Analytical Study of the Optimum Traffic Frequency for the HF Communications over Iraqi zone

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Abstract

In this project, the analyses for the dataset of the Optimum Traffic Radio Frequency parameter (FOT) have been made which lies within the range of HF-band (3-30 MHz). The values of the FOT parameter have been calculated using the (VOACAP) international modern communication model. In this analytical study, Iraq has been selected to be the region of study. So, the capital "Baghdad" has been chosen to represent as transmitting station while other thirty different locations distributed over Iraqi zone were represented as receiving stations. In this research, the influence of the time and orientation factors on the FOT parameter have been studied for the maximum and minimum solar cycle years 200٠ and 200٩. The results of the influence of the time factor showed a slit variation on the values of the FOT parameter, also the impact of the orientation factor was clear especially during summer time.

Key words: Frequency of Optimum Transmission (FOT), Optimum Working (Traffic) Frequency (OWF).

دراسة تحليلية لمعامل المرور الأمثل لاتصالات الترددات العالية فوق منطقة العراق

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الخلاصــــة

تم في هذا البحث إجراء تحليل لبيانات لمعامل تردد المرور الأمثل (FOT) للموجات الراديوية التي تقع ضمن نطاق جزمة الترددات العالية (HF) (٣-٣٠ ميغاهرتز). لقد تم حساب قيم معامل ألـ FOT باستخدام نموذج الاتصالات العالمي الحديث (VOACAP). تم في هذه الدراسة التحليلية اختيار العراق ليكون المنطقة المدروسة، حيث تم أختيار العاصمة "بغداد" لتمثل محطة الآرسال في حين تم انتخاب ثلاثون موقعاً مختلفاً موزعاً فوق نطاق منطقة العراق ليمثل محطات الاستقبال. في هذا البحث تم دراسة تأثير عاملي الوقت والاتجاه على قيم معامل الـ FOT لسنوات الدورة الشمسية العظمى والصغرى للأعوام ٢٠٠٠ و ٢٠٠٩. بينت نتائج الدراسة أن عامل الوقت قد أظهر تأثيراً قليلاً على قيم معامل الـ FOT، كما أظهرت تأثيراً واضحاً ل عامل الاتجاه وخصوصا خلال فصل الصيف.

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1. Introduction

In 1888 German physicist Heinrich Hertz made the sensational discovery of radio waves, a form of electromagnetic radiation with wavelengths too long for our eyes to see confirming Maxwell's ideas. He devised a transmitting oscillator, which radiated radio waves, and detected them using a metal loop with a gap at one side. When the loop was placed within the transmitter's electromagnetic field, sparks were produced across the gap. This proved that electromagnetic waves could be sent out into space, and be remotely detected. These waves were known as 'Hertzian Waves' and Hertz managed to detect them across the length of his laboratory [1]

Italian born Guglielmo Marconi was fascinated by Hertz's discovery, and realized that if radio waves could be transmitted and detected over long distances, wireless telegraphy could be developed. He started experimenting in 1894 and set up rough aerials on opposite sides of the family garden. He managed to receive signals over a distance of 100 meters, and by the end of 1895 had extended the distance to over a mile. In 1901first transatlantic signal sent-by Marconi from Ireland to Canada [2].

1. The Ionosphere

The ionosphere is a part of the upper atmosphere, comprising portions of the mesosphere, thermosphere and exosphere, distinguished because it is ionized by solar radiation. It plays an important part in atmospheric electricity and forms the inner edge of the magnetosphere, as shown in figure (1). The ionosphere is a shell of electrons and electrically charged atoms and molecules that surrounds the Earth, stretching from a height of about 50 km to more than 1000 km [4].

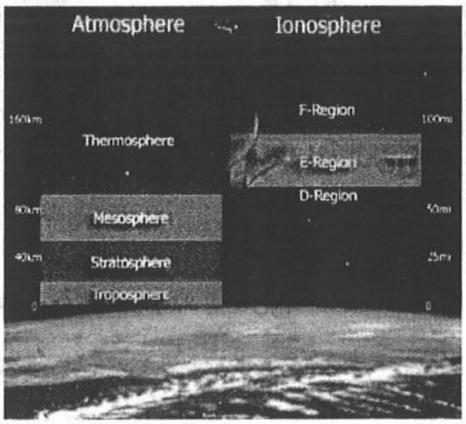

Fig. (1) Shows the Atmospheric layers [3].

The ionosphere has historically been divided according to the electron density and height into (D, E, F and Topside layers), so these regions may be further divided into several regularly occurring layers, such as (D, E, F and Topside layers), as shown in figure (1). During the day, F-layer is divided in to two layers (F1 & F2), while the D and E layers become much more heavily ionized. At night the F-layer is the only layer of significant ionization present, while the ionization in the E and D layers is extremely low [5].

2. Ionospheric Propagation Parameters

The ionospheric parameters describe the acceptable operation frequencies of a radio service between given terminals. These parameters affected by primary factor influence (electron density of ionization), so these parameters will be increase with higher ionization density and decrease with lower ionization density [6]. The ionospheric parameters can be described as following:-

- **Maximum Usable Frequency (MUF):** the highest frequency that will be reflected back to earth by the ionized layers. Above this frequency there is no reflection and thus no skip. MUF depends on the layer that is responsible for refraction/reflection and so contact between two stations relying on skip will depend on the amount of sunspot activity, the time of day, time of year, latitude of the two stations, and antenna transmission angle. The MUF is not significantly affected by transmitter power and receiver sensitivity [7].
- **Lowest Useable Frequency (LUF):** is the lowest radio frequency that ionosphere can refract over a selected point-to point path which considered the "upper decile" working just 10% of the time [7].
- **Frequency of Optimum (Working) Transmission (FOT):** is the highest effective (i.e. working) frequency that is predicted to be usable for a specified path and time for 90% of the days of the month [7].

The Optimum Traffic Frequency is the highest operational frequency which radio waves are returned to Earth by ionospheric refraction and which can be used to transmit over a particular path under given ionospheric conditions at a specific time. In the theory, frequencies higher than the FOT penetrate the ionosphere and continue on into space, while frequencies lower than the FOT tend to refract in the ionosphere and return back to Earth. Because the ionization of the ionospheric layers is extremely variable, the FOT must be statistically defined based on the intensity of F-region ionization.

The accepted working definition of FOT is that *it is the highest frequency predicted to occur via a normal reflection from the F2-layer (F-region at night) at a given time of day on a specified path*. This definition depends only on the mode of propagation and the path geometry and is independent of HF radio system parameters and received noise [6].

During a solar maximum, the FOT can rise higher part of HF band at daylight hours, but during solar minimum, can be at or below the lower part of the HF band. In practice, the FOT is not a sharp limit and propagation is often possible on frequencies greater than the theoretical FOT.

The operational frequency may be appreciably higher than the statistically-predicted FOT neither the ground nor the ionosphere is smooth reflectors. Scattering from irregularities will frequently allow signals to propagate to distances beyond the limit of the refracted wave. The received signal characteristics are nearly always optimal for sky wave communications when the link operating frequency is chosen at or just below the classical FOT [6].

3. The Selected Model

In this research the VOACAP International Communication Model has been adopted to be the model that will be used to get the dataset of the studied parameter for the specific transmitter and receiver station locations.

VOACAP stands for the Voice of America Coverage Analysis Program. It is an ionospheric model predicting the expected performance of HF transmissions. It takes into account tens of parameters to support the planning and operation of long distance amateur traffic or broadcast transmissions.

VOACAP is a "Point-to-Point" analysis tool. Point-to-Point means that the propagation is calculated not for a general coverage over a location or to provide a global status of the ionosphere, but rather for a specified path between a transmitter and a receiver [8].

VOACAP is based on the Ionospheric Communications Analysis and Prediction Program (IONCAP), a famous scientific product released in the '80s by the U.S. National Telecommunication and Information Administration free of rights.

Then VOA funded the U.S. Naval Research Laboratory (NRL) to make specific changes to the IONCAP methodology, and renamed it, as expected, to VOACAP so as to avoid confusion. That version of VOACAP was completed in April 1993 and distributed to participants at IES 93 (Ionospheric Effects Symposium May 1993, Alexandria, VA., USA). Simultaneous to funding NRL to enhance the model, VOA also funded the NTIA/ITS to enhance the user interface. A few months later NTIA/ITS had converted the program in a DOS-based application [9].

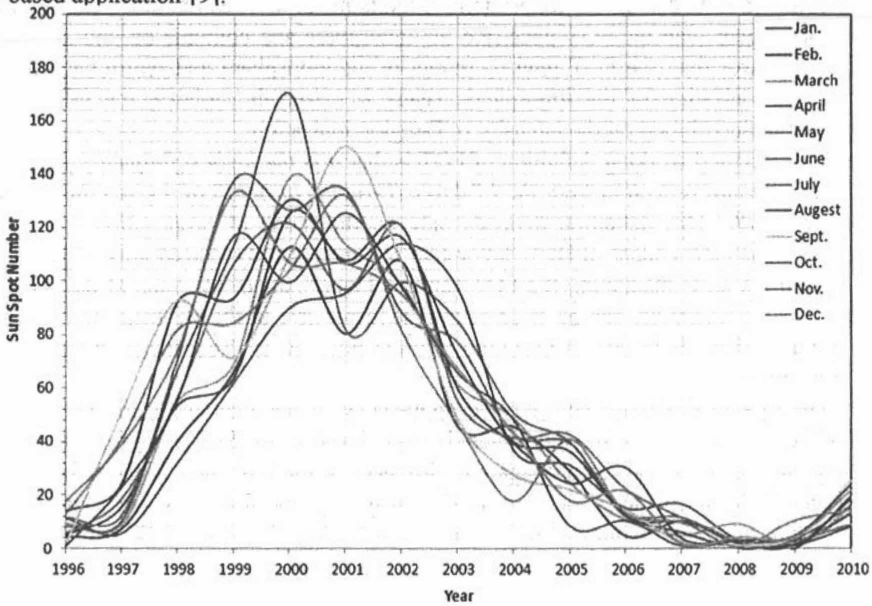

Fig. (2) Shows the observed sun spots for the solar cycle 23

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4. Test and Results

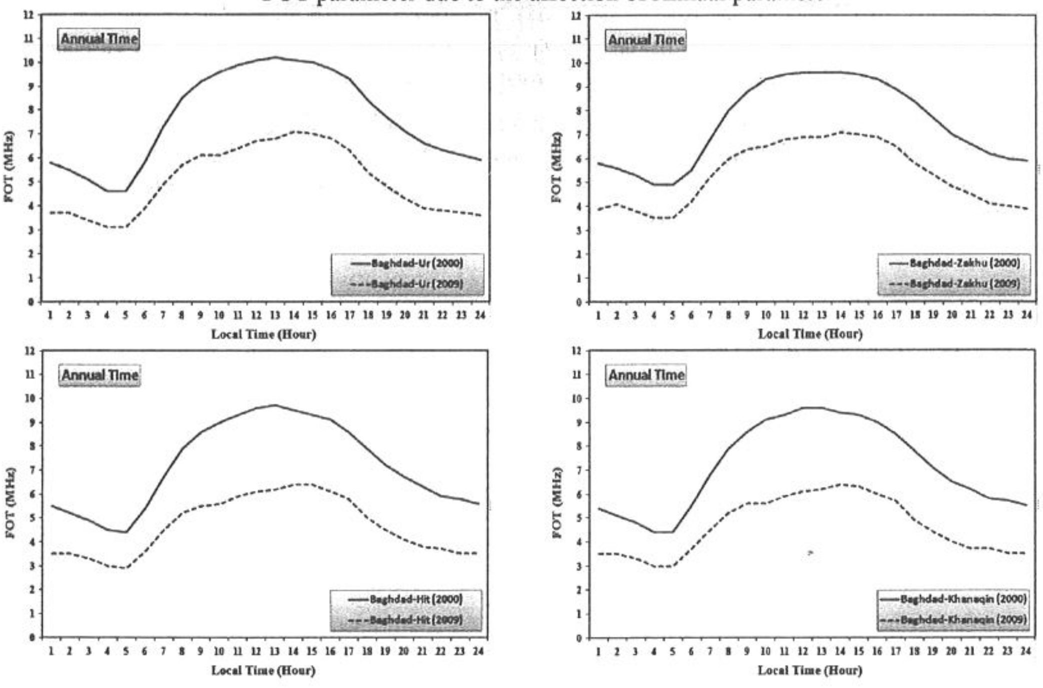
The aim of this project is to make an analytical study for the HF-International model in order to conduct the operational reliable Optimum Traffic Frequency "FOT", that can maintain the HF-links between the transmitter and receiver locations. In the present work the VOACAP model have been adopted to calculate the FOT between transmitting and receiving stations over Iraqi zone. In this study Iraq had been adopted to represent the region of study. The capital "Baghdad" had been selected to represent the transmitting station, and the other thirty different Iraqi cites represented the receiving stations.

The execution of international model had been conducted for the full HF range (2-30 MHz) and for 12 months of years (200٠, 200٩). The year 200٠ had been selected, because it represents the peak (maximum) of the 23 solar activity cycle, while the year 20٠٩ represents the lowest activity year (minimum) of the 23 solar cycle (see figure (2)) .

A statistical analysis of the output data file for the VOACAP model have been made using Microsoft Excel program. The analyses study for the FOT parameter had been made by studying the influence of the Time (Annual, and Seasonal) and Orientation parameters on the behavior of the FOT ionospheric parameter.

a. The Time Parameter:

5. In this part the influence variation of the **Annual Time** on the FOT parameter was studied for the years (2001 & 2010). Figure (3), shows samples of the statistical variation of the FOT parameter due to the affection of Annual parameter



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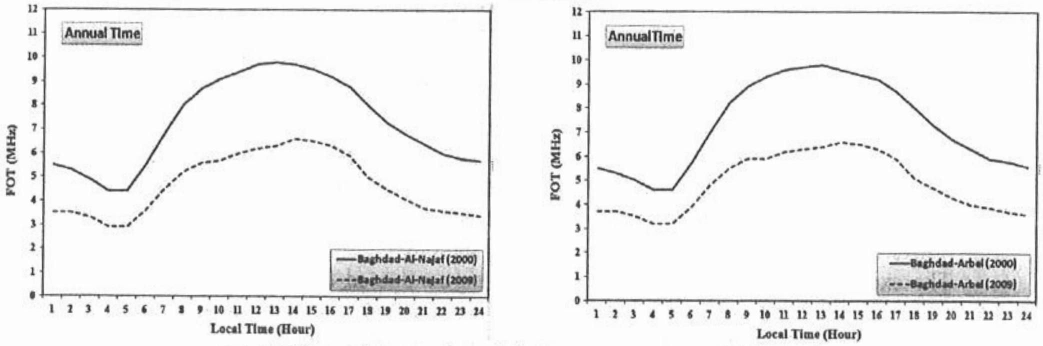

Fig. (3) Shows the annual statistical analysis for the FOT parameter.

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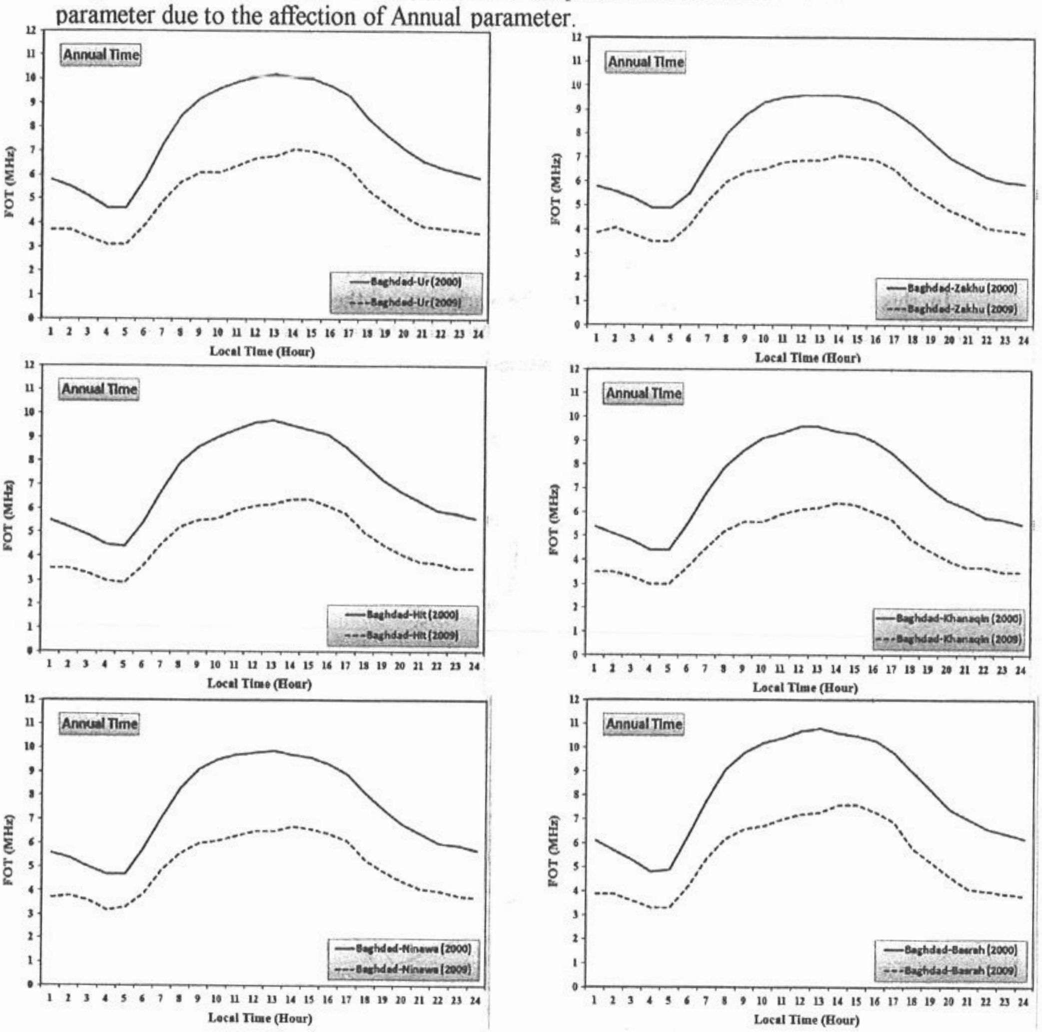

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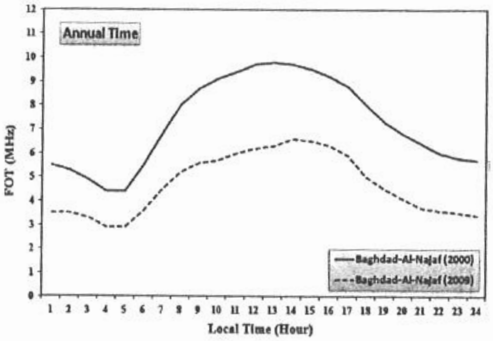


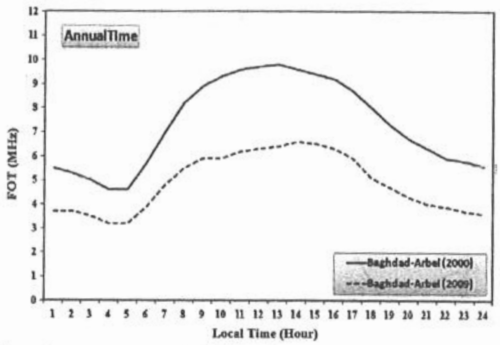
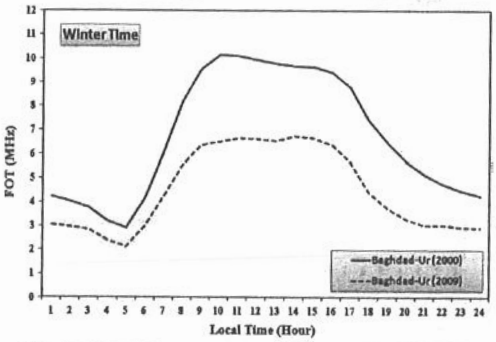
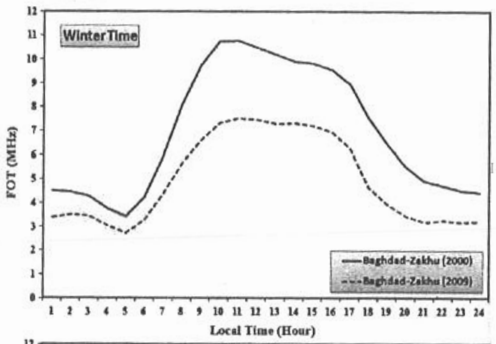
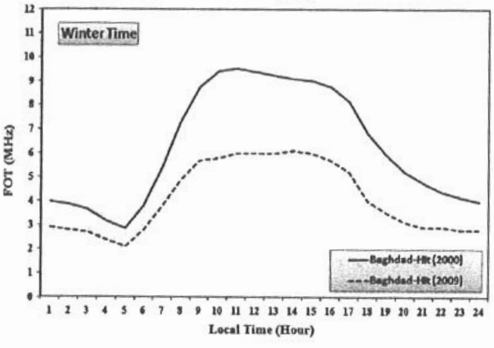


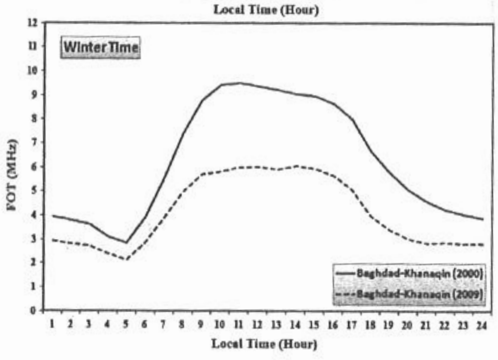
Fig. (3) Shows the annual statistical analysis for the FOT parameter.

In this part, the study was made for the variation of the **Seasonal** parameter. This parameter has been studied for the four seasons **(Winter, Spring, Summer, and Autumn)**. Figure (4) shows the variation of the FOT parameter in winter season.









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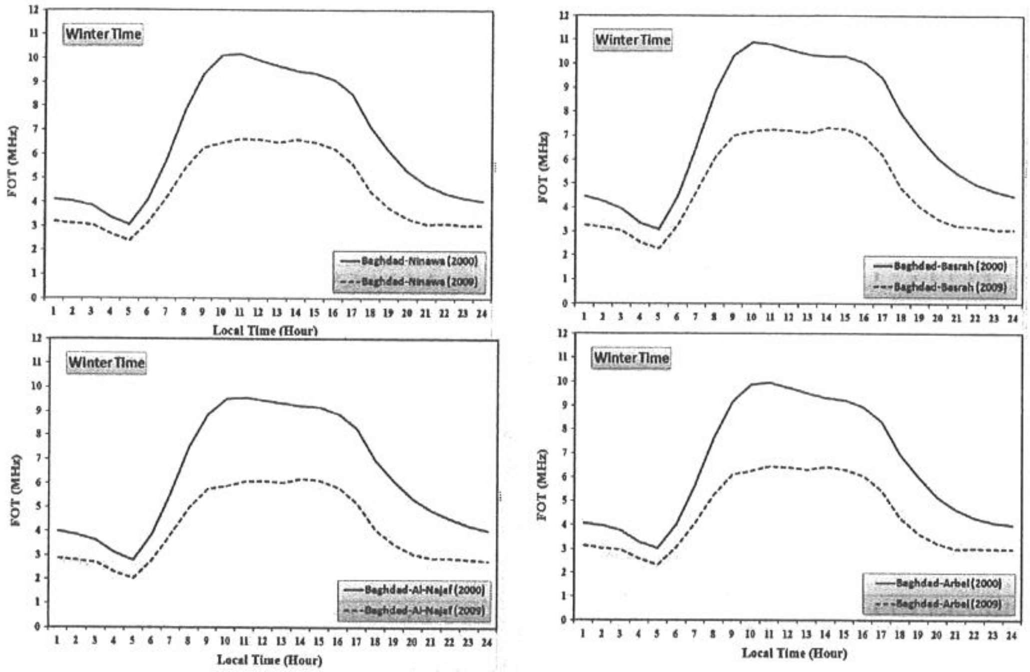

Figure (4) shows the variation of the FOT parameter during winter season.

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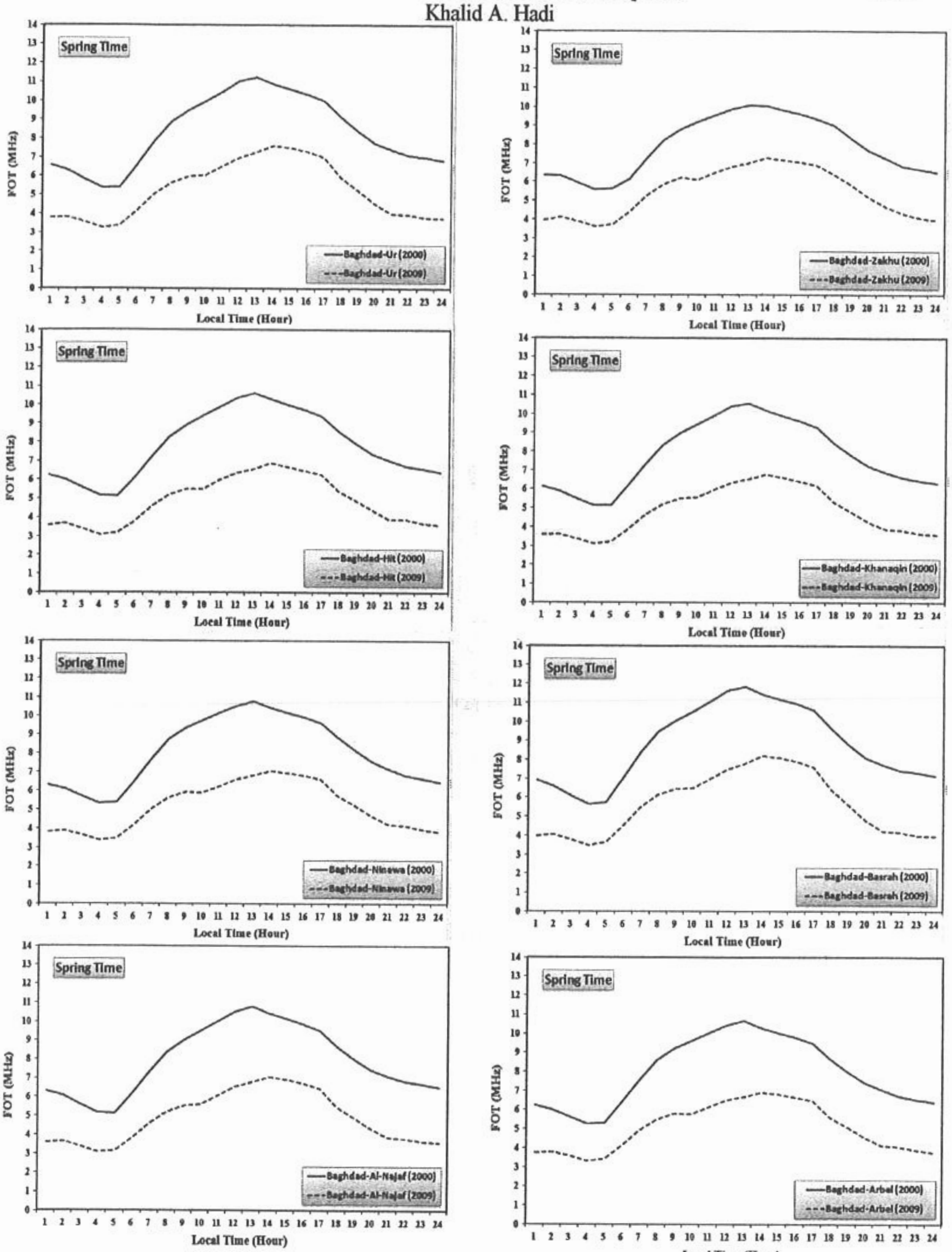

Figure (5) shows the variation of the FOT parameter during Spring season.

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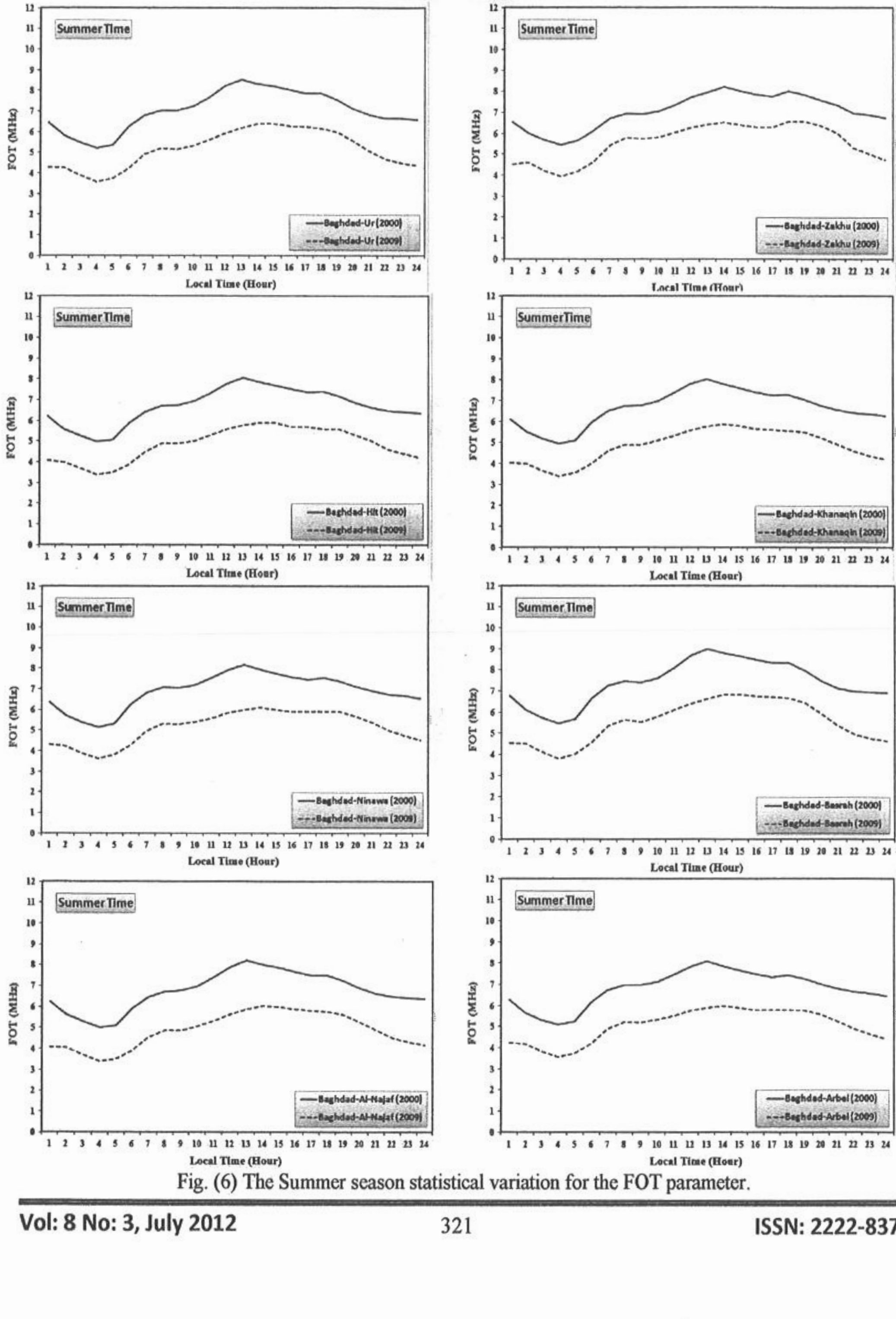

Fig. (6) The Summer season statistical variation for the FOT parameter.

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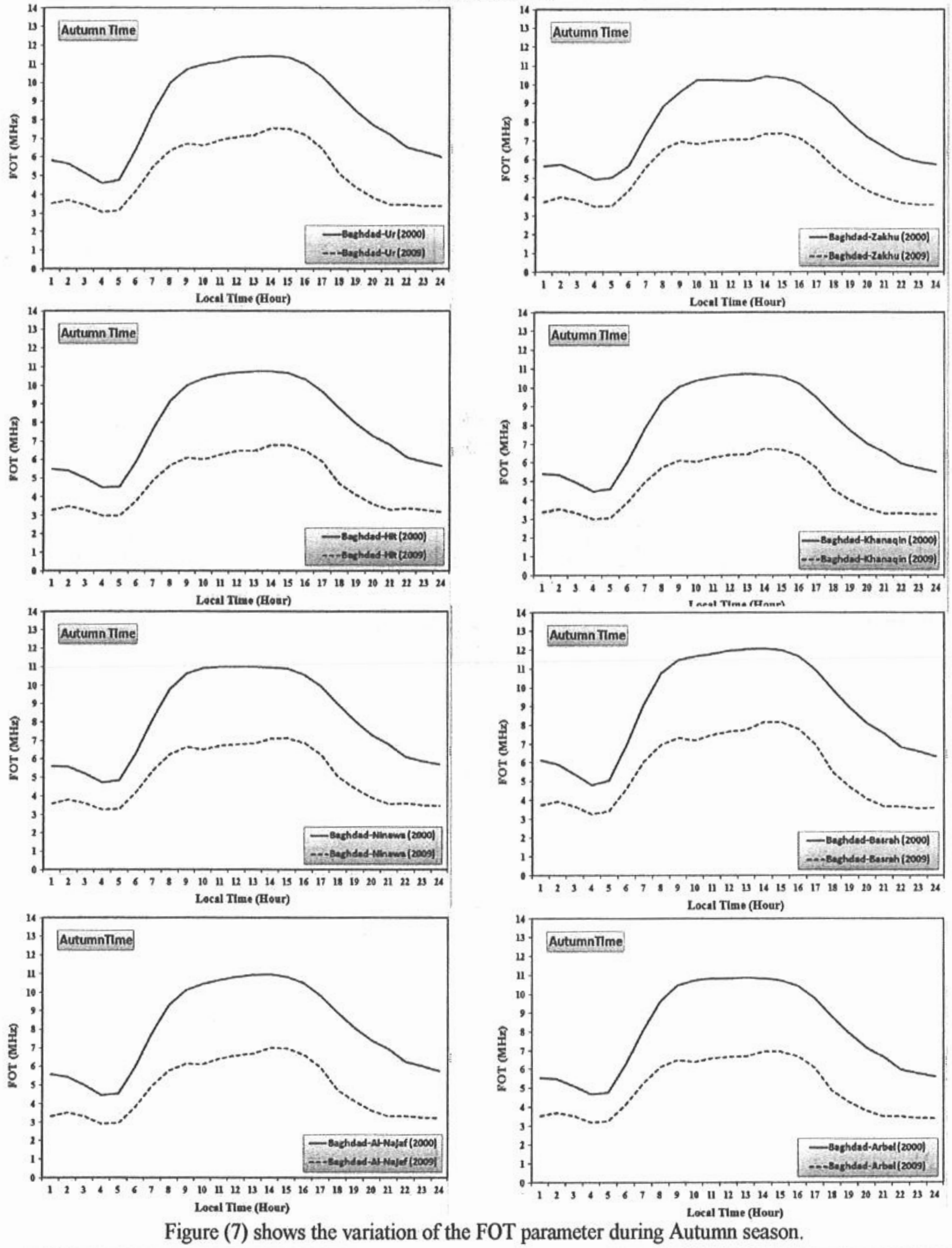
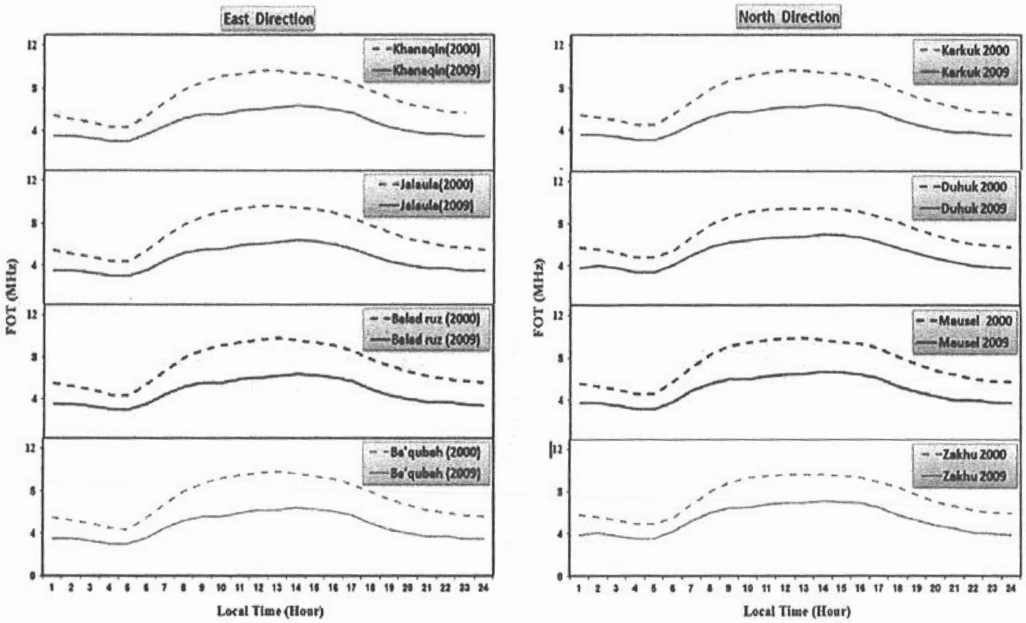


Figure (7) shows the variation of the FOT parameter during Autumn season.

b -The Orientation Parameter:

In This study, the Variations of the Orientation parameter were made for the four directions (North, South, East, and West). Also, this parameter has been studied for different seasons (Winter, Spring, Summer, and Autumn), and different locations distributed over Iraqi zone surround the transmitter station "Baghdad", Figure (8) shows samples of the variation of the FOT parameter in different direction (North, South, East, and West).



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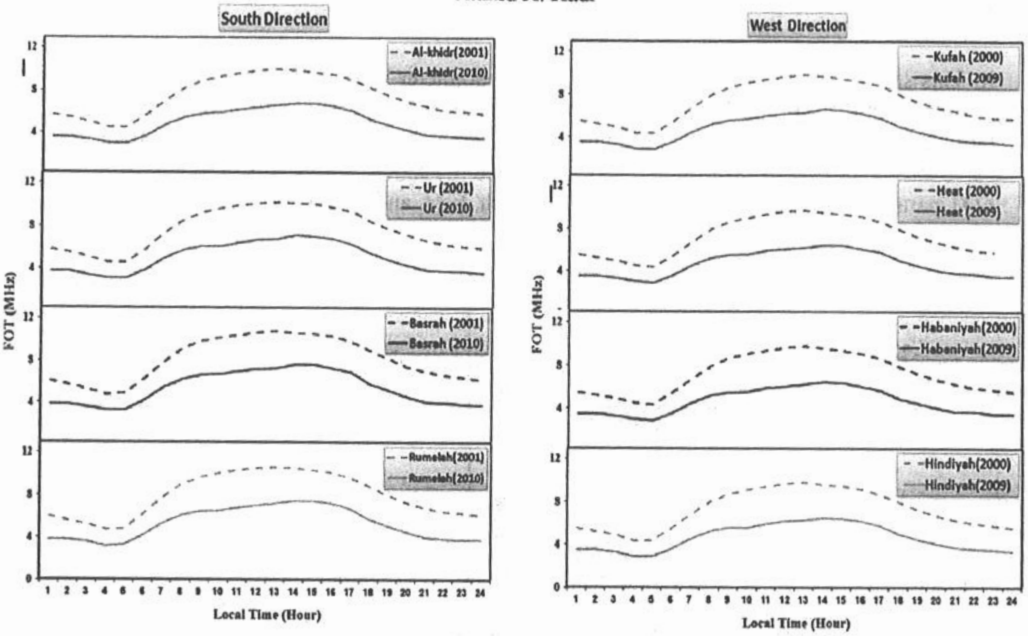

Fig. (8) The Orientation statistical analysis for the FOT parameter.

6. Discussion and Conclusions

The results that have achieved from the execution of the VOACAP international communication model for Iraqi zone have been analyzed in order to predict the reliable Optimum Traffic Frequency (FOT) that can maintain the link connection between the transmitter and receiver stations.

The analytical study have been made by studying the influence of the time (Annual and Seasonal) and Orientation factors on the behavior of the FOT parameter. The variation study have been made for two different years 200٠ and 200٩ which represents the maximum and minimum activity years of the 23 solar cycle.

The affection of the *Annual factor* on the FOT values has been studied for many sites that are located on different locations (different longitude & latitude) around the transmitting station "Baghdad". The variation of the Annual factor on the FOT parameter in the year 200٠ is larger than that of the year of 200٩, the reason of this difference is due to the variation of solar activity during the studied years, as shown in fig. (3).

The study of the *Seasonal affection* on the FOT values was made. The conducted study showed a variation in the values of the FOT parameters due to the influence of the Seasonal time factor, especially during the summer time that's due to the monthly sun spot number variation, as shown in figures (4), (5), (6), (7).

The last study, the affection of the *Orientation factor* on the FOT values has been studied for many sites that are located on different directions (North, South, East, and West) around the transmitting station "Baghdad". Samples of results of this study illustrated in figure (8) that shows the values variation of the FOT parameter. The orientational influence was clear for the variation of the FOT parameter within different directions and different solar activity years.

7. Reference

1. Pimsleur J. L. "Invention of Radio Celebrated in S.F. 100th birthday exhibit this weekend ". San Francisco Chronicle, p. A18 1995.
2. Rubin, J. "Guglielmo Marconi: The Invention of Radio", Holy blatherin Joseph, January 2006.
3. Tracking Solar Flares – The Earth's Ionosphere. http://solar-center.stanford.edu/SID/activities/ionosphere.html

4. Rawer K., "Wave propagation in the Ionosphere". 1st edition., Kluwer Academic Publishers, pp. 200, Dordrecht 1993. ISBN 0-7923-0775-5

5. Kelley, M. C, and Heelis, R. A., "The Earth's Ionosphere: Plasma Physics and Electrodynamics". San Diego: Academic Press, p.10, 1989.

6. Tomas H., "MUF, LUF, and FOT - The Basics of the Maximum Usable Frequency", 2004.

7. Hall M. and Barclay L., "Radio wave propagation", Peter Peregrinus Ltd., p.2, (1989)

8. Teters L.R., Lloyd J.L., Haydon G.W. and Lucas D.L., "Estimating the Performance of Telecommunication Systems Using the Ionospheric Transmission Channel", Institute for Telecommunication Sciences NTIA Report 83-127, July 1983.

9. Lane G., Rhoads F. J. and Deblasio L., "Voice of America coverage analysis program (VOACAP) user's manual", VOA B/ESA Report 01-93, PB93-155174, 1993