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(54) Title: METHOD AND SYSTEM FOR TRANSMITTING INPUT STREAM OF SYMBOLS IN MULTIPLE-INPUT / MUL-
TIPLE-OUTPUT WIRELESS COMMUNICATIONS SYSTEM
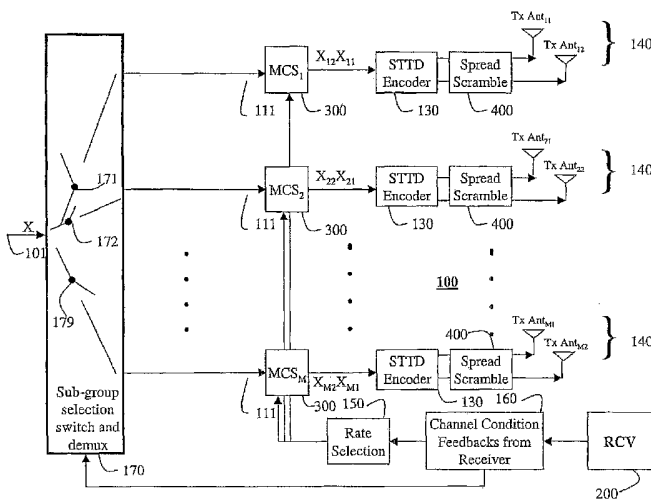
(57) Abstract: A method and system transmits an input stream of data symbols in a multiple-input / multiple-output wireless com-
munications system that includes M subgroups of transmitting antennas. A stream of data symbols is provided to a combined switch
and demultiplexer. The combined switch and demultiplexer selects a subset L of the M subgroups of antennas as active, where L < M.
The demultiplexer then splits the data stream into L substreams, which are fed to the L subgroups of antennas. Before transmission,
each of the L substreams is adaptively modulated and coded to a maximum data rate while achieving a predetermined performance
on an associated channel used to transmit the substream. Space-time transmit diversity encoding is applied to each coded substream
to generate multiple output streams, one output stream for each antenna of each of the L subgroups. The selection by the switch is
based on channel conditions fed back by a receiver of the output streams.

SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
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Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

Method and System for Transmitting Input Stream of Symbols in
Multiple-Input / Multiple-Output Wireless Communications
System

Technical Field

The invention relates generally to wireless communications, and
more particularly to multiple input/multiple output wireless
communications systems with variable rate encoding and subgroup
selection.

Background Art

In a wireless communication system, such as 3rd generation (3G)
wireless code-division multiple access (CDMA) system, it is
desired to concurrently support multiple services and multiple
data rates for multiple users in a fixed bandwidth channel. A
number of modulation and coding schemes (MCS) are known. One
scheme uses adaptive modulation and coding (AMC) to modulate
and encode user data symbols before transmission.

In order to increase the capacity of a wireless communication
system in fading channel environments, transmit diversity is
widely adopted. In 3G systems, an open loop solution uses two
antennas for transmission and a single antenna for reception.
In such a system, every two symbols of the transmitted data is

further encoded by a space-time transmit diversity (STTD) encoder

to generate four encoded symbols, two symbols for each antenna.

Each antenna transmits different symbol streams through the

channel to reach diversity gains.

To support real-time multimedia services in a fixed channel

bandwidth, multiple input/multiple output (MIMO) systems have

been developed for high data rate transmissions in wireless

communication systems, such as high speed downlink packet access

(HSDPA) in WCDMA systems. In a MIMO system, multiple antennas

are used by the transmitter and the receiver to increase the

capacity of the system.

In general, the system capacity is improved as the dimension

of the diversity, i.e., number of the antennas, increases. For

very high speed transmission, a large number of antennas might

be necessary to reach the target performances. One solution to

this problem is to extend the current STTD system to MIMO

configurations. In such a system, the compatibility with the

current STTD system needs to be remained in order to use current

STTD system for lower data rate transmission, such as voice

services, while the system capacity is improved due to the use

of MIMO configurations.

Disclosure of Invention

The invention provides a transmitter for multiple input/multiple

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output (MIMO) wireless communications systems. The invention is compatible with space time transmit diversity (STTD), which is widely adopted in 3G wireless communication systems, such as W-CDMA systems for the 3GPP standard, and CDMA2000 systems for the 3GPP2 standard.

The invention applies adaptive modulation and coding (AMC) to each subgroup of the antenna systems to match different channel conditions with required service performance and reach the maximal system capacities. More specifically, this invention is suitable for high data rate transmission for MIMO systems, while retaining compatibility with existing STTD schemes. The invention can be used for high data rate transmission, as well as for lower rate transmissions such as voice services, to increase the total number of the active users within one cell.

In the preferred embodiment, a subset of the available antenna subgroups are selected and used, depending on channel conditions.

Brief Description of Drawings

Figure 1 is a block diagram of a transmitter in a multiple-input/multiple-output wireless communications system according to the invention;

Figure 2 is a block diagram of a transmitter in a multiple-input/multiple-output wireless communications system

according to the invention with antenna subgroup selection;

Figure 3 is a block diagram of a modulation and coding scheme
block according to the invention; and

Figure 4 is a block diagram of a spreading and scrambling block
according to the invention.

Best Mode for Carrying Out the Invention

Figure 1 shows a transmitter 100 for a
multiple-input/multiple-output (MIMO) wireless communications
system according to the invention. The transmitter 100 includes
a demultiplexer 110 coupled to multiple (M) adaptive modulation
and coding (AMC) blocks 120. The output of each AMC block is
coupled to a space-time transmit diversity (STTD) encoder 130s.
The outputs of the STTD encoders are coupled to N antennas 140,
where each encoder is coupled to subgroups of antennas, for
example, groups of two.

The system 100 also includes a rate selector 150 receiving channel
conditions 160 from receivers, not shown. The channel conditions
can include the received signal-to-noise-ratio (SNR) for each
transmit channel. The channel conditions 160 can be updated
periodically, or as needed. The channel condition can be used
for rate selection 150.

During operation of the system 100, a stream of data symbols
X 101 is first demultiplexed 110 into M substreams 111, where
M is half the total number N antennas 140. The M substreams are
encoded by the M AMCs 120 at M data rates.

The M data rates are determined by the channel condition feedbacks
160 from the receivers, not shown. Accordingly, each AMCs encodes
the substream at a maximum data rate to achieve a predetermined
service performance for the associated channel. Essentially,
the service performance is a measure of the error rate, e.g.,
bit error rate (BER), frame error rate (FER), or SNR.

The AMCs 120 use a predefined combinations of modulations, e.g.,
QPSK, 8-PSK, 16-QAM, etc, and channel codings, such as
convolutional coding and turbo coding with various coding rates,
which define the information rates or capacity for each substream.
Here, a better channel condition means a higher data rate is
achievable with a predetermined service performance under such
a channel condition.

For each substream 111, the corresponding AMC block 120 outputs
the information symbols X_{i1} and X_{i2}, for i = 1, 2, …, M, which
are feed to the STTD encoder block 130, as shown in Fig.1. The
STTD 130 encodes the input information symbols and the outputs
are given by

$$\begin{bmatrix} X_{i2} & X_{i1} \\ -X_{i1}^* & X_{i2}^* \end{bmatrix},$$ (1)

where * is the complex conjugate. Each row of the STTD output matrix in Equation (1) represents the output to a specific transmit antenna 140. There are two transmit antennas for each substream 111, and therefore, there are total $N = 2M$ antennas 140.

In order to adaptively allocate different data rates for each substream 111, it is necessary for the receiver to perform channel or SNR estimations for the received signal from each transmit antenna, and report this back to the transmitter as the channel condition 160.

The feedback information can be encoded and modulated for transmission in order to reduce errors in the feedback information. The channel condition feedbacks can be updated periodically from the receivers. In general, higher update frequency is favorable in order to follow the channel condition closely, which achieves higher system capacity. In order to keep the feedback information amount a reasonable size, the number of modulation and channel coding combinations is as small as possible.

Selecting SubGroups of Antennas

However, under certain channel conditions, which are common, it is advantageous to resort to subgroup selection 170, as shown in Figure 2. With subgroup selection, only L subgroups of the M subgroups of antennas are used, where $L < M$. Subgroups of antennas that are not used are referred to as 'inactive', and the used subgroups of antennas are called 'active'.

One example of such a channel condition is when the transmitter determines that the signal to interference plus noise ratio (SINR) of a particular subgroup of antennas, as determined at a particular receiver 200 of the transmitted output streams, is insufficient to meet the bit error rate (BER) requirements of even the lowest rate modulation and coding scheme (MCS) 300 for the data stream of that subgroup. By shutting off the entire subgroup of antennas, the interference generated by this inactive subgroup is eliminated. Consequently, higher data rate can be selected for the remaining active subgroups, if the number of subgroups L is less than M. In such a case, based on which subgroups are inactive, the transmitter predetermines the appropriate MCSs 300 for the remaining L subgroups, based on the selected subgroups.

Even if all the subgroups can meet the BER requirements while active, shutting-off some of the subgroups can still increase the total data rate, due to a reduction in inter-subgroup interference. For a system where the total power radiated from

all the antennas is constrained, shutting off some subgroups
also ensures that a larger fraction of the total power is allocated
to active subgroups with a higher SINR. Without this solution,
target BERs, which are used to determine the MCS 300 for each
subgroups, based on feedback from the receiver 200, may not be
achievable.

The receiver can also perform MCS selection, either jointly or
independently, for all the subgroups, and feed this back to the
transmitter.

Under extreme adverse channel conditions, all the subgroups can
be made inactive. Surprisingly, this also can improve a total
performance of the system. This can occur when the channel
condition for every of the subgroups cannot meet minimum BER
requirements for a particular receiver. Transmitting under such
adverse conditions has two problems. First, no data are delivered
to the particular receiver, thus valuable bandwidth is needlessly
wasted. Second, transmitting under such conditions only cause
unnecessary interference for other receivers in the system. Thus,
selecting none of the subgroups, for a particular receiver,
increases the overall capacity of the system for the remaining
receivers.

Therefore, in the transmitter shown in Figure 2, only subgroups
that meet minimum SINR requirements are selected 170 by switches

171-179 to be active for transmission. Other subgroups are
deselected and inactive for transmission.

This can be done by feeding the multiple copies of the data stream
101, in parallel, to the switch 170. There is one copy for each
antenna subgroup. Only a subset of the copies of the data stream
corresponding to the active subgroups are passes through to the
demultiplexer. Effectively, the switch and demultiplexer 170
selects a set of the L substream 111 as being active for further
processing, where $L < M$. All other deselected copies of the M
substreams are inactive and no further processing is done on
those substreams. That is, the set of L substreams 111 can include
none or some of the M substreams.

Adapive Modulation and Coding

As shown in Figure 3, each MCS block 300 in Figure 2 include
three blocks for coding 310, interleaving 320, and symbol mapping
330. The operation performed by these three blocks depends on
the selected MCS for the subgroup.

Furthermore, code reuse has been added for use with this scheme.
In code reuse, the same orthogonal variable spreading factor
(OVSF) codes are used by all or some of the sub-groups transmitting
the streams. The presence of scrambling code(s), discussed below,
ensures that the inter-code interference is reduced by a factor

equal to the spreading gain. The allocation of the OVSF codes
to the various sub-groups may be optimized to further reduce
the inter-code interference.

Scrambling Codes

As shown in Figure 4, scrambling 400 is applied to each data
stream, e.g., X12X11 and -X12*X11*. For each subgroup, after
the STTD encoding 130, the subgroup is further demultiplexed
410 into N data substreams 411. Here N, is the number of orthogonal
variable spreading factor (OVSF) codes (OC) 420 used for
transmission. Each OC 420 is multiplied 425 times one of the
N demultiplexed steams 411. The spread streams are added 426.
This is followed by multiplication 435 with a scrambling code
(SC) 430.

The same scrambling code can be used for all subgroups to reduce
the complexity of the system. The scrambling codes reduces
inter-subgroup interference at the receiver.

It is to be understood that various other adaptations and
modifications may be made within the spirit and scope of the
invention. Therefore, it is the object of the appended claims
to cover all such variations and modifications as come within
the true spirit and scope of the invention.

CLAIMS

1. A method for transmitting an input stream of symbols in a multiple-input / multiple-output wireless communications system including M subgroups of transmitting antennas, comprising:

selecting L subgroups of the M subgroups of antennas, where L < M;

demultiplexing, the input stream into L substreams, there being one substream for each one of L selected subgroups of antennas;

adaptively modulating and coding each of the L substreams to a maximum data rate while achieving a predetermined performance on an associated channel used to transmit the substream; and

space-time transmit diversity encoding each of the L coded substreams into a set of output streams, there being one output stream in each set for each antenna of each one of the L subgroups of antennas.

2. The method of claim 1, further comprising:

feeding back, from a receiver, channel conditions; and

selecting the L substreams to be produced by the demultiplexing according to the channel conditions.

3. The method of claim 2, in which the channel conditions measure a signal to interference plus noise ratio of the output streams

received in the receiver.

4. The method of claim 1, in which the adaptive modulation and coding depends on the number L of the substreams.

5. The method of claim 1, in which L is zero to increase an overall capacity of the system including a plurality of receivers.

6. The method of claim 1, in which the adaptive modulating and coding, further comprises:

coding each substream;

interleaving each coded substream; and

symbol mapping each interleaved substream.

7. The method of claim 1, further comprising:

demultiplexing each output stream into a plurality demultiplexed output streams;

multiplying each of the plurality of demultiplexed output streams by an orthogonal variable spreading factor;

adding the demultiplexed output streams, for each output stream, after multiplication into a summed output stream corresponding to each output stream; and

multiplying each summed output stream by a scrambling code.

8. A system for transmitting an input stream of symbols in a

multiple-input / multiple-output wireless communications
system including M subgroups of transmitting antennas,
comprising:

a switch configured to select L subgroups of the M
subgroups of antennas, where L < M;

a demultiplexer configured to split the input stream
into L substreams, there being one substream for each one of
L subgroups of antennas;

means for adaptively modulating and coding each of the
L substreams to a maximum data rate while achieving a predetermine
performance on an associated channel used to transmit the
substream; and

means for space-time transmit diversity encoding each
of the L coded substream into a set of output streams, there
being one output stream in each set for each antenna of each
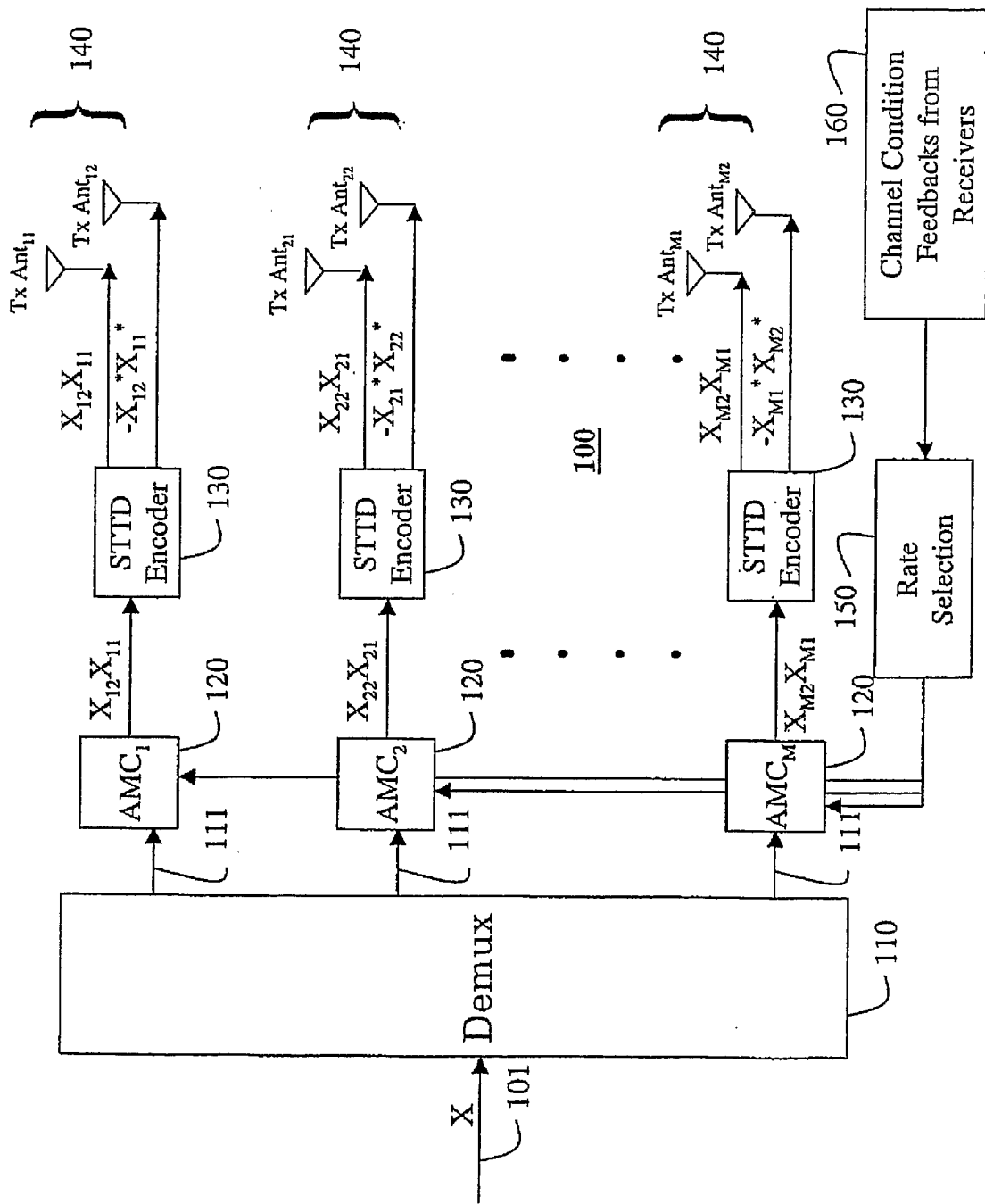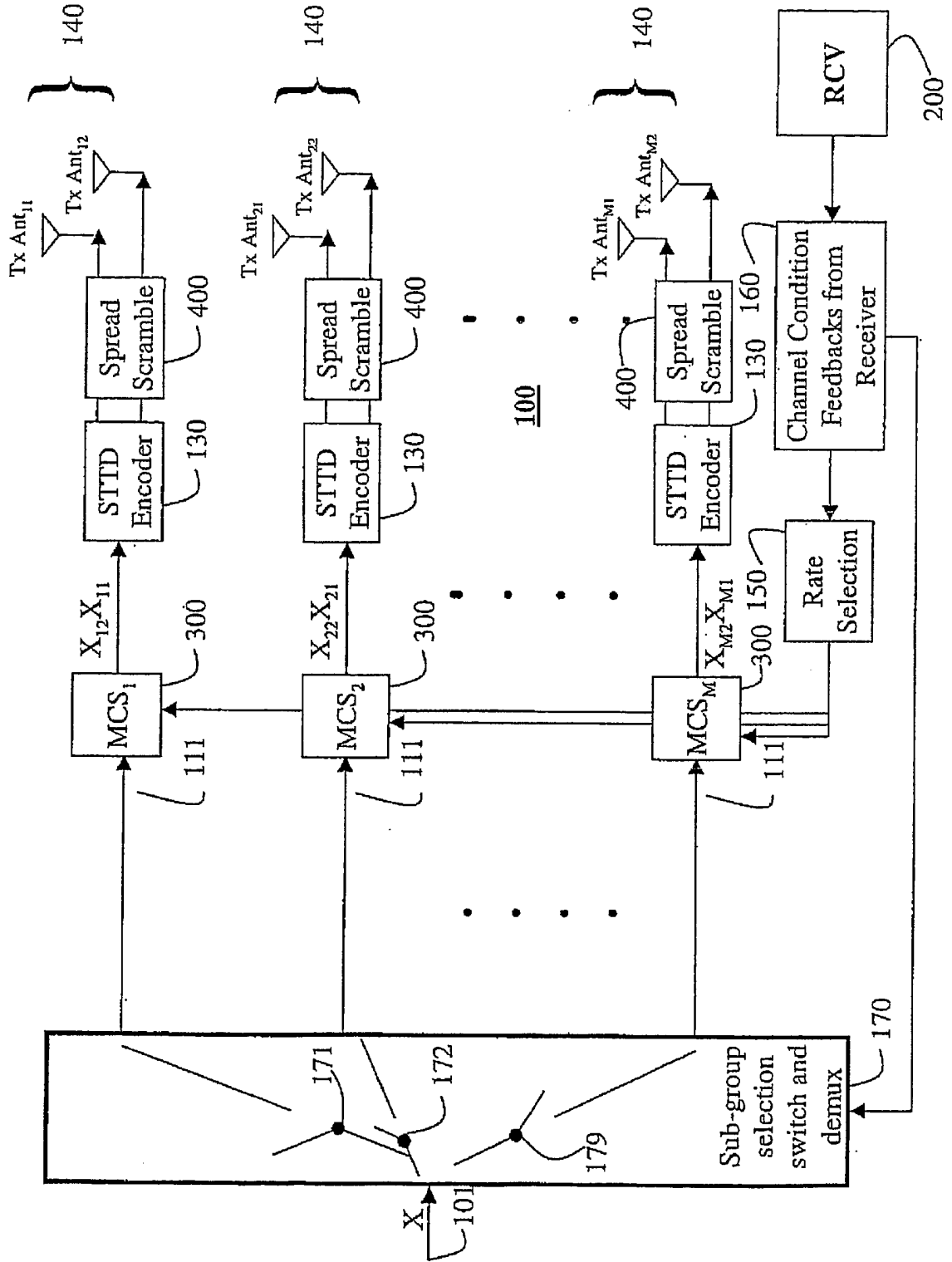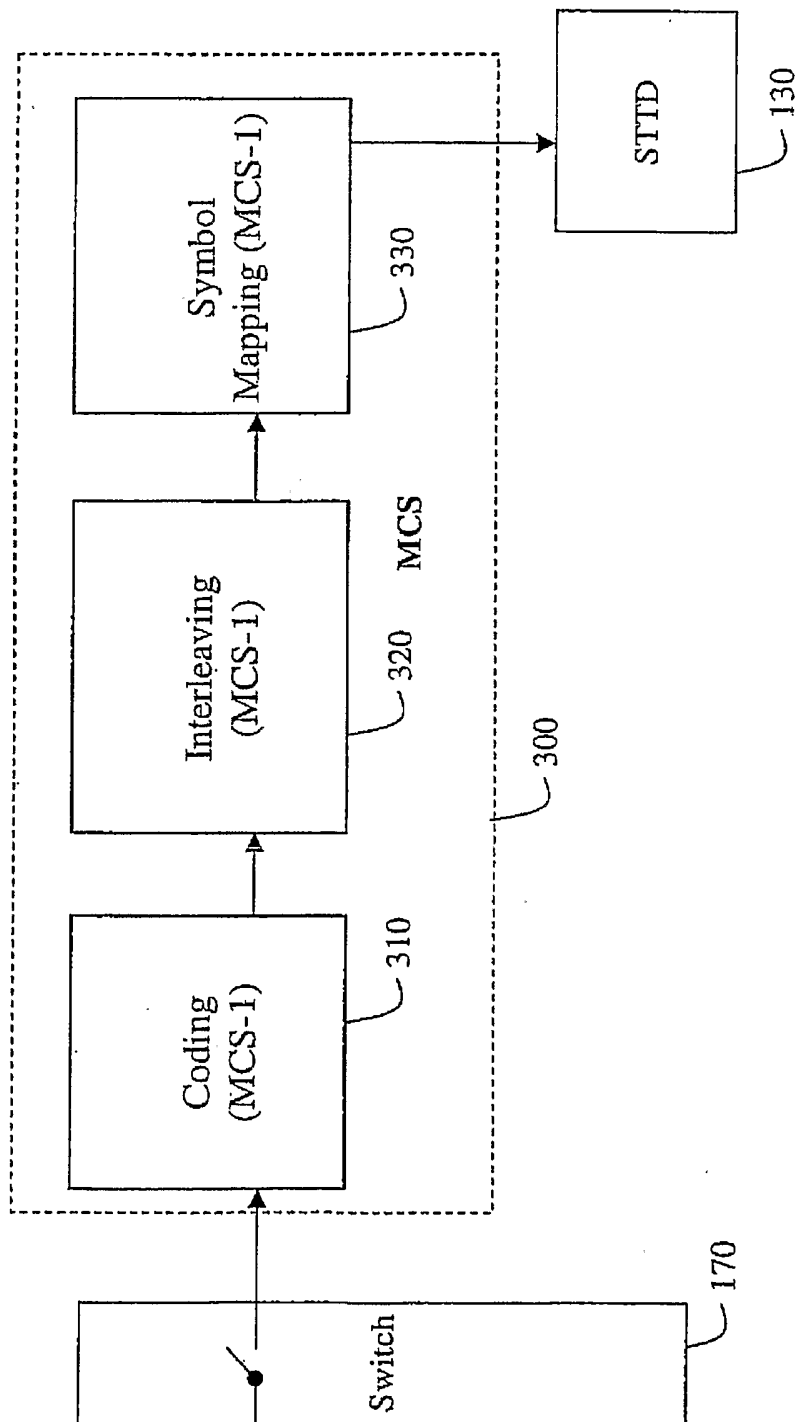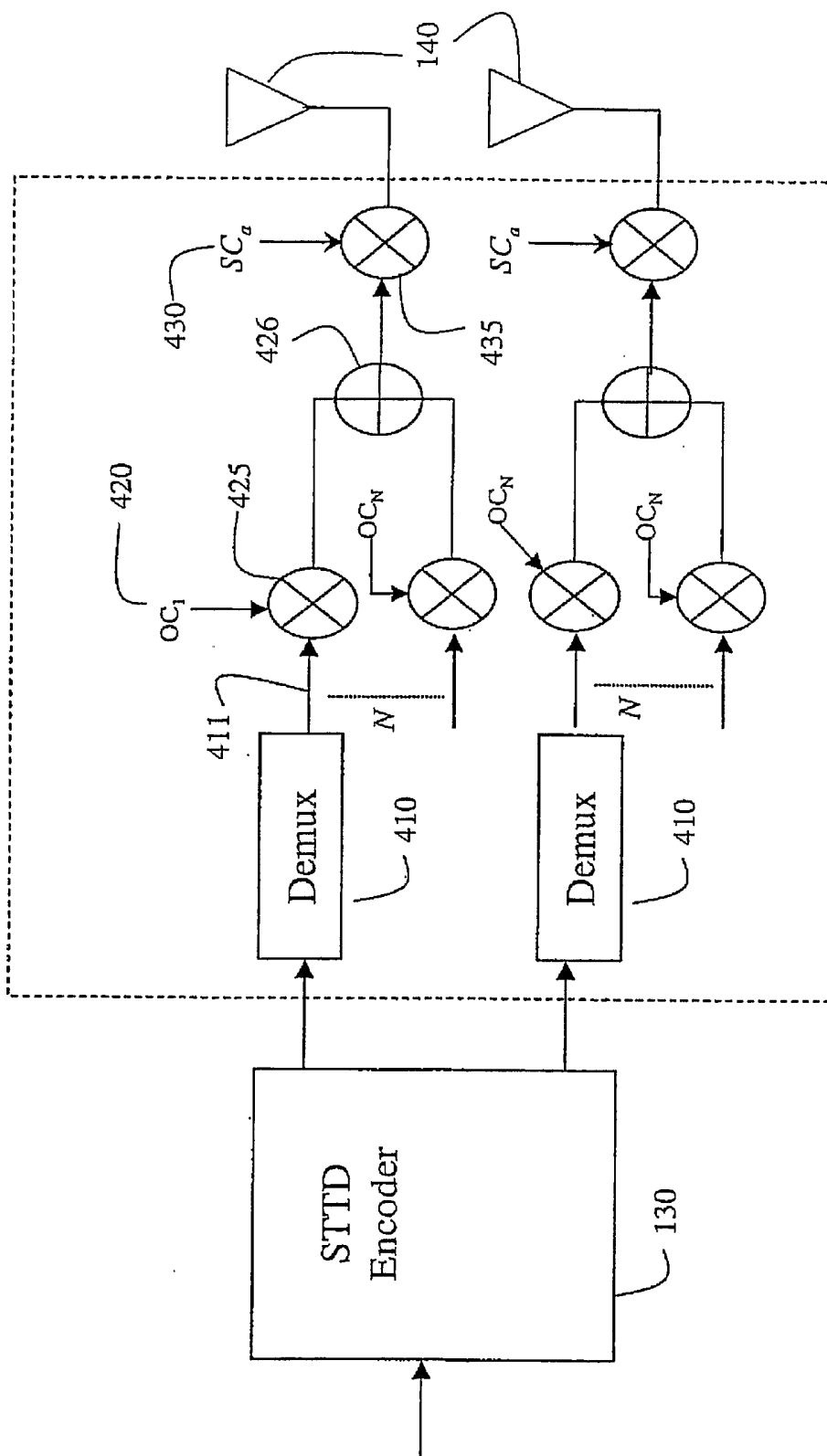one of the L subgroups of antennas.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04B7/06   H04L1/06

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)
IPC 7   H04B   H04L

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, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	KATZ M ET AL: "Combining space-time block coding with diversity antenna selection for improved downlink performance" VTC FALL 2001. IEEE 54TH. VEHICULAR TECHNOLOGY CONFERENCE. PROCEEDINGS. ATLANTIC CITY, NJ, OCT. 7 - 11, 2001, IEEE VEHICULAR TECHNOLGY CONFERENCE, NEW YORK, NY : IEEE, US, vol. VOL. 1 OF 4. CONF. 54, 7 October 2001 (2001-10-07), pages 178-182, XP010562669 ISBN: 0-7803-7005-8 abstract page 178, column 2, last paragraph - page 179, column 2, last paragraph	1-8
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