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กับดาวเทียม เนื่องจากฝนในภูมิภาคเอเชียตะวันออกเฉียงใต้

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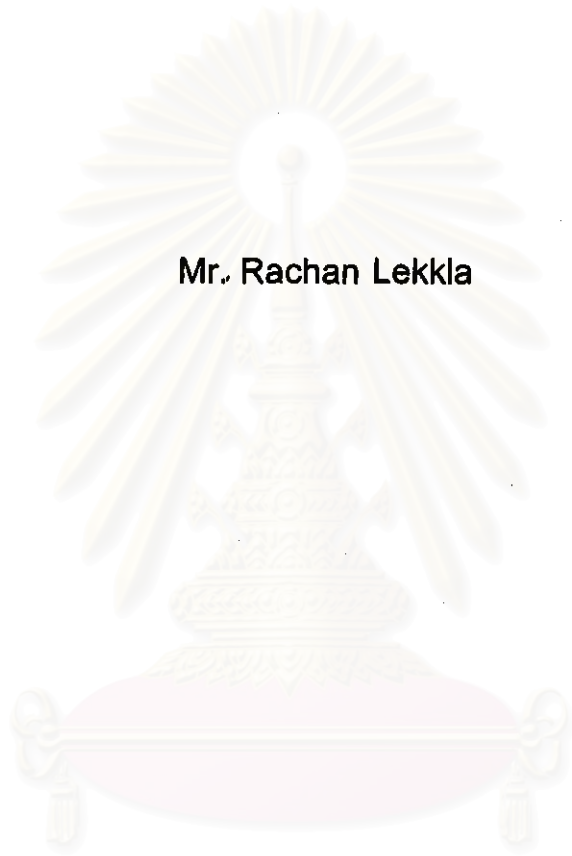
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**Analysis of Ku-band Rain Attenuation on Earth-Satellite Paths
in the Southeast Asia Region**

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สถาบันวิทยบริการ
จุฬาลงกรณ์มหาวิทยาลัย

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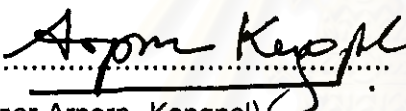
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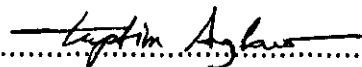
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งานวิจัยนี้เน้นถึงการศึกษาการลดทอนสัญญาณความถี่ 12GHz และความเข้มของฝนในเขตเอเชียตะวันออกเฉียงใต้โดยใช้ข้อมูลจากโครงการ Canada ASEAN Cooperation in the Ku-band Propagation Measurement Program on Earth-space Paths ข้อมูลการวัดประมาณ 3 ปี ในประเทศอินโดนีเซีย ประเทศสิงคโปร์ และประเทศไทย ถูกนำมาวิเคราะห์เพื่อให้เข้าใจถึงคุณลักษณะของการลดทอนสัญญาณและความเข้มของฝน ความรู้ที่ได้จากการวิเคราะห์นี้ ก็จะถูกนำมาใช้ในการพัฒนาการทำนายสถิติช่วงเวลารลดทอนสัญญาณ และสถิติการลดทอนสัญญาณทุก 2 ชั่วโมงในแต่ละวันซึ่งการทำนายที่แม่นยำนี้อาจยังไม่ได้มีการเผยแพร่มาก่อน

ผลการศึกษารวบรวมข้อมูลทั้งสิ้นประมาณ 24 ปี สามารถสรุปได้ดังนี้ 1) สถิติการแจกแจงการลดทอนสัญญาณสะสมจากการวัดในภูมิภาคเอเชียตะวันออกเฉียงใต้ เมื่อเปรียบเทียบกับแบบจำลองการทำนายการลดทอนสัญญาณในปัจจุบันพบว่าไม่มีแบบจำลองใด ๆ ให้ ผลลัพธ์สอดคล้องกับผลการวัดได้ อย่างไรก็ตามสถิติการแจกแจงแบบ Log-normal ให้ค่าใกล้เคียงกับข้อมูลการวัดทั้ง 4 ที่มากที่สุด 2) สถิติการแจกแจงความเข้มของฝนสะสมสามารถแทนได้ด้วยสถิติการแจกแจงแบบ Negative Exponential 3) สถิติการแจกแจงช่วงเวลารลดทอนสัญญาณสามารถแทนได้ด้วยสถิติการแจกแจงแบบ Double Exponential 4) สถิติการเปลี่ยนแปลงการลดทอนสัญญาณในแต่ละวันมีความสอดคล้องกับสถิติปริมาณฝนตกรายชั่วโมง 5) แบบจำลองการทำนายการลดทอนสัญญาณเนื่องจากฝนทุก 2 ชั่วโมงโดยใช้ความรู้จากการวิเคราะห์การเปลี่ยนแปลงการลดทอนสัญญาณ สถิติปริมาณฝนตกในแต่ละชั่วโมง และสถิติการแจกแจงแบบ Log-normal ที่ได้คิดค้นขึ้นนี้ ได้ถูกทดสอบกับข้อมูลการวัดจริง พบว่าแบบจำลองดังกล่าวสามารถนำไปประยุกต์ออกแบบระบบสื่อสารผ่านดาวเทียมเคยูแบนด์ได้โดยเฉพาะในบริเวณที่มีฝนตกชุกในเขตเอเชียตะวันออกเฉียงใต้

สถาบันวิทยบริการ
จุฬาลงกรณ์มหาวิทยาลัย

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ลายมือชื่อนิติ
ลายมือชื่ออาจารย์ที่ปรึกษา
ลายมือชื่ออาจารย์ที่ปรึกษาร่วม K. S. McCormick

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RACHAN LEKKLA : ANALYSIS OF KU-BAND RAIN ATTENUATION ON EARTH-SATELLITE PATH IN THE SOUTHEAST ASIA REGION. THESIS ADVISOR; PROF. PRASIT PRAPINMONGKOLKARN, Ph.D. THESIS CO-ADVISOR; STEWARD MCCORMICK, Ph.D, PRITI HETRAKUL, Ph.D. 194 pp, ISBN 974-639-037-6

This research is mainly concentrated on the study of 12 GHz rain attenuation along an earth-satellite path and point-rainfall intensity in Southeast Asia using the data from the "Canada-ASEAN Cooperation in the Ku-band Propagation Measurement Program on Earth-space Paths". Three years of measured data in Indonesia, Singapore, and Thailand were analyzed to obtain the knowledge of rain attenuation and rainfall intensity characteristics. The knowledge from these analysis are applied to develop a powerful model to predict fade-duration statistics and rain attenuation distribution at least every 2 hours of the day that has never been reported before.

Results of 24-year-data study can be summarized as follows: 1) the measured cumulative distributions of rain attenuation over a three-year period between February 1992 and March 1995 in Southeast Asia disagree with all prediction models, but the log-normal distribution proves to be more reasonably fitted to data of all experimental sites, 2) the measured cumulative distributions of rain intensity agree very well with the negative exponential distribution, 3) the fade duration distributions fit very well with the double exponential distribution, 4) the diurnal variations of rain attenuation statistics at all locations are well correlated with one-hour rainfall statistics, 5) the new model that predicts rain fade every two hours utilizing the knowledge of the diurnal variations statistics of rain attenuation and rainfall associated with the log-normal distribution, was developed and evaluated. Finally, it is found very useful for the design of Ku-band satellite communication system especially in the heavy rainfall regime of Southeast Asia.

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จุฬาลงกรณ์มหาวิทยาลัย

ภาควิชา ๖๐๖.๐๐๐.๐๐๐

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ลายมือชื่อนิติคุณ

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สถาบันวิทยบริการ
จุฬาลงกรณ์มหาวิทยาลัย

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LIST OF SYMBOLS

| SYMBOLS | DESCRIPTIONS |
|--------------------|---|
| α | specific attenuation in dB/km |
| α | threshold Attenuation in dB |
| β | ratio of convective rain:fall of Rice and Holmberg rainfall rate model |
| λ | wave length in meter |
| κ, Λ | the constants of specific attenuation |
| σ | the fraction of transmissivity |
| γ | threshold rain intensity in mm/h |
| ρ, μ | the fitted parameters of the exponential distribution of rain intensity distribution |
| ϕ, θ | empirical constants of ITU-R 732 model for worst month distribution |
| a, b, d | the fitted constants of double exponential distribution of fade duration distribution |
| i | the number of hour-interval |
| m | refractive index |
| n | number of selected hour-interval of a day |
| $n(a)d(a)$ | Drop size distribution |
| $n(a)$ | number of rain drop |
| $v(a)$ | raindrop velocity |
| x, y | the fitted constant of the power-law distribution of cumulative rain attenuation distribution |
| A | measured attenuation in dB |
| A(p) | measured attenuation at percentage time "p" |
| B_i | event of rain intensity exceeding threshold in i'th hour interval |
| D | fade duration time in seconds |
| D_q | threshold fade duration time in seconds |
| $F_y(\alpha), P_y$ | average or annual cumulative distribution of rain attenuation |
| $F_{Hi}(\alpha)$ | average cumulative distribution of rain attenuation in i'th hour interval |
| H_i | event of rain attenuation exceeding threshold in the i'th hour interval |
| M_1 | High rainfall rate with thunderstorms |
| M_2 | High rainfall rate without thunderstorms |
| $L_{eff}(p)$ | effective path length at percentage time "p" |
| P_w | average worst month distribution |
| $P(Y)$ | probability of event Y |
| $P(H Y)$ | conditional probability of event H given Y is known |
| $P(H,Y)$ | Joint probability of event H and event Y |

SYMBOLS

DESCRIPTIONS

| | |
|--------------------|--|
| R | observed rain intensity in mm/h |
| R _i | event of rainfall in i'th hour interval |
| T _s | increasing noise temperature in degree Kelvin |
| T _m | effective medium temperature in degree Kelvin |
| T _{sp} | atmospheric noise temperature in degree kelvin |
| T _{earth} | earth noise temperature in degree kelvin |
| T _{cs} | clear sky noise temperature in degree kelvin |
| T _{total} | total observation times |
| Y | event of rain attenuation exceeding threshold in all observation periods |
| Z | event of rainfall in 24 hours or all observation periods |



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LIST OF ABBREVIATIONS

| | |
|----------|---|
| ACTS | Advance Communications Technology Satellite |
| ASEAN | Association of Southeast Asia Nation |
| BER | Bit Error Rate |
| C/No | Carrier-to-noise Density |
| CAT | Communications Authority of Thailand |
| CCIR | International Radio Consultative Committee |
| CETUC | Catholic University of Rio de Janeiro, Brazil |
| CIDA | Canadian International Development Agency |
| COR | Correlation Coefficient |
| COV | Covariance of Variation |
| CRC | Communications Research Centre |
| DTH | Direct-to-Home |
| E/S | Earth Station |
| EIRP | Equivalent Isotropic Radiated Power |
| G/T | Gain-to-Noise Temperature |
| GPO | General Post Office |
| INTELSAT | International Telecommunications Satellite Organization |
| ISDN | Integrated Services Digital Network |
| ITCZ | Inter-tropical Convergence Zone |
| ITALSAT | Italian Communications Satellite System |
| ITU-R | International Telecommunication Union - Radiocommunication Sector |
| ITU-T | International Telecommunication Union - Transmission Sector |
| MEASAT | Malaysian Satellite System |
| NASA | National American Space Agency |
| OLYMPUS | European Satellite System |
| PALAPA | Indonesian Satellite System |
| RAM | Random Access Memory |
| THAICOM | Thai Communication Satellite System |
| VSAT | Very Small Aperture Terminal |