DEVELOPMENT OF A NEW RAIN ATTENUATION MODEL FOR THE DEPLOYMENT OF HIGH ALTITUDE PLATFORM STATIONS

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AUTHOR DECLARATION

I hereby declare that the work in this thesis is my own except for some equations which have been duly acknowledged. I declare that it has not been previously submitted to any academic institutions.

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ABSTRAK

Pelemahan hujan adalah sumber utama penyusutan isyarat HAPS, terutamanya bagi sistem yang beroperasi pada frekuensi melebihi 10 GHz. Pelemahan hujan boleh memberi kesan yang besar ke atas ketersediaan perkhidmatan sistem komunikasi radio yang beroperasi di Ka-band; 10 kali lebih besar daripada di C-band.

Model ITU-R pelemahan hujan menggunakan andaian bahawa hujan menembusi sepenuhnya laluan condong. Hakikatnya, laluan isyarat tidak sepenuhnya merentasi hujan, kerana jarak laluan berkesan bergantung kepada saiz sel hujan. Sebuah model yang boleh meramalkan pelemahan hujan bumi-angkasa apabila jalan isyarat sama ada sepenuhnya atau sebahagiannya dipengaruhi oleh hujan dibangunkan.

Bagi mewujudkan infrastruktur lengkap sistem komunikasi tanpa wayar, satelit boleh disepadukan dengan HAPS untuk menyediakan keupayaan yang tinggi untuk perkhidmatan. Oleh itu, model baru telah dibangunkan untuk meramalkan pelemahan hujan untuk sumber-sumber yang tidak bergerak seperti satelit Orbit Bumi Sederhana (MEO) dan Orbit Rendah Bumi (LEO). Kaedah baru untuk meramalkan pelemahan hujan untuk sumber-sumber bukan pegun juga dicadangkan. Kaedah ini menggunakan teorem 'konvolusi' untuk mengintegrasikan pelemahan hujan keseluruhan isyarat yang menembusi ke dalam hujan.

Berdasarkan 13 tahun data statistik hujan dengan masa integrasi selama 1 minit, penilaian terhadap ramalan pelemahan hujan telah dijalankan bagi rantau Semenanjung Malaysia bertujuan mengenal pasti lokasi terbaik untuk segmen stratosfera HAPS. Kajian ini dilaksanakan terhadap 10 stesen bumi yang menerima keamatan hujan tertinggi. Lokasi terbaik untuk bahagian utara dan platform selatan didapati berada di 4.11° N, 102.88° E, dan 2.23° N, 102.02° E masing-masing, di mana kedudukan terbaik segmen stratosfera telah dikaji dengan menggunakan matriks 10 * 10.

ABSTRACT

Rain attenuation is the primary source of High Altitude Platform Station's (HAPS) signal degradation, especially for the systems operating at frequencies above 10 GHz. Rain attenuation can have a significant impact on the service availability of radio communication systems that operate in the Ka-band where the rain attenuation is 10 times larger than at C-band.

ITU-R rain attenuation model assumes that the entire slant path is completely penetrated by rain, while in reality the signal path does not completely traverse the rain, because the length of the effective path depends on the rain cell size. A model that can predict the earth-space rain attenuation when the signal path is either completely or partially affected by the rain is developed.

To implement a complete infrastructure for wireless communications, a satellite can be integrated with HAPS to provide a high capability for the services. Therefore, a new model has been presented to predict the rain attenuation for non-stationary satellites such as the Medium Earth Orbit (MEO) and Low Earth Orbit (LEO). For verification, a new method to predict the rain attenuation for non-stationary sources is proposed. The method uses the convolution theorem to integrate the rain attenuation overall the signal which penetrated into the rain.

Based on thirteen years statistical rainfall data with an integration time of one min, an evaluation of predicting the rain attenuation has been conducted for the peninsular Malaysian region to identify the best location for placing the HAPS stratospheric segment. The study was done based on ten ground stations that suffer the highest rainfall intensities on the ground. The best locations for the northern and the southern platform were found to be at Sungai Lembing (4.11° N, 102.88° E), and Tanjung Kling (2.23° N, 102.02° E) respectively, where the best position of the stratospheric segment was investigated using a matrix of 10*10.

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ABBREVIATION

HAPS	High Altitude Platform Station/System
HALE	High Altitude Long Endurance
SPFs	Stratospheric Platforms
ITU-R	The International Telecommunication Union for Radio
CCIR	International Radio Consultative Committee
VPI	Virginia Polytechnic Institute
SU	State University
GHz	Gigahertz
EIRP	Effective Isotropic Radiated Power
MHz	Megahertz
H_2O	Water
O_2	Oxygen
UAC	Urban Area Coverage
SAC	Suburban Area Coverage
RAC	Rural Area Coverage
km	Kilometer
LOS	Line of Sight
ICT	Information and Communication Technology
IPLs	Inter-Platform Links
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
GEO	Geo-Stationary Earth Orbit
GPS	Global Positioning System
SAM	Simple Attenuation Model
dB	Decibel
CRC	Communication Research Center
mm	Millimeter
hr	Hour

DSD	Drop Size Distribution
MMD	Malaysian Metrological Department
MMO	Malaysia Meteorological Office
ES	Earth Station
SPP	Sub-Platform Point

LIST OF SYMBOLS

$A_{0.01}$	Predicted attenuation exceeded 0.01% of time in average year
C_S	Cloud speed
d	Separation between the two sites
d_R	Distance between the initial position of where the signal touched the cloud at the first moment of the penetration, and the edge of the rain cell
$EIRP$	Equivalent isotropic radiated power
F	Operational frequency
G_r	Receiver antenna gain
G_t	Transmitter antenna gain
$g(x')$	Specific attenuation for convolution model
H_0	Mean isotherm height above mean sea level
h_R	Rain height
h_S	Height above mean sea level of the earth station
$h(x')$	Effective slant path penetrated into the rain for convolution model
k	Power law parameter, which depends on polarization and frequency
L_1	Slant path penetrated in rain
L_E	Effective path length affected by the rain
L_{fs}	Free space loss
L_G	Horizontal projection of the slant path
L_s	Slant path length under the rain

L_{s3}	Slant path length under the rain
N_D	Number of raindrops
N_0	Fitting parameter for marshal-palmer model
P_r	Received power
P_t	Transmitted power
Q_t	Attenuation cross-section
$\mathrm{R}_{0.01}$	Horizontal reduction factor
$R_{0.01}$	Rainfall rate exceeded for 0.01% of time in average year
RC	Rain cell size
$\mathrm{R_E}$	Effective radius of the earth
S_S	Satellite speed
τ	Polarization tilt angle relative to the horizontal
$\mathrm{V}_{0.01}$	Vertical reduction factor
$v(D)$	Raindrop velocity
x	Horizontal projection of the non-affected path
α	Power law parameter, which depends on polarization and frequency
γ_R	Specific attenuation
Λ	Fitting parameter for marshal-palmer model
Ψ	Angle made by the azimuth of the propagation path
θ	Elevation angle (degrees)
φ	Latitude of the earth station (degree)

LIST OF APPENDIXES