TIL-TEK

Application Note No. 7
Radio Link Calculations
(Link_Calc.xls)

The following application note describes the application and utilization of the **"Link_Calc.xls"** worksheet. Link_Calc.xls is an interactive point to point radio link calculation worksheet which can be used by system designers to assist in the selection of the appropriate ***antennas***, cables, radio power output, etc ... . Attached to this document, is a list of reference descriptions which will individually describe each data, calculation and reference cells of the worksheet to assist the designer in modifying the inputs parameters such as to meet the desired performance objectives.

General: During system design, there are basically two major objectives which the system designer is aiming to meet while selecting the various components, they are;

a) Selecting the components in such a way that the maximum allowable Effective Isotropic Radiated Power (EIRP) allowed by the local regulating body such as Industry Canada or the FCC will not be exceeded. (eg.: $\leq$ 36 dBm EIRP on a point to multi-point link in the 2.4 GHz ISM Band)

b) Selecting the components in such a way as to obtain a receive signal fade margin which will provide the desired system performance (eg.: availability of 99.995 % or better).

NOTE 1: *Based on experience and industry standards, the model presented in the International Telecommunication Union, ITU Radiocommunication Assembly, Rec. ITU-R P.530 has been chosen by TIL-TEK to perform the availability calculations.*

NOTE 2: *Although availability is strictly left to the discretion of the system designer, based on experience and testing,* ***TIL-TEK*** *recommend that the availability objectives should be 99.995% or better annual one way. This will ensure a reliable high quality radio link.*

In some special cases where a figure of 99.995 % is not feasible due to either excessive antenna sizes or excessive EIRP, a figure of 99.95 % can be used if a degradation in performance is acceptable. In order to evaluate if this is acceptable for the specific application, it is also useful at times to evaluate the availability based on the "Outage Time" which is the predicted amount of time where the receive signal level will be below the threshold of the radio.

Utilization: Link calculations are performed by entering technical data for each piece of equipment that will be used to implement the radio link. Based on the data input in the cells denoted ***(Required)***, various computations are performed and the output is presented in the calculation (Read Only) cells of the worksheet, the end result being, "Availability" of the radio link. For details on each individual cell, please see the attached document entitled "Reference Descriptions".

REFERENCE DESCRIPTIONS

Note 1: *References labelled (Optional) are not required for the calculations but placed in the worksheet for reference.*

Note 2: *References labelled **(Required)** are required for the calculations.*

Note 3: *References labelled (Read Only) are calculation outputs based on input data and are protected against input as they contain complex formulas.*

Ref. 1: **"Site Name"**
(Optional)

Enter the specific name or site identification for reference purposes if desired.

Ref. 2: **"Antenna Type"**
(Optional)

Enter the specific antenna type for reference purposes if desired.

Ref. 3: **"Antenna Gain" (dBi)**
(Required)

Enter the gain (in dBi) of the antenna, which will be installed at this site. This information is available and specified by the antenna manufacturer.

Ref. 4: **"Transmission Line Type"**
(Optional)

Enter the specific type of transmission line, which will be used to interconnect the radio transmitter / receiver to the antenna for reference purposes if desired.

Ref. 5: **"Transmission Line Loss" (dB/100m)**
(Required)

Enter the transmission line loss characteristics (in dB/100m) of the specific transmission line, which will be used to interconnect the radio transmitter / receiver to the antenna. This information is available from the transmission line manufacturer. *(Some examples have been provided at the end of this document in Annex-A.)*

Ref. 6: **"Transmission Line Length" (m)**
(Required)

Enter the specific length of transmission line (in metres), which will be used to interconnect the radio transmitter / receiver to the antenna.

Ref. 7: **"Transmission Line Loss" (dB)**
(Read Only)

This information is the calculation of the specific transmission line loss (in dB) as per specifications. It was calculated as follows:

$$\textbf{Transmission Line Loss} = (T_{XL} \times L_{TX}) \div 100$$

Where: T_{XL} = Transmission line length in metres.
L_{TX} = Transmission Line Loss in dB/100m.

Ref. 8: **"Connector Loss" (dB)**
(Required)

Enter the sum of all expected connector losses which will be used to interconnect the radio transmitter / receiver to the antenna (in dB). This information is available and specified by the connector manufacturer. *(If unknown, a good "rule of thumb" to use at frequencies up to 3 GHz is 0.25 dB per connector.)*

Ref. 9: **"Divider / Combiner Loss" (dB)**
(Required)

In the case where a system uses a divider or combiner to combine radios or divide power between two or more antennas, enter the specified loss of the specific device (in db). This information is available and specified by the specific device manufacturer.

Ref. 10: **"Equipment Tolerances" (dB)**
(Required)

If there are other components, which will introduce losses between the radio equipment and antenna and/or if there are variances (+/-) in the equipment, enter the sum of all items (in dB) here. This information is available and specified by the component(s) manufacturers.

Ref. 11: **"Path Length" (Km)**
(Required)

Enter the distance (in Km) between the two sites where the calculations are to be performed for.

Ref. 12: **"Frequency" (GHz)**
(Required)

Enter the operating frequency of the radio equipment (in GHz). This is usually the centre frequency.

Ref. 13: **"Free Space Attenuation" (dB)**
(Read Only)

This information is the calculation of the attenuation (in dB) between the two sites due to the propagation of the radio signal through free space. It was calculated as follows:

Free Space Loss = 92.4 + 20 * LOG(D) + 20 * LOG(F)

Where: **D** = Path Length in Km.
F = Frequency in GHz.

Ref. 14: **"Diffraction Loss" (dB)**
(Required)

If the path is diffracted or obstructed and the amount of attenuation is known, enter the value (in dB) here. If the path is a clear line of sight path with adequate fresnel zone clearance (60% F1), enter "0".

Ref. 15: **"Radio Type"**
(Optional)

Enter the specific radio equipment type for reference purposes if desired.

Ref. 16: **"Transmitter Power" (dBm)**
(Required)

Enter the output power (in dBm) of the radio's transmitter here. This information is available and specified by the radio manufacturer.

Ref. 17: **"Free Space Receive Signal Level" (dBm)**
(Read Only)

This information is the calculation of the signal level (in dBm), expected at the receiver's input. It was calculated as follows:

$$RSL_{FS} = (P_{TX} + G_{ANT}) - (L_{TX} + L_{CONN} + L_{D/C} + L_{EQ} + FSL + L_{DIFF})$$

Where:

RSL_{FS}	=	Free Space Receive Signal Level in dBm.
P_{TX}	=	Transmitter power in dBm.
G_{ANT}	=	Sum of the two antenna gains in dBi.
L_{TX}	=	Sum of the two transmission line losses in dB.
L_{CONN}	=	Sum of the all connector losses in dB.
$L_{D/C}$	=	Sum of all divider / combiner losses in dB.
L_{EQ}	=	Sum of all Equipment Tolerances in dB.
FSL	=	Free space attenuation in dB.
L_{DIFF}	=	Diffraction loss in dB.

Ref. 18: **"Effective Isotropic Radiated Power (EIRP)" (dBm)**
(Read Only)

This information is the calculation of the effective radiated power (over isotropic) of the site (in dBm) to the atmosphere and utilized for regulatory purposes. It was calculated as follows:

$$EIRP = (P_{TX} + G_{ANT}) - (L_{TX} + L_{CONN} + L_{D/C} + L_{EQ})$$

Where:

EIRP	=	Effective Isotropic Radiated Power in dBm.
P_{TX}	=	Transmitter power in dBm.
G_{ANT}	=	Antenna gain of the site in dBi.
L_{TX}	=	Transmission line losses of the site in dB.
L_{CON}	=	Connector losses of the site in dB.
$L_{D/C}$	=	Divider / combiner losses of the site in dB.
L_{EQ}	=	Equipment Tolerances in dB.

Ref. 19: **"Receiver Threshold Criteria" (BER)**
(Optional)

Enter the performance characteristics of the radio's receiver as a function of Bit Error Rate (BER) at the minimum desired level for reference purposes if desired.

Ref. 20: **"Receiver Threshold Level" (dBm)**
(Required)

Enter the threshold of the radio's receiver, which is specified at the desired threshold criteria indicated above (in dBm). This information is available and specified by the radio manufacturer.

Ref. 21: **"Thermal Fade Margin" (dB)**
(Read Only)

This information is the calculation of the difference between the Free Space Receive Signal Level and the Receiver Threshold Level (in dBm). In summary it is the amount by which the signal level can naturally degrade to (fade), due to variations in atmospheric conditions prior to the equipment operating below it's specified threshold

Ref. 22 - **"Refractivity Gradient Below -100N/km" (PL) (%)**
(Required)

Enter the amount of time (between 0 - 100 %) that the relative refractivity gradient is below -100(N/Km) for the geographic region. This is required for the availability calculations as per ITU-R P.530. ***(For details on how to determine the value of PL (%), please refer to Annex-B.)***

Ref. 23 - "Site A Altitude" (AMSL) (m)
(Required)

Enter the site altitude (Above Mean Sea Level) in metres. This is required to determine the path inclination and grazing angle required for the availability calculations as per ITU-R P.530.

Ref. 24 - "Site B Altitude" (AMSL) (m)
(Required)

Enter the site altitude (Above Mean Sea Level) in metres. This is required to determine the path inclination and grazing angle required for the availability calculations as per ITU-R P.530.

Ref. 25 - "Site Latitude" (ºN or ºS)
(Required)

Enter the site latitude in degrees. This is required for the availability calculations as per ITU-R P.530.

Ref. 26 - "Longitudinal Coefficient" (Clon) (dB)
(Required)

This is a coefficient which is relative to the specific geographic location of the site and is referred to in dB's as follows:

For longitudes of North and South America, enter-		**-3**
For longitudes of Europe and Africa, enter	-	**3**
For all other longitudes, enter	-	**0**

This is required for the availability calculations as per ITU-R P.530.

Ref. 27 - "Site A Antenna Height" (AGL) (m)
(Required)

Enter the height of the site A antenna (Above Ground Level) in metres. This is required to determine the path inclination and grazing angle required for the availability calculations as per ITU-R P.530.

Ref. 28 - "Site B Antenna Height" (AGL) (m)
(Required)

Enter the height of the site B antenna (Above Ground Level) in metres. This is required to determine the path inclination and grazing angle required for the availability calculations as per ITU-R P.530.

Ref. 29 - "Worst Month Availability" (%)
(Read Only)

This information is the percentage of time (in %) that the "Free Space Signal Level" is predicted to be above the "Receiver Threshold Level" during the worst month of fading for the site's geographic location. It was calculated as per ITU-R P.530.

Ref. 30 - "Worst Month Outage Time" (sec.)
(Read Only)

This information is the amount of time (in sec.) that the "Free Space Signal Level" is predicted to be below "Receiver Threshold Level" during the worst month of fading for the site's geographic location. It was calculated as per ITU-R P.530.

Ref. 31 - "One Way Annual Availability" (%)
(Read Only)

This information is the amount of time (in sec.) that the "Free Space Signal Level" is predicted to be below "Receiver Threshold Level" during the year for the site's geographic location. It was calculated as per ITU-R P.530.

Ref. 32 - **"One Way Annual Outage Time" (sec.)**
(Read Only)

This information is the amount of time (in sec.) that the "Free Space Signal Level" is predicted to be below "Receiver Threshold Level" during the year for the site's geographic location. It was calculated as per ITU-R P.530.

Annex- A

Typical Examples of Transmission Line Specifications

Transmission Line Type	Attenuation in dB / 100 m			
	2.45 GHz	2.55 GHz	3.55 GHz	5.55 GHz
LMR 400 Type	22.0	22.4	26.9	34.6
LMR 600 Type	14.4	14.7	17.8	23.2
LMR 1200 Type	7.4	7.5	9.2	N / A
3/8" Foam Type	19.0	19.5	23.6	30.6
½" Foam Type	12.0	12.2	14.8	19.2
7/8" Foam Type	6.9	7.0	8.6	N / A
1-1/4" Foam Type	5.0	5.2	N / A	N / A
1-5/8" Foam Type	4.2	N / A	N / A	N / A

Annex- B

Determining the Percentage of Time the Refractivity Gradient is Less Than -100 N/km

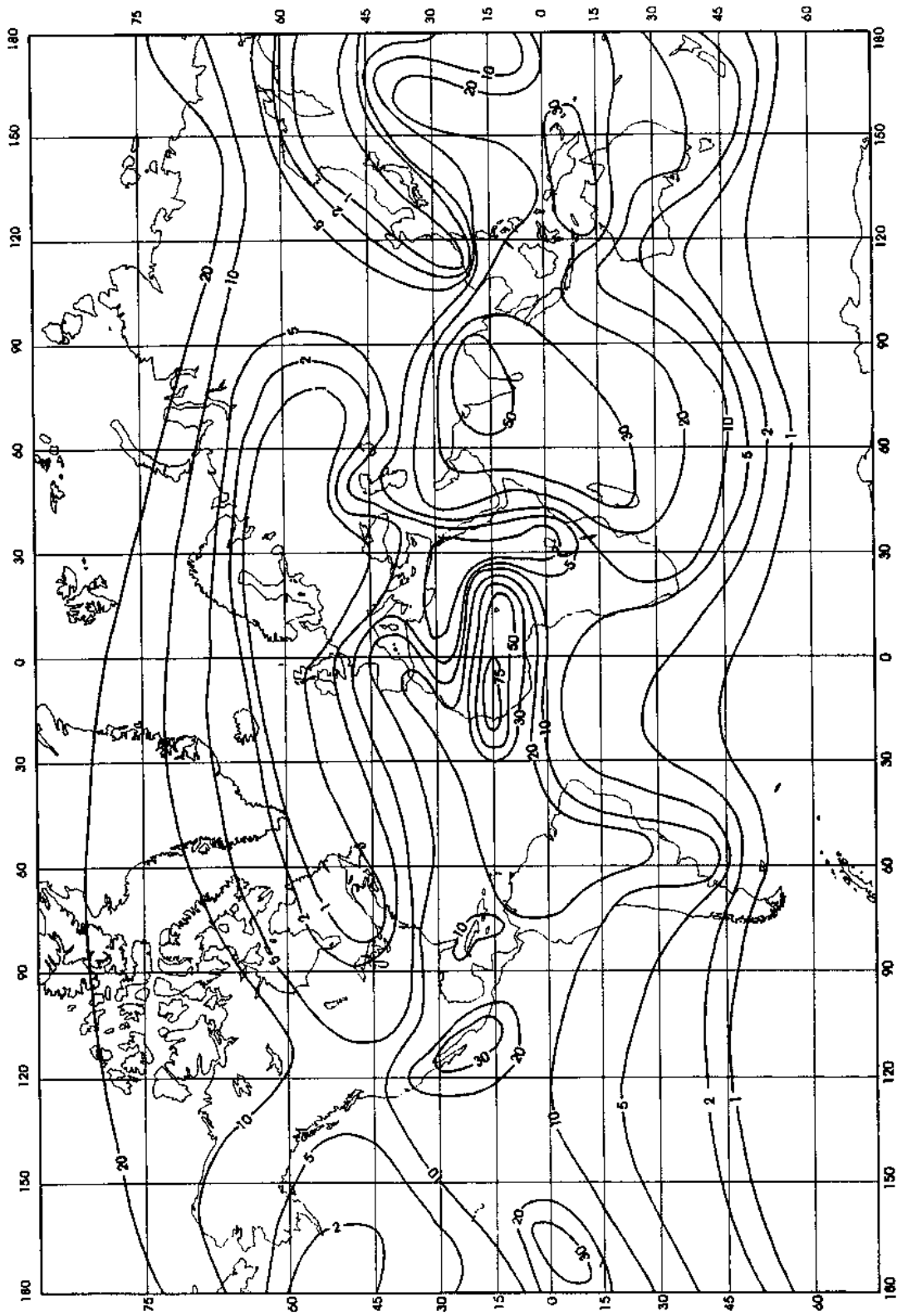
The percentage of time the refractivity gradient is less than -100 N/km *(PL in the Link_Calc.xls worksheet, reference cell # 22)* is dependent on geographic region and is determined as follows:

1 - For Latitudes greater than 60º N or 60º S

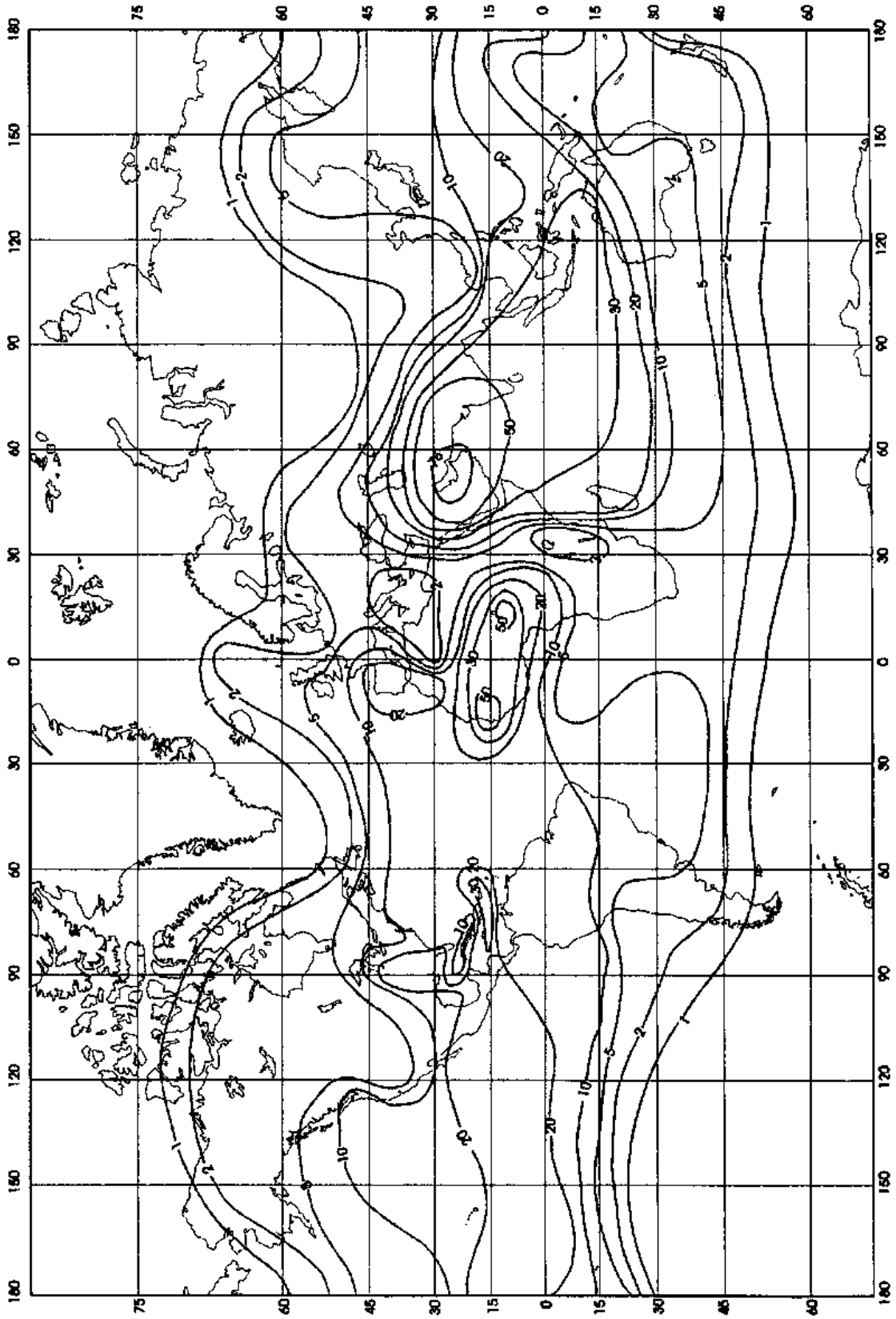
Based on the geographic location, review the attached Refractivity Gradient maps for the months of ***"May and August only",*** take the highest value the -100 N/km gradient is exceeded for the location of the link and use this value as ***"PL"*** in the Link_Calc.xls worksheet, Ref. 22.

2 - For Latitudes less than 60º N or 60º S:

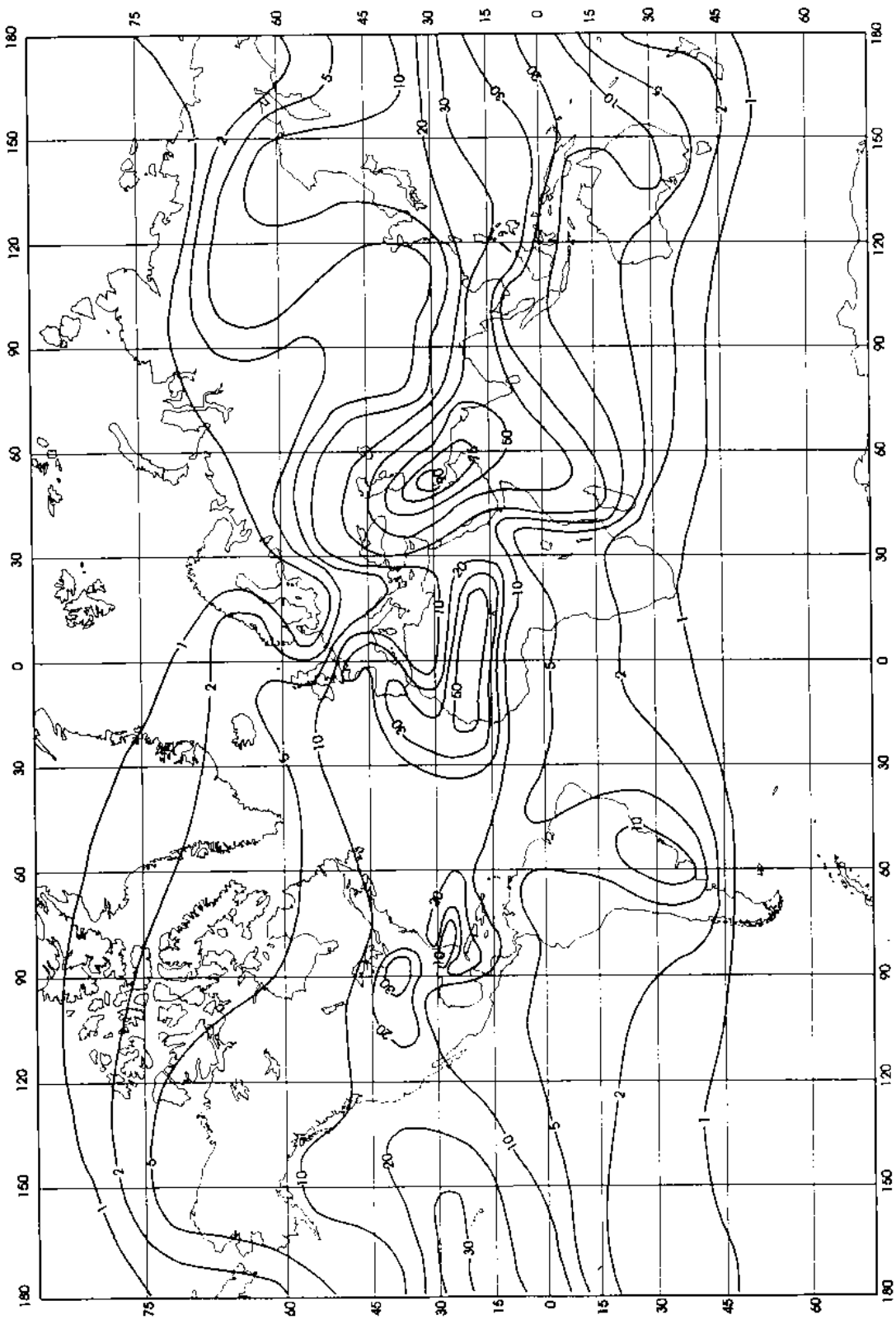
Based on the geographic location, review ***"ALL 4"*** attached Refractivity Gradient maps which are seasonally representative, take the highest value the -100 N/km gradient is exceeded for the location of the link and use this value as ***"PL"*** in the Link_Calc.xls worksheet, Ref. 22.



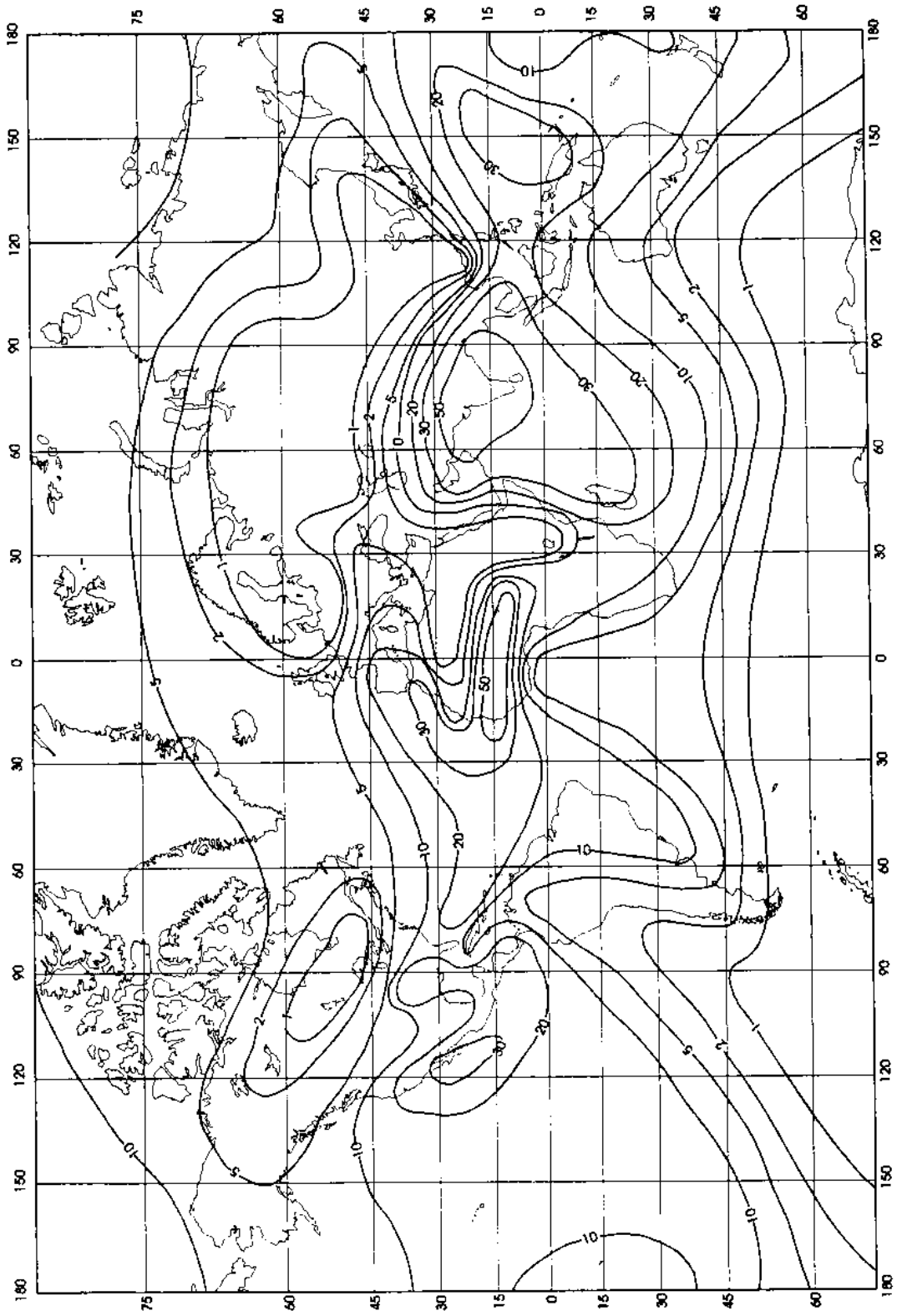
Percent of Time Gradient ≤ -100 N/km - February



Percent of Time Gradient ≤ -100 N/km - May



Percent of Time Gradient ≤ -100 N/km - August



Percent of Time Gradient ≤ -100 N/km - November