art. The invention is not limited by these aspects of any given implementation.

The present invention will now be described with reference to the attached figures. Various structures, systems and devices are schematically depicted in the drawings for purposes of explanation only and so as to not obscure the present invention with details that

are well known to those skilled in the art. Nevertheless, the attached drawings are included to describe and explain illustrative examples of the present invention. The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special
5 definition of a term or phrase, *i.e.*, a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be implied by consistent usage of the term or phrase herein. To the extent that a term or phrase is intended to have a special meaning, *i.e.*, a meaning other than that understood by skilled artisans, such a special definition will be expressly set forth in the specification in a definitional manner that directly
10 and unequivocally provides the special definition for the term or phrase.

Figure 5 conceptually illustrates one exemplary embodiment of a wireless communication system 500. In the illustrated embodiment, the wireless communication system 500 operates according to the Universal Mobile Telecommunication System (UMTS)
15 Long Term Evolution (LTE) standards and/or protocols. However, persons of ordinary skill in the art having benefit of the present disclosure should appreciate that the present invention is not limited to any particular set of standards and/or protocols. In alternative embodiments, the wireless communication system 500 (or portions thereof) may operate according to any communication standards and/or protocols including Code Division Multiple Access
20 (CDMA, CDMA2000) and derivatives thereof, other versions of UMTS such as UMTS High Speed Data Packet Access (HSDPA), and the like. The wireless communication system 500 includes a network 505 such as Internet and one or more mobile units 510. In the interest of clarity a single mobile unit 510 is shown in Figure 1. However, persons of ordinary skill in the art having benefit of the present disclosure should appreciate that the wireless

communication system 500 may provide wireless connectivity to any number of mobile units 510.

The wireless communication system 500 also includes a plurality of base stations 515(1-4). In some cases, the distinguishing indices (1-4) may be dropped when referring to the base stations 515 collectively. However, these indices may be used to indicate individual base stations 515 and/or subsets thereof. This convention may also be applied to other elements depicted in the drawings and indicated by a numeral and one or more distinguishing indices. Persons of ordinary skill in the art having benefit of the present disclosure should appreciate that the present invention is not limited to base stations 515. In alternative embodiments, the wireless communication system 500 may include any type of node capable of providing wireless connectivity to other nodes and/or mobile units 510. Exemplary nodes may include Flexnet node-Bs, base transceiver stations (BTSs), base station routers, WiMAX or WiFi access points, access networks, and the like. Furthermore, persons of ordinary skill in the art having benefit of the present disclosure should appreciate that a mobile unit, such as the mobile unit 510, may also function as a node in the wireless communication system 500.

In the illustrated embodiment, the mobile unit 510 establishes a wireless connection with the base station 515(4) over a wireless communication link or air interface 520. The base station 515(4) is communicatively coupled with the other base stations 515(1-3) over other wireless communication links or air interfaces indicated by double-headed arrows. In the interest of clarity the air interfaces between the base stations 515 are not indicated by numerals. The base station 515(1) is communicatively coupled to the network 505 by one or more wired and/or wireless connections. Accordingly, the base stations 515 may be used to

form a wireless backhaul link to the network 505. The wireless communication techniques described herein will be discussed in the context of base stations 515 that are used to form a wireless backhaul link. However, persons of ordinary skill in the art having benefit of the present disclosure should appreciate that the present invention is not limited to embodiments in which the base stations 515 form all or part of a wireless backhaul link. In alternative embodiments, the techniques described herein may be used for any type of communication between nodes in the wireless communication system 500.

The base station 515(4) may transmit and/or receive information over multiple air interfaces with multiple base stations 515. The base station 515(4) may be referred to as a source base station 515 (or a source node) when transmitting and a destination base station 515 (or destination node) when receiving information. In the illustrated embodiment, the base station 515(5) forms a direct link over the air interface to the base station 515(1), which may be referred to as a destination base station 515 (or a destination node) when receiving information and a source base station 515 (or source node) when transmitting information. The base station 515(4) may also transmit or receive information over air interfaces with the base stations 515(2-3), which may forward this information from the source node to the destination node, either directly or via one or more other nodes. The base stations 515(2-3) may therefore be referred to as relay base stations 515(2-3) or relay nodes. However, persons of ordinary skill in the art having benefit of the present disclosure should appreciate that the terms "source," "destination," and "relay" are not intended to imply any particular structural or functional difference between these nodes. In one embodiment, the base stations 515 may be substantially identical and may function as source, destination, and/or relay nodes as desired in various embodiments of the wireless communication system 500. Furthermore,

persons of ordinary skill in the art having benefit of the present disclosure should appreciate that the source, destination, and/or relay nodes do not need to be fixed entities such as base stations 515. In alternative embodiments, one or more of the source, destination, and/or relay nodes may be a mobile unit 510.

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In one embodiment, the base station 515(4) transmits backhaul information associated with the mobile unit 510 to the base stations 515(1-3). The transmitted information includes a modulated and encoded bit stream that is transmitted over the air interfaces between the base stations 515. The relay base stations 515(2-3) may receive the modulated and encoded bit stream, *e.g.*, via a radiofrequency antenna, and may demodulate the received bit stream to form soft information that may be provided to a decoder for subsequent decoding. The term "soft information" will be understood to refer, in accordance with usage in the art, to information produced by various demodulation techniques such that the soft information may be provided to a decoder for decoding. Soft information represents binary estimates of the coded bits in the data stream and reliability information associated with these bits. Examples of soft information include, but are not limited to, log likelihood ratios, noise variance estimations, estimated symbols, and the like. Soft information associated with a single bit stream, but received from multiple sources, may be combined prior to decoding to enhance the likelihood that the combined soft information will be successfully decoded to retrieve the coded bits in the bit stream. The relay base stations 515(2-3) may then quantize and/or encode the soft information and transmit (*e.g.*, forward or relay) this quantized and/or encoded information to one or more other base stations 515.

Figure 6 conceptually illustrates a first exemplary embodiment of a method 600 of relaying soft information. In the illustrated embodiment, the modulated and encoded information is received at the relaying node and demodulated (at 605). The demodulated information, *e.g.*, the noisy received symbols indicative of the received coded bits, is then used to compute (at 610) one or more log likelihood ratios. The sign of the log likelihood ratio indicates whether the corresponding bit is more likely to be a “0” or a “1” and the magnitude of the log likelihood ratio is a measure for the probability that this bit is estimated correctly. The computed (at 610) log likelihood ratios can serve as the decoder input signal for subsequent decoding of the coded bits. The demodulated information, *i.e.*, the log likelihood ratios, may also be used to estimate (at 615) the noise variance of the noisy received symbols. The log likelihood ratios and the noise variance are then quantized (at 620), encoded and modulated (at 625) for transmission to one or more other nodes in the network.

Figure 7 conceptually illustrates a second exemplary embodiment of a method 700 of relaying soft information. In the illustrated embodiment, the modulated and encoded information is received at the relaying node and demodulated (at 705). The demodulated information, *e.g.*, the noisy received symbols indicative of the received coded bits, is then used to estimate (at 710) the noise variance of the noisy received symbols. The received symbols and noise variance may, in some embodiments, be representative of the same information that is included in the log likelihood ratios. For example, mapping functions that can be used to compute the log likelihood ratios on the basis of received symbols are known in the art. Thus, the received symbols and noise variance may be used as the decoder input signal for subsequent decoding of the encoded bits. The soft information, *i.e.*, the received

symbols and the noise variance, is then quantized (at 715), encoded and modulated (at 720) for transmission to one or more other nodes in the network.

Referring back to Figure 5, the destination base station 515(1) receives the soft
5 information indicative of the backhaul information associated with the mobile unit 510 from each of the base stations 515(2-4). As discussed herein, the soft information may include log likelihood ratios, received symbols, and/or noise variances associated with the received symbols. The destination base station 515(1) may then combine the soft information received from the base stations 515(2-4) and decode the combined soft information. Techniques for
10 performing soft combining are known in the art and in the interest of clarity will not be discussed further herein. Since the information is received from the base stations 515(2-4) along different paths, soft combining this information may provide spatial diversity that may be improved the likelihood that the information will be successfully decoded at the destination base station 515(1). Moreover, the combined soft information may be
15 successfully decoded at the destination base station 515(1) even if none of the base stations 515(1-3) could have successfully decoded the information transmitted directly from the source destination base station 515(4).

In the illustrated embodiment, the base stations 515 employ a fixed relaying scheme
20 in which the base stations 515 always forward the soft information received from the source node to the destination node. However, the present invention is not limited to fixed relaying schemes and in alternative embodiments other schemes, such as selection relaying schemes and incremental relaying schemes, may be used. For example, one or more of the base stations 515 may use selection relaying to forward the message based on the quality of the

mobile radio channel between the relay node and the source node so that the soft information received from the source node is only forwarded to the destination node if the channel quality is sufficiently high. When the channel quality is low, the likelihood that the soft information will be undesirably noisy is increased, and so the relay node may elect not to forward the soft information to the destination node. In another alternative embodiment, one or more of the base stations 515 may use incremental relaying to decide whether to forward the information based on feedback information from the destination node, *e.g.* a single bit indicating the success or failure of the direct transmission. Selection and incremental relaying may require additional processing and/or overhead (relative to fixed relaying) to implement.

The base stations 515 may determine how best to transmit the soft information to the destination node and/or relay nodes. In one embodiment, each of the nodes may implement adaptive coding and modulation of the soft information when transmitting the soft information to the destination node and/or other relay nodes. Thus, information received at the destination node and/or other relay nodes from different source and/or relay nodes may be coded and/or modulated using different coding and/or modulation schemes. In other embodiments, the source and/or relay nodes may use different frequency bands and/or bandwidths for transmitting the soft information to the destination node and/or other relay nodes. In yet another embodiment, the source and/or relay nodes may use different wireless communication standards and/or protocols to forward or relay the soft information to the destination node and/or other relay nodes.

Embodiments of the techniques for relaying soft information described herein may be used in any type of wireless network including, but not limited to, ad-hoc networks, sensor

networks, and/or wireless mesh networks. The nodes in these networks may be used to perform cooperative diversity at the destination node in order to exploit spatial diversity so that the network forms a virtual antenna array for the destination node. The techniques described herein may have a number of advantages over conventional practice. For example, relaying soft information as described herein permits soft combining at the destination decoder, which may increase network capacity relative to conventional decode-and-forward techniques. Furthermore, relaying soft information does not require full decoding of the codeword at the relay node, which reduces the signal processing complexity relative to conventional decode-and-forward techniques.

The techniques for relaying soft information described herein also have a number of advantages over conventional amplifier-and-forward techniques. For example, relaying soft information allows the relay nodes to flexibly adapt the information to be forwarded (*e.g.*, by modifying the quantisation, code rate, and/or modulation scheme) to the mobile radio channel conditions between the relay node and the destination node. The relay nodes may also allocate the available relay resources (*e.g.*, power, bandwidth, number of codes, number of subcarriers, number of timeslots, and the like) to the link between the relay node and the destination node. As discussed above, the relay nodes may even use a different wireless communication standard and/or protocol for transmitting the soft information over the air interface between the relay node and the destination node.

The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended

to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

CLAIMS**WHAT IS CLAIMED:**

1. A method, comprising:

providing, to a destination node over a first air interface, soft information formed
5 based on encoded information received from a source node over a second interface, the soft
information being suitable as input to a decoder at the destination node.

2. The method of claim 1, comprising forming the soft information based on the encoded
information received from the source node, and wherein forming the soft information
10 comprises forming at least one binary estimate of at least one coded bit based on the encoded
information.

3. The method of claim 2, wherein forming the soft information comprises forming
information indicating reliability of said at least one binary estimate of said at least one coded
15 bit.

4. The method of claim 3, wherein forming the soft information comprises forming at
least one a log likelihood ratio based on the encoded information.

20 5. The method of claim 3, wherein forming the soft information comprises forming,
based on the encoded information, information indicative of at least one symbol and at least
one estimate of a noise variance of said at least one symbol.

6. The method of claim 1, wherein providing the soft information comprises:

quantizing the soft information;
encoding the quantized soft information; and
transmitting the encoded quantized soft information over the first air interface to the destination node.

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7. The method of claim 6, wherein encoding the quantized soft information comprises encoding the quantized soft information based on at least one channel condition or channel quality associated with the first air interface.

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8. The method of claim 6, wherein encoding the quantized soft information comprises encoding the quantized soft information such that at least one of a coding or modulation scheme, a frequency band or bandwidth, or a wireless communication standard used to encode the quantized soft information differs from at least one of a coding or modulation scheme, a frequency band or bandwidth, or a wireless communication standard used to
15 encode the information received from the source node.

9. The method of claim 1, wherein providing the soft information comprises providing the soft information in a form that permits of the destination node to combine the soft information with encoded information received from the source node.

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10. The method of claim 1, comprising receiving, from the source node over the second air interface, the encoded information.

11. A method, comprising:

receiving, from at least one relay node over a first air interface, soft information formed based on encoded information received at said at least one relay node from a source node over at least one second interface, the soft information being suitable as input to a decoder.

12. The method of claim 11, wherein receiving the soft information comprises receiving at least one binary estimate of at least one coded bit formed based on the encoded information.

13. The method of claim 12, wherein receiving the soft information comprises receiving information indicating reliability of said at least one binary estimate of said at least one coded bit.

14. The method of claim 13, wherein receiving the soft information comprises receiving at least one a log likelihood ratio formed based on the encoded information.

15. The method of claim 13, wherein receiving the soft information comprises receiving information indicative of at least one symbol and at least one estimate of a noise variance of said at least one symbol, the information indicative of said at least one symbol and said at least one estimate of a noise variance of said at least one symbol being formed based on the encoded information.

16. The method of claim 11, wherein receiving the soft information comprises receiving encoded quantized soft information over said at least one first air interface.

17. The method of claim 16, wherein receiving the encoded quantized soft information
5 comprises receiving quantized soft information that was encoded based on at least one channel condition or channel quality associated with the first air interface.

18. The method of claim 16, wherein receiving the encoded quantized soft information
10 comprises receiving the quantized soft information encoded using at least one of a coding or modulation scheme, a frequency band or bandwidth, or a wireless communication standard that differs from at least one of a coding or modulation scheme, a frequency band or bandwidth, or a wireless communication standard used to encode the information received from the source node.

15 19. The method of claim 11, comprising combining the soft information received from said at least one relay node with encoded information received from the source node.

20. The method of claim 19, comprising decoding the combined soft information.

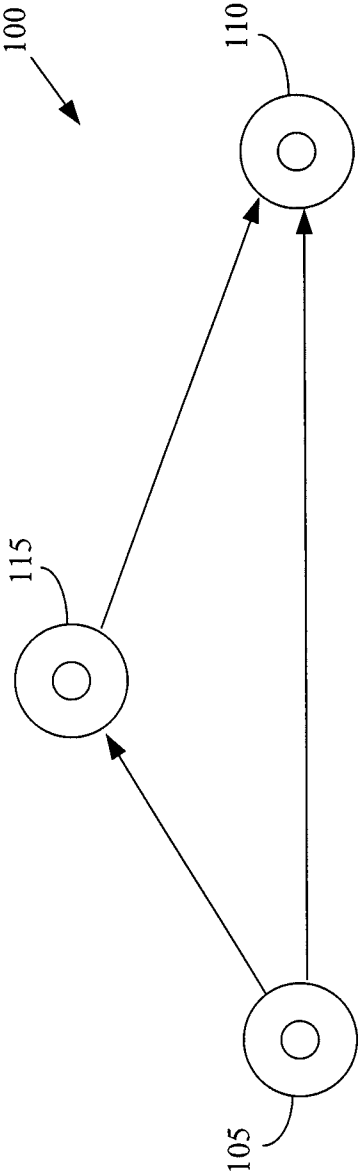


Figure 1

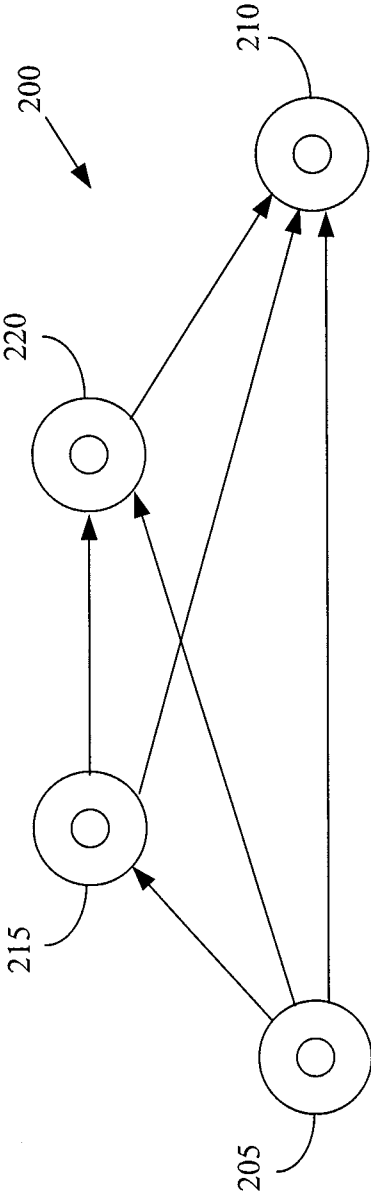


Figure 2

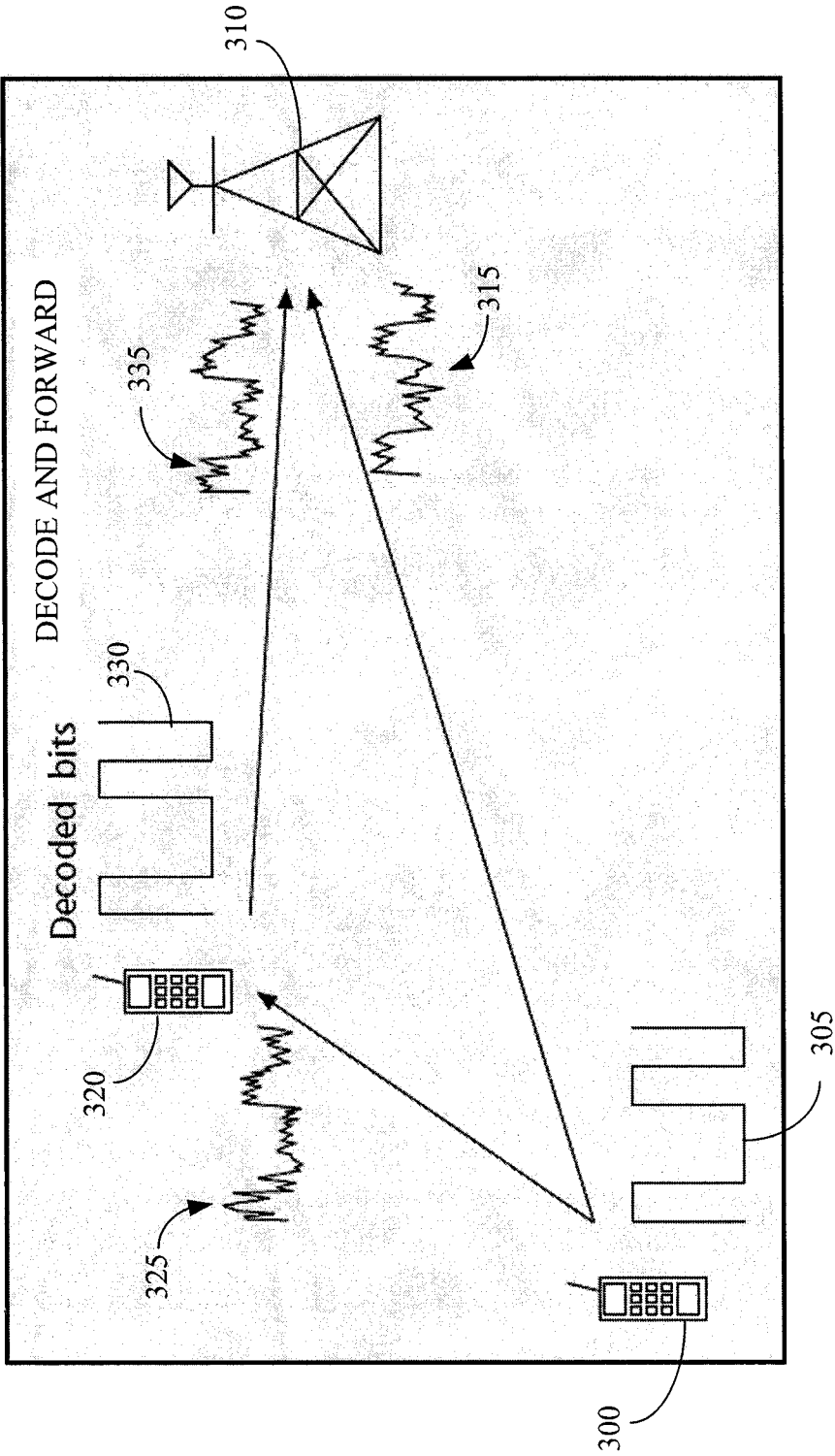


Figure 3

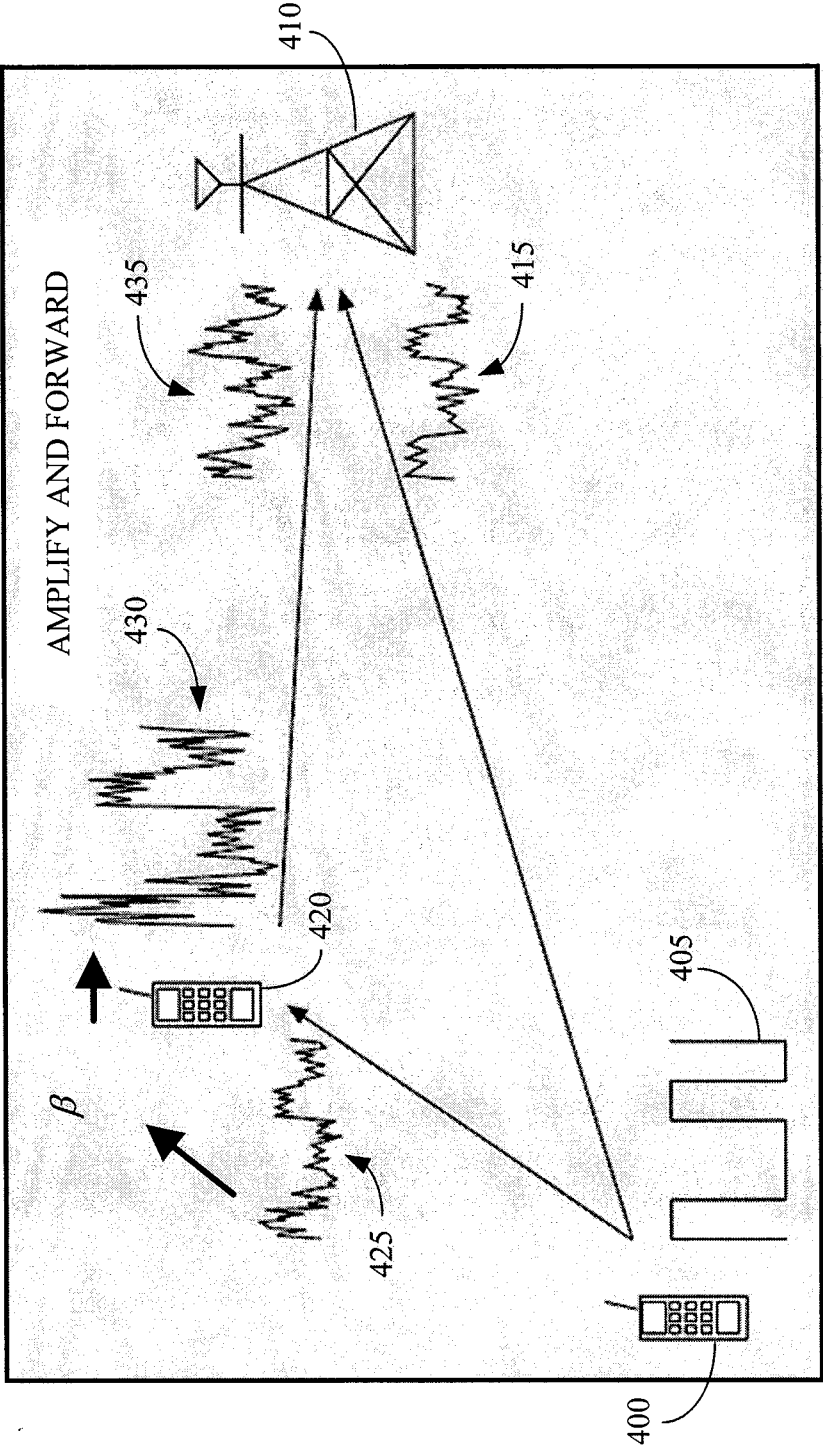


Figure 4

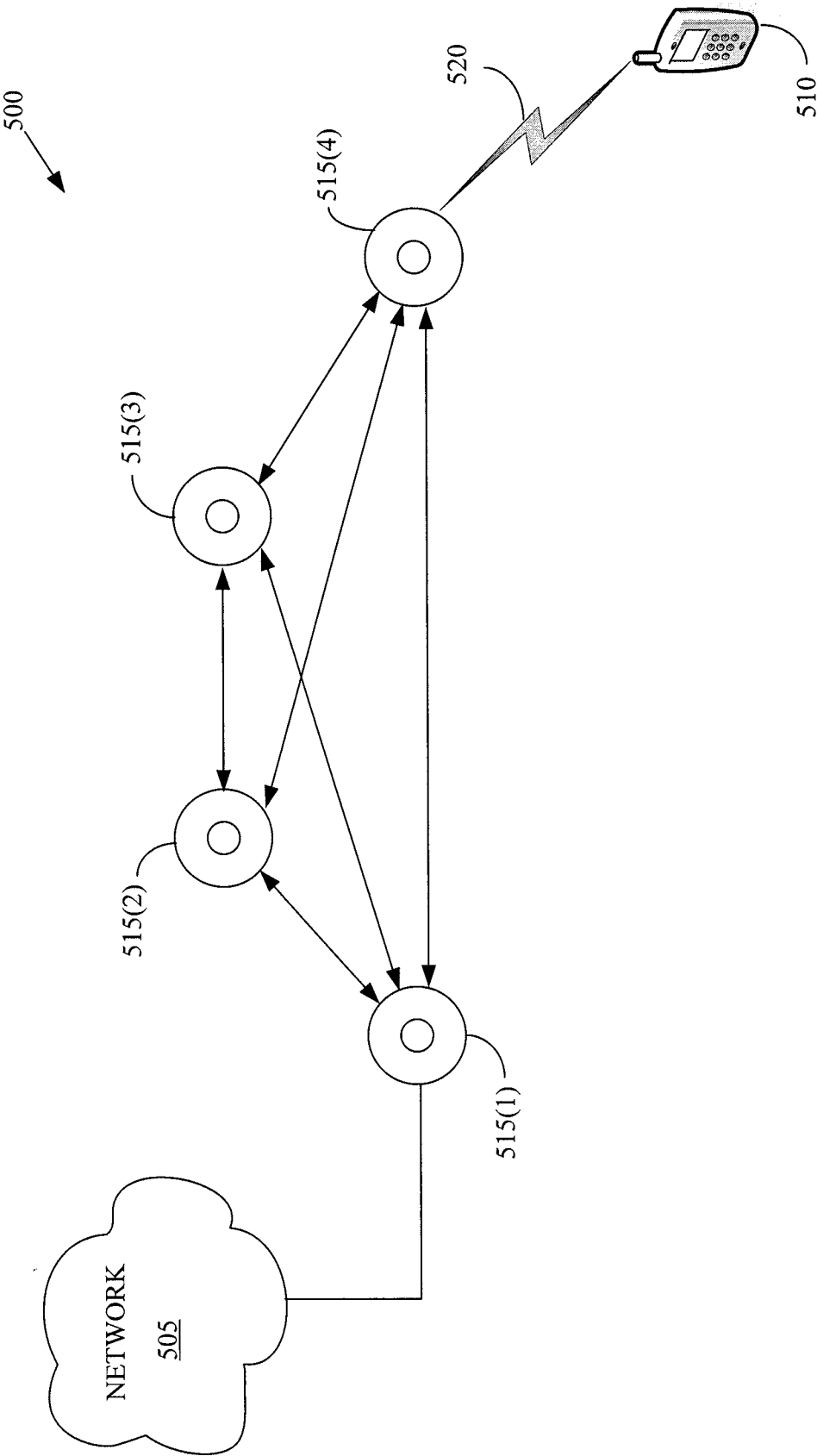


Figure 5

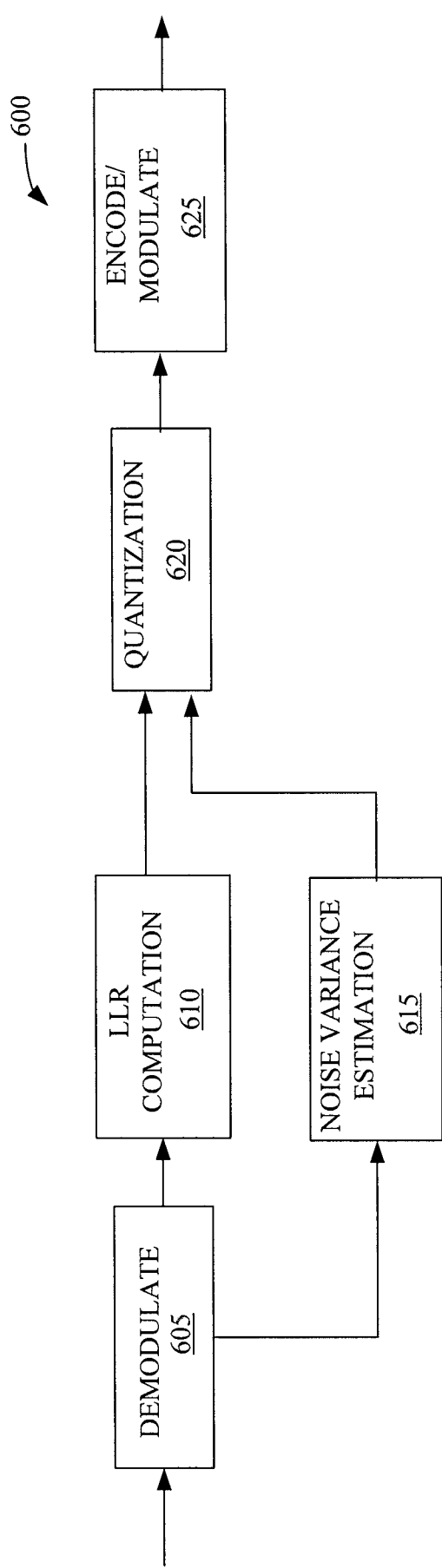


Figure 6

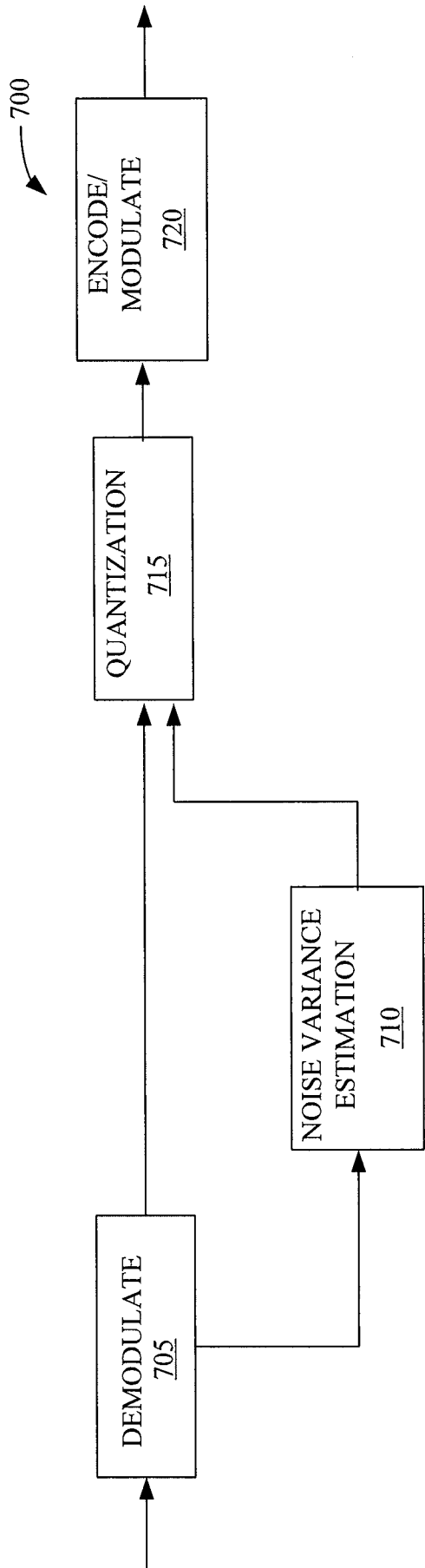


Figure 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/068338

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/02

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)
H04B

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 practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SNEESSENS H H ET AL: "Soft Decode and Forward Improves Cooperative Communications" 13 December 2005 (2005-12-13), COMPUTATIONAL ADVANCES IN MULTI-SENSOR ADAPTIVE PROCESSING, 2005 1ST IEEE INTERNATIONAL WORKSHOP ON PUERTO VALLARTA, MEXICO DEC. 13, 2005, PISCATAWAY, NJ, USA, IEEE, PAGE(S) 157-160 , XP010878976 ISBN: 0-7803-9322-8 the whole document ----- -/--	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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"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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"&" document member of the same patent family

Date of the actual completion of the international search

22 February 2008

Date of mailing of the international search report

04/03/2008

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/068338

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AVUDAINAYAGAM A ET AL: "Performance analysis of reliability filling on quasi-static fading channels" WIRELESS COMMUNICATIONS AND NETWORKING CONFERENCE, 2005 IEEE NEW ORLEANS, LA, USA 13-17 MARCH 2005, PISCATAWAY, NJ, USA,IEEE, 13 March 2005 (2005-03-13), pages 1024-1029, XP010791312 ISBN: 0-7803-8966-2 the whole document -----	1-20
X	WO 2007/003034 A (NORTEL NETWORKS LTD [CA]; PERIYALWAR SHALINI [CA]; WU SHIQUN [CA]) 11 January 2007 (2007-01-11) page 13, line 19 - page 14, line 21; figures 5A,5B -----	1-3, 9-13,19, 20
X	YONGHUI LI ET AL: "Distributed Turbo Coding with Soft Information Relaying in Wireless Sensor Networks" COMPUTER AS A TOOL, 2005. EUROCON 2005.THE INTERNATIONAL CONFERENCE ON BELGRADE, SERBIA AND MONTENEGRO 21-24 NOV. 2005, PISCATAWAY, NJ, USA,IEEE, 21 November 2005 (2005-11-21), pages 29-32, XP010916013 ISBN: 1-4244-0049-X the whole document -----	1-3, 11-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2007/068338

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007003034 A	11-01-2007	US 2007010196 A1	11-01-2007