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Faculty of Engineering
Department of Electronics and Communication Engineering

Modeling and simulation of IR-UWB Based Industrial WSN

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communications Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other University or Institution.

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CURRICULUM VITAE

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ABSTRACT

Two principal approaches are used to model a given radio wave propagation problem. The first is empirical based on measurements and statistics. Empirical models are easy to implement and fast because they only consider the distance between the transmitter and the receiver but are not accurate enough as different objects of the environment are not taken into consideration. The second is deterministic which exploits physical laws to simulate the signal propagation. Deterministic propagation-prediction models based on a combination of geometrical optics and the uniform theory of diffraction represent the unique solution for reliable estimations. The most famous of the second approach are the well-known ray tracing like models, based on the computation of the different paths according to the geometrical optical laws. The wave flow is represented in terms of rays obeying the Geometrical Theory of Diffraction (GTD) to estimate the power distribution in a given environment.

The propagation channel appears differently to Ultra Wideband (UWB) wireless systems than it does to Narrow Band (NB) sine wave systems.

Two main topics are of interest in the thesis. The first is that the power distribution is obtained as a function of the spatial coordinates to estimate the influence of different channel impairments like reflection and refraction at a given frequency. This is realized via a suitable modeling technique, ray tracing, and a custom simulator, matlab, and a reference open source simulator, Radio Propagation Simulator (RaPSor), for an optimization for the network performance. The second is that the UWB propagation channel statistics are calculated from the channel frequency response at a given reception point. This is simulated using matlab and the results were compared to those from practical experimentation for a typical scenario between a transmitting and a receiving point to estimate the channel transfer function. According to time domain corporation specifications, the bandwidth was selected to cover the 3.1-5.3 GHz band with center frequency 4.3 GHz. That is to account for practical considerations, for any further practical verification, and to make simulation parameters be as close as possible to the PULSON 400 Ranging and Communication Module (RCM) used for auto-survey of distributed sensors and localization systems.

Index Terms:
Propagation models, Deterministic prediction, Ray tracing, Ray launching, Wireless propagation, UWB, Spatial power distribution, Temporal power distribution.

SUMMARY

UWB is a new radio technology that promises to advance high-speed data transfers and enhance the personal area networking industry leading to new innovations and greater quality of services for the end user.

The first objective of the thesis is to certify the correctness of the approach used for simulating a 2D area to estimate the location for a receiving WSN node in a typical environment (spatial distribution).

The second objective is to validate the approach used for a UWB channel in estimating the channel transfer function between the transmitting and receiving nodes in a WSN (temporal distribution).

In Chapter 1, a brief introduction for the whole thesis has been drawn followed by research objectives and the organization of the thesis.

Chapter 2 gives a general overview of UWB technology including definition, historical evolution, UWB system design considerations including regulations and UWB channel followed by an overview of IR-UWB and ends with UWB characteristics.

Chapter 3 introduces the ray tracing concept for channel modeling. This includes propagation models, RT approach and application for RT for practically locating a receiving node in a WSN.

Chapter 4 continues with the UWB channel modeling using RT technique including a survey for the proposed modeling followed by an application of RT to roughly estimate the channel in a UWB environment (the achieved objective is to validate the correctness of the method for approximate estimation of the channel transfer function). At the end of the chapter, the comparison between the simulated and experimental results is presented.

Finally, a conclusion of the thesis and an outlook on the research points and the future work are discussed.

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LIST OF ABBREVIATIONS

AWGN	Additive White Gaussian Noise
CSMA	Carrier-Sense Multiple Access
DAA	Detect And Avoid
DSSS	Direct-Sequence Spread Spectrum
EC	European Commission
EIRP	Effective Isotropic Radiated Power
FCC	Federal Communication Commission
FDTD	Finite Difference Time Domain
GO	Geometrical Optics
GPS	Global Positioning System
GTD	Geometrical Theory of Diffraction
IF	Intermediate Frequency
IR-UWB	Impulse Radio UWB
LO	Local Oscillators
LOS	Line of Sight
MEMS	Micro-Electro-Mechanical Systems
MPC	Multi-Path Component
NB	Narrow Band
NLOS	Non-Line-of Sight
PDP	Power Delay Profile
RaPSor	Radio Propagation Simulator
RCM	Ranging and Communication Module
RSC	Radio Spectrum Committee
RT	Ray Tracing
SNR	Signal to Noise Ratio
S-V	Saleh-Valenzuela
TH	Time-Hopping
UTD	Uniform Theory of Diffraction
UWB	Ultra Wideband
VNA	Vector Network Analyzer
WLAN	Wireless Local-Area Network
WPAN	Wireless Personal-Area Network
WSNs	Wireless Sensor Networks
XML	Extensible Markup Language

LIST OF SYMBOLS

A_{eff}	Effective area of Rx antenna (m^2)
B	Channel bandwidth (Hz)
C	Channel capacity (bits/sec)
D	Largest dimension of Tx/Rx antenna (m)
$\bar{E}(r,\theta,\phi)$	Electric field in (θ,ϕ) direction r-meters away from Tx antenna (V/m)
$\bar{E}_i$	Electric field incident at a dielectric interface (V/m)
$\bar{E}_r$	Electric field reflected from a dielectric interface (V/m)
$\bar{E}_t$	Electric field transmitted through a dielectric interface (V/m)
f_L	Lower cut-off frequency (Hz)
f_H	Upper cut-off frequency (Hz)
f_{step}	Swept frequency step (Hz)
G_R	Rx antenna gain
G_T	Tx antenna gain
$G_\phi(\theta,\phi)$	ϕ-component of Tx antenna gain
$G_\theta(\theta,\phi)$	θ-component of Tx antenna gain
$\bar{H}_i$	Magnetic field incident at a dielectric interface (A/m)
$\bar{H}_r$	Magnetic field reflected from a dielectric interface (A/m)
$\bar{H}_t$	Magnetic field transmitted through a dielectric interface (A/m)
n_i	Refractive index for the incidence medium
n_t	Refractive index for the refraction medium
N_f	Frequency path loss exponent
N_r	Distance path loss exponent
P_R	Power captured by Rx antenna (W)
P_T	Power fed at the input of Tx antenna (W)
$P_T(f)$	Frequency dependent average received power (W)
PL	Path loss (dB)
r_{ff}	Far field distance (m)
S	Power density r-meters away from Tx antenna $(\mathrm{W/m^2})$
T	Transmission coefficient
$t_{channel}$	Channel length (sec)
v	Speed of the electromagnetic waves in the medium (m/sec)

β	Phase constant (rad/m)
Γ	Reflection coefficient
η_o	Intrinsic impedance of free space (120π Ω)
λ	Wavelength (m)
ω	Angular frequency (rad/sec)
ψ_ϕ	Relative phase of the component of the far zone fields in ϕ-direction (rad)
ψ_θ	Relative phase of the component of the far zone fields in θ-direction (rad)
σ_s	Standard deviation (dB)
τ	Time delay constant (sec)
θ_i	Incidence angle (rad)
θ_r	Reflection angle (rad)
θ_t	Refraction angle (rad)

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