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Practical Calculations of Reliable Long Range High Frequency Radio Communications in Libya

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Abstract: The Radio frequency transmission between 2 And 30 MHZ by conventional high-frequency (HF) radio; utilization of HF waves and their medium of transportation require the ionospheres. The ionospheres represent the most exclusive means by which long-distance radio communication can be transmitted without the need of repeaters and with relatively low-transmitter power is carried on by using the optimum transmission operating frequency. The aim of this research is to investigate in the long range HF radio communication in Libya at different times of a day as well as in different seasons of a year. The central radio propagation laboratory (CRPL) method of iono-spheric prediction of the National Bureau of Standards (NBS) in USA was used in practical calculations of reliable HF radio communication links in Libya. **The results** show that the predicted frequencies are changeable between 2 to about 19 MHz during daytimes and seasons over different routes between various points in Libya. The conclusion: the predicted frequencies are changeable, to suit changing in propagation conditions of the E-ionospheric reflecting layer related to the day times, seasons of the year and solar activity. Therefore, the optimal utilization of point to point HF radio communication systems will be obtained under ionospheric influence in Libya.

Keywords: Radio frequency Transmission, ionospheres, ionospheric prediction, point to point radio communication system, Libya

I. INTRODUCTION

In the high frequency radio communication systems, ionosphere is used as signal propagation medium and the ionospheric wave is considered as the normal propagation mode for HF waves over short, medium and large ranges. The theory of propagation conditions will lead to numerical results, which can be put to practical use for the establishment of long range HF radio communication in Libya. This is the purpose of this paper. The HF radio communications offer several significant commercial applications with broad usage range [1].

1.1 HF waves propagation

HF propagation is characterized by two wave components. First is; a ground-wave or surface-wave component and the second is, a sky-wave component. The surface-wave travels along the curvature of the earth. The means are probably a combination of diffraction and a type of wave-guide effect which uses the earth's surface and the lowest ionized layer of the atmosphere as the two wave-guide walls. It is one of the two original means of beyond the horizon propagation. The sky-wave gives HF an advantage which permits reliable communication (90% path reliability) for long distances. It is beamed into the sky and come down again after refraction by E or F2 ionospheric layers, returning to earth well beyond the horizon to reach receivers on the opposite side of the earth. It's path uncontrollable and varies with time of day, season, and solar activity. The manner in which the wave is propagated depends very much on the frequency of the wave [1]. For transmission using the F2 layer, the optimum working frequency (FOT) is about 85% of the maximum usable frequency (MUF), while propagation via E layer will be consistent, if a frequency is equal or close to MUF is used [2]. The E layer is useful for propagation up to 2000 Km with frequencies as high as 20 MHz [3].

1.2 Point –To- Point HF range

One of the most important elements to the successful operation of an HF system using the sky wave phenomenon is a point- to- point HF range. In a sky-wave communication system design, it is very important to determine point-to-point HF range for given routes (i.e., short, medium, long) as a function of the day times for different seasons, and this will be provided by high reliable communications [2]. Point-to-point HF range is limited by the maximum usable frequency (MUF) and the lowest usable frequency (LUF) [1].

MUF and LUF are the upper and the lower limiting frequencies for point-to-point sky wave communications. There is some other frequency above the LUF, usually just somewhere below the MUF, that is optimum working frequency [OWF]. OWF is often designated FOT, for the French equivalent [fr'quence optimum de travail] [1]. MUF, LUF and FOT vary greatly with; Time of the day, distance, season and direction. In the HF band, the operating frequency is optimum when it is near or equal to MUF, where signal suffer the least loss, and consequently good communication will be obtained. The optimum working frequency is selected near or equal to the MUF, to provide some margin for ionospheric irregularities and turbulence as well as for the statistical deviation of day-to-day ionospheric characteristics from the predicted monthly median value.

Practical communications are possible when the strength of the signal received is equal to or exceeds the minimum required field strength for satisfactory reception. LUF is also that frequency at which the received field strength equals the minimum required field strength [1]. The frequency at the nearest point where the reception becomes unusable would be the LUF [2].

II. METHODOLOGY

2.1 Calculating MUF and FOT

The MUF is the highest possible frequency capable of travelling between two points in the season of the year and at the hour of day under consideration. The calculations produce the median MUF (50 percent probability that this value is not exceeded).The FOT is defined as the highest possible frequency capable of travelling during 90% of time availability. This is usually the more advantageous frequency for use in a radio link.

The aim of this research is to investigate in the HF radio communication range in Libya. Therefore, the calculations of MUF and FOT will be made for the winter and the summer seasons, because there are seasonal variations, with significant differences between their conditions being apparent and both seasons represent the extreme propagation conditions [4]. The four seasons with the corresponding International Radio Consultative Committee (C.C.I.R) defined months are shown in Table.1 [5].

Table.1: The four seasons with the corresponding International Radio Consultative Committee (C.C.I.R) defined months

Season	Month
Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Autumn	September, October, November

2.2 Calculating LUF

The simplest method of calculating LUF is to calculate the received field and the required field for three different frequencies, e.g. the FOT, the half of the FOT and one quarter of the FOT. Then plot for each hour the curves of the field received and the required field as a function of frequency. The point of inter-section of these curves indicates the LUF for that particular hour.

Because, the HF radio communication range in Libya will be determined, then the LUF calculations will be done for January and June, which represent the extreme propagation conditions [4].

2.3 Relative value of propagation calculations

These calculations are based on the median values of certain physical quantities (fields, noise, etc.), but the latter sometimes show considerable variations around these median values. For example:

1. Atmospheric noise varies considerably from day to day,
2. Ionospheric characteristics are unforeseeably affected by perturbations,
3. It is extremely difficult to give an exact definition of the terrain (conductivity, shape),
4. Meteorological conditions change all the time.

2.4 HF Communication Range Estimation through Different Routes in Libya

The relevant calculations of the point-to-point HF communication in Libya using the CRPL method of ionospheric prediction, are taken for four radio communication routes (0, 500, 1000 and 1500 Km) as shown in the Table.2.

Table.2: HF radio communication routes in Libya

Great-Circle Distance [Km]	Radio Communication Link	Geographical coordinates
0	1. Tripoli	32 - 86° N – 13 - 18°E
	2. Benghazi	32 - 09° N – 20 - 10°E
	3. Sabha	27 - 05° N – 14 - 47°E
500	1. Tripoli &	32 - 86° N – 13 - 18°E
	Sirte	31 - 18° N – 16 - 61°E
	2. Benghazi &	32 - 09° N – 20 - 10°E
	Al Jaghabub	29 - 73° N – 24 - 53°E
	3. Sabha &	27 - 05° N – 14 - 47°E
	Ghat	24 - 93° N – 10 - 18°E
1000	1. Tripoli &	32 - 86° N – 13 - 18°E
	Benghazi	32 - 09° N – 20 - 10°E
	2. Sabha &	27 - 05° N – 14 - 47°E
	Al Jaghabub	29 - 73° N – 24 - 53°E
	3. Ghat &	24 - 93° N – 10 - 18°E
	Uzu	21 - 85° N – 17 - 50°E
1500	1. Tripoli &	32 - 86° N – 13 - 18°E
	Al Kufra	24 - 18° N – 23 - 34°E
	2. Al Beido &	32 - 72° N – 21 - 74°E
	Ghat	24 - 93° N – 10 - 18°E
	3. Tripoli &	32 - 86° N – 13 - 18°E
	Uzu	21 - 85° N – 17 - 50°E

In the calculations, the following points are considered:

1. The Zurich monthly sunspot numbers for the period December, February, June and August are as following in Table 3 [6]:

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Table.3: The Zurich monthly sunspot numbers for the period of; December, February, June and August

Month	The Zurich sunspot
De-	128.5
January	136.9
Febru-	167.5
June	170.7
July	174.1
August	175.5

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2. The transmitter power is 500 KW [7].
3. The antenna is rhombic antenna which is a very popular antenna in commercial point-to-point communications and providing a high gain antenna with a significant directivity [1].
4. The ground is poor because most of the ground in Libya is dry sand and desert. The poor ground will be found in rocky terrain, dry sand and deserts [4].

As shown in Table .2, for each great-circle distance, there are three radio communication links of different paths, and different geographical locations, are taken in the calculations of; MUF, FOT and LUF for each given hour of the day times as well as for the winter and the summer seasons. The median value for the three radio communication links at each given hour of the day times as well as in the winter and the summer seasons is considered as the predicted Path value of the considered great-circle distance.

III. Results and Discussion

The results are shown and are plotted in Figures.1 (A & B), Figure.2 (A & B) and Figure.3 (A & B).

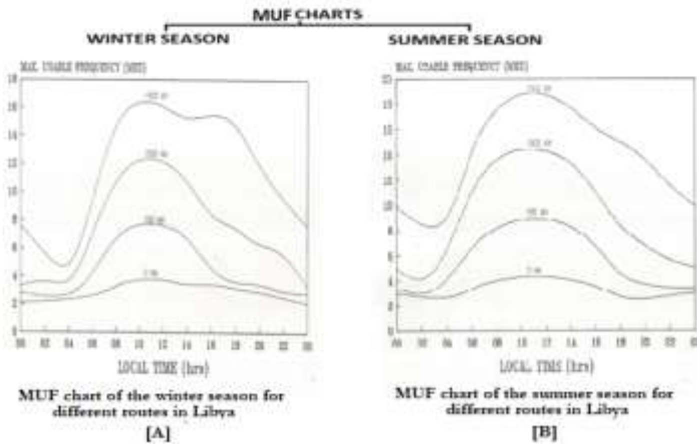

Fig.1: Maximum Usable Frequency (MUF) charts of both winter (A) and summer (B) seasons for different routes in Libya

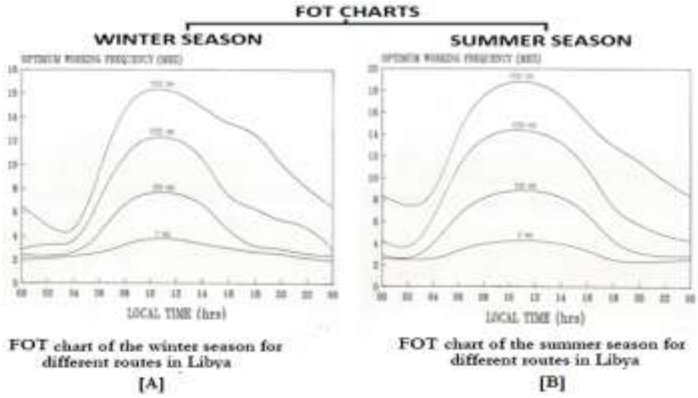

Fig.2: Optimum Working Frequency (fre'quence optimum de travail=FOT) charts of both winter (A) and summer (B) seasons for different routes in Libya

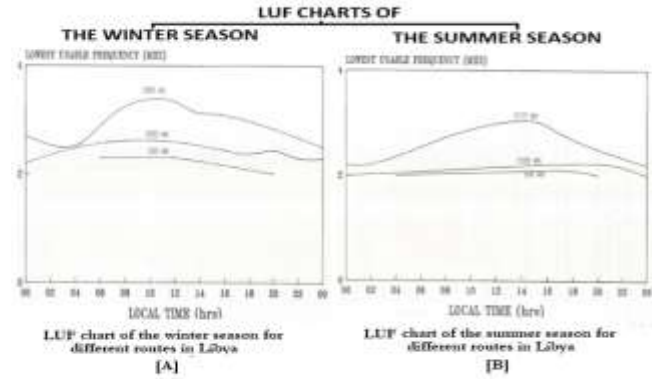

Fig.3: Lowest Usable Frequency (LUF) charts of both winter (A) and summer (B) seasons for different routes in Libya

The Figures (1, 2 and 3) show that:

1. The predicted frequencies decrease in the time interval between 00 and 04 hrs local time, and increase between 04 and 12 hrs local time to reach the maximum value between 10 and 12 hrs local time and again decrease between 12 and 00 hrs local time.
2. The predicted frequencies values in the summer season are greater than the predicted frequencies values in the winter season.
3. The predicted frequencies increase when the great-circle distance of the link increases.

IV. Conclusions

1. The HF radio communication range in Libya extends from 2 to 19 MHz.
2. The E-ionospheric reflecting layer is useful for HF propagation in Libya because the predicted frequencies FOT and MUF are equal or close to each other and HF radio communication distance between any two points for different routes in Libya is not exceeding 2000 Km.
3. The predicted frequencies of different routes reach the maximum value between 10 and 12 hours local time, and reach the minimum value between 02 to 04 hrs local time.

4. The change in the predicted frequencies which will be used over HF links in Libya is required, to suite the changes in propagation conditions of the E-ionospheric reflecting layer related to the daytimes, seasons of the year and solar activity. Therefore, a reliable HF radio communication links will be obtained over different routes between points under ionospheric influence in Libya. This is ensuring that the predicted frequencies will play a significant part in the HF wave propagation in Libya.
5. The predicted frequencies for different links have the same great circle distance, are approximately equal.
6. The CRPL method of ionospheric prediction is rather complex but it has the advantage of being usable for any path, anywhere in Libya.

V. RECOMMENDATIONS AND SUGGESTIONS FOR PROSPECTIVE STUDIES

- Experimental verification of the predicted results
- Determine the critical angle of transmission of the predicted results.
- Determine the propagation path loss for the predicted results.
- The continuous studying of the E layer parameters and measuring them by using the ionospheric sounding devices.

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