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**FOURTH ICTP-URSI-ITU(BDT) COLLEGE ON RADIOPROPAGATION:**
**Propagation, Informatics and Radiocommunication System Planning**

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***Miramare - Trieste, Italy***

# *Laboratory on Informatics for Radiocommunications*

## *Lecture 1*

## *"Propagation predictions concerning terrestrial line-of-sight microwave links"*

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**Geneva, Switzerland**

DOCUMENTS
CCIR STUDY GROUPS
PERIOD 1986-1990

DOC. IWP 1/2-214
MAY 18, 1988
ORIGINAL: English

JAPAN

# RADIO RELAY LINK PROPAGATION PATH DESIGN (M-LINK)

## 1. Introduction

Recent moves toward the information society have increased the world demand for radio relay links. The radio spectrum is limited, so these links must use it efficiently.

One way to do this, and at the same time reduce interference, is to locate each radio station in the best place. Finding such a place involves complicated calculations. Our new software package, " Radio Relay Link Propagation Path Design", enables anyone to find the best location for a radio station.

We have used this software to make efficient use of the radio spectrum and to provide good links, and we have done this work much faster than was possible before.

This easy-to-operate program will run on IBM PCs and the NEC 9800 series anywhere in the world.

~~in Basic~~

Features

- Written in IBM BASIC .
- Comprises 29 task modules .
- This 300 K byte program fits on one floppy disk .
- Each task can be selected from the task menu, started independently, and accessed directly.
- Conversational interface. The program asks you to input parameters one-by-one .
- Full color display makes the operation easy to understand .

## 2. Outline

The radio relay link propagation path design program comprises 29 task modules and one final message.

Fig.1 shows how the modules relate to each other.

There are information modules containing design information, and calculation modules. There is also a data file containing propagation parameters and typical antenna constants from the CCIR Green Book. This data is used in the calculations.

Fig.2 showes the task menu, the first screen to appear when the program is started. Any task may be selected and run.

Task 1 Microwave frequency bands and their application

- Actual microwave frequency bands
  Long distance circuit : 4, 5, 6, 8 Ghz bands .
  Branch circuit : 11,15 Ghz bands .
  Short distance circuit : 2, 7,11,15 Ghz bands.
- Indication of input parameter : frequency band, bandwidth, center frequency, system capacity , and CCIR recommendation number correspond to the description.

Task 2 Free space propagation

- Input of input parameters : frequency , section distance, transmitter output power, transmitting/receiving antenna gain, feeder loss.
- Calculation and indication of free space loss and received input power.

Task 3 Line-of-sight propagation

- Description and illustration show how a height pattern occurs at the receiving point becouse of the ground reflected wave.

Task 4 Tropospheric propagation

- Description of how radio propagation in the troposphere is affected by weather .
- Description of three propagation types characterized by the effective radius of earth (K).
- Description of applicable value by classification of K value accordinate the regional weather .

Task 5 Fresnel zone theorem

- Illustration of the radius of the first fresnel zone.
- Description says that the path must be designed to have two-thirds of the radius of the first fresnel zone.

Task 6 Diffraction

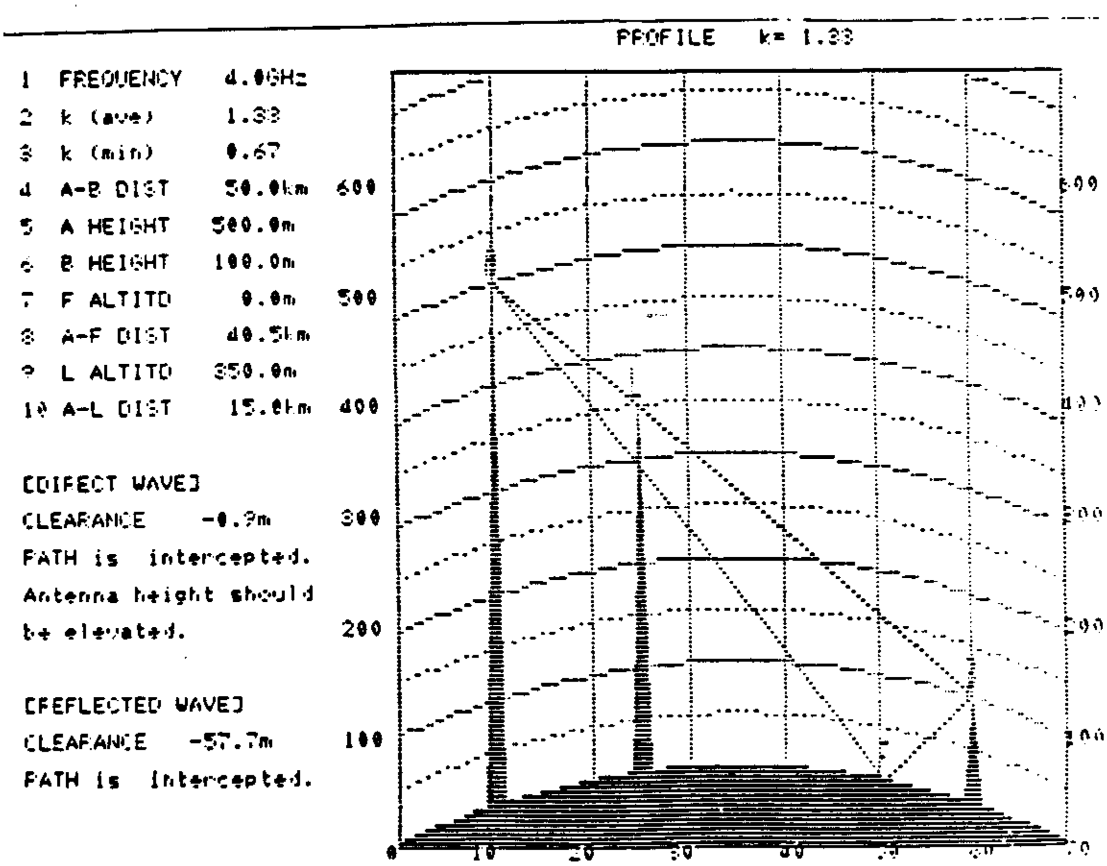
- Description and illustration show how the height of the obstacls affects the received input power.

Task 7 Planning of relay route

- Description and indication of the basic data of route planning : relay distance, path clearance, ground reflection, repeating angle, and station frequency .

Task 8 Profile drawing

- Input of input parameters : frequency, section distance, transmitting/receiving antenna height, distance to the reflection point , altitude of reflecion point, altitude of ridge, distance to ridge, and K value.
- Illustration of profile. We have prepared 24 scales of profile, which are adopted automatically to suit the given input parameters.
- Calculation and illustration of a profile showing the clearance by direct wave and reflected waves. These route are judged by the propagation standard. A comment is shown to help the designer choose whether to continue the calculation of the input parameters of this section or to change the route plan.



Task 9 Path clearance at ridge point

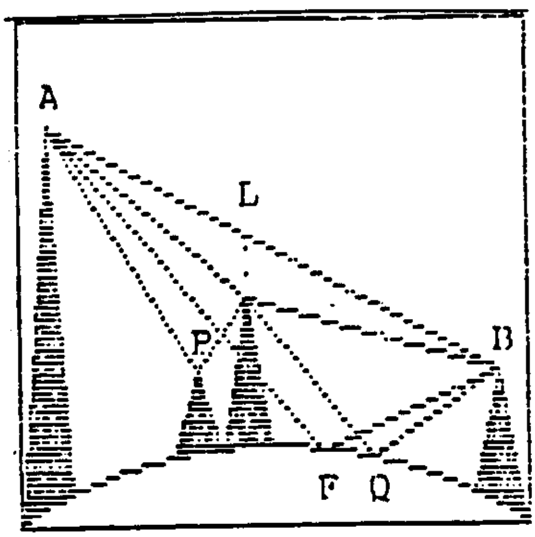
- Calculation and illustration of the clearance.
- Calculation of procedure and illustration of the clearance of reflected wave.

Task 10 Ridge diffraction loss

- Input of input parameters : K value (average, minimum), section distance, transmitting/ receiving antenna height, distance to the obstacle, altitude at the reflection point.
- Calculation and illustration of the ridge diffraction loss by direct wave and reflected wave.

Task 11 Direct wave and reflected wave losses

- Description of the effective ridge loss by direct wave and reflected wave.
- Description of the path of the reflected wave.




Task 12 Ground reflection loss

- Illustration of the reflected wave loss (experimental value for Japanese territory) by the classification of frequency and geographical and geological features at the reflect point.

Task 13 Locating the reflection point

- Input of input parameters : hop distance, transmitting/receiving antenna height, K value (average) and altitude of reflect point.
- Calculation and illustration of the location of reflection point.
- The 3rd equation uses Newton's approximate quantity value calculation method.

Task 14 Included angle between direct and reflected waves

- Input of input parameters : hop distance, transmitting/receiving antenna height, K value (average) and altitude of reflection point.
- Calculation and illustration of the included angle between direct and reflected wave.
- The third equation in Newton's approximate quantity value calculation method is used.

Task 15 Antenna directivity

- Description of the general pattern of antenna directivity. Uses the experimental values of the four meter diameter parabolic antenna that generally in Japan.

Task 16 Fading in line-of-sight transmission

- Description of increase of thermal noise by fading, and fading margin.

Task 17 Transmission quality standard on hypothetical reference circuit

- Illustration and description of the constitution of Hypothetical Reference Circuit.
- Description of standard of the allowable noise.
- Description of standard of the circuit dropout rate.

Task 18 Regulation regarding max. EIRP

- Description of standard of antenna radiated power limitation to limit mutual interferance between terrestrial and satellite systems.

Task 19 Distribution of received power during short term fading

- Description of standard of Rayleigh Fading Occurrence Probability and circuit dropout rate.
- Input of input parameters : frequency, hop distance, geographical features, effective reflective attenuation, transmitting/receiving antenna height.
- Calculation of Rayleigh Fading Occurrence Probability and circuit dropout rate, and comparison with CCIR Recommendation.
- Indication of whether the space diversity system is needed.

Task 20 Space diversity system

- Description and illustration of applicable condition of space diversity and antenna spacing pitch.

Task 21 Antenna elevation angle

- Calculation and illustration of transmitting/receiving antenna elevation and depression angle from the horizontal.

Task 22 Azimuth and distance to each station

- Input of latitude and longitude of each station.
- Calculation and illustration of azimuth from true north and distance toward station.
- Spherical trigonometry is adopted and the distance calculated is the great circle distance.

Task 23 Estimation of propagation path performances

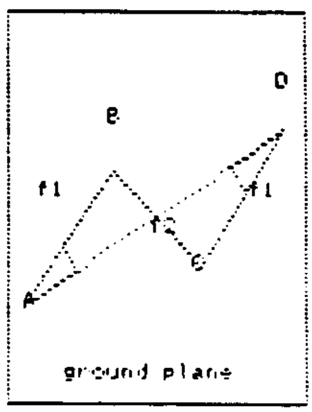
- Calculation together from item 2 until item 21 for propagation performances.
- Input parameter and output data are registered by data file and indicate together in item 29.

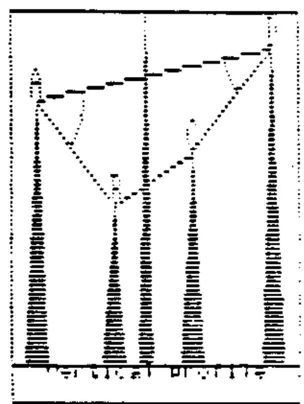
## Task 24 Over-reach interference

- Input of input parameters : frequency, antenna height, each section distance, azimuth toward respective station, altitude of ridge, distance to ridge point.
- Calculation and illustration of interference noise (D/U value).

OVER-REACH (SELF ROUTE INTERFERENCE) 4.0 GHz

| | | |
|---|---|---|
| 1 | A HEIGHT | 500.0m |
| 2 | B HEIGHT | 300.0m |
| 3 | C HEIGHT | 400.0m |
| 4 | D HEIGHT | 600.0m |
| 5 | A-B DISTANCE | 10.0km |
| 6 | B-C DISTANCE | 10.0km |
| 7 | C-D DISTANCE | 10.0km |
| 8 | A-D DISTANCE | 26.6km |
| 9 | ANGLE BAD | 4: 0: 0 |
| 10 | ANGLE ADC | 30: 0: 0 |
| 11 | RIDGE ALTITO | 700.0m |
| 12 | RIDGE DISTANCE | 14.0km |



| ---- A side ---- | | | ---- D side ---- | | |
|---|---|---|---|---|---|
| A side span loss difference | | 8.5dB | D side span loss difference | | 8.5dB |
| horizontal deflection | 4.0deg | 23.0dB | horizontal deflection | 30.0deg | 43.0dB |
| vertical deflection | 1.3deg | 8.0dB | vertical deflection | 0.9deg | 4.5dB |
| A-D ridge loss | | 32.9dB | A-D ridge loss | | 32.9dB |
| A side D/U | | 72.4dB | D side D/U | | 84.4dB |

**Task 25** Interference with other routes

- Input of input parameters : frequency, each latitude and longitude,transmitter output power, transmitting feeder loss, antenna polarization.
- Calculation and illustration of interference noise (D/U value).
- Can calculate mutual D/U for up to four routes.
- This program can be used by the relative location of station method, working selection is needed but in this case.

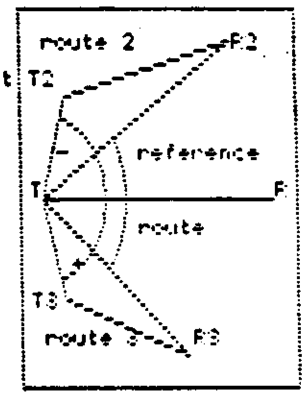
** Relative location of transmitting and receiving stations in each route **

(1) Designate a reference route and a reference point from among the routes to be examined.

(2) The reference point is meant for the transmitting point in the reference route.

(3) By using maps, obtain azimuths and distances towards the transmitting and receiving points in other routes measured from the reference point.

(4) Azimuth should be expressed as
plus(+) sign for clockwise direction.
minus(-) sign for anti-clockwise direction.



**Task 26** Interference to geostationary satellite orbit

- Calculation of direction angle difference between a station in the radio relay links and a geostationary satellite orbit.
- Judgement of whether the direction angle difference is greater or less than two degrees. The mutual interference is observed to help make this judgement.

**Task 27** Interference between terrestrial station and earth station

- Judgement of mutual interference between terrestrial station and earth station by total transmission loss.

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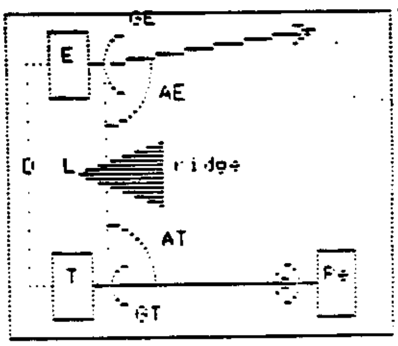
** Interference between terrestrial station and earth station (4.0 GHz) **

| | | |
|---|---|---|
| 1 | E ANT HEIGHT(m) | 100.0 |
| 2 | E ANT GAIN (dB) | 58.0 |
| 3 | ANGLE AE(d.m.s) | 100:30: 0 |
| 4 | E ANT DIRECTIVITY(dB) | 66.0 |
| 5 | T ANT HEIGHT(m) | 500.0 |
| 6 | T ANT GAIN (dB) | 42.5 |
| 7 | ANGLE AT(d.m.s) | 90: 0: 0 |
| 8 | T ANT DIRECTIVITY(dB) | 61.5 |
| 9 | E-T DISTANCE(km) | 20.0 |
| 10 | RIDGE ALTITD (m) | 400.0 |
| 11 | E-L DISTANCE(km) | 10.0 |
| 12 | k(average value) | 1.50 |




(E-T SPAN PROPAGATION LOSS 130.5dB)

(RIDGE DIFFRACTION LOSS 30.7dB)

EFFECTIVE TRANSMITTING LOSS 133.2dB

This path meets the standards, the route plan is acceptable.

## Task 28 Field survey

- Description of necessary items for desk work, primary survey and secondary survey.

| ITEM | CONTENT | DESK. | PRIM. | SECO. |
|---|---|---|---|---|
| Route map | hop distance, altitude | ○ | | |
| | azimuth | ○ | | |
| Site | topography, geology (steep,plain,sandy,rocky) | | ○ | ○ |
| | latitude, longitude | ○ | | |
| | altitude | ○ | | ○ |
| | land area (land readjustment) | ○ | | ○ |
| | acquisition of water for installation | | | ○ |
| Road | path, driveway | ○ | ○ | |
| | necessary length for new construction, repair | | ○ | ○ |
| Tower | antenna height above roof/ground | ○ | | ○ |
| | radome | ○ | ○ | |
| Power supply | in-take line length, reliability | | | ○ |
| Propagation path | profile | ○ | | ○ |
| | visibility(mirror test) | | | ○ |
| | topography around the reflection point | ○ | | ○ |
| | topography in the proximity of the site | | | ○ |
| | sketch | | | ○ |
| Maintenance | access route, time (summer, winter) | | | ○ |

**Task 29** Determination of system meeting required performances

- Description of various calculation necessary for judgement, and indication of actual dimensions.
- Indicate refer to the conclusion of works after read out data from datafile.

| EXECUTIVE SUMMARY | POINT A | POINT B |
|---|---|---|
| Antenna Height(m) | 554.3 m | 100.0 m |
| Antenna elevation angle | -0.67deg | 0.37deg |
| Included angle(direct and reflected waves) | 0.22deg | 1.05deg |
| Antenna directivity effect | 1.0 dB | 6.5 dB |
| Distance(km) to reflection point | 41.4 km | 8.6 km |
| Diffraction loss of ridge | 12.5 dB | |
| Geographical feature at reflection point | waterface | |
| Reflection loss | 0.0 dB | |
| Altitude(m) at reflection point | 0.0 m | |
| Effective loss of reflected wave | 20.0 dB | |
| Span distance(km) | 50.0 km | |
| Span loss | 141.4 dB | |
| Clearance(m) | 6.2 m | |
| Circuit dropout rate(month) of path | 1.85*10 -7 | |
| Circuit dropout rate(month) of CCIR REC.395-4 | 20.00*10 -7 | |
| Space diversity system | not necessary | |

**Task 30** Termination

## 3. Conclusion

This program can be used anywhere in the world. The only adjustment reeded is to modify the data file according to the propagation constant of the country you are in. We are sure that this program will help you to design radio relay links that use the spectrum efficiently.

## 4. Annex

Fig.1 STRACTURE CHART OF M-LINK SOFTWARE

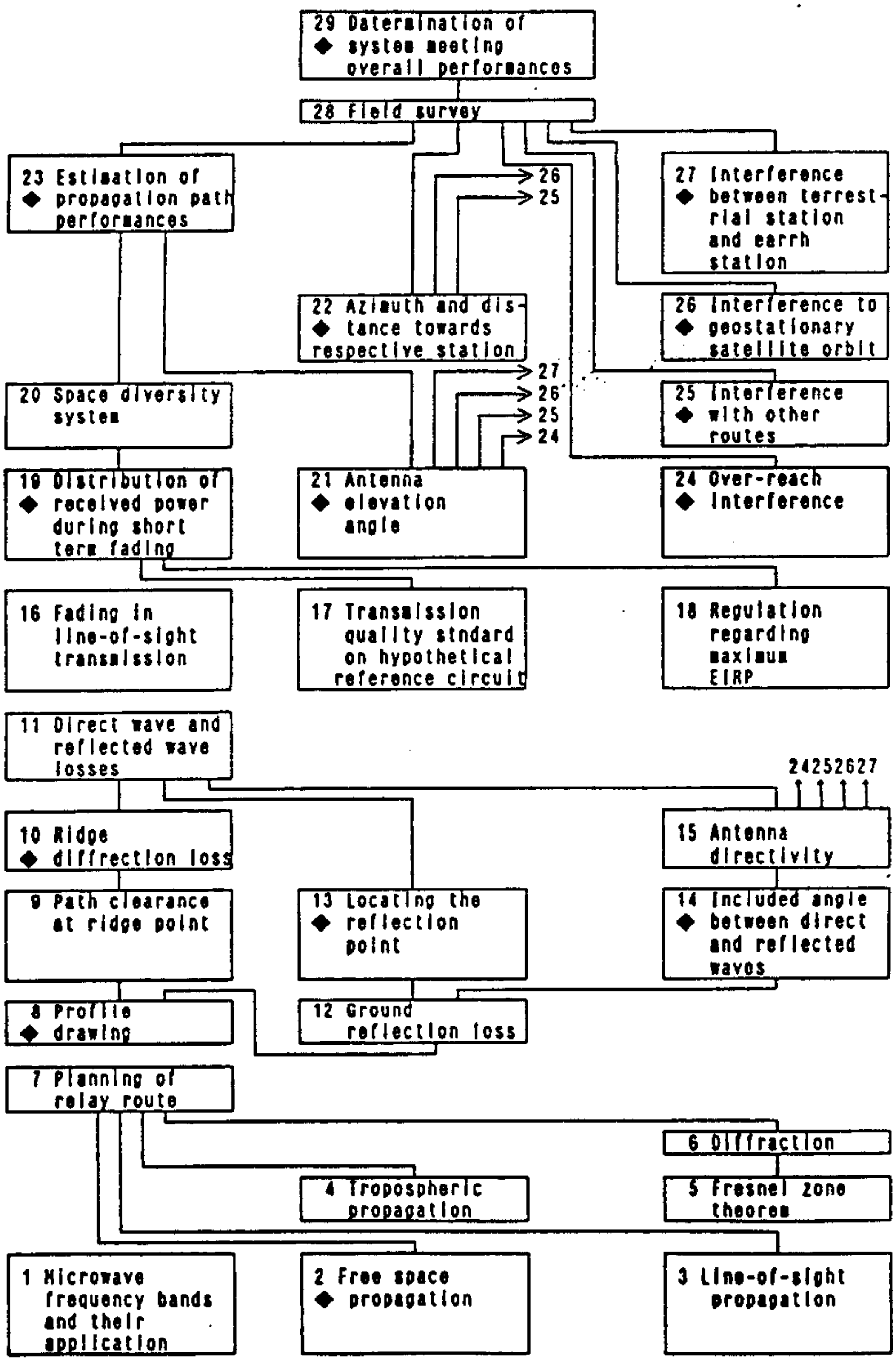


Fig.2 TASK MENU OF M-LINK SOFTWARE

◇ Calculation or Estimation

| | |
|---|---|
| 1 Microwave frequency bands and their application | |
| 2 Free space propagation | ◇ |
| 3 Line-of-sight propagation | |
| 4 Tropospheric propagation | |
| 5 Fresnel zone theorem | |
| 6 Diffraction | |
| 7 Planning of relay route | |
| 8 Profile drawing | ◇ |
| 9 Path clearance at ridge point | |
| 10 Ridge diffraction loss | ◇ |
| 11 Direct wave and reflected wave losses | |
| 12 Ground reflection loss | |
| 13 Locating the reflection point | ◇ |
| 14 Included angle between direct and reflected waves | ◇ |
| 15 Antenna directivity | |
| 16 Fading in line-of-sight transmission | |

| | |
|---|---|
| 17 Transmission quality standard on hypothetical reference circuit | |
| 18 Regulation regarding maximum EIRP | |
| 19 Distribution of received power during short term fading | ◇ |
| 20 Space diversity system | |
| 21 Antenna elevation angle | ◇ |
| 22 Azimuth and distance towards respective station | ◇ |
| 23 Estimation of propagation path performances | ◇ |
| 24 Over-reach Interference | ◇ |
| 25 Interference with other route | ◇ |
| 26 Interference to geostationary-satellite orbit | ◇ |
| 27 Interference between terrestrial station and earth station | ◇ |
| 28 Field survey | |
| 29 Determination of system meeting overall performances | |
| 30 Termination | |

! Blocks system

! Rec to code mode needed

Select item number (1-30) ?

! don't use

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*Laboratory on Informatics for Radiocommunications*

# Propagation predictions concerning terrestrial line-of-sight microwave links

*For this part of the Laboratory course, use is made of the computer program MLINK. The program contains 29 modules which provide a tutorial treatment of the subject and also the opportunity to perform calculations on example microwave links. The questions and examples below relate to certain of the modules where calculations can be undertaken.*

*To access MLINK, go to the directory \MLINK, call GWBASIC and load "START.BAS".*

## 1. Concerning item 2 - Free-space propagation

A microwave link has a span of 30 km. A transmitter power of 40 dBm feeds an antenna of gain 35 dB. The receiving antenna gain is 25 dB. The feeder loss, both at the transmitter and at the receiver, is 2 dB. Calculate the free-space loss and receiver input power level for the following frequencies:

| Frequency (GHz) | Free-space loss (dB) | Rx input power level (dBm) |
|---|---|---|
| 4 | | |
| 8 | | |
| 15 | | |

## 2. Concerning item 8 - profile drawing

One of the hops in a planned microwave link at 15 GHz has a distance of 30 km. The height of the transmitting antenna is 60 m and there is a terrain feature (ridge) 10 km from the transmitter, extending to a height of 25 m. Ground reflection is assumed to occur from a region of the path of height 10 m. The link is planned to operate during sub-refractive conditions corresponding to a value of k (effective Earth radius) = 0.6. What is the minimum height at which the receiving antenna can be installed in order to have an unobstructed path for the direct wave? (Assume that average atmospheric conditions correspond to k = 1.33).

If more extreme sub-refractive conditions prevail corresponding to a value of k = 0.5, will the receiving antenna height need to be modified to obtain terrain clearance and, if so, what is the new height?

## 3. Concerning item 10 - Ridge diffraction loss

**3.1** Using the parameters for the link described above (in 2), (with the calculated value for the minimum receiving antenna height and a minimum value of k = 0.6), use the program to tell you:

i) the radius of the first Fresnel Zone (FZ1);

ii) the clearance of the direct wave;

iii) the loss suffered by the direct wave due to the ridge.

**3.2** What would be the height of the receiving antenna needed to reduce the ridge loss to < 3 dB?

**3.3** What would be the height of the receiving antenna needed to reduce the ridge loss to 0 dB?

**3.4** What is the first Fresnel Zone clearance {(direct wave clearance) ÷ (FZ1 radius)} in each of the cases in 3.2 and 3.3?

## 4. Concerning items 13 (Locating the reflection point) and 14 (Included angle ....)

Invent a few examples to become familiar with these parameters.

## 5. Concerning item 19 - Distribution of received power during short-term fading

To demonstrate how fading due to atmospheric multipath influences the planning of a microwave link, the following path parameters can be used as an example in this program module.

| USA fading model | |
|---|---|
| Frequency: | 6 GHz, lower band |
| Path length: | 25 km |
| Reflection loss: | 15 dB |
| Climate type: | continental, temperate |
| Terrain type: | average |

Is the path acceptable?

What happens (and why) if the following parameters are changed **individually?**

i) the path length is increased to 30 km;

ii) the climate type is changed to "maritime sub-tropical";

iii) the ground type is changed to "smooth";

What is the result if the frequency is changed to 8 GHz (with all other parameters as originally specified)? If there appears to be a problem, what remedial action could be taken?

## 6. Concerning items 21 (Antenna elevation angle) and 22 (Azimuth and distance ....)

Invent some examples to become familiar with these modules.

## 7. Concerning item 23 - Estimation of propagation path performance

The following examples demonstrate how the items studied above are used in an overall assessment of a planned microwave path.

Example A

| | |
|---|---|
| Frequency: | 6 GHz, lower band |
| Average k value: | 1.33 |
| Minimum k value: | 0.6 |
| Path length: | 30 km |
| Tx antenna ht.: | 60 m |
| Rx antenna ht.: | 34 m |
| Height of reflection point F: | 10 m |
| Reflection point F "feature": | field |
| Ridge height: | 25 m |
| Ridge distance from Tx: | 10 km |
| Height of reflection point P: | 5 m |
| Reflection point P "feature": | field |
| Height of reflection point Q: | 8 m |
| Reflection point Q "feature": | field |

Example B

| | |
|---|---|
| Frequency: | 11 GHz |
| Average k value: | 1.33 |
| Minimum k value: | 0.6 |
| Path length: | 30 km |
| Tx antenna height: | 60 m |
| Rx antenna height: | 40 m |
| Height of reflection point F: | 10 m |
| Reflection point F "feature": | field |
| Ridge height: | 45 m |
| Ridge distance from Tx: | 10 km |
| Height of reflection point P: | 5 m |
| Reflection point P "feature": | field |
| Height of reflection point Q: | 5 m |
| Reflection point Q "feature": | field |

In each case, what is predicted and what, if anything, is recommended?

[If you want to investigate short-term fading, then select the "USA model" with a "continental, temperate" climate and "average" terrain.]

Try the above examples for:
- i) different frequencies,
- ii) different ridge height,
- iii) different type of ground terrain.