

Writing papers and getting them accepted Including basic LaTeX skills and understanding the review/publishing process

Ian McLoughlin

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation wireless systems. The use of multiple relays in a network can increase rates and increase network coverage. Information theoretic studies on multiple-relay systems have shown that improvements are possible in enabled relaying and spectral efficiency [4, 5]. Infrastructure-link reliability and spectral efficiency have been found beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-directed relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission modes, synchronization issues and excess bandwidth usage, in contrast with distributed/centralized relay selection schemes which can be time sensitive [7]. Furthermore, relay systems tend to have much lower implementation complexity [8] than full space-time coded alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for antenna devices [7, 9–12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relays is feedback on a frame-by-frame basis and used for relay selection at the transmitter (source). In general, the performance degrades as the feedback information becomes more outdated. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to phenomena such as Doppler changes, with the consequence of reduced selection accuracy. This effect has been explored in single antenna systems [15]. In general, the impact of delayed feedback on relay systems has been analysed [16], and recently the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with perfect knowledge at zero feedback delay, and the performance of a non-selective system (i.e. without CSI knowledge at the source) when feedback delays are greater than the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18].

This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using γ), but not plotted here because of space constraints. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r) and (N_d) are shown against γ_1 for correlations ρ_1 is a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19]. For $\rho_1 = 1, 0.9$ and 0.7 , where $\rho_1 = 1$ implies no delay or near perfect prediction. We set $\gamma_1 = 5\gamma_2$, to simulate a disparity between first and second hop channel gain. This is realistic

$$P_e = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{n\tilde{K}N_d - 1}N_d}{\tilde{K}N_d - 1} \sum_{j=0}^{N_s-1} \frac{(-1)^j}{j!(N_s-1-j)!} \sum_{k=0}^{N_d-1} n_{s,k} \theta_{s,k} / N_s + j - 1 \right] \sum_{k=0}^{N_d-1} \left[\frac{j}{k} \frac{A_k(1-\rho_1)^{j-k}}{(k-\rho_1+1)j!} \right]^{1-\rho_1} \\ \times \sum_{l=0}^{N_s-1} \frac{(1+\tilde{K}N_d+1)^{-1}}{l!+1} \frac{1}{\tilde{K}N_d+1} \sum_{p=0}^{N_s-1} \frac{1}{(l-p)!} \sum_{q=0}^{N_s-1} \frac{1}{(N_s-1-q)!q^{\beta}} \frac{(q+1)}{(k-\rho_1+1)j_1 j_2} \\ \times \frac{\Gamma(N_d+q+p+1.5)}{\Gamma(1/2) \Gamma(\alpha-\rho_1+1) \Gamma_1 + \Gamma(\beta/2) + 2\sqrt{\beta+1} \Gamma(k-\rho_1+1) \Gamma_1 \Gamma_2} \\ \times {}_2F_1(N_d+q+p+1.5, q+p-1+1.5; 1+N_d+1; \xi) \\ \xi = \frac{j+1/(k-\rho_1)+\beta\gamma_1+1/\gamma_2+\beta/2-2\sqrt{j+1/(k-\rho_1)+\beta\gamma_1\gamma_2}}{j+1/(k-\rho_1)+1/\gamma_1+1/\gamma_2+\beta/2+2\sqrt{j+1/(k-\rho_1)+\beta\gamma_1\gamma_2}}$$

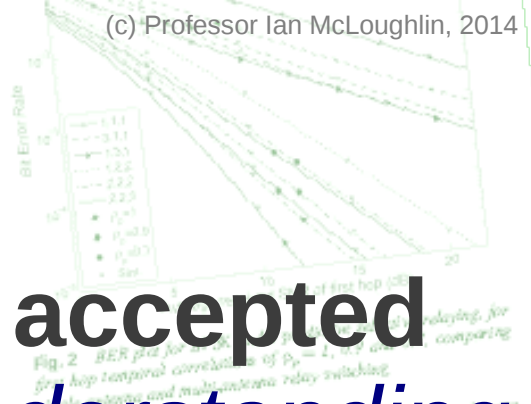


Fig. 2 BER plot for BPSK. The plot shows BER versus SNR (dB) for different relay configurations and diversity orders. The legend indicates configurations: (1,1), (1,1), (1,2), (2,2), (2,2), (2,2), (2,2), (2,2), (2,2), (2,2).

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Hands-on

Install and test LaTeX

Write an IEEE journal paper

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$$\begin{aligned}
& \times \sum_{i=0}^{N_s-1} \frac{\gamma_s (q(1-p_s) + 1)^{i+1}}{2(i+1)^{p+1} + N_s - 1} \\
& \times \sum_{p=0}^{N_s-1} \frac{1 - (p_s + 1)^{i+1}}{(1-p)^{i+1} p^i} \times \sum_{q=0}^{N_s-1} \frac{\gamma_d^{N_s-q}}{(N_s-1-q)! q^i} \\
& \times \left[\frac{\gamma_s (i+1) \gamma_r (1 + \gamma_r)}{(i-1) p_i + 1} \gamma_s \right]^{(q+p-2+1)/2} \\
& \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(i+1) \gamma_r (1 + \gamma_r)}{(i-1) p_i + 1} \gamma_s} \right) \quad (15)
\end{aligned}$$



Channel prediction relay selection

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Abstract: The use of relay destination are each equipped with information which is delay information being used to signal-to-noise ratio over a variable gain to the relay solutions are found for at relays and number of an switching delay, compared

Part A

Introduction to the course
 Introduction to LaTeX
 Getting started

1 Introduction

Co-operative relay technology is a solution for future systems such as the long-term evolution (LTE) systems and increased information theoretic enabled relaying, which link reliability and cost based (fixed) and beneficial in providing for wireless terminals [6]. However, to receive antennas wireless system to direct relay selection the signal to transmission rate bandwidth usage relay selection is Furthermore, self implementation alternatives. For selection is partial decode-and-forward antennas devices [7, 9–12]. Non-relay single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

CSI [18]. This paper aims to (i) investigate the performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Motivation

Q. Why do you want to write a paper?



A. To inform the word community about significant new advances, to disseminate useful ideas and contribute to the world body-of-knowledge....

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Channel prediction in non-cooperative multi-antenna relay selection systems

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Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is analysed. Both source and destination are each equipped with multiple receive but single transmit antennas. Since relay selection is a delay-limited operation, channel power prediction is employed to mitigate against the uncertainty in channel fading. During transmission, a source selects a relay based on the information being used to make switching decisions. A chosen relay then employs maximal ratio combining (MRC) to receive the signal from the source and retransmits it to the destination. Closed form diversity order results are derived for arbitrary numbers of relays and receive antennas, and used to compare relay selection systems compared with single antenna alternatives. To assess prediction performance, comparison is made to non-predictive systems.

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$$P_s = \frac{\sigma}{\sqrt{(2\pi)^2}} \int_0^{\pi/2} F_{\gamma_1}\left(\frac{x}{\beta}\right) \exp\left(-\frac{x^2}{2}\right) dx \quad (16)$$

Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_1 = 0.1, 0.3$ and 0.7 , comparing single antenna and multi-antenna relay switching

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \frac{1}{2} + 1$ in (15) setting $\gamma_1 = \frac{\alpha}{\beta}$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_s (see (17))

where $\Gamma[\cdot]$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation (4) the location of the page)

This approximation implicit in this closed form solution holds good in the moderate to high SNR regions.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation $P_{sim}(y_1)$ in (15) is directly verified by this (since BER is derived using y_1), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r) and (N_s, N_d) are shown against γ_1 for correlation $\rho_1 = 0.1, 0.3$ and 0.7 . It is seen from Fig. 2 that the BER performance of the system is degraded as the feedback delay increases. This effect has been explored in [10, 17] and recently the impact of delayed feedback on relay selection has been considered [10, 17] and relay selection has been considered with perfect knowledge at the source when feedback delays are present. Performance of a non-selective system (i.e. without CSI) is also shown for comparison. It is seen from the plot that the performance of a non-selective system is degraded when the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18].

$$P_s = \frac{\sigma}{\sqrt{(2\pi)^2}} \int_0^{\pi/2} \frac{\sum_{n=0}^{N_s-1} \sum_{p=0}^{N_r-1} \frac{1}{(1-p)!p!} \frac{\sum_{q=0}^{N_d-1} \frac{1}{(q-p)!} \frac{\Gamma(N_s+q+p+1.5)}{\Gamma(N_s+q+p+1.5, q+p-1+1.5, 2+N_s+1; \xi)}}{\sum_{n=0}^{N_s-1} \sum_{p=0}^{N_r-1} \frac{1}{(1-p)!p!} \frac{\sum_{q=0}^{N_d-1} \frac{1}{(q-p)!} \frac{\Gamma(N_s+q+p+1.5)}{\Gamma(N_s+q+p+1.5, q+p-1+1.5, 2+N_s+1; \xi)}}{\xi} \exp\left(-\frac{x^2}{2}\right) dx$$

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These lectures/seminars

Assume you need to write a paper now, and probably in future.

So we're going to adopt the **highest standard and most advanced** paper-publishing methods and technology.

Specifically we will use the same tools that the world's top authors and most famous scientific authors use. We will be learning how to structure and write papers, and get them published, using LaTeX.

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Channel prediction and cooperative multi-antenna relay selection systems

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Abstract: The use of multiple relays in amplify-and-forward relay selection is analysed, where the source, relay and destination are each equipped with multiple antennas. Since relay switching is based upon feedback information which is delay-limited, channel power prediction is used to assist in the relay selection process. During transmission, a relay selection algorithm employs max ratio combining at the destination and bit error rate information being used to make the selection decisions. The proposed system employs max ratio combining at the destination and bit error rate information being used to make the selection decisions. To assess prediction performance, the number of relays and number of antennas compared with single antenna alternatives. As a prediction performance metric, switching delay, comparison is made to non-predictive systems.

1 Introduction

Cooperative relay technology appears to be a promising solution for future fourth generation wireless systems such as the 4G systems. Several long-term evolution standards [1, 2] have been proposed that aim to provide a significant performance gain over existing systems. Several information theoretic models have been proposed for relay systems, showing that improved performance can be achieved through relaying [4, 5]. In particular, link reliability and spectral efficiency have been found to be improved in relay systems. However, to achieve high performance, at least two relays are needed for wireless terminals with limited number of antennas [6]. Furthermore, to achieve high performance, at least two relays are needed for wireless terminals with limited number of antennas [6]. However, to achieve high performance, at least two relays are needed for wireless terminals with limited number of antennas [6].

are available for selection, and performance is limited by the gain of the second hop. This paper extends these results to the case where source, destination and relay are equipped with multiple antennas. The effect of faded channel state information (CSI) on relay selection is also investigated. The proposed system employs max ratio combining at the destination and bit error rate information being used to make the selection decisions. To assess prediction performance, the number of relays and number of antennas compared with single antenna alternatives. As a prediction performance metric, switching delay, comparison is made to non-predictive systems.

$$\begin{aligned} & \times \sum_{p=0}^{N_s-1} \frac{1/\gamma_1 \theta(1-\theta)^{N_s-1-p}}{\theta(1+\theta)^{N_s-1-p}} \\ & \times \sum_{q=0}^{N_s-1} \frac{1/\gamma_2 (1+\theta)^{N_s-1-q}}{(1-\theta)^{N_s-1-q}} \\ & \times \left[\frac{\gamma_2 (q+1) \gamma_1 (1+\gamma_1)}{(1-\theta)^{q+1} + 1/\gamma_1} \right] \\ & \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\theta) \gamma_2 (1+\gamma_1)}{(1-\theta)^{q+1} + 1/\gamma_1}} \right) \end{aligned} \quad (15)$$

$$P_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_1} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

where α and β are chosen to define specific modulation schemes [9]. By approximating $\gamma_1 \approx \gamma_1 + 1$ in (15) setting $\gamma_1 = 1$, the integral in (16) can be solved using [21, eq. (2.2.1)] to give the gamma function, and $\gamma_1 = 1$ in (17) holds good in the moderate to high SNR regions.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since space limited, details are not shown here because of brevity). In different relay configurations, $N_s = 1$ and $N_s = 2$ are considered for correlation coefficients $\rho_1 = 0.1$ and $\rho_1 = 0.7$. In the first hop, an appropriate set for any given D is chosen. For $\rho_1 = 1$, the diversity between first and second hop is D .

$$\begin{aligned} P_s &= \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{N_s N_s - 1} N_s}{\frac{1}{2} N_s - 1} \sum_{k=0}^{N_s-1} \frac{(-1)^k}{k! (N_s - 1 - k)!} \sum_{j=0}^{N_s-1-k} \binom{N_s-1-k}{j} \frac{A^j (1-A)^{N_s-1-j}}{(1-A)^{j+1}} \right] \\ & \times \sum_{p=0}^{N_s-1} \frac{1/\gamma_1 + N_s + 1/\gamma_1}{1/\theta + 1/\theta^{N_s-1-p} [(1-\theta)^{q+1} + 1/\gamma_1]} \sum_{q=0}^{N_s-1} \frac{1/\gamma_2 (1+\theta)^{N_s-1-q}}{(1-\theta)^{N_s-1-q}} \\ & \times \frac{\Gamma(N_s + q + p + 1.5)}{\Gamma(1/2) \Gamma(1-\theta)^{q+1} \Gamma(1+\gamma_1) + \Gamma(1/2) + 2\sqrt{\beta} + 1/\theta(1-\theta)^{q+1} \Gamma(1+\gamma_1)} \\ & \times {}_2F_1(N_s + q + p + 1.5, q + p - 1 + 1.5; 1 + N_s + 1; \xi) \end{aligned}$$

$$\xi = \frac{\left[1 + 1/\theta(1-\theta)^{q+1} \Gamma(1+\gamma_1) + 1/\gamma_2 + \beta/2 - 2\sqrt{\beta} + 1/\theta(1-\theta)^{q+1} \Gamma(1+\gamma_1) \right]}{\left[1 + 1/\theta(1-\theta)^{q+1} \Gamma(1+\gamma_1) + 1/\gamma_2 + \beta/2 + 2\sqrt{\beta} + 1/\theta(1-\theta)^{q+1} \Gamma(1+\gamma_1) \right]}$$

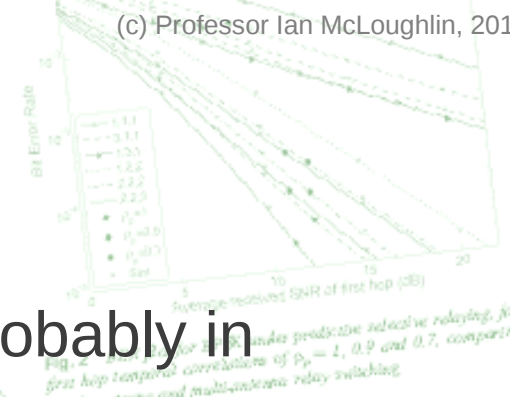


Fig. 1. BER performance for different diversity orders and correlation coefficients. The graph shows BER Error Rate vs Average received SNR of first hop (dB) for different diversity orders and correlation coefficients.

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and relays can lead to large performance improvements, but this is not necessarily true in every case since performance is limited by channel strength over one particular hop (as discussed below). As seen for any given diversity order, correlation tends to zero and diversity gain is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to PAF incoherent relaying). For example, the (3,1,1) and (2,2,2) results show that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to PAF incoherent relaying). For example, the (3,1,1) and (2,2,2) results show that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to PAF incoherent relaying).

Some characteristics of LaTeX?

It's not quick to learn. But once you learn it, it is a skill for life!

Use it to write:

- Papers
- Book chapters
- Books
- Research articles and reports
- Lecture notes
- Patents
- CV

You can even use it to prepare your presentations (I don't). This is called "Beamer".

The background features several technical documents and mathematical formulas. On the left, there's a paper titled "Cooperative relay technology appears to be a promising solution for future fourth generation wireless systems..." with authors S. Prakash and I.V. McLoughlin. In the center, there's a paper about "Performance of a non-selective system (i.e. without CSI)..." and another about "Performance of a non-selective system (i.e. without CSI)..." with authors S. Prakash and I.V. McLoughlin. On the right, there's a graph showing BER Error Rate vs. Average received SNR of first hop (dB) for different relay configurations. Below the graph, there's a text block discussing the performance of a non-selective system and the impact of feedback delay. At the bottom right, there's a complex mathematical equation for the BER, involving gamma functions and hypergeometric functions.

LaTeX is NOT a Word Processor

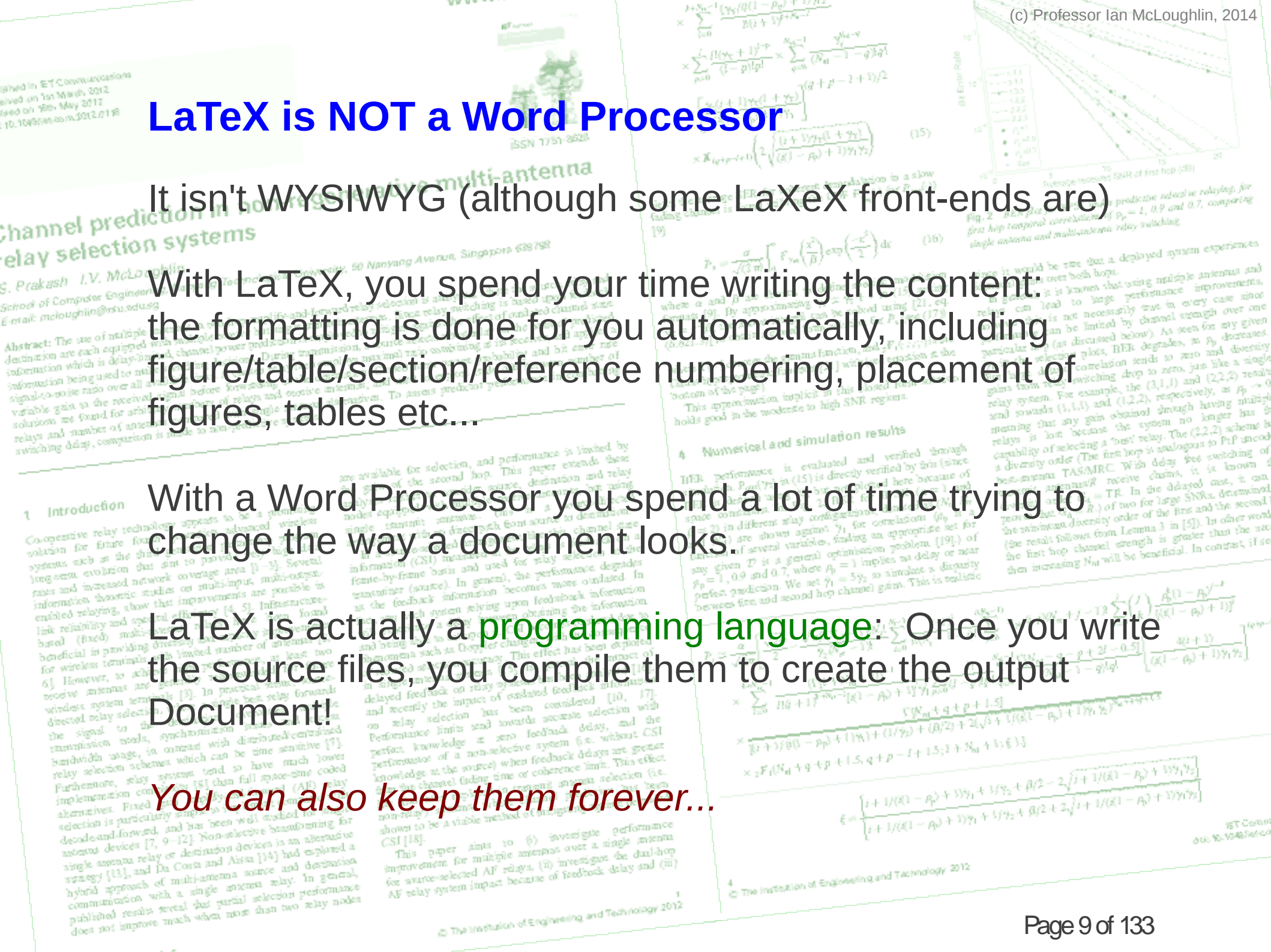
It isn't WYSIWYG (although some LaTeX front-ends are)

With LaTeX, you spend your time writing the content: the formatting is done for you automatically, including figure/table/section/reference numbering, placement of figures, tables etc...

With a Word Processor you spend a lot of time trying to change the way a document looks.

LaTeX is actually a programming language: Once you write the source files, you compile them to create the output Document!

You can also keep them forever...



LaTeX formatting

This is the same paper, only the title and the documentclass changed.

RESEARCH ARTICLE

Cooperative Multi-Antenna Relay Selection over Dual-Hop Nakagami-m Channels

Shiva Prakash and Ian Vince McLoughlin*

Broadcom Corp., India and Nanyang Technological University, Singapore

ABSTRACT

This paper presents a scheme for dual-hop amplify-and-forward multi-antenna, multi-relay selection over Nakagami-m channels. A source-selected best relay performs maximal ratio combining on received data, applies variable gain, and then uses beamforming to transmit to a destination device. Such a configuration is beneficial for end-to-end communication using single antenna mobile terminals and multi-antenna relay infrastructure. Closed form expressions for performance metrics are derived that cater for arbitrary number of relays, arbitrary number of receive and transmit antennas and different fading parameters. Results are verified through simulation. Furthermore, the influence of multiple antennas in such system is explored, as are the effect of fading, power imbalance between hops, and the impact of additional antennas, at different locations. Copyright © 2012 John Wiley & Sons, Ltd.

KEYWORDS
Relay selection; Multi-antenna; Wireless relay

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1. INTRODUCTION

Recent studies on MIMO cooperative relays, prompted by standardization discussions for IEEE802.16j and 3GPP LTE Advanced systems, demonstrate improvements in link reliability and spectral efficiency [1, 2, 3, 4]. Partial relay selection (PRS) [5, 6] overcomes synchronization, latency issues and onerous beaconing requirements in many alternative schemes [7, 8, 9]. However multiple antenna PRS [10] is yet to be fully explored in the literature, particularly its performance in relation to fading severity over both hops: this paper explores this, and extends the analysis to multi-antenna relays, with variable-gain relaying. In addition, we adopt a Nakagami-m fading model, which is considered accurate for urban radio multi-path propagation. In this system, one relay is selected by a transmission source, from several relatively clustered

candidates, based on maximum instantaneous SNR (signal to noise ratio). The selected relay uses maximal ratio combining (MRC) on its received signal before amplifying and transmitting to the destination using beamforming. We derive closed form solutions for outage probability and symbol error rate (SER) for generalised multi-antenna relay selection in Nakagami-m fading channels, catering for arbitrary numbers of receive, transmit antennas, and relays over both first and second hops. Diversity order is deduced, and the effect of fading severity analysed with respect to power imbalance between hops—a common urban scenario, which we will see can describe scenarios such as long distance communications into an urban area using relay transmission for last-mile linking. We also cater for arbitrary numbers of relays and antennas (both transmit and receive). Many degrees of freedom in this proposed PRS system, described in Section 2, can be

Mobile Communications Using Source-Selected Multi-Antenna AF Relays Over Dual-Hop Nakagami-m Channels

I. V. McLoughlin · S. Prakash

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Abstract This paper presents a scheme for dual-hop amplify-and-forward multi-antenna, multi-relay selection over Nakagami-m fading channels. A source-selected best relay performs maximal ratio combining on received data, applies variable gain, and then uses beamforming to transmit to a destination device. Such a configuration is beneficial for end-to-end communication using single antenna mobile terminals with multi-antenna relay infrastructure. Closed form expressions for performance metrics are derived that cater for arbitrary number of relays, arbitrary number of receive and transmit antennas and different fading parameters. Results are verified through simulation. Furthermore, the influence of multiple antennas, the effects of fading, power imbalance between hops, and the beneficial impact of additional relays are explored.

Keywords Relaying · AF relay · PRS · MIMO · Nakagami-m

1 Introduction

Cooperative Multi-Antenna Relay Selection over Dual-Hop Nakagami-m Channels

S. Prakash and I. V. McLoughlin

adjusted for performance gain over such schemes as [5, 6], which report performance saturation with increasing number of relays. Once Section 3 has developed important performance metrics, such trade offs will be explored in Section 4. Section 5 will conclude the paper.

2. SYSTEM MODEL AND ASSUMPTIONS

Consider a relay network in a flat fading Nakagami-m channel, comprising single antenna source S , destination D , and L intermediate relay nodes R_1, R_2, \dots, R_L each equipped with N_R receive and N_T transmit antennas. This arrangement is shown in Fig. 1. The channel matrix $\mathbf{H} = [h_{i,j}]_{M \times N}$, assumed correctly estimated at the relays, contains the gains of individual channel entries characterised by a Nakagami-m fading distribution $\mathcal{M}(m_i, 0)$. Shape and spread parameters are m_i and $\Omega = E[|h_{i,j}|^2] = 1$, where $E[\cdot]$ denotes expectation.

Based on SNR feedback information from the relays, S selects best relay R_i , $i: 1 \leq i \leq L$, which forwards amplified, but not regenerated, messages to D . Half-duplex transmission occurs in two phases as $S \rightarrow R_i \rightarrow D$ over orthogonal channels, with no direct link between S and D . In this system, there is also no need to synchronise or communicate between relays. The first transmission hop from S to the selected relay is denoted as $S \rightarrow R_i$. This is represented by channel vector $[h_{SR_i}]_{N_R \times 1}$. Let ξ_1 and ξ_2 be the power of the transmitted signal at S and R_i , and N_0 the power of the additive white Gaussian noise at R_i and D . The selected relay performs signal combining using the optimal MRC vector

$$[w_{RD}]_{N_R \times 1} = \frac{h_{RD}^*}{\sqrt{h_{RD}^* h_{RD}}} \quad (1)$$

Before transmitting the received signal to D , it is amplified by variable gain:

$$G = \sqrt{\frac{\xi_2}{N_0 + \xi_1 h_{RD}^* h_{RD}}} \quad (2)$$

choose so as to invert the fading effect of the first hop while limiting the output power [11]. R_i obtains the $R_i \rightarrow D$ channel vector $[h_{RD}]_{N_T \times 1}$ through monitoring

transmissions or beacon from D . The entries of this vector are distributed as $\mathcal{M}(m_2, 1)$. To perform transmit diversity beamforming over the second hop, R_i computes an optimal beamforming vector:

$$[w_{RD}]_{N_T \times 1} = \frac{h_{RD}}{\sqrt{h_{RD}^* h_{RD}}} \quad (3)$$

after which data is transmitted to D . With s as the transmitted symbol from S , the received signal at D is then

$$y_D = G w_{RD} h_{RD}^* (w_{SR_i} (h_{SR_i} s + n_{SR_i})) + n_D \quad (4)$$

where n_D is the noise sample at D , characterised as $\mathcal{CN}(0, N_0)$ and n_{R_i} is the noise vector at the selected relay modelled as $\mathcal{CN}(0, N_0 I_{N_R})$. The equivalent SNR at the destination can be derived as $\gamma_{eq} = \frac{\xi_1 \xi_2 h_{SR_i}^* h_{RD}}{N_0^2}$ [11], where

$$\gamma_1 = \frac{\xi_1 h_{SR_i}^* h_{SR_i}}{N_0} \quad (5)$$

and

$$\gamma_2 = \frac{\xi_2 h_{RD}^* h_{RD}}{N_0} \quad (6)$$

are the instantaneous SNRs of the first and second hops respectively.

3. PERFORMANCE METRICS

3.1. Outage Probability

An important quality of service measure in such systems is outage probability F_{out} : the probability that the instantaneous output SNR drops below a threshold γ_{th} , i.e. $F_{out}(\gamma_{th}) = P_{out}(\gamma_{eq} < \gamma_{th})$. From [11] we have:

$$F_{out}(\gamma_{th}) = \int_0^{\gamma_{th}} Pr\left\{\frac{\gamma_1 \gamma_2}{\gamma_1 + \gamma_2 + 1} < \gamma_{th} | \gamma_1, \gamma_2\right\} f_{\gamma_1}(\gamma_1) f_{\gamma_2}(\gamma_2) d\gamma_1 d\gamma_2 \quad (7)$$

With some rearrangement, the above integral can be expressed more conveniently in complementary form as:

$$1 - \int_{\gamma_{th}}^{\infty} \left(1 - F_{\gamma_1}\left(\frac{\gamma_2(\gamma_2 + 1)}{\gamma_2 - \gamma_{th}}\right)\right) f_{\gamma_1}(\gamma_1) d\gamma_1 \quad (7)$$

where $F_{\gamma_1}(\cdot)$ is the CDF (cumulative distribution function) of the random variable γ_1 , namely the instantaneous SNR at the best relay. To first calculate $F_{\gamma_1}(\cdot)$, let ξ_1 be the

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variable-gain relaying over a Nakagami-m channel, which is considered accurate for urban radio multi-path propagation. In this system, one relay is selected by a transmission source, from several relatively clustered candidates, based on maximum instantaneous SNR (signal to noise ratio). The selected relay uses maximal ratio combining (MRC) on its received signal before amplifying and transmitting to the destination using beamforming. We derive closed form solutions for outage probability and symbol error rate (SER) for generalised multi-antenna relay selection in Nakagami-m fading channels, catering for arbitrary numbers of receive, transmit antennas, and relays over both first and second hops.

Diversity order is deduced, and the effect of fading severity analysed with respect to power imbalance between hops—a common situation where a relay is not located exactly between source and destination. We consider that a fixed infrastructure of multi-antenna base station relays with single antenna mobiles is beneficial for both power and cost reasons, and does not lead to practical difficulties in ensuring spatial diversity in a limited size mobile device. Also, the derived results cater for arbitrary numbers of relays and transmit/receive antennas. Many degrees of freedom in this proposed PRS system, described in Sect. 2, can be adjusted for performance gain including adding more relays [9, 10] and allocating more antennas to receiver, transmitter or both. Following this, Sect. 3 develops important performance metrics and derives closed-form solutions, allowing some interesting system design trade offs to be explored in Sect. 4. Section 5 concludes the paper.

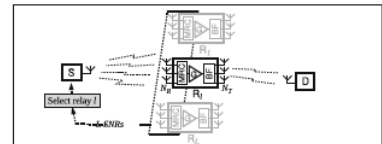
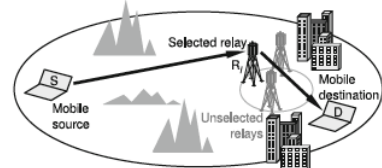


Fig. 1 A diagram of system deployment showing L relay nodes, of which one is selected by source S based upon CSI feedback. The selected relay R_i combines N_R receive antennas to obtain a signal which is first boosted by variable gain G and then beamformed over N_T transmit antennas to destination D . The system deployment diagram at the top highlights that the $S \rightarrow R_i$ hop may naturally experience a different gain to the $R_i \rightarrow D$ hop, and that communications between relays is unnecessary in this system. The beamforming (BF), MRC and non-regenerative gain functions of the multi-antenna relays are clearly shown in the lower part of the figure.

put) cooperative relays, prompted by stan-
dardization discussions for IEEE802.16j and 3GPP
LTE Advanced systems, demonstrate improve-
ments in link reliability [4, 6, 11, 12]. Partial relay selection
issues and onerous beaconing requirements
multiple antenna PRS [2, 14, 15] is less well
known in relation to fading severity over
the analysis to multi-antenna relays, with

ity of Science and Technology
EcoSpace Bellandar Village.



A Springer journal

\documentclass
[smallextended]
{svjour3}

You can reformat the paper for a
different journal in just a few
minutes by changing just this line.

A Wiley journal

\documentclass[times, doublespace]{wcmauth}

LaTeX

Note:

It all started in 1978 with TeX, then LaTeX in the 1980s, then TeTeX to 2006, XeTeX, etc... now there are many variants...

TeX

LATeX

XeTeX

We refer to them all as LaTeX. This is the "engine" that does the typesetting. Normally you would also use a front-end to control the engine, and various additional packages.

LaTeX on Mac OS-X

Personally, I use TeXShop as a front-end on the Mac:

The screenshot shows a Mac OS-X desktop environment. On the left, the TeXShop application window is open, displaying the LaTeX source code for a document. The code includes package declarations, title and author information, and the start of the document body. On the right, a PDF viewer window titled 'root.pdf' is open, showing the rendered output of the document. The PDF content includes the title, authors, an abstract, a table of mechanical index limits, and the beginning of the introduction.

TeXShop Source Code:

```

1 \documentclass[letterpaper, 10 pt, conference]{IEEEconf} % Comment this line out if you need a4paper
2 %\documentclass[a4paper, 10pt, conference]{IEEEconf} % Use this line for a4 paper
3 \IEEEoverridecommandlockouts % This command is only needed if you want to use the \thanks
  command
4
5 \overrideIEEEargins
6
7 \usepackage{graphics} % for pdf, bitmapped graphics files
8 \usepackage{epsfig} % for postscript graphics files
9 \usepackage{mathptmx} % assumes new font selection scheme installed
10 \usepackage{times} % assumes new font selection scheme installed
11 \usepackage{amsmath} % assumes amsmath package installed
12 \usepackage{amssymb} % assumes amsmath package installed
13
14 % Title.
15 % -----
16 \title{\LARGE\bf
17 A new mechanical index for gauging the human bio-effects of low frequency ultrasound
18 }
19
20 \author{Farzaneh Ahmadi\textsuperscript{1}$ and Ian Vince McLoughlin\textsuperscript{2}$}
21 \thanks{\textsuperscript{1}$ Farzaneh Ahmadi is with The University of Sydney, Australia (\textsuperscript{tt}\small ahmadi@ntu.edu.sg)
22 }%
23 \thanks{\textsuperscript{2}$ Ian Vince McLoughlin is with The National Engineering Laboratory of Speech and Language
24 Information Processing, The University of Science and Technology of China, Dept. 6, PO Box 4, Hefei, Anhui,
25 China (\textsuperscript{tt}\small ivm@ustc.edu.cn)}%
26 }%
27
28 \begin{document}
29
30
31 \maketitle
32 \thispagestyle{empty}
33 \pagestyle{empty}
  
```

PDF Content:

A new mechanical index for gauging the human bio-effects of low frequency ultrasound

Farzaneh Ahmadi¹ and Ian Vince McLoughlin²

Abstract—Low frequency ultrasound has a diverse set of industrial and medical applications ranging from high power industrial ultrasound equipment through to various therapeutic medical applications. In recent years, several speech interface applications have also been developed which exploit the low ultrasonic frequency region to augment human-computer interfacing. These devices tend to operate just above the threshold of human hearing where signals can be generated and detected using off-the-shelf audio hardware components. Mechanical index has long been one of the main criteria used for determining safety limits for human exposure to ultrasound, however it is known to be inaccurate below about 500 kHz. This paper revisits the mathematical and physical foundations of the mechanical index, in particular transient cavitation, and applies these to the low-frequency ultrasound region. Simulations are performed to evaluate the effects on both blood and water. From the results, a new mechanical index formulation is proposed, which extends down to significantly lower frequencies. The aim is to provide a gauge for determining bio-effects of emerging and future low frequency ultrasonic applications operating around 20 kHz to 100 kHz.

TABLE I
MECHANICAL INDEX LIMITS AS SPECIFIED BY THREE SIGNIFICANT STANDARDS RELATING TO DIAGNOSTIC ULTRASOUND.

Standard	MI	Applications
US FDA [10]	1.9	All except ophthalmology
	0.23	Ophthalmology
IEC [9]	0.3-0.7	Industrial
BMUS [11]	0.3	Restrict exposure time for lung/intestine
	0.7	Potential hazard

range), however the applications do not involve deliberate human exposure to the signals. Thus, these existing standards tend to focus on minimizing the risks to humans from airborne exposure. At present, there is no specific standard covering ultrasonic contact exposure for industrial applications [8].

By contrast, diagnostic medical ultrasound applications are predominantly contact methods, and thus several standards apply to ensure safety for high frequency applications. Thermal and mechanical indices (TI and MI respectively) are used to quantify ultrasound effects in IEC 60601 part 2-37 [9] and other significant standards. The formulation for TI extends directly to the LF range, however the direct application of MI as it is currently defined is extremely questionable in the LF ultrasonic region. For reference, Table I summarises the safe limits of MI as defined by the most significant standards relating to diagnostic ultrasound.

This paper will revisit the existing MI formulation theory in Section II, present simulations concerning its effectiveness (especially for LF ultrasound) in Section III, before proposing and exploring a modified definition of MI in Section IV. Section V then concludes the paper.

II. MECHANICAL INDEX

Introduced by Apfel and Holland in 1991 [12], MI serves as a means of quantifying the potential for bio-effects due to transient cavitation. If P_r is the peak rarefractional pressure in vivo in MPa and f is the frequency of the beam in MHz,

LaTeX on Linux

Previously I used TeXMaker on Ubuntu:

The screenshot shows the TeXMaker interface with the following content:

Document: /home/xm1/newtexmaker/tutorial.tex

Source Code (Left Panel):

```

13 \title{\textbf{Botan Tutorial}}
14 \author{Jack Lloyd \}
15 \texttt{lloyd@randombit.net}}
16 \date{2009/07/08}
17
18 \newcommand{\filename}[1]{\texttt{#1}}
19 \newcommand{\manpage}[2]{\texttt{#1}(#2)}
20
21 \newcommand{\macro}[1]{\texttt{#1}}
22
23 \newcommand{\function}[1]{\textbf{#1}}
24 \newcommand{\type}[1]{\texttt{#1}}
25 \renewcommand{\arg}[1]{\textsl{#1}}
26 \newcommand{\variable}[1]{\textsl{#1}}
27 \usepackage{hyperref}
28 \begin{document}
29
30 \maketitle
31
32 \tableofcontents
33
34 \parskip=5pt
35 \pagebreak
36 \error
37 \section{Introduction}
38
39 This document essentially sets up various simple scenarios and then
40 shows how to solve the problems using Botan. It's fairly simple, and
41 doesn't cover many of the available APIs and algorithms, especially
42 the more obscure or unusual ones. It is a supplement to the API
43 documentation and the example applications, which are included in the
44 distribution.
45
46 To quote the Perl man page: ``There's more than one way to do it.''
47 Divining how many more is left as an exercise to the reader.'
48

```

Rendered PDF (Right Panel):

std::cout << pipe.read_all_as_string() << std::endl;

4.3 User Authentication

Doing user authentication off a shared passphrase is fairly easy. Essentially, a challenge-response protocol is used - the server sends a random challenge, and the client responds with an appropriate response to the challenge. The idea is that only someone who knows the passphrase can generate or check to see if a response is valid.

Let's say we use 160-bit (20 byte) challenges, which seems fairly reasonable. We can create this challenge using the global random number generator (RNG):

```

byte challenge[20];
Global_RNG::randomize(challenge, sizeof(challenge), Nonce);
// send challenge to client

```

After reading the challenge, the client generates a response based on the challenge and the passphrase. In this case, we will do it by repeatedly hashing the challenge, the passphrase, and (if applicable) the previous digest. We iterate this construction 4096 times, to make brute force attacks on the passphrase hard to do. Since we are already using 160-bit challenges, a 160-bit response seems warranted, so we'll use SHA-1.

```

HashFunction* hash = get_hash("SHA-1");
SecureVector<byte> digest;
for(u32bit j = 0; j != 4096; j++)
{
    hash->update(digest, digest.size());
    hash->update(passphrase);
    hash->update(challenge, challenge.size());
}
digest = hash->final();
}
delete hash;
// send value of digest to the server

```

Table of Contents (Bottom Panel):

- Introduction
- Initializing the Library
- Hashing a File
- Symmetric Cryptography
 - Encryption with a passphrase
 - Authentication
 - User Authentication**
- Public Key Cryptography
- X.509v3 Certificates
- Special Topics

Messages / Log (Bottom Left):

```

! Undefined control sequence.
<recently read> \error
l.36 \error
The control sequence at the end of the top line

```

Bottom Bar: Structure Messages / Log Pdf Viewer UTF-8 Normal Mode

LaTeX on Linux

Now I often just run LaTeX on the command line....

The image shows a Linux desktop environment with two windows open. The left window is a text editor showing the source code of a LaTeX document named `Final_paper.tex`. The code includes a header with the author's name and affiliation, followed by a document structure with `\begin{document}`, `\maketitle`, `\begin{abstract}`, and `\end{abstract}`. The abstract text describes the paper's focus on reconstructing speech from whispers. The right window is a PDF viewer showing the rendered document, titled `Final_paper.pdf`. The PDF content includes the title **Reconstruction of continuous voiced speech from whispers**, the authors *Ian Vince McLoughlin, Jingjie Li, Yan Song*, and their affiliation: National Engineering Laboratory on Speech and Language Information Processing, The University of Science and Technology of China, Hefei, China. The PDF also includes an abstract and the beginning of an introduction section.

```

40 % University of Speechcity, Speechland \\
41 % {\small \tt RTyler@ling.speech.edu }
42
43 %
44 \begin{document}
45 \maketitle
46 %
47 \begin{abstract}
48 Whispers are an important secondary vocal communications mechanism, that can be necessary for communicating private information
49 and which are an integral aspect of natural human-to-human dialogue. Furthermore, they may be the primary communications method
50 of those suffering from certain forms of aphonia, such as laryngectomees. This paper considers the conversion of continuous
51 whispers to natural-sounding speech, and proposes a new reconstruction method based upon the synthesis of individual formants as
52 excitation source, followed by artificial glottal modulation. Early results show that the proposed method can improve quality
53 and intelligibility over the original whispers when evaluated using continuous speech. It requires neither \textit{a priori} nor
54 speaker-dependent information, is of relatively low-complexity and suitable for real-time processing.
55 \end{abstract}
56
57 \noindent{\bf Index Terms}: whispers, speech reconstruction, whisper-to-speech conversion
58
59 %
60 \section{Introduction}
61
62 In general, two approaches exist when handling whispered speech with computational speech systems such as ASR or speech
63 communications devices such as mobile phones.
64 The first is to modify the recognition engine or codec so that it operates directly with whispers. The second is to pre-process
65 the whisper input to convert it into a speech-like signal first. The second approach is naturally the preferred option for
66 speech communications systems such as mobile phones, where the assumption is made that if a user is whispering, it is due
67 specifically to conditions that pertain to the location of that user (i.e. in a quiet place, or to prevent eavesdropping of
68 private information). In these cases, no benefit is obtained if the other party in the conversation hears whispers -- in fact it
69 is preferable for them to hear normal-sounding speech. The second approach is also more widely applicable in that once whispers
70 can be reconstructed into speech, existing speech applications can be utilized with little or no modification. This paper is
71 specifically concerned with the second approach mentioned: the reconstruction of normal-sounding speech from whispers.
72
73 Probably the most cited approach to whisper-to-speech conversion is the mixed excitation linear prediction (MELP) based approach
74 pioneered by Morris et. al. \cite{morris2002reconstruction}, and still popular today \cite{huang2012reconstruction}. This method
75 uses a comparison of
76 normal and whispered speech samples from the same speaker to train a jump Markov linear system (JMLS)
77 which estimates pitch and voicing parameters. Although the technique works reasonably well, the main weaknesses are firstly that
78 it is inapplicable to situations where the users original voice has already been lost or is not available, and secondly that the
79 technique is unsuited to real-time operation. A code-excited linear predictor (CELP) based alternative was subsequently
80 developed \cite{speech:hamidtransbme_2010} to address the first weakness by deriving pitch excitation from a predefined pitch
81 model. Both methods have been shown to work well for phonemes, diphones and single-words, but results are significantly poorer
82 for continuous speech. Neither is low in computational complexity.

```

Reconstruction of continuous voiced speech from whispers

Ian Vince McLoughlin, Jingjie Li, Yan Song

National Engineering Laboratory on Speech and Language Information Processing
The University of Science and Technology of China, Hefei, China
ivm@ustc.edu.cn, jingjie@mail.ustc.edu.cn, songy@ustc.edu.cn

Abstract

Whispers are an important secondary vocal communications mechanism, that can be necessary for communicating private information and which are an integral aspect of natural human-to-human dialogue. Furthermore, they may be the primary communications method of those suffering from certain forms of aphonia, such as laryngectomees. This paper considers the conversion of continuous whispers to natural-sounding speech, and proposes a new reconstruction method based upon the synthesis of individual formants as excitation source, followed by artificial glottal modulation. Early results show that the proposed method can improve quality and intelligibility over the original whispers when evaluated using continuous speech. It requires neither *a priori* nor speaker-dependent information, is of relatively low-complexity and suitable for real-time processing.

Index Terms: whispers, speech reconstruction, whisper-to-speech conversion

1. Introduction

In general, two approaches exist when handling whispered speech with computational speech systems such as ASR or speech communications devices such as mobile phones. The first is to modify the recognition engine or codec so that it operates directly with whispers. The second is to pre-process the whisper input to convert it into a speech-like signal first. The second approach is naturally the preferred option for speech communications systems such as mobile phones, where the assumption is made that if a user is whispering, it is due specifically to conditions that pertain to the location of that user (i.e. in a quiet place, or to prevent eavesdropping of private information). In these cases, no benefit is obtained if the other party in the conversation hears whispers -- in fact it is preferable for them to hear normal-sounding speech. The second approach is also more widely applicable in that once whispers can be reconstructed into speech, existing speech applications can be utilized with little or no modification. This paper is specifically con-

deriving pitch excitation from a predefined pitch model. Both methods have been shown to work well for phonemes, diphones and single-words, but results are significantly poorer for continuous speech. Neither is low in computational complexity.

Specifically for laryngectomees, significant research has been undertaken on speech reconstruction. There are several research approaches aiming to return the ability to speak to this population apart from whisper-to-speech conversion [4][5]. Two primary methods are the CELP-based reconstruction engine mentioned [3] and statistical approaches such as those of Toda et al, specifically use of Gaussian-mixture models [6]. In fact, although his work generally involves using body-conducted speech (such as non-audible murmur microphone input), Toda has demonstrated that high levels of quality are possible when reconstructing speech from whispers. The major disadvantage is that the methods either involve some quite significant computational processing, or require *a priori* information regarding the speaker. This usually takes the form of specific clean speech utterances from the person whispering, collected during a training session. Obviously, this can be problematic for those who can not speak due to aphonia, or when multiple individuals whisper within a telephone conversation.

This paper introduces a new method sharing a similar rationale to the MELP and CELP-based source-filter approaches, but discarding much of their computational processing overhead. It does not require *a priori* or speaker-dependent information, is of relatively low computational complexity and is well suited to real-time operation. Performance, evaluated for whispered and whispered TIMIT sentences (i.e. whispers artificially generated from speech) yields reasonable performance, and subjective quality is improved over electrolarynx (EL) speech. The structure of the paper is as follows: Section 2 will investigate the relevant attributes of whispered speech before Section 3 introduces the processing framework and methodology of the new

```

ML/CNN/n/lt/9 F] \OMS/cmsy/n/
n/9 2
[2] <eval_diag.eps> <LibreOffice_spectrograms.eps>
Overfull \hbox (5.8287pt too wide) in paragraph at lines 246--258
[[[
[3]
Underfull \vbox (badness 10000) has occurred while \output is active [4]
(./Final_paper.bbl) [5] (./Final_paper.aux)
(see the transcript file for additional information)
Output written on Final_paper.dvi (5 pages, 38672 bytes).
Transcript written on Final_paper.log.
asian@fly:~/Documents/Publications/2013-/INTERSPEECH2013/SWSpaper_finalsubmit$ dvi2pdf Final_paper
asian@fly:~/Documents/Publications/2013-/INTERSPEECH2013/SWSpaper_finalsubmit$

```

LaTeX on Linux

Or I use the TeXstudio package

/home/asian/Documents/Publications/2013-/MachineHearing/machine_hearing.tex - TeXstudio

```

%% bare_jrnl.tex
%% V1.4
%% 2012/12/27
%% by Michael Shell
%% see http://www.michaelshell.org/
%% for current contact information.
%%
%% This is a skeleton file demonstrating the use of IEEEtran.cls
%% (requires IEEEtran.cls version 1.8 or later) with an IEEE journal paper.
%%
%% Support sites:
%% http://www.michaelshell.org/tex/ieeetran/
%% http://www.ctan.org/tex-archive/macros/latex/contrib/IEEEtran/
%% and
%% http://www.ieee.org/
%%
%% *** Authors should verify (and, if needed, correct) their LaTeX system ***
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%% *** not appear when using other class files. ***
%% The testflow support page is at:
%% http://www.michaelshell.org/tex/testflow/
%%
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%%
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%% ( http://www.latex-project.org/ ) version 1.3, and may be freely used,
%% distributed and modified. A copy of the LPPL, version 1.3, is included
%% in the base LaTeX documentation of all distributions of LaTeX released
%% since 2003/12/01 or later.

```

IEEE TRANSACTIONS ON AUDIO, SPEECH AND LANGUAGE PROCESSING, VOL. XX, NO. X, MAY 2014

Robust Sound Event Classification using Deep Neural Networks

Ian McLoughlin, Senior Member, IEEE, Haomin Zhang, Zhipeng Xie, Yan Song, and Wei Xiao

Abstract—The automatic recognition of sound events by computers is an important aspect of emerging applications such as automated surveillance, machine hearing and auditory scene understanding. Recent advances in machine learning, as well as in computational models of the human auditory system, have contributed to advances in this increasingly popular research field. Robust sound event classification, the ability to recognise sounds under real-world noisy conditions, is an especially challenging task. Classification methods translated from the speech recognition domain, using features such as mel-frequency cepstral coefficients, have been shown to perform reasonably well for the sound event classification task, although spectrogram-based or auditory image analysis techniques have reportedly superior performance in noise. This paper outlines a sound event classification framework that compares auditory image front end features with spectrogram image-based front end features, using support vector machine and deep neural network classifiers. Performance is evaluated on a standard robust classification task in different levels of corrupting noise, and with several system enhancements, and shown to compare very well with current state-of-the-art classification techniques.

Index Terms—Machine hearing, auditory event detection

I. INTRODUCTION

RICHARD F. Lyon of Google, in his prominent article of September 2010 [1], outlined the broad research field of machine hearing, in particular advocating a bio-mimetic approach in which machines attempt to model the human hearing apparatus. In fact, he and his group have since published a significant amount of research undertaken at Google using this approach [2]–[5]. In general, the published systems perform ear-like front-end auditory analysis, feature extraction, feature

detection or generalisation. The requirement is that a trained system, when presented with an unknown sound, is capable of correctly identifying the class of that sound. Furthermore, that the techniques should be robust to interfering acoustic noise.

In fact, many researchers have worked on sound event classification over the years, using a myriad of techniques and features. These range from parametric signal processing-based approaches [7]–[9] through to automatic speech recognition (ASR) inspired methods [10] which often make use of mel-frequency cepstral coefficients (MFCCs) [11] and similar features. One promising new approach uses time-frequency domain spectrogram image features (SIF), introduced by Jonathan Dennis et. al. [12]–[15]. As with Google, Dennis et. al. use biologically inspired front-end processing, novel feature extraction techniques, allied with various back-end classifiers and associated machine learning techniques. Unlike the Google approach, the systems introduced by Dennis are sound event detectors or classifiers, and have been evaluated under real-world conditions including severe levels of degraded acoustic background noise.

In this paper, both stabilised auditory image [6] and spectrogram features will be evaluated for standard robust sound event classification tasks. The former could loosely be described as a sound event classifier inspired by the audio retrieval approaches of Lyon et. al. [3], which we call the Google-SAI system. The latter SIF methods are closer to the work of Dennis [15]. In each case, the front end analysis and feature extraction operations are followed by back-end machine learning methods. In this paper, we primarily compare the use of support vector machines (SVM) and deep neural network

Other LaTeX distributions

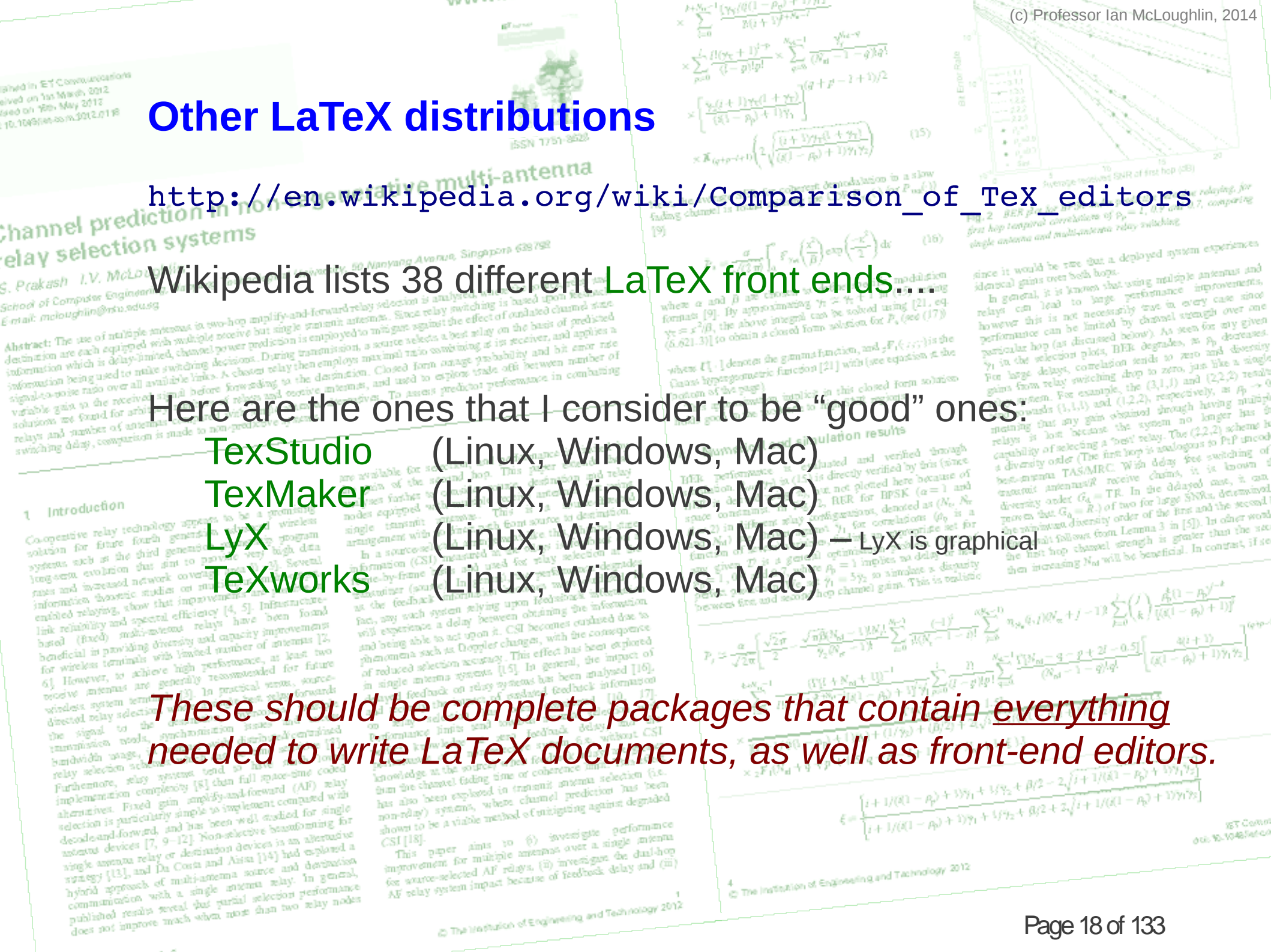
http://en.wikipedia.org/wiki/Comparison_of_Tex_editors

Wikipedia lists 38 different LaTeX front ends.....

Here are the ones that I consider to be "good" ones:

- TeXStudio (Linux, Windows, Mac)
- TeXMaker (Linux, Windows, Mac)
- LyX (Linux, Windows, Mac) — LyX is graphical
- TeXworks (Linux, Windows, Mac)

These should be complete packages that contain everything needed to write LaTeX documents, as well as front-end editors.



Useful programs and files

- .tex file - the "source code" of a LaTeX document
- latex - the program used to "compile" a .tex file to dvi
- dvi - device independent image file (like an object file)
- dvips - creates a PS output from a dvi file
- dvipdf - creates a PDF output from a dvi file
- PS - postscript (laser printer language from Adobe)
- PDF - portable document format (from Adobe)
- pdflatex - produces a PDF output directly from the .tex
- pslatex - produces a PS output directly from the .tex
- bibtex - this file creates a bibliography (see later)

Published in IET Communications
Received on 1st March 2012
Accepted on 7th May 2012
DOI: 10.1049/iet-com.2012.0118

channel prediction in non-regenerative multi-antenna relay selection systems

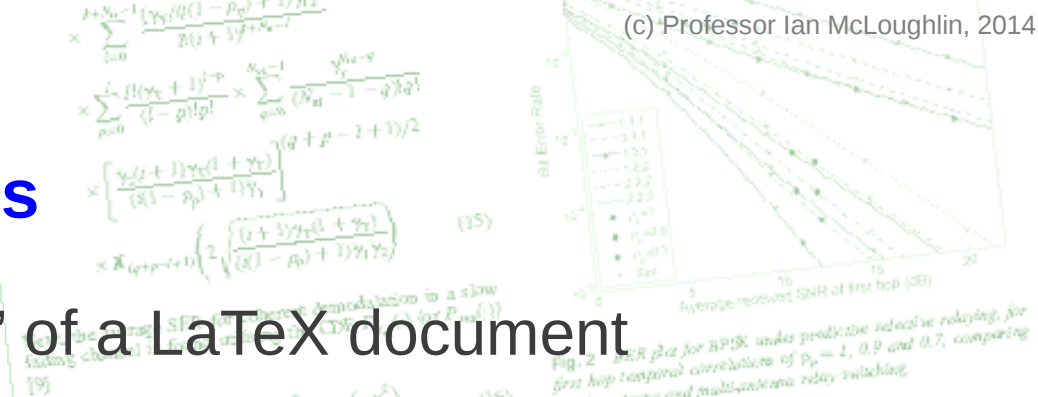
S. Prakash, I.V. M. McLoughlin
School of Computer Engineering
Email: mccloughlin@nus.edu.sg

Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is considered in this paper. Since relay switching is based on predicted channel state information, a source selects a best relay on the basis of predicted transmission, a source selects a best relay on the basis of predicted channel state information (CSI) measured at the relay. In a source-selected arrangement like this, channel state information (CSI) measured at the relay is feedback on a single transmit antenna. As the feedback information degrades as the feedback channel becomes noisy, the performance degrades. This approximation can be solved using (6.621.3) to obtain a closed form solution for P_e (see (17)).

1 Introduction
Cooperative relay technology appears to be a promising solution for future fourth generation wireless systems such as those that aim to provide very high data rates and increased information throughput. Enabled relaying link reliability based (fixed) relaying diversity with limited number of antennas to achieve high performance, at least two relays are generally recommended for wireless systems. In practical terms, source-selected relaying systems are particularly simple to implement compared with fixed gain amplify-and-forward (AF) relay systems. Fixed gain amplify-and-forward (AF) relay systems have been well studied for source-selected relaying systems. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes



Nanyang Technological University
50 Nanyang Avenue, Singapore 639798



where α and β are the average SNR at the relay and destination, respectively. By approximating $\gamma_1 = \alpha + \beta$, the above integral can be solved using (6.621.3) to obtain a closed form solution for P_e (see (17)).

Physical and simulation results
BER performance is directly related to this (since P_e is directly related to BER) and is shown in Fig. 2. The plot shows that performance degrades as ρ_p decreases and that multi-antenna relay switching outperforms single antenna relay switching. The plot also shows that performance degrades as the number of antennas N_r increases.

$$P_e = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_1} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx$$
$$P_e = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} \frac{1}{2} \left[1 + \frac{1}{\beta} \left(\frac{x}{\beta} \right) + \frac{1}{2} \left(\frac{x}{\beta} \right)^2 + \dots \right] \exp \left(-\frac{x^2}{2} \right) dx$$

Some other useful programs (Linux)

Conversion programs:

pstopdf & ps2pdf
pdftops & pdf2ps

Note: on Apple OS-X, just click on an EPS file or a PS file and then when it opens in Preview, "save as" a PDF.

"latex" uses EPS graphics files
"pslatex" uses PS graphics files
"pdflatex" uses PDF graphics files

All can use TIFF or JPEG files (but you should NOT use these as we will see later)

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Cooperative multi-antenna relay selection systems

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Abstract: The use of multiple antennas at source, relay and destination are each equipped with multiple antennas. Since relay switching is against the effect of faded channels, channel prediction is employed to make switching decisions. During transmission, a source selects a best relay based on the predicted signal-to-noise ratio over all available links. A chosen relay then employs maximal ratio combining of signals received from source and its own variable gain to the received signal before forwarding to the destination. Closed form outage probability and bit error rate solutions are found for arbitrary numbers of relays and receive antennas, and used to explore trade offs between number of relays and number of antennas compared with single antenna alternatives. To assess predictor performance in combating switching delay, comparison is made to non-predictive systems.

are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relays is feedback on a frame-by-frame basis and used for relay selection at the source. In general, the performance degrades as the number of antennas at the relays increases. In fact, any delay between the time that CSI is measured and relay selection occurs will reduce the performance of relay selection accuracy. The effect of the impact of reduced selection accuracy on the performance of relay selection in single antenna systems has been analysed [16], and delayed feedback on relay systems has been analysed [10, 17] and recently the impact of outdated feedback information on relay selection has been considered [10, 17].

Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $P_{out}(\cdot)$) [9]

$$P_s = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_n} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_1 + 1$ in (15) setting $\gamma_1 = x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_s (see (17))

where $\Gamma[\cdot]$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation at the bottom of the page)

This approximation implicit in this closed form solution holds good in the moderate to high SNR regions.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using γ), but not plotted here because of space constraints. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations $\rho_b = 1, 0.9$ and 0.7 (any of several variables, finding an appropriate set for any given D is a general optimisation problem [19]) of $\rho_b = 1, 0.9$ and 0.7 , where $\rho_b = 1$ implies no delay or near zero delay. This is realistic.

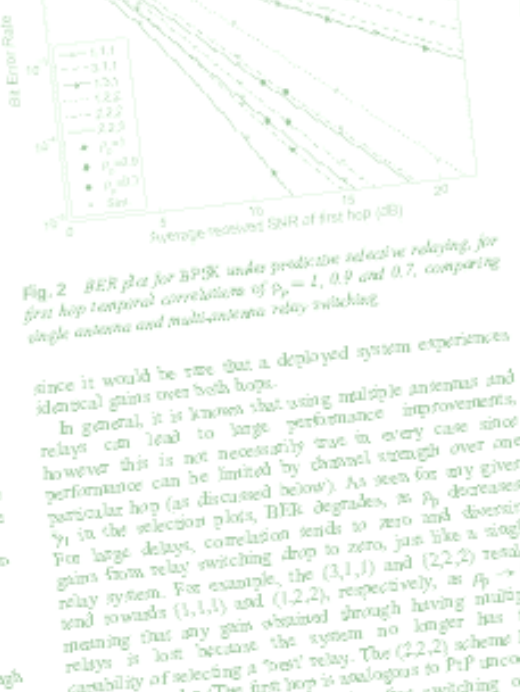


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_b = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_b decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results send towards (1,1,1) and (1,2,2), respectively, as $\rho_b \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to P/F uncoded transmission TAS/MRC. With delay free switching of best-antenna TAS/MRC receive chains, it is known that $G_d = R$). In the delayed case, it can be proven that $G_d = R$) of two for large SNRs, determined by the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second hop channel strength. In contrast, if we then increasing N_d will be beneficial. In contrast, if we

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$$\begin{aligned}
& \times \sum_{i=0}^{N_s-1} \frac{\gamma_s (q(1-\rho_q) + 1)^{i+1}}{2(i+1)^{p+N_s-1}} \\
& \times \sum_{p=0}^{N_s-1} \frac{1! (\gamma_s + 1)^{i+p}}{(i-p)! p!} \times \sum_{q=0}^{N_s-1} \frac{\gamma_s^{N_s-q}}{(N_s-1-q)! q!} \\
& \times \frac{\gamma_s (i+1) \gamma_s (i+\gamma_s)}{(i-\rho_q) + 1 \gamma_s} \gamma_s^{(q+p-2+1)/2} \\
& \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(i+1) \gamma_s (i+\gamma_s)}{(i-\rho_q) + 1 \gamma_s}} \right) \quad (15)
\end{aligned}$$



Channel prediction relay selection

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School of Computer Engineering
Email: ianmcloughlin@rnu.ac

Abstract: The use of relay destination are each equipped with information which is delay information being used to signal-to-noise ratio over a variable gain to the relay solutions are found for at relays and number of an switching delay, compared

Part B

About academic papers Paper structure and format Templates

1 Introduction

Co-operative relay technology is a promising solution for future wireless systems such as the long-term evolution (LTE) systems and increased information throughput enabled relaying, which link reliability and cost based (fixed) and mobile (mobile) nodes beneficial in providing for wireless terminals [6]. However, in a two-way antenna wireless system to direct relay selection the signal to transmission rate bandwidth usage relay selection is Furthermore, several implementation alternatives. For selection is partial decode-and-forward antennas devices [7, 9–12]. Non-relay single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

CSI [18]. This paper aims to (i) investigate the performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Academic Papers: requirements for the paper

A full journal paper

You have an idea that 'fits' and extends on previous work.

You test the idea.

Your results show that it is good compared to others work.

The idea or results are relevant, useful, & novel.

You are able to explain the idea, the motivation and the results.

A survey paper

An exhaustive and complete explanation of the field from a

senior and experienced author.

Usually requires a huge list of references!

The background image is a page from an academic paper titled "Cooperative Multi-Antenna Relay Selection Systems". It features a graph showing Bit Error Rate (BER) versus Average received SNR of first hop (dB) for BPSK under partial selection relaying. The graph compares single antenna and multi-antenna relay switching for correlation coefficients $\rho_{12} = 1, 0.9$ and 0.7 . Below the graph, there are mathematical equations for P_1 and a list of references.

Equation for P_1 :

$$P_1 = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_{12}}\left(\frac{x}{\beta}\right) \exp\left(-\frac{x^2}{2}\right) dx \quad (16)$$

Equation for ϵ :

$$\epsilon = \frac{\left\{ \frac{1 + 1/(\alpha - \beta) + 3\gamma_1 + 3\gamma_2 + \beta/2 - 2\sqrt{1 + 1/(\alpha - \beta) + 3\gamma_1\gamma_2}}{1 + 1/(\alpha - \beta) + 3\gamma_1 + 3\gamma_2 + \beta/2 + 2\sqrt{1 + 1/(\alpha - \beta) + 3\gamma_1\gamma_2}} \right\}^{(N_s - 1)}}$$

References:

- [1] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [2] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [3] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [4] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [5] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [6] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [7] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [8] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [9] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [10] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [11] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [12] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [13] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [14] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [15] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [16] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [17] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.
- [18] S. Prakash, I.V. McLoughlin, "Cooperative Multi-Antenna Relay Selection Systems", *Journal of Engineering and Technology*, 2012.

Academic Papers: requirements for the paper

A correspondence or letter

A short paper describing a recent advance.

The degree of novelty is often slightly less than a full paper.

Not much space to explain things, so normally used for incremental improvements.

Usually reviewed and then published quickly.

A top-tier conference paper

A recent advance, or a good idea with interesting results.

The standard of novelty is slightly lower than for a journal paper.

A second-tier conference paper

A convincing paper presenting a slightly novel idea, or some test/evaluation results that might be useful to others.

Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $P_{\text{out}}(\cdot)$) [9]

$$P_e = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_n}\left(\frac{x}{B}\right) \exp\left(-\frac{x^2}{2}\right) dx \quad (16)$$

This approximation holds good in the moderate to high SNR regions

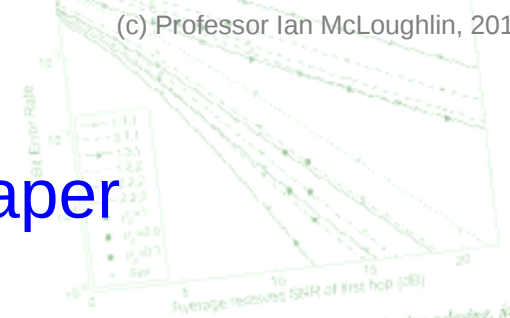


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_1 = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and relays can lead to large performance improvements, but this is not necessarily true in every case since the gain of a relay is not necessarily true in every case since the particular hop may be the weaker link. As seen for any given particular hop, the BER degrades, as ρ_1 decreases. The correlation tends to zero and diversity gain from relaying drops to zero and diversity relay system. For example, the (3,1,1) and (2,2) results send towards (1,1,1) and (1,2,2), respectively, as $\rho_1 \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to P/F incoherent transmission TAS/MRC. With delay free switching of best-antenna TAS/MRC receive comb, it is known proven that $G_d = TR$). In the delayed case, it can be shown that $G_d = R$) of two for large SNRs, determined by the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second hop channel strength will be beneficial. In contrast, if se-

$$P_e = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_n}\left(\frac{x}{B}\right) \exp\left(-\frac{x^2}{2}\right) dx$$

Academic Papers: your preparation

Good to know:

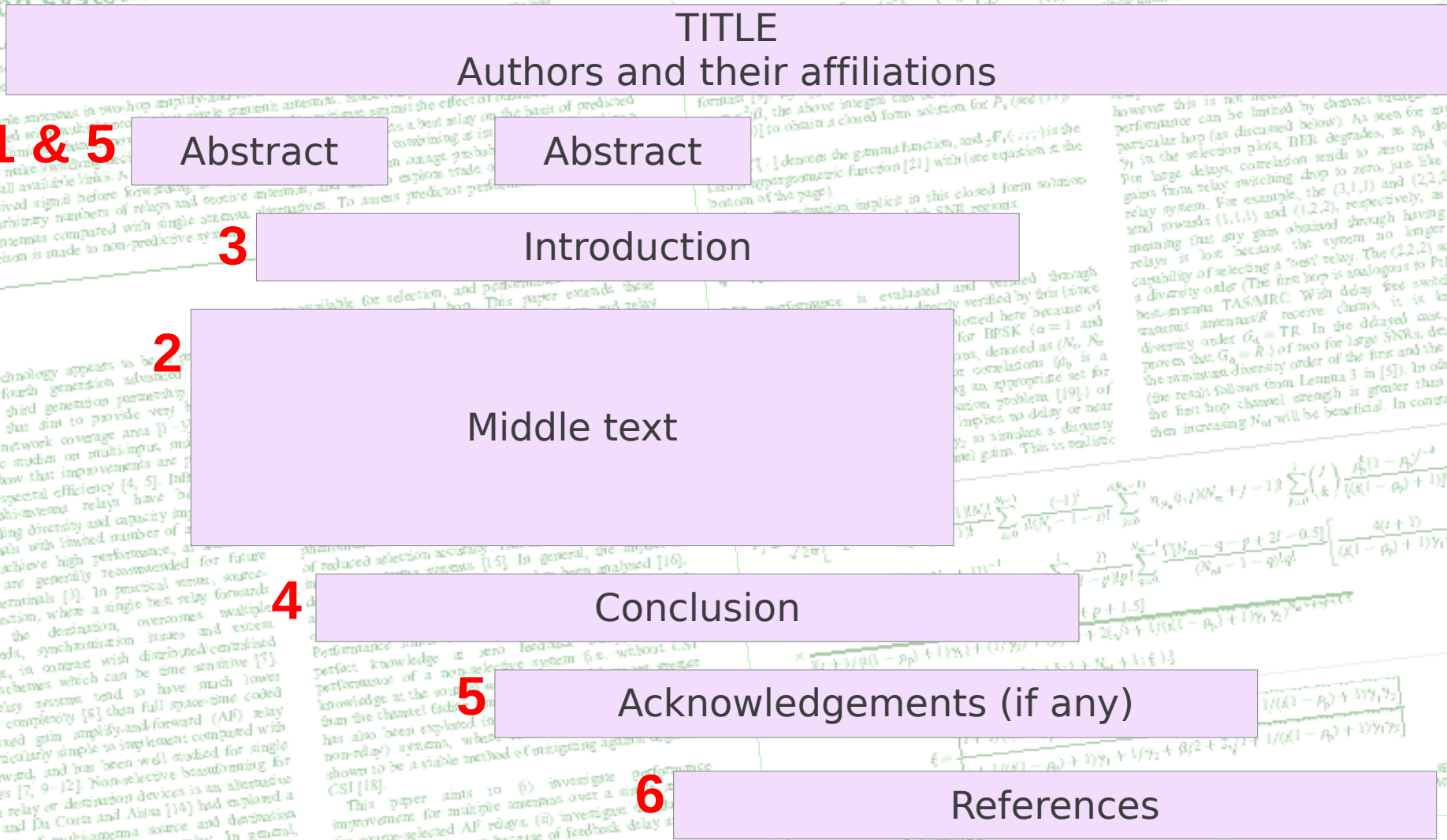
1. Identify which journal you are targetting, and know what the editors like to publish (what has been published previously in that journal?)
2. Some journals allow you to suggest reviewers...

Advanced students only: track paper download figures to identify 'hot' trends and topics...

Background image showing a journal cover and a technical paper page. The journal cover includes the title "Channel prediction in cooperative multi-antenna relay selection systems", authors "S. Prakash, I.V. McLoughlin", and "The Institution of Engineering and Technology 2012". The technical paper page includes mathematical equations, a figure (Fig. 2: BER plot for BPSK), and text discussing relay selection and performance metrics like BER and SNR. The paper is titled "Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF...".

Academic Papers: structural components

You don't write the paper in a linear sequence!!!



1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced systems such as the third generation partnership long-term evolution that aim to provide very high rates and increased network coverage area [1-3]. Information theoretic studies on multi-input, multi-output relaying, show that improvements are enabled by relaying, and spectral efficiency [4, 5]. In addition, link reliability and spectral efficiency have been improved by using multi-antenna relays have been shown to be beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [6]. However, to achieve high performance, a large number of antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-relay selection, where a single best relay forwards the signal to the destination, overcomes multiple relaying overheads, synchronization issues and excess transmission needs, synchronization issues and excess bandwidth usage, in contrast with distributed centralized relay selection schemes which can be time sensitive [7]. Furthermore, relay systems tend to have much lower implementation complexity [8] than full space-time coded alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for wireless devices [7, 9-12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results show that relay selection performance does not improve much when multiple relay nodes

TITLE
 Authors and their affiliations

Abstract

Introduction

Middle text

Conclusion

Acknowledgements (if any)

References

time

Paper structure: abstract

Abstract

I like to start by writing a draft abstract.

- what am I writing about (what is the subject area)
- what am I trying to do/prove/accomplish
- did it work out?
- the two or three impact areas of the work

After writing the paper, we can revisit the abstract & update it.

In the final paper, the abstract & conclusion should match!

$$\begin{aligned}
 & \times \sum_{p=0}^{N_m-1} \frac{\gamma_1 \gamma_2 (q(1-p) + (1-p)\gamma_1)}{2(p+1)^{p+1} \gamma_1 \gamma_2} \\
 & \times \sum_{p=0}^{N_m-1} \frac{(1+\gamma_1)^{p+1}}{(1-p)!} \times \sum_{q=0}^{N_m-1} \frac{\gamma_1^{q-p}}{(N_m-1-q)!} \\
 & \times \left[\frac{\gamma_1 (q+1) \gamma_2 (1+\gamma_1)}{(q+1) \gamma_1 + 1 \gamma_2} \right] \\
 & \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\gamma_1) \gamma_2 (1+\gamma_1)}{(q+1) \gamma_1 + 1 \gamma_2}} \right) \quad (15)
 \end{aligned}$$

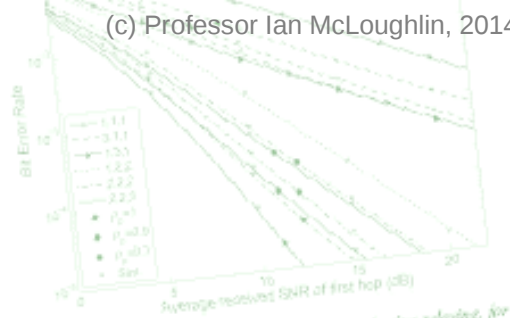


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_1 = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

average SER for coherent demodulation in a slow fading channel is found utilizing the CDF $F_{\gamma_m}(\cdot)$ (or $P_{out}(\cdot)$)

$$P_s = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_m} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

where σ is the standard deviation of the gamma function, and $\beta = \gamma_1 + 1$ in (15) setting $\gamma_1 = x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_s (see (17))

This approximation is valid in the high SNR region. The approximation implied in this paper is that the bottom of the plot is not accurate to high SNR region.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since γ is a random variable) but not plotted here because of the large number of curves. The BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations (N_s, N_r and N_d) are shown against γ_1 for correlation $\rho_1 = 1$ and 0.7 , where $\rho_1 = 1$ implies no delay or near zero delay. The BER is simulated a diversity order $G_R = R$ for two for large SNRs, determined by the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words, the first hop channel strength is greater than the second hop channel strength. In contrast, if second hop channel strength is greater than the first hop channel strength, then increasing N_d will be beneficial. In contrast, if second hop channel strength is greater than the first hop channel strength, then increasing N_d will be beneficial.

$$\begin{aligned}
 P_s &= \frac{\sigma}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{N_s N_d - 1} N_d}{\gamma_1 N_s - 1} \sum_{p=0}^{N_s-1} \frac{(-1)^p}{p!} \sum_{q=0}^{N_d-1} \frac{N_s \gamma_1 N_d + p - 1}{(N_s - 1 - p)!} \sum_{k=0}^{N_d-1} \frac{k}{(k+1)!} \right] \\
 & \times \sum_{p=0}^{N_s-1} \frac{(1+\gamma_1 + N_d + 1)^{-1}}{(1-p)!} \sum_{q=0}^{N_d-1} \frac{N_s \gamma_1 N_d - q - p + 2 - 0.5}{(N_s - 1 - q)!} \left[\frac{q(1+\gamma_1)}{(q+1) \gamma_1 + 1 \gamma_2} \right] \\
 & \times \frac{\Gamma(N_s + q + p + 1.5)}{\Gamma(1 + 1/2) \Gamma(N_s - p + 1) \Gamma(1 + 1/2) + \Gamma(1/2) \Gamma(N_s - p + 1) \Gamma(1 + 1/2)} \\
 & \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\gamma_1) \gamma_2 (1+\gamma_1)}{(q+1) \gamma_1 + 1 \gamma_2}} \right)
 \end{aligned}$$

This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Paper structure: main text

Middle text
Section II, III, IV...

This is the main content of the paper.

For me, I usually start by presenting the results. Unless I'm re-using parts of a previous paper (in that case I would start by updating the literature survey).

$$\begin{aligned} & \times \sum_{j=0}^{N_r-1} \frac{1/\gamma_2(q(1-\rho_p)+1)^j}{2(j+1)^{2+N_r-1}} \\ & \times \sum_{p=0}^{N_s-1} \frac{1/\gamma_1(\gamma_2+1)^{j+p}}{(j-p)!p!} \times \sum_{q=0}^{N_d-1} \frac{\gamma_2^{N_d-q}}{(N_d-1-q)!q!} \\ & \times \frac{\gamma_2(q+1)\gamma_2(1+\gamma_2)}{(\alpha_1-\rho_p)+1/\gamma_1} \frac{1}{(q+p-1+1)/2} \\ & \times \frac{1}{\Gamma(N_s+q+1)} \frac{1}{\Gamma(N_r+1)} \frac{1}{\Gamma(N_d+1)} \frac{1}{\Gamma(N_s+q+1)} \frac{1}{\Gamma(N_r+1)} \frac{1}{\Gamma(N_d+1)} \end{aligned} \quad (15)$$



Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_p = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching.

BER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_{s,d}}$ (or $P_{out}(t)$)

$$BER = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_{s,d}}\left(\frac{x}{\beta}\right) \exp\left(-\frac{x^2}{2}\right) dx \quad (16)$$

α and β are chosen to define specific modulation. By approximating $\gamma_1 \approx \gamma_2 + 1$ in (15) setting the above integral can be solved using [21, eq. 1] to obtain a closed form solution for P_s (see (17))

where $\Gamma(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation 4.2.1 (1))

4 Numerical and simulation results

BER performance is evaluated and verified through simulation $P_{out}(\gamma_2)$ in (15) is directly verified by this (since BER is derived using it), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations $\rho_p = 1, 0.9$ and 0.7 . The general optimisation problem [19], of finding an appropriate set for (N_s, N_r, N_d) to minimise the delay or near perfect system with the minimum complexity is a difficult problem and second hop channel gain is also taken into account.

$$\begin{aligned} & \times \sum_{j=0}^{N_r-1} \frac{1/\gamma_2(q(1-\rho_p)+1)^j}{2(j+1)^{2+N_r-1}} \\ & \times \sum_{p=0}^{N_s-1} \frac{1/\gamma_1(\gamma_2+1)^{j+p}}{(j-p)!p!} \times \sum_{q=0}^{N_d-1} \frac{\gamma_2^{N_d-q}}{(N_d-1-q)!q!} \\ & \times \frac{\gamma_2(q+1)\gamma_2(1+\gamma_2)}{(\alpha_1-\rho_p)+1/\gamma_1} \frac{1}{(q+p-1+1)/2} \\ & \times \frac{1}{\Gamma(N_s+q+1)} \frac{1}{\Gamma(N_r+1)} \frac{1}{\Gamma(N_d+1)} \frac{1}{\Gamma(N_s+q+1)} \frac{1}{\Gamma(N_r+1)} \frac{1}{\Gamma(N_d+1)} \end{aligned}$$

$$\epsilon = \frac{1 + 1/(\alpha_1 - \rho_p) + 1/\gamma_1 + 1/\gamma_2 + \beta/2 - 2\sqrt{1 + 1/(\alpha_1 - \rho_p) + 1/\gamma_1\gamma_2}}{1 + 1/(\alpha_1 - \rho_p) + 1/\gamma_1 + 1/\gamma_2 + \beta/2 + 2\sqrt{1 + 1/(\alpha_1 - \rho_p) + 1/\gamma_1\gamma_2}}$$

are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relay is feedback on a transmitter to aid the source in selecting the best relay. The feedback information becomes available at the source as being able to use the relay. The source can then select the best relay to use for transmission, with the consequence that the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with perfect knowledge at zero feedback delay, and the performance of a non-selective system (i.e. without CSI knowledge at the source) when feedback delays are greater than the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18]. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_p decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results send towards (1,1,1) and (1,2,2), respectively, as $\rho_p \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to P/P uncoded transmission TAS/MRC. With delay free switching of best-antenna TAS/MRC receive chains, it is known that $G_d = TR$. In the delayed case, it can be proven that $G_d = R$) of two for large SNRs, determined by the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second hop channel strength will be beneficial. In contrast, if second hop channel strength is greater than the first hop channel strength then increasing N_d will be beneficial. In contrast, if second hop channel strength is greater than the first hop channel strength then increasing N_d will be beneficial.

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Channel prediction and relay selection

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Abstract: The use of antenna selection for source and destination are each equipped with multiple antennas. Channel state information being used to make switching decisions. Closed form solution for BER is derived for a source-selected arrangement like this, channel state information (CSI) measured at the relay is feedback on a transmitter to aid the source in selecting the best relay. The feedback information becomes available at the source as being able to use the relay. The source can then select the best relay to use for transmission, with the consequence that the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with perfect knowledge at zero feedback delay, and the performance of a non-selective system (i.e. without CSI knowledge at the source) when feedback delays are greater than the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18]. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program long-term evolution that aim to provide very high data rates and increased network capacity. A key challenge in information theoretic models for multi-hop systems is the channel fading, which is usually assumed to be independent and identically distributed (i.i.d.) in space. However, in a practical system, the fading is correlated in space. This correlation can be exploited to improve the performance of the system. In a source-selected arrangement like this, channel state information (CSI) measured at the relay is feedback on a transmitter to aid the source in selecting the best relay. The feedback information becomes available at the source as being able to use the relay. The source can then select the best relay to use for transmission, with the consequence that the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with perfect knowledge at zero feedback delay, and the performance of a non-selective system (i.e. without CSI knowledge at the source) when feedback delays are greater than the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18]. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Paper structure: main text

Several sections of text

Literature survey:
What did other people do

My approach:
Describe the theory

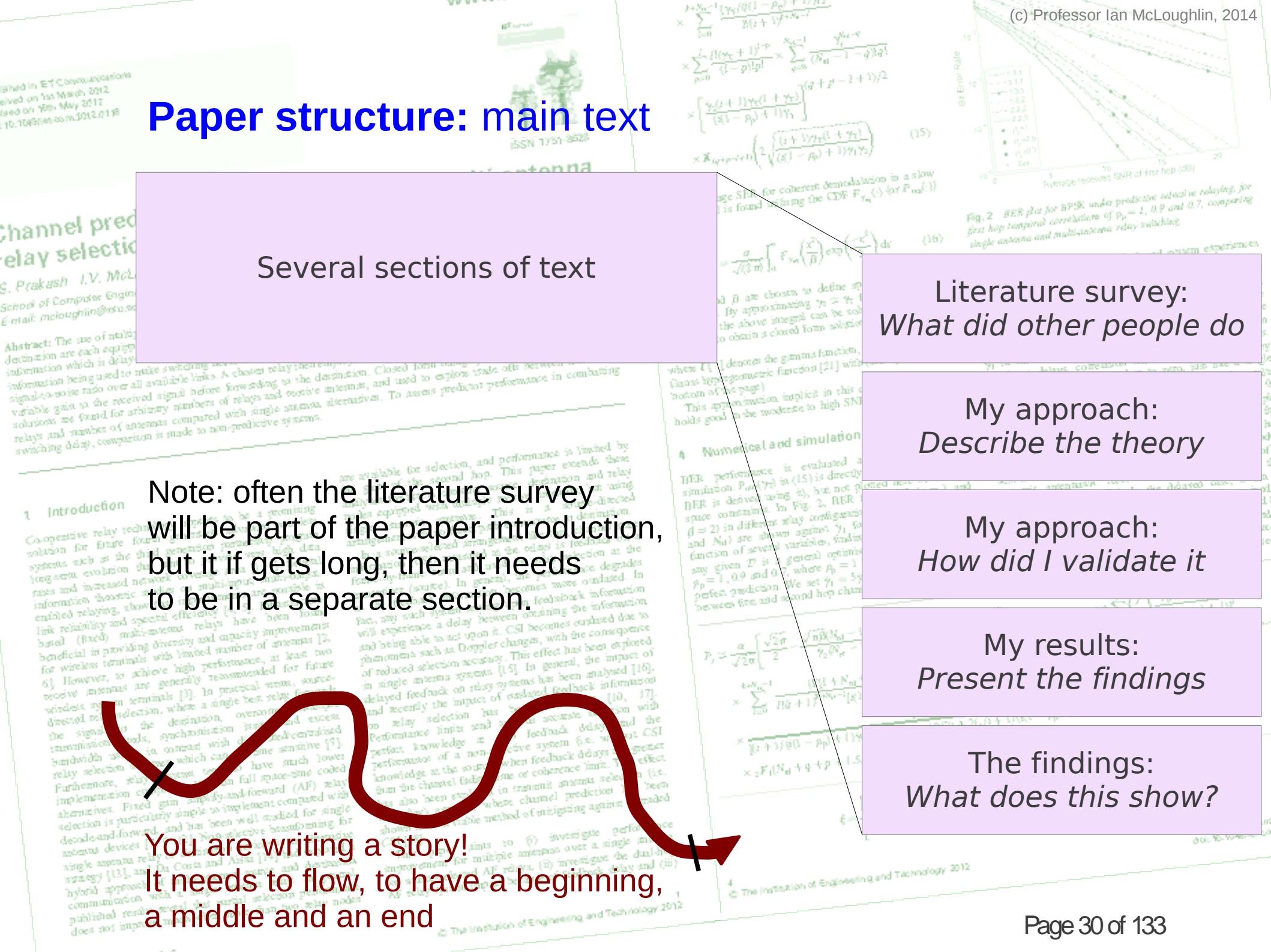
My approach:
How did I validate it

My results:
Present the findings

The findings:
What does this show?

Note: often the literature survey will be part of the paper introduction, but if it gets long, then it needs to be in a separate section.

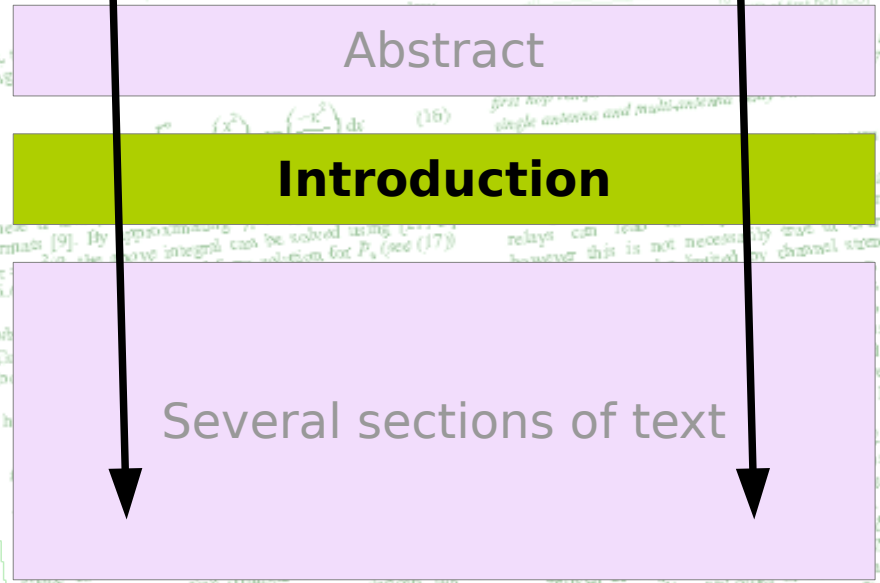
You are writing a story!
It needs to flow, to have a beginning, a middle and an end



Paper structure: introduction

Most people will download a paper after reading the abstract.

Then they will rely on the introduction to decide if they should read the paper.



What is this paper going to describe/establish/present?

What is the purpose of the paper?

What exactly will it show? *If there's a performance score, mention it here*

Why is this important?

What is the structure of this paper?

Sometimes: What is the notation used in the paper?

Paper structure: conclusion

The introduction described what the paper will show. Now the conclusion should match this:

What the paper did show.

The conclusion contains **nothing new!!**

It just repeats things for emphasis:

What did the paper show?

Why did we write this?

What is the importance of this?

Are there any other useful points?

If the paper has a performance score, repeat that in the conclusion....



Abstract

Introduction

Several sections of text

Conclusion



Paper structure: other parts

TITLE
Authors and their affiliations

The title is your "claim". Use it to attract attention. It's also very important in getting citations!! Some examples:

"MIMO Systems with Antenna Selection"

Short & simple & a wide 'claim' area. Doesn't say what the paper contains!

"Virtual branch analysis of symbol error probability for hybrid selection/maximal-ratio combining in Rayleigh fading"

Lots of keywords, but very specific. Describes exactly what the paper contains and what it analyses.

"A simple transmit diversity technique for wireless communications"

Students like the word "simple". Doesn't talk about analysis.

"Space-Time Coding"

This is a book (quite famous). The title 'claims' it describes everything about STC. It's probably true!

$$\begin{aligned} & \times \sum_{p=0}^{N_s-1} \frac{\gamma_1 \gamma_2 (1 - \rho_p) + \beta \gamma_1 \gamma_2}{2(p+1)^{2+\beta}} \\ & \times \sum_{q=0}^{N_s-1} \frac{\beta \gamma_1 \gamma_2 (1 + \gamma_1)^{2+\beta}}{(1 - \rho_q)!} \times \sum_{r=0}^{N_s-1} \frac{\gamma_1 \gamma_2 \beta}{(N_s - 1 - q)! q!} \\ & \times \frac{\gamma_1 \gamma_2 (1 + \gamma_1) \beta}{(1 - \rho_p) + \beta \gamma_1 \gamma_2} \\ & \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1 + \beta) \gamma_1 \gamma_2 (1 + \gamma_1)}{(1 - \rho_p) + \beta \gamma_1 \gamma_2}} \right) \end{aligned} \quad (15)$$

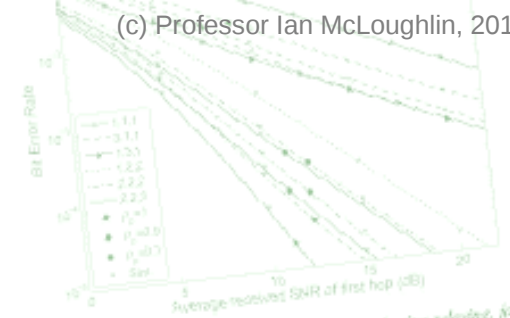


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_p = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

where $\Gamma(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation (17) for details) α and β are chosen to be $\alpha = 1$ and $\beta = 1$ (15) using [21, eq. (6.21.3)] to obtain a closed form solution for P_{out} (see (17))

$$P_{out} = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{nkN_s - 1} N_s}{\frac{1}{2} N_s - 1} \sum_{a=0}^{N_s-1} \frac{(-1)^a}{N_s - 1 - a!} \sum_{b=0}^{N_s-1} \frac{(-1)^b}{N_s - 1 - b!} \sum_{c=0}^{N_s-1} \frac{(-1)^c}{N_s - 1 - c!} \right] \times \dots$$

In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_p decreases. For large delays, correlation tends to zero and diversity gains from relay switching tend to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results tend towards (1,1,1) and (1,2,2), respectively, as $\rho_p \rightarrow 0$ meaning that any gain obtained through having multiple antennas in the system no longer has the diversity order (The first hop in the (2,2,2) scheme is best antenna TAS/MRC. With delay free switching of transmit antennas receive diversity, it is known that $G_d = R$). In the delayed case, it can be proven that $G_d = R$ of two for large SNRs, determined by the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second then increasing N_{rel} will be beneficial. In contrast, if se

$$\epsilon = \frac{\beta \gamma_1 \gamma_2 (1 + \gamma_1) \beta}{(1 - \rho_p) + \beta \gamma_1 \gamma_2} \times \frac{\beta \gamma_1 \gamma_2 (1 + \gamma_1) \beta}{(1 - \rho_p) + \beta \gamma_1 \gamma_2} \times \frac{\beta \gamma_1 \gamma_2 (1 + \gamma_1) \beta}{(1 - \rho_p) + \beta \gamma_1 \gamma_2} \times \dots$$

Paper structure: other parts

TITLE
Authors and their affiliations

Who are the authors and how do you set the order of authors?

The 1st author did most of the work and wrote the paper.

The 2nd author helped.

The 3rd author might be the supervisor of the 1st author.

The 4th author maybe helped a small amount, or just did nothing but has some right to be named there.

In general, it is not honest to add an author to a paper if they didn't contribute to the work in an intellectual way.

$$\begin{aligned}
 & \times \sum_{p=0}^{N_r-1} \frac{\gamma_1 \beta (1-\beta)^{p+1} \gamma_2}{2(p+1)^2 \gamma_1 \gamma_2} \\
 & \times \sum_{q=0}^{N_r-1} \frac{(1-\beta)^{q+1}}{(q+1)^2} \times \sum_{n=0}^{N_r-1} \frac{\gamma_1 \gamma_2 \beta^n}{(N_r-1-\beta)^n} \\
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 & \times \sum_{y=0}^{N_r-1} \frac{\gamma_1 \gamma_2 \beta^y}{(N_r-1-\beta)^y} \\
 & \times \sum_{z=0}^{N_r-1} \frac{\gamma_1 \gamma_2 \beta^z}{(N_r-1-\beta)^z} \\
 & \times \sum_{\dots} \dots
 \end{aligned}$$

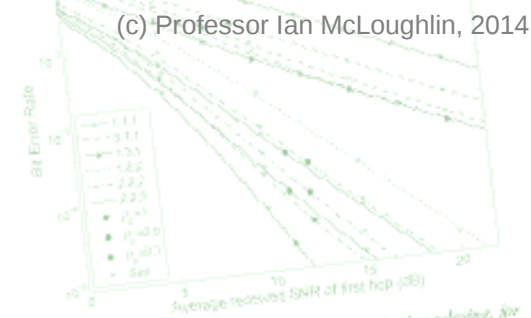


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_p = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

$$P_e = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_1} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

where $\Gamma(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation (4) at the bottom of the page)

This approximation is valid in high SNR regions.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using β), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_r, N_r, β) are shown against γ_1 for correlation ρ_p is a function of several variables, finding an appropriate set for any given D is a general optimization problem [19] of $\rho_p = 0.9$ and 0.7 , where $\rho_p = 1$ implies no delay or near zero delay.

$$\begin{aligned}
 P_e &= \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} \frac{\sqrt{2\pi} \sqrt{nkN_r - 1} \Gamma(N_r)}{\gamma_1 \gamma_2 \beta^n - 1} \sum_{n=0}^{N_r-1} \frac{(-1)^n}{n!} \sum_{k=0}^{N_r-1} \gamma_1 \gamma_2 \beta^k (N_r - 1 - k) \sum_{l=0}^{N_r-1} \frac{\beta^l (1-\beta)^{l+1}}{(k-l-\beta+1)^2} \\
 & \times \sum_{p=0}^{N_r-1} \frac{(1-\beta)^{p+1}}{(p+1)^2} \times \sum_{q=0}^{N_r-1} \frac{(1-\beta)^{q+1}}{(q+1)^2} \times \sum_{n=0}^{N_r-1} \frac{\gamma_1 \gamma_2 \beta^n}{(N_r-1-\beta)^n} \\
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 & \times \sum_{z=0}^{N_r-1} \frac{\gamma_1 \gamma_2 \beta^z}{(N_r-1-\beta)^z} \\
 & \times \sum_{\dots} \dots
 \end{aligned}$$

Paper writing: the writing process

You always start with a paper template...

Almost all journals and conferences have their own paper template. One of the most popular is the IEEEtran one used for all IEEE Journals and Conferences. This is IEEEtran.zip:

Template for most conferences

Computer society

Template for most journals

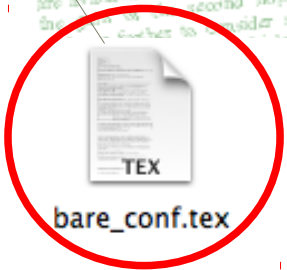
Magnetics society

Instructions

LaTeX class file



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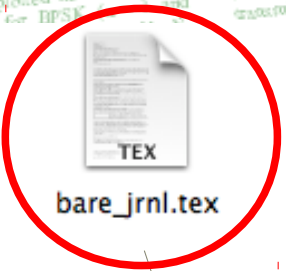
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changelog.txt



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IEEEtran.cls



README

bare_jrnl.tex

On my system, the commands are shown in black, the comments are shown in red...

> 90% of the template is comments!

Generally, we only read the comments when:

- 1) there's a problem
- 2) you have no other things you need to do

```

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2 %% V1.4
3 %% 2012/12/27
4 %% by Michael Shell
5 %% see http://www.michaelshell.org/
6 %% for current contact information.
7 %%
8 %%
9 %% This is a skeleton file demonstrating the use of IEEEtran.cls
10 %% (requires IEEEtran.cls version 1.8 or later) with an IEEE journal paper.
11 %%
12 %% Support sites:
13 %% http://www.michaelshell.org/tex/ieeetran/
14 %% http://www.ctan.org/tex-archive/macros/latex/contrib/IEEEtran/
15 %% and
16 %% http://www.ieee.org/
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19
20 *** Authors should verify (and, if needed, correct) their LaTeX system ***
21 *** with the testflow diagnostic prior to trusting their LaTeX platform ***
22 *** with production work. IEEE's font choices can trigger bugs that do ***
23 *** not appear when using other class files. ***
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48 %% ** Modified files should be clearly indicated as such, including **
49 %% ** renaming them and changing author support contact information. **
50 %%
51 %% File list of work: IEEEtran.cls, IEEEtran_HOWTO.pdf, bare_adv.tex,
52 %% bare_conf.tex, bare_jrnl.tex, bare_jrnl_compsoc.tex,
53 %% bare_jrnl_transmag.tex
54 %-----
55
56 % Note that the a4paper option is mainly intended so that authors in
57 % countries using A4 can easily print to A4 and see how their papers will
58 % look in print - the typesetting of the document will not typically be
59 % affected with changes in paper size (but the bottom and side margins will).
60 % Use the testflow package mentioned above to verify correct handling of
61 % both paper sizes by the user's LaTeX system.
62 %
63 % Also note that the "draftcls" or "draftclsnofoot", not "draft" option

```

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The way you write your paper is by adding your material directly into this file, or by adding a command to include the material.

- Text
- Equations
- Tables
- Listings
- Figures
- Bibliography

Add directly

Have them in a separate file, add a command to include them.

```

413
414
415
416 % The paper headers
417 \markboth{Journal of \LaTeX Class Files,~Vol.~11, No.~4, December~2012}%
418 {Shell \MakeLowercase{\textit{et al.}}: Bare Demo of IEEEtran.cls for Journals}
419 % The only time the second header will appear is for the odd numbered pages
420 % after the title page when using the twoside option.
421 %
422 % *** Note that you probably will NOT want to include the author's ***
423 % *** name in the headers of peer review papers. ***
424 % You can use \ifCLASSOPTIONpeerreview for conditional compilation here if
425 % you desire.
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427
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430 % If you want to put a publisher's ID mark on the page you can do it like
431 % this:
432 %\IEEEpubid{0000--0000/00$00.00--\copyright~2012 IEEE}
433 % Remember, if you use this you must call IEEEpubidadjcol in the second
434 % column for its text to clear the IEEEpubid mark.
435
436
437
438 % use for special paper notices
439 %\IEEEspecialpapernotice{(Invited Paper)}
440
441
442
443
444 % make the title area
445 \maketitle
446
447 % As a general rule, do not put math, special symbols or citations
448 % in the abstract or keywords.
449 \begin{abstract}
450 The abstract goes here.
451 \end{abstract}
452
453 % Note that keywords are not normally used for peerreview papers.
454 \begin{IEEEkeywords}
455 IEEEtran, journal, \LaTeX, paper, template.
456 \end{IEEEkeywords}
457

```


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New lines and spaces in text are not really important because LaTeX does all the typesetting for you. It means that these two Examples of paragraphs will be identical in the final paper:

This is a complete sentence. Note that spaces don't matter.

This is a complete sentence. Note that spaces don't matter.

But 2 newlines together signals a new paragraph:

This is a complete sentence. Note that spaces don't matter.

This is a new paragraph.

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% any text following a % is a comment (except \%)
\ is used to indicate the start of a command

Here is our first command:

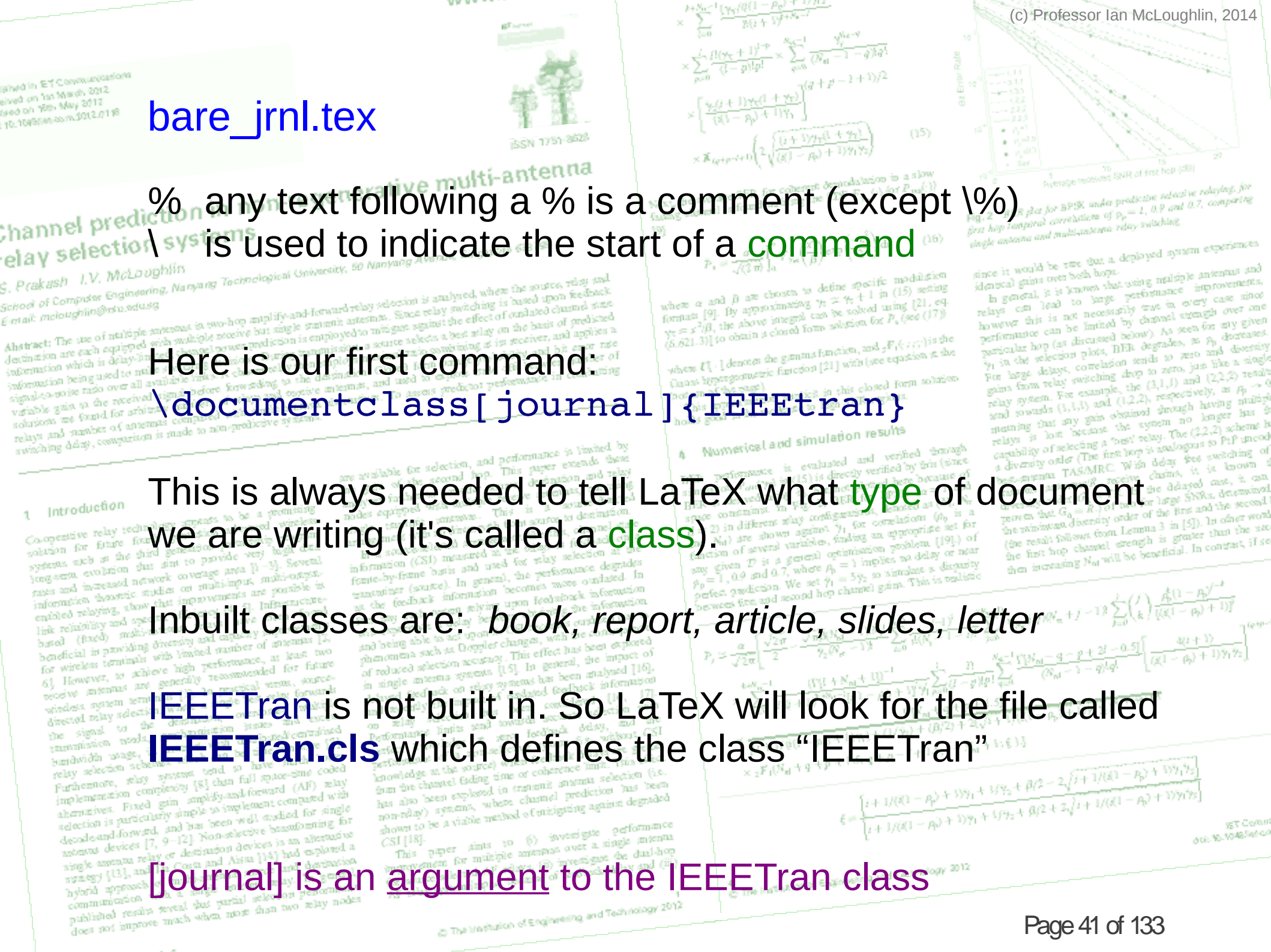
`\documentclass[journal]{IEEEtran}`

This is always needed to tell LaTeX what type of document we are writing (it's called a class).

Inbuilt classes are: *book, report, article, slides, letter*

IEEETran is not built in. So LaTeX will look for the file called **IEEETran.cls** which defines the class "IEEETran"

[journal] is an argument to the IEEETran class



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After `\documentclass` we would define any special packages that we want to use in the document (see later).

The next important command starts the document text:

`\begin{document}`

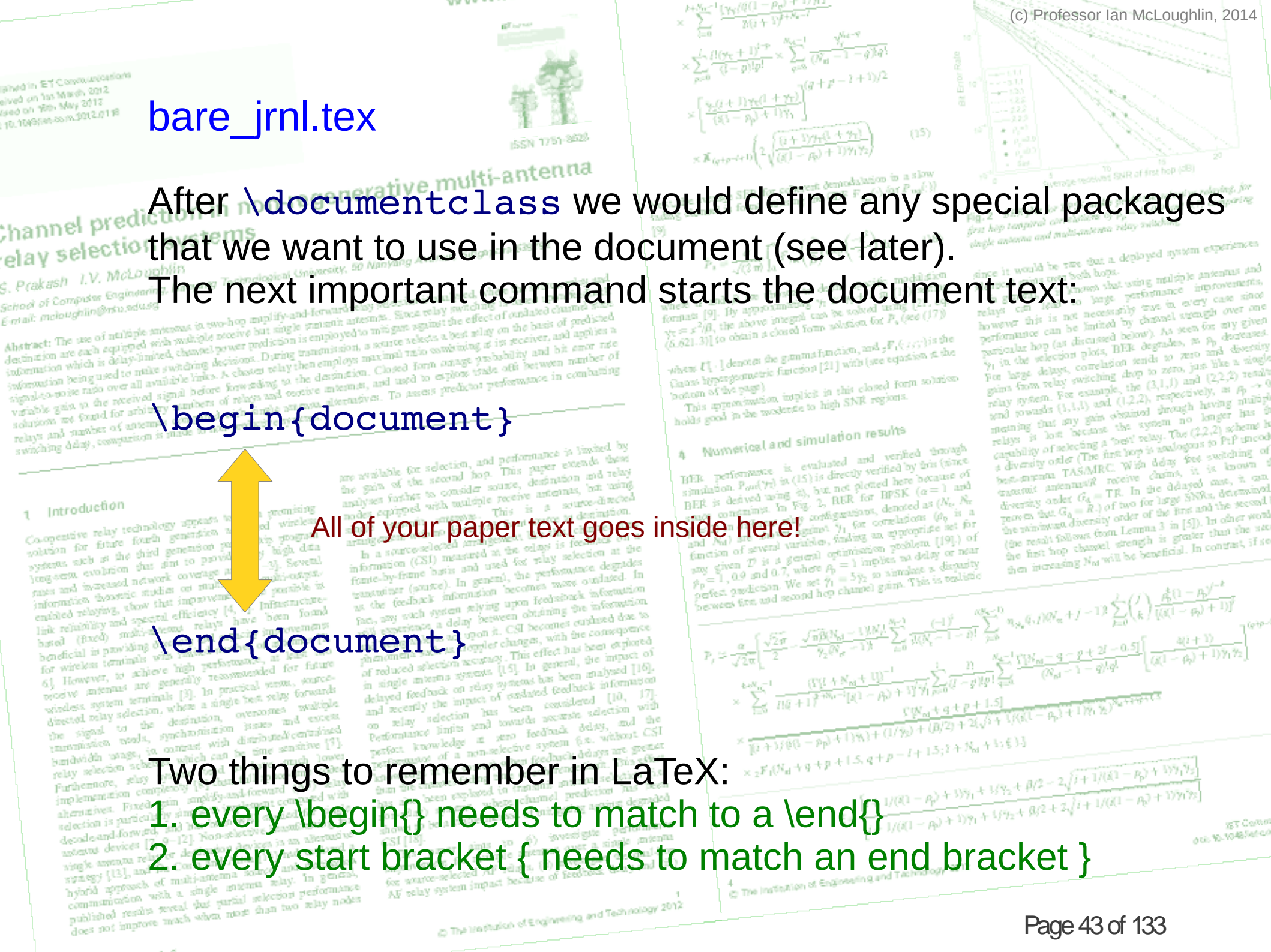


All of your paper text goes inside here!

`\end{document}`

Two things to remember in LaTeX:

1. every `\begin{}` needs to match to a `\end{}`
2. every start bracket `{` needs to match an end bracket `}`



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After that is the author list. Let's examine the structure of one:

```

\author{Michael~Shell,~\IEEEmembership{Member,~IEEE,}
        John~Doe,~\IEEEmembership{Fellow,~OSA,}
        and~Jane~Doe,~\IEEEmembership{Life~Fellow,~IEEE}}%
\thanks{M. Shell is with the Department
of Electrical and Computer Engineering,
Georgia Institute of Technology, Atlanta, GA, 30332 USA
e-mail: (see http://www.michaelshell.org/contact.html)}%
\thanks{J. Doe and J. Doe are with Anonymous University.}%
\thanks{Manuscript received April 19, 2005;
revised December 27, 2012.}}

```

The ~ means a non-breaking space. That's a space that won't become a newline (i.e. if you have A~B, then A and B will be on the same line).

We can force a newline with \\ or \newline

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The command `\maketitle` creates the text block that contains the title text – don't change it. Let's continue looking inside the document...

`\begin{abstract}`



The abstract text also goes inside here

`\end{abstract}`

Note on abstract:

1. different journals have different maximum lengths!
2. you should not include citations in the abstract
e.g. Antenna selection technologies [1] are well known...
3. you normally don't expand abbreviations in the abstract
e.g. as in maximal ratio combining (MRC)

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channel prediction in cooperative multi-antenna relay selection systems

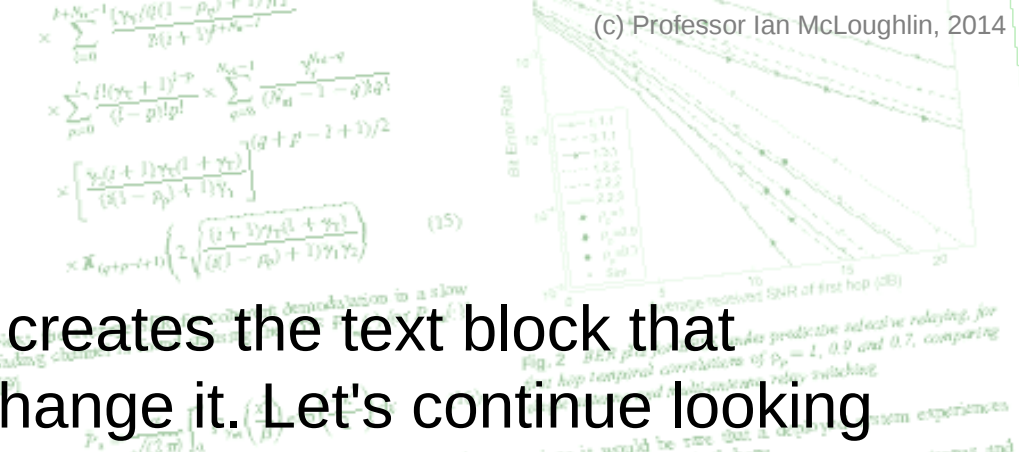
S. Prakash, I.V. McLoughlin, School of Computer Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 117573

Abstract: The use of multiple antennas in two-hop amplify-and-forward relay systems where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delay sensitive, channel power prediction is employed to mitigate against the effect of outdated channel state information being used to make relay selections. During transmission, a source selects a best relay on the basis of predicted signal-to-noise ratio over all available relays. This paper explores maximum ratio combining and form average probability and bit error rate solutions for arbitrary numbers of relays and receive antennas. To explore trade-offs between number of relays and number of antennas compared with single antenna alternatives. To assess predictor performance in combating switching delay, comparison is made to non-predictive systems.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation wireless systems such as the third generation partnership project long-term evolution that aim to provide higher data rates and increased network coverage area [1–3]. Several information theoretic studies on multi-input, multi-output relaying, show that improvements are possible in terms of spectral efficiency [4, 5]. Infrastructure-free relaying, where relays are not centrally located, has been found beneficial in providing diversity and coverage for wireless terminals with limited number of antennas [6]. However, to achieve high performance, at least two receive antennas are generally required for future wireless system terminals [3].

are available for selection. This paper considers the gain of the second hop. This paper considers relay analysis further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed relaying arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relay is fed back on a frame-by-frame basis and used for relay selection at the transmitter (source). In general, the performance degrades as the feedback information becomes more outdated. In such a system relying upon feedback information and the delay between obtaining the information and the relay selection accuracy. This effect has been explored in [7, 8]. In general, the impact of reduced selection accuracy is more pronounced in non-relay systems, where channel state information is not available at the source when feedback information is used for relay selection. This effect is more pronounced in relay systems where the channel state information is outdated towards accurate selection with respect to the destination. This effect is more pronounced in relay systems where the channel state information is outdated towards accurate selection with respect to the destination. This effect is more pronounced in relay systems where the channel state information is outdated towards accurate selection with respect to the destination.



where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_1 + 1$ in (15) setting $\gamma_1 \approx x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_b (see (17)) where $\Gamma(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation at the bottom of the page). This approximation implicit in this closed form solution holds good in the moderate to high SNR regions.

BER performance is evaluated through simulation. $P_{out}(\gamma_1)$ is directly verified by this (since BER is derived using γ_1), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r) and (N_s, N_r) are shown against γ_1 for correlation ρ_1 is a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19]. For $\rho_1 = 1, 0.9$ and 0.7 , where $\beta_1 = 5\gamma_1$, to simulate a diversity between first and second hop channel gain. This is realistic

$$P_b = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{\pi k N_s - 1} N_s}{\sqrt{2} N_s - 1} \sum_{n=0}^{N_s-1} \frac{(-1)^n}{N_s - 1 - n!} \sum_{j=0}^{N_s-1-n} \pi_n \Gamma_j / N_s + j - 1 \Gamma \sum_{k=0}^{N_s-1-n-j} \frac{A^k (1 - A)^{N_s-1-k}}{k! (k-1)!} \right]$$

Some examples – section heading

`\section{Introduction}`

Recent studies on MIMO (multi-input, multi-output) relays, prompted by standardization discussions for IEEE802.16j and 3GPP LTE (long term evolution) Advanced systems, have demonstrated improvements in link reliability and spectral efficiency `\cite{fan,pabst}`.

Motivated by this,.....

I. INTRODUCTION

Recent studies on MIMO (multi-input, multi-output) relays, prompted by standardization discussions for IEEE802.16j and 3GPP LTE (long term evolution) Advanced systems, have demonstrated improvements in link reliability and spectral efficiency [1], [2]. Motivated by this, in [3] the authors

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Channel prediction
Relay selection

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Abstract: The use of multiple relays in a network is a promising solution for future fourth generation wireless systems such as the third generation partnership program long term evolution that aim to provide very high data rates and increased network coverage. This paper considers information theoretic models of a network with a source, a relay and a destination. The relay is assumed to be a fixed gain amplify-and-forward (AF) relay. The authors investigate the impact of link reliability and spectral efficiency on the performance of a relay selection scheme. It is shown that a relay selection scheme based on fixed gain multi-antenna relays is beneficial in providing diversity for wireless terminals with limited antennas. However, to achieve high throughput, a relay selection scheme based on multiple antennas is generally preferred. The authors investigate the impact of relay selection on the performance of a relay selection scheme. It is shown that a relay selection scheme based on multiple antennas is generally preferred.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation wireless systems such as the third generation partnership program long term evolution that aim to provide very high data rates and increased network coverage. This paper considers information theoretic models of a network with a source, a relay and a destination. The relay is assumed to be a fixed gain amplify-and-forward (AF) relay. The authors investigate the impact of link reliability and spectral efficiency on the performance of a relay selection scheme. It is shown that a relay selection scheme based on fixed gain multi-antenna relays is beneficial in providing diversity for wireless terminals with limited antennas. However, to achieve high throughput, a relay selection scheme based on multiple antennas is generally preferred. The authors investigate the impact of relay selection on the performance of a relay selection scheme. It is shown that a relay selection scheme based on multiple antennas is generally preferred.

the gain of the relay. The authors investigate the impact of relay selection on the performance of a relay selection scheme. It is shown that a relay selection scheme based on multiple antennas is generally preferred.

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transmit antennas. The authors investigate the impact of relay selection on the performance of a relay selection scheme. It is shown that a relay selection scheme based on multiple antennas is generally preferred.

$$\frac{1}{1-p} \sum_{k=0}^{N_d-1} \binom{N_d-1}{k} \frac{A^k (1-A)^{N_d-k}}{[(k+1)A+1]^2}$$

$$\epsilon = \frac{j+1/(k_1-p_1)+3\gamma_1+1/\gamma_2+\beta/2-2\sqrt{j+1/(k_1-p_1)+3\gamma_1\gamma_2}}{j+1/(k_1-p_1)+1/\gamma_1+1/\gamma_2+\beta/2+2\sqrt{j+1/(k_1-p_1)+3\gamma_1\gamma_2}}$$

Some examples – subsection heading

\subsection{ERROR probability}

The average SER for coherent demodulation of various modulation schemes in a slow fading channel is

\cite{Yizhao}:

$$\bar{P}_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^\infty F_{\gamma_{eq}}(x^2/\beta) \exp(-x^2/2) dx,$$

where α and β determine specific Constellations, and $F_{\gamma_{eq}}(.)$ is the CDF of γ_{eq} .

.....

B. Error probability

The average SER for coherent demodulation of various modulation schemes in a slow fading channel is [5]: $\bar{P}_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^\infty F_{\gamma_{eq}}(x^2/\beta) \exp(-x^2/2) dx$, where α and β determine specific constellations, and $F_{\gamma_{eq}}(.)$ is the CDF of γ_{eq} . To facilitate finding a closed form solution of the above integral

More LaTeX peculiarities

Latex will convert these characters to "proper" quotes:

'hello'

'hello world'

'hello'

"hello world"



Note: don't use double quotes " in your .tex file!!!

More LaTeX peculiarities

Latex will also convert the following dashes:

`semi-precious`

`From 4--5pm`

`and continuing--`

Here are some useful formatting commands:

This is `\textit{italic}`

This is `\textbf{bold}`

This is `\texttt{computer}`

To write an entire section of text in computer type do this:

`{\tt your text goes here}`

Note: we normally don't use **colour** **text** in academic papers

Figure 19: BER Error Rate vs Average received SNR of first hop (dB). The plot shows several curves for different values of β (1.1, 1.3, 1.5, 1.7, 1.9, 2.1, 2.3, 2.5, 2.7, 2.9, 3.1). The curves generally decrease as SNR increases. A legend indicates that solid lines represent 'without predictive selective relaying' and dashed lines represent 'with predictive selective relaying, for $\beta = 1.1$ comparing'.

Equation (15):
$$\begin{aligned} & \times \sum_{p=0}^{M-1} \frac{(1+\gamma_p)(1-p)!}{(1-p)!p!} \times \sum_{q=0}^{N-1} \frac{\gamma_q^{p+q}}{(N-1-q)!q!} \\ & \times \left[\frac{\gamma_p(1+\gamma_p)(1+\gamma_q)}{(1-p)(1-p)! + 1\gamma_p} \right]^{(q+p-1+1)/2} \\ & \times \bar{K}_{(q+p-1+1)} \left(2 \sqrt{\frac{(1+\gamma_p)(1+\gamma_q)}{(1-p)(1-p)! + 1\gamma_p}} \right) \end{aligned} \quad (15)$$

Equation (19):
$$P_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} P_{\text{out}}\left(\frac{x}{\beta}\right) \frac{e^{-x^2}}{x^2} dx$$

Text: where α and β are chosen to define special forms [9]. By approximating $\gamma_p \approx \gamma_p + 1$ and $\gamma_q \approx x^2/\beta$, the above integral can be evaluated [6.621.3] to obtain a closed form solution:

Text: where $\Gamma(\cdot)$ denotes the gamma function, and $\text{Chi}_n(x)$ denotes the n -th order modified Bessel function of the second kind.

Text: This approximation is valid in the case of high SNR and holds good in the moderate to high SNR region.

Section 4: Numerical and simulation results

Text: The performance is evaluated and verified through numerical simulations. The results are directly verified by this (since the BER is derived from the closed form solution) because of the space constraint. In Fig. 19, BER is plotted for $\beta = 2$ in different relay configurations (for $\beta = 2$ and $N_{\text{relays}} = 2$ are shown against β as a function of several variables. For any given D is a general optimization parameter. We set $\beta_1 = 1$ and $\beta_2 = 0.9$ and 0.7 , where $\beta_1 = 1$ implies perfect prediction. We set $\beta_1 = 5$; $\beta_2 = 0.9$ and 0.7 between first and second hop.

Equation (20):
$$P_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} \frac{\sqrt{2\pi} \sqrt{nkN_d - 1}}{2} \frac{e^{-x^2}}{x^2} dx$$

Equation (21):
$$\epsilon = \frac{\left[\frac{1 + 1/(1-p) + 1/\gamma_1 + 1/\gamma_2 + \beta/2 - 2\sqrt{1 + 1/(1-p) + 1/\gamma_1}}{1 + 1/(1-p) + 1/\gamma_1 + 1/\gamma_2 + \beta/2 + 2\sqrt{1 + 1/(1-p) + 1/\gamma_1}} \right]}{\dots}$$

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More LaTeX peculiarities

DROPCAPS is where the first letter of a paragraph is made bigger (and the rest of the word is in capitals).

Some IEEE Journals use dropcaps, some don't.

`\IEEEPARstart{D}{ropcaps}` is where the first letter...

Most journals that we will write papers for don't use this!

But it's useful in writing reports, CVs and other documents that need to look good.

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E-10.1049/etm.2012.0118



Channel prediction in non-cooperative multi-antenna relay selection systems

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School of Computer Engineering
Email: mccloughlin@ntu.edu.sg

Abstract: The use of multiple antennas at each equipment is being widely adopted in wireless communication systems. This paper extends the existing channel prediction based relay selection scheme to multi-antenna systems. The proposed scheme is based on the prediction of the channel state information (CSI) at the relay nodes. The relay selection is based on the predicted CSI. The performance of the proposed scheme is compared with the existing channel prediction based relay selection scheme. The results show that the proposed scheme achieves a higher diversity gain than the existing scheme. The proposed scheme is also compared with the existing channel prediction based relay selection scheme. The results show that the proposed scheme achieves a higher diversity gain than the existing scheme.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program (3GPP) long term evolution (LTE) and IEEE 802.16m. The use of multiple antennas at each equipment is being widely adopted in wireless communication systems. This paper extends the existing channel prediction based relay selection scheme to multi-antenna systems. The proposed scheme is based on the prediction of the channel state information (CSI) at the relay nodes. The relay selection is based on the predicted CSI. The performance of the proposed scheme is compared with the existing channel prediction based relay selection scheme. The results show that the proposed scheme achieves a higher diversity gain than the existing scheme.

are available for selection, and performance is limited by the gain of the second hop. This paper extends the existing channel prediction based relay selection scheme to multi-antenna systems. The proposed scheme is based on the prediction of the channel state information (CSI) at the relay nodes. The relay selection is based on the predicted CSI. The performance of the proposed scheme is compared with the existing channel prediction based relay selection scheme. The results show that the proposed scheme achieves a higher diversity gain than the existing scheme.

$$P_{out} = \sum_{n=0}^{N-1} \frac{\gamma_1^n (1-\rho_1)^{n+1} \gamma_2^n}{\Gamma(n+1) \Gamma(n+1)} \times \sum_{p=0}^{N-1} \frac{\Gamma(n+1) \Gamma(p+1)}{\Gamma(n+p+1)} \times \sum_{q=0}^{N-1} \frac{\Gamma(n+p+1) \Gamma(q+1)}{\Gamma(n+p+q+1)} \times \left[\frac{\gamma_1 (q+1) \gamma_2 (q+1)}{\Gamma(n-p) + \Gamma(q)} \right] \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\gamma_1) \gamma_2 (q+1)}{\Gamma(n-p) + \Gamma(q)}} \right) \quad (15)$$



Fig. 2 BER plot for different diversity orders under predictive selective relaying. The correlation coefficients of $\rho_1 = 1, 0.9$ and 0.7 , comparing the performance of multi-antenna relay switching

where α and β are channel fading parameters. The above integral can be solved using [21, eq. (2.2)].

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since γ_1 and γ_2 are not plotted here because of space constraints). The results for $N=2$ and $N=4$ are shown against γ_1 for correlation coefficients $\rho_1 = 1, 0.9$ and 0.7 . The results show that the proposed scheme achieves a higher diversity gain than the existing scheme.

$$P_{out} = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{n\Gamma(N+1)N!}}{\Gamma(N+1)} \sum_{n=0}^{N-1} \frac{(-1)^n}{\Gamma(N-1-n)!} \sum_{k=0}^{N-1} \binom{N-1}{k} \frac{\Gamma(N-1-k)}{\Gamma(N-1-k)} \right] \times \sum_{l=0}^{N-1} \frac{\Gamma(l+N+1) \Gamma(l+1)}{\Gamma(l+1) \Gamma(l+1)} \sum_{p=0}^{N-1} \frac{\Gamma(l+p+1) \Gamma(p+1)}{\Gamma(l+p+1)} \sum_{q=0}^{N-1} \frac{\Gamma(l+p+1) \Gamma(q+1)}{\Gamma(l+p+q+1)} \left[\frac{\Gamma(l+1)}{\Gamma(l-p) + \Gamma(q)} \right] \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\gamma_1) \gamma_2 (q+1)}{\Gamma(l-p) + \Gamma(q)}} \right)$$

This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

More LaTeX peculiarities

When you quote small pieces of code in a paper, or the steps of an algorithm, you can use the `\verbatim` command:

following MATLAB command may be issued:

```
{\tt \begin{verbatim}
speech=wavrecord(16000,8000,1,'double');
\end{verbatim} }
```

This records 16,000 samples with a...

or integrated microphone, the following MATLAB command may be issued:

```
speech=wavrecord(16000,8000,1,'double');
```

This records 16 000 samples with a sample rate of 8kHz and places the

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DOI: 10.1049/iet-com.2012.0118



$$\begin{aligned}
& \times \sum_{i=0}^{N_s-1} \frac{\gamma_1 \gamma_2 (1 - \rho_1)^i + \gamma_1 \gamma_2}{2(i+1)^{p+1} + N_s - 1} \\
& \times \sum_{p=0}^{N_s-1} \frac{\gamma_1 \gamma_2 (1 - \rho_1)^{i+p}}{(i-p)! p!} \times \sum_{q=0}^{N_s-1} \frac{\gamma_1^{N_s-1-q} \gamma_2^{q-1}}{(N_s-1-q)! q!} \\
& \times \left[\frac{\gamma_2 (i+1) \gamma_1 (1 + \gamma_2)}{(i-1) \rho_1 + 1 + \gamma_1} \right]^{(q+p-2+1)/2} \\
& \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(i+1) \gamma_1 (1 + \gamma_2)}{(i-1) \rho_1 + 1 + \gamma_1} \gamma_2} \right) \quad (15)
\end{aligned}$$



Channel prediction relay selection

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Email: ianmcloughlin@rnu.ac

Abstract: The use of relay destination are each equipped with information which is delay information being used to variable gain to the received solutions are found for at relays and number of an switching delay, compared

Part C

The problem of plagiarism
LaTeX tables
LaTeX figures

1 Introduction

Co-operative relay technology is a solution for future systems such as the long-term evolution (LTE) systems and increased information theoretic enabled relaying, which link reliability and cost based (fixed) and beneficial in providing for wireless terminals [6]. However, in a two-way antenna wireless system to direct relay selection the signal to transmission use bandwidth usage relay selection is Furthermore, an implementation alternatives. For selection is partial decode-and-forward antennas devices [7, 9–12]. Non-relay single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

CSI [18]. This paper aims to (i) investigate the performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Quoting code and text

Remember that when you quote material, you **MUST** own it or have the **RIGHTS** to quote it.

Be extremely careful...

Copying ideas, text, programs, diagrams from websites, papers, or other people without permission or acknowledgement is called

PLAGIARISM

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Channel prediction in cooperative multi-antenna relay selection systems

S. Prakash, I.V. McLoughlin
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Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is analysed, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delayed, channel prediction is employed to mitigate against the effect of outdated channel state information being used to make selection. A closed form solution for the source selects a best relay on the basis of predicted signal-to-noise ratio over all available links. A closed form solution for the destination selects a best relay and bit error rate solutions are found for arbitrary numbers of relays and receive antennas, and used to explore the impact of a given number of relays and number of antennas compared with single antenna alternatives. To assess prediction performance in combating switching delay, comparison is made to non-predictive systems.

1 Introduction

Cooperative relay technology is a promising solution for future fourth generation wireless systems such as the third generation partnership project very high data rate long-term evolution that will support very high data rates and increased network capacity. Information theoretic studies on multiple antenna based (fixed) multi-antenna relays have been found beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are required. In a practical terms, source wireless system terminals may be able to select towards directed relay selection which can overcome the delay of the signal to the destination in space-time coded transmission tools, in contrast with space-time coded bandwidth usage, in contrast with space-time coded relay selection schemes which can be time sensitive [7]. Furthermore, relay systems tend to have much lower implementation complexity [8] than full space-time coded alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for antenna devices [7, 9–12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay antennas equipped with multiple receive antennas, but using a source-selected amplify-and-forward relay selection scheme. In source-selected amplify-and-forward relay selection at the transmitter (source), in general, the impact of the feedback information becomes more significant. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to phenomena such as Doppler changes, with the consequence of reduced selection accuracy. This effect has been explored for single antenna systems [15]. In general, the impact of delayed feedback on relay selection has been analysed [16] and it is shown that the impact of feedback delay is more significant when the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18]. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

$$P_e = \sum_{p=0}^{N_r-1} \frac{\gamma_1(q(1-\rho_p)+1)\gamma_2}{2^{(q+1)p+N_r-1}} \times \sum_{q=0}^{N_r-1} \frac{\Gamma(\gamma_1+1)^{q+1}}{(q-p)!q!} \times \sum_{q=0}^{N_r-1} \frac{\gamma_1^{q-p}}{(N_r-1-q)!q!} \times \left[\frac{\gamma_1(q+1)\gamma_2(1+\gamma_2)}{(\alpha_1-\rho_p)+1\gamma_1} \right] \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\gamma_2)\gamma_2(1+\gamma_2)}{(\alpha_1-\rho_p)+1\gamma_1\gamma_2}} \right) \quad (15)$$

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_1 + 1$ in (15) setting $\gamma_1 \approx x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_e (see (17))

$$P_e = \frac{\alpha}{\sqrt{\pi}\beta} \int_0^{\infty} F_{\gamma_1} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

where $F_{\gamma_1}(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation (4) in the bottom of the page)

This approximation implicit in this closed form solution holds good in the moderate to high SNR regions.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma_1)$ in (15) is directly verified by this (since BER is derived using β), but not plotted here because of the constraint in Fig. 2. BER for BPSK ($\alpha=1$ and $\beta=1$) is shown in Fig. 2. The diversity order (N_r) and the number of antennas at the receiver, denoted as (N_r , N_r) and (N_r , N_r) respectively, are shown in the legend. The function of several variables, similar to (15), is shown in Fig. 2. The general simulation problem (19) is solved for P_e using the general simulation problem (19) or near perfect prediction. We see that the performance is better between first and second hop channel gain. This is because

$$P_e = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{N_r(N_r-1)N_r}}{2(N_r-1)} \sum_{q=0}^{N_r-1} \frac{(-1)^q}{q!(N_r-1-q)!} \sum_{j=0}^{N_r-1} \binom{N_r-1}{j} \frac{A_j(1-\rho_p)^{j-1}}{[(\alpha_1-\rho_p)+1]^j} \right] \times \sum_{q=0}^{N_r-1} \frac{\Gamma(\gamma_1+N_r+1)^{q+1}}{(q-p)!q!} \times \frac{\Gamma(N_r+q+p+1.5)}{\Gamma(N_r+q+p+1.5, q+p-1+1.5, 1+N_r+1; \xi)} \times {}_2F_1(N_r+q+p+1.5, q+p-1+1.5, 1+N_r+1; \xi)$$
$$\xi = \frac{(1+\gamma_2)\gamma_2(1+\gamma_2)}{(\alpha_1-\rho_p)+1\gamma_1\gamma_2} + \frac{\beta/2 - 2\sqrt{1+(\alpha_1-\rho_p)+1\gamma_1\gamma_2}}{(1+\gamma_2)\gamma_2(1+\gamma_2)}$$

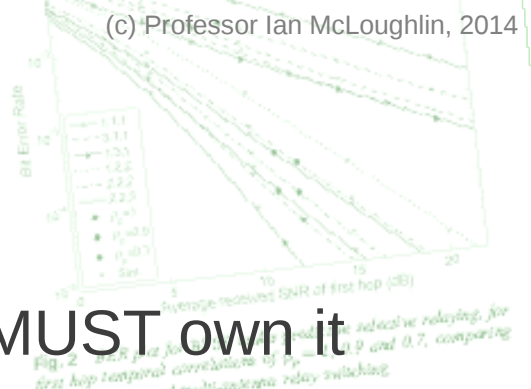


Fig. 2 BER performance for different diversity orders and antenna configurations. The first hop is analogous to PAF incoherent diversity order ($N_r = R$) of two for large SNRs, determined by the diversity order of the first and the second hop. The result shows that the performance is better between first and second hop channel gain. This is because

since it would be rare that a deployed system experiences identical gains over both hops.

In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_p decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results show towards (1,1,1) and (1,2,2), respectively, as $\rho_p \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to PAF incoherent diversity order ($N_r = R$) of two for large SNRs, determined by the diversity order of the first and the second hop. The result shows that the performance is better between first and second hop channel gain. This is because

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Channel prediction in cooperative multi-antenna relay selection systems

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Abstract: The use of multiple antennas in cooperative relay systems is considered, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Channel prediction is employed to improve the relay selection process. A source selects a best relay on the basis of prediction information being used to make switching decisions. A closed form solution for the signal-to-noise ratio over all available links. A closed form solution for the variable gain to the received signal before forwarding to the destination. Closed form solutions are found for arbitrary numbers of relays and receive antennas. Closed form solutions are found for arbitrary numbers of relays and receive antennas. To assess prediction performance in comparing relays and number of antennas compared with single antenna alternatives. switching delay, comparison is made to non-predictive systems.

1 Introduction

Co-operative relay technology appears as a promising solution for future fourth generation partnership program systems such as the third generation partnership program long-term evolution that aim to provide high data rates and increased network coverage. Information theoretic studies on multiple antenna based (fixed) multi-antenna relay systems have shown that improvements are possible in link reliability and spectral efficiency. Source-directed relay selection (SDRS) is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement the relay is feedback on a channel from the destination to the source. In a source-selected arrangement the relay is feedback on a channel from the destination to the source. In a source-selected arrangement the relay is feedback on a channel from the destination to the source. In a source-selected arrangement the relay is feedback on a channel from the destination to the source.

$$\begin{aligned} & \times \sum_{p=0}^{N_s-1} \frac{(1+\gamma_1)(1-\rho_p)^{q+p} + \gamma_2 \rho_p^{q+p}}{2^{(q+p+1)N_s}} \\ & \times \sum_{p=0}^{N_s-1} \frac{(1+\gamma_1)^{q+p}}{(1-\rho_p)^{q+p}} \times \sum_{q=0}^{N_s-1} \frac{\gamma_2^{q+p}}{(N_s-1-q)! q!} \\ & \times \left[\frac{\gamma_2(q+1)\gamma_1(1+\gamma_1)}{(1-\rho_p)^{q+1} + \gamma_1 \gamma_2} \right]^{(q+p-1)/2} \quad (15) \\ & \times \bar{K}_{(q+p+1)/2} \left(2 \sqrt{\frac{(1+\gamma_1)\gamma_2(1+\gamma_1)}{(1-\rho_p)^{q+1} + \gamma_1 \gamma_2}} \right) \end{aligned}$$

$$P_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_1} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

Numerical and simulation results
The BER performance is compared with that of a single antenna system. The first hop is assumed to be a Rayleigh fading channel. The BER is derived using (15), but not plotted here. The space constraint in Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r) and (N_d) are shown against γ_1 for correlations ρ_p of 1 and 0.9. The impact of several variables, finding an appropriate set for perfect prediction. We set $\gamma_1 = 1$ and $\gamma_2 = 1$.

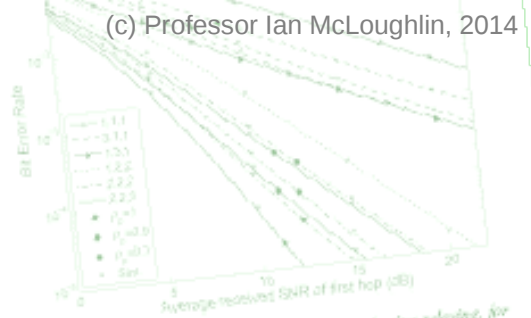


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_p = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and diversity tends to improve performance in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_p increases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results tend towards (1,1,1) and (1,2,2), respectively, as $\rho_p \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is analogous to the first hop is analogous to P/F incoherent relaying. The first hop is analogous to P/F incoherent relaying. The first hop is analogous to P/F incoherent relaying. The first hop is analogous to P/F incoherent relaying.

$$\begin{aligned} & P_s = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{N_s N_d - 1}}{2} \sum_{p=0}^{N_s-1} \frac{1}{(N_s-1-p)!} \sum_{q=0}^{N_s-1} \frac{\gamma_2^{q+p}}{(N_s-1-q)! q!} \right. \\ & \times \sum_{p=0}^{N_s-1} \frac{(1+\gamma_1)^{q+p}}{(1-\rho_p)^{q+p}} \sum_{q=0}^{N_s-1} \frac{\gamma_2^{q+p}}{(N_s-1-q)! q!} \\ & \times \left. F_1(N_s+q+p+1.5, q+p-1+1.5; 1+N_s+1; \xi) \right] \\ & \xi = \frac{(1+\gamma_1)(1-\rho_p)^{q+p} + \gamma_2 \rho_p^{q+p}}{(1-\rho_p)^{q+1} + \gamma_1 \gamma_2} \end{aligned}$$

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Regular Pulse Excitation (RPE) is a parametric coder that represents the pitch component of speech. It is most famously implemented in ETSI standard 06.10, and currently is the primary mobile speech communications method for over a third of the world's population, by any measure an impressive user base. This is due to its use in the GSM standard, developed in the 1980s as a pan-European digital voice standard. It was endorsed by the European Union, and quickly found adoption across Europe and then beyond.

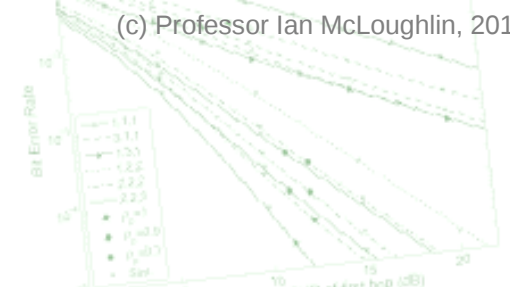
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RPE (Regular Pulse Excitation) is a type of coder that is used to describe the pitch signal in speech. RPE is part of ETSI standard 06.10. This is used in the GSM algorithm that started in the 1980s as a European Union digital voice standard. Now it is used by more than a third of the world's population.

What do you think?



$$\begin{aligned} & \times \sum_{n=0}^{N-1} \frac{\gamma_1(q(1-\rho_1) + 1)^n \gamma_2}{2^n(1+\gamma)^{n+1}} \\ & \times \sum_{p=0}^{N-1} \frac{(1+\gamma_1)^{p+1}}{(1-\rho_1)^{p+1}} \times \sum_{q=0}^{N-1} \frac{\gamma_2^{q-p}}{(2^q-1-\rho_2)^q} \\ & \times \left[\frac{\gamma_2(q+1)\gamma_1(1+\gamma_1)}{(2^q-1-\rho_2)(1+\gamma_1)} \right] \\ & \times \bar{N}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\gamma_1)\gamma_2(1+\gamma_1)}{(2^q-1-\rho_2)(1+\gamma_1)\gamma_1}} \right) \end{aligned} \quad (15)$$



1 Introduction

Co-operative relay technology is a promising solution for future fourth generation wireless systems such as the third generation partnership project long-term evolution that aim to provide very high data rates and increased network coverage area [1-3]. Several information theoretic models have been proposed for wireless relaying, such as amplify-and-forward, decode-and-forward, and space-time coded relaying. In a source-selected relay system, the relay selection is performed on a frame-by-frame basis. In general, the performance degrades in a source-selected relay system because of feedback delay and channel fading. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna system using AF relays, (ii) investigate the dual-hop relay system performance because of feedback delay and (iii) investigate the impact of channel fading on the performance of the relay system. The results show that the performance of the relay system does not improve much when more than two relay nodes are used. This is because of the feedback delay and channel fading. The results also show that the performance of the relay system is improved when the number of antennas is increased. This is because of the diversity gain provided by the multiple antennas. The results also show that the performance of the relay system is improved when the number of antennas is increased. This is because of the diversity gain provided by the multiple antennas.

...available for selection, this paper examines the performance of a source-selected relay system equipped with multiple antennas. This is a source-selected relay system where the relay selection is performed on a frame-by-frame basis. In a source-selected relay system, the relay selection is performed on a frame-by-frame basis. In general, the performance degrades in a source-selected relay system because of feedback delay and channel fading. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna system using AF relays, (ii) investigate the dual-hop relay system performance because of feedback delay and (iii) investigate the impact of channel fading on the performance of the relay system. The results show that the performance of the relay system does not improve much when more than two relay nodes are used. This is because of the feedback delay and channel fading. The results also show that the performance of the relay system is improved when the number of antennas is increased. This is because of the diversity gain provided by the multiple antennas.

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RPE (Regular Pulse Excitation) is a type of coder that is used to describe the pitch signal in speech. RPE is part of ETSI standard 06.10. This is used in the GSM algorithm that started in the 1980s as a European Union digital voice standard. Now it is used by more than a third of the world's population.

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Here is a better way of dealing with it. Regular Pulse Excitation (RPE) was developed in Europe to encode speech pitch signals. McLoughlin describes it as being "most famously implemented in ETSI standard 06.10, and currently is the primary mobile speech communications method for over a third of the world's population, by any measure an impressive user base" [1]. He goes on to describe how it was used in GSM which was "developed in the 1980s as a pan-European digital voice standard. It was endorsed by the European Union, and quickly found adoption across Europe and then beyond" [1].

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Cooperative multi-antenna channel prediction in relay selection systems

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Abstract: The use of multiple antennas in both source and relay nodes for channel prediction is analysed, where the source, relay and destination are each equipped with multiple receive antennas. A source-directed relay selection scheme is proposed in which channel prediction information which is delay-limited, channel power prediction is employed to select the best relay for the first hop. During transmission, a source selects a best relay using a variable gain to the received signal before forwarding to the destination. Closed form outage probability and bit error rate solutions are found for arbitrary numbers of relays and receive antennas, and used to explore trade-offs between number of relays and number of antennas for a given system. To assess predictor performance in combating switching delay, comparison of multiple antenna systems is provided.

1 Introduction

Cooperative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program long-term evolution that aim to provide very high data rates and increased network coverage [1]. Several information theoretic studies, on relay selection in a network-enabled relaying, show that improved performance is achieved with link reliability and spectral efficiency [4, 5]. Infrastructure-based (fixed) multi-antenna relays have been found beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [7].

In a source-selected arrangement like this, channel state information (CSI) measured at the relay is fed back on a delay-limited channel to the source. As the feedback channel is not perfect, the performance degrades as the feedback delay increases. In fact, any such system relying upon feedback has the potential to experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to phenomena such as Doppler changes, with the consequence of reduced selection accuracy. This effect has been explored in single antenna systems [15]. In general, the impact of imperfect CSI on relay selection systems has been analysed [16].



$$P_{out} = \sum_{n=0}^{N_r-1} \frac{\gamma_1 \gamma_2 (1 - \rho_1)^n + \gamma_2 \gamma_1 (1 - \rho_2)^n}{2(n+1)\gamma_1 \gamma_2 + \dots} \times \sum_{p=0}^{N_r-1} \frac{(1 - \rho_1)^p + (1 - \rho_2)^p}{(p+1)!} \times \sum_{q=0}^{N_r-1} \frac{\gamma_1 \gamma_2 (1 - \rho_1)^q + \gamma_2 \gamma_1 (1 - \rho_2)^q}{(q+1)!} \times \left[\frac{\gamma_1 \gamma_2 (1 + \gamma_1)(1 + \gamma_2)}{(1 - \rho_1) + (1 + \gamma_1) \gamma_2} \right] \times \bar{\alpha}_{(q+p+1)} \left(2 \sqrt{\frac{(1 + \gamma_1 \gamma_2)(1 + \gamma_1)}{(1 - \rho_1) + (1 + \gamma_1) \gamma_2}} \right) \quad (15)$$

Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_{n,1}}(\cdot)$ (or $P_{out}(\cdot)$) [9]

$$P_s = \frac{\alpha}{\sqrt{\pi}} \int_0^{\infty} F_{\gamma_{n,1}}\left(\frac{x}{B}\right) \exp\left(-\frac{x^2}{2}\right) dx \quad (16)$$

where α and B are chosen to define specific modulation schemes. For BPSK, $\alpha = \frac{1}{2}$ and $B = 1$ in (15) setting $\gamma_1 = \gamma_2 = 1$. For QPSK, $\alpha = \frac{1}{4}$ and $B = 1$ in (15) setting $\gamma_1 = \gamma_2 = 1$. For M-PSK, $\alpha = \frac{1}{M}$ and $B = 1$ in (15) setting $\gamma_1 = \gamma_2 = 1$. For M-QAM, $\alpha = \frac{1}{M}$ and $B = \frac{M-1}{M}$ in (15) setting $\gamma_1 = \gamma_2 = 1$. The gamma function $\Gamma(\cdot)$ and the Gaussian hypergeometric function ${}_2F_1(\cdot)$ with (see equation (2) of the page)

This approximation is valid in the high SNR regions. The numerical and simulation results are shown in Fig. 2. The BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_r, N_r, β) is shown against γ_1 for correlation $\rho_1 = \rho_2$ as a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19]. For $\gamma_1 = 1$ and $\beta = 2$, where $\beta = 1$ implies no delay or near zero delay, the BER is $1/2$. This is realistic between first hop and second hop channel gain. This is realistic

$$P_s = \frac{\alpha}{\sqrt{\pi}} \left[\frac{\sqrt{2\pi}}{2} - \frac{\sqrt{\pi k(N_r - 1)N_r}}{2(N_r - 1)} \sum_{n=0}^{N_r-1} \frac{(-1)^n}{n!(N_r - 1 - n)!} \sum_{p=0}^{N_r-1} \sum_{q=0}^{N_r-1} \frac{(-1)^q}{q!(N_r - 1 - q)!} \sum_{k=0}^{N_r-1} \frac{(-1)^k}{k!(N_r - 1 - k)!} \right] \left[\frac{4(1 + \gamma_1)}{(1 - \rho_1) + (1 + \gamma_1) \gamma_2} \right]^{(q+p+1)}$$

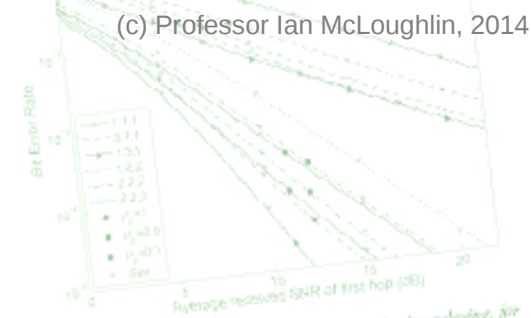


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since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and diversity can lead to large performance improvements, which is generally true in every case since performance can be degraded by channel strength over one particular hop (as discussed below). As seen for any given relay in the selection plots, BER degrades, as ρ_1 decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results tend towards (3,1,1) and (1,2,2), respectively, as $\rho_1 \rightarrow 0$. The diversity gains obtained through having multiple antennas at the relay node are not fully exploited in this scheme because of the delay between the two hops. The first hop is analogous to the first hop of a MRC. With delay free switching of transmit antennas receive diversity, it is known that $G_d = R$. In the delayed case, it can be proven that $G_d = R$ of two for large SNRs, determined the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second hop channel strength is beneficial. In contrast, if second hop

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Someone will find out. Maybe not this week, this month this year. Maybe they will only find it out when you are rich and famous.

Then... disaster will hit you. You made the disaster, you will suffer the consequences.

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Channel prediction in cooperative multi-antenna relay selection systems

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1 Introduction

Cooperative relay technology appears to be a promising solution for future fourth generation wireless systems such as the third generation partnership program long-term evolution that aim to provide very high data rates and increased network coverage area [1-3]. Several information theoretic studies on multi-input, multi-output enabled relaying, show that performance improvements are possible in link reliability and spectral efficiency. Cooperative relaying based (fixed) multi-antenna relaying can provide capacity improvements in providing high throughput and capacity improvements for wireless terminals [4].

However, to achieve high throughput and capacity improvements, multiple antennas are generally recommended for both source and destination terminals [5]. In practical terms, source-destination relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission nodes, synchronization issues and excess bandwidth usage, in comparison with distributed centralized relay selection schemes [6].

Furthermore, relay selection schemes can be time sensitive [7]. Furthermore, relay selection schemes can be time sensitive [7]. Furthermore, relay selection schemes can be time sensitive [7].

are available for selection, and performance is limited by the fading of the second hop. This paper extends these results to the case where the source, destination and relay nodes are equipped with multiple antennas. In a source-selected arrangement with no direct path from source to destination, a single transmit antenna at the source and multiple receive antennas at the destination are used. In a source-selected arrangement like this, channel state information (CSI) measured at the relay is fed back on a frame-by-frame basis and used for relay selection at the transmitter (source). In general, the performance degrades as the feedback information becomes more outdated. In this paper, the impact of outdated feedback information on the performance of a source-selected relay system is investigated. The impact of outdated feedback information on the performance of a source-selected relay system is investigated. The impact of outdated feedback information on the performance of a source-selected relay system is investigated.

Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $P_{out}(\cdot)$) [9]

$$P_s = \frac{\sigma}{\sqrt{\pi} \Gamma(m)} \int_0^\infty F_{\gamma_n} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

where α and β are chosen to define specific modulation schemes. For BPSK, $\alpha = 1$ and $\beta = 1$ in (15) setting $\gamma_n = \frac{1}{2} \ln \left(\frac{1 + \gamma_n}{1 - \gamma_n} \right)$. For QPSK, $\alpha = 1$ and $\beta = 1$ in (15) setting $\gamma_n = \frac{1}{2} \ln \left(\frac{1 + \gamma_n}{1 - \gamma_n} \right)$. For QPSK, $\alpha = 1$ and $\beta = 1$ in (15) setting $\gamma_n = \frac{1}{2} \ln \left(\frac{1 + \gamma_n}{1 - \gamma_n} \right)$.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma_n)$ in (15) is directly verified by this (since BER is derived using γ_n), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 1$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations ρ_r is a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19].

$$\epsilon = \frac{\sum_{p=0}^{N_s-1} \frac{(1+\gamma_1)^{p+1} \times \sum_{q=0}^{N_r-1} \frac{\gamma_1^{q+1}}{(q+1)! p!}}{(1-p)! p!}}{(N_s-1)! \gamma_1^{N_s-1}} \times \frac{\sum_{p=0}^{N_s-1} \frac{(1+\gamma_1)^{p+1} \times \sum_{q=0}^{N_r-1} \frac{\gamma_1^{q+1}}{(q+1)! p!}}{(1-p)! p!}}{(N_s-1)! \gamma_1^{N_s-1}} \times \frac{\sum_{p=0}^{N_s-1} \frac{(1+\gamma_1)^{p+1} \times \sum_{q=0}^{N_r-1} \frac{\gamma_1^{q+1}}{(q+1)! p!}}{(1-p)! p!}}{(N_s-1)! \gamma_1^{N_s-1}} \times \frac{\sum_{p=0}^{N_s-1} \frac{(1+\gamma_1)^{p+1} \times \sum_{q=0}^{N_r-1} \frac{\gamma_1^{q+1}}{(q+1)! p!}}{(1-p)! p!}}{(N_s-1)! \gamma_1^{N_s-1}}$$

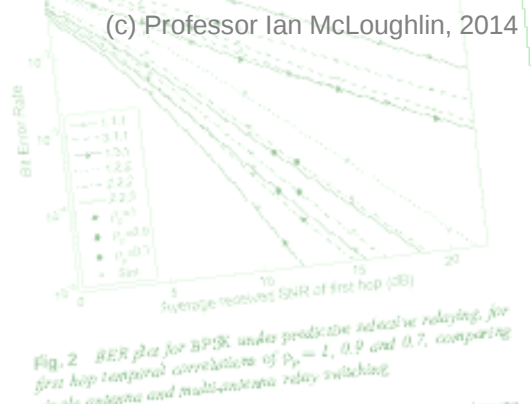


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_r = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and diversity order lead to large performance improvements. For large delays, the performance gain is not as significant as in the case since performance can be maintained over one hop. For large delays, the performance gain is not as significant as in the case since performance can be maintained over one hop.

The consequence of plagiarism

The German Defence Minister resigned in 2011 because he was found to have copied text in his PhD thesis written in 2006 (without giving a citation).

German Defence Minister Guttenberg resigns over thesis



The German army was being restructured under Mr zu Guttenberg, so his departure leaves a gap in government

German Defence Minister Karl-Theodor zu Guttenberg has stepped down after he was found to have copied large parts of his 2006 university doctorate thesis.

Mr Guttenberg, considered until recently a possible candidate for chancellor, has already been stripped of his PhD.

He told a news conference that it was "the most painful step of my life".

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Channel prediction in non-relay selective multi-antenna relay selection systems

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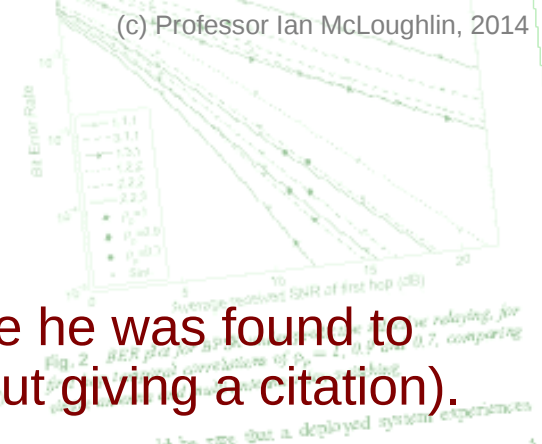
Abstract: The use of relay destination are each equipped with information which is delay information being used to variable gain to the received solutions we found for at relays and number of an switching delay, compared

1 Introduction

Co-operative relay solution for finite systems such as long-term evolution rates and increased information throughput link reliability and based (fixed) and beneficial in provided for wireless systems [6]. However, to receive antennas wireless system to directed relay side the signal to transmission via bandwidth usage relay selection. Furthermore, implementation alternatives. For selection is part decode-and-forward antenna device single antenna strategy [13]. hybrid approach communication published results does not improve

Source: The BBC

$$\sum_{p=0}^{N-1} \frac{(1-\rho)^{p+1} \gamma_1 \gamma_2 (1-\rho_0)^{p+1} \gamma_1 \gamma_2}{2(p+1)^2 + \gamma_1 \gamma_2} \times \sum_{q=0}^{N-1} \frac{(1-\rho)^{q+1} \gamma_1 \gamma_2 (1-\rho_0)^{q+1} \gamma_1 \gamma_2}{(q+1)^2 + \gamma_1 \gamma_2} \times \sum_{k=0}^{N-1} \frac{(1-\rho)^{k+1} \gamma_1 \gamma_2 (1-\rho_0)^{k+1} \gamma_1 \gamma_2}{(k+1)^2 + \gamma_1 \gamma_2}$$
$$\times \sum_{l=0}^{N-1} \frac{(1-\rho)^{l+1} \gamma_1 \gamma_2 (1-\rho_0)^{l+1} \gamma_1 \gamma_2}{(l+1)^2 + \gamma_1 \gamma_2} \times \sum_{m=0}^{N-1} \frac{(1-\rho)^{m+1} \gamma_1 \gamma_2 (1-\rho_0)^{m+1} \gamma_1 \gamma_2}{(m+1)^2 + \gamma_1 \gamma_2}$$
$$\times \sum_{n=0}^{N-1} \frac{(1-\rho)^{n+1} \gamma_1 \gamma_2 (1-\rho_0)^{n+1} \gamma_1 \gamma_2}{(n+1)^2 + \gamma_1 \gamma_2} \times \sum_{o=0}^{N-1} \frac{(1-\rho)^{o+1} \gamma_1 \gamma_2 (1-\rho_0)^{o+1} \gamma_1 \gamma_2}{(o+1)^2 + \gamma_1 \gamma_2}$$



since it would be rare that a deployed system experiences identical gains over both hops.
In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_0 decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) result send towards (1,1,1) and (1,2,2), respectively, as $\rho_0 \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to Pt incoherent TAS/MRC. With delay free switching of best antenna receive chains, it is known transmit antennas R receive chains, it is known diversity order $G_d = TR$. In the delayed case, it can be proven that $G_d = R$.) of two for large SNRs, determined the minimum diversity order of the first and the second (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second then increasing N_d will be beneficial. In contrast, if se

$$\sum_{k=0}^{N-1} \frac{(1-\rho)^{k+1} \gamma_1 \gamma_2 (1-\rho_0)^{k+1} \gamma_1 \gamma_2}{(k+1)^2 + \gamma_1 \gamma_2} \times \sum_{l=0}^{N-1} \frac{(1-\rho)^{l+1} \gamma_1 \gamma_2 (1-\rho_0)^{l+1} \gamma_1 \gamma_2}{(l+1)^2 + \gamma_1 \gamma_2} \times \sum_{m=0}^{N-1} \frac{(1-\rho)^{m+1} \gamma_1 \gamma_2 (1-\rho_0)^{m+1} \gamma_1 \gamma_2}{(m+1)^2 + \gamma_1 \gamma_2}$$
$$\times \sum_{n=0}^{N-1} \frac{(1-\rho)^{n+1} \gamma_1 \gamma_2 (1-\rho_0)^{n+1} \gamma_1 \gamma_2}{(n+1)^2 + \gamma_1 \gamma_2} \times \sum_{o=0}^{N-1} \frac{(1-\rho)^{o+1} \gamma_1 \gamma_2 (1-\rho_0)^{o+1} \gamma_1 \gamma_2}{(o+1)^2 + \gamma_1 \gamma_2} \times \sum_{p=0}^{N-1} \frac{(1-\rho)^{p+1} \gamma_1 \gamma_2 (1-\rho_0)^{p+1} \gamma_1 \gamma_2}{(p+1)^2 + \gamma_1 \gamma_2}$$

The consequence of plagiarism

Some questions

Big data: how will this affect plagiarism detection?

Internet

how will greater connectivity and availability affect the chance of your work being analysed in future?

Internationalisation

China will adopt more 'Western' ideas about intellectual property...

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Cooperative relay prediction in predictive multi-antenna relay selection systems

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Abstract: The use of multiple antennas at source and destination and forward relay selection is analysed, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delayed, channel power prediction is employed to mitigate against the effect of outdated channel state information being used to make relay selection. Channel power prediction is used to make relay selection based on predicted signal-to-noise ratio over all available relays. A source selects a best relay on the basis of predicted channel state information and transmits. In the relay selection process, a source selects a best relay on the basis of predicted channel state information and transmits. In the relay selection process, a source selects a best relay on the basis of predicted channel state information and transmits. To assess prediction performance, solutions are found for arbitrary numbers of relays and receive antennas. The results are compared with single antenna relay switching delay, comparison is made to non-predictive systems.

are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed relay selection system. In a source-directed relay selection system, the source selects a best relay on the basis of predicted channel state information (CSI) measured at the source. The CSI is used for relay selection. In a source-directed relay selection system, the source selects a best relay on the basis of predicted channel state information (CSI) measured at the source. The CSI is used for relay selection. In a source-directed relay selection system, the source selects a best relay on the basis of predicted channel state information (CSI) measured at the source. The CSI is used for relay selection.

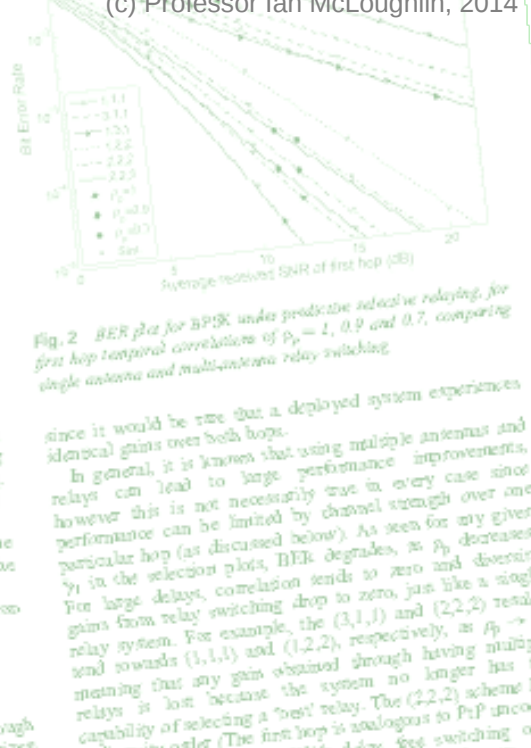
Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $P_{\text{out}}(\cdot)$) [9]

$$P_s = \frac{\alpha}{\sqrt{\pi} \Gamma(m)} \int_0^{\infty} F_{\gamma_n}\left(\frac{x}{\beta}\right) \exp\left(-\frac{x^2}{2}\right) dx \quad (16)$$

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_1 + 1$ in (15) setting $\gamma_1 \approx x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_s (see (17))

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{\text{out}}(\gamma_1)$ in (15) is directly verified by this (since BER is derived using β), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) for different relay configurations, denoted as (N_s, N_r, N_d) where $N_s = 1$ implies no delay of relay selection. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) for different relay configurations, denoted as (N_s, N_r, N_d) where $N_s = 1$ implies no delay of relay selection. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) for different relay configurations, denoted as (N_s, N_r, N_d) where $N_s = 1$ implies no delay of relay selection.



since it would be rare that a deployed system experiences identical gains over both hops.

In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_1 decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results tend towards (1,1,1) and (1,2,2), respectively, as $\rho_1 \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order of two for large SNRs, determined by the diversity order of the first and the second hop. In other words, the diversity order of the first hop is larger than the second hop. In contrast, if we then increasing N_d will be beneficial.

$$P_s = \frac{\alpha}{\sqrt{\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{\pi} \Gamma(N_d - 1/2) \Gamma(N_s)}{\Gamma(N_s - 1/2)} \sum_{n=0}^{N_s-1} \frac{(-1)^n}{n!} \sum_{j=0}^{N_s-1-n} \binom{N_s-1-n}{j} \frac{\Gamma(N_s - 1/2)}{\Gamma(N_s - 1/2 - j)} \right] \times \sum_{l=0}^{N_s-1} \frac{\Gamma(N_s + 1/2) \Gamma(N_s - 1/2)}{\Gamma(N_s - 1/2 - l) \Gamma(N_s + 1/2 + l)} \sum_{p=0}^{N_s-1-l} \frac{\Gamma(N_s - 1/2 - p) \Gamma(N_s + 1/2 + p - 0.5)}{\Gamma(N_s - 1/2 - p) \Gamma(N_s + 1/2 + p - 0.5)} \left[\frac{\Gamma(N_s + 1/2)}{\Gamma(N_s - 1/2 + 1)} \right]^{N_s - 1/2 + p - l}$$

$$\xi = \frac{\left[\frac{1 + 1/\Gamma(N_s - \rho_1) + 1/\gamma_1 + 1/\gamma_2 + \beta/2 - 2\sqrt{1 + 1/\Gamma(N_s - \rho_1) + 1/\gamma_1 \gamma_2}}{1 + 1/\Gamma(N_s - \rho_1) + 1/\gamma_1 + 1/\gamma_2 + \beta/2 + 2\sqrt{1 + 1/\Gamma(N_s - \rho_1) + 1/\gamma_1 \gamma_2}} \right]^{N_s - 1/2 + p - l}}{\Gamma(N_s + 1/2 + p - l)}$$

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The consequence of plagiarism

Times are changing...

Today you might be able to 'get away' with some plagiarism.

But your work will survive forever in digital form.

In future, people will judge your work based on the moral standards of the future.

It means you need to be very careful that your work is always written to the highest possible standard.

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Channel prediction for cooperative multi-antenna relay selection systems

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Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is analysed, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delayed in such channel power prediction is employed to mitigate against the effect of outdated channel state information being used to make relay selection decisions. During transmission, a source selects a best relay on the basis of predicted signal-to-noise ratio over all available relays. The system employs a maximal ratio combining at its receiver, and applies a variable gain to the received signal before forwarding it to the destination. The impact of channel prediction on the number of relays and number of antennas compared with single antenna alternatives. To assess prediction performance, comparison is made to non-predictive systems.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program long-term evolution that aim to provide very high data rates and increased network coverage area [1-3]. Several information theoretic approaches to multi-antenna enabled relaying, showing that relaying can increase the link reliability and spectral efficiency have been found beneficial in providing a performance gain over direct based (fixed) multi-antenna systems [4, 5]. However, to achieve high performance, as seen in wireless terminals with multiple antennas [6]. However, to achieve high performance, as seen in wireless terminals with multiple antennas [6]. However, to achieve high performance, as seen in wireless terminals with multiple antennas [6].

Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $P_{\text{out}}(\cdot)$) [9]

$$P_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_n}\left(\frac{x}{\beta}\right) \exp\left(-\frac{x^2}{2}\right) dx \quad (16)$$

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_n \approx \gamma_n + 1$ in (15) setting $\gamma_n = x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_s (see (17))

This approximation is valid for the sum of two independent Rayleigh variables, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the hypergeometric function. The error function $\text{erf}(\cdot)$ is defined as $\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$. This approximation is valid for the sum of two independent Rayleigh variables, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the hypergeometric function. The error function $\text{erf}(\cdot)$ is defined as $\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$.

4 Numerical and simulation results

The performance is evaluated and verified through numerical simulations. The BER is derived using the CDF of the SNR. In Fig. 2, BER for different relay configurations and diversity orders is shown against γ_1 for correlation $\rho_1 = 0.7$ and $\rho_1 = 1.0$. In general, the impact of delayed feedback on relay systems has been analysed [16], and recently the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with no feedback delay, and the impact of outdated channel state information becomes pronounced when the delay is non-negligible. This effect has been explored in single antenna systems [15]. In general, the impact of delayed feedback on relay systems has been analysed [16], and recently the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with no feedback delay, and the impact of outdated channel state information becomes pronounced when the delay is non-negligible. This effect has been explored in single antenna systems [15].

This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Fig. 2 BER plot for BPSK under predictive selective relaying for first hop temporal correlations of $\rho_1 = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

Tables in LaTeX

Back to LaTeX... Tables are important – we use them a lot when we want to structure text.

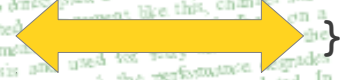
Not only when we want to put a TABLE into the paper.

1 Introduction

Co-operative relay technology is a promising solution for future fourth generation wireless systems such as the third generation long-term evolution that aim to provide higher rates and increased network coverage area [1–3]. Several information theoretic studies on multi-input, multi-output based (fixed) multi-antenna relaying, show that improved link reliability and spectral efficiency have been found beneficial in providing diversity and coding gains for wireless terminals with limited resources [4, 5]. However, to achieve high performance, source nodes are generally required to have multiple antennas [3]. In a typical relay forwards the signal to the destination, overcomes multiple transmission needs, synchronization issues and excess bandwidth usage, is often a bandwidth constrained relay selection schemes are required to have such Furthermore, fixed gain amplify-and-forward relay implementation is particularly simple to implement compared with decode-and-forward, and has been well studied for wireless devices [7, 9–12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

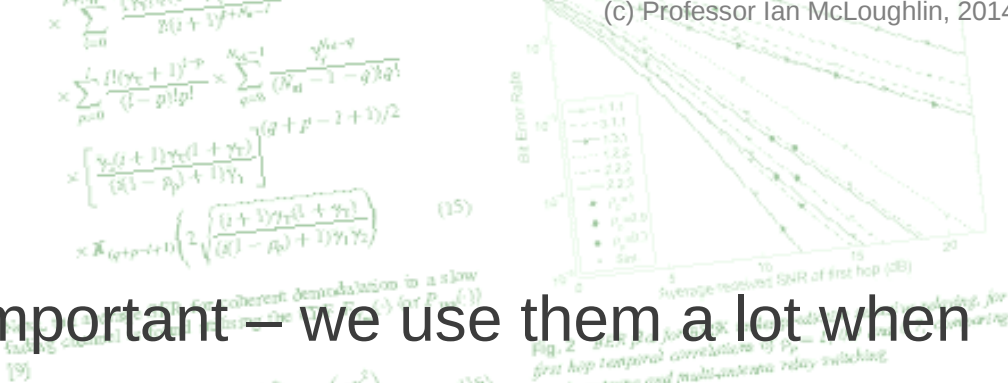
are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas and single transmit antennas. This is a more realistic arrangement with no direct path from source to destination information (CSI) is assumed to be available at the relay. In general, the performance of a relay-based system is limited by the feedback information becomes more outdated. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to channel changes such as Doppler changes, with the consequence of delayed feedback on relay selection. This effect has been explored in single antenna systems [15]. In general, the impact of delayed feedback on relay selection has been analysed [16], and recently the impact of outdated CSI on relay selection has been considered [10]. Performance limits tend towards accurate selection with perfect knowledge at zero feedback delay, and the performance of a non-selective system (i.e. without CSI knowledge at the source) when feedback delays are greater than the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18]. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

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\end{tabular}
\end{table}
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where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_1 + 1$ in (15) setting $\gamma_2 \approx x^2/\beta$, the above integral can be solved using [21, eq. 6.62.1] to obtain a closed form solution for P_e (see (17)) when $\rho_1 = \rho_2 = \rho$. The general case of $\rho_1 \neq \rho_2$ is the Gauss hypergeometric function ${}_2F_1$ (see the bottom of the page). This approximation implicit in this closed form solution holds good in the moderate to high SNR regions.

4 Numerical and simulation results

The BER is derived using (17), but not plotted here because of space constraints. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations ρ_1 is a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19]. For $\rho_1 = 1, 0.9$ and 0.7 , where $\rho_2 = 1$ implies no delay or near perfect prediction. We set $\gamma_1 = 5\gamma_2$ to simulate a disparity between first and second hop channel gain. This is realistic

$$P_e = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{n_k N_d - 1} N_d}{\frac{1}{2} N_d - 1} \sum_{n=0}^{N_s-1} \frac{(-1)^n}{n(N_s-1-n)!} \sum_{j=0}^{N_r-1} \frac{(-1)^j}{j(N_r-1-j)!} \sum_{k=0}^{N_d-1} \frac{(-1)^k}{k(N_d-1-k)!} \right] \times \frac{\sum_{i=0}^{N_s-1} \frac{(1+N_d+1)^{-i}}{i!} \sum_{p=0}^i \frac{i!}{(i-p)!p!} \sum_{q=0}^{N_r-1} \frac{(N_r-1-q)!q^q}{(q+p-1+1)!} \left[\frac{4(i+1)}{(k-1-\rho_1)+1} \gamma_1 \gamma_2 \right]^{i+p+q+1}}{\sum_{i=0}^{N_s-1} \frac{(1+N_d+1)^{-i}}{i!} \sum_{p=0}^i \frac{i!}{(i-p)!p!} \sum_{q=0}^{N_r-1} \frac{(N_r-1-q)!q^q}{(q+p-1+1)!} \left[\frac{4(i+1)}{(k-1-\rho_1)+1} \gamma_1 \gamma_2 \right]^{i+p+q+1}} \times {}_2F_1(N_d+q+p+1.5, q+p-1+1.5; 1+N_d+1; \xi)$$
$$\xi = \frac{(i+1)(k-1-\rho_1)+3\gamma_1+3\gamma_2+\beta/2-2\sqrt{i+1/(k-1-\rho_1)+3\gamma_1\gamma_2}}{(i+1)(k-1-\rho_1)+3\gamma_1+3\gamma_2+\beta/2+2\sqrt{i+1/(k-1-\rho_1)+3\gamma_1\gamma_2}}$$

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Tables in LaTeX

5 columns, all are LEFT justified 'l' (could be 'r' or 'c' instead, or use 'l' to give border lines)

Table II
MAXIMUM FREQUENCY FOR ALL METHODS AGAINST WORDLENGTH.

Size	CoreGen	FloPoCo	Cascaded	Tiling	Proposed
42-58	452.5MHz	256.6MHz	452.0MHz	419.9MHz	444.5MHz
59-64	444.2MHz	157.1MHz	451.5MHz	N/A	442.8MHz

```

\begin{table}
\centering
{\caption{Maximum frequency for all methods against wordlength.}
\begin{tabular}{llllll}
\hline
Size & CoreGen & FloPoCo & Cascaded & Tiling & Proposed\\
\hline
42--58 & 452.5MHz & 256.6MHz & 452.0MHz & 419.9MHz & 444.5MHz\\
59--64 & 444.2MHz & 157.1MHz & 451.5MHz & N/A & 442.8MHz\\
\hline
\end{tabular}
}
\label{fig_freq}
\end{table}

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Tables in LaTeX

Horizontal line

Divides the columns

End of line

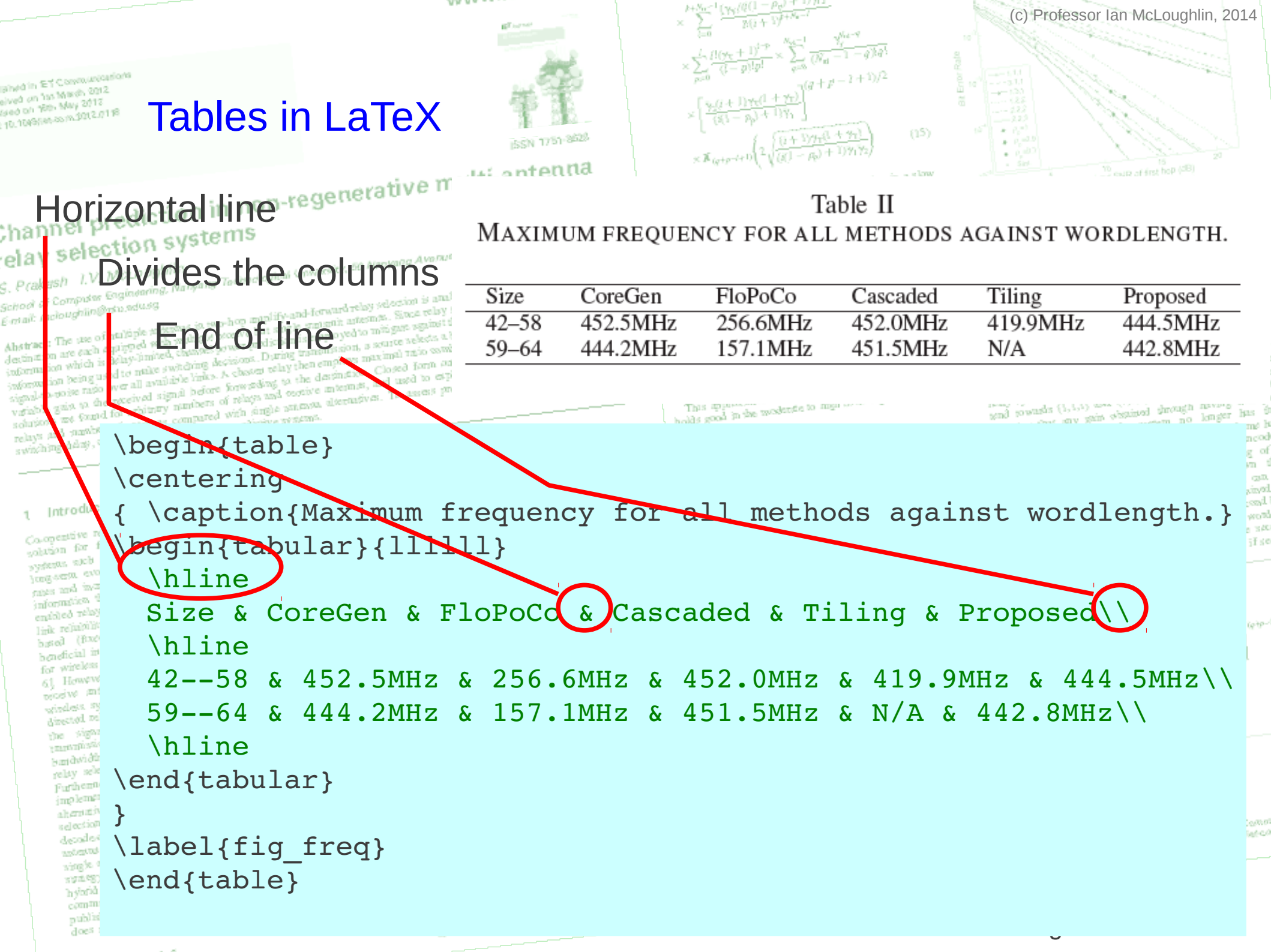
Table II
MAXIMUM FREQUENCY FOR ALL METHODS AGAINST WORDLENGTH.

Size	CoreGen	FloPoCo	Cascaded	Tiling	Proposed
42-58	452.5MHz	256.6MHz	452.0MHz	419.9MHz	444.5MHz
59-64	444.2MHz	157.1MHz	451.5MHz	N/A	442.8MHz

```

\begin{table}
\centering
{\caption{Maximum frequency for all methods against wordlength.}
\begin{tabular}{lllllll}
\hline
Size & CoreGen & FloPoCo & Cascaded & Tiling & Proposed \\
\hline
42--58 & 452.5MHz & 256.6MHz & 452.0MHz & 419.9MHz & 444.5MHz \\
59--64 & 444.2MHz & 157.1MHz & 451.5MHz & N/A & 442.8MHz \\
\hline
\end{tabular}
}
\label{fig_freq}
\end{table}

```



Tables in LaTeX

Define the caption text... (if we want the caption under the table, move this line to after `\end{tabular}`)

Table II
MAXIMUM FREQUENCY FOR ALL METHODS AGAINST WORDLENGTH.

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\begin{table}
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\hline
\end{tabular}
}
\label{fig_freq}
\end{table}

```

Define a label for us to `\ref` inside the paper...

Tables in LaTeX

Let's try another example. Assume we want a table like this:

TABLE II: Dual-link BER channel difference distribution

	$BER_{\delta(0)}^{-1}$	$BER_{\delta(1)}^{-1}$	.....	$BER_{\delta(9)}^{-1}$
Link A	1000	1100	.....	1900
Link B	1000	900	.....	100

How would we put this together??

Note: for now we will ignore the maths symbols...

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ISSN 1751-8628

Channel prediction in cooperative multi-antenna relay selection systems
S. Prakash, I.V. McLoughlin
School of Computer Engineering
Email: ianmcloughlin@ntu.edu.sg

Abstract: The use of antenna selection for future systems such as the long-term evolution rates and increased information theoretic gains enabled relaying, show that improvements are possible in link reliability and spectral efficiency [4, 5]. Infrastructure-based (fixed) multi-antenna relays have been found beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-directed relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission modes, synchronization issues and excess bandwidth usage, in contrast with distributed centralized relay selection schemes which can be time sensitive [7]. Furthermore, relay selection schemes can be implemented with implementation complexity [8] than full-duplex relaying alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for antenna devices [7, 9–12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and in [14] and [15] had explored a hybrid approach where a non-selective beamforming communication with a relay selection scheme. Published results reveal that partial selection performance does not improve much when more than two relay nodes

1 Introduction

Co-operative relay technology for future systems such as the long-term evolution rates and increased information theoretic gains enabled relaying, show that improvements are possible in link reliability and spectral efficiency [4, 5]. Infrastructure-based (fixed) multi-antenna relays have been found beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-directed relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission modes, synchronization issues and excess bandwidth usage, in contrast with distributed centralized relay selection schemes which can be time sensitive [7]. Furthermore, relay selection schemes can be implemented with implementation complexity [8] than full-duplex relaying alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for antenna devices [7, 9–12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and in [14] and [15] had explored a hybrid approach where a non-selective beamforming communication with a relay selection scheme. Published results reveal that partial selection performance does not improve much when more than two relay nodes

as the feedback information is not available. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to phenomena such as Doppler changes, with the consequence of reduced selection accuracy. This effect has been explored in single antenna systems [15]. In general, the impact of delayed feedback on relay systems has been analysed [16], and recently the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with perfect knowledge or zero feedback delay, and the impact of delayed feedback on relay selection is greater than the channel fading effect. In [18], the impact of delayed feedback on relay selection has also been explored in transmit diversity (non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18].

This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna system, (ii) investigate the dual-hop relay system, and (iii) investigate the impact of delayed feedback on relay selection. The paper is organized as follows. Section 2 describes the system model. Section 3 presents the BER analysis. Section 4 presents the BER analysis for the dual-hop relay system. Section 5 presents the BER analysis for the dual-hop relay system with delayed feedback. Section 6 presents the BER analysis for the dual-hop relay system with delayed feedback and antenna selection. Section 7 presents the BER analysis for the dual-hop relay system with delayed feedback and antenna selection. Section 8 presents the BER analysis for the dual-hop relay system with delayed feedback and antenna selection. Section 9 presents the BER analysis for the dual-hop relay system with delayed feedback and antenna selection. 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$$\begin{aligned}
& \times \sum_{p=0}^{N_m-1} \frac{(1-\rho_p)^{N_m-1-p}}{2^{N_m-1-p}} \times \sum_{q=0}^{N_m-1} \frac{(1-\rho_q)^{N_m-1-q}}{2^{N_m-1-q}} \\
& \times \sum_{p=0}^{N_m-1} \frac{(1-\rho_p)^{N_m-1-p}}{(1-\rho_p)!} \times \sum_{q=0}^{N_m-1} \frac{(1-\rho_q)^{N_m-1-q}}{(1-\rho_q)!} \\
& \times \left[\frac{\gamma_1 \gamma_2 (1+\gamma_1)(1+\gamma_2)}{(1-\rho_p)(1-\rho_q) + \gamma_1 \gamma_2} \right]^{(q+p-1)/2} \\
& \times \mathcal{K}_{(q+p+1)/2} \left(2 \sqrt{\frac{(1+\gamma_1)\gamma_2(1+\gamma_2)}{(1-\rho_p)(1-\rho_q) + \gamma_1 \gamma_2}} \right) \quad (15)
\end{aligned}$$

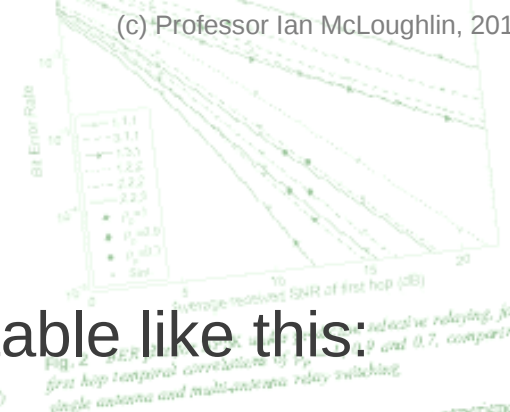


Fig. 2. BER for coherent demodulation in a slow fading channel for the dual-hop relay system. The first hop temporal correlation is $\rho_p = 0.1$ and 0.7 , comparing single antenna and multi-antenna relay switching.

antennas and improvements, any case since might over one is ρ_p decreases. o and diversity as like a single d (2,2,2) results vely, as $\rho_p \rightarrow 0$ having multiple longer has b (2,2,2) scheme b us to PtP uncod e switching of t is known ed case, it can N/A, determined). In other word er than the sec in contrast, if se

$$\begin{aligned}
P_e &= \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{n\beta N_m - 1} N_m}{\sqrt{2} \beta N_m - 1} \sum_{k=0}^{N_m-1} \frac{(-1)^k}{k!} \sum_{j=0}^{N_m-1} \binom{N_m-1}{j} \frac{A_j (1-\rho_j)^{N_m-1-j}}{(k(1-\rho_j) + 1)^j} \right. \\
& \times \sum_{p=0}^{N_m-1} \frac{(1+\gamma_1 + N_m + 1)^{-1}}{(1+\gamma_1)^{N_m-1-p} [(1-\rho_p) + \gamma_1]^{N_m-1-p}} \sum_{q=0}^{N_m-1} \frac{(1-\rho_q)^{N_m-1-q-p+2j-0.5}}{(1-\rho_q)^{N_m-1-q-p}} \left. \frac{4(1+\gamma_2)}{(k(1-\rho_p) + 1)\gamma_1 \gamma_2} \right] \\
& \times \frac{\Gamma(N_m + q + p + 1.5)}{\Gamma(1/2) \Gamma(1-\rho_p) \Gamma(1+\gamma_1) \Gamma(1+\gamma_2) + 2\sqrt{\gamma_1 \gamma_2} \Gamma(k(1-\rho_p) + 1)\gamma_1 \gamma_2^{N_m+q+p+1}} \\
& \times {}_2F_1(N_m + q + p + 1.5, q + p - 1 + 1.5; 1 + N_m + 1; \xi) \\
& \xi = \frac{(1+\gamma_1)(1-\rho_p) + \gamma_1 \gamma_2 + 1/\gamma_2 + \beta/2 - 2\sqrt{1+\gamma_1(k(1-\rho_p) + 1)\gamma_1 \gamma_2}}{(1+\gamma_1)(1-\rho_p) + \gamma_1 \gamma_2 + 1/\gamma_2 + \beta/2 + 2\sqrt{1+\gamma_1(k(1-\rho_p) + 1)\gamma_1 \gamma_2}}
\end{aligned}$$

Tables in LaTeX

We start with the basic template for a figure in an IEEE paper.

TABLE II: Dual-link BER channel difference distribution

	$BER_{\delta(0)}^{-1}$	$BER_{\delta(1)}^{-1}$	.....	$BER_{\delta(9)}^{-1}$
Link A	1000	1100	.....	1900
Link B	1000	900	.....	100

```

\begin{table}
\centering
{ \caption{ [ ] }
\begin{tabular}{ [ ] }
[ ]
\end{tabular}
}
\label{ [ ] }
\end{table}

```

Now we just need to fill in the missing parts,

Start with the number of columns...

Tables in LaTeX

We want:

5 columns

All are CENTRE justified

There are border lines ('|') between all columns except the outside ones...

So the column specification is:

`c|c|c|c|c`

TABLE II: Dual-link BER channel difference distribution

	$BER_{\delta(0)}^{-1}$	$BER_{\delta(1)}^{-1}$	.....	$BER_{\delta(9)}^{-1}$
Link A	1000	1100	.....	1900
Link B	1000	900	.....	100

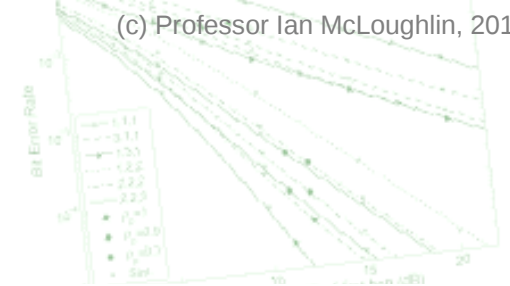
```

\begin{table}
\centering
{ \caption{  }
\begin{tabular}{c|c|c|c|c}

\end{tabular}
\end{table}
\label{  }
\end{table}

```

$$\begin{aligned}
& \times \sum_{p=0}^{N_1-1} \frac{\gamma_1 \theta (1 - \rho_1)^{p+1} \gamma_2}{2(p+1)^{p+1} \gamma_1} \\
& \times \sum_{q=0}^{N_2-1} \frac{\gamma_2 \theta (1 - \rho_2)^{q+1} \gamma_1}{2(q+1)^{q+1} \gamma_2} \\
& \times \left[\frac{\gamma_1 \gamma_2 (1 + \gamma_1)(1 + \gamma_2)}{(\delta_1 - \rho_1)(\delta_2 - \rho_2)} \right] \\
& \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1 + \gamma_1) \gamma_2 (1 + \gamma_2)}{(\delta_1 - \rho_1)(\delta_2 - \rho_2) \gamma_1 \gamma_2}} \right) \quad (15)
\end{aligned}$$



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Channel prediction in regenerative multi-antenna relay selection systems
 S. Prakash I.V. McLoughlin
 School of Computer Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 63
 E-mail: mccloughlin@ntu.edu.sg

Abstract: The use of multiple antennas at both source and destination relay selection is analysed, where the destination are each equipped with multiple receive but single transmit antennas. Since relay switching is not information which is delay-limited, channel power prediction is employed to mitigate against the effect of outdated information being used to make switching decisions. During transmission, a source selects a best relay on the basis of signal-to-noise ratio over all available links. A chosen relay then employs maximal ratio combining at its second hop to forward the signal to the destination. Closed form average probability of error expressions are derived for arbitrary numbers of relays and receive antennas, and used to explore trade-offs between variable gain to the received signal before forwarding to the destination. Comparison with single antenna relays and number of antennas is provided. To assess prediction performance, a comparison is made between the proposed system and a system without channel prediction.

1 Introduction
 Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program long-term evolution that aims to provide very high data rates and increased network capacity [1–3]. Several information theoretic studies have shown that relaying, enabled relaying, show that improved performance can be achieved through relaying [4, 5]. Infrastructure-based (fixed) multi-hop networks have been shown to be beneficial in providing diversity and capacity [6–8]. In general, the use of relays is beneficial in providing diversity and capacity [6–8]. In general, the use of relays is beneficial in providing diversity and capacity [6–8]. In general, the use of relays is beneficial in providing diversity and capacity [6–8].

Tables in LaTeX

Working from the top down, fill in the rows.

Start with a horizontal line...

Then, fill in the first row...

Note the space before the first '&' (i.e. the first cell is an empty one)

TABLE II: Dual-link BER channel difference distribution

	$BER_{\delta(0)}^{-1}$	$BER_{\delta(1)}^{-1}$	.....	$BER_{\delta(9)}^{-1}$
Link A	1000	1100	.....	1900
Link B	1000	900	.....	100

```

\begin{table}
\centering
{ \caption{  }
\begin{tabular}{c|c|c|c|c}
\hline
& BER & BER & ..... & BER \\
\end{tabular}
}
\label{  }
\end{table}

```

Tables in LaTeX

Next, we put two horizontal lines...

Then continue...

TABLE II: Dual-link BER channel difference distribution

	$BER_{\delta(0)}^{-1}$	$BER_{\delta(1)}^{-1}$	.....	$BER_{\delta(9)}^{-1}$
Link A	1000	1100	.....	1900
Link B	1000	900	.....	100

```

\begin{table}
\centering
{ \caption{ } }
\begin{tabular}{c|c|c|c|c}
\hline
& BER & BER & ..... & BER \\
\hline
Link A & 1000 & 1100 & ..... & 1900 \\
\hline
Link B & 1000 & 900 & ..... & 100 \\
\hline
\end{tabular}
}
\label{ }
\end{table}

```

Tables in LaTeX

Finally, complete the figure caption and give it a meaningful label...

TABLE II: Dual-link BER channel difference distribution

	$BER_{\delta_{(0)}}^{-1}$	$BER_{\delta_{(1)}}^{-1}$	.....	$BER_{\delta_{(9)}}^{-1}$
Link A	1000	1100	.....	1900
Link B	1000	900	.....	100

In this way, we can build up some really complicated tables.

This is especially good when we want a program-generated table!

```

\begin{table}
\centering
{ \caption{Dual-link BER channel
different distribution}
\begin{tabular}{c|c|c|c|c}
\hline
& BER & BER & ..... & BER\\
\hline
Link A & 1000 & 1100 & ..... & 1900\\
\hline
Link B & 1000 & 900 & ..... & 100\\
\hline
\end{tabular}
}
\label{tab:ber_diffs}
\end{table}

```

Tables in LaTeX – advanced topics

Here is a very complicated example...

```

\begin{tabular}{|c|c|c|c|c|}
\hline
& \multicolumn{4}{|l|}
{\textbf{Double ended measures}} &
{\textbf{Single end}} \\
Test & LLR & \small{SSNR} & IS
& P.862 & {P.563} \\
\hline
&&&&\[-2ex] % one very small row to
make space for the fraction below. ex
extends the row height
$S \rightarrow W$ & 0.827 & 26.92 & 12.70
& $\frac{1.234}{0.559}$ & $S=3.620$ \\
[0.4ex]
$W \rightarrow S'$ & 0.696 & 22.74 & 3.09
& $\frac{0.958}{0.589}$ & $W=2.864$ \\
[0.6ex]
$S \rightarrow S'$ & 0.789 & 25.55 &
10.44 & $\frac{0.680}{0.648}$ &
$S'=3.394$ \\
\hline
\end{tabular}
\end{table}

```

Table 1: Mean objective evaluation scores for original speech S , whispers W and reconstructed speech S' . P.862 scores are shown as $\frac{\text{RawMOS}}{\text{LQO}}$

Test	Double ended measures				Single end
	LLR	SSNR	IS	P.862	P.563
$S \rightarrow W$	0.827	26.92	12.70	$\frac{1.234}{0.559}$	$S = 3.620$
$W \rightarrow S'$	0.696	22.74	3.09	$\frac{0.958}{0.589}$	$W = 2.864$
$S \rightarrow S'$	0.789	25.55	10.44	$\frac{0.680}{0.648}$	$S' = 3.394$

\backslash multicolumn allows some text to span a few columns.

You must specify borders and justification.

[1ex] adds extra row height.

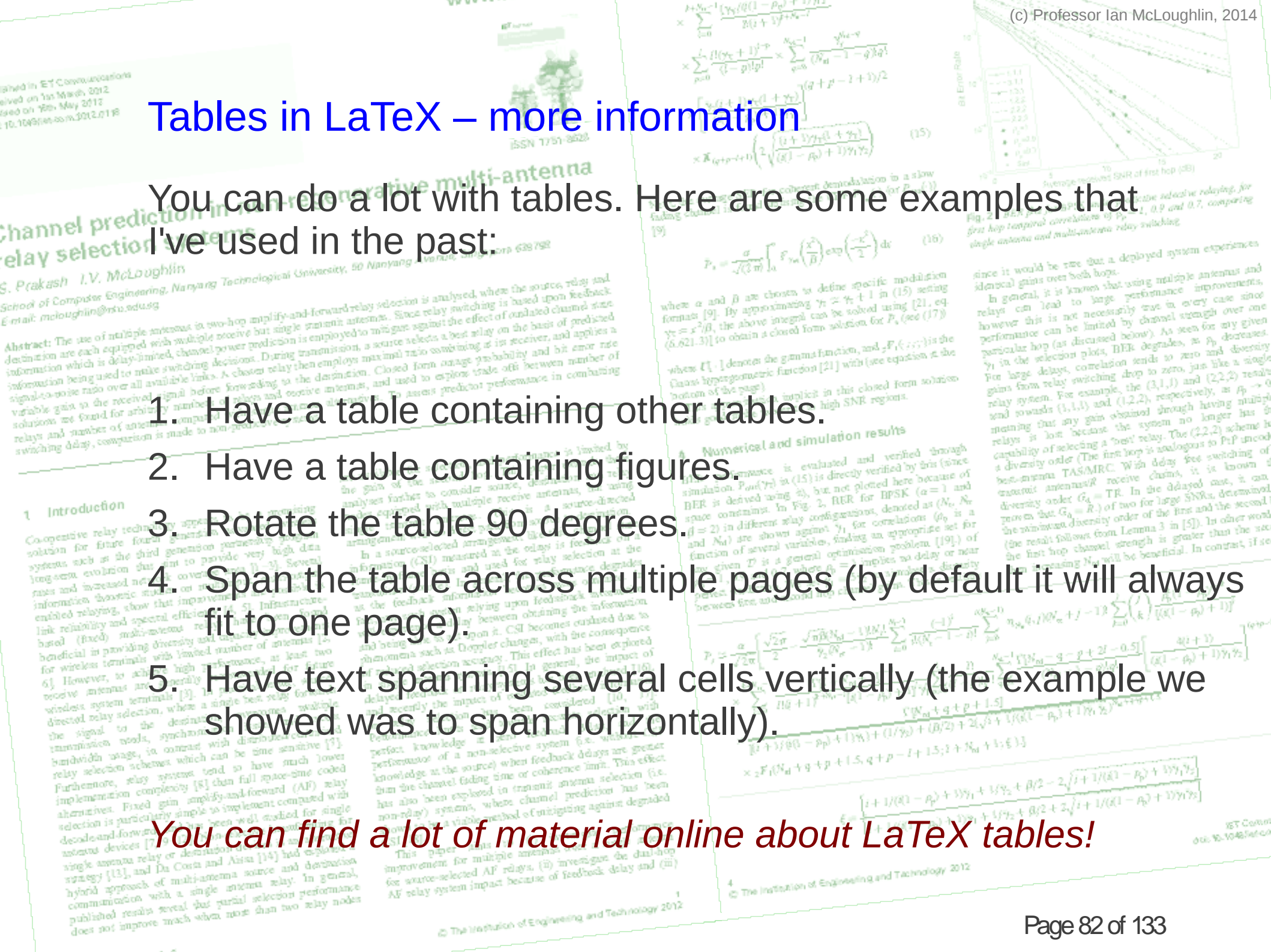
Anything between \$ and \$ is maths – ignore it for now.

Tables in LaTeX – more information

You can do a lot with tables. Here are some examples that I've used in the past:

1. Have a table containing other tables.
2. Have a table containing figures.
3. Rotate the table 90 degrees.
4. Span the table across multiple pages (by default it will always fit to one page).
5. Have text spanning several cells vertically (the example we showed was to span horizontally).

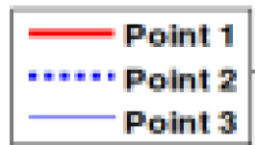
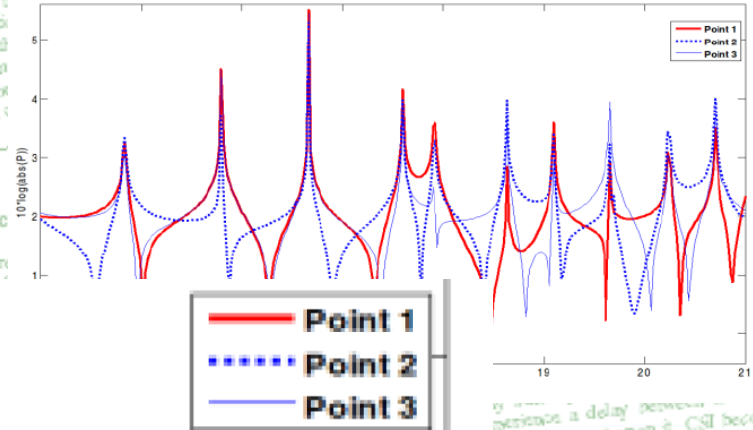
You can find a lot of material online about LaTeX tables!



Figures in LaTeX

Figures are important. They contribute a lot to the “look and feel” of any paper.

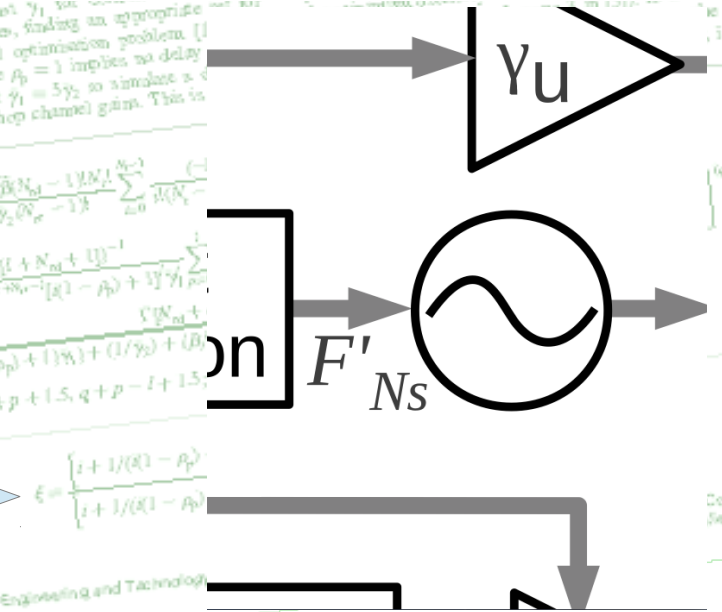
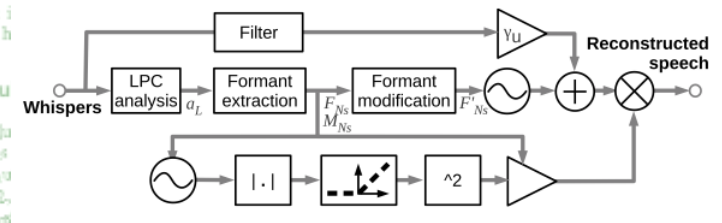
You should **ALWAYS** make sure your figures are in **vector format** (unless your figure is a photograph or similar)...



Bitmapped
 .jpg / .jpeg
 .bmp
 .tiff
 .gif

Vector
 .eps

.pdf
 .ps
 can
 be both



Figures in LaTeX

How do I create my figures?

From MATLAB/Octave – I just 'print' them as .eps files directly

From OpenOffice/LibreOffice spreadsheet plot (calc), I just create the plot, select it and export as .eps format.

For other figures, I draw the figure in OpenOffice/LibreOffice, then select it and export as .eps format. Very quick, very easy and 100% reliable.

Easy to convert between eps, pdf, ps on Linux and OS-X

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Channel prediction for cooperative multi-antenna relay selection systems

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Abstract: The use of multiple antennas at both source and destination are each equipped with multiple receive but single transmit antennas. Channel prediction is used upon feedback information which is delay-limited, channel power prediction is employed to improve system performance. During transmission, a source selects a best relay on the basis of published information being used to make switching decisions. During reception, a source selects a best relay on the basis of published information being used to make switching decisions. Closed form average probability and bit error rate solutions are found for arbitrary numbers of relays and receive antennas, and used to explore trade-offs between number of relays and number of antennas. Comparison is made with single antenna alternatives. To assess predictor performance in combating switching delay, comparison is made with single antenna alternatives.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program long-term evolution system to provide very high data rates and increased network capacity. Several information theoretic studies have shown that enabled relaying, show that improved spectral efficiency [4, 5]. Infrastructure link reliability and system performance based (fixed) multi-hop relaying is beneficial in providing diversity and capacity for wireless terminals with limited number of antennas [6]. However, to achieve the full potential of multiple antennas at source and destination, relay selection is required. In practical relay systems, a single best relay forwards the signal to the destination, overcomes multiple transmission needs, synchronization issues and excess bandwidth usage, in contrast with distributed centralized relay selection schemes which can be time sensitive [7]. Furthermore, relay systems tend to have much lower implementation complexity [8] than full space-time coded alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward (DF) relaying for relaying for antennas devices. Single antenna relay or diversity selection strategy [13], and Da Costa and Aissa [14] had a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes



$$\begin{aligned} & \times \sum_{p=0}^{N_s-1} \frac{\gamma_p (1-p)^{N_s-1-p}}{2^{(N_s-1-p)N_s}} \\ & \times \sum_{q=0}^{N_s-1} \frac{\gamma_q (1-q)^{N_s-1-q}}{2^{(N_s-1-q)N_s}} \\ & \times \left[\frac{\gamma_p (1-p) \gamma_q (1-q)}{(1-p)(1-q) + \gamma_p \gamma_q} \right]^{(q+p-1)/2} \\ & \times \bar{K}_{(q+p-1)/2} \left(2 \sqrt{\frac{(1+p)\gamma_p(1+q)}{(1-p)(1-q) + \gamma_p \gamma_q}} \right) \end{aligned} \quad (15)$$

where the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $P_{\text{out}}(\cdot)$) [19]

$$P_s = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} F_{\gamma_n} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^2}{2} \right) dx \quad (16)$$

where $\Gamma[\cdot]$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation at the bottom of the page)

This approximation is valid in high SNR regions.

Numerical and simulation results

The BER performance is analysed through simulation. The average BER is derived using (15), but not plotted here. BER is derived using (15), but not plotted here. BER is derived using (15), but not plotted here. BER is derived using (15), but not plotted here.

$$P_s = \frac{\sigma}{\sqrt{2\pi}} \int_0^{\infty} \frac{1}{2} \sqrt{2\pi} \frac{\gamma_p (1-p)^{N_s-1-p}}{2^{(N_s-1-p)N_s}} \frac{1}{2} \sqrt{2\pi} \frac{\gamma_q (1-q)^{N_s-1-q}}{2^{(N_s-1-q)N_s}} \frac{1}{2} \sqrt{2\pi} \frac{\gamma_p (1-p) \gamma_q (1-q)}{(1-p)(1-q) + \gamma_p \gamma_q}^{(q+p-1)/2} \frac{1}{2} \sqrt{2\pi} \bar{K}_{(q+p-1)/2} \left(2 \sqrt{\frac{(1+p)\gamma_p(1+q)}{(1-p)(1-q) + \gamma_p \gamma_q}} \right) \exp \left(-\frac{x^2}{2} \right) dx$$



Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_p = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops.

In general, it is known that using multiple antennas and diversity order $G_d = TR$. In the delayed case, it can be proven that $G_d = R$ for two for large SNRs, determined by the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words, the first hop channel strength is greater than the second hop channel strength. In contrast, if the

performance can be improved. As ρ_p decreases, performance can be improved. As ρ_p decreases, performance can be improved. As ρ_p decreases, performance can be improved.

Figures in LaTeX

Several ways to include figures, we will use the current IEEE paper method.

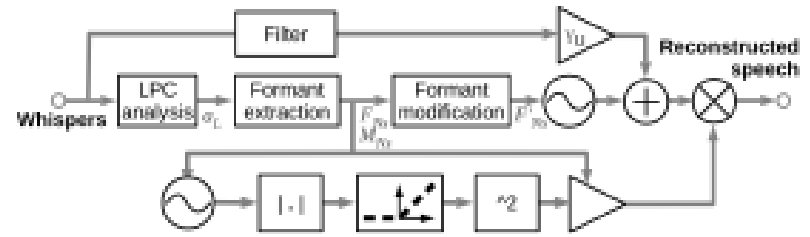


Figure 1: Block diagram of reconstruction mechanism.

```

\begin{figure}[t]
\centerline{\epsfig{figure=block_diag,width=80mm}}
\caption{{\it Block diagram of reconstruction mechanism.}}
\label{fig:blockdiag}
\end{figure}

```

This includes the file "block_diag.eps", scaling it to be 8cm wide and giving it the specified caption & label.

[t] means the figure will be located at the 'top' of a page if possible (we could have [b] for 'bottom' or [h] for 'here', but none are guaranteed to be in those locations...)

Figures in LaTeX

That was the 'new' method. Many journals and conferences still use the 'old' method.

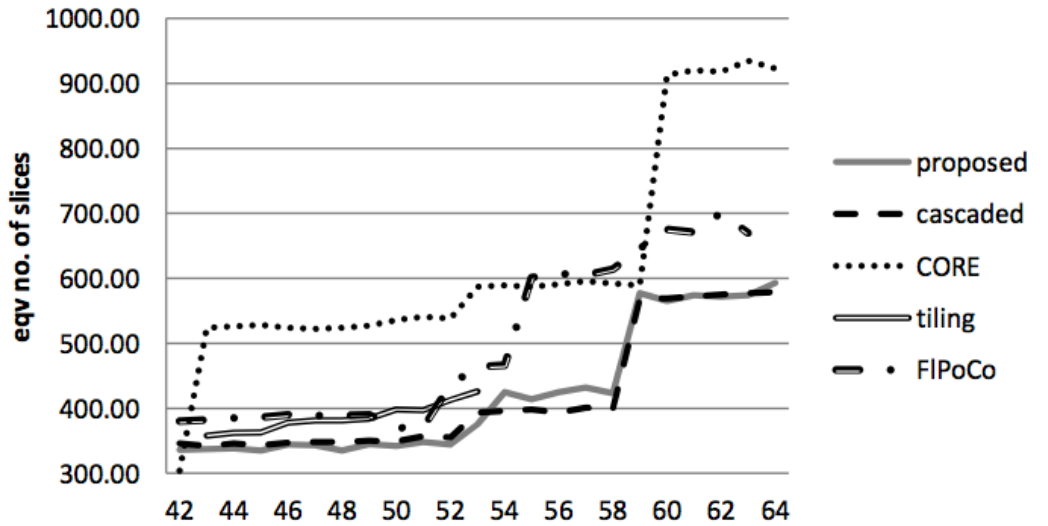


Figure 6. Equivalent Slice usage for All Methods

```

\begin{figure}
\centering
\includegraphics[width=10cm,height=6cm]{area.pdf}
\caption{Equivalent Slice usage for All Methods}
\label{fig_slice}
\end{figure}

```

Figures in LaTeX

By default, in a 2-column paper, figures fit into 1 column. But if you have a very 'wide' figure you can force it to fit across an entire page with:

```
\begin{figure*}

\end{figure*}
```

Figure 3. Adder alignment of squarer for four splits input

```
\begin{figure}

\end{figure}
```

Figure 4. Pipeline schematic of squarer for four splits input

Word Size	DSP	FIPoCo	Cascaded	Tiling	Proposed	CORE
42-52	6	6	5	5	9	
53	6	7	5	5	10	
54	6	7	NA	6	10	
55-58	7	7	NA	6	10	
59-64	10	10	NA	8	16	

Table 1 DSP USAGE FOR ALL METHODS

designed to finish the addition (one box in Fig. 4) and the total latency is 13. With such pipeline design, the system could achieve 450MHz.

The approach to even higher bit-width is similar to the above examples, where k splits could save $k - 2$ DSPs ($k > 2$). With carefully aligned adders and formations of DSP chains, the extra Slices overhead can be relatively small compared to the amount of DSP saved, however the exact implementation details of higher numbers of splits beyond four are not presented here for reasons of space.

IV. RESULTS

The proposed algorithm has been synthesised, placed and routed using ISE version 13.4, targeting Xilinx Virtex 6 FPGA (XC6VLX240T-1FFG1156). A design generator has been built to expand the algorithm across bit-width from 42 to 64. Both three splits (42 to 58 bits) and four splits (59 to 64 bits) inputs are covered in this generator. The cascaded squarer designs as well as the general purpose multiplier designs provided by CORE generator have been implemented for comparison across the same bit-width range. Similarly, squarers from FIPoCo tool have been compiled

experiments, this becomes the critical path in the design. The schematic of a 1 bit 3:1 compressor could be found in [15], where two functions are shared in one LUT. Limited by the $O5$ to $A/B/C/DMUX$ delay in a particular Slice, which is a compulsory path if the logic is combined in one LUT, the negative setup slack is around 20% of the

The same thing is true of table and table*

Figures in LaTeX

The subfig package allows you to include two graphs or diagrams as subfigures:

```
begin{figure*}
\label{fig:fig3}
\centering
\subfigure{
\includegraphics[trim=6mm 0mm 0mm
8mm,clip,width=9cm,height=5.8cm]
{figures/out_8new.eps}
}
\subfigure{
\includegraphics[trim=6mm 1mm 0mm
10mm,clip,width=9cm,height=5.8cm]
{figures/out_15new.eps}
}
\end{figure*}
```

Note: to make this work, you will need to “include” the package by adding this line after `\documentclass` at the top of your file:

```
\usepackage[tight,footnotesize]{subfigure}
```

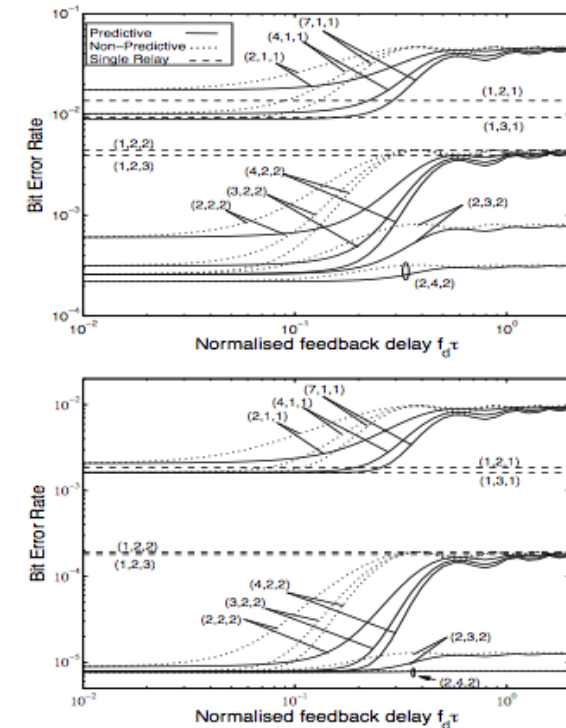


Figure 3: BER degradation due to feedback delay with and without prediction at $\bar{\gamma}_1 = 8dB$ (top) and $\bar{\gamma}_1 = 15dB$ (bottom) for different relay schemes with $\bar{\gamma}_2 = 5\bar{\gamma}_1$.

Figures in LaTeX

Finally, one more useful thing:

`\vspace{ }`

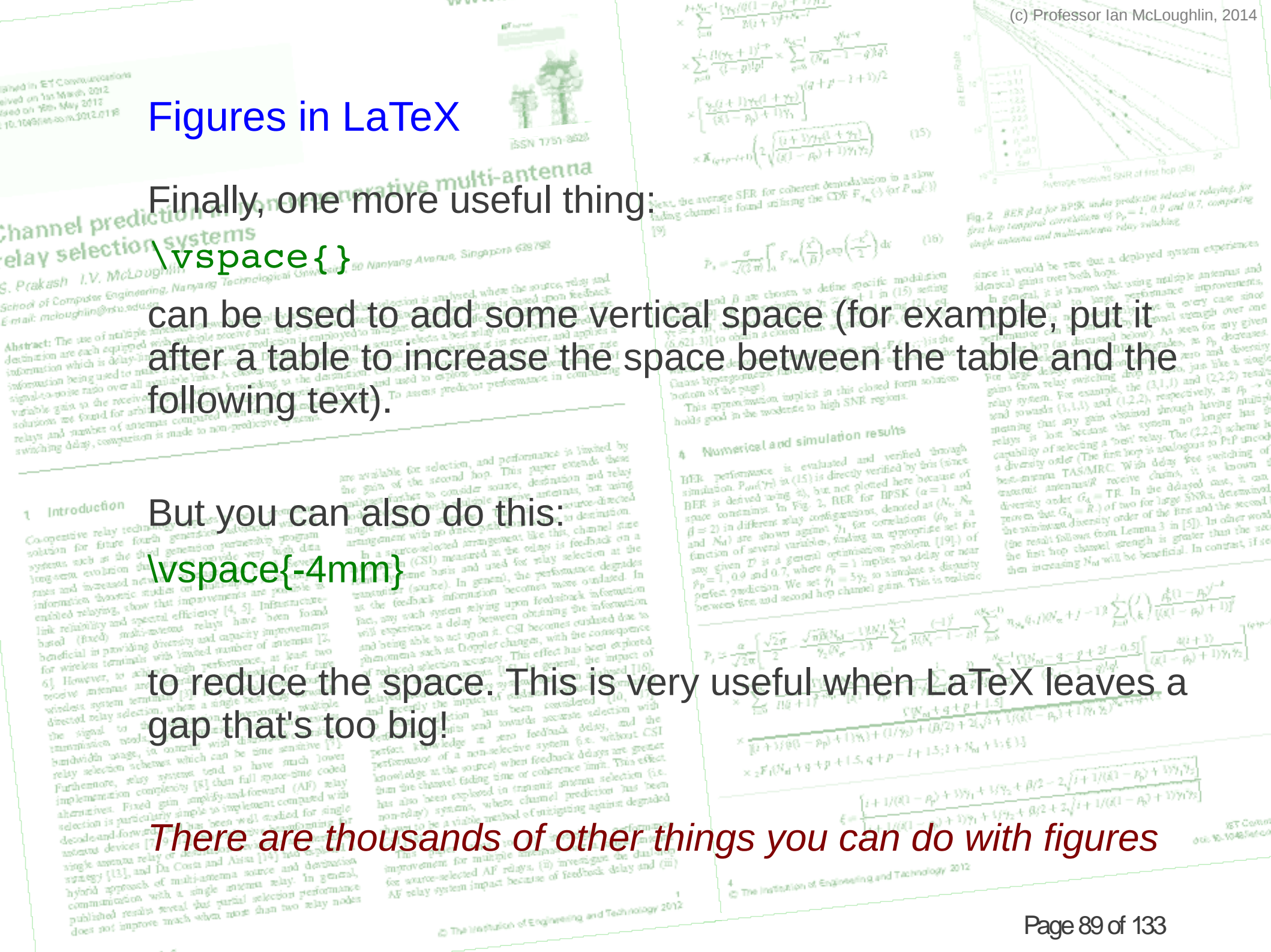
can be used to add some vertical space (for example, put it after a table to increase the space between the table and the following text).

But you can also do this:

`\vspace{-4mm}`

to reduce the space. This is very useful when LaTeX leaves a gap that's too big!

There are thousands of other things you can do with figures



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$$\begin{aligned}
& \times \sum_{i=0}^{N_s-1} \frac{\gamma_s (q(1-p_s) + 1)^{i+1}}{2(i+1)^{p+1} N_s^{-i}} \\
& \times \sum_{p=0}^{N_s-1} \frac{1! (\gamma_s + 1)^{i+p}}{(i-p)! p!} \times \sum_{q=0}^{N_s-1} \frac{\gamma_s^{i+q}}{(N_s-1-q)! q!} \\
& \times \left[\frac{\gamma_s (i+1) \gamma_s (i+\gamma_s)}{(i-p)! (i+1) \gamma_s} \right]^{(q+p-2+1)/2} \\
& \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(i+1) \gamma_s (i+\gamma_s)}{(i-p)! (i+1) \gamma_s}} \right) \quad (15)
\end{aligned}$$



Channel prediction relay selection

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Abstract: The use of relay destination are each equipped with information which is delay information being used to variable gain to the received solutions are found for at relays and number of an switching delay, compared

Part D

- LaTeX equations
- Code listings
- Bibliographies

1 Introduction

Co-operative relay technology is a solution for future systems such as the long-term evolution (LTE) systems and increased information throughput enabled relaying, which link reliability and cost based (fixed) and mobile (mobile) relays are beneficial in providing for wireless terminals [6]. However, in a two-way antenna wireless system to direct relay selection the signal to transmission rate bandwidth usage relay selection is Furthermore, an implementation alternatives. For selection is partial decode-and-forward antenna devices [7, 9–12]. Non-cooperative single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

CSI [18]. This paper aims to (i) investigate the performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Equations in LaTeX - overview

This is the strong point of LaTeX. It is why many people decide to use LaTeX. The equations formatting is really, really good.

$$\hat{\gamma}_i(k + \mathcal{D}) = \frac{\mathcal{E}_1}{N_0} \sum_{j=1}^{N_{rr}} |\hat{h}_{ij}(k + \mathcal{D})|^2$$

(1) Automatic

where \mathcal{E}_1 is the power of the transmitted signal at M_S and $\hat{h}_{ij}(k + \mathcal{D}) = \mathbf{w}_{opt}^H \tilde{\mathbf{h}}_{ij}$ is the

```
\begin{equation}
\{\hat{\gamma}_i(k + \mathbf{\mathcal{D}})\} =
\frac{\mathcal{E}_1}{N_0} \sum_{j=1}^{N_{rr}} \left\{ \left| \hat{h}_{ij}(k + \mathcal{D}) \right| \right\}^2
\end{equation}
```

Where \mathcal{E}_1 is the power of the transmitted signal at M_S and $\left\{ \hat{h}_{ij}(k + \mathcal{D}) \right\} \neq \mathbf{w}_{opt}^H \tilde{\mathbf{h}}_{ij}$ is the

Equations in LaTeX – invoking maths mode

To create a separate equation, we put it between

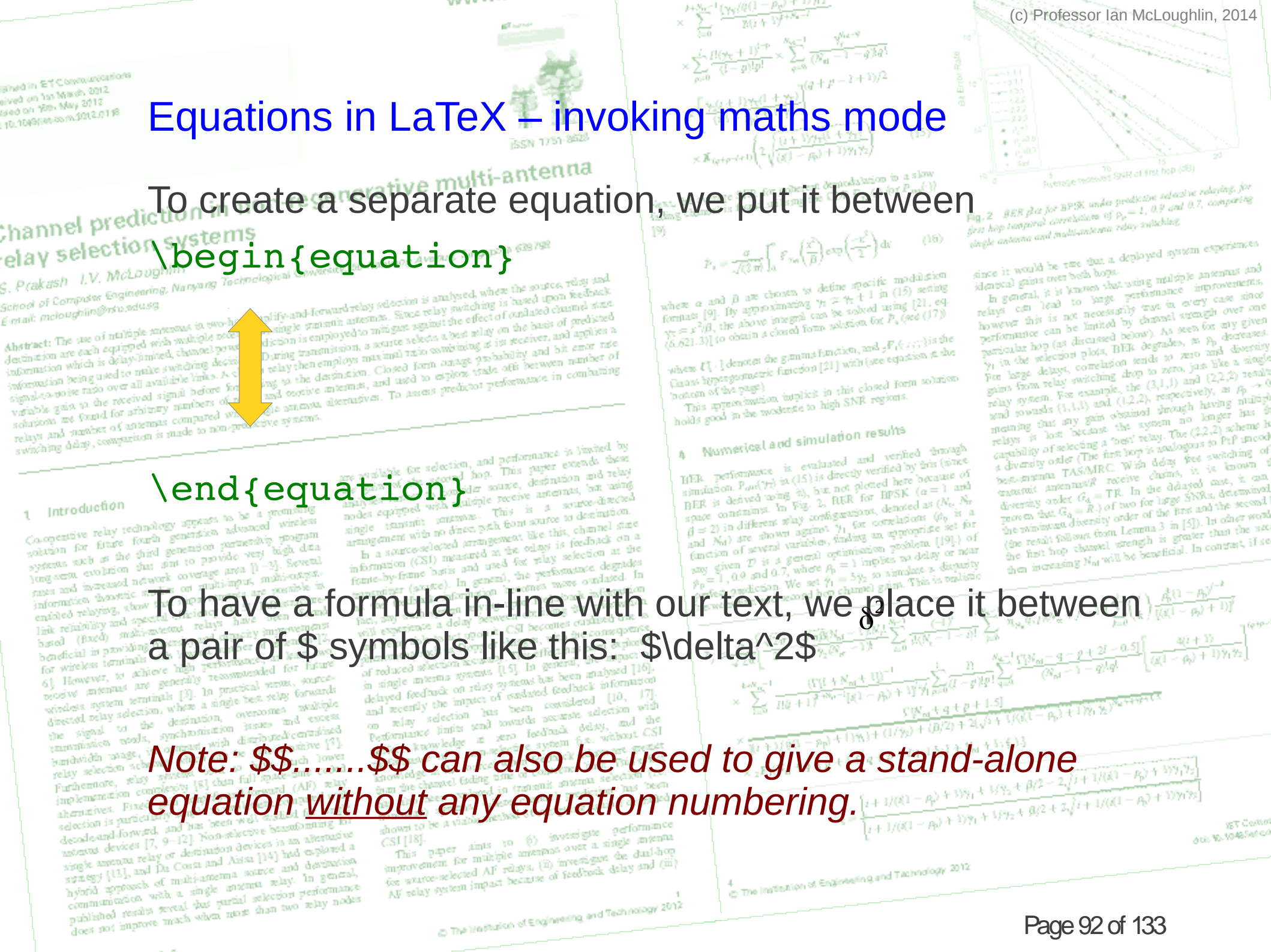
`\begin{equation}`



`\end{equation}`

To have a formula in-line with our text, we place it between a pair of \$ symbols like this: Δ^2

Note: $\$ \$ \dots \$ \$$ can also be used to give a stand-alone equation without any equation numbering.



Equations in LaTeX – further information on equations

This document can't teach you everything you need to know about equations in LaTeX, but will give you enough to get started.

Later, when you need something more, you can find almost everything you will ever need here:

http://www-h.eng.cam.ac.uk/help/tpl/textprocessing/latex_maths+pix/latex_maths+pix.html

You can also find many other resources on the web for LaTeX equation writing.

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Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is analysed, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delay-limited, channel power prediction is employed to mitigate against the effect of outdated channel state information being used to make switching decisions. During transmission, a source selects a best relay on the basis of predicted signal-to-noise ratio over all available links. A chosen relay then employs maximum ratio combining at its receiver, and applies a variable gain to the received signal before forwarding it to the destination. Closed form average probability and bit error rate solutions are found for arbitrary fading channels. Numerical results are presented to compare the performance in combating switching delay, compared to non-predictive systems.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program long-term evolution that will provide very high data rates and increased network coverage. Information theoretic studies on multi-input, multi-output link reliability and spectral efficiency of space-time based (fixed) multi-antenna relay systems have shown that improvements are possible in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-destination relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission modes, synchronization issues and excess bandwidth usage, in contrast with distributed centralized relay selection schemes which can be time sensitive [1]. Furthermore, relay selection schemes that are based on implementation complexity and to have much lower alternatives. Fixed gain amplify-and-forward relay selection is particularly attractive for single decode-and-forward relays, since it is simpler to implement in antenna devices [7, 9–12]. Non-predictive channel state information (CSI) based relay selection for single antenna relay or destination devices is an interesting strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

are available for selection, and performance gains are the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relays is feedback on a one-to-one basis. In general, the feedback information becomes more outdated as the number of relays increases. In a source-selected arrangement, the feedback information becomes more outdated as the number of relays increases. In a source-selected arrangement, the feedback information becomes more outdated as the number of relays increases. In a source-selected arrangement, the feedback information becomes more outdated as the number of relays increases.

This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

$$\begin{aligned} & \times \sum_{p=0}^{N_s-1} \frac{(1-\rho)^{p+1} \gamma_1^{p+1}}{2(p+1)! \gamma_1^{p+1}} \\ & \times \sum_{q=0}^{N_d-1} \frac{(1-\rho)^{q+1} \gamma_2^{q+1}}{(q+1)! \gamma_2^{q+1}} \\ & \times \sum_{k=0}^{N_s-1} \frac{(1-\rho)^{k+1} \gamma_1^{k+1}}{(k+1)! \gamma_1^{k+1}} \\ & \times \sum_{l=0}^{N_d-1} \frac{(1-\rho)^{l+1} \gamma_2^{l+1}}{(l+1)! \gamma_2^{l+1}} \end{aligned}$$

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_2 + 1$ in (15) setting $\gamma_2 = x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_b (see (17))

where $\Gamma(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation (4) for the definition of the parameters).

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using β), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlation ρ_1 is a function of several variables, finding an appropriate set for $\rho_1 = 0.1$ and 0.7 , where $\rho_1 = 1$ implies no delay or near perfect prediction. We set $\gamma_1 = 5\gamma_2$, to simulate a diversity order of two for large SNRs, where the first and second hop channel gain. This is realistic

$$\begin{aligned} P_b &= \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{N_s N_d - 1} N_s}{\sqrt{N_s - 1}} \sum_{k=0}^{N_s-1} \frac{(1-\rho)^{k+1} \gamma_1^{k+1}}{(k+1)! \gamma_1^{k+1}} \right. \\ & \times \sum_{l=0}^{N_d-1} \frac{(1-\rho)^{l+1} \gamma_2^{l+1}}{(l+1)! \gamma_2^{l+1}} \left. \frac{\Gamma(N_s + q + p + 1.5)}{\Gamma(N_s + q + p + 1.5, q + p - 1 + 1.5, 1 + N_s + 1; \xi)} \right] \\ & \times \frac{\Gamma(N_s + q + p + 1.5, q + p - 1 + 1.5, 1 + N_s + 1; \xi)}{\Gamma(N_s + q + p + 1.5, q + p - 1 + 1.5, 1 + N_s + 1; \xi)} \end{aligned}$$

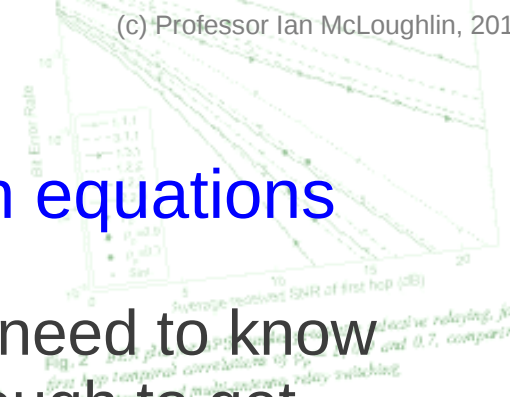


Fig. 2. BER performance for different relay configurations for $\rho_1 = 0.1$ and 0.7 , comparing the first hop temporal correlation to the second hop temporal correlation. The curves are for different relay configurations: (1,1,1), (2,1,1), (2,2,1), (2,1,2), (2,2,2), (3,1,1), (3,2,1), (3,1,2), (3,2,2).

Equations in LaTeX – how to write

Build it up gradually... Use `{ }` to set the precedence in displaying equations (they are not displayed unless you do `\{`).

Always close your brackets!!

Here are some examples:

```
\begin{equation}
  \label{eqn:mspa}
  B = \sum_{k=0}^{K-1} R_k P_k
\end{equation}
```

where P_k is the probability that the k th mode is selected:

```
\begin{equation}
  \label{eqn:msh}
  P_k = \int_{\hat{\gamma}_k}^{\hat{\gamma}_{k+1}} f_{\hat{\gamma}_{max}}(\hat{\gamma}) d\hat{\gamma}
\end{equation}
```

In fact $f_{\hat{\gamma}_{max}}(\hat{\gamma})$, the PDF of $\hat{\gamma}_{max}$, is independent of the modulation format

$$B = \sum_{k=0}^{K-1} R_k P_k \quad (5)$$

where P_k is the probability that the k th mode is selected:

$$P_k = \int_{\hat{\gamma}_k}^{\hat{\gamma}_{k+1}} f_{\hat{\gamma}_{max}}(\hat{\gamma}) d\hat{\gamma} \quad (6)$$

In fact $f_{\hat{\gamma}_{max}}(\hat{\gamma})$, the PDF of $\hat{\gamma}_{max}$, is independent of the modulation format and

Equations in LaTeX – how to write

Equations are numbered automatically. Use `\nonumber` to stop a number being displayed (see next page).

Labels and references work the same as with other labels:

$$BER(\hat{\gamma}) = \int_0^{\infty} BER(\gamma|\hat{\gamma})f(\gamma|\hat{\gamma})d\gamma \tag{10}$$

With the aid of eqn. (9) and (A-1), (A-6) we can solve (10) as:

```

\begin{equation} \label{eqn:instber}
{BER(\hat{\gamma})}=\int_{0}^{\infty} BER(\gamma|\hat{\gamma})
f(\gamma|\hat{\gamma})d\gamma
\end{equation}

```

With the aid of eqn. (`\ref{eqn:instber1}`) and (`\ref{eq:pdfint}`), (A-6) we can solve (`\ref{eqn:instber}`) as:

Note: in this example, the equation with label `{eq:pdfint}` is are located in the appendix to the paper.

Equations in LaTeX – how to write

If you have a few equations and you want to line them up neatly, you can use `\eqnarray` to help you:

$$\begin{eqnarray}
 P(d) & = & \sum_{m=0}^{L-1} (r_{d+m}^* r_{d+m+L}) \\
 R(d) & = & \sum_{m=0}^{L-1} |r_{d+m+L}|^2 \\
 M(d) & = & \frac{|P(d)|^2}{(R(d))^2},
 \end{eqnarray}
 \tag{1}$$

Whatever is between the & & on each line will be aligned – it doesn't have to be an = sign. \\ means the end of a line.

```

\begin{center}
\begin{eqnarray}
P(d) &=& \sum_{m=0}^{L-1} (r_{d+m}^* r_{d+m+L}) \nonumber \\
R(d) &=& \sum_{m=0}^{L-1} |r_{d+m+L}|^2 \nonumber \\
M(d) &=& \frac{|P(d)|^2}{(R(d))^2}, \\
\end{eqnarray}
\end{center}

```

Equations in LaTeX – how to write

Matrices are handled differently – using the array command:

$$\mathbf{C} = \begin{bmatrix} |s_{HH}|^2 & 0 & s_{HH}s_{VV}^* \\ 0 & 2|s_{HV}|^2 & 0 \\ s_{VV}s_{HH}^* & 0 & |s_{VV}|^2 \end{bmatrix}$$

```

\begin{eqnarray}
\textbf{C} =
\left[
\begin{array}{ccc}
|s_{HH}|^2 & 0 & s_{HH}s_{VV}^* \\
0 & 2|s_{HV}|^2 & 0 \\
s_{VV}s_{HH}^* & 0 & |s_{VV}|^2
\end{array}
\right]
\end{eqnarray}

```

Notice how the array command syntax is similar to the way tables are handled in LaTeX.

Code listings in LaTeX

You can include your code, without changing it, formatting or editing it. This is a very good way to NOT introduce errors! It requires the *listings* package: `\usepackage{listings}`

format it correctly so that the output can be inserted directly into the `ram.v` Verilog source code. This program, called `mac2mem.perl`, is given in Listing F4.

Listing F4. `mac2mem.perl`

```

1 #!/usr/bin/perl
2
3 while(<>){
4     if(/([0-9A-F]+):([0-9A-F]+)\s*(.*)/){
5         print "mem[12'h$1]_=$16'h$2;\t\\/\t$3\n";
6     } elsif(/(\s+(\w+:))/){
7         print "\t\t\t\t\\/\t$1\n";
8     }
9 }

```

This program, called `\textit{mac2mem.perl}`, is given in Listing `\ref{lst:mac2mem}`.

`\lstinputlisting[caption=mac2mem.perl, label=lst:mac2mem]{mac2mem.perl}`

The listings package has lots of options to change the way the code looks when printed.

Important things to remember

1. Backup your text as you write the paper
Just save a copy of the .tex file with a different name

2. Default language for spelling. Set it in your OS:

International English /
UK English

If you don't set the language it will default to the wrong version of English (many English-speaking countries have their own versions. UK English is the most standard one)

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Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is analysed, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delay-limited, channel power prediction is employed to mitigate against the effect of outdated channel state information being used to make switching decisions. During transmission, a source selects a best relay on the basis of predicted signal-to-noise ratio over all available links. A chosen relay then employs maximal ratio combining at its receiver, and applies a variable gain to the received signal before forwarding to the destination. Closed form outage probability and bit error rate solutions are found for arbitrary numbers of relays and receive antennas, and used to explore trade-offs between number of relays and number of antennas compared with single antenna alternatives. To assess predictor performance in combating switching delay, comparison is made with a single antenna alternative.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership project long-term evolution that aim to provide very high data rates and increased network coverage area [1–3]. Several information theoretic studies on multi-input, multi-output relaying, show that improvements are possible in channel reliability and spectral efficiency [4, 5]. Infrastructure-based (fixed) multi-antenna relays have been found beneficial in providing higher throughput and capacity improvements for wireless terminals [6]. However, to achieve high throughput and capacity improvements, multiple antennas are generally recommended for both wireless system terminals and relays. In this paper, we consider a direct relay selection scheme that relays the signal to the destination, overcomes fading and excess transmission power, and provides a significant increase in bandwidth usage, for a given relay selection scheme. Furthermore, relay systems tend to have much lower implementation complexity [8] than full space-time coded alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for antenna devices [7, 9–12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

are used for selection, and performance is limited by analysis. This paper extends these results to multiple relay nodes equipped with multiple receive antennas. This is a source-directed relay selection scheme. In a direct path from source to destination, information (CSI) measured at the relay is used for relay selection at the source. In general, the performance degrades as the feedback information becomes more outdated. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and acting upon it. CSI becomes outdated due to fading, and the system performance is degraded with the consequence of reduced selection accuracy. This is a well known problem in relay systems [15].

Relay selection has been extensively studied in the literature. Performance of a non-selective relay system is degraded when the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18]. This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

$$P_{out}(\gamma) = \sum_{n=0}^{N_r-1} \frac{\gamma^n (1-\rho)^{n+1} \Gamma(\beta)}{\Gamma(\beta+1) \Gamma(n+1)} \times \sum_{p=0}^{N_r-1} \frac{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)}{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)} \times \sum_{q=0}^{N_r-1} \frac{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)}{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)} \times \int_0^{\infty} \frac{e^{-\gamma x} x^{\beta-1}}{\Gamma(\beta)} dx \quad (15)$$

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_2 + 1$ in (15) setting $\gamma_2 = x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_{out} (see (17)) where $\Gamma(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation at the bottom of the page) This approximation is valid in high SNR regions.

4 Numerical and simulation results
BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using γ), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations ρ_1 of a few values. In general, finding an appropriate set for function of several variables, finding an appropriate set for any given D is a general optimisation problem [19]. For $\rho_1 = 1, 0.9$ and 0.7 , where $\rho_1 = 1$ implies no delay or near perfect prediction. We set $\gamma_1 = 5\gamma_2$, to simulate a disparity between first and second hop channel gain. This is realistic

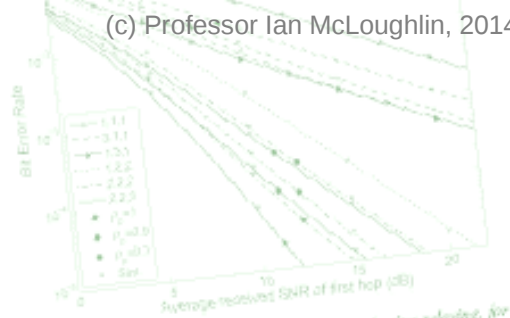


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_1 = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_1 decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results send towards (1,1,1) and (1,2,2), respectively, as $\rho_1 \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to P/F incoherent beamforming TAS/MRC. With delay free switching of transmit antennas/receive antennas, it is known proven that $G_d = R$). In the delayed case, it can be shown that $G_d = R$) of two for large SNRs, determined by the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second hop channel strength will be beneficial. In contrast, if second

$$P_{out}(\gamma) = \sum_{n=0}^{N_r-1} \frac{\gamma^n (1-\rho)^{n+1} \Gamma(\beta)}{\Gamma(\beta+1) \Gamma(n+1)} \times \sum_{p=0}^{N_r-1} \frac{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)}{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)} \times \sum_{q=0}^{N_r-1} \frac{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)}{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)} \times \int_0^{\infty} \frac{e^{-\gamma x} x^{\beta-1}}{\Gamma(\beta)} dx$$

$$P_{out}(\gamma) = \sum_{n=0}^{N_r-1} \frac{\gamma^n (1-\rho)^{n+1} \Gamma(\beta)}{\Gamma(\beta+1) \Gamma(n+1)} \times \sum_{p=0}^{N_r-1} \frac{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)}{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)} \times \sum_{q=0}^{N_r-1} \frac{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)}{\Gamma(\beta+1) \Gamma(n+1) \Gamma(p)} \times \int_0^{\infty} \frac{e^{-\gamma x} x^{\beta-1}}{\Gamma(\beta)} dx$$

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channel prediction in cooperative multi-antenna relay selection systems

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 E-mail: mccloughlin@ntu.edu.sg

Abstract: The use of multiple antennas in both source and relay nodes is analysed, where the source, relay and destination are each equipped with multiple receive antennas. A selection scheme is proposed upon feedback information which is delay-limited, channel state information is used to make switching decisions and bit error rate information being used to make switching decisions. A closed form solution for the average SER and bit error rate variable gain to the received signal before forwarding to the destination. Closed form solutions for the average SER and bit error rate solutions are found for arbitrary numbers of relays and receive antennas, and used to explore trade-offs between number of relays and number of antennas compared with single antenna alternatives. To assess predictor performance in combating switching delay, comparison is made to non-predictive systems.

Introduction

Co-operative relay technology appears as a promising solution for future fourth generation partnership program systems such as the third generation partnership program long-term evolution that aim to provide very high data rates and increased network coverage area [1-3]. Several information theoretic studies on multi-input, multi-output enabled relaying, show that improvements are possible in link reliability and spectral efficiency [4, 5]. Infrastructure-based (fixed) multi-antenna relaying systems are found beneficial in providing diversity and capacity gains [6-8] for wireless terminals with limited number of antennas [9]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-directed relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission nodes, increasing the diversity order and excess bandwidth usage, in a manner that can be done with low relay selection schemes that have much lower complexity. Furthermore, relay selection schemes with multiple antennas and implementation complexity are also being considered as alternatives. Fixed gain amplify-and-forward relaying selection is particularly simple to implement compared with decode-and-forward relaying selection. This effect has been well studied for single antenna relay or destination selection for multi-antenna devices [7, 10]. In [11], a relay selection strategy [13], and a relay selection and destination hybrid approach [14] are proposed. Published results reveal that pure selection performance does not improve much when more than two relay nodes

Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $F_{\gamma_n}(\cdot)$) [19]

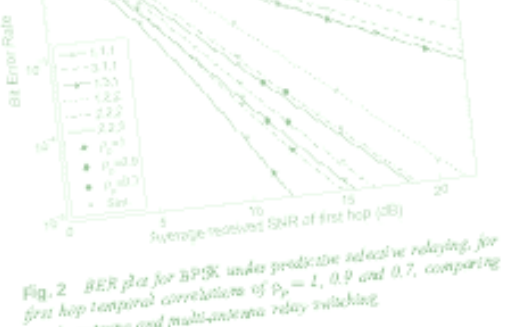
$$P_s = \frac{\alpha}{\sqrt{\Gamma(\alpha)}} \int_0^{\infty} F_{\gamma_n} \left(\frac{x}{\beta} \right) \exp \left(-\frac{x^\alpha}{\alpha} \right) dx \quad (16)$$

where $\Gamma(\cdot)$ denotes the gamma function, and ${}_2F_1(\cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation at the bottom of the page)

This approximation implicit in this closed form solution holds good in the moderate to high SNR regions.

Numerical and simulation results

The BER and SER are numerically verified through simulation [19] (15) but not plotted here. The BER is derived using (8), but not plotted here. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations ρ_p is a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19] of perfect prediction. We set $\gamma_1 = 5\gamma_2$ to simulate a disparity between first and second hop channel gain. This is realistic



since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and diversity tends to lead to large performance improvements, but this is not always the case since performance can be limited by the number of antennas given a particular hop (as discussed below). As seen in many given plots in the selection plots, BER degrades, as ρ_p decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and (2,2) results send towards (1,1) and (1,2,2), respectively, as $\rho_p \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2) scheme is the most robust to fading. The first hop is analogous to PAF incoherent relaying. With delay free switching of transmit antennas, i.e. no fading, it is known that $G_R = R$. In the delayed case, it can be proven that $G_R = R$ of two for large SNRs, determined the minimum diversity order of the first and the second hop (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second hop channel strength. In contrast, if we then increasing N_d will be beneficial. In contrast, if we

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Run Bibtex

Run latex (or pdflatex / pslatex)

Run latex (or pdflatex / pslatex)

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It's easy to get a Bibtex file. Download the citations from the web. i.e. **Google Scholar**:

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Google Scholar search results for 'ian vince mcloughlin'. The search bar shows the name and a search button. Below the search bar, it says 'About 4,860 results (0.10 sec)'. A sidebar on the left lists filters: 'Articles', 'Legal documents', 'Any time' (with sub-options: 'Since 2013', 'Since 2012', 'Since 2009', 'Custom range...'), and 'Sort by relevance'. The main results area shows a profile for 'User profiles for ian vince mcloughlin' with a feather icon, name 'Ian Vince McLoughlin', affiliation 'Professor, Dept. of Electronic Engineering & Information Systems, School of Information ...', email 'Verified email at ustc.edu.cn', and 'Cited by 435'. Below the profile is a link to a PDF review: '[PDF] Review: Line spectral pairs' by 'IV McLoughlin - Signal processing, 2008 - lintech.org'. The abstract of this review is visible: 'Abstract Linear prediction-based coders commonly utilise line spectral pairs (LSP) to represent linear prediction coefficients for reasons of filter stability and representational efficiency. Line spectral pairs have other useful properties such as an ordering relation...'. At the bottom of the results, there are links: 'Cited by 26', 'Related articles', 'All 4 versions', 'Cite', and 'More'.

```
@article{mcloughlin2008review,
title={Review: Line spectral pairs},
author={McLoughlin, Ian Vince},
journal={Signal processing},
volume={88},
number={3},
pages={448--467},
year={2008},
publisher={Elsevier North-Holland, Inc.}
}
```

A screenshot of the citation options menu in Google Scholar. The menu is titled 'Cite' and contains the following options: 'Copy and paste a formatted citation or use one of the links to import into a bibliography manager.', 'MLA McLoughlin, Ian Vince. "Review: Line spectral pairs." *Signal processing* 88.3 (2008): 448-467.', 'APA McLoughlin, I. V. (2008). Review: Line spectral pairs. *Signal processing*, 88(3), 448-467.', 'Chicago McLoughlin, Ian Vince. "Review: Line spectral pairs." *Signal processing* 88, no. 3 (2008): 448-467.', and a row of links: 'Import into BibTeX', 'Import into EndNote', 'Import into RefMan', and 'Import into RefWorks'. There is also a checkbox for 'Remember my bibliography manager and show import links on search result pages.' A red circle highlights the 'Import into BibTeX' link, and a red arrow points from this link to the corresponding line in the BibTeX code block on the left.

Bibtex – creating a .bib file

i.e for **IEEE Xplore**

The screenshot shows the IEEE Xplore Digital Library interface. At the top, there is a search bar and navigation tabs like 'BROWSE', 'MY SETTINGS', and 'MY PROJECTS'. Below the search bar, there is a breadcrumb trail: 'Browse Conference Publications > TENCON 2000. Proceedings'. The main title of the article is 'Hardware architecture for data concealment using sub-band coding, LSB coding and pseudo-random bit stream generators'. Below the title, the authors are listed as 'Adi, R.W. ; Sch. of Comput. Eng., Nanyang Technol. Inst., Singapore ; Tio, C.M.M. ; McLoughlin, I.'. There are tabs for 'Abstract', 'Authors', 'References', 'Cited By', 'Keywords', and 'Metrics'. At the bottom left, there is a 'Download Citations' panel with options for 'Citation Only', 'Citation & Abstract', 'BibTeX', 'Networks', 'EndNote, ProCite, RefMan', and 'Download Citation'. A red circle highlights the 'Download Citations' button, and another red circle highlights the 'BibTeX' option. A red arrow points from the 'BibTeX' option to the 'Download Citation' button.

```
@INPROCEEDINGS{892261,
author={Adi, R.W. and Tio, C. M M
and McLoughlin, I.},
booktitle={TENCON 2000.
Proceedings},
title={Hardware architecture for
data concealment using sub-band
coding, LSB coding and pseudo-
random bit stream generators},
year={2000},
volume={3},
pages={221-225 vol.3},
doi={10.1109/TENCON.2000.892261},}
```

Bibtex – creating a .bib file

i.e. for **ACM Digital Library**



Univ of Science and Technology of China

Reliability through redundant parallelism for micro-satellite computing

Full Text: Pdf

Authors: [Ian Vince McLoughlin](#) [Nanyang Technological University, Singapore](#)
[Timo Rolf Bretschneider](#) [European Aeronautic Defence and Space Company, Singapore](#)

Published in:



Journal
ACM Transactions on Embedded Computing Systems (TECS)
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Volume 9 Issue 3, February 2010
Article No. 26
ACM New York, NY, USA
[table of contents](#) doi> [10.1145/1698772.1698784](#)



2010 Article

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Tags: [cots](#) [components](#) [design](#) [fault tolerance](#) [fault tolerance](#) [fpga](#) [hardware redundancy](#) [micro-satellite](#) [on-board computer](#)

```
@article{McLoughlin:2010:RTR:1698772.1698784,
author = {Ian Vince McLoughlin and Timo Rolf Bretschneider},
title={Reliability through redundant parallelism for micro-satellite computing},
journal = {ACM Trans. Embed. Comput. Syst.},
issue_date = {February 2010},
volume = {9},
number = {3},
month = mar,
year = {2010},
pages = {26:1--26:25},
publisher = {ACM},
}
```

Bibtex – creating a .bib file

Sometimes we just add the entry manually, and we might need to edit the automatically-generated entries.

There are different types of entries, the order of items does not matter, but certain elements *must* be present.

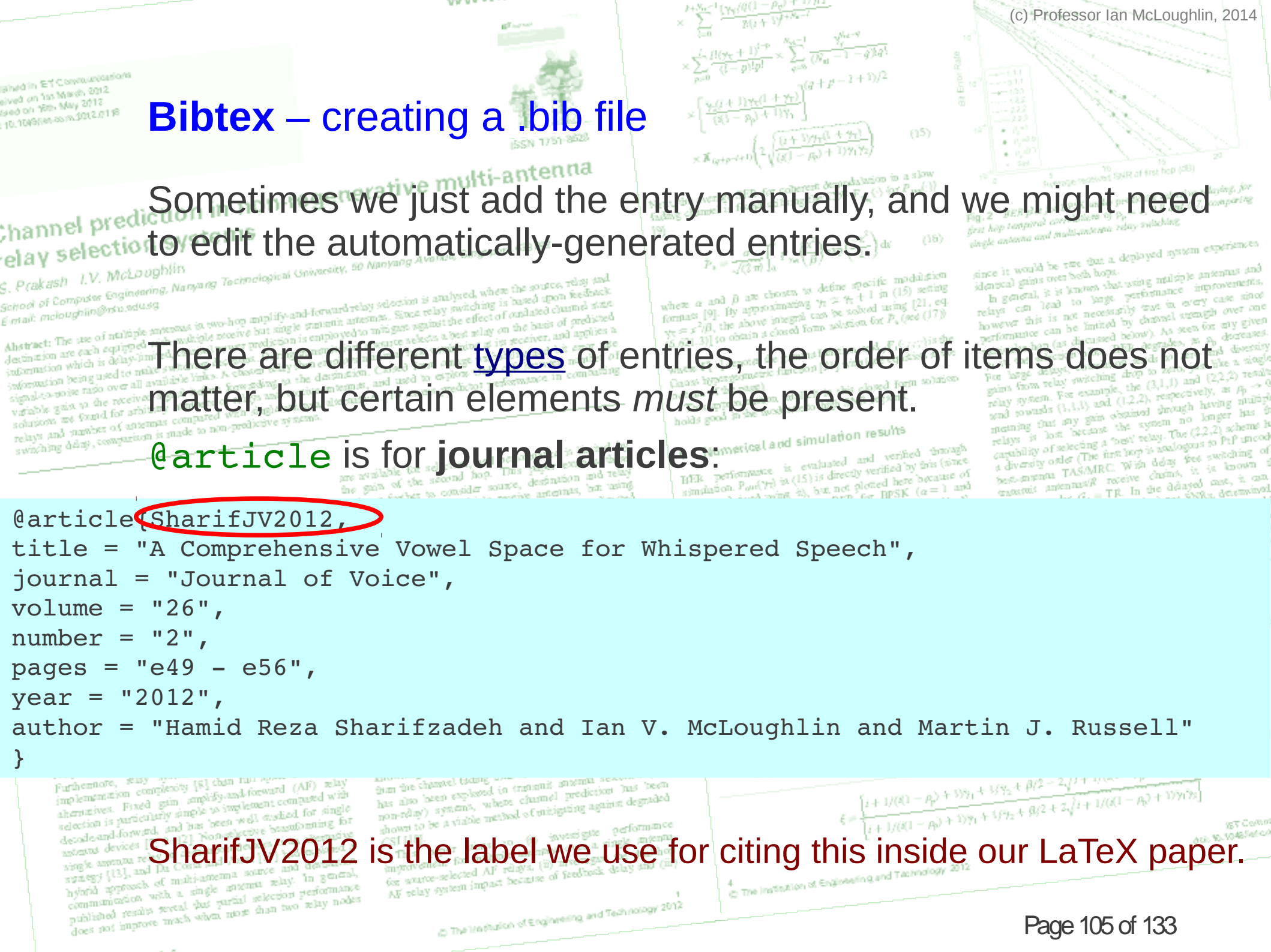
@article is for journal articles:

```

@article{SharifJV2012,
title = "A Comprehensive Vowel Space for Whispered Speech",
journal = "Journal of Voice",
volume = "26",
number = "2",
pages = "e49 - e56",
year = "2012",
author = "Hamid Reza Sharifzadeh and Ian V. McLoughlin and Martin J. Russell"
}

```

SharifJV2012 is the label we use for citing this inside our LaTeX paper.



Bibtex – creating a .bib file

@inproceedings is for conference papers:

```
@InProceedings{speech:IVMICCPOL,
  Author = {Ian Vince McLoughlin and Zhong Qiang Ding and Eng Chong Tan},
  Title = {Intelligibility evaluation of {GSM} coder for {M}andarin speech
  using {CDRT} },
  booktitle = "19th International Conference on the
  Computer Processing of Oriental Languages",
  vol=1,
  pages= {421-424},
  month=may,
  year = "2001"
}
```

Notes:

1. With Bibtex, don't worry about formatting – but you need to tell the system when to force the use of **capital letters**.
2. Give the authors names in full, surname last, separated by 'and'... Don't use any punctuation in the author list.

Bibtex – creating a .bib file

`@book` is for complete books, `@inbook` is for book chapters:

```
@book{CUPbook,
  Author       = {Ian Vince McLoughlin},
  Title        = {Applied Speech and Audio Processing},
  isbn         = {9-780-5215-1954-0},
  publisher    = "Cambridge University Press",
  year         = 2009
};

@inbook{AhmadiBook2009,
  author       = "Farzaneh Ahmadi and Ian Vince McLoughlin",
  title        = "The use of low frequency ultrasonics in speech
processing",
  booktitle    = "Recent Advances in Signal Processing",
  publisher    = "Itech Book Publishers",
  address      = "Vienna, Austria",
  year         = "2009",
  chapter      = "25",
  pages        = {503-528}
}
```

Bibtex – creating a .bib file

@phdthesis and, @electronic are also common:

```
@phdthesis{Hamidthesis,
  author      = "Hamid Reza Sharifzadeh",
  title       = "Reconstruction of natural sounding speech from whispers",
  school      = "Nanyang Technological University",
  address     = "Singapore",
  month       = jan,
  year        = "2011",
  url         = "http://hdl.handle.net/10356/46426"
}

@electronic{FPGA:opencores_webpage,
  title       = "Opencores webpages",
  url         = "http://www.opencores.org",
  month = may,
  year        = "2003"
};
```

You can find a more complete explanation of these entry types, and others, here.
<http://nwalsh.com/tex/texhelp/bibtex-7.html>

Bibtex – adding citations to the LaTeX document

If I have an entry in my .bib file, I can now cite that as a reference in my paper using the `\cite{ }` command to give a numeric reference like [24] and an entry in the list of references.

Create a bibliography database (.bib) containing paper citations...

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In fact there are a few variants of this basic command to change how the citation gets displayed in the text:

`\citet{lotfi09}` for Lotfi et al. (2009)

`\citep{lotfi09}` for (Lotfi et al., 2009)

`\citet*{lotfi09}` for Lotfi & Langensiepen (2009)

From "Writing a Scientific Paper in LaTeX"
Ahmad Lotfi, Nottingham Trent University, UK

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Adding the Bibliography in an IEEE paper is simple, just include these lines after the conclusion of the paper:

```
\bibliography{IEEEabrv,myreflist}
\bibliographystyle{IEEEtran}
```

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LaTeX will look for the following files in the current directory (if they are located elsewhere, just add the path to them in the command above):

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- IEEEabrv.bib - holds standard IEEE abbreviations
- IEEEtran.bst - IEEE bibliography style

IEEEabrv.bib and IEEEtran.bst are provided as part of the paper template for any IEEE journal or conference.

Bibtex – adding the bibliography

Bibtex handles the appearance for you. For example, here are the first 3 references for the same paper which has been compiled for three different journals. There is no change to my .bib file and almost no change to the .tex file to do this.

References IET Proceedings

- [1] R. Pabst *et al.*, “Relay-based deployment concepts for wireless and mobile broadband radio,” *IEEE Commun. Mag.*, vol. 42, no. 9, pp. 80 – 89, Sept. 2004.
- [2] D. da Costa and S. Aissa, “Cooperative dual-hop relaying systems with beamforming over Nakagami-m fading channels,” *IEEE Trans. Wireless Commun.*, vol. 8, no. 8, pp. 3950 – 3954, Aug. 2009.

IEEE Transactions

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- [1] R. Pabst *et al.*, “Relay-based deployment concepts for wireless and mobile broadband radio,” *IEEE Commun. Mag.*, vol. 42, no. 9, pp. 80 – 89, Sept. 2004.
- [2] D. da Costa and S. Aissa, “Cooperative dual-hop relaying systems with beamforming over Nakagami-m fading channels,” *IEEE Trans. Wireless Commun.*, vol. 8, no. 8, pp. 3950 – 3954, Aug. 2009.
- [3] R. Louie, Y. Li, and B. Vucetic, “Performance analysis of beamforming in two hop amplify and forward relay networks,” in *Proc. IEEE Int. Conf. Commun. (ICC)*, pp. 4311 – 4315, May 2008.

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A Springer journal (alphabetical order)

1. Adinoyi, A., & Yanikomeroglu, H. (2007). Cooperative relaying in multi-antenna fixed relay networks. *IEEE Transactions on Wireless Communications*, 6(2), 533–544.
2. Amarasuriya, G., Tellambura, C., & Ardakani, M. (2012). Joint relay and antenna selection for dual-hop amplify-and-forward mimo relay networks. *IEEE Transactions on Wireless Communications*, 11(2), 493–499.
3. Asghari, V., Maaref, A., & Aissa, S. (2010) Symbol error probability analysis for multihop relaying over Nakagami fading channels. In Proceedings of IEEE Wireless Communications and Networking Conference (WCNC), pp. 1–6, April 2010.

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ISSN 1751-8628

$$\begin{aligned}
& \times \sum_{l=0}^{N_s-1} \frac{\gamma_1 \gamma_2 (1 - \rho_1)^{l+1} \gamma_1}{2(l+1)^{p+1} \gamma_1} \\
& \times \sum_{p=0}^{N_s-1} \frac{l! (\gamma_1 + 1)^{l+p}}{(l-p)! p!} \times \sum_{q=0}^{N_s-1} \frac{\gamma_1^{N_s-q}}{(N_s-1-q)! q!} \\
& \times \left[\frac{\gamma_2 (l+1) \gamma_1 (l + \gamma_1)}{(l-1) \gamma_1 + 1 \gamma_1} \right]^{(q+p-2+1)/2} \\
& \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(l+1) \gamma_1 (l + \gamma_1)}{(l-1) \gamma_1 + 1 \gamma_1}} \right) \quad (15)
\end{aligned}$$



Part E

- Useful packages
- Debugging
- The review process
- Getting cited

1 Introduction

Co-operative relay technology is a promising solution for future wireless systems such as the long-term evolution (LTE) systems. LTE systems require high data rates and increased throughput. Information theoretic relaying, which enables relaying, enhances link reliability and is beneficial in providing a robust (fixed) and beneficial in providing for wireless terminals [6]. However, in a wireless system with multiple antennas, the direct relay selection scheme is not bandwidth efficient. Furthermore, relay selection is an implementation alternative. For selection is partial decode-and-forward (DF) relaying devices [7, 9–12]. Non-relay single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

CSI [18]. This paper aims to (i) investigate the performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

Some more useful packages

Euro symbol

Then use `\euro` to generate the symbol.

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`\textipa{U}`/.
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in vowels /I,ε,æ,Λ,U/. Des
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<http://blogs.fsfe.org/ciaran/?p=150>

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simplified-chinese-in-latex/

$$\begin{aligned}
& \times \sum_{p=0}^{N_M-1} \frac{\gamma_1 \theta(1-\rho_p) + \gamma_2 \theta(1-\rho_p)}{2(p+1)^{2+\alpha}} \\
& \times \sum_{q=0}^{N_M-1} \frac{\gamma_1 \theta(1-\rho_q) + \gamma_2 \theta(1-\rho_q)}{(q+1)^{2+\beta}} \\
& \times \sum_{r=0}^{N_M-1} \frac{\gamma_1 \theta(1-\rho_r) + \gamma_2 \theta(1-\rho_r)}{(r+1)^{2+\gamma}}
\end{aligned}$$



Next, the average SER for coherent demodulation in a slow fading channel is found as $P_s = \int_0^{\infty} P_b(x) f(x) dx$ (19)

where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 = \gamma_2 = 1$ in (15) setting $\gamma_1 = \gamma_2 = \beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_s (see (17))

$$P_s = \frac{1}{2} \int_0^{\infty} \frac{\Gamma(\alpha) \Gamma(\beta)}{\Gamma(\alpha+\beta)} x^{\alpha+\beta-1} e^{-x} dx \quad (16)$$

This approximation is valid in high SNR regions. holds good in the modern era.

Next, we denote the gamma function, and $\Gamma(\cdot)$ is the location of the page.

4 Numerical Results

BER performance is simulation $P_{out}(x)$ in BER is derived using space constraint in $\beta = 2$ in different relay configurations. and N_M are shown against γ_1 for considered set for function of several variables, finding an appropriate set for any given D is a general optimization problem [19]. of $\rho_p = 1, 0.9$ and 0.7 , where $\rho_p = 1$ implies no delay or near perfect prediction. We set $\gamma_1 = 5\gamma_2$ to simulate a disparity between first and second hop channel gain. This is realistic

$$P_s = \frac{\alpha}{\sqrt{2\pi}} \int_0^{\infty} \frac{\sqrt{2\pi} \Gamma(\alpha) \Gamma(\beta)}{\Gamma(\alpha+\beta)} x^{\alpha+\beta-1} e^{-x} dx$$

$$\begin{aligned}
& \times \sum_{p=0}^{N_M-1} \frac{\Gamma(\alpha+\beta+1)}{\Gamma(\alpha+1)\Gamma(\beta+1)} \frac{1}{(p+1)^{\alpha+\beta+1}} \\
& \times \sum_{q=0}^{N_M-1} \frac{\Gamma(\alpha+\beta+1)}{\Gamma(\alpha+1)\Gamma(\beta+1)} \frac{1}{(q+1)^{\alpha+\beta+1}} \\
& \times \sum_{r=0}^{N_M-1} \frac{\Gamma(\alpha+\beta+1)}{\Gamma(\alpha+1)\Gamma(\beta+1)} \frac{1}{(r+1)^{\alpha+\beta+1}}
\end{aligned}$$

$$\begin{aligned}
& \times \sum_{p=0}^{N_M-1} \frac{\Gamma(\alpha+\beta+1)}{\Gamma(\alpha+1)\Gamma(\beta+1)} \frac{1}{(p+1)^{\alpha+\beta+1}} \\
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\end{aligned}$$

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channel prediction in cooperative multi-antenna relay selection systems
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Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is analysed, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delay-limited, channel power prediction is employed to mitigate against the effect of outdated channel state information being used to make relay selection decisions. During transmission, a source selects a best relay on the basis of predicted signal-to-noise ratio over all relays. Then, the source employs maximal ratio combining at its receiver, and applies a variable gain to the received signal before relaying it to the destination. To assess the impact of channel prediction, solutions are found for arbitrary numbers of relays and compare them with single antenna alternatives. To assess the impact of relays and number of antennas compared with single antenna alternatives. To assess the impact of channel prediction, solutions are found for arbitrary numbers of relays and compare them with single antenna alternatives. To assess the impact of channel prediction, solutions are found for arbitrary numbers of relays and compare them with single antenna alternatives.

1 Introduction
Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the dense networks of femtocell and picocell networks. Evolution of the network architecture, increasing rates and increased network coverage are possible in information theoretic studies on multi-input multi-output based (fixed) multi-antenna systems. This is a source-directed arrangement with no direct path from source to destination. In general, the performance of relay systems is limited by the gain of the channel between the source and the relay. This is a source-directed arrangement with no direct path from source to destination. In general, the performance of relay systems is limited by the gain of the channel between the source and the relay. This is a source-directed arrangement with no direct path from source to destination. In general, the performance of relay systems is limited by the gain of the channel between the source and the relay.

Chinese
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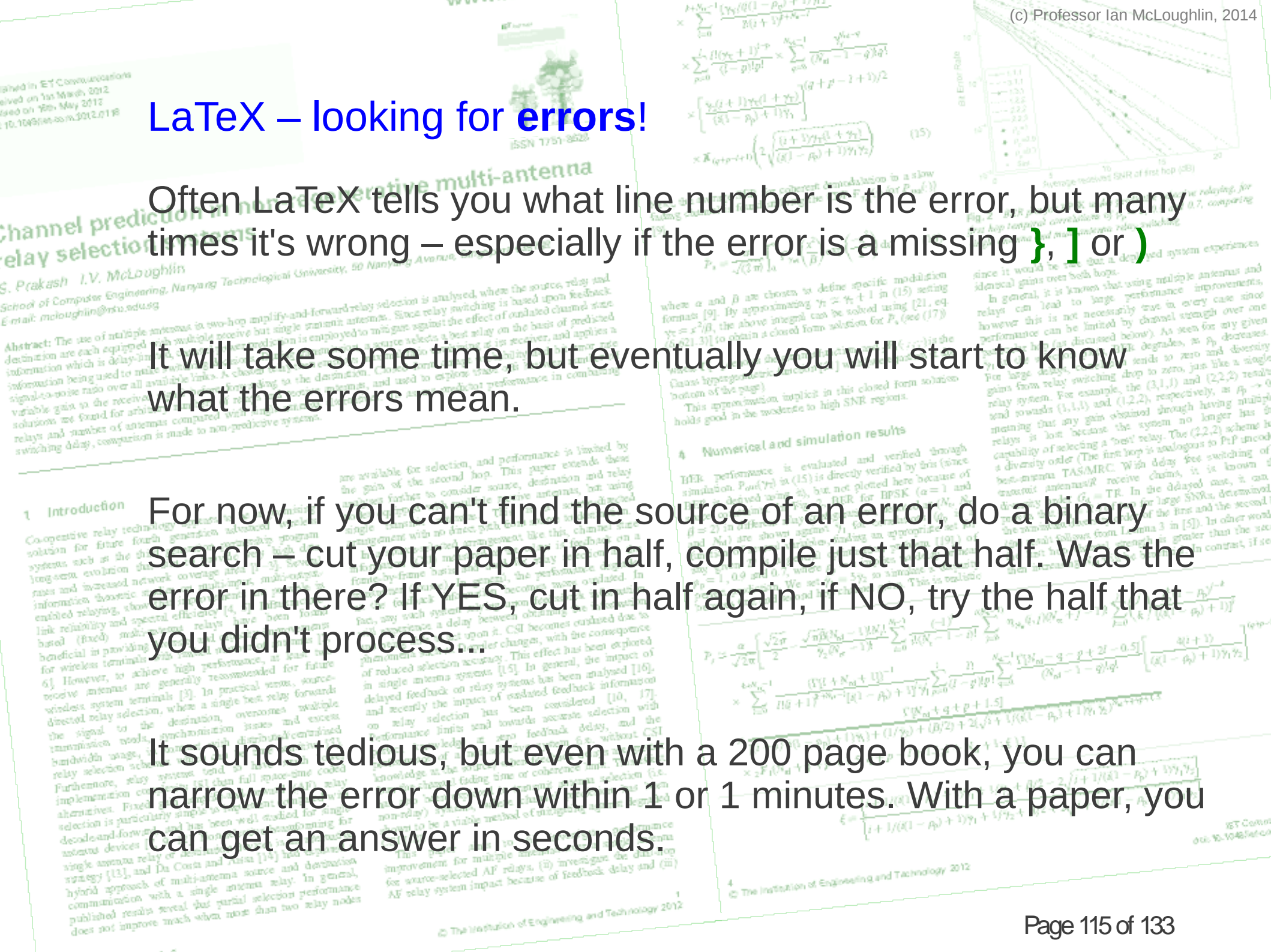
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What happens next?

Channel prediction in non-regenerative multi-antenna relay selection systems

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Keep waiting...

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the third generation partnership program long-term evolution that aim to provide very high data rates and increased network coverage area [1-3]. Several information theoretic studies on multi-input, multi-output, enabled relaying, show that improvements are possible in enabled relaying, show that improvements are possible in link reliability and spectral efficiency [4, 5]. Infrastructure-based (fixed) multi-antenna relays have been found beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-destination relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission modes, synchronisation issues and excess bandwidth usage, in contrast with distributed/centrised relay selection schemes which can be time sensitive [7]. Furthermore, relay systems tend to have much lower implementation complexity [8] than full space-time coded alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for wireless devices [7, 9-12]. Non-selective beamforming for single antenna relay or destination devices is an alternative strategy [13], and Da Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relays is feedback on a frame-by-frame basis. In general, the performance degrades as the feedback information becomes more outdated. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to phenomena such as Doppler changes, with the consequence of reduced selection accuracy. This effect has been explored in single antenna systems [15]. In general, the impact of delayed feedback on relay systems has been analysed [16], and recently the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with perfect knowledge at zero feedback delay, and the performance of a non-selective system (i.e. without CSI knowledge at the source) when feedback delays are greater than the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18].

This paper aims to (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

$$P_s = \sum_{j=0}^{N_s-1} \frac{\gamma_1 \gamma_2 (1 - \rho_1)^{j+1} (1 - \rho_2)^{j+1}}{2^{j+1} \gamma_1 \gamma_2} \times \sum_{p=0}^{N_r-1} \frac{(1 - \rho_1)^{p+1}}{(1 - \rho_1)^{p+1}} \times \sum_{q=0}^{N_d-1} \frac{\gamma_1 \gamma_2 (1 - \rho_1)^{q+1}}{(N_r - 1 - q)! q!} \times \left[\frac{\gamma_1 (1 + \gamma_2 (1 + \gamma_1))}{(1 - \rho_1) + 1 + \gamma_1} \right] \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1 + \gamma_2 \gamma_1 (1 + \gamma_1))}{(1 - \rho_1) + 1 + \gamma_1}} \right) \quad (15)$$

Next, the average SER for coherent demodulation in a slow fading channel is found utilising the CDF $F_{\gamma_n}(\cdot)$ (or $P_{out}(\cdot)$) [9]

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where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_1 \approx \gamma_2 + 1$ in (15) setting $\gamma_2 = x^2/\beta$, the above integral can be solved using [21, eq. (6.621.3)] to obtain a closed form solution for P_s (see (17)) where $\Gamma[\cdot]$ denotes the gamma function, and ${}_2F_1(\cdot, \cdot; \cdot; \cdot)$ is the Gauss hypergeometric function [21] with (see equation at the bottom of the page). This approximation implicit in this closed form solution holds good in the moderate to high SNR regions.

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using it), but not plotted here because of space constraints. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations ρ_{12} is a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19]. For $\rho_{12} = 1, 0.9$ and 0.7 , where $\rho_{12} = 1$ implies no delay or near perfect prediction. We set $\gamma_1 = 5\gamma_2$ to simulate a diversity between first and second hop channel gain. This is realistic

$$P_s = \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{2\pi} N_d - 1}{\sqrt{2\pi} N_d - 1} \sum_{j=0}^{N_s-1} \frac{(-1)^j}{j!(N_s - 1 - j)!} \sum_{p=0}^{N_r-1} \frac{(-1)^p}{p!(N_r - 1 - p)!} \sum_{q=0}^{N_d-1} \frac{(-1)^q}{q!(N_d - 1 - q)!} \sum_{k=0}^{j+1} \binom{j}{k} \frac{A^k (1 - A)^{j-k}}{(k - \rho_1) + 1} \right] \times \sum_{l=0}^{N_s-1} \frac{(1 + N_d + 1)^l}{(1 + 1)^{l+1} \gamma_1^{l+1} (1 - \rho_1)^{l+1} + 1} \sum_{p=0}^{N_r-1} \frac{1}{(1 - \rho_1)^{p+1}} \sum_{q=0}^{N_d-1} \frac{1}{(N_r - 1 - q)! q!} \left[\frac{4(1 + \gamma_1)}{(k - \rho_1) + 1 + \gamma_1} \right] \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1 + \gamma_2 \gamma_1 (1 + \gamma_1))}{(1 - \rho_1) + 1 + \gamma_1}} \right) \quad (17)$$

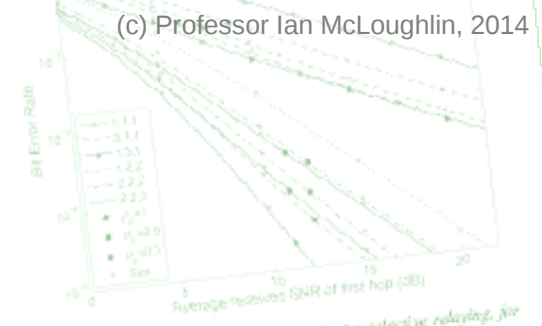


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_{12} = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops.

In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_{12} decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) results send towards (1,1,1) and (1,2,2), respectively, as $\rho_{12} \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to PtP incoherent TAS/MRC. With delay free switching of best-antenna TAS/MRC. With delay free switching of best-antenna TAS/MRC, it is known that $G_d = TR$. In the delayed case, it can be proven that $G_d = R$) of two for large SNRs, determined the minimum diversity order of the first and the second (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second hop channel strength will be beneficial. In contrast, if second

What happens next?

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Channel prediction in non-regenerative multi-antenna relay selection systems

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Abstract: The use of multiple antennas in two-hop amplify-and-forward relay selection is analysed, where the source, relay and destination are each equipped with multiple receive but single transmit antennas. Since relay switching is based upon feedback information which is delay-limited, channel prediction is employed to mitigate against the effect of outdated channel state information being used to make predictions. A closed-form solution for the maximal ratio combining at its receiver, and applies a variable gain to the received signal before forwarding to the destination. Closed-form outage probability and bit error rate solutions are found for arbitrary numbers of relays and receive antennas, and used to explore trade-offs between number of relays and number of antennas compared with single antenna alternatives. To assess predictor performance in combating switching delay, comparison is made to non-predictive systems.

Keep waiting....

1 Introduction

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are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relays is feedback on a frame-by-frame basis. In general, the performance degrades as the feedback information becomes more outdated. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to phenomena such as Doppler changes, with the consequence of reduced selection accuracy. This effect has been explored in single antenna systems [15]. In general, the impact of delayed feedback on relay systems has been analysed [16], and recently the impact of outdated feedback information on relay selection has been considered [10, 17]. The performance limits and towards accurate selection with multiple antennas and feedback delay, and the impact of fading on relay selection (i.e. without CSI) is also investigated. The paper is organised as follows: (i) investigate performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)

$$P_{out} = \sum_{j=0}^{N_s-1} \frac{\gamma_j (q(1-p_0) + 1)^{j+1}}{j!(1-p_0)^{j+1}} \times \sum_{p=0}^{N_d-1} \frac{(1-p)^{p+1}}{(1-p)!} \times \sum_{q=0}^{N_m-1} \frac{\gamma_1^{q+1}}{(N_m-1-q)!q!} \times \left[\frac{\gamma_2 (q+1) \gamma_1 (1+\gamma_1)}{(q+1-p_0) + 1) \gamma_1} \right] \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+p) \gamma_2 (1+\gamma_1)}{(q+1-p_0) + 1) \gamma_1}} \right) \quad (15)$$

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This approximation implicit in this closed form solution holds good in the moderate to high SNR regions. BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using it), but not plotted here because of space constraints. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlation ρ_b is a function of several variables, finding an appropriate set for any given D is a general optimisation problem [19]. For $\rho_b = 1, 0.9$ and 0.7 , where $\rho_b = 1$ implies no delay or near perfect prediction. We set $\gamma_1 = 5\gamma_2$, to simulate a disparity between first and second hop channel gain. This is realistic

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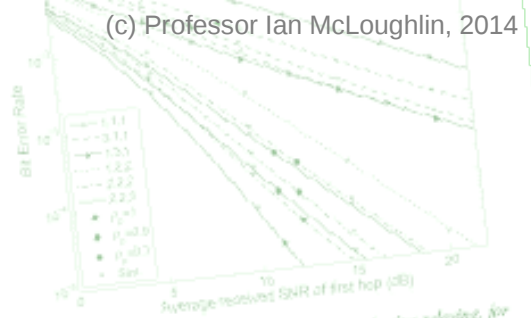


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What happens next?

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Channel prediction in non-regenerative multi-antenna relay selection systems

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Abstract: The use of multiple antennas in two-hop amplify-and-forward relaying systems is investigated. The source and destination are each equipped with multiple antennas. The relay is equipped with a single antenna. Channel prediction is used to make switching decisions. Information which is delay-limited is used to make switching decisions. The effect of prediction error on the BER is investigated. Closed form average BER expressions are derived for arbitrary numbers of relay antennas and number of antennas at the source and destination. Comparison of switching delay, comparison

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1 Introduction

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are available for selection, and performance is limited by the gain of the second hop. This paper extends these analyses further to consider source, destination and relay nodes equipped with multiple receive antennas, but using single transmit antennas. This is a source-directed arrangement with no direct path from source to destination. In a source-selected arrangement like this, channel state information (CSI) measured at the relay is fed back on a frame-by-frame basis. In general, the performance degrades as the feedback information becomes more outdated. In fact, any such system relying upon feedback information will experience a delay between obtaining the information and being able to act upon it. CSI becomes outdated due to phenomena such as Doppler changes, with the consequence of reduced selection accuracy. This effect has been explored in single antenna systems [15]. In general, the impact of delayed feedback on relay systems has been analysed [16], and recently the impact of outdated feedback information on relay selection has been considered [10, 17]. Performance limits tend towards accurate selection with perfect knowledge at zero feedback delay, and the performance of a non-selective system (i.e. without CSI knowledge at the source) when feedback delays are greater than the channel fading time or coherence limit. This effect has also been explored in transmit antenna selection (i.e. non-relay) systems, where channel prediction has been shown to be a viable method of mitigating against degraded CSI [18].

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where α and β are chosen to define specific modulation formats [9]. By approximating $\gamma_n \approx \gamma_n + 1$ in (15) setting $\gamma_n = x^2/\beta$, the integral in (16) can be solved using [21, eq. (21.3)] to obtain

where $\Gamma(\cdot)$ is the gamma function and γ_n is the location of the source.

4 Numerical Results

BER performance simulation. BER is a function of SNR ($\beta = 2$) in dB and N_{rel} (number of relay antennas). Any given perfect scenario is simulated between first and second hop channels.



$$\begin{aligned} & \times \sum_{p=0}^{N_{\text{rel}}-1} \frac{\gamma_1 \gamma_2 (\beta(1-\rho_p) + 1) \gamma_1}{2(\beta+1)^{p+1} \gamma_1 \gamma_2} \\ & \times \sum_{q=0}^{N_{\text{rel}}-1} \frac{\beta(1-\rho_q)^{q+1}}{(q-p)! p!} \times \sum_{q=0}^{N_{\text{rel}}-1} \frac{\gamma_1 \gamma_2 \beta^{q-p}}{(N_{\text{rel}}-1-q)! q!} \\ & \times \frac{\gamma_1 \gamma_2 (\beta(1-\rho_p) + 1) \gamma_1}{(\beta(1-\rho_p) + 1) \gamma_1} \\ & \times \frac{\beta(1-\rho_q)^{q+1}}{(q-p)! p!} \times \frac{\gamma_1 \gamma_2 \beta^{q-p}}{(N_{\text{rel}}-1-q)! q!} \\ & \times \frac{\gamma_1 \gamma_2 (\beta(1-\rho_p) + 1) \gamma_1}{(\beta(1-\rho_p) + 1) \gamma_1} \\ & \times \frac{\beta(1-\rho_q)^{q+1}}{(q-p)! p!} \times \frac{\gamma_1 \gamma_2 \beta^{q-p}}{(N_{\text{rel}}-1-q)! q!} \end{aligned} \quad (15)$$

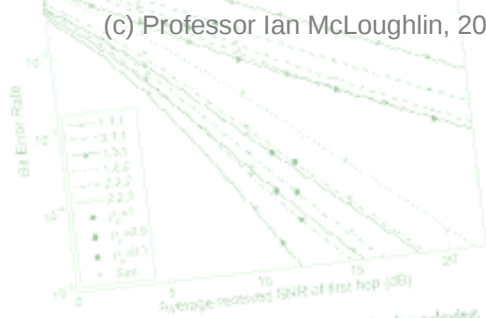


Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_p = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and relays can lead to large performance improvements, but this is not necessarily true in every case since the selection gain can be limited by channel strength over one hop (as discussed below). As seen for any given correlation plot, BER degrades, as ρ_p decreases. For large delays, correlation tends to zero and diversity gain from relay switching drops to zero and diversity order of a relay system. For example, the (3,1,1) and (2,2,2) results show that any gain obtained through having multiple relays is lost because the system no longer has the ability to select a 'best' relay. The (2,2,2) scheme is diversity order of two for large SNRs, determined by the first hop channel strength is greater than the second hop channel strength. In contrast, if the

$$\begin{aligned} P_s &= \frac{\alpha}{\sqrt{2\pi}} \left[\frac{\sqrt{2\pi}}{2} \frac{\sqrt{N_{\text{rel}} N_{\text{rel}} - 1} N_{\text{rel}}}{\gamma_1 \gamma_2 \beta^{N_{\text{rel}} - 1}} \sum_{p=0}^{N_{\text{rel}}-1} \frac{(-1)^p}{p!} \sum_{q=0}^{N_{\text{rel}}-1} \frac{N_{\text{rel}} \gamma_1 \gamma_2 \beta^{q-p}}{(N_{\text{rel}}-1-q)! q!} \sum_{k=0}^{N_{\text{rel}}-1} \binom{N_{\text{rel}}-1-k}{k} \frac{\beta(1-\rho_k)^{k+1}}{(\beta(1-\rho_k) + 1)^{k+1}} \right] \\ & \times \sum_{p=0}^{N_{\text{rel}}-1} \frac{\gamma_1 \gamma_2 (\beta(1-\rho_p) + 1) \gamma_1}{(\beta(1-\rho_p) + 1) \gamma_1} \sum_{q=0}^{N_{\text{rel}}-1} \frac{\beta(1-\rho_q)^{q+1}}{(q-p)! p!} \sum_{q=0}^{N_{\text{rel}}-1} \frac{\gamma_1 \gamma_2 \beta^{q-p}}{(N_{\text{rel}}-1-q)! q!} \left[\frac{\beta(1-\rho_q)^{q+1}}{(\beta(1-\rho_q) + 1) \gamma_1 \gamma_2} \right] \\ & \times \frac{\beta(1-\rho_p)^{p+1}}{(\beta(1-\rho_p) + 1) \gamma_1 \gamma_2} \left[\frac{\beta(1-\rho_p)^{p+1}}{(\beta(1-\rho_p) + 1) \gamma_1 \gamma_2} \right] \\ & \times {}_2F_1(N_{\text{rel}} + q + p + 1.5, q + p - 1 + 1.5; 1 + N_{\text{rel}} + 1; \xi) \end{aligned}$$

$$\xi = \frac{\beta(1-\rho_p)^{p+1}}{(\beta(1-\rho_p) + 1) \gamma_1 \gamma_2} \left[\frac{\beta(1-\rho_q)^{q+1}}{(\beta(1-\rho_q) + 1) \gamma_1 \gamma_2} \right]$$

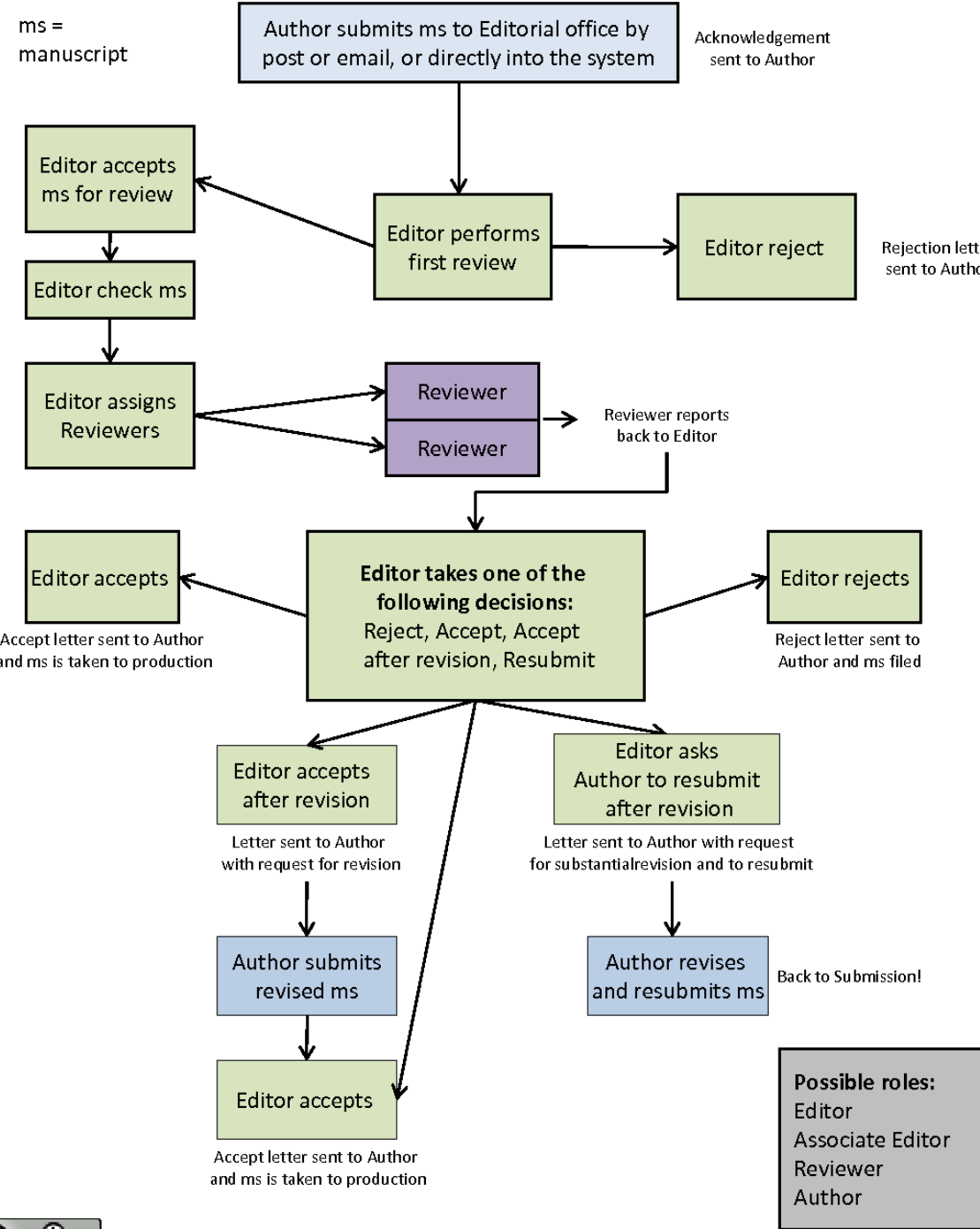
Editorial flow chart – from submission to decision – small journal

The editor

The editor decides to accept/reject the paper.

This is the approximate flowchart of the usual editorial process for a journal paper.

A conference paper is simpler – a TPC (Technical Programme Committee) does the job of the editor



Notification about review result

There are several possible outcomes from the paper review process. Although the wording might be slightly different, here is the spectrum of responses:

- 1. Unconditional rejection
- 2. Reject, but encouraged to resubmit after making major changes
- 3. Accept with mandatory changes
- 4. Unconditional acceptance (very rare)



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Channel prediction in non-regenerative multi-antenna relay selection systems

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Abstract: The use of multiple relays in cooperative communication systems is a promising solution for future fourth generation advanced wireless systems such as the distributed antenna system (DAS). In this paper, we investigate the impact of channel prediction on the performance of a multi-antenna relay selection system. We consider a source-relay-destination system where the relay is equipped with multiple antennas and the destination is also equipped with multiple antennas. The relay is equipped with multiple antennas and the destination is also equipped with multiple antennas. The relay is equipped with multiple antennas and the destination is also equipped with multiple antennas. The relay is equipped with multiple antennas and the destination is also equipped with multiple antennas.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation advanced wireless systems such as the distributed antenna system (DAS). In this paper, we investigate the impact of channel prediction on the performance of a multi-antenna relay selection system. We consider a source-relay-destination system where the relay is equipped with multiple antennas and the destination is also equipped with multiple antennas. The relay is equipped with multiple antennas and the destination is also equipped with multiple antennas. The relay is equipped with multiple antennas and the destination is also equipped with multiple antennas.

Next, the average SER for coherent demodulation in a slow fading channel is found utilizing the CDF $F_{\gamma_n}(\cdot)$ (or $P_{out}(\cdot)$)

$$P_{out} = \int_0^{\infty} \frac{\Gamma(\alpha)}{\Gamma(\alpha)^2} \frac{\Gamma(\beta)}{\Gamma(\beta)^2} \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha + \beta)^2} \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha + \beta)^2} \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha + \beta)^2} \dots$$

4 Numerical and simulation results

BER performance is evaluated and verified through simulation. $P_{out}(\gamma)$ in (15) is directly verified by this (since BER is derived using β), but not plotted here because of space constraint. In Fig. 2, BER for BPSK ($\alpha = 1$ and $\beta = 2$) in different relay configurations, denoted as (N_s, N_r, N_d) are shown against γ_1 for correlations ρ_{12} is a function of the delay spread T_m and the channel gain γ_1 . The BER performance is shown for $\rho_{12} = 1, 0.9$ and 0.7 . It is seen that the BER performance is significantly improved when the delay spread T_m is small (perfect prediction). We set $\gamma_1 = 5$, to simulate a disparity between first and second hop channel gain. This is realistic

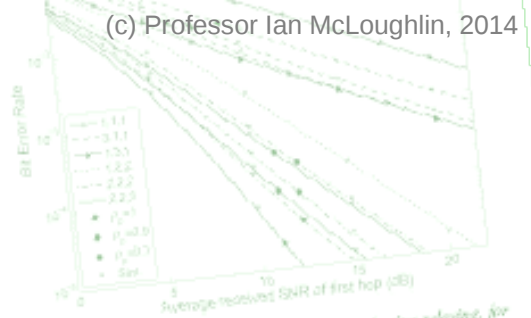


Fig. 2 BER plot for BPSK under predictive selective relaying for two hop temporal correlations of $\rho_{12} = 1, 0.9$ and 0.7 , comparing single-relay and multi-antenna relay switching

Response to reviewers

Some typical IEEE statistics on the length of time taken to respond to authors:

IEEE Transactions on Instrumentation and Measurement (TIM) <i>Regular Issue</i> Paper Submission and Review Process Statistics ¹ May 1, 2012 to April 30, 2013								Initial Decision				Final Decision			
Papers Reviewed w/ Decision	Average Days to Initial Decision	St. Dev. of Initial Decision	Median of Initial Decision	Average Days to Final Decision	St. Dev. of Final Decision	Median of Final Decision	Percentage Accepted	In 60 Days	In 90 Days	In 120 Days	In 180 Days	In 60 Days	In 90 Days	In 120 Days	In 180 Days
513	60	28	55	100	63	84	45	63%	90%	97%	100%	35%	54%	68%	90%

An acceptance rate of 45% is quite high. Usually we will be nearer the 25% to 30% range for journals, and 50% for a typical conference.

Response to reviewers



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16th May 2012

COM-2012-0118

Channel Prediction in Non-Regenerative Multi-antenna Relay Selection Systems

Dear Professor Shen,

Thank you for the good news that this paper is accepted for *IET Communications* subject to minor corrections.

We are also grateful to the reviewers for their good quality and timely review. On the following two pages, we have outlined the updates and corrections that we have made to the paper in response to the review comments. We are confident that we have addressed each of the reviewer's points fully.

Along with this letter I have uploaded a complete PDF plus all LaTeX source files. I hope that your editorial team find that this is all satisfactory. Please feel free to contact me at any time if further actions are necessary.

(5) A nice letter always helps!

Yours sincerely,

Dr Ian McLoughlin SrMIEEE, MIEE, CEng
Associate Professor
Computing Systems
School of Computer Engineering
Nanyang Technological University
Block NA, Nanyang Avenue, Singapore 639708

(2) Work through each reviewers comments in turn.

(3) Point-by-point, reproduce the main part of each point.

(4) For each point, say what you will do or justify why you won't be making any changes.

(1) Always thank the reviewers!

Response to reviewers comments

First of all, the authors would like to thank both reviewers and the editorial team. We were grateful to note that the reviewers had read the paper carefully and taken pains to understand the content; we are also pleased with the positive nature of their comments.

Reviewer: 1

The authors have applied the concept of channel prediction to combat the effect of CSI feedback delays in relaying systems. To my best knowledge, the novelty of the work is high as the topic has not been widely addressed in the literature. Additionally, the method seems to have practical value as it is shown that channel prediction can be used to combat larger delays. As such after a minor revision, I recommend the work for publication.

We are happy to see such positive comments, thank you.

My minor comments are as follows:

1. The mathematical analysis behind the current work largely stems from prior work on the literature. The only difference is that the correlation between the old and new channels are manipulated using channel prediction. This fact must be clearly stated in the paper and authors must concentrate on the results. Its practical value could be discussed in length.
2. The literature survey on outdated CSI and relay systems is not sufficient. For example, some recent results on the topic are missing;

Example:

[R1] A.M. Soysa, H. A. Suraweera, C. Tellambura and H. K. Garg, "partial and opportunistic relay selection with outdated channel estimates," *IEEE Transactions on Communications*, vol. 60, 2012. (to appear - available in IEEE Xplore Early Access)

[R2] D. S. Michalopoulos, H. A. Suraweera, G. K. Karagiannidis and R. Schober, "Relay selection with outdated channel estimates," in *Proc. IEEE GLOBECOM 2010*, Miami, FL, Dec. 2010, pp. 1-6.

The authors are encouraged to discuss the main difference of the current work in relation to [R1] and [R2]. (in terms of the mathematical analysis provided in this work)

1. There are some major differences between existing work and the current paper. Firstly, the mixture of multiple antennas and outdated CSI had not been explored before in such systems. Secondly, we derived closed form solutions for BER/outage probability. Not only are these novel, but they also extend to arbitrary quantities of:

- receive antennas

Preparing final 'publication packet'

Once your paper has been unconditionally accepted, you will be asked to upload a final 'publication packet'. Usually a zip file which contains everything needed to create the final paper.

It will need to include the following:

1. Your .tex file for the paper.
2. Your .bbl file (this is the output from Bibtex — you can also cut the contents of the .bbl file and paste it into your .tex in the references section to replace the `\bibliography{}`).
3. All of the .eps graphics files and any listings.
4. A copy of any .sty, .cls and .bst files.

Proof checking

The editorial team will probably contact you to look at the proofs: to answer any questions they have and search for errors.

ARTICLE IN PRESS

A Comprehensive Vowel Space for Whispered Speech

*Hamid Reza Sharifzadeh, *Ian V. McLoughlin, and †Martin J. Russell, *Singapore, †Birmingham, United Kingdom

Summary: Whispered speech is a relatively common form of communications, used primarily to selectively exclude or include potential listeners from hearing a spoken message. Despite the everyday nature of whispering, and its undoubted usefulness in vocal communications, whispers have received relatively little research effort to date, apart from some studies analyzing the main whispered vowels and some quite general estimations of whispered speech characteristics. In particular, a classic vowel space determination has been lacking for whispers. For voiced speech, this type of information has played an important role in the development and testing of recognition and processing theories over the past few decades and can be expected to be equally useful for whisper-mode communications and recognition systems.

This article aims to redress the shortfall by presenting a vowel formant space for whispered speech and comparing the results with corresponding phonated samples. In addition, because the study was conducted using speakers from Birmingham, the analysis extends to discuss the effect of the common British West Midlands accent in comparison with Standard English (Received Pronunciation). Thus, the article presents the analysis of formant data showing differences between normal and whispered speech while also considering an accentual effect on whispered speech.

Key Words: Whispered speech–Vowel space–British West Midlands accent–Formant analysis–Acoustic characteristics.

INTRODUCTION

Acoustic measurements of phonated vowels and diphthongs form foundational material for the speech processing and recognition fields. Wide research efforts,^{1–7} mainly based on acoustic characteristics of normal vowels, show the importance of these measurements, whereas numerous studies,^{8–10} in turn, have considered formant patterns in terms of vowel diagrams and the corresponding characteristics of normal vowels.

Despite the strong literature supporting normal vowels, little research effort has been spent on whispered speech relating to vowel space. Apart from the studies describing the vocal mechanism of whispers' production mostly on a glottal level,^{11–14} as well as a recent study on whispered consonants,¹⁵ the few notable studies on whispered vowels^{16–18} are mainly concentrated on a few main vowels /I, ε, æ, Δ, Ū/ and conclude with general comments on vowel placement such as "higher

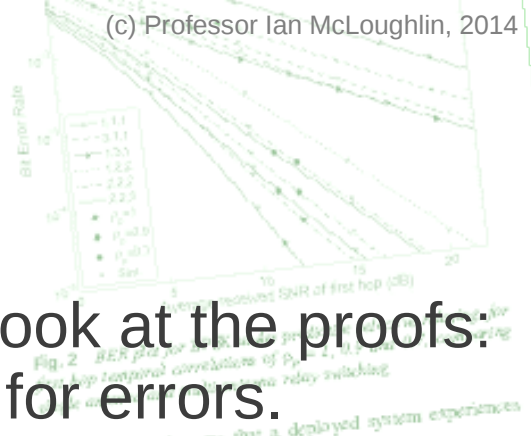
whispers) are produced by normally speaking people to deliberately reduce perceptibility, such as whispering into someone's ear in a theater, and are usually spoken in a relaxed manner with little effort.¹¹ Stage whispers, however, are used if the listener is some distance away from the speaker²¹ and are actually a whispery voice, which includes partial phonation.²² The more common soft whispers, produced by people who are not aware they are the focus of this study.

As mentioned, the lack of physical feature and the most of whispered speech. It implies of whispered speech. It implies pitch and the harmonic relation from this.²³ In a source filter source of excitation in whisper the pharynx adjusted so that Exhaled air passes directly through

Comment on T6/01/11 10:05:39 PM hamid Options

It seems these IPA letters have different font sizes; i. e. first and fourth symbols (IPA letters) are bigger than second and third. Please use the same font size.

I added this comment to the editors.



nce it would be rare that a deployed system experiences (several) gains over both hops.
 In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BERK degrades, as ρ_1 decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2) results tend towards (1,1,1) and (1,2,2), respectively, as $\rho_1 \rightarrow 0$ meaning that any gain obtained through having multiple relays is lost because the system no longer has the capability of selecting a 'best' relay. The (2,2,2) scheme is a diversity order (The first hop is analogous to PtP uncoded best-antenna TAS/MRC. With delay free switching of transmit antennas/ receive chains, it is known diversity order $G_d = TR$. In the delayed case, it can be proven that $G_d = R$) of two for large SNRs, determined the minimum diversity order of the first and the second (the result follows from Lemma 3 in [5]). In other words the first hop channel strength is greater than the second then increasing N_{rel} will be beneficial. In contrast, if se

$$\sum_{k=0}^{N_{rel}-1} \binom{N_{rel}-1-k}{k} \frac{A^k (1-A)^{N_{rel}-1-k}}{[(k+1) \rho_1 + 1]^{N_{rel}-1-k}}$$

$$\sum_{k=0}^{N_{rel}-1} \binom{N_{rel}-1-k}{k} \frac{A^k (1-A)^{N_{rel}-1-k}}{[(k+1) \rho_1 + 1]^{N_{rel}-1-k}}$$

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Channel prediction in non-regenerative multi-antenna relay selection systems

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Abstract: The use of multiple antennas in two-hop amplify-and-forward relays are each equipped with multiple receive but single transmit antennas. Channel prediction in non-regenerative multi-antenna relay selection systems is employed to make switching decisions. During transmission, the relay selects the best relay based on the channel prediction information being used to make switching decisions. During transmission, the relay selects the best relay based on the channel prediction information being used to make switching decisions. During transmission, the relay selects the best relay based on the channel prediction information being used to make switching decisions.

1 Introduction

Co-operative relay technology appears to be a promising solution for future fourth generation wireless systems such as the third generation partnership program long-term evolution that aim to provide very high data rates and increased network coverage area [1-3]. Several information theoretic studies on multi-input, multi-output, enabled relaying, show that improvements are possible in link reliability and spectral efficiency [4, 5]. Infrastructure-based (fixed) multi-antenna relays have been found beneficial in providing diversity and capacity improvements for wireless terminals with limited number of antennas [2, 6]. However, to achieve high performance, at least two receive antennas are generally recommended for future wireless system terminals [3]. In practical terms, source-relay selection, where a single best relay forwards the signal to the destination, overcomes multiple transmission modes, synchronization issues and excess bandwidth usage, in contrast with distributed techniques. Furthermore, relay systems tend to have much lower implementation complexity [8] than full space-time code alternatives. Fixed gain amplify-and-forward (AF) relay selection is particularly simple to implement compared with decode-and-forward, and has been well studied for single antenna devices [7, 9-12]. Non-selective beamforming, single antenna relay or destination devices is an alternative strategy [13], and Du Costa and Aissa [14] had explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

$$\begin{aligned} & \times \sum_{l=0}^{N_d-1} \frac{\gamma_1 \gamma_2 (1-p)^{l+1} \gamma_1}{2(l+1)^{p+1} \gamma_1} \\ & \times \sum_{p=0}^{N_d-1} \frac{l! \gamma_1 (1-p)^{l+1}}{(l-p)! p!} \times \sum_{q=0}^{N_d-1} \frac{\gamma_2^{q-p}}{(N_d-1-q)! q!} \\ & \times \left[\frac{\gamma_1 (l+1) \gamma_2 (1+\gamma_2)}{(l-1) \gamma_1 + 1 \gamma_2} \right]^{(q+p-1)/2} \\ & \times N_d^{(q+p-1)/2} \left[2 \sqrt{\frac{(l+1) \gamma_2 (1+\gamma_2)}{(l-1) \gamma_1 + 1 \gamma_2}} \right] \end{aligned} \quad (15)$$



Fig. 2 BER plot for BPSK under predictive selective relaying, for first hop temporal correlations of $\rho_1 = 1, 0.9$ and 0.7 , comparing single antenna and multi-antenna relay switching

since it would be rare that a deployed system experiences identical gains over both hops. In general, it is known that using multiple antennas and relays can lead to large performance improvements, however this is not necessarily true in every case since performance can be limited by channel strength over one particular hop (as discussed below). As seen for any given γ_1 in the selection plots, BER degrades, as ρ_1 decreases. For large delays, correlation tends to zero and diversity gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) result in gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) result in gains from relay switching drop to zero and diversity relay system. For example, the (3,1,1) and (2,2,2) result in gains from relay switching drop to zero and diversity relay system.

Congratulations!!!



Your paper is finally published

$$\begin{aligned} & \sum_{k=0}^{N_d-1} \frac{N_d!}{k!} \left[\frac{1}{(k-1) \gamma_1 + 1 \gamma_2} \right]^{(k-1)/2} \\ & \times \sum_{p=0}^{N_d-1} \frac{N_d!}{p!} \frac{N_d - q - p + 2l - 0.5}{(N_d - 1 - q)! q!} \left[\frac{4(l+1)}{(l-1) \gamma_1 + 1 \gamma_2} \right]^{(q+p-1)/2} \\ & \times N_d^{(q+p-1)/2} \left[2 \sqrt{\frac{(l+1) \gamma_2 (1+\gamma_2)}{(l-1) \gamma_1 + 1 \gamma_2}} \right] \end{aligned}$$

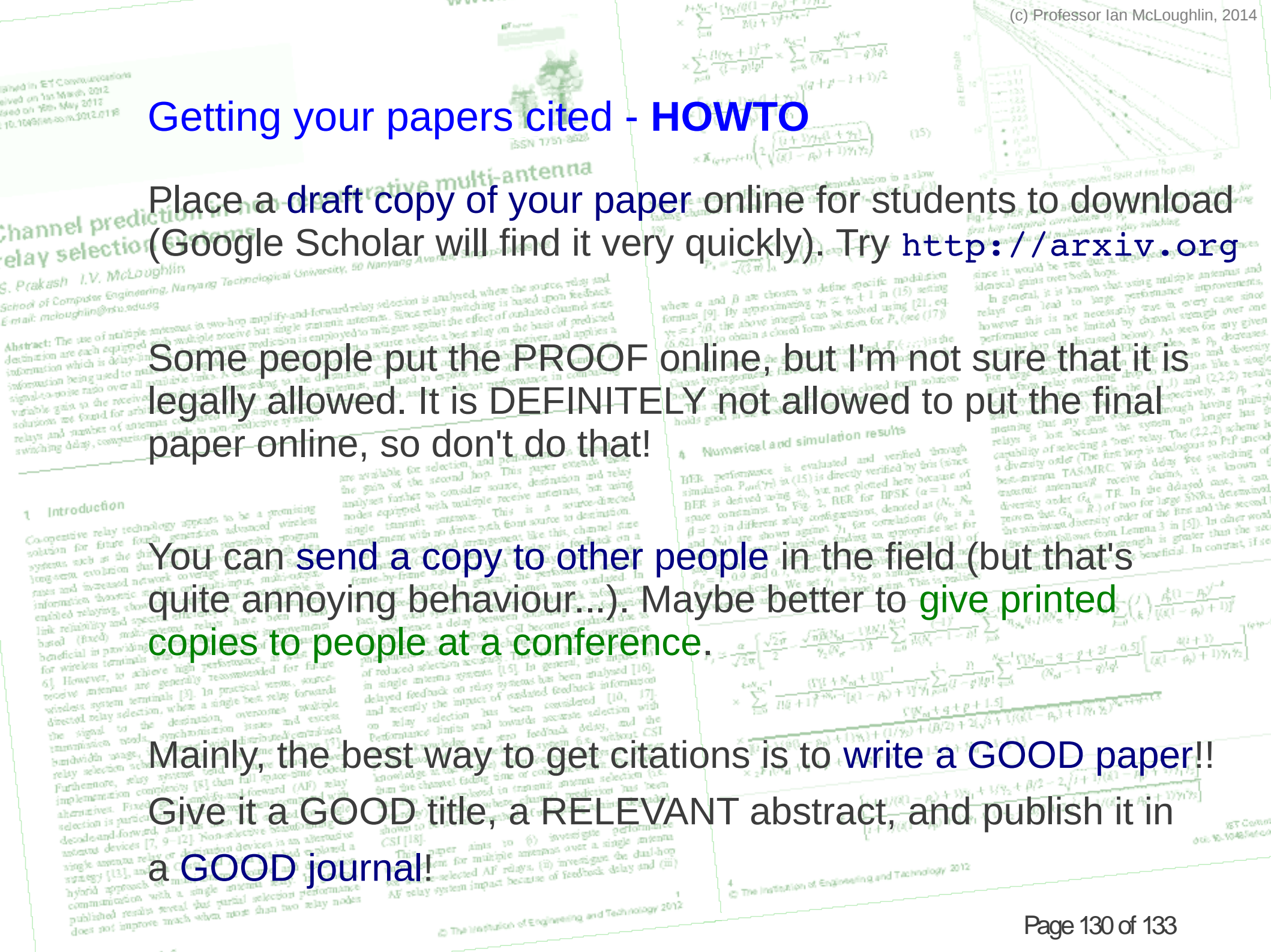
Getting your papers cited - HOWTO

Place a draft copy of your paper online for students to download (Google Scholar will find it very quickly). Try <http://arxiv.org>

Some people put the PROOF online, but I'm not sure that it is legally allowed. It is DEFINITELY not allowed to put the final paper online, so don't do that!

You can send a copy to other people in the field (but that's quite annoying behaviour...). Maybe better to give printed copies to people at a conference.

Mainly, the best way to get citations is to write a GOOD paper!! Give it a GOOD title, a RELEVANT abstract, and publish it in a GOOD journal!



What is a GOOD journal?

For speech/audio signal processing, we normally consider the following to be good journals (the list is not in any order):

- ★ IEEE Journals e.g. *IEEE Trans. Audio Speech and Language Processing*
- IET Journals e.g. *IET Signal Processing*
- Most ACM Transactions.
- Electronics Letters
- Speech Communications Journal (Elsevier)
- Journal of Voice
- ★ Journal of the Acoustical Society of America (JASA)
- Signal Processing Journal (Elsevier)
- The Audio Engineering Society (AES) journal

For an objective measure, we can use the Thomson-Reuters Journal Citation Report (JCR) "Impact Factor". As a rough guide, IF > 1 is good.



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$$\begin{aligned}
& \times \sum_{i=0}^{N_s-1} \frac{\gamma_1 \rho (1-\rho)^i + (1-\rho)^{i+1}}{2(i+1)^{p+N_s-1}} \\
& \times \sum_{p=0}^{N_s-1} \frac{(1-\rho)^{p+1}}{(1-\rho)! p!} \times \sum_{q=0}^{N_s-1} \frac{\gamma_2^{q+1}}{(q+1)! q!} \\
& \times \left[\frac{\gamma_2 (q+1) \gamma_1 (1+\gamma_2)}{(q+1) \gamma_1 + 1 \gamma_2} \right]^{(q+p-2+1)/2} \\
& \times \bar{K}_{(q+p+1)} \left(2 \sqrt{\frac{(1+\gamma_2) \gamma_1 (1+\gamma_2)}{(q+1) \gamma_1 + 1 \gamma_2}} \right) \quad (15)
\end{aligned}$$



Channel prediction relay selection

S. Prakash I.V. McLoughlin
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Abstract: The use of relay destination are each equipped with information which is delay information being used to variable gain to the received solutions are found for at relays and number of an switching delay, compared

The End

Thank you!!

1 Introduction

Co-operative relay technology is a promising solution for future wireless systems such as the long-term evolution (LTE) systems. The evolution of LTE systems has led to increased data rates and increased information throughput. This has enabled relaying, which improves link reliability and coverage. Relaying is based on (fixed) and mobile relays, which are beneficial in providing coverage for wireless terminals [1]. However, to achieve the full potential of a wireless system, the relays must be able to direct the signal to the destination. This is achieved by relay selection [2]. Furthermore, relay selection is a key component of the implementation of relay systems. For relay selection, partial decode-and-forward (DF) relays are used [7, 9–12]. Non-coherent relays are used for single antenna relay or destination devices in an alternative strategy [13], and Du Costa and Aissa [14] have explored a hybrid approach of multi-antenna source and destination communication with a single antenna relay. In general, published results reveal that partial selection performance does not improve much when more than two relay nodes

CSI [18]. This paper aims to (i) investigate the performance improvement for multiple antennas over a single antenna for source-selected AF relays, (ii) investigate the dual-hop AF relay system impact because of feedback delay and (iii)