Fixed and Mobile Radio Link Planning

HF Prediction

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TABLE OF CONTENTS

LIST OF FIGURES & TABLES

ABSTRACT

This report contains the procedure and findings of the laboratory exercise investigating a high frequency radio-telephony link between Edinburgh and Cairo using the ionosphere as a medium for propagation.

The report centres on the CCIR recommendations for planning radio links and in particular, on one day in January and one in July which are the extremes of the ionisation cycle for the year. Using these days, sunspot activities of 0, 100 and the actual (predicted) values were examined to establish the link validity.

This allowed, primarily the frequency bands to be calculated, as they would have to be changed frequently each day the link is operational.

The losses of the link were then calculated with an aim to calculating the power required to be transmitted.

On conclusion, it was felt that the link investigated was perhaps not the best choice of link as it has too many factors that are only just within the limits for any radio link.

INTRODUCTION

The purpose of this laboratory exercise was to investigate the design of a single channel, single side band, High Frequency (HF) radio-telephony link between Edinburgh, Scotland and Cairo, Egypt. The link was to be operational between April 1999 and April 2000.

Factors considered when planning the link were:

1. Minimum power to had be used (to avoid spectral pollution).
2. Operational frequencies throughout the year.
3. A measure of overall circuit reliability.

Due to changes in the atmosphere, (caused by seasonal changes, daylight / night and cosmic / solar activity) the radio link path is not constant in length and attenuation. The CCIR has recommendations for radio link planning that take into account most of these phenomena, which were followed in the planning of the link. It should be noted that it is impossible to take into account all the factors which could affect a radio link as many are unpredictable.

The CCIR recommends taking four possible times of the year in planning a radio link, these are:

1. January (at sunspot activity minimum)
2. July (at sunspot activity minimum)
3. January (at sunspot activity maximum)
4. July (at sunspot activity maximum)

BACKGROUND OF HF RADIO COMMUNICATIONS

The method of propagating HF radio signals over great distances is by means of "bouncing" the signal off the ionoshpere.

The ionosphere is a region of the atmosphere which has been ionised by the highest frequency radiation from the sun, i.e. ultra violet and x-ray radiation.

HF frequencies are in the range 3MHz to 30MHz. Below these frequencies, the ground component of the signal dominates and is hence considered to be transmitted along the ground. Above these frequencies, there is no ground component, but these higher frequencies penetrate through the ionosphere. Hence, only line of sight transmission is possible, either between two ground stations or a ground station and a satellite.

The ionosphere is categorised into layers, each with its own unique properties. These layers are as follows:

1. D-Layer
    - Altitude about 50 - 90 km.
    - Maximum ionisation of the layer around noon and seasonal maximum in the summer.
    - Disappears at night.
    - High attenuation (inversely proportional to the square of the frequency).
2. E-Layer
    - Altitude about 90 - 130 km.
    - Maximum ionisation of the layer around noon and seasonal maximum in the summer. Ionisation depends on zenith angle of the sun.
    - Disappears at night.
    - Maximum useable propagation distance about 2000km per hop.
3. F1-Layer
    - Altitude about 130 - 210 km.
    - Disappears at night.
    - Only occasionally used as a reflecting layer due to its periodic existence.
4. F2-Layer
    - Altitude about 250 - 400 km.
    - Principle reflecting layer for long distance HF communication.
    - Exists at a lower ionisation density at night.
    - Height and ionisation vary diurnally, seasonally and over the sunspot cycle.
    - Maximum useable propagation distance about 4000km per hop.

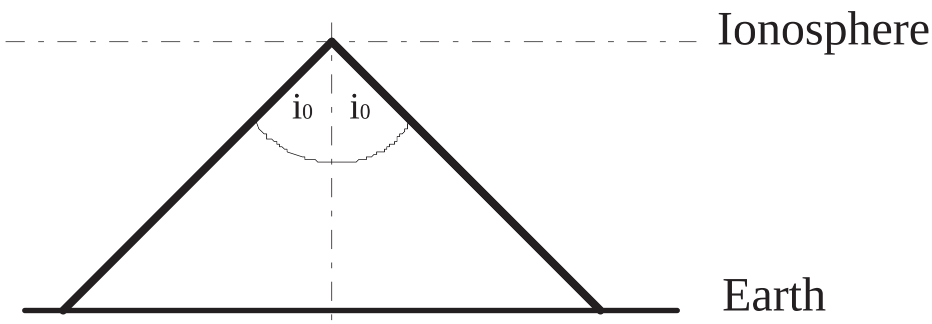
The height of the layer "borders" can be found by using "sounding" principles (as used in sonar equipment). An RF pulse (starting at the low end of the HF frequency range) is directed vertically and the time for the reflection to come back is noted. From this time the height of the reflection can be calculated (distance = speed * time). As the frequency is gradually increased, the reflection time will suddenly become greater. This distance (time) represents a border between two layers and is caused by the frequency going beyond the critical frequency (f_c) of the previous layer. The critical frequency has been found to have the following relationship to the ionisation density:

$$f_c = 9\sqrt{N}$$

where N is the ionisation density in electrons/m^3

If, instead of vertically, the signal is transmitted at an inclination to the ionosphere as follows:

Figure 1 - Ionospheric reflection



The maximum useable frequency for the link (f_{muf}) is given as follows:

$$f_{muf} = \frac{f_c}{\cos i_0}$$

Using these principles and the CCIR recommendations, a radio link can be planned.

HF PREDICTION

The first requirement of planning a global radio link is to determine the geographical locations of the two radio stations. For this, an atlas was consulted and the following information obtained:

Table 1 - Geographical locations of stations

Station	**Latitude**	**Longitude**
A - Edinburgh, Scotland	55.57° North	3.13° West
B - Cairo, Egypt	30.03° North	31.15° East

Calculation of great circle distance

The angle subtended by these two locations at the centre of the earth is given by the equation:

$$\cos\alpha = \sin L_A \ \sin L_B \ + \ \cos L_A \ \cos L_B \ \cos L_O$$

where

L_A is the latitude of station A

L_B is the latitude of station B

L_O is the difference in longitudes of station A and station B

Hence the equation becomes:

$$\cos\alpha = \sin 55.57° \ \sin 30.03° \ + \ \cos 55.57° \cos 30.03° \ \cos(31.15° + 3.13°)$$

$$\cos\alpha = 0.4128 \ + \ 0.4045$$

$$\cos\alpha = 0.8173$$

$$\therefore \alpha = 35.185°$$

From this, the ground distance can be calculated from the following:

$$D = 111.5 * \alpha$$

$$D = 111.5 * 35.185$$

$$D = 3923km$$

In order to reduce power, it is felt that a single "hop" link should be employed as multi hops require multiple penetrations of the D-layer of the ionoshpere. This layer is a high attenuator, so more power will be required from the transmitter to reach the destination. The maximum distance that can be traversed by "bouncing" off the E-layer is 2000km, so the signal must be bounced off the F2-layer. The maximum distance that can be traversed off the F2-layer is 4000km. It was felt that although marginal, a single hop off the F2-layer could be achieved.

Calculation of great circle transmission direction

For setting up the antennae at the two stations, the direction of transmission (based on a standard compass layout) for each stations can be calculated from the following:

$$\sin C_{AB} = \frac{\cos L_B \ \ \sin L_O}{\sin \alpha}$$

$$\sin C_{AB} = \frac{\cos 30.03° \ \ \sin 34.28°}{\sin 35.185°}$$

$$\sin C_{AB} = 0.8462$$

$$\therefore \ \ C_{AB} = 57.8°$$

Also:

$$\sin C_{BA} = \frac{\cos L_A \ \ \sin L_O}{\sin \alpha}$$

$$\sin C_{BA} = \frac{\cos 55.57° \ \ \sin 34.28°}{\sin 35.185°}$$

$$\sin C_{BA} = 0.5527$$

$$\therefore \ \ C_{BA} = 35.55°$$

However, since station B (Cairo) is east of station A (Edinburgh), 180° must be added to the transmit direction (sine function is symmetrical about 0°).

Hence, C_{BA} = 215.55°

Determination of useable frequency bands

For a more accurate prediction of the radio link for the given time span, the sunspot activities for the period were obtained off the internet from the Ham Radio Online Website (see reference 2). The sunspot numbers are as follows (April 1999 to April 2000):

Table 2 - Sunspot Numbers

Month	April	May	June	July	August	September
Sunspot Number	135	139	141	144	148	150
Confidence Level	23	22	22	23	24	23

October	November	December	January	February	March	April
151	151	154	154	153	152	151
23	24	24	24	25	25	25

Hence, as well as using the CCIR recommendations of sunspot number = 0 and 100 for January and July, the actual (predicted) sunspot numbers shall be used.

CCIR Recommendations

The recommendations have several global maps all drawn to the same great circle scale. With the aid of tracing paper and a pen, information is transferred from one map onto the tracing paper and then the tracing paper is overlaid onto the rest of the maps to extract more information. The steps were as follows: (Note that figure numbers quoted are from reference 1)

1. The outline, equator and zero meridian of the first map [fig.4.7] were traced. The two stations were marked on the tracing and joined up. Using a ruler, the mid point of the radio path was marked. This is the critical point as it is this where the radio path reflects[1] off the ionosphere.
2. The tracing was placed onto two maps (for January [fig.4.8a] and July [fig.4.8b]) and was slid along in both directions, in 2 hour steps with the midpoint of the path on each meridian. At these points, the zenith angle (angle of the sun from vertical) was read off the maps. The time and zenith angle are recorded in columns 1 and 2 respectively of tables 3 to 8.
3. Using the zenith angle and the sunspot number, the Estimated Junction Frequency (equivelant to f_{muf}) to traverse a distance of 2000km, bouncing off the E-layer - EJF(2000)E was obtained from a nomogram[2] [fig.4.9]. This is shown in column 3 of the tables. Note that zenith angles greater that 100° are ignored as the sun is beneath the horizon and no longer ionises the E-layer, which disappears during night time.
4. The EJF to traverse the actual distance of the link - EJF(d)E was obtained from another nomogram [fig.4.10]. As the distance is greater than 2000km, the EJF(2000)E values were taken. These are shown in column 4 of the tables.

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[1] Radio signals area actually refracted by the ionic radiation of the ionoshpere. They are described as reflections for simplicity.

[2] Nomogram: a graphical representation of an equation. Two variables are shown as scaled lines. The variables are joined with a straight line. The line will intersect a third line which is the answer to the equation

5. The EJF(0)F2 and EJF(4000)F2 for sunspot numbers of 0 and 100 were obtained from nomograms for January [figs.4.11.1 - 4.11.12(a)(b)(c)(d)] and July [figs.4.12.1 - 4.12.12(a)(b)(c)(d)]. These are entered in columns 5 and 6 of tables 3, 4, 6, 7.
6. The EJF(0)F2 and EJF(4000)F2 were calculated for the actual sunspot numbers using the formulae:

$$EJF(0)F2 = EJF(0)F2_0 \;+\; 0.01\left[EJF(0)F2_{100} \;-\; EJF(0)F2_0\right]R_{12}$$

$$EJF(4000)F2 = EJF(4000)F2_0 \;+\; 0.01\left[EJF(4000)F2_{100} \;-\; EJF(4000)F2_0\right]R_{12}$$

   where R_{12} is the sunspot number. Entered into columns 5 and 6 of tables 5 and 8.
7. The EJF to traverse the actual distance of the link - EJF(d)F2 was obtained from another nomogram [fig.4.13]. As the distance is approximately 4000km (at least from the scale on the nomogram), the EJF(4000)F2 values were taken. These are shown in column 7 of the tables.
8. The fréquence optimal de travail (FOT), which is a frequency to give a safety margin on transmissions, of the F2 layer is calculated using the formula:

$$FOT(d)F2 = 0.85 \;*\; EJF(d)F2$$

   The frequencies are entered into column 8 of the tables.
9. The definitive EJF for the radio link is determined by a comparison of EJF(d)E and EJF(d)F2. The maximum of the two frequencies is entered into column 9 of the tables.
10. Similarly, the definitive FOT of the radio link is determined by comparison of EJF(d)E and FOT(d)F2. The maximum of the two frequencies is entered into column 10 of the tables.
11. Graphs are drawn of EJF(d)E (column 4), EJF(d)Upper (column 9) and FOT(d)Upper (column 10) against time (column 1).
12. From these graphs the useable frequency band is the gap in between the EJF(d)E and FOT(d)Upper traces. Lines are drawn on the graphs which indicate the frequencies to use throughout the day. Care is taken not to cross any of the traces and to use fixed frequencies for as long a period as possible throughout the day. This cuts down the number of frequency changes the system shall have to make during operation.

Table 3 - July, Sunspot = 0

1 Time UT	2 Zenith Angle Degrees	3 EJF(2000)E MHz	4 EJF(d)E MHz	5 EJF(0)F2 MHz	6 EJF(4000)F2 MHz	7 EJF(d)F2 MHz	8 FOT(d)F2 MHz	9 EJF Upper MHz	10 FOT Upper MHz
0	115	-	-	4.5	11.8	11.8	10.03	11.8	10.03
2	110	-	-	3.6	10	10	8.5	10	8.5
4	96	5.1	5.1	3.9	11.7	11.7	9.945	11.7	9.945
6	77	10.4	10.4	5.2	16.5	16.5	14.025	16.5	14.025
8	55	14.2	14.2	5.5	17	17	14.45	17	14.45
10	33	16.2	16.2	5.7	18	18	15.3	18	16.2
12	22.5	16.7	16.7	5.7	17.4	17.4	14.79	17.4	16.7
14	32.5	16.2	16.2	5.5	17	17	14.45	17	16.2
16	54	14.2	14.2	5.4	17	17	14.45	17	14.45
18	75	10.8	10.8	6.1	19.5	19.5	16.575	19.5	16.575
20	93	6	6	6.1	19.5	19.5	16.575	19.5	16.575
22	107	-	-	5	15	15	12.75	15	12.75

Figure 2 - Graph of July, sunspot = 0

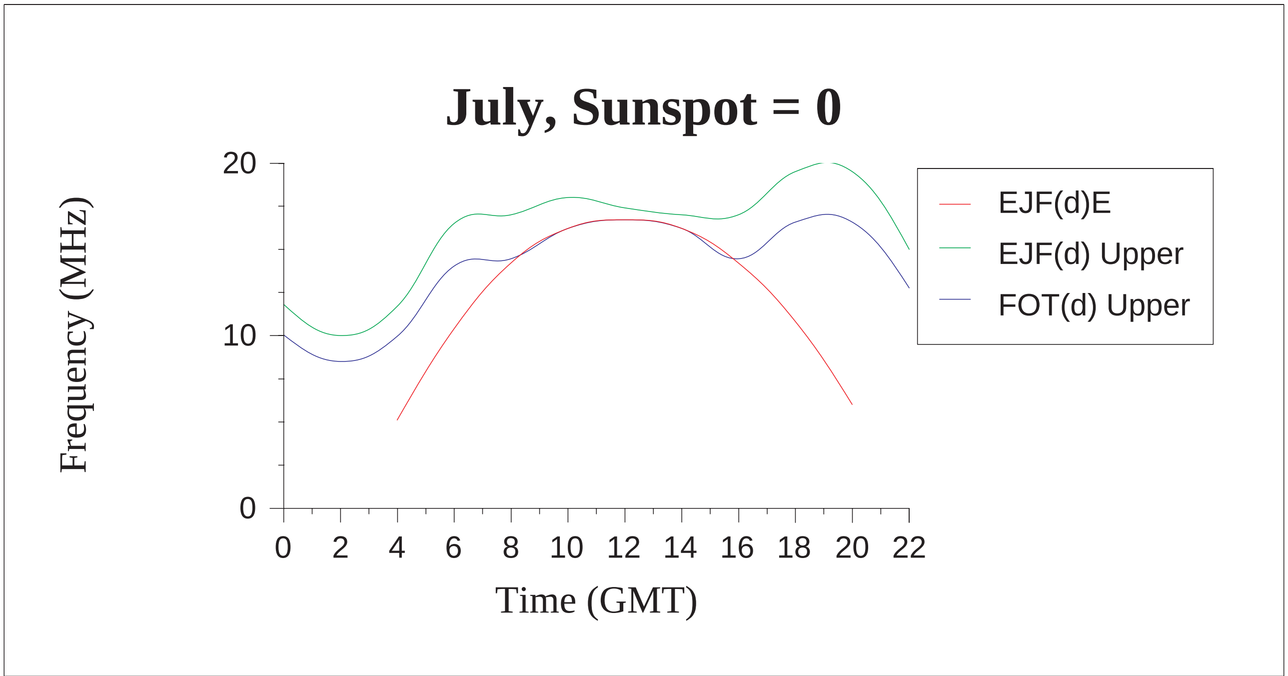


Table 4 - July, sunspot = 100

1 Time UT	2 Zenith Angle Degrees	3 EJF(2000)E MHz	4 EJF(d)E MHz	5 EJF(0)F2 MHz	6 EJF(4000)F2 MHz	7 EJF(d)F2 MHz	8 FOT(d)F2 MHz	9 EJF Upper MHz	10 FOT Upper MHz
0	115	-	-	7	19.5	19.5	16.575	19.5	16.575
2	110	-	-	6.25	17.5	17.5	14.875	17.5	14.875
4	96	5.6	5.6	6.25	18	18	15.3	18	15.3
6	77	12	12	7.2	21.5	21.5	18.275	21.5	18.275
8	55	16	16	7.6	22.5	22.5	19.125	22.5	19.125
10	33	18.1	18.1	8	24.5	24.5	20.825	24.5	20.825
12	22.5	18.6	18.6	8.2	23.5	23.5	19.975	23.5	19.975
14	32.5	18.2	18.2	7.8	23	23	19.55	23	19.55
16	54	16.2	16.2	7.8	24	24	20.4	24	20.4
18	75	12.5	12.5	8.4	25.5	25.5	21.675	25.5	21.675
20	93	7.2	7.2	8.2	24.5	24.5	20.825	24.5	20.825
22	107	-	-	7.5	22	22	18.7	22	18.7

Figure 3 - Graph of July, sunspot = 100

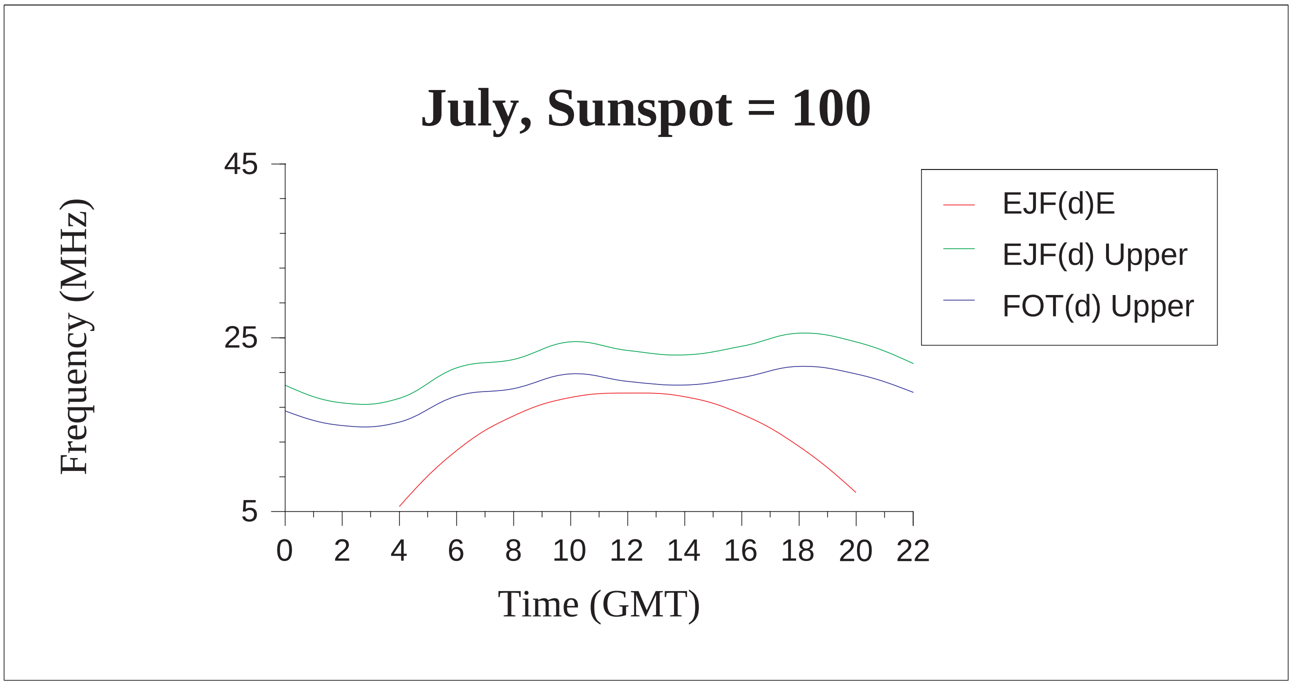


Table 5 - July, sunspot = 144

1	2	3	4	5	6	7	8	9	10
Time	Zenith Angle	EJF(2000)E	EJF(d)E	EJF(0)F2	EJF(4000)F2	EJF(d)F2	FOT(d)F2	EJF Upper	FOT Upper
UT	Degrees	MHz	MHz	MHz	MHz	MHz	MHz	MHz	MHz
0	115	-	-	8.1	22.888	22.888	19.4548	22.888	19.4548
2	110	-	-	7.416	20.8	20.8	17.68	20.8	17.68
4	96	6	6	7.284	20.772	20.772	17.6562	20.772	17.6562
6	77	13.1	13.1	8.08	23.7	23.7	20.145	23.7	20.145
8	55	16.6	16.6	8.524	24.92	24.92	21.182	24.92	21.182
10	33	18.7	18.7	9.012	27.36	27.36	23.256	27.36	23.256
12	22.5	19.3	19.3	9.3	26.184	26.184	22.2564	26.184	22.2564
14	32.5	18.75	18.75	8.812	25.64	25.64	21.794	25.64	21.794
16	54	16.75	16.75	8.856	27.08	27.08	23.018	27.08	23.018
18	75	13.1	13.1	9.412	28.14	28.14	23.919	28.14	23.919
20	93	7.25	7.25	9.124	26.7	26.7	22.695	26.7	22.695
22	107	-	-	8.6	25.08	25.08	21.318	25.08	21.318

Figure 4 - Graph of July, sunspot = 144

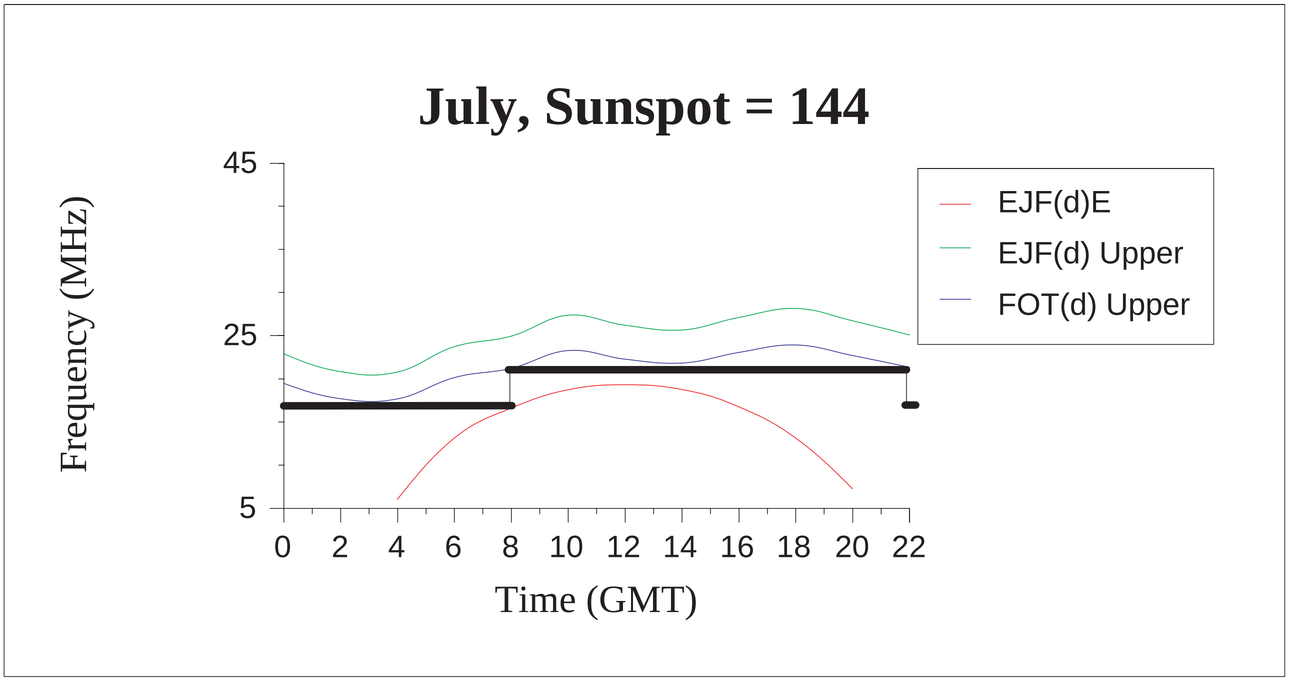


Table 6 - January, sunspot = 0

1 Time UT	2 Zenith Angle Degrees	3 EJF(2000)E MHz	4 EJF(d)E MHz	5 EJF(0)F2 MHz	6 EJF(4000)F2 MHz	7 EJF(d)F2 MHz	8 FOT(d)F2 MHz	9 EJF Upper MHz	10 FOT Upper MHz
0	157	-	-	37	11	11	9.35	11	9.35
2	147	-	-	37	11.5	11.5	9.775	11.5	9.775
4	127	-	-	32	9	9	7.65	9	7.65
6	107	-	-	37	12	12	10.2	12	10.2
8	82	9.2	9.2	57	21	21	17.85	21	17.85
10	63	13.1	13.1	64	23	23	19.55	23	19.55
12	55	14.2	14.2	63	23	23	19.55	23	19.55
14	62	13.2	13.2	61	21.5	21.5	18.275	21.5	18.275
16	77	10.4	10.4	48	17	17	14.45	17	14.45
18	100	-	-	37.5	11.5	11.5	9.775	11.5	9.775
20	130	-	-	43	11	11	9.35	11	9.35
22	145	-	-	36	11	11	9.35	11	9.35

Figure 5 - January, sunspot = 0

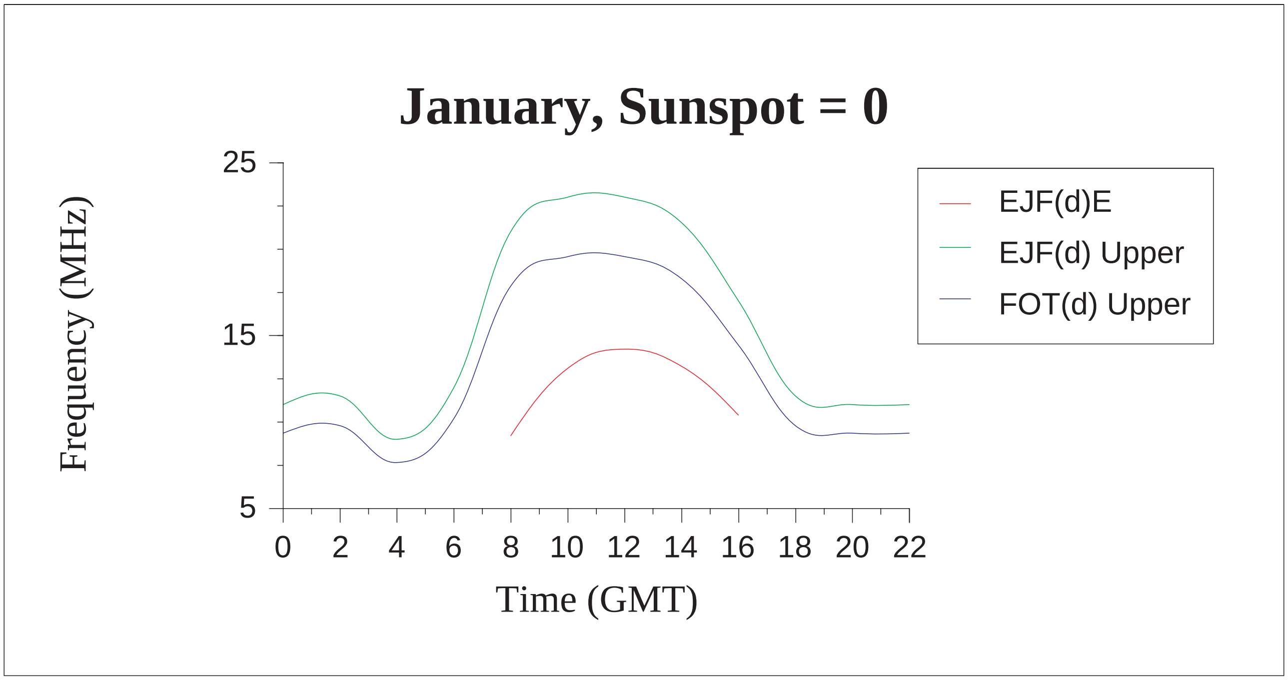


Table 7 - January, sunspot = 100

1 Time UT	2 Zenith Angle Degrees	3 EJF(2000)E MHz	4 EJF(d)E MHz	5 EJF(0)F2 MHz	6 EJF(4000)F2 MHz	7 EJF(d)F2 MHz	8 FOT(d)F2 MHz	9 EJF Upper MHz	10 FOT Upper MHz
0	157	-	-	44	12	12	10.2	12	10.2
2	147	-	-	42	11	11	9.35	11	9.35
4	127	-	-	35	9.5	9.5	8.075	9.5	8.075
6	107	-	-	50	15	15	12.75	15	12.75
8	82	10.5	10.5	92	32	32	27.2	32	27.2
10	63	14.75	14.75	101	34.5	34.5	29.325	34.5	29.325
12	55	16	16	102	33	33	28.05	33	28.05
14	62	15	15	96	31	31	26.35	31	26.35
16	77	12	12	80	26	26	22.1	26	22.1
18	100	-	-	57.5	17.5	17.5	14.875	17.5	14.875
20	130	-	-	47.5	13	13	11.05	13	11.05
22	145	-	-	42.5	11.5	11.5	9.775	11.5	9.775

Figure 6 - Graph of January, sunspot = 100

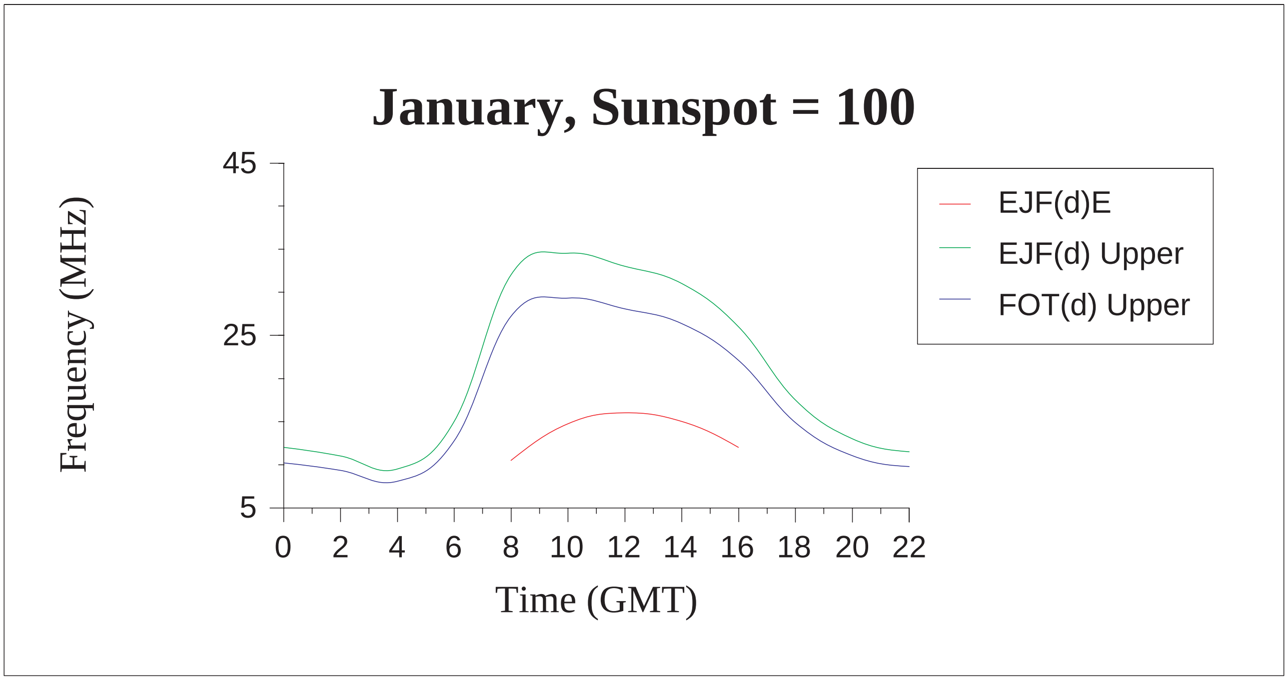
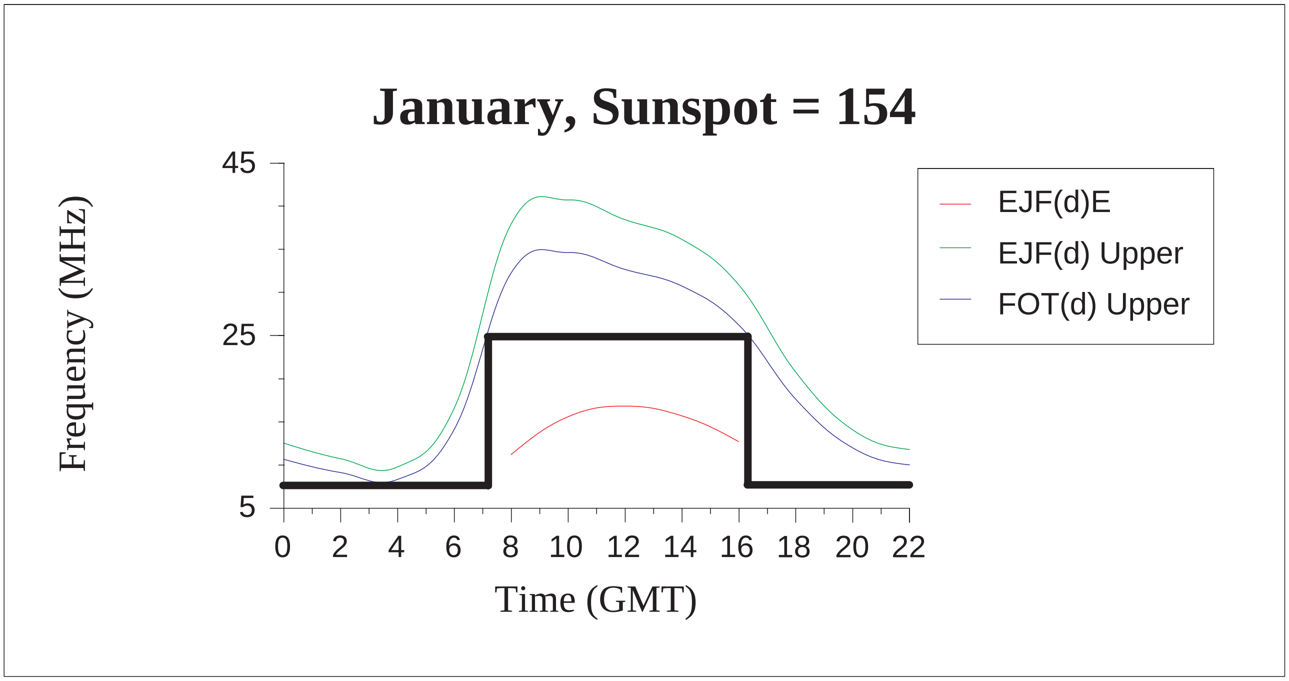


Table 8 - January, sunspot = 154

1	2	3	4	5	6	7	8	9	10
Time	Zenith Angle	EJF(2000)E	EJF(d)E	EJF(0)F2	EJF(4000)F2	EJF(d)F2	FOT(d)F2	EJF Upper	FOT Upper
UT	Degrees	MHz	MHz	MHz	MHz	MHz	MHz	MHz	MHz
0	157	-	-	47.78	12.54	12.54	10.659	12.54	10.659
2	147	-	-	44.7	10.73	10.73	9.1205	10.73	9.1205
4	127	-	-	36.62	9.77	9.77	8.3045	9.77	8.3045
6	107	-	-	57.02	16.62	16.62	14.127	16.62	14.127
8	82	11.2	11.2	110.9	37.94	37.94	32.249	37.94	32.249
10	63	15.6	15.6	120.98	40.71	40.71	34.6035	40.71	34.6035
12	55	16.8	16.8	123.06	38.4	38.4	32.64	38.4	32.64
14	62	15.7	15.7	114.9	36.13	36.13	30.7105	36.13	30.7105
16	77	12.7	12.7	97.28	30.86	30.86	26.231	30.86	26.231
18	100	-	-	68.3	20.74	20.74	17.629	20.74	17.629
20	130	-	-	49.93	14.08	14.08	11.968	14.08	11.968
22	145	-	-	46.01	11.77	11.77	10.0045	11.77	10.0045

Figure 7 - Graph of January, sunspot = 154



Since the actual (predicted) sunspot numbers are known for the radio link duration, any calculations from here shall only be concerned with January, sunspot = 154 and July, sunspot = 144.

It should be noted that for July, sunspot = 0, between the hours of 08:00 and 16:00 the link is unusable. This is shown by the fact that the trace for EJF(d)E and FOT(d)Upper overlap, indicating that the maximum useable frequency for both layers is the same value. Hence, the radio signal will pass into outer space. If a frequency lower than this is used, then the signal will reflect off the E-layer and come back to earth 2000km short of the target (maximum propagation distance for single hop off the E-layer is 2000km).

The useable frequencies are thus:

July

22:00 - 08:00 12MHz

08:00 - 22:00 20MHz

January

16:30 - 07:00 7.5MHz

07:00 - 16:30 25MHz

Calculation of launch angle

In order to calculate the launch angle of the radio transmission, the altitude of the F2 layer must be known. This was read from figs.4.1 and 4.2, January and July respectively (from reference 1). These were entered into column 2 of tables 9 and 10 along with the time in column 1. With this information, the launch angle is calculated from:

$$\Delta = \tan^{-1}\left[\frac{\cos(\alpha/2) - (R/R+h)}{\sin(\alpha/2)}\right]$$

where

Δ is the launch angle

α is the great circle angle

R is the radius of the earth (approx. 6370 km)

h is the height of the F2-layer

For example, July 10:00, F2-layer altitude = 375:

$$\Delta = \tan^{-1}\left[\frac{\cos(35.185°/2) - (6370/6370+375)}{\sin(35.185°/2)}\right]$$

$$\Delta = \tan^{-1}\left[\frac{0.9532 - 0.9444}{0.3022}\right]$$

$$\Delta = \tan^{-1}(0.0292)$$

$$\therefore \Delta = 1.67°$$

The launch angles are calculated in column 3 of the tables.

It can be observed from the tables that at certain times, the launch angle is negative. This is due to the fact that the range of this link is on the limit of a single hop off the F2 layer. Due to low altitudes of the F2 layer at certain times, the link becomes unreliable. However, since these are all predictions, it is not necessarily the case that the link will not operate. For the purpose of this investigation, a launch angle of 0° shall be assumed at these times. The corrected launch angle values are entered into column 4 of the tables.

Calculation of Path Attenuation

In order to determine the transmitter power that is required for the system, the losses of the radio link must be calculated, again, these figures are predicted. The losses of an HF radio link can be expressed as follows:

$$L_{Sys} = L_{Fr} + L_I + L_B + Y_F - (G_s + G_e)$$

where:

L_{Sys} is the total loss (in dB) of the link.

L_{Fr} is the losses (in dB) arising from the free-space attenuation.

L_I is the losses (in dB) in the ionosphere (penetration of the D-layer).

L_B is the losses (in dB) on reflection on the ground (only for multi-hop paths).

Y_F is the fading reserves (in dB).

G_s is the gain of the transmitting antenna (in dB).

G_e is the gain of the receiving antenna (in dB).

Free-space losses

In order to calculate the free-space losses, the free-space path length must be calculated from the following equation:

$$P = 2\,(R + h) * \frac{\sin(\alpha/2)}{\cos\Delta}$$

The path lengths are entered into column 5 of the tables. The free space loss, L_{FR} is calculated from the following equation:

$$L_{FR} = 20\log\left(4\pi P/\lambda\right)$$

$$L_{FR} = 32.44 + 20\log f + 20\log P$$

where

f is in MHz

P is in km

The operating frequencies of the link are transferred from the earlier graphs into column 6 of the tables and the values of free-space loss are entered into column 7 of the tables.

Losses in the ionosphere

The losses through absorption on penetration of the D-layer are dependant on the zenith angle of the sun and the sunspot number.

The zenith angle of the sun was transferred from previous measurements into column 8 of the tables. With this and the sunspot number, the absorption index of the D layer can be found by using the nomogram in fig.4.22 of reference 1. The results are in column 9 of the tables.

In the northern hemisphere, January must have a correction factor of 1.5 applied to all values of absorption index. This is due to the "winter anomaly," and these have been incorporated into column 9 of January.

This information , along with launch angle and frequency used are transferred onto another nomogram, fig.4.23 of reference 1 to give the loss in dB of the hop. These results are shown in column 10 of the tables.

Losses due to reflections on the ground

Since this is a single hop link, there are no reflections from ground bounces.

Fading Reserves

The losses calculated so far assume a stable state of the radio path. However, there are continuous fluctuations in layer heights, ionisation densities, cloud cover etc. The CCIR recommends a fading reserve of 14dB to assure the link is available for 90% of the time. For an availability of 50%, a fading reserve of 5.8dB should be placed on the link.

The link will use the fading reserve of 14dB as the link is on the limit of propagation for the F2 layer.

Table 9 - Losses for July

1	2	3	4	5	6	7	8	9	10	11	12
Time	F2 Layer Height	Launch Angl	Launch Angl	Path Length	Link Frequenc	LFR	Zenith Angl	bsorption Inc	LI	YF	otal loss LS
UT	km	Degrees	Degrees	km	MHz	dB	Degrees		dB	dB	dB
0	287	-0.699	0	4023.538	15.5	128.339	115	0	0	14	142.339
2	290	-0.617	0	4025.351	15.5	128.343	110	0	0	14	142.343
4	292	-0.563	0	4026.56	15.5	128.345	96	0.25	3.7	14	146.295
6	300	-0.346	0	4031.395	15.5	128.356	77	0.45	7	14	149.806
8	340	0.734	0.734	4055.904	20	130.622	55	0.92	8	14	153.542
10	375	1.667	1.667	4078.452	20	130.671	33	1.3	11.5	14	157.471
12	380	1.8	1.8	4081.762	20	130.678	22.5	1.45	12.5	14	158.628
14	380	1.8	1.8	4081.762	20	130.678	32.5	1.33	11.5	14	157.508
16	367	1.455	1.455	4073.204	20	130.659	54	0.93	7.5	14	153.089
18	305	-0.21	0	4034.417	20	130.576	75	0.48	4	41	176.056
20	275	-1.027	0	4016.285	20	130.537	93	0.13	1	14	145.667
22	275	-1.027	0	4016.285	15.5	128.323	107	0	0	14	142.323

Table 10 - Losses for January

1	2	3	4	5	6	7	8	9	10	11	12
Time	F2 Layer Height	Launch Angl	Launch Angl	Path Length	Link Frequenc	LFR	Zenith Angl	bsorption Inc	LI	YF	otal loss LS
UT	km	Degrees	Degrees	km	MHz	dB	Degrees		dB	dB	dB
0	280	-0.89	0	4019.307	7.5	122.024	157	0	0	14	136.024
2	278	-0.945	0	4018.098	7.5	122.022	147	0	0	14	136.022
4	273	-1.081	0	4015.076	7.5	122.015	127	0	0	14	136.015
6	270	-1.163	0	4013.263	7.5	122.011	107	0	0	14	136.011
8	248	-1.768	0	3999.966	25	132.44	82	0.525	3	14	149.965
10	248	-1.768	0	3999.966	25	132.44	63	1.095	5	14	152.535
12	245	-1.85	0	3998.153	25	132.436	55	1.35	7	14	154.786
14	235	-2.126	0	3992.109	25	132.423	62	1.17	6	14	153.593
16	225	-2.403	0	3986.064	25	132.41	77	0.705	3.5	14	150.615
18	220	-2.542	0	3983.042	7.5	121.946	100	0.03	2	41	164.976
20	245	-1.85	0	3998.153	7.5	121.978	130	0	0	14	135.978
22	270	-1.163	0	4013.263	7.5	122.011	145	0	0	14	136.011

Calculation of Power

As can be seen from tables 9 and 10, the maximum loss is approx. 165dB. To calculate the power required to transmit a signal over this link, the gain and noise factors of the transmitting and receiving antennas must be taken into account.

Also, the modulation scheme decided upon plays a vital role in an acceptable signal-to-noise ratio (generally speaking, an acceptable signal-to-noise ratio for such a link is 10dB).

From all of this information, the link would be calculated from the receiver input backwards, through the antenna, over the link, through the transmit antenna and finally an actual power level would be calculated.

CONCLUSION

This lab exercise has provided an opportunity to experience the element of risk that is associated with planning a radio link over long distances. The link is subject to severe variations in performance and reliability over its life span due to any number of factors, like the time of the day / year and sunspot activity (which at is at a high for the next few years - see reference 2).

For this particular link, if done again, the choice of a 2 hop link would have to be investigated as it is felt that the length of the link is too close to the limit of the propagation distance for a single hop. Also, the current link is impossible to achieve, as some of the launch angles required by calculation are negative.

However, in this time of advancing technologies, fixed radio links that are reflected off the ionosphere are becoming a thing of the past. The availability of cellular telephones, satellite communications, fibre optic links to countries all over the world and more importantly, the internet, have made communications on a global scale easier to access and far more reliable than it has ever been in the past.

REFERENCES

1. Planning and Engineering of Shortwave Links, Gerhard Braun, Siemens Hayden, 1982. Chapter 4
2. HAM Radio Online <http://www.hamradio-online.com/1996/jul/solarp.html>