EFFECT OF NEGATIVE SPATIAL/TEMPORAL CORRELATION ON THE PERFORMANCE OF MAXIMAL RATIO COMBINING IN A WCDMA CELLULAR SYSTEM

By

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Dissertation Summary

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This dissertation deals with the study of *smart antenna concepts* for *Wideband Code Division Multiple Access (WCDMA)* systems. A smart antenna model with spatial/temporal channel, correlated fading and maximal-ratio combining (MRC) is proposed. An analytical approach is used to develop a robust and accurate model. The proposed model provides considerable improvement in system gain at no extra cost to hardware. This system uses inherent signal information such as direction of arrival, fading and correlation between multipath components of arriving signals, to significantly improve system performance under certain conditions. The proposed technique is realised by combining three sub models namely direction of arrival, fading and diversity combining. The model is then evaluated for system performance.

The first sub-system model, viz. the *spatial* or *direction of arrival model,* is realised by considering *scatterer distribution* and *angular location* of mobiles. A *Gaussian bell shape distribution* for scatterers is considered, with the assumption that the density of scatterers is highest near the mobile and progressively reduces as we go further from the centre of the bell, i.e., away from the mobile. Although a *uniform angular distribution* of mobiles is assumed, the mobile user distribution can be easily modified or adapted to match any real life operational scenario.

The second sub-model is the *temporal fading model*. Two temporal models, namely the *exponential* and *Gaussian*, are used to calculate channel parameters for *Line-of-Sight (LOS)* (typically urban) and *Non-Line-of-Sight (NLOS)* (typically bad urban) environments respectively. The channel parameters represent the combined effect of direction of arrival and temporal fading.

The third sub-model is the *diversity combiner model*. A probability density function for an MRC is calculated that takes into account the number of *diversity branches*, *signal power*, *temporal fading*, *constant correlation model* and *correlation coefficient* that gives a relationship between multipath signals. An important contribution is made to the existing research in this field by calculating system gain for signals with negative correlation coefficients.

The overall performance of the proposed spatial/temporal system model is evaluated using two evaluation criteria, namely *bit error rate* (BER) and *probability of outage*. The system is evaluated for *Non-Coherent Frequency Shift Keying (NC-FSK), Differentially Coherent Phase Shift Keying (DC-PSK), Coherent Frequency Shift Keying (C-FSK)* and *Coherent Phase Shift Keying (C-PSK)* digital modulation schemes. Considerable improvement in system gain is observed with all modulation schemes in specific operational scenarios with negatively correlated signals or where such conditions can be enforced.

Opsomming Afrikaans

Hierdie verhandeling handel oor die studie van intelligente antenna-konsepte vir Wyeband-Kode-Divise Multi-Toegang (WCDMA) stelsels. 'n Intelligente antennamodel met ruimtelike/temporale kanaal, gekorreleerde seinverswakking en maksimale verhoudingskombinering ('maximum-ratio-combining') word voorgestel. 'n Analitiese benadering word gevolg om 'n robuuste en akurate model te ontwikkel. Die voorgestelde model verskaf 'n annsienlike verbetering in stelselwins teen minimum addisionele hardewarekoste. Die stelsel ontgin inherente seininformasie, soos invalshoek, seinverswakking (deining) en korrelasie tusen multipadkomponete van die invalseine, om die stelselfunksionaliteit en- werkverrigting noemenswaardig te verbeter. Die voorgestelde tegniek is gerealiseer deur die aanwending en kombinasie van drie submodelle, naamlik invalshoek, seinverswakking (deining) en diversiteitskombinering. Die werkverrigting van die voorgestelde model word ge-evalueer deur gebruik te maak van maatstawwe soos bisfouttempometing en die bepaling van die waarskynlikheid dat die stelsel bokant 'n gespesifiseerde minimum bisfoutlimiet sal funksioneer ('probability of outage').

Die eerste submodel, naamlik die *ruimtelike of direksionele invalshoekmodel*, is gerealiseer deur die *verpreiding van seinobstruksies* en die *hoekdistribusie van mobiele selfooneenhede* in ag te neem. 'n *Klokvormige Gaussiese transmissie-obstruksiedistribusie* is aanvaar met die aanname dat die digtheid van distribusie hoogste is naby die mobiele selfoon en stelselmatig afneem namate verder weg van die middelpunt van die klok (dws die selfoon) beweeg word. Hoewel '*n uniforme hoekverspreiding* van selfone aanvaar is, kan die selfoon-gebruikersdistribusiemodel sonder moeite gemodifiseer of aangepas word om enige situasie in die praktyk voor te stel.

Die tweede submodel is die *temporale seinverswakkingsmodel*. Twee temporale verspreidingsmodelle, naamlik *eksponensiëel* en *Gaussies,* is gebruik om die kanaalparameter(s) van respektiewelik die *Siglyn-* (tipies stedelike omgewing) en *Nie-Siglyn-* (tipies swak stedelik omgewing) gevalle te bereken. Die kanaalparameters verteenwoordig die gekombineerde effek van die invalshoek en temporale seinverswakking (deinning).

Die derde submodel is die *diversiteistskombineerdermodel.* 'n Waarskynlikheidsdigtheidsfunksie vir 'n maksimale verhoudingskominbeerder word bereken. Hierdie digtheidsfunksie neem die aantal *diversiteitstakke, seinsterkte, temporale seinverswakking, konstante korrelasiemodel en die korrelasiekoëffisiënt*, wat 'n indikasie is van die ooreenkoms tussen multipadseine, in ag. 'n Belangrike bydrae word in hierdie verhandeling tot bestaande navorsing in die veld gedoen deur die berekening van die stelselaanwins vir seine met negatiewe korrelasiekoëffisiënte.

Die algehele werkverrigting van die voorgestelde ruimtelike/temporale model word evalueer deur van twee evalueringskriteria, naamlik *bisfouttempo en die waarskynlikheid dat die stelsel bokant 'n gespesifiseerde minimum bisfoutlimiet sal funksioneer ('outage probability')* gebruik te maak. Die stelsel is evalueer vir Nie-Koherente Frekwensie-Skuif-Sleuteling (NK-FSK), Differensiële-Koherente Fase-skuif-Sleuteling (DK-PSK) en Koherente Fase-Skuif-Sleuteling (K-PSK) syfermodulasietegnieke. Resultate toon dat aansienlike stelselaanwinste verkry kan word deur die eksploitering van bepaalde temporaal-ruimtelike operasionele situasies waarin negatiewe seinkorrelasie voorkom of afgedwing kan word.

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List of Abbreviations

3G	Third Generation
4G	Fourth Generation
AOA	Angle Of Arrival
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CDTD	Code Division Transmit Diversity
CFSK	Coherent Frequency Shift Keying
CPFSK	Continuous Phase Frequency Shift Keying
CSC	Complex Symbol Combining
DBF	Digital Beam Forming
DCFSK	Differentially Coherent Frequency Shift Keying
DOA	Direction Of Arrival
DPSK	Differential Phase Shift Keying
DS-CDMA	Direct Sequence CDMA
DSP	Digital Signal Processing
DS-SS	Direct Sequence Spread Spectrum
EFD	Exponential Fading Distribution
ESPRIT	Estimation of Signal Parameters via Rotational Invariance Techniques
ETSI	European Telecommunication Standards Institute
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
FSC	Full Spectrum Combining
FSK	Frequency Shift Keying
GBSBEM	Geometrically Based Single Bounce Elliptical Model
GFD	Gaussian Fading Distribution
GPRS	General Packet Radio System
GSM	Global System for Mobile
I	Inphase

IMT-2000	International Mobile Telecommunication 2000
LOS	Line Of Sight
MBS	Mobile Broadband Systems
MDPSK	Minimum differential Phase Shift Keying
MMIC	Monolithic Microwave Integrated Circuit
MPSK	M-ary Phase Shift Keying
MR	Maximal Ratio
MRC	Maximal-Ratio Combining
MRRC	Maximal-Ratio Receiver Combining
MUSIC	MUltiple Signal Identification and Classification
NCFSK	Non Coherent Frequency Shift Keying
NLOS	Non Line Of Sight
PDF	Probability Density Function
PLMN	Public Land Mobile Network
PN	Pseudo-Noise
PSK	Phase Shift Keying
Q	Quadrature phase
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SC	Selection Combining
SDMA	Space Division Multiple Access
SER	Symbol Error Rate
SNR	Signal to Noise Ratio
TD-CDMA	Time-Division CDMA
TDMA	Time Division Multiple Access
TDTD	Time Division Transmit Diversity
TOA	Time of Arrival
UMTS	Universal Mobile Telecommunication System
VHE	Virtual Home Environment
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network
WLL	Wireless Local Loop

List of Symbols

ρ	Correlation co-efficient
Φ	Cumulative direction of arrival
κ	Rice factor
θ_0	DOA due to user distribution, measured from some reference
ϕ_0	DOA of the main received path
σ^2	Variance of a distribution
θ_b	Angle of scattering point with reference to BS
ϕ_I	DOA at the Rx after single bounce
θ_I	DOA at the Tx after single bounce
φ_K	Phase shift
α_l	Location of peak *l* in user pdf
γ_l	Weight of peak *l* in user pdf
δ_m	*m*-parameter decay rate
Ω_M	Signal power received on branch *M*
σ_m	Standard deviation of fading parameter *m*
α_b	½ antenna beam width
A_{norm}	Normalisation factor
D	Distance of scatterer from BS
d_o	T-R separation
E_0/N_0	Bit energy to-noise density
f_c	Carrier frequency
Γ	Gamma function
G_M	Antenna gain on branch *M*
h_r	Receiver height
h_t	Transmitter height
i	Symbol interval index
K	No of users
m	Nakagami's fading parameter
M	Number of diversity branches
m_0	Nakagami fading of the main received path

$m_k(t)$	Data sequence
N	No of chips
P_e	Probability of error
$PN_k(t)$	PN code sequence
Q	Q – Function
R_c	Cell radius
r	distance of mobile from base station
$R(t)$	Transmitted radio signal
r_b	Distance of mobile from BS
S	Fading signal power
$S(t)$	Modulated signal
θ	Spatial DOA
μ	Spatial/temporal channel fading parameter
w_l	Width of peak l in user pdf
w_M	Weighting on branch M
Z_M	Correlator output
L_M	Number of multipath
$U(t)$	IF or base band CDMA signal with multipath
Z	Correlator
ω_c	Carrier frequency
ς	A positive definite ($2M\times 2M$) covariance matrix
$\wedge$	Is an M×M square Symmetric matrix
υ	Twice variance (σ^2)
γ	Signal – to – Noise ratio
S_k	Instantaneous power in the kth signal
R	Arbitrary correlation matrix
Ψ_S	Characteristic function of the pdf of MRC diversity system
α	A constant that determines the modulation scheme when calculating Probability of BER
Ω	Average signal power
S_c	Received signal strength in volts
α_F	Amplitude of a fading channel
σ	Standard deviation

r_K	Signal received on a diversity branch
X_{ck}	Amplitude of the in phase component of the received signal on *k*th branch of a diversity system
X_{sk}	Amplitude of the quadrature phase component of the received signal on *k*th branch of a diversity system
I	A $2M \times 2M$ identity matrix
λ	A constant representing real numbers
T	A diagonal matrix
t_k	Symbol interval index