WEEK: 9

Lab: 7

Lab Title: **Visualize Tools (VisTools); Visual Interference Analysis**

a. **Software Description:**

VisTools is a program that contains various tools derived from the Visual Interference Analysis Software package which could be used to calculate parameters frequently used in Radio-Communication Analysis.
For example, free space path loss, or peak gain of an antenna could be calculated quickly and easily.

b. **Objective:**

Through this program, the students will be able to calculate the major parameters of a communication link such as path loss, spread loss, noise temperature, half power beamwidth, off-axis gain, G/T, C/N and PD. The equation used to calculate these parameters are discussed in the 17 page tutorial.

c. **Procedure:**

1. Go to www.transfinite.com site,
2. Download "VisTools version 2, radio engineering tools for your desktop,"
3. Click on VisTools.Doc,
4. Read through the 17 page tutorial,
5. Click on the VisTool.exe,
6. Follow these steps:

    - Calculate spread loss (Ls) for LEO, MEO & GEO and plot Ls vs. D; for D=700km, 10,000 km, and 36,000 km,
    - Calculate path loss (Lfs) at c, ku, and ka bands and plot Lfs vs. frequency for f=4, 12, and 20 GHz.,
    - Calculate Noise Temperature (N), at bandwidth specified below and plot N vs. Bandwidth for: B=10 Hz, 1 KHz, 10 KHz, 1MHz, and 1 GHz; T=300 K,
    - Calculate antenna peak gain for ant size of 2m, 5m, 12m, and 16m at c, ku, and ka bands and plot

peak gain (dBi) vs. Frequency(4,12,20GHz) for above antenna sizes,

- **Calculate peak gain (dBi) for 3 dB beamwidth values of 0.8744, 0.75, 0.65, and 0.5 when Efficiency =0.7. Plot peak gain vs. 3dB beamwidth.,**
- **Calculate relative gain for the above 3dB beamwidth values when off axis angle=0.1 degree for the different gain pattern specified,. Plot 3dB beamwidth vs. relative gain for these gain patterns,**
- **Calculate Figure Of Merit (G/T), for peak gains of 30, 35, 40, 45, 50, and 52 dB at T=300 K. Plot G/T vs. peak gain,**
- **Calculate C/N rate at c, ku, and ka bands and plot C/N (dB) vs. f(GHz) of 4, 12, and 20 GHz.,**
- **Calculate C/(N+1) ratio at C/N obtained in previous step and plot C/(N+1) vs. C/N.**
- **Calculate power flux density (PFD) for antenna sizes of 1, 5, and 10 meters and at c, ku, and ka bands. Plot PDF vs. dish size at 4, 12, and 20 GHz.**

In each case, explain the behavior you observe in your results.

Visualyse

Tools

Important Note

The VisTool program and this document are supplied "as is", and Transfinite Systems Ltd is not liable in any way for their use including any inaccuracies or omissions. Included in this document are Terms and Conditions of use that should be read before running the software.

TRANSFINITE SYSTEMS

Table of Contents

1. Introduction

VisTools is a program that contains various tools derived from Visualyse, the Visual Interference Analysis Software package, which you can use to calculate parameters frequently used in radio-communication analysis. For example you can calculate free space path loss or the peak gain of an antenna quickly and easily without having to remember the formula or program spreadsheets. These tools are combined together to produce simple link budget calculators.

Visualyse Tools can be accessed on a range of platforms including:

- Windows
- Palm Computing

Please check out the terms and conditions at the end of this document.

For radio communication simulation software, we can provide you with the Visualyse simulation package. More information about Visualyse can be found later in this document.

If you have ideas for more tools let us know as we continue to develop the Visualyse Tools.

3. Tools

This section describes the tools themselves. Note that there can be minor differences between implementations on different platforms.

3.1 Constants

This section uses the following constants:

Constant	Value	Units
c	2.998e5	km/s
R_e	6378.145	km
μ	3.9860125e5	km
K	-228.6	dBK

3.2 General Tools

3.2.1 dB Calculation

The dB tool converts between dB (d) and absolute (a) using:

$$a = 10^{d/10}$$

$$d = 10\log_{10}(a)$$

3.2.2 Frequency to Wavelength

The Frequency tool converts between frequency f and wavelength λ using:

$$c = f\ \lambda$$

where c is the speed of light

3.2.3 Spreading Loss

The Path loss tool calculates the spreading loss used in power flux density calculations. The parameters used are:

- Distance D in km
- Spreading loss L_s in dB/m^2

These can be calculated from the other using:

$$L_s = \frac{1}{4\pi D^2}$$

Note that L_s is in metres while D is in Km so there is the conversion factor of 1000 is also used.

3.2.4 Path Loss

The Path loss tool calculates the free space path loss. The parameters used are:

- Frequency and Frequency units
- Path Length
- Path Loss

Each of these three can be calculated from the other using:

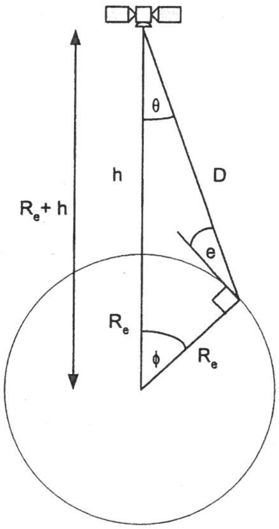


Figure 1. Field of View Parameters

The equations are standard trigonometry:

$$R_e^2 = (R_e + h)^2 + D^2 - 2(R_e + h)D\cos\theta$$

$$(R_e + h)^2 = D^2 + R_e^2 - 2DR_e\cos(e + \pi/2)$$

$$D^2 = R_e^2 + (R_e + h)^2 - 2(R_e + h)R_e\cos\phi$$

$$\frac{\sin\theta}{R_e} = \frac{\sin\phi}{D} = \frac{\sin(e + \pi/2)}{(R_e + h)}$$

$$\frac{\pi}{2} = \theta + \phi + e$$

3.4 Gain Calculations

The various gain tools all use the same inter-related parameters, shown in the Venn diagram below.

Three basic gain patterns are available:

- Parabolic
- 29-25logϕ
- 32-25logϕ

The various gain patterns are described below.

3.4.3.1 Parabolic Gain Pattern

These parameters are related using the following equation:

$$G_{rel} = -12\left(\frac{\theta}{\theta_{3dB}}\right)^2$$

3.4.3.2 29-25logϕ

This represents a gain pattern with parabolic main beam and side lobe of shape 29-25logϕ similar to that in ITU-R RR Appendix 30B Earth Station A. The equations are:

Calculate:

$$\text{D}/\lambda = \frac{D}{\lambda} = \sqrt{\frac{G_{\max(absolute)}}{\eta\pi^2}}$$

$$G_1 = \min\left(G_{\max,} \; -1 + 15\log\frac{D}{\lambda}\right)$$

$$\varphi_m = \frac{20\lambda}{D}\sqrt{(G_{\max} - G_1)}$$

$$\varphi_r = 15.85\left(\frac{D}{\lambda}\right)^{-0.6}$$

Noting that all angles here are in degrees, then:

$$G = G_{\max} - 2.5x10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 \qquad 0 \le \varphi \le \varphi_m$$

$$G = G_1 \qquad \varphi_m < \varphi \le \varphi_r$$

$$G = 29 - 25\log\varphi \qquad \varphi_r < \varphi \le 36.3$$

$$G = -10 \qquad 36.3 < \varphi \le 180$$

Then relative gain is:

$$G_{rel} = G - G_{\max}$$

3.4.3.3 32-25logϕ

This represents a gain pattern with parabolic main beam and side lobe of shape 32-25logϕ similar to that in ITU-R RR Appendix 30B Earth Station B. The equations are:

Calculate:

- other losses, L_{other}, entered directly
- receive peak gain GRX_{max}, entered either directly or using the peak gain tool
- receive relative gain GRX_{rel}, entered either directly or using the offaxis gain tool
- receive power, C, either entered directly or calculated from EIRP or C/N using

$$C = EIRP - L_{fs} - L_{other} + GRX_{max} + GRX_{rel}$$

- receive noise, N, either entered directly or using the noise tool
- receive C/N, either entered directly or calculated using:

$$C/N = C - N$$

Note that:

- if C is changed directly the C/N_0, EIRP and transmit power fields update accordingly
- if the EIRP field is changed directly, the C, C/N, and transmit power fields update accordingly
- if the transmit power field is changed directly, the EIRP, C and C/N, fields update accordingly
- if the C/N field is changed directly the C, EIRP, and transmit fields update accordingly

3.5.2 C/(N+I)

This tools is based upon the relationships between the following four link criteria:

- C/N
- I/N
- C/I
- C/(N+I)

Using the equations such as:

$$\frac{C}{I} = \frac{{}^{C}\!/_{N}}{{}^{I}\!/_{N}}$$

$$\frac{C}{N+I} = \frac{{}^{C}\!/_{N}}{1 + {}^{I}\!/_{N}}$$

$$\frac{C}{N+I} = \frac{1}{\dfrac{1}{{}^{C}\!/_{N}} + \dfrac{1}{{}^{C}\!/_{I}}}$$

$$\left(1 + \frac{I}{N}\right)\left(\frac{C}{N+I}\right) = \frac{C}{N}$$

Both C/N and I/N can be calculated using the link budget tool discussed above. When changing C/I and C/(N+I) either the C/N or I/N could be changed, and so an option is available to select which is to be fixed.

4. What is *Visualyse*?

Visualyse™ is the standard, recognised, software package to model radio frequency systems. The *Visual Interference Analysis Software* can be used to analyse a wide range of radio communication systems, both satellite (GSO and NGSO systems) and terrestrial systems, and interactions between them.

From the beginning, *Visualyse*™ was designed to be both powerful and easy to use, employing the full capacities of Microsoft Windows™ to display the behaviour of complex systems.

Visualyse™ has been designed for interference modelling, with concepts such as station dynamics and link criteria such as C/(N+I) built in. You can quickly define and analyse complex simulations that would take years of study using conventional tools.

Visualyse™ is above all **Visual**, so that the results are not numbers from a black box, but explanations with clear visual descriptions.

Visualyse™ can be used to analyse systems in the BS, BSS, FS, FSS, MS, MSS, Aeronautical, Maritime, Inter-Satellite, Earth Exploration, Radio Astronomy, Radio navigation, Space operation, and other services.

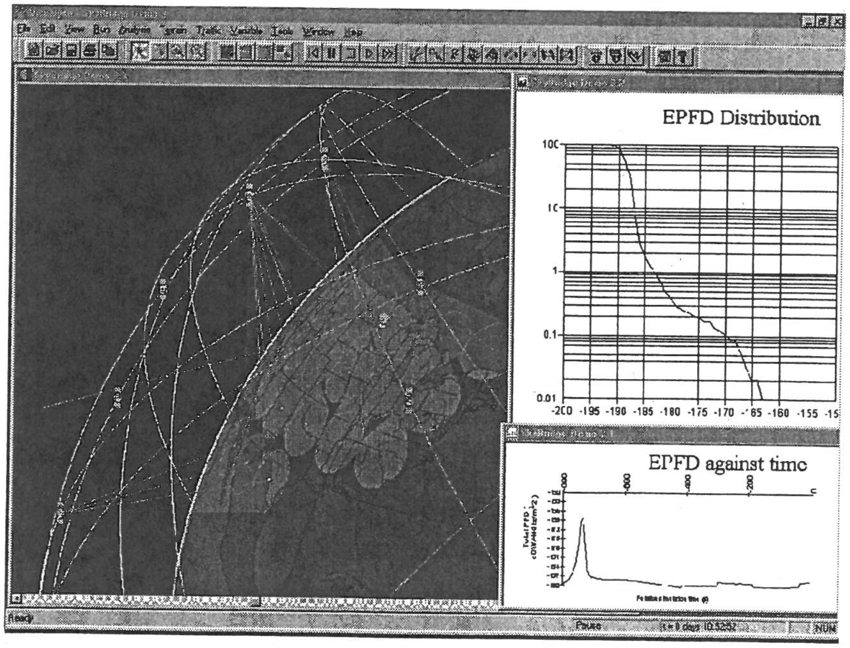
Visualyse can be enhanced by five add-on Modules:

Terrain Module: to handle terrain based propagation including analysis of terrain paths, visibility, and diffraction losses, including full graphical representation of terrain area and terrain paths.

Traffic Module: handling traffic loading where by links switch on and off, including state machines, time of day variations, and exclusion zones.

Monte-Carlo: any of the input variables can be defined using Monte Carlo techniques, with standard distributions and user defined tables. Variables can also be defined explicitly for various time steps.

IDWM Module: Visualyse provides an interface into the ITU database of geo-climatic parameters, IDWM.



7. Terms and Conditions

YOU SHOULD READ CAREFULLY THE FOLLOWING TERMS AND CONDITIONS

LICENSE AND ACCEPTANCE OF THIS SOFTWARE

These Terms and Conditions set out the basis upon which Transfinite Systems Limited ("the Licensor") will grant you ("the Licensee") a non-exclusive non-transferable license to use the software.

Loading the software into any computer indicates your acceptance of these Licence Terms and Conditions.

LICENSEES UNDERTAKINGS

(a) Not to translate, adapt, vary or modify the software.

(b) Not to sell or otherwise distribute the software for financial benefit.

(c) Not to dissemble, decompile or reverse engineer the software provided however that in the case of decompilation, the Licensee may incidentally decompile the software only if it is essential so to do in order to achieve interoperability of the software with another software program ("Permitted Purpose") and provided the information obtained by the Licensee during such decompilation is only used for the permitted purpose and is not disclosed or communicated to any third party whom it is not necessary to disclose or communicate such information without the Licensors prior written consent and is not used to create any software which is substantially similar to the expression of the software nor used in any manner which would be restricted by copyright.

WARRANTY

(a) The Licensee acknowledges that the software is not error-free and agrees that the existence of errors does not constitute a breach of this License.

(b) To the extent permitted by the applicable law, the Licensor disclaims all other warranties with respect to the software either express or implied including but not limited to any implied warranties of merchantability, or fitness or quality for any particular purpose and/or use.

ALL OTHER WARRANTIES AND CONDITIONS EXPRESS OR IMPLIED STATUTORY OR OTHERWISE ARE HERBY EXCLUDED TO THE FULLEST EXTENT PERMITTED BY LAW.

LICENSORS LIABILITY

(a) The Licensor shall not be liable to the Licensee for any loss or damage whatsoever or howsoever caused arising directly or indirectly in connection with this licence or the software its use, installation or otherwise except to the extent that such liability many not be lawfully excluded under the law.

(b) Not withstanding the generality of (a) above the Licensor expressly excludes liability for indirect, special, incidental, or consequential loss or damage which may arise in respect of the software, its use, the system or in respect of other equipment or property, or for loss of profit, business, revenue, goodwill or anticipated savings.

(c) In the event that any exclusion contained in this licence shall be held to be invalid for any reason and the Licensor becomes liable for loss or damage that may lawfully be limited, such liability shall be limited to the licence fee paid by the Licensee for the software.

(d) The Licensor does not exclude liability for death or personal injury to the extent only that the same arises as a result of the negligence of the Licensor, its employees, agents or authorised representatives.

COPYRIGHT, PATENTS, TRADE MARKS, AND OTHER INTELLECTUAL PROPERTY RIGHTS

You are permitted to load, install and use the software contained in this package on any number of CPUs for which the Licensee wishes to use the software.

The copyright and other intellectual property rights in this software is owned by Transfinite Systems Limited.

The Licensee acknowledges that any and all of the copyright, trade marks, trade names, patents, and other intellectual property rights subsisting in or used or in connection with the software including all documentation and manuals relating thereto are and remain the sole property of the Licensor. The Licensee shall not during or at any time after the expiry or termination of this licence in any way question or dispute the ownership by the Licensor thereof.

CONFIDENTIAL INFORMATION

All information, data, drawings, specifications, documentation, software listings, source, or object code which the Licensor may have imparted and may from time to time impart to the Licensee relating to the software (other than the ideas and principles which underlie the software) is proprietary and confidential. The Licensee hereby agrees that it shall use the same solely in accordance with the provisions of this licence and it shall not at any time during or after expiry or termination of this licence, disclose the same, whether directly or indirectly, to any third party without the Licensors prior written consent.

The Licensee further agrees that it shall not itself or through any subsidiary, agent or third party use such confidential information to copy, reproduce, translate, adapt, vary, modify, decompile, disassemble, or reverse engineer the software nor shall the Licensee sell, lease, licence, sub-license or otherwise deal with the software or any part or parts or variations, modifications, copies, release, versions or enhancements thereof or have any software or other program written or developed for itself based on any confidential information supplied to it by the Licensor.

TERMINATION

This Licence shall terminate forthwith if the Licensee is in breach of any terms condition or provision of this licence. Upon termination you shall destroy all disks and documentation including any of the software recorded on the hard disk of any computer under your control of return the same forthwith to the Licensor.

LAW

The parties hereby agree that the licence concluded between them and constituted on these Terms and Conditions shall be construed in accordance with English law and the parties hereby submit to the exclusive jurisdiction of the English Courts.

Explanation of how satellite links work

A satellite link comprises two parts, the uplink and the downlink.

a. Satellite links: The Upwards satellite link

First, consider the uplink. The earth station transmits a signal. This signal comes from the transmitter, which may be a solid-state power amplifier (SSPA) or traveling wave tube amplifier (TWTA). Most commonly VSAT terminals have solid state power amplifiers mounted at the dish and as close to the feed as possible to minimize waveguide attenuation losses. These dish mounted units are often block up converters (BUC) or Transmit Receive Integrated Assembly (TRIA) which change the frequency of the signals from L band (in the cross site inter facility link (IFL) cable) to the microwave frequency for transmission (C band, Ku or Ka band). BUCs have a rated output power, such as 2 watts for single carrier operation or 0.5 watts for multi-carrier operation. For ease of calculation the 2 watts power needs to be converted to dBW by doing 10 x log (power in watts), so a 2 watt BUC has a single carrier output power capability of +3 dBW (2 watt) or, for multi-carrier operation -6 dBW (0.25 watt) output power per carrier for each of two equal power carriers.

The output power of the BUC is fed to the dish, which concentrates the power in the direction of the satellite rather than allowing the power to be radiated evenly in all directions. This characteristic of the antenna is called gain, measured in dBi, which means gain relative to an isotropic, omni-directional antenna.

The combination of BUC power and satellite dish gain produces equivalent isotropic radiated power (EIRP), so for example. 2 watt BUC power + 40 dBi antenna gain produces 43 dBW EIRP.

The transmit EIRP of the earth station may be achieved by having a variety of sizes of BUC power and dish size. A large dish with low power BUC can produce the same EIRP as a small dish with high power BUC. There are limiting considerations to this. Small dishes may cause unacceptable interference to adjacent satellites. To minimise cost, choose a larger dish plus lower power BUC and take account of the cost of the electricity used.

Find the distance to the satellite, as this will give you the spreading loss in the up satellite link. Distances between approx 35860 km (sub satellite point) to approx 41756 km (edge of visibility) and are applicable for geostationary satellites.

The satellite receive beam will have a G/T value for the direction from your earth station. Review the uplink beam coverage map and determine the satellite receive G/T in the direction from your site. Values like -8 to +10 dBK are typical. Broad, earth coverage global beams have the lowest G/T; their beam width is approx 17.5 deg, which is what the earth looks like from a geostationary orbit position. Spot beams (say 1 deg diameter) have the highest uplink G/T.

Now learn this link budget equation:

- **C/Nup = earth station EIRP - path loss + satellite G/T - bandwidth +228.6 dB**

Go to the link budget calculator and play with some numbers. The EIRP you can transmit can be varied by changing the BUC power and dish size and so, as a result, the uplink C/N will vary. You obviously need a decent uplink C/N (say more than 10 or 20 dB) but once it is adequate how do you decide what correct EIRP is needed?. Note how the link budget calculator tells you what is the uplink power flux density that you are producing at the satellite. Write this figure down. You need to consider the required required power flux density into the satellite. If you were transmitting a single large 36 MHz satellite TV carrier and aiming to saturate the transponder you would need to produce the PFDsat for the transponder. The satellite up-link beam pattern will have contours specifying both G/T and PFDsat. Read off the PFDsat for your site and this will tell you the PFD that you need to produce for single carrier, full transponder operation. You can ask the satellite operator to adjust the satellite transponder gain, and thus PFDsat, by setting attenuator switches on the satellite. This will allow you to trade off earth station costs, convenience and quality. Higher gain might be attractive if your uplink were a mobile TV uplink truck or if you were having problems producing enough uplink power. The penalty is lower uplink C/N and greater susceptibility to uplink interference.

- For single carrier whole transponder operation PFD required = PFDsat

The satellite operator will normally have several nominal transponders gain set settings. e.g. low gain for multi-carrier operation amongst large dishes, medium gain for single carrier operation and high gain for multi-carrier VSAT return links. If you were transmitting a small carrier into a multi-carrier operation transponder you need to do the following calculation as a starting point. Note that the satellite will have a PFDsat and input back off specified (e.g. 6 dB input back off for multi-carrier operation). Note your carrier bandwidth and the transponder bandwidth. I am assuming here that you want your fair share of the satellite power, proportional to the bandwidth. This is a good starting point but you may prefer to have your fair share of the power (and pay the normal amount) or have more power (and pay more) depending on your dish sizes. As a rule it will be better to always spend more on larger dishes and reduce your space segment costs.

- For multi-carrier operation, PFD required = PFDsat - transponder input back off - 10 x log (your carrier bandwidth / total transponder bandwidth)

Now adjust your uplink EIRP till you get the required PFD at the satellite. Check that the uplink C/N is still reasonable.

b. Satellite links: The Downward satellite link

The downlink EIRP from the satellite is either:

- For single carrier, whole transponder operation, Satellite downlink carrier EIRP = the EIRP shown on the down-link beam contour

or

- For multi-carrier operation, Satellite downlink carrier EIRP = EIRP (as per beam contour) - transponder output back off - 10 x log (your carrier bandwidth / transponder bandwidth)

Consider the downlink receive earth station. This will have a diameter size, receive frequency and system noise temperature. Put these together and you will get the receive earth station G/T. The equation for G/T is: Earth station G/T = Gain - 10 log (system noise temperature)

Now use the link budget equation for satellite links:

- **C/Ndown = satellite downlink EIRP - path loss + earth station G/T - bandwidth +228.6 dB**

c. Satellite links: Miscellaneous noise entry factors in satellite links

Earth station intermodulation noise: If you are operating a multi-carrier BUC put in say 30 dB interference

Uplink interference from other earth stations pointed to nearby satellite: If you are a low power spectral density uplink put 25 dB, otherwise 30 dB.

Uplink interference from multiple beams on same satellite: In any, put 30 dB.

Uplink cross polar interference: Put in 30 dB, if you can't trust the installers and NOC staff, put in 25 dB.

Transponder intermodulation: If multi-carrier the put in 21 dB

Down-link interference from other nearby satellite: If you are a low power spectral density uplink put 25 dB, otherwise 30 dB.

Down-link interference from multiple beams on same satellite: In any, put 30 dB.

Down-link cross polar interference: Put in 30 dB, if you can't trust the installers, put in 25 dB.

Finally add them all together to obtain the total link budget C/N