

(21) Application No: 0515830.8

(22) Date of Filing: 01.08.2005

(71) Applicant(s):
Toshiba Research Europe Limited
(Incorporated in the United Kingdom)
32 Queen Square, BRISTOL, BS1 4ND,
United Kingdom

(72) Inventor(s):
Magnus Stig Torsten Sandell

(74) Agent and/or Address for Service:
Marks & Clerk
90 Long Acre, LONDON, WC2E 9RA,
United Kingdom

(51) INT CL:
H04L 1/00 (2006.01) **H04Q 7/20** (2006.01)
H04Q 7/22 (2006.01)

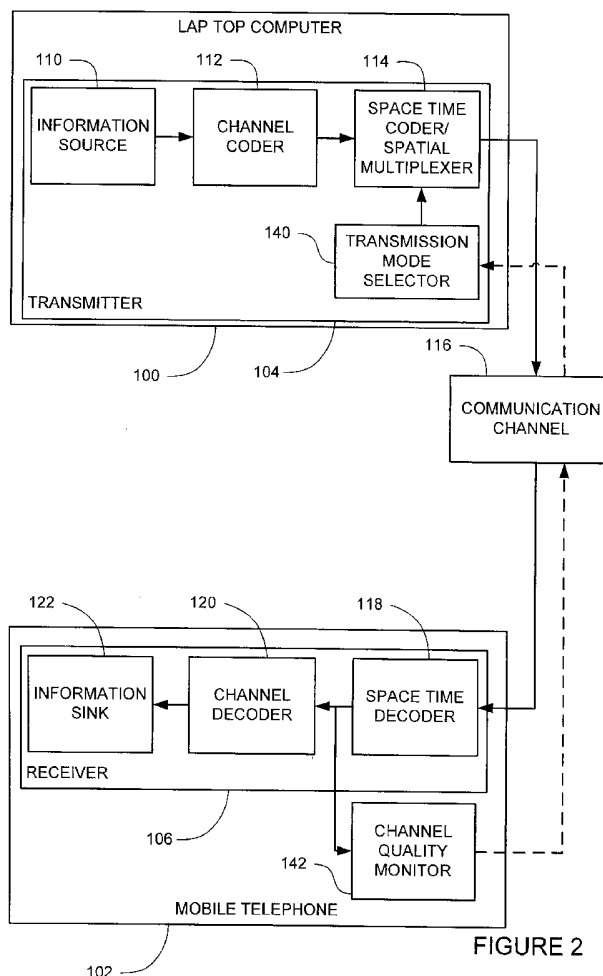
(52) UK CL (Edition X):
H4L LDXX

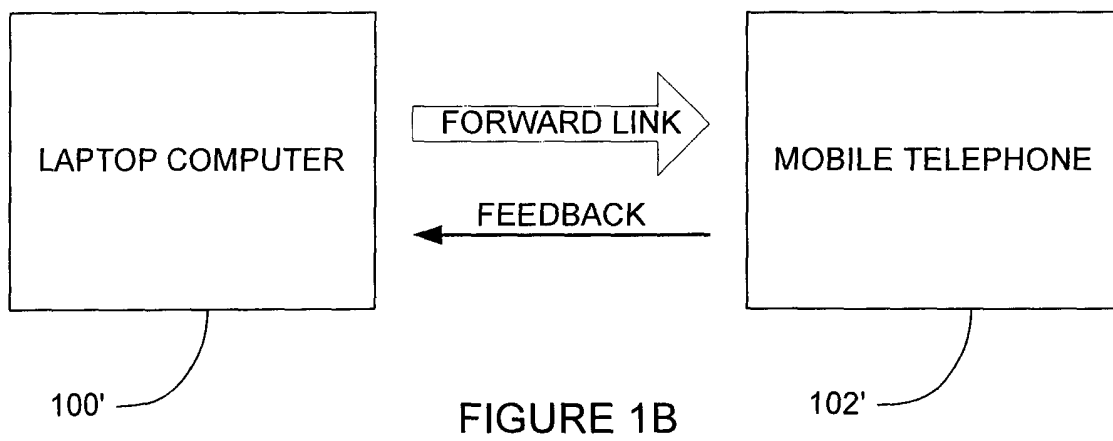
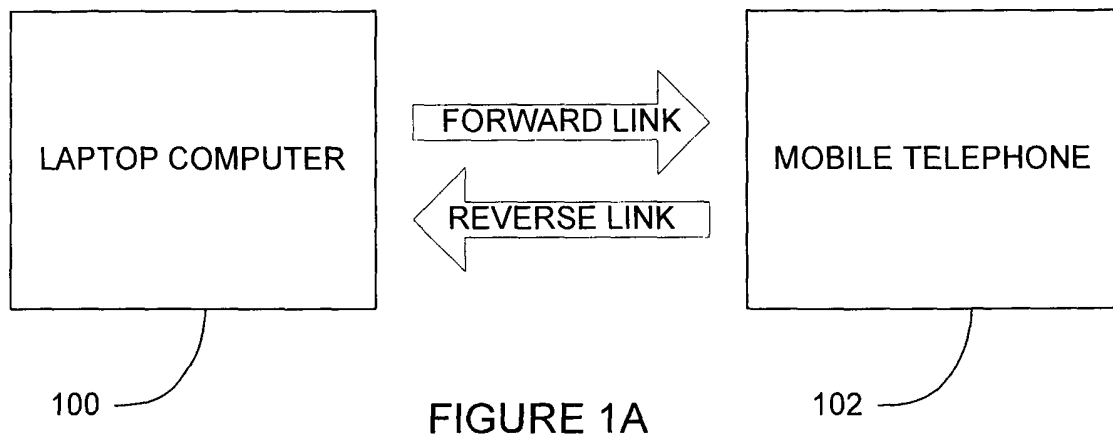
(56) Documents Cited:
GB 2390954 A **GB 2330729 A**
EP 1137217 A1 **US 20050249159 A1**

(58) Field of Search:
UK CL (Edition X) **H4L**
INT CL **H04L, H04Q**
Other: **Online : wpi ; epodoc ; paj**

(54) Abstract Title: **Wireless communication apparatus**

(57) A communications method and apparatus provides selection of a most appropriate transmission mode, by making a determination of channel quality. The channel quality is determined as a preliminary, or front end processing stage, prior to channel decoding. This takes advantage of inherent quality information in the soft likelihood data decoded on a signal, and avoids the need for substantial reconfiguration of the channel decoding stage.





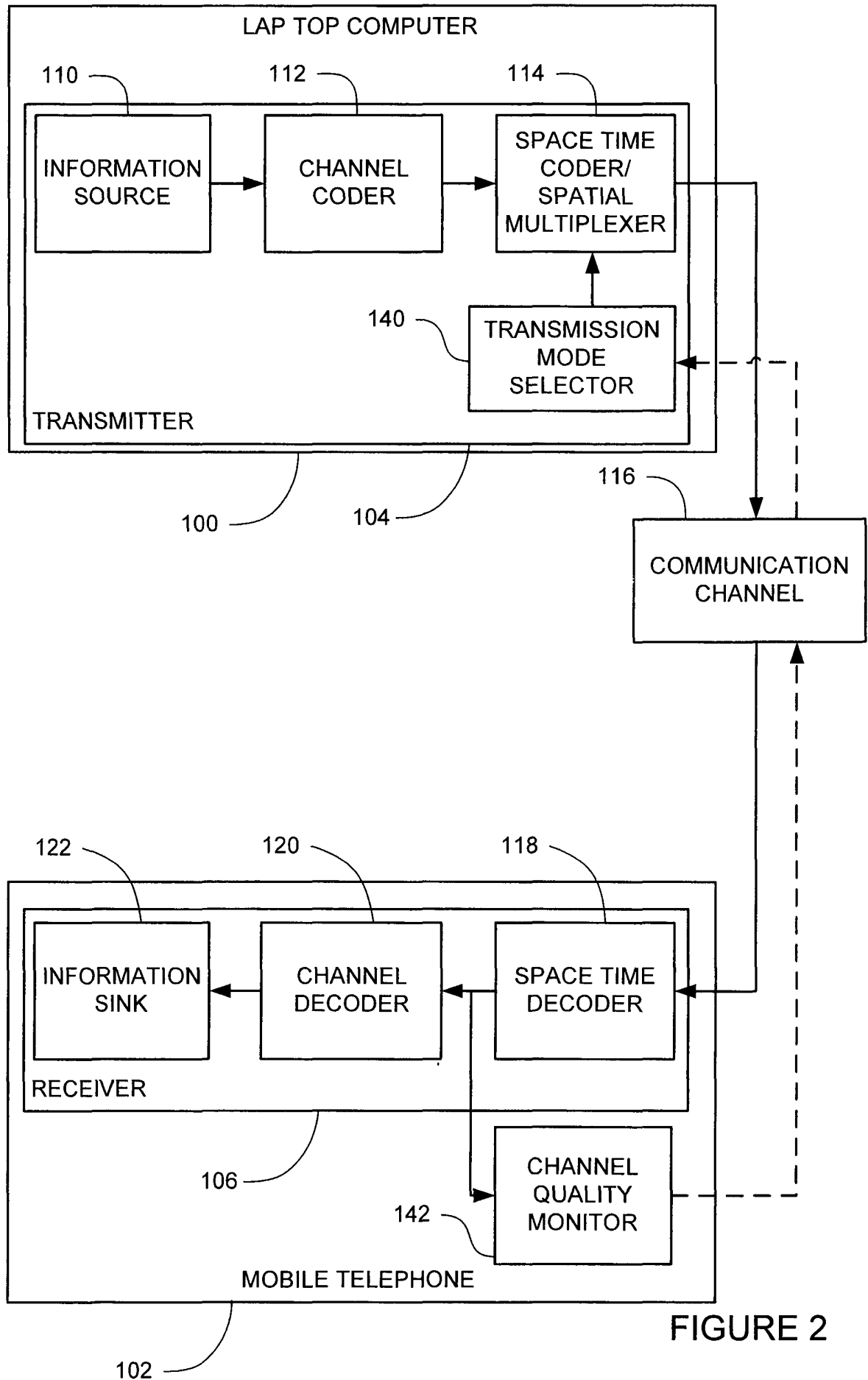


FIGURE 2

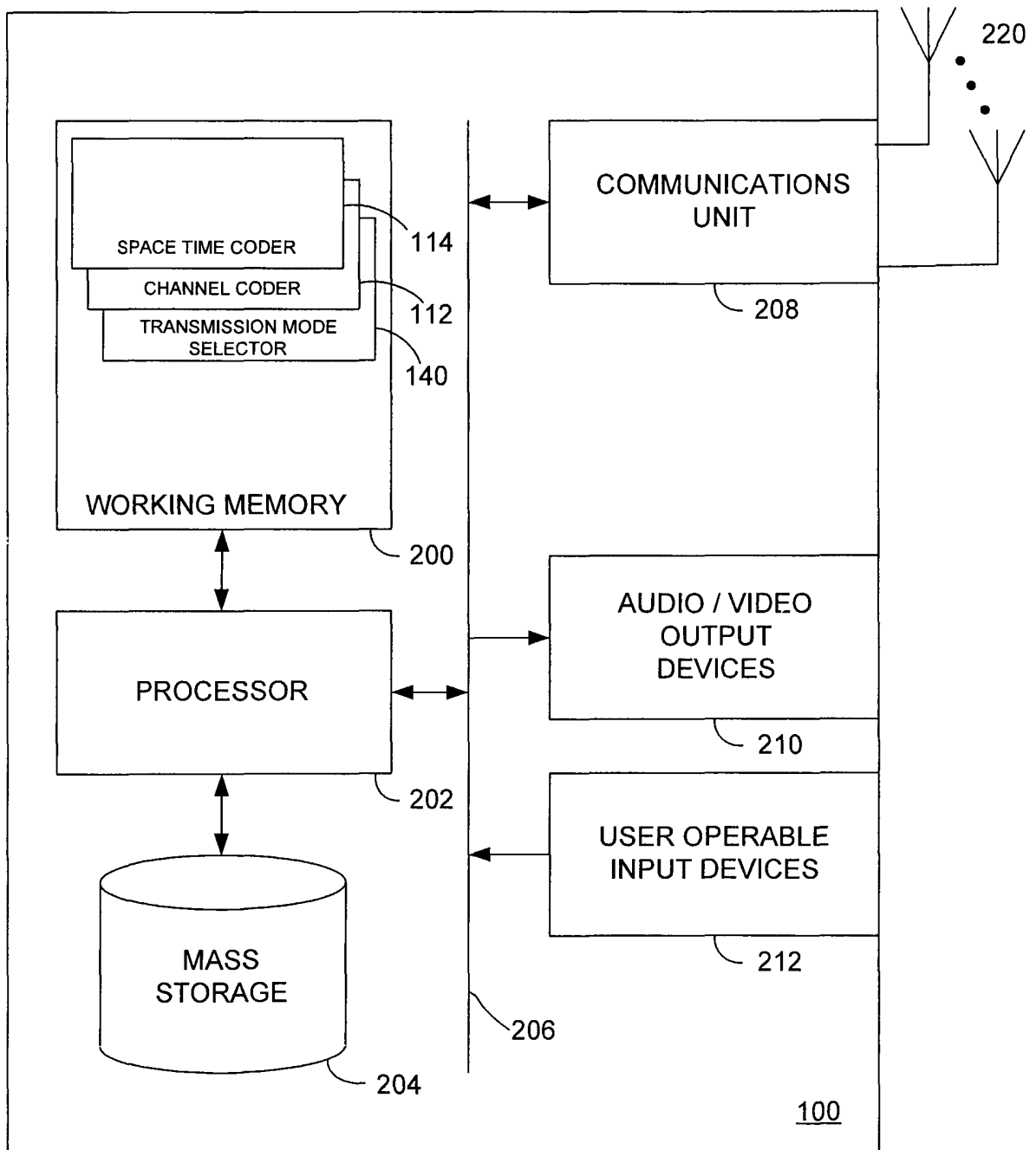


FIGURE 3

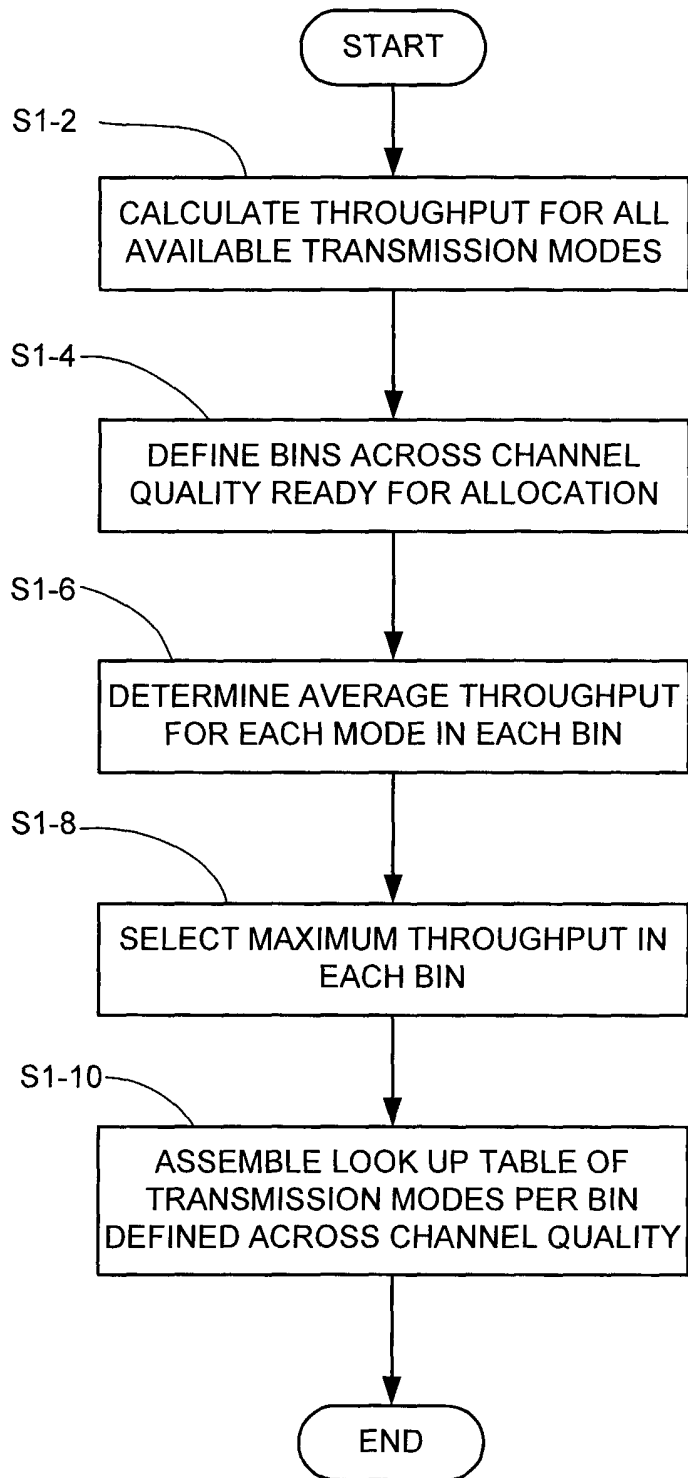
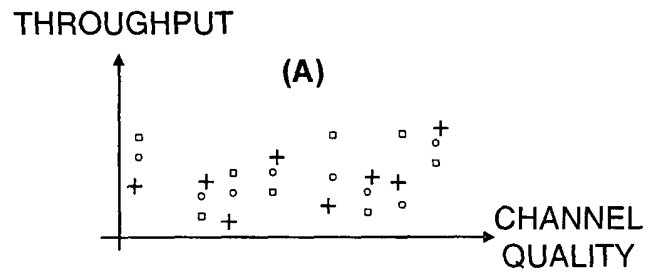


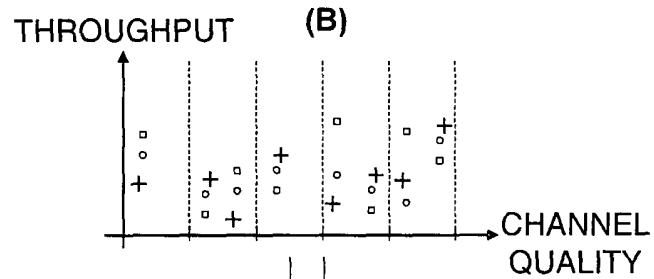
FIGURE 4

KEY:

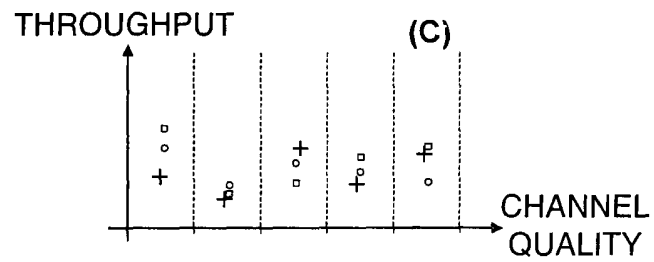
MODE 1 □
 MODE 2 ○
 MODE 3 +



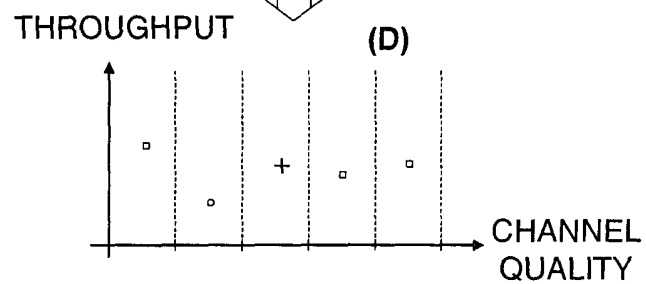
CREATE BINS



AVERAGE



MAXIMUM



SELECTION RULE

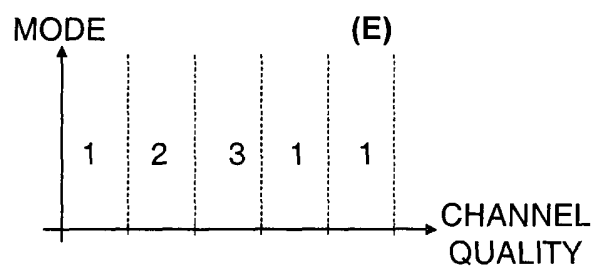


FIGURE 5

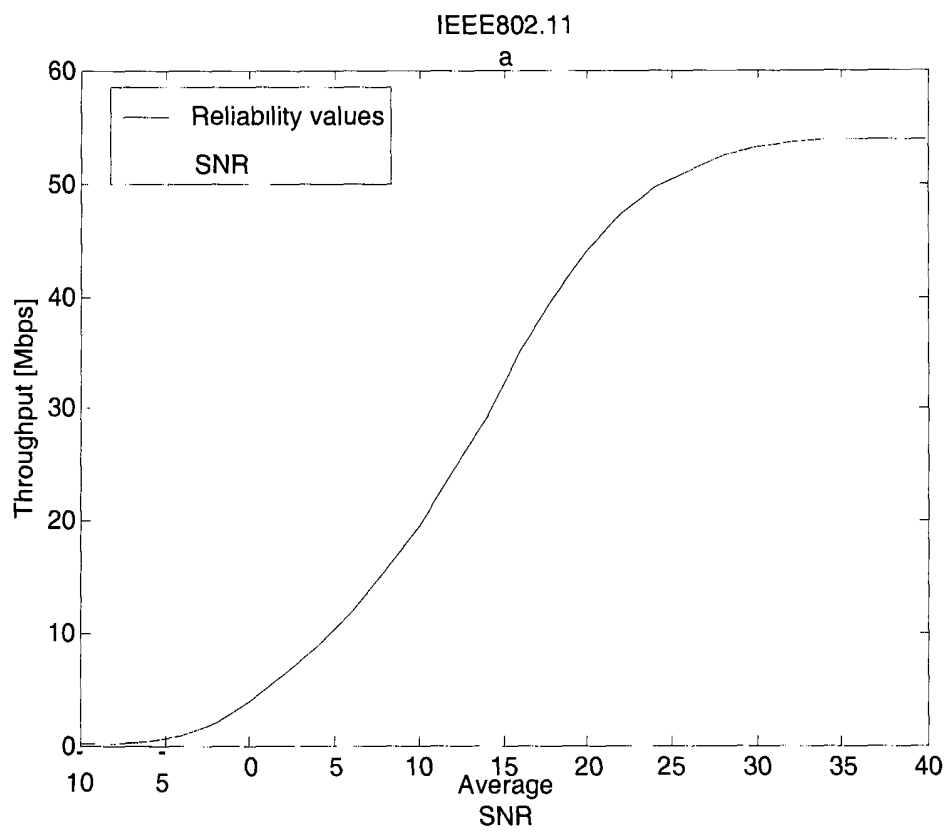


FIGURE 6

Wireless Communications Apparatus

The present invention concerns a wireless communications link between two mobile stations in a wireless communications system.

In wireless communications systems, the link between two mobile stations is susceptible to variation in link quality, for instance due to shadowing or fading. It is desirable in such a system to configure a communications link such that control of the link is governed, at least in part, by a need to maximise data throughput and thereby to increase the capacity of the system as a whole. In order to achieve this, it is important that the transmission format can be changed dynamically, i.e. during the maintenance of the communications channel, and not merely on establishment of the channel at the outset. This can be achieved by estimating a channel quality parameter which will indicate which transmission mode is most suitable at a particular point in time.

In communications systems, it is preferable to employ link adaptation in order to aim for a maximised throughput. Link adaptation involves adaptive change of certain transmission parameters (for example power, modulation, or code rate). Typically, a high data rate gives rise to a high error rate. Therefore it is undesirable to transmit at an excessively high data rate as this will cause too many errors and thus low data throughput. On the other hand, retaining a conservative data rate to avoid a high error rate will lead to slow throughput of a given quantity of bits. By using different code rates, modulations and space-time codes, it is possible to choose the most appropriate link transmission characteristics to achieve a desired data rate. This approach is typical, for example, in MIMO systems.

For example, wireless communication can be effected using TDD transmission modes. In such an arrangement, forward and reverse links are time multiplexed on the same channel. In that way, channel quality can be monitored by a receiving node, and returned to the transmitting node on the reverse channel. This estimated channel quality

can then be used to select the transmission parameters, for the “forward” link. It will be appreciated that the same approach can be taken to selecting transmission parameters for the reverse link.

Alternatively, FDD can be employed. In this case, the forward and reverse link are on different frequencies, and so the channel quality can be estimated at the receiving station on the forward link and passed back to the other station via a feedback channel.

In either case, the object of link adaptation is to estimate the optimal transmission mode for the present channel conditions. This presents a problem, in that it is necessary to describe the channel in such a way that a decision can be taken on the most appropriate transmission mode to use.

Several publications describe possible channel quality parameters, and ways in which the selected parameter can be estimated. In SISO systems, the instantaneous SNR is often used to determine the channel quality. In contrast, in MIMO systems, the instantaneous SNR is generally not appropriate since it does not take into account the interference between the different spatial streams.

“A general optimal switching scheme for link adaptation” (Tang, F.; Deneire, L.; Engels, M.; Moonen, M.; 54th IEEE Vehicular Technology Conference, 7-11 Oct. 2001: Volume 3, Pages 1598 - 1602) describes an approach involving the use of signal-to-interference-plus-noise-ratio (SINR) as the channel quality parameter.

In “Link adaptation in a multi-antenna system” (Jungnickel, V.; Haustein, T.; Pohl, V.; von Helmolt, C.; The 57th IEEE Semiannual IEEE Vehicular Technology Conference, 22-25 April 2003: Volume 2, Pages 862 - 866), eigenvalues/condition number of the channel matrix are used to determine the quality of the link.

In “Feasible criteria of link adaptation for wireless LANS using soft output Viterbi decoder” (Horisaki, K.; Namekata, M.; Saito, T.; Uekawa, Y.; Aikawa, T.; 59th IEEE Vehicular Technology Conference, 17-19 May 2004: Volume 3, Pages 1792 - 1796)

the soft output from a Viterbi decoder is used. However, the way in which this is harnessed is complex, and there is a general desire to reduce complexity in data processing apparatus where possible.

It is thus an aim of an aspect of the present invention to provide a method of estimating channel quality, so that link adaptation can take place. The present invention is concerned with this estimate of channel quality, and it is envisaged that at least one of the previously disclosed techniques, or future improvements thereon, for link adaptation, can be used with the present invention once channel quality has been estimated.

The present invention will now be explained further by means of examples of specific embodiments, with reference to the accompanying drawings, in which:

Figures 1A and 1B illustrate a communications system illustrating exemplary implementations of the invention;

Figure 2 illustrates a simplified diagram of operational stages of communication arranged across a wireless communications channel;

Figure 3 illustrates a laptop computer for use in a communications system to implement a specific embodiment of the invention;

Figure 4 illustrates a flow diagram of a method of determining a look up table for management of transmission mode selection in the illustrated specific embodiment;

Figure 5 illustrates a flow diagram of a specific example of establishment of a look up table in accordance with the process illustrated in figure 4; and

Figure 6 illustrates a graph of throughput against average signal quality after link adaptation in accordance with the invention, for a simulation using the described embodiment.

The following description of a specific embodiment of the invention is made in the context of figure 1, showing two examples in which a lap top computer is shown in wireless communication with a mobile telephone. The lap top computer 100 of the first arrangement, as shown in Figure 1A, is in wireless communication with a mobile telephone 102 in transmission modes in a time-division duplex (TDD) system. That is, the two devices 100, 102 share the same channel. Hence, the laptop computer 100 is able to estimate the channel quality from the “reverse” link when the mobile phone 102 transmits back to the laptop computer. This estimated channel quality can then be used to select the transmission parameters, for the “forward” link.

In figure 1B, a frequency-division duplex (FDD) system is employed. Again, a laptop 100' and a mobile telephone 102' are implemented. In this case, the forward and reverse link are on different frequencies, and so the channel quality can be estimated at the mobile telephone 102' on the forward link and passed back to the laptop computer 100' via a feedback channel.

Figure 2 illustrates a block diagram of the communication system illustrated in figure 1A, with functional blocks showing schematically the performance of the specific embodiment of the invention. The lap top computer 100 is shown comprising a transmitter 104 configured with an information source 110, a channel coder 112 and a space time coder 114 in accordance with a conventional MIMO transmitter device. This, as will be described further, is effectively implemented using existing hardware and software components of the computer 100.

The transmitter 104 further comprises means (not shown), which will in practice include a multiple element antenna unit, for placing encoded data in a communication channel 116.

The mobile phone 102 comprises a receiver 106 which correspondingly comprises means (not shown) for receiving data placed in the communication channel 116. The receiver 106 then comprises a space time decoder 118, a channel decoder 120 and an information sink 122.

The space time decoder 118 acts as a front-end processing unit, operable to calculate a soft estimate of the bits transmitted over the air, while the channel decoder 120 uses the redundancy of the channel code to estimate the data bits (“useful” information).

It will be appreciated that, in use, the lap top computer 100 will also implement the complementary functions and structures of a receiver, and correspondingly the mobile phone 102 those of the transmitter, but that these are omitted from the schematic drawings and accompanying description for reasons of clarity.

The receiver 106 further comprises a channel quality monitor 142 which takes the soft information from the space time decoder and determines a channel quality parameter on the basis of the soft information. The soft values determined by the space time decoder represent the reliability of the bit estimates. These can then be used to determine the channel quality. If these reliability values, typically log-likelihood ratios (LLR), are large, this indicates a reliable channel whereas, if they are small, the channel quality is low.

This channel quality information is then passed back to the transmitter 104 on the return or feedback path as the case may be. The transmitter 104 of the lap top computer further comprises a transmission mode selector 140 which determines a transmission mode selection on the basis of prior determination of the most appropriate transmission mode for a given channel quality.

The lap top 100 implemented in accordance with the present invention is illustrated in figure 3. The lap top 100 is illustrated as being of conventional form, with the advanced processing capabilities that would now be considered substantially standard. The lap top 100 comprises a processor 202 operable to execute machine code instructions stored in a working memory 200 and/or retrievable from a mass storage device 202 (such as flash memory or even a miniature hard disk drive). By means of a general-purpose bus 206, user operable input devices 212 are in communication with the processor 202. The user operable input devices 212 comprise any means by which an input action can be interpreted and converted into data signals.

Audio/video output devices 210 are further connected to the general-purpose bus 206, for the output of information to a user. Audio/video output devices 210 include any device capable of presenting information to a user, for example, a speaker and a video display unit.

A communications unit 208 is connected to the general-purpose bus 206, and further connected to a set of antennas 220. By means of the communications unit 208 and the antennas 220, the lap top 100 is capable of establishing wireless communication with the mobile telephone 102. The communications unit 208 is operable to convert data passed thereto on the bus 206 to a signal carrier in accordance with a communications protocol previously established for use by a system in which the lap top 100 is appropriate for use, for example 802.11a.

In the lap top 100 of figure 3, the working memory 200 stores applications which, when executed by the processor 202, cause the establishment of the space time coder 114, the channel coder 112 and the transmission mode selector 140.

It will be appreciated that the mobile telephone 102 will, in accordance with the foregoing, also be of a substantially conventional construction, save for also comprising the channel quality monitor 142. This thus enables implementation of the specific embodiment of the invention as described above, and whose process of execution will now be described in further detail with reference to figures 4 and 5.

The described reliability values, used as a channel quality parameter, calculated as described above by the channel quality monitor 142 can be used in several ways to perform link adaptation. An example will now be described using a look-up table, with reference to figure 4 which illustrates a flow diagram setting out the steps executed in the process, and figure 5 which illustrates an example of the implementation of the process.

In a first step S1-2 the throughput for a particular channel realisation is calculated for all possible transmission modes. As illustrated in graph (a) in figure 5, in this case three transmission modes are implemented. The throughput is defined as the product of the

data rate and the probability of successful transmission of a packet, i.e., the average amount of data that is successfully transmitted. For each channel realisation, a point for each transmission mode is plotted on the graph. This graph can be stored as a look up table for later reference.

It will be appreciated that this step is performed off line, i.e. before commencement of transmission. Further, this look up table can be trained adaptively on the basis of results derived from received and transmitted signals during use of the equipment.

Then, in step S1-4, the simulation continues for a large number of channel realisations (to capture the stochastic nature of the channel) and SNR values (to capture the wide range of transmitter-receiver condition, such as path loss and shadow fading). As illustrated in graph (b) in figure 5, “bins” of channel quality values are defined, to group values that are almost the same.

In step S1-6, the average throughput for each mode is then computed within each bin (see graph (c) in figure 5). For each bin, the maximum of these computed averages is taken in step S1-8, as shown in graph (d) of figure 5. Finally, in step S1-10, a look up table is assembled storing the identity of the transmission mode with the highest throughput for each bin (as shown in graph (e) of figure 5).

Once the look-up table has been constructed in this way, it can be used by the device concerned (whichever of the laptop 100 or the mobile phone 102 is performing the assessment) to select the transmission mode to be used in future transmission. In the present example, the look up table is constructed and retained in the transmission mode selector 142 of the mobile telephone 102.

To illustrate further the application of the specific embodiment of the invention, figure 7 illustrates the performance of the described process of link adaptation when applied to an IEEE802.11a system which has 8 different modes (different modulations and code rates). The “front-end processing” in this case is a simple demodulator computing soft values using the channel and noise variance. An existing technique for channel quality estimation is used to compute the SNR of the received signal, defined as the power of

the “useful” signal divided by the noise variance. Link adaptation using both techniques are simulated and the throughput curves are presented. Apart from having much lower complexity, the LLR-based link adaptation demonstrates better performance than the previous approach.

It will be understood that, in alternative embodiments, wherein another communications system is used, the space time decoder will be substituted for another appropriate front-end processing unit. For example, in a single-input single-out (SISO) system, the front end processing unit will be a demodulator or equaliser compensating for the channel. In a CDMA system it would typically be a rake receiver. The invention is described herein in detail with reference to MIMO by way of example only.

Moreover, it will be understood that the function of the channel quality monitoring and the link adaptation can be performed at the same unit, in a bi-directional system.

Whereas the described embodiment involves communication between a laptop computer and a mobile station, it will be appreciated that the invention is also applicable to other suitably configured mobile equipment such as a camera or a personal organiser, and to less movable or fixed equipment such as a base station, an access point, a printer or the like.

The described embodiment of the invention imposes no additional constraint on the specification of a suitable device to implement the channel decoder. A conventional channel decoder can be used, which has evident advantages with regard to design cost. The channel decoder is only required to provide hard decisions, and is not required to provide soft output. The use of the BCJR algorithm in the channel decoder can thus be avoided.

The reader will appreciate that the invention described herein and exemplified above can be applied to a variety of transmission technologies. For example, using TDD technology, a station can estimate link quality from a received signal, and then use this estimate for transmission. This is because the forward and reverse links in such

technologies share a channel. This is consistent with the arrangement set out in figure 1A.

Alternatively, using FDD technology, a station can generate a link quality estimate from a received signal and then send either that estimate, or a recommended transmission mode, back to the other station for future use. This is commensurate with the arrangement illustrated in figure 1B.

CLAIMS:

1. A method of controlling wireless communication in a communications system, wherein the system offers at least two transmission modes from which one is to be selected for use, the method comprising determining channel quality and selecting one of said transmission modes on the basis of channel quality, said step of determining channel quality including the step of monitoring reliability of data borne on a signal received at a receiver of the system, prior to channel decoding of said data.
2. A method in accordance with claim 1, wherein the step of determining channel quality includes the step of intercepting soft information prior to channel decoding in the receiver, and using reliability information in said soft information as channel quality information.
3. A method in accordance with claim 2, wherein the reliability information comprises log-likelihood ratios.
4. A method in accordance with any preceding claim comprising determining a representative throughput measure for each transmission mode with respect to channel quality, and establishing a transmission mode selection rule on the basis of said determining step.
5. A method in accordance with claim 4 wherein the steps of determining and establishing are executed off line.
6. A method in accordance with claim 4 or claim 5 wherein the step of determining a representative throughput measure for a particular transmission mode comprises recording throughput and channel quality for a plurality of channel realisations, and storing the same.
7. A method in accordance with claim 6 wherein the step of establishing a transmission mode selection rule comprises the step of quantizing the expected range of

channel quality in said channel into a plurality of sub-ranges and, for each sub-range, determining the most appropriate transmission mode for use.

8. A method in accordance with claim 7 wherein the step of determining the most appropriate transmission mode for use comprises considering, on the basis of stored throughput and channel quality information, which transmission mode is most likely to deliver maximum throughput for the sub-range concerned.

9. A method of determining an indication of channel quality in a wireless communication system, comprising receiving, at a receiver, a signal in accordance with a wireless communications protocol, determining reliability information from the received signal, the reliability information being suitable for use in a channel decoding process, and determining a channel quality indication from the reliability information.

10. A method in accordance with claim 9 wherein the step of determining reliability information comprises intercepting information prior to execution of a channel decoding process.

11. A method in accordance with claim 9 or claim 10 wherein the step of determining reliability information comprises extracting log-likelihood information from the received signal.

12. A wireless communications apparatus comprising signal receiving means for receiving a signal over a communications channel, channel quality determining means, for determining, from said received signal and prior to channel decoding, an indication of channel quality, and transmission mode selection means operable to select a transmission mode for use on said channel on the basis of channel quality.

13. Apparatus in accordance with claim 12 and further comprising transmission mode selection rule determining means operable to determine a transmission mode rule governing the selection of transmission mode.

14. Apparatus in accordance with claim 13 wherein said transmission mode selection rule determining means is operable to determine a transmission mode selection rule on the basis of previously recorded information describing transmission throughput with respect to channel quality.
15. Apparatus in accordance with claim 14 wherein said transmission mode selection rule determining means is operable to adapt said transmission mode rule on the basis of operation of said apparatus.
16. Apparatus in accordance with any one of claims 12 to 15 operable to transmit and receive on the same communications channel, and operable to transmit in accordance with the transmission mode selected by the transmission mode selection means.
17. Apparatus in accordance with any one of claims 12 to 16 operable to transmit information defining said channel quality measure on said communications channel.
18. Apparatus in accordance with any one of claims 12 to 16 operable to transmit information defining said selected transmission mode on said communications channel.
19. A computer program product comprising executable instructions operable to configure general purpose computer communications apparatus to perform the method of any of claims 1 to 11.



Application No: GB0515830.8

Examiner: Mr Richard Howe

Claims searched: 1-8,12-19

Date of search: 3 January 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	1,12	GB2390954 A Motorola - see abstract
A	1,12	GB2330729 A Motorola - see abstract
A	1,12	EP1137217 A1 Telefonaktiebolaget LM Ericsson - see abstract
A	1,12	US2005/0249159 A1 Abraham et al - see abstract

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category	P	Document published on or after the declared priority date but before the filing date of this invention
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X:

H4L

Worldwide search of patent documents classified in the following areas of the IPC

H04L; H04Q

The following online and other databases have been used in the preparation of this search report

Online : wpi ; epodoc ; paj