

## The Aerial Wetted Path of Geostationary Transmission

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### Abstract:

The aerial effective wetted path of geostationary satellite transmission focused to the Earth's surface was both defined taking into account the warm sector of rainy cloud and estimated as a function of signal strength. A standard path of 4.88 km was obtained for Caracas with a 60 cm dish parabolic receptor pointing with a 55° elevation angle to an associated direct TV satellite in Ku band. Such function helps to estimate rainfall intensity with  $\pm 3$  mm/h bulk error for stormy weather. Myriad of users of direct TV and other satellite applications with their receptors providing signal strength may apply the present issue to estimate paths and rain rates but doing verifications and adjusts by new coordinates and new dish sizes.

**Keywords:** Wetted, path, satellite, rainfall, geostationary, signal, strength

### 1. Introduction

The information transmitted from geostationary satellites toward receptors located at the Earth's surface must to cross the lower part of the atmosphere named *troposphere* in which the phenomenon of attenuation of the electromagnetic energy of the waves used for transmission occurs. The rain produces strong attenuation through a descending sloped distance across water droplets named here effective wetted path ( $D$ , km) with its vertical component supposed proportional to the rainfall intensity  $R$  (mm/h). Formulas give  $R$  from the unitary attenuation  $\gamma$  (dBz//km). Even though those receptors are not designed as rain gauges, the signal strength ( $S$ , %), most of the time included as a menu option in the commands of equipment, may be used to calculate decibels (dBz) but  $D$  remains unknown. Figure 1 shows the antenna of a receptor of direct TV transmission broadcasted by the G-3C satellite in a moment during a rainy event; the signal strength  $S$  was attenuated by rain from 98% to 80%. The objective here is then the estimation of  $D$  as a function of  $S$  to late calculate  $R$ . The  $R$  value may be considered important in times of abundant or scarce rain for human use of fresh water, thus any new issue on this matter would be reported. Receptors of direct TV transmission are considered here but other options may be useful. Myriad of users of direct TV and other satellite applications with receptors providing signal strength may apply the issue reported here to estimate both paths and rain rates but doing verifications and adjusts by new coordinates and new dish sizes.

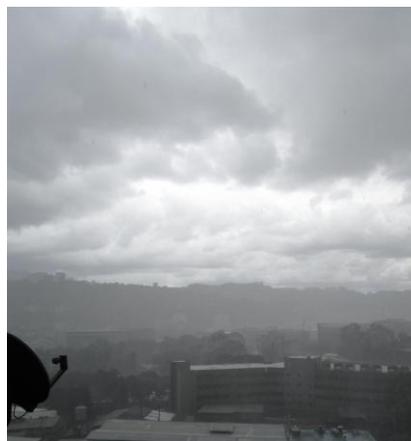


Figure 1. Image of a parabolic antenna of Direct TV receptor (TC121) during a rainy event.

## 2. Specific rainfall attenuation theory

A geostationary satellite transmits radio waves to the Earth's surface that can be captured by special device named receiver which has parabolic antenna composed by dish and horn at the front of the dish. The radio waves, most of the time in the microwave band, are composed by a combination of carrier, subcarrier and encoded data rename popularly *the signal*. The transmission must to cross the troposphere where a phenomenon named attenuation occurs. This phenomenon consists in the energy withdrawal of the carrier due to permanent and temporary factors. The permanent or basic attenuation is caused by fixed factors as the Fresnel divergence and energy abortion by  $\text{CO}_2$  and  $\text{O}_2$ . Energy withdrawal named *rain fade* caused by energy absorption and dispersion by temporary rainfall droplets is here the subject matter of study. Droplets reflect radio waves energy but water molecules absorb it. The relative signal strength  $S$  is measured respect to a standard from 0% to 100% by a meter included in the receptor. In the perfect receptor  $S=0\%$  for strong *rain fade* with no detected signal but  $S=100\%$  for no rainfall. The radio waves must to cross the troposphere in which the attenuation can be maximized by strong rains; the total length across rain showers in the clouds and below the clouds is the effective wetted path  $D$  (km). Designed for Caracas, Figure 2 helps to understand the wetted path dimension of the direct TV transmissions (Satellite G-3C) across a 12000 m high troposphere during heavy rainy episodes. The descending inclined wetted path runs  $D_0=4883$  m from the  $0^\circ\text{C}$  ice level to TC121 crossing the condensation level at 500 m above TC121. The horizontal projection of this path reaches 2801 m. TC121 is located at altitude 877 m but 33 m above the soil. Data for that figure were obtained from [1]. In the present case  $S$  was measured with the TC121 receptor referred in Figure 1. The real  $D$  can be different to  $D_0$  (km).

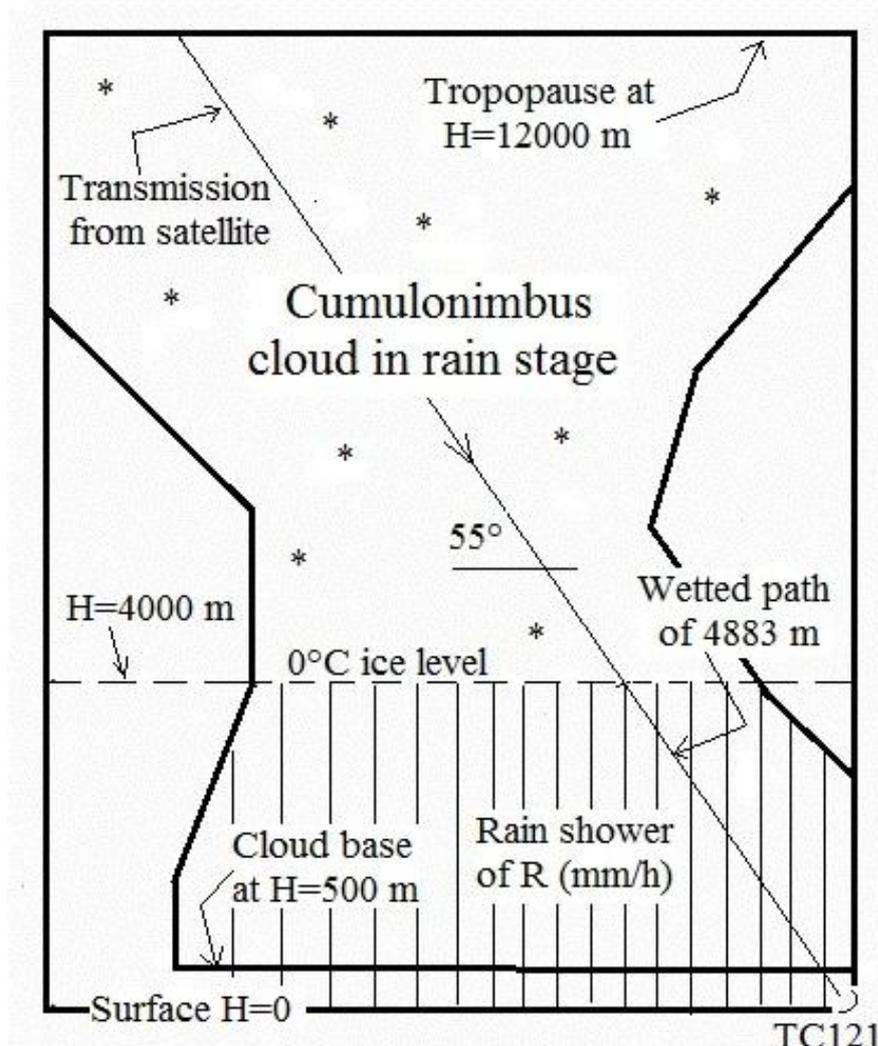


Figure 2. Standard scheme of transmission crossing a large rain stage cumulus over TC121.

The  $D$  valued will be actualized as follows. During no rains  $S=S_{max}$  but during rains  $S$  is less than  $S_{max}$  and the attenuation is:

$$\gamma = [-\log(S/S_{max})]/D \quad (1)$$

Where  $\gamma$  is the bulk unitary attenuation in dBz/km,  $S$  is the signal strength measured with the meter in the receiver at a moment with rainfall and  $S_{max}$  is local  $S$  measured without rainfall; both for a specific satellite transponder. A transponder is a satellite device used to focus radio waves to areas of the Earth's surface. Most references present a standard formula for rain attenuation like this:

$$\gamma = a \cdot R^b \quad (2)$$

Where  $\gamma$  is the bulk unitary attenuation in dBz/km of horizontal radio wave at a specific moment crossing a falling down vertical shower of rainfall  $R$  (mm/h); constants  $a$  and  $b$  are parameters depending of the radio wave frequency. The International Telecommunication Union (ITU) presents mean values  $a=0.0242$  and  $b=1.1879$  for 12 GHz [2].  $D=0$  for  $R=0$ . To actualize  $D$  for each moment was used  $c$  value between 0 and 1 with the following linear interpolation:

$$D = c \cdot (1 - S/S_{max}) \cdot D_0 \quad (3)$$

### 3. Rain gauging experiments

During the years 2008 to 2012 were collected observational data of 7 storms that permitted to obtain pairs of true rainfall intensity  $R^*$  and  $S$ . In an electronic sheet was programmed the calculation of  $R$  from  $S$  assuming  $c$  values until the mean error of  $R^*$  minus  $R$  reaches zero with a specific standard deviation. The  $c=1.84$  gave the zero error with standard deviation  $\pm 2.9$  mm/h. In those experiments was used transponder 13 with  $S_{max}=98$ . Table 1 shows results summary. The attenuation Beer's law may be used also for calculations but this was not intended here.

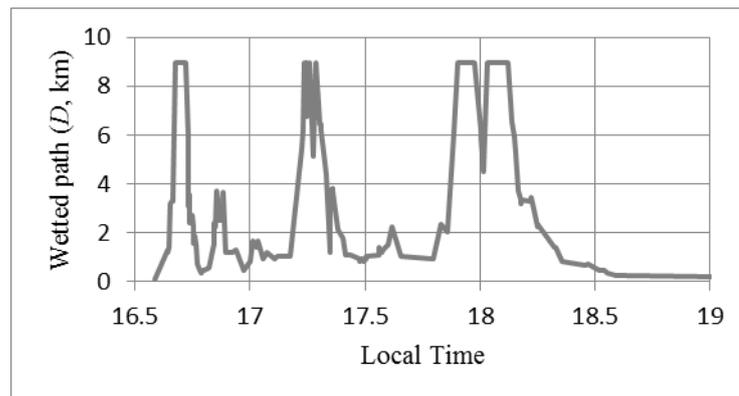
Day	Begin	End	$R$ (mm/h)	$R^*$ (mm/h)	Error (mm/h)
10Aug2009	16:00	17:00	14.7	17.0	-2.3
15Nov2009	13:00	14:00	13.4	13.0	0.4
30Jul2009	19:13	19:31	20.6	15.0	5.6
04Oct2009	16:58	18:45	15.9	15.1	0.8
23Oct2008	16:58	18:34	12.7	16.3	-3.5
04May2011	13:46	13:53	13.4	13.7	-0.3
12Jun2012	15:28	15:28	17.5	18.0	-0.5
					2.9

### 4. Effective or bulk wetted path

The maximum occasional value of the inclined wetted path corresponding to heavy cumulonimbus (Cb) rains reached temporary 1.84 times the standard value of 4.88 km or near 9 km assuring the presence of water droplets above the 0°C ice level inside Cb. Observations during jet flying in the area permitted detect the joint occurrence of ice crystal and droplets above the 0°C ice level touching the windows of the jets occasional. More information of this fact is not available due to notable gap of cloud physic studies in the area. The top of this kind of Cb clouds reaches height of 12 km near the *tropopause*.

### 5. Final verification

In 16 August 2014 for the 150 minutes from 16:35 to 19:05 local time were collected 157 values of  $S$  which were transformed in 157 values of  $R$  using the above formulation with  $c=1.84$  to obtain a bulk intensity value of 19 mm/h against a measured value of 18 mm/h. Figure 3 shows detail of  $D$  variation during this complex rainy event. *Out-of-signal time* was 12 minutes. The error +1 mm/h is inside the above mentioned bulk of  $\pm 3$  mm/h, thus it may be considered acceptable. With this verification the present stage of research touches final but further research should be expected to minimize errors.



**Figure 3. Histogram of wetted path during stormy episode of 16 August 2014.**

## 6. Conclusions

It has been possible to estimate the wetted path of satellite transmission and the rainfall intensity from the signal strength measured with a low cost direct TV receptor during stormy weather episodes. An error of nearly  $\pm 3$  mm/h was obtained. The change of receptor to a dish of 120 cm instead the 60 cm used actually is recommendable to minimize error. Occasional *out-of-signal* events of heavy rainfall constitute the main restriction of the present development. As satellite geostationary transmission runs downward over an inclined path and the above mentioned rain attenuation formula was designed for horizontal path, more specific research on this subject must be undertaken to minimize errors doubtless.

## 7. Acknowledgments

We owe thanks to both the Telecommunication Technicians Ramon Arturo Hernandez who teaches us *rain fade* calculations and the Electronic Engineer Diego Stanfield who advices us on the possibility of watching the signal strength using menu options in most satellite receptors as that of direct TV.

## References

- [1] L.G. Hidalgo and J. A. Hidalgo. Cálculo de la intensidad de lluvia por satélite. ISBN 9789801252429. 2011.
- [2] ITU. Specific attenuation model for rain for use in prediction models. ITU-R P-838-P. 2005

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