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# Measurement of Wet Antenna Losses on 26 GHz Terrestrial Microwave Link in Malaysia

**S. K. A. Rahim · A. Y. Abdulrahman · T. A. Rahman · M. R. Ul Islam**

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**Abstract** This letter discusses the effect of antenna losses due to rain on a 26 GHz microwave link and the technique of extracting the losses from the measured rain attenuation. A 2-feet parabolic dish antenna with horizontal polarization has been used in the study. The measurement results have been compared with those obtained from other locations in Malaysia and some other Published Research works. The study will provide useful information in the microwave link planning and design in tropical regions; and it can also be adapted to satellite communication operating at ka-band.

**Keywords** Wet antenna losses · Link budget · Tropical climates · Rain attenuation

## 1 Introduction

It was first discovered during the Advanced Communication Technology Satellite (ACTS) Propagation Experiment that the ACTS propagation terminal (APT) antennas are sensitive to rain water (and dew) on both the antenna reflector surface and the feed window [1]. That is, the rain attenuation data usually contain some other losses like scintillation and rain effects on the antenna. The amount of water on the wet antenna can cause additional signal losses up to few decibels. These losses are unwanted and must therefore be filtered out in order to accurately estimate the desired rain attenuation due to the propagation path. In this letter we present the results obtained from a series of wet antenna testing conducted on the 26 GHz experimental microwave link at Universiti Teknologi Malaysia (UTM), Malaysia.

S. K. A. Rahim · A. Y. Abdulrahman (✉) · T. A. Rahman · M. R. U. Islam
Wireless Communication Centre (WCC), Fakulti of Electrical Engineering,
Universiti Teknologi Malaysia (UTM), 81310 Skudai-Johor, Malaysia
e-mail: abdulrahman.yusuf@yahoo.com

## 2 The Effects of Rain on Antenna

Wet antenna attenuation depends on antenna direction, the dish size, rainfall rate, materials and wetting conditions of antenna radome, reflector surfaces and radome thickness [2]. Other factors include frequency of radio wave and elevation angle [3]. The Gibble's formulation for a laminar flow, where the water thickness is predicted to be random all over the radome, is given by the following expression [4]:

$$t = \left[\frac{3\mu_S r_A}{2g}\right]^{1/3} \tag{1}$$

where t is the water layer thickness on the hemispherical radome, $r_A$ is the radius of the radome in the rain field, R; $\mu_S$ is the specific viscosity of water (typically, $10^{-6}m^2/s$) and the gravitational acceleration, $g = 9.8m^2/s$. From an experiment conducted on a 20 GHz transmission link, losses of up to 8 dB had been recorded under the assumption that the water layer thickness is uniform over the radome. In most of the results reported by researchers on ACTS Propagation experiments, the attenuation values due to water droplets on the feed were generally less than 0.3 dB; while the attenuation due to water droplets on the reflector could be up to 8 dB depending on frequency, direction of the antenna, roughness of the reflector surface and so on [5,6]. According to [7] the wet antenna could produce up to 8 dB additional loss. In a similar propagation studies conducted using a water sheet of 0.03 inches thickness, the attenuation due to the wet reflector surface at 12.2 GHz was about 10 dB [8].

## 3 Methodology

The link was set between Wireless Communication Research Laboratory (WCRL) and the Base Transmit Station (BTS) tower, at a separation distance of 300 m within UTM, Malaysia (Lat.: 1.45°N and Long.: 103.75°E). The microwave system consists of a microwave MINI-LINK operating at 26 GHz with horizontal polarization and data acquisition and processing system. The experimental link employs 2-feet parabolic dish antennas for both transmit and receive sides and has availability of 99.5%. Both antennas are horizontally polarized (that is, the elevation angle is approximately zero degrees) and they were covered with radome during rain attenuation measurement. The link budget parameters are as follows: maximum transmit power is +18:0 dBm; frequency band is 24.5–26.5 GHz; antennas' gain and size for both transmit and receive sides (0.6 m, 37.0 dBi).

The AGC level of received signal has been sampled and recorded every second for the microwave link. A Casella rain gauge, fitted with a programmable data logger, was positioned very close to the receiving antenna for the purpose of recording the simulated rain rate data. The gauge is of tipping bucket type and the bucket size is 0.5 mm of rain. The tipping time could not be recorded, but the number of tips was recorded and stored in the built-in data logger of the rain gauge. The sensitivity of the rain gauge is 0.5 mm/ min and the availability is 100%. The duration of measurement is 1 year.

The cumulative distributions (CDFs) of total rain attenuation and rain rate data at respective percentages of time rain rate is exceeded in a year are shown in Table 1.

The total attenuation data presented in Table 1 consist of the measured excess attenuation and the wet antenna factor; which must be subtracted in order to predict the attenuation losses accurately.

**Table 1** The measured total rain attenuation and rain rate data from UTM-Skudai

| Percentage of time (%) | 0.001 | 0.003 | 0.01 | 0.3 | 0.1 | 0.3 | 1.0 |
|---|---|---|---|---|---|---|---|
| Rain attenuation (dB) | 17 | 14 | 11 | 9 | 6 | 4 | 1.32 |
| Rain rate ( mm/h) | 177 | 153 | 125 | 91 | 52 | 38 | 22 |

### 3.1 Wet Antenna Experiments

Four types of wet antenna experiments have been carried out on the 26 GHz experimental link in UTM, Malaysia. The tests were carried out on clear-sky weather conditions, when there were no rain impairments, scintillations and other atmospheric absorptions along the propagation path.

The first test was performed by simulating the coverage of tiny little drops of water during light drizzling. The water droplets were sprayed from a fine water sprayer to create a uniform distribution on the radome surface. The second test was simulating the down-flow of water droplets a few millimeters wide, vertically across the surface of the radome. In order to produce a stream of water, the sprayer was adjusted to create dry spaces between the rivulets thereby allowing water to flow down the radome surface. In the third test, a thin layer of water was applied on the radome surface by using a piece of cloth for wiping the whole surface of the radome. The fourth test was simulation of a heavy rain rate whereby the sprayed water formed a thick layer (approximately 0.25–0.3 mm) and flowing down across the radome surface. This was achieved by splashing water on the radome. For each test, the spraying process was repeated thrice after the surface dried out.

### 3.2 Statistical Analysis of Wet Antenna Losses

According to [4], the predicted rain attenuation exceeded for p% of an average year is obtained from:

$$A_{R\%p} = \gamma_{R\%p} L_T r_{d\%p} + A_W \tag{2}$$

where $\gamma_{R\%p}$ is the specific attenuation (dB/km) and $r_{d\%p}$ is the reduction factor at the p percent of time. The value of $\gamma_{R\%p}$ depends on the rain rate, $R_{\%p}$ exceeded at p% in an average year, and ITU-R parameters: k and $\alpha$ that depend on frequency, rain temperature, and polarization [9]. Reduction factor is equal to 1.0 since the link is 0.3 km and $A_W$ is the wet antenna loss on both antennas during rain. That is,

$$A_W = A_{W,\text{transmit}} + A_{W,\text{receive}} \tag{3}$$

The losses are expressed as the difference between the received signal level of the dry antenna and the receive signal level of the wet antenna. That is,

$$A_W = RSL_{dry} - RSL_{wet} \tag{4}$$

The difference in the two measurements accounts for the wet antenna factor as stated in Eq. (4). The wet antenna attenuation $A_{W0.01}$ exceeded for 0.01% of an average year were measured for different spraying tests, as shown in Table 2.The attenuation to be exceeded for other percentages, p of an average year may be calculated from the value of $A_{W0.01}$ by using the following [10]:

$$A_{W\%p} = 0.12 \cdot A_{W0.01} \cdot p^{(-(0.546+0.043 \cdot \log 10(p)))} \tag{5}$$

**Table 2** Results of wet antenna testing at UTM, Malaysia at 26 GHz

| Test type conducted | Wet antenna attenuation (dB) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.001 | 0.003 | 0.01 | 0.03 | 0.1 | 0.3 | 1.0 |
| Splashing | 5.5610 | 3.9624 | 2.5951 | 1.6824 | 0.9953 | 0.5860 | 0.3120 |
| Sheeting | 3.6361 | 2.5908 | 1.6968 | 1.1000 | 0.6496 | 0.3831 | 0.2040 |
| Rivulet | 1.4972 | 1.0668 | 0.6987 | 0.4529 | 0.2675 | 0.1578 | 0.0840 |
| Droplet | 0.8555 | 0.6069 | 0.3992 | 0.2588 | 0.1528 | 0.0902 | 0.0480 |

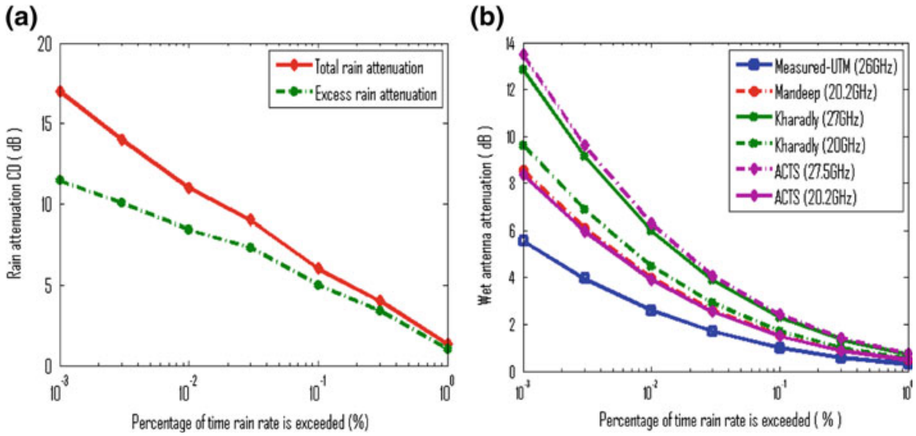


**Fig. 1** Comparison of **a** 1 year rain attenuation CDF of the total and excess rain attenuation, **b** measured wet antenna attenuation at UTM with other locations

The wet antenna losses were in the range of 0.4 dB (droplet tests) to 3 dB (splashing tests) at 0.01% of time rain attenuation is exceeded. The comparison of 1 year rain attenuation CDFs for the total and excess rain attenuation over the 26 GHz link are presented in Fig. 1a. While Fig. 1b presents the comparison of the measured wet antenna attenuation at UTM with other locations.

From Fig. 1b, it can be clearly seen that at 0.01 percent of time, the maximum wet antenna losses recorded (with the splashing test) were approximately 2.6 dB. This value is comparable with similar tests carried out at Universiti Sains Malaysia (USM), Malaysia; and some other published research works at University of British Colombia (UBC), Colombia [11]. For instance, at 0.01% of time, the maximum wetting antenna losses recorded at UTM, Malaysia was 2.6 dB. For UBC, Columbia, the losses are 6 and 4.5 dB on the 27 and 20.2 GHz links, respectively. Also, for USM, Malaysia, the average attenuation value is 4 dB (on the 20.2 GHz link). Finally, for the ACTS propagation experiments, the wet antenna attenuation values are 6.3 dB (on 27.5 GHz link) and 3.9 dB (20.2 GHz link).

This slight difference in our results may be due the following reasons. First, the thickness of water layers on radome and reflector surface used by other researchers might have resulted in higher values. For instance, at USM, the thickness of water used was 20 inches; compared to approximately, between 0.009 and 0.012 inches used in our tests. Another possible reason is that a 0.6 m parabolic dish has been used in this study and the link length is 0.3 km, whereas smaller diameter dishes (0.3–0.35 m) were used by other researchers. Moreover, our study was focused on terrestrial microwave applications and therefore horizontal polarization has been used for the two interacting antennas. While for the results compared, the application is targeted for satellite propagation and therefore other forms of polarization have been used.

## 4 Conclusion

The wet antenna loss could be considered as the main reason for higher measured attenuation as compared to the predicted models. Therefore, the estimation of wet antenna effects is crucial to microwave designers as it allows the discrimination of losses due to wet antenna effect from rain attenuation due to the propagation path. The attenuation resulting from the wet antenna testing is in the range of 0.4–3 dB; this is a significant value which must not be allowed to misrepresent the value of rain attenuation predictions. It was also found that the wet antenna effect is largely dependent on radio wave frequency, dimensions of the receiving antenna dish and the wetting conditions of antenna radome. The high loss could also be caused by the roughness of the reflector surface due to manufacturing processes. The dielectric coating over the metal screen reflector may retard the flow of water down the reflector. Wet antenna effect is more severe at higher frequencies, higher elevation, longer link lengths and smaller antenna dish.

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## Author Biographies

**S. K. A. Rahim** obtained his first degree from University of Tennessee, USA majoring in electrical engineering, graduating in 1996, M.Sc. in Engineering (Communication Engineering) from Universiti Teknologi Malaysia (UTM) in 2001 and Ph.D. in Wireless Communication System from University of Birmingham, UK in 2007. Currently, Dr. Sharul is a senior lecturer at Wireless Communication Centre, Faculty of Electrical Engineering, UTM Skudai. His research interests include Smart Antenna on Communication Systems and wireless mobile communications. He is a member of the following professional bodies: IEEE Malaysia Section, Board of Engineer Malaysia (MBEM), Institute of Engineer Malaysia (MIEM) and Eta Kappa Nu Chapter (International Electrical Engineering Honour Society, University of Tennessee). He has published and co-authored a number of technical papers on rain attenuations, smart antenna designs and measurement, in both national and international journals and conferences.

**A. Y. Abdulrahman** obtained his Bachelor's and Master's degrees from University of Ilorin, Nigeria in 1999 and 2005, respectively. He is currently a full-time Ph.D. research student at Wireless Communication Centre (WCC), Fakulti of Elektrical Engineering, Universiti Teknologi Malaysia (UTM), Malaysia. His research interests include Wireless Mobile systems, radio propagation and rain attenuation studies, especially in the tropics. Abdulrahman is currently working on development of a transformation model for inverting terrestrial rain attenuation data for satellite applications at Ku-band in tropical regions. He has published more than three papers in International Journals related to rain attenuation issues in tropical regions.

**T. A. Rahman** is a Professor at Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM). He obtained his B.Sc. in Electrical & Electronic Engineering from University of Strathclyde UK in 1979, M.Sc. in Communication Engineering from UMIST Manchester UK and Ph.D. in mobile radio communication engineering from University of Bristol, UK in 1988. He is the Director of Wireless Communication Centre (WCC) UTM. His research interests include radio propagation, antenna and RF design and indoors and outdoors wireless communication. He has also conducted various short courses related to mobile and satellite communication for the Telecommunication Industries and Government bodies since 1990. He has wealth of teaching experience in the area of mobile radio, wireless communication system and satellite communication. He has published more than 120 papers related to wireless communication in national / international journals and conferences.

**M. R. Ul Islam** obtained his B.Sc. degree in Computer Science from National University of Bangladesh and M.Eng. degree in Telecommunications Engineering from Universiti Teknologi Malaysia (UTM) in 2003 and 2007, respectively. He is currently a Ph.D. Research officer in Wireless Communication Center at UTM, Malaysia. His research interests include antenna and propagation; and he has published more than 6 conference and journal papers on antenna and propagation issues.