Scopus

Documents

Alam, M.M.[a b c] , Islam, M.R.[c] , Koohestani, M.[b d] , Elsheikh, E.A.A.[e]

Prediction of Time Diversity Gain for Earth-to-Satellite Microwave Link Design Based on Real Time Rain Intensity Measurement

(2023) *IEEE Access*, 11, pp. 53588-53597.

DOI: 10.1109/ACCESS.2023.3249962

[a] Institut National des Sciences Appliquees, University of Rennes 1, Rennes, 35708, France
[b] ESEO School of Engineering, Department of Electrical and Electronic Engineering, Angers, 49100, France
[c] International Islamic University Malaysia (IIUM), Kulliyyah of Engineering, Department of Electrical and Computer Engineering, Kuala Lumpur, 53100, Malaysia
[d] Institute of Electronics and Telecommunications of Rennes (IETR), University of Rennes 1, Rennes, 35042, France
[e] King Khalid University, College of Engineering, Department of Electrical Engineering, Abha, 62529, Saudi Arabia

Abstract
The propagation impairments by rain strongly affect the earth-to-satellite links operating at frequencies higher than 18 GHz mainly due to the severe performance degradation of satellite communication system. The time diversity technique with appropriate time delay between successive transmissions has been found effective in mitigating the rain fade. However, time diversity analysis demands measured rain attenuation data, where the latter is unavailable at most of the places to be able to design future high frequency links. The time diversity gain prediction model has been found to be robust for time diversity improvement. Here, we propose a new model for the rain rate with and without the time delay considering the three variables of rain rate, time delay and frequency. The rain rate and time delay functions were first used to derive the constants by the regression from the rain rate and rain rate gain. The constant for the frequency function was then extracted from the cumulative distribution function of the attenuation predicted by the analytically obtained ITU-R and gain equations. The proposed model was validated using one-year rain rate and attenuation data measured at two different locations in Malaysia demonstrating a 7% prediction inaccuracy when compared to the existing models, therefore, it can be reliably used for future earth-to-satellite link designs by using measured rain rate at any higher frequencies. © 2013 IEEE.

Author Keywords
rain attenuation; Rain rate; time delay; time diversity technique

Index Keywords
Distribution functions, Electromagnetic wave attenuation, Forecasting, Frequency bands, Interactive computer systems, Rain, Satellite communication systems, Satellite links, Satellites, Time delay, Time measurement; Attenuation, Attenuation measurements, Delay effects, Diversity techniques, Predictive methods, Rain attenuation, Rain rates, Real - Time system, Satellite communications, Time diversity, Time diversity technique, Time-delays; Real time systems

References

- Kourogiorgas, C.I., Panagopoulos, A.D., Livieratos, S.N., Chatzarakis, G.E.
  Time diversity prediction modeling using copula functions for satellite communication systems operating above 10 GHz
  (2014) *Proc. 31st Gen. Assem. Sci. Symp. (URSI GASS)*, pp. 10-14.
  Aug.

- Shrestha, S., Choi, D.-Y.
  Diurnal and monthly variations of rain rate and rain attenuation on Ka-band satellite communication in South Korea
  (2018) *Prog. Electromagn. Res. B*, 80, pp. 151-171.

- Ismail, A.F., Din, J., Tharek, A.R., Islam, M.R., Abdullah, K.
  Analyses of rain fade countermeasure technique time diversity at 26 GHz
  (2012) *Proc. Ieee Asia-Pacific Conf. Antennas Propag.*, pp. 217-218.
  Aug.

- Arapoglou, P.-D.-M., Panagopoulos, A.D., Cottis, P.G.
  An analytical prediction model of time diversity performance for Earth-space fade

mitigation
(2008) *Int. J. Antennas Propag.*, 2008, pp. 1-5.
Jan.

- Kourogiorgas, C.I., Livieratos, S.N., Panagopoulos, A.D., Chatzarakis, G.E.
Modeling of joint rainfall rate and rain attenuation statistics using Archimedean copula functions
(2014) *Proc. 8th Eur. Conf. Antennas Propag. (EuCAP)*, pp. 509-512.
Apr.

- Pan, Q.W., Allnutt, J.E., Tsui, C.
Evaluation of diversity and power control techniques for satellite communication systems in tropical and equatorial rain climates
(2008) *Ieee Trans. Antennas Propag.*, 56 (10), pp. 3293-3301.
Oct.

- Ippolito, L.J.
Radio propagation for space communications systems
(1981) *Proc. Ieee*, 69 (6), pp. 697-727.
Jun.

- Udofia, K.M., Otung, I.E.
Evaluating time diversity performance on an on-board processing satellite to Earth station downlink
(2008) *Proc. 2nd Int. Conf. Next Gener. Mobile Appl., Services, Technol.*, pp. 325-330.
Sep.

- Kotamraju, S.K., Korada, C.S.K.
Precipitation and other propagation impairments effects at microwave and millimeter wave bands: A mini survey
(2019) *Acta Geophys.*, 67 (2), pp. 703-719.
Apr.

- Ventouras, S., Callaghan, S.A., Wrench, C.L.
Long-Term statistics of tropospheric attenuation from the Ka/U band ITALSAT satellite experiment in the United Kingdom
(2006) *Radio Sci.*, 41 (2), pp. 1-19.
Apr.

- Pimienta-Del-Valle, D., Riera, J.M., Garcia-Del-Pino, P.
Time and orbital diversity assessment with Ka-And Q-band slant-path propagation experiments in Madrid
(2019) *Ieee Trans. Antennas Propag.*, 67 (2), pp. 1193-1201.
Feb.

- Matricciani, E.
Time diversity in satellite links affected by rain: Prediction of the gain at different localities
(2007) *Proc. 2nd Eur. Conf. Antennas Propag. (EuCAP)*, pp. 1-5.
Nov.

- Saad, N.W.M., Ismail, A.F., Badron, K., Sobli, N.H.M., Din, J., Rahman, T.A.
Assessments of time diversity rain fade mitigation technique for V-band space-Earth link operating in tropical climate
(2013) *Int. J. Electr. Energy*, 1 (4), pp. 268-273.

- Fukuchi, H., Saito, T.
Novel mitigation technologies for rain attenuation in broadband satellite communication system using from Kato W-band
(2007) *Proc. 6th Int. Conf. Inf., Commun., Signal Process.*, pp. 8-12.
Dec.

- Ng, Y.-Y., Singh, M.S.J., Thiruchelvam, V.
Performance analysis of 60-min to 1-min integration time rain rate conversion models in Malaysia
(2018) *J. Atmos. Sol.-Terr. Phys.*, 167, pp. 13-22.
Jan.

- Garcia-Del-Pino, P., Benarroch, A., Riera, J.M.
Comparison of recent rainfall rate models using Spanish data
(2014) *Proc. 8th Eur. Conf. Antennas Propag. (EuCAP)*, pp. 42-45.
Apr.

- Alam, M.M., Rafiqul, I.M., Badron, K., Farah, D.A.R., Lwas, A.K., Dao, H.
Time diversity gain analysis for Earth to satellite link based on measured rain rate
(2018) *Proc. 7th Int. Conf. Comput. Commun. Eng. (ICCCE)*, pp. 109-113.
Sep.

- Matricciani, E.
Probability distributions of rain attenuation obtainable with linear combining techniques in space-To-Earth links using time diversity
(2018) *Int. J. Satell. Commun. Netw.*, 36 (2), pp. 220-237.
Mar./Apr.

- Matricciani, E.
Time diversity as a rain attenuation countermeasure in satellite links in the 10-100 GHz frequency bands
(2006) *Proc. 1st Eur. Conf. Antennas Propag. (ESASP)*, pp. 1-6.
Nov.

- Hodge, D.B.
An improved model for diversity gain on Earth-space propagation paths
(1982) *Radio Sci.*, 17 (6), pp. 1393-1399.
Nov./Dec.

- (2015) *Propagation Data and Prediction Methods Required for the Design of Earth-Space Telecommunication Systems*,
document ITU-R 618-12

- (2013) *Rain Height Model for Prediction Mrthods*,
document ITU-R P.839-4

- (2017) *Characteristics of Precipitation for Propagation Modelling*, 6.
document ITU-R 837-7

- (2005) *Specific Attenuation Model for Rain for Use in Prediction Methods*, pp. 1-5.
document ITU-R 838-3

- (2021) *Acquisition Presentation and Analysis of Data in Studies of Tropospheric Propagation*, pp. 311-318.
document ITU-R 311-18

- Matricciani, E.
Global formulation of the synthetic storm technique to calculate rain attenuation only from rain rate probability distributions
(2008) *Proc. Ieee Antennas Propag. Soc. Int. Symp.*, pp. 1-4.
Jul.

- Alam, M.M., Rafiqul, I.M., Badron, K., Dyana, R.A.F., Dao, H., Hassan, M.R., Lwas, A.K.
Investigation of time diversity gain for Earth to satellite link using rain rate gain
(2019) *Bull. Electr. Eng. Informat.*, 8 (3), pp. 951-959.
Sep.

- Lwas, A.K., Islam, M.R., Habaebi, M.H., Mandeep, S.J., Ismail, A.F., Zyoud, A.
Effects of wind velocity on slant path rain-Attenuation for satellite application in Malaysia
(2015) *Acta Astronaut.*, 117, pp. 402-407.
Dec.

- Alam, M.M., Hasan, M.R., Islam, M.R., Habaebi, M.H., Basahel, A., Singh, M.
Prediction of time diversity gain-comparison between ITU-R P. 618-13 using a concept of rain rate with delay and synthetic storm technique
(2022) *Int. J. Interact. Mobile Technol.*, 16 (11), pp. 178-192.

- Ismail, A.F., Watson, P.A.
Characteristics of fading and fade countermeasures on a satellite-Earth link operating in an equatorial climate, with reference to broadcast applications
(2000) *Ieee Proc. Microw., Antennas Propag.*, 147 (5), pp. 369-373.
Nov.

- Alam, M.M., Islam, M.R., Salam, M.A., Muhammad, N.
Prediction of rain rate distribution with time delay based on measured 1-min rain intensity data to mitigate fades on satellite link
(2018) *Proc. 7th Brunei Int. Conf. Eng. Technol. (BICET)*, pp. 1-4.
Nov.

- Rafiqul, I.M., Lwas, A.K., Habaebi, M.H., Alam, M.M., Chebil, J., Mandeep, J.S., Zyoud, A.
Analysis of time diversity gain for satellite communication link based on Ku-band rain attenuation data measured in Malaysia
(2018) *Int. J. Elect. Comput. Eng.*, 8 (4), pp. 2608-2613.

Correspondence Address
Alam M.M.; Institut National des Sciences Appliquees, University of Rennes 1, France

Publisher: Institute of Electrical and Electronics Engineers Inc.

ISSN: 21693536
Language of Original Document: English
Abbreviated Source Title: IEEE Access
2-s2.0-85149397144
Document Type: Article
Publication Stage: Final
Source: Scopus