

Capacity of Multiple-Input Multiple-Output Wireless Communication Systems Operating in the HF Band

by

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Abstract

Spatial multiplexing is a wireless communication technique that employs MIMO (multiple-input multiple-output) antenna arrays and spatial signal processing to effectively establish multiple parallel spatial data pipes within the same frequency band. The number of parallel spatial data pipes that can be supported is dependent on a number of factors, one of the most significant of these being multipath richness. In general, a channel that is rich in multipath will be capable of supporting a large number of parallel spatial data pipes, leading to high capacities.

The HF (high frequency) band is subject to significant multipath caused by multiple refractions and reflections between the ionospheric layers and the earth's surface, making it a possible candidate for MIMO techniques. In this thesis, the capacity offered by spatial multiplexing in the HF band is investigated. To the best of our knowledge, no such investigation has previously been conducted. The approach taken involves collection of multi-channel HF sounder data from which antenna and propagating mode correlation measurements are made. The antenna and mode correlation measurements are used to generate stochastic channel matrices, from which estimates of MIMO capacity can be calculated.

The key contributions presented include estimation of HF MIMO capacity from ionograms, development of a multi-channel receiver for HF radio research, development of a model for the HF MIMO channel matrix, and development and application of a technique for estimating HF MIMO capacity from multi-channel receiver data. The results obtained from the investigation indicate that spatial multiplexing offers a significant increase in capacity compared with single channel communication techniques, and should therefore be seriously considered for future HF radio systems. A major application that stands to benefit from HF MIMO technology is ship based communications.

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Declaration

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Design and implementation of the Multi-Channel Receiver system was a challenging task which involved contributions from several individuals. Kevin Zacher created the layouts and schematics for the ADC and MCR boards. Kiet To designed the DDC chip. Darren Dicera wrote firmware and embedded software for the controller FPGA. Matthew Goss assisted with the layout of the DDC chip, performed systems engineering tasks, and wrote the Console software. Matthew Trinkle assisted with integration and testing of the MCR system during the final stages of the project.

Collection of radio data could not have been possible without the assistance of Warren Marwood, Angus Massie, and the ISRD of DSTO who provided access to the receive antenna array and RF front-end infrastructure. The ISRD also provided ionosonde data logs required to perform initial HF MIMO capacity calculations.

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List of Acronyms

3GPP	3rd Generation Partnership Project
ADC	analog-to-digital converter
AGC	automatic gain control
AM.....	amplitude modulation
AWGN	additive white Gaussian noise
BER	bit error rate
BLAST	Bell Laboratories layered space-time
BPF	band pass filters
CCDF	complementary cumulative distribution function
CIC	cascade integrate comb
codec	coder decoder
CORDIC	co-ordinate rotation digital computer
COTS	commercial off-the-shelf
CSI.....	channel state information
DDC	digital down converter
demux	demultiplexer
DFT	discrete Fourier transform

List of Acronyms

DSTO	Defence Science and Technology Organisation
FDTD	finite difference time domain
FFT	fast Fourier transform
FIFO	first-in first-out
FIR	finite impulse response
FMCW	frequency modulated continuous wave
FPGA	field programmable gate array
GPS	global positioning system
HF	high frequency
I/O	input/output
IEEE	Institute of Electrical and Electronics Engineers
IF	intermediate frequency
iid	independent identically distributed
LAN	local area network
LCM	lowest common multiple
LLISP	Low Latitude Ionospheric Sounding Project
LO	local oscillator
LOS	line-of-sight
MCR	multi-channel receiver
MIMO	multiple-input multiple-output
MISO	multiple-input single-output
MTBF	mean time between failures
MTTR	mean time to recovery

MUF	maximum usable frequency
OFDM	orthogonal frequency division multiplexing
PDF	probability density function
PLL	phase locked loop
PPS	pulses per second
PRBS	pseudo-random binary sequence
PSD	power spectral density
QAM	quadrature amplitude modulation
Rx	receiver
SFDR	spur free dynamic range
SIMO	single-input multiple-output
SISO	single-input single-output
SNR	signal-to-noise ratio
SRAM	static random access memory
TCP/IP	transmission control protocol/internet protocol
Tx	transmitter
UTC	co-ordinated universal time
UTRA	Universal Terrestrial Radio Access
V-BLAST	vertical BLAST
WiSE	Wireless Systems Engineering

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