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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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Additional inventors are being named on the ____none____ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max):

Control and Data Signaling in SC-FDMA Communication Systems

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☐ Application Data Sheet. See 37 CFR 1.76

☐ CD(s), Number of CDs ____________

☐ Drawing(s) *Number of Sheets* ____________

☐ Other (specify) ____________

☑ Specification (e.g. description of the invention) *Number of Pages* 7

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(if appropriate)

TELEPHONE 516-228-3565 Docket Number: 678-3235(P15725-US/ST)

Control and Data Signaling in SC-FDMA Communication Systems

Aris Papasakellariou and Joonyoung Cho
June 4, 2007

1. Introduction

The disclosed invention considers the transmission of positive or negative acknowledgement signals (ACK or NAK, respectively) and channel quality indicator (CQI) signals in a single-carrier frequency division multiple access (SC-FDMA) communications system as it is known in the art and is further considered in the development of the 3GPP E-UTRA long term evolution (LTE). The invention assumes the uplink (UL) communication corresponding to the signal transmission from mobile user equipments (UEs) to a serving base station (Node B). The ACK/NAK and CQI signals may also be referred to as the physical uplink control channel (PUCCH) or simply the control channel. The invention further assumes that ACK/NAK or CQI signals are transmitted together with data signals carrying the service information.

The ACK or NAK signal is in response to the correct or incorrect, respectively, data packet reception in the downlink (DL) of the communication system which corresponds to signal transmission from the serving Node B to a UE. The CQI signal transmitted from a reference UE is intended to inform the serving Node B of the channel conditions for channel-dependent scheduling of DL data. Either or both of the ACK/NAK and CQI signals may be transmitted simultaneously with or separately from the data signal. As previously mentioned, the disclosed invention considers the former case. This case may also be referred to as data-associated transmission of the ACK/NAK and/or CQI signals.

The UEs are assumed to transmit control and/or data signals over a transmission time interval (TTI) corresponding to a sub-frame. **Figure 1** shows the sub-frame structure assumed in the disclosed invention. The sub-frame has duration of one millisecond and comprises of two slots. Each slot further comprises of seven symbols and each symbol further comprises of a cyclic prefix in order to mitigate interference due to channel propagation effects as it is known in the art. Furthermore, the middle symbol in each slot carries the transmission of reference signals (RS), also known as pilots, which are used to provide channel estimation and allow coherent demodulation of the received signal (DM RS).

The transmission bandwidth (BW) is assumed to comprise of frequency resource units which will be referred to as resource blocks (RBs). Each RB in a symbol is assumed to comprise of 12 sub-carriers and UEs are allocated a multiple N of consecutive RBs for the data transmission. Nevertheless, the above values are only illustrative and not restrictive to the embodiment of the disclosed invention.

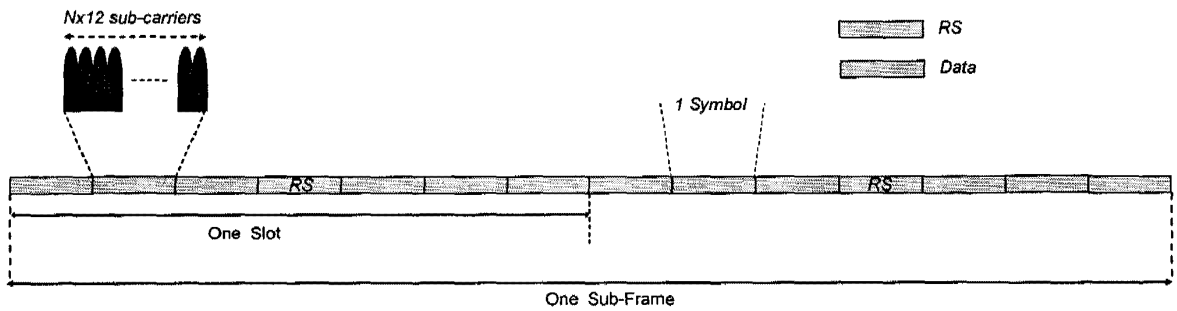

Figure 1: Structure of the UL Sub-Frame.

An exemplary transmitter structure for SC-FDMA signaling is shown in **Figure 2**. In order to transmit the control (ACK/NAK and/or CQI) bits, certain data bits (such as, for example, the parity bits in case of turbo coding) may be punctured and replaced by the control bits in order to maintain the single-carrier property. The discrete Fourier transform (DFT) of the combined bits is then obtained, the sub-carriers corresponding to the assigned transmission bandwidth are selected, the inverse fast Fourier transform (IFFT) is performed and finally the cyclic prefix (CP) and filtering are applied to the transmitted signal. This time division multiplexing (TDM) between the control (ACK/NAK and or CQI) and data signals prior to the DFT is necessary to preserve the single carrier property of the transmission.

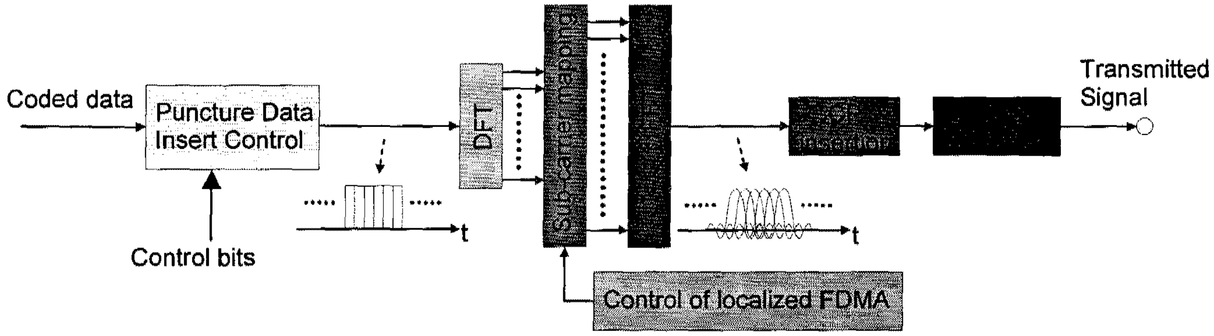

Figure 2: Multiplexing of Control and Data Signals

2. Placement of Data-Associated ACK/NAK and CQI Signals

The main object of the invention is the placement in the UL sub-frame of the ACK/NAK and CQI signals by considering aspects related to their reception performance and other general SC-FDMA communication system requirements. Another object of the invention is the enhancement of the overall reception reliability for the data signal.

A first observation for the UL sub-frame structure in **Figure 1** is that the demodulation RS (DM RS) exists only in the middle symbol of each slot. In case of high speeds, this results to substantially degraded channel estimate for symbols located further away from the DM RS (that is, for symbols near the beginning and end of each slot). This may be acceptable for data transmission which is coded, has typically a relatively large target block error rate (BLER) of 10% or above, and can benefit from retransmissions though a conventional HARQ process. Conversely, the CQI and particularly the ACK/NAK have much stricter performance requirements.

The second observation relates to the transmission of a sounding RS (SRS) in synchronous systems. The SRS has a wideband nature and is transmitted by UEs in order to serve the purposes of UL frequency domain channel dependent scheduling, timing estimation for synchronous operation, and power control as it is known in the art. **Figure 3** illustrates the concept of SRS transmission. The SRS typically has larger transmission bandwidth than the data and the DM RS. It is transmitted periodically in one of the symbols of the UL sub-frame (in the example of **Figure 3**, the SRS is transmitted in the first symbol and once every two sub-frames).

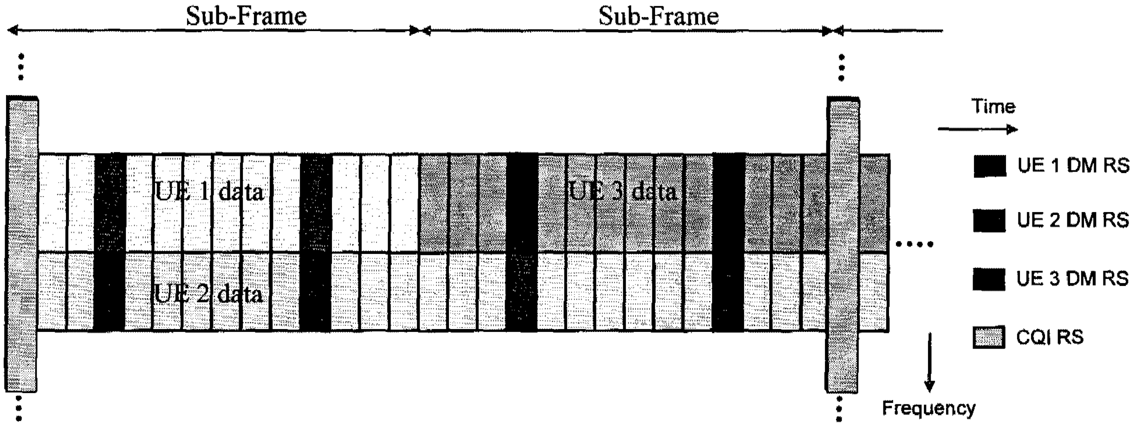

Figure 3: Multiplexing of Control and Data Signals

Because the DM RS is assumed to have a contiguous spectrum, the SRS cannot be transmitted at the middle symbol of each slot because it will create mutual interference with the DM RS (clearly, the DM RS transmission is necessary for the data demodulation and cannot be omitted). Distributing the CQI and ACK/NAK signals substantially over the entire UL sub-frame will either severely restrict the placement of the SRS or introduce additional complexity and performance loss in the reception of ACK/NAK and/or CQI signals as puncturing will be dynamically needed in a symbol depending on whether or not the SRS is transmitted in that symbol. Having as many as possible locations for the SRS transmission is desirable in synchronous systems because, for proper UL CQI and power control measurements, the SRS should capture interference from data transmission and not from other SRS transmission, that is, SRS transmission from neighboring cells and Node Bs should not coincide.

Subsequently, a brief set of simulation results for the raw bit error rate (BER) is provided to illustrate the impact of inaccurate channel estimation on the data reception quality as a function of the symbol position in the slot and the UE speed. **Table 1** provides the simulation assumptions which provide the most optimistic setup for the performance loss of symbols further away from the DM RS because:

a) Transmission bandwidth is 1 RB. This maximizes power per sub-carrier.
b) Channel frequency selectivity is large and there are 2 uncorrelated receiver antennas. This maximizes the slope of the raw BER curve.
c) Operating signal-to-interference and noise ratio (SINR) is large. This minimizes the impact of inaccurate channel estimation.

Table 1: Simulation Assumptions

Parameters	Assumptions
Operating Bandwidth @ Carrier Frequency	5MHz @ 2.6 GHz
Modulation Scheme	QPSK
Data Transmission Bandwidth (BW)	1 RB
UE Speed	3, 30, 120 and 350 kmph
Transmission Type	Localized (at same RB) over the sub-frame at 3, 30 Kmph Frequency Hopping Between Slots at 120 and 350 Kmph
Channel Model	GSM - TU6
Number of Receive Antennas	2
Number of Transmit Antennas	1

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