



شبكة المعلومات الجامعية  
التوثيق الإلكتروني والميكروفيلم

# بسم الله الرحمن الرحيم



**MONA MAGHRABY**



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التوثيق الإلكتروني والميكروفيلم



# شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلم



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# جامعة عين شمس

## التوثيق الإلكتروني والميكروفيلم

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**MONA MAGHRABY**



# **INTERFERENCE MITIGATION AND OPTIMAL FAIR RESOURCE ALLOCATION USING ANGULAR DIVERSITY TECHNIQUES IN VLC SYSTEMS**

By

**Mona Elsayed Hosney Ibrahim**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University in  
Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
in  
**Electronics and Communications Engineering**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
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Under the Supervision of

**Prof. Dr. Khaled Mohamed  
Fouad Elsayed**

**Dr. Hossam Abd-Alaziz  
Ibrahim Selmy**

.....  
Professor of Electronics and  
Communication Engineering Department  
Faculty of Engineering, Cairo University

.....  
Associate Professor,  
Communication Engineering Department  
National Institute of Laser science, Cairo University

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Approved by the  
Examining Committee

---

**Prof. Dr. Khaled Mohamed Fouad Elsayed,**

Thesis Main Advisor

---

**Dr. Hossam Abd-Alaziz Ibrahim Selmy,**

Advisor

Associate professor,  
at National Institute of Laser science, Cairo university

---

**Prof. Dr. Hebat-Allah Mostafa Mourad,**

Internal Examiner

---

**Prof. Dr. Hossam Mohamed Hassan Shalaby,**

External Examiner

Professor of electronics and communication department,  
Faculty of Engineering, Alexandria university.

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
2021



**Engineer's Name:** Mona Elsayed Hosney Ibrahim  
**Date of Birth:** 18/07/1989  
**Nationality:** Egyptian  
**E-mail:** monyhosney@gmail.com  
**Phone:** 01099832707  
**Address:** 474, third district elmgawra 3,  
6<sup>th</sup> of October  
**Registration Date:** 1/10 /2014  
**Awarding Date:** .... /.... /2021  
**Degree:** Master of Science.  
**Department:** Electronics and Communications Engineering.



**Supervisors:**

Prof. Dr Khaled Mohamed Fouad Elsayed Dr.  
Hossam Abd-Alaziz Ibrahim Selmy

**Examiners:**

Prof. Hossam M. H. Shalaby (External examiner)  
Professor at faculty of engineering, Alexandria  
university  
Prof. Hebat-Allah M. Mourad (Internal examiner)  
Prof. Khaled M. Fouad (Thesis main advisor)  
Dr. Hossam Ibrahim A. Selmy (Advisor)  
Associate professor at National Institute of laser  
science, Cairo university.

**Title of Thesis:**

Interference Mitigation and optimal Fair Resource Allocation using Angular Diversity  
Techniques in VLC systems

**Key Words:**

VLC, Angular Diversity, Resource Allocation, CCI.

**Summary:**

The high increase of data demands requires searching for a new techniques of data transmission. Visible Light Communication (VLC) is one of the solutions that can be used in the nearest future because of its great advantages. However; it suffers from some challenges. One of these challenges is Limited LED bandwidth. This can be solved either by making frequency reuse to be one or fair resource allocation among distributed users. In this thesis, these two points have been discussed and simulated using diversity techniques i.e.; Angular Diversity Receiver (ADR), and Angular Diversity Transmitter (ADT). The first part is making frequency reuse and solve Co-channel interference (CCI) problem which acceptable Bit-error rate at different scenarios. The second part is on making resource allocation optimization using two search algorithms (exhaustive and heuristic search algorithm) that maximize the minimum Signal to Interference Noise Ratio(SINR). Both algorithms achieve superior performance. However heuristic algorithm achieves very low complexity comparing others.

# Disclaimer

I hereby declare that this thesis is my original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Mona Elsayed Hosney Ibrahim

Date:

Signature:



# ACKNOWLEDGMENT

First of All, I need to thank and praise Allah Subhana Wa Tallah who granted me the health and the knowledge to finish this work.

Secondly, I would like to express my deepest gratitude to my supervisors Prof. Dr/ Khaled Fouad, and Dr. Hossam selmy for their continuous support, extreme patience, valuable guidance, and encouragement that led to complete this work.

Also, Special thanks to Dr. Hoda Boghdady, and Dr. Ashraf Abd Elhak, Professor of transmission department at National Telecommunication Institute, for their encouragement and valuable help offered in many ways.

Finally, I would like to send special thanks to my Mom, my Dad, my lovely husband “Ahmed Saeed”, my brother "Mostafa Saeed", and all of my family for their kind understanding, encouragement, and patience during the time devoted to this thesis.

**Mona Hosney**

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# NOMENCLATURE

$A$	Total number of distinct sets
$\mathbf{A}_{\text{alloc}}$	Allocation matrix between each LED $f$ of ADT's $j$
$A_d$	Photo-detector effective area
$a$	Allocation element of the allocation matrix
$\bar{a}$	Binary allocation vector
$A_d$	Photo-detector active area
$A_i$	Set of possible combinations of received LED indices
$A_i^*$	A selected set of LEDs indices
$\mathbf{A}_{\text{opt}}$	Optimum Allocation matrix
$c$	Speed of light
$C_i$	Correlation Coefficient
$D^j$	Desired LED $j$
$d_{ij}$	Distance from the LED $j$ to the PD $i$
$d_{jk}$	Distance from LED $j$ to the center of reflecting element $k$
$d_{ik}$	Distance from center of reflecting element $k$ to the PD $i$
$F$	Total number of LEDs per ADT
$\mathbf{H}(t)$	Channel response matrix
$h_{ij}(t)$	Sum of LOS and NLOS channel gain between LED $j$ and PD $i$
$h_{ij}^{\text{los}}$	LOS channel response from the transmitted LED $j$ to PD $i$
$h_{ij}^{\text{Nlos}}$	NLOS channel response from the transmitted LED $j$ to PD $i$
$h_{ijf}^{\text{los}}$	LOS channel response from the transmitted LED $f$ of ADT $j$ to PD $i$
$h_{ijf}^{\text{Nlos}}$	NLOS channel response from the transmitted LED $f$ of ADT $j$ to PD $i$
$l_j$	Indicator o number of LOS received signals
$K$	Total number of reflected elements
$L$	Number of possible non-repeated sets
$L_x, L_y, L_z$	Length, width, and height of the room, respectively
$m$	Order of Lambertian emission
$M$	Total number of single PD
$N$	Total number of ADTs
$\mathbf{N}(t)$	AWGN matrix
$n_i(t)$	AWGN added to PD $i$
$\hat{n}_i$	Normal vector with the PD
$N_{\text{los}}$	Number of LOS signals
$N_r$	Total number of ADR's PDs
$N_t$	Total number of LEDs
$P_j(t)$	OOK pilot training modulated sequence vector
$P_q(t)$	Pilot training bit
$P_s$	Source optical power
$P_t$	Transmitted Optical Power

$q$	Length of pilot signal
$Q$	Total number of all LEDs for all ADTs
$R$	Photo-detector responsivity
$r$	ADR / ADT circle radius
$R(\phi)$	Lambertian radiant intensity
$\hat{\mathbf{S}}_i$	Estimated pilot pattern
$\hat{S}_{lmn}$	Elements of matrix $\hat{\mathbf{S}}_i$
$\mathbf{S}_i(\mathbf{t})$	Received Pilot signal
SINR	Signal to interference noise ratio
$S_{mn}$	Elements of matrix $\mathbf{S}$
$T_s$	Sampling period
$\mathbf{X}(\mathbf{t})$	Optical intensity-modulated signal matrix for all LEDs
$x_j(\mathbf{t})$	Optical intensity-modulated signal for LED $j$
$X_r, Y_r, Z_r$	Coordinates of the center of the PD body
$\hat{X}_{ML}$	Recovered transmitted signal
$X_i^{PD}, Y_i^{PD}, Z_i^{PD}$	Coordinates of ADR PDs
$x_i, y_i, z_i$	Coordinates of Single PD
$\mathbf{Y}(\mathbf{t})$	Generated photo-current for all PDs
$y_i(\mathbf{t})$	Generated photo-current for PD $i$
$\alpha_{jk}$	The angle of incidence at reflecting element $k$ with respect to LED $j$
$\alpha_{fjk}$	The angle of incidence at reflecting element $k$ with respect to LED $f$ of ADT $j$
$\beta_{ik}$	Irradiance angle at reflecting element $k$ with respect to PD $i$
$\gamma_i$	The azimuth of single PD $i$
$\gamma_f^j$	The azimuth of LED $f$ for ADT $j$
$\gamma_{PD}$	PD azimuth angle
$\gamma_R$	Whole receiver horizontal orientations angle
$\Delta A$	Reflection element area
$\delta_i$	Elevation of single PD
$\delta_{PD}^i$	The total elevation angle of the ADR
$\delta_f^j$	Elevation of LED $f$ for ADT $j$
$\delta_r$	ADR tilting angle
$\delta_{tilt}$	ADR's PDs tilting angle
$\epsilon(H)$	Sum of square error for channel estimation
$\theta_{ij}$	The incident angle at PD $i$ with respect to LED transmitter $j$
$\theta_{ijf}$	The incident angle at PD $i$ with respect to LED transmitter $f$ of ADT $j$
$\theta_{ik}$	The incident angle at PD $i$ with respect to reflecting element $k$
$\rho$	Reflection Coefficient
$\sigma_n^2$	Noise variance
$\sigma_{sh}^2$	Shot noise
$\sigma_{th}^2$	Thermal noise
$\Phi$	Angle of emission
$\phi_{1/2}$	Semi half-angle
$\Phi_{ij}$	The angle of irradiance at the LED transmitter $j$ to PD $i$