CENTRE NATIONAL D'ÉTUDES SPATIALES

ITU-R PROPAGATION MODELS SOFTWARE LIBRARY

Bouchra Benammar / Centre National d'Etudes Spatiales

18, avenue Edouard Belin – 31401 Toulouse Cedex 9

Tel : +33 (0)5 61 27 36 73

e-mail : bouchra.benammar@cnes.fr

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Introduction

This document presents a Dynamic Link Library (DLL) developed by CNES, France to compute propagation losses for Earth to Space (or Space to Earth) transmission links. A DLL is a library of functions that is not included in executables and that can be loaded and used dynamically. Dynamic Link Libraries are useful way to run simulations or computations on various Microsoft applications with only one single file that contains all the functions. It allows an easy and flexible management of the upgrade of the DLL functions

This DLL contains functions based on the ITU-R P. models recommended to compute the gas, clouds, rain attenuation and scintillation.

CNES provides freely this software on its freeware website (http://logiciels.cnes.fr).

Please note that this software can be used only with the acceptation of the user license (available at the following webpage : https://logiciels.cnes.fr/en/license/33/250).

All the propagation models used in this software are available in the recommendations of the International Telecommunications Union (http://www.itu.int).

The Dynamic Link Library

The DLL is composed of entry points that contain the algorithms of the ITU-R P. models. The accessible functions allow the computation of the following values:

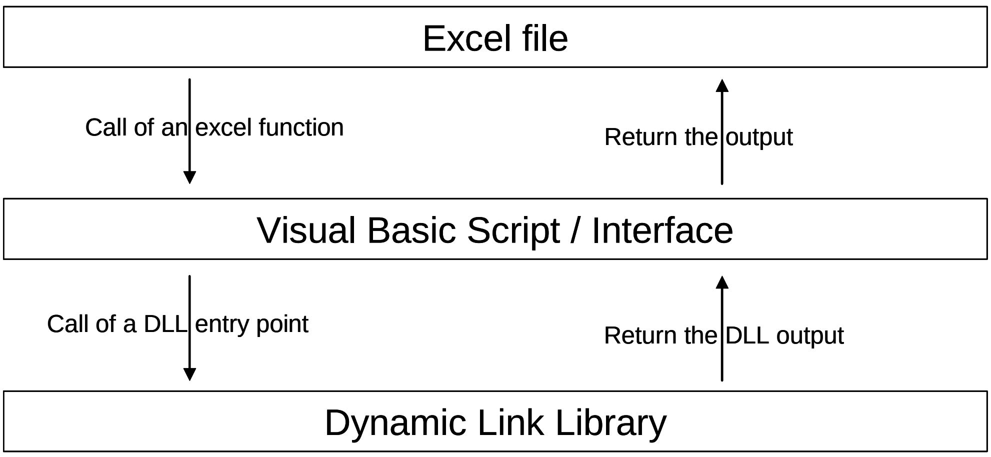
- Atmospheric gases attenuation in dB (ITU-R P.676-10 Annex 2 – see [2])
- Rain attenuation in dB (ITU-R P.618-12 – see [2])
- Clouds attenuation in dB (ITU-R P. 840-6– see [2])
- Scintillation in dB (ITU-R P.618-12 – see [2])
- Rain intensity in dB (ITU-R P. 837-6 – see [2])
- Wet term of refraction co-index (ITU R-P.453– see [2])
- Rain height (ITU-R P. 839-4– see [2])
- Total Columnar content (ITU-R P. 840-6– see [2])
- Water vapour content (ITU-R P. 836-5– see [2])
- Temperature (ITU-R P. 1510– see [2])
- Version (DLL version management)
- Cross polar discrimination (ITU-R P.618-12 – see [2])
- Mean radiating temperature (ITU-R P.618-12 – see [2])
- Sky noise temperature (ITU-R P.618-12 – see [2])
- Long term frequency scaling (ITU-R P.618-12 – see [2])

These functions have been checked with the validation examples provided on the ITU website (see [1) and are compliant.

Example of the use of the DLL with Excel

Dynamic Link Libraries can be used by various Microsoft Applications and by some programming languages such as C or Matlab for example. This paragraph explains how to use the DLL in an Excel file (a typical example of link budget computation).

First of all, the DLL has to be in a directory that is accessible by Excel. Typically, most of the Microsoft DLLs are in the c:/winnt/system32 directory. To access to the DLL propagation models, a simple Visual Basic (VB) script is needed inside the Excel file. This kind of interface defines links between DLL entry points and Excel functions names. The figure below presents a layer representation of the configuration.



The advantage of this kind of configuration is that end-users does not have to care about the propagation models (they are included in the DLL) : all the Excel files refer to one Dynamic Link Library for computation of propagation losses. The same functions are used for every Excel file and upgrades of the Dynamic Link Library will not affect the excel file used by the end-users if it is due to bugs or if it does not modify the inputs of the model (the old DLL have only to be replaced by the new one : no modification are needed in the excel file).

VB scripts can be imported in Excel files. Such, a VB script is provided with the DLL. It has to be imported to make the propagation models accessible to any Excel user. Then, the propagation models can be used in cells like any other Excel functions:

```
=Rain_Intensity(43.0;2.0;0.01)
```

Example of the use of the DLL with Matlab

This part was kindly submitted by Steven Gobien (BAE Systems)

NOTE: Assuming that propa.dll and propa.h are in the C:\ directory on the installation machine, and assuming that MATLAB is installed in the C:\ directory (the MATLAB function “loadlibrary” has a BUG in that it cannot call a DLL in a path with spaces… the default MATLAB installation directory is c:\Program Files\ on Windows machines… you must install MATLAB into a directory with no spaces to call external DLLs)

This loads the DLL library into MATLAB :

```
loadlibrary 'propa' 'C:\propa.h'
```

And here is an example of calling one of the functions (Calcule_coincide_refraction) with the arguments 32 and 34… the functions and their associated parameters can be found within the header file.

```
calllib('propa','Calcule_coindice_refraction',32,34)
```

Example of the use of the library with Linux

Since 2016, a static and a shared library are available for Linux both in 32 and 64 bits. The files are named propaVV.a and propaVV.so with VV ={32, 64}.

References :

[1] Validation Examples : http://www.itu.int/ITU-R/study-groups/rsg3/validation/index.html

[2] ITU-R P. Rec. : http://www.itu.int/rec/recommendation.asp?type=products&lang=e&parent=R-REC-P

Annex 1 : User Manual

1. Where to install the DLL ?

The DLL provided has to be installed in a directory that is accessible by Microsoft Applications. It is recommended to extract the DLL from the zip file in one of the following directories : c:\windows\system32 or c:\winnt\system32.

In the case of Windows XP Professional x64 Edition Version 2003 Service Pack 2, a modified propa.bas VB script (propa_XPpro_x64.bas) must be used and put propa.dll in the directory C:\WINDOWS\SysWOW64. (***This trick and the modified VB script were kindly submitted by Michael Maguire (SpaceX)***)

This procedure has to be done only once and then for each upgrade of the DLL.

2. The Excel example file

An example file is provided with the DLL. It is an Excel file (named demoprop.xls) that gives examples of the use of the DLL propagation functions. It is composed of two data sheets :

- A data sheet ‘Propagation’ that contains a propagation losses computation
- A data sheet ‘Link Budget’ that contains a link budget computation

The interface with the DLL functions is a Visual Basic script. Examples of function calls are given in the two data sheets.

3. How to create a new Excel file

If a user wants to use the DLL functions in a new Excel file, he has to import the Visual Basic script in it. For this, a small file (propa_en.bas) is provided and has to be used as defined below :

- Create a new Excel file
- Tools -> Macro -> Visual Basic Editor
- File -> Import
- Choose the file propa_en.bas (in the directory where it is located).

After this procedure, the interface is installed in this new Excel file. The Visual Basic Editor can be closed and the DLL functions are accessible in the Excel cells as described below

4. How to use the DLL functions in Excel

With the Visual Basic script, it is possible to call the DLL functions like any other Excel function.

For example, to compute the rain intensity exceeded during 0.01 % of an average year at the location (43°N, 2°E), the following command has to be entered in an Excel cell :

```
=Rain_Intensity(43.0;2.0;0.01)
```

It is of course possible to use references to other cells instead of numerical values.

Annex 2 : List of functions

The table below presents the functions available :

THE FUNCTIONS			
Functionality	**Name in propa.bas**	**French DLL Entry points**	**English DLL Entry points**
Attenuation due to atmospheric gases (eq. 28 of P. 676)	Agaz	Calcule_Agaz	gaseous_attenuation
Attenuation due to atmospheric gases (eq. 29 of P. 676)	Agaz_exceeded	Calcule_Agaz_depassee	gaseous_attenuation_exc
Rain Attenuation	Arain	Calcule_Apluie	rain_attenuation
Cloud Attenuation	Acloud	Calcule_Anuages	cloud_attenuation
Scintillation	Iscint	Calcule_Scintillation	Scintillation
Rain intensity	Rain_Intensity	Calcule_intensite_pluie	rain_intensity
Wet term of refraction co-index	Nwet	Calcule_coindice_refraction	NWET
Rain height	Rain_height	Calcule_hauteur_pluie	rain_height
Total Columnar Content of liquid water	TCC	Calcule_contenu_eau_liquide	LWCC
Surface Water Vapour density	WVC	Calcule_vapeur_d_eau	SWVD
Integrated Water Vapour Content	Iwvc	Calcule_contenu_vapeur_eau	IWVC
Temperature	Temperature	Calcule_temperature	temperature
version	version	version	version
Long term frequency scaling	EFSR	Calcule_Along_terme	EFSR
XPD	XPD	XPD	XPD
Noise temperature	Tnoise	temperature_bruit	Noise_temperature
Mean radiating temperature	Tmr	temperature_radiance_moyenne	TMR

The tables below give the description of the inputs and the outputs of the functions.
Note that the following functions require a latitude positive for location in the North hemisphere and negative for South hemisphere

ATTENUATION COMPUTATION FUNCTIONS			
Name	**Input**	**Output**	**Remarks**
Agaz	Frequency (GHz) Elevation (radians) Temperature (°K) Water Vapour density (g/m^3)	Atmospheric gazes attenuation (dB)	Frequency ≤ 350 GHz Elevation ≥ 5°
Agaz_exceeded	Frequency (GHz) Elevation (radians) Temperature (°K) Integrated Water Vapour Content (kg/m^2)	Atmospheric gazes attenuation exceeded during p % of an average year (dB)	Frequency ≤ 350 GHz Elevation ≥ 5°
Arain	Latitude (°) Frequency (GHz) Elevation (radians) Unavailability (%) Station Height (km) Rain Height (km) Rain Intensity exceeded during p % of an average year (mm/h) Tilt angle (°)	Rain attenuation (dB) exceeded during p % of an average year	Frequency ≤ 55 GHz 0.001% ≤ Unavailability ≤ 5%
Acloud	Frequency (GHz) Elevation (radians) Total Columnar Content of liquid water(kg/m^2)	Clouds attenuation (dB) exceeded during p % of an average year	Frequency ≤ 200 GHz 1% ≤ Unavailability ≤ 50 %
Iscint	Wet term of refraction co-index Frequency (GHz) Elevation (radians) Unavailability (%) Station Height (km) Antenna efficiency Antenna Diameter (m)	Scintillation standard deviation (dB) exceeded during p % of an average year	7GHz ≤ Frequency ≤ 20 Ghz Elevation ≥ 4° 0.01 ≤ Unavailability ≤ 50% 0 ≤ Antenna Efficiency ≤ 1
XPD	Rain attenuation exceeded for p(%) of time (dB) Tilt angle (°) Frequency (GHz) Path elevation angle (°) Percentage of time (%)	Cross polar discrimination long term statistics based on rain attenuation (dB)	6 ≤ Frequency ≤ 55GHz Elevation ≤ 60° Tilt angle = 45° for circular polarised fields.
EFSR	equiprobable excess rain attenuation on link frequency f1 (dB) Frequency f1 (GHz) Frequency f2 > f1 (GHz)	equiprobable excess rain attenuation on link f2	f2 > f1

INFORMATION FUNCTIONS

Name	Input	Output	Remarks
Version	none	DLL version number	

CLIMATIC PARAMETERS COMPUTATION FUNCTIONS			
Name	**Input**	**Output**	**Remarks**
Rain_Intensity	Latitude (°) Longitude (°) Unavailability (%)	Rain Intensity (mm/h) exceeded during p % of an average year	For the ITU Rain Attenuation model, Rain Intensity has to be computed with a time percentage of 0.01%
Nwet	Latitude (°) Longitude (°)	Wet term of refraction co-index	
Rain_height	Latitude (°) Longitude (°)	Rain height (km)	
TCC	Latitude (°) Longitude (°) Unavailability (%)	Total Columnar Content of liquid water (kg/m^2) exceeded during p % of an average year	1% ≤ Unavailability ≤ 50 %
WVC	Latitude (°) Longitude (°)	Annual Surface Water Vapour density (g/m^3)	0.1% ≤ Unavailability ≤ 50 %
iwvc	Latitude (°) Longitude (°) Unavailability (%)	Annual Integrated Water Vapour Content (kg/m^2) exceeded during p % of an average year	0.1% ≤ Unavailability ≤ 50 %
Temperature	Latitude (°) Longitude (°)	Temperature (°K)	
Tmr	Surface temperature (°K)	TMR (°K)	Equ. 67 of recommendation ITU-R-P 618-12.
Tnoise	Total attenuation except scintillation (dB) Mean radiating temperature (°K)	Sky noise temperature	If TMR is not available use TMR = 275 K

Remarks : Total Attenuation is not obtained by the summation of the contributions of each propagation phenomenon (see example file). It can be computed with the following relation (see ITU-R P.618-12)

$$A_{Totale} = A_{gaz} + \sqrt{\left(A_{pluie} + A_{nuages}\right)^2 + I_{Scint}^2} \quad \text{(en dB)}$$

Annex 3 : Change log

DLL Version	Change
20160810	Modification: - Parameter ro in function "Agaz_exceeded" has been removed. This function is no longer compatible with former implementations. Upgrades: - Water vapour and total columnar liquid content maps upgraded. - Cloud_attenuation function upgraded to ITU-R P 840-6. Addition: - Cross polar discrimination (ITU-RP 618-12). - Long term frequency scaling (ITU-RP 618-12). - Mean radiating temperature and noise temperature (ITU-R P 618-12). The propa library is now available under 32 and 64 bits for both WINDOWS and LINUX (shared and static) operating systems.
20100917	Minor Bug Fix : the rain rate related parameters (including rain attenuation) prediction was erroneous for longitude between 358,75° and 360° creating a slight discontinuity between negative and positive longitudes. The bug has been fixed. Upgrade : Input longitude can now be in both [0°;360°] and [-180°;180°] ranges. Negative longitude values are now allowed. A validity test is now applied on input latitude and longitude values. If these values are not in valid ranges ([-90°;90°] for latitude and [0°;360°] or [-180°;180°] for longitude), an output value equal to -999 is provided by functions using these input parameters. Excel sample file : Addition of a test checking if the input unavailability is greater than 1%. If not, the cloud and gaseous attenuations are computed considering a minimum unavailability forced to be equal to 1% since it is recommended by Rec. ITU-R P.618-9. This modification concerns both the "Propagation" and the "Link budget" sheets.
20090304	Upgrade : Rain intensity digital maps (ITU-R P.837-5) approved in August 2007 are now used. Provision of a method to solve the installation problem for Windows XP Pro x64 version.

20060213	Minor Bug Fix : The interpolation of the Integrated Water Vapour and Liquid Vapour Contents was wrong (log in percentage and log in Content instead of linear in Content). The bug has been fixed. Minor Bug Fix : The interpolation of the Liquid Water Content gave nil values for some percentages. The bug has been fixed.
20050718	Minor Bug Fix : the function used to compute the scintillation can not return a negative value now. Upgrade : New recommendations ITU-R P.676-6 (gaseous attenuation) and ITU-R P. 838-3 (specific rain attenuation) published in march 05 are now used. Upgrade : Entry points with English names are now available

DLL Version	Change
20040603	Minor Bug Fix : The interpolation of the total columnar content was wrong for some cases of availabilities between 2 and 3 %. The bug has been fixed. Minor Bug Fix : When the gaseous attenuation function was called from a C program, the values of specific attenuations were printed. The printing of these values was used for debug and has been removed. Minor Bug Fix : The mean-annual numerical map used to compute the temperature was not the one recommended by the ITU. The bug has been fixed, some difference may appear for some location. Upgrade : Water vapour attenuation can now be computed using both methods described in Annex 2 (§ 2.2.1) of Rec. ITU-R P. 676-5 using the Integrated Water Vapour Content or the mean annual surface Water Vapour density. Results from the IWVC method has been checked successfully with Annex 12 of Document 3M/45-E (“Validation examples for prediction methods in recommendation ITU-R P. 618”)
20031202	Removal of the unavailability as an input parameter in the cloud attenuation function (not needed because of the use of the exceeded Total Columnar Content of liquid water as an input parameter of the function) Bug fixes for the computation of the specific attenuation due to dry air and water vapour Upgrade of the function used to compute the kappa and alpha parameters for the specific rain attenuation
20031007	Initial version