Application Data Sheet 37 CFR 1.76	Attorney Docket Number	UT09-0465
	Application Number	
Title of Invention	VARIABLE RATE SUPERPOSITION CODING WITH SUCCESSIVE DF IN RELAYING SYSTEMS	

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Application Information:

Title of the Invention	VARIABLE RATE SUPERPOSITION CODING WITH SUCCESSIVE DF IN RELAYING SYSTEMS		
Attorney Docket Number	UT09-0465	**Small Entity Status Claimed**	☐
Application Type	Provisional		
Subject Matter	Utility		
Suggested Class (if any)		**Sub Class (if any)**	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		**Suggested Figure for Publication (if any)**	

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	UT09-0465
	Application Number	

Title of Invention	VARIABLE RATE SUPERPOSITION CODING WITH SUCCESSIVE DF IN RELAYING SYSTEMS

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	**Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S. C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

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Prior Application Status			Remove
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This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	UT09-0465
	Application Number	

Title of Invention	VARIABLE RATE SUPERPOSITION CODING WITH SUCCESSIVE DF IN RELAYING SYSTEMS

If the Assignee is an Organization check here. ☒			
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Address 2			
City	Seoul	**State/Province**	
Country i	KR	Postal Code	150-721
Phone Number		Fax Number	
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Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.					
Signature	/Andrew S. Park/			Date (YYYY-MM-DD)	2009-04-03
First Name	Andrew	Last Name	Park	Registration Number	47841

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PROVISIONAL APPLICATION FOR UNITED STATES PATENT
IN THE NAMES OF

Dong In KIM, Han Byul SEO, Byoung Hoon KIM and Wan CHOI

for

VARIABLE RATE SUPERPOSITION CODING WITH SUCCESSIVE DF IN RELAYING SYSTEMS

prepared by:

KBK & Associates

Customer Number: 67487

Attorney Docket Number: UT09-0465

Total Number of pages: 11 (including cover)

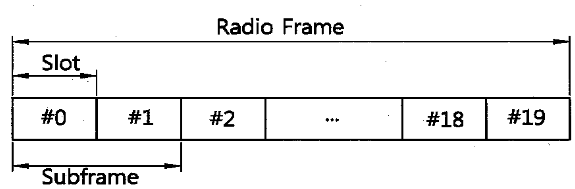
Provisional Application

Title of Invention	**Variable Rate Superposition Coding (VRSC) with Successive DF (SuDF) in relaying systems**
Related Technology Field	**Wireless Communications, Relay**
Related Specification	**LTE Advanced**

1. Summary of Invention

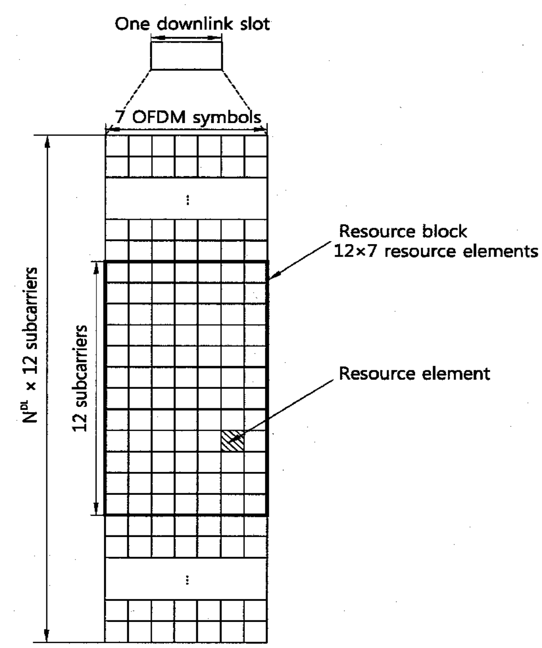
2. Background

Techniques, apparatus and systems described herein can be used in various wireless access technologies such as code division multiple access (CDMA), frequency division multiple access (FDMA), time division multiple access (TDMA), orthogonal frequency division multiple access (OFDMA), single carrier frequency division multiple access (SC-FDMA), etc. The CDMA may be implemented with a radio technology such as Universal Terrestrial Radio Access (UTRA) or CDMA2000. The TDMA may be implemented with a radio technology such as Global System for Mobile communications (GSM)/ General Packet Radio Service (GPRS)/ Enhanced Data Rates for GSM Evolution (EDGE). The OFDMA may be implemented with a radio technology such as institute of electrical and electronics engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802-20, evolved-UTRA (E-UTRA) etc. The UTRA is a part of a universal mobile telecommunication system (UMTS). 3rd generation partnership project (3GPP) long term evolution (LTE) is a part of an evolved-UMTS (E-UMTS) using the E-UTRA. The 3GPP LTE employs the OFDMA in downlink and employs the SC-FDMA in uplink. LTE-advance (LTE-A) is an evolution of the 3GPP LTE. For clarity, this application focuses on the 3GPP LTE/LTE-A. However, technical features of the present invention are not limited thereto.



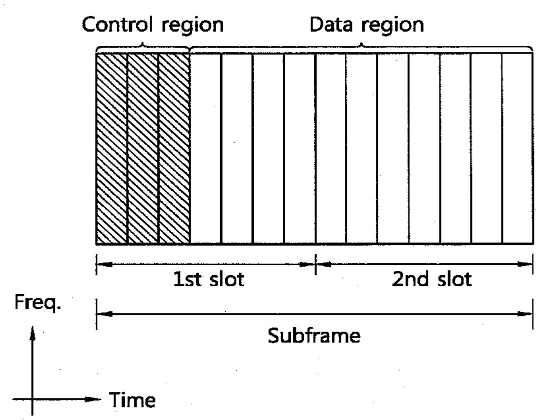
<FIG.1 structure of a radio frame of 3GPP LTE>

In FIG. 1, a radio frame includes 10 subframes. A subframe includes two slots in time domain. A time for transmitting one subframe is defined as a transmission time interval (TTI). For example, one subframe may have a length of 1 millisecond (ms), and one slot may have a length of 0.5 ms. One slot includes a plurality of orthogonal frequency division multiplexing (OFDM) symbols in time domain. Since the 3GPP LTE uses the OFDMA in the downlink, the OFDM symbol is for representing one symbol period. The OFDM symbol may also be referred to as an SC-FDMA symbol or a symbol period. A resource block (RB) is a resource allocation unit, and includes a plurality of contiguous subcarriers in one slot. The structure of the radio frame is shown for exemplary purposes only. Thus, the number of subframes included in the radio frame or the number of slots included in the subframe or the number of OFDM symbols included in the slot may be modified in various manners.



<FIG.2 resource grid for one downlink slot >

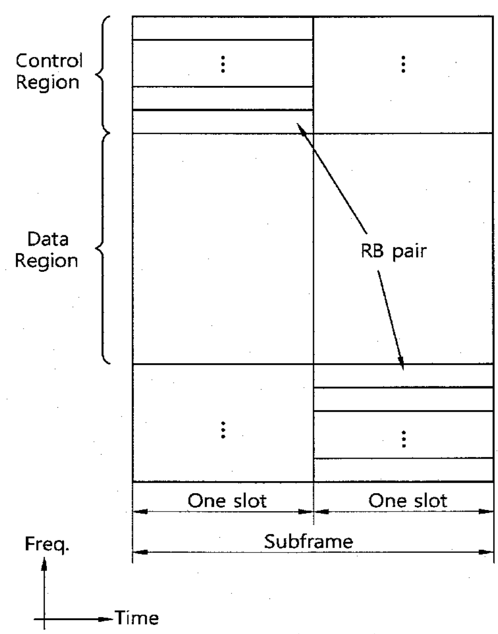
In FIG. 2, a downlink slot includes a plurality of OFDM symbols in time domain. It is described herein that one downlink slot includes 7 OFDM symbols, and one resource block (RB) includes 12 subcarriers in frequency domain as an example. However, the present invention is not limited thereto. Each element on the resource grid is referred to as a resource element. One RB includes 12×7 resource elements. The number N^{DL} of RBs included in the downlink slot depends on a downlink transmit bandwidth. The structure of an uplink slot may be same as that of the downlink slot.



<FIG. 3 structure of downlink subframe>

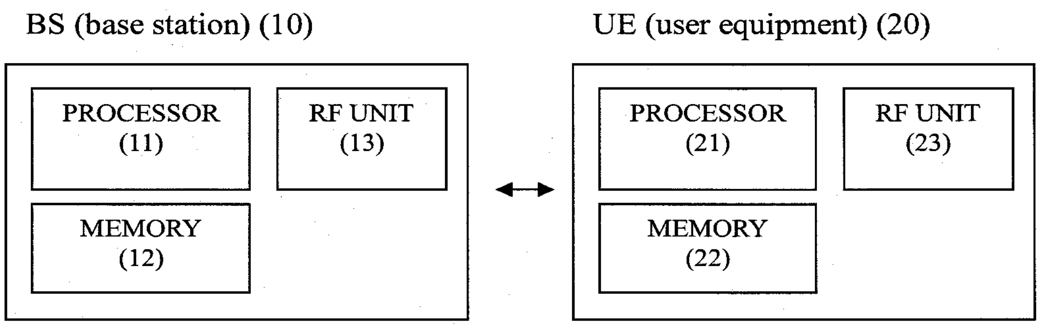
In FIG. 3, a maximum of three OFDM symbols located in a front portion of a 1st slot within a subframe correspond to a control region to be assigned with a control channel. The remaining OFDM symbols correspond to a data region to be assigned with a physical downlink shared chancel (PDSCH). Examples of downlink control channels used in the 3GPP LTE includes a physical control format indicator channel (PCFICH), a physical downlink control channel (PDCCH), a physical hybrid ARQ indicator channel (PHICH), etc. The PCFICH is transmitted at a first OFDM symbol of a subframe and carries information regarding the number of OFDM symbols used for transmission of control channels within the subframe. The PHICH is a response of uplink transmission and carries an HARQ acknowledgment (ACK)/not-acknowledgment (NACK) signal. Control information transmitted through the PDCCH is referred to as downlink control information (DCI). The DCI includes uplink or downlink scheduling information or includes an uplink transmit (Tx) power control command for arbitrary UE groups.

The PDCCH may carry a transport format and a resource allocation of a downlink shared channel (DL-SCH), resource allocation information of an uplink shared channel (UL-SCH), paging information on a paging channel (PCH), system information on the DL-SCH, a resource allocation of an upper-layer control message such as a random access response transmitted on the PDSCH, a set of Tx power control commands on individual UEs within an arbitrary UE group, a Tx power control command, activation of a voice over IP (VoIP), etc. A plurality of PDCCHs can be transmitted within a control region. The UE can monitor the plurality of PDCCHs. The PDCCH is transmitted on an aggregation of one or several consecutive control channel elements (CCEs). The CCE is a logical allocation unit used to provide the PDCCH with a coding rate based on a state of a radio channel. The CCE corresponds to a plurality of resource element groups. A format of the PDCCH and the number of bits of the available PDCCH are determined according to a correlation between the number of CCEs and the coding rate provided by the CCEs. The BS determines a PDCCH format according to a DCI to be transmitted to the UE, and attaches a cyclic redundancy check (CRC) to control information. The CRC is masked with a unique identifier (referred to as a radio network temporary identifier (RNTI)) according to an owner or usage of the PDCCH. If the PDCCH is for a specific UE, a unique identifier (e.g., cell-RNTI (C-RNTI)) of the UE may be masked to the CRC. Alternatively, if the PDCCH is for a paging message, a paging indicator identifier (e.g., paging-RNTI (P-RNTI)) may be masked to the CRC. If the PDCCH is for system information (more specifically, a system information block (SIB) to be described below), a system information identifier and a system information RNTI (SI-RNTI) may be masked to the CRC. To indicate a random access response that is a response for transmission of a random access preamble of the UE, a random access-RNTI (RA-RNTI) may be masked to the CRC.



<FIG. 4 structure of uplink subframe>

In FIG. 4, an uplink subframe can be divided in a frequency domain into a control region and a data region. The control region is allocated with a physical uplink control channel (PUCCH) for carrying uplink control information. The data region is allocated with a physical uplink shared channel (PUSCH) for carrying user data. To maintain a single carrier property, one UE does not simultaneously transmit the PUCCH and the PUSCH. The PUCCH for one UE is allocated to an RB pair in a subframe. RBs belonging to the RB pair occupy different subcarriers in respective two slots. This is called that the RB pair allocated to the PUCCH is frequency-hopped in a slot boundary.



<FIG. 5 system for implementing present invention>

In FIG. 5, a wireless communication system includes a BS 10 and one or more UE 20. In downlink, a transmitter may be a part of the BS 10, and a receiver may be a part of the UE 20. In uplink, a transmitter may be a part of the UE 20, and a receiver may be a part of the BS 10. A BS 10 may include a processor 11, a memory 12, and a radio frequency (RF) unit 13. The processor 11 may be configured to implement proposed procedures and/or methods described in this application. The memory 12 is coupled with the processor 11 and stores a variety of information to operate the processor 11. The RF unit 13 is coupled with the processor 11 and transmits and/or receives a radio signal. A UE 20 may include a processor 21, a memory 22, and a RF unit 23. The processor 21 may be configured to implement proposed procedures and/or methods described in this application. The memory 22 is coupled with the processor 21 and stores a variety of information to operate the processor 21. The RF unit 23 is coupled with the processor 21 and transmits and/or receives a radio signal. The BS 10 and/or the UE 20 may have single antenna and multiple antenna. When at least one of the BS 10 and the UE 20 has multiple antenna, the wireless communication system may be called as multiple input multiple output (MIMO) system.

3. Prior Arts in the Same Field of the Invention

By the broadcast nature of wireless channel, an intermediate node can relay the signal from source to destination using either amplify-&-forward (AF) or decode-&-forward (DF) relaying protocol. When orthogonal channels are used for simple relaying, the information loss cannot be avoided due to half-duplexing operation. It is known in literature that *non-orthogonal* AF (NAF) [1] can use joint ML detection for inter-symbol interference channel due to the relaying where a new symbol from the source overlaps with the prior symbol from the relay under time-division duplexing. This approach avoids the information loss by virtue of *non-orthogonal channelization* through the joint ML detection.

4. Composition and Method of the Invention

Unlike the existing approach, this invention proposes *variable rate superposition coding* (VRSC) that carries multiple parallel data streams with different rates, where each data stream is subject to inter-stream interferences. By exploiting the successively varying rate allocation among the streams, the relay can decode them using the *SIC (successive interference cancellation) starting from the data stream at the lowest rate*. In conjunction with this coding, we implement the *successive* DF (SuDF) that allows decoding-and-forwarding *part* of the multiple data streams, where the *successfully decoded data streams at higher rates come first*, based on the successive decoding. The latter helps to mitigate the inter-stream interferences among the data streams from relay to destination. Therefore, the destination can first decode the favorable (higher SINR) *cooperative* data streams and then the less favorable (lower SINR) *regular payload* data streams from source to destination, using the SIC. Base station (BS) is the source and UE is the destination in downlink case, and UE is the source and BS is the destination in uplink case.

<u>Proposed VRSC Coding</u>: The proposed VRSC coding is illustrated in FIG. 5, where the specific rate and power allocation can be optimized to minimize the end-to-end outage performance for the SIC combined with SuDF, given the channel outage is a dominant source to the channel error.

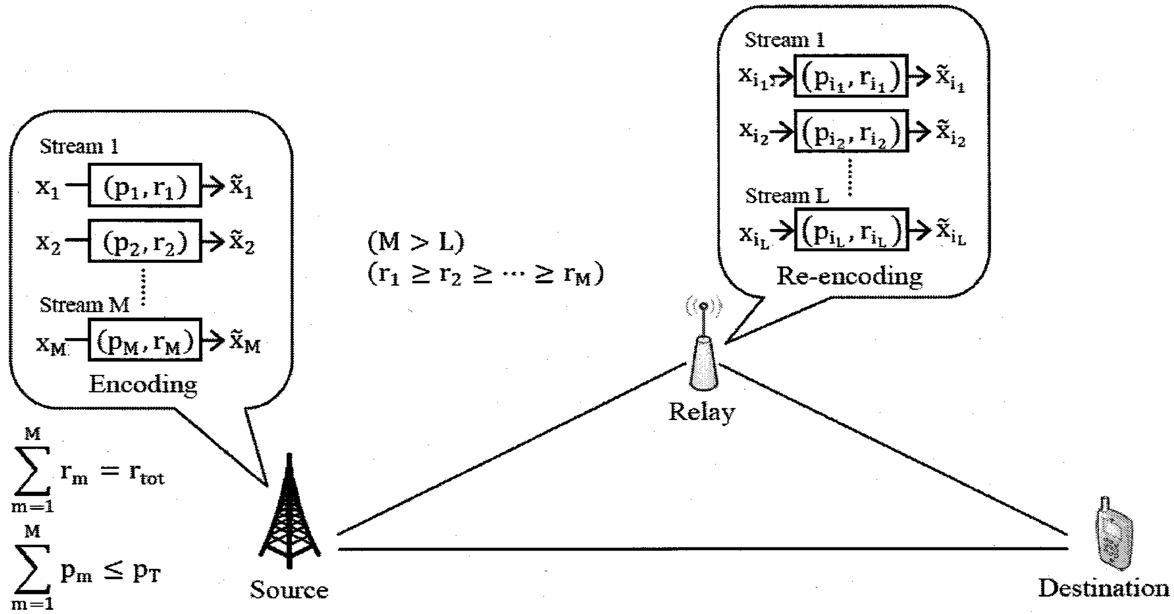


FIG. 5. Variable rate superposition coding (VRSC).

The VRSC coding scheme can easily be applied to the case of multiple transmit antennas, where the total number of transmit antennas n_S can be partitioned into a few subgroups, each containing n_{Si}, $i = 1,2, \cdots, M$ with $n_S = n_{S1} + n_{S2} + \cdots + n_{SM}$. Then, an optimal rate and power allocation for the VRSC coding can *proactively* be performed to implement the *successive* DF based on the SIC, assuming the *average* channel gain information is available.

Successive DF: The main idea behind SuDF relaying protocol is to decompose multiple parallel data streams into a number of sub-parallel data streams from the successive decoding. At the relay, the *successfully decoded* data streams are first ordered in an increasing rate, *part* of which are then formed in the subgroup to be sent to the destination, whereas the data streams at *relatively lower rates* (not being sent) are stored in buffer for later retransmission if hybrid ARQ is initiated by an incorrect reception of their original data streams directly from the source, even with the SIC at the destination.

This way the *cooperative* data streams are likely to be decoded successfully at the destination because of less inter-stream interferences, and also the *regular payload* data streams benefit from the SIC starting from the data stream at the lowest rate, as well as less inter-stream interferences after the SIC that eliminates the *cooperative* data streams.

FIG. 6 shows one realization of the SuDF in conjunction with the proposed VRSC coding when orthogonal space-time block code (OSTBC) is employed.

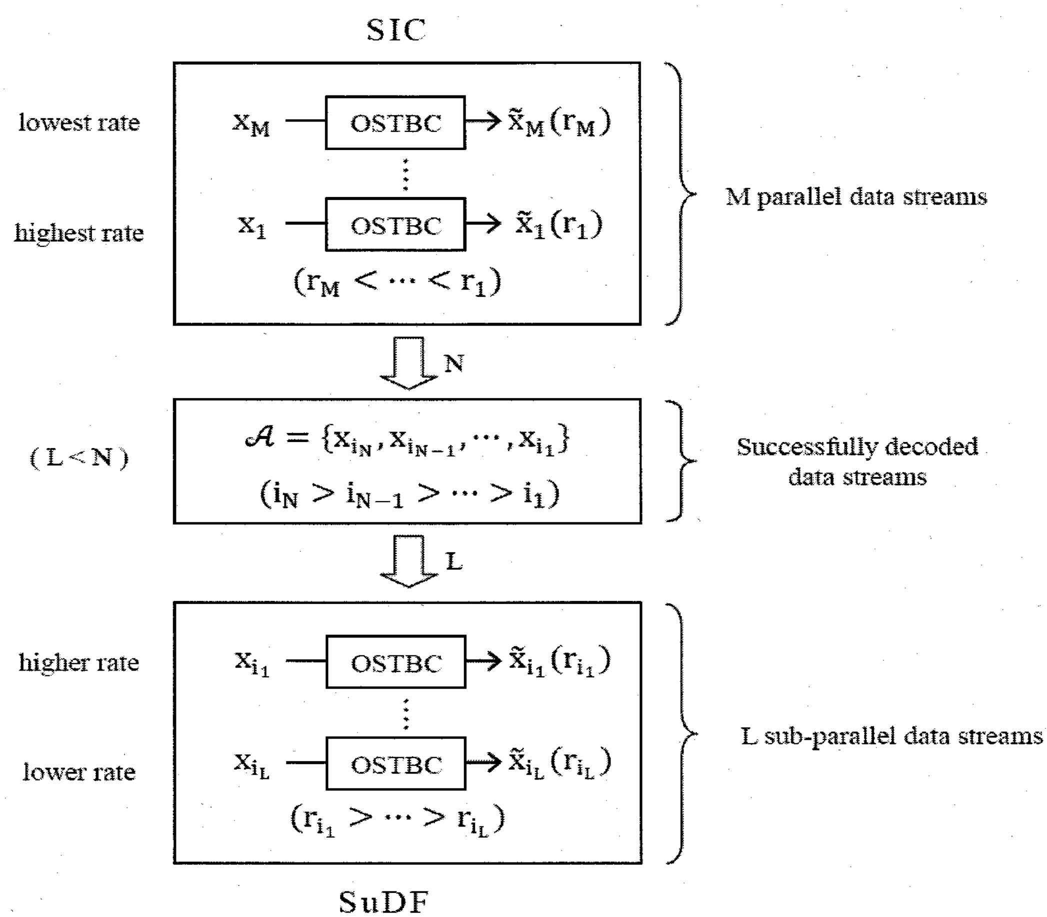


FIG. 6. Successive decode-&-forward (SuDF).

In the proposed SuDF relaying protocol, the signal processing procedure at the relay can be described using FIG. 7. In the *listening phase*, the relay shall try to decode the current packet containing M data streams, based on the SIC, starting from the lowest rate, i.e., r_M. The destination may be listening to the transmission in this phase and keep the received signal for the possible use in the following data recovery. The destination and relay may feedback the decoding result to the source by sending ACK/NACK of each data stream.

Suppose that N out of total M data streams are successfully decoded at the relay, then the *decodable* set $\mathcal{A}$ can be formed into $\mathcal{A} = \{X_{i_N}, X_{i_{N-1}}, \cdots X_{i_1}\}$ with $N = |\mathcal{A}| \leq M$. Next, the SuDF relaying protocol selects a *part* of the decodable N data streams in the set $\mathcal{A}$, which shall produce the *cooperative* subset $\mathcal{B} = \{X_{i_1}, X_{i_2}, \cdots X_{i_L}\} \subset \mathcal{A}$ with $L = |\mathcal{B}| \leq N$. As an example, the relay may sort out the decodable N data streams in the decreasing order of the data rate and select L data streams with the highest rate. The cooperative subset is determined such that the destination can successfully decode the data streams in the cooperative subset and recover all the M data streams by applying using forwarded by the relay.

Finally, the relay shall map the data stream X_{i_j} into n_{R,i_j} transmit antennas for $j = 1,2,\cdots,L$, given $n_R = n_{R,i_1} + n_{R,i_2} + \cdots + n_{R,i_L}$ antennas at the relay, and deliver the corresponding symbol $\tilde{X}_{i_j}$ in the relay to destination link. The source may participate in the signal transmission of this *cooperating phase* by transmitting the signal of all or a part of the L data streams in the cooperative subset. The source or relay may inform the destination of the data streams transmitted in the cooperating phase by a high-layer signaling or a control channel. If the set $\mathcal{A}$ is empty, the relay shall remain quiet since there is no reliable data stream available for transmission in the cooperating phase. Note that the rest (N-L) data streams may be stored in buffer for later retransmission by hybrid ARQ for error recovery.

The destination first decodes the L data streams transmitted in the cooperating phase and subtracts their signal components from the signal received in the listening phase of the relay. Then, the destination decodes the remaining (M-L) data streams.

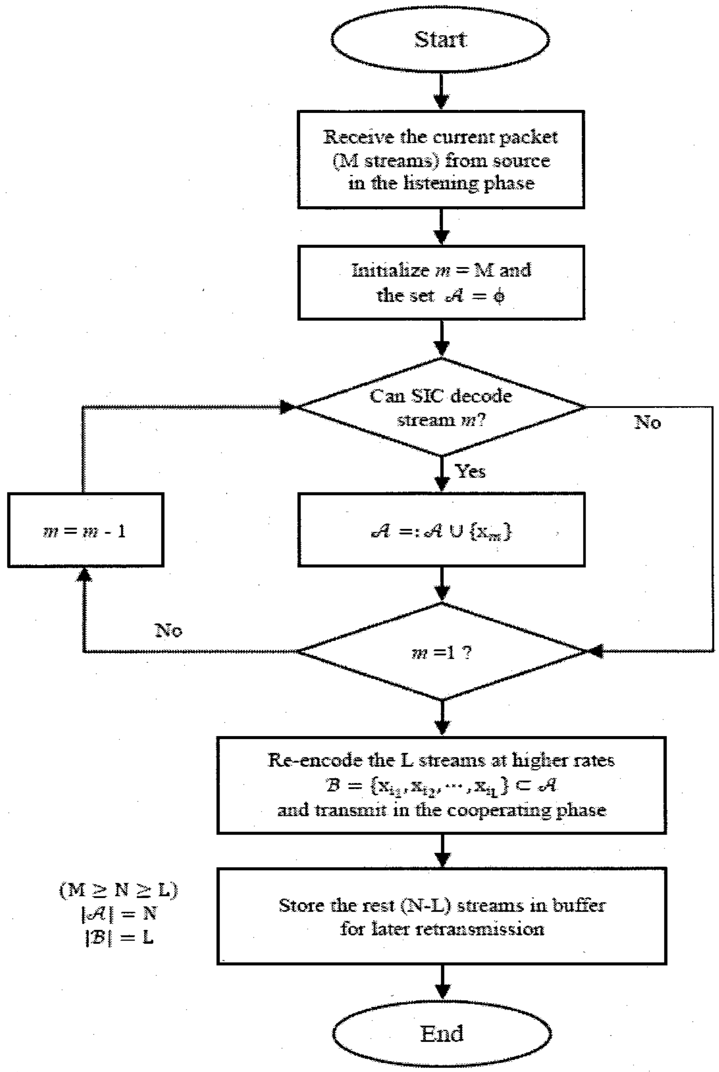


Fig. 7. The signal processing flow diagram at the relay for the proposed SuDF protocol.

References

[1] K. Azarian, H. Gamal, and P. Schniter, "On the achievable diversity-multiplexing tradeoff in half-duplex cooperative channels," *IEEE Trans. Info. Theory*, vol. 51, pp. 4152-4172, Dec. 2005.

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	VARIABLE RATE SUPERPOSITION CODING WITH SUCCESSIVE DF IN RELAYING SYSTEMS
First Named Inventor/Applicant Name:	Dong In KIM
Filer:	Andrew S. Park/Soyoun MOON
Attorney Docket Number:	UT09-0465

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Provisional Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
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Provisional application filing	1005	1	220	220
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
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Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**220**

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EFS ID:	5088446
Application Number:	61166251
International Application Number:	
Confirmation Number:	6858
Title of Invention:	VARIABLE RATE SUPERPOSITION CODING WITH SUCCESSIVE DF IN RELAYING SYSTEMS
First Named Inventor/Applicant Name:	Dong In KIM
Customer Number:	67487
Filer:	Andrew S. Park/Soyoun MOON
Filer Authorized By:	Andrew S. Park
Attorney Docket Number:	UT09-0465
Receipt Date:	03-APR-2009
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1	Application Data Sheet	UT09-465_USP0_ADS.pdf	1252103 22f63c49478b88e6bcc7074459e4bb851def811b	no	5
Warnings:					
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2	Specification	UT09465_SPEC.pdf	1001766 7caed52078a1b21b509d2849b74f80f35b096617	no	11
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3	Fee Worksheet (PTO-06)	fee-info.pdf	29920 0260b06ff0ef5ad77b35c645d1388b02f454dcda	no	2
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