Radio-Relay Planning Tool

RLTool

for the design and planning of digital radio-relay networks

Version 3.20 and higher

Short-form description

RLTool is a Windows[1]-supported program for planning Radio-Relay Hops, Circuits and Networks. The program runs on an MS Windows platform, either from MS Windows 98 or NT (or higher).

The following planning elements are included:

- *(Geographical and topographical) Network layout,* including the layout for radio circuits (or links).
- *Hop geometry calculation*, including the preparation of path profile charts, the determination of antenna heights and the analysis of path profiles, both with respect to path clearance and ground reflections
- *Determination of optimum antenna spacing* as protection against ground-reflected rays, including the calculation of its effectiveness relative varying *k* factor
- *Performance and availability prediction,* both for radio hops and radio circuits (or links) including hardware and cable-line sections unavailability
- *Frequency planning and interference prediction*

RLTool is transparent with respect to

- radio-frequency ranges
- capacities
- transmission hierarchies (PDH or SDH)
- planning objectives
- type of equipment and manufacturers.

[1] Windows is a registered trademark of Microsoft Corporation

The network to be designed may include equipment from different manufacturers, different capacities and radio frequency (r.f.) ranges.

RLTool provides for the planning and design of individual hops as well as complete networks. It also facilitates the use of passive repeaters, both antennas back-to-back and plane reflectors. Cable lines can be included in order to predict the overall performance and unavailability of mixed-media circuits and connections.

The formulae used in the program are based on the relevant ITU recommendations. The number of hops and circuits (or *links*), which can be handled by the program, as well as the number of hops included in a circuit, are only limited by the capacity of the PC used. The results are presented as tables, and for the profiles, as profile charts. For a better overview, the radio-relay network and its associated hops, as well as the various links established over this network, and the harmful interference paths are shown as geographical network layout charts. The tables and the charts are presented on the screen as different windows, they can also be printed on paper. All data, input data and results, are stored in a data file.

The man-machine interface is based on menus and sub menus. The input data are inserted via dialogue boxes or from data files respectively. The equipment data - radios, antennas, feeders - can be loaded from program-attached databases. Such internal databases can be ordered from *K&K Engineering* or may be created on a menu-based dialog. ITU-R recommended data, such as planning objectives, meteorological data, clearance requirements etc can be obtained from program-internal databases. The input data from earlier planned networks, stored in data files, can be loaded at any later time.

Program features

1 Network layout

The basis for the program is the *Network layout*, which is a geographical presentation of the network. The chart shows the complete network - *see the above figure*. Most of the input data insertion can be controlled from this window.

The network layout may be based on freely selected positions of the radio sites or on co-ordinate-defined positions. The co-ordinates can be inserted manually or downloaded from a data file. A manually designed network layout can, at any time, be transferred to the co-ordinate controlled layout by applying either individual or á block co-ordinate insertion.

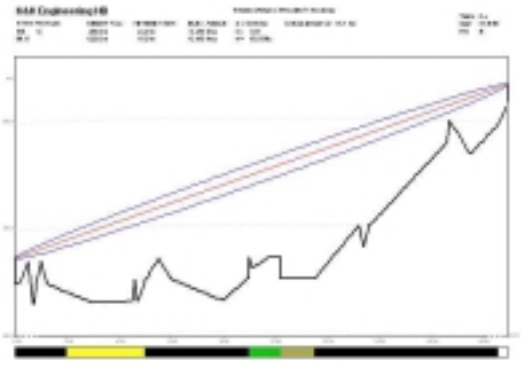
The scale for the chart can either be determined by the operator, *eg to 1:250 000, 1:100 000, etc*, or *RLTool* selects the scale which gives the best utilization of the chart.

The network chart can be printed on any paper size.

2 Profile charts

RLTool presents the path profile as a chart - *see the figure to the right*. The chart shows

- the contour of the terrain crossed by the radio beam,
- superimposed objects, such as single trees, forests, buildings etc.,
- the 1st Fresnel zone for the selected antenna heights,
- the surface type as a colour bar below the distance axis - water, sand, meadows, forests etc, and
- if relevant, ground reflections.



As default, the profile chart is presented for a *k* factor = 1.33. It can, however, be shown for any other *k* factor.

The profile data can be given by the operator via an input data dialogue window, a data file, or be loaded from a digital map database. At the same time the surface type can be defined. Additionally to the map

data, objects not shown on the map or not included in the database – buildings, trees etc. -, can be inserted and overlaid on the profile.

3 Antenna heights

Based on the profile data, *RLTool* calculates and optimises the necessary antenna heights, taking into account the clearance requirements for 2 different *k* figures, one for standard atmosphere and one for anomalous propagation conditions. Both the clearance and *k* figures can be given manually, or ITU-R recommended figures could be loaded from an internal database.

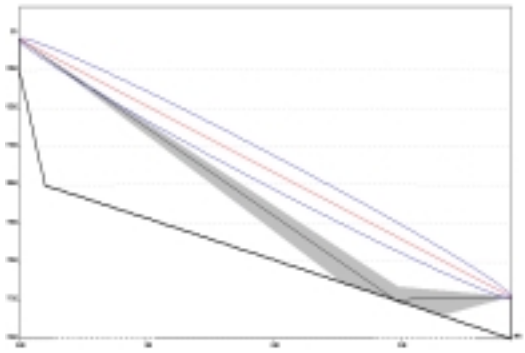
4 Profile analysises

Each profile will be analysed with respect to

- clearance of the 1st Fresnel zone
- risk for ground reflections

based on the calculated or selected antenna heights. The analysis will be performed for a *k*-value range of 0.5 - ∞

When investigating possible ground reflections, the slope of the terrain is taken into considerations. Furthermore, each ground segment is tilted in order to compensate for the difference between the real surface contour and that contour obtained from maps etc. Discovered potential reflection points and areas are both shown on the profile chart and as tables.



To counteract the influence of ground-reflected rays, *RLTool* proposes the optimum antenna separation for space-diversity protection, and calculates its effectiveness for varying *k* factors.

5 Total hop attenuation during fading-free time

The following parameters are included in the calculation:

- free-space basic attenuation (*RLTool* uses always the beam path length when calculating the free-space attenuation, taking the difference in altitude between the sites into consideration)
- additional attenuation(s), which may be caused by
  - obstacles
  - partial clearance
  - r.f. attenuators
  - periscope antennas
- attenuation due to atmospheric gases
- attenuation in the antenna feeder at the transmitting and receiving end
- attenuation in the RF-branching assembly of the radio-relay equipment
- antenna gain at the transmitting and receiving end
- gain in a passive repeater

6 Hop performance and unavailability calculations

The calculations are always performed for both directions of transmission. They consider the propagation conditions and their variations, and the influence of rain.

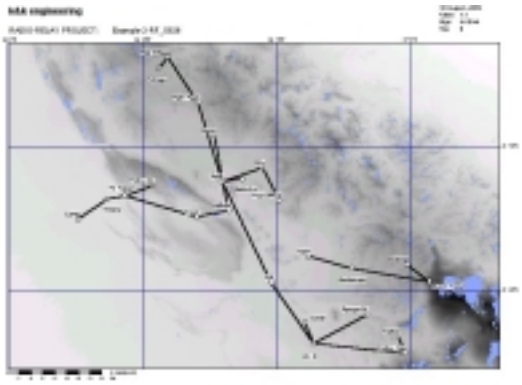
The following parameters are considered:

- the r.f. (centre frequency) in *GHz*
- the beam path length in *km.* If the site co-ordinates are given, *RLTool* calculates this parameter automatically
- the point refractivity gradient in the lowest 65 *m* of the atmosphere not exceeded for 1% of an average year. The figure can be obtained on a 1.5° grid resolution in latitude and longitude from a data file available from ITU-R. This data file is incorporated in *RLTool*

- the area terrain roughness, defined as the standard deviation in *m* of the terrain heights (in *m*) within a 110 *km* x 110 *km* area with a 30" resolution. The terrain data are obtained from the Globe *gtopo30* database, which is associated to the program
- the antenna heights above seal level in *m*
- the hop inclination in *milliradians,* based on the hop geometry and calculated by *RLTool*
- the hop length in *km* influenced by rain - the *effective* path length, calculated by *RLTool*
- the clock-minute *average annual* rainfall rate (or rainfall intensity) in *mm/h* exceeded for 0.01% of the time. If not known, *RLTool* obtains this figure from a data file available from ITU-R, is incorporated in *RLTool*
- the Rx input level during fading-free time, calculated by *RLTool*
- the equipments' Tx power level, their threshold level and signature data. ATPC is considered, if provided. These data can be loaded from the internal equipment database.

Dependent on the planning objectives selected, the exceeding of these objectives is counted as performance degradation or as unavailability.

7 Terrain database



The calculation of the terrain roughness - *see above* - requires the access to a terrain database. ITU-R recommends the *gtopo30* database. This database can be accessed by *RLTool*.

If the terrain profiles shall be generated from a digital map database, *RLTool* offers the following options:

- customer-made data files in ASCII format
- access to the global terrain database from the *US Geodetical Service*, available free-of-charge from the Internet
- local or national terrain database (In this case, *K&K Engineering* needs to know the format of the database)

The terrain's topography can be underlaid the network layout.

8 Improvement of the performance by diversity reception

RLTool supports the following diversity configurations:

- frequency diversity
- space diversity
- combined space and frequency diversity

and calculates the diversity improvement, based on the diversity parameters - frequency separation and/or antenna spacing - and on results from the calculations as per section 6.

9 Overall performance and unavailability

According to the ITU-R, the planning objectives are defined for the radio-relay link, ie the radio circuit, and not for the individual hop. In order to compare the predicted performance and unavailability with the planning objectives, the hops have to be combined to radio links. The minimum number of hops in a link is 1 hop.

In principal, the link layout is a copy of the network layout. On that layout, the hops included in the link are defined by clicking the hops (ie the interconnection lines between the sites). The link shown to the right consists of 4 hops connecting Rancher St with City.

This operation has to be carried out for each link, ie each link has its own layout chart. Also cable lines may be included in a link.

RLTool tests that the selected link capacity does not exceed the capacity of the hop with the lowest capacity.

RLTool combines the performance data from the individual hops to the overall performance of the circuit and processes the data in accordance with the selected ITU-R recommendations. If a cable line is included in the circuit, its performance is also included in the overall performance.

Similarly, the link's unavailability is predicted. It consists of three predictable events:

- unavailability due to rain
- unavailability due to multipath propagation
- hardware faults.

To consider unpredictable events, such as human factor etc, *RLTool* allows reserving a selectable margin of the unavailability objective for unpredictable events. The default figure is 20%.

The prediction of the hardware unavailability is based on the following parameters:

- the system configuration
- failure rate (failures per time unit) - the sum of the failure rates for the individual tandem connected units in the system
- mean-time-to-repair *(MTTR)* for the single structure, in the same time unit as the failure rate

and additionally for hardware-protected structures:

- failure rate (failures per time unit) for the (non-duplicated) splitting and switching device(s) proper
- mean-time-to-repair for the (non-duplicated) splitting and switching device(s) proper, in the same time unit as the failure rate

The hardware unavailability includes also that from cable lines.

The equipment failure rates can be obtained from the internal equipment database or given by the operator.

10 Planning objectives

The operator can either select its own planning objectives or the ITU-R recommended objectives, either the ones stated in ITU Recommendations G.821 and F.557, or those in G.826 and G.827.

RLTool has all the numerical values for the ITU-R planning objectives in its internal database. By activating one of the alternatives stated above, the corresponding data will apply for the link concerned. Only for the custom-defined planning objectives, the numerical figures have to be inserted by the operator.

11 Frequency planning and interference prediction

This activity is based on the following data:

- co-ordinates of all radio sites
- equipment data, incl. interference sensibility
- antenna data, incl. radiation pattern
- all radio frequencies (The radio frequencies can be selected from an ITU-R recommended r.f. channel plan, included as a program-internal database, or selected freely.)

Automatic selection of the upper (U) and lower (L) halfband of the planned r.f. range assures an optimum utilization of the available radio frequencies. However, *RLTool* facilitates the possibility to perform interference calculations also for radio sites operating both as an *L* and *U* stations.

Existing sites or networks – not subject to the planning - operating in the planned frequency band(s) may interfere with the planned network. To consider that, these sites can be included in the calculations.

All frequencies within the same r.f. band are tested against each other. Hereby, the bandwidth of the disturbed receiver and the spectrum bandwidth of the disturbing transmitter are considered, as well as the modulation scheme (4FSK, 4PSK, 16QAM, 128QAM etc.) and the antenna discrimination for both the disturbing and the disturbed signal, as these will influence the interference effect.

If a radio path includes a passive repeater, interfering signals reaching a disturbed receiver via this repeater are included in the calculation.

For each receiver the individual interfering levels and the total interference loading is calculated.

12 Interference network chart

In addition to the *Frequency list* and the *Cumulative interference calculation* report, *RLTool* generates an *Interference network* chart. This chart shows all individual interference connections with a signal level higher than a selectable threshold.

Clicking an interference path leads one directly to the associated interference report.

The example shown in the chart to the right indicates a harmful interference between the paths Hill – Village and Hill – Valley.

13 ATPC functionality

If the selected RL equipment utilizes ATPC (Adaptive Transmitter Power Control), *RLTool* will include it in its performance and interference prediction by calculating all path and performance parameters related to fading-free time with the equipment's operating maximum Tx output level decreased by the figure of the selected ATPC range, and the fading-related performance and unavailability with the operating maximum Tx output.

14 Bit stream disposition

Each hop in a network may belong to more than one link, where each link occupies one or more 2 *Mbit/s* channels. In order to facilitate the design and the extension of a network, the utilization of the hops' capacity is displayed: In the link layout chart, the number of 2 *Mbit/s* channels employed by the respective link is shown for each hop, together with the number of free 2 *Mbit/s* channels still available on each hop. A table summarises the total 2 *Mbit/s* disposition for the complete network.

15 Defaults and tests

Default values have been set for a number of input data, such as the signature's delay figure, or the system configuration, the *k* factor etc. These data can be edited by the operator.

The program includes also a great number of tests, either testing the correctness of inserted data, eg whether the stated r.f. band is allocated for radio-relay networks, or if the hops in a planned link can provide the requested bit stream capacity, or the likelihood of calculated figures, such as the fading margin, etc.

16 Further information

A more detailed description - *Functional Description KKE0701* - is available on *K&K Engineering's* Website `http://www.kk-engineering.a.se/download.html`. A DEMO-version of *RLTool* can be downloaded free of charge from the same Website. The demo version differs from the licensed version by not having the facilities of saving input data and results from the calculations. Neither can the results be printed.

K&K Engineering has also published 4 handbooks related to radio-relay networks:

- *Planning and engineering of radio-relay systems*
- *Performance and availability as applied to digital radio-relay systems*
- *Frequency planning of digital radio-relay systems*
- *Performance and availability – Principles and formulae*

These handbooks are enclosed free of charge in the *RLTool* program package. They can also be ordered separately.

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